ABSTRACTS

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Welcome to IPAC 21

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MOPAB001 **Power Deposition in Superconducting Dispersion Suppressor Magnets Downstream of the Betatron Cleaning Insertion for CERN LHC in the HL-LHC era**

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The power deposited in dispersion suppressor magnets downstream of the Large Hadron Collider (LHC) betatron cleaning insertion is governed by off-momentum particles scattered out of the primary collimators. In order to mitigate the risk of magnet quenches during periods of short beam lifetime in future High-Luminosity (HL-LHC) operation, new dispersion suppressor (DS) collimators are considered for installation (one per beam). In this paper, we present FLUKA simulations for both protons and Pb ions at 7 TeV, predicting the power deposition in the DS magnets, including the new higher-field dipoles 11T which are needed to integrate the collimator in the cold region next to the cleaning insertion. The simulated power deposition levels for the adopted HL-LHC collimator configuration and settings are used to assess the quench margin by comparison with the present estimated quench levels.

MOPAB002 **Risk of Halo-Induced Magnet Quenches in the Beam Dump Insertion Region of the CERN LHC during HL-LHC operation**

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After the High Luminosity (HL-LHC) upgrade, the LHC will be exposed to a higher risk of magnet quenches during periods of short beam lifetime. Collimators in the extraction region (IR6) assure the protection of magnets against asynchronous beam dumps, but they also intercept a fraction of the beam halo leaking from the betatron cleaning insertion. In this paper, we assess the risk of quenching nearby quadrupoles during beam lifetime drops. In particular, we present an empirical analysis of halo losses in IR6 using LHC Run 2 (2015-2018) beam loss monitor measurements. Based on these results, the halo-induced power density in magnet coils expected in HL-LHC is estimated using FLUKA Monte Carlo shower simulations.

MOPAB003 **Machine Learning Analysis of Electron Cooler Operation for RHIC**

***X. Gu**, A.V. Fedotov, D. Kayran (BNL)*

A regression machine learning algorithm was applied to analyze the operation data of RHIC with electron cooler LEReC during the 2020 physics run. After constructing a black-box surrogate model from the XGBoost algorithm and plotting their partial dependency plots for different operation parameters, we can find the effects of an individual parameter on the RHIC luminosity and optimize it accordingly offline.

MOPAB004 **JSPEC - A Simulation Program for IBS and Electron Cooling**
***H. Zhang**, S.V. Benson, M.W. Bruker, Y. Zhang (JLab)*
Intrabeam scattering is an important collective effect that can deteriorate the properties of a high-intensity beam, and electron cooling is a method to mitigate the IBS effect. JSPEC (JLab Simulation Package for Electron Cooling) is an open-source program developed at Jefferson Lab, which simulates the evolution of the ion beam under the IBS and/or the electron cooling effect. JSPEC has been benchmarked with BETACOOL and experimental data. In this report, we will introduce the features of JSPEC, including the friction force calculation, the IBS expansion rate and electron cooling rate calculation, and the beam-dynamic simulations for the electron cooling process; explain how to set up the simulations in JSPEC; and demonstrate the benchmarking results.

MOPAB005 **Studies for an LHC Pilot Run With Oxygen Beams**
***R. Bruce**, R. Alemany-Fernández, H. Bartosik, M.A. Jebramcik, J.M. Jowett, M. Schaumann (CERN)*
Motivated by the study of collective effects in small systems with oxygen-oxygen (O-O) collisions, and improvements to the understanding of high-energy cosmic ray interactions from proton-oxygen (p-O) collisions, a short LHC oxygen run during Run 3 has been proposed. This article presents estimates for the obtainable luminosity performance in these two running modes based on simulations of a typical fill. The requested integrated luminosity, projected beam conditions, data-taking and commissioning times are considered and a running scenario is proposed.

MOPAB006 **Optics Configurations for Improved Machine Impedance and Cleaning Performance of a Multi-Stage Collimation Insertion**
***R. Bruce**, R. De Maria, M. Giovannozzi, N. Mounet, S. Redaelli (CERN)*
For a two-stage collimation system, the betatron phase advance between the primary and secondary stages is usually set to maximise the absorption of secondary particles outscattered from the primary. Another constraint is the contribution to the ring impedance of the collimation system, which can be decreased through an optimized insertion optics, featuring large values of the beta functions. In this article we report on first studies of such an optics for the CERN LHC. In addition to a gain in impedance, we show that the cleaning efficiency can be improved thanks to the large beta functions, even though the phase advance is not set at the theoretical optimum.

MOPAB007 **Prospect for Interaction Region Local Coupling Correction in the LHC Run 3**
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Successful operation of large scale particle accelerators depends on the precise correction of unavoidable magnet field or alignment errors

present in the machine. In the LHC Run 2, local linear coupling in the Interaction Regions (IR) has been proven to have a severe impact on beam size and hence the luminosity - up to a 50% decrease -, making its handling a target for Run 3 and High Luminosity LHC (HL-LHC). However, current measurement methods are not optimised for local IR coupling. In this contribution, an approach to accurately minimise IR local coupling based on correlated external variables such as the |C-| is proposed. The validity of the method is demonstrated through simulations and benchmarked against theoretical values, such as Resonance Driving Terms (RDTs) and Ripken parameters.

MOPAB008 **Exploiting the Beam-Beam Wire Demonstrators in the Next LHC Run 3**

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After the successful experiments performed during the LHC Run 2 with the Beam-Beam Wire demonstrators installed, on Beam 2, in the frame of the HL-LHC project, two of the four wire demonstrators were moved to Beam 1. The objective is to gain operational experience with the wire compensation also on that beam and therefore fully exploit the demonstrators' potential. This paper proposes a numerical validation of the wire implementation using Run 3 scenarios and explores the optimization of those devices in that respect.

MOPAB009 **Review of the Fixed Target Operation at RHIC in 2020**

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As part of the Beam Energy Scan (BES) physics program, RHIC operated in Fixed Target mode at various beam energies in 2020. The fixed target experiment, achieved by scraping the beam halo of the circulating beam on a gold ring inserted in the beam pipe upstream of the experimental detectors, extends the range of the center-of-mass energy for BES. The machine configuration, control of rates, and results of the fixed target experiment operation in 2020 will be presented in this report.

MOPAB010 **RHIC Beam Energy Scan Operation With Electron Cooling in 2020**

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RHIC provided Au-Au collisions at beam energies of 5.75 and 4.59 GeV/nucleon for the physics program in 2020 as a part of the Beam Energy Scan II experiment. The operational experience at these energies will be reported with emphasis on their unique features. These unique features include the addition of a third harmonic RF system to enable a large longitudinal acceptance at 5.75 GeV/nucleon, the application of additional lower frequency cavities for alleviating space charge effects, and the world-first operation of cooling with an RF-accelerated bunched electron beam.

MOPAB012 **Energy Deposition Study of the CERN HL-LHC Optics v1.5 in the ATLAS and CMS Insertions**

***M. Sabate-Gilarte**, F. Cerutti (CERN)*

The High Luminosity Large Hadron Collider (HL-LHC) is the approved CERN project aiming at further increasing the integrated luminosity of the LHC by a factor 10. As such, it implies a complete redesign of the experimental high-luminosity insertions of ATLAS and CMS. The progressive evolution of the new layout and optics requires a continuous analysis of the radiation environment, to which magnets and other equipment are exposed to. This is assured by means of Monte Carlo simulations of the collision debris on the evolving machine model. The latter featured several developments, such as the explicit inclusion of the cold protection diodes of the final focusing circuits as well as the crab cavities cryomodule. This work presents the most updated characterization of the radiation field with FLUKA and its impact in the insertion region and the dispersion suppressor of Point 1 and 5, for the HL-LHC optics v1.5 released in 2019. Various optimization and mitigation studies are highlighted, providing key information for maximizing the lifetime of new and present magnets.

MOPAB013 **Radiation to Electronics Impact on CERN LHC Operation: Run 2 Overview and HL-LHC Outlook**

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After the mitigation measures implemented during Run 1 (2010-2012) and Long Shutdown 1 (LS1, 2013-2014), the number of equipment failures due to radiation effects on electronics (R2E) leading to LHC

beam dumps and/or machine downtime has been sufficiently low as to yield a minor impact on the accelerator performance. During Run 2 (2015-2018) the R2E related failures per unit of integrated luminosity remained below the target value of 0.5 events/fb-1, with the sole exception of the 2015 run during which the machine commissioning took place. However, during 2018, an increase in the failure rate was observed, linked to the increased radiation levels in the dispersion suppressors of the ATLAS and CMS experimental insertions, significantly affecting the Quench Protection System located underneath the superconducting magnets in the tunnel. This work provides an overview of the Run 2 R2E events during LHC proton-proton operation, putting them in the context of the related radiation levels and equipment sensitivity, and providing an outlook for Run 3 and HL-LHC operation.

MOPAB014 **First High Spin-Flip Efficiency for High Energy Polarized Protons**

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In order to minimize the systematic errors for the Relativistic Heavy Ion Collider (RHIC) spin physics experiments, flipping the spin of each bunch of protons during the stores is needed. Experiments done with single RF magnet at energies less than 2 GeV have demonstrated a spin-flip efficiency over 99%. At high energy colliders with Siberian snakes, a single magnet spin flipper does not work because of the large spin tune spread and the generation of multiple, overlapping resonances. Over past decade, RHIC spin flipper design has evolved and a sophisticated spin flipper, constructed of nine-dipole magnets, was developed to flip the spin in RHIC. A special optics choice was also used to make the spin tune spread very small. In recent experiment, 97% spin-flip efficiency was measured at both 24 and 255 GeV for the first time. The results show that efficient spin flipping can be achieved at high energies.

MOPAB015 **Feasibility of Polarized Deuteron Beam in the EIC**

H. Huang, *F. Méot, V. Ptitsyn, V.H. Ranjbar, T. Roser (BNL)*

The physics program in the EIC calls for polarized neutron beam at high energies. The best neutron carriers are 3He nuclei and deuterons. Both neutron carries are expected to be used by spin physics program in the EIC. Due to the small magnetic moment anomaly of deuteron particles, much higher magnetic fields are required for spin rotation, so full Siberian snake is not feasible. However, the resonance strength is in general weak and the number of resonances is also small. It is possible to deal with individual resonances with conventional methods, such as betatron tune jump for intrinsic depolarizing resonances; and a weak partial snakes for imperfection resonances. The study shows that accelerating polarized deuteron beyond 100GeV/n is possible in the EIC.

MOPAB016 **Small Longitudinal Emittance Setup in Injectors with Gold Beam for Beam Energy Scan in RHIC**

H. Huang, *C.J. Gardner, C. Liu, V. Schoefer, K. Zeno (BNL)*

In recent years, RHIC physics program calls for gold beam collisions with energies at and lower than the nominal RHIC injection energy. To get shorter bunches at the three higher energies (9.8GeV/c, 7.3GeV/c and 4.75GeV/c), RHIC 28MHz cavities were used. The longitudinal emittance out of injectors needs to fit in the 28MHz cavities in RHIC. At two lower energies (4.6 and 3.85 GeV/c), the 9MHz RF cavities were used, which set different requirements from injectors. Extensive beam studies were carried out to establish needed beam parameters, such as bunch intensities and longitudinal emittances. In general, enough intensity can be provided for all energies within the longitudinal emittance constraint. This paper summarizes the recent injector operation experiences for various energies.

MOPAB017 **Influence of Injection Kicker Post-pulses on Storage of Ion Stack in NICA Collider**

E. Syresin, *A. Tuzikov, N.O. Zagibin (JINR)*

The peculiarity of the injection kicker power supply in NICA collider is related to same post pulse of the magnetic field which is appeared after a regular injection pulse. The magnetic field of this post pulse became to an increase of the stack ion angle spread during each injection cycle. When the stack ion angles reaches the acceptance angle the ions are lost in the collider. Influence of the injection kicker post pulse on the storage of the ion stack is considered in this paper in presence of the electron cooling and ion electron recombination losses.

MOPAB018 **SASE Gain-Curve Measurements with MCP-Based Detectors at the European XFEL**

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Radiation detectors based on microchannel plates (MCP) are used for characterization of the Free-Electron Laser (FEL) radiation and measurements of the Self-amplified spontaneous emission (SASE) gain curve at the European XFEL. Photon pulse energies are measured by the MCPs with an anode and by a photodiode. There is one MCP-based detector unit installed in each of the three photon beamlines downstream of the SASE1, SASE2, and SASE3 undulators. MCP detectors operate in a wide dynamic range of pulse energies, from the level of spontaneous emission up to FEL saturation. Their wavelength operation range overlaps with the whole range of radiation wavelengths of SASE1 and SASE2 (from 0.05 nm to 0.4 nm), and SASE3 (from 0.4 nm to 5 nm). In this paper we present results of SASE gain-curve measurements by the MCP-based detectors.

MOPAB019 **Possible Application of Round-to-Flat Hadron Beam Creation Using 3rd Order Coupling Resonances for the Electron-Ion Collider**

J. Kallestrup *(PSI) X. Gu (BNL)*

An Electron-Ion Collider (EIC) is planned to be built in Brookhaven National Laboratory with the contribution from Jefferson National Laboratory. To have a high luminosity, both the EIC ion bunch and the EIC electron bunch are designed to be flat during their collision. The existing injector source provides a round beam of width 2.5 um rad transverse emittances. In this paper we investigate the option of dynamically crossing the 2Qx-Qy coupling resonance in order to create a flat-beam with emittance ratio Ex/Ey of up to 4. Furthermore, we explore the possibility of using a pulsed- or AC skew sextupole magnets to achieve a similar effect. Using one of these methods for flat beam creation will help lower the ion beam cooling time.

MOPAB020 **Improvements to the SLS Booster Synchrotron Performance Towards SLS 2.0**

J. Kallestrup*, M. Aiba (PSI)*

The Swiss Light Source (SLS) storage ring will undergo a major upgrade to a multi-bend achromat lattice. The existing injector complex will be reused with few modifications. However, the SLS booster synchrotron has not been studied since the initial commissioning in years 2000-2001. We plan to apply an emittance exchange in the booster to lower the horizontal emittance, which is a critial parameter for the injection. Here, we present improvements to the SLS booster as a preparation for SLS 2.0 upgrade project. The vertical beam size is decreased by 50% by the use of vertical orbit correctors without beam position monitors, leading also to suppression of vertical dispersion and a factor 10 reduction of the transverse coupling coefficient. The emittance exchange reflected these improvements in the horizontal emittance, achieving a factor of 9-10 reduction. Lastly, a fast head-tail instability limiting the injection rate into the storage ring is discovered and subsequently suppressed by correcting the chromaticities.

MOPAB021 **A Dispersive Quadrupole Scan Technique for Transverse Beam Characterization**

J. Kallestrup*, M. Aiba (PSI) N. Carmignani, T.P. Perron (ESRF)*

Quadrupole scans are one of the standard techniques to characterize the transverse beam properties in transfer lines or linacs. However, in the presence of dispersion the usage of regular quadrupole scans will lead to erroneous estimates of the beam parameters. The standard solution to this problem is to measure the dispersion and then subtract it in the post-analysis of the quadrupole scan measurements assuming the design energy spread. Here we show that the dispersive contribution to the beam size can be included in the quadrupole scan procedure, forming a linear system of equations that can be solved to obtain both the betatronic and dispersive beam parameters. The method is tested at both the SLS and ESRF booster-to-ring transfer lines leading

to reasonable estimates of the beam parameters.

MOPAB022 **Failsim: A Numerical Toolbox for the Study of Fast Failures and Their Impact on Machine Protection at the CERN Large Hadron Collider**

***C. Hernalsteens**, G. Sterbini, O.K. Tuormaa, C. Wiesner, D. Wollmann (CERN)*

The High Luminosity LHC (HL-LHC) foresees to reach a nominal, levelled luminosity of $5{\cdot}10^{34}$ cm^{-2} s^{-1} through a higher beam brightness and by using new equipment, such as larger aperture final focusing quadrupole magnets. The HL-LHC upgrade has critical impacts on the machine protection strategy, as the stored beam energy reaches 700 MJ for each of the two beams. Some failure modes of the novel active superconducting magnet protection system of the inner triplet magnets, namely the Coupling-Loss Induced Quench (CLIQ) systems, have been identified as critical. This paper reports on FailSim, a Python-language framework developed to study the machine protection impact of failure cases and their proposed mitigation. It provides seamless integration of the successive phases required by the simulation studies, i.e., verifying the optics, preparing and running a MAD-X instance for multiple particle tracking, processing and analysing the simulation results and summarising them with the relevant plots to provide a solid estimate of the beam losses, their location and time evolution. The paper also presents and discusses the result of its application on the spurious discharge of a CLIQ unit.

MOPAB023 **Experimental Test of a New Method to Verify Retraction Margins Between Dump Absorbers and Tertiary Collimators at the LHC**

***C. Wiesner**, W. Bartmann, C. Bracco, R. Bruce, J. Molson, M. Schaumann, C. Staufenbiel, J.A. Uythoven, M. Valette, J. Wenninger, D. Wollmann, M. Zerlauth (CERN)*

The protection of the tertiary collimators (TCTs) and the LHC triplet aperture in case of a so-called asynchronous beam dump relies on the correct retraction between the TCTs and the dump region absorbers. A new method to validate this retraction has been proposed, and a proof-of-principle experiment was performed at the LHC. The method uses a long orbit bump to mimic the change of the beam trajectory caused by an asynchronous firing of the extraction kickers. It can, thus, be performed with circulating beam. This paper reports on the performed beam measurements, compares them with expectations and discusses the potential benefits of the new method for machine protection.

MOPAB024 **Efficient Coupling of Hydrodynamic and Energy-Deposition Codes for Hydrodynamic-Tunnelling Studies on High-Energy Particle Accelerators**

***C. Wiesner**, F. Carra, J. Kruse-Hansen, M. Masci, D. Wollmann (CERN) Y. Nie (KIT)*

The machine-protection evaluation of high-energy accelerators comprises the study of beyond-design failures, including the direct beam

impact onto machine elements. In case of a direct impact, the nominal beam of the Large Hadron Collider (LHC) would penetrate more than 30 meters into a solid copper target. The penetration depth due to the time structure of the particle beam is, thus, significantly longer than predicted from purely static energy-deposition simulations with 7 TeV protons. This effect, known as hydrodynamic tunnelling, is caused by the beam-induced density depletion of the material at the target axis, which allows subsequent bunches to penetrate deeper into the target. Its proper simulation requires, therefore, to sequentially couple an energy-deposition code and a hydrodynamic code for the different target densities. This paper describes a method to efficiently couple the simulations codes Autodyn and FLUKA based on automatic density assignment and input file generation, and presents the results achieved for a sample case.

MOPAB025 **First Experiments With Accelerated Ion Beams in the Booster of Nica Accelerator Complex**

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The NICA accelerator complex in JINR consist of two linear injector chains, a 578 MeV/u superconducting (SC) Booster synchrotron, the existing SC synchrotron Nuclotron, and a new SC collider that has two storage rings. The construction of the facility is based on the Nuclotron technology of SC magnets with an iron yoke and hollow SC cable. Assembly of the Booster synchrotron was finished in autumn of 2020 and first machine Run and experiments with ion beams were successfully done in December 2020. The results of this Run are discussed in this paper.

MOPAB026 **RHIC Delayed Abort Experiments**

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For RHIC to operate at its top energy (100 GeV/n) while protecting the future sPHENIX detector, spontaneous and asynchronous firing of abort kicker modules (pre-fires) have to be avoided. A new triggering circuit for the abort kickers was implemented with relatively slow mechanical relays in series with the standard fast thyratron tubes. The relays prevents unwanted pre-fires during operation, but comes at

the expense of a long latency - about 7 milliseconds - between the removal of beam permit and the actual firing of the abort kickers. Protection considerations of RHIC's superconducting magnets forbid delaying energy extraction from the main dipoles and quadrupoles for too long after a quench. The beam has thus to circulate in both RHIc rings for a few milliseconds as the current in dipole and quadrupole circuit is being extracted. We present the results of delayed abort experiments conducted in July 2018 with the analysis of fast orbit and tune measurements and discuss the safety implications of this implementation for future RHIC operation.

MOPAB027 **Improving the Luminosity Burn-Off Estimate by Considering Single-Diffractive Effects**

***F.F. Van der Veken**, H. Burkhardt, M. Giovannozzi, V.K.B. Olsen (CERN)*

Collisions in a high-luminosity collider result in a continuous burn-off of the circulating beams that is the dominant effect that reduces the instantaneous luminosity over time. In order to obtain a good estimate of the luminosity evolution, it is imperative to have an accurate understanding of the burn-off. Typically, this is calculated based on the inelastic cross-section, as it provides a direct estimate of the number of protons that participate in inelastic collisions, and are hence removed. Likewise, protons that participate in elastic collisions will remain in the machine acceptance, still contributing to luminosity. In between these two regimes lie diffractive collisions, for which the protons have a certain probability to remain in the machine acceptance. Recent developments of the SixTrack code allow it to interface with Pythia, thus allowing for more precise simulations to obtain a better estimate of the diffractive part of the cross-section. In this paper, we will mainly concentrate on slowly-drifting protons that are close to the acceptance limit, resulting from single-diffractive scattering.

MOPAB028 **Using Machine Learning to Improve Dynamic Aperture Estimates**

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The dynamic aperture (DA) is an important concept in the study of nonlinear beam dynamics. Several analytical models used to describe the evolution of DA as a function of time, and to extrapolate to realistic time scales that would not be reachable otherwise due to computational limitations, have been successfully developed. Even though these models have been quite successful in the past, the fitting procedure is rather sensitive to several details. Machine Learning (ML) techniques, which have been around for decades and have matured into powerful tools ever since, carry the potential to address some of these challenges. In this paper, two applications of ML approaches are presented and discussed in detail. Firstly, ML has been used to efficiently detect outliers in the DA computations. Secondly, ML techniques have

been applied to improve the fitting procedures of the DA models, thus improving their predictive power.

MOPAB029 **Burn-Off With Asymmetric Interaction Points**

***R. Tomás**, I. Efthymiopoulos, G. Iadarola (CERN)*

LHC can host above 2700 proton bunches per ring providing collisions in the ATLAS, CMS, LHCb and ALICE interaction points. ATLAS and CMS are placed symmetrically so that they feature the same colliding bunch pairs. However this is not the case for LHCb, hence introducing unwanted bunch-by-bunch variations of the bunch intensity as the physics fill evolves. We present first analytical derivations, numerical simulations and experimental data in different bunch train collision configurations.

MOPAB030 **Research and Development Progress of CEPC RF Shield Bellows**

***J.M. Liu**, Y.H. Guan, S.M. Liu, B. Tan, P.C. Wang (DNSC) H. Dong, Y. Ma (IHEP) H.Y. He, T. Huang (IHEP CSNS)*

The circular electron positron collider (CEPC) is a candidate for the next-generation electron positron collider, which can be used to accurately measure the Higgs and electroweak bosons. The RF shield bellow is a vacuum component necessary for the construction of CEPC. Therefore, a RF shield bellow model machine with an elliptical cross-section was designed and processed for technical verification. Based on the traditional interdigital structure, a special contact force testing device was also designed to reduce measurement errors. The on-off status of the circuit was used by the device to determine whether the spring finger was pulled up, thus reducing the influences of human factors in the measurement process. It can be known from the measurement results of the model machine that the contact force of the spring finger is between 120g and 130g, which can satisfy the technical requirements.

MOPAB031 **Development and Operation of Vacuum System for Rapid Cycling Synchrotron to Target Beam Transfer Line of China Spallation Neutron Source**

***J.M. Liu**, Y.H. Guan, S.M. Liu, B. Tan, P.C. Wang (DNSC) H. Dong (IHEP) H.Y. He, T. Huang (IHEP CSNS)*

China Spallation Neutron Source (CSNS) is a major scientific project during the National Eleventh Five-Year Plan. It consists of a negative hydrogen ion linear accelerator, a rapid cycling synchrotron (RCS), a linac to RCS beam transfer line (LRBT), an RCS to target beam transfer line (RTBT), and a target station. As an important part of CSNS, the RTBT connects the rapid cycling synchrotron and the target window. This paper described the design requirements, technical solutions, and operating conditions of the vacuum system for the CSNS RCS to target beam transfer line. In addition, the fast valve protection system and its verification results were also expounded. The CSNS has been in operation for over three years, during this period, the beam

power has been gradually improved from 10KW to 100KW, and the vacuum system for RTBT has been operating stably.

MOPAB032 **Estimates of Collective Effects for the FCC-ee Pre-Booster Ring**
O. Etisken, *F. Antoniou, K. Oide, Y. Papaphilippou, F. Zimmermann (CERN) A.K. Çiftçi (Izmir University of Economics)*
The FCC-e^+e^- injector complex needs to produce and to transport high-intensity e^+ and e^- beams at a fast repetition rate for topping up the collider at its collision energy. Two different options are under consideration as pre-accelerator before the bunches are transferred to the high-energy booster: either using the existing SPS machine or designing a completely new ring. The purpose of this paper is to present the studies of collective effects with analytical estimates for both the pre-booster ring design options including space charge (SC), longitudinal micro-wave instability (LMI), transverse mode coupling instability (TMCI), ion effects, electron cloud (e-cloud), coherent synchrotron radiation (CSR), and intra-beam scattering (IBS).

MOPAB033 **Monochromatization of e^+e^- Colliders with a Large Crossing Angle**
V.I. Telnov *(BINP SB RAS)*
The relative center-of-mass energy spread at e^+e^- colliders is much larger than the widths of narrow resonances, which greatly lowers the resonance production rates of J/Psi, Psi-prime, Upsililon(nS), n=1-3. Thus, a significant reduction of the center-of-mass energy spread would open up great opportunities in the search for new physics in rare decays of narrow resonances, the search for new narrow states with small partial e^+e^- width. The existing monochromatization scheme is only suitable for head-on collisions, while e^+e^- colliders with crossing angles (the so-called Crab Waist collision scheme) can provide much higher luminosity. In this report, a new monochromatization method for colliders with a large crossing angle is discussed. The contribution of the beam energy spread to the spread of the center-of-mass energy is canceled by introducing an appropriate energy-angle correlation at the interaction point; the relative RMS mass spread of about (3-5)10^{-6} seems possible. Limitations of the proposed method are also considered. This monochromatization scheme is very attractive for the Upsilon-meson region and below.

MOPAB034 **VEPP-4M Collider Operation in High Energy**
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VEPP-4M is an electron positron collider equipped with the universal KEDR detector for HEP experiments in the beam energy range from 1 GeV to 6 GeV. A unique feature of VEPP-4M is the high precision beam energy calibration by resonant polarization technique which allows conducting of interesting experiments despite the low luminosity

of the collider. Recently we have started new luminosity acquisition run above 2 GeV. The hadron cross section was measured from 2.3 GeV to 3.5 GeV has been done. The luminosity run for gamma-gamma physics has been started. The luminosity at $\psi(1S)$-meson has been obtained. For the beam energy calibration the laser polarimeter is used. The paper discusses recent results from VEPP-4M collider.

MOPAB035 **Modified Lattice of the Compact Storage Ring in the cSTART Project at Karlsruhe Institute of Technology**

***A.I. Papash**, E. Bründermann, B. Härer, A.-S. Müller, R. Ruprecht, J. Schaefer, M. Schuh (KIT)*

A very large acceptance compact storage ring (VLA-cSR) is under design at the Institute for Beam Physics and Technology (IBPT) of the Karlsruhe Institute of Technology (KIT, Germany). The combination of a compact storage ring and a laser wakefield accelerator (LWFA) might be the basis for future compact light sources and advancing user facilities. Meanwhile, the post-LWFA beam should be adapted for storage and accumulation in a dedicated storage ring. Modified geometry and lattice of a VLA-cSR operating at 50 MeV energy range have been studied in detailed simulations. The main features of a new model are described here. The new design, based on 45^{o} bending magnets, is suitable to store the post-LWFA beam with a wide momentum spread (1% to 2%) as well as ultra-short electron bunches in the fs range from the Ferninfrarot Linac- Und Test- Experiment (FLUTE). The DBA-FDF lattice with relaxed settings, split elements, and higher-order optics of tolerable strength allows improving the dynamic aperture to an acceptable level. This contribution discusses the lattice features in detail and different possible operation schemes of a VLA-cSR.

MOPAB036 **Different Operation Regimes at the KIT Storage Ring KARA (Karlsruhe Research Accelerator)**

***A.I. Papash**, M. Brosi, E. Huttel, A. Mochihashi, A.-S. Müller, R. Ruprecht, P. Schreiber, M. Schuh, N.J. Smale (KIT)*

The KIT storage ring KARA operates in a wide energy range from 0.5 to 2.5 GeV. Different operation modes have been implemented at KARA, so far, the double-bend achromat (DBA) lattice with non-dispersive straight sections, the theoretical minimum emittance (TME) lattice with distributed dispersion, different versions of low-compaction factor optics with highly stretched dispersion function. Short bunches of a few ps pulse width are available at KARA. Low-alpha optics has been simulated, tested and implemented in a wide operational range of the storage ring and is now routinely used at 1.3 GeV for studies of beam bursting effects caused by coherent synchrotron radiation in the THz frequency range. Different non-linear effects, in particular residual high-order components of the magnetic field, generated in high-field superconducting wigglers have been studied and cured. Based on good agreement between computer simulations and experiments, a new operation mode at high vertical tune was implemented. The beam performance during user operation as well as at low-alpha regimes has

been improved. A specific optic with negative compaction factor was simulated, tested and is in operation.

MOPAB037 **On Possibility of Alpha-buckets Detecting at the KIT Storage Ring KARA (Karlsruhe Research Accelerator)**

A.I. Papash, *T. Boltz, M. Brosi, A.-S. Müller, R. Ruprecht, P. Schreiber, M. Schuh, N.J. Smale (KIT)*

Computer studies of longitudinal motion have been performed with the objective to estimate the possibility of detection of alpha-buckets at the KIT storage ring KARA (Karlsruhe Research Accelerator). The longitudinal equations of motion and the Hamiltonian were expanded to high order terms of the energy deviation of particles in a beam. Roots of third order equation for three leading terms of momentum compaction factor and free energy independent term were derived in a form suitable for analytical estimations. Averaged quadratic terms of closed orbit distortions caused by misalignment of magnetic elements in a ring lead to orbit lengthening independent of particle energy deviation. Particle transverse excursions were estimated and are taken into account. Simulations have been bench-marked on existing experiments at Metrology Light Source (MLS) in Berlin (Germany) and SOLEIL (France). Parameters of three simultaneous beams and alpha buckets at MLS and SOLEIL have been reproduced with high accuracy. A computer model of KARA was used to predict behavior and the dynamics of possible simultaneous beams in the ring.

MOPAB038 **Robustness Studies and First Commissioning Simulations for the SOLEIL Upgrade Lattice**

D. Amorim, *A. Loulergue, L.S. Nadolski, R. Nagaoka (SOLEIL)*

Diffraction limited light sources will use very strong focusing elements to achieve their emittance goal. The beam will therefore be more sensitive to magnet field and alignment errors. Impact of errors on the lattice proposed for the SOLEIL upgrade was studied with the Accelerator Toolbox (AT) code. The performance achieved with the imperfect lattice will be presented. In particular the effect of girders misalignment was also accounted for. As the lattice uses a large number of permanent magnets for the beam bending as well as the focusing, challenges arise in terms of beam correction. The correctors and BPMs location and number will be investigated to maximize their efficiency, and corrector magnet strength required to obtain a closed orbit will be studied. The commissioning strategy, and in particular the method used to achieve the first turns and a stored beam in the machine will also be exposed.

MOPAB039 **Comparison of Amplitude Tune Dependence of NSLSII Lattices with Models and its Relation to Long Term Circumference Change**

L.H. Yu, *G. Bassi, Y. Hidaka, B. Podobedov, V.V. Smaluk, G.M. Wang, X. Yang (BNL)*

The comparison of amplitude tune dependence measured for NSLSII

lattices with models indicated the large change of amplitude tune dependence over time apparently can not be solely explained by magnets variation or beta function changes, but it seems can be explained by energy changes. On the other hand, the energy change required by fitting with the amplitude tune dependence change is too large to be explained by the RF frequency change and the change of the sum of correctors in the period of the measurements. To explain this apparent contradiction, our analysis shows the long term storage ring circumference change can explain the apparent energy change. Our data indeed shows a seasonal change of the amplitude tune dependence over long term observation. This clearly also indicated a relation to long term closed orbit drift. Hence the current work indicates a new strategy to study how to use amplitude tune dependence as a guideline to analyze long term lattice parameter shifts and closed orbit drift, and improve the orbit and machine performance stability.

MOPAB040 **Hard X-Ray Medium-Energy FEL**

L.H. Yu *(BNL)*

We develop a tool for the calculation to study the conditions for a hard x-ray FEL oscillator based on an electron beam in the medium energy range from 3 to 4.5 GeV. We show that the approach developed by K.J. Kim et al. for the small-signal low gain formula can be modified so that the gain can be derived without taking the "no focusing approximation" adopted in the approach so that a strong focusing can be applied. We also derive the formula to allow for the gain calculation of harmonic lasing. The gain in this formula can be cast in the form of a product of two factors with one of them only depends on the harmonic number, undulator period, and gap. Thus this factor can be used to show that it is favorable to use harmonic lasing to achieve hard x-ray FEL working in the medium energy range and in the small-signal low gain regime.

MOPAB041 **Convergence Map With Action-Angle Based on Square Matrix for Nonlinear Lattice Optimization**

L.H. Yu*, Y. Hidaka, F. Plassard, V.V. Smaluk (BNL) Y. Hao (FRIB)*

We apply square matrix method to obtain in high speed a "convergence map", which is similar but different from frequency map. The convergence map is obtained from solving nonlinear dynamical equation by iteration of perturbation method and study the convergence. The map provides information about the stability border of dynamical aperture. We compare the map with frequency map from tracking. The result indicates the new method may be applied in nonlinear lattice optimization, taking the advantage of the high speed (about 10–50 times faster) to explore x, y and the off-momentum phase space.

MOPAB042 **Beam Dynamics Investigation for a New Project of Compton Back Scattering Photon Source at NRNU MEPhI**

V.S. Dyubkov, *I.A. Ashanin, M. Gusarova, Yu.D. Kliuchevskaia, M.V. Lalayan, S.M. Polozov, A.I. Pronikov, V.I. Rashchikov (MEPhI)*

The activities on physical models design of a compact monochromatic radiation source in the x-ray range based on inverse Compton scattering are started at NRNU MEPhI. There are comparison of two schemes of the photon source here: one of them is considered to be based on linac with variable energy of 20-60 MeV only and the other one is considered as accelerator complex where linac is supposed to be used as injector to medium size storage ring (energy up to 60 MeV). Preliminary results of linac structures and storage ring design as well as electron dynamics simulation are discussed

MOPAB043 **Validation of APS-U Beam Dynamics Using 6-GeV APS Beam**

L. Emery, *P.S. Kallakuri, R.R. Lindberg, A. Xiao (ANL)*

Several beam measurements at the Advanced Photon Sources were done with a lowered-energy beam of 6 GeV in order to verify or validate calculation codes and some predictions for the APS-U. Though the APS lattice is obviously different from that of the APS-U some aspects of the beams at 6 GeV are similar, for example, the synchrotron radiation damping rate. At 6 GeV, one can also store more current and run with a higher rf bucket allowing the characterization of larger momentum aperture lattices. We report measurements (or plans of measurements) on general instabilities thresholds, lifetime, and other subtle effects. The important topic of ion instabilities at 6 GeV is covered in a separate paper by J. Calvey at this conference.

MOPAB044 **Gas Bremsstrahlung Measurements in the Advanced Photon Source Storage Ring**

J.C. Dooling, *A.R. Brill, J.R. Calvey (ANL)*

In the Advanced Photon Source Upgrade storage ring (SR), small-aperture vacuum chambers provide limited conductance for pumping. Non-evaporable getter (NEG) coatings will be used in the SR to support the vacuum. Ion pumps and cold-cathode gauges are typically located away from the vacuum chamber transporting the beam. Measuring gas bremsstrahlung (GB) photons in low-conductance chambers provides a method to determine the pressure at the beam location. We report on GB measurements made in the ID-25 beamline. A Pb:Glass calorimeter radiator generates Cherenkov radiation when high-energy photons cause pair-production within the glass. A photomultiplier tube converts the light pulses to electrical signals. Data was obtained during normal machine operations starting in January 2020. Data collection was facilitated using a 4-channel ITech Beam Loss Monitor FPGA that allows for control of thresholds and attenuation settings in both counting and pulse-height acquisition modes. Count rates and spectra were recorded for the three primary fill patterns typically used during SR operations as well as during gas injec-

tion experiments; results of these measurements will be presented.

MOPAB045 **Measurements and Simulations of High Charge Beam in the APS Booster**

***J.R. Calvey**, J.C. Dooling, K.C. Harkay, K.P. Wootton, C. Yao (ANL)*

For the APS-Upgrade, swap-out injection will require the booster to support up to 17 nC bunch charge, several times what is used in the present APS. Booster injection efficiency drops sharply at high charge, and is the present bottleneck limiting high charge transport through the injectors. Particle tracking simulations have been used to understand what causes are limiting the injection efficiency, and to guide plans for improving it. In particular, bunch length blowup in the injected beam and beam loading in the RF cavities have been identified as the biggest factors. Simulations and measurements have also been done to characterize beam properties along the booster energy ramp. So far, a bunch charge of 12 nC has been successfully extracted from the booster.

MOPAB046 **Plan for Operating the APS-Upgrade Booster with a Frequency Sweep**

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The APS-Upgrade presents several challenging demands to the booster synchrotron. Swap-out injection requires the booster to capture a high charge bunch (up to 17 nC), accelerate it to 6 GeV, and maintain a low emittance at extraction for injection into the storage ring. To accommodate these conflicting demands, the RF frequency will be ramped between injection and extraction. However, the RF cavity tuners will remain static, which means the couplers will need to withstand a high reflected power at extraction. This paper presents a plan for a system that will meet the requirements for injection efficiency, extracted emittance, and equivalent power at the coupler. Results from tracking simulations and beam studies with a frequency ramp will also be shown.

MOPAB047 **A CAD Tool for Linear Optics Design: A Use Case Approach**

***J. Bengtsson** (HZB) , T.J.R. Nicholls, W.A.H. Rogers (DLS)*

The formula relevant for linear optics design of synchrotrons are derived systematically from first principles, i.e., an exercise in Hamiltonian dynamics. Equipped with these, the relevant use cases are then captured; for a streamlined approach. To enable professionals, i.e., software engineers, to efficiently prototype & architect a CAD tool available to mechanical engineers since the mid-1960s. In other words, robust design of a modern synchrotron is an exercise in/pursuit of the art of Engineering-Science.

MOPAB048 **Robust Design and Control of the Nonlinear Dynamics for BESSY-III**

***J. Bengtsson**, M. Abo-Bakr, P. Goslawski, A. Jankowiak, B.C. Kuske (HZB)*

The design philosophy for a robust prototype lattice design for BESSY

III, i.e., that is insensitive to small parameter changes, e.g. engineering tolerances - based on a higher-order-achromat, a la: SLS, NSLS-II, MAX IV, and SLS 2 - is outlined & presented. As usual, a well optimized design requires a clear understanding of the end-user requirements and close collaboration between the linear optics designer and nonlinear dynamics specialist for a systems approach.

MOPAB049 **Gyroresonant Acceleration of Electrons by an Axisymmetric Transverse Electric Field**

E.A. Orozco, *O. Otero Olarte (UIS)*

The acceleration of electrons using gyromagnetic autoresonance consist on the sustaint of the electron cyclotron resonant condition through of a magnetic field which increase on time, this scheme was propose by K. S. Golovanivsky. In this work, we considerer the gyroresonant acceleration of electrons using an axisymmetric transverse electric field and its limitations. The 2D acceleration of electrons by a TE011 cylindrical mode is studied numerically. The trajectory, energy and phase-shift between the electron transverse velocity and the electric field are determined by the numerical solution of the relativistic Newton-Lorentz equation using a finite difference scheme. The growth rate of the magnetic field obtained is such that it maintains the phase difference within the acceleration band. The study includes the evolution of the energy for electrons initially ubicated in diferents initial points. For an electron that starts from rest and located at the radial midpoint of the transverse central plane of the cavity, it is reaches an energy close to 560 keV in 625 cycles of the microwave field using an electric field amplitude of 1 kV/cm and a frequency of 2.45 GHz.

MOPAB050 **Spatial Autoresonance Acceleration of Electrons by an Axisymmetric Transverse Electric Field**

E.A. Orozco, *O. Otero Olarte (UIS)*

In this research, The autoresonance acceleration of electrons by an axisymmetric transverse electric field in presence of a stationary inhomogeneous magnetic field is studied. The dynamics of electrons is determined by the numerical solution of the relativistic Newton-Lorentz equation using a finite difference scheme. The inhomogeneous external magnetic field is generated with a three-coil system and calculated using the Biot-Savart law. The electrons move along a TE011 cylinder cavity in a stationary magnetic field whose axis coincides with the cavity axis. The magnetic field profile obtained is such that it keeps the phase difference between the electric field vector of the microwave mode and the velocity vector of the particle within the acceleration band. For an electron injected longitudinally with an energy of 1 keV and that starts at the radial midpoint of the cavity, it is accelerated up to an energy of about 185 keV using an electric field amplitude of 14 kV/cm and a frequency of 2.45 GHz at a distance of 14 cm.

MOPAB051 **Operation of the ESRF Booster with the New EBS Storage Ring**
N. Carmignani, *L.R. Carver, S.M. Liuzzo, T.P. Perron, S.M. White (ESRF)*
The Extremely Brilliant Source (EBS) has replaced the old ESRF Storage Ring (SR) during the 2019 one-year shutdown. The injector chain, composed of a Linac, a booster synchrotron, and two transfer lines, was not replaced. Nevertheless, some major hardware upgrades were anticipated prior to the long shutdown to ensure its long-term reliability. The shutdown interventions focused on reducing the machine circumference to cope with the new RF frequency of the SR. The status of the upgraded booster will be presented with a focus on the strategy used to lower horizontal emittance especially via emittance exchange.

MOPAB052 **Study of Beam Transmission Efficiency in Injection and Ramping Process of the HEPS Booster**
Y.M. Peng, *Z. Duan, Y. Jiao, C. Meng (IHEP)*
A high-bunch-charge mode, with a bunch charge of approximately 14.4 nC at 200 mA, has been proposed for the storage ring of High Energy Photon Source (HEPS). In order to reduce the bunch charge requirement to the injector, high-energy accumulation in the HEPS booster is proposed to combine with the on-axis swap-out injection. This allows reducing the requirement of bunch charge accelerated in HEPS booster (500 MeV-6 GeV) from over 14.4 nC to about 5 nC. It is expected that the overall transmission efficiency during the low energy injection and ramping process of the booster should be higher than 80% to fulfill the requirement. In this paper, we present the simulation results of transmission efficiency and potential improvement measures.

MOPAB053 **Progress of Lattice Design and Physics Studies on the High Energy Photon Source**
Y. Jiao, *Y. Bai, X. Cui, C.C. Du, Z. Duan, Y.Y. Guo, P. He, X.Y. Huang, D. Ji, H.F. Ji, S.C. Jiang, B. Li, C. Li, J.Y. Li, N. Li, X.Y. Li, P.F. Liang, C. Meng, W.M. Pan, Y.M. Peng, Q. Qin, H. Qu, S.K. Tian, J. Wan, B. Wang, J.Q. Wang, N. Wang, Y. Wei, G. Xu, H.S. Xu, F. Yan, C.H. Yu, Y.L. Zhao (IHEP) X.H. Lu (IHEP CSNS)*
The High Energy Photon Source (HEPS) is a 34-pm, 1360-m storage ring light source being built in the suburb of Beijing, China. The HEPS construction started in mid-2019. While the physics design has been basically determined, modifications on the HEPS accelerator physics design have been made since 2019, in order to deal with challenges emerging from the technical and engineering designs. In this paper, we will introduce the new storage ring lattice and injector design, and also present updated results of related physics issues, including impedance and collective effects, lattice calibration, insertion device effects, injection design studies, etc.

MOPAB054 **Start-to-End Simulation of a Free-Electron Laser Driven by a Laser-Plasma Wakefield Accelerator**

W. Liu, *Y. Jiao, S. Wang (IHEP)*

The rapid development of laser-plasma wakefield accelerator (LPA) has opened up a new possible way to achieve ultra-compact free-electron laser (FEL). To this end, LPA experts have made many efforts to generate electron beams with sub-micrometer emittance and low energy spread. Recently, a new laser modulation method was proposed for generating EUV coherent pulse in an LPA-driven FEL. The simulation demonstration of this scheme is based on the Gaussian beam. However, the distribution of the LPA beam is not Gaussian. To further verify the feasibility of the method mentioned above, a start-to-end simulation is required.

MOPAB055 **Generation of Coherent Attosecond X-ray Pulses in the Southern Advanced Photon Source**

W. Liu, *Y.Z. Zhao (IHEP CSNS) , Y. Jiao, S. Wang (IHEP)*

Southern Advanced Photon Source (SAPS) is a fourth-generation storage ring light source that has been considered for construction in Guangdong province of China, adjacent to the China Spallation Neutron Source. As a low-emittance storage ring, the natural emittance of SAPS is below 100 pm. One of the benefits is that the brightness is about 2 orders high than 3rd generation light sources. However, like many other storage ring-based light sources, the time resolution is limited by the electron bunch length in the range of picoseconds. In this work, we propose a new scheme for the generation of coherent attoseconds X-ray pulses with a high repetition rate in SAPS. A numerical demonstration of the scheme is presented.

MOPAB056 **Optimization of a TBA with Stable Optics and Minimal Longitudinal Dispersion and CSR-Induced Emittance Growth**

C. Zhang, *Y. Jiao (IHEP) C.-Y. Tsai (HUST)*

In the beam transfer line which often consists of dipoles to deflect the beam trajectory, longitudinal dispersion effect and emission of coherent synchrotron radiation (CSR) will lead to beam phase space distortion, thus degrading the machine performance. In this study, optimizations of a triple-bend achromat (TBA) cell are conducted using the multi-objective particle swarm optimization (MOPSO) method to suppress the CSR-induced emittance growth and minimize the longitudinal dispersion functions up to high orders, simultaneously. For the longitudinal dispersion function, results of three optimization settings are reported, which makes the TBA design first-order, second-order, and higher-order isochronous. Furthermore, we study the shortest possible beamline length of the higher-order isochronous TBA design, which may pave the way to designing a more compact beam transfer line.

MOPAB057 **Evaluation of Pulsed Septum Leakage Fields and Compensation for the Advanced Photon Source Upgrade**

***M. Borland**, M.S. Jaski, J. Wang (ANL)*

The Advanced Photon Source upgrade is considering two options for injection: vertical-plane injection with a DC Lambertson septum and horizontal-plane injection with a pulsed septum. In the latter case, pulsed leakage fields are a concern as they will cause transient beam motion and emittance dilution. In this paper, we describe results of modeling the effect of such leakage fields on the beam. We also evaluate methods of compensating for the leakage fields, including the limited time response of correction elements. Several septum drive-pulse shapes are considered and compared.

MOPAB058 **Swap-Out Safety Tracking for the Advanced Photon Source Upgrade**

***M. Borland**, J.S. Downey, M.S. Jaski (ANL)*

The Advanced Photon Source upgrade will operate in swap-out mode, which is similar to top-up but involves complete replacement of individual depleted bunches in a single shot. As with top-up, safety is a concern given that this process will take place with beamline shutters open. We describe the methods used to model swap-out safety, including creation and validation of a full ring lattice based on 3D field maps. We also describe a new method of implementing complex, intersecting channels for electron beams and photon beams, as well as a method of easily identifying potentially dangerous stray particles. Numerous potential errors (e.g., magnet shorts) were modeled, giving a reliable indication of performance of proposed stored beam and magnet interlocks.

MOPAB059 **Tools for Use of Generalized Gradient Expansions in Accelerator Simulations**

***M. Borland**, R.R. Lindberg, R. Soliday (ANL)*

A common assumption in simulation of accelerators is that the magnets can be approximated using a hard-edge model, perhaps with some edge effects implemented in an impulse approximation. This is usually a good assumption but ignores details of the longitudinal variation of the magnetic fields, which makes it straightforward to implement symplectic tracking. Use of generalized gradient expansions provides an alternative approach that can suppress numerical deficiencies that may be present in computed or measured 3D field maps. However, the computation of the expansions is not particularly straightforward. In this note, we describe several recently-developed tools that make this process fairly painless and allow tracking with such expansions in the program ELEGANT. We show several examples of using the tools for simulations related to the Advanced Photon Source Upgrade.

MOPAB061 **Comparison Simulation Results of the Collimator Aperture in HEPS Storage Ring**

***Y.L. Zhao**, Y. Jiao, N. Li (IHEP)*

The High Energy Photon Source (HEPS) is a 6 GeV diffraction-limited storage ring light source, which is under construction and planned to be in operation in 2025. To protect the sensitive elements from being damaged and reduce the radiation level of the site, collimators will be installed in the storage ring to localize the particle losses. The Touschek scattering is the main cause of particle losses during daily nominal operations. Based on the elegant simulations, we evaluate the physical design of the collimators, especially analysis the collimator performance with different collimator apertures. The simulation results will be introduced in this paper.

MOPAB062 **A Single Dipole Source for Broad-Band Soft Photon Beamlines in Diamond-II**

***M. Apollonio**, G. Cinque, H. Ghasem, A.N. Jury, I.P.S. Martin, R. Rambo (DLS)*

Diamond-II is a project based at Diamond Light Source for an upgrade towards a Storage Ring characterized by a reduction of a factor 20 in its natural emittance and a doubling of the number of straight sections. At Diamond-II the majority of existing beamline capacity should be maintained, while enhancing their performance thanks to the increase in brightness at the source points. The substantial modification of the lattice imposes a likewise re-design of the broad-band sources, presently based on standard dipoles. In this paper we discuss a possible solution for the IR/THz beamline B22 operating within a photon energy range between 1meV and 1eV. This proposal, ideal for low critical energy and single source point sources, entails the insertion of a dipole in one of the newly created mid-cell straights of the machine, while reducing the bending power of the nearby gradient dipoles. After performing the linear matching of the lattice, reproducing a comparable phase advance in the modified cell, we studied the non-linear dynamics of the system. Comparison of the main observables (Dynamic Aperture, Injection Efficiency and Lifetime) with the baseline case is discussed.

MOPAB063 **Commissioning Strategy for Diamond-II**

***M. Apollonio**, R.T. Fielder, H. Ghasem, I.P.S. Martin (DLS)*

At Diamond Light Source we are working on the upgrade towards a machine aimed at a factor 20 reduction in emittance and an increase of the capacity for beamlines. Crucially the success of the programme depends on the ability to inject and capture the electrons in the storage ring, and finally reach control of beam alignment and the linear optics. The paper presents the series of strategies adopted to achieve the commissioning of the machine, from the threading procedure ensuring the first turn of the electron beam, to the orbit corrections in the storage ring. Beam based alignment of the quadrupoles and skew quadrupoles is illustrated and restoration of the linear optics (LOCO)

for the storage ring is presented. Main performance parameters (Dynamic Apertures, Injection Efficiency and Lifetime) are calculated to evaluate the performance of the commissioned lattices.

MOPAB064 **The Design of Four Dump for High Energy Photon Source(HEPS)**
***Q.Y. Liu**, Z.J. Ma, H.Y. Shi, Q.B. Wang (IHEP)*
The High Energy Photon Source (HEPS) is the first fourth-generation light source under construction in China. It is located in Huairou Science city, Beijing. It is planned to be completed in the middle of 2025. HEPS is composed of Linac, low-energy transport line, booster, high-energy transport line, storage ring, and 14 beamline stations. It is designed to operate at 200 mA stored beam current with a top-up model at 6 GeV energy. The circumference of the storage ring is 1360.4 meters, and the emittance is less than 60 pm-rad. HEPS will become the most significant and brightest synchrotron X-ray source in the world when it is completed. HEPS has four beam-dumps. One is located at the end of the Linac with 1.875 W beam power at 500 MeV. One is located in the storage ring with 2.8 W beam power at 6 GeV. And the other two are used for energy analysis of the Linac, a high-energy analysis station (500 MeV,0.8 W) and a low-energy analysis station (60 MeV, 0.27 W). Through Monte Carlo simulation calculations, carbon, iron, lead as well as polyethylene are selected as the beam-dumps, shielding materials to make sure the dose rate outside the bulk shielding satisfies the requirements.

MOPAB065 **Optimization of the Lattice Replacement Options for the Next Generation Australian Synchrotron**
***R. Auchettl**, R.T. Dowd, Y.E. Tan (AS - ANSTO)*
The design of a next generation Australian Synchrotron replacement lattice is a multi-objective and multi-constrained problem. Our group was tasked to produce a low emittance design while re-using the existing tunnel infrastructure and injector system. Our objectives coupled with the set infrastructure constraints are not straightforward to achieve with manual design. Several variables act at cross-purposes to one-another, leading to a conflicting trade-off between objectives. Recently we have investigated replacement options for the Australian Synchrotron containing longitudinal gradient and reverse bends in the form of a 4BA (4-bend achromat) lattice. In this work, optimise the lattice design for a potential fourth generation Australian Synchrotron facility. We outline the baseline 4BA solution to the lowest emittance lattice that can reuse the existing tunnels and injector system.

MOPAB066 **Dual Octupole Emittance Growth Correction of the Compact-Light XFEL Bunch Compressors**
***R. Auchettl**, R.T. Dowd (AS - ANSTO) T.K. Charles (The University of Liverpool)*
An optimized CompactLight X-Ray Free Electron Laser (FEL) bunch compressor design is presented. In this work, we insert an octupole into the center of the two sequential bunch compressors. We show

how this scheme can adjust the compression, while correcting the undesirable peak current profile and emittance growth.

MOPAB068 **Collective Effects Studies for the SOLEIL Upgrade**
***A. Gamelin**, D. Amorim, P. Brunelle, W. Foosang, A. Loulergue, L.S. Nadolski, R. Nagaoka, R. Ollier, M.-A. Tordeux (SOLEIL)*
The SOLEIL upgrade project aims to replace the actual SOLEIL storage ring by a 4th generation light source. The project has just finished its conceptual design report (CDR) phase. Compared to the SOLEIL storage ring, the upgraded storage ring design includes many new features of 4th generation light sources that will impact collective effects, such as reduced beam pipe apertures, a smaller momentum compaction factor and the presence of harmonic cavities (HC). To mitigate them, we rely on several damping mechanisms provided by the synchrotron radiation, the transverse feedback system, and the HC (Landau damping and bunch lengthening). This article presents a first estimate of the collective effects impact of the upgraded design.

MOPAB069 **Equilibrium Bunch Density Distribution With Multiple Active and Passive RF Cavities**
***A. Gamelin** (SOLEIL) N. Yamamoto (KEK)*
This paper describes a method to get the equilibrium bunch density distribution with an arbitrary number of active or passive RF cavities in uniform filling. This method is an extension of the one presented by M. Venturini which assumes a passive harmonic cavity and no beam loading in the main RF cavity.

MOPAB070 **mbtrack2, a Collective Effect Library in Python**
***A. Gamelin**, W. Foosang, R. Nagaoka (SOLEIL)*
This article introduces mbtrack2, a collective effect library written in python3. The idea behind mbtrack2 is to build a coherent object-oriented framework to work on collective effects in synchrotrons. mbtrack2 is composed of different modules allowing to easily write scripts for single bunch or multi-bunch tracking using MPI parallelization in a transparent way. The base of the tracking model of mbtrack2 is inspired by mbtrack, a C multi-bunch tracking code initially developed at SOLEIL. In addition, many tools to prepare or analyse tracking simulations are included.

MOPAB071 **Progress with the Booster Design for the Diamond-II Upgrade**
***I.P.S. Martin**, C. Christou, M.P. Cox, R.T. Fielder, J. Kallestrup, A. Shahveh, W. Tizzano (DLS) A.D. Brynes, J.K. Jones, B.D. Muratori, H.L. Owen (STFC/DL/ASTeC)*
Efficient injection into the Diamond-II storage ring will require an emittance and bunch length substantially below the values produced from the existing booster. Whilst an earlier design for a replacement based on TME cells was able to meet the target values of <30 nm.rad and <40 ps respectively, several technical constraints have led to a rethink of this solution. The revised booster lattice utilises a larger number of cells based on combined-function magnets with lower peak

fields that still meets the emittance and bunch length goals. In addition, the new ring has been designed to have low impedance to maximise the extracted charge per shot. In this paper we describe the main features of the lattice, present the status of the engineering design and quantify the expected performance.

MOPAB072 **Single-Bunch Thresholds for the Diamond-II Storage Ring**
***T. Olsson**, R.T. Fielder (DLS)*
The proposed Diamond Light Source upgrade will see the storage ring replaced with a multibend achromat lattice, increasing the capacity of the facility whilst reducing the emittance and providing higher brightness for the users. As part of the design work, tracking studies have been performed to determine the single-bunch thresholds including both the resistive-wall and geometric contributions to the impedance. As the machine design also foresees a third order harmonic cavity, the paper also provides an initial assessment of the effects of bunch lengthening on the single-bunch thresholds.

MOPAB073 **Some Simulation Results on the Beam Lost at the Collimator During Beam Dumping in HEPS**
***X. Cui**, Y. Jiao, Y.L. Zhao (IHEP)*
The High Energy Photon Source (HEPS) is a 6 GeV storage ring light source under construction in China. Several collimators installed in the vacuum chamber will be used as beam dump in the storage ring operation. Preliminary simulations showed that the temperature rise caused by the beam power deposited on the collimators will far exceed the melting point of the collimator material. In order to cure this problem, special kickers are proposed to be installed in the ring to modulate the beam during beam dumping, thereby increasing the size of the beam hit on the collimators. In this article, some simulation results of the density of particles on the collimators during beam dumping for different HEPS lattice and different kicker parameters are shown.

MOPAB074 **Preliminary Study of Design Method for Hybrid MBA Lattice**
***J.J. Tan**, Z.H. Bai, Z.L. Ren, L. Wang, J.H. Xu, P.H. Yang (USTC/NSRL) Q. Zhang (INEST)*
Nonlinear optimization of hybrid multi-bend-achromat (HMBA) lattice is a difficult task due to its quite limited variables of multipole magnets. As a result, it is necessary to consider nonlinear potential of the lattice in its linear design. Nonlinear dynamics can be estimated by nonlinear driving terms and detuning terms. In this paper, we propose a design method for HMBA lattice. In this method, objective functions include emittance and two indicators of nonlinear dynamics, which consist of nonlinear driving terms and detuning terms. As an example, an HMBA lattice for a 2.2 GeV storage ring with circumference of 460.8 m was designed to demonstrate the method.

MOPAB075 **Proposal of the Southern Advanced Photon Source and Current Physics Design Study**

S. Wang, *J. Chen, L. Huang, Y. Jiao, B. Li, Z.P. Li, W. Liu, S.Y. Xu (IHEP) Y. Han, X.H. Lu, Y.Z. Zhao (IHEP CSNS) X. Liu (Department of Energy Sciences, Tokyo Institute of Technology)*

It has been considered to build a mid-energy fourth-generation storage ring light source neighbouring the China Spallation Neutron Source, in Guangdong Province, the south of China. The light source is named the Southern Advanced Photon Source (SAPS). Preliminary physics design studies on the SAPS have been implemented for a few years. In this paper, we will describe considerations of technical roadmap and key parameter choice for this light source, and introduce the up-to-date lattice designs and related physics studies on the SAPS.

MOPAB077 **Anomaly Detection in Accelerator Facilities Using Machine Learning**

A. Das *(Stanford University) M. Borland, L. Emery, X. Huang, H. Shang, G. Shen (ANL) D.F. Ratner (SLAC) R.M. Smith, G.M. Wang (BNL)*

Synchrotron light sources are user facilities and usually run about 5000 hours per year to support many beamlines operations in parallel. Reliability is a key parameter to evaluate machine performance. Even many facilities have achieved >95% beam reliability, there are still many hours of unscheduled downtime and every hour lost is a waste of operation costs along with a big impact on individual scheduled user experiments. Preventive maintenance on subsystems and quick recovery from machine trips are the basic strategies to achieve high reliability, which heavily depends on experts' dedication. Recently, SLAC, APS, and NSLS-II collaborated to develop machine-learning-based approaches aiming to solve both situations, hardware failure prediction and machine failure diagnosis to find the root sources. In this paper, we report our facility operation status, development progress, and plans.

MOPAB078 **CB-II Prototype Test Stand Design**

G.M. Wang, *F.A. DePaola, L. Doom, R.P. Fliller, III, R. Gambella, T.V. Shaftan, S.K. Sharma (BNL)*

Modern synchrotron light sources are competing intensively to increase X-ray brightness and, eventually, approach the diffraction limit, which sets the final goal of lattice emittance. Recently, we propose a new optics solution aimed at reaching low emittance, using a lattice element "Complex Bend". The Complex Bend is a sequence of dipole poles interleaved with strong alternate focusing so as to maintain the beta-function and dispersion oscillating at low values. By integrating this element in the NSLS-IIU upgrade, the designed lattice emittance is around 30 pm-rad. To prove the feasibility of this new design, we have planned the key element prototype test, in the beamline with 200 MeV beam energy. Currently, we have finished the designed and fabricated the prototype complex bend, with a gradient at 140 T/m. In this

paper, we report the test beamline design and commissioning plans.

MOPAB079 **Experience of the first six years operations and plan in NSLS-II**
G.M. Wang *(BNL)*
NSLS-II is a 3 GeV third-generation synchrotron light source at BNL. The storage ring was commissioned in 2014 and began its routine operations in the December of the same year. Since then, we have been continuously installing and commissioning new insertion devices, their front-ends, and beamlines. At this point, the facility hosts 28 operating beamlines from various radiation sources, including damping wiggler, IVU, EPU, 3PW, and bending magnets for infrared beamlines. Over the past six years, the storage ring performance continuously improved, including 500 mA with limited insertion devices close due to RF power limitation and routinely 400 mA top off operation, >95% operation reliability, maintenance of beam motion short- and long-term stability. In this paper, we report NSLS-II accelerator operations experience and plans for future facility developments.

MOPAB081 **Feasibility Study of Using Multipole Injection Kicker (MIK) and Sextupole for TPS Injection**
K.-K. Lin*, C.K. Chan, C.-C. Chang, H.-P. Chang, Y.-S. Cheng, M.-S. Chiu, Y.L. Chu, C.-S. Fann, K.T. Hsu, S.Y. Hsu, K.H. Hu, J.C. Huang, C.-S. Hwang, S.H. Lee, C.Y. Wu, C.S. Yang (NSRRC) S.-Y. Lee (Indiana University)*
Feasibility of applying MIK/sextupole injection at TPS is evaluated in this study. This study adopts layout similar to MAX IV injection scheme and their collaboration project with SOLEIL for MIK. Although the light source service fulfills present user needs, yet the increasing demands for a transparent injection is inevitable in the foreseeable future. Notice that this preliminary study is constrained under routine user operation, the optional pinger ceramic chamber, located between existing injection kicker-3 and kicker-4, is chosen for the purpose. Kick strength requirement of the MIK is estimated with minor trajectory adjustment upstream at the booster to storage ring transfer line. Since the realization of MIK fabrication takes time, therefore a fast-built sextupole is prepared to examine the proposed injection scheme beforehand. The test result will be described in this report.

MOPAB082 **Implementation of Using IGBT-Switch Based Pulser for TPS Booster Extraction Kickers**
C.-S. Fann*, H.-P. Chang, C.L. Chen, Y.-S. Cheng, K.T. Hsu, S.Y. Hsu, K.-K. Lin, K.L. Tsai, C.Y. Wu (NSRRC)*
A pair of thyratron-switch-based pulse-forming-network (PFN) pulser has been operating successfully in the past 5 years for TPS booster extraction kickers. In order to improve the flattop of drive-current pulse and to extend possible electron bunch train adjusting knob required, an IGBT-switch-based pulser has been designed, fabricated, and installed onto the TPS booster for its characteristics verification. In this report, the overall technical considerations for the pulser upgrade is

described and its beam commissioning results is given for illustration purpose.

MOPAB084 **Acceptance Tests and Installation of the IVU and Front End for the XAIRA Beamline of ALBA**

***J. Campmany**, J. Marcos, V. Massana (ALBA-CELLS Synchrotron)*

XAIRA is a new beamline being built at ALBA synchrotron for macromolecular crystallography (MX) devoted to the study of small bio crystals. It aims at providing a full beam with a size of 3x1 μm^2 FWHM (hxv) and flux of $>3{\cdot}10^{12}$ ph/s (250 mA in Storage Ring) at 1 Å wavelength (12.4 keV) to tackle MX projects for which only tiny (<10 μm) or imperfect crystals are obtained. Besides, XAIRA aims at providing photons at low energies, down to 4 keV, to support MX experiments exploiting the anomalous signal of the metals naturally occurring in proteins (native phasing), which is enhanced in the case of small crystals and long wavelengths. To this end, an in-vacuum undulator has been built by a consortium between Kyma and Research Instruments companies. In this paper, we present the results of the Site Acceptance Tests made at ALBA using a new bench developed to measure closed structures, and also the steps done for its installation in the ALBA tunnel.

MOPAB085 **Design of a Short Multipole Wiggler and the Front End for the New ALBA Beamline Faxtor**

***J. Campmany**, J. Marcos (ALBA-CELLS Synchrotron)*

FAXTOR is a new hard XR tomography beam line that is being built at ALBA in order to fulfil the needs that cannot be currently covered by the MISTRAL VUV and soft XR beamline. This beam line needs a small source size as well higher than 10^{12} Photons per second through an aperture of 4x1 mm2 in the whole range 5 to 60 KeV, for a current of 250 mA in Storage Ring with source size maintained below 310 μm horizontal and 25 μm vertical. The contract was awarded to AVS-US Company. In this paper we present the design finally selected as well as the preliminary design carried out by manufacturer to implement the conceptual model designed by ALBA.

MOPAB086 **Design of Front End and a 3-Pole-Wiggler as a Photon Source for BEATS Beamline at SESAME**

***J. Campmany**, J. Marcos (ALBA-CELLS Synchrotron) M. Al Nadjawi, M. Attal, G. Lori (SESAME) I. Cudin (Elettra-Sincrotrone Trieste S.C.p.A.) S. Guiducci (INFN/LNF) P. Van Vaerenbergh (ESRF)*

BEATS is an international collaboration funded by EU in order to design and implement an XR tomography beam line in SESAME Jordanian synchrotron. ALBA contribution consists in the design of the photon source and the Front End elements. In this paper we present the conceptual designs of both the 3-pole wiggler uses as photon source as well as the Front End elements designed for the beamline.

MOPAB087 **Design of a Multi-bunch Feedback Kicker in SPEAR3**
***K. Tian**, J.B. Langton, NL. Parry, J.A. Safranek, J.J. Sebek (SLAC)*
The new Multi-bunch feedback kickers have been designed to replace the current device loaned from ALS. In this paper, we first present the specification of the kickers based on the beam physics requirements. Then the mechanical design of the kicker is elaborated. Numerical simulations, both in time domain and in frequency domain, are conducted for evaluating the shunt impedance and beam coupling impedance of the kicker. Surface heating induced from the beam or the external source is estimated from the numerical results as well.

MOPAB088 **Beam-Based Measurement on Ferrite Dampers Performance in an in Vacuum Undulator**
***K. Tian**, A. Ringwall, J.J. Sebek (SLAC)*
In this paper, we first present the tracking studies for SPEAR3 with the new BL17 ID and estimate its impact on the dynamic aperture of the low emittance lattice. Then the ferrite dampers installations in the device is briefly reviewed. After that, we will show that, based on beam-based measurements, the performance of the dampers is as being expected from earlier numerical studies.

MOPAB089 **Effect of Different Models of Combined-function Dipoles on the HEPS Parameters**
***Y.Y. Guo**, Y. Jiao, N. Li (IHEP)*
The high energy photon source (HEPS) is a 6 GeV, kilometer-scale storage ring light source being built in Beijing, China. In the current ring lattice, the combined-function dipoles are used and assumed to have constant dipole field. However, in the actual magnet design, an eccentrically placed quadrupole is adopted, in which the bending field along the trajectory is not constant. In this paper, we will present the effect of the two models of combined-function dipoles on the parameters of the storage ring.

MOPAB090 **Status of HEPS Insertion Devices Design**
***X.Y. Li**, Y. Jiao, H.H. Lu, S.K. Tian (IHEP)*
HEPS is a 4th generation light source with the energy of 6 GeV and ultralow emittance of 34 pm.rad. A total of 14 beamlines with 19 insertion devices has been planned in the first phase, including 6 cryogenic undulators, 5 in-vacuum undulators, and two special non-planar IDs. The schemes and parameters of all the IDs are planned to be determined in this year. We report on the status of the design of these IDs and their effects on beam dynamics.

MOPAB091 **Injection Section Upgrading with the Septum-Magnet Replacement in KEK-PF Ring**
***C. Mitsuda**, K. Harada, N. Higashi, T. Honda, Y. Kobayashi, H. Miyauchi, S. Nagahashi, N. Nakamura, T. Nogami, T. Obina, M. Tadano, R. Takai, H. Takaki, Y. Tanimoto, T. Uchiyama, A. Ueda (KEK)*
In 2015, the water leakage happened at the cooling pipe of the in-vacuum septum magnet installed into the injection point. Because

the maintenance of the leakage needed the total replacement of the magnet, the water circulation was stopped permanently, and accordingly, the light absorber was installed upstream in the storage ring to prevent the synchrotron light of the bending magnet from coming to the septum wall. This treatment temporally worked well, but the beam injection efficiency was decreased to about 30% due to the physical aperture narrowed by the absorber. With the desired replacement of septum magnet to maintainable out-vacuum type, the injection section upgrading was simultaneously planned to recover and improve the injection efficiency. In this upgrade, the injection beam is closed to the stored beam more than before by adapting the thinner septum structure as a way to improve the injection efficiency. And some new ideas are introduced in the part of monitor and beam duct, for example, realtime beam monitor, thinner Inconel duct. The detailed design of the upgraded injection section and technical points will be reviewed in this conference.

MOPAB092 **Project of Wuhan Photon Source**

***H.H. Li**, Y. Deng, J.H. He, Y. Nie, L. Tang, J. Wang, Y.X. Zhu (IAS)*

Wuhan Photon Source (WHPS) has been designed as a fourth-generation light source, which consists of a low energy storage ring (1.5 GeV), a medium energy storage ring (4.0 GeV), and a linac working as a full energy injector. It has been planned to build the low energy light source first as the Phase I project, and then the medium energy light source after its completion. The low energy storage ring has been optimized with the main design parameters as following: An 8-cell, 500 mA storage ring, with a circumference of 180 m and nature emittance 238.4 pm-rad. Based on hybrid-7BA lattice structure, it reaches the soft X-ray diffraction limit. And at the middle of each cell, a 3.5 T superB magnet is used to extend the photon energy to the hard X-ray region. The swap-out injection is chosen due to the small dynamic aperture and a full energy S-band LINAC will be used as its injector. A 3rd harmonic cavity is designed for bunch lengthening to keep a sufficient lifetime. More details of the WHPS phase I project will be described in this paper.

MOPAB093 **Operational Status of Photon Factory Light Sources**

***T. Honda**, Y. Kobayashi, C. Mitsuda, S. Nagahashi, R. Takai, H. Takaki (KEK)*

One of the recent topics of Photon Factory light sources, PF-ring and PF-AR, is a construction of a GeV-class beamline for testing detectors at the PF-AR. The bremsstrahlung photons generated by a thin carbon wire are brought to a copper target to generate e^+e^- pairs. Sufficient count rates can be expected when the thin wire touching halo of the stored beam, and the test beamline can be used without disturbing the synchrotron radiation experiments. In addition to the usual 6.5-GeV operation, a low-energy operation at 5-GeV was started recently at PF-AR to secure operation time by saving electricity costs. At the PF-ring, the injection section has been upgraded with the septum-magnet

replacement. By the top-up injection and improved bunch feedback, the hybrid-fill mode operation has become convenient for both single-bunch users and multi-bunch users, and about 30% or 40% of the user time is scheduled as the hybrid-fill mode now.

MOPAB095 **Concept Design for the CLS2 Accelerator Complex**
M.J. Boland *(University of Saskatchewan)*
The Canadian Light Source has been in operation since 2005 and is now looking at a design concept to upgrade to a fourth generation storage ring. A brief overview is given of a possible accelerator complex layout, including some details on the lattice design and injection system. A full energy linac is being explored as an option for top-up injection and to future proof the facility for a potential FEL upgrade in the future.

MOPAB096 **Rocking Curve Imaging Experiment at SSRL 10^{-2} Beamline**
A. Halavanau*, J.P. MacArthur, G. Marcus, R.A. Margraf, Z. Qu, T. Sato, D. Zhu (SLAC)*
Stanford Synchrotron Radiation Lightsource (SSRL) serves a wide scientific community with its variety of X-ray capabilities. Recently, we have employed a wiggler source located at beamline 10^{-2} to perform high resolution rocking curve imaging (RCI) of diamond and silicon crystals. In-house X-ray RCI capability is important for the upcoming cavity-based x-ray source development projects at SLAC, such as cavity-based XFEL (CBXFEL) and X-ray laser oscillator (XLO). In this proceeding, we describe theoretical considerations, and provide experimental results, validating the design of our apparatus. We also provide a plan for future improvements of the RCI@SSRL program.

MOPAB097 **Dual Color Self-Seeding at LCLS-II Soft X-Ray Undulator Line**
A. Halavanau*, D. Cocco, E. Hemsing, G. Marcus, D.S. Morton (SLAC) G.R. Wilcox (Cornell University)*
A new grating design is examined for the soft x-ray self-seeding system (SXRSS) at LCLS-II to ultimately produce stable two-color XFEL pulses. The grating performance is analyzed with Fourier optics methods. The final XFEL performance is assessed via full numerical XFEL simulations that substantiate the feasibility of the proposed design.

MOPAB098 **Multi-Bunch LCLS Improvement Plan**
A. Halavanau*, S. Carbajo, F.-J. Decker, A.K. Krasnykh, A.A. Lutman, A. Marinelli, C.E. Mayes, D.C. Nguyen (SLAC)*
Current and future experiments at LCLS require XFEL pulse trains of variable time separation. The cavity based XFEL (CBXFEL) project requires multiple pulses separated by 220 ns, the X-ray Laser Oscillator (XLO) uses 15 ns spaced pulse trains and Matter under Extreme Conditions (MEC) experiments need a shortly spaced (less than 5 ns) pulse trains. In this proceeding, we discuss the LCLS multi-bunch improvement plan and report on its recently status and progress.

MOPAB099 **Intensity Fluctuations Reduction in the Double-Bunch FEL at LCLS**
G. Zhou, *A. Halavanau, C. Pellegrini (SLAC)*
We report results on the performance of the double-bunch FEL (DBFEL) system at LCLS, including start-to end simulations and a list of scientific applications. We also discuss how to reduce intensity DBFEL fluctuations, extending a recently proposed (Phys. Rev. Lett. 125, 044801 (2020)) enhanced self-seeding scheme to the hard X-ray regime.

MOPAB100 **Progress report on population inversion-based X-ray laser oscillator**
A. Halavanau, *U. Bergmann, D. DePonte, F.-J. Decker, A.A. Lutman, C. Pellegrini (SLAC)*
The population inversion X-ray Laser Oscillator (XLO) is a fully coherent, transform limited hard X-ray source. It operates by repetitively pumping inner-shell atomic transitions with an XFEL, in a closed Bragg cavity. XLO will produce very bright monochromatic X-ray pulses for applications in quantum optics, X-ray interferometry and metrology. We report the progress to build the first XLO operating at the copper alpha line, using LCLS 9 keV SASE X-ray pulses as a pump.

MOPAB101 **Hollow Beam Generation at FACET-II**
A. Halavanau, *S.J. Gessner (SLAC) J.B. Rosenzweig (UCLA)*
In this proceeding, we investigate the spatial laser shaping techniques, required for a hollow electron beam generation at FACET-II facility. We especially focus on the case of a circular beamlet arrangement, also known as 'necklace' beams. We study, via numerical simulations, the resulting e-beam dynamics in the FACET-II photoinjector, beam propagation through the high energy section, as well as possible experimental applications of the 'necklace' beams.

MOPAB102 **CSR Impedance Calculation for HEPS Storage Ring**
H.S. Xu, *X.Y. Li, N. Wang (IHEP)*
High Energy Photon Source (HEPS) is under construction in Beijing, China. The relatively complete impedance model has been built up based on the element-by-element impedance calculation. However, Coherent Synchrotron Radiation (CSR) impedance, which might affect the longitudinal performance of the beam, was not included in the impedance model of the HEPS storage ring in the preliminary design stage. For completeness, we would like to take the CSR impedance into consideration. The most important contributions to the total CSR impedance come from the bending magnets and insertion devices. We therefore calculate the CSR impedance from both above mentioned elements in HEPS storage ring. The influence of the CSR impedance on the microwave instability threshold is studied and presented.

MOPAB103 **Study of Transverse Oscillation Coupling and Possibility of Its Minimization in SKIF (Novosibirsk)**

D. Leshenok *(BINP) G.N. Baranov, E.B. Levichev, S.A. Nikitin (BINP SB RAS)*

The vertical emittance and, in general, the vertical beam size and angular divergence are of paramount importance in the SKIF (Russian acronym for Siberian Circular Photon Source) project developed in Novosibirsk. Therefore, a detailed simulation of the corresponding influence of possible errors in the storage ring was carried out with cross-validation by different methods. Variants of cross-coupling correction are proposed and modeled to obtain a vertical emittance of the order of one picometer simultaneously with minimizing vertical dispersion.

MOPAB105 **Simulation Study of Direct RF Feedback by using the MBTRACK code**

N. Yamamoto *(KEK)*

The direct RF feedback has been employed as an additional function of low level RF system in recent storage rings. The direct RF feedback reduces the cavity impedance as seen by the beam, and allows us to reduce the beam loading effect for maximizing the stored beam current. For the purpose to investigate the impact of the direct RF system to the bunch lengthening system which is key technology for diffraction-limited synchrotron light sources to maintain their extreme low emittance, the direct RF feedback has been implemented to the beam tracking code MBTRACK. In the presentation, the detail of the implemented function and a result of benchmarking tests for the static Robinson instability will be reported. Furthermore, the impact for the bunch lengthening system will be also discussed.

MOPAB106 **Enhancing the MOGA Optimization Process at ALS-U With Machine Learning**

Y. Lu*, M.P. Ehrlichman, T. Hellert, S.C. Leemann, H. Nishimura, C. Sun, M. Venturini (LBNL)*

The bare lattice optimization for the linear and nonlinear ALS-U storage ring lattice, even without reverse bending, comprises 11 degrees of freedom (DoF) and is therefore a very complex and highly time-consuming process. This design process relies heavily on multi-objective genetic algorithms (MOGA), usually requiring many months of experienced scientists' time. The main problem lies in having to evaluate numbers of candidate lattices due to the stochastic process of MOGA. Although almost all of these candidates are eventually rejected, they nevertheless require extensive particle tracking to arrive at a Pareto front. We therefore propose a novel Machine Learning (ML) pipeline that nonlinear tracking is replaced by two well-trained neural networks (NNs) to predict dynamic aperture (DA) and momentum aperture (MA) for any lattice candidate. Initial training of these models takes only several minutes on conventional CPUs while predictions are then rendered near instantaneously. We present this novel method and demonstrate the resulting orders of magnitude speedup of the ML-

enhanced MOGA process on a 2-DoF problem as well as first results on a more complex 11-DoF problem.

MOPAB107 **RF Plans for the Diamond-II Upgrade**

***C. Christou**, P. Gu, P.J. Marten, S.A. Pande, A.F. Rankin (DLS)*

The RF system for the proposed Diamond-II upgrade will be based on normal-conducting EU HOM-damped cavities powered by high powered solid state amplifiers and controlled by digital low level RF systems built on the microTCA platform. Reasons for these design choices are discussed, and experience of the selected technologies in the Diamond-I ring are reviewed. The storage ring will also include a third harmonic cavity, and the different design options for this device are discussed. RF design of the booster ring is presented, and details are given of an upgraded linac and gun design intended to improve the charge delivered for top-up.

MOPAB108 **ESRF-EBS 352.37 MHz Radio Frequency System**

***J. Jacob**, P.B. Borowiec, A. D'Elia, G. Gautier, V. Serrière (ESRF)*

The ESRF 352 MHz Radio Frequency (RF) system has been upgraded and tailored to the new 4th Generation Extremely Brilliant Source EBS, that was installed in 2019 and commissioned in 2020. The five former five-cell cavities were replaced with 13 single cell strongly HOM damped cavities that were developed in house, 10 of which are powered from existing 1 MW klystron transmitters. The remaining three cavities are individually fed by three 150 kW solid state amplifiers. All this required a reconstruction in record time of an elaborate WR2300 waveguide network. The low level RF system as well as the cavity and transmitter control system have been rebuilt. The RF design, commissioning and operation experience will be reported, including plans for a 4th harmonic RF system for bunch lengthening to further improve the performance of the new EBS ring.

MOPAB109 **A Lattice for PETRA IV Based on the Combination of Different Arc Cell Designs**

***J. Keil**, I.V. Agapov, R. Brinkmann (DESY)*

The 6 GeV synchrotron light source PETRA III at DESY is in user operation since 2009. In 2016 investigations of upgrading PETRA III into a diffraction limited storage ring at 10 keV have been started. The ambitious goal is to achieve an emittance in the range of 10^{-30} pm*rad. For the conceptual design report (CDR) of PETRA IV a lattice based on hybrid multi-bend achromats (HMBA) has been chosen. It consists of eight arcs connected by eight long straight sections whereas each arc consists of eight HMBA cells. While this lattice variant has an advantage in terms of simplicity of magnet and girder design it is challenging in regards of multipole strengths and beam dynamic properties. However, only a part of all eight arcs will be used for undulator beamlines. This offers the possibility to choose a more relaxed optics design in the arcs without undulators while preserving the ultra-low emittance. In addition, the use of reverse bends in the undulator cells allows smaller beta functions at the undulators for an increased brilliance. The design

and the beam dynamic properties of this combi lattice are discussed in this paper and compared to the lattice based on HMBA cells.

MOPAB110 **An Electron Synchrotron Lattice Based on Theoretic Minimal Emittance Cell**

H.C. Chao *(DESY)*

A design of an electron synchrotron featuring the theoretic minimal emittance (TME) cells is presented. It has 32 superperiods and the circumference is around 300 m. It offers versatile functions with the equilibrium emittance less than 10 nm-rad at 6 GeV. The beam energy can go up to 7 GeV. Locations with proper phase advances are found to form effective vertical orbit bumps, which can be used for the injections and extraction. A tune scan study shows the sweet spot for the working point. Some discussions of other usages and studies of synchro-betatron coupling effects are also included in this article.

MOPAB112 **A Modified Hybrid 6BA Lattice for the HALF Storage Ring**

Z.H. Bai*, G.Y. Feng, T.L. He, W. Li, W.W. Li, G. Liu, Z.L. Ren, L. Wang, P.H. Yang, S.C. Zhang, T. Zhang (USTC/NSRL)*

In this paper, we propose a modified hybrid 6BA lattice as the baseline lattice of the Hefei Advanced Light Facility (HALF) storage ring. Similar to the Diamond-II lattice, the proposed lattice cell has one long straight section and one mid-straight section; but the two bend units adjacent to the mid-straight are LGB/RB units (LGB: longitudinal gradient bend, RB: reverse bend), which can give both lower emittance and shorter damping times. The designed HALF storage ring, with an energy of 2.2 GeV and 20 lattice cells, has a natural emittance of about 85 pm·rad.

MOPAB113 **A Low-emittance Booster Lattice Design for the SOLEIL Upgrade**

M.-A. Tordeux*, A. Loulergue, R. Nagaoka (SOLEIL) , Z.H. Bai, G. Liu, T. Zhang (USTC/NSRL)*

The SOLEIL storage ring upgrade will require an injected beam with small transverse and longitudinal sizes. To meet this requirement, the present booster also needs to be upgraded, aiming to reduce the emittance below 10 nm·rad. A multi-bend achromat lattice is designed in this context for the booster upgrade, which consists of two superperiods to respect the present race-track configuration. The lattice is a 16BA HOA (Higher-Order Achromat) type lattice, composed of 14 unit cells, 2 matching cells and a long straight section, and combined-function bending magnets are used in the unit cells to both save space and reduce the emittance. The natural emittance of the designed booster is 5.2 nm·rad at the final energy of 2.75 GeV. This paper presents the general constraints, linear lattice design and nonlinear dynamics optimization for the booster upgrade.

MOPAB114 **Development of a Decoherence Kicker for the ALS Upgrade Project (ALS-U)**

***C. Sun**, S. De Santis, M.P. Ehrlichman, T. Hellert, T. Oliver, G. Penn, C. Steier, M. Venturini, W.L. Waldron (LBNL)*

The Advanced Light Source (ALS) at Lawrence Berkeley National Laboratory is upgrading the existing storage-ring lattice to a nine-bend-achromat lattice with on-axis swap-out injection. The upgraded storage ring will provide a highly focused beam of about 10 um in both horizontal and vertical directions with a single bunch train energy of about 60 J at 2.0 GeV. Such a small and intense beam could cause damage to the transfer line vacuum chambers in case of extraction element failures or damage to the storage ring vacuum chamber in case of RF failures. To mitigate these potential damages, a fast kicker magnet (so-called decoherence kicker) will be installed in the ALS-U storage ring and activated to dilute the beam charge density either on a train to be swapped out a few 100s turns before extraction or on the whole beam after RF failures. In this paper, we will present both physics and engineering designs of this decoherence kicker.

MOPAB115 **ATS/STA Transfer Line Design for the ALS Upgrade Project (ALS-U)**

***C. Sun**, M.P. Ehrlichman, T. Hellert, M. Juchno, J.-Y. Jung, M. Mardenfeld, J.R. Osborn, G. Penn, C. Steier, C.A. Swenson, M. Venturini (LBNL)*

At the Advanced Light Source Upgrade (ALS-U), an on-axis swap-out injection will be used to replenish depleted bunches in the storage ring with refreshed bunches from the full energy accumulator ring. To implement this scheme, two transfer lines are required between the storage ring and the accumulator ring: the accumulator-to-storage-ring (ATS) transfer line and the storage-ring-to-accumulator (STA) transfer line. The design of the ATS/STA transfer lines is a challenging task as they must fit within a tight injection region while also accommodating the storage and accumulator rings at different elevations. Moreover, the ATS/STA design needs to meet both the boundary conditions and optics requirements. In this paper, we will present a design option for these ATS/STA transfer lines.

MOPAB116 **A Flexible Injection Scheme for the ESRF-EBS**

***S.M. White**, N. Carmignani, L.R. Carver, M. Dubrulle, L. Hoummi, S.M. Liuzzo, M. Morati, T.P. Perron (ESRF)*

The ESRF-EBS storage ring light source started commissioning in 2019 and successfully resumed users operation in 2020. Due to the smaller emittance and consequently reduced lifetime frequent injections are required that can potentially disturb beam lines experiments. In addition, operating the machine with low beta straight section and reduced insertion devices (ID) gaps are considered, therefore reducing the vertical aperture of the machine. Alternatives to the standard off-axis injection scheme allowing for efficient injection in reduced apertures with minimized perturbations are explored. A flexible layout for po-

tential integration in the ESRF-EBS lattice is proposed.

MOPAB117 **Single Bunch Collective Effects in the EBS Storage Ring**
***L.R. Carver**, E. Buratin, N. Carmignani, F. Ewald, L. Hoummi, S.M. Liuzzo, T.P. Perron, B. Roche, S.M. White (ESRF)*
The ESRF storage ring (SR) has been dismantled and replaced by the Extremely Brilliant Source (EBS) which has now been commissioned. Beam based measurements have been performed to characterise the impedance of the new machine and to make a first comparison with predictions. The results from instability threshold scans and tune shift measurements will be presented, as well as bunch length and position variation with current and microwave threshold measurements.

MOPAB118 **The Impact of Short-Range Wakes on Injection Into the ALS-U Accumulator Ring**
***G. Penn**, M.P. Ehrlichman, T. Hellert, C. Steier, C. Sun, M. Venturini, D. Wang (LBNL)*
As part of the ALS-U design, bunches with small charge will be added to the accumulator ring in a manner that initially leaves both the stored and injected bunches displaced from the nominal orbit. While the beam current is below instability thresholds, transient effects due to the combination of short-range wake fields and large initial displacements can have an impact on injection efficiency. In this paper, the impact of wake fields on the two bunches is detailed using the elegant simulation code, and different techniques to optimize the injection efficiency are explored.

MOPAB119 **Comparisons Between AT and Elegant Tracking**
***G. Penn**, T. Hellert, M. Venturini (LBNL)*
The simulation codes Elegant and Accelerator Toolbox (AT) are both in common use for the study of particle accelerators and light sources. They use different software platforms and have different capabilities, so there is a strong motivation to be able to switch from one version to another to achieve different goals. In addition, it is useful to directly compare results for benchmarking studies. We discuss differences in tracking methods and results for various elements, and explore the impact on simulations performed with lattices designed for the ALS-U. In addition to single-particle tracking, global properties such as chromaticity, dynamics aperture, momentum aperture and beam lifetime are also investigated. We have also developed scripts to translate AT lattices into elegant lattice files to facilitate comparisons.

MOPAB120 **Update on Injector for the New Synchrotron Light Source in Thailand**
***T. Chanwattana**, S. Chunjarean, N. Juntong, K. Kittimanapun, S. Klinkhieo, P. Sudmuang (SLRI) K. Manasatitpong (Synchrotron Light Research Institute (SLRI))*
Design of the new 3-GeV synchrotron light source in Thailand, Siam Photon Source II (SPS-II), has been updated. The SPS-II accelerator complex consists of a 150-MeV injector linac, a 3-GeV booster synchrotron and a 3-GeV storage ring. The RF system of both storage ring

and booster is based on a frequency of 119 MHz. In this paper, design considerations and specifications of the SPS-II injector linac are presented. A study on the injector linac in multi-bunch mode (MBM) and single-bunch mode (SBM) was done to get appropriate parameters for top-up injection and different filling patterns in the storage ring.

MOPAB121 **Progress towards Soft X-ray Beam Position Monitor Development**

***B. Podobedov**, C. Eng, S. Hulbert, C. Mazzoli (BNL) D. Donetski, K. Kucharczyk, J. Liu, R. Lutchman (Stony Brook University)*

X-ray beam position monitors (BPMs) are instrumental for storage ring light sources, where they reliably provide positional measurements of high-power beams in hard X-ray beamlines. However, despite a growing need, coming especially from coherent soft X-ray beamlines, non-invasive soft X-ray BPMs have not been demonstrated yet. We are presently working on a funded R&D proposal to develop a non-invasive soft X-ray BPM with micron-scale resolution for high-power white beams. In our approach, multi-pixel GaAs detector arrays are placed into the beam halo and beam position is inferred from the pixel photocurrent levels. Presently, the first detector array prototypes have been manufactured and are being prepared for low-power beam tests. The mechanical design of a BPM test-stand, which will be installed in the 23-ID canted soft X-ray undulator beamline at NSLS-II, is well under way. In addition, we are developing new algorithms of beam position calculation which take full advantage of extended multi-pixel detector arrays. In this paper we will review our design choices and discuss recent progress.

MOPAB122 **Present Status of HiSOR**

***M. Katoh** (UVSOR) K. Goto, **M. Katoh**, M. Shimada (HSRC) H. Miyauchi (KEK)*

HiSOR is a compact synchrotron light source of 700MeV. The circumference is 22m. The ring has two straight sections for undulators, which provide high brilliance VUV radiation. Two 180 bending magnets have 2.7 T field strength, which provide broadband radiation in VUV and soft X-ray range. The injector is a 150 MeV microtron. The beam injection is made twice a day with a 5 hour interval. Although the accelerators are being operated stably, the large emittance of 400nm makes it difficult to compete with high brilliance light sources of new generations. The compactness of the configuration makes it difficult to introduce new technologies. We have started seeking possible upgrades.

MOPAB123 **Radiation Safety Considerations For The APS Upgrade Injector**

***K.C. Harkay**, J.R. Calvey, S. Chitra, G.I. Fystro, M.J. Henry, E.E. Heyeck, B.J. Micklich, K.P. Wootton (ANL)*

The Advanced Photon Source Upgrade (APS-U) is a high-performance fourth-generation storage ring light source based on multibend achromat optics. As such, APS-U will require on-axis injection. The injectors

will need to supply full-current bunch replacement in the ring; therefore, the injected bunch charge will be up to five times higher than what is typical for APS. A program was conducted to measure the radiation dose above the injector transport line to the APS storage ring for both normal operation conditions and controlled loss scenarios. Standard survey meters were used to record the dose. A review of the dose data identified opportunities to minimize the potential dose under normal APS-U high charge operation and fault conditions; these include improving the supplemental shielding and adding engineered controls. In addition, the dose data provide a benchmark for evaluating new radiation monitors for APS-U.

MOPAB124 **APS Booster Injection Horizontal Trajectory Control Upgrade**
***H. Shang**, J.R. Calvey, G.I. Fystro, A.F. Pietryla, C. Yao (ANL)*
The APS booster is a 7-GeV electron synchrotron with a 0.5-second cycle. The booster runs a set of injection control programs that correct the beam trajectory in the horizontal and longitudinal planes, and the betatron tunes. Recently we developed a single-turn BPM controllaw program for horizontal trajectory control to replace the previous FFT based horizontal controllaw program. We present the system configuration and results.

MOPAB125 **APS Upgrade Status**
***H. Cease**, G. Decker, E. Dunn, T. Fornek, R.O. Hettel, J.S. Kerby, J. McGhee, E. Peoples-Evans, M. Ramanathan (ANL)*
The Advanced Photon Source Upgrade (APS-U) at Argonne National Laboratory (ANL) is implementing a fourth generation Multi-Bend Achromat (MBA) lattice to replace the existing APS storage ring. The resulting hard-x-ray synchrotron radiation facility will have brightness and coherent flux orders of magnitude better than the current machine. New accelerator equipment will replace existing accelerator components in the existing APS storage ring, and Insertion Devices are being updated or fully replaced to take advantage of the new electron beam properties. The APS-U features nine Beamlines that are either entirely new or are significant modifications of existing APS beamlines, and these are explicitly designed to capitalize on the strengths of the APS-U storage ring. Two feature beamlines are of lengths which extend beyond the existing facility, and construction of the long beamline building to house these have started. The remaining sixty operating beamlines will undergo either enhancements or improvements to ensure the beamline is able to utilize the capabilities of the APS-U storage ring. The construction status for accelerator equipment and feature beamlines will be presented.

MOPAB126 **BESSY III & MLS II - Status of the development of the new photon science facility in Berlin**
***P. Goslawski**, M. Abo-Bakr, F. Andreas, M. Arlandoo, J. Bengtsson, K. Holldack, J.G. Hwang, A. Jankowiak, B.C. Kuske, J. Li, A.N. Matveenko, T. Mertens, A. Meseck, E.C.M. Rial, M. Ries, M.K. Sauerborn, A. Schälicke, M. Scheer, P. Schnizer, L. Shi, J. Viefhaus (HZB)*

J. Lüning (UPMC)

HZB operates and develops two synchrotron radiation sources at Berlin Adlershof. The larger one, BESSY II with an energy of 1.7 GeV and 240 m circumference is optimized for soft-X rays and in operation since 1999. The smaller one is the MLS (Metrology Light Source), owned by the Physikalische Technische Bundesanstalt (PTB) - Germany's National Metrology Institute. It is designed to fulfill the special metrology needs of the PTB with an energy of 0.6 GeV and 48 m circumference, covering the spectral range from THz and IR to EUV/VUV. In 2020 a discussion process has been started to define the requirements for successors of BESSY II and MLS and to study the possibilities integrate them into a new photon science facility in Berlin Adlershof. Here, we give a status report and present a first envisaged parameter space to both machines (see also MOPAB262, MOPAB220, MOPAB048, MOPAB242).

MOPAB127 **Construction of an Impedance Model for Diamond-II**

***R.T. Fielder**, T. Olsson (DLS)*

Impedance models for accelerators have traditionally been presented in a static form, usually as tables or spreadsheets which must be read manually. As part of the Diamond-II upgrade work, we have developed an impedance model using a lattice structure. This allows more direct integration with simulation codes while keeping important information easily human readable. We present here a description of this implementation method, along with an overview of the Diamond-II impedance model derived from the latest engineering design.

MOPAB128 **Operational Use of Pinger Magnets to Counter Stored Beam Oscillations During Injection at Diamond Light Source**

***R.T. Fielder**, M. Apollonio, I.P.S. Martin (DLS)*

Diamond uses a four kicker bump injection scheme. Due to a variety of factors it has become more difficult to perfectly match the four kicks while maintaining injection efficiency, resulting in some disturbance to the stored beam during top-up. This has consequences for beamlines which may see degraded beam quality during injections. A gating signal is provided, but this is not appropriate for all experiments, and in any case ideally would not be required. The disturbance to the stored beam can be partly controlled using the existing diagnostic pinger magnets installed in the storage ring. We present here a comparison of different compensation schemes and tests with beamlines, along with initial experiences operating during user beam time. Use of these magnet also provides proof of principle for any future, purpose-built compensation kickers.

MOPAB131 **Synchrotron SOLEIL Upgrade Project**

***A. Nadji** (SOLEIL)*

To remain competitive in the future, SOLEIL is also working on an upgrade project plan based on Multi-Bend Achromat (MBA) lattices. The Technical Design Report of the project is expected to start in early 2021 immediately after the completion of the Conceptual Design Report

(CDR) phase. The achieved equilibrium emittance in the CDR reference lattice (80 pm-rad) is about 50 times smaller than that of the existing storage ring (4000 pm-rad). By operating on a linear coupling resonance, round beam sizes in Insertion Devices straight sections of less than 10 microns RMS in both planes can be produced. These performances rely on the use of a 10 mm inner diameter circular copper vacuum chamber with NEG-coating allowing reaching strong quadrupole gradients and very strong sextupole and octupole strengths. As all these technical challenges are pushing the engineering technology to the limits, they are being investigated through an intensive R&D program based on extensive numerical simulations, prototyping, and measurement with the beam. Extensive use of the pure permanent magnet technology beyond what has been done so far in the other similar projects is considered in this project.

MOPAB132 **The MultiMegaWatt Target Station for the European Spallation Source Neutrino Super Beam**

***E. Baussan**, E. Bouquerel, L. D'Alessi, M. Dracos, P. Poussot, J. Thomas, J. Wurtz, V. Zeter (IPHC) P. Cupial, M. Koziol, L.J. Lacny, J. Snamina (AGH University of Science and Technology) I. Efthymiopoulos (CERN) T. Tolba (University of Hamburg)*

One of the next challenges in fundamental physics is to understand the origin of matter/antimatter asymmetry in the Universe. In particular, intense neutrinos could play an important role to elucidate this mystery and better understand the expansion of the Universe. The ESSnuSB collaboration proposes to use the proton linac of the European Spallation Source currently under construction in Lund (Sweden) to produce a very intense neutrino super beam, in parallel with the spallation neutron production. A very challenging part of the proposed facility is the Target Station which will have to afford 5 MW proton beam power. This poster will present the hadronic collector and the whole facility to produce the next generation of neutrino superbeam.

MOPAB133 **Recovering the Positron Beam After Muon Production in the Lemma Muon Source**

***I. Drebot** (INFN-Milano) M.E. Biagini, O.R. Blanco-García, A. Giribono, S. Guiducci, C. Vaccarezza, A. Variola (INFN/LNF) S.M. Liuzzo (ESRF)*

In the LEMMA muon source proposal a positron beam at 45 GeV is used to produce muons at threshold by interaction with some targets. In order to release the required intensity on the main positron source, orders of magnitude higher than the state of the art, the possibility to recover the primary positron beam after the interaction with the targets was studied. The particles distribution, with a strongly degraded energy spread after the interac- tion, was injected back into a low emittance, large energy acceptance 45 GeV ring. Studies of injection efficiency were performed. The possibility of compressing the beam in a linac before injection was also studied. As a result, even without compression, about 80% of the disrupted e^+ beam can be injected back

into the ring.

MOPAB134 **Normalized Transverse Emittance Reduction via Ionization Cooling in MICE 'Flip Mode'**

P.B. Jurj *(Imperial College of Science and Technology, Department of Physics)*

Low emittance muon beams are central to the development of a Muon Collider and can significantly enhance the performance of a Neutrino Factory. The international Muon Ionization Cooling Experiment (MICE) has recorded several million individual muon tracks passing through a liquid hydrogen or a lithium hydride absorber and has demonstrated the ionization cooling of muon beams. Previous analysis used a restricted data set, and the beam matching was not perfect. In this analysis, beam sampling routines were employed to account for imperfections in beam matching at the entrance into the cooling channel and enable an improvement of the cooling measurement. A study of the normalized transverse emittance change in the MICE cooling channel set up in a flipped polarity magnetic field configuration is presented. Additionally, the evolution of the canonical angular momentum across the absorber is shown and the characteristics of the cooling effect are discussed.

MOPAB137 **Interaction Region Design for DWA Experiments at FACET-II**

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The extremely intense beam generated at FACET-II provides the unique opportunity to investigate the effects of beam-driven GV/m fields in dielectrics exceeding meter-long interaction lengths. The diverse range of phenomena to be explored, such as material response in the terahertz regime, suppression of high-field pulse damping effects, advanced geometry structures, and methods for beam break up (BBU) mitigation, all within a single UHV vacuum vessel, requires flexibility and precision in the experimental layout. We present here details of the experimental design for the dielectric program at FACET-II. Specifically, consideration is given to the alignment of the dielectric structures due to the extreme fields associated with the electron beam, as well as implementation of electron beam and Cherenkov radiation-based diagnostics.

MOPAB138 **Dielectric Wakefield Acceleration With a Laser Injected Witness Beam**

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The plasma photocathode concept, whereby a two-species gas mixture is used to generate a beam -driven accelerating wakefield and a

laser-ionized generation of a witness beam, was recently experimentally demonstrated. In a variation of this concept, a beam-driven dielectric wakefield accelerator is employed, filled with a neutral gas for laser-ionization and creation of a witness beam. The dielectric wakefields, in the terahertz regime, provide comparatively modest timing requirements for the injection phase of the witness beam. In this paper, we provide an update on the progress of the experimental realization of the hybrid dielectric wakefield accelerator with laser injected witness beam at the Argonne Wakefield Accelerator (AWA), including engineering considerations for gas delivery, and preliminary simulations.

MOPAB139 **High Resolution Imaging Design Using Permanent Magnet Quadrupoles at BNL UEM**

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Ultrafast electron microscopy techniques have demonstrated the potential to reach very high combined spatio-temporal resolution. In order to achieve high resolution, strong focusing magnets must be used as the objective and projector lenses. In this paper, we discuss the design and development of a high-resolution objective lens for use in the BNL UEM. The objective lens is a quintuplet array of permanent magnet quadrupoles, which in sum, provide symmetric focusing, high magnification, and control of higher order aberration terms. The application and design for a proof-of-concept experiment using a calibrated slit for imaging are presented. The image resolution is monitored as a function of beam parameters (energy, energy spread, charge, bunch length, spot size), and quintuplet lens parameters (drifts between lenses).

MOPAB140 **Gas Sheet Ionization Diagnostic for High Intensity Electron Beams**

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The characterization of high intensity charged particle beams in a minimally interceptive, and non-destructive manner is performed using an ionization diagnostic. In this application, a neutral gas is tailored into a thin sheet, or curtain-like, distribution at the interaction point with an electron beam. The electron beam ionizes the neutral gas in localized space, leaving a footprint of the beam transverse distribution. The ion cloud is subseqeuntly imaged with a series of electrostatic lenses to a detector plane. The resultant image is used in a reconstruction algorithm to reconstruct the beam profile at the interaction point. In this paper, we present progress on the development of this diagnostic for the characterization of high charge, 10GeV electron beams with small transverse distributions.

MOPAB141 **Terahertz Driven Compression and Time-Stamping Technique for Single-Shot Ultrafast Electron Diffraction**

***M.A.K. Othman**, A.E. Gabriel, M.C. Hoffmann, F. Ji, E.A. Nanni, E.J.C. Snively, X.J. Wang (SLAC)*

Ultrafast structural dynamics are well understood through pump-probe characterization using ultrafast electron diffraction (UED). Advancements in electron diffraction and spectroscopy techniques open new frontiers for scientific discovery through interrogation of ultrafast phenomena, such as quantum phase transitions. Previously, we have demonstrated that strong-field THz radiation can be utilized to efficiently manipulate and compress ultrafast electron probes, and also offer temporal diagnostics with sub-femtosecond resolution enabled by the inherent phase locking of THz radiation to the photoemission optical drive. In this work, we demonstrate a novel THz compression and time-stamping technique to probe solid-state materials at time scales previously inaccessible with standard UED. A high-frequency THz generation method using the organic OH-1 crystals is employed to enable a threefold reduction in the electron probes length and overall timing jitter. These time-stamped probes are used to demonstrate a substantial enhancement in the UED temporal resolution using pump-probe measurement in both photoexcited single crystal and polycrystalline samples.

MOPAB142 **A Compact, Low-Field, Broadband Matching Section for Externally-Powered X-Band Dielectric-Loaded Accelerating Structures**

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It has been technically challenging to efficiently couple external radiofrequency (RF) power to cylindrical dielectric-loaded accelerating (DLA) structures. This is especially true when the DLA structure has a high dielectric constant. This contribution presents a novel design of a matching section for coupling the RF power from a circular waveguide to an X-band DLA structure with a dielectric constant ϵ_r=16.66 and a loss tangent $\tan\theta = 3.43 \times 10^{-5}$. It consists of a very compact dielectric disk with a width of 2.035 mm and a tilt angle of 60 degrees, resulting in a broadband coupling at a low RF field which has the potential to survive in the high-power environment. To prevent a sharp dielectric corner break, a 45-degree chamfer is added. Moreover, a microscale vacuum gap, caused by metallic clamping between the thin coating and the outer thick copper jacket, is studied in detail. Based on simulation studies, a prototype of the DLA structure with the matching sections was fabricated. Results from preliminary bench measurements and their comparison with design values will also be discussed.

MOPAB143 **Simulations for MeV Energy Gain in Multi-Micron Vacuum Channel Dielectric Structures Driven by a CO_2 Laser**

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Dielectric Laser Accelerators (DLAs) have been demonstrated as a novel scheme for producing high acceleration gradients (~1 GV/m) within the damage threshold of the dielectric. The compactness of the DLAs and the low emittance of the output electron beam make it an attractive candidate for future endoscopic devices to be used in tumor irradiation. However, due to the small accelerating distances(sub-mm), the total energy gain is limited to sub-MeV which remains an obstacle for its realistic applications. Also, these DLAs operate under solid-state lasers with wavelengths near IR (800 nm to 2 um), where required sub-micron vacuum channel at such wavelengths imposes major aperture restrictions for the amount of charge to be accelerated. Here, we present numerical simulation results for a dielectric structure excited by a CO_2 laser with a wavelength of 10.6 um. Upon injecting a 50 MeV electron bunch through a 5.3 um diameter of vacuum channel width, our simulation suggests an energy gain beyond 1 MeV. These results are the initial steps for the realization of an mm-scale DLA capable of producing MeV energy electron beams.

MOPAB144 **Investigation of Optimization of Dielectric Terahertz Acceleration Structures**

A.E. Gabriel, *E.A. Nanni (SLAC)*

THz-frequency accelerating structures could provide the accelerating gradients needed for next generation particle accelerators with compact, GV/m-scale devices. Current THz accelerators are limited by significant losses during transport of THz radiation from the generating nonlinear crystal to the electron acceleration structure. In addition, the spectral properties of high-field THz sources make it difficult to couple THz radiation into accelerating structures. Dielectric accelerator structures reduce these losses because THz radiation can be coupled laterally into the structure, as opposed to metallic structures where THz radiation must be coupled along the beam path. In order to utilize these advantages, we are investigating the optimization of THz accelerating structures for comparison between metallic and dielectric devices. These results will help to inform future designs of improved dielectric THz acceleration structures.

MOPAB145 **Acceleration and Focusing of Positron Bunch by Electron Bunch Wakefield in the Dielectric Waveguide Filled With Plasma**

G.V. Sotnikov, *R.R. Kniaziev, P.I. Markov (NSC/KIPT)*

The results of the numerical PIC-simulation of accelerated positron bunch focusing in the plasma dielectric wakefield accelerator unit, filled with radially inhomogeneous plasma that has vacuum channel inside are presented. The Wakefield was created by drive electron

bunch in quartz dielectric tube with external and internal diameters of 1.2 mm and 1.0 mm, respectively. The tube was embedded in cylindrical metal waveguide. The internal area of dielectric tube has been filled with different transverse density profiles of plasma: homogeneous density and inhomogeneous density created in capillary discharge. Drive bunch electrons energy was 5 GeV, drive bunch charge was 3 nC. The test positron bunch had the same parameters as the drive bunch except for the charge of 0.05 nC. Results of numerical PIC simulation have shown the possibility of simultaneous acceleration and focusing of test positron bunch in the wakefield excited by drive electron bunch. The dependence of transport and acceleration of positron bunch on size of vacuum channel is studied.

MOPAB146 **Status of the C-Band Engineering Research Facility (CERF-NM) Test Stand Development at LANL**

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C-Band structures research is of increasing interest to the accelerator community. The RF frequency range of 4-6 GHz gives the opportunity to achieve significant increase in the accelerating gradient, and having the wakefields at the manageable levels, while keeping the geometric dimensions of the structure technologically convenient. Strong team of scientists, including theorists researching properties of metals under stressful thermal conditions and high electromagnetic fields, metallurgists working with copper as well as alloys of interest, and accelerator scientists developing new structure designs, is formed at LANL to develop a CERF-NM facility. A 50 MW, 5.712 GHz Canon klystron, was purchased in 2019, and laid the basis for this facility. As of Jan-21, the construction of the Test Stand has been finished and the high gradient processing of the waveguide components has been started. Future plans include high gradient testing of various accelerating structures, including benchmark C-band accelerating cavity, a proton ß=0.5 cavity, and cavities made from different alloys. An upgrade to the facility is planned to allow for testing accelerator cavities at cryogenic temperatures.

MOPAB147 **Efficient, High Power THz Radiation Outcoupling From a Beam Driven Dielectric Wakefield Accelerator**

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Wakefields in dielectric structures are a useful tool for beam diagnostics and manipulation with applications including acceleration, shaping, chirping, and THz radiation generation. It is possible to use the produced THz radiation to diagnose the fields produced during the DWA interaction but, to do so, it is necessary to effectively outcouple this radiation to free space for transport to diagnostics such

as a bolometer or interferometer. To this end, simulations have been conducted using CST Studio for a 10 GeV beam with FACET-II parameters in a slab-symmetric, dielectric waveguide. Various termination geometries were studied including flat cuts, metal horns, and the "Vlasov antenna". Simulations indicate that the Vlasov antenna geometry is optimal and detailed studies were conducted on a variety of dielectrics including quartz, diamond, and silicon. Multiple modes were excited and coherent Cherenkov radiation (CCR) was computationally generated for both symmetric and asymmetric beams. Finally, we include witness beams to study transport and acceleration dynamics as well as the achievable field gradients.

MOPAB148 **Betatron Radiation Models and Beam Parameter Reconstruction for Plasma Acceleration Experiments at FACET-II**

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Future plasma acceleration experiments at FACET-II will measure betatron radiation in order to provide single-shot non-destructive beam diagnostics. We discuss three models for betatron radiation: a new idealized particle tracking code with Liénard-Wiechert radiation, a Quasi-Static Particle-in-Cell (PIC) code with Liénard-Wiechert radiation, and a full PIC code with radiation computed via a Monte-Carlo QED Method. Predictions of the three models for the E-310 experiment are presented and compared. Finally, we discuss beam parameter reconstruction from the double differential radiation spectrum.

MOPAB149 **Ion Motion in Flat Beam Plasma Accelerators**

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Intense beams, such as those in proposed plasma based linear colliders, can not only blow out electrons to form a bubble but can also attract ions towards the beam. This violates the assumption that the ions are stationary on the timescale of the beam, which is a common assumption for shorter and less intense beams. While some research has been done on understanding the physics of ion motion in blowout Plasma Wakefield Accelerators (PWFAs), this research has almost exclusively focused on cylindrically symmetric beams, rather than flat asymmetric emittance beams which are often used in linear colliders in order to minimize beamstrahlung at the final focus. This contribution investigates both analytically and computationally ion motion of a flat beam scenario in order to understand the basic physics as well as how to mitigate emittance growth, beam hosing and quadrupole.

MOPAB150 **Optimization of the Gain Medium Delivery System to XLO**

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X-ray laser oscillator, dubbed XLO, is a recently proposed project at SLAC to build the first population inversion X-ray laser. XLO utilizes a train of XFEL SASE pulses to pump atomic core-states. The resulting amplified spontaneous emission radiation is recirculated in a backscattering Bragg cavity and subsequently amplified. XLO could provide fully coherent, transform-limited X-ray pulses with 50 meV bandwidth and 10^{10} photons. Currently, XLO is being considered for operation at the copper K-alpha line at 8048 eV. In this work, we focus on the optimization of gain medium delivery in the XLO cavity. We consider a fast, subsonic jet of copper nitrate solution, moving through a cylindrical nozzle. We focus on the nozzle geometry optimization and possible diagnostics of the jet-XFEL interaction point.

MOPAB151 **A Stable Drive Beam for High Gradient Dielectric Wakefield Acceleration**

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A high accelerating gradient, with stable beam transport, is necessary for the next generation of particle accelerators. Dielectric wakefield accelerators are a potential solution to this problem. In these proceedings, we present simulation studies of electron bunches in the self-wake regime inside a planar dielectric structure. This is analogous to driving beams in a dielectric wakefield accelerator. The transverse and longitudinal wake fields are investigated for dielectric plate gaps, various transverse beam sizes, and longitudinal bunch profiles. The effects of these on the stability of drive bunches, and acceleration of a witness bunch, are discussed in the context of electron bunches that can be produced with conventional linac RF technology.

MOPAB152 **High Power Tests of Brazeless Accelerating Structures**

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A typical accelerating structure is a set of copper resonators brazed together. This multi step process is expensive and time consuming. In an effort to optimize production process for rapid prototyping and overall reduction of accelerator cost we developed a split block brazeless accelerating structure. In such structure the vacuum is sealed by the use of knife edges, similar to an industry standard conflat technology. In this paper we present high power tests of several different brazeless structures. First, an inexpensive 1 MeV accelerator powered by radar magnetron. Second, a high gradient power extractor tested at Argonne Wakefield Accelerator Facility. In this experiment a high charge electron beam generated a 180 MW peak power pulse. Finally, we report on high power testing of a brazeless x-band accelerating structure at

SLAC.

MOPAB153 **Laser Microfabrication for Accelerator Applications**

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Laser microfabrication allows high precision ablation of materials at sub-mm scale. When laser pulse length is shorter than about 10 picoseconds the heat affected zone is minimized and ablation occurs without melting. Work-pieces processed in this fashion exhibit less structural damage and are expected to have a higher damage thresholds. In this paper we will review several case studies of laser-microfabricated components for accelerator and x-ray applications. Ablated materials include diamond, quartz, tungsten, copper, YAG:Ce and silicon.

MOPAB154 **Multi-Cell Accelerating Structure Driven by a Lens-Focused Picosecond THz Pulse**

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Recently, gradients on the order of 1 GV/m level have been obtained in a form of a single cycle (~1 ps) THz pulses produced by conversion of a high peak power laser radiation in nonlinear crystals (~1 mJ, 1 ps, up to 3% conversion efficiency). Such high-intensity radiation can be utilized for charged particle acceleration. However, these pulses are short in time (~1ps) and broadband, therefore a new accelerating structure type is required. In this paper, we propose a novel structure based on focusing of THz radiation in accelerating cell and stacking such cells to achieve a long-range interaction required for an efficient acceleration process. We present an example in which a 100 microJoule THz pulse produces a 600 keV energy gain in 5 mm long 10 cell accelerating structure for an ultra-relativistic electron. This design can be readily extended to non-relativistic particles. Such structure had been laser microfabricated and appropriate dimensions were achieved.

MOPAB155 **Magnetic Breakdowns in Side-Coupled X-Band Accelerating Structures**

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Side coupled accelerating structures are popular in the industrial realizations of linacs due to their high shunt impedance and ease of tuning. We designed and fabricated a side-coupled X-band accelerating structure that achieved 133 MOhm/m shut impedance. This structure was fabricated out of two halves using a novel brazeless approach. The two copper halves are joined together using a stainless steel joining piece with knife edges that bite into copper. This structure had been tested at high power at SLAC National Accelerator Laboratory. The performance of the structure had been limited by magnetic breakdowns on the side-coupling cells. In this paper we will present results of the high gradient tests and after-test analysis. Scanning electron microscopy images show a typical magnetic-field induced breakdown.

MOPAB156 **Wakefields and Transverse Bunch Dynamics Studies of a Plasma-Dielectric Accelerating Structure**

***K. Galaydych**, I.N. Onishchenko, G.V. Sotnikov (NSC/KIPT)*

A theoretical investigation of a wakefield excitation in a plasma-dielectric accelerating structure by a drive electron bunch in the case of an off-axis bunch injection is carried out. The structure under investigation is a round dielectric-loaded metal waveguide with channel for the charged particles, filled with homogeneous cold plasma. In this paper we focus on the spatial distribution of the bunch-excited wakefield components, which act on both the drive and test bunches, and on transverse bunch dynamics. Dependence of the drive bunch propagation distance on its offset is studied.

MOPAB159 **Matching of an RFQ and Multicusp Ion Source with Compact LEBT**

***L.H. Waites**, J.M. Conrad, J. Smolsky, D. Winklehner (MIT)*

The IsoDAR project is a neutrino experiment that requires a high current H^{2+} beam at 60 MeV/amu, which will be produced by a cyclotron. A critical aspect of the design is the injection, which comprises an ion source, a compact low energy beam transport section (LEBT), and a radio-frequency quadrupole (RFQ) buncher embedded in the cyclotron yoke. The LEBT is optimized to match the desired input Twiss parameters of the RFQ. Here we report on the latest results from the ion source commissioning, and on the design and optimization of the LEBT with matching to the RFQ. With this ion source, we have demonstrated a 76% H^{2+} fraction at a current density of 11 mA/cm^2 in DC mode. The design of the LEBT includes a chopper, steering elements, and focusing elements, to achieve the desired matching, which according to our simulations leads to ~95% transmission from the ion source to the exit of the RFQ.

MOPAB160 **Tools for the Development and Applications of the IsoDAR Cyclotron**

***L.H. Waites**, J.R. Alonso, J.R. Alonso, J.M. Conrad, D. Koser, J. Smolsky, D. Winklehner (MIT)*

The IsoDAR cyclotron is a 60 MeV cyclotron designed to output 10mA of protons in order to be a driver for a neutrino experiment. However, this high power can be used in other useful and important applications outside of particle physics. The IsoDAR cyclotron accelerates H^{2+}, which allows the beam to be highly versatile and important for the development of high-power targets. This could help alleviate a huge bottleneck in the medical isotope community. IsoDAR could also be used for the development of materials. The accelerator system uses many new tools, including novel methods of applying machine learning, as well as several of the uses of this new technology. With these applications and tools, the IsoDAR cyclotron can have an important impact on the accelerator, medical, and physics communities.

MOPAB161 **Excitation of the W-Band Structure by the Electron Beam**
M.V. Arsentyeva *(BINP SB RAS)*
W-band structure of cavities is under development at Budker institute of nuclear physics (Russia). For the first experiments with the structure excitation the electron beam is to be used. To this end, the electron beam from the SKIF light source will be used. Layout of the projected experiment is described. This study includes also analytical estimations of the W-band structure excitation based on the parameters of the exciting beam. These estimations are compared with the spectrum of the excited field in the structure obtained in the simulations.

MOPAB162 **The First Trial of XY-Coupled Beam Phase Space Matching for Three-Dimensional Spiral Injection**
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The most recent measurement of muon g-2 results in a 3.8σ discrepancy with the equally precise theoretical prediction. The J-PARC muon g-2/EDM experiment (E34) is in preparation to decipher this discrepancy and unravel the new physics beyond the standard model. The precision goal for g-2 is 0.1 ppm. To achieve this precision goal a novel 3-D spiral injection scheme has been devised to inject and store the beam into a small diameter MRI-type storage magnet for E34. The new injection scheme features smooth injection with high storage efficiency for the compact magnet. However, the spiral injection scheme is an unproven idea, therefore, a Spiral Injection Test Experiment (SITE) at KEK Tsukuba Campus is underway to establish this injection scheme. Due to the axial symmetric field of the solenoid magnet, a strongly XY-coupled beam is required. To produce the required phase space for the solenoid-type storage magnet, a beam transport line consisting of three rotatable quadrupole magnets has been designed and built for SITE. The vertical beam size reduction by means of phase space matching and other geometrical information has been successfully measured by the wire scanners.

MOPAB163 **First Synchronous Measurement of Single-Bunched Electron and Positron Beams With a Wideband Feedthrough-BPM at the Positron Capture Section of the SuperKEKB Injector Linac**
M.A. Rehman*, F. Miyahara, T. Suwada (KEK)*
The SuperKEKB is an asymmetric e^-/e^+ collider with 40 times higher luminosity than the KEKB project, to explore the new physics beyond the standard model. For the SuperKEKB, the positrons are created by striking the accelerated electrons at a tungsten target. The secondary electrons are also produced during the positron creation process and accelerated in the capture section. Because of phase slipping in the capture section, the secondary electron bunch is only ~180 ps away from the positron. Conventional stripline-type BPM

cannot detect such closely spaced and opposite polarity signals due to slow frequency response and high cable losses. Therefore, a new wideband feedthrough-type beam position monitor was developed. It was successfully employed at the positron capture section of the SuperKEKB injector linac for the first synchronous measurement of the electron and positron beams. The cable losses effect also has been deembedded to reveal correct signal properties. This paper describes the initial results of synchronous measurement of e^-/e^+ transverse position.

MOPAB164 **Miniature, High Strength Transport Line Design for Laser Plasma Accelerator-Driven FELs**

***S. Fatehi**, A. Bernhard, A.-S. Müller, M.S. Ning (KIT)*

Laser-plasma acceleration is an outstanding candidate to drive the next-generation compact light sources and FELs. To compensate large chromatic effects using novel compact beam optic elements in the beam transport line is required. We aim at designing miniature, high strength, normal conducting and superconducting transport line magnets and optics for capturing and matching LPA-generated electron bunches to given applications. Our primary application case is a demonstration experiment for transverse gradient undulator (TGU) FELs, to be performed at the JETI laser facility, Jena, Germany. In this contribution, we present the current design of the beam transport line magnets and the beam optics calculations.

MOPAB165 **Identical Focusing of Train of Relativistic Positron Gaussian Bunches in Plasma**

***D.S. Bondar** (KhNU) V.I. Maslov, I.N. Onishchenko (NSC/KIPT)*

Focusing of both electron and positron bunches in an electron-positron collider is necessary. The focusing mechanism in the plasma, in which all electron bunches are focused identically, has been proposed earlier. This mechanism is considered for positron bunches by using simulation with LCODE. Three types of lenses with different trains of cosine profile positron bunches are considered depending on the bunch length, the distance between bunches, and their charge. It has been shown that all positron bunches are focused identically at special parameters of the first positron bunch, wherein the middle of bunches are focused weaker than their fronts.

MOPAB166 **Wakefield Excitation by a Sequence of Laser Pulses in Plasma**

***D.S. Bondar** (KhNU) V.I. Maslov, I.N. Onishchenko (NSC/KIPT)*

PIC simulation by means of 2.5D UMKA code of the wakefield excitation by a sequence of three Gaussian laser pulses in plasma was carried out. The dependence of excited wakefield intensity on power and width of laser pulses was investigated. It was shown the coherent addition of wakefield, excited by each laser pulse of the sequence, for linear case, while for the nonlinear case the coherency was destroyed. The profiled sequence of laser pulses was also considered. The possibility to obtain the same total wakefield excited by the profiled sequence of

laser pulses with decreasing intensity, as for the uniform sequence was studied.

MOPAB167 **Wakefield Excitation in Plasma of Metallic Density by a Laser Pulse**

D.S. Bondar *(KhNU) V.I. Maslov, I.N. Onishchenko (NSC/KIPT)*

Recently the proposal to use X-ray Exawatt pulse for particle acceleration in a crystal has been declared. Short X-ray high-power pulse excites wakefield in electron plasma of metallic density which can be used for high gradient acceleration of charged particles. This wakefield is suited for laser wakefield acceleration. In this paper there are simulated with PIC code UMKA: excitation of the large wakefield amplitude up to several TV/m in electron plasma of metallic density by a powerful X-ray laser pulse; laser-plasma wakefield acceleration of self-injected electron bunch in such setup; combined acceleration by plasma wakefield driven by a laser pulse (LPWA) and by self-injected electron bunch (PWFA).

MOPAB168 **Nanoplasmonic Accelerators Towards Tens of TeraVolts per Meter Gradients using Nanomaterials**

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Ultra-high gradients which are critical for future advances in high-energy physics, have so far relied on plasma and dielectric accelerating structures. While bulk crystals were predicted to offer unparalleled TV/m gradients that are at least two orders of magnitude higher than gaseous plasmas, crystal-based acceleration has not been realized in practice. We have developed the concept of nanoplasmonic crunch-in surface modes which utilizes the tunability of collective oscillations in nanomaterials to open up unprecedented tens of TV/m gradients. Particle beams interacting with nanomaterials that have vacuum-like core regions, experience minimal disruptive effects such as filamentation and collisions, while the beam-driven crunch-in modes sustain tens of TV/m gradients. Moreover, as the effective apertures for transverse and longitudinal crunch-in wakes are different, the limitation of traditional scaling of structure wakefields to smaller dimensions is significantly relaxed. The SLAC FACET-II experiment of the nano2WA collaboration will utilize ultra-short, high-current electron beams to excite nonlinear plasmonic modes and demonstrate this possibility.

MOPAB169 **Generating 510 MW of X-Band Power for Structure-Based Wakefield Acceleration Using a Metamaterial-Based Power Extractor**

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We present our recent results generating 510 MW of power at 11.7 GHz

using a metamaterial-based metallic power-extractor for application in structure-based wakefield acceleration (SWFA). SWFA is a novel acceleration scheme in which high-charge electron bunches are passed through a power extractor structure to produce a high-intensity wakefield. This wakefield can then be used to accelerate a witness bunch in the same beamline or passed to a separate acceleration beamline. MIT's approach uses a specialized metamaterial for the power extractor design. By using a metamaterial, we can overcome some of the challenges faced by other SWFA techniques. Here, we discuss the Stage 3 experiment. The Stage 1 and Stage 2 experiments successfully demonstrated the functionality of the metamaterial approach by generating high power RF pulses using the 65 MeV electron beam at the Argonne Wakefield Accelerator (AWA) facility. The 510 MW result from Stage 3 experiment is the highest power generated to-date for SWFA at AWA, and was enable by significant design improvements, including an all-copper structure, fully-symmetric coupler design, and breakdown risk-reduction treatment.

MOPAB170 **Recent Advances in Plasma-Based Beam Dumps**

G.X. Xia, *C. Davut (UMAN) A. Bonatto, B.S. Nunes (IF-UFRGS) A. Bonatto, L. Liang, X. Wang (The University of Manchester) A. Bonatto (Universidade Federal de Ciências da Saúde de Porto Alegre) L. Liang (Cockcroft Institute) R.P. Nunes (UFRGS)*

Plasmas can sustain very strong electric fields (10-100 GV/m) which may be used for particle acceleration and deceleration. Plasma-based beam dumps have been recently proposed to absorb the spent beam energy from particle accelerators by utilizing strong deceleration fields. Studies have shown that this would greatly reduce the radiation hazards and miniaturize the overall footprint of accelerators. In this talk, recent advances in plasma-based beam dumps are discussed. Optimization strategies for beam energy extraction using passive and active plasma beam dumps for EuPRAXIA facility are presented.

MOPAB171 **Numerical Simulation on Plasma-Based Beam Dumps Using Smilei**

S. Kumar, *C. Davut, G.X. Xia (UMAN) A. Bonatto, C. Davut, L. Liang (The University of Manchester) A. Bonatto (Universidade Federal de Ciências da Saúde de Porto Alegre) B.S. Nunes (IF-UFRGS) R.P. Nunes (UFRGS)*

The active plasma beam dump utilizes a laser to generate a plasma wakefield and decelerate an externally injected beam to low energy. We use the particle-in-cell code "Smi-lei" for the investigation of electron beam energy loss in plasma. In this research work, we optimize the laser and plasma parameters to investigate the active plasma beam dump scheme. In doing so, most of the beam energy will be deposited in the plasma. The optimization strategy for the beam energy loss in plasma is presented.

MOPAB173 **Physics Program for AWAKE Run 2**
P. Muggli *(MPI)*
Run 1 experimental results demonstrate many characteristics of the self-modulation (SM) in plasma of a long, 400GeV SPS proton bunch. Externally injected, 19MeV electrons were accelerated to 2GeV. Based on these results, we are assembling a physics and experiment program aiming at producing a multi-GeV electron bunch with emittance and energy spread sufficiently low for possible early applications to high-energy physics experiments. Plans include two plasmas, the first for SM, the second for acceleration, and of scalable length, separated by an injection region. The first plasma includes a density step to maintain large-amplitude wakefields after saturation of the SM process. Seeding of the SM process may be obtained from an electron bunch. The 150MeV witness electron bunch from an S-band gun, X-band linac has parameters that produce plasma electron blow out and loading of the wakefields in order to minimize final energy spread and emittance. We are studying the possibility of using a helicon plasma source for the accelerator, a source that can in principle be very long (100s of m).

MOPAB174 **Foil Hits Reduction by Minimizing Injection Beam Size at the Foil in J-PARC RCS**
P.K. Saha*, H. Harada, K. Okabe, F. Tamura, M. Yoshimoto (JAEA/ J-PARC) H. Hotchi (KEK)*
The uncontrolled beam loss caused by the foil scattering of the circulating beam during multi-turn charge-exchange injection is one of the main sources for high residual radiation at the injection area of J-PARC 3-GeV rapid cycling synchrotron. We studied to reduce foil hits of the circulating beam by minimizing the vertical injection beam size at the foil and using a smaller vertical foil size. The vertical foil size was reduced according to the injection beam size by maintaining the stripping efficiency. As a result, the number of circulating beam passing through foil was significantly reduced due to smaller foil size. The simulation and measurement results of the foil hits reduction are presented in this paper.

MOPAB175 **Advanced Concepts and Technologies for Heavy Ion Synchrotrons**
P.J. Spiller*, O. Boine-Frankenheim, L.H.J. Bozyk, S. Klammes, H. Kollmus, D. Ondreka, I. Pongrac, N. Pyka, C. Roux, K. Sugita, St. Wilfert, T. Winkler, D.F.A. Winters (GSI)*
New concepts and technologies are developed to advance the performance of heavy ion synchrotrons. Besides fast ramping of superconducting magnets, extreme UHV technologies to stabilize dynamic vacuum and charge related loss, broad band MA cavities, space charge compensation by means of electron lenses and new cooling technologies, e.g. laser cooling, show great promise to advance the forefront of beam parameters. Several of these technologies and concepts are developed and tested at GSI/FAIR. Progress and plans will be reported.

MOPAB177 **ELENA Commissioning and Status**

***C. Carli**, M.E. Angoletta, W. Bartmann, L. Bojtár, F. Butin, B. Dupuy, Y. Dutheil, M.A. Fraser, P. Freyermuth, D. Gamba, L.V. Jørgensen, B. Lefort, O. Marqversen, M. McLean, S. Ogur, S. Pasinelli, L. Ponce, G. Tranquille (CERN)*

The Extra Low ENergy Antiproton ring ELENA is a small synchrotron recently constructed and commissioned to decelerate antiprotons injected from the Antiproton Decelerator AD with a kinetic energy of 5.3 MeV down to 100 keV. Controlled deceleration in the synchrotron, equipped with an electron cooler to reduce losses and generate dense bunches, allows the experiments, typically capturing the antiprotons in traps and manipulating them further, to improve the trapping efficiency by one to two orders of magnitude. During 2018, bunches with an energy of 100 keV with parameters close to nominal have been demonstrated, and first beams have been provided to an experiment in a new experimental zone. The magnetic transfer lines from the AD to the experiments have been replaced by electrostatic lines from ELENA. Commissioning of the new transfer lines and, in parallel, studies to better understand the ring with H^- beams from a dedicated source, have started in autumn 2020. The first 100 keV antiproton physics run using ELENA will start in late summer 2021.

MOPAB178 **Systematic Effects Limiting the Sensitivity of "Magic Energy" Proton EDM Rings**

***C. Carli**, M. Haj Tahar (CERN)*

Proposals to measure a possible Electric Dipole Moment (EDM) of protons in an electro-static storage ring are studied by a world-wide community. The machine is operated at the so-called "magic energy" to satisfy the "frozen spin" condition such that, without imperfections and with the well known magnetic moment of the particle, the spin is always oriented parallel to the direction of movement. The effect of a finite EDM is a build-up of a vertical spin component. Any effect, other than a finite EDM, leading as well to a build-up of a vertical spin limits the sensitivity of the experiment. Such "systematic effects" are caused by machine imperfections, such as magnetic fields inside the magnetic shield surrounding the ring, and misalignments of electro-static elements or of the RF cavity. Operation of the machine with counter-rotating beams helps mitigating some of the effects. The most dangerous effects are those, which cannot be disentangled from an EDM by combining measurements from both counter-rotating beams, such as an average residual radial magnetic field penetrating the magnetic shield or a combination of magnetic fields and misalignments of electric elements.

MOPAB179 **Simulations of AGS Boosters Imperfection Resonances for Protons and helions**

***K. Hock**, H. Huang, F. Méot, N. Tsoupas (BNL)*

As part of the effort to increase the polarization of the proton beam for the physics experiments at RHIC, a scan of orbit harmonic corrector strengths is performed in the Booster to ensure polarization transmis-

sion through the |G gamma|=3 and 4 imperfection resonances is optimized. These harmonic scans have been simulated using quadrupole alignment data and accurately match experimental data. The method used to simulate polarized protons is extended to polarized helions for crossing the |G gamma|=5 through |G gamma|=10 imperfection resonances and used to determine the corrector strength required to cross each resonance.

MOPAB180 **AGS Dynamic Aperture at Injection of Polarized Protons and Helions**

***K. Hock**, H. Huang, F. Méot, N. Tsoupas (BNL)*

Polarized helions are part of the physics program for the future EIC. An AC dipole has been installed in the AGS Booster to preserve polarization as helions are accelerated to |Ggamma|=10.5. Extraction from the AGS Booster at |Ggamma|=7.5 is possible but: would involve crossing an intrinsic resonance in the AGS, and would be the lowest rigidity beam injected into the AGS, and therefore experiences strong distortions of the optical functions because of the AGS two partial snakes. This lower rigidity would exacerbate the optical distortions from the snake, reducing the dynamic aperture. A comparison of the dynamic aperture of protons at Ggamma=4.5 to that of helions at |Ggamma|=7.5 and |Ggamma|=10.5 show that extraction at |Ggamma|=10.5 provides a larger dynamic aperture. This larger aperture would allow helions to be placed inside the spin tune gap generated by the two partial helices in AGS earlier in the cycle.

MOPAB181 **Non-Delivery Time Reduction at MedAustron**

***L. Adler**, S. Danzinger, F. Farinon, F. Feichtinger, G. Guidoboni, N. Kahn, C. Kurfürst, D.A. Prokopovich, A. Wastl (EBG MedAustron) L.C. Penescu (Abstract Landscapes)*

MedAustron is a cancer treatment center in Austria providing proton and carbon ion beams to three clinical and one non-clinical research beam lines. The slow extraction of particles from the synchrotron follows a third order resonance extraction scheme. Currently, for every change of extraction energy a new spill needs to be generated. Besides the beam-on time of the particle delivery, every spill is also comprised of non-delivery time components e.g. the multiturn injection, acceleration or magnet conditioning. For small tumor target volumes, this non-delivery time is the major contribution to the overall treatment time. A dedicated performance improvement project (supported with a grant from the state of lower Austria) was executed with the goal to reduce these non-delivery times without affecting important clinical beam parameters such as the beam size or penetration depth. The implemented reduction of the non-delivery time >50% could be achieved, resulting in beam-on time reductions for reference treatment plans between 25% (largest proton PTV) and 58% (smallest carbon PTV). Results of commissioning efforts, technical details and the achieved optimizations will be presented.

MOPAB182 **Automated Synchrotron Lattice Design and Optimisation Us-**

ing a Multi-Objective Genetic Algorithm

***X. Zhang**, S.L. Sheehy (The University of Melbourne) E. Benedetto (TERA) E. Benedetto (CERN)*

As part of the Next Ion Medical Machine Study (NIMMS), we present a new method for designing synchrotron lattices. A step-wise approach was used to generate random lattice structures from a set of feedforward neural networks. These lattice designs are optimised by evolving the networks over many iterations with a multi-objective genetic algorithm (MOGA). The final set of solutions represent the most effi- cient and feasible lattices which satisfy the design constraints. It is up to the lattice designer to choose a design that best suits the intended application. The automated algorithm presented here randomly samples from all possible lattice layouts and reaches the global optimum over many iterations. The requirements of an efficient extraction scheme in hadron therapy synchrotrons impose stringent constraints on the lat- tice optical functions. Using this algorithm allows us to find the global optimum that is tailored to these constraints and to fully utilise the flexibilities provided by new technology.

MOPAB183 **A framework for Dynamic Aperture studies for colliding beams in the High-Luminosity Large Hadron Collider**

***S. Kostoglou**, H. Bartosik, Y. Papaphilippou, G. Sterbini (CERN)*

During the last physics run of the Large Hadron Collider (LHC), Dynamic Aperture (DA) studies have been successfully employed to optimize the accelerator's performance by guiding the selection of the beam and machine parameters. In this paper, we present a framework for single-particle tracking simulations aiming to refine the envisaged operational scenario of the future LHC upgrade, the High-Luminosity LHC (HL-LHC), including strong non-linear fields such as beam-beam interactions. The impact of several parameters and beam processes during the cycle is initially illustrated with frequency maps and then quantified with DA studies.

MOPAB184 **Unsupervised learning techniques for tune cleaning measurement**

***H. Garcia Morales** (Oxford University, Physics Department) E. Fol, R. Tomás (CERN)*

Precise measurements of tune and its stability are crucial for various optics analyses in the LHC, e.g. for the determination of the beta star using K-modulation. LHC BBQ system provides tune measurements online and stores the tune data. We apply unsupervised machine learning techniques on BBQ tune data in order to provide an automatic outlier detection method for better measurements of tune shifts and unexpected tune jitters.

MOPAB185 **HL-LHC Local Linear Correction at the Interaction Regions**

***H. Garcia Morales** (Oxford University, Physics Department) J.F. Cardona (UNAL) R. Tomás (CERN)*

Magnetic imperfections of the HL-LHC inner triplet are expected to

generate a significant β-beating. For that reason, improved local optics correction techniques at the low-β insertions is essential to ensure a high luminosity performance in the HL-LHC. In this study, we compare different strategies for local optics correction at the Interaction Regions with respect to their final performance in terms of residual β-beating. Supervised learning techniques are also explored to predict the inner triplet magnetic error contributions.

MOPAB186 **Comparison of Segment-by-Segment and Action-Phase-Jump Techniques in the Calculation of IR Local Corrections in LHC**
H. Garcia Morales *(Oxford University, Physics Department) J.F. Cardona (UNAL) R. Tomás (CERN)*
The correction of the local optics at the Interaction Regions of the LHC is crucial to ensure a good performance of the machine. In this paper, we compare two different techniques for local optics correction: Action-Phase Jump and Segment-by-Segment techniques. The comparison is made in view of future machine configurations such as Run 3 LHC optics and HL-LHC optics.

MOPAB187 **Design and Calculation of the RF System of DC140 Cyclotron**
ZabanovA. S. Zabanov *(JINR/FLNR) J. Franko, G.G. Gulbekyan, I.V. Kalagin, N.Yu. Kazarinov, S.V. Mitrofanov, V.A. Sokolov, K. Verlamov (JINR)*
Flerov Laboratory of Nuclear Reaction of Joint Institute for Nuclear Research carries out the works under creating of FLNR JINR Irradiation Facility based on the cyclotron DC140. The facility is intended for SEE testing of microchip, for production of track membranes and for solving of applied physics problems. The main systems of DC140 are based on the DC72 cyclotron ones that now are under reconstruction. The DC140 cyclotron is intended for acceleration of heavy ions with mass-to-charge ratio A/Z within interval from 5 to 5.5 up to two fixed energies 2.124 and 4.8 MeV per unit mass. The intensity of the accelerated ions will be about 1 pmcA for light ions (A<86) and about 0.1 pmcA for heavier ions (A>132). The designed RF-system of the DC-72 cyclotron with a half-wave cavity is not suitable due to the big vertical size. For this reason, a new quarter-wave RF-system was developed for the DC140 cyclotron project. The results of calculating the parameters of the new RF-system are given in this work.

MOPAB189 **Beam Commissioning of XiPAF Synchrotron**
H.J. Yao*, X. Guan, Y. Li, X.Y. Liu, M.W. Wang, X.W. Wang, Y. Yang, W.B. Ye, H.J. Zeng, S.X. Zheng (TUB) W.L. Liu, D. Wang, Z.M. Wang (NINT)*
XiPAF (Xi'an 200MeV Proton Application Facility) is a project to fulfill the need for the experimental simulation of the space radiation environment. It comprises a 7 MeV H^- linac, a 60-230 MeV proton synchrotron, and experimental stations. The Installation of the synchrotron, beamline and one experimental station were completed at the end of December 2019, and commissioning has just begun. Circulating beam around the synchrotron was observed on the first day of

operation, and now 10-200 MeV proton beam directly extracted from the synchrotron had been transported to the experimental station for user experiments. The results of the commissioning and data analysis are presented in this paper.

MOPAB190 **An 8 GeV Linac as a Booster Replacement for the Multi-Megawatt Fermilab Power Upgrade**

***D.V. Neuffer**, S.A. Belomestnykh, M. Checchin, D.E. Johnson, S. Posen, V.S. Pronskikh, N. Solyak, V.P. Yakovlev (Fermilab)*

Increasing the Main Injector (MI) beam power above ~1.2 MW requires replacement of the 8 GeV Booster by a higher intensity alternative. Previously, rapid-cycling synchrotron (RCS) and Linac solutions were considered for this purpose. In this paper, we consider the Linac version that produces 8 GeV H^- beam for injection into the Recycler Ring (RR) or Main Injector (MI). The Linac takes ~1 GeV beam from the PIP-II Linac and accelerates it to ~2 GeV in a cw SRF linac, followed by a ~2-8 GeV pulsed linac using 1300 MHz cryomodules. The linac components incorporate recent improvements in SRF technology. The linac configuration and beam dynamics requirements are presented. Injection options are discussed. Research needed to implement the Booster replacement is described.

MOPAB191 **Method Development for Cavity Failure Compensation in a Superconducting Linac**

***F. Bouly** (LPSC)*

Reliability is a major challenge within the perspective of improving the performances and sustainability of MegaWatt class accelerators. To optimize the operational costs of such accelerators the availability requirements are becoming more and more challenging. These requirements are even more stringent in the case of Accelerator Driven systems (ADS). As an example, for the MYRRHA (Multipurpose Hybrid Research Reactor for High-tech Applications) ADS demonstrator, the actual availability limit is set to a maximum of 10 beam interruptions (longer than 3 seconds) over a 3-month operating cycle. For this purpose, the accelerator design is based on a redundant and fault-tolerant scheme to enable rapid mitigation of a cavity failure. The adopted strategy is to apply for local compensation: a failed cavity is compensated by several neighboring cavities. Beam dynamics studies and method developments to apply such a failure compensation scheme are here reviewed. First simulation results for superconducting linac retuning and potential future improvements will be discussed.

MOPAB192 **LILac Energy Upgrade to 13 MeV/u**

***B. Koubek** (BEVATECH)*

In the frame of the NICA (Nuclotron-based Ion Collider fAcility) ion collider upgrade a new light ion LINAC for protons and ions will be built in collaboration between JINR and BEVATECH GmbH. While ions with a mass-to-charge ratio up to 3 will be fed into the NUCLOTRON ring with an energy of 7 MeV/u, protons are supposed to be accelerated up to an energy of 13 MeV using a third IH structure. This energy

upgrade comprises a third IH structure, a dual-use Debuncher cavity as well as an extension of the LLRF control system built on MicroTCA technology.

MOPAB194 **First 3D Printed IH-Type Linac Structure - Proof-of-Concept for Additive Manufacturing of Linac rf Cavities**

***H. Haehnel**, U. Ratzinger (IAP)*

Additive manufacturing (or "3D printing") has become a powerful tool for rapid prototyping and manufacturing of complex geometries. As technology is evolving, the quality and accuracy of parts manufactured this way is ever improving. Especially interesting for the world of particle accelerators is the process of 3D printing of stainless steel (and copper) parts. We present the first fully functional IH-type drift tube structure manufactured by metal 3D printing. A 433 MHz prototype cavity has been constructed to act as a proof-of-concept for the technology. The cavity is designed to be UHV capable and includes cooling channels reaching into the stems of the DTL structure. We present the first experimental results for this prototype.

MOPAB195 **Development of a Disk-and-Washer Cavity for the J-PARC Muon g-2/EDM Experiment**

***Y. Takeuchi**, J. Tojo (Kyushu University) E. Cicek, K. Futatsukawa, N. Kawamura, T. Mibe, M. Otani, T. Yamazaki, M. Yoshida (KEK) Y. Iwashita (Kyoto ICR) R. Kitamura, Y. Kondo, T. Morishita (JAEA/J-PARC) Y. Nakazawa (Ibaraki University) N. Saito (J-PARC, KEK & JAEA) Y. Sue, K. Sumi, M. Yotsuzuka (Nagoya University, Graduate School of Science) H.Y. Yasuda (University of Tokyo)*

At J-PARC, an experiment using muons accelerated by a linac is planned to measure the anomalous magnetic moment of muons and to search for the electric dipole moment. A 1296 MHz disk and washer (DAW) coupled cavity linac (CCL) is being developed for use in the middle beta section of the muon linac. The DAW CCL consists of 14 tanks with 11 cells each. All tanks are connected by bridge couplers and electromagnetic quadrupole doublets for focusing are installed in each bridge coupler. The basic design of the DAW cavity has already been completed, and now detailed cavity design studies and manufacturing process studies are underway. In this poster, we will report about these studies and the preparation status of manufacturing the DAW cavity.

MOPAB196 **Field tuning of the 1 MeV/n RFQ at KOMAC**

***H.-J. Kwon**, Y.-S. Cho, J.J. Dang, W.-H. Jung, D.-H. Kim, H.S. Kim, K.H. Kim, S. Lee (Korea Atomic Energy Research Institute (KAERI))*

A 1 MeV/n Radio-frequency Quadrupole (RFQ) is under development at Korea Multi-purpose Accelerator Complex (KOMAC), the purposes of which are swift ion beam irradiation and compact neutron source. The RFQ was designed to accelerate ions with mass to charge (A/q) ratio up to 2.5. The designed peak current was 10 mA with 10% duty ratio. The RFQ is four vane structure resonated at 200 MHz. It has total

40 frequency tuners. There are no dipole rods and resonant coupling plate because the mode separation was large enough and the length of the RFQ was only two times of the wavelength. In this paper, the development status and field tuning results of the 1 MeV/n RFQ are presented.

MOPAB198 **The study on magnet sorting of the CSNS/RCS dipoles**

Y. Li, *Y.W. An (IHEP) , Z.P. Li, S.Y. Xu (DNSC)*

The 1.6GeV rapid cycling synchrotron (RCS) of the China Spallation Neutron Source (CSNS) is a high-power pulsed proton machine aiming for 500kW output beam power. Now, the routine output beam power has been increased to 100kW. However, the horizontal bare orbit in the ring is large (15mm) and the number of correctors is small, which brings great challenges to the ramp-up of beam power. It is found that the bare orbit in AC mode is 3-4mm larger than that in DC mode. The reason is that the AC dipoles field error is larger than DC dipoles field error. Therefore, it is proposed to sort dipoles again according to the AC dipoles field error. In order to reduce the risk of beam commissioning, fewer magnets should to be moved to achieve smaller orbit. The best results of moving two to six magnets were calculated. After sorting, the orbit can be reduced by 3-4mm, which reduces the difficulty of orbit correction.

MOPAB200 **Parameters Measurements of Proton Beam Extracted from CSNS/RCS**

Z.P. Li, *Y.W. An, M.Y. Huang (IHEP) Y. Li, S.Y. Xu (DNSC) H.Y. Liu (IHEP CSNS)*

In order to study the emittance evolution of the circulating beam in the fast-cycling synchrotron (RCS) of the Chinese Spallation Neutron Source (CSNS), parameter measurements of the beam extracted at different times were carried out. The measurements were mainly based on wire-scanners mounted in RCS to target transport line (RTBT) for beam profile measurement, and different methods were applied in the solution processes. The emittance and C.S parameters of the extracted beam at different times were obtained and studied, which provided an important reference basis for the beam commissioning of RCS. The beam envelope along the RTBT has been matched and re-measured, which was in good agreement with the design optics.

MOPAB201 **Design of Simplified Octupole Magnet and its Application in BNCT Beam Spot Uniformization**

C.D. Deng, *Z.P. Li (DNSC) S. Li, Y.Q. Liu, H.F. Ouyang, X. Wu, Y.W. Wu (IHEP)*

We proposed and developed two simplified multipole magnet prototypes, one is octupole and the other is dodecapole. Magnets with this novel structure can supply much higher saturation fields in a smaller aperture and has a simpler structure. The measurement results of the magnet prototype show that the integrated magnetic field distribution of the simplified magnet has a deviation of less than 3% compared with the standard magnet, which is sufficient to meet general application

requirements. In the research project of the BNCT test device conducted by the Dongguan Neutron Science Center, a horizontal and a vertical simplified octupole magnet were used to uniformize the beam spot in front of the target. The beam experiment results show the effect well.

MOPAB203 **Benchmark of Superconducting Cavity Models at SNS Linac**
A.P. Shishlo *(ORNL)*
A benchmark of superconducting cavity models against Time-of-Flight measurements at the SNS linac is presented. The superconducting part of SNS linac (SCL) includes 81 RF cavities that accelerates H^- beam from 185.6 MeV to the final energy of 1 GeV. During the operation some of cavities can become unstable, and its amplitudes should be reduced, or they should be completely switched off. In this case, the SCL is retuned by using a linac simulation code. This simulation tool relay on an accuracy of the superconducting cavity model. This paper describes the comparison of the measured beam acceleration by one of the SCL cavities and simulations of this process. Different cavity models are used in simulations. The subject of this study is limited to the longitudinal beam dynamics, so no effects on transverse beam characteristics have been considered.

MOPAB204 **The Start-to-End Model of MYRRHA Phase 1 Accelerator**
A. Ponton*, U. Dorda, A. Gatera, D. Vandeplassche (SCK•CEN) M.A. Baylac, D. Bondoux, F. Bouly, E. Froidefond (LPSC) R.M. Bodenstein (JLab) E. Bouquerel, E.K. Traykov (IPHC) H. Kraft, L. Perrot (Université Paris-Saclay, CNRS/IN2P3, IJCLab)*
The MYRRHA project at SCK•CEN is an ADS composed of a subcritical nuclear reactor driven by a 2.4 MW linear proton accelerator (600 MeV, 4 mA CW beam). The accelerator is being designed to achieve unprecedented reliability and availability, explaining the phased approach in its installation. The first phase currently ongoing until 2026 aims at demonstrating the fault compensation strategy for the 600 MeV linac on a 100 MeV linac. The MYRRHA phase 1 accelerator will deliver a 100 MeV, 4 mA CW proton beam. The accelerated beam will be sent to a PTF (Proton Target Facility) for various applications including ISOL, fusion research and isotope production. The design of the 100 MeV accelerator is being validated by beam dynamics calculations and error studies. The first components of its injector composed of an ECR (Electron Cyclotron Resonance) proton source, an LEBT (Low Energy Beam Transport line) and an RFQ (Radio Frequency Quadrupole) are currently being commissioned at the Centre de Ressources du Cyclotron (CRC) in Louvain-la-Neuve. The updated model of the 100 MeV linac from the source to the PTF and related error studies will be presented.

MOPAB205 **Minerva (Myrrha Phase 1) RFQ Beam Commissioning**

A. Gatera*, J. Belmans, F. Davin, W. De Cock, F. Doucet, L. Parez, F. Pompon, A. Ponton, D. Vandeplassche (SCK•CEN) F. Bouly (LPSC) C. Joly, L. Perrot (Université Paris-Saclay, CNRS/IN2P3, IJCLab) H. Podlech (IAP) J. Tamura (JAEA/J-PARC) C. Zhang (GSI)*

The MYRRHA project aims at coupling a 600 MeV proton accelerator to a subcritical fission core operating at a thermal power of 60 MW. The nominal proton beam for this ADS has an intensity of 4 mA and is delivered in a quasi-CW mode. Phase 1 of the project will realize a 100 MeV, 4 mA superconducting linac with the mission of ensuring the ADS requirements in terms of reliability and fault tolerance. As part of the reliability optimization program the integrated prototyping of the MINERVA injector is ongoing. The front-end of the injector is composed of an ECR proton source, a 2.6 m long LEBT (low energy beam transport line) and a four-rod RFQ accelerating the beam to 1.5 MeV. The present contribution focuses on the current beam tests on the RFQ, including beam matching, RF conditioning, assessment of the cavities' performances and accelerated beam characterisation.

MOPAB206 **The RF Parameters of Heavy Ions Linac**

A. Sitnikov*, G. Kropachev, T. Kulevoy, D.N. Selesnev, A.I. Semennikov (ITEP) M.L. Smetanin, A.V. Telnov, N.V. Zavyalov (VNIIEF)*

The new linac for A/Z = 8, output energy 4 MeV/u and 3 mA current is under development at NRC "Kurchatov Institute"-ITEP. The linac consists of Radio-Frequency Quadrupole (RFQ) with operating frequency 40 MHz and two sections of Drift Tube Linac (DTL) with operating frequency 80 and 160 MHz, correspondently. Both DTL has a modular structure and consists of separated individually phased resonators with focusing magnetic quadrupoles located between the cavities. The DTL_1 is based on the quarter-wave resonators meanwhile DTL_2 is based on IH 5-gap resonators. The 6D beam matching between RFQ and DTLs is provided by magnetic quadrupole lenses and 2-gaps RF-bunchers. The paper presents results of the radio-frequency (RF) design of linac accelerating structures.

MOPAB207 **Design Guideline for Minimizing Space-Charge-Induced Emittance Growth**

C. Zhang *(GSI)*

Space-charge-induced emittance growth is a big concern for designing low-energy and high-intensity linacs. The Equipartitioning Principle was introduced to minimize space-charge-induced emittance growth by removing free energy between the transverse and longitudinal degrees of freedom. In this study, a different design guideline is being proposed. It suggests holding the ratio of longitudinal emittance to transverse emittance around one and take advantage of low emittance transfer for minimizing emittance growth. Using a high-intensity RFQ accelerator as an example, a comparison between the two design methods has been made.

MOPAB208 **LLRF Measurements and Cu-plating at the First-of-Series Cavity Section of the Alvarez 2.0 at GSI**

M. Heilmann, *T. Dettinger, X. Du, L. Groening, S. Mickat, A. Rubin (GSI)*

The Alvarez 2.0 will replace the existing post-stripper DTL of the GSI UNILAC. Today's GSI comprises the UNILAC and the synchrotron SIS18 and is going to serve as the injector chain for the Facility of Antiproton and Ion Research (FAIR). The new Alvarez-type DTL is operated at 108.4 MHz providing acceleration from 1.4 MeV/u to 11.4 MeV/u along a total length of 55 meters. The first-of-series (FoS) cavity section has 12 RF-gaps along a total length of 1.9 m. It is the first cavity section of the new DTL. All main components were delivered in 2019, followed by successful SAT and installation of the 11 drift tubes and copper-plating. Completion of first low level RF-measurements prior to copper plating and the subsequent plating are major project milestones. These proceedings report on the results and compares them to simulation using CST Microwave Studio.

MOPAB209 **Commissioning of SANAEM RFQ Accelerator**

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The former SANAEM RFQ is upgraded with a newly manufactured cavity, made of oxygen-free copper (OFC), having the capability of accelerating protons from 20 keV to 1.3 MeV. In the assembling of cavity vanes, flanges, etc., indium wire is preferred over the brazing process providing a more flexible and easy method for vacuum sealing. After assembling the cavity, argon plasma cleaning is performed for the final cleaning and RF pre-conditioning. Vacuum tests revealed that levels of 2×10^{-7} mbar could be achieved quite easily. RF power conditioning of the RFQ cavity is successfully completed with the observation of quite few sparks. In the commissioning tests with the proton beam, a magnetic analyzer is used to measure the energy of the particles. This paper presents the strategy and the results concerning the commissioning of the proton beam with special emphasis on the RFQ cavity.

MOPAB210 **High-Gradient Booster for Enhanced Proton Radiography at LANSCE**

S.S. Kurennoy, *Y.K. Batygin (LANL)*

Increasing energy of proton beam at LANSCE from 800 MeV to 3 GeV improves radiography resolution ~10 times. We propose accomplishing this energy boost with a compact cost-effective linac based on cryo-cooled normal conducting high-gradient RF accelerating structures. High-gradient structures exceeding 100 MV/m have been developed for electron acceleration and operate with short RF pulse lengths below 1 us. Though such parameters are unusual for typical proton linacs, they fit perfectly for proton radiography (pRad) applications. The pRad limits contiguous trains of beam micro-pulses to less than 80 ns to prevent blur in images. For a compact pRad booster at LANSCE, we develop a staged design: a short section to capture and compress

the 800-MeV proton beam followed by the main high-gradient linac. Our beam dynamics study addresses the beam magnetic focusing and minimizing its energy spread, which are challenging in high-gradient structures but very important for successful pRad operation.

MOPAB211 **Beam Coupling Impedances of Ferrite-Loaded Cavities: Calculations and Measurements**

***S.S. Kurennoy**, R.C. McCrady (LANL)*

We have developed an efficient method of calculating impedances in cavities with dispersive ferrite dampers. The ferrite dispersive properties in the frequency range of interest are fitted in CST, which allows using both wakefield and lossy eigenmode solvers. A simple test cavity with or without ferrite inserts is explored both numerically and experimentally. The resonance frequencies and beam coupling impedances at cavity resonances are calculated with CST to understand the mode structure. The cavity transverse coupling impedances are also measured on a test stand using a two-wire method. We compare results of impedance calculations and measurements for a few different configurations, with and without ferrites, to ensure a complete understanding of the cavity resonances and their damping with ferrite. These results are important to provide adequate damping of undesired transverse modes in induction-linac cells.

MOPAB212 **3-D Quantum Lifetime**

***H. Zhao**, M. Blaskiewicz (BNL)*

The quantum lifetime of electron beam in storage rings is defined by the particle loss caused by the aperture limitation. Based on the equilibrium beam distribution produced by radiation damping and quantum excitation, the 1-d quantum lifetime has been well studied by A. Piwinski. In this paper, we give the derivation of the 3-d quantum lifetime, which can be applied to machines with elliptical aperture and momentum acceptance.

MOPAB213 **Characterization of Linear Optics and Beam Parameters for the APS Booster With Turn-by-Turn BPM Data**

***X. Huang**, H. Shang, C. Yao (ANL)*

We take turn-by-turn (TBT) BPM data on the energy ramp of the APS Booster, and analyze the data with the independent component analysis. The extraction kicker was used to excite the betatron motion. The linear optics of the machine is characterized with the TBT BPM data. We also analyze the decoherence pattern of the kicked beam, from which we are able to derive beam distribution parameters, such as the momentum spread.

MOPAB214 **Linear Optics Measurement and Correction for the APS Ring With Turn-by-Turn BPM Data**

***X. Huang**, V. Sajaev, Y.P. Sun, A. Xiao (ANL)*

We measure the linear optics of the APS storage ring from turn-by-turn BPM data taken when the beam is excited with an injection kicker. Decoherence due to chromaticity and amplitude-dependent detuning is

observed and compared to theoretic predictions. Independent component analysis is used to analyze the data, which separates the betatron normal modes and synchrotron motion, despite contamination of bad BPMs. The beta functions and phase advances are subsequently obtained. The method is used to study the linear optics perturbation of an insertion device.

MOPAB215 **Using ICA for Retrieving Teng Parameters**

A. Lauterbach *(IAP) G. Franchetti (GSI)*

The blind source separation (BSS) method of Independent Component Analysis (ICA) is explored as a new approach for the reconstruction of the transfer matrix of Linear Coupling Parameterization. ICA is a method to detangle independent signals out of several measurements of their mixtures. In BSS-calculations, it is usually not possible to retrieve the mixing matrix, for the source signals, as well as the matrix, are unknown. Combining the parameterization model of D.A. Edwards and L.C. Teng with the standard ICA approach, it is though possible to retrieve the mixing matrix, as the form of the original uncoupled motion is known. At the same time arises the possibility to recalculate the parameters of Edwards and Teng through a system of equations of the one turn map components. It can be shown as a proof of concept, that the parameters can be reconstructed up to high accuracy for a simulated, non-perturbed signal.

MOPAB216 **20-24 GeV FFA CEBAF Energy Upgrade**

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A proposal was formulated to increase the CEBAF energy from the present 12 GeV to 20-24 GeV by replacing the highest-energy arcs with Fixed Field Alternating Gradient (FFA) arcs. The new pair of arcs would provide six or seven new beam passes, going through this magnet array, allowing the energy to be nearly doubled using the existing CEBAF SRF cavity system. One of the immediate accelerator design tasks is to develop a proof-of-principle FFA arc magnet lattice that would support simultaneous transport of 6-7 passes with energies spanning a factor of two. We also examine the possibility of using combined function magnets to configure a cascade, six-way beam split switchyard. Finally, a novel multi-pass linac optics based on a weakly focusing lattice is being explored.

MOPAB217 **A Storage Ring for MESA**

C.P. Stoll*, A. Meseck (KPH) B. Ledroit (HIM)*

The Mainz Energy-recovering Superconducting Accelerator (MESA) is an Energy Recovery Linac (ERL) facility under construction at the Johannes Gutenberg-University in Mainz. It provides the opportunity for precision physics experiments with a 1 mA c.w. electron beam in its initial phase. In this phase experiments with unpolarised, high density

10^{19} atoms cm^2 gas jet targets are foreseen at the Mainz Gas Internal Target Experiment (MAGIX). To allow experiments with thin polarised gas targets with sufficiently high interaction rates in a later phase, the beam current has to be increased to up to 100 mA, which would pose significant challenges to the existing ERL machine. Thus, it is proposed here to use MESA in pulsed operation with a repetition rate of several kHz to fill a storage ring, providing a quasi c.w. beam current to a thin gas target. For this purpose, the existing optics need to be extended and adapted, a suitable injection and extraction scheme is necessary and beam target interaction must be investigated. First considerations on these topics are presented here.

MOPAB218 **Beam Dynamic Design of a Deuterium IH DTL**
X.D. Yu *(TUB)*
This paper mainly describes beam dynamics and high-frequency design results of a deuteron interdigit H-mode drift tube linac (IH-DTL). The IH DTL is designed to accelerate deuteron from 2MeV to 11MeV with peak current intensity of 20mA. Conventional negative synchronous phase approach and FODO focusing method with permanent magnet quadrupole (PMQ) are adopted to improve transmission efficiency of this high deuteron current. After 3 times coupled iterations of electromagnetic and beam dynamics modeling, the final length of the IH-DTL is 2.6 meters with 100% transmission efficiency and the final peak wall power is 517 kW (with 1.25 coefficient).

MOPAB219 **Physics design of a 7 MeV/325 MHz Alvarez-type DTL**
S. Wang *(TUB)*
A 6mA, 325MHz Drift Tube Linac has been designed as a part of 7 MeV H^- linac injection based on Xi'an Proton Application Facility. The injection is comprised of a 50 keV negative hydrogen ion source, a two-solenoid magnetic lens Low Energy Beam Transport system (LEBT), a Radio Frequency Quadrupole (RFQ), a Drift Tube Linac (DTL). This paper mainly presents the physical design of the DTL. In chapter II, the geometric parameters are optimized to maximize the effective shunt impedance and the transit time factor. In chapter III, the 2D and 3D results are presented by superfish and CST, and the beam dynamics are calculated by Parmila Program. In chapter IV, the single and combined error analysis is necessary for this whole work.

MOPAB220 **Towards Deterministic Design of MBA-Lattices**
B.C. Kuske *(HZB)*
Since the pioneering work of MAX IV, multi-bend achromat (MBA) lattices have become the standard in lattice design for 4th generation lights sources as well as upgrades of 3rd generation storage rings. The distribution of the bending angle to many weak dipoles enables to reach unprecedented low emittance and highest brightness. In their most basic form, MBA-lattices consist of a repetitive unit cell and two identical matching cells on either end of the achromatic arc. The simplicity of both cells allows for a unique determination of the linear lattice parameters in dependence on boundary conditions defined by

the design goals. Those might be the emittance, momentum compaction factor, chromaticity, as well as phase advances with respect to achieving higher-order achromatic structures. A scan of optional lattice prototypes is quickly obtained. We demonstrate this concept and apply it in the design of the first candidates for the lattice of BESSY III, a green-field 4th generation storage ring being currently planned at HZB, Berlin, Germany.

MOPAB221 **Developments of a Pulse Kicker System for the Three-Dimensional Spiral Beam Injection of the J-PARC Muon g-2/EDM Experiment**

***K. Oda**, H. Hirayama, H. Iinuma, Y. Sato, M. Sugita (Ibaraki University) M. Abe, K. Furukawa, T. Mibe, H. Nakayama, S. Ohsawa, M.A. Rehman, N. Saito, K. Sasaki (KEK) R. Matsushita (The University of Tokyo, Graduate School of Science)*

The J-PARC muon g-2/EDM experiment aims to perform ultra-precise measurements of anomalous magnetic moments (g-2) and electric dipole moments (EDM) from the spin precession of muons in a precise magnetic field and to explore new physics beyond the Standard Model. On experimental requirements, the beam must be stored in a compact storage orbit with a diameter of 66 cm, which is about 1/20th smaller than that of the previous experiment. To be realized, we adopt an unprecedented injection technique called the three-dimensional spiral injection scheme. In this scheme, the beam is injected from upward of the solenoidal storage magnet. The vertical beam motion along the solenoid axis is controlled by a few 100 ns pulse kicker. Once the beam is guided into the center fiducial storage volume, the muon beam is stored by the weak focusing magnetic field. Therefore, stable and accurate control of the pulse kicker is one of the major technical challenges to realize the ultra-precise measurement of the muon spin precession. In this presentation, we discuss the performance of the prototype pulse kicker device and future plan for installation of it to our test bench with an electron beam.

MOPAB222 **Comparison of Two Preliminary Lattice Designs for SSRL-X**

***J. Kim**, J.A. Safranek, M. Song, K. Tian, Z. Zhang (SLAC) X. Huang (ANL)*

SSRL-X is a 3.5 GeV green-field low-emittance storage ring proposal with ~400 m circumference and ~20 cells which could be built at SLAC National Accelerator Laboratory. Starting from the two most competitive low-emittance lattice types known so far, multi-bend achromat (MBA) with TME-like unit cells and hybrid seven-bend achromat (H7BA), achievable emittance and magnet requirements are explored. Two preliminary lattice designs from the two lattice types are presented. Both lattices have an equilibrium emittance of ~60 pm. Dynamic aperture and Touschek lifetime are also compared. We discuss which type of lattice is more promising for SSRL-X in terms of emittance, nonlinear performance, and magnet requirements.

MOPAB223 **Modification of Beam Ellipse at the End of Booster-to-SPEAR3 (BTS) Transport Line**

***J. Kim**, K. Tian (SLAC)*

SPEAR3, a 3GeV storage ring with 10 nm emittance, is now preparing lowering emittance to 7 nm and 6 nm in order. Optimization of 6 nm lattice has not been finished and its dynamic aperture and injection efficiency could be further improved. As one of ways to increase injection efficiency, we stretched and rotated horizontal beam ellipse at the septum position to avoid hitting septum wall and dynamic acceptance limit. Responses between strengths of upstream quadrupoles and Twiss function at the septum were measured with the quadrupole scan technique. We present correction of horizontal beam ellipse with few numbers of quadrupole knobs and its validation.

MOPAB224 **Optimization and Error Studies for the USSR HMBA Lattice**

***L. Hoummi**, N. Carmignani, L.R. Carver, S.M. Liuzzo, T.P. Perron, S.M. White (ESRF) I.A. Ashanin, S.M. Polozov (MEPhI) T. Kulevoy (ITEP) T. Kulevoy (NRC)*

Several new accelerator facilities will be built in Russia in the next few years. One of those facilities is a 6 GeV storage ring (SR) light source, the Ultimate Source of Synchrotron Radiation (USSR) to be built in Protvino, near Moscow. The Cremlin+ project aims to incorporate in this activity the best experience of European Accelerator Laboratories. The optimization of such optics including realistic errors and a commissioning-like sequence of corrections, using Multi-Objective Genetic Algorithms (NSGA-II) is presented. Several corrections schemes are also tested.

MOPAB225 **A HMBA Lattice Design Study for the 4 GeV Light Source**

***S.W. Jang**, E.-S. Kim (KUS)*

The 4th generation storage ring (4GSR) project will start from 2022 in South Korea. We proposed HMBA (Hybrid Multi-Bend Achromatic) lattice for 4GSR with super-bend at the center of the lattice. The 4GSR lattice is designed to combined HMBA lattice with a 4 GeV, 53 pm-rad emittance and 843m. The storage ring including 32 long with 5.65m, 16 short straight with 1.3m sections for IDs and 16 super-bend sections for more different type of beam line experiments. A calculated dynamic aperture is more larger than 15mm in both direction and the beam life time is expected to 4.7 hour. In this paper, we will describe the study results of the HMBA lattice design with a 4GeV light source.

MOPAB226 **Analytical Description of the Steerer Parameters in the Bilinear-Exponential Model at DELTA**

***S. Koetter** (DELTA)*

At DELTA, a 1.5 GeV synchrotron radiation source operated by the TU Dortmund University, an analytical description of the steerer parameters in the bilinear-exponential (BE) model has been developed. The BE model describes the coupled orbit response in a storage ring. It is used in the closed-orbit bilinear-exponential analysis (COBEA) algorithm to decompose orbit response matrices into beta function, betatron

phase, and a scaled dispersion. After introducing the BE model and the analytical steerer parameters, a simulation-based comparison of the BE model and another coupled orbit response model is presented.

MOPAB228 **Introducing two Energy-Correction Schemes at DELTA**
S. Koetter *(DELTA)*
At DELTA, a 1.5 GeV synchrotron light source operated by the TU Dortmund University, two methods to correct the beam energy of the storage ring have been tested. The first one is capable of maintaining the current beam energy. The second method is used to find the optimal orbit length. Here, the ideas behind both methods are explained and first test results are presented. Numerical studies are shown together with measurement results.

MOPAB229 **Compensations of Third-Order Resonances in J-PARC MR**
T.Y. Yasui*, S. Igarashi, T. Koseki, Y. Kurimoto, Y. Morita, K. Ohmi, Y. Sato, T. Shimogawa (KEK)*
The main ring synchrotron (MR) of the Japan Proton Accelerator Research Complex (J-PARC) provides high-power proton beams for the neutrino and hadron experiments. In the fast extraction (FX) operation, the beams are injected with the energy of 3 GeV and the intensity of 3.3×10^{13} protons per bunch, and accelerated to 30 GeV. Most of the beam losses are observed in the low-energy period, because the space charge tune spread is large, and crosses various kinds of resonances. In this study, the compensations of the third-order resonances are performed. The present operation tune is $(\nu_x, \nu_y) = (21.35, 21.43)$ in FX operation. The nearest third-order structure resonance is $\nu_x - 2\nu_y = -21$. It was clearly compensated by optimizing the phase advances in the arc sections. The compensation was confirmed by the aperture survey simulations and demonstrated by the three different experiments. The third-order nonstructure resonances near the operation tune are $3\nu_x = 64$ and $\nu_x + 2\nu_y = 64$. They are simultaneously compensated by introducing four trim coils of the sextupole magnets. The beam loss was successfully reduced by adopting the compensations.

MOPAB230 **The optics design for the Final Focus System of CLIC 380 GeV.**
A. Pastushenko*, R. Tomás (CERN) A. Faus-Golfe (Université Paris-Saclay, CNRS/IN2P3, IJCLab)*
The first stage of the Compact Linear Collider (CLIC) is planned to be at the center-of-mass energy of 380 GeV. The final focus system (FFS) was re-optimized for this energy and for L* of 6 m (distance between the Interaction Point (IP) and the last quadrupole, QD0). Furthermore, the FFS optics was optimized for the vertical beta-function of 70 microns to approach the Hourglass effect limit. This paper reports the exploration of shortening the Final Doublet (FD) within the FFS to reduce the chromaticity. In addition, an alternative optics design is investigated with a different dispersion profile along the FFS, which outperforms the previous optics with the same β^*, increasing luminosity by 5 %.

MOPAB231 **Tunability Study of the Ultra-Low β^* Optics at ATF2 With New Octupole Setup and Tuning Knobs**

A. Pastushenko, *R. Tomás (CERN) A. Faus-Golfe (Université Paris-Saclay, CNRS/IN2P3, IJCLab) K. Kubo, S. Kuroda, T. Naito, T. Okugi, N. Terunuma, R.J. Yang (KEK)*

The main goal of the Accelerator Test Facility 2 (ATF2) is to demonstrate the feasibility of future linear colliders' final focus systems. The Ultra-low β^* optics of ATF2 is designed to have the same chromaticity level as CLIC. To ease the tuning procedure, a pair of octupoles was installed in ATF2 in 2017. This paper reports the optimizations performed to the octupoles' setup for Ultra-low β^* optics including the new alignment technique, based on the waist shift and the new tunning knobs constructed for this optics. The full tuning procedure including the static errors is simulated for this setup.

MOPAB232 **Observation of Polarization-Dependent Changes in Higher-Order Mode Responses as a Function of Transverse Beam Position in Tesla-Type Cavities at FAST**

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Higher-order modes (HOMs) in superconducting rf cavities present problems for an electron bunch traversing the cavity in the form of long-range wakefields from previous bunches. These may dilute the emittance of the macropulse average, especially with low emittance beams at facilities such as the European X-ray Free-electron Laser (XFEL) and the upgraded Linac Coherent Light Source (LCLS-II). Here we present observations of HOMs driven by the beam at the Fermilab Accelerator Science and Technology (FAST) facility. The FAST facility features two independent TESLA-type cavities (CC1 and CC2) after a photocathode rf gun followed by an 8-cavity cryomodule. The HOM signals were acquired from cavities using bandpass filters of 1.75 ± 0.15 GHz, 2.5 ± 0.2 GHz, and 3.25 ± 0.2 GHz and recorded using an 8-GHz, 20 GSa/s oscilloscope. The frequency resolution obtained is sufficient to separate polarization components of many of the HOMs. These HOM signals were captured from CC1 and cavities 1 and 8 of the cryomodule for various initial trajectories through the cavities, and we observe correlations between trajectory, HOM signals, and which polarization component of a mode is affected.

MOPAB234 **Analysis of the Chromatic Vertical Focusing Effect of Dipole Fringe Fields**

K. Hwang, *C.E. Mitchell, R.D. Ryne (LBNL)*

There have been questions regarding the impact of the dipole fringe-field models (used by accelerator codes including ELEGANT and MADX) on vertical chromaticity. Here, we analyze the cause of the disagreement among codes and suggest a correction.

MOPAB235 **Transverse 2d Phase-Space Tomography Using Beam Position Monitor Data of Kicked Beams**

K. Hwang, *C.E. Mitchell, R.D. Ryne (LBNL)*

The time-series Beam Position Monitor (BPM) data of kicked beam is a function of lattice parameters and beam parameters including phase-space density. The decoherence model using the first-order detuning parameter has an exact solution when the beam is Gaussian. We parameterize the beam phase-space density by multiple Gaussian kernels of different weights, means, and sizes to formulate the inverse problem for 2D phase-space tomography. Numerical optimization and Bayesian inference are used to infer the beam density.

MOPAB236 **Ion Beam Dynamics in Linac-100 Facility at Jinr**

S.M. Polozov, *V.S. Dyubkov, Y. Lozeev, T.A. Lozeeva, A.V. Samoshin (MEPhI)*

The heavy-ion linac LINAC-100 is a superconducting driver-accelerator proposed as one of the prospective projects at JINR. Its goal is to accelerate primary stable isotope CW high-intensity beams to energies up to 100 MeV/u. This linac is discussed as the first stage of a new rare isotope facility DERICA (Dubna Electron-Radioactive Ion Collider fAcility), being under development at JINR since 2017. LINAC-100 is supposed to work with a wide range of beams with A/Z 3.5Ã·7, Uranium U^{34+} being the heaviest. Its concept has undergone many changes, mostly considering stripping cells to increase accelerator efficiency. During the latest investigations of various stripping cells, Uranium beam stripping at the energy 10 MeV/u and utilizing three adjacent charge states 59-61+ resulted in 60% output beam intensity preservation (or 30 pA overall output current). The current layout of the LINAC-100 is the following: one or two (separately for light and heavy ions) normal conducting front-end linacs, gas stripper cell at 10 MeV/u, and the SC section. In this paper three charge state Uranium beam dynamics in the current version of SC LINAC-100 section is presented.

MOPAB237 **Design and Optimization of a Superconducting Gantry With Large Momentum Acceptance Applied to Proton Therapy**

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Proton therapy (PT) is a precise and effective radiotherapy method for tumors. To reduce the weight and footprint of normal conducting gantries applied to PT, a lightweight superconducting (SC) gantry with large momentum acceptance is studied at HUST. To achieve momentum acceptance higher than 10%, a symmetric local-achromatic beamline was adopted by using AG-CCT bending magnets. Design procedures includes (1) a high-order beam optics fitting; (2) validation by beam tracking in realistic magnetic fields. Due to the fitting complexity, especially for AG-CCT fringe fields cross-talk, a generic algorithm with NSGA-III was applied to achieve global optimization. Paral-

lel computation with CUDA technique was used for fast calculation of magnetic fields. Design results show that a momentum acceptance of ±8% can be achieved. The sensitivity and influence on beam behavior of critical parameters of AG-CCTs will be analysed and demonstrated. This paper will describe the systematic design procedures of this SC gantry, and techical considerations on curved CCT magnet manufacture.

MOPAB238 **LCLS-II Configuration Optimization with a Gaussian-Profile Injector Laser**

***Y. Ding**, N.R. Neveu (SLAC)*

In this paper we discuss the development of a standard configuration for the LCLS-II SC-linac with bunch charge of 20 pC, 50 pC and 100 pC, respectively. The injector laser has a Gaussian-shape temporal profile. For all the three bunch charges, we optimized the linac settings with fixed BC1 and BC2 R56 values.

MOPAB239 **Simulation and Optimization of the Spin Coherence Time of Protons in a Prototype EDM Ring**

***M. Vitz**, A. Lehrach (FZJ)*

The matter-antimatter asymmetry might be understood by investigating the EDM (Electric Dipole Moment) of elementary charged particles. A permanent EDM of a subatomic particle violates time-reversal and parity symmetry at the same time and would be, with the currently achievable experimental accuracy, a strong indication for physics beyond the Standard Model. The JEDI-Collaboration (Jülich Electric Dipole moment Investigations) in Jülich is preparing a direct EDM measurement for protons and deuterons: first at the storage ring COSY (COoler SYnchrotron) and later at a dedicated storage ring. A prototype EDM ring is an intermediate step before building the final storage ring to demonstrate sufficient beam lifetime and SCT (Spin Coherence Time) in a pure electrostatic ring as well as in a storage ring with combined electric and magnetic bending elements. In order to study the effect of E-B-deflectors on the orbit and the spin motion, the software library Bmad is used. The first results of the optics and spin simulations, with a focus on the optimization of the SCT, towards the prototype EDM ring will be discussed.

MOPAB240 **Estimates of Damped Equilibrium Energy Spread and Emittance in a Dual Energy Storage Ring**

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A dual energy storage ring design consists of two loops at markedly different energies. As in a single-energy storage ring, the linear optics in the ring design may be used to determine the damped equilibrium emittance and energy spread. Because the individual radiation events in the two rings are different and independent, we can provide analytical estimates of the damping times in a dual energy storage ring. Using the damping times, the values of damped energy spread, and

emittance can be determined for a range of parameters related to lattice design and rings energies. We present analytical calculations along with simulation results to estimate the values of damped energy spread and emittance in a dual energy storage ring. We note that the damping time tends to be dominated by the damping time of the high energy ring in cases where the energy of the high energy rings is significantly greater than that of the low energy ring.

MOPAB241 **Design of the Proton and Electron Transfer Lines for AWAKE Run 2c**

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The AWAKE Run 1 experiment achieved electron acceleration to 2 GeV using plasma wakefield acceleration driven by 400 GeV, self-modulated proton bunches from the CERN SPS. The Run 2c phase of the experiment aims to build on these results by demonstrating acceleration to ~10 GeV while preserving the quality of the accelerated electron beam. To realize this, there will be an additional plasma cell, to separate the proton bunch self-modulation and the electron acceleration. A new 150 MeV beamline is required to transport and focus the witness electron beam to a beam size of several microns at the injection point. This specification is designed to preserve the beam emittance during acceleration, also requiring micron-level stability between the driver and witness beams. To facilitate these changes, the Run 1 proton transfer line will be reconfigured to shift the first plasma cell 40 m downstream. The Run 1 electron beamline will be adapted and used to inject electron bunches into the first plasma cell to seed the proton bunch self-modulation. Proposed adjustments to the proton transfer line and studies for the designs of the two electron transfer lines are detailed in this contribution.

MOPAB242 **A Six-Bend-Achromat Lattice for a 2.5 GeV Diffraction-Limited Storage Ring**

J. Li*, M. Abo-Bakr, P. Goslawski (HZB) Z.H. Bai (USTC/NSRL)*

HZB has proposed a 2.5 GeV diffraction-limited storage ring as the upgrade of BESSY II. A Six-Bend-Achromat lattice based on Higher-Order Achromat, as one of the possible solutions, has been designed to meet the requirements of low emittance, compact layout, large dynamic aperture and large momentum acceptance. The linear lattice design and the nonlinear performance are presented in this paper.

MOPAB245 **Theoretical Analysis of the Conditions for an Isochronous and CSR-Immune Triple-Bend Achromat with Stable Optics**

C. Zhang*, Y. Jiao, Y. Jiao (IHEP) , C.-Y. Tsai (HUST)*

Transport of high-brightness beams with minimum degradation of the phase space quality is pursued in modern accelerators. For the beam transfer line which commonly consists of bending magnets, it would be desirable if the transfer line can be isochronous and coherent synchrotron radiation (CSR)-immune. For multi-pass transfer line, the

achromatic cell designs with stable optics would bring great convenience. In this paper, based on the transfer matrix formalism and the CSR point-kick model, we report the detailed theoretical analysis and derive the condition for a triple-bend achromat with stable optics in which the first-order longitudinal dispersion (i.e., R56) and the CSR-induced emittance growth can be eliminated. The derived condition suggests a new way of designing the bending magnet beamline that can be applied to the free-electron laser (FEL) spreader and energy recovery linac (ERL) recirculation loop.

MOPAB246 **Design of the MEBT for the JAEA-ADS project**

***B. Yee-Rendón**, Y. Kondo, F.M. Maekawa, S.I. Meigo, J. Tamura (JAEA/J-PARC)*

The Medium Energy Beam Transport (MEBT) will transport a CW proton beam with a current of 20 mA and energy of 2.5 MeV from the exit of the normal conducting Radiofrequency Quadrupole (RFQ) to the superconducting Half-Wave resonator (HWR) section. The MEBT must provide a good matching between the RFQ and HWR, effective control of the emittance growth and the halo formation, enough space for all the beam diagnostics devices, among others. This work reports the first lattice design and the beam dynamics studies for the MEBT of the JAEA-ADS.

MOPAB247 **Multipacting studies for the JAEA-ADS Five-cell Elliptical Superconducting RF cavities**

***B. Yee-Rendón**, Y. Kondo, F.M. Maekawa, S.I. Meigo, J. Tamura (JAEA/J-PARC) E. Cicek (KEK)*

The Five-cell Elliptical Superconducting Radio-Frequency Cavities (SRFC) provide the final acceleration in the JAEA-ADS linac (from 208 MeV to 1.5 GeV); thus, their performance is essential for the success of the JAEA-ADS project. After their optimization of the cavity geometry to achieve a high acceleration gradient with lower electromagnetic peaks, the next step in the R&D strategy is the accurate estimation of beam-cavity effects which can affect the performance of the cavities. To this end, multipacting studies were developed to investigate its effect in the cavity operation regimen and find countermeasures. The results of this study will help in the development of the SRFC models and in the consolidation of the JAEA-ADS project.

MOPAB248 **Injection Schemes for the SOLEIL Upgrade**

***M.-A. Tordeux**, P. Alexandre, R. Ben El Fekih, P. Brunelle, L. Hoummi, A. Loulergue, L.S. Nadolski, R. Nagaoka (SOLEIL)*

Injection into the SOLEIL upgrade storage ring is much more challenging compared to the case of the current ring. Thanks to the experience gained in the development, manufacture and commissioning of a Multipole Injection Kicker (MIK) on the MAX IV 3 GeV storage ring, the SOLEIL pulsed magnet team is currently developing new MIK magnets that will serve as the basis for the injection schemes in the upgrade storage ring. We then propose two kinds of injections: firstly,

a betatron off-axis injection that should be compatible with the full-coupling storage ring tuning, and secondly, a synchrotron on-axis injection by creating a large horizontal dispersion bump at the injection point.

MOPAB249 **Global Optimization Techniques for Ultrafast Electron Microscopy Imaging Applications**

C.C. Hall *(RadiaSoft LLC) G. Andonian, I.I. Gadjev, M. Ruelas (RadiaBeam)*

Permanent magnet quadrupoles (PMQ) are a promising replacement for solenoids as lens elements for ultrafast electron microscopy (UEM) beamlines. In this work we examine design optimization of a high-resolution objective lens for a UEM with realistic PMQs. A global optimizer was used to minimize aberrations in the objective lens while achieving nanometer-level resolution. The optimization process is described including the magnet modeling, calculation of tracking matrix coefficients, and inclusion of engineering constraints on magnets and their placement.

MOPAB250 **A Modular Framework for Start-to-End Accelerator Optimization**

C.C. Hall *(RadiaSoft LLC)*

Many particle accelerator modeling codes include built-in optimization tools, however, it is often necessary to use external optimization libraries to do such work. Executing start-to-end simulations using multiple codes coupled together, or making use of new optimization algorithms often means users are left to write extensive wrapper code to manage the optimization workflow. The rsopt framework modularizes the process of optimizations and parameter scans, decoupling the optimization algorithm, simulation setup, and simulation execution steps to make it easy to swap between optimization libraries, accelerator codes, or run environments. Templating of many common accelerator codes is provided by Sirepo, allowing use of existing input files. Platform-independent execution of simulations is provided by the libEnsemble library. In this paper we describe the principle components and setup of rsopt along with several use cases.

MOPAB253 **Comparison of Transfer Map Derivation Methods for Static Magnetic Fields**

J.A. Crittenden*, S. Wang (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)*

We compare methods for deriving transfer maps for static magnetic fields, including field-map tracking and tracking elements defined by multipole content. Building on prior work on quantitative evaluation of the accuracy of finite-element models used to produce field maps, we assess the tradeoffs between computing time and fidelity to the underlying magnetic field, including fringe fields, of the various approximate methods. We illustrate our approach using the example of electromagnets in the south arc of the 6-GeV Cornell High Energy Synchrotron Source, which have been operating since 2019.

MOPAB254 **Measurement of Horizontal Beam Size Using Sextupole Magnets**

J.A. Crittenden*, K.E. Deitrick, H.X. Duan, G.H. Hoffstaetter, V. Khachatryan, D. Sagan (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)*

The quadratic dependence of sextupole fields on position results in a beam-size-dependent kick on a beam traversing a sextupole magnet. A change in sextupole strength changes the closed orbit and the tune of the beam in a storage ring. Measuring both therefore allows conclusions about the beam size in the sextupole. Here we derive the pertinent formula and discuss the applicability to storage rings. In particular we investigate the measurement accuracy that can be achieved at the Cornell High Energy Synchrotron Source. The Cornell Electron-positron Storage Ring underwent a major upgrade in 2018 with the goal of reducing the emittance by a factor of four. A variety of beam size measurement methods have been developed to monitor the positron beam size, including visible synchrotron light and interferometry. We investigate the sensitivity of the sextupole method and compare to other measurement techniques. The design horizontal emittance of the 6-GeV positron beam is about 30 nm-rad with typical beam sizes of about 1 mm, setting the scale for the required accuracy in the beam-size measurement.

MOPAB255 **Demonstration of a Novel Longitudinal Phase Space Linearization Method without Higher Harmonics**

R. Stark *(University of Hamburg) K. Flöttmann, M. Hachmann (DESY) F.J. Grüner (Center for Free-Electron Laser Science, Universität Hamburg) B. Zeitler (CFEL)*

Nonlinear correlations in the longitudinal phase space of electron bunches can be a decisive limitation to the achievable bunch length compression and attainability of small energy spreads. To overcome the restrictions imposed by nonlinear distortions, the longitudinal phase space distribution must be linearized. Previously, a novel linearization procedure based on the controlled expansion of the bunch between two radio frequency cavities operated at the same fundamental frequency has been presented in B. Zeitler *et al.*, *Phys. Rev. ST Accel. Beams*, vol. 18, p. 120102, 2015. A demonstration of this linearization method is presented in this work.

MOPAB256 **Development of Pulsed Beam System for the Three Dimensional Spiral Injection Scheme in the J-PARC muon g-2/EDM Experiment**

R. Matsushita *(The University of Tokyo, Graduate School of Science) M. Abe, K. Hurukawa, T. Mibe, H. Nakayama, S. Ohsawa, M.A. Rehman, N. Saito, K. Sasaki (KEK) H. Hirayama, H. Iinuma, K. Oda, Y. Sato, M. Sugita (Ibaraki University) N. Saito (J-PARC, KEK & JAEA) T. Takayanagi (JAEA/J-PARC)*

The J-PARC muon g-2/EDM experiment aims to measure the anomalous magnetic moment(g-2) and electric dipole moment(EDM) of the

muon with higher precision than the previous BNL E821 experiment. A brand-new three-dimensional spiral injection scheme is employed to inject and store muon beam into a 66 cm diameter of storage magnet. Feasibility studies are ongoing by use of 80 keV electron beam at KEK test bench, to develop skills on control transverse beam motion; so-called X-Y coupling, with DC beam. As a next step, towards store the beam by use of a kicker system, a pulsed beam should be generated from the DC beam with an intended time structure to meet a pulse kicker's duration time, without changing transverse phase space characteristics. In this presentation, the development of a beam chopper device and the evaluation of pulse beam profile are discussed.

MOPAB257 **Effects of Mode Launcher on Beam Dynamics in Next Generation High Brightness C-Band Guns**
***A. Giribono**, D. Alesini, F. Cardelli, G. Di Raddo, M. Ferrario, A. Gallo, J. Scifo, C. Vaccarezza, A. Vannozzi (INFN/LNF) G. Castorina (AVO-ADAM) L. Ficcadenti (INFN-Roma) G. Muti (Sapienza University of Rome) G. Pedrocchi (Rome University La Sapienza)*
High-brightness RF photo-injectors plays nowadays a crucial role in the fields of radiation generation and advanced acceleration schemes. A high gradient C-band photoinjector consisting of a 2.5 cell gun followed by TW sections is here proposed as an electron source for radiation user facilities. The paper reports on beam dynamics studies in the RF injector and illustrates the effects on the beam quality of the mode launcher with a focus on the compensation of the quadrupole RF components.

MOPAB258 **Corrections of Non-Linear Field Errors With Asymmetric Optics in LHC and HL-LHC Insertion Regions**
***J. Dilly**, E.H. Maclean, R. Tomás (CERN)*
Existing correction schemes to locally suppress resonance driving terms in the error-sensitive high-beta regions of the LHC and HL-LHC have operated on the assumption of symmetric beta-functions of the optics in the two rings. As this assumption can fail for a multitude of reasons, such as inherently asymmetric optics and unevenly distributed errors, an extension of this correction scheme has been developed removing the need for symmetry by operating on the two separate optics of the beams at the same time. Presented here is the impact of this novel approach on dynamic aperture as an important measure of particle stability.

MOPAB259 **Corrections of Feed-Down of Non-Linear Field Errors in LHC and HL-LHC Insertion Regions**
***J. Dilly**, E.H. Maclean, R. Tomás (CERN)*
The optics in the insertion regions of the LHC and its upgrade project the High Luminosity LHC (HL-LHC) are very sensitive to local magnetic errors, due to the extremely high beta-functions present. In collision optics, the non-zero closed orbit in the same region leads to a "feed-down" of high-order errors to lower orders, causing additional effects detrimental to beam lifetime. An extension to the proven

method for correcting these errors by locally suppressing resonance driving terms has been undertaken, not only taking this feed-down into account, but also adding the possibility of utilizing it such that the powering of higher-order correctors will compensate for lower order errors. The impact of these corrections on measures of particle stability, namely dynamic aperture and amplitude detuning are presented in this contribution.

MOPAB260 **Optics Corrections with LOCO on Sirius Storage Ring**
M.B. Alves *(LNLS)*
Sirius is a 4th generation 3GeV synchrotron light source at the Brazilian Center for Research in Energy and Materials (CNPEM). In this work, we report the results of linear optics and coupling corrections during the commissioning of Sirius storage ring, using the Linear Optics from Closed Orbits (LOCO) algorithm. Beam-based measurements were performed to verify independently the impact of corrections on storage ring parameters.

MOPAB261 **NSLS-II Storage Ring Lattice Analysis using Response Matrices**
J. Choi *(BNL)*
Affected from various sources, the NSLS-II storage ring lattice is slightly changing operation to operation and, for the operational performance, we are continually optimizing the lattice and maintaining the response matrices for the feedback and lattice analysis. Because not all sources are identified, we are investing efforts to identify as many as possible. As one of such efforts, we also study the measured response matrices. In this paper, we present the results of lattice studies using a pair of recently measured response matrices.

MOPAB262 **First Thoughts on Lattices for a possible Metrology Light Source 2**
M. Arlandoo*, M. Abo-Bakr, P. Goslawski, J. Li (HZB)*
The Physikalisch-Technische Bundesanstalt (PTB), in cooperation with the Helmholtz-Zentrum Berlin (HZB), operates the Metrology Light Source (MLS), which is a low-energy electron storage ring. The MLS can be operated in a low-alpha mode to produce coherent synchroton ration in the far-IR and THz spectral range. In the scope of the Conceptual Design process for a BESSY II successor, the PTB also requested for an MLS successor to cover their increasing demands on synchrotron radiation. A combination of two different machines, one optimized for low emittance (BESSY III) and one for flexible timing capabilities (MLS II), would provide best radiation capabilities for our user community. In this paper, we discuss the demands on the MLS II and propose first lattice candidates which may meet the needs of the PTB and HZB. Currently, we focus on linear lattices for standard user mode with first steps towards nonlinear optimization.

MOPAB263 **Preliminary Beam Dynamics Studies for 200 MeV Superconducting Linac Planned at KOMAC**

***S. Lee**, J.J. Dang, H.S. Kim, H.-J. Kwon (Korea Atomic Energy Research Institute (KAERI)) Y.-S. Cho (KAERI)*

Korea Multi-purpose Accelerator Complex (KOMAC) is planning an energy upgrade of the existing 100 MeV proton linac to 200 MeV using a superconducting Half Wave Resonator (HWR) operating at 350 MHz. A cryomodule is planned to house four HWR cavities with a warm doublet focusing lattice structure. Matching between the already existing DTL section and HWR section is designed and studied. We report the preliminary study of the beam dynamics of the 200 MeV superconducting linac carried out at KOMAC.

MOPAB264 **Commissioning of the DESIR High-Resolution Separator at CENBG**

***J. Michaud**, B. Blank, L. Daudin, S. Leblanc, L.S. Serani (CENBG) F. Méot (BNL) F. Varenne (GANIL)*

DESIR is the low-energy part of the SPIRAL2 ISOL facility under construction at GANIL. The high-resolution mass separator (HRS) included in DESIR is a 180 degree symmetric online separator with two 90 degree magnetic dipole sections arranged with electrostatic quadrupoles, sextupoles and a multipole on the mid plane. The HRS is now completely mounted at CENBG and under commissioning for the next 2 to 3 years before its transfer at the entrance of the DESIR facility. The objective is to test, characterise and correct all HRS elements contributing to the higher order aberration by performing experimental measurements and comparing them with the results from different simulation tools. The recently mounted pepperpot-type emittancemeter will allow us to observe the emittance figures and dynamically tune the multipole to improve the optical parameters of the HRS. We will present the first results concerning the hexapolar correction with the multipole, the associated emittance measurements and the resolution currently achieved.

MOPAB265 **Design and Simulation of Permanent Magnetic Quadrupole Lenses for Low Energy Ion Beams**

***J.D. Kaiser**, A. Ateş, H. Haehnel, U. Ratzinger (IAP)*

A Permanent Magnetic Quadrupole Triplet is designed for a focusing-channel for a 10 keV He-Beam with a current up to 10mA. For the highest possible gradient, each Singlet is made of at least 24 and up to 42 industrial standard and therefore cheap nickel-plated NdFeB block magnets. The total length of the triplet will be 120mm with an aperture diameter of 41mm. Two possible technical realizations are discussed. In the first case each Singlet has its own casing which consists of two half-shells which can easily be mounted around a beam tube and can be moved independently. A first prototype 3D-printed out of plastic was already manufactured. For the second case the shell is mounted inside of a beam tube. This makes it possible to examine the movement of the beam inside the quadrupoles with small raspberry pi camera modules.

The beam dynamics simulations are performed with Tracewin by importing magnetic field maps generated by CST Studio Suite.

MOPAB266 **Start-to-End Study on Laser and RF Jitter Effects for MAX-IV SXL**

***S.P. Pirani**, B.S. Kyle (MAX IV Laboratory, Lund University) F. Curbis, M.A. Pop, S. Werin (Lund University) W. Qin (DESY)*

A Soft X-ray free electron laser (FEL) for the MAX IV Laboratory is currently in the design phase and it will use the existing 3 GeV linac. Present stability limits in the RF and the photocathode laser will affect the performance of the FEL. One of the critical elements for the design of a FEL is to have an estimation on jitter effects of the accelerator parameters on the X-ray radiation. In this regard, we implemented a start-to-end study using Astra, Elegant and Genesis in order to assess possible variations in pulse energy, photon pulse length and spectral width in the Soft X-ray Laser (SXL) radiation. This investigation provides insights on the final SXL performance variation due to RF and laser related jitter affecting the electron beam.

MOPAB267 **End to End Simulations of Antiproton Transport and Degradation**

***S. Padden**, E. Kukstas, P. Pusa, V. Rodin, C.P. Welsch (The University of Liverpool) K. Nordlund (HIP) V. Rodin, C.P. Welsch (Cockcroft Institute)*

The ELENA ring decelerates anti-protons to 100 keV down from 5.3 MeV with transport to experiments handled by electrostatic transfer lines. Even at 100 keV antiprotons are still too high in energy for direct injection into an ion trap, and this is why degrader foils are used to further lower the energy. This contribution presents full end-to-end simulations from the point of extraction until passing through the foil using realistic beam transport simulations coupled with accurate simulations of degrader foils via the use of density functional theory and molecular dynamics. Particles are tracked from the point of extraction until their injection into the trap with full physical modeling at all time steps. The results of this study provide a versatile platform for the optimization of low energy ion experiments towards specific targets.

MOPAB268 **Design of a Continuous Wave Heavy Ion RFQ for BISOL**

***S. Liu**, M.Y. Han, Y.R. Lu, Q.Y. Tan, Z. Wang (PKU)*

The Beijing isotope separation online (BISOL) facility will be used to study the new physics and technologies at the limit of the nuclear stability. The post accelerator for BISOL facility aims to accelerate radioactive beams to 150MeV/u. As an injector for the downstream superconducting linac, a 4-vane RFQ operating at 81.25MHz is needed to accelerate high-charge-state ions such as $^{132}Sn^{22+}$ from 3keV/u to 500keV/u in CW mode. We have compared two kinds of beam dynamics of BISOL RFQ with and without a Multi-Harmonic Buncher (MHB) bunching the continuous wave beam up-stream of the RFQ. The results indicate that it is possible to keep transverse emittance growth within tolerable limits while the longitudinal emittance is

much smaller than the design without an external buncher. The acceleration of multi-charge beams simultaneously in the RFQ is also discussed in this paper.

MOPAB269 **Three Approaches for Complete Measurement of the Transverse Beam Optics Along the Fermilab Muon Campus Extraction Line**

***B.D. Simons**, M.J. Syphers (Northern Illinois University) D. Stratakis, M.J. Syphers (Fermilab)*

Traditionally, the process of measuring the optical parameters of a beamline has employed the use of one of two standard methods, namely the three-screen method or a quadrupole magnet scan. Both require either an area of zero dispersion to perform the measurements or knowledge of the dispersion function and momentum spread beforehand in order to provide accurate results. There is however a third method that can be used to measure the standard optical parameters, the beam parameters, the dispersion function, and the momentum spread simultaneously. This method, aptly named the six-screen method, is an extension of the more standard three-screen method. Utilizing the simulation environment of G4beamline, we simulated the 8 GeV proton beam in the M4 beamline and measured the optical and beam parameters using the two standard approaches. Those results were then used as a reference to check the viability of employing the less standard six-screen method in the M4 line. If shown to be a viable option, the six-screen method could be used to retrieve the dispersion function and momentum spread of the beam without needing to change the energy of the beam.

MOPAB270 **Beam Dynamics Studies in a Standing Wave Ka-band Linearizer**

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Next-generation FEL user facilities require high-quality electron beams with kA peak current. The combination of a high brightness RF injector and a magnetic compression stage represents a very performant solution in terms of electron beam emittance and peak current. One of the important issues is the design of a proper device that acts as a linearizer for the beam longitudinal phase space. Recently, the design of a SW Ka band RF accelerating structure has been proposed with promising results. The paper reports on electron beam dynamics studies in the described RF structure.

MOPAB271 **Application of Surrogate-Model Methods for the Beam Optics Optimization in a Proton Therapy Facility**

***Y.C. Liao**, Q.S. Chen, X. Liu, B. Qin (HUST)*

Proton therapy has attracted much attention in recent years thanks to its Bragg Peak characteristic. In the beam optics design of the proton

beamline, the match/optimization algorithm relies strongly on the initial value in the conventional code (e.g. TRANSPORT, MAD-X). This process is very time-consuming and needs many trials and errors. In this paper, we propose a novel surrogate model method to overcome this issue. Firstly, the data from the beam optics calculation was trained to generate a surrogate model, and then multi-objective optimization algorithms are applied to this model for searching the optimal solution in a large parameter space. It turns out that this method can greatly reduce the calculation time and increase the level of automation. There is no need for designers to set the weight value of each objective and the initial value of the solution, and a Pareto solution set with good diversity can be provided after the optimization.

MOPAB272 **Consideration the Prospects of Beam Diagnostic System Upgrade in the Transport Channels of Injection Complex VEPP-5**
K.V. Astrelina*, F.A. Emanov (BINP SB RAS) F.A. Emanov (NSU)*
Transport electron and positron channels from linear accelerator to storage ring of Injection Complex VEPP-5 (BINP, Novosibirsk) have complicated 3D configuration and equipped only with luminophore screens as a beam test. For the regular machine operations the non-destructive beam diagnostic system is required to adjust the electron and positron beam trajectories and minimize the beam losses. The proposal of new beam position monitors (BPM) assembling is considered. Newly added BPMs allow one to control the beam trajectory during operations. Collecting beam position data in several points makes it possible to calculate and correct the beamline parameters: Twiss parameters, dispersion, beam energy variations. The possible configuration of the new BPMs placing is suggested and the rate of beam loss reducing due the additional diagnostics is estimated.

MOPAB273 **Nonlinear Coupling Resonances in X-Y Coupled Betatron Oscillations Near the Main Coupling Resonance in VEPP-2000 Collider**
S.A. Kladov*, E. Perevedentsev (BINP SB RAS)* ***S.A. Kladov****, E. Perevedentsev (NSU)*
In the vicinity of the linear coupling resonance where the working point of the collider is positioned, we study the effect of nonlinear coupling resonances on the single-particle phase space, beam sizes and the waveform of coherent beam motion. The latter is interesting for diagnostics of the nonlinear dynamics.

MOPAB274 **Two-Stream Effects in Coherent Beam-Beam Oscillations in VEPP-2000 Collider Near the Linear Coupling Resonance**
S.A. Kladov*, E. Perevedentsev (BINP SB RAS)* ***S.A. Kladov****, E. Perevedentsev (NSU)*
Synchro-betatron motion of colliding bunches may cause limitations of the high-luminosity performance. For a round beam collider operated near the linear coupling resonance, we present theoretical predictions of the beam-beam coherent synchro-betatron oscillation behavior under the influence of x-y coupling.

MOPAB275 **Study on Supports of BPM Displacement Measurement System for HLS**

C.H. Wang, *P. Lu, B.G. Sun, T.Y. Zhou (USTC/NSRL)*

HLS is the second-generation light source with energy of 800 MeV and emittance of less than 40 nm-rad. In order to improve the beam orbit stability and correct the errors introduced in the orbital feedback system due to movement of the vacuum chamber and BPM, a system for measuring BPM displacement will be built. It requires a high degree of mechanical and thermal stability for its supports. The support should have a higher eigen-frequency to minimize the amplification of ground vibration. In this paper, a series of simulation, including finite element analysis (FEA), measurement and analysis have been done upon the support to make sure it can meet the requirements of the stability of the BPM displacement measurement system.

MOPAB276 **Investigation on the injection of the Arronax Cyclotron 70XP**

F. Poirier, *F. Bulteau-harel, T. Durand, X. Goiziou, C. Koumeir, C. Lassalle, H. Trichet (Cyclotron ARRONAX) F. Haddad (SUBATECH)*

A 70 MeV cyclotron is being used at the Arronax GIP (Interest Public Group), France, for various types of R&D on nuclear, biological and chemical reactions with beams and radioisotopes production. In order to adapt its usage for experiments and users demands of high peak intensity, above an equivalent average of a few μA, the injection is being adapted. Several studies are thus being performed in this section. These include the newly installed chopper-based system and the injection collimator. This paper details the various studies, specifically the signal purity obtained in the pulsed mode. A mode particularly adapted for flash irradiation.

MOPAB277 **Installation, Use and Follow-Up of an Emittance-Meter at the Arronax Cyclotron 70XP**

F. Poirier, *R. Bellamy, F. Bulteau-harel, C. Castel, T. Durand, X. Goiziou, F. Haddad, R. Lelièvre, G. Mechin, L. Perrigaud, J. Poudevigne, H. Trichet (Cyclotron ARRONAX) T. Adam, P.G. Graehling, M. Heine, C. Maazouzi, F.R. Osswald, E.K. Traykov (IPHC) A. Dinkov, S. Wurth (IJCLab) F. Haddad (SUBATECH)*

The 70 MeV cyclotron group of the Arronax GIP (Interest Public Group), France, foresees to increase its beam intensity on target. For this, several beam studies are being performed in the various sections of the accelerator including the injection. Thus, an Allison-type emittance-meter has been installed in this section above the cyclotron and downstream a quadrupole triplet. Installation and the first results of a campaign of measurements are presented including high intensity runs, up to 1 mA for 40 keV H^- ions. The emittance-meter is expected to be used with several accelerators throughout the world. Therefore, a strategy on the follow-up of the activation of sample materials used in the equipment is being established and is described in the paper.

MOPAB278 **Prototype of the Bunch Arrival Time Monitor for SHINE**
***X.Q. Liu**, L.W. Lai (SARI-CAS) Y.B. Leng, R.X. Yuan, N. Zhang, Y.M. Zhou (SSRF)*
Bunch arrival time monitor (BAM) is an important tool to investigate the temporal characteristic of electron bunch in free electron lasers (FEL). Since the timing jitter of electron bunch will affect the FEL's stability and the resolution of time-resolved experiment at FELs, it is necessary to precisely measure the electron bunch's arrival time information to stabilize the electron bunch's timing jitter using beam-based feedback. The bunch arrival time monitor based on electro-optic modulator (EOM) is currently under development. In this paper, we will introduce the recent progress of the RF pickup, the optical front-end and the electrical back-end of the bunch arrival time monitor prototype for shanghai high-repetition-rate XFEL and extreme light facility (SHINE).

MOPAB279 **Non-Invasive Beam Profile Monitoring for the HL-LHC Hollow Electron Lens**
***A. Salehilashkajani**, N. Kumar, O. Sedlacek, C.P. Welsch, H.D. Zhang (The University of Liverpool) M. Ady, N.S. Chritin, N. Jens, O.R. Jones, R. Kersevan, T. Lefèvre, T. Lefèvre, S. Mazzoni, G. Papazoglou, A. Rossi, G. Schneider, R. Veness (CERN) P. Forck, S. Udrea (GSI) N. Kumar, O. Sedlacek, C.P. Welsch, H.D. Zhang (Cockcroft Institute)*
A Hollow Electron Lens (HEL) is currently under development for the High-Luminosity upgrade of the Large Hadron Collider (HL-LHC). In this device, a hollow electron beam co-propagates with a central proton beam and provides active halo control in the LHC. To ensure the concentricity of the two beams, a non-invasive diagnostic instrument is currently being commissioned. This instrument is a compact version of an existing prototype that leverages beam induced fluorescence with supersonic gas curtain technology. This contribution includes the design features of this version of the monitor, recent progress, and future plans for tests at the Cockcroft Institute and the electron lens test stand at CERN.

MOPAB280 **Split Ring Resonator Experiment - Simulation Results**
***J. Schaefer** (KIT)*
FLUTE (Ferninfrarot Linac- Und Test-Experiment) is a compact linac-based test facility for accelerator and diagnostics R&D. An example for a new accelerator diagnostics tool currently studied at FLUTE is the split-ring-resonator (SRR) experiment, which aims to measure the longitudinal bunch profile of fs-scale electron bunches. Laser-generated THz radiation is used to excite a high frequency oscillating electromagnetic field in the SRR. Particles passing through the SRR gap are time-dependently deflected in the vertical plane, which allows a vertical streaking of an electron bunch. This principle allows a diagnosis of the longitudinal bunch profile in the femtosecond time domain and will be tested at FLUTE. This contribution presents an overview of the

SRR experiment and the results of various tracking simulations for different scenarios as a function of laser pulse length and bunch charge. Based on these results possible working points for the experiments at FLUTE will be proposed.

MOPAB281 **Research on Resolution Evaluation of Stripline BPM at SXFEL-U**

***B. Gao**, J. Chen, Y.B. Leng (SSRF)*

48 stripline BPMs are installed in the injection section and linear acceleration section of Shanghai X-ray Free Electron Laser (SXFEL) for electron beam position measurement. These two sections require resolution of 20 μm@100pC. Resolution evaluation is an important step in BPM installation and commissioning. This paper presents BPM resolution evaluation methods based on correlation analysis. Experimental methods, data processing and result analysis will be discussed

MOPAB282 **Development of a Multi-Camera System for Non-Invasive Intense Ion Beam Investigations**

***A. Ateş**, H. Haehnel, U. Ratzinger, K. Volk, C. Wagner (IAP)*

The continued popularity of miniaturized cameras integrated into smartphones is leading to further research for more advanced CMOS camera sensors. This made CMOS technology even superior to scientific CCD cameras. Due to the lower power consumption and high flexibility, a multicamera system can be developed more effectively. At the Institute of Applied Physics at Goethe University Frankfurt (IAP) a prototype of a beam induced rest gas fluorescence monitor (BIF) was developed and tested successfully. The BIF consists of x and y single board cameras integrated into the vacuum chamber. A multi-camera system was installed in the LEBT area of the FRANZ project at the IAP within the first diagnostic chamber. This system consists of six cameras. With this equipment it is possible to investigate the beam along a 484 mm path in x and y direction. The developments on the reconstruction and image processing methods are in progress.

MOPAB283 **Simulations of Space-Charge and Guiding Fields Effects on the Performance of Gas Jet Profile Monitoring.**

***O. Sedlacek**, N. Kumar, A. Salehilashkajani, C.P. Welsch, H.D. Zhang (The University of Liverpool) P. Forck, S. Udrea (GSI) N. Kumar, A. Salehilashkajani, **O. Sedlacek**, C.P. Welsch, H.D. Zhang (Cockcroft Institute) S. Mazzoni, **O. Sedlacek** (CERN)*

Gas jet based profile monitors inject a usually curtain shaped gas jet across a charged particle beam and exploit the results of the minimally invasive beam-gas interaction to provide information about the beam's transversal profile. Such monitor will be installed as part of the High Luminosity LHC upgrade at CERN in the Hollow Electron Lens (HEL). The HEL represents a new collimation stage increasing the diffusion rate of halo particles by placing a high intensity hollow electron beam concentrically around the LHC beam. The gas jet monitor will use the fluorescence radiation resulting due to the beam-gas interaction to create an image of the profiles of both hollow electron and

LHC beams However, the high beam space-charge and strong guiding magnetic field of the electron beam cause significant displacements of the excited molecules, as they are also ionized, and thus image distortions. This work presents preliminary simulation results showing expected fluorescence images of the hollow electron profile as affected by space-charge and guiding fields using simulation tools such as IPMsim. The influence of the estimated electron beam and gas jet curtain parameters are investigated.

MOPAB284 **Status of the Dedicated Electron Diagnostic Beamline at AXSIS**

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AXSIS (Attosecond X-ray Science: Imaging and Spectroscopy) is a compact, accelerator-driven X-ray source currently under construction at DESY Hamburg. It comprises a THz-powered electron gun and THz-driven linac for all-optical electron extraction and acceleration to several MeV with the goal of providing X-rays generated by inverse Compton scattering for photon science experiments. For the commissioning and characterisation of the THz gun and linac the facility includes a dedicated accelerator testing area, for which an electron diagnostic beamline has been designed and is currently under construction. The challenges imposed by the AXSIS project on the development of the diagnostics beamline are the wide ranges of bunch charge (15 fC to 3 pC) and energy (5 MeV to 20 MeV) expected from the THz-driven accelerator as well as the limited available space of only ca. 2.5 metres length. In this contribution we present an overview of the design and the current commissioning status of the electron diagnostic beamline as well as plans for future steps.

MOPAB286 **Data Science Enabled MeV Ultrafast Electron Diffraction System**

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A MeV ultrafast electron diffraction (MUED) instrument is a unique characterization technique to study ultrafast processes in materials by a pump-probe technique. This relatively young technology can be advanced further into a turn-key instrument by using data science and artificial intelligence (AI) mechanisms in conjunctions with high-performance computing. This can facilitate automated operation, data acquisition and real time or near- real time processing. AI based system controls can provide real time feedback on the electron beam which is currently not possible due to the use of destructive diagnostics. Deep learning can be applied to the MUED diffraction patterns to recover valuable information on subtle lattice variations that can lead to a greater understanding of a wide range of material systems. A data science enabled MUED facility will also facilitate the application

of this technique, expand its user base, and provide a fully automated state-of-the-art instrument. We will discuss the progress made on the MUED instrument in the Accelerator Test Facility of Brookhaven National Laboratory.

MOPAB287 **The Development of Single Pulse High Dynamic Range BPM Signal Detector Design at AWA**

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Single pulse high dynamic range BPM signal detector has been on the most wanted list of Argonne Wakefield Accelerator (AWA) Test Facility for many years. Unique capabilities of AWA beamline require BPM instrumentation with an unprecedented dynamic range, thus cost effective solution could be challenging to design and prototype. Our most recent design, and the results of our quest for a solution, are shared in this paper.

MOPAB288 **Real-time Edge AI for Distributed Systems (READS): Progress On Beam Loss De-blending for the Fermilab Main Injector and Recycler**

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The Fermilab Main Injector enclosure houses two accelerators, the Main Injector and Recycler. During normal operation, high intensity proton beams exist simultaneously in both. The two accelerators share the same beam loss monitors (BLM) and monitoring system. Beam losses in the Main Injector enclosure are monitored for tuning the accelerators and machine protection. Losses are currently attributed to a specific machine based on timing. However, this method alone is insufficient and often inaccurate, resulting in more difficult machine tuning and unnecessary machine downtime. Machine experts can often distinguish the correct source of beam loss. This suggests a machine learning (ML) model may be producible to help de-blend losses between machines. Work is underway as part of the Fermilab Real-time Edge AI for Distributed Systems Project (READS) to develop a ML empowered system that collects streamed BLM data and additional machine readings to infer in real-time, which machine generated beam loss.

MOPAB289 **Machine Learning Training for HOM reduction and Emittance Preservation in a TESLA-type Cryomodule at FAST**

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Low emittance electron beams are of high importance at facilities like the LCLS-II at SLAC. Emittance dilution effects due to off-axis beam

transport for a TESLA-type cryomodule (CM) have been shown at the Fermilab Accelerator Science and Technology facility. The results showed the correlation between the electron beam-induced cavity high-order modes (HOMs) and submacropulse centroid slewing and oscillation downstream of the CM. Mitigation of emittance dilution can be achieved by reducing the HOM signals and the variances in the submacropulse beam positions downstream of the CM. Here we present a Machine Learning based optimization and model construction for HOM signal level reduction using Neural Networks and Gaussian Processes. To gather training data we performed experiments using single bunch and 50 bunch electron beams with charges up to 125 pC/b. We measured HOM signals of all cavities and beam position with a set of BPMs downstream of the CM. The beam trajectory was changed using V/H125 corrector set located upstream of the CM. The results presented here will inform the LCLS-II injector commissioning and will serve as a prototype for HOM reduction and emittance preservation.

MOPAB290 **Machine Learning-Based LLRF and Resonance Control of Superconducting Cavities**

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Superconducting radio frequency (SRF) cavities with high loaded quality factors that operate in continuous wave (CW) and low beam loading are sensitive to microphonics-induced detuning. Cavity detuning can result in an increase of operational power and/or in a cavity quench. Such SRF cavities have bandwidths on the order of 10 Hz and detuning requirements can be as tight as 10 Hz. Passive methods to mitigate vibration sources and their impact in the cryomodule/cavity environment are widely used. Active resonance control techniques that use stepper motors and piezoelectric actuators to tune the cavity resonance frequency by compensating for microphonics detuning have been investigated. These control techniques could be further improved by applying Machine Learning (ML), which has shown promising results in other particle accelerator control systems. In this paper, we describe a Low-level RF (LLRF) and resonance control system based on ML methods that optimally and adaptively tunes the control parameters. We present simulations and test results obtained using a low power test bench with a cavity emulator.

MOPAB291 **Design of Cavity BPM Pickup for EuPRAXIA@SPARC_LAB**

Sh. Bilanishvili *(INFN/LNF)*

EuPRAXIA@SPARC_LAB will make available at LNF a unique combination offering three different options. A high-brightness electron beam with 1 GeV energy generated in a novel X-band RF linac; A PW-class laser system, and a compact light-source directly driven by a plasma accelerator. Plasma and conventional RF linac driven FEL provide beam with parameters of 30- 200pC charge range, 10-100Hz repetition rate, and 1 GeV electron energy. The control of the charge and the tra-

jectory monitoring at a few pC and a few um is mandatory in this machine. Particularly in the plasma interaction region, where the pickup resolution under 1 um is required. As a possible solution, a cavity beam position monitor (cBPM) is proposed. A prototype in the C-band frequency range has been designed. The pickup was optimized for low charge and single-shot bunches. The poster presents the process to achieve the required specifications. The simulations were performed to study RF properties and the electromagnetic response of the device. Finally, the overall performance of the pickup is discussed, and theoretical resolution is approximated.

MOPAB293 **Electro-Optical Diagnostics at KARA and FLUTE - Results and Prospects**

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Electro-optical (EO) methods are nowadays well-proven diagnostic tools, which are utilized to detect THz fields in countless experiments. The world's first near-field EO sampling monitor at an electron storage ring was developed and installed at the KIT storage ring KARA (Karlsruhe Research Accelerator) and optimized to detect longitudinal bunch profiles. This experiment with other diagnostic techniques builds a distributed, synchronized sensor network to gain comprehensive data about the phase-space of electron bunches as well as the produced coherent synchrotron radiation (CSR). These measurements facilitate studies of physical conditions to provide, at the end, intense and stable CSR in the THz range. At KIT, we also operate FLUTE (Ferninfrarot Linac- und Test-Experiment), a new compact versatile linear accelerator as a test facility for novel techniques and diagnostics. There, EO diagnostics will be implemented to open up possibilities to evaluate and compare new techniques for longitudinal bunch diagnostics. In this contribution, we will give an overview of results achieved, the current status of the EO diagnostic setups at KARA and FLUTE and discuss future prospects.

MOPAB294 **Implementing Electro-Optical Diagnostics for Measuring the CSR far-field at KARA**

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For measuring the temporal profile of the coherent synchrotron radiation (CSR) at the KIT storage ring KARA (Karlsruhe Research Accelerator) an experimental setup based on electro-optical spectral decoding (EOSD) is currently being implemented. The EOSD technique allows single-shot, phase-sensitive measurements of the far-field radiation on a turn-by-turn basis at rates in the MHz range. Therefore, the resulting THz radiation from the dynamics of the bunch evolution, e.g. the microbunching, can be observed with high temporal resolution. This far-field setup is part of the distributed sensor network at KARA. Addi-

tionally to the information acquired from the near-field EOSD spectral decoding and the horizontal bunch profile monitor, it enables to monitor the longitudinal phase-space of the bunch. In this contribution, the characterization of the far-field setup is summarized and its implementation is discussed.

MOPAB295 **Simulation Study of Emittance Measurement Using a Genetic Algorithm for Space Charge Dominated Beams**

H.D. Zhang, *C.P. Welsch (Cockcroft Institute) C.P. Welsch,* ***H.D. Zhang*** *(The University of Liverpool)*

The quadrupole scan method is one of the traditional ways to measure beam emittance in an accelerator. The required devices are simple: several quadrupole magnets and a beam profile monitor. Beam sizes are measured from the beam profile monitor with different quadrupole settings to bring the beam through its waist and then fitted to a quadratic equation to determine the Twiss parameters. measured data from a quadrupole scan taking the beam through its waist is fitted to a quadratic equation and this allows determining the Twiss parameters. However, with increasing beam intensity, the transfer function becomes non-linear and this causes a deviation of the fitted emittance from its real value, making it no longer useful. In this contribution, a genetic algorithm is applied to find the optimum quadrupole scan fit in space-charge dominated electron beams. Results from simulations using different space charge levels are presented and scenarios identified where this method can be applied.

MOPAB296 **Statistical Analysis of 2D Single-Shot PPRE-Bunch Measurements**

M. Koopmans, *J.G. Hwang, A. Jankowiak, M. Ries, A. Schälicke, G. Schiwietz (HZB)*

The pulse picking by resonant excitation (PPRE) method is used to realize pseudo single-bunch radiation from a complex filling pattern at the BESSY II storage ring. The PPRE bunch is excited in the horizontal plane by a quasi-resonant incoherent perturbation to increase the emittance of this bunch. Therefore, the synchrotron light of the PPRE bunch can be separated by collimation from the radiation of the main bunch train at dedicated beamlines for timing users. The properties of the PPRE bunch depend on the storage ring settings and on the excitation parameters. It is not trivial to distinguish between the wanted intrinsic bunch broadening and an additional position fluctuation of the PPRE bunch. Using the potential of the new diagnostics beamline with the possibility to observe an additional spatial dimension with a fast streak camera, we introduce a new method to study the properties of the PPRE bunch. Applying a statistical analysis to a series of single-turn images enables distinguishing between horizontal orbit motion and the broadening of the bunch due to the excitation. Measurements are presented and the results are compared with data from the BPM system.

MOPAB297 **Bunch-Resolved 2D Diagnostics at BESSY II - A Combination of Interferometry and Streaking**

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Due to the complexity of the filling pattern in the BESSY II electron-storage ring, bunch resolved diagnostics are required for machine commissioning and to ensure the long-term quality and stability of operation. Low-alpha operation and a possible VSR upgrade, in addition, demand bunch-length measurements with ps resolution. Therefore a dedicated beamline equipped with a fast streak camera was set up and successfully commissioned. Couplings between time- and space-coordinates do also call for bunch-selective and correlated multi-parameter detection methods. Thus, the same beamline and the streak camera have been made capable of direct beam-profile imaging and interferometry of the vertical beam size using the X-ray blocker bar method. The characteristic dip in the center of the image of the pi-polarized synchrotron radiation can be observed at the streak camera and used to extract bunch resolved information about the vertical beam size. The streak camera measurements are validated with direct imaging measurements from a regular CCD. The results are converted into absolute values by diffraction simulations and by comparison to beam size measurements with pinhole monitors.

MOPAB298 **Structural Optimization Design for BPM Support of HEPS**

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The stability of beam orbit is absolutely the key performance indexes of a modern synchrotron radiation light source, which affects the performance of accelerator and the quality and stability of synchronouss light in experimental line station directly. As a fourth generation synchrotron radiation light source, High Energy Photon Source (HEPS) has characteristics of high energy and low emissivity, which requires very high stability of beam orbit. Beam position monitor (BPM) is an precise instrument used for measuring beam position and orbit, and its mechanical vibration amplitude must less than 100nm. Therefore, a independent support need to be distinctively designed . Based on the thermal stability and vibration stability, an ultra stability structure of rigid support is designed and optimized . Through the finite element modal analysis of ANSYS, the thermal expansion variation and the characteristic frequency of the support is verified.

MOPAB299 **Optimum Design of Faraday Cup Structure for Beam Adjustment of CSNS**

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Faraday cup was used to absorb and stop the beam during the two phases of beam commissioning, such as the front end (FE) system and

the temporary line after the drift tube linac (DTL) at the Chinese Spallation Neutron Source (CSNS). According to the beam physical parameters, graphite was selected to stop the beam directly and oxygen-free copper, which is just behind the graphite, as the thermal conductive material. Through the analysis and comparison of the target type and cooling efficiency, the single slant target was determined. The inclination angle of the target surface to the beam was set to 10^{o}, meanwhile a new waterfall type water-cooling structure with parallel tunnels was designed to improve the cooling efficiency. The finite element software ANSYS was used for thermal analysis of the model, by which the diameter and space of water cooling tunnel was optimized. Structure analysis and stress deformation were checked to ensure the reliability of the manufacturing. With the Faraday cup discussed in this paper, the beam commissioning went well.

MOPAB300 **Description of the Beam Diagnostics Systems for the SOCIT, SODIT and SODIB Applied Research Stations Based on the NICA Accelerator Complex**

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Within the framework of the NICA project an Innovation Block is being constructed. It includes an applied research station for microchips with a package for Single Event Effects (SEE) testing (energy range of 150-500 MeV/n, the SODIT station), an applied research station for testing of decapsulated microchips (ion energy up to 3,2 MeV/n, the SOCIT station), and an applied research station for space radiobiological research and modelling of influence of heavy charged particles on cognitive functions of the brain of small laboratory animals and primates (energy range 500-1000 MeV/n, the SODIB station). The systems for diagnostics and control of the beam characteristics during the certification and adjustment as well as the systems for online diagnostics and control of the beam characteristics of the SOCIT, SODIT and SODIB applied research stations are described.

MOPAB301 **A Concept for Reconstruction of the Capsulated Microchip Structure Using Its Interaction With High-Energy Ion Beams of the NICA Accelerator Complex**

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Within the framework of the NICA project an applied research station for irradiation by long-range ions (SODIT) is being constructed for testing radiation hardness of semiconductor micro- and nanoelectronics products in the energy range of 150-350 MeV/n. Calculations for the interaction of high-energy gold ions with the microchip and strip detector structures are performed using the GEANT4 simulation toolkit. A concept was developed for reconstruction of the capsulated

microchip structure in terms of depth and in terms of cross-section using interaction with high-energy ions at the technical station for irradiation by long-range ions. The possibility of localizing the radiation-vulnerable area of the microchip is evaluated.

MOPAB302 **Characterization of the Full Transverse Phase Space of Electron Bunches at ARES**

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The ARES linear accelerator at the SINBAD facility (DESY) is dedicated to perform accelerator R&D studies with sub-fs short electron bunches to test novel acceleration techniques and diagnostics devices. Currently, the commissioning of the linac is ongoing and first experiments are being performed. For this, the knowledge of the full phase space of the particle beams is of high interest to, for example, optimize the accelerator performance and identify possible errors in the beam line. Tomographic methods can be used to gain insight into the full 4D transverse phase space and its correlations. Here, simulation results and first experimental preparations of a 4D transverse phase-space tomography of electron bunches at ARES are presented and discussed.

MOPAB303 **Design of the X-Ray Beam Size Monitor for the Advanced Photon Source Upgrade**

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A beam size monitor provides an intuitive display of the status of the beam profile and motion in an accelerator. In the present work, we outline the design of the X-ray electron beam size monitor for the Advanced Photon Source Upgrade. Components and anticipated performance characteristics of the beam size monitor are outlined.

MOPAB304 **Beam Diagnostics for Multi-Objective Bayesian Optimization at the Argonne Wakefield Accelerator Facility**

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Particle accelerators must achieve certain beam quality objectives for use in different experiments. Usually, optimizing certain beam objectives comes at the expense of others. Additionally, there are many input parameters and a limited number of diagnostics. Therefore, accelerator tuning becomes a multi-objective optimization problem with a limited number of observations. Multi-objective Bayesian optimization was recently proposed as an efficient method to find the Pareto front for an online accelerator tuning problem with reduced number of observations. In order to experimentally test the multi-objective Bayesian optimization method, a novel accelerator diagnostic is being designed to measure multiple beam quality metrics of an electron

beam at the Argonne Wakefield Accelerator Facility. Here, we present a design consisting in a pepper-pot mask, a dipole magnet and a scintillation screen, which allows a simultaneous measurement of the electron beam energy spread and vertical emittance. Additionally, a surrogate model for the vertical emittance was constructed with only 60 observations and without prior knowledge of the objective function nor diagnostics constraints.

MOPAB305 **Overview of the Optical Diagnostics of the ThomX Compact Compton Source**

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We present an overview of the optical diagnostics of the ThomX compact Compton source. ThomX is a compact light source based on Compton scattering. It features a linac and a storage ring in which the electrons have an energy of 50 MeV. The optical diagnostics of ThomX include screen stations and synchrotron radiation monitors. The screen stations are used to monitor the bean at single pass locations (linac and transport lines), they all include a YAG:Ce screen and an optical transition radiation monitor. One station is also fitted with a Cerenkov screen for bunch length measurement. The synchrotron radiation monitor allows both transverse and longitudinal profile monitoring of the beam. We report on the readiness testing of each of these diagnostics and their expected performances.

MOPAB306 **Overview of the Electronic Diagnostics of the Thomx Compact Compton Source**

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We present an overview of the electronic diagnostics of the ThomX compact Compton source. ThomX is a compact light source based on Compton scattering. It features a linac and a storage ring in which the electrons have an energy of 50 MeV. The electronic diagnostics include stripline and button beam position monitors readout by electronics from libera, Integrating current transformers and Faraday cups readout by home made electronics and a beam loss monitor based on an optical fiber stretching along all the accelerator and using a photomultiplier tube to convert the loss signal into an electronic signal readout by home made electronics. We report on the readiness testing of each of these diagnostics and their expected performances.

MOPAB307 **Study of Long Pepper-Pots for the ThomX Project**

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We report on simulations on long pepper to be installed at the end of a 50 MeV linac. Simulations have been performed as part of the ThomX

project to demonstrate that single shot emittance measurements are possible at the end of the 50 MeV linac. Two types of simulations are presented here: ballistic simulations and more advanced simulations based on G4Beamline.

MOPAB308 **Diagnostics Data Alignment Using the Tango Control System for the ThomX Compact Compton Source**

***N. Delerue**, I. Chaikovska, V. Chaumat, P. Gauron, V. Kubytskyi, J.C. Marrucho, H. Monard, A. Moutardier (Université Paris-Saclay, CNRS/IN2P3, IJCLab)*

For the commissioning of the ThomX compact Compton source, accurate determination of the beam orbit on a shot to shot basis is important. At beam repetition rates of 1 Hz or above this is not possible using the standard control system tools as data from different diagnostics may arrive from different shot. We discuss on different strategies available to achieve this and present the result of some tests of these strategies as well as a dedicated device server that collects aligned data and rearms the trigger once this is done.

MOPAB309 **Testing of Radiofrequency Waveguides Made by Additive Manufacturing**

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Additive manufacturing allows a new approach to mechanical design, however previous studies have shown that it is obliges us to rethink our approach to the suitability of accelerator parts. As part of our effort to validate as many accelerator components as possible using additive manufacturing, we report on the design and tests of RF waveguides using additive manufacturing.

MOPAB310 **Vertical Beam Size Measurement Progress at XSR beamline in Canadian Light Source**

***Y. Yousefi Sigari**, D. Bertwistle, M.J. Boland (CLS) M.J. Boland (University of Saskatchewan)*

A key feature of third-generation light sources is their small vertical opening angle, which is difficult to measure experimentally. To reconstruct the vertical phase space, one can scan the beam's position using X-ray synchrotron radiation (XSR) and a pinhole camera. The XSR diagnostic beamline, operational in the wavelength region of 0.05 - 0.15 nm, in Canadian Light Source (CLS) is qualified to measure the beam position with X-ray radiation. Using the corrector magnets in CLS lattice made of 12 identical double-bend achromats (DBA) cells, vertical iterations can be executed parallel to the beam's original orbit. The outcomes of this experiment are: 1) the vertical beam positions that are monitored by BPMs, and 2) the X-ray image of the beam that is projected through the pinhole. The bumps were simulated using Matlab Middle Layer (MML) for Accelerator control systems to get an insight of the source point's position in the XSR's bending magnet. The simulation shows the position of the source point depends on which corrector sets are chosen.

MOPAB313 **Argonaut - A Robotic System for Cryogenic Environments**

***W. Pellico**, N.M. Curfman, M. Wong-Squires (Fermilab)*

Fermilab and the HEP community invest significant resources into liquid argon detectors. The largest and most expensive of these detectors will be located in the Deep Underground Neutrino Experiment (DUNE). However, recent experiences have shown that there are limited avenues of monitoring, intervention, and interaction in the internal liquid environment. This proposal shows a technological path that could provide a valuable tool to ensure or at least improve the management of these HEP detectors. The development of a robotic system named Argonaut will demonstrate several technologies including 1) demonstration of suitable mobility of a small robotic device at liquid argon temperatures, 2) demonstration of wireless communication, 3) demonstration of improved diagnostics capabilities - such as tunable optics with motion control, 4) demonstration of interconnectivity of a robotic system with hardware residing within the detector. This initial research will be a seed for extended development in cold robotics and associated technologies. This work will allow FNAL to contribute a significant technology capability to recent efforts to cryogenic detector operations.

MOPAB314 **Surrogate Modeling for MUED with Neural Networks**

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Electron diffraction is among the most complex and influential inventions of the last century and contributes to research in many areas of physics and engineering. Not only does it aid in problems like materials and plasma research, electron diffraction systems like the MeV ultra-fast electron diffraction(MUED) instrument at the Brookhaven National Lab(BNL) also present opportunities to explore/implement surrogate modeling methods using artificial intelligence/machine learning/deep learning algorithms. Running the MUED system requires extended periods of uninterrupted runtime, skilled operators, and many varying parameters that depend on the desired output. These problems lend themselves to techniques based on neural networks(NNs), which are suited to modeling, system controls, and analysis of time-varying/multi-parameter systems. NNs can be deployed in model-based control areas and can be used simulate control designs, planned experiments, and to simulate employment of new components. Surrogate models based on NNs provide fast and accurate results, ideal for real-time control systems during continuous operation and may be used to identify irregular beam behavior as they develop.

MOPAB315 **Beam Diagnostics for Commissioning and Operation of the FAIR Proton Linac**

T. Sieber, *P. Forck, S. Udrea (GSI) J. Herranz, A. Vizcaino-de-Julian (Proactive Research and Development)*

For the planned antiproton experiments at FAIR a dedicated proton injector Linac is currently under construction. It will be connected via the old UNILAC transfer beamline to SIS18 and has a length of ~30 m. The Linac will accelerate protons up to a final energy of 68 MeV, at a pulse length of 35 µs and a maximum repetition rate of 4 Hz. It will operate at 325 MHz and consists of a new so called "Ladder" RFQ type, followed by a chain of CH-cavities, partially coupled by rf-coupling cells. We have worked out a diagnostics system, which allows detailed measurement and study of all beam parameters during commissioning and later during regular operation. The diagnostics devices will - in a first step - be installed on a diagnostics testbench for stepwise commissioning. We present the concepts for Linac and testbench with some special emphasis on energy measurements with spectrometer and SEM Grid profile measurements.

MOPAB316 **Commissioning the New Beam Instrumentation Following the Upgrade of the LHC Injector Chain**

F. Roncarolo, *S. Bart Pedersen, J.M. Belleman, D. Belohrad, M. Bozzolan, C. Bracco, S. Di Carlo, J. Emery, A. Goldblatt, A. Guerrero, S. Levasseur, A. Navarro Fernandez, E. Renner, H.S. Sandberg, J.W. Storey (CERN) A. Navarro Fernandez (UPC) E. Renner (TU Vienna)*

The LHC injectors Upgrade (LIU) program has been fully implemented during the second long shutdown (LS2), which took place in 2019-20. In this context, new or upgraded beam instrumentation was developed to cope with H^- beam in LINAC4 and the new Proton Synchrotron Booster (PSB) injection systems which would provide high brightness proton beams in the rest of the injector complex. After a short overview of the newly installed diagnostics, the main focus of this paper will move to the instruments already commissioned with the beam. This will include LINAC4 diagnostics, the PSB H^0/H^- monitor, the PSB Trajectory Measurement System, and the PS beam gas ionization monitor. In addition, particular emphasis will be given to the first operational experience with the new generation of fast wire scanners installed in all injector synchronous.

MOPAB317 **Spectral Analysis of Cyclotron Radiation for Electron Beam Diagnostics**

B. Leung, *P. Piot (Northern Illinois University)*

The spectral distribution of the cyclotron radiation emitted by non-ultra-relativistic electrons traveling through solenoidal lenses can be used to characterize ensemble-averaged properties of a beam. In this paper we explore the potential use of cyclotron radiation to measure the energy spread and transverse emittance of a beam while remaining unintrusive. We specifically discuss the relation between the spectral

properties of cyclotron radiation and the beam statistical properties and perform first principle particle-in-cell simulation to validate our findings.

MOPAB318 **Beam Characterization of Five Electrode ECR Ion Source**

H.M. Kewlani, *S. Gharat, S. Krishnagopal, J.V. Mathew, S.V.L.S. Rao (BARC) B. Dikshit,* ***H.M. Kewlani***, *S. Krishnagopal (Homi Bhbha National Institute (HBNI), DAE)*

A five electrode ECR Ion Source (ECRIS) was developed for the Low Energy High-Intensity Proton Accelerator (LEHIPA) at BARC. The ECRIS is operated at the energy of 50 keV with a beam current of 20 mA. The ECRIS characterization is done for the beam current, beam emittance, and proton fraction in continuous and pulse beam operation. The pulsed beam operation of the ion source starting from 500 µs to 200 ms of pulse on time with a repetition rate of 1 to 10 Hz. The transverse beam emittance measurement is done by using an Allison scanner. The beam emittance characterization experiments are conducted by varying applied microwave power to the plasma, operating gas pressure of plasma and puller voltage. The measured beam emittance is in the range of 0.3 pi.mm. mrad to 0.4 pi.mm. mrad for 50 keV beam. In this paper beam emittance experiment setup and results are discussed.

MOPAB319 **Development of a Fast Betatron Tune and Chromaticity Measurement System for COSY**

P.J. Niedermayer, *C. Böhme, B. Breitkreutz, V. Kamerdzhiev, A. Lehrach (FZJ) A. Lehrach (RWTH)*

A fast tune measurement is developed for the Cooler Synchrotron COSY at the Institut für Kernphysik of Forschungszentrum Jülich. Betatron oscillations of the beam are excited with a band-limited RF signal via a stripline kicker. Resonant transverse oscillations are then observed using capacitive beam position monitors. Based on the bunch-by-bunch beam position data the betatron tune is determined. The usage of bunch-by-bunch data is characteristic of the new system. It allows for a discrete tune measurement within a few milliseconds, as well as continuous tune monitoring during beam acceleration. The high precision tune measurement also enables determination of the beam chromaticity. Therefore, the beam momentum is varied by means of the RF frequency and the subsequent tune change is determined. For routine use during beam operation and experiments, the developed method is integrated into the control system.

MOPAB320 **The CMS ECAL Enfourneur: A Gigantic Machine With a Soft Touch**

V. Pettinacci *(INFN-Roma)*

The electromagnetic calorimeter (ECAL) of the CMS experiment at the LHC is composed of 75848 scintillating lead tungstate crystals arranged in a barrel section and two endcaps. The barrel part is made of 36 supermodules (SM), 2.7 tons each, and is installed inside the CMS

magnet. There are 18 SMs on each side of CMS, with each SM containing 1700 crystals. During Long Shutdown 3, all ECAL SMs must be extracted to refurbish the electronics in preparation for HL-LHC. A dedicated machine called the "Enfourneur" is used to extract and re-insert the SMs inside CMS, with a required accuracy of about 1mm. In order to speed up the extraction and insertion process, two Enfourneurs will be employed, operating in parallel on both sides. In view of the purchase of the second Enfourneur, the design has been improved, starting from the feedback of past operations. The improvements to the new Enfourneur design include increased space for the operators, optimization of the operations and the controls with the use of electric motors, and an updated alignment system. Handling plans inside the CMS cavern have been defined in order to be compliant with the rest of CMS structures and procedures.

MOPAB321 **Schlieren Imaging for Flow Visualisation of Gas Jet in Vacuum for Accelerator Applications**

***S. Rosily**, B. Dikshit, S. Krishnagopal (Homi Bhbha National Institute (HBNI), DAE) S. Krishnagopal, **S. Rosily** (BARC)*

Schlieren imaging was explored for flow visualising of a gas jet in vacuum for beam profile monitor application. In supersonic gas jet based beam profile monitors, the high density jet flows through various differentially pumped skimmer stages before being shaped into a sheet. Schlieren imaging is a well known technique used in aerodynamic studies to visualise gas flow. This technique is explained in the paper along with a gist of other flow visualisation techniques. An Z-type schlieren imaging setup used to view the high density flow features of a pulsed supersonic gas jet inside vacuum is described in detail. Flow around a Pitot probe in supersonic flow was simulated and the resultant density profile obtained was compared with the image obtained using schlieren imaging. The flow features including a detached shock around the tip of the probe was observable at medium and high vacuum after processing the image. Image processing algorithms and tools useful for this application are also discussed.

MOPAB322 **Electronics for Bead-pull Measurement of Radio Frequency Accelerating Structures in LEHIPA**

***S. Rosily**, S. Krishnagopal (Homi Bhbha National Institute (HBNI), DAE) S. Krishnagopal, S. Singh (BARC)*

For carrying out bead-pull characterisation of RFQ and DTL at the Low Energy High Intensity Proton Accelerator of BARC, a controller for simultaneous motion of 64 axis, tuners or post couplers, was developed. Also, a bead motion controller with integrated phase measurement sensor was developed. The paper discusses the requirements of the system, the architecture of the control systems, operation and results. The results obtained from the sensor was compared to that obtained using an independent USB VNA. The advantages of the system especially with addition of internal phase measurement sensor including minimising position error, flexibility in beadpull to selectively

increase resolution at specified locations and ease of implementing auto-tuning algorithms are discussed.

MOPAB323 **Commissioning of the LCLS-II Prototype HOM Detectors with Tesla-Type Cavities at Fast**

***J.P. Sikora**, J.A. Diaz Cruz, B.T. Jacobson (SLAC) J.A. Diaz Cruz (University of New Mexico) D.R. Edstrom, A.H. Lumpkin, P.S. Prieto, J. Ruan, R.M. Thurman-Keup (Fermilab)*

Experiments at the Fermilab Accelerator Science and Technology (FAST) facility detected electron beam-induced high order mode (HOM) signals from Tesla superconducting cavities. This paper describes some of the signal detection hardware used in this experiment, as well as measurements of the HOM signal magnitude versus beam trajectory. These measurements were made both with a single bunch and with a train of 50 bunches at bunch charges from 400 pC/b down to 10 pC/b. The detection hardware is designed for use with the Tesla superconducting cavities of LCLS-II at SLAC and is based on a prototype already in use at Fermilab. The HOM signal passes through a bandpass filter that is centered on several cavity dipole modes and a zero bias Schottky diode detects its magnitude. Direct comparisons were made between the FNAL chassis and the SLAC prototype for identical beam steering conditions. To support measurements with bunch charges as low as 10 pC, the SLAC detector has RF amplification between the bandpass filter and the diode detector. With this hardware, usable HOM signal measurements are obtained with a single bunch of 10 pC in cryomodule cavities as will be needed for LCLS-II.

MOPAB324 **High Voltage Design and Evaluation of Wien Filters for the CEBAF 200 keV Injector Upgrade**

***G.G. Palacios Serrano**, P.A. Adderley, J.F. Benesch, D.B. Bullard, J.M. Grames, C. Hernandez-Garcia, A.S. Hofler, D. Machie, M. Poelker, M.L. Stutzman, R. Suleiman (JLab) H. Baumgart, **G.G. Palacios Serrano** (ODU)*

High-energy nuclear physics experiments at the Jefferson Lab Continuous Electron Beam Accelerator Facility (CEBAF) require highly spin-polarization electron beams, produced from strained super-lattice GaAs photocathodes, activated to negative electron affinity in a photogun operating at 130 kV dc. A pair of Wien filter spin rotators in the injector defines the orientation of the electron beam polarization at the end station target. An upgrade of the CEBAF injector to better support the upcoming MOLLER experiment requires increasing the electron beam energy to 200 keV, to reduce unwanted helicity correlated intensity and position systematics and provide precise control of the polarization orientation. Our contribution describes design, fabrication and testing of the high voltage system to upgrade the Wien spin rotator to be compatible with the 200 keV beam. This required Solidworks modeling, CST and Opera electro- and magnetostatic simulations, upgrading HV vacuum feedthroughs, and assembly techniques for improving electrode alignment. The electric and magnetic fields

required by the Wien condition and the successful HV characterization under vacuum conditions are also presented.

MOPAB325 **Development of Bunch Width Monitor With High Time Resolution for Low Emittance Muon Beam in the J-PARC Muon g-2 / EDM Experiment**

M. Yotsuzuka, *T. Iijima, K. Inami, Y. Sue, K. Sumi (Nagoya University, Graduate School of Science) T. Iijima (KMI) Y. Kondo (JAEA) T. Mibe (KEK) Y. Nakazawa (Ibaraki University) M. Otani, N. Saito (J-PARC, KEK & JAEA) Y. Takeuchi (Kyushu University) H.Y. Yasuda (University of Tokyo)*

The J-PARC muon g-2/EDM experiment plans to measure the muon anomalous magnetic moment and electric dipole moment sensitive to new physics with high precision. This experiment uses a novel method using the low-emittance muon beam achieved by cooling and re-acceleration. In the muon linac consisting of four different accelerating cavities, the main cause of the emittance growth is the beam mismatch between the different cavities. Especially for the cavity in the low-beta section (ß=0.08-0.27), the longitudinal acceptance is narrow and beam mismatch has a significant impact. In order to perform beam matching in the low-beta cavity, a new beam monitor that can measure the low-emittance muon beam with high time resolution is required. Therefore, we developed a bunch width monitor (BWM) using a microchannel plate. The time resolution of the BWM was measured to be 40 picoseconds on the test bench using a picosecond pulse laser. It means that the BWM is possible to perform diagnosis with a phase accuracy of 1% for the acceleration phase of 324 MHz. We also evaluated factors that limit the current time resolution. In this presentation, the results of an evaluation of the BWM are reported.

MOPAB326 **Maximum Entropy Reconstruction of 4D Transverse Phase Space from 2D Projections: with Application to Laser Wire Measurements in the SNS HEBT**

C.Y. Wong, *A.P. Shishlo (ORNL)*

We employ the principle of maximum entropy (MENT) to reconstruct 4D transverse phase space from its 2D projections. Emittance devices commonly measure two specific 2D projections, i.e. the horizontal and vertical phase space distributions. We show that: 1) given only these two 2D projections, their product is the analytic MENT solution to the 4D distribution; and 2) additional 2D projections provide information on inter-plane coupling in the MENT reconstruction of the 4D phase space which can be solved numerically. At the Spallation Neutron Source (SNS), laser wires in the high energy beam transport (HEBT) enable non-invasive two-slit type transverse phase space measurements. Laser wires play the role of the first slit whereas physical wires downstream of a drift act as the second slit. We reconstruct the 4D phase space in the HEBT using all four horizontal/vertical permutations of the two slits where: 1) the two configurations with parallel slits constitute ordinary 2D phase space measurements in either plane;

and 2) the two configurations with perpendicular slits carry coupling information.

MOPAB327 **Beam Loss Diagnostics System for SKIF Synchrotron Light Source**

X.C. Ma *(BINP) S.V. Ivanenko, E.A. Puryga (Budker Institute of Nuclear Physics) A.D. Khilchenko, Yu.I. Maltseva, O.I. Meshkov (BINP SB RAS) Yu.I. Maltseva, O.I. Meshkov (NSU)*

The Siberian ring photon source (SKIF) is a new generation synchrotron light source designed and built by the Budker Institute of Nuclear Physics. The beam loss diagnostics system is a tool for monitoring beam loss information. It is widely used in modern large accelerators to provide a basis for diagnosing and locating machine faults, optimizing and debugging working beam parameters, and improving beam lifetime. Two types of beam loss monitor (BLM) will be applied on SKIF: fiber-based Cherenkov beam loss monitor (CBLM) and scintillator-based BLM (SBLM). Multi-mode silica fibers CBLM will be installed on linear accelerator and transfer lines. 128 SBLMs will be placed around the storage ring, dynamic ranges and sophisticated electronic equipment are employed to cover different SKIF operating modes. This article represents the details of design of beam loss diagnostics of SKIF, introduces the simulation and experimental studies of CBLM and SBLM.

MOPAB328 **Beam Instrumentation for Linear Accelerator of SKIF Synchrotron Light Source**

X.C. Ma *(BINP) M.V. Arsentyeva, E.A. Bekhtenev, V.M. Borin, G.V. Karpov, Yu.I. Maltseva, O.I. Meshkov, D.A. Nikiforov, O.A. Pavlov, V.G. Tcheskidov, V. Volkov (BINP SB RAS) M.V. Arsentyeva, E.A. Bekhtenev, V.M. Borin, Yu.I. Maltseva, O.I. Meshkov, D.A. Nikiforov (NSU) V.M. Borin (NSTU)*

A new synchrotron light source SKIF of the 4th generation is under construction at BINP SB RAS (Novosibirsk, Russia). The linear accelerator is SKIF's injector to provide 200 MeV electron beam. The set of diagnostics will be applied for tuning of the linear accelerator and measurements of beam parameters from electron RF gun to output of the accelerator. It includes 8 fluorescent screens for the beam transverse dimensions measurement, 2 Cherenkov probes for the beam duration measurement, magnetic spectrometer with range from 0.6 to 200 MeV, and some beam charge and current measurement devices, as Faraday cup, FCT, BPM along linear accelerator. Numerical simulations of diagnostics elements and results of beam dynamics simulations are introduced in paper. Brief description of the design and parameters of each diagnostics system is presented. Possible scenarios of linear accelerator tuning are also discussed.

MOPAB329 **Operations of Copper Cavities at Cryogenic Temperatures**

H. Wang*, U. Ratzinger, M. Schuett (IAP)*

How the anomalous skin effect by copper affects the efficiency of copper- cavities will be studied in the experiment, especially at lower

temperatures. The accurate quality factor Q and resonant frequency of three coaxial cavities will be measured over the temperature range from 300 to 22 K. The three coaxial cavities have the same structure, but different lengths, which correspond to resonant frequencies: around 100 MHz, 220 MHz and 340 MHz. The motivation is to check the feasibility of an efficient pulsed, liquid nitrogen cooled ion linac.

MOPAB330 **Production and Performance Evaluation of a Compact Deflecting Cavity to Measure the Bunch Length in the cERL**

***D. Naito**, Y. Honda, T. Miyajima, N. Yamamoto (KEK)*

At the KEK compact energy recovery linac, we try to generate an infrared free-electron laser (FEL). To generate the FEL, an electron bunch should be compressed along the longitudinal direction. The measurement of the bunch length is key to optimize the bunch compression. We plan to measure the bunch length by deflecting cavities in the burst mode. The deflecting cavities are required to be a time resolution of 33 fs in order to not only measure the bunch length but also resolve the structure inside the electron bunch. To achieve the requirement, we developed a c-band cavity whose RF input port is compact. The deflecting cavity is a single cell and normal conducting cavity. The deflection mode of the cavity is TM110. The 12 cavities will be located at the exit of undulators. In this presentation, we explain the design of our cavity and report the production of the first cavity. We also report the evaluation of the resonance frequency, the unloaded Q and the external Q of the cavity. From the measurements and simulations, the R/Q is estimated to be 1 mega orms. The time resolution of the cavity is expected to be 400 fs when the input RF power is 1 kW and the beam energy is 20 MeV.

MOPAB331 **Design Consideration of a Longitudinal Kicker Cavity for Compensating Transient Beam Loading Effect in Synchrotron Light Sources**

***D. Naito**, S. Sakanaka, T. Takahashi, N. Yamamoto (KEK) T. Yamaguchi (Sokendai)*

In ultra-low-emittance synchrotron light sources, bunch-lengthening using the combination of main and harmonic cavities is limited by the transient beam-loading (TBL) effect which is caused by gaps in the fill pattern. To manage this effect, we proposed a TBL compensation technique using a wide-band longitudinal kicker cavity. In the future KEK-LS storage ring, for example, the kicker cavity should provide a compensation voltage of 50 kV with a -3dB bandwidth (BW) of about 5 MHz, as well as its higher-order modes (HOM) should be damped sufficiently. In this presentation, we report our conceptual design of the kicker cavity. We employed the single-mode (SM) cavity concept so that harmful HOMs are dumped by rf absorbers on the beam pipes. The distinctive feature of the SM cavity is its simple structure since it has no HOM damper on the cavity. Another feature is its low R/Q by which the TBL effect in the kicker cavity itself can be reduced significantly. We employed a frequency of 1.5 GHz (third-harmonic) and R/Q

of 60 orms through optimizations. Using this kicker cavity with a double rf system, a bunch lengthening by a factor of 4.3 (i.e., 40.9 ps) is expected for the KEK-LS case.

MOPAB332 **Design of 4th Harmonic RF Cavities for ESRF-EBS**

***A. D'Elia**, J. Jacob, V. Serrière, X.W. Zhu (ESRF)*

An active 4th harmonic RF system for bunch lengthening is under study at the ESRF to improve the performance of the new EBS storage ring, mainly for few bunch operation with high currents per bunch, by reducing Touschek and intrabeam scattering, thereby increasing the lifetime and limiting the emittance growth. It will also reduce impedance heating of the vacuum chambers. The 4th Harmonic 1.41 GHz normal conducting cavity design takes inspiration from the KEK idea of using a TM020 mode exhibiting a reduced R/Q but a higher unloaded Q with respect to TM010. We propose to use multicell cavities for their compactness, the reduced number of required ancillaries and the ease of control for a reduced number of cavities. The drawback is the complexity of the model and the necessity to damp the lower order TM010 mode (LOM) as well as the higher order modes (HOM). The RF design of a 4th harmonic multicell damped cavity will be presented.

MOPAB333 **ESRF-EBS 352 MHz HOM Damped RF Cavities**

***A. D'Elia**, J. Jacob, V. Serrière (ESRF)*

For the new ESRF-EBS Storage Ring (SR), HOM damped RF cavities were needed to cope with the reduced thresholds for Longitudinal Coupled Bunch Instabilities (LCBI). The 352 MHz cavities were designed at the ESRF based on an improved version of the 500 MHz EU/ALBA/BESSY structures. A short description of the cavity design will be presented as well as an overview of the fabrication, the preparation and the performance of 13 such cavities for the ESRF-EBS SR. A study of the impedance of a whole cavity equipped with its ancillaries (HOM absorbers, ion pump and tuner) will be presented. One of the three HOM absorbers, the smaller one on top of the cavity, was finally not installed on the machine. The reasons and a detailed analysis in terms of HOM impedances that justifies this choice will be reported.

MOPAB334 **Status and Recent Development of FAIR Ring RF Systems**

***U. Laier**, R. Balßs, C. Christoph, M. Frey, P. Hülsmann, H. Klingbeil, H.G. König, D.E.M. Lens, J.S. Schmidt, A. Stuhl, K.G. Thomin, T. Winnefeld (GSI) H. Klingbeil (TEMF, TU Darmstadt)*

Five different Ring RF Systems are required for the operation of FAIR (Facility for Antiproton and Ion Research). These systems have to operate at frequencies between 310 kHz and 3.2 MHz, with gap voltages up to 40 kVp and duty cycles from $5{\cdot}10^{-4}$ up to cw. All systems will be realized using inductively loaded (ferrite or magnetic alloy) cavities driven by tetrode-based amplifiers fed by switch-mode power supplies. To stabilize the amplitude, resonance frequency and phase, versatile digital feedback and feedforward control will be used. This contribution will present the latest development on the power part and the LLRF of the four RF systems of the SIS100 (SIS100 Acceleration,

SIS100 Bunch Compression, SIS100 Barrier Bucket and SIS100 Longitudinal Feedback) as well as the CR Debuncher system which is part of the Collector Ring. The progress of these systems varies by a large degree. This note will give an overview regarding the status of the design, procurement, realization, testing, optimization, commissioning and preparation for installation of these RF systems.

MOPAB335 **SNS Warm Linac Circulator Breakdown Considerations for the PPU Project**

***G.D. Toby**, Y.W. Kang, S.-H. Kim, S.W. Lee, J.S. Moss (ORNL)*

Multipacting in accelerating structures is a complex phenomenon about which there is much to be understood. While multipacting research efforts have primarily been focused on superconducting radio frequency (SRF) systems, normal conducting accelerating structures which have a higher thermal capacity, and a greater vacuum pressure tolerance could benefit from additional investigation. This research details multipacting simulation methods and the results of 3-D electromagnetic simulations of RF vacuum windows used on normal conducting linac (NCL) cavities. Benchmarking of the peak electric fields in these structures, benefits of material processing and possible techniques for reducing or eliminating multipacting activities are discussed.

MOPAB336 **Multipacting Analysis of Warm Linac RF Vacuum Windows**

***G.D. Toby**, Y.W. Kang, S.-H. Kim, S.W. Lee, J.S. Moss (ORNL)*

Multipacting in accelerating structures is a complex phenomenon with which there is much to be understood. While multipacting research efforts have primarily been focused on superconducting radio frequency (SRF) systems, normal conducting accelerating structures that have a higher thermal capacity and a greater vacuum pressure tolerance could benefit from additional investigation. This research details multipacting simulation methods and the results of 3-D electromagnetic simulations of RF vacuum windows used on normal conducting linac (NCL) cavities. Possible techniques for reducing and eliminating multipacting activities in these structures are discussed.

MOPAB337 **Design Study of the HEBT Spiral Buncher Cavities for the High Current Injector at IUAC**

***S. Kedia**, R. Ahuja, R. Mehta, C.P. Safvan (IUAC)*

Two high energy beam transport (HEBT) cavities have been designed to provide the longitudinal beam bunching between drift tube linac and superconducting super-buncher of the superconducting linear (SC-LINAC) accelerator. The spiral type cavities were chosen over standard quarter wave-type geometry due to its higher shunt impedance. The TRACE-3D ion-optical codes have been used to determine the bunching voltage and physical location of the cavities. The two-gap RF cavity requires 80 kV/gap to provide the longitudinal beam bunching at the entrance of the superconducting buncher. The CST-MWS simulations were performed to design the spiral type bunching cavities.

The various parameters including shunt impedance, quality factor, average accelerating field, and total power loss were determined using CST-MWS simulations. The ratio of drift tube radius to the gap was optimized to achieve the maximum effective electric field with minimum field penetration within the gap. The SolidWorks software has been used to prepare a mechanical model for the fabrication.

MOPAB339 **Design Of An X-band 3MeV Standing-wave Accelerating Structure With Nose-cone Structure Made From Two Halves**
***F. Liu**, H.B. Chen, J. Shi, C.-X. Tang, H. Zha (TUB)*
This work presents an X-band 3MeV standing-wave accelerating structure with nose cones made from two halves. Milling two longitudinally split halves is one economic method to manufacture accelerating structure for decrease of welding, with increasing the difficulty in machining. This linear accelerator includes 4 buncher cavities and 4 accelerating cavities, and nose cone is applied to achieve high shunt impedance. A technical prototype is under fabrication to bring two milled halves manufacture way into practical application.

MOPAB340 **Experimental Tests With the First Segment of ESS-Bilbao RFQ Linac**
***J.L. Muñoz**, I. Bustinduy, A. Conde, N. Garmendia, P.J. González, J. Martin, A. Zugazaga (ESS Bilbao)*
The ESS-Bilbao RFQ is an assembly of four segments, each one about 800 mm in length. The first segment has been manufactured before the others, so it could be thoroughly tested in order to validate the chosen technological approach for the RFQ, as it uses polymeric vacuum gaskets and bolts instead of brazing. In this paper we report on the tests run with the segment and their results. Vacuum tests, metrology measurements, low power RF tests as well as extensive tuning tests measuring the cavity resonant quadrupolar frequency as a function of cooling water temperature have been done. Experimental results are compared to the expected values obtained from numerical simulations. We describe the experimental set-ups for the measurements and the simulations. Results are analyzed with the aim of validating the design, and also to provide predictions for tuning and operation of the whole RFQ. As a consequence of the positive results of the tests reported here, the remaining segments have already been tendered.

MOPAB341 **First C-Band High Gradient Cavity Testing Results at LANL**
***E.I. Simakov**, R.L. Fleming, D. Gorelov, M.F. Kirshner, J.W. Lewellen, T. Tajima (LANL) X. Lu, E.A. Nanni, S.G. Tantawi (SLAC) M.E. Middendorf (ANL) M.S. Schneider (MSU)*
This poster will report the results of high gradient testing of the two proton β=0.5 C-band accelerating cavities. The cavities for proton acceleration were fabricated at SLAC and tested at high gradient C-band accelerator test stand at LANL. One cavity was made of copper, and the second was made of a copper-silver alloy. LANL test stand was constructed around a 50 MW, 5.712 GHz Canon klystron and is capable to

provide power for conditioning single cell accelerating cavities for operation at surface electric fields up to 300 MV/m. These β=0.5 C-band cavities were the first two cavities tested on LANL C-band test stand. The presentation will report achieved gradients, breakdown probabilities, and other characteristics measured during the high power operation.

MOPAB342 **Design, Fabrication, and Commissioning of the Mode Launchers for High Gradient C-Band Cavity Testing at LANL**

***E.I. Simakov**, J.E. Acosta, D. Gorelov, M.F. Kirshner, J.W. Lewellen (LANL) P. Borchard (Dymenso LLC) M.S. Schneider (MSU)*

This poster will report on the design, fabrication, and operation status of the new high gradient C-band TM01 mode launchers for the high gradient C-band test stand at LANL. Modern applications require accelerators with optimized cost of construction and operation, naturally calling for high-gradient acceleration. At LANL we commissioned a test stand powered by a 50 MW, 5.712 GHz Canon klystron. The test is capable of conditioning single cell accelerating cavities for operation at surface electric fields up to 300 MV/m. The rf field is coupled into the cavity from a WR187 waveguide through a mode launcher that converts the fundamental mode of the rectangular waveguide into the TM01 mode of the circular waveguide. Several designs for mode launchers were considered and the final design was chosen based on a compromise between the field enhancements, bandwidth, and simplicity and cost of fabrication. Four mode launchers were fabricated and cold-tested. Two mode launchers with the best transmission characteristics were installed and conditioned to high power. The presentation will report achieved gradients, breakdown probabilities, and other characteristics measured during operation.

MOPAB343 **Optimization of the Parasitic-Mode Damping on the 1.5 GHz TM020-type Harmonic Cavity**

***T. Yamaguchi** (Sokendai) D. Naito, S. Sakanaka, T. Takahashi, N. Yamamoto (KEK)*

Bunch-lengthening harmonic cavity is one of the essential tools to mitigate the intrabeam scattering in the 4th-generation synchrotron light sources. For this purpose, we proposed a normal-conducting 1.5 GHz harmonic cavity of TM020-type. Thanks to its low R/Q (68 ohms) and high unloaded Q (34,000), bunch gap transient in the harmonic cavity can be reduced to ~20% as compared to that in a typical TM010 cavity. Furthermore, harmful parasitic modes in this cavity can be heavily damped by installing ferrites where no magnetic fields of TM020-mode exist. However, some of the parasitic modes, e.g. TM021 and TM120 modes, are difficult to damp because their field patterns are similar to that of the TM020 mode. To damp such modes effectively, we optimized the cavity inner shape by tailoring the curvature at the cavity equator, the shape of the nose cones, and introducing "bumps" on the inner wall. Our goals of the coupling impedances are fxR < 2.4[kohm GHz] and RT < 23 kohm/m in the longitudinal and the transverse

planes, respectively. As a result of optimization, we almost achieved these goals. To confirm our simulation results, fabrication of a low-power test cavity is in progress.

MOPAB344 **Machine Learning Models for Breakdown Prediction in RF Cavities for Accelerators**

***C. Obermair**, A. Apollonio, T. Cartier-Michaud, N. Catalán Lasheras, L. Felsberger, W.L. Millar, W. Wuensch (CERN) **C. Obermair**, F. Pernkopf (TUG)*

Radio Frequency (RF) breakdowns are one of the most prevalent limits in RF cavities for particle accelerators. During a breakdown, field enhancement associated with small deformations on the cavity surface results in electrical arcs. Such arcs degrade a passing beam and if they occur frequently, they can cause irreparable damage to the RF cavity surface. In this paper, we propose a machine learning approach to predict the occurrence of breakdowns in CERN's Compact LInear Collider (CLIC) accelerating structures. We discuss state-of-the-art algorithms for data exploration with unsupervised machine learning, breakdown prediction with supervised machine learning, and result validation with Explainable-Artificial Intelligence (Explainable AI). By interpreting the model parameters of various approaches, we go further in addressing opportunities to elucidate the physics of a breakdown and improve accelerator reliability and operation.

MOPAB345 **Machine Learning with a Hybrid Model for Monitoring of the Protection Systems of the LHC**

***C. Obermair**, A. Apollonio, Z. Charifoulline, M. Maciejewski, A.P. Verweij (CERN) **C. Obermair**, F. Pernkopf (TUG)*

The LHC is the world's largest particle accelerator and uses a complex set of sophisticated and highly reliable machine protection systems to ensure a safe operation with high availability for particle physics production. The data gathered during several years of successful operation allow the use of data-driven methods to assist experts in finding anomalies in the behavior of those protection systems. In this paper, we derive a model that can extend the existing signal monitoring applications for the LHC protection systems with machine learning. Our hybrid model combines an existing threshold-based system with a SVM by using signals, manually validated by experts. Even with a limited amount of data, the SVM learns to integrate the expert knowledge and contributes to a better classification of safety-critical signals. Using this approach, we analyze historical signals of quench heaters, which are an important part of the quench protection system for superconducting magnets. Particularly, it is possible to incorporate expert decisions into the classification process and to improve the failure detection rate of the existing quench heater discharge analysis tool.

MOPAB346 **Broadband Frequency Electromagnetic Characterisation of Coating Materials**

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In the new generation of particle accelerators and storage rings, collective effects have to be carefully analyzed. In particular, the finite conductivity of the beam pipe walls is a major source of impedance and instabilities. A reliable electromagnetic (EM) characterisation of different coating materials is required up to hundreds of GHz due to very short bunches. We propose two different measurement techniques for an extended frequency characterization: (i) a THz time domain setup based on the signal transmission response of a tailored waveguide to infer the coating EM properties from 100 to 300 GHz or even further. This technique has been tested both on NEG and amorphous Carbon films. (ii) a resonant method, based on dielectric cavities, to evaluate the surface resistance Rs of thin conducting samples at low (GHz) frequencies. Due to its high sensitivity, Rs values can be obtained for very thin (nanometric) coatings or for copper samples with a laser treated surface, since they have an expected conductivity very close to bulk copper.

MOPAB347 **High Power Coupler Conditioning for B*ERL*inPro Energy Recovery Linac Injector**

A. Neumann, *W. Anders, F. Göbel, A. Heugel, S. Klauke, J. Knobloch, M. Schuster, Y. Tamashevich (HZB)*

Helmholtz Zentrum Berlin is currently finalizing the construction of the demonstrator Energy Recovery Linac B*ERL*inPro. The first part, which will be commissioned, will be the injector consisting of a superconducting RF (SRF) photo-injector (Gun) and a Booster module made up of three two cell SRF cavities. For the latter the 2.3 MeV beam from the gun needs to be accelerated to 6.5 MeV, whereas one Booster cavity will be operated in zero-crossing mode for bunch-shortening. Thus, for the final stage with a 100 mA beam, the twin power couplers of the Booster cavity need to deliver up to 120 kW in travelling continous wave (CW) mode at 1.3 GHz each. To achieve that, a dedicated coupler conditioning setup was installed and commissioned. Here, we will present the first conditioning results with the B*ERL*inPro Booster fundamental power couplers in pulsed and CW regime.

MOPAB348 **Portable 2.5 MeV X-Band Linear Accelerator Structure**

A.V. Mishin, *K. Brown, M. Denney, D. Fischer, N.P. Hanson, S. Proskin, J. Stammetti (Varex Imaging)*

Two versions of 2.5 MeV X-Band linear accelerator structure have been designed and tested. The first is a traditional single input linac, and the other one is a dual input, two section linac with power input through a 3 dB coupler. The linac is designed for a portable linac system, which can be used for security screening, non-destructive testing, medical and industrial CT, and, perhaps, some other applications.

MOPAB349 **New Accelerator Beam Centerline (ABC) Production Line at Varex Imaging Corporation**

A.V. Mishin *(Varex Imaging)*

In January 2017, a Salt Lake City Component Division of Varian Medical (Varian), producer of X-ray tubes, detectors, and imaging panels has been spun off, giving birth to a new public company Varex Imaging Corporation (Varex), which also includes the Security and Inspection Products (SIP) linac producer in Las Vegas. Based on Varian asset acquisition of two small LLCs in May 2016, 8 months prior to the transition, a new business branch within Varex has been established, which included distribution of the betatrons and detector arrays as well as pilot production line for Accelerator Beam Centerlines (ABC). In 3 years, we moved ABC production from Fremont, CA to Salt Lake in Utah and improved it; several ABCs have been designed, produced, and qualified. A number of new products in energy range of 1-20 MeV are under development, based on the new ABCs used as components for SIP linear accelerator systems and ABCs sold to third parties for applications other than Security and NDT. The new products will brag broad energy and dose rate regulation, smooth and reliable operation, providing extended benefits to our customers.

MOPAB350 **RF Buncher Cavity for Polarized He-3 Beam at BNL**

T. Kanesue*, S.M. Trabocchi (BNL) A. Murata (TIT)*

A 100.625 MHz quarter-wave-resonator type rf buncher cavity was designed and fabricated for polarized He-3 operation at BNL. This cavity will be installed in the existing EBIS-To-Booster beam line with required effective voltage of more than 40 kV. The drift tube's inner diameter and gap length are 80 mm and 5 mm, respectively. Since accurate alignment and mechanical stability are required due to the small gap size, the cavity main body including inner wall, stem, and a drift tube were machined from a bulk copper by CNC machining. The result of low power test well agreed with simulation and the cavity was completed as designed without modification. The cavity rf design and test results will be shown.

MOPAB351 **Using an RFQ to Transport Intense Heavy Ion Beams from an ECR Ion Source**

G.O. Rodrigues *(IUAC) R.W. Hamm (R&M Technical Enterprises)*

In the transport of high intensity, heavy ions from an ECR ion source through a low energy beam transport (LEBT) section, space charge can limit the transmission. It has been proposed to use a Radio Frequency Quadrupole (RFQ) to efficiently address this problem. The stray magnetic field of the ECR ion source can be used to provide focusing against the space charge blow-up when using the Direct Plasma Injection Scheme (DPIS) developed for laser ion sources. The RFQ will focus and transport the injected beam, eliminating most of the charge states extracted from the ECR ion source. This narrowing of the charge state distribution is a filter, reducing the low energy beam transport problem, as well as the emittance growth for the desired beam. A com-

bined extraction/matching system has been designed for direct injection into a 48.5 MHz RFQ for the production of $238U^{40+}$ (0.52 mA) and $209Bi^{30+}$ (1.047 mA) beams. The IGUN code has been used to design the injection directly into the RFQ. The RFQ design has been modified with a pre-buncher built into the vanes to narrow the transmitted charge state distribution as much as possible. The design details of this system will be presented.

MOPAB352 **High Power Test of a Dielectric Disk Loaded Accelerator for a Two Beam Wakefield Accelerator**

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As part of the Argonne 500 MeV short pulse Two Beam Wakefield Acceleration Demonstrator, a single cell X-band dielectric disk loaded accelerator (DDA) has been designed, fabricated, and tested at high power at the Argonne Wakefield Accelerator. The DDA should provide a short pulse (~20 ns) high gradient (>300 MV/m) accelerator while maintaining a reasonable r/Q and high group velocity. This will allow a significantly larger RF-to-beam efficiency than is currently possible for conventional accelerating structures. A low loss barium titantate ceramic, $\mu_r = 50$, was selected, and a low temperature brazing alloy chosen to preserve the dielectric properties of the ceramic during brazing. High power testing produced breakdown at the triple junction, resulting from the braze joint design. No evidence of breakdown was observed on the iris of the disk, indicating that the maximum surface electric field on the dielectric was not reached. An improved braze joint has been designed and is in production, with high power testing to follow.

MOPAB353 **Design of a compact Ka-Band Mode Launcher for High gradient Accelerators**

***G. Torrisi**, G.S. Mauro, G. Sorbello (INFN/LNS) M. Behtouei, L. Faillace, B. Spataro, A. Variola (INFN/LNF) V.A. Dolgashev (SLAC) L. Faillace, M. Migliorati (Sapienza University of Rome) M. Migliorati (INFN-Roma1) J.B. Rosenzweig (UCLA) G. Sorbello (University of Catania)*

In this work, we present the RF design of a table-top Ka-Band mode launcher operating at 35.98 GHz. The structure consists of a symmetrical 4-port WR28 rectangular-TE10-to-circular-TM01 mode converter that is used to couple a peak output RF power of 5 MW (pulse length up to 50 ns and repetition rate up to 100 Hz) in Ka-Band linear accelerator able to achieve very high accelerating gradients (up to 200 MV/m). Numerical simulations have been carried out with the 3D full-wave commercial simulator Ansys HFSS in order to obtain a preliminary tuning of the accelerating field flatness at the operating frequency f0=35.98 GHz. The main RF parameters, such as reflection coefficient,

transmission losses, and conversion efficiency are given together with a verification of the field azimuthal symmetry which avoids dipole and quadrupole deflecting modes. To simplify future manufacturing, reduce fabrication costs, and also reduce the probability of RF breakdown, the proposed new geometry has "open" configuration. This geometry eliminates the flow of RF currents through critical joints and allows this device to be milled from metal blocks.

MOPAB354 **A Novel RF Cavity for a GHz Repetition-Rate Electron Injector**
***A. Rajabi**, O.J. Luiten, P.H.A. Mutsaers, X.F.D. Stragier, W.F. Toonen, R.G.W. van den Berg (TUE)*
The Advanced Continuous-wave Electron (ACE) injector at the Eindhoven University of Technology is a GHz repetition-rate electron injector capable of producing low emittance, high repetition-rate electron bunches. The injector is based on a custom-designed thermionic electron gun and two dual-mode RF cavities for chopping the continuous beam and compressing the produced bunches. The most straightforward shape for a dual-mode RF cavity is a rectangular box. However, using such a cavity as a beam deflector in which the magnetic fields are essential requires a considerable amount of RF power. A novel RF cavity was designed and constructed to solve the power consumption problem. An overview of the cavity's design and characterization is presented, together with a comparison between the measurement results and simulated properties.

MOPAB355 **Multi-Objective Optimization of RF Structures**
***S.J. Smith**, R. Apsimon, G. Burt, M.J.W. Southerby (Cockcroft Institute, Lancaster University) S. Setiniyaz (Cockcroft Institute) S. Setiniyaz (Lancaster University)*
In this work, we apply multi-objective optimization methods to single-cell cavity models generated using non-uniform rational basis splines (NURBS). This modeling method uses control points and a NURBS to generate the cavity geometry, which allows for greater flexibility in the shape, leading to improved performance. Using this approach and multi-objective genetic algorithms (MOGAs) we find the Pareto frontiers for the typical key quantities of interest (QoI) including peak fields, shunt impedance and the modified Poynting vector. Visualizing these results becomes increasingly more difficult as the number of objectives increases, therefore, in order to understand these frontiers, we provide several techniques for analyzing, visualizing and using multi-dimensional Pareto fronts specifically for RF cavity design.

MOPAB356 **The ESS MEBT RF Buncher Cavities Conditioning Process**
***I. Bustinduy**, N. Garmendia, P.J. González, A. Kaftoosian, S. Masa, I. Mazkiaran, L.C. Medina, J.L. Muñoz (ESS Bilbao) J. Etxeberria, J.P.S. Martins (ESS)*
As part of the 5 MW European Spallation Source (ESS), the Medium Energy Beam Transport (MEBT) was designed, assembled, and installed in the tunnel since May 2020 by ESS-Bilbao. This section of the accelerator is located between the Radio Frequency Quadrupole (RFQ) and

the Drift Tube Linac (DTL). The main purpose of the MEBT is to match the incoming beam from the RFQ both transversely and longitudinally into the DTL. The longitudinal matching is achieved by three 352.209 MHz RF buncher cavities. In this paper, we focus on the RF conditioning process for each set of power coupler and buncher cavity. For this purpose, different tools were developed on EPICS and Python as well as electronics hardware such as Fast Interlock Module (FIM) and timing system. These tools served to automatize both the cavity frequency tuning and the power ramp-up process and will be described in detail in the following sections.

MOPAB357 **The New Design of the RF System for the SPS-II Light Source**

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The new light source facility in Thailand, SPS-II, is a ring-based 3 GeV light source with a circumference of approximately 330 m. The target stored beam current is 300 mA with an emittance of below 1.0 nm rad. The injector has been changed from a full energy linac to a booster injector with 150 MeV linac. The main RF frequency has been reconsidered to a low-frequency range at 119 MHz. Low frequency is chosen with the benefit of low RF voltage for a high RF acceptance together with experience with the present ring RF system of 118 MHz. Details of RF frequency consideration will be discussed. The requirements and details of the RF systems in the booster ring and the storage ring will be presented.

MOPAB358 **Design and Measurement of the 1.4 GHz Cavity for LEReC Linac**

B.P. Xiao, *J.C. Brutus, J.M. Fite, K. Hamdi, D. Holmes, K.S. Smith, J.E. Tuozzolo, T. Xin, A. Zaltsman (BNL)*

The Low Energy RHIC electron Cooler (LEReC) is the first electron cooler based on rf acceleration of electron bunches. To further improve RHIC luminosity for heavy ion beam energies below 10 GeV/nucleon, a normal conducting RF cavity at 1.4 GHz was designed and fabricated for the LINAC that will provide longer electron bunches for the LEReC. It is a single-cell cavity with an effective cavity length shorter than half of the 1.4 GHz wavelength. This cavity was fabricated and tested on-site at BNL to verify RF properties, i.e. the resonance frequency, FPC coupling strength, tuner system performance, and high power tests. In this paper, we report the RF test results for this cavity.

MOPAB359 **Operational Experience and Redesign of the Tuner Without Spring Fingers for the LEReC Warm Cavity**

B.P. Xiao, *J.M. Brennan, J.C. Brutus, K. Mernick, S. Polizzo, S.K. Seberg, F. Severino, K.S. Smith, A. Zaltsman (BNL)*

A folded coaxial tuner without spring fingers was designed for the Low Energy RHIC electron Cooler (LEReC) 2.1 GHz warm cavity. During RHIC run 2019, this tuner was found to cause cavity trips via different failure modes. After analyzing these failure modes, a new straight

coaxial tuner without spring fingers was proposed and was installed. We show the operational experience of the new tuner in this paper.

MOPAB360 **Study on the Anomalous Skin Effect of Normal Conducting Film**

***B.P. Xiao**, M. Blaskiewicz, T. Xin (BNL)*

For the radiofrequency (RF) applications of normal conducting film with large mean free path at high frequency and low temperature, the anomalous skin effect differs considerably from the normal skin effect with field decaying exponentially in the film. Starting from the relationship between the current and the electric field (E field) in the film, the amplitude of E field along the film depth is calculated, and is found to be non-monotonic. The surface impedance is found to have a minimum value at certain film thickness.

MOPAB361 **Threshold in Filling Failure of RF Cavity Caused by Beam Loading in Multipactor**

***J. Pang** (USTC/NSRL) Y. Dong (Institute of Applied Physics and Computational Mathematics) Y. Du (Institute of Fluid Physics,, China Academy of Engineering Physics)*

A pulsed RF cavity would be heavily detuned caused by beam loading of multipactor current in the RF filling process. Multipactor zone would be expended by several times than that in static states with assumptions of fixed voltage and no beam loading. The dynamic of multipactor in the RF filling process was simulated by coupling with parameters of external circuit with the developed simulation code, and test in experiments with a parallel-plate resonator. Threshold of RF voltage, which means the lower boundary of peak voltage of multipactor zone, had been quantified with different cavity parameters. When we increased the gap length, the measured threshold became larger due to the ionization in background gas. Then the secondary emission factor would be increased in simulation for consistence with the experiment results. Additionally, some multipactor phenomenon could not be predicted precisely because the simulation code did not take account of ionization. The hysteresis of phase and energy of ionization electrons would be a new driving factor for the growth of multipactor in certain conditions.

MOPAB362 **Atomistic Modeling of the Coupling Between Electric Fields and Bulk Plastic Deformation in Rf Structures**

***S. Bagchi**, D. Perez (LANL)*

A notable bottleneck in achieving high-gradient RF technology is dictated by the onset of RF breakdown. While bulk mechanical properties are known to significantly affect breakdown propensity, the underlying mechanisms coupling RF fields to bulk plastic deformation in experimentally relevant thermo-electrical loading conditions remain to be identified at the atomic scale. Here, we present results of large-scale molecular dynamics simulations (MD) to investigate possible modes of coupling. We consider the activation of Frank-Read (FR) sources, which leads to dislocation multiplication, under the action

of bi-axial thermal stresses and surface electric-field. With a charge-equilibration formalism incorporated in a classical MD model, we show that a surface electric field acting on an either preexisting or dislocation-induced surface step, can generate a long-range resolved shear stress field inside the bulk of the sample. We investigate the feedback between step growth following dislocation emission and subsequent activations of FR sources and discuss the regimes of critical length-scales and densities of dislocations, where such a mechanism could promote RF breakdown precursors.

MOPAB363 **Design, Characteristics and Dynamic Properties of Mobile Plunger-based Frequency Tuning System for Coaxial Half Wave Resonators**

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The practical realization of a prototype of the frequency tuning system (FTS) for coaxial half-wave cavities (HWR) for the Nuclotron-based Ion Collider fAcility (NICA) injector is presented. The impact of FTS on electromagnetic parameters of copper HWR prototype is experimentally studied and discussed. The most important parameters like tuning range, tuning sensitivity, the dependence of the resonant frequency on the position of the plungers are estimated. The effective operation algorithms of the proposed FTS are discussed and analyzed. The dynamic characteristics of FTS are investigated and showed the ability to adjust the frequency with an accuracy of about 70 Hz.

MOPAB364 **Shielded Pair Method for Cylindrical Surface Resistance Measurement at Cryogenic Temperature**

***K. Brunner**, S. Calatroni, F. Caspers (CERN) D. Barna (Wigner Research Centre for Physics, Institute for Particle and Nuclear Physics)*

The shielded pair resonator method was already used in the past at CERN to measure the surface resistivity of the LHC beam screen both at room temperature and cryogenic temperature. We have refined and adapted the measurement to be able to measure other types of beam screens and also to operate in a strong dipolar magnetic field. This is necessary for testing the properties of HTS coated beam screens or the possible effects of coatings and surface treatments for e-cloud suppression. Several calibration runs were done at cryogenic temperatures (4.2 K) measuring the surface resistivity of a copper pipe to identify the precision, stability and reproducibility achievable using this method. This work describes the challenges of the measurement and ways to mitigate them.

MOPAB365 **Construction and First Test Results of the Barrier and Harmonic RF Systems for the NICA Collider**

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This paper reports on the design features and construction progress of the three RF systems for the NICA collider being built at JINR, Dubna. Each of the two collider rings has three RF systems named RF1 to 3. RF1 is a barrier bucket system used for particles capturing and accumulation during injection, RF2 and 3 are resonant systems operating at 22nd and 66th harmonics of the revolution frequency and used for the 22 bunches formation. The RF systems are designed and produced by Budker INP. Solid state RF power amplifiers developed by the Triada-TV company, Novosibirsk, are used for driving the RF2 and three cavities. Two RF1 stations were already delivered to JINR, the prototypes of the RF2 and 3 stations were built and successfully tested at BINP. Series production of all eight RF2 and sixteen RF3 stations is in progress. The design modifications and test results are presented.

MOPAB366 **Improving Magnetic Materials for RCS Cavity Tuners**

R.L. Madrak, *N.M. Curfman, G.V. Romanov, C.-Y. Tan, I. Terechkine (Fermilab) G. Das, A.K. Samanta (Ceramic Magnetics, Inc., National Magnetics Group, Inc.)*

Within the Lab Directed R&D Program at Fermilab, and in partnership with National Magnetics, we have recently begun to study and attempt to improve the loss parameter in garnet material. This could be used for fast tuner applications such as in rapid cycling synchrotrons.

MOPAB369 **Measurement of Transverse Symmetry of Cavity Field Distribution**

S.X. Dong *(USTC/NSRL)*

Based on J. C. Slater's microwave cavity perturbation theory, this article introduces a perturbation body into the resonant cavity, the cavity resonance frequency will be disturbed, and its frequency change is related to the electric and magnetic field strength at the location of the perturbation body. In a regular guided system, the transverse component of the guided wavefield can be completely determined by the longitudinal component. For the TM_{010} mode in the circular waveguide and ITC cavity, only the axial electric field E_z and the toroidal magnetic field H_θ exist. By measuring the axial electric field E_z and the symmetry of the cavity itself, the transverse magnetic field distribution of the cavity is obtained.

MOPAB370 **X-Band RF Spiral Load Optimization for Additive Manufacturing Mass Production**

H. Bursali *(Sapienza University of Rome) N. Catalán Lasheras, R.L. Gerard, A. Grudiev, O. Gumenyuk, P. Morales Sanchez, B. Riffaud (CERN) J. Sauza-Bedolla (Lancaster University)*

The CLIC main linac uses X-band traveling-wave normal conducting accelerating structures. The RF power not used for beam acceleration nor dissipated in the resistive wall is absorbed in two high power RF loads that should be as compact as possible to minimize the total footprint of the machine. In recent years, CERN has designed, fabricated and successfully tested several loads produced by additive manufacturing. With the current design, only one load can be produced in the 3D printing machine at a time. The aim of this study is optimizing the internal cross-section of loads in order to create a stackable design to increase the number of produced parts per manufacturing cycle and thus decrease the unit price. This paper presents the new design with an optimization of the internal vacuum part of the so-called RF spiral load. In this case, RF and mechanical designs were carried out in parallel. The new cross section has showed good RF reflection reaching less than -30 dB in simulations. The final load is now ready to be manufactured and high-power tested. This new load will not only provide cost saving but also faster manufacturing for mass production.

MOPAB371 **A Coupon Tester for Normal Conducting High-Gradient Materials**

J.W. Lewellen*, D. Gorelov, D. Perez, E.I. Simakov (LANL) M.S. Schneider (Michigan State University)*

A coupon tester is an RF structure used to subject a material sample to very high RF fields, with the fields on the sample, or coupon, being higher than elsewhere in the cavity. To date, most such cavities were originally intended to explore the RF properties of superconducting materials, and can expose the sample to strong magnetic fields, but weak to no electric fields. As part of a program to develop materials and structures for high-gradient (> 100 MV/m), low-breakdown-rate normal-conducting accelerators, we have designed a C-band (5.712 GHz) cavity intended to subject samples to both magnetic and electric fields comparable to those experienced in high-gradient structure designs, using a TM-mode cavity; the electric and magnetic fields along the sample coupon can be directly compared to the fields on the iris of high-gradient structures. This poster will present the design criteria for our coupon tester cavity, nominal operating parameters, and our structure concept. The cavity design will be refined over the next several months, and will be constructed and in service near the start of 2022.

MOPAB372 **KARVE: a Nanoparticle Accelerator for Space Thruster Applications**

***J.W. Lewellen**, L.R. Danielson, A. Essunfeld, J.A. Hollingsworth, M.A. Holloway (LANL) E.K. Lewis (NASA Johnson Space Center)*

We present a concept for using RF-based acceleration of nanoparticles (NPs) as a means of generating thrust for future space missions: the Kinetic Acceleration & Resource Vector Engine (KARVE) thruster. Acceleration of nanoparticles (NPs) via DC accelerators has been shown to be feasible in dust accelerator labs such as the Heidelberg dust accelerator and the 3 MV hypervelocity dust accelerator at the Colorado Center for Lunar Dust and Atmospheric Studies. In contrast, KARVE uses RF-driven acceleration of nanoparticles as the basis of a thruster design lying between chemical and ion engines in performance: more efficient than chemical engines in terms of specific impulse; and higher thrust than ion engines. The properties of multi-gap RF accelerators also allow an on-the-fly tradeoff between specific impulse and thrust.

MOPAB374 **Creating Exact Multipolar Fields in Accelerating RF Cavities via an Azimuthally Modulated Design**

***L.M. Wroe**, S.L. Sheehy (JAI) R. Apsimon (Cockcroft Institute, Lancaster University) M. Dosanjh (CERN) S.L. Sheehy (The University of Melbourne)*

In this paper, we present a novel method for designing RF structures with specifically tailored multipolar field contributions. This has a range of applications, including the suppression of unwanted multipolar fields or the introduction of wanted terms, such as for quadrupole focusing. In this article, we outline the general design methodology and compare the expected results to 3D CST simulations.

MOPAB375 **Preliminary Design and Simulation of Test Benches for Coaxial Power Couplers**

***M.X. Fan** (IHEP)*

As one of the most key components for the superconducting cavity, the power coupler not only feeds the power coming from the power source to the cavity with high efficiency and stability but also assumes the role of the transition from room temperature to low temperature and the isolation of the atmosphere and vacuum. Coaxial power couplers are widely used as superconducting cavity couplers for a long time. However, Due to the cleanliness requirements of the superconducting cavity, the power coupler must be individually high-power conditioned at least once in advance. Therefore, a test bench for power couplers is required. In this paper, according to the requirement of CSNS, different types of test benches are compared firstly. Second, the test bench working at 324 MHz and 648 MHz are designed separately. Finally, some conclusions are outlined at the end of this paper.

MOPAB376 **Design and Fabrication of a Quadrupole Resonator for SRF R&D**

***R. Monroy-Villa**, W. Hillert, M. Wenskat (University of Hamburg, Institut für Experimentalphysik) S. Gorgi Zadeh, P. Putek (Rostock University, Faculty of Computer Science and Electrical Engineering) **R. Monroy-Villa**, D. Reschke, J.H. Thie (DESY)*

As superconducting radio-frequency (SRF) cavities are now approaching the theoretical limits of the material, a variety of different surface treatments have been developed to further improve their performance; although no fully understood theory is yet available. Small superconducting samples are studied to characterize their material properties and their evolution under different surface treatments. To study the RF properties of such samples under realistic SRF conditions at low temperatures, a test cavity called quadrupole resonator (QPR) is currently being fabricated. In this work we report the status of the QPR at Universität Hamburg in collaboration with DESY. Our device is based on the QPRs operated at CERN and at HZB and its design will allow for testing samples under cavity-like conditions, i.e., at temperatures between 2K and 8 K, under magnetic fields up to 120mT and with operating frequencies of 433 MHz, 866 MHz and 1300 MHz. Fabrication tolerance studies on the electromagnetic field distributions and simulations of the static detuning of the device, together with a status report on the current manufacturing process, will be presented.

MOPAB377 **Unprecedented Gradients of 50 MV/m in Tesla Shaped Nb SRF Cavities via Modified Low Temperature Bake**

***D. Bafia**, A. Grassellino, O.S. Melnychuk, A.S. Romanenko, Z-H. Sung (Fermilab) J. Zasadzinski (IIT)*

We discuss the modified low temperature bake, a new surface treatment for 1.3 GHz TESLA-shaped niobium SRF cavities capable of producing unprecedented accelerating gradients of above 50 MV/m. In addition to this exceptional performance, a bifurcation in vertical test results is observed after retesting cavities without disassembly in between. Atomic Force Microscopy studies on cavity cutouts give a possible mechanism for this branching in performance, namely, the dissociation and growth of room temperature niobium nano-hydrides that exist near the RF surface, which are made superconducting only through the proximity effect. In-situ low temperature baking of cavity cutouts reveals a dissociation of these room temperature nano-hydrides, which may explain the increase in performance of cavities subjected to similar in-situ heating in the dewar.

MOPAB378 **Origins and Implications of the Resonant Frequency Dip Near Tc in Nb SRF Cavities**

***D. Bafia**, M. Checchin, A. Grassellino, A.S. Romanenko (Fermilab) J. Zasadzinski (IIT)*

We discuss recent studies on the dip phenomenon present in the frequency behavior near the transition temperature of Nb TESLA shaped SRF cavities. We show that this dip phenomenon occurs in the

presence of dilute concentrations of impurities within the RF layer achieved via various surface processing techniques. In the case of N impurities, the quality factor at mid field is found to vary linearly with the magnitude of the dip, suggesting that both parameters are tied to the interface properties of niobium. The observed phenomena are related to the average electronic mean free path. To explore possible superconducting origins, the conductivities of two cavities that exhibit different features near Tc are calculated. These findings give insight on the mechanisms behind ultra-high Q_0 in Nb SRF cavities.

MOPAB379 **Topology Optimization on SRF Cavities for Nuclear and High Energy Physics**

H. Gassot *(Université Paris-Saclay, CNRS/IN2P3, IJCLab)*

Topology optimization has been developed for more than twenty years. The progress of additive manufacturing boosts the development in topological optimization since the design can be completely innovated and realized by 3D printing. The potential for cost reductions thanks to weight minimization give an interesting perspective for the small production of niobium superconducting radio-frequency cavities, commonly used in accelerators. The traditional manufacturing technologies of cavities are based on multi-stage processes while additive manufacturing technologies can built fully functional parts in a single operation. For modern accelerators that use superconducting linac, including energy recovery linacs (ERLs), it is particularly important to know the perspectives of additive manufacturing for SRF cavities. In this paper, we try to build a preliminary perception of topological optimization in superconducting cavities manufacturing innovation.

MOPAB380 **Status and Progress of the RF System for High Energy Photon Source**

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High Energy Photon Source (HEPS) is a 6 GeV diffraction-limited synchrotron light source currently under construction in Beijing. It adopts a double-frequency RF system with 166.6 MHz as fundamental and 499.8 MHz as third harmonic. The fundamental cavity is making use of a superconducting quarter-wave β=1 structure and the third harmonic is of superconducting elliptical single-cell geometry for the storage ring, while normal-conducting 5-cell cavities are chosen for the booster ring. A total of 900 kW RF power shall be delivered to the beam by the 166.6 MHz cavities and the third harmonic cavities are active. All cavities are driven by solid-state power amplifiers and the RF fields are regulated by digital low-level RF control systems. The cavity and ancillaries, high-power RF system and low-level RF control system are in the prototyping phase. This paper presents the current status and progress of the RF system for HEPS.

MOPAB381 **Continuing Advances in Secondary Ion Mass Spectrometry for N-Doped Niobium**

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Accurate Secondary Ion Mass Spectrometry (SIMS) measurement of nitrogen in niobium relies on the use of standards made by ion implantation into niobium specimens closely equivalent to accelerator cavity material. Analysis of the standards permits conversion of nitrogen signal intensity to nitrogen content by determination of relative sensitivity factors (RSF). Accurate RSF values for ppm-range nitrogen contents are increasingly critical, as more precision is sought in processes for next-generation superconducting radio-frequency (SRF) accelerator cavities. Factors influencing RSF value measurements were investigated with the aim of reliably attaining better than 10% accuracy in N concentrations at various depths into the bulk. This has been accomplished for materials typical of SRF cavities at the cost of great attention to all aspects.

MOPAB382 **Synchrotron Light Shielding for the 166 MHz Superconducting RF Section at High Energy Photon Source**

X.Y. Zhang, *Z.Q. Li, Q. Ma, P. Zhang (IHEP)*

The High Energy Photo Source (HEPS) project has been under construction since 2019, and will be first diffraction-limited synchrotron light source in China. A 6 GeV electron beam with 200 mA current will be stored in the main ring. If synchrotron light produced from this energetic electron beam hits the superconducting cavity's surface, it would cause thermal breakdown of the superconductivity. In the current lattice design, these lights cannot be fully blocked by the collimator in the upstream lattice cell, therefore a shielding scheme inside the rf section is required. This however brings great challenges to the already limited space. The design of the collimator has been focused on fulfilling shielding requirements while optimizing beam impedance, synchrotron light power density, thermal and mechanical stabilities. Shielding materials are subsequently chosen with dedicated cooling to ensure long-term stable operations. In this paper, a shielding scheme inside the rf section of the HEPS storage ring is presented. The synchrotron light mainly from the upstream bending magnet is successfully block. The sensitivity to beam position movement and installation error is also analyzed.

MOPAB383 **Pressure Test for Large Grain and Fine Grain Niobium Cavities**

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The pressure test was performed using a fine grain (FG) and a large grain (LG) niobium cavities. The cavity is 1.3 GHz 3-cell TESLA-like shape. The cavity was housed in a steel vessel. Water is supplied into the vessel and the cavity outside is pressurized. The applying pressure and the natural frequency of cavity were measured during the pres-

sure test. The FG and LG cavities were deformed greatly and the pressure dropped suddenly at 3.4 MPa and 1.6 MPa, respectively. The frequency shifted up to 3.4 MHz and 1.3 MHz, respectively. There was no leak after the pressure test, so the cavity did not rupture under above pressure. The result of the pressure at LG cavity is less half than that of the FG cavity. We calculated the stress distribution in the structure by applying outer water pressure using a FEM. The maximum stress at cell when above test pressure is applied, are 146 MPa in FG and 73 MPa in LG, respectively. These stresses are similar to tensile strength of niobium specimen measure by ourselves. The result of pressure tests agrees well with the calculation.

MOPAB384 **Nb_3Sn Coating of Twin Axis Cavity for Accelerator Applications**
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A Superconducting twin axis cavity consisting of two identical beam pipes that can accelerate and decelerate beams within the same structure has been proposed for the Energy Recovery Linac (ERL) applications. There are two niobium twin axis cavities at JLab fabricated with the intention of later Nb_3Sn coating and now we are progressing to coat them using vapor diffusion method. Nb_3Sn is a potential alternate material for replacing Nb in SRF cavities for better performance and reducing operational costs. Because of advanced geometry, larger surface area, increased number of ports and hard to reach areas of the twin axis cavities, the usual coating approach developed for typical elliptical single-axis cavities must be evaluated and requires to be adjusted. In this contribution, we report the first results from the coating of a twin axis cavity and discuss current challenges with an outlook for the future.

MOPAB385 **An Overview of RF Systems for the EIC**
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The Electron Ion Collider (EIC) to be constructed at Brookhaven National Laboratory in the USA will be a complex system of accelerators providing high luminosity, high polarization, variable center of mass energy collisions between electrons and protons or ions. To achieve this a variety of RF systems are required. They must provide for capture, formation and storage of Ampere-class beams in the electron and hadron storage rings (ESR and HSR), fast acceleration of high-charge polarized electron bunches in the rapid cycling synchrotron (RCS), provision of cold high current electron bunches in the high-energy cooler ERL and precise high-gradient crabbing of electrons and hadrons either side of the interaction point. The challenges include strong HOM damping in the storage ring cavities and cooler ERL, very high fundamental mode power in the ESR and cooler injector, extremely stable low-noise operation of the crab cavities, mitigation of transient beam loading from gaps, and operating over a wide range of energies and beam currents. We describe the high-level system para-

meters and principal design choices made and progress on the R&D plan to develop these state of the art systems.

MOPAB386 **Development of Nitrogen-Doping Technology for SHINE**

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The Shanghai HIgh repetition rate XFEL aNd Extreme light facility (SHINE) is under construction, which needs six hundred 1.3GHz cavities with high quality factor. In this paper, we present the newest studies on single cell cavities with nitrogen doping and cold EP treatment, showing an obvious improvement compared with the previous results.

MOPAB388 **Status of the High Power Couplers for ESS Elliptical Cavities**

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In the framework of the European Spallation Source (ESS), CEA Paris-Saclay is responsible for the delivery of 30 cryomodules (9 medium beta ($\beta = 0.67$) and 21 high beta ($\beta = 0.86$) ones). Each cryomodule contains 4 elliptical cavities equipped with a radio frequency power coupler. The ESS nominal pulse is 1.1 MW maximum peak power over a width of 3.6 ms at a repetition rate of 14 Hz. The design of the couplers for medium beta and for high beta cavities is the same, except a small difference of the antenna penetration to adjust the Q_{ext}. The mass production of the 120 couplers started and all the medium beta couplers have been conditioned at room temperature. The first cryomodules equipped with the power couplers were successfully tested at high RF power and with cavities at 2K reaching the ESS nominal pulse. The main issue at the start of the series production could be fixed and it was due to bad TiN coatings that caused abnormal dielectric losses in the window. Thus, this paper deals with the TiN coating defect, presents the conditioning procedure and gives a conditioning report of these 36 couplers.

MOPAB390 **Development of a 166.6-MHz Low-Level RF System by Direct Sampling for High Energy Photon Source**

***D.B. Li**, H.Y. Lin, Q.Y. Wang, P. Zhang (IHEP)*

A digital low-level radio frequency (LLRF) system by direct sampling has been proposed for 166.6 MHz superconducting cavities at High Energy Photon Source (HEPS). The RF field inside the cavities has to be controlled better than ±0.1% (peak to peak) in amplitude and ±0.1 deg (peak to peak) in phase. Considering that the RF frequency is 166.6 MHz, which is well within the analog bandwidth of modern high-speed ADCs and DACs, direct RF sampling and direct digital modulation can be achieved. A digital LLRF system utilizing direct sampling has therefore been developed with embedded experimental physics and industrial control system (EPICS) in the field programmable gate

array (FPGA). The performance in the lab has been characterized in a self-closed loop with a residual peak-to-peak noise of ±0.05% in amplitude and ±0.03 deg in phase, which is well below the HEPS specifications. Further tests on a warm 166.6 MHz cavity in the lab are also presented.

MOPAB391 **Conduction Cooling Methods for Nb_3Sn SRF Cavities and Cryomodules**

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Rapid progress in the performance of Nb_3Sn SRF cavities during the last few years has made Nb_3Sn an energy efficient alternative to traditional Nb cavities, thereby initiating a fundamental shift in SRF technology. These Nb_3Sn cavities can operate at significantly higher temperatures than Nb cavities while simultaneously requiring less cooling power. This critical property enables the use of new, robust, turnkey style cryogenic cooling schemes based on conduction cooling with commercial cryocoolers. Cornell University has developed and tested a 2.6 GHz Nb_3Sn cavity assembly which utilizes such cooling methods. These tests have demonstrated stable RF operation at 10 MV/m and the measured thermal dynamics match what is found in numerical simulations.

MOPAB392 **Alternative RF tuning Methods Performed on Spoke Cavities for ESS and MYRRHA Projects**

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In order to obtain the target frequency in operation, the resonant frequency of superconducting radiofrequency cavities is controlled and adjusted from the manufacturing to the end of preparation phase. Reaching this right frequency can be challenging due to the narrow frequency range defined by the tuning sensitivity of the cavity and the capability of the tuner. Mechanical deformation until plasticity is attained is of great interest to tune SRF cavities when large frequency shift is needed. But once a cavity is dressed with its helium tank, the only accessible part is its beam pipe, reducing the mechanical action to a push/pull action. This limited possibility has hence to be skilfully associated with chemical etching. An original mechanical tuning of Spoke dressed cavities consists in increasing the pressure inside the helium tank to induce a permanent deformation of the cavity walls. The frequency shift induced by nonlinear deformation is numerically evaluated in order to determine the pressure increments. Both methods were successfully performed on the cavities of the ESS accelerator and of the Myrrha project.

MOPAB393 **Design of an RF-Dipole Crabbing Cavity System for the Electron-Ion Collider**

***S.U. De Silva**, J.R. Delayen (ODU) J. Henry, F. Marhauser, H. Park, R.A. Rimmer (JLab)*

The Electron-Ion Collider requires several crabbing systems to facilitate head-on collisions between electron and proton beams in increasing the luminosity at the interaction point. One of the critical rf systems is the 197 MHz crabbing system that will be used in crabbing the proton beam. Many factors such as the low operating frequency, large transverse voltage requirement, tight longitudinal and transverse impedance thresholds, and limited beam line space makes the crabbing cavity design challenging. The rf-dipole cavity design is considered as one of the crabbing cavity options for the 197 MHz crabbing system. The cavity is designed including the HOM couplers, FPC and other ancillaries. This paper presents the detailed electromagnetic design, mechanical analysis, and conceptual cryomodule design of the crabbing system.

MOPAB394 **Preliminary BCP Flow Field Investigation by CFD Simulations and PIV in a Transparent Model of a SRF Elliptical Low Beta Cavity**

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Standard vertical Buffered Chemical Polishing (BCP) is one of the main surface treatment for Superconducting Radiofrequency (SRF) cavities. A finite element Computational Fluid Dynamic (CFD) model has been developed. Uncertainties in the solution of fluid simulations are not negligible due to the complex geometry of a SRF cavity; thus without an experimental validation, results from this type of simulations cannot be confidently used to improve the process. To this aim, an experimental study was started to investigate the fluid dynamics of the BCP process by means of Particle Image Velocimetry (PIV) technique. Similitude on Reynolds number and Refractive Index Matching (RIM) technique were also implemented to replace the dangerous BCP mixture with a glycerine-water mixture. The paper describes the preliminary results from simulations and experiment.

MOPAB395 **Nb_3Sn Thin Film Synthesis for SRF Application by Co-sputtering**

***N. Schäfer**, L. Alff, N. Karabas, M. Major (TU Darmstadt)*

Nowadays Nb is commonly used for superconducting radio frequency (SRF) cavities. Nb_3Sn is a promising thin film material for SRF cavities as it can empower the cavity to operate at higher acceleration fields and higher temperatures. This is achievable by a higher quality factor since the surface resistivity is lower with respect to Nb-only cavities at radiofrequency. Several approaches could be used for deposition of Nb_3Sn thin films (e.g. sputtering, evaporation, and CVD).

The applicability to successfully coat cavities was demonstrated for several processes with their respective disadvantages. Nb_3Sn is either synthesized by a deposition of Sn on the Nb cavity or a stoichiometric deposition of Nb and Sn. Film Thickness, and especially stoichiometry are essential for the high potential of the Nb_3Sn material properties. A new Co-Sputtering process is used in the Advanced Thin Film Technology group to form high performance layers at unprecedented low process temperatures. This process is able to overcome the detrimental diffusion of Sn at elevated temperatures.

MOPAB396 **Measurements of Magnetic Field Penetration in Superconducting Materials for SRF Cavities**

***I.H. Senevirathne**, J.R. Delayen, A.V. Gurevich (ODU) J.R. Delayen, A-M. Valente-Feliciano (JLab)*

Superconducting radiofrequency (SRF) cavities used in particle accelerators operate in the Meissner state. To achieve high accelerating gradients, the cavity material should stay in the Meissner state under high RF magnetic field without penetration of vortices through the cavity wall. The field onset of flux penetration into a superconductor is an important parameter of merit of alternative superconducting materials other than Nb which can enhance the performance of SRF cavities. There is a need for a simple and efficient technique to measure the onset of field penetration into a superconductor directly. We have developed a Hall probe experimental setup for the measurement of the flux penetration field through a superconducting sample placed under a small superconducting solenoid magnet which can generate magnetic fields up to 500 mT. The system has been calibrated and used to measure different bulk and thin film superconducting materials. This system can also be used to study SIS multilayer coatings that have been proposed to enhance the vortex penetration field in Nb cavities.

MOPAB397 **Tests at High RF Power of the First ESS Medium Beta Cryomodules**

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In addition to the production of the 30 medium and high beta cryomodules of the ESS LINAC, CEA perform the test at high RF power of two prototype cryomodules and of the three first cryomodules of each type assembled at CEA Saclay. We present the success and difficulties to reach the challenging ESS RF pulse, E_{acc} = 16.7 MV/m (M-Beta) and E_{acc}=19.9MV/m (H-Beta), Pforward = 1.1 MW, RF pulses length = 3.6ms at 14 Hz. The piezo tuners efficiently compensated the Lorentz forces detuning and could stabilize the accelerating field better than 1% over the full length of the expected ESS 2.86 ms beam pulse. After the successful test, the first medium beta cryomodule has been shipped to ESS where the final acceptance test will be performed.

MOPAB398 **Nitrogen-Doped Niobium for SRF Cavities at TU Darmstadt**
M. Major, *L. Alff, M. Arnold, J. Conrad, S. Flege, R. Grewe, N. Pietralla (TU Darmstadt)*
Niobium is the standard material for superconducting RF (SRF) cavities for particle acceleration. Superconducting materials with higher critical temperature or higher critical magnetic field allow cavities to work at higher operating temperatures or higher accelerating fields, respectively. Enhancing the surface properties of the superconducting material in the range of the penetration depth is also beneficial. One direction of search for new materials with better properties is the modification of bulk niobium by nitrogen doping. In the Nb-N phase diagram, the cubic delta-phase of NbN has the highest critical temperature. Niobium samples were annealed and N-doped in the high-temperature furnace at TU Darmstadt and investigated at its Materials Research Department with respect to structural modifications. Secondary ion mass spectrometry showed at which conditions N-diffusion takes place. X-ray diffraction (XRD) confirmed the appearance of NbN and Nb_2N phases for the optimized doping process. XRD pole figures also showed grain growth during sample annealing. A single-cell cavity was N-doped using the parameters of the optimized recipe.

MOPAB400 **Development of Helium Vessel Welding Process for SNS PPU Cavities**
P. Dhakal, *E. Daly, G.K. Davis, J.F. Fischer, N.A. Huque, K. Macha, P.D. Owen, K.M. Wilson, M. Wiseman (JLab)*
The Spallation Neutron Source Proton Power Upgrade cavities are produced by Research Instrument with all the cavity processing done at vendor sites with final chemistry applied to the cavity to be electropolishing. Cavities are delivered to Jefferson Lab, ready to be tested. One of the tasks to be completed before the arrival of production-ready PPU cavities is to develop a robust helium vessel welding protocol. We have successfully developed the process and applied it to three six-cell high beta cavities. Here, we present the summary of RF results, welding process development, and post helium vessel RF results.

MOPAB401 **In-Situ EXAFS Investigations of Nb-Treatments in N_2, O2 and N_2-O2 Mixtures at Elevated Temperatures**
P. Rothweiler, *B. Bornmann, J. Klaes, D. Lützenkirchen-Hecht, R. Wagner (University of Wuppertal)*
Smooth polycrystalline Nb metal foils were treated in dilute gas atmospheres using a temperature of 900 ^{o}C. Transmission mode X-ray absorption spectroscopy (EX-AFS) at the Nb K-edge was used to investigate changes in the atomic short-range order structure of the bulk Nb-material in-situ. The experiments were performed in a dedicated high-vacuum cell that allows treatments in a dilute gas atmosphere and temperatures of up to 1200 ^{o}C. Typical treatments include (i) preheating at 900 ^{o}C under high-vacuum, (ii) gas exposure at the desired pressure and temperature, and (iii) cooldown to room temperature un-

der vacuum. EXAFS data were collected during the entire procedure with a time resolution of 1 s. For the treatments in N_2 at T = 900°C, the data show subtle changes in the Nb-EXAFS, that are compatible with N-doping of the bulk Nb, and the results suggest Nb uptake on octahedral interstitial sites. However, even a small O2-partial pressure leads to distinct oxidation of the Nb. The results will be discussed in more detail in the presentation.

MOPAB402 **Study of the Niobium Oxide Structure and Microscopic Effect of Plasma Processing on the Niobium Surface**

***B. Giaccone**, M. Martinello (Fermilab) J. Zasadzinski (IIT)*

A study of the niobium oxide structure is presented here, with particular focus on the niobium suboxides. Multiple steps of argon sputtering and XPS measurements were carried out until the metal surface was exposed. The sample was then exposed to air and the oxide regrowth was studied. In addition, three Nb samples prepared with different surface treatments were studied before and after being subjected to plasma processing. The scope is investigating the microscopic effect that the reactive oxygen contained in the glow discharge may have on the niobium surface. This study suggests that the Nb_2O_5 thickness may increase, although no negative change in the cavity performance is measured since the pentoxide is a dielectric.

MOPAB404 **A Low Emittance Compact Proton Injector for a Proton Therapy Facility**

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To meet the requirements of a Proton Therapy Facility funded by the National Key Research and Development Program of China, a new compact ion source-LEBT integrated proton injector was developed at Peking University (PKU). It consists of a typical PKU permanent magnet compact 2.45 GHz ECR ion source (PMECRIS) and an electrostatic LEBT with an electrostatic lens, a beam chopper, a set of beam steers, an ACCT, a bellow, an e-trap, and a valve. A 1000 L/s molecular pump is adopted to maintain the vacuum for this integrated injector. The length from RF matching plane to RFQ front flange is about 450 mm. Chopper is used to shorten the pulse length from ms to μs with sharp edges. Test results of this PMECR source prove that it has the ability to deliver a proton beam with a current from 10 mA to 90 mA with a duty factor of 3%(100Hz/0.3ms) and its RMS emittance less than 0.1 mm·mrad at 30 keV. The acceptance tests of this integrated injector have been performed with a 30 keV hydrogen beam. A required proton current of 18 mA with ripple wave less than 0.1 mA successfully passed through a 20 mm aperture diaphragm at RFQ entrance flange. Its rms emittance is about 0.06 mm·mrad.

MOPAB405 **Study of Targets to Produce Molybdenum-99 Using 30 MeV Electron Linear Accelerator**

***T.S. Dixit**, A.P. Deshpande, R. Krishnan, A. Shaikh (SAMEER)*

Two approaches to produce 99Mo are studied using GEANT4 are reported in this paper. First, in converter target approach, bremsstrahlung photons are generated in a high Z target. The emitted photons then hit 100Mo secondary target, producing 99Mo through (gamma, n) reaction. Second, in direct target approach, high energy electron beam hits 100Mo target, where both (e, gamma) and (gamma, n) reactions take place simultaneously. A 30 MeV, 5-10 kW beam power electron linac is under development at SAMEER. The acceleration gradient required to achieve 30 MeV energy will be provided by two linacs operated in series configuration and the high average beam power will be achieved by running the system at high duty operation. Main aim of this study is to optimize experimental parameters to maximize specific activity of 99Mo. Since, 100Mo is very expensive material therefore judicious use of the material is very important. Hence, optimization of electron beam energy and target dimensions are studied in detail in both the approaches. It is found that the direct target approach gives higher specific activity compared to the converter target approach.

MOPAB406 **New Results Obtained at IFIN-HH Using the TR19 Cyclotron**

***T.R. Esanu**, L.S. Craciun, L. Teodorescu (IFIN-HH)*

The TR19 cyclotron installed at Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH)is mainly designed and used for production of medical radioisotopes such as: 18F, 64Cu, Zr89. It is designed to extract protons with energy between 14-19 MeV and a maximum current of 300 microA on target (target selector with the possibility of installing 4 different targets. Attached to the cyclotron is installed a 6 meters long beam line equipped with three powerful quadrupoles. From January 2018, the Cyclotron Research Group started to develop new ways to operate all the equipments to extract, scatter and transport proton currents. Using extreme conditions while operating our equipment we obtained proton beam with currents between tens of picoA and 100 femptoA. A newly installed Solid Target Station for Cu64 production was tested with good results related to production yields and beam alignment to the target-paper burn tests were performed. Preliminary results were obtained and will be presented. We will also present a new method to obtain a neutron activator in line with the cyclotron for new radioisotope production.

MOPAB407 **H2020-HITRIPlus and $H_2$020-I.FAST: a European Integrated Program for Developing Superconducting Magnets for Medical Heavy Ion Therapy**

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A European collaboration has been formed to develop superconducting magnets for heavy ion therapy. The collaboration is part of two parallel initiatives, called HITRIPlus and I.FAST, recently approved by the European Commission under the H_2020 framework programme. Both HITRIPlus and I.FAST include a work package dedicated to design and technology advance for superconducting magnets for hadron therapy synchrotron and gantry, for 430 MeV/nucleon ions (C-ions) with 10^{10} ions/pulse. The magnets for synchrotron and gantry feature about 60-90 mm diameter, near 5 T peak field with a field change of 0.1-1 T/s and good field quality. The paper will illustrate the two programs, with HITRIPlus being mainly infrastructure design-oriented and I.FAST being mainly technology-oriented. Various superconductor options (classical superconductors or HTS) and layout variants, like classical CosTheta and novel Canted CosTheta (CCT), with curved multifunction (dipole and quadrupole), magnets are discussed. These projects should provide design inputs for a new hadron therapy centre to be placed in the South East Europe (SEEIIST project) in the next decade.

MOPAB408 **Current Status of SC230 Superconducting Cyclotron for JINR Medico-Biological Center**
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Progress in the design of a compact superconducting cyclotron accelerating the beam of protons to 230 MeV dedicated for proton therapy and medico-biological research is presented. The intense beam of the accelerator will be used in the new FLASH RT method investigations.

MOPAB409 **FLUKA Simulations of Ac-225 Production Using Electron Accelerators: Validation Through Comparison With Published Experiments**
***T.V. Szabo**, I.C. Moraes (CNPEM) F.A. Bacchim Neto (LNLS) P.V. Guillaumon (USP/LAL) H.B. de Oliveira (IPEN)*
Targeted Alpha Therapy (TAT) is an active area of study worldwide. This technique has shown a potential in nuclear medicine to treat metastatic disease by alpha particles that deposit energy in small regions nearby cancer cells. Ac-225 is an important alpha-emitting that can be used for cancer TAT. This radioisotope shows good potential for medical applications, therefore is important to study ways of increase its production and availability. One possible path for the Ac-225 product is to radiate a radium target (Ra-226) on a linear electron accelerator (LINAC). Isotope production studies could be implemented using computational tools. In this work, Monte Carlo simulations with FLUKA code were performed and compared to experimental results. We studied Ac-225 production by photonuclear reactions using a 24 MeV electron beam LINAC hitting a tungsten electron-photon converter. Different energies and geometries were also simulated to obtain

optimal production conditions. The specific activity values obtained with simulations had a good agreement with published experimental results.

MOPAB410 **Preliminary Studies of a VHEE Linear Accelerator System for FLASH Radio Therapy**

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The Flash Radio Therapy is a revolutionary new technique in the cancer cure: it spares healthy tissue from the damage of the ionizing radiation maintaining the tumor control as efficient as in conventional radiotherapy. To allow the implementation of the FLASH Therapy concept into actual clinical use, it is necessary to have a linear accelerator able to deliver the very high dose and very high dose rate (>10^6 Gy/s) in a very short irradiation time (beam on time < 100ms). Low energy S-band Linacs (up to 7 MeV) are being used in Radiobiology and preclinic applications but in order to treat deep tumors, the energy of the electrons should achieve the range of 60-100 MeV. In this paper, we address the main issues in the design of a compact C band (5.712 GHz) electron linac-VHEE for FLASH Radio Therapy. We present preliminary studies on C-band structures at La Sapienza and at INFN-LNS, aiming to reach a high accelerating gradient and high current necessary to deliver a dose >1 Gy/pulse, with very short electron pulse.

MOPAB411 **Quantifying DNA Damage in Comet Assay images using Neural Networks**

***S.J.K. Dhinsey**, T. Greenshaw, C.P. Welsch (The University of Liverpool) J.L. Parsons (Cancer Research Centre, University of Liverpool) C.P. Welsch (Cockcroft Institute)*

Proton therapy for cancer treatment is a rapidly growing field and increasing evidence suggests it induces more complex DNA damage than photon therapy. Accurate comparison between the two treatments requires quantification of the DNA damage the cause, which can be assessed using the Comet Assay. The program outlined here is based on neural network architecture and aims to speed up analysis of Comet Assay images and provide accurate, quantifiable assessment of the DNA damage levels apparent in individual cells. The Comet Assay is an established technique in which DNA fragments are spread out under the influence of an electric field, producing a comet-like object. The elongation and intensity of the comet tail (consisting of DNA fragments) indicate the level of damage incurred. Many methods to measure this damage exist, using a variety of algorithms. However, these can be time consuming, so often only a small fraction of the comets available in an image are analysed. The automatic analysis presented in this contribution aims to improve this. To supplement the training and testing of the network, a Monte Carlo model will also be presented

to create simulated comet assay images.

MOPAB412 **Accelerator Production of Mo-99 Using Mo-100**

***J.L. McCarter**, M.J. Brennan, S.M. Burns, J.T. Harvey, S.W. Kelley, T.A. Montenegro, Q. Schiller (NorthStar Medical Technologies, LLC)*

Tc-99m is an essential radionuclide for nearly 45,000 diagnostic nuclear medicine tests in the U.S. each day. Its daily production depends on Mo-99, which must be replenished weekly due to Mo-99's 2.75 day half-life. Mo-99 is currently supplied from uranium fission production and depends on overseas nuclear reactors that average 50 years old. Their age in combination with shipment uncertainties make the availability of Mo-99 fragile and subject to severe shortages. The U.S. has one domestic, FDA-approved supplier that produces Mo-99, NorthStar Medical RadioIsotopes. Currently, NorthStar produces Mo-99 via the irradiation of Mo-98 in a nuclear reactor. In the future, NorthStar will also irradiate Mo-100 with accelerator created x-rays to produce Mo-99. This process will use 2 distinct, 40 MeV, 125 kW average electron accelerators, Rhodotrons produced by IBA. Accelerator produced Mo-99 has several advantages over that produced by reactors, including a redundant supply and an ability to adjust irradiation timing to meet radiopharmacy demands. NorthStar is currently installing and commissioning this accelerator based system, and will enter production in late-2022.

MOPAB413 **The Next Ion Medical Machine Study at CERN: Towards a Next Generation Cancer Research and Therapy Facility With Ion Beams**

***M. Vretenar**, V. Bencini, E. Benedetto, M.R. Khalvati, A.M. Lombardi, M. Sapinski, D. Tommasini (CERN) E. Benedetto, M. Sapinski (TERA) P. Foka (GSI)*

Cancer therapy with ions has several advantages over X-ray and proton therapy, but its diffusion remains limited primarily because of the size and cost of the accelerator. To develop technologies that might improve performance and reduce accelerator cost with respect to present facilities, CERN has recently launched the Next Ion Medical Machine Study (NIMMS), leveraging CERN expertise in accelerator fields to disseminate technologies developed for basic science. A perspective user and key partner of NIMMS is the SEEIIST (South East European International Institute for Sustainable Technologies), established to build in the region an innovative facility for combined cancer therapy and biomedical research with ion beams. For SEEIIST and other potential users, three options are being considered. Conceptual designs of a warm-magnet synchrotron at high beam intensity, of a compact superconducting synchrotron, and of a high-frequency linear accelerator have been compared in terms of cost, risk and development time. The development of curved superconducting magnets, of compact synchrotrons and ion gantries, and of linacs is being pursued within EU-funded projects or specific collaborations

MOPAB414 **A Novel Facility for Cancer Therapy and Biomedical Research With Heavy Ions for the South East European International Institute for Sustainable Technologies**

***S. Damjanovic**, H. Schopper (SEEIIST) U. Amaldi, E. Benedetto, M. Sapinski (TERA) E. Benedetto, G. Bisoffi, M. Dosanjh, M. Sapinski, M. Vretenar (CERN) G. Bisoffi (INFN/LNL) **S. Damjanovic**, M. Durante, P. Foka, C. Graeff (GSI) Th. Haberer (HIT) S. Rossi (CNAO Foundation) H.J. Specht (Universität Heidelberg)*

The South East European International Institute for Sustainable Technologies (SEEIIST) proposes the construction of a major joint Research Infrastructure in the region, to rebuild cooperation after the recent wars and overcome lasting consequences like technology deficits and brain drain, having at its core a facility for cancer therapy and biomedical research with heavy ions. Beams of ions like Carbon are an advanced way to irradiate tumours but more research is needed, while the higher investment costs than for other radiation treatments have so far limited the European facilities to only four. This initiative aims at being strongly innovative, beyond the existing European designs. While the initial baseline relies on a conservative warm-magnet synchrotron, superconducting magnets for an advanced version of the synchrotron and for the gantry are being developed, with a potential for reductions in size, cost, and power consumption. Both warm and superconducting designs feature high beam intensity for faster treatment, and flexible extraction for novel treatment methods. A novel injector linac has the potential for producing radioisotopes in parallel with synchrotron injection.

MOPAB415 **Failure Rates and Downtimes of Multi-Leaf Collimators in Indonesia**

***G.S. Peiris** (The University of Melbourne)*

One of the greatest barriers to cancer treatment in Low and Middle-Income Countries (LMICs) is the access to Radiotherapy Linear Accelerators (LINACs). Not only are the LINACs complex, the harsh environment of LMICs cause frequent breakdowns resulting in downtimes ranging from days to months. Recent research has identified a disparity between LMICs and High Income Countries (HICs) and determined the Multi-Leaf Collimator (MLC) as a component needing re-evaluation. The MLC causes over 30% of the problems in RT LINACs, but the modes of failure and quantify the extent of the damage done are yet to be quantified. Using data from across Indonesia, we show the pathways to failure of RT Machines and frequency of breakdowns over time. A component of the MLC needs to be replaced every 9.98 faults per 1000 patients treated and the MLC itself breaks down on average every 36±1.8 days. When comparing the downtime by leaf width, the data shows 5mm leaves contribute 18.27±6.5% to all breakdowns while 10mm makes up 15.87±4.3%. These results outline the need to reassess the current generation of RT LINACs and ultimately work towards guiding future designs to be robust enough for all environments.

MOPAB416 **BDSIM Developments for Hadron Therapy Centre Applications**

***E. Ramoisiaux**, E. Gnacadja, C. Hernalsteens, N. Pauly, R. Tesse, M. Vanwelde (ULB) S.T. Boogert, L.J. Nevay (Royal Holloway, University of London) C. Hernalsteens (CERN) W. Shields (JAI)*

Hadron therapy centres are evolving towards reduced-footprint layouts, often featuring a single treatment room. The evaluation of beam properties, radiation protection quantities, and concrete shielding activation via numerical simulations poses new challenges that can be tackled using the numerical beam transport and Monte-Carlo code Beam Delivery Simulation (BDSIM), allowing a seamless simulation of the dynamics as a whole. Specific developments have been carried out in BDSIM to advance its efficiency toward such applications, and a detailed 4D Monte-Carlo scoring mechanism has been implemented. It produces tallies such as the spatial-energy differential fluence in arbitrary scoring meshes. The feature makes use of the generic boost::histogram library and allows an event-by-event serialisation and storage in the ROOT data format. The pyg4ometry library is extended to improve the visualisation of critical features such as the complex geometries of BDSIM models, the beam tracks, and the scored quantities. Data are converted from Geant4 and ROOT to a 3D visualisation using the VTK framework. These features are applied to a complete IBA Proteus One model.

MOPAB417 **Preliminary Study of a Large Energy Acceptance FFA Beam Delivery System for Particle Therapy**

***J.S.L. Yap**, E.R. Higgins, S.L. Sheehy (The University of Melbourne)*

The availability and use of ion beams for radiotherapy has grown significantly, led by technological developments to exploit the dosimetric advantages offered by charged particles. The benefits of particle therapy (PT) are well identified however its utilisation is still limited by high facility costs and technological challenges. A possibility to address both of these can be considered by improvements to the beam delivery system (BDS). Existing beamlines and gantries transport beams with a momentum range of ±1% and consequently, adjustments in depth or beam energy require all the magnetic fields to be changed. The speed to switch energies is a limiting constraint of the BDS and a determinant of the overall treatment time. A novel concept using fixed field alternating gradient (FFA) optics enables a large energy acceptance (LEA) as beams of varying energies can traverse the beamline at multiple physical positions given the same magnetic field. This presents the potential to provide faster, higher quality treatments at lower costs, with the capability to deliver advanced PT techniques such as multi-ion therapy. We explore the applicability and benefits of a LEA BDS.

MOPAB418 **Tracking and LET Measurements with the MiniPIX-TimePIX Detector for 60 MeV Clinical Protons**

***J.S.L. Yap**, C.P. Welsch (Cockcroft Institute) N.J.S. Bal (NIKHEF) M.D. Brooke (University of Oxford) C. Granja, C. Oancea (ADVACAM s.r.o) A. Kacperek (The Douglas Cyclotron, The Clatterbridge Cancer Centre NHS Foundation Trust) C.P. Welsch, **J.S.L. Yap** (The University of Liverpool)*

Recent advancements in accelerator technology have led the rapid emergence of particle therapy facilities worldwide, affirming the need for enhanced characterisation methods of radiation fields and radiobiological effects. The Clatterbridge Cancer Centre, UK operates a 60 MeV proton beam to treat ocular cancers and facilitates studies into proton induced radiobiological responses. Accordingly, an indicator of radiation quality is the linear energy transfer (LET), a challenging physical quantity to measure. The MiniPIX-Timepix is a miniaturised, hybrid semiconductor pixel detector with a Timepix ASIC, enabling wide-range measurements of the deposited energy, position and direction of individual charged particles. High resolution spectrometric tracking and simultaneous energy measurements of single particles enable the beam profile, time, spatial dose mapping and LET (0.1 to >100 keV/µm) to be resolved. Measurements were performed to determine the LET spectra in silicon, at different positions along the Bragg Peak (BP). We discuss the experimental setup, preliminary results and applicability of the MiniPIX for clinical environments.

MOPAB419 **Acceleration and Measurement of Alpha Particles and Hydrogen Molecular Ions with the HZB Cyclotron**

***G. Kourkafas**, J. Bundesmann, A. Denker, T. Fanselow, J. Röhrich (HZB) J. Heufelder, A. Weber (Charite)*

The HZB cyclotron has treated more than 4000 patients with eye tumors using protons. The accelerator can also provide heavier ions which could be suitable for ocular radiation therapy. Helium ions exhibit less lateral spread, increased relative biological effectiveness and a sharper Bragg-Peak compared to protons of the same range, while minimizing nuclear fragmentation and thus excessive dose downstream the irradiated volume compared to more heavy ions. When accelerating fully stripped helium ions (alpha particles), hydrogen molecular ions can also be accelerated to the same energy with a small tuning of the machine due to having almost the same mass-to-charge ratio, yielding a proton beam of double current after the beam exits the vacuum window towards the target. The acceleration and characterization of these two ion species are described in this paper, suggesting the feasibility of a corresponding clinical cyclotron for ocular or even deep-seated tumors.

MOXX — Opening Plenary

Chair: L. Liu (LNLS)

MOXX01 **Scientific Opportunities for 4th Generation Storage Ring Light Sources**

H. Westfahl Jr. *(LNLS)*

The new generation of storage ring light sources based on Multi-Bend Achromat (MBA) magnet lattice provides electron beams with size and divergence that match the phase space of the x-ray photons, approximating their so-called diffraction limit. The dramatic increase in brightness and transversely coherent photon flux from such improvement, combined with advances in mechatronics, optics, detectors, and computing, open new avenues of research within spatiotemporal scales previously inaccessible. This talk will present exciting scientific opportunities to explore the characteristics of biological, hierarchical, and condensed matter systems on these new light sources and particularly on Sirius, the new Brazilian 4th generation storage ring.

MOXX02 **Building the Facility for Rare Isotope Beams**

T. Glasmacher *(FRIB)*

Once every decade or two, the Office of Nuclear Physics in the U.S. Department of Energy Office of Science has embarked on building a new accelerator-based user facility to enable nuclear scientists to make discoveries. Following construction starts for CEBAF in the 1980's and for RHIC in the 1990's, the Facility for Rare Isotope Beams (FRIB) project started in 2009 with the goal to build the most powerful superconducting heavy-ion linear accelerator. FRIB construction at Michigan State University is now 96% complete, the superconducing linac has been commissioned. FRIB is being managed to early completion in 2021 with user operation starting in early 2022. I will give an overview of the FRIB science and construction progress accomplished by a committed team delivering FRIB for a community of 1,400 scientists.

MOXX03 **Women in Science: The Inconvenient Truth**

M.C. Barbosa *(UFRGS)*

Women are underrepresented in the areas of physics, mathematics, engineering and technology at all levels and the percentage of women decreases as advances and the career ladder. In the talk we present evidences of this phenomena, indicate the importance of the presence of women in all fields and we show some actions that help in construct the equity.

MOXA — Monday Oral Parallel A

Chair: K.C. Harkay (ANL)

MOXA01 **Commissioning and Restart of ESRF-EBS**

S.M. White *(ESRF)*

The ESRF operates a 6 GeV 4th generation light source, the ESRF-EBS. This storage ring is the first to implement the Hybrid Multi-Bend Achromat lattice (HMBA). The HMBA lattice provides a reduction of the horizontal emittance of approximately a factor 30 with respect to the former Double Bend Achromat (DBA) structure, considerably improving the brilliance and transverse coherence of the ESRF accelerator complex while maintaining large horizontal acceptance and excellent lifetime performance. In this report, the characteristics of the HMBA lattice will be reviewed and the beam commissioning results and first operation experience of the new ESRF storage ring will be presented.

MOXA02 **Status of the APS-U Project**

R.O. Hettel *(ANL)*

The Advanced Photon Source Upgrade (APS-U) project at the Argonne National Laboratory will replace the existing 7-GeV, 1.1-km circumference double bend storage ring lattice with a new 6-GeV hybrid 7BA lattice that will reduce horizontal electron emittance from 3 nm-rad to 43 pm-rad, including IBS effects for 200-mA operation. With new optimized permanent magnet and superconducting undulators, an increase in spectral brightness of two to three orders of magnitude in the 20-100 keV X-ray energy range will be realized. The project includes nine new high performance beamlines and fifteen enhanced beamlines that will exploit the high brightness and coherence of the new facility. The project is in full swing, more than 50% complete by cost, and is on schedule for first beam sometime in mid-2023, subject to a potential slip due to the impact of COVID-19. The vast majority of technical implementations, some pushing the state-of-the-art,have been decided,are in process and will be discussed in this article.

MOXA03 **Sirius Commissioning Results and Operation Status**

L. Liu*, M.B. Alves, A.C.S. Oliveira, X.R. Resende, F.H. de Sá (LNLS)*

Sirius is a 4th generation 3 GeV synchrotron light source that has just finalized the first commissioning phase at the Brazilian Center for Research in Energy and Materials (CNPEM) campus in Campinas, Brazil. This paper describes the main Accelerator Physics issues faced during the storage ring commissioning, methods that were used to work them out and the current operation status of the machine.

MOXB — Monday Oral Parallel B

Chair: F. Sannibale (LBNL)

MOXB01 **Progress Towards Realisation of Steady-State Microbunching at the Metrology Light Source**

J. Feikes, *A. Kruschinski, J. Li, A.N. Matveenko, Y. Petenev, M. Ries (HZB) A. Chao (SLAC) X.J. Deng, W.-H. Huang, C.-X. Tang, L.X. Yan (TUB) A. Hoehl, R. Klein (PTB)*

Coherent radiation is a powerful scheme for storage-ring-based synchrotron radiation sources as its intensity increases with the square of the number of radiating electrons. Formation of bunches or subbunches shorter than the radiation wavelength, i.e., microbunching, is necessary for the radiation from different electrons to add in phase and therefore cohere. Recently at the MLS it has been shown that in dedicated isochronous optics an electron beam energy modulation induced by an externally applied 10^{64}-nm-wavelength laser in an undulator leads to the formation of sub-um microbunches one turn later, providing the basis for the implementation of steady-state microbunching in electron storage rings to generate high-repetition, high-power coherent radiation. Here we report on the recent progress and continuing development of this experiment.

MOXB02 **First Results of the IOTA Ring Research at Fermilab**

A. Valishev, *D.R. Broemmelsiek, A.V. Burov, K. Carlson, B.L. Cathey, S. Chattopadhyay, N. Eddy, D.R. Edstrom, J.D. Jarvis, V.A. Lebedev, S. Nagaitsev, H. Piekarz, A.L. Romanov, J. Ruan, J.K. Santucci, V.D. Shiltsev, G. Stancari (Fermilab) A. Arodzero, A.Y. Murokh, M. Ruelas (RadiaBeam) D.L. Bruhwiler, J.P. Edelen, C.C. Hall (RadiaSoft LLC) S. Chattopadhyay, S. Szustkowski (Northern Illinois University) A. Halavanau, Z. Huang, V. Yakimenko (SLAC) M. Hofer (TU Vienna) M. Hofer, R. Tomás (CERN) K. Hwang, C.E. Mitchell, R.D. Ryne (LBNL) K.-J. Kim (ANL) K.-J. Kim, Y.K. Kim, N. Kuklev, I. Lobach (University of Chicago) T.V. Shaftan (BNL)*

The IOTA ring at Fermilab is a unique machine exclusively dedicated to accelerator beam physics R&D. The research conducted at IOTA includes topics such as nonlinear integrable optics, suppression of coherent beam instabilities, optical stochastic cooling and quantum science experiments. In this talk we report on the first results of experiments with implementations of nonlinear integrable beam optics. The first of its kind practical realization of a two-dimensional integrable system in a strongly-focusing storage ring was demonstrated allowing among other things for stable beam circulation near or at the integer resonance. Also presented will be the highlights of the world's first demonstration of optical stochastic beam cooling and other selected results of IOTA's broad experimental program.

MOXB03 **Copper Based Radio Frequency Structures: Are We at the End of Road for This Technology?**

S.G. Tantawi *(SLAC)*

We will present an overview of recent advances in high gradient copper structures operating at room temperature and at cryogenic temperature. We will include the advances that enabled us to understand better the underlying fundamental physics that govern the breakdown phenomena in high field vacuum structures. We will then present the recent advances in linac topologies that take advantage of this basic understanding of the breakdown phenomena. We will also showcase how these advances are being utilized for many different medical, industrial, and discovery machines. Our presentation will not be limited to electron accelerators but will also include advances for high gradient hadron linacs.

MOXC — Monday Oral Session C

Chair: T.O. Raubenheimer (SLAC)

MOXC01 **Combined Effect of Beam-Beam Interaction and Beam Coupling Impedance in Future Circular Colliders**

***Y. Zhang**, N. Wang (IHEP) E. Carideo (CERN) M. Migliorati (Rome University La Sapienza) M. Zobov (INFN/LNF)*

The future large scale electron-positron colliders, such as FCC-ee in Europe and CEPC in China, will rely on the crab waist collision scheme with a large Piwinski angle. Differently from the past generation colliders both luminosity and beam-beam tune shifts depend on the bunch length in such a collision scheme. In addition, for the future circular colliders with extreme beam parameters in collision several new effects become important such as beamstrahlung, coherent X-Z instability and 3D flip-flop. For all these effects the longitudinal beam dynamics plays an essential role and should be taken into account for the collider luminosity optimization. In this paper we discuss an impact of the longitudinal beam coupling impedance on the collider performance.

MOXC02 **Improved Lifetime of a High Spin Polarization Superlattice Photocathode**

***L. Cultrera** (BNL)*

Highly spin polarized electron beams are required for the operation of a wide range of accelerators and instruments. The production of such electrons requires the use of Negative Electron Affinity (NEA) activated GaAs-based cathodes operated in photoelectron guns. Because of their extreme sensitivity to poor vacuum conditions the degradation of the photoemission process is so strong that NEA activated GaAs-based photocathodes can only survive in the extreme vacuums typical of DC gun. State-of-the-art on photocathode technology for spin polarized beam productions are summarized. Recent results on the use of robust NEA coating based on the Cs-Te and Cs-Sb leading to improved operational lifetime of a high spin polarization photocathode are reviewed.

MOXC03 **The Interstellar Space in an Electrostatic Cryogenic Storage Ring**

***R. von Hahn** (MPI-K)*

Traditionally, particle accelerators have been built to provide increasingly high energies and intensities to reproduce the very first moments of our Universe after the Big Bang to investigate for example the formation of the building blocks of matter. In the last decade, however, the interest also focuses on the formation and dynamics of molecules in the early and today's Universe, which places completely different demands on particle accelerators. High energies are not needed. Instead, they have to provide near to interstellar conditions such as an ultrahigh vacuum of or less than 10^{-14} mbar and cryogenically cooled

environments for the stored particles. This allows extremely long observation periods to investigate quantum state properties and opens up completely new insights in different fields of physics. The electrostatic cryogenic storage ring CSR at the Max Planck Institute for Nuclear Physics in Heidelberg was conceived, designed and constructed to achieve these goals and is successfully in operation since 2015. This talk will sum up motivation, design, construction and first results obtained with the CSR, a worldwide unique machine with great new opportunities.

TUPAB001 **DAΦNE Commissioning for SIDDHARTA-2 Experiment**

C. Milardi, *D. Alesini, O.R. Blanco-García, M. Boscolo, B. Buonomo, S. Cantarella, A. D'Uffizi, A. De Santis, C. Di Giulio, G. Di Pirro, A. Drago, L.G. Foggetta, G. Franzini, A. Gallo, S. Incremona, A. Michelotti, L. Pellegrino, L. Piersanti, R. Ricci, U. Rotundo, L. Sabbatini, A. Stecchi, A. Stella, A. Vannozzi, M. Zobov (INFN/LNF) J. Chavanne, G. Le Bec, P. Raimondi (ESRF)*

DAΦNE, the Frascati lepton collider, has completed the preparatory phase in order to deliver luminosity to the SIDDHARTA-2 detector. DAΦNE colliding rings rely on a new interaction region, which implements the well-established Crab-Waist collision scheme, and includes a low-beta section equipped with newly designed permanent magnet quadrupoles, and vacuum components. Diagnostics tools have been improved, especially the ones used to keep under control the beam-beam interaction. The horizontal feedback in the positron ring has been potentiated in order to achieve a higher positron current. Luminosity diagnostics have been also updated so to be compatible with the new detector design. The commissioning was initially focused on recovering the optimal dynamical vacuum conditions, outlining alignment errors, and optimizing ring optics. For this reason, a detuned optics, featured by relaxed low-b condition at the interaction point and Crab-Waist Sestupoles off, has been applied. In a second stage a low-b optics has been implemented to test collisions with a preliminary setup of the experiment detector. Machine preparation and the first luminosity results are presented and discussed.

TUPAB002 **Round Colliding Beams: Successful Operation Experience**

D.B. Shwartz, *O.V. Belikov, D.E. Berkaev, D.B. Burenkov, V.S. Denisov, A.S. Kasaev, A.N. Kirpotin, S.A. Kladov, I. Koop, A.A. Krasnov, A.V. Kupurzhanov, G.Y. Kurkin, M.A. Lyalin, A.P. Lysenko, S.V. Motygin, E. Perevedentsev, V.P. Prosvetov, Yu.A. Rogovsky, A.M. Semenov, A.I. Senchenko, L.E. Serdakov, D.N. Shatilov, P.Yu. Shatunov, Y.M. Shatunov, M.V. Timoshenko, I.M. Zemlyansky, Yu.M. Zharinov (BINP SB RAS) S.A. Kladov, I. Koop, A.A. Krasnov, M.A. Lyalin, E. Perevedentsev, Yu.A. Rogovsky, Y.M. Shatunov (NSU)*

VEPP-2000 electron-positron collider operating in the beam energy range of 150-1000 MeV is the only machine originally designed for and successfully exploiting Round Beams Concept. After injection chain upgrade including link to the new BINP injection complex VEPP-2000 proceeded with data taking since 2017 with luminosity limited only by beam-beam effects. At the low energies (300-600 MeV/beam) the novel technique of effective emittance controlled increase by weak coherent beam shaking allowed to suppress the limiting flip-flop effect and resulted in additional luminosity gain factor of 4. The averaged delivered luminosity at the omega-meson production energy

(2*391 MeV) achieved L = 2*10^{31} $cm^{-2}s^{-1}$/IP. At the top energies above nucleon-antinucleon production threshold the stable operation with luminosity of L = 5*10^{31} $cm^{-2}s^{-1}$/IP resulted in high average data taking rate of 2 pb^{-1}/day in 2020.

TUPAB003 **Final Focus Solenoids Beam-Based Positioning Tests**
D.B. Shwartz *(BINP SB RAS)*
The final focusing at the VEPP-2000 electron-positron collider is done by 13 T superconducting solenoids. The misalignment of solenoids not only provides closed orbit distortions but also harmful for dynamic aperture reduction due to strong nonlinear fringe fields. The final beam-based alignment of solenoids was foreseen but turned out to be not a trivial procedure. Here we present the test study of solenoids positioning reconstruction procedure based on circulating beam orbit responses.

TUPAB004 **Comparison of Accelerator Codes for Simulation of Lepton Colliders**
L. van Riesen-Haupt*, H. Burkhardt, T. Persson, R. Tomás (CERN)*
This paper compares simulation results obtained with SAD, MAD-X and the PTC implementation in MADX for the design studies of the FCC-ee. On-momentum and off-momentum optics are explored for the various programs. Particle tracking with and without synchrotron radiation are used to compare amplitude detuning and emittance. Finally, this paper outlines how well-established SAD features such as tapering have recently been integrated into MADX.

TUPAB005 **Emittance Estimates for the Future Circular Collider**
L. van Riesen-Haupt*, T.K. Charles, R. Tomás, F. Zimmermann (CERN) T.K. Charles (The University of Liverpool)*
The alignment strategy of the FCC-ee has a large impact on its luminosity. Larger alignment tolerances result in increased coupling and a subsequently higher vertical emittance. At the same time, tighter alignment tolerances around the 100 km ring are a major cost driver. This paper applies analytical emittance estimate methods to the FCC-ee and compares their predictions to data from simulations with different alignment tolerances. These methods can be used to help understand the impact of misalignments of certain magnet groups and to come up with an efficient alignment strategy.

TUPAB006 **The Impact of Beam Position Monitor Tilts on Coupling Measurements**
L. van Riesen-Haupt*, R. Tomás (CERN)*
The measurement and correction of coupling resonance driving terms is a key tool for improving the performance of synchrotrons. These terms are measured by exciting the beam and observing the subsequent motion in the horizontal and vertical planes through beam position monitors. This paper outlines the impact of tilt errors in these monitors to the distortion of the amount of coupling measured between the planes and how the computation of the resonance driving

terms is affected by these tilts. It also attempts to use these results for mimicking tilt errors in simulations and discusses how discrepancies in measured resonance driving terms could be used to estimate the tilt errors that cause them.

TUPAB007 **A Correction Scheme for the Magnet Imperfection on the CEPC collider ring**

B. Wang, *Y. Wang, Y. Wei, C.H. Yu, Y. Zhang (IHEP)*

This paper describes the error correction scheme for the CEPC CDR lattice in Higgs mode, which has a small beta function at the interaction point. The low emittance optics has an enhanced sensitivity to the magnet misalignments and field errors, especially for the final focus quadrupole misalignment. The magnet imperfection will cause the closed orbit distortion and optics distortion. The correction scheme for these magnet imperfections includes the closed orbit correction, the dispersion correction, the beta function correction and the betatron coupling correction. The resulting performance and the dynamic aperture for the corrected lattice are studied.

TUPAB008 **Progress of the First Turn Commissioning Simulation for HEPS**

B. Wang, *Z. Duan, D. Ji, Y. Jiao, Y.L. Zhao (IHEP)*

The High Energy Photon Source (HEPS) is 6 GeV, kilometer-scale, 4th generation storage ring light source. The lattice has an ultralow emittance and strong focusing such that the beam dynamics is very sensitive to the magnet misalignments and other error sources. Getting the first turn and establishing the closed orbit is essential for accelerator commissioning. This paper describes a simulation algorithm for achieving the first turn commission based on the latest HEPS storage ring lattice. We developed a new accelerator toolbox (AT)-based program for automatic optimizing the first turn commissioning. The algorithm and simulation results will be presented in this paper.

TUPAB009 **SuperKEKB Optics Measurements Using Turn-by-Turn Beam Position Data**

J. Keintzel, *R. Tomás (CERN) H. Koiso, G. Mitsuka, A. Morita, K. Ohmi, Y. Ohnishi, H. Sugimoto, M. Tobiyama, R.J. Yang (KEK)*

SuperKEKB, an asymmetric electron-positron collider, has recently achieved the world record instantaneous luminosity of $2.8 \times 10^{34}\,\mathrm{cm^{-2}s^{-1}}$ using crab-waist collision scheme. In order to reach the design value of $6 \times 10^{35}\,\mathrm{cm^{-2}s^{-1}}$ a vertical beta function at the interaction point of 0.3 mm is required, demanding unprecedented optics control. Turn-by-turn beam position data could enable fast optics measurements for rapid identification of unexpected error sources. Experiments exploring various data acquisition techniques at different squeezing steps during commissioning are presented and compared to results obtained from closed orbit distortion.

TUPAB010 **Impact of Bunch Current on Optics Measurements in SuperKEKB**

J. Keintzel, *R. Tomás, F. Zimmermann (CERN) T. Ishibashi, H. Koiso, G. Mitsuka, A. Morita, K. Ohmi, Y. Ohnishi, H. Sugimoto, S. Terui, M. Tobiyama, R.J. Yang, D. Zhou (KEK)*

SuperKEKB has recently achieved the world record instantaneous luminosity of 2.8×10^{34} cm^{-2}s^{-1} and aims at reaching a target luminosity of about 6×10^{35} cm^{-2}s^{-1}. To accomplish this goal it is planned to increase beam currents up to 3.6 A and 2.6 A for the positron and the electron ring, respectively. Increasing the beam currents and, in particular, the number of leptons per bunch, can impact the optics parameters obtained by turn-by-turn measurements, such as the betatron tune or phase advance. Optics measurements performed at various bunch currents can give first indications of possible intensity dependent effects. In this paper, the effect of varying bunch current on optics measurements at SuperKEKB is explored.

TUPAB011 **Momentum Compaction Factor Measurements in the Large Hadron Collider**

J. Keintzel, *L. Malina, R. Tomás (CERN)*

The Large Hadron Collider (LHC) at CERN and its planned luminosity upgrade, the High Luminosity LHC (HL-LHC) demand well-controlled on- and off-momentum optics. Optics measurements are performed by analysing Turn-by-Turn (TbT) data of excited beams. Different techniques to measure the momentum compaction factor from these data are explored, taking into account the possibility to combine them with RF-voltage scans in future experiments.

TUPAB012 **Simulation of Beam-Induced Backgrounds in Belle II**

A. Natochii *(University of Hawaii)*

The Belle II super B-factory experiment is served by the SuperKEKB electron-positron collider, which recently reached a world-record instantaneous luminosity of 2.8x10^{34} cm^{-2} s^{-1}. Modelling the beam backgrounds at this high-current machine requires a good understanding of the processes which lead to particle losses. Such losses can cause harmful effects to sensitive accelerator and detector components and reduce the reconstruction performance. In this presentation, we will i) give a detailed overview of an improved algorithm for the collimation system optimisation, ii) compare simulated background rates against measurements, and iii) predict the effect of possible machine upgrades. The presented background simulation based on the Strategic Accelerator Design (SAD) software framework predicts beam losses with improved accuracy. The good agreement with the experiment allows us to study major particle loss mechanisms in SuperKEKB and to develop countermeasures for further background reduction in Belle II.

TUPAB013 **A CLIC Dual Beam Delivery System for Two Interaction Regions**

***V. Cilento**, R. Tomás (CERN) A. Faus-Golfe (Université Paris-Saclay, CNRS/IN2P3, IJCLab)*

The Compact Linear Collider (CLIC) could provide e^+e^- collisions in two detectors simultaneously possibly at a repetition frequency twice the design value. In this paper, a novel dual Beam Delivery System (BDS) design is presented including optics designs and the evaluation of luminosity performance with synchrotron radiation (SR) and solenoid effects for both energy stages of CLIC, 380 GeV and 3 TeV. In order to develop the novel optics design, parameters such as the longitudinal and the transverse detector separations were optimized. The luminosity performance of the novel CLIC scheme was evaluated by comparing the different BDS designs for both energy stages of CLIC. The dual CLIC BDS design provides a good luminosity and proves to be a viable candidate for future linear collider projects.

TUPAB014 **A Design of ILC Positron Source With Alternate Periodic Structure Cavity for Equivalent Circuit**

***S. Konno** (HU/AdSM)*

The International Linear Collider (ILC) is the next project in high-energy physics. The ILC is studying an e-driven method in which an electron beam is incident on a metal target as a positron generation method. Since the beam cannot be reused in the ILC, a large number of positrons is required, and there is concern about target damage. In order to prevent target damage, it is necessary to increase the efficiency of positron generation per electron. A large diameter (2a = 60mm) Alternate Periodic Structure cavity (APS cavity) is used for the positron capture accelerator. In order to prevent target damage, it is necessary to increase generation efficiency, and the APS cavity plays a major role. Since the beam is generated and accelerated by 66 mulch bunches at 6.15ns intervals, it is necessary to compensate for beam loading, but for that purpose, we should understand the transient state of the accelerating electric field in the APS cavity. In this talk, we will report the description of the transient state under the multi bunch acceleration condition of the APS cavity by the equivalent circuit model, and the effect on the positron generation efficiency.

TUPAB015 **Beam Loading Compensation of APS Cavity With Off-Crest Acceleration in ILC e-Driven Positron Source**

***M. Kuriki**, S. Konno, H. Nagoshi (HU/AdSM) T. Omori, J. Urakawa, K. Yokoya (KEK) T. Takahashi (Hiroshima University, Graduate School of Science)*

In E-Driven positron source of ILC, the generated positron is captured by RF accelerator by APS cavity. The positron is initially placed at the deceleration phase and gradually slipped down to acceleration phase. Because the beam-loading is expected to be more than 1A with a multi-bunch format, the compensation is essential to obtain uniform intensity over the pulse. A conventional method for the compensation

is controlling the timing, but it doesn't work in off-crest case. In this manuscript, we discuss the compensation with the phase and amplitude modulation on the input RF.

TUPAB016 **ESS RFQ: Installation and Tuning at Lund**

***P. Hamel**, D. Chirpaz-Cerbat, M. Desmons, A.C. France, O. Piquet (CEA-IRFU) A. Dubois, Y. Le Noa (CEA-DRF-IRFU)*

The 352 MHz Radio Frequency Quadrupole (RFQ) for the European Spallation Source ERIC (ESS) has been delivered by the end of 2019. It has been provided by CEA, IRFU, Saclay/France. It consists of five sections with a total length of 4.6 m and accelerates the 70 mA proton beam from 75 keV up to 3.6 MeV. It will be fed with 900 kW peak power through two coaxial loop couplers. The installation process (alignment, vacuum test), as well as the tuning process based on bead-pull measurements, is presented in this paper.

TUPAB017 **Study of Conduction-Cooled Superconducting Quadrupole Magnets Combined With Dipole Correctors for the ILC Main Linac**

***Y. Arimoto**, S. Michizono, Y. Morikawa, N. Ohuchi, T. Oki, H. Shimizu, K. Umemori, X. Wang, A. Yamamoto, Y. Yamamoto, Z.G. Zong (KEK) V.S. Kashikhin (Fermilab)*

A superconducting rf (SRF) cryomodule for International Linear Collider(ILC) Main Linac equips focus/steering magnets. The magnets are "superferric" magnets with four superconducting (SC) race track coils conductively cooled from the cryomodule LHe supply pipe. The quadrupole field gradient and dipole field are 40 T/m and 0.1 T, respectively. The magnet length and iron-pole radius are 1 m and 0.045 m, respectively. It is known that dark current is generated at SRF cavities and accelerated through the following linac string. The dark current reaches and heats the SC magnets. It is estimated that the power deposition in the magnet may reach more than a few watts and temperature of the SC coils may locally reach to critical temperature of NbTi. It is important to make the magnet not reach quench with sufficient conduction cooling. We aim to realize the SC magnet which can stably operate under such condition. We plan to develop test coils made of three types of SC materials, NbTi, Nb_3Sn, and MgB_2 and study thermal characteristics and stability . We will develop a short model magnet, based on the test coil results. Here, we will present the magnet design study and the R&D plan.

TUPAB018 **An X-Band Linac Design for the XARA Upgrade to CLARA**

***M.S. Sullivan**, R.M. Jones (UMAN) A.D. Brynes, L.S. Cowie, P.H. Williams (STFC/DL/ASTeC) A.D. Brynes, L.S. Cowie (Cockcroft Institute) K. Yokoya (KEK)*

In order to explore physics in the EUV to soft X-ray region, a compact ~1 GeV/c accelerator upgrade to the existing CLARA facility at Daresbury Laboratory has been proposed. This upgrade XARA (X-Band Accelerator for Research and Application) will use the front end of CLARA Phase 2 as an S-band injector of ~180 MeV/c, sub-ps FWHM, 250

pC electron bunches. The work done for the EuPRAXIA@SPARC_LAB project has been studied as a starting point. A RF parameter study has been carried out for a structure operating in the 2 pi/3 mode at a frequency of 11.9942 GHz which is fed by a SLED klyston setup. After combining the RF parameter study with an analysis of the short-range transverse wakefields, the optimal structure parameters are outlined. The wakes are then combined with beam dynamics simulations using the Elegant code to investigate the wakes impact on the quality of the beam, and compared to an analytical study to good agreement.

TUPAB019 **A High-Resolution, Low-Latency, Bunch-by-Bunch Feedback System for Nano-Beam Stabilization**

***R.L. Ramjiawan**, D.R. Bett, N. Blaskovic Kraljevic, T. Bromwich, P. Burrows, G.B. Christian, C. Perry (JAI) D.R. Bett (CERN) N. Blaskovic Kraljevic (ESS) G.B. Christian (DLS)*

A low-latency, bunch-by-bunch feedback system employing high-resolution cavity Beam Position Monitors (BPMs) has been developed and tested at the Accelerator Test Facility (ATF2) at the High Energy Accelerator Research Organization (KEK), Japan. The feedback system was designed to demonstrate nanometer-level vertical stabilization at the focal point of the ATF2 and can be operated using either a single BPM to provide local beam stabilization, or by using two BPMs to stabilize the beam at an intermediate location. The feedback correction is implemented using a stripline kicker and the feedback calculations are performed on a digital board constructed around a Field Programmable Gate Array (FPGA). The feedback performance was tested with trains of two bunches, separated by 280ns, at a charge of ~1nC, where the vertical offset of the first bunch was measured and used to calculate the correction to be applied to the second bunch. The BPMs have been demonstrated to achieve an operational resolution of ~20nm. With the application of single-BPM and two-BPM feedback, beam stabilization of below 50nm and 41nm respectively has been achieved with a latency of 232ns.

TUPAB020 **A Sub-Micron Resolution, Bunch-by-Bunch Beam Trajectory Feedback System and Its Application to Reducing Wakefield Effects in Single-Pass Beamlines**

***D.R. Bett**, P. Burrows, C. Perry, R.L. Ramjiawan (JAI) **D.R. Bett** (CERN) K. Kubo, T. Okugi, N. Terunuma (KEK)*

A high-precision intra-bunch-train beam orbit feedback correction system has been developed and tested at the KEK Accelerator Test Facility, ATF2. The system uses the vertical position of the bunch measured at two beam position monitors to calculate a pair of kicks which are applied to the next bunch using two upstream kickers, thereby correcting both the vertical position and trajectory angle. Using trains of two electron bunches separated in time by 187.6ns, the system was optimised so as to stabilize the beam offset at the feedback BPMs to better than 350nm, yielding a local trajectory angle correction to within 250nrad. The quality of the correction was verified using three down-

stream witness BPMs and the results were found to be in agreement with the predictions of a linear lattice model used to propagate the beam trajectory from the feedback region. This same model predicts a corrected be am jitter of c.1nm at the focal point of the accelerator. Measurements with a beam size monitor at this location demonstrate that reducing the trajectory jitter of the beam by a factor of 4 also reduces the increase in the measured beam size as a function of beam charge by a factor of ~1.6.

TUPAB021 **The New Concept of the Muon Collider**

Y.A. Chesnokov *(IHEP)*

The idea of a muon Collider has been developed since the 70s. Modern muon Collider designs are very expensive and complex and require building a chain of new superconducting accelerators to solve problems with short muon lifetimes and reduced beam emittance. Here we want to propose a Collider variant where muons can be obtained at the hadron Collider at high energy using focusing curved crystals. The essence of our proposal is that two internal targets are installed in two different rings of one of the large hadron colliders (TeV class). Two focusing crystalline systems form the parallel beams of secondary pions and kaons. The beams are formed in Muon decay tunnels about a kilometer long. The parameters of the muon beam were calculated using the Monte Carlo method, taking into account the kinematics of the two-particle decay of pions into muons and neutrinos. The muon beam size in the pulse range 450-550 GeV/s fits into the aperture of typical quadrupole lenses with a diameter of 200 mm. We obtain the luminosity value 10^{24} cm^{-2} s^{-1}. The undeniable positive quality of this offer is its simplicity.

TUPAB022 **Novel Applications of Bent Crystals at Accelerators**

Y.A. Chesnokov *(IHEP)*

At present, crystal elements are used in regular U70 runs and provide half of the particle beams for physical experiments. Here we describe focusing crystal elements, which expand the boundaries of application of bent crystals at accelerators. New methods of production of particle beams: pion, kaon, neutrino and muons are proposed. New variant of muon collider is described. The idea of a muon Collider has been developed since the 70s. In these projects, muons are produced at targets at low or intermediate energies. Then, after reducing the emittance, they should accelerate very quickly, since the lifetime is very short (τ_μ=2 μs in the rest frame). Here we propose the option of the Collider, where the muons can be obtained on the hadron Collider at high energy using a focusing bent crystals.

TUPAB023 **Design Considerations of a High Intensity Booster for PETRA IV**

H.C. Chao*, I.V. Agapov, S.A. Antipov (DESY)*

A 6 GeV booster lattice with a high intensity capacity for the PETRA IV project is presented. Firstly the requirements and constraints are articulated. Due to the geometric constraints the ring will be installed

in racks mounted on ceilings. Then following some design strategies of reaching high intensity limit, a lattice is designed and presented. The topics covering the linear optics, nonlinear dynamics, orbit correction, orbit bump, and some instability studies are investigated.

TUPAB024 **Lattice Options Comparison for a DLSR Injector**

***H.C. Chao**, I.V. Agapov, S.A. Antipov (DESY)*

DESY IV, as a part of the injector chain, must have lower emittance for PETRA IV injection. Depending on the scenarios of the injector, two lattice options for DESY IV are presented. They are designed for different purposes. The first option comes with a high momentum compaction factor with acceptable emittance. It is designed to be a full intensity booster. The other option is with low emittance dedicated to be an accumulator at high energies. The general beam dynamics properties are simulated and discussed. Their strengths and weaknesses are compared.

TUPAB025 **Design of a 500 MeV Prototype Laser-Plasma Injector for DESY-II**

***S.A. Antipov** (CERN) I.V. Agapov, R. Brinkmann, A. Ferran Pousa, A. Martinez de la Ossa (DESY) M. Thevenet (LBNL)*

The present state of progress in laser wakefield acceleration (LWFA) calls for a practical demonstration of its usefulness. We propose a design of a prototype injector to deliver 500 MeV low-intensity electron beams to the DESY-II electron synchrotron. Our design is utilizes presently available conventional accelerator technology, such as a chicane and an X-band RF dechirper, to significantly reduce the energy spread and jitter of the LWFA beam. Combined with a small emittance LWFA this provides a high beam quality injector.

TUPAB026 **Application of Plasma Lenses as Optic Matching Device for Positron Sources at Linear Colliders**

***M. Formela**, N. Hamann, G.A. Moortgat-Pick (University of Hamburg) K. Flöttmann, G.A. Moortgat-Pick (DESY) S. Riemann (DESY Zeuthen)*

In the baseline design of the International Linear Collider (ILC) an undulator-based positron source is forseen. The proposed luminosity of the recently chosen first energy stage with $\sqrt{s}$=250 GeV requires an improvement by a factor of 2500 to the world's first linear collider, the past SLC experiment. This ambitious luminosity goal can only be achieved, if all technological boundaries are being pushed. One such area is the captured positron number, which is primarily determined in the capture section within the positron source and specifically by its optical matching device. It is responsible for transforming the phase-space of the outgoing particles produced in the target for the succeeding accelerator sections. The plasma lens is a new candidate for this task. It being an especially adequate method due its magnetic field being azimuthal. Optimizing an idealised tapered active plasma lens for the ILC led us to a design with improved captured positron yield, outperforming ILC's currently proposed quarter wave transformer by

approximately 50%. The captured yield also proved to be stable within ±1.5% for deviations in design parameters of ±10%.

TUPAB027 **Review of Accelerator Limitations and Routes to Ultimate Beams**

F. Zimmermann *(CERN) R.W. Aßmann (DESY) M. Bai, G. Franchetti (GSI)*

Various physical and technology-dependent limits are encountered for key performance parameters of accelerators such as high-gradient acceleration, high-field bending, beam size, beam brightness, beam intensity and luminosity. This paper will review these limits and the associated challenges. Possible figures-of-merit and pathways to ultimate colliders will also be explored.

TUPAB028 **Permanent Magnets Future Electron Ion Colliders at RHIC and LHeC**

D. Trbojevic*, S.J. Brooks, V. Litvinenko, T. Roser (BNL) G.H. Hoffstaetter (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) V. Litvinenko (Stony Brook University)*

We present a new 'green energy' approach to the Energy Recovery Linac (ERL) and Recirculating Linac Accelerators (RLA) for the future Electron Ion Colliders (EIC) using single beam line made of very strong focusing combined function permanent magnets and the Fixed Field Alternating Linear Gradient (FFA-LG) principle. We are basing our design on recent very successful commissioning results of the Cornell University and Brookhaven National Laboratory ERL Test Accelerator.

TUPAB030 **Superb Fixed Field Permanent Magnet Proton Therapy Gantry**

D. Trbojevic*, S.J. Brooks, T. Roser, N. Tsoupas (BNL)*

We present the top notch design of the proton therapy gantry made of permanent magnets with very strong focusing. This represents a superb solution fulfilling all cancer treatment requirements for all energies without changing any parameters. The proton energy range is between 60-250 MeV. The beam arrives to the patient focused at each required treatment energy. The scanning system is place between the end of the gantry and the patient. There are multiple advantages of this design: easy operation, no significant electrical power - just for the correction system, low weight, low cost. The design is based on the recent very successful commissioning of the permanent magnet ERL 'CBETA' at Cornell University.

TUPAB031 **Construction and Installation of the New CERN Proton Synchrotron Internal Beam Dumps**

K.G. Andersen*, M. Calviani, A. Cherif, T. Coiffet, A. De Macedo, S. Devidal, J.-M. Geisser, S.S. Gilardoni, M.M.J. Gillet, E. Grenier-Boley, J.M. Heredia, A. Majbour, F. Monnet, M.R. Monteserin, F.-X. Nuiry, D. Pugnat, G. Romagnoli, Y.D.R. Seraphin, J.A.F. Somoza, N. Thaus (CERN)*

In the framework of the CERN Large Hadron Collider Injectors Upgrade (LIU) Project, the Proton Synchrotron (PS) has been equipped

with two new movable Internal Dumps (PSID), each of them capable of absorbing particle beams of an energy of up to 100 kJ. These dumps replace the old Internal Dumps, which have been operated in the accelerator complex since their installation in 1975 until their decommissioning and removal from the machine during the second LHC Long Shut down (LS2). This contribution will address the construction and testing phases of the new PSIDs, including the assembly of the dump core, its actuation system and the respective shielding, mechanical running-in tests, metrology adjustments, Ultra-High Vacuum (UHV) and impedance acceptance tests. The described installation work was completed successfully, and the new generation Dumps are currently operational in the PS machine.

TUPAB033 **Photocathode Stress Test Bench at INFN LASA**

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In the framework of the preparatory activities to the BriXSino project, a test bench for testing Cs_2Te photocathode at 100 MHz laser repetition rate has been installed at INFN LASA. This high repetition operation mode is foreseen to be the base operation mode of BriXSino and a qualification of the Cs_2Te photocathodes is a key component. While we are not at full specification due to the limited HV of the present DC gun, we discuss the status of the test bench and the initial results.

TUPAB034 **Development of Multi-Alkali Antimonides Photocathodes for High-Brightness RF Photoinjectors**

D. Sertore, *P. Michelato, L. Monaco (INFN/LASA) G. Guerini Rocco, C. Pagani (Università degli Studi di Milano & INFN) W. Hillert (University of Hamburg, Institut für Experimentalphysik) M. Krasilnikov, S.K. Mohanty, A. Oppelt, H.J. Qian, F. Stephan (DESY Zeuthen)*

Multi-alkali antimonide-based photocathodes are suitable candidate for the electron sources of next-generation high brightness RF photoinjectors due to their excellent photoemissive properties especially, like low thermal emittances and high sensitivity to visible light. The former stands out, paving the way towards CW operations. Based on the previous successful development of Cesium Telluride photocathodes, we are now channelling our efforts toward an R&D activity focused on KCsSb and NaKSb(Cs) photocathodes. Parallel to that R&D activity, we have installed a new dedicated photocathode production system at the INFN-LASA to start the preparation of these photocathodes for their test in the PITZ photoinjector at DESY in Zeuthen. In this paper, detailed experimental results obtained from the KCsSb, along with a preliminary result from the NaKSb(Cs) photocathode material as well as the status of the overall project are presented.

TUPAB035 **ESS Medium Beta Cavities Status at INFN LASA**

***D. Sertore**, M. Bertucci, M. Bonezzi, A. Bosotti, A. D'Ambros, A.T. Grimaldi, P. Michelato, L. Monaco, R. Paparella (INFN/LASA) C. Pagani (Università degli Studi di Milano & INFN)*

INFN Milano contributes in-kind to the ESS ERIC Superconducting Linac supplying 36 cavities for the Medium Beta section of the proton accelerator. The production has reached completion, being all the cavities mechanical fabricated, BCP treated and, for most of them, also qualified with vertical test at cold. In this paper, we report on the results and lessons learnt and the actions taken both for quality control managing and recovery of the few cavities that did not reach the project goal after the first qualification test.

TUPAB036 **The Accelerator Design Progress for EIC Strong Hadron Cooling**

***E. Wang**, S. Peggs, V. Ptitsyn, FJ. Willeke (BNL) S.V. Benson (JLab) D. Douglas (Douglas Consulting) C.M. Gulliford, G.H. Hoffstaetter (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) C.E. Mayes (Xelera Research LLC)*

The Electron-Ion Collider will achieve a luminosity of 10^{34} cm^{-2} s^{-1} by incorporating strong hadron cooling to counteract hadron Intra-Beam Scattering, using a coherent electron cooling scheme. An accelerator will deliver the beams with key parameters, such as 1 nC bunch charge, and 10^{-4} energy spread. The paper presents the design and beam dynamics simulation results. Methods to minimize beam noise, the challenges of the accelerator design, and the R&D topics being pursued are discussed.

TUPAB037 **The Design of a High Charge Polarized Preinjector for the Electron-Ion Collider**

***E. Wang**, W. Liu, V.H. Ranjbar, J. Skaritka, N. Tsoupas (BNL) J.M. Grames, J. Guo (JLab)*

The design of the electron pre-injector of the Electron-Ion Collider (EIC) project to generate 4 x 7 nC bunch has been advancing to meet the requirements for injection into the Rapid Cycling Synchrotron (RCS). The major challenges are high charge transport and achieving small energy spread from 3 GHz traveling-wave plate(TWP). The designed preinjector includes the polarized electron source, bunching section, TWP Linac, zigzag phase space manipulation and spin rotator. In this report, we will discuss the RF frequency selection and the way to reduce energy spread down to 0.2% by longitudinal phase space manipulate. We will also report the results of beamline simulation using space charge code and the conceptual design of spin rotator.

TUPAB038 **Simulation of the Filling Pattern Dependent Regenerative Beam Breakup Instabilities in Energy Recover Linacs**

***S. Setiniyaz**, P.H. Williams (Cockcroft Institute) R. Apsimon (Cockcroft Institute, Lancaster University) P.H. Williams (STFC/DL/ASTeC)*

The interaction of a transversely displaced beam with the higher modes (HOM) of the accelerating cavities causes building up HOM voltages in the cavity, which in turn kicks the beam and increases the offset further. This is known as regenerative beam breakup (BBU) instability and it sets the beam threshold current for the stable beam operation. A study by Setiniyaz *et al.* **[Setiniyaz2020]** showed the filling pattern and recombination schemes of multi-turn energy recovery linacs (ERLs) can create many different beam loading transients, which can have a big impact on the cavity fundamental mode voltage and RF stabilizes. In this work, we extend the study of the filling pattern and recombination schemes to the BBU instabilities and threshold current. In the ERLs, the accelerated and decelerated bunches can be ordered differently while they pass through the cavity and form different filling patterns. Each pattern has a unique bunch energy sequence and bunch arrival times and hence interacts with cavity uniquely and thus drives BBU differently. In this paper, we introduce a simulation tool to investigate the filling pattern dependence of the ERL BBU instability.

TUPAB040 **Design Concept for the Second Interaction Region for Electron-Ion Collider**

***B.R. Gamage** (JLab)*

The possibility of two interaction regions (IRs) is a design requirement for Electron-Ion Collider (EIC). There is also a significant interest from the nuclear physics community to have a 2nd IR with measurement capabilities complementary to those of the 1st IR. While the 2nd IR will be in operation over the entire energy range of ~20GeV to ~140GeV center of mass (CM), it is optimized to have the highest luminosity at a lower CM energy range (~45GeV to ~80GeV). The 2nd IR can also provide an acceptance coverage complementary to that of the 1st. In this paper, we present a brief overview and the current progress of the 2nd IR design in terms of the parameters, magnet layout, and beam dynamics.

TUPAB041 **Detector Solenoid Compensation for the Electron-Ion Collider**

***B.R. Gamage** (JLab)*

The central detector in the present EIC design includes a 4 m long solenoid with an integrated strength of up to 12 Tm. The electron beam passes on-axis through the solenoid, but the hadron beam has an angle of 25 mrad. Thus the solenoid couples horizontal and vertical betatron motion in both electron and hadron storage rings, and causes a vertical closed orbit excursion in the hadron ring. The solenoid also couples the transverse and longitudinal motions of both beams, when crab cavities are also considered. In this paper, we present schemes for

closed orbit correction and coupling compensation at the IP, including crabbing.

TUPAB042 **Large Radial Shifts in the EIC Hadron Storage Ring**

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The Electron Ion Collider will collide hadrons in the Hadron Storage Ring (HSR) with ultra-relativistic electrons in the Electron Storage Ring. The HSR design trajectory includes a large radial shift over a large fraction of its circumference, in order to adjust the hadron path length to synchronize collisions over a broad range of hadron energies. The design trajectory goes on-axis through the magnets, crab cavities and other components in the six HSR Insertion Regions. This paper discusses the issues involved and reports on past and future beam experiments in the Relativistic Heavy Ion Collider, which will be upgraded to become the HSR.

TUPAB043 **Design Options for a Future Upgrade of the Australian Synchrotron Light Source**

***R.T. Dowd**, M.P. Atkinson, R. Auchettl, J. Chi, Y.E. Tan, D. Zhu, K. Zingre (AS - ANSTO)*

In recent years, there has been a revolution in lattice design, with the next generation low emittance, high brightness light sources being conceived. In order to stay competitive on the world stage, we investigated lattice replacement options for the Australian Synchrotron with the aim to reduce beam emittance by a factor of 10 or more while reusing as much existing infrastructure as possible. In this work, we outline alternative lattice designs utilising longitudinal gradient dipoles and reverse bends. We evaluate options of using both the existing 216m storage ring tunnel as well site options for building a larger circumference storage ring.

TUPAB044 **Preliminary Study of the on-Axis Swap-Out Injection Scheme for the Southern Advanced Photon Source**

***Y. Han**, X.H. Lu, Y.Z. Zhao (IHEP CSNS) L. Huang, Y. Jiao, X. Liu, S. Wang (IHEP)*

The Southern Advanced Photon Source (SAPS) is a project under design, which aims at constructing a 4th generation storage ring with emittance below 100 pm.rad at the electron beam energy of around 3.5 GeV. The extremely low emittance will result in a very small dynamic aperture for the storage ring which makes it difficult to use the conventional off-axis accumulation injection. In this case, it is probably necessary to consider the transverse on-axis injection or the longitudinal injection. In this paper, the transverse on-axis swap-out injection scheme for the SAPS storage ring is presented. The preliminary parameters of the septum magnets and fast kickers are carefully evaluated.

TUPAB045 **Preliminary Design of the Low Energy Injector for the Southern Advanced Photon Source**

Y. Han *(IHEP CSNS) Y. Jiao, B. Li, X. Liu, S. Wang (IHEP)*

The Southern Advanced Photon Source (SAPS) is a project under design, which aims at constructing a 4th generation storage ring with emittance below 100 pm.rad at the electron beam energy of around 3.5 GeV. At present, two injector options are under consideration. One is a full energy booster plus a low energy injector, and another is a full energy linac injector. In this paper, a preliminary design of the low energy injector is presented, which consists of an DC thermionic electron gun, a bunching section and an accelerating section. The beam energy at the end of the injector is about 150 MeV.

TUPAB046 **Preliminary design of the Full Energy Linac Injector for the Southern Advanced Photon Source**

X. Liu *(Institute of High Energy Physics, CAS) Y. Jiao, B. Li, S. Wang (IHEP)*

A 4th generation mid-energy range diffraction limited storage ring, named as the Southern Advanced Photon Source (SAPS), is under consideration to be built at the same campus as China Spallation Neutron Source (CSNS), providing a charming one-stop solution for fundamental sciences and industrial applications. While the design of the ring is still under study, a full energy Linac has been proposed as one candidate option for its injector, with the capability of being used as an X-ray Free Electron Laser (XFEL) in the near future. In this paper, an overview of the preliminary design of the Linac is given and simulation results are discussed.

TUPAB047 **Bunch Compressor Design in the Full Energy Linac Injector for the Southern Advanced Photon Source**

B. Li *(IHEP CSNS) Y. Jiao, X. Liu, S. Wang (IHEP)*

A mid-energy fourth-generation storage ring light source named the Southern Advanced Photon Source (SAPS), has been considered to be built neighboring the China Spallation Neutron Source (CSNS). A full energy linac has been proposed as an injector to the storage ring, with the capability to generate high brightness electron beams to feed a Free Electron Laser (FEL) at a later stage. To achieve the high peak current in FELs, space charge, RF structure wakefield, coherent synchrotron radiation (CSR), RF curvature, and the second-order momentum compaction factor should be carefully considered and optimized during the bunch compression processes. In this paper, physic design and simulation results of the bunch compressors are described.

TUPAB048 **HMBA Optics Correction Experience at ESRF**

S.M. Liuzzo*, N. Carmignani, L.R. Carver, L. Farvacque, T.P. Perron, P. Raimondi, S.M. White (ESRF)*

The ESRF-EBS storage ring, successfully commissioned in 2020, operates the HMBA lattice, first proposed in and then adopted in several recent upgrade programs. The successful and timely commissioning of the storage is in large part due to the excellent optics control achieved

over that period. Design performance were obtained with lower than predicted correction strengths, localized for the most part in the vicinity of sextupoles. This remarkable behavior is not only the result of the corrective actions taken during the commissioning but also of the extremely accurate conception and alignment of the machine. This report summarizes the steps that lead to the present performances and discusses their stability over time.

TUPAB049 **USSR HMBA Storage Ring Lattice Options**

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Several new accelerator facilities will be built in Russia in a few years from now. One of those facilities is a 6GeV storage ring (SR) light source (USSR - Ultimate Source of Synchrotron Radiation) to be built in Protvino, near Moscow. The Cremlin+ project aims to incorporate in this activity the best experience of European Accelerator Laboratories. The design of the optics for this SR is presented here in two declinations leading to 70 pm-rad equilibrium horizontal emittance. The first is a 40 cells lattice, the second is the same but includes high field Short Bending magnet sources in each cell. Optics and high order multipole optimizations are performed to obtain sufficient lifetime and dynamic aperture for a conservative off-axis injection.

TUPAB050 **A Long Booster Option for the USSR 6GeV Storage Ring**

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The design of the optics of a full length 6 GeV booster for the USSR (Ultimate Source of Synchrotron Radiation) are presented. This option already followed with success by other laboratories, would allow to obtain a small emittance injected beam thus enabling smooth top-up operation. Details of the design inspired by the ESRF DBA lattice and the possible operating modes are described. The transfer lines booster to storage ring are also addressed in this paper.

TUPAB051 **Elettra and Elettra 2.0**

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The status of the Italian 2.4/2.0 GeV third generation light source Elettra is presented together with the future upgrade concerning the new ultra-low emittance light source Elettra 2.0 that will provide ultra-high brilliance while the very short pulses feasibility study for time resolved experiments is in progress.

TUPAB052 **Current Studies of Applying Machine Learning to Accelerator Physics at IHEP**

***J. Wan**, Y. Jiao (IHEP)*

In recent years, machine learning (ML) has attracted increasing interest among the accelerator field. As a complex collection of multiple physical subsystems, the design and operation of an accelerator can be very nonlinear and complicated, while ML is taken as a powerful tool to solve such nonlinear and complicated problems. In this study, we report on several successful applications of ML to accelerator physics at IHEP. The nonlinear dynamics optimization of the High Energy Photon Source (HEPS) that is a 4th-generation light source is a challenging topic. In this optimization, we use a ML surrogate model to fast select the potentially competitive solutions for a multiobjective genetic algorithm that can significantly improve the convergence rate and the diversity among obtained solutions. Besides, we also tried to apply a generative adversarial net to solve one-to-many problems of longitudinal beam current profile shaping. Unlike most supervised machine learning methods than cannot learn one-to-many maps, the generative adversarial net-based method is able to predict multiple solutions instead of one for a 4-dipole chicane to realize several desired custom current profiles.

TUPAB053 **Design Progress of ALS-U 3rd Harmonic Cavity**

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A higher-harmonic rf cavity (HHC) system is required in the ALS-U storage ring to lengthen the bunches, reduce intrabeam-scattering effects, and improve Touschek beam lifetime. A 3rd harmonic, normal conducting, passive-cavity system has been chosen based on beam-dynamics requirements and cost considerations. We have explored two options for ALS-U 3HC system: a high-R/Q re-entrant cavity with waveguide HOM dampers, and a low-R/Q system with two elliptical cavities and HOM beam line absorbers. In this paper, we present the recent progress on the cavity design and related beam dynamics studies.

TUPAB054 **CDR Baseline Lattice for the Upgrade of SOLEIL**

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Previous MBA studies converged toward a lattice composed of 20 7BA solution elaborated by adopting the sextupole pairing scheme with dispersion bumps originally developed at the ESRF-EBS. It provided a low natural horizontal emittance value of 70-80 pm-rad range at an energy of 2.75 GeV. Due to difficulties to accommodate such lattice geometry in the SOLEIL present tunnel as well as to preserve at best the beamline positioning, alternative lattice based on HOA (Higher-Order Achromat) type cell has been recently investigated. The HOA type cell being more modular and possibly exhibiting larger momentum acceptance as well as low emittances, a solution alternating 7BA and 4BA

cells was then identified as the best to adapt the current beamline positioning. The SOLEIL CDR upgrade reference lattice is then composed of 20 HOA cells alternating 7BA and 4BA giving a natural horizontal emittance of 80 pm-rad. The linear and non-linear beam dynamic properties of the lattice along with the possibility of horizontal off-axis injection at full betatron coupling are presented.

TUPAB055 **USSR - the Project of the Ultimate Synchrotron Radiation Source in Russia**

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Several new accelerator facilities will be built in Russia in the next few years. One of those facilities is an USSR (Ultimate Source of Synchrotron Radiation) project aimed at building of the diffraction limited 4th generation synchrotron light source in the Protvino (Moscow region). The accelerator complex will consists of a 6 GeV storage ring with the horizontal emittance <70pm and a full energy linear accelerator for beam injection. The same linear accelerator will be also used to drive a free electron laser. The synchrotron radiation source is being developed in collaboration with several European Laboratories (ESRF, DESY, LNF-INFN and EuXFEL) in framework of the CREMLIN-plus project (Horizon2020). The status of the accelerator project is presented and discussed in this paper.

TUPAB056 **Heavy Ion CW-RFQ Development**

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Here we present a CW-RFQ for acceleration of ions from boron to uranium with a mass-to-charge ratio up to 7 ($238U^{34+}$) with current up to 1 emA. The CW-RFQ can be used for different applications, for example as an initial part for accelerating complex for rare isotope production using the Inflight method (fragmentation of a fast beam of stable nuclei and in-flight separation of fragments) or accelerating complex for superheavy elements production. The results of beam dynamics

providing the 100% beam transport as well as the RF parameters for CW-RFQ resonator are presented and discussed.

TUPAB057 **Carbon Beam at I-3 Injector for Semiconductor Implantation**

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Carbon implantation can be effectively used for axial minority charge carriers lifetime control in various silicon bulk and epitaxial planar structures. When carbon is implanted, more stable recombination centers are formed and silicon is not doped with additional impurities, as for example, when irradiated with protons or helium ions. Economically, such a process competes with alternative methods, and is more efficient for obtaining small lifetimes (several nanoseconds). I-3 ion injector with laser-plasma ion source in Institute for theoretical and experimental physics (ITEP) is used as ion implanter in semiconductors. The ion source uses pulsed CO_2 laser setup with radiation-flux density of 10^{11} W/cm^2 at target surface. The ion source produces beams of various ions from solid targets. The generated ion beam is accelerated in the two gap RF resonator at voltage of up to 2 MV per gap. Resulting beam energy is up to 4 MV per charge. Parameters of carbon ion beam generated and used for semiconductor samples irradiation during experiments for axial minority charge carriers lifetime control in various silicon bulk and epitaxial planar structures are presented.

TUPAB058 **Online Optimizations of Several Observable Parameters at the Advanced Photon Source**

Y.P. Sun *(ANL)*

Online optimizations are known to be powerful tools which may quickly and efficiently improve the particle accelerator key performance parameters in a model-independent way. In this paper, it is presented on the online optimizations of several observable parameters at the Advanced Photon Source storage ring. These observable parameters include the beam lifetime, injection efficiency and topup efficiency, transverse beam sizes, and turn by turn beam position monitors. It is demonstrated that the particle accelerator performance may be greatly enhanced in a relatively short time frame, by optimizing these observable parameters.

TUPAB059 **Measurement of the Advanced Photon Source lifetime at different level of beta-beating**

Y.P. Sun *(ANL)*

Linear optics correction of a particle accelerator may not be perfect due to the existence of different errors sources in response matrix measurements and optics correction process. Previous numerical simulation study has shown that the single particle beam dynamics performance may be highly correlated with the level of residual beta-beating. In this paper, the machine study results on beam lifetime of the APS storage ring is presented. The experiment is performed at different

level of predefined beta-beating with negligible betatron tunes variations. As expected, the measured beam lifetime has an inverse correlation with the level of beta-beating.

TUPAB060 **Machine Learning on Beam Lifetime and Topup Efficiency**
Y.P. Sun *(ANL)*
Unsupervised and supervised machine learning techniques are applied on automatic clustering and prediction of the Advanced Photon Source operation data of lifetime and topup efficiency. The clustering of beam lifetime and topup efficiency is consistent with either true label or the kernal density estimation. The k-means clustering, spectral clustering, and Gaussian mixtures methods are employed and benchmarked. The predictions of beam lifetime and topup efficiency is performed with trained deep neural network, and compared to measurements.

TUPAB061 **Anomaly Detection by Principal Component Analysis and Autoencoder Approach**
Y.P. Sun *(ANL)*
Two popular ways of dimensionality reduction, principal component analysis (PCA) and autoencoder, are employed to identify the abnormal events in the Advanced Photon Source operation process. It is observed that the beam dump from magnet trip may be predicted by analyzing the magnet capacitor temperatures. There is reasonable agreement between the principal component analysis and the autoencoder approaches, on predicting possible system fault which triggers a stored beam dump.

TUPAB062 **Expediting APS-U Long-Term Particle Tracking With Arbitrary Order Taylor Map**
Y.P. Sun *(ANL)*
Truncated power series algebra was integrated within explicit symplectic integration to formulate an arbitrary order multivariate Taylor map for any given particle accelerator lattice. Tracking simulation performed with these Taylor maps shows good long term stability and physics accuracy. There is good agreement in long term particle tracking simulations between Taylor map and element by element tracking of APS-U lattice, when the particle is within 1 to 10 sigma of stored beam. It is demonstrated that most of the lower order resonance driving terms, plus chromatic and geometric aberrations are reasonably preserved by the Taylor map approach. Last but maybe most important, the computation time is reduced by a factor of 20 to 50, when compared to symplectic integration based element by element tracking.

TUPAB063 **Study of PF-Ring Infrastructure Improvements Using Temperature Measurements in the Ring Tunnel**
N. Nakamura*, K. Haga, T. Nogami, M. Tadano (KEK)*
Temperature measurements have been performed in the PF-ring tunnel in order to understand the infrastructure performance and the

temperature stability towards the PF upgrade project, where better beam stability will be required. Based on the temperature measurements, possible improvements of the PF-ring infrastructure such as an air-conditioning system have been studied to enhance the temperature stability in the PF-ring tunnel. In this paper, we present results of the temperature measurements in the PF-ring tunnel and a proposal of the PF-ring infrastructure improvements for the temperature stabilization.

TUPAB064 **Specifications and Performance of a Chicane Magnet for the cERL IR-FEL**

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The IR-FEL was constructed in the Compact ERL (cERL) at KEK from October 2019 to May 2020 for the purpose of developing high-power mid-infrared lasers for high-efficiency laser processing utilizing molecular vibrational absorption. The chicane magnet was newly installed between two IR-FEL undulators in the cERL in order to increase the FEL gain and pulse energy by converting the energy modulation to the density modulation in an electron bunch. It consists of three dipole magnets with laminated yokes made of 0.1-mm-thick permalloy sheets and the coil currents of the three magnets are independently controlled by three power supplies with the maximum current of 10 A. The maximum closed orbit bump made by the chicane magnetic field has the longitudinal dispersion(R56) of -6 mm. The coil-current ratio of the three dipole magnets was tuned after installation to make its orbit bumps closed and then the chicane magnet was used in the FEL operation. We present specifications and operational performance of the chicane magnet.

TUPAB065 **Solaris Storage Ring Performance After 6 Years of Operation**

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Solaris is a third generation light source operating since 2015 in Kraków, Poland. Between 2015 and 2018 the synchrotron as well as two beamlines were commissioned. During commissioning phases, the good performance of Solaris storage ring has been reached. The beam optics was brought close to the design one. Since October 2018 Solaris storage ring is in the user operation mode. Moreover, two other beamlines with the elliptically polarized undulators used as source were installed and are under commissioning now. In 2020 the total beam availability of 93% was reached with the average circulating current of 400 mA and the total lifetime of 15 h. Over last two years few improvements of the storage ring were done to optimize the storage ring performance. The Landau cavities were tuned to improve the Touschek lifetime and suppress the instabilities. Two diagnostics beamlines were installed and commissioned allowing for the beam sizes in

three planes and emittance measurements. The storage ring optics was fine-tuned to increase the dynamic aperture.

TUPAB066 **Status of the Short-Pulse Source at DELTA**

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At the synchrotron light source DELTA operated by the TU Dortmund University, the short-pulse source employs the seeding scheme coherent harmonic generation (CHG) and provides ultrashort pulses in the vacuum ultraviolet and terahertz regime. Here, the interaction of laser pulses with the stored electron bunches result in a modulation of the longitudinal electron density which gives rise to coherent emission at harmonics of the laser wavelength. Recently, investigations of the influence of the Gouy phase shift at the focal point of the laser pulses on the laser-electron interaction have been performed. For the planned upgrade towards the more sophisticated seeding scheme echo-enabled harmonic generation (EEHG) featuring a twofold laser-electron interaction, simulations of the ideal parameters of the laser beams have been carried out.

TUPAB067 **Production of 120 MeV Gamma Ray Beams at the Duke FEL and HIGS Facility**

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In this paper we report extension of the operational energy of the gamma ray beams produced at Duke High Intensity Gamma-ray Source (HIGS) up to ~120MeV, opening up a new high energy region of gamma rays for photonuclear physics research. This achievement is based upon development of radiation robust, thermally stable, high-reflectivity fluoride (LaF3/MgF2) multilayer VUV FEL mirrors, enabling us to maintain stable high intensity FEL lasing at the wavelengths of around 175nm. We discuss the challenges of HIGS operation at high gamma and high electron beam energies with the downstream FEL mirror exposed to extremely hush radiation. The experience of the first HIGS user operation with high intensity, high gamma-ray beam energies (85 and ~120MeV) using these new mirrors is also discussed.

TUPAB068 **Management of FEL Mirror Degradation at the Duke FEL and HIGS Facility**

S.F. Mikhailov, *V. Popov, Y.K. Wu (FEL/Duke University)*

The Duke FEL/HIGS (Free Electron Laser/High-Intensity Gamma-ray Source) operates in the wide range of beam energies (240 MeV - 1.2 GeV) and of the wavelengths (175-1100 nm). Currently, it can produce gamma rays of 1.0 - ~120 MeV. The maximum total flux of gammas produced by the HIGS facility is up to $2{\cdot}10^{10}$ gammas per second. During the production of the high gamma flux, FEL mirrors suffer a strong degradation, especially while operating in the VUV range. The downstream mirror may be severely damaged by the high harmonics

of the wiggler radiation. This limits the operation of the VUV mirrors for the production of high gamma-ray flux to mostly circular polarization, with much less on-axis harmonic radiation. We developed a program of continuous monitoring of the FEL mirrors which allows us to use them for thousands of hours of high flux operation before their total degradation. We discuss particular sources and consequences of degradation for the variety of mirrors of different wavelengths. We also present estimations of the lifetime of the mirrors depending on the wavelength, polarization, and total gamma flux.

TUPAB069 **The Sabina Terahertz/Infrared Beamline at SPARC-Lab Facility**
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Following the EU Terahertz (THz) Road Map, high-intensity, ps-long, THz)/Infrared (IR) radiation is going to become a fundamental spectroscopy tool for probing and control low-energy quantum systems ranging from graphene, and Topological Insulators, to novel superconductors. In the framework of the SABINA project, a novel THz/IR beamline based on an APPLE-X undulator emission will be developed at the SPARC-Lab facility at LNF-INFN. Light will be propagated from the SPARC-Lab to a new user lab facility nearly 20 m far away. This beamline will cover a broad spectral region from 3 THz to 30 THz, showing ps- pulses and energy of tens of μJ with variable polarization from linear to circular. The corresponding electric fields up to 10 MV/cm, are able to induce non-linear phenomena in many quantum systems. The beamline, open to user experiments, will be equipped with a 5 T magnetic cryostat and will be synchronized with a fs laser for THz/IR pump, VIS/UV probe experiments.

TUPAB070 **A Proposal for MHz Level Repetition Rate External Seeded Free-Electron Lasers**
X.F. Wang *(SINAP) C. Feng (SARI-CAS) W.Q. Zhang (DICP)*
The repetition frequency of the free-electron laser facilities which are based on the self-amplified spontaneous emission mode can reach the MHz level. However, for the external seeded free-electron lasers, the limitation of the average power of the seed laser forces its repetition frequency to be only on the order of kHz. A new technology is proposed here to achieve MHz level repetition rate for external seeded free-electron laser.

TUPAB071 **Beam Line Design and Instrumentation for THz@PITZ - the Proof-of-Principle Experiment on a THz SASE FEL at the PITZ Facility**
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In order to allow THz pump-X-ray probe experiments at full bunch

repetition rate for users at the European XFEL, the Photo Injector Test Facility at DESY in Zeuthen (PITZ) is building a prototype of an accelerator-based THz source. The goal is to generate THz SASE FEL radiation with a mJ energy level per bunch using an LCLS-I undulator driven by the electron beam from PITZ. Therefore, the existing PITZ beam line is extended into a tunnel annex downstream of the existing accelerator tunnel. The beam line extension in the PITZ tunnel consists of three quadrupole magnets, a bunch compressor, a collimation system and a beam dump. In the second tunnel a dipole magnet allows to serve two beam lines, one of them the THz@PITZ beam line. It consists of one LCLS-I undulator for the production of the THz radiation, a quadrupole triplet in front of it and a quadrupole doublet behind it. For the electron beam diagnostic six new screen stations are built, three of them also allow for the observation of the THz radiation for measurements. In addition six BPMs and a new BLM system for machine protection and FEL gain curve measurement will be installed. The progress of this work will be presented.

TUPAB072 **The Status of a Grating Monochromator for Soft X-Ray Self-Seeding Experiment at SHINE**

K.Q. Zhang *(SSRF) H.X. Deng, C. Feng, B. Liu, T. Liu (SARI-CAS)*

The research status of a grating monochromator for soft X-ray self-seeding experiment at SHINE has been presented in this paper. The monochromator system includes the vacuum cavity, optical elements, and mechanical movement devices. Until now, the vacuum cavity has finished the manufactured process completely, the optical mirrors have finished machining and measured by the longitudinal trace profiler (LTP) and atomic force microscope (AFM). To make sure the monochromator system can achieve an optical resolution of 1/10000 at the photon energy of 700-1300eV, the system has been integrated and tested recently. In this year, the previous online experiment will be performed in the shanghai soft X-ray free-electron laser (FEL) user facility.

TUPAB073 **The Design of EEHG Cascaded Harmonic Lasing for SXFEL User Facility**

K.Q. Zhang*, C. Feng (SSRF) H.X. Deng, B. Liu, T. Liu (SARI-CAS)*

The preliminary design and simulation results of EEHG cascaded harmonic lasing for the SXFEL user facility have been presented in this paper. Using the basic seeded beamline of the SXFEL user facility, the designed parameters are optimized to obtain full coherent FEL output at the 90th harmonic of a 265 nm seed laser. According to the designed parameters and the layout of the SXFEL user facility, the detailed simulations are carried out, the results show that the seeded beamline of the SXFEL user facility can generate 2.93 nm full coherent radiation by the proposed method, which indicates that the method can extend the photon energy range of a seeded FEL and the method can be achieved at the SXFEL user facility.

TUPAB074 **S-Band Transverse Deflecting Structure Design for Compact-Light**

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The CompactLight project is currently developing the design of a next generation hard X-ray FEL facility, which is based on high-gradient X-band (12 GHz) structures. However, to carry out pump-and-probe experiments in the project, two-bunch operation with a spacing of 10 X-band rf cycles is proposed. A sub-harmonic transverse deflecting structure working at S-band is proposed to direct the two bunches into two separate FEL lines. The two FEL pulses will have independently tunable wavelengths and can be combined in a single experiment with a temporal delay between pulses of ± 100 fs. The rf design of the transverse deflector is presented in this paper.

TUPAB076 **High-Gradient Breakdown Studies of an X-Band Accelerating Structure Operated in the Reversed Taper Direction**

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The results of high-gradient tests of a tapered X-band traveling-wave accelerator structure powered in reversed direction are presented. Powering the tapered structure from the small aperture, normally output, at the end of the structure provides unique conditions for the study of gradient limits. This allows high fields in the first cell for a comparatively low input power and a field distribution that rapidly falls off along the length of the structure. A maximum gradient of 130 MV/m in the first cell at a pulse length of 100 ns was reached for an input power of 31.9 MW. Details of the conditioning and operation at high-gradient are presented. Various breakdown rate measurements were conducted at different power levels and rf pulse widths. The structure was standard T24 CLIC test structure and was tested in Xbox-3 at CERN.

TUPAB077 **Novel Open Cavity for Rotating Mode SLED-Type RF Pulse Compressors**

X.W. Wu, *A. Grudiev (CERN)*

A new X-band high-power rotating mode SLAC Energy Doubler (SLED)-type rf pulse compressor is proposed. It is based on a novel cavity type, a single open bowl-shape energy storage cavity with high Q_0 and compact size, which is coupled to the waveguide using a compact rotating mode launcher. The novel cavity type is applied to the rf pulse compression system of the main linac rf module of the klystron-based option of the Compact Linear Collider (CLIC). Quasi-spherical rotating modes of $TE_{1,2,4}$ and $TE_{1,2,13}$ are proposed for the correction cavity and storage cavity of the rf pulse compression system respectively. The storage cavity working at $TE_{1,2,13}$ has a Q_0 of 240000 and a diameter less than 33 cm. The design of the pulse compressor and in particular of the high-Q cavity will be presented in detail.

TUPAB078 **Relative Timing Jitter Effects on Two-stage Seeded FEL at SHINE**

H.X. Yang *(SINAP) H.X. Deng, B. Liu, D. Wang, K.S. Zhou (SARICAS)*

The synchronization between the ultrashort electron beam and external seed laser is essential for seeded FELs, especially for a multi-stage one. In this paper, we demonstrate a simple method to obtain the correlations between the pulse energy and relative timing jitter for evaluating the corresponding effects. In this method, the sensitivity of the output FEL performance against electron beam properties is demonstrated by scanning the electron beam and seed lasers, and the fitted curve is used to predict the pulse energy in different timing jitter by random sampling. The results indicate that the pulse energy of the first-stage EEHG is more stable than the second-stage HGHG. Meanwhile, the rise of bunch charge from 100 pC to 300 pC can reduce the timing control requirement by a factor of least 3 for the RMS timing jitter in our numerical simulations based on the parameters of Shanghai High-Repetition-Rate XFEL and Extreme Light Facility. The timing jitter study can demonstrate the feasibility of the EEHG-HGHG cascading scheme in different current profiles for generating Fourier-transform-limited soft X-ray FEL.

TUPAB079 **Using ER@CEBAF to Show That a Multipass ERL Can Drive an XFEL**

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A multi-pass recirculating superconducting CW linac offers a cost effective path to a multi-user facility with unprecedented scientific and industrial reach over a wide range of disciplines. We propose such a facility as an option for a potential UK-XFEL. Energy Recovery enables multi-MHz FEL sources, for example, an X-ray FEL oscillator or regenerative amplifier FEL. Additionally, combining with external lasers and/or self-interaction would provide access to MeV and GeV gamma-rays via inverse Compton scattering at high average power for nuclear and particle physics applications. An opportunity exists to demonstrate the necessary point-to-parallel longitudinal matches to drive an XFEL and successfully energy recover at the upcoming 5-pass up, 5-pass down Energy Recovery experiment on CEBAF at JLab termed ER@CEBAF. We show candidate matches and simulations supporting the minimal necessary modifications to CEBAF this will require. This includes linearisation of the longitudinal phase space in the injector and a reduction in the dispersion of the arcs, both of which increase the energy acceptance of CEBAF. We expect to commence initial tests of these adaptations on CEBAF during 2021.

TUPAB080 **Design and Status of the Beam Switchyard for the SXFEL-UF**
***S. Chen**, R. Wang (SSRF) H.X. Deng, X. Fu, B. Liu (SARI-CAS)*
SXFEL-UF, a soft X-ray FEL user facility located in Shanghai, which is the upgrade of the existing test facility, is under commissioning since early this year. Electron energy increases from 840 MeV to 1.5 GeV and a SASE FEL beamline will be added besides the existing seeding FEL beamline. In order for simultaneous operation of the two beamlines, a beam switchyard is built between the linac and the two FEL beamlines. In this paper, the physics design of the beam switchyard is described and the status of the early commissioning results is shown.

TUPAB081 **Design of the Beam Distribution System of SHINE**
***S. Chen**, M. Gu, R. Wang (SSRF) H.X. Deng, X. Fu (SARI-CAS)*
In shanghai, a hard X-ray free electron laser project named SHINE is under design. It will be based on a superconducting linac running in CW mode. On the first stage, there will be three parallel undulator lines downstream the linac. For simultaneous operation of the three undulator lines, a beam distribution system based on fast kickers will be installed between linac and undulator lines. The physics design of this beam distribution system is described in this paper.

TUPAB082 **Analysis of the Effect of Energy Chirp in Implementing EEHG at SXL**
***M.A. Pop**, F. Curbis, B.S. Kyle, S.P. Pirani, W. Qin, S. Werin (MAX IV Laboratory, Lund University) F. Curbis, S. Werin (Lund University) W. Qin (DESY)*
As a part of the efforts to improve the longitudinal coherence in the design of the Soft X-ray FEL (the SXL) at MAX IV, we present a possible implementation of the EEHG harmonic seeding scheme partly integrated into the second bunch compressor of the existing LINAC. A special focus is given to the effect of CSR on the resulting EEHG bunching and on how this unwanted effect might be controlled.

TUPAB083 **Dual Energies in the LCLS Copper Linac**
***F.-J. Decker**, C. Bianchini Mattison, D.K. Bohler, A. Brachmann, W.S. Colocho, S. Condamoor, M.L. Gibbs, K.H. Kim, A.A. Lutman, T.J. Maxwell, J.A. Mock, H.-D. Nuhn, J.C. Sheppard, H. Smith, T.J. Smith, M. Stanek, S. Zelazny, Z. Zhang, C.M. Zimmer (SLAC)*
For LCLS-II two undulators were installed at SLAC, one for soft and one for hard x-rays. Before the superconducting linac gets turned on the copper linac is providing beams at 120 Hz to these two beam destinations. The 120 Hz can be split in many different ratios between soft and hard via a pulsed magnet. To get an optimized beam for the quite different photon energies the pulsed linac components like modulators and RF can provide many different beam parameters, mainly energies and bunch lengths for the two undulator lines. How this was implemented with timing setups of triggers and finally after the split the necessary matching of the transverse phase space will be discussed.

TUPAB084 **An Empirically-Derived ABCD Matrix for Transverse Dynamics Studies in Seeded Free-Electron Lasers**

R. Robles *(Stanford University) Z. Huang, G. Marcus (SLAC)*

We present a simple empirical method for deriving an ABCD matrix for studying the transverse dynamics of the radiation field in seeded, high-gain free-electron lasers before saturation. In spite of the inherently nonlinear nature of FEL optical guiding, the ABCD matrix we find is able to predict the evolution of the FEL mode size and centroid to a high degree of accuracy across a large range of input mode characteristics. This scheme enables extremely fast simulation of transverse dynamics, which in turn greatly simplifies numerical studies of seeded FEL systems. Of particular interest in that regard is the x-ray regenerative amplifier free-electron laser, in which the x-ray beam propagates through an optical cavity many hundreds of times, thereby making traditional simulation methods cumbersome and time consuming.

TUPAB085 **Three-Dimensional Radiative Effects in the Compression of Ultra-Short Micro-Bunched Electron Beams**

R. Robles*, J.B. Rosenzweig (UCLA) S.B. van der Geer (Pulsar Physics)*

Micro-bunched current profiles have recently gained traction as an alternative to bulk compression in certain free-electron laser applications. The attraction of the micro-bunched structure is owed in part to its promise to minimize deleterious effects associated with coherent synchrotron radiation during compression. Simultaneously, these profiles push the boundaries of traditional one-dimensional CSR simulation models which assume the bunch length to far exceed the transverse beam size in the bunch rest frame - an assumption which may be violated by the sub-micron length micro-bunches. Here we present simulation studies of the impact of three-dimensional CSR effects on micro-bunching based compression schemes using the General Particle Tracer code.

TUPAB086 **FLASH2020+ Plans for a New Coherent Source at DESY**

E. Allaria*, N. Baboi, K. Baev, M. Beye, G. Brenner, F. Christie, C. Gerth, I. Hartl, K. Honkavaara, B. Manschwetus, J. Mueller-Dieckmann, R. Pan, E. Plönjes-Palm, O. Rasmussen, J. Rönsch-Schulenburg, L. Schaper, E. Schneidmiller, S. Schreiber, K.I. Tiedtke, M. Tischer, S. Toleikis, R. Treusch, M. Vogt, L. Winkelmann, M.V. Yurkov, J. Zemella (DESY)*

With FLASH2020+, a major upgrade of the FLASH facility has started to meet the new requirements of the growing soft-x ray user community. The design of the FEL beamlines aims at photon properties suitable to the needs of future user experiments with high repetition rate XUV and soft X-ray radiation. By the end of the project, both existing FEL lines at FLASH will be equipped with fully tunable undulators capable of delivering photon pulses with variable polarization. The use of the external seeding at 1 MHZ in burst mode is part of the design of the new FLASH1 beamline, while FLASH2 will exploit novel lasing concepts

based on different undulator configurations. The new FLASH2020+ will rely on an electron beam energy of 1.35 GeV that will extend the accessible wavelength range to the oxygen K-edge with variable polarization. The facility will be completed with new laser sources for pump and probe experiment and new experimental stations.

TUPAB087 **Full Characterization of the Bunch-Compressor Dipoles for FLUTE**

***Y. Nie**, A. Bernhard, E. Bründermann, A.-S. Müller, M.J. Nasse, R. Ruprecht, J. Schaefer, M. Schuh, Y. Tong (KIT)*

The Ferninfrarot Linac- Und Test-Experiment (FLUTE) is a KIT-operated linac-based test facility for accelerator research and development as well as a compact, ultra-broadband and short-pulse terahertz (THz) source. As a key component of FLUTE, the bunch compressor (chicane) consisting of four specially designed dipoles will be used to compress the 40-50 MeV electron bunches after the linac down to single fs bunch length. The maximum vertical magnetic field of the dipoles reach 0.22 T, with an effective length of 200 mm. The good field region is ±40 mm and ±10.5 mm in the horizontal and vertical direction, respectively. The latest measurement results of the dipoles in terms of field homogeneity, excitation and field reproducibility within the good field regions will be reported, which meet the predefined specifications. The measured 3D magnetic field distributions have been used to perform beam dynamics simulations of the bunch compressor. Effects of the real field properties on the beam dynamics, which are different from that of the ASTRA built-in dipole field, will be discussed.

TUPAB089 **Proof-of-Principle Experiment Design for PEHG-FEL in SXFEL User Facility**

***Z. Qi**, H.X. Deng, C. Feng, B. Liu (SARI-CAS) S. Chen, Z.T. Zhao (SSRF)*

In this paper, we demonstrate a proof-of-principle experimental design for phase-merging enhanced harmonic generation (PEHG) free electron laser (FEL) in Shanghai Soft X-ray Free Electron Laser (SXFEL) user facility. The simulation results indicate that, taking advantage of the beam switchyard, the normal modulator and the seeded FEL line in SXFEL user facility, together with an oblique incident seed laser, we can perform the phase-merging effect in PEHG and finally get an 8.86nm FEL radiation through the undulator, which is the 30th harmonic of the seed laser.

TUPAB090 **Preliminary Error Analysis and Light Source Stability Calculation for SHINE**

***Z. Qi** (SARI-CAS)*

We demonstrate the preliminary error analysis and light source stability calculation for Shanghai HIgh repetition rate XFEL aNd Extreme light facility (SHINE). The SHINE XFEL part will consist of an 8GeV CW linac and 3 undulator lines FEL-I, FEL-II, FEL-III. It aims to cover a wide range of photon energies of 3-15keV (FEL-I), 0.4-3keV (FEL-II),

10-25keV (FEL-III). Among them FEL-III will be the hardest FEL beam line. The nominal photon energy of FEL-III is 15keV. Given this, we study the impact of the component error and electron beam jitter on FEL-III 15keV radiation.

TUPAB091 **Options for High-Repetition-Rate Seeded FEL**

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In high-gain free-electron lasers (FELs), external seeding and harmonic generation techniques have been shown to be valid solutions for the generation of fully coherent and stable radiation down to soft x-ray wavelengths. However, the required seed lasers cannot generate pulses with sufficient energy at the repetition-rates accessible with superconducting accelerators which deliver electron bunches at repetition-rates of several MHz. Therefore, the seed laser becomes the limiting factor which determines the maximum repetition-rate for future seeded FEL. In this paper, we propose two different schemes which overcome the limitations and enable the generation of seeded radiation at high-repetition-rates. In one case, an optical klystron scheme is exploited in the seeding process and allows to reduce the requirements in seed laser power, making the use of seed lasers at higher repetition-rates or shorter wavelengths possible. In the second case, an optical cavity is used instead of the seed laser source. The length of the cavity can be adjusted to match the repetition-rate of the electron bunches independently of the seed laser source.

TUPAB092 **Demonstration FELs using UC-XFEL Technologies at the SAMURAI Laboratory**

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The ultra-compact x-ray free-electron laser (UC-XFEL), described in [J. B. Rosenzweig, et al. 2020 New J. Phys. 22 093067], combines several cutting edge beam physics techniques and technologies to realize an x-ray free electron laser at a fraction of the cost and footprint of existing XFEL installations. These elements include cryogenic, normally conducting RF structures for both the gun and linac, IFEL bunch compression, and short-period undulators. In this work, several stepping-stone, demonstrator scenarios under discussion for the UCLA SAMURAI Laboratory are detailed and simulated, employing different subsets of these elements. The cost, footprint, and technology risk for these scenarios are considered in addition to the anticipated engineering and physics experience gained.

TUPAB093 **Positron Driven Dielectric Wakefields**
***N. Majernik**, G. Andonian, P.D. Hoang, J.B. Rosenzweig, O. Williams (UCLA) C.I. Clarke, M.J. Hogan, B.D. O'Shea, V. Yakimenko (SLAC)*
Future collider schemes based on advanced acceleration methods using wakefields must deliver high fields for both electrons and positrons. In this paper, we present the first results of positron driven wakefields in a dielectric structure at high fields. THz interferometric measurements are used to characterize structure wakefield properties, including revealing information on spectral content via the extraction and detection of coherent Cherenkov radiation (CCR). This work is a vital stepping stone towards the realization of a wakefield based linear collider, capable of accelerating both electrons and positrons at gradients ~GV/m in a robust, solid-state fashion.

TUPAB094 **Multi-Start Foil Wound Solenoids for Multipole Suppression**
***N. Majernik**, A. Fukasawa, J.B. Rosenzweig, A. Suraj (UCLA)*
Solenoids for beam transport are typically wound helically, with each layer of wire being laid down on top of the previous, or as "pancakes" where the wire is wound radially in before crossing over and winding out. Both of these approaches break rotational symmetry and introduce higher-order multipole moments which can be deleterious to beam emittance. For high brightness beams, this can be particularly problematic. To this end, a solenoid employing multi-start foil windings is simulated and compared to conventional choices. With appropriate design, this approach can forbid certain multipoles by symmetry.

TUPAB095 **Arbitrary Longitudinal Pulse Shaping With a Multi-Leaf Collimator and Emittance Exchange**
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Drive and witness beams with variable current profiles and bunch spacing can be generated using an emittance exchange beamline (EEX) in conjunction with transverse masks. Recently, this approach was used to create advanced driver profiles and demonstrate record-breaking plasma wakefield transformer ratios [Roussel, R., et al., Phys. Rev. Lett. 124, 044802 (2020)], a crucial advancement for effective witness acceleration. Presently, these transverse masks are individually laser cut, making the refinement of beam profiles a slow process. Instead, we have proposed the used of a UHV compatible multileaf collimator (MLC) to replace these masks. An MLC permits real-time adjustment of the beam masking, permitting faster optimization in a manner highly synergistic with machine learning. Beam dynamics simulations have shown that practical MLCs offer resolution that is functionally equivalent to that offered by the laser cut masks. In this work, the engineering considerations and practical implementation of such a system at the AWA facility are discussed and the results of benchtop tests are

presented.

TUPAB096 **Optimizing the Beam Brightness in a Photoinjector for Future Free-Electron Lasers**

***O. Mohsen**, P. Piot (Northern Illinois University) M.P. Kelly, T.B. Petersen, P. Piot (ANL)*

High brightness electron beams are an essential component that drives current and future light sources including Free-Electron lasers (FELs). The possible use of a superconducting gun to support high-repetition-rate bright-beam generation is discussed and beam-dynamics simulations. We explore the design via multi-objective optimization to seek optimum solutions for beam parameters as required to drive future FELs taking considering as an example the LCLS-II-HE requirements.

TUPAB097 **High Repetition Rate Compact THz Source**

***O. Mohsen**, P. Piot (Northern Illinois University) P. Piot (ANL)*

A compact THz source is a tool sought after for multiple applications including pump-probe experiments and imaging. In this work, we present initial beam-dynamics studies for the generation of THz sources via a low-energy electron source coupled to a dielectric-lined waveguide. The THz radiation is generated by the electron beam interaction with the dielectric waveguide which generates coherent Cherenkov radiation. The performance of the source and tunability are demonstrated via first-principle simulations.

TUPAB098 **Recent Progress Toward a Conduction-Cooled Superconducting Radiofrequency Electron Gun**

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High-repetition-rate electron sources have widespread applications. This contribution discusses the progress toward a proof-of-principle demonstration for a conduction-cooled electron source. The source consists of a simple modification of an elliptical cavity that enhances the field electric field at the photocathode surface. The source was cooled to cryogenic temperatures and preliminary measurements for the quality factor and accelerating field were performed. Additionally, we present future plans to improve the source along with simulated beam-dynamics performances.

TUPAB099 **Construction of an Infrared FEL at the Compact ERL**

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The compact Energy Recovery Linac (cERL) has been in operation at KEK since 2013 to demonstrate ERL performance and develop ERL technology. Recently KEK has launched an infrared FEL project with a competitive funding. The purpose of this project is to build a mid-infrared FEL at the cERL, and to use that FEL as a light source for construction of the processing database required for industrial lasers. The FEL system is composed of two 3-m undulators and a matching section between them, and generates light with a maximum pulse energy of 0.1 micro-J at the wavelength of 20 microns with an 81.25 MHz repetition rate. The FEL is also expected to become a proof-of-concept machine for ERL base FELs for future EUV lithography.

TUPAB100 **FEL design elements of SABINA: A Free Electron Laser For THz-MIR Polarized Radiation Emission**

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SABINA, acronym of "Source of Advanced Beam Imaging for Novel Applications", will be a Self-Amplified Spontaneous Emission Free Electron Laser (SASE FEL) providing a wide spectral range (from THz to MIR) of intense, short and variable polarization pulses for investigation in physics, chemistry, biology, cultural heritage, and material science. In order to reach these goals high brightness electron beams within a 30-100 MeV energy range, produced at SPARC photo-injector, will be transported up to an APPLE-X undulator through a dogleg. Space charge effects and Coherent Synchrotron Radiation (CSR) effects must be held under control to preserve beam quality. Studies on beam transport along the undulator and of the properties of the radiation field have been performed with "Genesis 1.3" simulation code. A downstream THz optics photon delivery system has also been designed to transport radiation on the long path from the undulator exit up to user experimental area.

TUPAB101 **Monte Carlo Simulations and Neutron and Gamma Fluence Measurements to Investigate Stray Radiation in the European XFEL Undulator System**

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The European X-ray Free Electron Laser (XFEL) is an user facility research centre generating extremely bright and ultra-short SASE x-ray pulses. The laser flashes are generated when electrons of GeV energies pass the undulator systems. Even if the dominating contribution of the radiation field in the undulator is from spontaneous undulator radiation, also electron losses can be observed, e.g. during beam steering or due to beam halo, not captured by the upstream collimation system. The interactions of those particles with the vacuum vessel wall result

in the emission of stray radiation. The LB 6419 detector allows to measure both the neutron and the gamma component in the pulsed radiation fields nearby the undulators. Usually, the real-time measurements show the dominance of the gamma signals. However, in case of particle loss occurs, a neutron signal is observed. In addition, Monte Carlo (MC) simulations conducted using the Geant4 code indicate that neutrons are also present within the undulator's magnets volume. In this work, we present the LB 6419 measurement data and compare these to our MC simulations, to characterize the radiation field nearby the undulator segment.

TUPAB102 **A New 2nd Bunch Compression Chicane for the FLASH2020+ Project**

***M. Vogt**, J. Zemella (DESY)*

The first stage of the FLASH2020+ project is an upgrade of the FLASH injector beamline. Within this framework, the 2nd bunch compression chicane (BCC) will be completely redesigned. The old S-chicane will be replaced with a new C-chicane which is 3.5m shorter thereby generating space a new section for re-matching the beam from the injector into the linac. The new BCC will be equipped with quad/skew-quad units in both legs of the chicane to compensate correlations of the transverse degrees of freedom with the longitudinal ones. Since quadrupoles tend to have a circular bore, the chicane is designed with movable round vacuum chambers and movable dipoles for maintaining full flexibility in choosing the compression parameters. This article describes the technical details and introduces a thin-lens model of BCCs which allows analytical estimates on the effects of powering the quad/skew-quad units on optics parameters as well as estimates on the required strengths of these magnets in order to remove correlations of the magnitudes typically observed at FLASH.

TUPAB103 **Discussion on CSR instability in EEHG Simulation**

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Echo-Enabled Harmonic Generation (EEHG) is an external seeding technique for XUV and soft X-ray Free Electron Lasers (FEL). It has recently been experimentally demonstrated and currently many facilities worldwide intend to incorporate it in user operation. The EEHG process relies on very accurate and complex transformations of electron beam phase space by means of a series of undulators coupled to lasers and dispersive chicanes. As a result of the phase space manipulation, electrons are bunched at a high harmonic of the seed laser wavelength allowing coherent emission at few nm wavelength. Dispersion occurring in strong chicanes is imperative for implementation of this scheme and effective electron bunching generation. However, strong chicanes at the same time can be source of beam instability effects, such as Coherent Synchrotron Radiation (CSR), that can signif-

icantly grow in these conditions and suppress the bunching process. Therefore, there is a common need to investigate such effects in detail. Here, we discuss their treatment with simulation codes applied to a typical EEHG setup.

TUPAB104 **Redesign of the FLASH2 Post-SASE Undulator Beamline**

F. Christie, *J. Rönsch-Schulenburg, S. Schreiber, M. Vogt, J. Zemella (DESY)*

FLASH2 is one of the two SASE (Self-Amplified Spontaneous Emission) undulator beamlines lines comprising variable gap undulators to produce radiation in the XUV and soft X-ray regime at FLASH. Downstream of the SASE undulators the beamline is currently undergoing a major redesign. During shutdowns in summer 2020 and winter 2021 two PolariX TDSs (Polarizable X-band Transverse Deflecting Structure) were installed, as well as additional diagnostics, to monitor the longitudinal phase space density of the electron bunches. Additionally, an afterburner undulator will be integrated in the next shutdown to produce circularly polarized light with wavelengths down to 1.39 nm. In this paper, we will present the modifications that were and will be made to the electron beamline in the course of this redesign.

TUPAB105 **Simulation Studies for Dark Current Signature From DLS RF Gun**

J. Karmakar, *M. Aggarwal, S. Ghosh, B. Karmakar, P. Patra, B.K. Sahu, A. Sharma (IUAC)*

The Delhi Light source (DLS) is an upcoming compact THz facility at IUAC, New Delhi, based on pre-bunched FEL. RF conditioning of the 2.6 cell S-band RF gun is presently carried out with a Cu photo-cathode (PC) plug and dark current is produced when substantial accelerating field is reached inside the cavity. To identify the possible field emission sites contributing to dark current, single electron ASTRA simulations are done with a phase scan of the RF field. The simulation is extended to include multi-particle emission from the PC edge as a ring. The energies present in the dark current is analysed from the the Fowler Nordheim current plot and energy phase scan plot. The distribution of few dark current energies and their respective trajectories upto the YAG screen at a given solenoid setting is traced and shown in the simulations. We also present the dark current images captured during the initial RF conditioning and try to compare it with the simulations.

TUPAB106 **Simulation Calculations of Compact THz Facility at IUAC, New Delhi**

J. Karmakar, *S. Ghosh (IUAC)*

A compact THz radiation source based on the principle of pre-bunched Free Electron Laser is at the commissioning stage at Inter University Accelerator Centre (IUAC), New Delhi. The facility will generate low emittance train of electron micro-bunches (2, 4, 8 or 16 numbers) from a RF photo-cathode gun in the energy range of 4 to 8 MeV and inject into a compact undulator to generate coherent THz radiation in the frequency range of ~0.18 to 3.0 THz. To optimize the in-

tensity at a given frequency, the beam bunching factor and the betatron oscillation amplitude in the non-wiggling plane of the electronμbunches inside the undulator has been maximized and minimized respectively. The paper presents the optimized beam optics simulation results for two frequencies viz 0.5 and 2 THz. The on-axis radiation spectral intensity computed by in-house developed code using the trajectory data of the beam optics simulation is also presented for the two frequencies.

TUPAB107 **Accelerator and Light Source Research Program at Duke University**

Y.K. Wu *(FEL/Duke University)*

The accelerator and light source research program at Duke Free-Electron Laser Laboratory (DFELL), TUNL, is focused on the development of the storage ring based free-electron lasers (FELs) and a state-of-the-art Compton gamma-ray source, the High Intensity Gamma-ray Source (HIGS) driven by the storage ring FEL. With a maximum total flux of about $3{\cdot}10^{10}$ gamma/s and a spectral flux of more than 1,000 gamma/s/eV around 10 MeV, the HIGS is the world's highest-flux Compton gamma-ray source. Operated in the energy range from 1 to 100 MeV, the HIGS is a premier Compton gamma-ray facility in the world for a variety of nuclear physics research programs, both fundamental and applied. In this work, we will describe our recent light source development to enable the production of gamma rays in the higher energy range from 100 and 120 MeV. We will also provide a summary of our recent accelerator physics and FEL physics research activities.

TUPAB108 **First VUV Oscillator FEL Operation below 170 nm**

Y.K. Wu*, S.F. Mikhailov, M. Pentico, V. Popov, G. Swift, P.W. Wallace, J. Yan (FEL/Duke University) M.W. Ahmed (TUNL)*

The short wavelength operation of FEL oscillators is limited by the availability of high-reflectivity FEL mirrors in the VUV wavelength. We report our success to extend oscillator FEL operation below 170 nm using a storage ring FEL. This progress is based on advanced developments in fabricating radiation robust, thermally stable, high-reflectivity fluoride-based multilayer mirrors. Several thin-film techniques have been optimized to produce high-density coatings and/or protective capping layers to ensure the high performance of the FEL mirrors. Using these fluoride multilayer mirrors (LaF3/MgF2), we have demonstrated FEL lasing from 168.6 to 179.7 nm with excellent stability and reproducibility. This broad lasing range is the result of a relatively large FEL gain (> 22%). Operating this VUV FEL around 173 nm, we have produced the first 120 MeV gamma rays via Compton scattering at the High Intensity Gamma-ray Source (HIGS), opening up a new high energy region of gamma rays for photonulear physics research.

TUPAB109 **Characterization of the X-ray Angular Pointing Jitter in the LCLS Hard X-ray Undulator Line**

***R.A. Margraf**, Z. Huang, J.P. MacArthur, G. Marcus, T. Sato, D. Zhu (SLAC) Z. Huang (Stanford University)*

The angular pointing jitter of X-ray pulses produced by an X-ray Free-Electron Laser (XFEL) depends on both intrinsic properties of the SASE (Self-amplified spontaneous emission) process and jitters in beamline variables such as electron orbit. This jitter is of interest to the Cavity-Based XFEL (CBXFEL) project at SLAC, which will lase seven undulators inside an X-ray cavity of four diamond Bragg mirrors. The CBXFEL cavity has a narrow angular bandwidth, thus large angular jitters cause X-rays to leak out of the cavity and degrade cavity efficiency. To understand contributors to angular pointing jitter, we studied the pointing jitter of the Linac Coherent Light Source (LCLS) Hard X-ray Undulator line (HXU). Monochromatic and pink X-rays were characterized at the X-ray Pump Probe (XPP) instrument. We found pulses with high monochromatized pulse energy and small electron beam orbit in the undulator have the lowest angular pointing jitter. We present here our measurement results, discuss why these factors correlate with pointing stability, and propose a strategy for CBXFEL to reduce angular pointing jitter and account for angular pointing jitter in cavity efficiency measurements.

TUPAB110 **Measurement and Correction of RF Kicks in the LCLS Accelerator to Improve Two-Bunch Operation**

***R.A. Margraf**, F.-J. Decker, Z. Huang, G. Marcus (SLAC) Z. Huang (Stanford University)*

RF kicks, caused by a misalignment of an electron beam and acceleration structure, produce an electron orbit in the accelerator which decreases the final energy of the accelerated electron beam and is detrimental to lasing electron bunches in an X-ray Free Electron Laser (XFEL). RF kicks can depend on the RF waveform of the accelerating structure, so controlling this effect is particularly important when two or more electron bunches are accelerated within an RF fill time. Multi-bunch modes have been successfully developed for the Linac Coherent Light Source (LCLS) accelerator at SLAC, and are being continually improved to accommodate new experiments. One such experiment, the Cavity-Based XFEL (CBXFEL) project will require two electron bunches separated by 218.5 ns which must be identical in energy and orbit. To reduce variation in energy and orbit between the two bunches, we studied the RF kicks produced by each of 75 accelerator segments in the LCLS linac at several RF timings. Here, we discuss these measurements and propose a method to correct RF kicks in the LCLS accelerator using corrector dipoles and quadrupoles.

TUPAB111 **Layout of the Laser Heater for FLASH2020+**

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The major upgrade FLASH2020+ of the FEL user facility FLASH includes an improved injector layout for the generation of the high-brightness electron beam as well as an externally seeded FEL beamline. Microbunching gain of initial modulations or shot-noise fluctuations degrade the electron beam quality, which is in particular harmful to the external seed process. To minimize the microbunching gain by a controlled increase of the uncorrelated energy spread, the installation of a laser heater is foreseen directly upstream of the first bunch compression chicane. In this paper, we present the layout of the laser heater section, which follows the original proposal published almost 20 years ago and differs in several aspects from the common layout implemented at many other FEL facilities. The considerations that have been made for the optimisation of the laser heater parameters are described in detail.

TUPAB112 **SASE FEL Intensity Enhancement by Considering Impact of Self-Seeding Section**

***C.H. Shim** (PAL)*

Most of XFEL facilities have utilized the self-seeding section, which is generally installed in the middle of undulator line,to increase the spectral intensity and the longitudinal coherence. When the SASE FEL is on operation, however, the self-seeding section can disrupt the lasing process of the SASE FEL. Micro-bunching structure in the electron beam, which has been developed along the unudlator line before the section, can be collapsed by the linear longitudinal dispersion of the drift space. In this presentation, we discuss about the impact of self-seeding section on the SASE FEL intensity with GENESIS simulation results. Also, the experimental results will be showed.

TUPAB113 **Highlights From the Conceptual Design Report of the Soft X-Ray Laser at MAX IV**

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The SXL (Soft X-ray Laser) project developed a conceptual design for a soft X-ray Free Electron Laser in the 1|–|5 nm wavelength range, driven by the existing MAX IV 3 GeV linac. In this contribution we will focus on the FEL operation modes developed for the first phase of the project based on two different linac modes. The design work was supported by the Knut and Alice Wallenberg foundation and by several Swedish

universities and organizations (Stockholm, Uppsala, KTH Royal Institute of Technology, Stockholm-Uppsala FEL center, MAX IV laboratory and Lund University).

TUPAB114 **FEL Performance and Beam Quality Assessment of Undulator Line for the Compactlight Facility.**

***H.M. Castañeda Cortés**, D.J. Dunning, N. Thompson (STFC/DL/ASTeC)*

The H_2020 CompactLight Project aims for the design of innovative, cost-effective, compact FEL facilities to generate higher peak brilliance radiation in the soft and hard X-ray. In this paper we assess via simulation studies the performance of a variably polarising APPLE-X afterburner positioned downstream of a helical Super Conducting Undulator (SCU). We discuss the optimum balance between the active SCU length and the afterburner length, considering the peak brilliance and pulse energy of the output. Our studies are complemented with analysis of the optical beam quality of the afterburner output to determine the design constraints of the photon beamline that delivers the FEL output to the experimental areas.

TUPAB115 **Status Report of the Superconducting Free-Electron Laser FLASH at DESY**

***J. Rönsch-Schulenburg**, F. Christie, K. Honkavaara, M. Kuhlmann, S. Schreiber, R. Treusch, M. Vogt, J. Zemella (DESY)*

The free-electron laser in Hamburg (FLASH) is a high brilliance XUV and soft X-ray SASE FEL user-facility at DESY. FLASH's superconducting linac can accelerate several thousand electron bunches per second in 10 Hz bursts of up to 800 µs length. The long bunch trains can be split in two parts and shared between two undulator beamlines. During 2020, FLASH supplied, in standard operation, up to 500 bunches at 10 Hz in two bunch trains with independent fill patterns and compression schemes. The FLASH2 undulator beamline comprises variable gap undulators that allow different novel lasing schemes. A third beamline accommodates the FLASHForward plasma wakefield acceleration experiment. We report on the FLASH operation in 2019 - 2021 and present a few highlights.

TUPAB116 **Toward THz Coherent Undulator Radiation Experiment With a Combination of Velocity Bunchings**

***Y. Sumitomo**, K. Hayakawa, Y. Hayakawa, K. Nogami, T. Sakai, T. Tanaka (LEBRA) N. Sei (AIST)*

We have launched a research program to generate the THz coherent undulator radiations, following the proposal of the combination of velocity bunchings at Nihon University. The combination of velocity bunchings is an efficient way of bunch compression allowing a range of energy choices, in other words, a range of quasi-monochromatic radiation wavelengths generated at the undulator. In addition to the existing wideband THz light sources (0.1 - 2 THz) by the coherent edge and transition radiations currently available at Nihon Univ., the development of a high peak-power and quasi-monochromatic coherent ra-

diation should accelerate the activities including the material science related to the THz bandwidths. In this presentation, we illustrate the program and report the current status of the experiment.

TUPAB117 **Eigenmode Decomposition for Free-Electron Lasers Using Bayesian Analysis**

***P. Liu**, W. Li, Y.K. Wu, J. Yan (FEL/Duke University)*

Laser beams from an optical cavity, such as free-electron laser (FEL) resonators, are typically a mixture of the cavity's eigenmodes, such as the Hermite-Gaussian (HG) modes or Laguerre-Gaussian (LG) modes. Robust evaluation of the eigenmode spectrum of a multimode laser beam has various applications in laser development, research, and utilization. In this work, a general eigenmode decomposition method for a multimode laser beam has been developed based on Bayesian analysis. This problem is transformed into a linear system and then solved using a Gaussian probabilistic model. Using Bayesian analysis, prior knowledge about the mode content is further incorporated into the solution to improve the results for laser beams contaminated with complex disturbances. The decomposition of the beam image from the incoherent intensity addition of HG modes is discussed with different types of noise or disturbances. The simulation results have been used to show the robustness of this method. This method can be straightforwardly extended into other cases such as the wavefront decomposition into the coherent superposition of HG and LG modes.

TUPAB118 **Coherently Mixed Orbital Angular Momentum Photon Beams From a Storage Ring FEL**

***P. Liu**, H. Hao, S.F. Mikhailov, V. Popov, Y.K. Wu, J. Yan (FEL/Duke University) A. Afanasev (GWU) S.V. Benson (JLab)*

Orbital angular momentum (OAM) photon beams have been widely investigated during the past decades and exploited in numerous fields. They have been generated using conventional lasers and linac-based FELs. We report here the first experimental production of coherently mixed (CM) OAM beams from a storage ring FEL. This is achieved by using a special spatial mask to suppress the fundamental modes and provide the necessary cylindrical symmetry for the OAM beams. With this method, up to the fourth-order CM OAM FEL beams have been generated, and measurements using various diagnostic techniques indicate a high quality of the produced CM OAM beams. Using this CM OAM FEL, it becomes possible to produce OAM gamma-rays via Compton scattering. The developed technique can also be readily extended to generate OAM x-rays using an x-ray FEL oscillator.

TUPAB119 **Beam Loss Study for the Implementation of Dechirper at the European XFEL**

***J.J. Guo** (University of Chinese Academy of Sciences) W. Decking, M.W. Guetg, **J.J. Guo**, S. Liu, W. Qin, I. Zagorodnov (DESY) Q. Gu, **J.J. Guo** (SINAP) Q. Gu (Shanghai Advanced Research Institute)*

The European XFEL is a free-electron laser facility based on superconducting linac with high repetition rate up to 4.5 MHz. Wakefield struc-

ture (also called dechirper module) is planned to be installed in front of the SASE beam line at the European FEL, which can be used as a kicker for two-color scheme or a dechirper to control the bandwidth of SASE radiation. When the beam pass through the dechirper module, strong longitudinal and transverse wakefields can be excited to introduce a correlated energy chirp and a kick along the bunch. However, due to the relatively small gap of dechirper, beam halo particles hitting the dechirper module can lead to energy deposition and generate additional radiation, which can cause serious damage to the downstream undulators. For this reason, simulations have been performed using BDSIM to define the maximum acceptable beam halo, and the results are presented in this paper.

TUPAB120 **Sub 10 fs Synchronization of Two Mode Locked Lasers With Two Color Balanced Optical Cross Correlator**

C.L. Li, *X.T. Wang, W.Y. Zhang (Shanghai Advanced Research Institute) H.X. Deng, L. Feng, B. Liu, J.G. Wang (SARI-CAS)*

The Shanghai soft X-ray free electron laser (SXFEL) user facility is under commission. The planned Shanghai high repetition rate X-ray free electron laser and extreme light facility (SHINE) is under construction. The two facilities generate X-ray light pulses in the femtosecond range. For the driver lasers, seed lasers and pump lasers, it is crucial to synchronize these lasers to the same reference timing laser, which can provide ultralow noise optical signals and ultrashort optical pulses in time domain. In this paper, we present the progress of the development of two color balanced optical cross correlator system to synchronize two mode locked laser systems with an accuracy better than 10fs. The system is being tested by locking an 800nm laser oscillator to a reference 1550nm timing laser.

TUPAB121 **Photoinjector Drive Laser Temporal Shaping for Shanghai Soft X ray Free Electron Laser**

C.L. Li, *X.T. Wang, W.Y. Zhang (Shanghai Advanced Research Institute) X.L. Dai (SSRF) H.X. Deng, L. Feng, B. Liu, J.G. Wang (SARI-CAS)*

Shanghai soft X ray free electron laser (SXFEL) initial designed shape of the photocathode driver laser is flattop produced by α-BBO stacking. The advantage of this design is attractive in producing electron bunch with low initial emittance and high uniformity along the electron bunch. However, some unavoidable modulations are generated along the laser pulse which trigger the electron bunch modulation generated at the source, which is due to the fast response time (tens of femtosecond) of copper cathode. In order to eliminate the modulation of electron bunch, temporal Gaussian driver laser was designed and tested, measurement results show the electron bunch longitudinal modulation was removed. In this paper, we present two kinds of driver laser pulse temporal shaping methods based on α-BBO stacking and UV grating pair shaping. Moreover, corresponding electron bunch temporal profile are also presented.

TUPAB122 **SASE3 Variable Polarization Project at the European XFEL**

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At the European XFEL, two undulator systems for hard and one for soft X-rays have been successfully put into operation. The SASE3 soft X-ray undulator system generates linearly polarized radiation in the horizontal plane. One of the requirements for extending the radiation characteristics is the ability to obtain different polarization modes. These include both right and left circular, elliptical polarization, or linear polarization at an arbitrary angle. For this purpose, a system consisting of four APPLE X helical undulators developed at the Paul Scherrer Institute (PSI) is used. This paper presents the design parameters of the SASE3 undulator system after modifying it with the helical afterburner. It also describes the methods and the design solutions different from those used at PSI. The status and schedule of the project are introduced.

TUPAB125 **Studies of Particle Losses From the Beam in the European XFEL Following Scattering by a Slotted Foil**

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One technique for producing short radiation pulses in an FEL involves the use of a slotted foil in a bunch compressor. However, the scattering of particles from the foil can lead to increased particle losses and the generation of secondary particles. This is a particular concern for high rep-rate FELs, such as the European XFEL, where there are plans to implement the slotted-foil technique for short pulse generation. The study reported here aims to characterise the impact of a slotted foil in the European XFEL on the radiation dose in the front section of one of the undulators. Simulations were performed using BDSIM: this code tracks primary particles along the beamline, models the interaction between particles and accelerator components and tracks secondary particles produced by these interactions. The results indicate the amount of energy deposited in the front section of one of the FEL undulators, and provide a basis for optimisation of the collimation system to keep the energy deposition and radiation doses within acceptable limits.

TUPAB126 **Spectral Gap in the Middle Infrared FEL Oscillator of FELiChEM**

Y.P. Zhu, *H.T. Li, Z. Zhao (USTC/NSRL)*

A phenomenon of spectral gap is observed in the Middle Infrared FEL Oscillator of FELiCHEM: the laser power falls down at the particular wavelength. Starting with the experimental data, this paper focuses on the simulation calculation and analysis of the effect from using the partial waveguide. The relationship between waveguide and spectral gap is revealed.

TUPAB127 **Spare Gun Multi-Physics Analysis for LCLS-II**

L. Xiao, *C. Adolphsen, E.N. Jongewaard, X. Liu, C.-K. Ng, F. Zhou (SLAC)*

LBNL APEX VHF normal conducting gun was adopted for LCLS-II CW operation to provide ultra-bright high repetition rate X-ray pulses. The initial LCLS-II gun and injector commissioning showed excessive dark current dominated by field emission around the cathode plug outer diameter and the gun cavity nose. There is a concern that the dark current may get worse with time of operation. It is planning to build a spare rf gun largely based on the current LCLS-II gun to replace current LCLS-II gun. The proposed spare gun has a reduced the peak electrical fields around the cathode plug corner and cavity nose by 10% through further optimizing APEX gun cavity shape. In addition, there are some moderate modifications on the engineering design to increase mechanical robustness and vacuum performance. SLAC developed parallel finite-element electromagnetic code suite ACE3P is used to apply for the spare gun modeling including RF, thermal and structural analysis at static and transient states to ensure its successful operation in LCLS-II. In this paper, the spare gun multi-physics analysis is described.

TUPAB129 **Beam Based Alignment in a Compact THz-FEL Facility**

Q.S. Chen, *T. Hu, K.F. Liu, X. Liu, B. Qin, Y.Q. Xiong (HUST)*

In this paper, we presented the beam based alignment results in a compact THz-FEL facility. The alignment was divided into two sections, the transport line and the optical line. In the transport line, all the five quadrupoles upstream of the undulator were adjusted one by one to fit the electron beam from the traveling wave linac. In the optical line, a set of auxiliary coils were winded on the yokes of the quadrupole downstream of the double bend achromat (DBA) to produce a vertical steering force. Another combined steering magnet, together with the auxiliary coils, corrected the beam orbit in the optical line. With the dispersion free test, the displacement between the magnetic centers of the quads and the beam orbit was less than 0.1mm.

TUPAB131 **Measurement of Coherent Smith-Purcell Radiation Using Ultra-Short Electron Bunch at T-Acts**

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Electron Photon Science)
The coherent Smith-Purcell radiation (SPR) emitted as a short electron bunch passes over a periodic metal surface is expected to be applied as a non-destructive beam diagnostic tool. The longitudinal profile of the electron bunch can be deduced by the measured spectrum of the coherent SPR, which is compared with the theoretical one for single electron. There are several theoretical models that explain the SPR mechanism, such as the surface current (SC) model and the van den Berg model. But the difference of estimation in radiation intensity between different models is not trivial, and also the experimental data to evaluate those validity is not enough. At test accelerator, t-ACTS, in Tohoku University we are conducting experimental research on coherent SPR in the terahertz frequency region using an ultra-short electron bunch of about 100 fs. The status and results of the experiment will be presented.

TUPAB133 **Brazing free RF Pulse Compressor for High Gradient Accelerators**
L. Kankadze, *D. Alesini, F. Cardelli, G. Di Raddo, M. Diomede (INFN/LNF)*
EURPRAXIA@SPARC_LAB, is a proposal to upgrade the SPARC_LAB test facility (at LNF, Frascati) to a soft X-ray user facility based on plasma acceleration and high-gradient X-band (11.9942 GHz) accelerating modules. Each module is made up of a group of 4 TW sections assembled on a single girder and fed by one klystron by means of one rf pulse compressor system and a low attenuation circular waveguide network that transports the rf power to the input hybrids of the sections. The pulse compressor is based on a single Barrel Open Cavity (BOC). The BOC use a 'whispering gallery' mode which has an intrinsically high quality factor and operates in a resonant rotating wave regime. Compared to the conventional SLED scheme it requires a single cavity instead of two cavities and a 3-dB hybrid. A new brazeless mechanical design has been proposed and is described in the present paper together with the electro-magnetic and thermo-mechanical simulations.

TUPAB134 **Linac-to-Booster Optimization Procedure Towards High Transmission for the Alba Injector**
R. Muñoz Horta, *D. Lanaia, E. Marín, F. Pérez (ALBA-CELLS Synchrotron)*
ALBA is a third generation synchrotron light source that consists of 3 accelerators (Linac, Booster and Storage ring) and two transfer lines, Linac-to-Booster (LTB) and Booster-to-Storage (BTS). The ALBA accelerators team has defined a robust procedure that optimizes the beam performance from Linac to Booster in terms of transmission and stability. The implemented beam-based alignment and global orbit correction techniques have been investigated first in simulations and afterwards successfully implemented in the machine.

TUPAB135 **Exascale Modeling of Plasma-Based Particle Accelerators**

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Modeling of advanced particle accelerators often requires significant parallel computing resources. The modern particle-in-cell frameworks WarpX, developed in the Exascale Computing Project, became recently available for desktop- to leadership-scale advanced accelerator modeling. We present the latest capabilities and applications of the WarpX application for advanced accelerator research, including advanced solvers and physics modules.c Furthermore, high-resolution simulations tend to create immense challenges in data-processing capabilities (100s of TBytes to PBytes per simulation), which can limit or even prevent gaining scientific insights from computational modeling. We present scalable analysis methods for in particle accelerator research. Specifically, we will present platform agnostic, including GPU-accelerated, in situ data analysis and visualization techniques. We describe specific implementations in WarpX as well as overarching generalizations in the Open Standard for Particle-Mesh Data (openPMD) community.

TUPAB136 **On Nonlinear Electron Beam Dynamics in a Plasma Environment**

***H.Y. Barminova** (MEPhI) , B. Kak (RUDN University)*

The nonlinear dynamics of an electron beam propagating in a low-density plasma is investigated. The beam envelope equation is obtained analytically for the case of an axisymmetric beam using a model approximation close to the Kapchinsky-Vladimirsky model. Solutions of the envelope equation are presented for various initial conditions (beam current, initial beam radius, transverse beam emittance).

TUPAB137 **Pion-Production Target Design for Mu2e-Ii: Radiation Damage and Thermal Analysis**

***V.S. Pronskikh**, I. Fang, D.V. Neuffer, D. Pushka (Fermilab) K.R. Lynch, J.L. Popp (CUNY)*

The central aim of the Mu2e experiment being built at Fermilab is a search for the neutrinoless conversion of a negative muon into an electron in the field of a nucleus. The baseline Mu2e will be using the 8-kW 8-GeV proton beam to generate pions in a radiatively cooled, finned, segmented tungsten rod target. The future includes a proposed extension of the experiment (Mu2e-II) at the linac complex PIP-II. Mu2e-II will allow improving the sensitivity by increasing the stopped muons in the experiment by another factor of 10 or more. Mu2e-II will probe New Physics mass scales up to 10^5 TeV by utilizing a 10^0-kW proton beam, which requires a new target design. In this talk we discuss our recent progress in R&D for a target station conceptual design for Mu2e-II based on thermal and radiation damage analyses. We use the MARS15 and G4beamline simulation packages to estimate the feasi-

bility of several target options. At the present stage of analysis, our simulations have allowed us to rule out some designs, and to estimate the range of required working parameters and constraints for others under consideration.

TUPAB138 **Determination of the Phase of Wakefield Driven by a Self-Modulated Proton Bunch in Plasma**

***K. Moon**, M. Chung (UNIST) P. Muggli (MPI-P)*

The phase of wakefield driven by a self-modulated proton bunch depends on the type of seeding method and by the beam-plasma parameters. Particularly when a preceding electron bunch generates seed wakefield, the proton bunch modulation is strongly affected by the seed bunch dynamics along with the plasma. Intrinsic wakefield dephasing from self-modulation of proton bunch can lead to complex evolution of the bunch and wakefield, making it difficult to design an experimental setup for witness beam injection. Using the particle-in-cell code FBPIC, we investigate in detail the trends of seed electron and driver proton bunch parameter sensitivity to the phase of wakefield in time in the proton bunch frame. We focus on the parameters affecting the phase of the wakefield through the beam's radial dynamics, such as beam emittance, radial size, energy, and beam to plasma density ratio. Parameter variations are compared to those in the case of the phase of wakefield driven by a non-evolving seed bunch.

TUPAB139 **Laser-Ionized Gas Jet as Passive Underdense Plasma Lens for Relativistic Electron Beams**

***C.E. Doss**, R. Ariniello, J.R. Cary, K.D. Hunt-Stone, V. Lee (CIPS) J.R. Cary (Tech-X) M.D. Litos (Colorado University at Boulder)*

Plasma lensing to focus relativistic electron beams is a promising area of research with many potential applications and regimes of operation. One example is the passive, underdense regime, where focusing fields are provided by the nonlinear blowout wake in the plasma as a driver propagates through. These lenses are characterized by their linear focusing fields and an ability to accommodate electron beams with high energy-density. One method of generating an underdense passive plasma lens is by using a femtosecond laser pulse propagating transversely to the electron beamline to ionize a region of gas in the outflow of a gas jet nozzle. The laser parameters can be adjusted to tune the plasma lens thickness, and the gas jet parameters are adjusted to change the density of the plasma lens. Effects of nonuniform density profiles due to the gas jet outflow profile are analyzed, and early experimental results using a single electron beam at FACET-II are discussed.

TUPAB141 **On the Development of a Low Peak-Power, High Repetition-Rate Laser Plasma Accelerator at IPEN**

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In this work, the current status on the development of a laser plasma

accelerator at the Nuclear and Energy Research Institute (Instituto de Pesquisas Nucleares e Energéticas, IPEN/CNEN), in São Paulo, Brazil, is presented. Short pulses to be produced by an under-development near-TW, kHz laser system will be used to ionize a gas jet, with a density profile designed to optimize the self-injection of plasma electrons. The same laser pulse will also drive a plasma wakefield, which will allow for electron acceleration in the self-modulated regime. The current milestone is to develop the experimental setup, including electron beam and plasma diagnostics, required to produce electron bunches with energies of a few MeV. Once this has been achieved, the next milestone is to produce beams with energies higher than 50 MeV. Besides kickstarting the laser wakefield accelerator (LWFA) technology in Brazil, this project aims to pave the way for conducting research on the production of radioisotopes by photonuclear reactions, triggered by LWFA-accelerated beams.

TUPAB142 **Simulation Study of Laser Wakefield Acceleration Varying the Down-Ramp Length of a Gas Jet**

R.P. Nunes *(UFRGS) , A. Bonatto (Universidade Federal de CiÃªncias da SaÃºde de Porto Alegre) E.P. Maldonado (ITA) R.E. Samad, N.D. Vieira (IPEN-CNEN/SP)*

In this work, particle-in-cell simulations were carried out to investigate the role of the down-ramp length of a H_2 gas jet in accelerating electrons ionized by the laser pulse. The laser and plasma density were chosen so that the system is operating in the self-modulated regime. Preliminary results show how the down-ramp length can control the injection of electrons in the first bubble induced in the plasma by the laser pulse.

TUPAB143 **Laser Pulse Dynamics in the Self-Modulated Regime**

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In this work, particle-in-cell simulations were carried out to investigate the dynamics of a laser pulse propagating along a H_2 gas jet. The laser-driven wakefield and the density of ionized electrons are analyzed during the pulse propagation through the gas jet. The laser and plasma quantities were chosen in order to have the system operating in the self-modulated regime. Results show how the self-modulation fragments the laser pulse, originating higher-amplitude pulses that can induce bubble formation with wave-breaking and particle injection.

TUPAB144 **Beam-Driven Plasma Accelerators as Plasma Cathodes**

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Plasma wakes excited by intense charged particle beams are capable of sustaining GV/m-level accelerating gradients and thereby promise a drastic reduction in size and cost of future particle-accelerator facilities. Beam-driven plasma wakefield accelerators have demonstrated great success in efficiently transferring energy of tens of GeV from a drive to a trailing beam in under a meter. Normally the trailing beams observing the high accelerating gradients are injected into plasma from the same accelerator source as the beams driving the wake. However, the formation of trailing beams inside the plasma accelerator promises considerable improvement in key beam parameters such as emittance and bunch length. The combination of this capability with the strong accelerating gradients suggests that beam-driven plasma cathodes could greatly improve the brightness of electron beams. Recent experimental results obtained at various facilities will be presented, followed by next steps for promising future developments.

TUPAB145 **Methods for Numerical Noise Mitigation in Quasistatic Three-Dimensional Particle-in-Cell Code LCODE3D**

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We discuss a new quasistatic 3D particle-in-cell code LCODE3D for simulating plasma wakefield acceleration, which is a modified version of the quasistatic 2D3V code LCODE, focus on the numerical noise of the plasma solver and propose methods for reducing it. We compare different particle shape functions, as these functions affect the code stability. We also introduce the so-called dual plasma approach, which improves stability and dampens small-scale noise. After applying the proposed methods, the results of the new code closely agree with LCODE simulation results.

TUPAB146 **High Brightness Electron Beams from Dragon Tail Injection and the E-312 experiment at FACET-II**

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The advent of optically triggered injection in multi component plasma wakefield accelerators has been shown to enable a substantial increase

in witness electron beam quality. Here we present a novel way of using the overlap of laser and beam radial fields to locally liberate electrons from the tunneling ionization of the non-ionized gas species. These liberated ultracold electrons gain sufficient energy to be trapped in the accelerating phase at the back of the plasma blowout. This method of controlled injection has advantages in precision timing since injection is locked to peak beam current and has the potential of generating beams with very low emittance and energy spread. This method has been investigated using particle-in-cell (PIC) simulations. This scenario corresponds to a planned experiment, E-312, at SLAC's FACET-II facility.

TUPAB147 **Asymmetric Beam Driven Plasma Wakefields at the AWA**

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In future plasma wakefield acceleration-based scenarios for linear colliders, beams with highly asymmetric emittance are expected. In this case, the blowout region is no longer axisymmetric, but elliptical in cross-section, which implies that the focusing is not equal in the two transverse planes. In this paper, we analyze simulations for studying the asymmetries in flat-beam driven plasma acceleration using the round-to-flat-beam transformer at the Argonne Wakefield Accelerator. Beams with high charge and emittance ratios, in excess of 100:1, are routinely available at the AWA. We use particle-in-cell codes to compare various scenarios including a weak blowout, where the plasma focusing effect exhibits higher order mode asymmetry. Further, practical considerations for tunable plasma density using capillary discharge and laser ionization are compared for implementation into experimental designs.

TUPAB148 **Optical-Period Bunch Trains to Resonantly Excite High Gradient Wakefields in the Quasi-Nonlinear Regime and the E-317 Experiment at FACET-II**

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Periodic electron bunch trains spaced at the laser wavelength created via inverse free electron laser (IFEL) bunching can be used to resonantly excite plasmas in the quasi-nonlinear (QNL) regime. The excitation can produce plasma blowout conditions using very low emittance beams despite having a small charge per bunch. The resulting plasma density perturbation is extremely nonlinear locally, but preserves the resonant response of the plasma electrons at the plasma frequency. This excitation can produce plasma blowout conditions using very low emittance beams despite having a small charge per bunch. To match the resonance condition, the plasma wavelength has to be equal to the laser period of a few microns. This corresponds to a high den-

sity plasma resulting in extremely large wakefield amplitudes. Matching the beam into such a dense plasma requires an extremely short focusing beta function. We present the beam-plasma interaction using quasi-static particle-in-cell (PIC) simulations and discuss the microbunching and focusing mechanism required for this scheme which would be a precursor to the planned experiment, E-317, at SLAC's FACET-II facility.

TUPAB149 **Optical Diagnostics for Density and Width Measurement in PWFA Plasma Source**

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The performance of an electron beam-driven plasma wakefield accelerator (PWFA) requires precise control of its plasma density profile. Deployment of appropriate plasma diagnostic methodologies is, therefore, necessary. The PWFA plasma source is a long and narrow, laser-ionized gas filament, being less than 1 mm in diameter and up to 1 m in length with a typical core density of $10^{16\text{-}18}$ cm^{-3}. Due to its geometry and density range, it is challenging to diagnose accurately. Laser shadowgraphy and plasma afterglow optical imagery are two robust and easily implemented approaches that possess complimentary strengths. The former has an ultrafast response but provides a longitudinally integrated signal. The latter provides fine-scale longitudinal resolution, but its signal is time-integrated. To correctly interpret such time-integrated signals, the temporal evolution of the plasma filament formation and decay is modeled. Experimental results of a method that combines signals of these two methodologies to diagnose the plasma density profile at the time of formation supported by simulations are presented.

TUPAB150 **An Analytic Approach to Describing the Evolution of the Witness Beam in A Plasma Based Accelerator**

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Plasma-based accelerators are a promising alternative to conventional electron accelerators. These plasma-based accelerators must control the dynamics of the accelerated beam (the witness beam) in order to meet the demanding beam requirements of light sources and other applications. Due to the large betatron phase advance in the plasma, chromatic effects play a strong role in shaping the evolution of the beam. We present an analytic approach to calculating evolution of the beam due to these effects. We include the modification of the longitudinal phase space due to acceleration, the effects of mismatch between the beam and the plasma, the effects of transverse offsets between the driver and witness, and the effects of the plasma density ramp. Finally, we show an example of how our approach can be used to optimize a plasma-based, high brightness injector.

TUPAB151 **Energy Stabilization of Laser-Plasma Accelerators**

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Despite outstanding progress in recent years, laser-plasma accelerators still face major challenges towards demonstrating stable, high-quality electron beams. In particular, the large energy spread and jitter, which are typically above the percent range, prevent their use for most practical applications. Here, we present a novel concept for longitudinal phase-space manipulation which can drastically reduce the energy spread and jitter of laser-plasma accelerators to the sub-permille range. This degree of stability and performance would finally allow for their use as compact drivers for coherent light sources, or as injectors for state-of-the-art storage rings. At DESY, this solution is currently being considered for the conceptual design of an advanced 6 GeV laser-plasma injector option for the future PETRA IV synchrotron.

TUPAB152 **Modeling of Emittance Growth Due to Coulomb Collisions with Plasma Electrons in Plasma-Based Accelerators**

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Coulomb collisions with background plasma are one source of emittance degradation in plasma accelerators. This work shows that the emittance growth due to Coulomb collisions can be correctly captured in particle-in-cell (PIC) simulations, with a proper Monte Carlo binary collision module. The theory of the emittance growth due to Coulomb collisions with plasma ions is extended from a monoenergetic matched beam to a mismatched beam with energy spread. Furthermore, collisions with plasma electrons are also added into the theory, which leads to a similar amount of emittance growth in addition to that caused by collisions with ions in the linear acceleration regime. All theoretical estimations are compared with PIC simulation results, and good agreements are achieved.

TUPAB153 **Modeling of Capillary Discharge Plasmas for Wakefield Accelerators and Beam Transport**

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Next generation accelerators demand sophisticated beam sources to reach ultra-low emittances at large accelerating gradients, along with improved optics to transport these beams without degradation. Capillary discharge plasmas can address each of these challenges. As sources, capillaries have been shown to increase the energy and quality of wakefield accelerators, and as active plasma lenses they provide orders-of-magnitude increases in peak magnetic field. Capillaries are sensitive to energy deposition, heat transfer, ionization dynamics, and magnetic field penetration; therefore, capillary design requires careful modeling. We present simulations of capillary discharge plasmas us-

ing FLASH, a publicly-available multi-physics code developed at the University of Chicago. We report on the implementation of 2D and 3D models of capillary plasma density and temperature evolution with realistic boundary and discharge conditions. We then demonstrate laser energy deposition to model channel formation for guiding intense laser pulses. Lastly, we examine active capillary plasmas with varying fill species and compare our simulations against experimental studies.

TUPAB154 **Modeling and Optimization of High Current Thermionic Energy Converters**

***N.M. Cook**, J.P. Edelen, C.C. Hall, Y. Hu, X. Tan (RadiaSoft LLC)*

Thermionic emitters are an essential technology for particle accelerators, enabling high current electron sources for a range of applications. One promising application of these emitters is that of thermionic energy converters, which leverage thermionic emission across a narrow gap with large temperature differentials to act as an efficient heat-to-electricity transformer. Recent advances in emitter materials enable the design and operation of TEC devices with micro-gap spacing, enabling substantive increases in average current and power density, making these devices competitive with or superior to traditional thermoelectrics. However, optimizing the efficiency of these devices requires the consideration of self-consistent effects and particle surface interactions. We present a novel analytical model which predicts the operating characteristics of micro-gap thermionic converters operating in space-charge-limited regimes and in the presence of particle-surface reflections. We validate this model using self-consistent particle-in-cell simulations. Finally, we compute theoretical device efficiencies, and predict device performance for a range of operating conditions.

TUPAB155 **Obtaining Accelerated Electron Bunch of High Quality in Plasma Wakefield Accelerator**

***R.T. Ovsiannikov** (KhNU) I.P. Levchuk (Yarovaya), V.I. Maslov, I.N. Onishchenko (NSC/KIPT)*

Earlier, high-gradient accelerating electrons of a relativistic beam was demonstrated. However, due to dynamic processes in the plasma, there are problems in maintaining the small size and small energy spread of the accelerated electron bunch while maintaining sufficient values of the accelerating wakefields. Also, the question arises about the values of the limiting bunch dimensions at which the accelerating process is stable. To form a stable accelerated electron bunch, a method is usually used that involves the formation of the same accelerating fields at the location of the bunch. The same fields (plateau due to beam loading) in the region of the accelerated bunch allow all its parts to move as a whole, and ensure the preservation of the spatial distribution of electrons over time, which, in fact, means an accelerated beam of good quality. In this report, the problem of electron bunch accelerating by a short or long electron driver-bunch is consid-

ered.

TUPAB156 **Optimal Field Shape, Accelerating Positron Bunch in Plasma Wakefield**

R.T. Ovsiannikov *(KhNU) I.P. Levchuk (Yarovaya), V.I. Maslov, I.N. Onishchenko (NSC/KIPT)*

The quality of the electron or positron beam, accelerated in plasma accelerators, is still insufficient for applications. Accurate control over the properties of the electron or positron beam is a key issue for wakefield plasma accelerators. The effect of the presence of a witness-beam (the effect of the spatial charge distribution of the witness beam) to compensate the energy spread of the positron beam in plasma wakefield accelerators has been studied. This paper presents the results of a numerical simulation on the optimization of the parameters of the driver-bunch and witness-bunch for the formation of a self-consistent longitudinal distribution of the accelerating plateau-type field, which leads to the same values of the wakefield for the whole bunch of accelerated particles and minimizing bunch degradation during acceleration by means of an ion-driver-bunch with external injection into the plasma wake accelerator. The dependence of the longitudinal distribution of the accelerating wakefield on the density and shape of the accelerated bunch in the blowout regime was investigated. Plateau formation and energy spread compensation were observed.

TUPAB157 **Obtaining Long Accelerated Electron Bunch of Good Quality in Plasma Wakefield Accelerator at High Transformer Ratio**

R.T. Ovsiannikov *(KhNU) I.P. Levchuk (Yarovaya), V.I. Maslov, I.N. Onishchenko (NSC/KIPT)*

The efficiency of electron acceleration by a wakefield, excited in a plasma by an electron bunch, is determined by the transformer ratio. The transformer ratio is the ratio of energy acquired by the witness to energy lost by the driver. The transformer ratio can be increased by shaping driver-bunch. In this work, using a non-linear version of the 2d3v code lcode, numerical simulation of excitation of a wakefield in a plasma in blowout regime by a shaped relativistic electron bunch was performed. There is also the problem of maintaining the small dimension and small energy spread of the accelerated electron bunch while maintaining sufficient values of the accelerating gradient and the transformer ratio. Also, the question arises about the values of the limiting dimension of the witness-bunch at which the acceleration process is stable. Numerical simulation solves the problem of electron bunch acceleration of the best quality with simultaneous maximization of the transformer ratio and maximization of the witness bunch length, at which the accelerating gradient and the focusing force are constant.

TUPAB158 **Electron Witness Constraints for AWAKE**

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The AWAKE project at CERN successfully demonstrated the use of a

proton driver to accelerate an electron witness in plasma. One of the key goals for AWAKE Run2 is to better control this acceleration, separating the proton-beam-modulation and electron-acceleration stages in order to achieve high energy electrons with high beam quality. Controlled acceleration additionally requires careful tuning of the witness bunch parameters at the injection point. In this work, we use particle-in-cell simulations to study the tolerances for this matching, and discuss techniques to loosen these constraints.

TUPAB159 **Awake Run 2 at CERN**

E. Gschwendtner *(CERN)*

The AWAKE Run 2 experiment, starting in 2021 at CERN, aims to achieve high-charge bunches of electrons accelerated to high energy (~10 GeV) while maintaining beam quality. AWAKE Run 2 also aims to show that the process is scalable so that, by the end of the run, the AWAKE-scheme technology could be used for first particle physics applications. The first two phases of Run 2 include the investigation of the seeding of the proton bunch self-modulation with the current electron beam in the existing AWAKE facility and the test of a second new plasma source with a density step allowing to maintain strong accelerating fields. In the third phase of Run 2, electrons with an energy of 150 MeV, produced in a newly installed electron source, will be injected into a second plasma source and accelerated to high energies (several GeVs) while keeping good emittance. In the fourth phase, it is planned to replace the second plasma source with a scalable one, which eventually could be used for long-distance acceleration and first applications. In this paper, we present the program of the four phases of AWAKE Run 2, the technical challenges and the proposed schedule.

TUPAB160 **Preparation for Electron-Seeding of Proton Bunch Self-Modulation in AWAKE**

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The next milestone of the Advanced Wakefield Experiment (AWAKE) at CERN will be to demonstrate that the self-modulation of a long proton bunch can be seeded by a short electron bunch preceding it. This seeding method will lead to phase-reproducible self-modulation of the entire proton bunch, as required for the future AWAKE program. In the Spring of 2021, before receiving proton beams from the CERN SPS, AWAKE plans to hold a dry run of the electron seeding experiments, to commission the system and to determine the parameter scans that will be used in experiments with protons. Electron bunches of 10^{-20} MeV with varying charge, radius, emittance and energy will be sent in 10 m of low-density plasma. The effects of beam-plasma interactions on the amplitude of the wakefields driven by the different bunches will be studied by observing the energy spectra at the end of the plasma. This paper presents preliminary experimental results from the first two days of measurements as well as the beginning of a simulation-based study of electron propagation in plasma.

TUPAB162 **EMP Generation by Laser-Plasma Interaction**

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The 2D optical field ionization of neutral gases and the subsequent plasma expansion has been computed using the VSim particle-in-cell computational application. Ionization by the laser pulse generates a plasma column, and the time-dependent ponderomotive force from the laser envelope drives plasma oscillations in the direction of laser propagation within this column. This plasma current then generates an electromagnetic pulse that radiates into the surrounding neutral gas. We present simulation results to characterize this terahertz EMP behavior for varying plasma and laser parameters, and we develop a model for the generation and evolution of the EMPs. We demonstrate the potential to extract diagnostic parameters, like the plasma density or the laser's normalized vector potential, from an observed EMP through the application of this model. In addition, we present 2D PIC simulation results for the formation of plasma channels as potential laser-plasma accelerators.

TUPAB163 **Developing a 50 MeV LPA-Based Injector at ATHENA for a Compact Storage Ring**

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The laser-driven generation of relativistic electron beams in plasma and their acceleration to high energies with GV/m-gradients has been successfully demonstrated. Now, it is time to focus on the application of laser-plasma accelerated (LPA) beams. The "Accelerator Technology HElmholtz iNfrAstructure" (ATHENA) of the Helmholtz Association fosters innovative particle accelerators and high-power laser technology. As part of the ATHENAe pillar several different applications driven by LPAs are to be developed, such as a compact FEL, medical imaging and the first realization of LPA-beam injection into a storage ring. The latter endeavor is conducted in close collaboration between Deutsche Elektronen-Synchrotron (DESY), Karlsruhe Institute of Technology (KIT) and Helmholtz Institute Jena. In the cSTART project at KIT, a compact storage ring optimized for short bunches and suitable to accept LPA-based electron bunches is in preparation. In this conference contribution we will introduce the 50 MeV LPA-based injector and give an overview about the project goals. The key parameters of the plasma injector will be presented. Finally, the current status of the project will be summarized.

TUPAB164 **Modulation Frequency of a Proton Bunch in Plasmas With Density Gradients**

P.I. Morales Guzman, *F. Batsch, P. Muggli, T. Nechaeva (MPI-P) A.-M. Bachmann (MPI) J.M. Vieira (IPFN)*

We study the details of the modulation frequency of a 400 GeV, long proton bunch undergoing self-modulation (SM) in a plasma with linear density gradients. We compare modulation frequencies of slices at various transverse positions of time-resolved images of the bunch obtained in the AWAKE experiment to those produced by the particle-in-cell code OSIRIS and show that there is good agreement. Using simulations, we look into the evolution of the system along the propagation. We found that for negative gradients, the modulation frequency of the bunch core adapts to the local plasma frequency. This is not the case for positive gradients. Theory predicts that the wakefields' phase velocity slows down along the bunch and along the propagation during SM growth. This phase slippage is affected by the one introduced by the gradients, leading to the different frequency responses. We also show that in simulations the closest agreement between local plasma frequency and modulation frequency among the gradient used, occurs for 0.5 %/m. At this value, considering the wakefields' amplitude and dephasing, the maximum possible energy gain of an injected electron bunch is the largest.

TUPAB165 **Transition From Instability-Based to Phase-Controlled Self-Modulation of a Relativistic Particle Bunch in Plasma**

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We experimentally demonstrate different self-modulation (SM) regimes of a relativistic proton bunch in the beam-driven plasma wakefield accelerator AWAKE. A relativistic ionization front in plasma provides various initial wakefield amplitudes for the SM of a long proton bunch, depending on relative position within the bunch. Results show that when the ionization front is placed near the bunch head, the bunch self-modulates at the plasma frequency but with a random, uncontrolled modulation phase distribution. By moving the ionization front closer to the bunch center, i.e., by increasing the initial transverse wakefields, we seed the SM and obtain control over the phase of the micro-bunches. Their phase, and thus the phase of the wakefields that externally injected electrons experience is reproducible from event to event with 3 to 7% rms variations all along the bunch. The phase reproducibility is a key requirement for deterministic external electron injection into the accelerating and focusing wakefields. The observation of the transition between these two SM regimes is an important finding for the design of SM-based accelerators in general.

TUPAB166 **A New Design of a Dressed Balloon Cavity With Superior Mechanical Properties**

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Superconducting spoke cavities are prone to multipactor - resonant raise of a number of electrons due to secondary emission. Recently proposed and tested by TRIUMF balloon-type spoke cavity showed an outstanding multipactor (MP) suppression property but unfortunately serious Q degradation at high fields. A new fully developed design of a dressed balloon cavity which can be used for any proton linac SSR2 section is developed. The design incorporates additional EP ports for high Q-factor demonstration. Superior properties are demonstrated, such as effective multipactor suppression, 40% lower Lorentz force coefficient, zero sensitivity to external pressure. This paper presents the results of coupled structural Multiphysics analysis, and engineering design of the dressed balloon cavity with EP ports.

TUPAB167 **Status of SRF Conduction Cooled Photogun for UED/UEM**

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Benefiting from the rapid progress on RF photogun technologies in the past two decades, the development of MeV range ultrafast electron diffraction/microscopy (UED and UEM) has been identified as an enabling instrumentation. UEM or UED use low power electron beams with modest energies of a few MeV to study ultrafast phenomena in a variety of novel and exotic materials. SRF photoguns become a promising candidate to produce highly stable electrons for UEM/UED applications because of the ultrahigh shot-to-shot stability compared to room temperature RF photoguns. SRF technology was prohibitively expensive for industrial use until two recent advancements: Nb_3Sn and conduction cooling. The use of Nb_3Sn allows to operate SRF cavities at higher temperatures (4K) with low power dissipation which is within the reach of commercially available closed-cycle cryocoolers. Euclid is developing a continuous wave (CW), 1.5-cell, MeV-scale SRF conduction cooled photogun operating at 1.3 GHz. In this paper, the technical details of the design and first experimental data are presented.

TUPAB168 **Beam Commissioning of a 325MHz Proton IH-DTL at Tsinghua University**

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The inter-digital H-mode drift tube linac (IH-DTL) is widely used as the main component of injectors for medical synchrotrons. This paper describes the beam commissioning of a compact 325 MHz IH-DTL with modified KONUS beam dynamics at Tsinghua University (THU). This

IH-DTL accelerates the proton beam from 3 MeV to 7 MeV in 1m. The average energy of the beam is 7.0 MeV with the energy spread range of -0.6 MeV to 0.3 MeV. The output transverse normalized RMS emittance of the beam is 0.58 (x)/0.58 (y) pi mm mrad with the input emittance of 0.43 (x)/0.37 (y) pi mm mrad. The beam test results show good agreement with the beam dynamics design.

TUPAB169 **Overall Concept Design of a Heavy-Ion Injector for XiPAF-Upgrade**

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A heavy-ion injector can be used for SEE study. In this paper, the primary beam dynamics design of a heavy-ion injector for the XiPAF upgrade is presented. The injector consists of an ECR heavy-ion source, a LEBT, an RFQ, and a DTL. The mass charge ratio can be up to 6.5. The RFQ can accelerate heavy ions to 500keV/u, and the DTL can accelerate the ions to 2 MeV/u, which can meet the requirement of the synchrotron.

TUPAB170 **Decoupling Transverse Coupled Beam in a DTL With Tilted PMQs**

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The coupling of the beam is widely studied in the accelerator physics field. Projected transverse emittances easily grow up if the beam is transversely-coupled. If we decouple the transverse coupled beam, the transverse emittance can be small. The matrix approach based on the symplectic transformation theory for decoupling the coupled beam is summarized. For a proton accelerator, the transverse coupled beam is introduced by an RFQ tilted by 45^{o}. The beam is decoupled with the first five tilted quadrupoles mounted in the DTL section. A study on the gradient choice of the quadrupoles and the space charge effect is given in this paper.

TUPAB171 **Linear Transfer Matrix of a Half Solenoid**

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Solenoid magnets can provide strong transverse focusing to electrons and ions with relatively small energies. For the ECR heavy-ion source, the ions are extracted at the central area of the solenoid, the beam is coupled at the exit of the source. The coupling caused by the solenoids can lead to the growth of projected transverse emittance, which has been widely studied with great interest. It is important to study the transfer matrix of a half solenoid to study the beam optics in an ECR souce, thus the property of the beam can be given. Based on the transfer matrix calculation, the summary of the linear transfer matrix of a

half solenoid can be given. The beam optics in a half solenoid is studied.

TUPAB172 **Quadrupole Magnet Design for a Heavy-Ion IH-DTL**
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Xi'an Proton Application Facility (XiPAF) will be upgraded to provide heavy-ion beams with a heavy-ion injector. The injector consists of an ECR heavy-ion source, a Low Energy Beam Transport line (LEBT), a Radio Frequency Quadrupole (RFQ), an Interdigital H-mode Drift Tube Linac (IH-DTL), and a Linac to Ring Beam Transport line (LRBT). The IH-DTL can accelerate the ions with mass to charge up to 6.5 from 0.4 MeV/u to 2 MeV/u. To provide transverse focusing, the electromagnetic quadrupoles are installed inside the drift tubes of IH-DTL, thus the magnet needs to be high-gradient and compact. This paper gives the quadrupole magnet design for the heavy-ion IH-DTL. The results show that the quadrupole magnet design can meet the requirements.

TUPAB173 **ESS Drift Tube Linac Manufacturing, Assembly and Tuning**
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The Drift Tube Linac (DTL) for the ESS Linac will accelerate H^+-beams of up to 62.5 mA peak current from 3.62 to 90 MeV. The structure consists of five cavities. The first cavity (DTL1) is a 7.6 m long tank containing 60 drift tubes, 23 fixed tuners, 3 movable tuners and 24 post-couplers, operating at a frequency of 352.21 MHz and an average accelerating field of 3.0 MV/m. The cavity is now assembled at ESS, the results of alignment and tuning are here presented. The DTL1 "as-built" as been analyzed from the beam dynamics point of view. The manufacturing of DTL4 and DTL3 is completed and they are now under assembly at ESS. DTL2 and DTL5 manufacturing will be completed within 2021. The paper describes the production and assembly stages, with a focus on the statistics of quality check in terms of metrology, alignment, leak tests.

TUPAB174 **Basic Design Study for Disk-Loaded Structure in Muon LINAC**
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The world's first disk-loaded structure (DLS) at the high-velocity part of a muon LINAC is under development for the J-PARC muon g-2/EDM

experiment. We have simulated the first designed constant impedance DLS to accelerate muons from ß = 0.7 to 0.94 at an operating frequency of 1296 MHz and a phase of -10 degrees to ensure longitudinal acceptance and have shown the quality of the beam meets our requirements. Because the structure needs a high RF power of 80 MW to generate a gradient of 20 MV/m, a constant gradient DLS with the higher acceleration efficiency is being studied for lower operating RF power. In this poster, we will show the cell structure design yielding a gradient of 20 MV/m with lower RF power.

TUPAB175 **ESSnuSB Linac and Transfer Line: Lattice Design and Error Studies**

***N. Blaskovic Kraljevic**, M. Eshraqi, B.T. Folsom (ESS)*

The ESS neutrino superbeam (ESSnuSB) project is being studied as an upgrade to the European Spallation Source (ESS). This proposed upgrade consists of adding an H^- source to the existing beamline in order to send H^- pulses in between proton pulses, effectively doubling the beam power from 5 MW to 10 MW. In this contribution, we present the 2.5 GeV linear accelerator (linac) lattice and the design of the transfer line from the linac to the accumulator ring, where pulses would be stacked to achieve short proton pulses of high intensity. The results of error studies, quantifying the effect of accelerator imperfections and H^- ion stripping losses on the beam transport through the linac and transfer line, are also presented.

TUPAB176 **ESS Proton Beam Trajectory Correction**

***N. Blaskovic Kraljevic**, M. Eshraqi, N. Milas, R. Miyamoto (ESS)*

The proton linac of the European Spallation Source (ESS) is under construction in Lund, Sweden. Beam trajectory correction is essential to mitigate the effect of accelerator element misalignment, constituting the first step to minimise beam losses. The correction will be performed using correctors distributed along the accelerator, based on the beam position monitor (BPM) readout. Three trajectory correction techniques are considered: one-to-one steering, Singular Value Decomposition (SVD), and MICADO (selecting a subset of correctors for the trajectory correction). The performance of the three methods is simulated for the ESS linac and a comparison of the outcomes is presented.

TUPAB177 **Simulating Magnetized Electron Cooling for EIC with JSPEC**

***S.J. Coleman**, D.L. Bruhwiler, B. Nash, I.V. Pogorelov (RadiaSoft LLC) H. Zhang (JLab)*

We present a possible electron cooling configuration for the proposed Electron Ion Collider (EIC) facility, developed using a Nelder-Mead Simplex optimization procedure built into JSPEC, an electron cooling code developed at Jefferson Lab. We show the time evolution of the emittance of the ion beam in the presence of this cooler evaluated assuming the ion distribution remains Gaussian. We also show that bi-gaussian distributions emerge in simulations of ion macro-particles. We show how intra-beam scattering can be treated with a core-tail

model in simulations of ion macro-particles. The Sirepo/JSPEC and Sirepo/Jupyter apps will be presented, with instructions enabling the community to reproduce our simulations.

TUPAB178 **Recommissioning of the CRYRING@ESR Electron Cooler**
***C. Krantz**, Z. Andelkovic, C. Dimopoulou, W. Geithner, T. Hackler, F. Herfurth, R. Hess, M. Lestinsky, E. Menz, A. Reiter, J. Roßbach, C. Schroeder, A. Täschner, G. Vorobjev (GSI) C. Brandau, S. Schippers (Justus-Liebig-University Giessen, I. Physics Institute, Atomic and Molecular Physics) V. Hannen, D. Winzen (Westfälische Wilhelms-Universität Münster, Institut für Kernphysik) C. Weinheimer (Institut für Kernphysik, Westfälische Wilhelms-Universität Münster)*
The heavy-ion storage ring CRYRING has been recommissioned downstream of GSI's ESR, which it complements as dedicated low-energy machine. A key element of CRYRING@ESR is its electron cooler, which features one of the coldest electron beams available. This enables efficient phase-space cooling and, in addition, provides very high energy resolution when used as internal electron target. We report on technical upgrades that have been made as part of the re-installation of the cooler at GSI/FAIR and share first results obtained after recommissioning.

TUPAB179 **Design of an MBEC Cooler for the EIC**
***W.F. Bergan**, P. Baxevanis, M. Blaskiewicz, E. Wang (BNL) G. Stupakov (SLAC)*
Reaching maximal luminosity for the planned electron-ion collider (EIC) calls for some form of strong hadron cooling to counteract beam emittance increase from IBS. We discuss plans to use microbunched electron cooling (MBEC) to achieve this. The principle of this method is that the hadron beam will copropogate with a beam of electrons, imprinting its own density modulation on the electron beam. These electron phase space perturbations are amplified before copropogating with the hadrons again in a kicker section. By making the hadron transit time between modulator and kicker dependent on hadron energy and transverse offset, the energy kicks which they receive from the electrons will tend to reduce their longitudinal and transverse emittances. We discuss details of the analytic theory and searches for optimal realistic parameter settings to achieve a maximal cooling rate while limiting the effects of diffusion and electron beam saturation. We also place limits on the necessary electron beam quality. These results are corroborated by simulations.

TUPAB180 **Plasma Simulations for an MBEC Cooler for the EIC**
***W.F. Bergan** (BNL)*
In order to reach its maximum luminosity, the electron-ion collider (EIC) is being designed to use microbunched electron cooling (MBEC) to cool the hadron beam. This involves having the hadron beam imprint on a beam of electrons, enhancing the perturbations in the electron beam using the microbunching instability, and feeding back on

the original hadron beam to correct deviations in hadron energy, and, through the use of dispersion, the transverse emittances. This process has been modelled analytically in the linear regime. However, in order to maximize the cooling rate, we wish to know how much saturation in the electron beam is acceptable before the effects of nonlinearity cause significant deviations from the analytic results. To understand this, we have developed a code to do fast one-dimensional plasma simulations of hadrons and electrons as they move through the MBEC section of the EIC. In addition to permitting us to understand the effects of saturation, other effects are included which do not fit easily in the analytic formalism.

TUPAB181 **Demonstration of Electron Cooling using a Pulsed Beam from an Electrostatic Electron Cooler**

M.W. Bruker, *S.V. Benson, A. Hutton, K. Jordan, T. Powers, R.A. Rimmer, T. Satogata, A.V. Sy, H. Wang, S. Wang, H. Zhang, Y. Zhang (JLab) J. Li, F. Ma, X.M. Ma, L.J. Mao, X.P. Sha, M.T. Tang, J.C. Yang, X.D. Yang, H.W. Zhao (IMP/CAS) H. Zhao (BNL)*

Electron cooling continues to be an invaluable technique to reduce and maintain the emittance in hadron storage rings in cases where stochastic cooling is inefficient and radiative cooling is negligible. Extending the energy range of electron coolers beyond what is feasible with the conventional, electrostatic approach necessitates the use of RF fields for acceleration and, thus, a bunched electron beam. To experimentally investigate how the relative time structure of the two beams affects the cooling properties, we have set up a pulsed-beam cooling device by adding a synchronized pulsing circuit to the conventional electron source of the CSRm cooler at Institute of Modern Physics. We show the effect of the electron bunch length and longitudinal ion focusing strength on the temporal evolution of the longitudinal and transverse ion beam profile and demonstrate the detrimental effect of timing jitter as predicted by theory and simulations. Compared to actual RF-based coolers, the simplicity and flexibility of our setup will facilitate further investigations of specific aspects of bunched cooling such as synchro-betatron coupling and phase dithering.

TUPAB182 **The Electron Cooling for High Energy**

V.B. Reva, *E.A. Bekhtenev, O.V. Belikov, M.I. Bryzgunov, A.V. Bubley, V.A. Chekavinskiy, A.P. Denisov, M.G. Fedotov, A.D. Goncharov, K. Gorchakov, V.C. Gosteyev, I.A. Gusev, G.V. Karpov, M.N. Kondaurov, V.R. Kozak, N.S. Kremnev, V.M. Panasyuk, V.V. Parkhomchuk, A.V. Petrozhitskii, D.N. Pureskin, A.A. Putmakov, D.V. Senkov, K.S. Shtro, D.N. Skorobogatov, R.V. Vakhrushev, A.A. Zharikov (BINP SB RAS)*

The project of new accelerator complex NICA relating to nuclear and hadron physics require a more powerful longitudinal and transverse cooling that stimulates searching new technical solutions. The new accelerator complex NICA is designed at the Joint Institute for Nu-

clear Research (JINR, Dubna, Russia) to do experiment with ion-ion and ion-proton collision in the energy range 1-4.5 GeV/u for studying the properties of dense baryonic matter at extreme values of temperature and density with planned luminosity 10^{27} $cm^{-2}s^{-1}$. This value can be obtained with help of very short bunches with small transverse size. This beam quality can be realized with help of stochastic and electron cooling at energy of the physics experiment. The electron cooling system on 2.5 MeV consists of two coolers, which cool both ion beams simultaneously. The Budker Institute of Nuclear Physics (BINP SB RAS) has already built and commissioned the electron cooling system for the NICA booster, and now it develops the high voltage electron cooling system for the collider. The article describes the construction and status of the cooler development.

TUPAB185 **Improved Beam Control at COSY Jülich**

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The need to improve beam control at the COSY facility resulted in numerous upgrades of parts of the control system as well as beam instrumentation hardware over the last few years. The effort was also supported by the regular magnet alignment campaigns. Beam based alignment, automatic orbit correction and ORM measurements benefitted from the EPICS-based access to the orbit control and beam instrumentation devices. The upgrades of the BPM system that included bunch-by-bunch data processing and automatic in-situ gain calibration enabled the reduction of the orbit rms deviation to submillimeter levels. Automated retrieval of accelerator parameters from the database and deeper integration of the machine model by means of GitLab CI-CD functionality lead to shorter machine setup time and better reproducibility of parameters. New Save&Restore and alarming functionality as well as upgrading the Control System Studio (CSS) improved the user experience in the control room. The fast progress was made possible by the close collaboration between IKP and the industry partner Cosylab d.d. We discuss the most recent upgrades and machine performance as well as further plans.

TUPAB186 **Longitudinal Dynamics in the Prototype vFFA Ring for ISIS2**

D.J. Kelliher, *J.-B. Lagrange, S. Machida, C.R. Prior, C.T. Rogers (STFC/RAL/ISIS) A.P. Letchford, J. Pasternak (STFC/RAL) J. Pasternak (Imperial College of Science and Technology, Department of Physics) E. Yamakawa (JAI)*

A vertical Fixed Field Accelerator (vFFA) is a candidate for a future high-power (MW-class) spallation source at ISIS. In order to assess the feasibility of this novel ring, a prototype is currently being designed. Here we consider the longitudinal dynamics in the prototype ring. A key requirement of future neutron spallation sources is flexibility of operation to best serve multiple target stations. Beam stacking allows a rapid cycling, high intensity machine to operate at lower repetition

rates but with higher peak output. Here we show how beam stacking can be realised in the vFFA while minimising the peak RF voltage required.

TUPAB187 **Reconstruction of U400M Cyclotron: Upgrade of U400M Cyclotron Magnetic Structure**

I.A. Ivanenko, *G.G. Gulbekyan, I.V. Kalagin, N.Yu. Kazarinov, N.F. Osipov, V.A. Semin (JINR)*

U400M isochronous cyclotron was created on the base of U300 classic cyclotron and is under operation at FLNR, JINR since 1996. At the present time the cyclotron electromagnet with 4 meter pole diameter needs a reconstruction that includes a replacement of magnet main coil, corrections of the magnetic field at the central region and at the extraction radius. For measurements and shimming of cyclotron magnetic field the automatic mapping system, based on 14 Hall probes, will be created.

TUPAB188 **InnovaTron: An Innovative High-Intensity Industrial Cyclotron for Production of Tc-99m and Other Frontier Medical Radioisotopes**

G. D'Agostino, *Q. Flandroy, E. Forton, W.J.G.M. Kleeven, J. Mandrillon, V. Nuttens, E. van der Kraaij (IBA)*

Tc-99m is the most used radioisotope in nuclear medicine. It is almost exclusively produced with a few ageing research reactors worldwide. In response to growing concerns about Tc-99m availability and its increasing demand, alternative production routes are being explored. The EU-funded InnovaTron project aims at designing an innovative compact high-intensity self-extracting cyclotron able to deliver proton beams with currents up to 5 mA or more for the direct production of Tc-99m. It could be also used for production of high quantities of other frontier medical radioisotopes. The proton beams exit without using an electrostatic deflector to overcome its current limitations. A prototype cyclotron was built by IBA in 2001. Currents up to 2 mA were extracted from it. However, at higher intensities, the extraction efficiency was not higher than 70-75% and the extracted emittance was rather large. The InnovaTron project will implement new technological solutions in the self-extracting cyclotron to be used for large-scale industrial applications. An overview on the InnovaTron project is here presented together with the first simulation results.

TUPAB189 **Design and Simulation of Beam Transport Lines of DC140 Cyclotron**

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Flerov Laboratory of Nuclear Reaction of Joint Institute for Nuclear Research carries out the works under creating of FLNR JINR Irradiation Facility based on the cyclotron DC140. The DC140 cyclotron is intended for acceleration of heavy ions with mass-to-charge ratio A/Z within interval from 5 to 5.5 up to two fixed energies 2.124 and 4.8 MeV per unit mass. The intensity of the accelerated ions will be

about 1 pmcA for light ions (A<86) and about 0.1 pmcA for heavier ions (A>132). The beam transport system has three lines: for SEE testing of microchip, for production of track membranes and for solving of applied physics problems. The design and simulation of the beam transport system from cyclotron is presented in this report. The beam focusing in the beam lines is provided by set of quadrupole lenses. The beam diagnostics system consists of the Faraday caps, luminophores and the magnetic scanning system.

TUPAB190 **Design and Simulation of the Extraction System of DC140 Cyclotron**

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Flerov Laboratory of Nuclear Reaction of Joint Institute for Nuclear Research carries out the works under creating of FLNR JINR Irradiation Facility based on the cyclotron DC140. The facility is intended for SEE testing of microchip, for production of track membranes and for solving of applied physics problems. The DC140 cyclotron is intended for acceleration of heavy ions with mass-to-charge ratio A/Z within interval from 5 to 5.5 up to two fixed energies 2.124 and 4.8 MeV per unit mass. The intensity of the accelerated ions will be about 1 pmcA for light ions (A<86) and about 0.1 pmcA for heavier ions (A>132). The system based on four main elements - electrostatic deflector, focusing magnetic channel, Permanent Magnet Quadrupole lens and steering magnet is used in the DC140 cyclotron for extraction of the accelerated beam. The design and simulation of the beam extraction system from the DC140 cyclotron are presented in this report.

TUPAB191 **Design and Simulation of the Axial Injection Beam Line of DC140 Cyclotron of FLNR JINR**

N.Yu. Kazarinov, *V. Bekhterev, G.G. Gulbekyan, I.A. Ivanenko, I.V. Kalagin, S.V. Mitrofanov, N.F. Osipov, V.A. Semin (JINR) Lisov,V.I. Lisov (JINR/FLNR)*

Flerov Laboratory of Nuclear Reaction of Joint Institute for Nuclear Research carries out the works under creating of FLNR JINR Irradiation Facility based on the cyclotron DC140. The facility is intended for SEE testing of microchip, for production of track membranes and for solving of applied physics problems. The main systems of DC140 are based on the DC72 cyclotron ones that now are under reconstruction. The DC140 cyclotron is intended for acceleration of heavy ions with mass-to-charge ratio A/Z within interval from 5 to 5.5 up to two fixed energies 2.124 and 4.8 MeV per unit mass. The intensity of the accelerated ions will be about 1 pmcA for light ions (A<86) and about 0.1 pmcA for heavier ions (A>132). The injection into cyclotron will be realized from the external room temperature 18 GHz ECR ion source. The design and simulation of the axial injection system of the DC140 cyclotron is presented in this report.

TUPAB192 **Studies on Momentum Collimation for CSNS-RCS Upgrades**
***Y.W. An**, J. Chen, S.Y. Xu, Y. Yuan (IHEP) X.H. Lu, J.B. Yu (IHEP CSNS)*
The CSNS project was a high intensity pulsed facility, and achieved the the design goal of 100kW in 2020. The upgrades of the CSNS are proposed, and the momentum collimator is a component of the upgrades. This paper will show the design scheme of the momentum collimator and the simulation results are also presented.

TUPAB193 **Operation and Maintenance of Chinese Spallation Neutron Source Stripper Foil**
***J.X. Chen**, X.J. Nie, A.X. Wang, Y.J. Yu (IHEP CSNS) L. Kang, L. Liu (IHEP) J.B. Yu (DNSC)*
The stripper foil system is the essential equipment of the spallation neutron source to achieve negative hydrogen injection. More than 99% of negative hydrogen ions complete the charge stripper in the primary stripper foil during the injection process. The remaining ions will lead to the in-dump after the secondary foil or absorbed by the negative hydrogen scraper. This paper introduces some work records of operation and maintenance of stripper foil system.

TUPAB194 **Operation Status of CSNS/RCS Transverse Collimation System**
***J.B. Yu**, J.X. Chen, L. Liu, X.J. Nie, C.J. Ning, G.Y. Wang, A.X. Wang, J.S. Zhang (IHEP CSNS) L. Kang, Q.B. Wu, S.Y. Xu (IHEP)*
In order to meet the requirements of daily maintenance of CSNS/RCS, the transverse collimation system was designed to concentrate the uncontrollable beam loss in this region. Based on physical parameters, considering the processing technology, the area was rationally arranged; combined with the requirements of physical and radiation protection, under the premise of meeting the use requirements, fully consider the limit switch, mechanical hard limit and other components, increasing the output control signals of rotary encoder and displacement sensor, the movement of the absorbers were monitored. At present, the beam collimation system has been running with no mechanical failure for two years on CSNS, and it plays an active role in beam power boost and beam loss control, which proves that the structural design of the system is reasonable.

TUPAB195 **Local Orbit Correction Application for CSNS-RCS High Intensity Commissioning**
***Y.W. An**, Y. Li, S.Y. Xu, Y. Yuan (IHEP) M.T. Li (IHEP CSNS)*
The China Spallation Neutron Source (CSNS) is a high intensity hadron pulse facility which achieved the design goal in March, 2020. The Rapid Cycling Synchrotron (RCS) is the important part of the CSNS which accelerates the proton beam from 80MeV to 1.6GeV. During the high intensity commissioning of the RCS, an local orbit correction application was developed. Because of the good performance of the local orbit controlling at the ramping stage, the beam loss was optimized effectively in the process of the acceleration. In the paper, the efficiency

of the beam loss optimization during the acceleration is given and the future plans were proposed.

TUPAB196 **Achievement of 100-kW Beam Operation in CSNS/RCS**

***S.Y. Xu**, Y.W. An, J. Chen, L. Huang, M.Y. Huang, Y. Li, S. Wang (IHEP) H.Y. Liu, X.H. Lu (IHEP CSNS)*

The China Spallation Neutron Source (CSNS) is an accelerator-based science facility. CSNS is designed to accelerate proton beam pulses to 1.6 GeV kinetic energy, striking a solid metal target to produce spallation neutrons. CSNS has two major accelerator systems, a linear accelerator (80 MeV Linac) and a 1.6 GeV rapid cycling synchrotron(RCS). The RCS accumulates and accelerates the proton beam to 1.6 GeV and then extracts the beam to the target at the repetition rate of 25 Hz. The Beam commissioning of CSNS/RCS had been started since April 2017. The most important issue in high-power beam commissioning is the beam loss control, as well as the control of induced activities, to meet the requirement of manual maintenance. A series of beam loss optimization work had been done to reduce the uncontrolled beam loss. At the end of February 2020, the CSNS reached the design beam power of 100 kW with very low uncontrolled beam loss.

TUPAB198 **ESS DTL Tuning Using Machine Learning Methods**

***J.S. Lundquist**, N. Milas, E. Nilsson (ESS) S. Werin (Lund University)*

The European Spallation Source, currently under construction in Lund, Sweden, will be the world's most powerful neutron source. It is driven by a proton linac with a current of 62.5 mA, 2.86 ms long pulses at 14 Hz. The final section of its normal-conducting front-end consists of a 39 m long drift tube linac (DTL) divided into five tanks, designed to accelerate the proton beam from 3.6 MeV to 90 MeV. The high beam current and power impose challenges to the design and tuning of the machine and the RF amplitude and phase have to be set within 1% and 1 degree of the design values. The usual method used to define the RF set-point is signature matching, which can be a time consuming and challenging process, and new techniques to meet the growing complexity of accelerator facilities are highly desirable. In this paper we study the usage of Machine Learning to determine the RF optimum amplitude and phase. The data from a simulated phase scan is fed into an artificial neural network in order to identify the needed changes to achieve the best tuning. Our test for the ESS DTL1 shows promising results, and further development of the method will be outlined.

TUPAB199 **Progress on the Proton Power Upgrade at the Spallation Neutron Source**

***M.S. Champion**, C.N. Barbier, M.S. Connell, J. Galambos, M.P. Howell, S.-H. Kim, J.S. Moss, B.W. Riemer, K.S. White (ORNL) E. Daly (JLab) N.J. Evans, G.D. Johns (ORNL RAD)*

The Proton Power Upgrade Project at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory will double the proton power capability from 1.4 to 2.8 MW. This will be accomplished through

an energy increase from 1.0 to 1.3 GeV and a beam current increase from 26 to 38 mA. The energy increase will be accomplished through the addition of 7 cryomodules to the linear accelerator (Linac). The beam current increase will be supported by upgrading several radio-frequency systems in the normal-conducting section of the Linac. Upgrades to the accumulator ring injection and extraction regions will accommodate the increase in beam energy. A new 2-MW-capable target and supporting systems will be developed and installed. Conventional facility upgrades include build-out of the existing klystron gallery and construction of a tunnel stub to facilitate future beam transport to the second target station. The project received approval to proceed with construction in October 2020. Procurements are in progress, and some installation activities have already occurred. Most of the installation will take place during three outages in 2022-2023. The project early finish is planned for 2025.

TUPAB200 **Status of the Electron Lens for Space Charge Compensation in SIS18**

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At GSI a project has been initiated to investigate the option of space charge compensation (SCC) by use of an electron lens in order to overcome space charge (SC) limits in the synchrotrons SIS18 and SIS100 for the Facility for Antiproton and Ion Research (FAIR). The repeated crossing of resonance lines due to the synchrotron motion in bunched beams is considered one of the main drivers of SC induced beam loss in the synchrotrons. Electron lenses provide a compensation of ion beam SC by virtue of their negative charge interacting with the ions in the overlap region while a time-varying compensation can be achieved by the modulation of the electron beam. In order to demonstrate space charge compensation of bunched ion beams, an electron lens is under development for the application in SIS18. In this contribution, the status of the electron lens design will be reported putting special emphasis on its main components: the RF modulated electron gun, that is being developed within an ARIES collaboration, and the magnet system.

TUPAB201 **Vacuum Tube Operation Tuning for a High Intensity Beam Acceleration in J-PARC RCS**

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Tetrode vacuum tubes in the J-PARC RCS are used under a reduced filament voltage condition compared with the rating value to prolong the tube life time. One tube reached the end of life in 2020; it was the first case in the RCS after 60,000 hours operation time. This means the reduced filament voltage works well because the tube has been running beyond an expected life time suggested by the tube manufac-

turer. However, an electron emission from the filament is decreased by the reduced filament voltage. Although the large amplitude of the anode current is necessary for the high intensity beam acceleration to compensate an wake voltage, a solid-state amplifier to drive a control grid circuit almost reaches the output power limit because of the poor electron emission. We changed the filament voltage reduction rate from 15 % to 5 %; the required power of the solid-state amplifier was fairly reduced, whereas the accelerated beam power was same. We will describe the measurement results of the vacuum tube parameters in terms of the filament voltage tuning.

TUPAB203 **Electromagnetic Simulations of a Novel Proton Linac Using VSim on HPC**

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We discuss electromagnetic simulations of accelerating structures in a high performance computing (HPC) system. Our overarching goal is to resolve the linac operation in a large ensemble of initial beam conditions. This requires a symbiotic relation between the electromagnetic solver and HPC. The linac is being developed by Ion Linac Systems to produce a low-energy, high-current, proton beam. We use VSim, an electromagnetic solver and PIC software developed by Tech-X to determine the electromagnetic fundamental mode of operation of the accelerating structures and discuss its implementation at the THETA supercomputer in the Argonne Leadership Computing Facility.

TUPAB204 **Upgrade of Los Alamos Accelerator Facility as a Fusion Prototypic Neutron Source**

Y.K. Batygin, *E.J. Pitcher (LANL)*

The Fusion Prototypic Neutron Source (FPNS) is considered to be a testbed for scientific understanding of material degradation in future nuclear fusion reactors. The primary mission of FPNS is to provide a damage rate in samples of 8-11 dpa/calendar year with He/dpa ratio of 10 appm in irradiation volume of 50 cubic cm or larger with irradiation temperature 300-1000 deg C and flux gradient less than 20%/cm in the plane of the sample. Los Alamos Neutron Science Center (LANSCE) is an attractive candidate for FPNS project. Accelerator Facility was designed and operated for an extended period as a 0.8-MW Meson Factory. Existing setup of the LANSCE accelerator complex can nearly fulfill requirements of the fusion neutron source station. The primary function of the upgraded accelerator systems is the safe and reliable delivery of a 1.25-mA continuous proton beam current at 800-MeV beam energy from the switchyard to the target assembly to create 1 MW power of proton beam interacting with a solid tungsten target. The present study describes existing accelerator setup and further development required to meet the needs of FPNS project.

TUPAB205 **Advancement of LANSCE Front End Accelerator Facility**
***Y.K. Batygin**, D. Gorelov, S.S. Kurennoy, J.W. Lewellen, N.A. Moody, L. Rybarcyk (LANL)*
The LANSCE accelerator started routine operation in 1972 as a high-power facility for fundamental research and national security applications. To reduce long-term operational risk, we propose to develop a new Front End of accelerator facility. It contains 100-keV injector with 3-MeV RFQ, and 6-tanks Drift Tube Linac to accelerate particles up to energy of 100 MeV. The low-energy injector concept includes two independent transports merging H^+ and H^- beams at the entrance of RFQ. Beamlines are aimed to perform preliminary beam bunching in front of accelerator section with subsequent simultaneous acceleration of two different beams in a single RFQ. The paper discusses design topics of new Front End of accelerator facility.

TUPAB206 **Matching of Intense Beam in Six-Dimensional Phase Space**
***Y.K. Batygin** (LANL)*
Beam matching is a common technique that is routinely employed in accelerator design to minimize beam losses. Despite being widely used, a full theoretical understanding of beam matching in 6D phase space remains elusive. Here, we present an analytical treatment of 6D beam matching of a high-intensity beam onto an RF structure. We begin our analysis within the framework of a linear model, and apply the averaging method to attain a matched solution for a set of 3D beam envelope equations. We then consider the nonlinear regime, where the beam size is comparable with the separatrix size. Starting with a Hamiltonian analysis in 6D phase space, we attain a self-consistent beam profile and show that it is significantly different from the commonly used ellipsoidal shape. Subsequently, we analyze the special case of equilibrium with equal space charge depression between all degrees of freedom. A comparison of beam dynamics for equipartitioned, equal space charge depression, and equal emittances beams is given.

TUPAB207 **J-PARC RCS: Recent Efforts Towards a Higher Beam Power Beyond 1 MW**
***H. Hotchi** (KEK) H. Harada, N. Hayashi, M. Kinsho, K. Okabe, P.K. Saha, Y. Shobuda, F. Tamura, K. Yamamoto, M. Yamamoto, M. Yoshimoto (JAEA/J-PARC)*
The J-PARC RCS has successfully demonstrated the 1-MW design beam operation at 25 Hz with very low fractional beam loss of the order of 10^{-3}. This success opened a possibility of further beam power ramp-up. Receiving this, we have recently initiated further high-intensity beam tests towards a higher beam power beyond 1 MW. The present goal is to accomplish a 1.5-MW-equivalent high-intensity beam acceleration within acceptable beam loss levels, increasing both the injection pulse length (0.5 ms to 0.6 ms) and the injection peak current (50 mA to >60 mA). This paper presents the latest result of the 1.5 MW beam test, especially focusing on our approach to beam loss issues.

TUPAB208 **FETS-FFA Ring Study**

***J.-B. Lagrange**, D.J. Kelliher, A.P. Letchford, S. Machida, C.R. Prior, C.T. Rogers (STFC/RAL/ISIS) S.J. Brooks (BNL) C. Brown (Brunel University) J. Pasternak (STFC/RAL) J. Pasternak (Imperial College of Science and Technology, Department of Physics) E. Yamakawa (JAI)*

ISIS is the spallation neutron source at the Rutherford Appleton Laboratory in the UK, providing a proton beam with a power of 0.2 MW. Detailed studies are under way for a major upgrade, including the use of Fixed Field alternating gradient Accelerator (FFA). A proof-of-principle FFA ring, called FETS-FFA is planned to investigate the feasibility of this kind of machine for the required MW beam power. This paper discusses the study of the FETS-FFA ring case.

TUPAB209 **The Particle Tracking Code Fixfield**

***J.-B. Lagrange** (STFC/RAL/ISIS)*

FixField is a code developed to track particles in Fixed Field alternating gradient Accelerators (FFAs). This paper discusses the structure and features of the code.

TUPAB210 **Construction Status of the COMET Experimental Facility**

***Y. Fukao** (KEK)*

COMET (COherent Muon to Electron Transition) is an experimental project that hunts for a phenomenon of the conversion from the muon to the electron (mu-e conversion). The mu-e conversion violates the lepton flavor universality and its discovery indicates a proof of the physics beyond the standard model of the particle physics. The experiment utilizes a high-intensity primary proton-beam of J-PARC (Japan Proton Accelerator Research Complex). The proton beam is injected to a target about 700mm long to generate a high intensity muon beam so as to accumulate huge statistics and achieve the final goal of a sensitivity of 10^{-16}. Supposing high radiation level caused by the high intensity beam and the thick target, careful design is required for the experimental facility such as radiation shield, radioactivation, and maintenance procedure of apparatus. Construction of the experimental facility is underway at a high pace towards an engineering run in 2022 and the first physics run in 2023. In this presentation, we would like to present a current status of the COMET facility construction.

TUPAB211 **The Accelerator System of IFMIF-DONES Multi-MW Facility**

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The IFMIF-DONES (DEMO-Oriented Neutron Early Source) facility

has passed the preliminary design phase and the detailed design phase is very much advanced. Next step will be the preparation phase for the construction of the facility. The DONES facility aims at developing a database of fusion-like radiation effects on materials to be used in future fusion reactors up to damage levels expected in the EU DEMO. It will be based on an intense neutron source created by an accelerated deuteron beam (125 mA CW, 40 MeV) impinging on a liquid lithium curtain. The DONES Accelerator Systems (AS) will be responsible of delivering this 5 MW D^+ beam with very high availability. The beam acceleration will be performed by several stages: an ion source and LEBT, an RFQ, a MEBT, an SRF Linac and a HEBT transporting and delivering an optimized profile down to the target. A high power RF system and several ancillaries will ensure the equipment is properly operated. This contribution will report the present status of the AS design, the main challenges faced, the R&D programme to overcome them, and the prospects for the construction and commissioning of the DONES accelerator in Granada (Spain).

TUPAB213 **Important Drift Space Contributions to Non-Linear Beam Dynamics**

***J. Frank**, M. Arlandoo, P. Goslawski, J. Li, T. Mertens, M. Ries (HZB)*

This paper presents an in-depth analysis of the non-linear contributions of drift spaces in beam dynamics for the creation of Transverse Resonance Island Buckets (TRIBs). TRIBs have been successfully generated in BESSY II and MLS at the Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (HZB). They offer the possibility of generating a second stable orbit and, by populating the orbit with a different electron bunch pattern, allow to effectively have two distinct radiation sources in the same machine individually tailored to different user needs. We demonstrate the generation of TRIBs by order of non-linearity on simple lattice configurations by only treating the drift space as the non-linear element. Moreover, we also insert other non-linear magnets to show how they modify the already generated TRIBs from the drift spaces. We conclude by giving a qualitative analysis of the occurring effects, which provides a guideline as to when the linear approximation is insufficient and the non-linear contribution has to be taken into account.

TUPAB214 **Alpha Buckets in Longitudinal Phase Space: A Bifurcation Analysis**

***J. Frank**, M. Arlandoo, P. Goslawski, T. Mertens, M. Ries (HZB)*

At HZB's BESSY II and MLS facilities we have the ability to tune the momentum compaction factor α up to second non-linear order. The non-linear dependence $\alpha(\delta)$ brings qualitative changes to the longitudinal phase space and introduces new fix points $\alpha(\delta) = 0$ which produce the so-called α-buckets. We present with this paper an analysis of this phenomena from the standpoint of bifurcation theory. With this approach we were able to characterize the nature of the fix points and their po-

sition in direct dependence on the tunable parameters. Furthermore, we are able to place stringent conditions onto the tunable parameters to either create or destroy α-buckets.

TUPAB215 **Novel Non-Linear Particle Tracking Approach Employing Lie Algebraic Theory in the TensorFlow Environment**
J. Frank, *M. Arlandoo, P. Goslawski, J. Li, T. Mertens, M. Ries, L. Vera Ramirez (HZB)*
With this paper we present first results for encoding Lie transformations as computational graphs in Tensorflow that are used as layers in a neural network. By implementing a recursive differentiation scheme and employing Lie algebraic arguments we were able to reproduce the diagrams for well known lattice configurations. We track through simple optical lattices that are encountered as the main constituents of accelerators and demonstrate the flexibility and modularity our approach offers. The neural network can represent the optical lattice with predefined coefficients allowing for particle tracking for beam dynamics or can learn from experimental data to fine-tune beam optics.

TUPAB216 **Modeling Particle Stability Plots for Accelerator Optimization With Adaptive Sampling**
M. Schenk, *L. Coyle, T. Pieloni (EPFL) M. Giovannozzi, A. Mereghetti (CERN) E. Krymova, G. Obozinski (SDSC)*
One key aspect of accelerator optimization is to maximize the dynamic aperture (DA) of a ring. Given the number of adjustable parameters and the compute-intensity of DA simulations, this task can benefit significantly from efficient search algorithms of the available parameter space. We propose to gradually train and improve a surrogate model of the DA from SixTrack simulations while exploring the parameter space with adaptive sampling methods. Here we report on a first model of the particle stability plots using convolutional generative adversarial networks (GAN) trained on a subset of SixTrack numerical simulations for different ring configurations of the Large Hadron Collider at CERN.

TUPAB217 **Effect of Undulators on Transverse Resonant Island Orbits**
E.C.M. Rial, *J. Bahrdt, P. Goslawski, A. Meseck, M. Ries, M. Scheer (HZB)*
For one week in October 2020, BESSY II offered a Two Orbit mode to users for the first time. In this Two Orbit mode, the existence of transverse resonant island buckets are exploited to store a second beam in the storage ring as an 'island orbit', away from the primary beam axis. This mode was offered with free range of motion of the 12 out of vacuum undulators installed at the BESSY II ring. Diagnostics of the island orbit were limited to a single camera monitoring bending magnet radiation from a single dipole. A significant motion of the island orbit was observed on this diagnostic and correlated with undulator motion. This observation is reported, and simulations presented to demonstrate how this motion could arise. Correction schemes are suggested and discussed.

TUPAB218 **Fully Covariant Two-Particle Space-Charge Dynamics Using the Liénard-Wiechert Potentials**

***B.T. Folsom**, E. Laface (ESS)*

Space charge models typically assume instantaneous propagation of the electromagnetic fields between particles in a bunch, describing forces in the frame of the reference particle. In this paper, we construct a space-charge tracking code from the retarded Liénard-Wiechert potentials, which are covariant by design, in a Lagrangian formulation. Such potentials are manipulated with covariant derivatives to produce the necessary equations of motion that will be solved in a test system of two particles at various relative energies. Magnetic dipole moment dynamics are also evaluated where applicable.

TUPAB219 **Equilibrium and Non-Linear Beam Dynamics Parameters From Sirius Turn-by-Turn BPM Data**

***X.R. Resende**, M.B. Alves, L. Liu, F.H. de Sá (LNLS)*

A considerable amount of beam information is conveyed by Turn-by-Turn (TbT) data of Beam Position Monitors (BPM). In this work such data sets are analyzed for Sirius, the Brazilian 4th Generation 3GeV synchrotron light source. In particular, equilibrium and non-linear beam dynamics parameters determining decoherence patterns in TbT position data are estimated and compared with corresponding values of the nominal storage ring model.

TUPAB220 **Longitudinal Dynamics with Harmonic Cavities under the Over-stretching Conditions**

***J.Y. Xu**, H.S. Xu (IHEP)*

Higher harmonic cavities (HHCs) are often used to lengthen the bunches, mainly for increasing the Touschek lifetime or for suppressing the coupled-bunch instabilities in electron storage rings. There have been quite many studies on the beam dynamics with the consideration of HHCs. We revisited the basic longitudinal dynamics with HHCs. The derivation of the longitudinal equations of motion with HHCs will be presented in this paper. The difference in the number of fixed points at different HHC settings (mainly under the over-stretching conditions) is also discussed.

TUPAB222 **Application and Development of the Streak Camera Measurement System at HLS-II**

***Y.K. Zhao**, S.S. Jin, P. Lu, B.G. Sun, J.G. Wang, F.F. Wu, T.Y. Zhou (USTC/NSRL)*

The dual-axial scan streak camera plays an important role in the super-fast optical measurement and the beam diagnosis of the accelerators. Indeed, the development of the synchrotron light measurement system by virtue of the streak camera provides an effective tool and research platform for accelerator physics and super-fast optical phenomenon. In this paper, the configuration of the streak camera measurement system is roughly described. And the experimental researches are simultaneously performed, including the bunch lengthening, the potential-well distortion, the longitudinal bunch oscilla-

tions, and the beam evolution during the single bunch operation mode in the HLS-II storage ring. Moreover, the effects of the RF modulation on the beam lifetime and longitudinal bunch beam dynamics are carried out.

TUPAB223 **Design of Double- and Multi-Bend Achromat Lattices with Large Dynamic Aperture and Approximate Invariants**

***Y. Li**, R.S. Rainer, V.V. Smaluk (BNL) K. Hwang, C.E. Mitchell, R.D. Ryne (LBNL)*

A numerical method to design nonlinear double- and multi-bend achromat (DBA and MBA) lattices with approximate invariants of motion is described. The search for such nonlinear lattices is motivated by Fermilab's Integrable Optics Test Accelerator (IOTA), whose design is based on an integrable Hamiltonian system with two invariants of motion. While it may not be possible to design an achromatic lattice for a dedicated synchrotron light source storage ring with one or more exact invariants of motion, it is possible to tune the sextupoles and octupoles in existing DBA and MBA lattices to produce approximate invariants. In our procedure, the lattice is tuned while minimizing the turn-by-turn fluctuations of the Courant-Snyder actions Jx and Jy at several distinct amplitudes, while simultaneously minimizing diffusion of the on-energy betatron tunes. The resulting lattices share some important features with integrable ones, such as a large dynamic aperture, trajectories confined to invariant tori, robustness to resonances and errors, and a large amplitude-dependent tune-spread.

TUPAB224 **Non-Linear Variation of the Beta-Beating Measured From Amplitude**

***T. Pugnat**, B. Dalena (CEA-IRFU) A. Franchi (ESRF) R. Tomás (CERN)*

Accelerator physics needs advanced modeling and simulation techniques, for beam stability studies but also for the measurement of beam parameters like the Twiss parameters. A deeper understanding of magnetic field non-linearities effects will greatly help in the improvement of future circular collider design, performance, and diagnostics. This paper studies the variation of the β-beating with the action of the particle generated by non-linear Resonance Driving Terms, both from a theoretical and an experimental point of view.

TUPAB225 **3D Magnetic Field Analysis of LHC Final Focus Quadrupoles With Beam Screen**

***T. Pugnat**, B. Dalena, C. Lorin (CEA-IRFU) S. Bagnis (CEA-DRF-IRFU)*

During the LHC commissioning, a discrepancy in the non-linear corrector strengths between the model and the beam-based values has been observed. This has motivated the reconstruction of the 3D finite element model for the LHC final focusing MQXA type magnet. The longitudinal higher orders magnetic field pseudo-harmonics are computed taking into account ovalization of the magnet, interconnections

design, and beam screens. The effect of this 3D field on the computation of the nonlinear correctors is evaluated and compared with beam-based corrector values.

TUPAB226 **Study of the Third-order Parametric Resonance induced by RF Modulation**

***P.F. Liang**, H.S. Xu (IHEP)*

There were both analytic and experimental studies on the effects of RF modulation on bunch lengthening in electron storage rings. Nevertheless, the increase of bunch energy spread will happen in the meantime. Therefore, the degradation of bunch quality may limit the potential applications of the RF modulation technique. As a consequence, we believe that the comprehensive studies of the parametric resonance induced by RF modulation are necessary for understanding the physics picture better and seeking new possibilities of applications of this technique. The studies on the beam dynamics closed to the $3v_s$ RF phase modulation would be presented here. Based on the basic longitudinal synchrotron equations of motion, we obtained analytically the longitudinal modulated Hamiltonian and various parameters in longitudinal phase space, such as the fixed points, island tune, island width. The validity of the analytic results was checked by simulations. Furthermore, the dependence of the bunch parameters, such as energy spread and bunch length, on the modulation settings is also discussed in this paper.

TUPAB227 **Simultaneous Compensation of Phase and Amplitude Dependent Geometrical Resonances Using Octupoles**

***F. Plassard**, Y. Hidaka, Y. Li, T.V. Shaftan, V.V. Smaluk, G.M. Wang (BNL)*

As the new generation of light sources are pushing toward diffraction limited storage rings with ultra-low emittance beams, nonlinear beam dynamics become increasingly difficult to control. It is a common practice for modern designs to use a sextupole scheme that allows simultaneous correction of natural chromaticity and energy independent, or geometrical, sextupolar resonances. However, the remaining higher order terms arising from the cross talks of the sextupole families set a strong limitation on the achievable dynamic aperture. This paper presents a simulation-based recipe to use octupoles together with this sextupole scheme to provide simultaneous self-compensation of linear amplitude dependent tune shift together with phase-dependent octupolar and higher order geometrical resonant driving terms. The correction method was built based on observations made on a simple FODO model, then applied to a realistic low emittance lattice, designed in the framework of the upgrade of the National Synchrotron Light Source II (NSLS-II).

TUPAB228 **IOTA Run 2 Beam Dynamics Studies in Nonlinear Integrable Systems**

***N. Kuklev**, Y.K. Kim (University of Chicago) S. Nagaitsev, A.L. Romanov, A. Valishev (Fermilab)*

Nonlinear integrable optics is a promising design approach for suppressing fast collective instabilities. To study it experimentally, a new storage ring, the Integrable Optics Test Accelerator (IOTA), was built at Fermilab. IOTA has recently completed its second scientific run, incorporating many hardware and instrumentation improvements. This report presents the results of the two integrable optics experiments - the quasi-integrable Henon-Heiles octupole system and the fully integrable Danilov-Nagaitsev system. We demonstrate tune spread and dynamic aperture in agreement with tracking simulations, and a stable crossing of the integer resonance. Based on recovered single-particle phase space dynamics, we show low invariant jitter and Poincaré surfaces of section consistent with intended effective Hamiltonian. We conclude by outlining future plans and efforts towards proton studies and larger designs.

TUPAB229 **Optimal Phase Space Reconstruction in Storage Rings**

***N. Kuklev**, Y.K. Kim (University of Chicago) A. Valishev (Fermilab)*

Nonlinear integrable optics is a novel design approach for suppressing fast collective instabilities, currently under study at the Fermilab Integrable Optics Test Accelerator (IOTA). To analyze nonlinear beam dynamics experimentally, accurate 4D phase space recovery from turn-by-turn beam position data is required under challenging conditions of high signal noise and strong decoherence. In this paper, we report on the development of such an algorithm. It includes compensation of octupolar and chromatic decoherence effects and a novel extension of N-BPM method for determining optimal sets and weights of BPM pairs for momentum recovery. This algorithm also incorporates systematic and statistical errors to provide final measurement uncertainties. We present benchmarks on simulation and experimental data, and discuss future extensions and heuristics to better account for unknown experimental systematics.

TUPAB230 **Parallel Multi-Objective Bayesian Optimization for Design of Advanced Storage Rings**

***N. Kuklev**, Y.K. Kim (University of Chicago)*

Nonlinear integrable optics is an advanced design approach for suppressing fast collective instabilities. It was recently successfully implemented at the Fermilab Integrable Optics Test Accelerator (IOTA). Optimization of IOTA and future integrable rings presents unique challenges due to small tolerances on lattice optics and nonlinear dynamics. Conventional methods, including simplex and multi-objective genetic algorithms (MOGA), perform poorly in such conditions. In this paper, we present a novel machine learning method - Parallel Multi Objective Bayesian Optimization (PMOBO). It combines the ad-

vantages of Gaussian Process techniques with MOGA-like batch sampling, allowing for efficient and fast parameter space exploration. We demonstrate superior PMOBO convergence speed as compared to MOGA and other state of the art techniques. We also discuss performance scaling, robustness to noisy inputs, and integration of heuristics like surrogate models. We conclude with an overview of future efforts in hyperparameter tuning and experimental applications.

TUPAB231 **Cooling of an Annular Beam by Using Nonlinear Effects**
***F. Capoani**, M. Giovannozzi, R. Tomás (CERN) A. Bazzani, **F. Capoani** (Bologna University)*
In recent years, nonlinear effects have been used to modify the transverse beam distribution by crossing nonlinear resonances adiabatically. This allows generating transversally split beams, in which the initial single Gaussian is divided into several ones depending on the order and stability type of the resonance used. Nonlinear effects could be used to try and cool a beam by acting on its transverse beam distribution. In this paper, we present and discuss the special case of a beam with an annular distribution, showing how the resulting emittance could be reduced by means of nonlinear effects.

TUPAB232 **Linear Coupling and Adiabaticity of Emittance Exchange**
***F. Capoani**, M. Giovannozzi (CERN) A. Bazzani, **F. Capoani** (Bologna University) A.I. Neishtadt (IKI) A.I. Neishtadt (Loughborough University)*
In circular accelerators, crossing the coupling resonance induces the exchange of the transverse emittances, provided the process is adiabatic. In this paper, we introduce a theoretical framework to analyze the resonance-crossing process, based on Hamiltonian mechanics, which is capable of explaining all the features of the emittance exchange process.

TUPAB233 **Diffusive Models for Nonlinear Beam Dynamics**
***C.E. Montanari**, A. Bazzani (Bologna University) M. Giovannozzi, **C.E. Montanari** (CERN)*
Diffusive models for representing the nonlinear beam dynamics in a circular accelerator ring have been developed in recent years. The novelty of the work presented here with respect to older approaches is that the functional form of the diffusion coefficient is derived from the time stability estimate of the Nekhoroshev theorem. In this paper, we discuss the latest results obtained for simple models of nonlinear betratron motion.

TUPAB234 **Exploring Accelerators for Intense Beams with the IBEX Paul Trap**
***J.A.D. Flowerdew** (University of Oxford) D.J. Kelliher, S. Machida (STFC/RAL/ISIS) S.L. Sheehy (STFC/RAL/ASTeC)*
Accelerators built from linear components will exhibit bounded and stable particle motion in the ideal case. However, any imperfections in field strength or misalignment of components can introduce chaotic

and unstable particle motion. All accelerators are prone to such non-linearities but the effects are even more significant in high intensity particle beams with the presence of space charge effects. This work aims to explore the non-linearities which arise in high intensity particle beams using the scaled experiment, IBEX. The IBEX experiment is a linear Paul trap that allows the transverse dynamics of a collection of trapped particles to be studied by mimicking the propagation through multiple quadrupole lattice periods whilst remaining stationary in the laboratory frame. IBEX is currently undergoing a non-linear upgrade with the goal of investigating Non-linear Integrable Optics (NIO) in order to improve our understanding and utilisation of high intensity particle beams.

TUPAB235 **Dynamic Aperture Optimization in the EIC Electron Storage Ring with Two Interaction Points**

***D. Marx**, Y. Li, C. Montag, S. Tepikian, F.J. Willeke (BNL) Y. Cai, Y.M. Nosochkov (SLAC) G.H. Hoffstaetter, G.H. Hoffstaetter, J.E. Unger (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)*

In the Electron-Ion Collider (EIC), which is currently being designed for construction at Brookhaven National Laboratory, electrons from the electron storage ring will collide with hadrons, producing luminosities up to 10^{34} cm^{-2} s^{-1}. The baseline design includes only one interaction point (IP), and optics have been found with a suitable dynamic aperture in each dimension. However, the EIC project asks for the option of a second IP. The strong focusing required at the IPs creates a very large natural chromaticity (about -125 in the vertical plane for the ring). Compensating this linear chromaticity while simultaneously controlling the nonlinear chromaticity to high order to achieve a sufficient momentum acceptance of 1% (10 sigma) at 18 GeV is a considerable challenge. A scheme to compensate higher-order chromatic effects from 2 IPs by setting the phase advance between them does not, by itself, provide the required momentum acceptance for the EIC Electron Storage Ring. A thorough design of the nonlinear optics is underway to increase the momentum acceptance using multiple sextupole families, and the latest results are presented here.

TUPAB236 **Progress on the Electron Gun Design for a McMillan Electron Lens in the Fermilab Integrable Optics Test Accelerator (IOTA)**

***B.L. Cathey**, G. Stancari (Fermilab)*

This paper covers the progress made so far in designing the first McMillan electron lens for the Fermilab IOTA ring. The novel design allows for an increase in tune spread without limiting the dynamic aperture due to its integrability. Shown are simulations for an electron gun design to generate the specific required current density distribution for the nonlinear integrable system in IOTA.

TUPAB237 **Symplectic Tracking Through Field Maps**
S.D. Webb *(RadiaSoft LLC) B.T. Folsom, E. Laface, R. Miyamoto (ESS)*
For many applications, it is necessary to track particles using field maps, instead of an analytic representation of the fields which is typically not available. These field maps come about while designing elements such as realistic magnets or radiofrequency cavities, and represent the field geometry on a mesh in space. However, simple interpolation of the fields from the field maps does not guarantee that the resulting tracking scheme satisfies the symplectic condition. Here we present a general method to decompose the field-map potential in the sum of interpolating functions that produces, by construction, a symplectic integrator.

TUPAB238 **Algorithm to Analyze Complex Magnetic Structures Using a Tube Approach**
B. Riemann*, M. Aiba (PSI)*
Modern synchrotron light sources often require sophisticated multipole field distributions that need to be realized by complex magnet structures. To pre-validate these magnet structures via simulations, the extraction procedure needs to output standard multipoles as well as fringe effects. The approach presented in this manuscript uses a volumetric grid map of the magnetic flux density as input. After computation of the reference trajectory (leapfrog integration), a large linear system is solved to compute transverse polynomial coefficients of the magnetic scalar potential in a series of interconnected thin cylinders (linear basis functions) along with that reference. The import of these coefficients into a lattice simulation is discussed using a modification of the tracking code Tracy. The shown approach is routinely used to check models of SLS 2.0 magnets for their properties.

TUPAB239 **Radiation of a Charged Particle Bunch Moving Along a Deep Corrugated Surface With a Small Period**
E.S. Simakov*, A.V. Tyukhtin (Saint Petersburg State University)*
We investigate the electromagnetic radiation of a bunch moving along a corrugated conductive surface. It is assumed that wavelengths under consideration are much more than the period of the corrugation. In this case, the corrugated structure can be replaced with a smooth surface on which so-called equivalent boundary conditions (EBC) are fulfilled. In fact, we deal with anisotropic surface characterized by certain matrix impedance. Here, we consider the case of deep corrugation, i.e. we assume that the depth of the structure is much more than its period (the case of shallow corrugation was studied earlier). Using the EBC we obtain electromagnetic field components which are presented in form of spectral integrals. It is shown that the bunch generates surface waves propagating in the plane of the structure, whereas volume radiation is absent at the frequencies under consideration. We also consider the energy losses of the bunch. Typical dependences of a spectral density of the energy losses on corrugation parameters are ob-

tained and analyzed. It is demonstrated that the features of the surface waves can be used for the bunch diagnostics.

TUPAB240 **The Impact of Trajectory-Shaped Coil on the Beam Dynamics in the SC230 Superconducting Cyclotron**

I.D. Lyapin, *O. Karamyshev, V. Malinin, D. Popov (JINR/DLNP) G.A. Karamysheva (JINR)*

In this paper, we compared the effect of the cyclotron coil shape on the beam dynamics. Two models were created. The first has a conventional round coil, the second has a coil that follows the trajectory of the protons. Parameters of extracted beams are discussed.

TUPAB241 **The Geometric Investigation of the RF-Cavities to Optimize the Beam Parameters in S-Band Dual LINACs**

A. Khosravi, *B. Shokri (LAPRI) N. Khosravi (ILSF)*

The RF characteristics of an accelerating tube are primarily assigned to geometrical features of a cavity. As a consequence of this geometry, the final electric field will make the shape of our Gaussian bunch and the final dose. The accelerating field can be studied considering the nose cone, gap, and bore radius. In dual electron linacs, the role of input power and bunch current is inevitable. Therefore, the geometrical issues of RF-cavities are studied in a 6MeV electron on-axis SW tube. To make an accurate comparison, each RF-cavity is designed and optimized by POISSON SU-PERFISH. The optimized cavities are imported to the PIC solver of CST. Then the beam characteristics are studied on a predefined target.

TUPAB242 **The Beam-Study of the Side and On-Axis RF Coupled Cavities in S-Band 6MeV LINACs**

A. Khosravi, *B. Shokri (LAPRI) N. Khosravi (ILSF)*

The geometry of side and on-axis RF cavities are two magnetic-coupled designs for the different LINAC applications. The electromagnetic fields, RF power, beam parameters, thermal stability, and manufacturing costs are the most critical factors in cavity type selection in each application. In this article, both RF-cavities are optimized in POISSON SUPERFISH code to compare the beam parameters accurately. Then the optimized cavities are making a tube and compare in ASTRA 1D code and CST 3D software. At last, the thermal sensitivity of both models is studied in MPHYSICS module of the CST. As a result, the final decision can be achieved on the side or on-axis cavities considering the input power, costs, beam properties, and thermal stability for the different applications of the LINACs

TUPAB243 **Investigation of the Buncher effect on Beam Properties in SW 3-6MeV LINACs**

A. Khosravi, *B. Shokri (LAPRI) N. Khosravi (ILSF)*

The best quality of an electron beam is the primary goal of a linear accelerator design. Beam-study on a buncher section can lead us to a better perspective of the modulation and acceleration of a beam to optimize the final Gaussian beam. Five setups of different bunchers

are designed, optimized, and presented in this article. A more brilliant and converged beam with a higher current, transverse emittance and smaller beam size is the study's goal.

TUPAB244 **The Wakefield Study of the RF-Shielded Bellows at the ILSF Storage Ring**

N. Khosravi, *E. Ahmadi, M. Akhyani (ILSF) M. Akhyani (EPFL) , A. Khosravi (LAPRI)*

The corrugated geometry of the bellows made it critical to be shielded with an RF-Shield. Different types of RF-shields can be applied to the ILSF vacuum chamber to cover this component's destructive impedance peaks. Then, Impedance study and optimization of the RF-shields can improve the impedance budget. In this article, two common types of RF-shields are simulated in CST software.

TUPAB245 **Wake Field and Heat Load study of the Gate Valves at ILSF Storage Ring**

N. Khosravi, *E. Ahmadi, M. Akhyani (ILSF) M. Akhyani (EPFL) S. Dastan (IPM) , A. Khosravi (LAPRI)*

As one part of the ILSF storage ring, the rf-shield of the gate valves generates considerable interest in terms of wake impedance and heat-load. Inside the gate valves, there is a vacuity, which causes low frequencies resonances, and it can lead to beam instabilities. Therefore, controlling and eliminating these frequencies will be substantial. A radio frequency rf-shield structure, which conceals this transverse gap of the gate valves, is indispensable for low emittance chambers. This paper analyzes the wake impedance and thermal behavior of a finger-band RF shield in the gate valve.

TUPAB246 **Numerical Simulation and Beam Dynamics Study of a Hollow-Core Woodpile Coupler for Dielectric Laser Accelerators**

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Hollow core dielectric microstructures powered by lasers represent a new and promising area of accelerator research thanks to the higher damage threshold and accelerating gradients with respect to metals at optical wavelengths. In this paper we present the design of a dielectric Electromagnetic Band Gap (EBG) mode converter for high-power coupling of the accelerating mode in Dielectric Laser Accelerators (DLAs). The design is wavelength-independent, and here we propose an implementation operating at 90.505 GHz (wavelength 3.3 mm) based on a silicon woodpile structure. The coupler is composed by two perpendicularly coupled hollow-core waveguides: a TE-like mode waveguide (excited from RF/laser power) and a TM-like mode accelerating waveguide. The structure has been numerically designed and optimized, presenting Insertion Losses (IL) < 0.3 dB and an efficient mode conversion in the operating bandwidth. The properties and effectiveness

of the confined accelerating mode have been optimized in order to derive the needed accelerating gradient. The simulated electric field has been used as input for Astra beam-dynamics simulations in order to compute the beam properties.

TUPAB247 **Influence of the Profile of the Dielectric Structure on the Electric Fields Excited by a Laser in Dielectric Accelerators Based on Chip**

***A. Vasyliev**, O.O. Bolshov, K. Galaydych, A.I. Povrozin, G.V. Sotnikov (NSC/KIPT)*

To provide experimental researches at the NSC KIPT theoretical studies and computations of the electron acceleration in a dielectric laser accelerator have been carried out. Laser accelerator consists of two periodic quartz structures on diffraction gratings or Chips, symmetrically located along both sides of the vacuum accelerating channel. Using PIC numerical simulations, electromagnetic fields excited by laser radiation with a wavelength of 800 nm in dielectric laser accelerators were investigated. The influence of the shape and depth of the profile of diffraction gratings or Chip structures on the distribution of the electric field in the interaction space has been studied. For modeling, different types of profiles were taken, both in serial and a unique structure. In consequence of the analysis of the obtained results, estimated efficiency of acceleration was defined for each type of profile. The rectangular profile of the diffraction grating with the maximum accelerating gradient was selected as optimal for the next experiments.

TUPAB248 **A Parallel Time Domain Thermal Solver for Transient Analysis of Accelerator Cavities**

***C.-K. Ng**, L. Ge, Z. Li, L. Xiao (SLAC)*

Simulation of thermal effects in accelerator cavity is normally performed assuming steady state solution where a static thermal solver suffices to evaluate temperature gradients and impacts on mechanical design. However, during the rf pulse ramp up or the machine system cool-down process, when the field in the cavity changes rapidly, transient effects need to be taken into account. A parallel time domain thermal solver has been developed in the finite element multi-physics code suite ACE3P with integrated electromagnetic, thermal and mechanical modeling capabilities. The implementation takes advantage of the parallel computation infrastructure of ACE3P and shares most of the ingredients in mesh generation, matrix assembly, time advancement scheme and postprocessing. In this paper, we will outline the finite element formulation of the transient thermal problem and verify the implementation against analytical solutions and existing numerical results. The thermal solver has also been coupled to ACE3P mechanical solver, allowing stress and strain analysis during the transient stage. Application of the transient thermal solver to realistic accelerator cavities will be presented.

TUPAB249 **Diffraction at the Open-Ended Dielectric-Loaded Circular Waveguide**

***S.N. Galyamin**, A.V. Tyukhtin, V.V. Vorobev (Saint Petersburg State University)*

Contemporary beam and THz technologies are tightly interlaced during last years. Strong THz fields allow realization of THz driven electron guns, THz bunch compression, streaking and THz driven wakefield acceleration. Inversely, dielectric capillaries similar to those used for THz bunch manipulation can be in turn utilized for development of high-power narrow-band THz sources. Mentioned cases involve interaction of THz waves and particle bunches with an open end of certain dielectric loaded waveguide structure, most frequently a circular capillary. For further development of the discussed prospective topics a rigorous approach allowing analytical investigation of both radiation from open-ended capillaries and their excitation by external source would be extremely useful. We present an elegant and efficient rigorous method for solving circular open-ended dielectric-loaded waveguide diffraction problems based on Wiener-Hopf technique. We deal with the case of uniform dielectric loading and internal excitation by a waveguide mode. S-parameters, near-field and far-field distributions are presented. The obtained results can be also applied to the narrow band wakefield.

TUPAB250 **Axicon-Based Concentrator for Cherenkov Radiation**

***S.N. Galyamin**, A.V. Tyukhtin (Saint Petersburg State University)*

We propose a new type of axisymmetric dielectric target - an "axicon-based concentrator" - which effectively concentrates generated Cherenkov radiation (CR) into a small vicinity of a focus point. It consists of two "glued" bodies of revolution: a hollow axicon and a hollow "lens." A theoretical investigation of the radiation field produced by a charge moving through the discussed radiator is performed for the general case where a charge trajectory is shifted with respect to the structure axis. The idea of a dielectric target with a specific profile of the outer surface and suitable analytical methods were presented and developed in our preceding papers. An essential advantage of the current version of the device is that it allows the efficient concentration of CR energy from relativistic particles, making this device extremely prospective for various applications such as beam-driven THz sources and bunch diagnostic systems.

TUPAB251 **Impedance Studies of a Corrugated Pipe for KARA**

***S. Maier**, M. Brosi, A. Mochihashi, A.-S. Müller, M.J. Nasse, M. Schwarz (KIT)*

At the KIT storage ring KARA (KArlsruhe Research Accelerator) it is planned to install an impedance manipulation structure in a versatile chamber to study and eventually control the influence of an additional impedance on the beam dynamics and the emitted coherent synchrotron radiation. For this purpose the impedance of a corrugated pipe is under investigation. In this contribution, we present first re-

sults of simulations showing the impact of different structure parameters on its impedance and wake potential.

TUPAB252 **Minimization of NICA Collider Impedance**
***S.A. Melnikov**, I.N. Meshkov (JINR) K.G. Osipov (JINR/VBLHEP)*
The paper presents the results of the longitudinal impedance minimization for the beam tube section in the arches of the NICA collider ring, consisting of a pumping pipe, a BPM station, and a bellows assembly, and considers the contribution of the impedance of this section to the ion beam stability in the NICA collider ring. To confirm the efficiency of the optimized design, a BPM prototype was fabricated, and a test bench was built for further laboratory measurements.

TUPAB253 **EIC Beam Dynamics Effects Due to Transverse Monopole Wakefields**
***B. Podobedov** (Brookhaven National Laboratory (BNL), Electron-Ion Collider) M. Blaskiewicz (BNL)*
Transverse monopole wakefields could be of concern to the EIC due to their contribution to the beam size blow-up at the interaction point as well as potential interference with the crab-cavity operation. These wakefields (which impose s-dependent kick to the beam particles even when the beam follows the design orbit) occur in transversely asymmetric structures, or when the orbit is offset from a symmetry plane. In the EIC electron storage ring the monopole wakefields mainly come from asymmetric collimators, as well as from other vacuum chamber components with significantly off-centered design beam orbit, for instance at the super-bends. We estimate beam dynamics effects due to these wakefields analytically and compare the results with tracking by elegant. So far, we find that the magnitude of the effects is well within the EIC design tolerances.

TUPAB254 **Limiting Coherent Longitudinal Beam Oscillations in the EIC Electron Storage Ring**
***B. Podobedov** (Brookhaven National Laboratory (BNL), Electron-Ion Collider) M. Blaskiewicz (BNL)*
We study coherent longitudinal beam oscillations in the EIC electron storage ring (ESR). We show that to avoid unacceptable hadron emittance growth due to finite crossing angle, the amplitude of these oscillations needs to be limited to a fraction of a millimeter. Using an analytical model we estimate the amplitude of these oscillations under the two scenarios: 1) the beam is passively stable and the oscillations are driven by RF phase noise only; 2) a coupled-bunch instability, presently expected in the ESR, is damped by a longitudinal feedback system. We show that, for the 2nd scenario, comfortable specifications for RF phase noise and feedback sensor noise will be sufficient to maintain the oscillation amplitude within the required limits.

TUPAB255 **Longitudinal Beam Dynamics and Coherent Synchrotron Radiation at cSTART**

***M. Schwarz**, E. Bründermann, D. El Khechen, B. Härer, A. Malygin, A.-S. Müller, M.J. Nasse, A.I. Papash, R. Ruprecht, J. Schaefer, M. Schuh, P. Wesolowski (KIT)*

The compact STorage ring for Accelerator Research and Technology (cSTART) project aims to store electron bunches of LWFA-like beams in a very large momentum acceptance storage ring. The project will be realized at the Karlsruhe Institute of Technology (KIT, Germany). Initially, the Ferninfrarot Linac- Und Test-Experiment (FLUTE), a source of ultra-short bunches, will serve as an injector for cSTART to benchmark and emulate laser-wakefield accelerator-like beams. In a second stage a laser-plasma accelerator will be used as an injector, which is being developed as part of the ATHENA project in collaboration with DESY and Helmholtz Institute Jena (HIJ). With an energy of 50 MeV and damping times of several seconds, the electron beam does not reach equilibrium emittance. Furthermore, the critical frequency of synchrotron radiation is 53 THz and in the same order as the bunch spectrum, which implies that the entire bunch radiates coherently. We perform longitudinal particle tracking simulations to investigate the evolution of the bunch length and spectrum as well as the emitted coherent synchrotron radiation. Finally, different options for the RF system are discussed.

TUPAB256 **Investigation of Damping Effects of the Crab Cavity Noise Induced Emittance Growth**

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Crab cavities will be installed at the two main interaction points (IP1 and IP5) of the High Luminosity LHC (HL-LHC) in order to minimize the geometric reduction of the luminosity due to the crossing angle. Two prototype crab cavities have been installed into the SPS machine and were tested with a proton beam in 2018, to study the expected emittance growth induced by RF noise. The measured emittance growth was found to be a factor 2-3 lower than predicted from the available analytical and computational models. Damping mechanisms from the transverse impedance, which is not included in the available theories, are studied as a possible explanation for the observed discrepancy.

TUPAB257 **Analysis of Multibunch Spectrum for an Uneven Bunch Distribution in a Storage Ring**

***R. Li**, F. Marhauser (JLab)*

The EIC design requires an uneven bunch distribution pattern for the beams in each collider ring. Such uneven bunch fill gives a complex structure for the beam current spectrum, and at high average beam current, this complex current spectrum could have a potential impact

on the beam dynamics. In this study, we analyze the beam current spectrum for a filling pattern with bunch trains and gaps. Good agreements between the analytical results and direct Fourier transform will be shown, and the dependence of the bunch spectrum on the filling pattern will be illustrated and discussed.

TUPAB258 **Impact of the Coherent Beam-Beam Interaction on the Collisionless Damping of the Transverse Coupled-Bunch Instability**
R. Li *(JLab) M. Blaskiewicz (BNL)*
In the EIC design, at high average-current operation, the transverse coupled-bunch instability (TCBI) induced by the transverse resistive wall wakefield in the electron storage ring (eSR) causes concern and requires mitigation. A natural mitigation mechanism is provided by the beam-beam interaction at the interaction point (IP), which gives a strong collision-less damping for the TCBI in the eSR. In this study, using a simplified simulation model, we investigate how this collision-less damping from the beam-beam interaction behaves when the coherent beam-beam interaction at IP is considered. Our method and results will be presented in this paper.

TUPAB260 **A Beam Screen to Prepare the RHIC Vacuum Chamber for EIC Hadron Beams: Conceptual Design and Requirements**
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The Electon Ion Collider (EIC) hadron ring will use the existing Relativistic Heavy Ion Collider storage rings, including the superconducting magnet arcs. The vacuum chambers in the superconducting magnets and the cold mass interconnects were not designed for EIC beams and so must be updated to reduce its resistive-wall heating and to suppress electron clouds. To do so without compromising the EIC luminosity goal, a stainless steel beam screen with co-laminated copper and a thin layer of amorphous carbon will be installed. This paper describes the main requirements that our solution for the hadron ring vacuum chamber needs to satisfy, including impedance, aperture limitations, vacuum, thermal and structural stability, mechanical design, installation and operation. The conceptual design of the beam screen currently under development is introduced.

TUPAB261 **Ferrite Loaded Cavity Impedance Simulation**
L. Huang*, X. Li, S. Wang, S.Y. Xu (IHEP) B. Wu (IHEP CSNS)*
The Rapid Cycling Synchrotron of the China Spallation Neutron Source is a high-intensity proton accelerator, it accumulates the 80 MeV proton beam and accelerates it to 1.6 GeV in 20 ms. The transverse coupling bunch instability is observed in beam commissioning. The source has been investigating from the commissioning. The RF acceleration system consists of eight ferrite-loaded cavities. The impedance is simulated and there is a narrow-band impedance of the ferrite cavity at about 17 MHz

TUPAB262 **The Characteristic of the Beam Position Growth in CSNS/RCS**
***L. Huang**, S. Wang (IHEP) , S.Y. Xu (DNSC)*
An instability of the beam position growth is observed in the beam commissioning of the Rapid Cycling Synchrotron of the China Spallation Neutron Source. To simplify the study, a series of measurements have been performed to characterize the instability in the DC mode with consistent energy of 80 MeV. The measurement campaign is introduced in the paper and it conforms to the characteristics of the coupled bunch instability.

TUPAB263 **The Phase Loop Status of the RF System in CSNS/RCS**
***L. Huang**, X. Li, S. Wang (IHEP) M.T. Li, H.Y. Liu (IHEP CSNS) Y. Liu (DNSC)*
The Rapid Cycling Synchrotron (RCS) of the China Spallation Neutron Source (CSNS) is a high intensity proton accelerator. The acceleration system consists of eight ferrite loaded cavities. The RCS is the space charge dominant machine and it is mitigated through the bunch factor optimization in the beam commissioning, so the injected beam will occupy a larger bucket size and unavoidable mismatch with the bucket, thus the dipole oscillation is excited. The phase loop scheme is designed to restrict the oscillation in the RF system, but the transmission efficiency is reduced by the phase loop and the bunch factor also increases, so the phase loop scheme is studied. To keep the phase loop but also maintain the transmission efficiency, we optimized the original phase loop scheme, but the beam loss still increases small when the loop on.

TUPAB264 **Shielding of CSR Wake in a Drift**
***G. Stupakov** (SLAC)*
A one-dimensional model of coherent synchrotron radiation (CSR) wakefield is used in computer codes for the simulation of relativistic electron beams. It includes transient effects at the entrance and exit from a bending magnet of finite length. In the ultra-relativistic limit, v=c, the exit CSR wake decays inversely proportional to the distance from the magnet end. To calculate the total energy loss of the beam one needs to integrate this wake to infinity, but the integral diverges. This means that one has to either drop the assumption of the infinite value of the Lorentz factor or take into account the shielding effect of the metal walls in the vacuum chamber. In practice, the latter effect is often dominant. In this work, we derive formulas for the CSR wake in the drift after an exit from the magnet that incorporates the shielding by two parallel metal plates. They allow computing the energy loss of different particles in the beam.

TUPAB265 **Bunch Lengthening of the HALF Storage Ring in the Presence of Passive Harmonic Cavities**
***T.L. He**, Z.H. Bai, G.Y. Feng, W. Li, W.W. Li, G. Liu, L. Wang, H. Xu, S.C. Zhang (USTC/NSRL)*
A passive 3rd harmonic RF system, being necessary for the Hefei Advanced Light Facility (HALF) storage ring under design, will be em-

ployed to lengthen the bunches for suppressing the intrabeam scattering and improving the beam lifetime. However, the transient beam loading due to the fundamental mode may significantly reduce the bunch lengthening. Since the scale of transient effects is proportional to R/Q, the effects of R/Q on bunch lengthening, in uniform fill pattern with the near-optimum condition fulfilled, are analyzed by multi-bunches multiparticles tracking simulation. It indicates that the passive superconducting harmonic cavity with a lower R/Q is preferred by HALF.

TUPAB266 **Periodic Transient Beam Loading Effects Predicted by a Semi-Analytical Method**

***T.L. He**, Z.H. Bai, G. Feng, W. Li, W.W. Li, G. Liu, L. Wang, H. Xu, S.C. Zhang (USTC/NSRL)*

In this paper, we improve a semi-analytical method, which can be not only used for bunch lengthening under equilibrium conditions, but also applied to the prediction of a periodic transient beam loading effect. This periodic transient is induced by the presence of the passive harmonic cavity and might be encountered under specific conditions for a ultra-low emittance storage ring with a higher beam current.

TUPAB267 **Investigation of Beam Impedance and Heat Load in a High Temperature Superconducting Undulator**

***D. Astapovych**, H. De Gersem, E. Gjonaj (TEMF, TU Darmstadt) T.A. Arndt, E. Bründermann, N. Glamann, A.W. Grau, B. Krasch, A.-S. Müller, R. Nast, D. Saez de Jauregui, A. Will (KIT)*

The use of high temperature superconducting (HTS) materials can enhance the performance of superconducting undulators (SCU), which can later be implemented in free electron laser facilities, synchrotron storage rings and light sources. In particular, the short period < 10 mm undulators with narrow magnetic gap < 4 mm are relevant. One of the promising approaches considers a 10 cm meander-structured HTS tapes stacked one above the other. Then, the HTS tape is wound on the SCU. The idea of this jointless undulator has been proposed by, and is being further developed at KIT. Since minimizing the different sources of heat load is a critical issue for all SCUs, a detailed analysis of the impedance and heat load is required to meet the cryogenic system design. The dominant heat source is anticipated to be the resistive surface loss, which is one of the subjects of this study. Considering the complexity of the HTS tape, the impedance model includes the geometrical structure of the HTS tapes as well as the anomalous skin effect. The results of the numerical investigation performed by the help of the CST PS solver will be presented and discussed.

TUPAB269 **Transverse Impedance of Lossy Circular Metal-Dielectric Waveguides**

***M. Ivanyan**, L.V. Aslyan (CANDLE SRI) K. Flöttmann, F. Lemery (DESY)*

The properties of the transverse impedance of a dielectric-loaded metallic circular waveguide are investigated taking into account losses

in the outer metallic pipe and in the inner dielectric layer. The dispersion relations, impedances, and wake functions for dipole modes are analyzed and compared for thin and thick dielectric layer cases. The correspondence of the resonant frequencies of the longitudinal monopole and transverse dipole impedances is established.

TUPAB270 **Thermal Transition Design and Beam Heat-load Estimation for the COLDDIAG Refurbishment**

***H.J. Cha**, N. Glamann, A.W. Grau, A.-S. Müller, D. Saez de Jauregui (KIT)*

The COLDDIAG (cold vacuum chamber for beam heat load diagnostics) developed at Karlsruhe Institute of Technology has been modified for more studies at cryogenic temperatures different from the previous operations at 4 K in a cold bore and at 50 K in a thermal shield. The key components in this campaign are two thermal transitions connecting both ends of the bore at 50 K with the shield at the same or higher temperature. In this paper, we present design efforts for the compact transitions, allowed heat intakes to the cooling power margin and mechanical robustness in the cryogenic environment. A manufacture scheme for the transition and its peripheral is also given. In addition, the beam heat loads in the refurbished COLDDIAG are estimated in terms of the accelerator beam parameters.

TUPAB272 **Observation of Long-Range Wakefield Effects Downstream of an Off-Resonance Tesla-Type Cavity at FAST**

***A.H. Lumpkin**, D.R. Edstrom, A. Lunin, P.S. Prieto, J. Ruan, R.M. Thurman-Keup (Fermilab) J.A. Diaz Cruz (University of New Mexico) J.A. Diaz Cruz, B.T. Jacobson, J.P. Sikora (SLAC)*

The interest in controlling emittance dilution effects due to off-axis beam transport in accelerator cavities and the resulting dipolar modes is especially important for the facilities with lower emittance beams. The Fermilab Accelerator Science and Technology (FAST) facility has a unique configuration of two single cavities after the photocathode rf gun followed by a cryomodule. The second capture cavity (CC2) was run 15 kHz off resonance and without rf power while a 25-MeV beam was injected into it. The beam centroid effects were tracked by 10 rf button BPMs with bunch-by-bunch position readout capability downstream in a 12-m drift. Possible LRW effects seemed to dominate our previously observed near-resonant HOM effects at mode 14 in this cavity. This mode also shifted in frequency compared to that of the tuned case based on direct measurements. Submacropulse vertical position slewing of 1400 microns at 11 m downstream was observed with a 125 pC/bunch, 50 bunches per macropulse, and 25-MeV beam. The y-position slew amplitudes as a function of z were also measured. Horizontal positions also showed a slew effect. Both are emittance-dilution effects which one wants to mitigate.

TUPAB273 **Observations on Submicropulse Electron-Beam Effects From Short-Range Wakefields in Tesla-Type Superconducting Rf Cavities**

***A.H. Lumpkin**, D.R. Edstrom, J. Ruan, R.M. Thurman-Keup (Fermilab) J.A. Diaz Cruz (University of New Mexico) J.A. Diaz Cruz, B.T. Jacobson, F. Zhou (SLAC)*

In previous experiments at the Fermilab Accelerator Science and Technology (FAST) facility, the effects of higher-order modes (HOMs) in TESLA-type cavities on submacropulse centroid motion were elucidated. We now have extended our investigations to short-range wakefields (SRWs) in these cavities. The latter result in submicropulse effects where the transverse wakefields cause head-tail centroid shifts. We used a Hamamatsu C5680 UV-visible synchroscan streak camera to synchronously sum the OTR from each of the 50 micropulses in the macropulse. We generated the y-t effect in the 41-MeV beam by purposely steering the beam off axis in y at the entrance of the first capture cavity. The head-tail transverse kicks within the 11-ps-long micropulses of 500 pC each were observed at the 100-micron level for steering off-axis in one cavity and several 100 microns for two cavities. These SRW results will be compared to simulations from the ASTRA model of a single micropulse in FAST. Since the SRW kicks go inversely with energy, these emittance-dilution effects are particularly relevant to the LCLS-II injector commissioning plans where <1 MeV beam will be injected into a TESLA-type cryomodule.

TUPAB274 **Investigations of Long-Range Wakefield Effects in a TESLA-type Cryomodule at FAST**

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The preservation of low emittance of electron beams during transport in the accelerating structures of large facilities is an ongoing challenge. In the cases of the TESLA-type superconducting rf cavities currently used in the European X-ray Free-electron Laser (XFEL) and the under-construction Linac Coherent Light Source upgrade (LCLS-II), off-axis beam transport may result in emittance dilution due to transverse long-range wakefields (LRWs) and short-range wakefields (SRW). To investigate such effects, experiments were performed at the Fermilab Accelerator Science and Technology (FAST) facility with its unique configuration of two TESLA-type cavities after the photocathode rf gun followed by an 8-cavity cryomodule CM). We generated beam trajectory changes with the H/V125 corrector set located 4 m upstream of the cryomodule. At 125 pC/bunch, 50 bunches, 25-MeV input, and 100-MeV exit energy, we observed for the first time submacropulse position slews of up to 500 microns at locations ~3 m after the CM and a centroid oscillation at a difference frequency of 240 kHz further downstream. Both are emittance-dilution effects which we mitigated with selective upstream beam steering.

TUPAB275 **Enhanced Orthogonal Polarization Component Treatment in COTRI Model for Microbunched Beam Diagnostics**
D.W. Rule *(Private Address) , A.H. Lumpkin (ANL)*
We present the results of modifying our coherent optical transition radiation interferometry (COTRI) model's treatment of the perpendicular polarization of OTR, Iperp. Our previous analytic approximation for Iperp was for beam divergences, sy << 1/g, where g is the Lorentz factor and sy is the rms y-component of the beam divergence. We have replaced our analytical form with a Gaussian quadrature for the convolution of Iperp with the divergence in theta-y. This extends the range of divergences we reliably model to sy > 1/g. Ipar, the parallel polarization in the model,is unchanged. Iperp is polarized along the y-axis and is proportional to the square of the y-component of the beam's velocity distribution. We illustrate our results with two cases: 1) beam energy E=1 GeV, OTR wavelength 633 nm, Q=235 pC, microbunching fraction, bf=1%, divergences of 0.1-0.7 mrad, and rms beam sizes 2,10, and 30 microns; 2) E=375 MeV, wavelength 266 nm, Q=300 pC, bf=10%, divergences of 0.1-0,7 mrad, and rms beam sizes of 10,25,50, and 100 microns. We will present two cases that would be of interest for the diagnostics of laser-plasma accelerator beams and pre-bunched FELs, respectively.

TUPAB276 **Proposed Longitudinal Profile Diagnostics for Optical Stochastic Cooling of Stored Electrons in the IOTA Ring**
A.H. Lumpkin*, J.D. Jarvis, V.A. Lebedev (Fermilab)*
One of the predicted signatures of successful optical stochastic cooling (OSC) in the Fermilab Integrable Optics Test Accelerator (IOTA) ring is reduction of the bunch length. The IOTA OSC experiment is designed for a low nominal beam current (~0.1 microAmps of 100-MeV electrons) to reduce intrabeam scattering (IBS), and during cooling, OSC is expected to reduce the bunch length from ~200 ps to ~130 ps. These equilibrium bunch lengths can be measured using a streak camera and the optical synchrotron radiation (OSR) generated in a ring dipole by the circulating beam. A similar measurement was previously performed at the Advanced Photon Source with a Hamamatsu C5680 synchroscan streak camera operating at 117.3 MHz. In this case, synchronous summing of OSR resulted in a bunch length measurement of 276 ± 30 ps using only 57 electrons circulating at 425 MeV. At IOTA, a C5680 streak camera has been modified to operate at the 11th harmonic of the ring's revolution frequency of 7.50 MHz and is being installed on an OSR port. The integrated system will have sufficient sensitivity and resolution for measuring the evolution and equilibrium values of the bunch length during OSC experiments.

TUPAB277 **Bunch Length Characterizations for the Solaris Injector LINAC**
A. Curcio*, M.A. Knafel, G.W. Kowalski, R. Panaś, M. Waniczek, A.I. Wawrzyniak (NSRC SOLARIS)*
During 2020 the first characterization of bunch length and bunch profile in the Solaris injector LINAC has been performed since the start

of its operation. In absence of more sophisticated bunch length diagnostics, we have adopted an inversion algorithm applied to beam energy spectra. In practice, the method applies a transformation matrix which maps the particle energy into the particle longitudinal coordinate along the bunch. The construction of this matrix is made analytically, based on the solution of the Liouville equation for the study of the longitudinal beam dynamics. The analytic approach has been benchmarked with experimental measurements of the beam properties along the machine and cross-checked with other tools, as particle tracking and/or beam optics codes. The final results are presented. Moreover, a new diagnostic station at the end of the LINAC has been installed which will host experiments of coherent radiation emission that will be used to confirm the validity of our observations. Preliminary simulations of the coherent spectra are finally reported.

TUPAB278 **The HL-LHC Beam Gas Vertex Monitor - Simulations for Design Optimisation and Performance Study**

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The Beam Gas Vertex (BGV) instrument is a non-invasive transverse beam profile monitor being designed as part of the High Luminosity Upgrade of the LHC (HL-LHC) at CERN. Its aim is to continuously measure bunch-by-bunch beam profiles, independent of beam intensity, throughout the LHC cycle. The primary components of the BGV monitor are a gas target and a forward tracking detector. Secondary particles emerging from inelastic beam-gas interactions are detected by the tracker. The beam profile is then inferred from the spatial distribution of reconstructed vertices of said interactions. Based on insights and conclusions acquired by a demonstrator device that was operated in the LHC during Run 2, a new design is being developed to fulfill the HL-LHC specifications. This contribution describes the status of the simulation studies being performed to evaluate the impact of design parameters on the instrument's performance and identify gas target and tracker requirements.

TUPAB279 **First Tests of Beam Position Monitor Electronics with Bunch Resolving Capabilities**

***G. Rehm**, F. Falkenstern, J. Kuszynski, A. Schälicke (HZB)*

We are reporting on first tests of a beam position monitor using 1 GS/s data streams of signals from a four button pickup. The system digitizes signals of ~2 GHz bandwidth using a choice of sampling frequency that realizes equivalent time sampling. The data is subsequently processed in the Fourier domain to unfold the aliased spectral lines and apply an impulse response correction per channel. After transforming back into time domain, individual bunch signals can be clearly identified and selected for further processing and decimation. The paper will provide detail on the hardware implementation and demonstrate the bunch resolving capabilities, long term stability and beam inten-

sity dependence using beam tests in BESSY-II and synthetic signals.

TUPAB280 **Quantum Gas Jet Scanner Based Beam Profile Monitors**
N. Kumar, *A. Salehilashkajani, C.P. Welsch, H.D. Zhang (Cockcroft Institute)* ***N. Kumar***, *A. Salehilashkajani, C.P. Welsch, H.D. Zhang (The University of Liverpool)*
A quantum gas jet scanner-based beam profile monitor is under development at the Cockcroft Institute (CI), the UK for beam diagnostics based on the principle of ionization detection induced in a quantum gas jet interacting with an ionizing primary beam that shall be characterized. It promises superior position resolution and high signal intensity resulting from a strongly focused quantum gas jet. In order to achieve the gas jet with a diameter of less than 100 μm, a novel focusing method exploiting the quantum wave function of the neutral gas atoms, generate an interference pattern with a single maximum acting as an ultra-thin gas jet. An 'atom sieve' has been designed for generating the interference pattern, applying the principle of a photon sieve. It will be analogous to a mechanical wire scanner though with a minimal interception. The idea of moving a quantum gas jet through the beam is proposed for transverse profiling. This contribution provides a general overview of the design, working principle, the results obtained from initial measurements carried out at CI and University of Bergen (Norway), for designing the same and possible methods for optimizing the scanner's design.

TUPAB281 **Gas-Mixing to Improve the Resolution of Non-Invasive Gas Jet-Based Ionization Profile Monitors**
N. Kumar, *A. Salehilashkajani, C.P. Welsch, H.D. Zhang (Cockcroft Institute)* ***N. Kumar***, *A. Salehilashkajani, C.P. Welsch, H.D. Zhang (The University of Liverpool)*
Ionization beam profile monitor using a supersonic gas jet is an attractive option for the characterization of low and medium energy beams. In this scheme, a primary beam crosses a 45-degree tilted thin gas curtain which causes ionization of gas molecules in the jet. The generated ions are then collected using an electrostatic extraction system to determine the 2D transverse profile of the primary beam. The most commonly used gases for the jet are neon and nitrogen. The signal from the gas jet is always super-imposed with the signal resulting from residual gases in the interaction chamber. CST simulations indicate that the gas jet speed is a key factor for the separation of the jet and the residual gas signals. To obtain a good signal separation, one can increase the velocity of the gas jet. This can be accomplished by generating a gas jet that mixes heavier and lighter gases. This contribution gives a general overview of the monitor design, discusses the effects of gas mixing and CST simulation results. It also presents experimental results obtained with Helium, and Nitrogen, as well as a mixture of them using different percentages and the impact on measurement resolution.

TUPAB282 **Optical Beam Loss Monitor Based on Fibres for Beam Loss Monitoring and RF Breakdown Detection**

***N. Kumar**, C.P. Welsch, J. Wolfenden (The University of Liverpool)*
***N. Kumar**, C.P. Welsch, J. Wolfenden (Cockcroft Institute)*

Standard beam loss monitors are used to detect losses at specific locations which is not a practical solution for loss monitoring throughout the whole beam-line. Optical fibre beam loss monitors (oBLMs) are based on the detection of Cherenkov radiation from high energy charged particles having the advantage of covering more than 100 m of an accelerator with a single detector. This system was successfully installed at the Australian Synchrotron covering the entire facility for beam loss measurements. Successful measurements were also demonstrated on the Compact Linear Accelerator for Research and Applications (CLARA), UK with sub-metre beam loss resolution. oBLMs are non-invasive monitors for the detection of the beam loss and RF breakdown within particle accelerators, which has been developed by the QUASAR Group based at the Cockcroft Institute/University of Liverpool, UK in collaboration of D-Beam Ltd, UK. This paper discusses the overview of the system, the incorporation of the monitor into the accelerator diagnostic system, calibration experiment of oBLM and future plans for the system.

TUPAB283 **Feasibility Study of ChDR Diagnostic Device in the LHC**

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In recent years Cherenkov Diffraction Radiation (ChDR) has been reported as a phenomenon suitable for various types of particle accelerator diagnostics. As it would typically work best for highly relativistic beam, past studies and experiments have been mostly focusing on the lepton machines. This contribution investigates the prospects on the utilization of ChDR as a diagnostic tool for the Large Hadron Collider (LHC). Based on theoretical considerations and simulation results we estimate the properties of the expected radiation, both in the incoherent and coherent domain, and we compare them with the requirements of the existing diagnostic systems. We also address the potential problem of the use of dielectric radiators in circular machines, where secondary electrons could potentially lead to the creation of electron clouds inside the beam pipe that may affect the radiator.

TUPAB284 **BPM for the High Energy Beam Transport Line of MINERVA Project at SCK•CEN**

***H. Kraft**, L. Perrot (Université Paris-Saclay, CNRS/IN2P3, IJCLab)*

This paper presents the status of developments concerning button type BPM. Results of our analytical model BPMOK will compare the measurements done at IPHI facility at CEA-Saclay and GANIL/SPIRAL2 in Caen. The measurements aims to compare the response of the analytical model depending on beam positions, sizes, intensi-

ties and energies. BPMOK is validated to predict BPM responses in order to make parametric studies. Starting from already existing BPM built for the MINERVA LINAC, the analytical model is used to design the BPM for the HEBT.

TUPAB285 **Broadband Imaging of Coherent Radiation as a Single-Shot Bunch Length Monitor With Femtosecond Resolution**

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Bunch length measurements with femtosecond resolution are a key component in the optimisation of beam quality in FELs, storage rings, and plasma-based accelerators. This contribution presents the development of a novel single-shot bunch length monitor with femtosecond resolution, based on broadband imaging of the spatial distribution of emitted coherent radiation. The technique can be applied to many radiation sources; in this study the focus is coherent transition radiation (CTR) at the MAX IV Short Pulse Facility. Bunch lengths of interest at this facility are <100 fs FWHM; therefore the CTR is in the THz to Far-IR range. To this end, a THz imaging system has been developed, utilising high resistivity float zone silicon lenses and a pyroelectric camera; building upon previous results where single-shot compression monitoring was achieved. This contribution presents simulations of this new CTR imaging system to demonstrate the synchrotron radiation mitigation and imaging capability provided, alongside initial measurements and a bunch length fitting algorithm, capable of shot-to-shot operation. A new machine learning analysis method is also discussed.

TUPAB286 **Experience with On-line Optimizers for APS Linac Front End Optimization**

***H. Shang**, M. Borland, X. Huang, Y. Sun (ANL) M. Song, Z. Zhang (SLAC)*

While the APS linac lattice is set up using a model developed with ELEGANT, the thermionic RF gun front end beam dynamics has been difficult to model. One of the issues is that beam properties from the thermionic gun can vary from time to time. As a result, linac front end beam tuning is required to establish good matching and maximize the charge transported through the linac. We have been using a traditional simplex optimizer to find the best settings for the gun front end magnets and steering magnets. However, it takes a long time and requires some fair initial conditions. Therefore, we imported other on-line optimizers, such as robust conjugate direction search (RCDS) which is a classic optimizer as simplex, multi-objective particle swarm (MOPSO), and multi-generation gaussian process optimizer (MG-GPO) which is based on machine learning technique. In this paper we report our experience with these on-line optimizers for maximum bunch charge transportation efficiency through the linac.

TUPAB287 **Application of Artificial Neural Network in the APS Linac Bunch Charge Transmission Efficiency**

***H. Shang**, Y. Sun (ANL) T. Xu (Northern Illinois University)*

In recent years there has been a rapid growth in machine learning (ML) and artificial intelligence (AI) applications in accelerators. As the scale of complexity and sophistication of modern accelerators grows, the difficulties in modeling the machine increase greatly in order to include all the interacting subsystems and to consider the limitation of various diagnostics to benchmark against measurements. Tools based on ML can help substantially in revealing correlations of machine condition and beam parameters that are not easily discovered using traditional physics model-based simulations, reducing machine tuning up time etc among the many possible applications. While at APS we have many excellent tools for the optimization, diagnostics, and controls of the accelerators, we do not yet have ML-based tools established. It is our desire to test ML in our machine operation, optimization, and controls. In this paper, we introduce the application of neural networks to the APS linac bunch charge transmission efficiency.

TUPAB288 **Multi-Objective Bayesian Optimization for Accelerator Characterization**

***R.J. Roussel** (Enrico Fermi Institute, University of Chicago) A.L. Edelen, A. Hanuka (SLAC)*

Maximizing the performance of an accelerator facility often necessitates multi-objective optimization, where operators must balance trade-offs between multiple objectives simultaneously, often using limited, temporally expensive beam observations. When compared to optimization of simulated beamlines using parallelized methods, experimental multi-objective optimization is extremely expensive due to the inherent serialized nature of accelerator operation and the large number of observations needed to converge to a solution. Here, we introduce a multi-objective Bayesian optimization scheme, which finds the full Pareto front efficiently in a serialized manner. This method uses a set of Gaussian process surrogate models, along with a multi-objective acquisition function to conduct optimization, which reduces the number of observations needed to converge to a solution by at least an order of magnitude over current methods. We demonstrate how this method can be modified to specifically solve optimization challenges posed by the tuning of accelerators. This includes the addition of optimization constraints, objective preferences and costs related to changing accelerator parameters.

TUPAB289 **Towards Hysteresis Aware Bayesian Regression and Optimization**

***R.J. Roussel** (University of Chicago) A. Hanuka (SLAC)*

Algorithms used today for accelerator optimization assume a simple proportional relationship between an intermediate tuning parameter and the resultant field or mechanism which influences the beam. This neglects the effects of hysteresis, where the magnetic or mechanical

response depends not only on the current parameter value, but also on the historical parameter values. This prevents the use of one to one surrogate models, such as Gaussian processes, to assist in optimization when hysteresis effects are not negligible, since identical points in input space no longer correspond to a same point in output space. In this work, we demonstrate how Bayesian inference can be used in conjunction with Gaussian processes to jointly model both the hysteresis cycle of magnetic elements and the beam response. Using this technique we demonstrate how to model the hysteresis cycle of a magnet during accelerator operation in situ by only measuring the beam response, without direct magnetic field measurements. This allows us to quickly build accurate statistical models of the beam response that can be used for rapid tuning of accelerators where hysteresis effects are dominant.

TUPAB290 **Demonstration of Machine Learning Model-Based Front-end Optimization of the Advanced Photon Source Linac**
***A. Hanuka**, J.P. Duris (SLAC) H. Shang, Y. Sun (ANL)*
The electron beam for the Advanced Photon Source (APS) at Argonne National Laboratory is generated from a thermionic RF gun and accelerated by an S-band linear accelerator |–| the APS linac. While the APS linac lattice is set up using a model developed with ELEGANT, the thermionic RF gun front-end beam dynamics have been difficult to model. One of the issues is that beam properties from thermionic guns can vary. As a result, linac front-end beam tuning is required to establish good matching and maximize the charge transported through the linac. A traditional Nelder-Mead simplex optimizer has been used to find the best settings for the sixteen quadrupoles and steering magnets. However, it takes a long time and requires some fair initial conditions. The Gaussian Process (GP) optimizer does not have the initial condition limitation and runs several times faster. In this paper, we report our data collection and analysis for the training of the GP hyperparameters and discuss the application of GP optimizer on the APS linac front-end optimization for maximum bunch charge transportation efficiency through the linac.

TUPAB291 **Subsystem Level Data Acquisition for the Optical Synchronization System at EuXFEL**
***M. Schütte**, A. Eichler, T. Lamb, V. Rybnikov, H. Schlarb, T. Wilksen (DESY)*
The optical synchronization system for the European X-Ray Free-Electron Laser provides sub-10 femtosecond timing precision for the accelerator subsystems and experiments. This is achieved by phase locking a mode-locked laser oscillator to the main RF reference and distributing the optical pulse train carrying the time information via actively propagation-time stabilized optical fibers to multiple end-stations. Making up roughly one percent of the entire European XFEL, it is the first subsystem to receive a large-scale data acquisition system for storing not just hand-selected information, but in fact all diagnos-

tic, monitoring, and configuration data relevant to the optical synchronization available from the distributed control system infrastructure. A minimum of 100 TB per year may be stored in a persistent archive for long-term health monitoring and data mining whereas excess data is stored in a short-term ring buffer for high-resolution fault analysis and feature extraction algorithm development. This paper describes scale, challenges and first experiences from the optical synchronization data acquisition system.

TUPAB292 **Automation of the ReAccelerator Linac Phasing**

***D.J. Barofsky**, A.I. Henriques, T.J. Kabana, A.S. Plastun (FRIB) D.B. Crisp, A. Lapierre, S. Nash, A.C.C. Villari (NSCL)*

The ReAccelerator (ReA) at the National Superconducting Cyclotron Laboratory at Michigan State University is a unique facility, as it offers the possibility to reaccelerate not only stable, but rare-isotope beams produced by fast-projectile fragmentation or fission. At ReA, beams are accelerated using a Radio-Frequency-Quadrupole and a superconducting linear accelerator before being delivered to experiments. Beam preparation time plays a major role in the availability of beams to experiments. One of the major time consuming tasks is the linac phasing, since there are 23 resonator cavities to be phased, usually with very low beam intensities. This procedure was automated using a combination of EPICS (Experimental Physics and Industrial Controls System) In/Output Controllers (IOCs) and IOC triggered scripts to scan the resonator phase delay and measure the change in beam energy. We have developed user-friendly tools to phase the linac, which have been tested, making the task of phasing substantially easier. In this presentation, we will present our methodology, challenges faced, tools developed, and initial results of the application for automating the phasing of the ReA linac.

TUPAB295 **Upgrade to the Epics Control System at the Argonne Wakefield Accelerator Test Facility**

***W. Liu**, J.M. Byrd, D.S. Doran, G. Ha, A.N. Johnson, P. Piot, J.G. Power, J.H. Shao, G. Shen, C. Whiteford, E.E. Wisniewski (ANL)*

The Argonne Wakefield Accelerator (AWA) Test Facility has used a completely homebrewed, MS Windows-based control system for the last 20 years. In an effort to modernize the control system and prepare for an active machine learning program, the AWA will work with the Advanced Photon Source (APS) controls group to upgrade its control system to EPICS. The EPICS control system is expected to facilitate collaborations and support the future growth of AWA. An overview of the previous AWA control and data acquisition system is presented, along with a vision and path for completing the EPICS upgrade.

TUPAB296 **LLRF Upgrade at the Argonne Wakefield Accelerator Test Facility**

***W. Liu**, D.S. Doran, G. Ha, P. Piot, J.G. Power, J.H. Shao, C. Whiteford, E.E. Wisniewski (ANL) L.R. Doolittle, D. Filippetto, D. Li, S. Paiagua, C. Serrano, V.K. Vytla (LBNL)*

The Argonne Wakefiled Accelerator (AWA) Test Facility designed and operated a homemade LLRF system for the last 20 years. It is based on NI-PXI products that has now become obsolete. The AWA's LLRF cannot keep up with the increasing stability demands of AWA's upgraded facility. An overhaul of the system is strongly desired. With the support from DOE-HEP, the AWA is collaborating with Lawrence Berkeley National Laboratory (LBNL)to upgrade its LLRF system with modern instrumentation to meet the growing stability demands. An overview of AWA's current LLRF system performance is presented together with the upgrade plan and expectations.

TUPAB297 **Data Archive System for Superconducting RIKEN Linear Accelerator at RIBF**

***A. Uchiyama**, N. Fukunishi, M. Kidera, M. Komiyama (RIKEN Nishina Center)*

At RIKEN Nishina Center, superconducting RIKEN Linear Accelerator (SRILAC) was newly installed at downstream of existing accelerator and upgraded for the search experiments of super-heavy-elements with atomic numbers of 119 and higher. For the data archiving and the data visualization in RI Beam Factory (RIBF) project, we have utilized RIBFCAS (RIBF control archive system) since 2009. For the number of archived data point was expected to increase dramatically for SRILAC, we introduced the Archiver Appliance for improvement of the data archiving performance. On the other hand, to realize a user-friendly system about the data visualization, the data of RIBFCAS and the Archiver Appliance should be visualized on the same system. In this system, by implementing a Web application to convert the RIBFCAS data to JSON format, it became possible to unify the data format with the Archiver Appliance and display the data with the same viewer software. In the SRILAC beam commissioning, it became to useful system for finding anomalies and understanding the behavior of superconducting cavity. In this conference, we report the system implementation, developed tool, and the future plan in detail.

TUPAB298 **First Steps Toward an Autonomous Accelerator, a Common Project Between DESY and KIT**

***A. Eichler**, F. Burkart, J. Kaiser, W. Kuropka, O. Stein (DESY) E. Bründermann, A. Santamaria Garcia, C. Xu (KIT)*

Reinforcement Learning algorithms have risen in popularity in recent years in the accelerator physics community, showing potential in beam control and in the optimization and automation of tasks in accelerator operation. The Helmholtz AI project "Machine Learning toward Autonomous Accelerators" is a collaboration between DESY and KIT that works on investigating and developing RL applications for the

automatic start-up of electron linear accelerators. The work is carried out in parallel at two similar research accelerators: ARES at DESY and FLUTE at KIT, giving the unique opportunity of transfer learning between facilities. One of the first steps of this project is the establishment of a common interface between the simulations and the machine, in order to test and apply various optimization approaches interchangeably between the two accelerators. In this paper we present the first results on the common interface and its application to beam focusing in ARES, and the idea of laser shaping with spatial light modulators at FLUTE.

TUPAB299 **Tuned Delay Unit for a Stochastic Cooling System at NICA Collider**

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Stochastic cooling is one of the crucial NICA (Nuclotron-based Ion Collider fAcility) subsystems. This system requires fine tuning of the response delay to the kicker, for both longitudinal and transverse stochastic cooling systems. The use of a digital delay line allows to add additional features such as a frequency dependent group velocity correction. To analyse the capabilities of the digital delay unit, a prototype of the device was created and tested. The article presents the characteristics of the prototype, its architecture and principle of operation, test results and estimations for the future developments.

TUPAB300 **CRYRING@ESR local Ion Source-Optimization utilizing Bi-Objective Genetic and Matrix-Profile Algorithm**

W. Geithner, *Z. Andelkovic, O. Geithner, F. Herfurth, V. Rapp (GSI) A. Neméth (Atato) F. Wilhelmstötter (emarsys)*

Employing the local ECR ion source of the FAIR phase 0 ion storage ring CRYRING@ESR, we set up an IT-environment for on-line data processing and applications based on the data available from beam diagnostic instruments and input signals controlling the ion source. As a first proof of principle, we implemented a closed-loop optimization software controller based on bi-objective Genetic Optimization. As one property for optimization we used the ion beam current measured with a Faraday-cup detector. As second optimization-property we the on-line processed time-resolved signal of the individual ion-source pulses employing the relatively new Matrix-Profile Algorithm which provides a measure for the shot-by-shot variability of the consecutive pulses. We will report on the status of the data logging framework, the implementation of related software programs and the results of first tests.

TUPAB302 **Arrival Time Stabilization at Flash Using the Bunch Arrival Corrector Cavity (BACCA)**

B. Lautenschlager, *Ł. Butkowski, M.K. Czwalinna, B. Dursun, M. Hierholzer, S. Pfeiffer, H. Schlarb, Ch. Schmidt (DESY)*

For pump-probe and seeding experiments at free electron lasers, a

femtosecond precise bunch arrival time stability is mandatory. To stabilize the arrival times a fast longitudinal intra bunch-train feedback (L-IBFB) using bunch arrival time monitors is applied. The electron bunch energy prior to a bunch compression chicane is modulated by superconducting radio frequency (SRF) cavities to compensate fast arrival time fluctuations of the subsequent bunches. A broadband normal conducting RF cavity was installed in front of the first bunch compression chicane at FLASH. The L-IBFB uses the normal conducting cavity for small but fast energy corrections together with the SRF cavities for larger and slower corrections. Current measurements show arrival time stabilities of the electron bunches towards 5 fs (rms) at the end of the linac, if the normal conducting cavity acts together with the SRF cavities in the L-IBFB system.

TUPAB303 **BPM Temperature Influence on Beam Orbit at HLS Storage Ring by Machine Learning**

***K.M. Chen**, F.Y. Wang (USTC/NSRL)*

The stability of a synchrotron radiation light source is an extremely important performance. By reasonable design, the short-term (within 1 hour) stability of beam orbit can generally be controlled well. However, for the long-term drift, due to the lack of related monitoring and effective feedback measures, it is usually difficult to get a good control. So the long-term stability of the fourth-generation light sources brings new challenges to beam measurement and control. In recent years, deep learning based on neural network has been applied more and more widely and can do with more and more complex problems, which can be applied to almost all fields. Therefore, based on the theoretical analysis of the influence of BPM temperature drift on electron beam orbit, the long-term running data of Hefei light source (HLS) was preliminarily analyzed by deep learning, and the influence of BPM temperature drift on electron beam orbit in the storage ring was finally obtained. The related research can provide a certain reference for the long-term stability control of the light source.

TUPAB304 **Preliminary investigation of the Noises and Updates on Physics Studies of FOFB in HPES**

***X.Y. Huang**, Y. Jiao, Y. Wei (IHEP)*

High Energy Photon Source (HEPS) is a Fourth-generation storage ring light source in China and is under construction. Noises, such as the ambient mechanical vibration and the power supply ripples of magnets, may induce large orbit motions of electron bunches and hence dramatically degrade the emitted photon beam quality. The effect of noises becomes significant and needs to be considered very carefully, especially when the emittances of the electron beam approach the diffraction limit of x-ray. For the HEPS, the noises are modelled and the total beam orbit motion is evaluated considering the spectral characteristics of all the transformation processes from the errors to the orbit. In this paper, we present the preliminary calculation of the effects of noises in HEPS, and the control of the orbit motion with the

FOFB system.

TUPAB305 **Adaptive Machine Learning for Time-Varying Particle Accelerators**

A. Scheinker *(LANL)*

Particle accelerators are difficult to control, they are composed of thousands of coupled components and accelerate intense beams experiencing complex collective effects such as coherent synchrotron radiation and space-charge forces. Accelerator scientists are starting to utilize machine learning (ML such as random forests, convolutional neural networks, and Gaussian processes) for accelerator tuning, diagnostics, and optimization by learning directly from data such as TCAV-based LPS images. ML approaches have focused on time-invariant problems for which a relationship between parameters and objective functions can be memorized. Responding to unmodeled and time-varying changes remains a major challenge requiring new approaches coupling adaptive feedback with ML and reinforcement learning (RL) to actively respond to unmodeled disturbances. We give an overview of adaptive feedback, ML, and RL and new adaptive ML and RL techniques for time-varying accelerator applications. We present results for the LANSCE linear accelerator, FACET-II at SLAC, and the HiRES ultrafast electron diffraction (UED) accelerator and the Neutralized Drift Compression Experiment (NDCX-II) at LBNL.

TUPAB306 **Status of Beam-Based Feedback Research and Development for Continuous Wave SRF Linac ELBE**

A. Maalberg*, M. Kuntzsch (HZDR) E. Petlenkov (TalTech)*

The superconducting electron linear accelerator ELBE at Helmholtz-Zentrum Dresden-Rossendorf is a versatile light source operated in continuous wave mode. As the demand on the beam stability increases, the improvement of the beam control schemes currently installed at ELBE becomes highly relevant. This improvement can be achieved by an upgrade of the existing digital MicroTCA.4-based LLRF control scheme by beam-based feedback. By presenting both the design and implementation details of the new control scheme this contribution reports the status of the work in progress.

TUPAB307 **Robust Optical Instrumentation for Accelerator Alignment Using Frequency Scanning Interferometry**

M. Sosin*, H. Mainaud Durand, F. Micolon, V. Rude, J.M. Rutkowski (CERN)*

The precise alignment of components inside particle accelerators is an important engineering challenge in high-energy physics. Optical interferometry, being a precise, optical distance measurement technique, is often a method of choice in such applications. However, classical fringe-counting interferometers present several drawbacks in terms of system complexity. Due to the increasing availability of broadband, high-speed, sweeping laser sources, Frequency Scanning Interferometry (FSI) based systems, using Fourier analysis of the interference signal, are becoming a subject of growing interest. In the

framework of the High-Luminosity LHC project at CERN, a range of FSI-based sensor solutions have been developed and tested. It includes the optical equipment for monitoring the position of cryogenic components inside their cryostats and FSI instrumentation like inclinometers and water-based levelling sensors. This paper presents the results of preliminary tests of these components.

TUPAB308 **Mechanical Consolidation of the LHC Triplet Magnet Supporting System for Remote Alignment**

***F. Micolon**, N. Bourcey, J-B. Deschamps, A. Herty, S.L.N. Le Naour, T. Mikkola, V. Parma, D. Ramos, V. Rude, M. Sosin (CERN)*

Given the high radiation area and the tight alignment tolerances, the LHC inner triplet magnets were designed to be realigned remotely using motorized supporting jacks. However, during run 2 the LHC triplet realignment system started to show an unexpected behavior with erratic load variations on the magnet supporting jacks when operated. It was then decided to freeze any further realignment of the LHC triplet magnet for the remainder of the run. Subsequently, a project team was set up at CERN to understand better the conditions leading to such unexpected behavior and to study and propose a technical consolidation for the realignment system of the LHC triplet magnet. A fully instrumented magnet string using LHC triplet spare magnets was assembled and used at CERN to provide a realistic test bench for this study. This paper reports on the work undertaken to study the triplet magnet overall realignment kinematic, the findings on the readjustment system malfunction and details the consolidation solution implemented for the next LHC run

TUPAB309 **Alignment Verification and Monitoring Strategies for the Sirius Light Source**

***R. Oliveira Neto**, R. Junqueira Leão, L.R. Leao (CNPEM)*

The approach for the alignment of Sirius is the use of portable coordinate metrology instruments in a common reference, via a network of stable points previously surveyed. This type of network is composed of a dense distribution of points materialized in the form of embedded target holders on the special slab and radiation shielding. Phenomena such as ground movements, temperature gradients and vibrations could lead to misalignment of the components, possibly causing a degradation in machine performance. Therefore, the relative positions of the accelerator magnets need to be periodically verified along with the structures surrounding it to ensure a good reference to future alignment operations. This paper will present the status of Sirius monitoring systems, including data from the first months of operation of the hydrostatic levelling sensors. Also, possibilities with simplified network measurements for detecting structural deformations and assessing its stability will be presented, along with a proposal of a photogrammetric reconstruction of the alignment profile of the storage ring. Finally, it will be shown a compilation of analysis on the deformation of the Sirius facilities.

TUPAB310 **Establishing a Metrological Reference Network for the Alignment of Sirius**

H. Geraissate, *G.R. Rovigatti de Oliveira (LNLS) R. Junqueira Leão (CNPEM)*

Sirius is the Brazilian 4th generation synchrotron light source. It consists of three electron accelerators and it has room for up to 38 beamlines. To make the alignment of Sirius components possible, there is a need for a network of points comprising the installation volume, allowing the location of portable coordinate instruments on a common reference frame. This work describes the development of such networks for the whole Sirius facility. The layout of the networks is presented together with the survey strategies. Details are given on how the calculations combined laser trackers and optical level measurements data and how the Earth curvature compensation was performed. A novel laser tracker orientation technique applied for linking networks on different environments is also presented. Finally, the uncertainty estimation for the resulting network and its deformation history is shown.

TUPAB311 **Nonlinear Correctors Tuning for the Collector Ring Isochronous Mode**

M.A. Lyalin, *I. Koop, D.B. Shwartz (BINP SB RAS) I. Koop,* ***M.A. Lyalin***, *D.B. Shwartz (NSU)*

One of the operating modes for the Collector Ring (CR) under construction in Darmstadt is the isochronous mode, in which the captured ions circulate with an equal period regardless of their momentum. The measurement of the orbital period by the time-of-flight sensors makes it possible to precisely determine the mass to the charge ratio of the ion under study. For this, the change of the circulation period should not exceed dT/T of 10^{-6} in the entire momentum acceptance of the 0.62%. Modeling in the Strategic Accelerator Design code showed that without nonlinear effects compensation, the orbital period variation is 10^{-5}. In this work, the parameters of nonlinear correctors, which are sextupoles and quadrupoles in CR, are determined, necessary for the isochronous mode implementation.

TUPAB312 **BOLINA, a Suite for High-Level Beam Optimization**

V. Martinelli *(INFN/LNL)*

A high-level software called BOLINA (Beam Orbit for LINear Accelerators) has been designed to fully characterise and automatically correct the trajectory in order to help operators during beam transport with an easily scalable suite for LINACs. Currently, the high-level software, interfaced with the EPICS control system, automatically manages accelerator devices to preserve the beam quality including beam-based alignment and, in the near future, dispersion-free steering software. The suite has been developed to satisfy and switch the software easily to a different machine using interceptive /non-interceptive diagnostics. The software was designed for Eli-np in Romania using BPM, and is now under testing using Beam Profiler grids in the Legnaro INFN laboratory using Tandem-Alpi, Adige S^{1+} and, in the future, the SPES

facility.

TUPAB313 **Arrangement Optimization of Quadrupoles and Correctors for Beam Alignment**

***L. Xu**, Q.M. Zhang (Xi'an Jiaotong University) H.X. Deng (SARICAS) N. Huang (UCAS) N. Huang (SINAP)*

In the X-ray free-electron laser (XFEL), the alignment and stability of beam orbit have a great impact on power and qualities of the generated X-ray pulses. Currently, the beam-based alignment (BBA) is the most widely used technique in beam alignment. In order to find the best arrangement of quadrupoles and correctors, a mathematical model is established based on the transmission matrix method. With this model, several simple arrangements of quadrupoles and correctors are selected to simulate the beam alignment process. It is found that when two correctors adjust two quadrupoles, the beam can pass through the center of quadrupoles approximately collimated.

TUPAB314 **SPS Personnel Protection System: from Design to Commissioning**

***T. Ladzinski**, T. Hakulinen, F. Havart, V. Martins De Sousa Dos Rios, M. Munoz Codoceo, P. Ninin, J.P. Ridewood, E. Sanchez-Corral Mena, D. Vaxelaire (CERN)*

During the second long shutdown (LS2) of the accelerator complex at CERN, the access system of the Super Proton Synchrotron (SPS) was completely renovated. This complex project was motivated by the technical obsolescence and lack of sufficient redundancy in the existing system, as well as by the need for homogenisation of technologies and practices across the different machines at CERN. The new Personnel Protection System includes 16 state-of-the-art access points making sure that only fully identified, trained and authorised personnel can enter the facility and an interlock system with a rationalized number of safety chains designed to meet the current safety standards. The control part is based on Siemens 1500 series of programmable logic controllers, complemented by a technologically diverse relay logic loop for the critical safety functions. This paper presents the new system and the design choices made to permit fast installation in a period where the access system itself was heavily used to allow vast upgrades of the SPS accelerator and its infrastructure. It also covers the verification and validation methodology and lessons learned during the commissioning phase.

TUPAB315 **Development of Disaster Prevention System for Accelerator Tunnel**

***K. Ishii**, K. Bessho (KEK) N. Yamamoto (J-PARC, KEK & JAEA)*

In an enclosed space such as a particle accelerator tunnel, ensuring worker safety during a disaster is an issue of critical importance. It is necessary to have a system in which the manager can know from outside the tunnel whether there is any worker left behind and whether the worker is escaping in the right direction. Because a global positioning system (GPS) is not available in the tunnel, we are developing a

disaster prevention system that uses Wi-Fi to transmit the positioning of workers and two-way communication. The Wi-Fi access point (AP) installed in the tunnel should be radiation resistant. Additionally, the equipment carried by the worker is convenient and easy to carry. We tested the radiation hardness of commercial AP devices and developed a smartphone application to perform location information transmission and simultaneous character transmission. In 2019, we installed the system on the J-PARC Main Ring and started its operation. In this paper, the functions of the developed system and its prospects are described.

TUPAB316 **New Operational Quantities for Radiation Protection by ICRU and ICRP: Impact on Workplaces at Accelerators**

***Th. Otto**, M. Widorski (CERN)*

In radiation protection, Effective Dose E quantifies stochastic radiation detriment. E is defined as a weighted sum of absorbed dose to organs and tissues and cannot be measured directly. ICRU has defined operational quantities to measure effective dose approximately, such as Ambient dose equivalent H*(10). At high energies, the estimates provided by H*(10) deviate strongly from effective dose. In 2020, ICRU and ICRP have recommended new operational quantities for external radiation with a definition close to the one of effective dose, and published an extensive collection of conversion coefficients from particle fluence to the new quantities (1). Ambient dose H* serves for operational monitoring purposes. The new definition alleviates the observed discrepancies of H*(10) with effective dose. In this paper, we present a numerical study of effective dose E, ambient dose equivalent H*(10) and ambient dose H* in radiation fields at workplaces at proton- and electron accelerators. These places include locations behind primary shielding, in access mazes and in the vicinity of activated accelerator components.

TUPAB317 **Benchmarking of the Radiation Environment Simulations for the CMS Experiment**

***I.L. Azhgirey**, I.A. Kurochkin, A.D. Riabchikova (IHEP) D. Bozzato, A.E. Dabrowski, P. Kicsiny, S. Mallows, J. Wanczyk (CERN)*

Radiation Simulations group of the Beam Radiation Instrumentation and Luminosity Project of the CMS experiment provide for CMS radiation environment and radiation effects simulation and benchmarking of these calculations with CMS data and other data from LHC measuring devices. We present some results of such benchmarking and the reliability analysis of the simulation procedures for radiation environment calculations at the LHC.

TUPAB318 **The Beamline Safety Interlock System of Taiwan Photon Source**

***C.F. Chang**, C.Y. Chang, C.Y. Liu, H.Y. Yan (NSRRC)*

The energy of synchrotron radiation generated by bremsstrahlung radiation and magnet is rather high, which may cause serious radiation damage to human body or even imperil people's life. The beamline

therefore must be equipped with radiation-protection system; in addition, the overheat of optical components exposed to synchrotron radiation will lead to the damage of optical components and devices. In consequence, the beamline should be furnished with the cooling-protection system to cool down optical components and devices. The Beamline Safety Interlock System targets at protecting the personnel and the safety of devices, limiting the radiation dose to a security value for experimental personnel or staffs exposing to radiation on the site as well as preventing beamline components from being exposed to overheat or vacuum damages to improve the effectiveness of beamline.

TUPAB319 **SNS Credited Beam Power Limit System Preliminary Design**
C. Deibele *(ORNL) K.L. Mahoney (ORNL RAD)*
The Controls Group at the Spallation Neutron Source (SNS) is designing a programmable signal processor based credited safety control that calculates pulsed beam power based on beam kinetic energy and charge. The system must reliably shut off the beam if the average power exceeds 2.145 MW averaged over 60 seconds. This paper discusses architecture and design choices needed to develop the system under the auspices of a programmable radiation-safety credit control.

TUPAB320 **Physical Design of the Radiation Shielding for the CMS Experiment at LHC**
I.L. Azhgirey*, I.A. Kurochkin, A.D. Riabchikova (IHEP) D. Bozzato, A.E. Dabrowski, S. Mallows (CERN)*
The design of the radiation shielding for the CMS experiment at the LHC requires a simulation of the radiation environment using a model of the CMS experimental setup, accelerator components and the experimental hall infrastructure. The radiation simulations are used to optimise the design of the CMS detectors components and also the interface of the CMS detector with LHC accelerator. The Beam Radiation Instrumentation and Luminosity Project of CMS is responsible for giving important input into the optimisation and upgrade of radiation shielding used in CMS and also the radiation environment simulations software infrastructure. This contribution describes the organization of this work, the simulation software environment used for this part of CMS experiment activity and recent radiation simulation results used to optimise the forward shielding for CMS.

TUPAB321 **Functional Safety Approach for Hazard Controls at the Facility for Rare Isotope Beams**
K.C. Schrock*, D. Stout (FRIB)*
The Functional Safety framework for managing hazards, per standards IEC 61508 and IEC 61511, is applied to a broad class of environmental, safety, and health (ESH) hazards at the Facility for Rare Isotope Beams (FRIB). A tailored approach using qualitative assessment and incorporating passive and administrative controls provides an integrated process that can be used for all non-standard industrial hazards such as

prompt or induced radiation, oxygen deficiency, high power lasers, reactive metals, flammable gasses, and more. FRIB's system for hazard assessment and implementation of hazard controls is described, with examples and comparisons to the quantitative approach and methods applied at other laboratories.

TUPAB322 **Redesign and Upgrade of the LHC Access Control System**

***T. Hakulinen**, S. Di Luca, G. Godineau, R. Nunes, G. Smith (CERN)*

The old LHC Access Control System (LACS) was based on a single access control solution, which integrated software and hardware into one monolithic application encompassing all the different subsystems (access control, video surveillance, interphones, biometry, equipment control, safety elements). Both the hardware and software were approaching end-of-life by the vendor before the CERN Long Shutdown 2 (LS2). The new design is based on a distributed approach, where the different subsystems are integrated in a flexible manner with well-defined interfaces, which will permit much easier single sub-system management, upgrades, and even full replacements if necessary. From the system point of view, the focus is on the advantages that this redesign brings to system operation, testing, and management. Procedurally the interest is in the overall management of a very complex in-place upgrade of a system, where the new implementation needed to coexist with the old during its constant simultaneous solicitation over the LS2.

TUPAB323 **Modular Type Quick Splicing Method for TPS Beamline Radiation Shielding Hutch**

***C.Y. Chang**, C.H. Chang, S.H. Chang, Chen,C.L. Chen, Y.-C. Lin, J.C. Liu, D.G. Liu, H.Y. Yan (NSRRC)*

The synchrotron light source is transported to the experimental station through a beamline with specified optics, such as mask, mirror, slit, monochromator. Generally, standard beamline should use solid materials (stainless steel, tungsten, lead, and PE) to block bremsstrahlung and synchrotron radiations, even the neutron. The radiation-shielded hutch surrounds the peripheral area of the beamline with iron and lead panels. It requires blocking the scattering radiation to protect the person against radiation hazards. A modularized radiation shielding hutch includes the frame, wall, and ceiling cover that can assemble on-site through splicing. This method could greatly shorten the installation. Besides, we designed the modular ceiling cover units with a quick mounting/opening function to easily enable the maintenance and installation of large optical components. The details of the concept design for the fixed-point radiation shielding hutch in the TPS beamline are also reported that includes the configurations of the radiation shielding wall panels, frames, and pipes/cables arrangements.

TUPAB324 **Real-Time Radiation Monitoring System With Interlock Protection Mechanism in Taiwan Photon Source**

Y.-C. Lin, *A.Y. Chen, C.-R. Chen, S.J. Huang, S.P. Kao, S.Y. Lin, J.C. Liu, P.J. Wen (NSRRC)*

To ensure radiation safety for personnel working in the facility, the Radiation and Operation Safety Division has installed a real-time radiation monitoring system in the working area to monitor gamma rays and neutrons, for which the annual dosage limit is designed to be less than 1 mSv/year. Considering 2000 working hours for users and staff members, we have derived a control dose rate limit 2 μSv/4h for interlock protection. If the accumulated radiation dose monitored with the system exceeds 2μSv within a 4-h counting interval, the radiation monitoring station sends a signal to the interlock system to stop injection until the next counting period interval. This paper introduces the radiation monitoring system and its related design information in Taiwan Photon Source.

TUPAB325 **Data-Driven Risk Matrices for CERN's Accelerators**

T. Cartier-Michaud, *A. Apollonio, G.B. Blarasin, B. Todd, J.A. Uythoven (CERN)*

A risk matrix is a common tool used in risk assessment, defining risk levels with respect to the severity and probability of the occurrence of an undesired event. Risk levels can then be used for different purposes, e.g. defining subsystem reliability or personnel safety requirements. Over the history of the Large Hadron Collider (LHC), several risk matrices have been defined to guide system design. Initially, these were focused on machine protection systems, more recently these have also been used to prioritize consolidation activities. A new data-driven development of risk matrices for CERN's accelerators is presented in this paper, based on data collected in the CERN Accelerator Fault Tracker (AFT). The data-driven approach improves the granularity of the assessment, and limits uncertainty in the risk estimation, as it is based on operational experience. In this paper the authors introduce the mathematical framework, based on operational failure data, and present the resulting risk matrix for LHC.

TUPAB326 **Injection Optimization and Study of XiPAF Synchrotron**

X.Y. Liu, *X. Guan, Y. Li, M.W. Wang, X.W. Wang, H.J. Yao, W.B. Ye, H.J. Zeng, S.X. Zheng (TUB) W.L. Liu, D. Wang, M.C. Wang, Z.M. Wang, Y. Yang (NINT)*

The synchrotron of XiPAF (Xi'an 200MeV proton application Facility) is a compact proton synchrotron, which using H^- stripping injection and phase space painting scheme. Now XiPAF is under commissioning with some achievements, the current intensity after injection reach 43mA, the corresponding particle number is $2.3 \cdot 10^{11}$, and the injection efficiency is 57%. The simulation results by PyOrbit show that the injection efficiency is 77%. In this paper, we report how the injection intensity and efficiency were optimized. We analyzed the difference between simulation and experiments, and quantitatively investigate

the factors affecting injection efficiency through experiments.

TUPAB327 **Developing Robust Digital Twins and Reinforcement Learning for Accelerator Control Systems at the Fermilab Booster**

D.L. Kafkes, *C. Herwig, W. Pellico, G.N. Perdue, A.F. Quintero-Parra, B.A. Schupbach, K. Seiya, J.M. St. John, N.V. Tran (Fermilab) J.M. Duarte (UCSD) Y. Huang (PNNL) R.T. Keller (CU-APAM) M. Schram (JLab)*

We describe the offline machine learning (ML) development for an effort to precisely regulate the Gradient Magnet Power Supply (GMPS) at the Fermilab Booster accelerator complex via a Field-Programmable Gate Array (FPGA). As part of this effort, we created a digital twin of the Booster-GMPS control system by training a Long Short-Term Memory (LSTM) to capture its full dynamics. We outline the path we took to carefully validate our digital twin before deploying it as a reinforcement learning (RL) environment. Additionally, we demonstrate the use of a Deep Q-Network (DQN) policy model with the capability to regulate the GMPS against realistic time-varying perturbations.

TUPAB328 **Machine Learning for Time Series Prediction of an Accelerator Beam to Recognize Equipment Malfunction**

C.C. Peters *(ORNL RAD) W. Blokland, D.L. Brown, F. Liu, C.D. Long, D. Lu, P. Ramuhalli, D.E. Womble, J. Zhang, A.P. Zhukov (ORNL)*

The Spallation Neutron Source (SNS) is an accelerator based pulsed neutron source based on a 1 GeV pulsed proton Superconducting Radio Frequency (SRF) linear accelerator (linac). Since beginning high power beam operation in 2006 correlations have been found linking abrupt beam loss events to SRF cavity instabilities. With the planned upgrades to double the beam power we expect increased rates of degradation and the importance of minimizing these beam loss events will become ever more important. To further limit degradation, we are developing machine learning approaches to monitor the beam and to detect, predict and prevent beam loss events. Initial research has shown that precursors to beam loss events are detectable. The initial steps are to use ML-based classification to recognize anomalies and to use Long Short-Term Memory (LSTM) autoencoders to predict beam loss. In this paper, we describe recent progress in applying machine learning for recognizing anomalies and predicting beam loss and present initial results of our research using acquired data from different diagnostics and the Machine Protection System (MPS).

TUPAB329 **Pattern Based Parameter Setup of the SNS Linac**

C.C. Peters *(ORNL RAD) A.P. Shishlo (ORNL)*

Theoretical and practical aspects of beam tuning procedures used for the SNS linac are discussed. The SNS linac includes two sections of beam acceleration. Acceleration in the first section up to 185.5 MeV is done with a room temperature copper linac which consists of both Drift Tube Linac (DTL) and Coupled Cavity Linac (CCL) Radio Frequency (RF) cavities. The second section consists of 81 Superconduct-

ing RF (SRF) cavities which accelerate the beam to the final beam energy of 1 GeV. The linac is currently capable of delivering an average beam power output of 1.44 MW with typical yearly operating hours of around 4500 hours. Due to the high power output and high availability of the linac, activation of accelerator equipment is a significant concern. The linac tuning process consists of three stages: model based setup of amplitudes and phases of the RF cavities, empirical beam loss reduction, and then documentation of the final amplitudes and phases of RF cavities after the empirical tuning. The final step is needed to ensure fast recovery from an SRF cavity failure. This paper discusses models, algorithms, diagnostic tools, software, and practices that are used for these stages.

TUPAB331 **A Cloud Based Toolbox for Accelerator Controls Interfaces and Optimization**

***J.P. Edelen**, E. Carlin, M.V. Keilman, P. Moeller, R. Nagler (RadiaSoft LLC)*

Modern particle accelerator facilities generate large amounts of data and face increasing demands on their operational performance. As the demand on accelerator operations increases so does the need for automated tuning algorithms and control to maximize uptime with reduced operator intervention. Existing tools are insufficient to meet the broad demands on controls, visualization, and analysis. We have developed a cloud based toolbox featuring a generic virtual accelerator control room for the development of automated tuning algorithms and the analysis of large complex datasets. This framework utilizes tracking codes combined with with algorithms for machine drift, low-level control systems, and other complications to create realistic models of accelerators. These models are directly interfaced with control toolboxes allowing for rapid prototyping of tuning algorithms. In this paper, we will provide an overview of our interface and demonstrate its utility for building beamline controls displays directly from accelerator simulation lattices. We will also demonstrate the use of our interface for testing online optimization and control algorithms.

TUPAB333 **Status of PIP-II 650 MHz Prototype Dressed Cavity Qualification**

***G.V. Eremeev**, S.K. Chandrasekaran, F. Furuta, M. Martinello, Y.M. Pischalnikov, K.S. Premo, G. Wu (Fermilab)*

PIP-II linac will have nine low-beta cryomodules with four cavities each and four high-beta cryomodules with six cavities each. Collaborative efforts between Fermilab and the international partners are ongoing to design, fabricate, and qualify dressed cavities and their components. After qualification of 0.9 HB650 cavities at Fermilab, several pre-production 0.92 and 0.61 cavities have been fabricated and are being qualified. We present the current status of cavity qualification for PIP-II.

TUPAB334 **Nb_3Sn SRF Cavity Performance and Fabrication Progress at Cornell University**

***R.D. Porter**, G. Gaitan, M. Liepe, N.A. Stilin, Z. Sun (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)*

Nb_3Sn is the best material for advancing SRF cavity performance beyond what can be achieved using niobium, which is nearing its fundamental performance limits. The material promises 4.2 K operation, improved quality factors, and nearly twice the potential accelerating gradient compared to niobium (~100 MV/m for Tesla elliptical style cavities). Current state-of-the-art Nb_3Sn cavities achieve 4.2 K operation with quality factors in excess of $2*10^{10}$, and reach 17-24 MV/m in CW operation. This already reaches the specification for many current SRF accelerators, but further advancements can be made. Here we present progress at Cornell university in improving the Nb_3Sn accelerating gradient, and in new Nb_3Sn fabrication techniques that should lead to further performance improvements.

TUPAB336 **Technical Applications of Niobium Used in Superconducting Cavities for Particle Accelerators**

***J.W. Fang** (USTC/NSRL)*

Recently, the researched on superconducting cavity have attracted much attention all over the world. Superconducting cavities performances for next-generation accelerators are correlated to materials and surface technical treatments. The application of superconducting materials used in radio frequency cavities must be evaluated rigorously for their characteristic of radio frequency (RF) and behavior in vacuum, while process procedures require plenty of experimental results to assist with the construction of superconducting cavities. Niobium offers unquestionable superiorities for enhancing characteristic of radio frequency due to their high unloaded quality factor Q_0. Processing a surface with lower secondary electron yield (SEY) is one of major measures of mitigating electron multipacting appearance. Here, material properties compliance with superconducting cavities at cryogenic temperature have been investigated. To this achievement, a campaign of cryogenic SEY measurements of Nb has been launched by custom measurement system in NSRL. This paper is aimed to provide crucial parameters for design and construction of superconducting cavities.

TUPAB338 **Surface Roughness Reduction of Nb_3Sn Thin Films via Laser Annealing for Superconducting Radio-Frequency Cavities**

***Z. Sun**, M. Ge, M. Liepe, T.E. Oseroff, R.D. Porter (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) A.B. Connolly, M.O. Thompson (Cornell University)*

Superconducting radio frequency (SRF) cavities, a key component of particle accelerators, await new SRF materials beyond the state-of-the-art niobium. Nb_3Sn is one of the most competitive candidates, since

it increases the superheating field, allows the operation temperature up to 4K, and improves cavity efficiency. Surface roughness and grain boundaries, however, significantly affect the RF performance of current Nb_3Sn cavities. Here, we explore a post laser annealing technique to reduce the surface roughness. In doing so, we deposited a TiN laser-absorber on Nb_3Sn and Nb surfaces, and then annealed the samples by laser scanning via different laser systems. The Nb_3Sn surface roughness was minimized to 10^1 nm (Ra) by laser annealing via 308 nm, 35 ns pulses. Surface imaging and Fourier analysis revealed laser annealing is able to remove sharp edges and <1 um wavelength features.

TUPAB339 **High Power Test of the Antenna Adjustable Power Coupler for 325 MHz Superconducting Cavities**
J.Y. Yoon, *E.-S. Kim, C.S. Park, S.H. Park (KUS) J. Bahng (Korea University Sejong Campus) K.R. Kim (PAL)*
The power coupler is development at Korea University for a Single Spoke Resonator (SSR) of heavy ion accelerator. Our power coupler is a coaxial capacitive type based on a conventional 3-1/8 inch electronic industries alliance (EIA) 50 Ω coaxial transmission line with a titanium nitride (TiN) coated single ceramic window. A high power test is rectangular test cavity with high vacuum and various measuring equipment, such as an arc detector, a power meter, and an electron pick-up probe. The interlock system under vacuum and arc instrumentations prevent the RF window from breaking the power coupler window during the high power test. We conduct high power tests for more than 12 hrs at 12 kW in a 325 MHz continous wave (CW) mode to verify the performance of the designed power coupler.

TUPAB340 **Design of the Magnetic Shielding for 166-MHz and 500-MHz Superconducting RF Cavities at High Energy Photon Source**
L. Guo, *Y. Chen, J. Li, Z.Q. Li, Q. Ma, P. Zhang, X.Y. Zhang, H.J. Zheng (IHEP)*
Five 166 MHz quarter-wave β=1 superconducting cavities and two 500 MHz single-cell elliptical superconducting cavities have been designed for the storage ring of High Energy Photon Source (HEPS). It is necessary to shield magnetic field for superconducting cavities to reduce the residual surface resistance due to magnetic flux trapping during cavity cool down. The magnetic shielding for both 166 MHz and 500 MHz superconducting cavities have been designed. The residual magnetic field inside the cavities have been calculated by using Opera-3D simulation software. The geographic location of the cavity being installed at the HEPS site and the fringe field of the upstream magnet are considered. These are reported in this paper.

TUPAB341 **Optimization of Two-Cell Cavities for the W and H Working Points of the FCC-ee Considering Higher-Order Mode Effects**
S. Udongwo, *S.G. Zadeh, U. van Rienen (Rostock University, Faculty of Computer Science and Electrical Engineering) R. Calaga (CERN)*

The lepton collider of the future circular collider (FCC-ee) aims at conducting precision measurements on the Z, W, and H bosons and the top quark. The present RF baseline considers single-cell cavities at 400 MHz for the high current Z-pole working point, four-cell 400 MHz cavities for the W and H working points, and a hybrid RF system composed of four-cell 400 MHz and five-cell 800 MHz cavities for the high energy tt working point. The W working point has shown limitations in the achievable HOM damping for beam stability requirements using four-cell cavities. A two-cell cavity is studied as an alternative scenario for the current W- and H-RF setups with a special focus on HOM damping during the optimization of the RF geometry.

TUPAB342 **Preliminary Cryogenic Cold Test Results of the First 9-Cell LSF Shape Cavity**

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Following successful prototyping and testing of single- & 5-cell LSF shape cavities, the first 9-cell LSF shape cavity LSF9-1 was successfully constructed using an innovative process at JLab with the in-house facilities. The cavity was then shipped to KEK for post-fabrication mechanical adjustment and ILC TDR style treatment and surface processing. Cold testing was carried out at the JLab VTA facility, instrumented with a suite of Kyoto instruments. Favorable values for the bath pressure detuning sensitivity and Lorentz force detuning coefficient were experimentally measured, validating the design improvement in cell stiffeners. Pass-band measurements indicate 4 out of 9 cells reaching gradient capability of > 45 MV/m, including 2 cells reaching 51 MV/m. Cornell OST detectors identified the cell and location responsible for the current hard quench limit. Multipacting-like barriers observed in end cells are investigated both analytically and numerically. The cavity was shipped to FNAL and received a light EP at the joint ANL/FNAL facility for further cold testing at Jlab. Two new 9-cell LSF cavities are being constructed including one made of large-grain niobium material.

TUPAB343 **Final Design Studies for the VSR DEMO 1.5 GHz Coupler**

***E. Sharples-Milne**, V. Dürr, P. Echevarria, J. Knobloch, A. Neumann, A.V. Vélez, N.W. Wunderer (HZB)*

With the 1.5 GHz couplers for the Variable pulse length Storage Ring (VSR) DEMO now in the manufacturing stages, the studies that led to the final coupler design will be presented. The system specific constraints and design modifications that combat the challenges of thermomechanical stresses, higher order mode (HOM) propagation and dimensional constraints are explored. This includes S-Parameter analysis, an in-depth study of the coupling factor, and multipacting studies for the average (1.5 kW) and peak (16 kW) power.

TUPAB344 **Evaluation of Anisotropic Magnetoresistive (AMR) Sensors for a Magnetic Field Scanning System for SRF Cavities**
***I.P. Parajuli**, G. Ciovati, J.R. Delayen, A.V. Gurevich (ODU) G. Ciovati, J.R. Delayen (JLab)*
One of the significant causes of residual losses in superconducting radio-frequency (SRF) cavities is trapped magnetic flux. The flux trapping mechanism depends on many factors that include cool-down conditions, surface preparation techniques, and ambient magnetic field orientation. Suitable diagnostic tools are not yet available to quantitatively correlate such factors' effect on the flux trapping mechanism. A magnetic field scanning system (MFSS) consisting of AMR sensors, fluxgate magnetometers, or Hall probes is recently commissioned to scan the local magnetic field of trapped vortices around 1.3 GHz single-cell SRF cavities. In this contribution, we will present results from sensitivity calibration and the first tests of AMR sensors in the MFSS.

TUPAB345 **Availability Modeling of the Solid-State Power Amplifiers for the CERN SPS RF Upgrade**
***L. Felsberger**, A. Apollonio, T. Cartier-Michaud, E. Montesinos, J.C. Oliveira, J.A. Uythoven (CERN)*
As part of the LHC Injector Upgrade program a complete overhaul of the Super Proton Synchrotron Radio-Frequency (RF) system took place. New cavities have been installed for which the solid-state technology was chosen to deliver a combined RF power of 2 MW from 2560 RF amplifiers. This strategy promises high availability as the system continues operation when some of the amplifiers fail. This study quantifies the operational availability that can be achieved with this new installation. The evaluation is based on a Monte Carlo simulation of the system using the novel AvailSim4 simulation software. A model based on lifetime estimations of the RF modules is compared against data from early operational experience. Sensitivity analyses have been made, that give insight to the chosen operational scenario. With the increasing use of solid-state RF power amplifiers, the findings of this study provide a useful reference for future application of this technology in particle accelerators.

TUPAB346 **Development of a 500-MHZ 150-KW Solid-State Power Amplifier for High Energy Photon Source**
***Y.L. Luo**, T.M. Huang, J. Li, H.Y. Lin, Q. Ma, Q.Y. Wang, P. Zhang, F.C. Zhao (IHEP)*
A 500-MHz 150-kW solid-state power amplifier (SSA) has been developed to test the 500-MHz normal conducting cavities for High Energy Photon Source (HEPS) booster ring. It will also be used to power normal conducting cavities in the initial beam commissioning stage of the HEPS storage ring. A total number of 96 amplifier modules are combined initially by coaxial and later by waveguide combiners to deliver the 150-kW RF power. The final output is of EIA standard WR1800 rectangular waveguide. Each amplifier module consists four transis-

tors equipped with individual circulator and load and outputs 2-kW RF power. Modularity, redundancy and satisfactory RF performance are demonstrated. In the final stage of HEPS project, this 150-kW amplifier will be modified to a 100-kW amplifier to join the other five 100-kW SSAs for normal operation of the booster cavities. The development and test results are presented in this paper.

TUPAB347 **Development of a 166-MHz 260-kW Solid-State Power Amplifier for High Energy Photon Source**

Y.L. Luo, *T.M. Huang, J. Li, H.Y. Lin, Q. Ma, Q.Y. Wang, P. Zhang, F.C. Zhao (IHEP)*

166-MHz 260-kW solid-state power amplifiers have been chosen to drive the 166.6-MHz superconducting cavities for the storage ring of High Energy Photon Source. Highly modular yet compact are desired. A total number of 112 amplifier modules of 3 kW each are combined in a multi-stage power combining topology. The final output is of 9-3/16" 50 Ω coaxial rigid line. Each amplifier module consists of 3 LDMOS transistors with individual circulator and load. Thermal simulations of the amplifier module have been conducted to optimize cooling capabilities for both travelling-wave and full-reflection operation scenarios. High efficiency, sufficient redundancy and excellent RF performances of the 260-kW system are demonstrated. A control system is also integrated and EPICS is used to manage the monitored data. The design and test results of the amplifier system are presented in this paper.

TUPAB348 **Magnetron R&D for High Efficiency CW RF Sources for Industrial Accelerators**

H. Wang, *K. Jordan, R.M. Nelson, R.A. Rimmer, S.O. Solomon (JLab) B.R.L. Coriton, C.P. Moeller, K.A. Thackston (GA)*

The scheme of using high-efficiency magnetrons to drive radiofrequency accelerators has been demonstrated at 2450 MHz in CW mode. Magnetron test stands at JLab and GA have been set up to further test the noise figure and the locking speed of the injection phase-lock method. For higher power applications, power combining experiments using a TM010 cavity-type combiner and a magic tee for the binary combiner while using a single clean injection signal has been carried out at 2450 MHz. The frequency pulling effect between the magnetron and a low-Q cavity has been shown to enhance the frequency locking bandwidth compared to the injection phase-lock alone. The principle has been studied by the equivalent circuit simulation, analytical model, and finally confirmed experimentally on the magnetrons. Due to the pandemic delay in 2020, the equivalent high power tests using a 75kW, 915MHz industrial magnetron will be done in 2021 and will be reported in a future paper.

TUPAB349 **High Efficiency, Low Cost, RF Sources for Accelerators and Colliders**

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Calabazas Creek Research, Inc. (CCR) and its collaborators are developing high efficiency, low cost RF sources. Phase and Amplitude Controlled Magnetrons: CCR, Fermilab, and Communications & Power Industries, LLC (CPI) recently developed a 100 kW, 1.3 GHz magnetron system with amplitude and phase control. The system operated at more than 80% efficiency and demonstrated rapid control of amplitude and phase. Multiple Beam Triodes: CCR, in collaboration with CPI and JP Accelerator Works, Inc., is developing 200 kW, pulsed and CW RF sources from 350 to 700 MHz with projected efficiencies exceeding 80% and cost of $0.50/Watt. Prototype tubes are scheduled for tests in spring 2021. High Efficiency Klystrons:CCR, CPI, and Leidos, Inc. are building a 1.3 GHz, 100 kW klystron operating at 80% efficiency. High power testing is scheduled for summer 2021. Multiple Beam IOTs: CCR and Georgia Tech Research Institute are developing MBIOTs with simplified input coupling and high efficiency. Simulations indicate that 3rd harmonic drive power can increase the efficiency 8-10 %. The program is developing a prototype tube to produce 200 kW peak, 100 kW average power at 704 MHz.

TUPAB350 **Design of 71 MHz Power Amplifier in a Single-ended Architecture for IRANCYC$_1$0 Cyclotron**

F. Babagoli Moziraji, *H. Afarideh (AUT) M. Dehghan (Shahid Beheshti University) F. Ghasemi (NSTRI)*

In this paper, the design and simulation of a high power amplifier to provide the required power of a cyclotron accelerator (IRANCYC-10) is presented step-by-step. By combining four modules of this amplifier, a power of 2.5 kW can be achieved to start the main power amplifier. The single ended designs amplifier can generate 1 kW the operating frequency of 71MHz continuous wave (CW). The purpose of choosing this type of design is simplicity to build without the need for a balun, low weight to build high power, as well as cost-effectiveness. The gain and PAE of the SSPA are 21.21 and 71%, respectively. There are also ways to reduce the size of the amplifier.

TUPAB351 **The Progress of 300kW Home-Made Fully Solid-State Transmitter for TPS**

T.-C. Yu, *F.Y. Chang, M.H. Chang, S.W. Chang, L.J. Chen, F.-T. Chung, Y.D. Li, M.-C. Lin, Z.K. Liu, C.H. Lo, Ch. Wang, M.-S. Yeh (NSRRC)*

To support the stable operation of Taiwan Photon Source (TPS) with 500mA beam current and the increasing beam line construction, a 3rd RF plant is thus constructed for such demand. The RF power source

of the other 2 RF plants adopts klystron type transmitter and the 3rd RF plants is transferred to new technology of solid-state for better redundancy and easier maintenance. Base on the success of solid-state power amplifier development in 2020, a 3rd RF power source is thus decided to be made in house by solid-state technology. The 300kW solid-state transmitter is constructed by 4 80 kW SSPA towers and power combined by 3 WR1800 hybrid couplers. Each SSPA tower is consisted of 110 880W final stage SSPA modules with 4 100W pre-amplifiers and 6 600W drive amplifiers. The pre and drive amplifiers are power combined for higher redundancy. The DC power are economical industrial 48V AC-DC rack mount power supplies which are parallel connected for higher total DC power and best redundancy. The architecture and present progress will be presented in this article.

TUPAB352 **Development of Diagnostic Analog Signal Processing Module for Solid-State Power Amplifier (V8-1b version)**

F.-T. Chung, *T.-C. Yu (NSRRC)*

The focus of this article is to complete the manufacture analog signal processing module and successfully installed to the Solid-State Power Amplifier (SSPA). Important key for analog signal processing module how to designed,Component selected,acceptance test, module assembly and Anti-Electro Magnetic Interference (EMI). All Signals installed on SSPA will be transmitted to the PLC and LLRF control system via communication protocol (modbus). The analog signal processing module is to provide precise data in which be used for long-term monitoring or diagnostic for SSPA.

TUPAB353 **Remote Commissioning of 400 kW 352 MHz Amplifiers**

C. Pasotti, *A. Cuttin, A. Fabris (Elettra-Sincrotrone Trieste S.C.p.A.) A. Frizzi, G. Zardi (Itelco Broadcast Srl) M. Rossi (DB Science)*

In the framework of the European Spallation Source ERIC (ESS ERIC) In-Kind collaboration, Elettra Sincrotrone Trieste has the task to deliver 26 400 kW 352 MHz Radio Frequency Power Station (RFPS) units. They will feed the Spoke Cavities section of the proton Linac. The RFPS manufacturing contract has been awarded to the European Science Solutions consortium (ESS-C) gained the. The production of the amplifiers is well underway and it has reached a steady rate of delivery. Each RFPS is subject to a Factory Acceptance Test (FAT). In this contribution, the main results of the FATs are presented, together with the FAT remote session protocol. This protocol has been specifically developed to cope with the traveling and in persons meeting restrictions imposed by the COVID-19 pandemic.

TUPAB354 **352-MHz Solid State RF System Development at the Advanced Photon Source**

D. Horan, *D.J. Bromberek, N.P. DiMonte, A. Goel, T.J. Madden, A. Nassiri, G. Trento, G.J. Waldschmidt (ANL)*

Development effort is underway on a 352MHz, 200kW solid state rf system intended as the base design to replace the existing klystron-based

rf systems presently in use at the Advanced Photon Source (APS). A sixteen-input, 200kW final combining cavity was designed, built, and successfully tested to 29kW CW in combiner mode, and to 200kW CW in back-feed mode, where an external klystron was used to transmit power into the combining cavity. A four-port waveguide combiner was also tested in both backfeed and combiner mode to 193kW and 26kW respectively. Slow and fast interlock systems were designed and implemented to support the testing process. An EPICS and Programmable Logic Controller (PLC)-based system was developed to control, communicate with, and monitor the rf amplifiers used in the combiner-mode test, and to monitor and log system performance parameters relating to the combining cavity. Low-level rf control of the cavity in 29kW combiner-mode operation was achieved using the existing APS analog low-level rf hardware. Test data and design details are presented.

TUPAB355 **Design and Implementation of a Production Model Bias Tee**
***T.L. Larter**, E. Gutierrez, S.H. Kim, D.G. Morris, J.T. Popielarski, T. Xu, S. Zhao (FRIB)*
The Facility for Rare Isotope Beams (FRIB) includes two types of half wave SC resonators (HWR) operating at 322MHz. The fundamental power couplers used to transmit RF power into the HWRs commonly suffer from multipacting which can result in long conditioning times. A bias tee can be used to apply a high voltage to the couplers to help alleviate multipacting. A production version of the bias tee was commissioned for use at FRIB. The bias tee went through several design revisions to diagnose and correct thermal dissipation issues. This paper will discuss details of design and challenges faced during production validation of the bias tee.

TUPAB356 **Electron Beam Direct Driven Systems**
***M. Schuett**, U. Ratzinger (IAP)*
State of the art high power feeder for RF cavities used as accelerators generally require RF amplifiers consisting of a vacuum tube, such as a klystron or Grid Tubes. In addition, a number of cost intensive RF auxiliary devices are needed: Modulator, waveguides, circulator, power dump and couplers. The equipment requires significant floor space within the linac building. Alternatively, we propose a direct driven system. Aμbunched electron beam is injected directly into the cavity. A high perveance bunched electron beam can be generated by a standard electron gun combined with a deflecting beam chopper, an off-the-shelf IOT or klystron, respectively. The pulse rate is determined by the resonance frequency of the cavity. The resonator hereby acts like the output cavity of a klystron: Within its propagation through the cavity the beam is decelerated increasing the stored energy of the accelerator. We present 3D particle PIC simulations evaluating the geometry and beam properties in order to optimize the coupling efficiency and cavity excitation of state-of-art CH particle accelerator structures.

TUPAB357 **Development of the X-Band Megawatt-Class Coaxial Magnetrons**

***J.Y. Liu**, H.B. Chen, Y.S. Han, J. Shi, C.-X. Tang, C.J. Wang, J. Wang, H. Zha (TUB)*

X-band coaxial magnetrons are preferred for industrial and medical accelerators owing to the compact size, low cost and high efficiency. A conditioning and high power test stand for X-band magnetrons has been built in Tsinghua University. Two X-band magnetrons named "MGT-1#" and "MGT-2#" were tested at this stand. The maximum anode currents of both magnetrons reached 100 A after the conditioning process. Maximum peak output power of 1.71 MW and 1.89 MW was achieved for "MGT-1#" and "MGT-2#", respectively. The efficiencies of the two magnetrons are both about 50%.

TUPAB358 **Novel 500 MHz Solid State Power Amplifier Module Development at Sirius**

***M.H. Wallner**, R.H. Farias, A.P.B. Lima, F. Santiago de Oliveira (LNLS)*

A new solid state power amplifier (SSPA) module is being developed at the Brazilian Center for Research in Energy and Materials (CNPEM) to drive one of the superconducting RF cavities to be installed at Sirius, its new 3 GeV fourth generation synchrotron light source. Several prototypes have been built and tested in-house, and a planar balun was designed to achieve a push-pull configuration at deep class AB operation. Efforts to optimize heat exchange in various ways have been made. Results obtained thus far are presented and the next steps concerning development are discussed.

TUPAB359 **Magnetic Field Measurement and Beam Performance Test of Ceramics Chamber with Integrated Pulsed Magnet at KEK-PF**

***Y. Lu** (Sokendai) K. Harada, Y. Kobayashi, C. Mitsuda, S. Nagahashi, T. Nogami, T. Obina, R. Takai, H. Takaki, T. Uchiyama, A. Ueda (KEK)*

An air-core magnet named Ceramics Chamber with integrated Pulsed Magnet(CCiPM) is being developed at the photon factory of KEK(KEK-PF), which will have several applications for the future light source. One prototype has been developed as a dipole kicker, whose bore is only 30mm. Due to the type and structure, it's expected to have strong magnetic field and high repetition rate. After finishing the offline measurement of magnetic field and evaluation of vacuum tightness, the CCiPM was installed in the beam transport-dump line of PF to have an online beam performance and durability test. The results of the magnetic field measurement and beam performance test will be reviewed.

TUPAB361 **Study and Design of a Switching Magnet for the MYRRHA Project**

***E. Froidefond**, D. Bondoux, F. Bouly (LPSC) D. Vandeplassche (SCK•CEN)*

The MYRRHA project aims at building an Accelerator Driven System demonstrator, which consists of two injectors and a superconducting

linac. The proton beam from the first injector accelerated up to 17 MeV goes to the linac (600 MeV) through a Medium Energy Beam Transfer line (MEBT). Whereas in the meantime, the beam from the second injector is sent to a beam dump. In case of failure in the first injector, the beam of the awaiting injector is sent to the linac. A switching magnet located at the junction of the two injection lines performs this beam switch in less than 1.5 seconds. A magnetic design and a mechanical structure of this magnet proposed to the MYRRHA project are presented.

TUPAB362 **Physical Design of Electrostatic Deflector in CSNS Muon Source**

Y.W. Wu, *S. Li, J.Y. Tang, X. Wu (IHEP) C.D. Deng, Y. Hong (DNSC) Y.Q. Liu (IHEP CSNS)*

CSNS will build a muon source at the end of the RTBT. In the current design, the muon source propose two schemes, namely the baseline scheme and the baby scheme. High voltage electrostatic deflectors (ESD) are used to deflect the beam in the two schemes. A three-channel ESD with 400 kV HV is employed in the baseline scheme and a 210 kV dual-channel ESD in the simplified scheme. According to physical requirements, the electric field concentration factor is introduced, and the electrode of ESD is theoretically designed. 2D and 3D simulations are carried out to analyze the characteristics of electric field distribution by OPERA. The geometry of the electrodes also met the requirements of electric field uniformity, high voltage resistance and mechanical strength at the same time. In the baseline scheme and the baby scheme, the ESD electric field concentration factors are 1.36 and 1.53, and the maximum electric field is 6.78MV/m and 4.6MV/m, respectively. The design meets the requirements and is reasonably feasible.

TUPAB363 **Feasibility Study for the Novel CERN PS Fast Extraction Septum**

T. Helseth, *M.G. Atanasov, B. Balhan, J.C.C.M. Borburgh, L. Ducimetière, M.A. Fraser, T. Kramer (CERN)*

In the framework of accelerator consolidation, a feasibility study for a novel CERN PS extraction septum has been conducted. Functional requirements have been established and, accordingly, a system of two septa magnets and their associated pulse generator is proposed. The magnetic septum design is based on eddy current topology. Magnetic simulations in Flux 2D and Opera 3D of a conceptual design have been carried out. The short length and high amplitude of the current pulse required to drive the eddy current septa imply that none of the power converters currently used for septa magnets at CERN will be suitable. Pulse generator topologies derived from kicker generators have therefore been explored and simulated in Spice. The conceptual magnet and generator design along with simulation results are presented in this paper.

TUPAB364 **Dipole CR FAIR**

K.K. Riabchenko, *A.Yu. Pakhomov, T.V. Rybitskaya, A.A. Starostenko, A.S. Tsyganov, K.V. Zhiliaev (BINP SB RAS)*

The design of CR dipole magnets (24+2 pieces) for the FAIR project in Germany began in 2014 at BINP. CR is a special storage ring where the main emphasis is placed on efficient stochastic pre-cooling of intense beams of stable ions, rare isotopes, or antiprotons. This type of magnet is an iron-based electromagnet with a straight pole, sector form is realized by cutting ends. The maximum field value is 1.6 T. The integrated over the length of the magnet field quality as a function of radius is $d\mathrm{B}l/\mathrm{B}l = \pm 10^{-4}$ with 190 mm good field region as required from the beam dynamics simulations. This challenging field quality is necessary mainly for precise experiments with ion beam in the ISO regime. Below 1.6 T the value $d\mathrm{B}l/\mathrm{B}l$ can be higher with a linear approximation up to $\pm 2.5 \times 10^{-4}$ at the field level of 0.8 T. The first prototype has been manufactured at the end of 2020. Here we describe features of the dipole, 3D calculations, and measurements of the magnetic field.

TUPAB365 **Demonstration of ZEPTO Permanent Magnet Technology on Diamond Light Source.**

A.R. Bainbridge, *B.J.A. Shepherd (STFC/DL/ASTeC) N. Krumpa (STFC/DL) I.P.S. Martin, W. Tizzano (DLS)*

The use of permanent magnets (PM's) in place of traditional electromagnets is becoming more common in accelerator systems around the world. This change is being driven by the desire to reduce both the energy costs and carbon footprint of accelerators. However, the problem remains that it is difficult to adjust the field strength of PM systems. STFC and CERN have a longstanding collaboration in the Zero-Power Tuneable Optics (ZEPTO) project which aims to develop PM systems that are tuneable via moving the PM blocks within a static pole structure. This collaboration has previously produced 3 prototype magnets (2 quadrupoles and 1 dipole) for the proposed CLIC accelerator and aims to expand suitability to a variety of accelerators. We are now demonstrating this technology on a real machine by installing a ZEPTO magnet on Diamond Light Source. We outline the design, construction, and improvement of this technology demonstrator, highlighting the innovations over previous generations of ZEPTO technology that account for previously observed drawbacks.

TUPAB366 **Design and Realization of New Solenoids for High Brightness Electron Beam Injectors**

A. Vannozzi, *D. Alesini, A. Giribono, C. Vaccarezza (INFN/LNF)*

High-brightness, high-current electron beams are the main requirement for fourth generation light sources such as free-electron lasers (FELs), energy recovery Linacs (ERLs) and high-energy linear colliders. The most successful device for producing such beams is the Radio-Frequency photoinjector where a key element is the gun solenoid. Its main task is to limit the beam emittance growth in the first acceleration stages by imposing a spiraling motion to the beam. This paper is

focused on two magnets: the first one is the solenoid gun for the new photoinjector at INFN-LNF SPARC_LAB test facility. The design, the realization, and all the measurements performed at the factory and at LNF are shown. Moreover, the design of a solenoid for a novel C-band gun for CompactLight project is presented. Both magnets have been designed with the goal to reach the same integrated field of the gun solenoid currently installed at SPARC_LAB, with an integrated field quality of $5{\cdot}10^{-4}$ in a good field radius of 30mm and 10mm radius respectively for SPARC_LAB and CompactLight solenoid. This one is equipped with a bucking coil to limit the field on cathode that could led to an undesired emittance growth.

TUPAB367 **A Novel Design of High Gradient Quadrupole Magnet**
Y. Zhu *(SINAP)*
High gradient quadrupole magnet has become a key element with the development of diffraction-limited storage ring. The gradient of magnetic field of a quadrupole magnet depends on the inscribed radius, ampere-turns per pole and magnetic efficiency. However, the radius and ampere-turns per pole can not be reduced or increased indefinitely. Design a novel magnetic circuit to improve the gradient of quadrupole magnets by improving magnetic efficiency. The magnetic efficiency of saturated magnets can be further improved by installing permanent magnets on both sides of the poles, thus further improving the gradient of magnetic field. A high gradient quadrupole magnet with the gradient greater than 100T/m was designed to verify the theory by simulation calculation with Poisson for 2D analysis and OPERA for 3D analysis. By optimizing the good field area of the quadrupole magnet, it is found that the installation of permanent magnets has little effect on the magnetic field quality. And the installation of the permanent magnet block basically does not occupy the space of the beam pipe and coil in the center of the magnet.

TUPAB368 **Design of the Longitudinal Gradient Dipole Magnets for HALF**
M.Y. Mingyao *(Wang) Z.L. Ren, H. Xu (USTC/NSRL)*
Hefei Advanced Light Facility (HALF) is the fourth generation diffraction-limited storage ring light source project in China. The lattice of the storage ring consists of six different dipoles with longitudinal gradients. The longitudinal-gradient dipoles (LGBs) are permanent magnets. This paper presents the designed construction of LGBs and the magnetic field results using OPERA3D. By optimizing the shape of the polar surface, the magnetic field uniformity is optimized to about 5×10-4. With some movable adjusting block, the magnetic field can be controlled accurately. The temperature stability of the magnet is better than 0.0074 T*mm/^{o}C by setting temperature compensating shunt.

TUPAB369 **A Fast Non-Linear Model for the EBS Combined Sextupole-Corrector Magnets**
G. Le Bec *(ESRF)*
Corrector are often integrated in higher order accelerator magnets. In the new ESRF-EBS storage ring, the sextupoles include additional

windings allowing for dipole and skew quadrupole corrections. The accurate modelization of such magnets is not as trivial as it may appear, due to their non-linearities and to the crosstalk between their channels. Changing any corrector current induce non-linear errors in the other corrector channels and in the main sextupole strength, making difficult the trimming of the magnets. A model based on a non-linear excitation curve and quadratic contributions from corrector currents was developed. This model is very fast and was included in the accelerator control system to compute the corrector currents in real-time. It was tested against 3D magnetic simulations and magnetic measurements and compared to a simpler matrix-based model.

TUPAB370 **Development of Long Coil Dynamic Magnetic Field Measurement System for Dipole Magnets of HEPS Booster**

Y.Q. Liu, *F.S. Chen, C.D. Deng, W. Kang, S. Li, X. Wu, Y.W. Wu, J.X. Zhou (IHEP) C.D. Deng, Y.W. Wu (DNSC)*

A magnetic field measurement system for dipole magnets of High Energy Photon Source Booster is designed and developed. The system uses the long coil upflow method to measure the dynamic integral field of the magnet, and the long coil transverse-translation method to measure the integral field distribution error of the magnet. In this paper, the design and implementation of the magnetic measuring system are introduced in detail, and the magnetic field measurement results of the prototype magnet are shown. The measurement results show that the repeatability of the dynamic integral field measurement system is about 2 in 10,000, and the repeatability of the uniform distribution of the integral field is better than 1 in 10,000, which meets the test requirements of the discrete integral field of bulk magnets ±1 parts per thousand and the uniformity of the integral field ±5×10-4@6GeV and $\pm 1 \times 10^{-3}$ @0.5GeV.

TUPAB371 **Improved Permanent Magnets for Particle Accelerators**

J.T. Dreikorn, *F.-J. Börgermann, C. Brombacher, K. Üstüner (Vacuumschmelze GmbH & Co. KG)*

Improved Permanent Magnets for Particle Accelerators Permanent Magnets (PM) based on Rare Earth (RE) alloys are widely used in Particle Accelerators and supplementary devices. They can be used for fully PM excited devices with fixed or tunable fields or as part of hybrid structures, combining permanent and electromagnets. Typical are high-end Materials as well as tight tolerances for dimensions, magnetic moments, magnetization direction, the requirement of magnetic homogeneity, and the resistance against radiation damage. We introduce the latest Sm2Co17 and RE2Fe14B alloys including the possibility of post sintering Tb diffusion process for the later ones. For many applications a homogeneous orientation of the magnet is necessary. However, it could be shown that a rotating magnetization inside a PM works like a Halbach and is able to increase the magnetic field strength inside an air gap. The understanding, use, and tailoring of local orientation inside the PM can help to further improve the performance of

PM-based devices. The poster will give an overview of the state of the art of PM especially designed for use in beam guide lines.

TUPAB372 **Status of SIS100 Quadrupole Doublet Module Series Manfacturing**

***T. Winkler**, A. Bleile, L.H.J. Bozyk, V.I. Datskov, J. Ketter, P. Kowina, J.P. Meier, N. Pyka, C. Roux, P.J. Spiller, K. Sugita, A. Waldt, St. Wilfert (GSI)*

The 83 Quadrupole Doublet Modules (QDM) for the heavy-ion-synchrotron SIS100 of the FAIR project at GSI are highly integrated cryogenic modules containing multiple magnets. Each of eleven different QDM types consists of two units, where one unit consists of one quadrupole magnet as well as corrector magnets depending on the modules position in the accelerator Ion-Optical Lattice. Additionally, the QDMs contain cryogenic collimators, beam diagnostics, as well as cryogenic UHV beam pipes. The modules contain parts from multiple suppliers increasing the logistics behinds the QDMs design further. We present the process of the module integration, give details on the current integration status and present an outlook on the timeline for the QDM integration planning.

TUPAB373 **Design of a Delta-type Superconducting Undulator at the IHEP**

***J.H. Wei** (IHEP CSNS) C.D. Deng (DNSC) L. Gong, X.Y. Li, X.C. Yang (IHEP) Y. Li (DESY)*

Undulators play an important role in the 4th generation radiation light source. In order to satisfy different requirements of the experiments, various undulator structures have been proposed. The Delta-type undulator can provide circular polarized radiation. Conventional undulators are usually made of permanent magnets, but the application of the superconducting technology in the undulator is developing quickly. Compared to the permanent magnet undulators, superconducting undulators can provide higher photon flux with the same magnetic pole gap and period length, especially when the period length is longer than 20 mm. An R&D project is underway to produce a protype of a Delta-type superconducting undulator with 28 mm long period and 12 mm gap at the IHEP. The structure design and the simulation results of the magnetic field are presented in this paper.

TUPAB374 **Development of a Quench Detection System for the FAIR Superconducting Devices**

***V. Raginel**, M. Dziewiecki, W. Freisleben, P.B. Szwangruber, L. Theiner (GSI)*

The Facility for Antiproton and Ion Research (FAIR), which is presently under construction in Darmstadt (Germany), will incorporate a large variety of superconducting devices like magnets, currents leads and bus bars. These components depend on an active protection in case of a transition from superconducting to the resistive state, so-called quench. In this framework, a FAIR Quench Detection System (F-QDS) is being developed based on analog and digital electronics and will be implemented in several machines of the FAIR complex. This paper

describes the development of the F-QDS. First, the parameters of the superconducting devices relevant for quench detection are presented. Then, an overview of the F-QDS electronics is given followed by a description of the system integration to the infrastructure of various machines. Initial test results of the F-QDS prototype system are presented and discussed.

TUPAB375 **Commissioning and Operation of Superconducting Multipole Wiggler at Siam Photon Source**

P. Sunwong, *S. Boonsuya, S. Chaichuay, T. Chanwattana, Ch. Dhammatong, A. Kwankasem, C.P. Preecha, T. Pulampong, P. Sittisard, V. Sooksrimuang, S. Srichan, P. Sudmuang, N. Suradet, S. Tancharakorn (SLRI)*

A new insertion device, Superconducting Multipole Wiggler (SMPW) with the peak field strength of 3.5 T, was installed in the storage ring of Siam Photon Source as a radiation source for a new hard X-ray beamline. Cool-down process, as well as magnet training, was performed with careful tuning of liquid helium filling procedure for efficient management of liquid helium supply. The filling procedure was also optimized for safe operation of the magnet. The SMPW commissioning was successfully carried out with electron beam and the effect of SMPW on electron beam dynamics was observed. It can be minimized using quadrupole magnets and horizontal/vertical correctors.

TUPAB376 **The Results of Magnetic Measurements for the NICA Booster Magnets**

A.V. Shemchuk, *I.I. Donguzov, M.A. Kashunin, D.A. Zolotykh (JINR/VBLHEP) V.V. Borisov, A.V. Bychkov, A.M. Donyagin, O. Golubitsky, H.G. Khodzhibagiyan, S.A. Kostromin, M.M. Shandov (JINR)*

The booster synchrotron structure of the NICA project includes 48 quadrupole and 40 dipole superconducting magnets. Serial production and testing of these magnets are near completion at the Veksler and Baldin Laboratory of High Energy Physics of the Joint Institute for Nuclear Research (VBLHEP JINR). One of the important tasks is to measure the parameters of the magnetic field. At the beginning of December 2019 almost 100 percent of magnets have undergone magnetic measurements under cryogenic conditions. The paper describes the main results of magnetic measurements of quadrupole magnets.

TUPAB377 **The HL-LHC Superferric High Order Corrector Magnets: from Prototypes to Series Production**

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INFN is developing at the LASA lab (Milano, Italy) the High Order (HO) corrector magnets for the High Luminosity-LHC (HL-LHC) project,

which will equip the new interaction regions. All the HO correctors are based on a novel superferric design, never used so far in colliders, which allows a relatively simple, modular, and easy way to construct a magnet. Five prototypes, from skew quadrupole to dodecapole, have been designed and tested at LASA, the series production in industry is ongoing. Several optimizations were implemented to meet both requirements for LHC operation, i.e. radiation hardness, easiness of installation, safe operation over years, and requirements for series production, i.e. standardization of procedures and components for different magnets, minimization of the number of components, standardization of the quality control systems and acceptance tests. We discuss the various improvements and solutions, the on-going production in Industry and the acceptance tests at LASA, in view of the experience acquired with the prototyping and first production phases.

TUPAB378 **Superconducting Dipole Magnets for the SIS100 Synchrotron**
F. Kaether*, P. Aguar Bartolome, A. Bleile, G. Golluccio, J. Ketter, P. Kosek, F. Kurian, V. Marusov, J.P. Meier, S.S. Mohite, C. Roux, P.J. Spiller, K. Sugita, A. Szwangruber, P.B. Szwangruber, A. Warth, H.G. Weiss (GSI)*
The Facility for Antiproton and Ion Research (FAIR) is currently under construction at GSI Darmstadt, Germany. For its main accelarator, the SIS100 synchrotron, 110 superconducting dipole magnets has been produced and extensively tested. The fast-ramped Nuclotron-type superferric dipoles were manufactured with high effort regarding a precise magnetic field which could be proven by magnetic field measurements with high accuracy. Stable operation conditions at 4.5 K were achieved including an excellent quench behaviour and precise geometrical and electrical properties. An overview on design, production, operation, tests and measurement results will be given.

TUPAB379 **Superconducting Magnets for Super-FRS: Production and Testing Status**
H. Müller*, A. Chiuchiolo, E.J. Cho, G. Golluccio, F. Greiner, P. Kosek, M. Michels, C. Roux, K. Sugita, V.V. Velonas, M. Winkler (GSI) H. Allain, A. Madur (CEA-IRFU) A. Borceto, G. Drago, G. Valesi (ASG) M. Garcia Escudero, J. Lucas (Elytt Energy) G. Riddone, S. Russenschuck (CERN)*
The Super FRS is a two-stage in flight separator to be built next to the site of GSI, Darmstadt, Germany as part of FAIR (Facility for Antiproton and Ion Research). Its three branches allow to carry out a wide variety of experiments. Due to the large acceptance needed, the magnets of the Super-FRS require a large aperture and therefore only a superconducting solution is feasible. A superferric design was chosen in which the magnetic field is shaped by an iron yoke. For the dipole magnets only the superconducting coils are in a cryostat. These magnets are manufactured by Elytt Energy (Spain). The multiplets, assemblies of quadrupoles and higher order multipole magnets, are completely immersed in a liquid Helium bath. They are being built at

ASG (Italy). The first of two first of series multiplets, a short assembly containing 2 magnets, was tested at a dedicated test facility at CERN (Switzerland). The 2nd FoS multiplet, containing 9 magnets, and the FoS dipole will be tested soon. Series production of the multiplets has started. In this paper we will present the status of production and testing of the different superconducting magnets for Super-FRS.

TUPAB380 **Testing of the First of Series Quadrupole Doublet Module for the SIS100 Synchrotron**

P. Aguar Bartolome*, M. Al Ghanem, M. Becker, A. Bleile, R. Bluemel, L.H.J. Bozyk, V.I. Datskov, W. Freisleben, A. Kario, P. Kowina, K.K. Kozlowski, F. Kurian, S. Lindner, J.P. Meier, T. Miertsch, S.S. Mohite, V.P. Plyusnin, I. Pongrac, C. Roux, C. Schroeder, P.J. Spiller, K. Sugita, A. Szwangruber, P.B. Szwangruber, F. Walter, H. Welker, St. Wilfert, T. Winkler, S. Zeller (GSI)*

A new international facility for antiproton and ion research (FAIR) is currently under construction in Darmstadt, Germany. The high intensity primary beam required for different research experiments will be provided by the SIS100 heavy ion synchrotron. The synchrotron is composed of fast cycling superconducting magnets from which about 300 will be integrated in Quadrupole Doublet Modules (QDM). Each module consists of two units composed of a quadrupole and corrector magnets. The First of Series Quadrupole Doublet Module was delivered to the test facility at GSI in November 2019. The assembled doublet was subjected to a dedicated test program to verify the functionality of the module components at cryogenic temperature and operating conditions. The results obtained during the testing campaign will be presented.

TUPAB381 **Thermal Analysis of the RHIC Arc Dipole Magnet Cold Mass with the EIC Beam Screen**

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The EIC will make use of the existing RHIC storage rings with their superconducting (SC) magnet arcs. A stainless-steel beam screen with co-laminated copper and a thin amorphous carbon (aC) film on the inner surface will be installed in the beam pipe of the SC magnets. The copper will reduce the beam-induced resistive-wall (RW) heating from operation with the higher intensity EIC beams, that if not addressed would make the magnets quench. Limiting the RW heating is also important to achieve an adequately low vacuum level. The aC coating will reduce secondary electron yield which could also cause heating and limit intensity. Among all the RHIC SC magnets, the arc dipoles present the biggest challenge to the design and installation of beam screens. The arc dipoles, which make up for 78% (2.5 km) length of all SC magnets in RHIC, expect the largest RW heating due to their smallest aperture. These magnets are also the longest (9.45 m each), thus experiencing the largest temperature rise over their length, and have a

large sagitta (48.5 mm) that increases the difficulty to install the beam screen in place. This paper presents a detailed thermal analysis of the magnet-screen system.

TUPAB382 **Magnetic Measurements on the First Series Magnets of the High Order Super-Ferric Correctors for HL-LHC**

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In the framework of an agreement between CERN and INFN (National Institute for Nuclear Physics) for the High Luminosity LHC (HL-LHC) project, the LASA Laboratory of INFN-Milan has developed a novel type of magnet, based on a super-ferric design, for the High Order (HO) correctors magnets for the HL-LHC new insertions region around the ATLAS and CMS Experiments of LHC. These corrector magnets, are composed by five families: skew quadrupole, normal/skew sextupole, octupole, decapole and dodecapole order, and they will be installed in one cold mass called Corrector Package, a "prima" for super-ferric in a collider. The first series magnets have been built and tested at 4.2 K at LASA, and magnetic measurements have been carried out both at room temperature (at low current) and at cold (operating current) in order to validate the field quality specifications. The paper presents the measuring equipment and will discuss the measurement results of transfer function and field multipoles for the various magnet types, the suitability for collider operation and the feedback to production. Moreover, the comparison of measurements with respect to the 3-D model calculations is presented.

TUPAB383 **Magnetic Field Performance of the First Serial Quadrupole Units for the SIS100 Synchrotron of FAIR**

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The FAIR project is a new international accelerator complex, currently under construction in Darmstadt, Germany. The heavy-ion synchrotron SIS100 is the main accelerator of the whole complex. It will provide high-intensity primary beams with a magnetic rigidity of 100 Tm and a maximum repetition rate up to 4 Hz. The series production and testing of superconducting quadrupole units began in 2020 at JINR, Dubna. The first batch of units was delivered to Germany in September 2020. Each unit is subjected to a comprehensive testing program both at ambient temperature and under cryogenic conditions. We present the performance characteristics of the first quadrupole units (consisting of a lattice quadrupole magnet and correcting magnet mechanically and hydraulically coupled to a quadrupole). The main attention is paid to the field quality of the series of 6 quadrupoles

measured by the same probe.

TUPAB384 **Design, Development and Testing of 1.5T Cryogen Free Superconducting Magnet for 300mm Bore Diameter MRI System**
***S.S. Rajan**, S. Malhotra, P. Rai, U.G.P.S. Sachan (BARC)*
A 1.5 T, high uniformity cryogen-free superconducting magnet is designed and developed to carry out Magnetic Resonance Imaging(MRI) of human extremities and Neonatal. The superconducting magnet has a bore of 300mm diameter and is designed to have a uniformity of 10PPM in a Diametrically Spherical Volume(DSV) of 160mm. Genetic algorithm-based optimization was carried out for the electromagnetic design of the coil system to achieve the required uniformity with required stray field specifications. The magnet is cooled using P-T cryocooler. The paper discusses the electromagnetic, thermal, and structural design of the magnet. Cooldown and preliminary test results of the superconducting magnet will be presented.

TUPAB385 **Design, Development and Testing of a Compact 2T Water-Cooled Electromagnet for XMCD Experimental Beamline**
***S.S. Rajan**, D. Bhattacharya, S. Malhotra, P. Rai, P. Trivedi (BARC)*
A compact 2T water-cooled electromagnet is designed, developed, and tested to carry out XMCD experiments in Indus-2 BL-09 Beamline. The electromagnet is designed to develop 2T in an air gap of 25mm. The size of the electromagnet has to be equal to or less than 300mm x 300mm due to space constraints. The pole of the electromagnet is made up of Iron-Cobalt alloy and is optimally shaped to develop the required magnetic field with minimum MMF. The electromagnet is integrated with its power supply which has a built-in polarity reversal system tested for its rated performance.

TUPAB386 **Design Study of the Nb_3Sn Cos-Theta Dipole Model for FCC-hh**
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In the context of the Future Circular Collider hadron-hadron (FCC-hh) R&D program, the Italian Institute of Nuclear Physics (INFN), in collaboration with CERN, is responsible for designing and constructing the Falcon Dipole (Future Accelerator post-LHC Costheta Optimized Nb_3Sn Dipole), which is an important step towards the construction of High Field Nb_3Sn magnets for a post LHC collider. The magnet is a short model with one aperture of 50 mm and the target bore field is 12 T (14 T 'ultimate' field). The dipole is pre-loaded with the Bladder&Key technique to minimize the stress on the coils at room temperature, which are prone to degradation because of the Nb_3Sn cable strain-sensitivity. The electro-mechanical 2D design is focused on the performance, the field quality and the quench protection, with emphasis to the stresses on the the conductor. The Falcon Dipole has

been modelled in a 3D FEM to determine the peak field distribution and the influence of the coil ends on the field quality.

TUPAB387 **Superconducting Solenoid Field Measurement and Optimization**

***S. Ma**, A. Arnold, P. Murcek, A.A. Ryzhov, J. Schaber, J. Teichert, R. Xiang, P.Z. Zwartek (HZDR) H.J. Qian (DESY Zeuthen)*

The solenoid is a significant part of an electron injector to provide a proper focusing, and preserve the beam projected emittance. A superconducting solenoid is applied for the SRF photoinjector at HZDR. The solenoid itself can degrade electron beam quality due to magnetic field imperfections like multipole components. In order to determine the field aberrations in the solenoid, we measured the superconducting solenoid magnetic field in the cryomodule. A simple and effective method is used to analyze the multipole field components, which will be presented in this paper.

TUPAB388 **Efficiency, Power Loss, and Power Factor Measurement of Quadrupole Magnet Power Supplies at the Spallation Neutron Source**

***S. Harave** (ORNL) B. Morris (SLAC)*

The linear accelerator (LINAC) quadrupole magnets are powered by 42 silicon-controlled rectifier (SCR) based power supplies at the Spallation Neutron Source (SNS) facility of Oak Ridge National Laboratory. These 35V, 525A power supplies are bulky, inefficient and require both air and water cooling. The reliability of the SNS facility is impacted due to water leaks internal to power supplies and current readback issues associated with their unique control system interface, resulting in multiple downtime events. Hence, an alternate solution is necessary for the continued reliable operation of the SNS. To mitigate the above-mentioned problems, this paper proposes the use of off-the-shelf Switch Mode Power Supplies (SMPS) rated for 20V, 500A with serial control interface. These SMPS are air-cooled, more efficient and more compact owing to their switching speeds of approximately 160 kHz. The performance enhancements of the SMPS in comparison with the existing SCR power supply are discussed in detail in this paper. The features of the SMPS, along with experimental results for both power supplies, like efficiency, power losses and stability, are presented. Ongoing work is also discussed.

TUPAB389 **High Precision Four Quadrant Converter With GaN Technology**

***M. Incurvati**, T. Margreiter, R. Staerz (MCI) T. Riedler (NTUT)*

New proton therapy facilities for the cure of tumors as well as high-energy photon sources are currently being installed all around the world. In this field, the request for special power supplies for corrector, scanning, and quadrupole magnets are increasing. For these applications, mandatory requirements are high bandwidth and current stability as well as low output ripple which are conflicting constraints. A feasibility study, prototype development, measurements,

and investigations on the control methodology of a wide-bandgap GaN semiconductor-based power module is presented in the paper. The developed power module features the following characteristics: Eurocard standard PCB, bipolar 4Q operation, minimum switching frequency 100 kHz, bandwidth 5 kHz, output voltage and current up to 200 V / 8 A, output current ripple <20 ppm. The enlisted characteristics make it suitable for high inductive loads requiring fast transients (scanning magnets). An RST controller will be developed and a system identification approach to the transfer function of two parallel-connected power modules will be presented along with simulations assessing the performance.

TUPAB391 **Cryopanels in the room temperature Heavy Ion Synchrotron SIS18**

***S. Aumüller**, L.H.J. Bozyk, P.J. Spiller (GSI) K. Blaum (MPI-K)*

The FAIR complex at the GSI Helmholtzzentrum will generate heavy ion beams of ultimate intensities. To achieve this goal, medium charge states have to be used. However, the probability for charge exchange in collisions with residual gas particles of such ions is much higher than for higher charge states. In order to lower the residual gas density to extreme high vacuum conditions, 65% of the circumference of SIS18 are already coated with NEG, which provides high and distributed pumping speed. Nevertheless, nobel and nobel-like components, which have very high ionization cross sections, do not get pumped by this coating. A cryogenic environment at moderate temperatures, i.e. at 50-80K, provides high pumping speed for all heavy residual gas particles. The only typical residual gas species, that cannot be pumped at this temperature is hydrogen. With an additional NEG coating the pumping will be optimized for all residual gas particles. The installation of cryogenic surfaces in the existing room temperature synchrotron SIS18 at GSI has been investigated. A prototype quadrupole chamber with cryogenic surfaces, first measurements, and simulations of the adapted accelerator are presented.

TUPAB392 **Conceptual Design of the Vacuum System for the Future Circular Collider FCC-ee Main Rings**

***R. Kersevan**, C. Garion (CERN)*

The Future Circular Collider study program comprises several machine concepts for the future of high-energy particle physics. Among them there is a twin-ring e^-e^+ collider capable to run at beam energies between 45.6 and 182.5 GeV, i.e. the energies corresponding to the resonances of the Z, W, H bosons and the top quark. The conceptual design of the two 100-km rings has advanced to what is believed to be a working solution, i.e. capability to deal with low-energy (45.6 GeV) high-current (1390 mA) version as well as the high-energy (182.5 GeV) low-current (5.4 mA) one, with intermediate energy and current steps for the other 2 resonances. The limit for all of the versions is given by the 50 MW/beam allotted to the synchrotron radiation (SR) losses. The paper will outline the main beam/machine parameters, the vacuum

requirements, and the choices made concerning the vacuum chamber geometry, material, surface treatments, pumping system, and the related pressure profiles. The location of lumped SR photon absorbers for the generic arc cell has been determined. An outline of the studies needed and envisaged for the near future will also be given.

TUPAB393 **Study of Remote Helium Mass Spectrometer Leak Detection**
***H.Y. He**, D.H. Zhu (IHEP CSNS) , J.M. Liu (DNSC)*
In order to solve the problem that the vacuum system of the accelerator can't be close to the operation for a long time, a long-distance helium mass spectrometer leak detection system is explored by studying the structure of the conventional round tube vacuum box of the vacuum system, which integrates the online vacuum leak detection, defect diagnosis and process design, improves the digital operation, realizes the accurate and effective detection of the leak location range and leak rate, and provides the technology for the remote leak detection of the vacuum system. Support.

TUPAB394 **XPS Studies of Non-Evaporable Getter Coatings Deposited With Alloy Target at Different Activation Temperatures**
***S. Wang** (USTC/NSRL)*
Non-evaporable getter (NEG) thin films provide distributed pumping and low gas desorption properties, which allow to achieve low pressure in narrow and conductance limited chambers. It is the ideal solution to deal with the small aperture of vacuum chambers for the new generation Diffraction-Limited Storage Ring. In this paper, NEG thin films have been deposited by a developed DC magnetron sputtering system using alloy target. The deposition parameters have been modified in order to optimize thin film properties, such as plasma condition, magnetron field and so on. The microstructures of Ti-Zr-V films with different deposition parameters are investigated by Scanning Electron Microscopy (SEM) and Atomic Force Microscope (AFM). Films on OFC copper and silicon substrates in Argon ambient to exhibit a columnar growth pattern with nanocrystalline grains. The compositions and the corresponding chemical bondings are analyzed by X-ray Photoelectron Spectroscopy (XPS) after in-situ activation for 1 hour at different temperatures in ultra-high vacuum. The results showed that oxide layer on the top of Ti-Zr-V films gradually disappeared with increasing activation temperatures.

TUPAB395 **Vacuum System Models for Minerva Linac Design**
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The goal of the MYRRHA project is to demonstrate the technical feasibility of transmutation in a 100 MW Accelerator Driven System (ADS) by building a new flexible irradiation complex at Mol (Belgium). The MYRRHA facility requires a 600 MeV accelerator delivering a maximum proton current of 4 mA in continuous wave operation, with an additional requirement for exceptional reliability. Supported by SCK•CEN

and the Belgian federal government the project has entered in its phase I: this includes the development and the construction of the linac first part, up to 100 MeV. We here review the MINERVA linac vacuum system modelling studies that enabled to validate the choice of materials and vacuum equipment. The strengths and weaknesses of the vacuum design, highlighted by the models, will be discussed as well as the required improvements.

TUPAB396 **The Thermal Outgassing Rate of Materials Using in the Vacuum Systems**

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There are many rarely used materials in vacuum systems that are poorly investigated in terms of vacuum properties. For example, phosphors, scintillating materials, ferrites, various adhesives, etc. In addition, new organic materials are being developed with mechanical properties similar to those of conventional steel. The use of such materials is very promising in vacuum technology. This article presents the thermal degassing performance of several rarely used materials and promising materials for vacuum applications.

TUPAB397 **R&D of CEPC Vacuum System**

Y. Ma *(IHEP)*

CEPC vacuum system include booster, electron, positron ring and MDI. which is the most challengeble project in the world. Some key issues have been considered. Extruded copper and aluminum vacuum pipe have been designed and carried out. NEG coating on positron ring vacuum pipes was proposed to suppress the secondary electron yields. RF shielding bellows is R&D to absorb the thermal expansion and mechnical misalignment.

TUPAB398 **Vacuum Issues with Argon Gas in the LANSCE Accelerator**

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In the Los Alamos Neutron Science Center (LANSCE) accelerator, there are about 220 500-L/s ion pumps running all the time. The oldest pumps recorded in the current system were installed in 1983. All the ion pumps are diode type ion pumps. In 2017, we started to suffer from ion pumps trips in an accelerator module 15 (M15) that includes 3 500-L/s ion pumps and they caused beam down times of the accelerator during the production run cycles. This paper reports the details of these trips, how we found it was argon gas that was causing the trips and how we tried to reduce it.

TUPAB399 **RF Characterisation of New Coatings for Future Circular Collider Beam Screens**

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Laser Processing Research Center)
For the future high energy colliders being under the design at this moment, the choice of a low surface impedance beam screen coating material has become of fundamental importance to ensure sufficiently low beam impedance and consequently guaranteed stable operation at high currents. We have studied the use of high-temperature superconducting coated conductors as possible coating materials for the beam screen of the FCC-hh. In addition, amorphous carbon coating and laser-based surface treatment techniques are effective surface treatments to lower the secondary electron yield and minimise the electron cloud build-up. We have developed and adapted different experimental setups based on resonating structures at frequencies below 10 GHz to study the response of these coatings and their modified surfaces under the influence of RF fields and DC magnetic fields up to 9 T. Taking the FCC-hh as a reference, we will show that the surface resistance for REBCO-CCs is much lower than that of Cu. Further we show that the additional surface modifications can be optimised to minimise their impact on the surface impedance. Results from selected coatings will be presented.

TUPAB400 **Manufacturing of Ceramic Vacuum Chambers for Sirius on-Axis Kicker**
R. Defavari, *O.R. Bagnato, M.W.A. Feitosa, F.R. Francisco, D.Y. Kakizaki, R.L. Parise, R.D. Ribeiro (LNLS)*
Ceramic vacuum chambers were produced by LNLS for the Sirius kickers. Alumina tubes with an elliptical inner shape of 9.5 mm (V) x 29 mm (H) and 500 mm long were successfully manufactured by a Brazilian company. Metallic F136 titanium flanges were brazed to Nb inserts using Ag-58.5Cu-31.5Pd wt% alloy, these inserts were brazed to the ceramic using Ag-26.7Cu-4.5Ti wt% active filler metal. A titanium film was coated inside the chamber using argon plasma by RF Magnetron Sputtering technique. Samples have been investigated by Scanning Electron Microscopy (SEM) to measure film thickness along the inner section of the tube, coating morphology, chemical composition and homogeneity. The total electrical resistance of the tube was also monitored during the sputtering process to achieve the desired value (0.2 ohms/square). In this contribution, we present the results of an On-Axis kicker manufacturing process developed by LNLS.

TUPAB401 **Mechanical Design, Fabrication and Characterization of Electron Beam Position Monitors for Sirius**
R. Defavari, *O.R. Bagnato, M.W.A. Feitosa, F.R. Francisco, G.R. Gomes, D.Y. Kakizaki, R.L. Parise, R.D. Ribeiro (LNLS)*
Beam Position Monitors were designed and manufactured to meet Sirius operation requirements. Final dimensional accuracy and stability of the BPM were achieved by careful specification of its components' manufacturing tolerances and materials. AISI-305 Stainless Steel was used for the BPM support fabrication due to magnetic and thermal expansion constraints. High purity molybdenum for the electrode pin

and Ti6Al4V F136 G23 alloy for housing was used to manufacture the sensor components for their thermal characteristics. The electrical insulator was made of high alumina. The materials were joined by an active metal brazing process using 0,01mm accurate fixtures. The brazed sensors were subjected to dimensional, mechanical, and metallurgical testing, as well as leak detection and optical microscopy inspection at each stage. The sensors were joined in Ti6Al4V F136 BPM bodies using TIG welding. Dimensional sorting was used to choose groups of sensors-to-body, and body-to-support pairs during the final assembly. 160 BPMs are currently in operation on Sirius storage ring. In this contribution, we present the results of BPM manufacturing and testing processes developed for Sirius.

TUPAB402 **Review of Technologies for Ion Therapy Accelerators**

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Cancer therapy using protons and heavier ions such as carbon has demonstrated advantages over other radiotherapy treatments. To bring about the next generation of clinical facilities, the requirements are likely to reduce the footprint, obtain beam intensities above 10^{10} particles per spill, and achieve faster extraction for more rapid, flexible treatment. This review follows the technical development of ion therapy, discussing how machine parameters have evolved, as well as trends emerging in technologies for novel treatments such as FLASH. To conclude, the future prospects of ion therapy accelerators are evaluated.

TUPAB403 **Clinical Particle Accelerators for Magnetically Focussed Proton Minibeam Radiation Therapy**

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Proton minibeam radiation therapy (pMBRT) is a novel therapeutic strategy that has proven to significantly increase the therapeutic index of high-grade gliomas in rodents. It requires submillimetric beam sizes which are roughly one order of magnitude smaller than state-of-the-art pencil beams. In order to fully exploit the potential of pMBRT, these minibeams should be generated through magnetic focussing, however this also poses certain constraints on the beam arriving from the accelerator. We developed a new design for a nozzle (last beamline elements before the patient) capable of generating such magnetically focussed proton minibeams. In Monte Carlo simulations performed with the framework TOPAS, we evaluated the performance of this new nozzle for several beam models of different clinical centres and accelerators. We found that minibeams can only be achieved when the beam entering the nozzle has a low enough divergence and small enough emittance. Synchrotron-based facilities could satisfy these constraints

whereas cyclotrons are likely not able to deliver the required beams. Very good results were also observed for a novel laser-hybrid accelerator design (LhARA).

TUPAB404 **Monte Carlo Studies for Shielding Design for High Energy Linac for Medical Isotope Generation**

***N. Upadhyay**, S. Chacko (University of Mumbai) , A.P. Deshpande, T.S. Dixit, P.S. Jadhav, R. Krishnan (SAMEER)*

The widely used radioactive tracer Technetium-99m (99mTc) is traditionally produced from Uranium via 235U (n, f) 99Mo reactions which depends heavily on nuclear reactors. Design studies for an alternative, cleaner approach for radioisotope generation using a high energy electron linac were initiated at SAMEER to generate 99Mo. The electron beam from a 30 MeV linac with an average current of 350 μA will be bombarded on a convertor target to produce X-rays which will be bombarded on enriched 100Mo target to produce 99Mo via (g, n) reaction. 99mTc will be eluted from 99Mo. The photons and neutrons produced in the process should be shielded appropriately to ensure radiation safety. This paper brings out the use of Monte Carlo techniques for photon and neutron shielding for our application. We used FLUKA to calculate the fluence, angular distribution and dose for photons and neutrons. Then, we introduced various layers of lead followed by HDPE, 5% borated HDPE and 40% boron rubber to ensure that the proposed shielding is sufficient to completely shield the photon as well as neutron radiation and hence is safe for operation.

TUPAB405 **Design of High Energy Linac for Generation of Isotopes for Medical Applications**

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After successful implementation of 6 and 15 MeV electron linear accelerator (linac) technology for Cancer Therapy in India, we initiated the development of high energy high current accelerator for the production of radioisotopes for diagnostic applications. The accelerator will be of 30 MeV energy with 350 μA average current provided by a gridded gun. The linac is a side coupled standing wave accelerator operating at 2998 MHz frequency operating at p/2 mode. The choice of p/2 operating mode is particularly suitable for this case where the repetition rate will be around 400 Hz. Klystron with 7 MW peak power and 36 kW average power will be used as the RF source. The modulator will be a solid-state modulator. The control system is FPGA based setup developed in-house at SAMEER. A retractable target with tungsten will be used as a converter to generate X-rays via bremsstrahlung. The x-rays will then interact with enriched 100Mo target to produce 99Mo via (g, n) reaction. Eluted 99mTc will be used for diagnostic applications. The paper lists the challenges and novel schemes developed at SAMEER to

make a compact, rugged, and easy to use system keeping in mind local conditions.

TUPAB406 **Search for New Isotope Production Pathways**
L.F. Dabill *(Coe College) A. Hutton (JLab)*
The isotope group at Jefferson Lab is carrying out R&D for producing medically interesting radioisotopes, especially those with theranostic (therapeutic and diagnostic) attributes. Here the search for viable production mechanisms has been expanded to multi-step reactions where a daughter is produced from the target and decays into a medically interesting granddaughter radioisotope. It is difficult to find efficient production routes when investigating both the initial excitation reaction as well as the decay routes leading to medically interesting isotopes. The overall goal of this project is to create a structured code in Python to find these decay routes by automatically exploring the large number of isotopes and their possible decay modes. The program structure is described, and preliminary results are presented.

TUPAB407 **A Novel Beam Optics Concept to Maximize the Transmission Through Cyclotron-based Proton Therapy Gantries**
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Most of the conventional beam optics of cyclotron-based proton gantries were designed to provide point-to-point focus in both planes with an imaging factor between 1 and 2 from the entrance of the gantry to the patient. This means that a small beam size at the gantry entrance is required to achieve the required small beam size at the patient. Due to the typically used beam emittance, this in turn results in large beam divergence at the gantry entrance, increasing the possibility of beam losses along the gantry as the beam envelope gets close to the apertures. To maximize transmission through the gantry, we propose a novel beam optics concept using 3:1 imaging. It reduces the beam divergence at the gantry entrance by factor 3 while still achieving a small beam size at the patient. The beam envelope is better controlled and keeps clear of the apertures compared to the 1:1 or 1:2 imaging beam envelope. For PSI Gantry 2, the novel 3:1 imaging beam optics increase the proton beam transmission for lower energies by 40% compare to 1:1 imaging beam optics. The usage of small imaging factors can help to maximize transmission for different gantry lattices, thus reducing treatment times.

TUPAB408 **A Novel Automatic Focusing System for the Production of Radioisotopes for Theranostics**
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A research program on the production of novel radioisotopes for theranostics is ongoing at the 18 MeV Bern medical cyclotron laboratory

equipped with a solid target station. Targets are made of rare and expensive isotope enriched materials in form of compressed 6 mm diameter pellets. The irradiation of such a small target is challenging. A specific capsule has been developed made of two aluminum halves kept together by permanent magnets. Since the beam extracted from a medical cyclotron is about 12 mm FWHM, an automatic compact focusing system was conceived and constructed to optimise the irradiation procedure. It is based on a 0.5 m long magnetic system, embedding two quadrupoles and two steering magnets, and a non-destructive beam monitoring detector located in front of the target. The profiles measured by the detector are elaborated by a specific software that, through a feedback optimisation algorithm, acts on the magnets and keeps the beam focused on target. Being about 1 m long, it can be installed in any existing medical cyclotron facility. The design of the first prototype together with the results of the first beam tests are presented.

TUPAB409 **FLUKA and Geant4 Monte Carlo Simulations of a Desktop, Flat Panel Source Array for 3D Medical Imaging**
T. Primidis, *C.P. Welsch (The University of Liverpool)* ***T. Primidis***, *C.P. Welsch (Cockcroft Institute) V. Soloviev (Adaptix Imaging)*
Digital tomosynthesis (DT) is a 3D imaging modality with a lower cost and lower dose than computed tomography. A DT system made of a flat panel array with 45 X-ray sources, but compact enough to fit on the desktop is near market realisation by the company Adaptix Ltd. This work presents a framework of FLUKA and Geant4 Monte Carlo (MC) simulations of the Adaptix system including the X-ray beam generation and the final image quality. The results show that MC methods offer an insight into the performance details of such an innovative device at different levels between the X-ray emitter array and the detector. As such, a large portion of the design and optimisation of such novel X-ray imaging systems can be done with a single toolkit. Finally, the modularity of the approach allows other tools to be imported at various steps within the framework and thus provide answers to questions that cannot be addressed by general-purpose MC codes.

TUPAB410 **Finite Element Analysis and Experimental Validation of Low-Pressure Beam Windows for XCET Detectors at CERN**
J.B.O. Buesa Orgaz *(CERN)*
In the framework of the renovation and consolidation of experimental areas at CERN, a low-pressure design beam superimposed windows (250 µm Mylar and 150 µm polyethylene) for the Threshold Cherenkov counters (XCET) has been modelled and verified for its implementation. The XCET is a detector used to count the number of selected charged particles in the beam by adjusting the pressure that leads to the emission of Cherenkov photons only above certain pressure threshold. Simultaneously, the charged particles pass from a vacuum environment to the pressurized refractive gas vessel through a solid interface. Minimal material in this solid interface is therefore crucial

to avoid interactions of the low-energy particles which may lead to beam intensity loss or background production. Hence, thin and low-density materials are required to mitigate multiple scattering and energy loss of the incoming particles while still allowing the needed pressures inside the counter vessel. A XCET validation methodology was conducted using Finite Element Analysis (FEA), followed by experimental validations performing burst pressure tests and using Digital Image Correlation (DIC).

TUPAB411 **Conceptual Design of Hybrid Energy Recovery Internal Target Ring**

***Y. Ishi**, Y. Mori, T. Uesugi (Kyoto University, Research Reactor Institute)*

A concept of ERIT in a hadron circular accelerator was proposed for the production of secondary particles such as pions at Kyoto University Research Reactor Institute (KURRI) in 2008. It has been tested using the real proton machine named ERIT FFAG ring. Since the energy of this machine is 11 MeV, the proof of principle has been done only for the energy recovery mechanism but not for the secondary particle production. We propose an extended concept HYERIT which adopts two different k values within the one ring: one is a high k for the acceleration and the other is a low k for the ERIT scheme. This design study provides an intense pion production with a compact footprint of the ring.

TUPAB412 **New 3 MeV and 7 MeV Accelerators for Cargo Screening and NDT**

***S. Proskin**, D. Fischer, A.V. Mishin (Varex Imaging)*

For decades evaluating of cargo and non-destructive testing of objects have been utilizing high energy systems based on particle accelerators. End users wish for lower prices, better image quality, and convenience of utilization. In recent years Varex Imaging, world leader in innovation, development, and manufacture of X-ray imaging component solutions, has been developing a series of new accelerator products with improved parameters and a goal of replacing existing dated systems and growing of emerging markets. New S-band energy regulated 3 MeV and 7 MeV linear accelerators have been designed, tested at Varex Imaging and their customer sites. Novel linacs benefit is in dramatically increased output, reduced beam spot, longer operation, and improved versatility. Authors will outline recent progress and future endeavors in linear accelerator development with regards to improvement of accelerating structures, X-ray targets, and corresponding RF components.

TUPAB413 **Rapid Browser-Based Visualization of Large Neutron Scattering Datasets**

D.L. Bruhwiler, *K. Bruhwiler, P. Moeller, R. Nagler (RadiaSoft LLC) C.M. Hoffmann, Z.J. Morgan, A.T. Savici, M.G. Tucker (ORNL) A. Kuhn, J. Mensmann, P. Messmer, M. Nienhaus, S. Roemer, D. Tatulea (NVIDIA)*

Neutron scattering makes invaluable contributions to the physical, chemical, and nanostructured materials sciences. Single crystal diffraction experiments collect volumetric scattering data sets representing the internal structure relations by combining datasets of many individual settings at different orientations, times and sample environment conditions. In particular, we consider data from the single-crystal diffraction experiments at ORNL. A new technical approach for rapid, interactive visualization of remote neutron data is being explored. The NVIDIA IndeX 3D volumetric visualization framework is being used via the HTML5 client viewer from NVIDIA, the ParaView plugin, and new Jupyter notebooks, which will be released to the community with an open source license.

TUPAB415 **Irradiation Methods and Infrastructure Concepts of New Beam Lines for NICA Applied Research**

G.A. Filatov, *A. Agapov, A.V. Butenko, K.N. Shipulin, A. Slivin, E. Syresin, A. Tuzikov, A.S. Vorozhtsov (JINR) S. Antoine, W. Beeckman, X.G. Duveau, J. Guerra-Phillips, P.J. Jehanno (SIGMAPHI S.A.)*

Nowadays space exploration has faced the issue of radiation risk to microelectronics and biological objects. The new beamlines and irradiation stations of the Nuclotron-based Ion Collider fAcility (NICA) at JINR are currently under construction to study this issue. The beamline parameters, different methods for homogeneous irradiation of targets such as scanning, and beam profile shaping by octupole magnets are discussed. A short description of the building infrastructure, magnet elements, and detectors for these beamlines is also given.

TUPAB416 **Depth-Dose Distribution Dependence on the Energy Profile of Linear and Laser Wakefield Accelerator Electron Beams**

T.A. Nguyen *(VNUHCM)*

The depth-dose distributions of 10 MeV electron beams used for food irradiation and sterilization purposes at Research and Development Center for Radiation Technology, HCMC, Vietnam are measured and the results are well reproduced by the MCNP simulations. We extend the simulations to predict the dose depth distribution for 10 MeV electron beams with the energy profiles of a model Laser Wake Field accelerator (LWFA). The dosimetry and simulation results show that the maximum dose of the depth-dose curve inside the product is 1.4 times surface dose with an area density limit of 8.6 g/cm^2 for two-sided irradiation with nearly mono-energetic beams from the linear accelerator and the corresponding parameters for LWFA are 1.2 times surface dose and 13.0 g/cm^2, respectively.

TUPAB417 **Pushing Spatial Resolution Limits In Single-Shot Time-Resolved Transmission Electron Microscopy at the UCLA Pegasus Laboratory**

P.E. Denham*, P. Musumeci (UCLA)*

We present the design of a high-speed single shot relativistic electron microscope planned for implementation at the UCLA PEGASUS Laboratory capable of imaging with less than 30 nm spatial resolution and image acquisition time on the order of 10 ps. This work is based on a multi-cavity acceleration scheme for producing relativistic beams (3.75 MeV) with suppressed rms energy spread ($\sigma_\delta \approx 5e-5$), and a means to reduce smooth space charge aberrations by generating a quasi-optimal 4D particle distribution at the sample plane. Start-to-end simulation results are used to validate the entire setup. Ultimately, a feasible working point is demonstrated.

TUXX — Tuesday Combined Oral Session

Chair: P. Klysubun (SLRI)

TUXX01 **Review of High Brightness Photoinjectors**

H.J. Qian *(DESY Zeuthen)*

High brightness photoinjectors have become the enabling technology in accelerator based light sources, ultrafast electron microscopy, energy recovery linac for ion cooling and many other advanced accelerator concepts. To match the frontiers of these scientific applications, photoinjectors continue to develop for both higher peak and higher average beam brightness. In this review, state of the art photoinjector performances and developments are presented.

TUXX02 **Towards the Globatron for Tomorrow**

Y.K. Kim *(University of Chicago)*

PLEASE ADD ABSTRACT

TUXA — Tuesday Oral Parallel A

Chair: T. Satogata (JLab)

TUXA01 **Advances in Understanding of Ion Effects in Electron Storage Rings**

***J.R. Calvey**, M. Borland, T.K. Clute, J.C. Dooling, L. Emery, J. Gagliano, J.E. Hoyt, P.S. Kallakuri (ANL)*

Ion instability, in which beam motion couples with trapped ions in an accelerator, is a serious concern for high-brightness electron storage rings. For the APS-Upgrade, we plan to mitigate coherent ion instability using a compensated gap scheme. To study incoherent effects (such as emittance growth), an IONEFFECTS element has been incorporated into the particle tracking code ELEGANT. The simulations include multiple ionization, transverse impedance, and charge variation between bunches. Once these effects are included, the simulations show good agreement with measurements at the present APS. We have also installed a gas injection system, which creates a controlled pressure bump of Nitrogen gas in a short section of the APS ring. The resulting ion instability was studied under a wide variety of beam conditions. For cases with no or insufficient train gaps, large emittance growth was observed. IONEFFECTS simulations of the gas injection experiment and APS-U storage ring show the possibility of runaway emittance blowup, where the blown-up beam traps more ions, driving further instability.

TUXA02 **Beam Dynamics Optimization in High-Brightness Electron Injectors**

***C.E. Mitchell** (LBNL)*

The next generation of X-ray free electron lasers requires beams with increasingly high peak current and low emittances at ~MHz repetition rates, placing increased demands on the performance of high-brightness electron photoinjector sources. To explore the high- dimensional parameter space associated with photoinjector design, global multiobjective optimization methods based on genetic algorithms or similar tools play a critical role. We review our experience applying these tools both to understand and to optimize simulated injector beam performance for projects such as LCLS-II (at SLAC), the Advanced Photoinjector EXperiment (at LBNL), APEX2, and potential future high-brightness FEL electron sources.

TUXA03 **Progress in Mastering Electron Clouds at the Large Hadron Collider**

***G. Iadarola**, B. Bradu, L. Mether, K. Paraschou, V. Petit, G. Rumolo, L. Sabato, G. Skripka, M. Taborelli, L.J. Tavian (CERN) K. Paraschou (AUTH)*

During the second operational run of the Large Hadron Collider (LHC) a bunch spacing of 25 ns was used for the first time for luminosity production. With such a spacing, electron cloud effects are much more

severe than with the 50-ns spacing, which had been used in the previous run. Beam-induced conditioning of the beam chambers mitigated the e-cloud formation to an extent that allowed an effective exploitation of 25 ns beams. Nevertheless, even after years of conditioning, e-cloud effects remained very visible, affecting beam stability and beam quality, and generating strong heat loads on the beam screens of the superconducting magnets with puzzling features. In preparation for the High Luminosity LHC upgrade, remarkable progress has been made in the modeling of the e-cloud formation and of its influence on beam stability, slow losses and emittance blow up, as well as in the understanding of the underlying behavior of the beam-chamber surface. In this contribution, we describe the main experimental observations from beam operation, the outcome of laboratory analysis conducted on beam screens extracted after the run, and the main advancements in the modeling of these phenomena.

TUXA04 **Coherent Excitations and Circular Attractors in Cooled Ion Bunches**

***S. Seletskiy**, A.V. Fedotov, D. Kayran (BNL)*

In electron coolers, under certain conditions, a mismatch in either gamma-factors or trajectory angles between an electron and an ion beam can cause the formation of a circular attractor in the ion beam phase space. This leads to coherent excitations of the ions with a small synchrotron or betatron amplitude and results in unusual beam dynamics, including bifurcations. In this paper, we consider the effect of coherent excitations and discuss its implications both for Low Energy RHIC Electron Cooler (LEReC) and for high energy electron coolers proposed for the Electron-Ion Collider (EIC).

TUXA05 **Measurements of Beam-Beam Interactions in Gear-Changing Collisions in DESIREE**

***E.A. Nissen** (JLab) A. Källberg, A. Simonsson (Stockholm University)*

In this work, we perform measurements on the interactions of colliding beams in a gear-changing system. Gear-changing was first demonstrated in DESIREE in May of 2020 and showed several promising avenues to measure beam-beam effects. DESIREE has a unique collision scheme where the beams are moving in the same direction, which provides for unique interactions. This experiment used a 4 on 3 gear changing system with one bucket in each ring left empty, this allows us to see the bunch profile while undergoing collisions. We then measured the bunch length over time and used a Fourier transform to extract longitudinal evolution data and compared it to baseline data of uncollided beams.

TUXA06 **Loss of Transverse Landau Damping by Diffusion in High-Energy Hadron Colliders**

***S.V. Furuseth**, X. Buffat (CERN) **S.V. Furuseth** (EPFL)*

Circular hadron colliders rely on Landau damping to stabilize the beams. Landau damping depends strongly on the bunch distribution,

which is often assumed to be Gaussian in the transverse planes. In this paper, we introduce and explain an instability mechanism observed in the LHC, where Landau damping is eventually lost due to a diffusion that modifies the transverse bunch distribution. The mechanism is caused by a wide-spectrum noise that excites the transverse motion of the beam, which consequently produces wakefields that drive a narrow-spectrum diffusion. It is shown that this diffusion efficiently lowers the stability diagram at the frequency of the least stable coherent mode, leading to a loss of Landau damping after a latency. A semi-analytical model agrees with measurements in dedicated latency experiments performed in the LHC. This instability mechanism explains the need for a stability margin in octupole current in the LHC, relative to the amount needed to stabilize a Gaussian beam. We detail the impact of this mechanism and possible mitigations for the LHC and HL-LHC.

TUXA07 **Beam Dynamics Study in a Dual Energy Storage Ring for Ion Beam Cooling**

B. Dhital, *G.A. Krafft (ODU) Y.S. Derbenev, D. Douglas, A. Hutton, G.A. Krafft, F. Lin, V.S. Morozov, Y. Zhang (JLab)*

A dual energy storage ring designed for beam cooling consists of two closed rings with significantly different energies: the cooling and damping rings. These two rings are connected by an energy recovering superconducting RF structure that provides the necessary energy difference. In our design, the RF acceleration has a main linac and harmonic cavities both running at crest that at first accelerates the beam from low energy E_L to high energy E_H and then decelerates the beam from E_H to E_L in the next pass. The purpose of the harmonic cavities is to extend the bunch length in a dual energy storage ring as such a longer bunch length may be very useful in a cooling application. Besides these cavities, a bunching cavity running on zero-crossing phase is used outside of the common beamline to provide the necessary longitudinal focusing for the system. In this paper, we present a preliminary lattice design along with the fundamental beam dynamics study in such a dual energy storage ring.

TUXB — Tuesday Oral Parallel B

Chair: C. Vaccarezza (INFN/LNF)

TUXB01 **Cascaded Terahertz-Driven Acceleration Recent Progress at Tsinghua University**

***H. Xu**, Y.-C. Du, W.-H. Huang, R.K. Li, C.-X. Tang, L.X. Yan (TUB)*

Efficient acceleration and manipulation of high-brightness electron beams using terahertz waves in a compact setup has been recently a hot research topic in acceleration community. Previous works have achieved multi-MV/m acceleration gradient and dozens of keV energy gain while leaving room for further improvements in the high-energy regime. Here, we experimentally demonstrate whole-bunch acceleration and cascaded terahertz-driven acceleration of a relativistic beam with a record energy gain of 204 keV. A terahertz-driven all-optical electron source is now under development, which hold great potential for terahertz-driven ultrafast electron diffraction and related scientific discoveries.

TUXB02 **Precision Control of Plasma Wakefields for Highly Efficient and Energy-Spread-Preserving Electron Acceleration**

***S. Schröder**, S. Bohlen, L.A. Boulton, R.T.P. D'Arcy, S. Diederichs, J.M. Garland, P. Gonzalez-Caminal, A. Knetsch, C.A. Lindstrøm, G. Loisch, A. Martinez de la Ossa, J. Osterhoff, K. Poder, L. Schaper, B. Schmidt, B. Sheeran, G.E. Tauscher, S. Wesch, J.C. Wood, J. Zemella (DESY) L.A. Boulton (USTRAT/SUPA) J. Chappell (UCL)*

Plasma-wakefield accelerators driven by intense particle beams promise to significantly reduce the size of future high-energy facilities. These applications require an energy-efficient acceleration process with a well-controlled energy spectrum, both of which can be achieved simultaneously by tailoring the plasma wakefield. A prerequisite for such control of the wakefield is its precise measurement. Here we discuss a new measurement technique that enables femtosecond-level sampling of the longitudinal electric fields and that is particularly powerful due to its operational simplicity. Using this method, we experimentally demonstrated optimal beam loading in a nonlinear electron-driven plasma accelerator by wakefield flattening at the few-percent level. Bunches were accelerated at a gradient of 1.3 GV/m and with an energy-transfer efficiency of (42±4)% while preserving per-mille energy spreads with full charge coupling. These results open the door to the high-quality operation of future plasma accelerators through precise control of the acceleration process.

TUXB03 **Recent results and future perspectives for high-quality electron beams from plasma accelerators**

***R. Pompili** (INFN/LNF)*

Next-generation plasma-based accelerators can push electron bunches to gigaelectronvolt energies within centimeter distances. So

far, several experiments have demonstrated high gradient and succesfull beam acceleration but the resulting beam quality, in terms of energy spread and emittance, is still lower than the state-of-the-art conventional accelerators. Several proof-of-principle experiments have recently demonstrated very promising results thanks to contribution from different scientific communities with different expertise (lasers, rf-accelerators,plasma). These findings will significantly impact the optimization of the acceleration module and its implementation in forthcoming compact machines for user-oriented applications. An overview of these recent achievements and of the recent results obtained in the framework of the EuPRAXIA collaboration will be presented and discussed in this talk.

TUXB04 **Fabrication and tuning of a THz-driven electron gun**

***S.M. Lewis**, A.A. Haase, J.W. Merrick, E.A. Nanni, M.A.K. Othman, S.G. Tantawi (SLAC) **S.M. Lewis** (Fermilab)*

We have developed a THz-driven field emission electron gun and beam characterization assembly. The two cell standing-wave gun operates in the pi mode at 110.08 GHz. It is designed to produce 360 keV electrons with 500 kW of input power supplied by a 110 GHz gyrotron. Multiple gun structures were electroformed in copper using a high precision diamond-turned mandrel. The field emission cathode is a rounded copper tip located in the first cell. The cavity resonances were mechanically tuned using azimuthal compression. This work will discuss details of the fabrication and tuning and present the results of low power measurements.

TUXB05 **Intense Channeling Radiation as a Tool for a Hybrid Crystal-Based Positron Source for Future Colliders**

***L. Bandiera**, A. Mazzolari, M. Romagnoni, A.I. Sytov (INFN-Ferrara) L. Bomben, V. Mascagna (INFN MIB) G. Cavoto (INFN-Roma) I. Chaikovska, R. Chehab (Université Paris-Saclay, CNRS/IN2P3, IJCLab) D. De Salvador (Univ. degli Studi di Padova) L.G. Foggetta (INFN/LNF) E. Lutsenko, M. Prest (Università dell'Insubria & INFN Milano Bicocca) M. Soldani (Università degli Studi di Ferrara) V.V. Tikhomirov (INP BSU) E. Vallazza (INFN-Trieste)*

There is a strong need for intense positron sources for future colliders. A crystal-based hybrid positron source could be an alternative to conventional sources based on the e^- conversion into e^+ in a thick target. The basic idea of the hybrid source is to split the e^+ converter into a gamma-quanta radiator plus a gamma-to-positron converter. In such a scheme an e^- beam crosses a thin axially oriented crystal with emission of "channeling radiation", characterized by a considerably larger amount of photons w.r.t. standard bremsstrahlung. The net result is an increase in the number of e^+ produced at the converter target. In the hybrid scheme, only photons reach the converter, thereby reducing the Peak Energy Deposition Density (PEDD) in the target. Here we present the results of a test conducted at the DESY TB with 5.6 GeV

e^- interacting with a W crystal. A huge enhancement in the radiated energy and in the photon emission has been recorded and reproduced with Monte Carlo simulations. This study is relevant for the design of the FCC-ee positron source. Indeed, through Monte Carlo, we also investigated the best parameters of the crystal radiator suited for the FCC-ee e^+ source.

TUXB06 **High Transformer Ratio Plasma Wakefield Acceleration and Current Profile Reconstruction Using Emittance Exchange**

R.J. Roussel *(Enrico Fermi Institute, University of Chicago) G. Andonian, A. Deng, C.E. Hansel, G.E. Lawler, W.J. Lynn, R. Robles, J.B. Rosenzweig, K. Sanwalka (UCLA) S. Baturin (Northern Illinois University) M.E. Conde, D.S. Doran, G. Ha, J.G. Power, J. Seok, C. Whiteford, E.E. Wisniewski (ANL)*

To overcome limits on total acceleration achievable in plasma wakefield accelerators, specially shaped drive beams can be used to increase the transformer ratio, implying that the drive beam deceleration is minimized in comparison with acceleration obtained in the wake. We report the results of a nonlinear PWFA, high transformer ratio experiment using high-charge, longitudinally asymmetric drive beams in a plasma cell. An emittance exchange process is used to generate variable drive current profiles, in conjunction with a long (multiple plasma wavelength) witness beam. The witness beam is energy-modulated by the wakefield, yielding a response that contains detailed spectral information in a single-shot measurement. Using these methods, we generate a variety of beam profiles and characterize the wakefields, directly observing beam-loaded transformer ratios up to 7.8. Further, a spectrally-based current reconstruction technique, validated by 3D particle-in-cell simulations, is introduced to obtain the drive beam profile from the decelerating wakefield data.

TUXB07 **High-Current H^{2+} Beams from a Compact Cyclotron using RFQ Direct Injection**

D. Winklehner*, J.M. Conrad, D. Koser, J. Smolsky, L.H. Waites (MIT)*

For the IsoDAR neutrino experiment, we have developed a compact and cost-effective cyclotron-based driver to produce high current beams (cw proton beam currents of >10 mA at 60 MeV). This is a factor of 4 higher than the current state-of-the-art for cyclotrons and a factor of 10 compared to what is commercially available. All areas of physics that call for high cw currents can greatly benefit from this result; e.g. particle physics, medical isotope production, and energy research. This increase in beam current is possible in part because the cyclotron is designed to include and use vortex-motion, allowing clean extraction. Such a design process is only possible with the help of high-fidelity codes, like OPAL. Another novelty is the use of an RFQ embedded in the cyclotron yoke to bunch the beam during axial injection. Finally, using H^{2+} relieves some of the space charge constraints during injection. In this paper, we will give an overview of the project and

then focus on the design and simulations of the cyclotron itself. We will describe the physics, computational tools, and simulation results. At the end, we will describe how we are including machine learning in the simulations.

TUXC — Tuesday Oral Parallel C

TUXC01 **Fabrication and Test Challenges of the SC Transport Solenoid for Mu2e Experiment**

***M.J. Lamm**, G. Ambrosio, K.E. Badgley, J.S. Brandt, D.A. Evbota, A. Hocker, V. Lombardo, T.H. Nicol, P. Schlabach (Fermilab)*

A muon transport system (TS) is being built for the Fermilab Mu2e Experiment. The system consists of 52 superconducting solenoid magnets organized into two separately powered and cryostated elements TSu/TSd. Each cryostated element is further segmented into seven test units that form the TSu/TSd cold mass. The s-shaped geometry of the transport as well as its magnetic coupling to adjacent solenoid elements provides challenging requirements for the system design and fabrication. The acceptance campaign for the 14 test units is nearly completed and one of the two cold masses has been fully mechanically assembled. After presenting an overview of the Mu2e solenoid system, we report on the fabrication and test challenges and progress on the TS system including quench performance and coil alignment.

TUXC02 **The LCLS-II-HE R&D Program: New Insights into Improving the Performance of Nitrogen-Doped SRF Cavities**

***D. Gonnella**, S. Aderhold, J.T. Maniscalco, M.C. Ross (SLAC) D. Bafia, M. Checchin, A. Grassellino, S. Posen (Fermilab) A.D. Palczewski, C.E. Reece (JLab)*

Nitrogen doping has now been demonstrated to produce SRF cavities of unprecedented Q_0 values when manufactured in an industrial setting. LCLS-II has shown over 300 cavities with an average Q_0 of more than $3{\cdot}10^{10}$ at 16 MV/m and represents an overwhelming success of the doping protocol. LCLS-II-HE will add an additional 23 superconducting cryomodules to the LCLS-II linac, requiring cavities to operate at similar levels of high Q_0 but at 21 MV/m instead of 16 MV/m. Nitrogen-doped cavities have been historically plagued by lower quench fields than other cavity preparation methods. Therefore, an R&D effort was launched to improve upon the quench fields of doped cavities while maintaining the high Q_0. Here we present results on single-cells and 9-cells from new doping recipe pursuits, transfer of these new recipes to cavity vendors, and results on vendor-produced 9-cell cavities. This program has led to the discovery of the importance of the cold electropolish for producing higher quench fields. Finally, we will show results from the first cryomodule produced with these new cavities operating at HE gradients.

TUXC03 **Ferro-Electric Fast Reactive Tuner Applications for SRF Cavities**

***N.C. Shipman**, A. Castilla, M.R. Coly, F. Gerigk, A. Macpherson, N. Stapley, H. Timko (CERN) I. Ben-Zvi (BNL) G. Burt, A. Castilla (Cockcroft Institute, Lancaster University) C.-J. Jing, A. Kanareykin (Euclid TechLabs, LLC)*

A Ferro-Electric fast Reactive Tuner (FE-FRT) is a novel type of RF cavity tuner containing a low loss ferroelectric material. FE-FRTs have no moving parts and allow cavity frequencies to be changed extremely quickly (on the timescale of 100s of ns or less). They are of particular interest for SRF cavities as they can be placed outside the liquid helium environment and without an FE-FRT it's typically very difficult to tune SRF cavities quickly. FE-FRTs can be used for a wide variety of use cases including microphonics suppression, RF switching, and transient beam loading compensation. This promises entirely new operational capabilities, increased performance and cost savings for a variety of existing and proposed accelerators. An overview of the theory and potential applications will be discussed in detail.

TUXC04 **Electron Desorption From Porous Materials of Interest for Future Accelerators**

***L. Spallino**, M. Angelucci, R. Cimino, G. Costella (INFN/LNF) G. Costella (Sapienza University of Rome)*

Laser ablated Cu surfaces (LASE) have been proposed to mitigate electron cloud phenomena due to their porous structure. When such surfaces are used as cryogenic components in accelerators, they will undergo thermal fluctuation, photon, and e-irradiation. A rigorous evaluation of their overall behavior in such vacuum conditions is clearly required. Our studies on thermal desorption of gas from LASE have shown that the morphology gives rise to a vaster and higher desorption temperature (T) with respect to what has been observed from a flat surface. This implies that gas desorption from LASE will occur in an unexpected T range, but also that cryosorbed gas will be on those surfaces at temperatures and quantities very different from what is expected to occur on flat surfaces. This gas can participate in other desorption mechanisms, such as e-desorption. Here we report some measurements of e-desorption yield from such LASE treated surfaces at low T. Such results can be useful to predict the gas quantity finally delivered in accelerators' cryogenic vacuum from a porous surface under e-irradiation.

TUXC05 **Production and testing of NICA collider magnets**

***D. Nikiforov**, H.G. Khodzhibagiyan, M.V. Petrov (JINR) Yu.G. Bespalov, S.A. Kostromin (JINR/VBLHEP)*

The commissioning of the accelerating complex NICA (Nuclotron-based Ion Collider fAcility) will be carried out at the end of 2022. The NICA complex includes a heavy ion linear accelerator (HILAc) and three superconducting (SC) rings new Booster synchrotron (Booster), synchrotron - Nuclotron, and collider. Collider has a two-aperture

structure and consists 327 SC magnets. The report presents the results of cryogenic tests of SC magnets on a cryogenic test bench, such as research quench histories of the SC coils, measurement static heat leak and dynamic heat releases, search cold leaks. More than 80% of the collider's dipole magnets successfully passed cryogenic tests at the end of January 2021. The first successful cryogenic tests of quadrupole lenses with correcting SC magnets were carried out.

TUXC06 **Visualizing lattice dynamic behavior by acquiring a single time-resolved MeV diffraction image**

X. Yang, *T.V. Shaftan, V.V. Smaluk, J. Tao, L. Wu, Y. Zhu (BNL) W. Wan (ShanghaiTech University)*

We explore the possibility of visualizing the lattice dynamic behavior by acquiring a single time-resolved MeV UED image. Conventionally, multiple UED shots with varying time delays are needed to map out the entire dynamic process. The measurement precision is limited by the timing jitter between the pulses of laser pump and UED probe. We show that, by converting the longitudinal time of an electron bunch to the transverse position of a Bragg peak on the detector, one can obtain the full lattice dynamic process in a single electron pulse. We propose a novel design of a time-resolved UED with the capability of capturing a wide range of dynamic features in a single diffraction image. The work presented here is not only an extension of the ultrashort-pulse pump/long-pulse probe scheme being used in transient spectroscopy studies for decades but also advances the capabilities of MeV UED for future applications with tunable electron probe profile and detecting time range with femtosecond resolution. Furthermore, we present numerical simulations illustrating the capability of acquiring a single time-resolved diffraction image based on the case-by-case studies of lattice dynamic behavior.

TUXC07 **Modified Halbach Magnets for Emerging Accelerator Applications**

S.J. Brooks *(BNL)*

The original circular Halbach magnet design creates a strong pure multipole field from permanent magnet pieces without intervening iron. This design has been extended recently at the CBETA 4-turn ERL, whose return loop includes combined-function (dipole+quadrupole) Halbach-derived magnets, plus a modular system of tuning shims to improve all 216 magnets' relative field accuracy to better than 10^{-3}. This paper describes further modifications of the Halbach design enable a larger range of accelerator applications in the future: (1) open-midplane designs to allow synchrotron radiation in light sources and other high-energy electron rings, ERLs or RLAs to escape. (2) Quadrupole magnets with an oval aperture allow larger gradients than a circular aperture, provided the beam is more extended in one axis than the other, as usual for a quadrupole in a focussing system. These can be used in compact hadron therapy gantries. (3) New collider complexes often require multiple rings for acceleration or top-up, accumulation,

collision and cooling. Multi-aperture permanent magnets are possible to cheaply and compactly build ring systems with several stable orbits separated by a few cm.

TUXC08 **Simulation and Experiments of Multi-Harmonics Buncher on SSC-Linac in HIRFL**

Q.Y. Kong *(IMP/CAS)*

A compact dual-gap Multi-Harmonics Buncher has been successfully used at the SSC-Linac, a linear accelerator dedicates to beam injection into SSC in HIRFL. At present, the SSC-Linac has a normal conducting ECR ion source with output energy at 3.728keV/u, a 4-rod RFQ increases the energy to 143keV/u. Further acceleration up to 0.58 MeV/u will be completed by two normal conducting IH-DTL. Finally beam will inject into SSC which operates at 13.417MHz, and SSC-Linac operates at 53.667MHz. In that case, no more than 25% of the beam injected into SSC can be captured in theory. To increase the longitudinal capture efficiency, an independent MHB (Multi-Harmonics Buncher) with three harmonics had been installed into the LEBT section. The fundamental frequency of the MHB is 13.417MHz. The buncher adopts the mechanical structure of double gaps and sawtooth waveform is generated by multi-harmonics synthetic technology. Beam performance with MHB have been simulated with code BEAMPATH. Besides, $84Kr^{14+}$ beam has been bunched successfully using the MHB in our experiments, the maximum ratio 86.02% of particles in central bunch to satellite bunch has been measured via BPM downstream of the RFQ.

WEPAB001 **Accelerator Challenges of the LHeC**

***B.J. Holzer**, K.D.J.A. André, O.S. Brüning (CERN) S.A. Bogacz (JLab) M. Klein (The University of Liverpool)*

The LHeC project studies the design of a future electron-proton collider at CERN that will run in parallel to the standard LHC operation. For this purpose, the existing LHC storage ring will be combined with an Energy Recovery Linac (ERL), to accelerate electrons up to kinetic energy of 50 GeV. This concept - also applicable to the FCC-eh collider and studied at the PERLE project as prototype version - allows a peak luminosity of 10^{34} cm^{-2} s^{-1}. A sophisticated design of the RF structures, linacs, arcs, and interaction region is required. The electrons are accelerated and, after the interaction point, their energy is recovered through the same RF structures. While this energy recovery concept is a very promising approach, severe challenges are set by the layout of the interaction region, the beam separation concept and the design of the linac and arc lattice for the highest possible momentum acceptance. Emittance control and beam-beam effect of both, electron and proton beams, have been studied in front-to-end simulations and will be presented. We summarise the design principles of the ERL, the optimization of the arc lattice, and the main parameters of the project.

WEPAB002 **The Interaction Region of the Electron-Ion Collider EIC**

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This paper presents an overview of the Interaction Region (IR) design for the planned Electron-Ion Collider (EIC) at Brookhaven National Laboratory. The IR is designed to meet the requirements of the nuclear physics community. The IR design features a ±4.5 m free space for the detector; a forward spectrometer magnet is used for the detection of hadrons scattered under small angles. The hadrons are separated from the neutrons allowing detection of neutrons up to ±4 mrad. On the rear side, the electrons are separated from photons using a weak dipole magnet for the luminosity monitor and to detect scattered electrons (e-tagger). To avoid synchrotron radiation backgrounds in the detector no strong electron bending magnet is placed within 40 m upstream of the IP. The magnet apertures on the rear side are large enough to allow synchrotron radiation to pass through the magnets.

The beam pipe has been optimized to reduce the impedance; the total power loss in the central vacuum chamber is expected to be less than 90 W. To reduce risk and cost the IR is designed to employ standard NbTi superconducting magnets, which are described in a separate paper.

WEPAB003 **Overview of the Magnets Required for the Interaction Region of the Electron-Ion Collider (EIC)**

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The planned electron-ion collider (EIC) at Brookhaven National Laboratory (BNL) is designed to deliver a peak luminosity of 1x10^{34} cm^{-2} s^{-1}\$. This paper presents an overview of the magnets required for the interaction region of the BNL EIC. To reduce risk and cost the IR is designed to employ conventional NbTi superconducting magnets. In the forward direction the magnets for the hadrons are required to pass a large neutron cone and particles with a transverse momentum of up to 1.3 GeV/c, which leads to large aperture requirements. In the rear direction the synchrotron radiation fan produced by the electron beam must not hit the magnet apertures, which determines their aperture. For the forward direction a mostly interleaved scheme is used for the optics, whereas for the rear side 2-in-1 magnets are employed. We present an overview of the EIC IR magnet design including the forward spectrometer magnet B0.

WEPAB004 **Electron-Ion Luminosity Maximization in the EIC**

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The electron-ion luminosity in EIC has a number of limits, including the ion intensity available from the injectors, the total ion beam current, the electron bunch intensity, the total electron current, the synchrotron radiation power, the beam-beam effect, the achievable beta functions at the interaction points (IPs), the maximum angular spreads at the IP, the ion emittances reachable with stochastic or strong cooling, the ratio of horizontal to vertical emittance, and space charge effects. We map the e-A luminosity over the center-of-mass energy range for some ions ranging from deuterons to uranium ions. For e-Au collisions the present design provides for electron-nucleon (e-Au) peak luminosities of 1.7x10^{33} cm^{-2}s^{-1} with stochastic cooling, and 4.7x10^{33} cm^{-2}s^{-1} with strong hadron cooling.

WEPAB005 **Design Status Update of the Electron-Ion Collider**

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The design of the electron-ion collider EIC to be constructed at Brookhaven National Laboratory has been continuously evolving towards a realistic and robust design that meets all the requirements set forth by the nuclear physics community in the White Paper. Over the past year activities have been focused on maturing the design, and on developing alternatives to mitigate risk. These include improvements of the interaction region design as well as modifications of the hadron ring vacuum system to accommodate the high average and peak beam currents. Beam dynamics studies have been performed to determine and optimize the dynamic aperture in the two collider rings and the beam-beam performance. We will present the EIC design with a focus on recent developments.

WEPAB006 **EIC Crab Cavity Multipole Analysis**

***Q. Wu**, Y. Luo, B.P. Xiao (BNL) S.U. De Silva (ODU) J.A. Mitchell (CERN)*

Crab cavities are specialized RF devices designed for colliders targeting high luminosities. It is a straightforward solution to retrieve head-on collision with crossing angle existing to fast separate both beams after collision. The Electron Ion Collider (EIC) has a crossing angle of 25 mrad, and will use local crabbing to minimize the dynamic aperture requirement throughout the rings. The current crab cavity design for the EIC lacks axial symmetry. Therefore, their higher order components of the fundamental deflecting mode have a potential of affecting the long-term beam stability. We present here the multipole analysis and preliminary particle tracking results from the current crab cavity design.

WEPAB008 **Numerical Noise Study in EIC Beam-Beam Simulations**

***D. Xu**, Y. Hao (FRIB) Y. Luo, C. Montag (BNL) J. Qiang (LBNL)*

In the Electron-Ion Collider (EIC) design, a flat beam collision scheme is adopted to achieve 10^{34} luminosity. We found that the vertical growth of the proton beam is much larger than of the round beam. In this article we present the numerical noise study about the number of macroparticles, the electron slice number, and the electron bunch

length. Both weak-strong and strong-strong simulation methods are used. It turns out the proton emittance growth in the strong-strong simulation mainly comes from the numberical noise. This study helps us to perform beam-beam simulation correctly for EIC.

WEPAB009 **Study of Harmonic Crab Cavity in EIC Beam-Beam Simulations**

***D. Xu**, Y. Hao (FRIB) Y. Luo, C. Montag (BNL) J. Qiang (LBNL)*

In the Electron-Ion Collider (EIC) design, crab cavities are adopted to compensate the geometric luminosity loss from the crossing angle. From previous studies, higher-order synchro-betatron resonances are excited since the hadron beam is long and the crossing angle is large. To reduce the luminosity degradation rate, different combinations of harmonic crab cavities are studied with both weak-strong and strong-strong simulation methods. The frequency map analysis (FMA) is also used for comparison. This study helps determine the crab cavity parameters for the future EIC.

WEPAB010 **Full Range Tune Scan Studies Using Graphics Processing Units With CUDA in EIC beam-beam Simulations**

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The hadron beam in the Electron-Ion Collider (EIC) suffers high order betatron and synchro-betatron resonances. In this paper, we present a weak-strong full range (0.0–0.5) fractional tune scan with a step size as small as 0.001. Multiple Graphics Processing Units (GPUs) are used to speed up the simulation. A code parallelized with MPI and CUDA is implemented. The good tune region from weak-strong scan is further checked by the self-consistent strong-strong simulation. This study provides beam dynamics guidance in choosing proper working points for the future EIC.

WEPAB011 **Update on the Low Emittance Tuning of the E+/e$^-$ Future Circular Collider**

***T.K. Charles** (The University of Liverpool) B.J. Holzer, F. Zimmermann (CERN) K. Oide (KEK)*

The FCC-ee project studies the design of a future 100 km e+/e circular collider for precision studies and rare decay observations in the range of 90 to 350 GeV center of mass energy with luminosities in the order of 10^{35} cm^{-2} s^{-1}. To achieve ultra-low vertical emittance a highly effective emittance tuning scheme is required. In this paper, we describe a comprehensive correction strategy used for the low emittance tuning. The strategy includes Dispersion Free Steering, linear coupling compensation based on Resonant Driving Terms and beta beat correction utilising response matrices.

WEPAB012 **Preliminary Investigation Into Accelerators for in-Situ Cultural Heritage Research**

***T.K. Charles** (The University of Liverpool) A. Castilla (CERN) A. Castilla (Lancaster University)*

Ion Beam Analysis (IBA) centres have provided researchers with pow-

erful techniques to analyse objects of cultural significance in a non-destructive and non-invasive manner. However, in some cases it is not be feasible to remove an object from the field or museum and transport it to the laboratory. In this conference proceedings, we report the initial results of an investigation into the feasibility of a compact accelerator that can be taken to sites of cultural significance, for PIXE analysis. In particular, we consider the application of a compact, robust accelerator that is capable to producing 2 MeV protons that can be taken into the field to perform PIXE measurements on rock art. We detail the main challenges and considerations for such a device, as well as highlighting the potential benefits of this new accelerator application.

WEPAB013 **A New Algorithm for Positron Source Parameter Optimisation**
***Y. Zhao**, L. Ma (SDU) S. Döbert, A. Latina (CERN)*
In this report, we proposed a new simple and efficient algorithm for positron source parameter optimisation, which is based on iterations of scan of free parameters in the simulation. The new algorithm is fast, simple and convincing since the results can be visually drawn and flexibly tuned and it has an advantage that it can easily handle realistic parametric problems with more than one objective quantities to optimise. The optimisation of the main parameters of the CLIC positron source at the 380 GeV stage is presented as an example to demonstrate how the algorithm works.

WEPAB014 **Optimisation of the CLIC Positron Source**
***Y. Zhao**, L. Ma (SDU) H.M.A. Bajas, S. Döbert, A. Latina (CERN)*
In this report, we reoptimised the CLIC positron source at all collision energy stages. Simulation, optimisation algorithm and results were all improved compared with previous studies. Two different target schemes were studied and compared in terms of the advantages and disadvantages. The spot size of the injected electron beam was also optimised to achieve a compromise between large positron yields and safe energy deposition. The matching device for the capture of positrons was simulated and optimised with both improved analytic and realistic field maps. Conical aperture and front and rear gaps of the matching device were also considered for the first time. The optimised positron source is expected to have the lowest cost.

WEPAB015 **Comparison of Different Matching Device Field Profiles for the FCC-ee Positron Source**
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In this report, we compared different matching device field profiles for the FCC-ee positron source. The matching device is used to capture positrons with magnetic field. A flux concentrator was designed with a conical inner chamber. A smaller aperture and a larger aperture were studied. An analytic field profile was also studied using an adiabatic

formula. The peak field of the analytic profile as well as beam and target parameters was optimised to achieve a maximum positron yield. A safe energy deposition in the target was guaranteed by requiring a constraint on the deposited power and peak energy deposition density.

WEPAB016 **Snowmass'21 Accelerator Frontier: Goals and Progress**
V.D. Shiltsev *(Fermilab) S.A. Gourlay (LBNL) T.O. Raubenheimer (SLAC)*
Snowmass'21 is decadal particle physics community planning study. It provides an opportunity for the entire particle physics community to come together to identify and document a scientific vision for the future of particle physics in the U.S. and its international partners. Snowmass will define the most important questions for the field of particle physics and identify promising opportunities to address them. The P5, Particle Physics Project Prioritization Panel, will take the scientific input from Snowmass and develop a strategic plan for U.S. particle physics that can be executed over a 10 year timescale, in the context of a 20-year global vision for the field. Here we present the goals, progress and plans of the Snowmass'21 Accelerator Frontier.

WEPAB017 **General Approach to Physics Limits of Ultimate Colliders**
V.D. Shiltsev *(Fermilab)*
The future of the particle physics is critically dependent on feasibility of future energy frontier colliders. The concept of the feasibility is complex and includes at least three factors: feasibility of energy, feasibility of luminosity, and feasibility of cost and construction time. Here we discuss major beam physics limits of ultimate accelerators, take a look into ultimate energy reach of possible future colliders. We also foresee a looming paradigm change for the HEP research as the thrust for higher energies by necessity will mean lower luminosity.

WEPAB018 **Space-Charge Effects in Ionization Beam Profile Monitors**
V.D. Shiltsev *(Fermilab)*
Ionization profile monitors (IPMs) are widely used in accelerators for non-destructive and fast diagnostics of high energy particle beams. At high beam intensities, the space-charge forces make the measured IPM profiles significantly different from those of the beams. We analyze dynamics of the secondaries in IPMs and develop an effective algorithm to reconstruct the beam sizes from the measured IPM profiles. Efficiency of the developed theory is illustrated in application to the Fermilab 8 GeV proton Booster IPMs.

WEPAB019 **RF Harmonic Kicker R&D Demonstration and Its Application to the RCS Injection of the EIC**
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The Rapid Cycling Synchrotron (RCS) of the Electron-Ion Collider (EIC) at Brookhaven National Laboratory (BNL) is an accelerating component of the electron injection complex, which provides polarized electrons in electron-ion collisions in the main Electron Storage

Ring (ESR). We present the injection scheme into the RCS based on an ultra-fast harmonic kicker, whose "five odd-harmonic modes" prototype was developed in the context of the Jefferson Lab EIC (JLEIC) conceptual design. In its early stage of R&D, the sharp (~3 ns width) waveform construction, beam dynamics, and pulsed power operation with short ramping time (~10 μs) will be discussed together with the fabrication work of the JLEIC prototype.

WEPAB020 **The Relation Between Field Flatness and the Passband Frequency in the Elliptical Cavities**

***G.-T. Park**, R.A. Rimmer, H. Wang (JLab)*

A technique that predicts the field flatness of the operating pi-mode based on the passband frequency is highly desirable when the direct measurement of the field is not available. Such a technique was developed for the SNS-PPU cavity, a 6-cell SRF cavity whose field flatness is important for cold operation. In this paper, we will present the theory on the relations between field profile and passband frequencies of the arbitrary deformed cavities, the simulation studies, and comparison with the experimental measurements.

WEPAB021 **Development and Testing of a Cherenkov Beam Loss Monitor in CLEAR Facility**

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Beam Loss Monitors are fundamental diagnostic systems in particle accelerators. Beam losses are measured by a wide range of detectors with excellent results; most of these devices are used to measure local beam losses. However, in some accelerators there is the need to measure beam losses continuously localized over longer distances i.e., several tens of meters. For this reason, a beam loss detector based on long optical fibres is now under study. As part of the design, several simulations, comparing different possible detection scenarios, have been performed in FLUKA and bench-marked with experimental data. An experimental campaign was performed with an electron beam in the CERN Linear Electron Accelerator for Research (CLEAR) in November 2020. The light emitted from the optical fibre was captured using Silicon Photo-Multipliers (SiPM) coupled at each fibre's end. In this poster, the first results of a beam loss detector based on the capture of Cherenkov photons generated by charged particles inside multimode silica fibres are presented.

WEPAB022 **Round to Flat Beam Transformation Experiment at KEK STF**

***S. Aramoto** (Hiroshima University)*

ILC (International Linear Collider) is an electron-positron linear collider. Because the particle passes the interaction point (IP) only once in a linear collider, the luminosity is enhanced by squeezing the beam size down to nm. To suppress Beamstrahlung effect simultaneously, the beam shape at IP should be flat, 5.7 x 640 nm in geometry and 0.04 x 10 mm-mrad in emittance. In the current design of ILC (ILC-TDR), the asymmetric emittance beam is made by the radiation damping in

storage ring. We propose to generate the equivalent beam with the phase-space rotation technique instead of the radiation damping. The beam is then transformed to asymmetric emittance by RFBT (Round to Flat Beam Transformation). Then, exchange ϵ_x and ϵ_z by TLEX (Transverse to Longitudinal Emittance eXchange). Finally, ϵ_x = 10 mm-mrad and ϵ_y = 0.04 mm-mrad are obtained. To demonstrate this idea, an experiment will be carried out at KEK-STF (Superconducting Test Facility). Simulation and experimental results will be presented.

WEPAB023 **Crystal Collimation of 20 MJ Heavy-Ion Beams at the HL-LHC**
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The concept of crystal collimation at the Large Hadron Collider (LHC) relies on the use of bent crystals that can deflect halo particles by a much larger angle than the standard multi-stage collimation system. Following an extensive campaign of studies and performance validations, a number of crystal collimation tests with Pb ion beams were performed in 2018 at energies up to 6.37 Z TeV. This paper describes the procedure and outcomes of these tests, the most important of which being the demonstration of the capability of crystal collimation to improve the cleaning efficiency of the machine. These results led to the inclusion of crystal collimation into the LHC baseline for operation with ion beams in Run 3 as well as for the HL-LHC era. A first set of operational settings was defined.

WEPAB024 **Release of Crystal Routine for Multi-Turn Proton Simulations Within SixTrack v5**
M. D'Andrea, *A. Mereghetti, D. Mirarchi, V.K.B. Olsen, S. Redaelli (CERN)*
Crystal collimation is studied as a possible scheme to further improve the efficiency of ion collimation at the High Luminosity Large Hadron Collider (HL-LHC), as well as for possible applications in the CERN program of Physics Beyond Colliders. This concept relies on the use of bent crystals that can deflect high-energy halo particles at large angles, of the order of tens of urad. In order to reproduce key experimental results of crystal collimation tests and predict the performance of this system when applied to present and future machines, a dedicated simulation routine was developed. This routine is capable of modeling both coherent and incoherent interactions of beam particles with crystal collimators, and is fully integrated into the magnetic tracking and collimator modeling provided by the single-particle tracking code SixTrack. This paper describes the implementation of the routine in the latest version of SixTrack and its most recent improvements, in particular regarding the treatment of the crystal miscut angle.

WEPAB025 **Collimation Strategies for Secondary Beams in FCC-hh Ion-Ion Operation**

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The target peak luminosity of the CERN FCC-hh during Pb-Pb collisions is more than a factor of 50 greater than that achieved by the LHC in 2018. As a result, the intensity of secondary beams produced in collisions at the interaction points will be significantly higher than previously experienced. With up to 72 kW deposited in a localised region by a single secondary beam type, namely the one originated by Bound Free Pair Production (BFPP), it is essential to develop strategies to safely intercept these beams, including the ones from ElectroMagnetic Dissociation (EMD), in order to ensure successful FCC-hh Pb-Pb operation. A series of beam tracking and energy deposition simulations were performed to determine the optimal solution for handling the impact of such beams. In this contribution the most advanced results are presented, with a discussion of different options.

WEPAB026 **Optics Measurements and Correction Plans for the HL-LHC**

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The High Luminosity LHC (HL-LHC) will require stringent optics correction to operate safely and deliver the design luminosity to the experiments. In order to achieve this, several new methods for optics correction have been developed. In this article, we outline some of these methods and we describe the envisioned strategy of how to use them in order to reach the challenging requirements of the HL-LHC physics program.

WEPAB027 **Optics Correction Strategy for Run 3 of the LLHC**

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The Run 3 of the LHC will continue to provide new challenges for optics corrections. In order to succeed and go beyond what was achieved previously, several new methods to measure and correct the optics have been developed. In this article we describe these methods and outline the plans for the optics commissioning in 2022.

WEPAB028 **MAD-X for Future Accelerators**

***T. Persson**, H. Burkhardt, L. Deniau, A. Latina, P.K. Skowroński (CERN)*

The feasibility and performance of the future accelerators must, to a large extent, be predicted by simulation codes. This implies that simulation codes need to include effects that previously played a minor

role. For example, in large electron machines like the FCC-ee the large energy variation along the ring requires that the magnets strength is adjusted to the beam energy at that location, normally referred to as tapering. In this article, we present new features implemented in the MAD-X code to enable and facilitate simulations of future colliders.

WEPAB029 **Challenges for the Interaction Region Design of the FCC-ee**
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The FCC-ee is a proposed future high-energy, high-intensity and high precision lepton collider. Here, we present the latest developments for the FCC-ee interaction regions, which shall ensure optimum conditions for the particle physics experiments. We discuss measures of background reduction and a revised interaction region layout including a low impedance compact beam chamber design. We also discuss the possible impact of the radiation generated in the interaction region including beamstrahlung.

WEPAB031 **Frequency Dependence of Plasma Cascade Amplification**
G. Wang, *V. Litvinenko, J. Ma (BNL) V. Litvinenko (Stony Brook University)*
A new type of amplifier, plasma cascade amplifier (PCA) has been proposed for a coherent electron cooling (CeC) system. Previously, the 1D model for PCA assumes that the transverse distribution of the density perturbation in the electrons is uniform and consequently, the plasma frequency does not depend on the wavelength of the perturbation. This assumption is valid if the longitudinal wavelength of the beam frame is much shorter than the transverse width of perturbation. In this work, we explore the PCI gain at a long wavelength by assuming the perturbation in the electron density has a non-uniform transverse profile. Specifically, we solve the 3D Poisson equation for given charge distribution (longitudinal sinusoidal, transversely Gaussian, or Beer-can), average the electric field over the transverse plane, and then apply it to 1D Vlasov equation. Similar to the previous calculation, the Vlasov equation can be reduced to a Hill's equation but the plasma frequency now depends on the longitudinal wavelength of the density perturbation in the electrons. By numerically solving Hill's equation, we obtain the gain of a PCA and compare it with the results from 3D SPACE simulations.

WEPAB032 **Studies of the Short-Range Wakefields for the Electron Storage Ring in the Electron Ion Collider**
G. Wang, *M. Blaskiewicz, A. Blednykh, M.P. Sangroula (BNL)*
During the estimates of impedance budget for the Electron Storage Ring (ESR) of Electron-Ion Collider (EIC), various codes, including

GdfidL, CST and ECHO3D, have been used to calculate the short-range wake-fields due to the vacuum components. The ECHO 3D code demonstrates more reliable results for the tapered type of structures rather than the GdfidL code, where the stepsize needs to be dramatically decreased to achieve a high-performance calculation. Impedance of the following components are discussed and compared in details: Interaction Region (IR) chamber, bellows, and synchrotron radiation mask (flange absorber).

WEPAB033 **Lattice Design of the CEPC Collider Ring for a High Luminosity Scheme**

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A high luminosity scheme of the CEPC has been proposed aiming to increase the luminosity mainly at Higgs and Z modes. In this paper, the high luminosity scheme will be introduced briefly, including the beam parameters and RF staging. Then, the lattice design of the CEPC collider ring for the high luminosity scheme will be presented, including the bare lattice design and dynamic aperture optimization at Higgs energy.

WEPAB034 **A Compact Spin Rotator for the EIC Electron Storage Ring**

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Comprehensive strategies have been considered and developed for the electron polarization in the Electron-Ion Collider (EIC) in order to deliver the required high average polarization (at least 70%). Spin rotators in the Electron Storage Ring (ESR) are a key feature that rotates the vertical polarization in the arcs to the longitudinal at the collision points. The reference EIC electron spin rotator design has fixed geometry; these spin rotators are very long so they complicate the tunnel layout. An alternative spin rotator based on solenoids with integrated quadrupole windings has been proposed. Similar techniques with integrated solenoid-dipole or solenoid-quadrupole fields in a combined-function magnet are explored and, if acceptable, may provide a compact design of a spin rotator for the ESR in the EIC. This may make the geometric layout of the spin rotator simpler and more flexible compared to the reference design. This paper reports two possible designs of a spin rotator with combined-function magnets and discusses the feasibility of applying these two designs in the ESR.

WEPAB035 **Exploration of Spin Tune Modes in the EIC Electron Storage Ring**

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The design of the Electron-Ion Collider (EIC) aims to attain a high longitudinal electron polarization (at least 70%) at the collision points as

required by the nuclear physics program. The design-orbit spin tune in the Electron Storage Ring (ESR) is approximately proportional to the beam energy. Therefore, the electron beam energy for collisions has to be chosen to avoid first-order spin-orbit depolarizing resonances. Depolarization due to such resonances excited by the synchrotron radiation, as well as synchrotron sidebands of these resonances, has been confirmed in spin tracking simulations for the ESR. In this paper, we discuss a technique that can make the design-orbit spin tune independent of the beam energy and avoid resonances with the betatron and synchrotron tunes, and thus improve the electron polarization. We explore the capability of implementing energy-independent integer and half-integer spin tune modes in the ESR.

WEPAB036 **Achievement of 200,000 Hours of Operation at KEK Electron Positron Injector Linac**

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KEK electron positron injector linac initiated the injection operation into Photon Factory (PF) light source in 1982. Since then for 39 years, it has served for multiple projects, namely, TRISTAN, PF-AR, KEKB, and SuperKEKB. Its total operation time has accumulated 200 thousand hours on May 7, 2020. We are extremely proud of the achievement following continuous efforts by our seniors. The construction of the injector linac started in 1978, and it was commissioned for PF with 2.5 GeV electron in 1982. In parallel, the positron generator linac was constructed for the TRISTAN collider project. The slow positron facility was also commissioned in 1992. After the KEKB asymmetric-energy collider project was commissioned in 1998 with direct energy injections, the techniques such as two-bunch acceleration, simultaneous injections, were developed. As the soft structure design of the linac was too weak against the great east Japan earthquake, it took three years to recover. Then the construction and commissioning for the SuperKEKB project went on, and the simultaneous injection into four storage rings contributes to the both elementary particle physics and photon science.

WEPAB037 **Advanced Acceleration Mode Switching for Simultaneous Top-Up Injection at KEK Electron/Positron Injector Linac**

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The electron positron injector linac at KEK continues to deliver electrons up to 7 GeV and positrons up to 4 GeV into four storage rings and a positron damping ring for elementary particle physics and photon science since 40 years. It started the simultaneous top-up injections successfully for the first time in May 2019 into those four rings of SuperKEKB HER/LER, PF and PF-AR with various beam properties by pulse-to-pulse modulations at 50 Hz to avoid interference. This injection scheme required high-speed beam-mode switching to match the complex parameters of these rings by improving hardware and software components. It succeeded to achieve 3.7 times higher integrated luminosity in SuperKEKB. As the beam lifetime of the SuperKEKB rings are less than ten minutes, this scheme is indispensable for the higher integrated luminosity. Since then, tt has contributed to those experiments with stable stored beams.

WEPAB038 **Commissioning of a New X-band, Low-Noise LLRF System**

A.V. Edwards *(CERN)*

To increase beam energy in the CLEAR facility at CERN and study the CLIC accelerating structure prototype in operating conditions, the first X-band test facility at CERN was upgraded in 2020. Both, the acquisition and software systems at X-band test stand 1 (Xbox1) were upgraded to exhibit low phase noise which is relevant to klystron based CLIC and to the use of crab cavities in the beam delivery system. The new LLRF uses down-conversion which necessitates a local oscillator which can be produced by two different methods. The first is a PLL, a commonly used technique which has been previously employed at the other X-band facilities at CERN. The second is a novel application of a single sideband up-convertor. The up-convertor system has demonstrated reduced phase noise when compared with the PLL. The commissioning of the new system began in late 2020 with the conditioning of a 50 MW Klystron. Measurements of the quality of the new LLRF will be shown. These will compare the PLL and up-convertor with particular attention on the quality of the phase measurements. Also, a preliminary study of phase shifts in the waveguide network due to temperature changes will be presented.

WEPAB039 **Construction of a Compact Electron Injector Using a Gridded RF Thermionic Gun and a C-Band Accelerator**

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(SES) K. Yanagida (JASRI)

A compact and low-cost 1 GeV injector linac was designed and constructed to provide injection beams to the soft X-ray synchrotron radiation facility NewSUBARU instead of the SPring-8 injector system, which will be shutdown. The total length of the injector linac needs to be less than 70 m to fit into the existing tunnel. To this end, an RF electron gun with a gridded thermionic cathode directly attached to a 238 MHz RF cavity was developed and adopted. The 500 keV, 0.6 ns, 1 nC beam emitted from the cavity is compressed to 3 ps by velocity bunching driven by a 476 MHz RF cavity and a S-band RF structure. The short-pulsed beams are accelerated up to 1 GeV with 16 C-band RF structures. In the C-band accelerator section, the klystron output of 50 MW is multiplied 4 times by a pulse compressor and fed to the 4 RF structures to generate a high accelerating field of 31 MV/m. A low-level RF system consisting of a MTCA.4 based high-speed digitizers and RF frontend boards has been constructed. This injector system is used at the 3 GeV SR facility currently under construction in Sendai. In this paper, we report the design outline and the operational performance of the injector system.

WEPAB040 **Characterization of Low Emittance Electron Beams Generated by Transverse Laser Beam Shaping**

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Linac based X-ray free electron laser demand a high beam quality from the electron source, therefore RF photoinjectors are used to generate the electron bunches for state of the art beam brightness. One important figure of merit for these injectors is the transverse emittance of the generated electron beam, which can be minimized by shaping the photocathode laser pulses. Best performance can be achieved with ellipsoidal laser pulses, but 3D shaping is technically challenging. Typically, a quasi-uniform transverse laser profile is truncated from the Gaussian profile generated by the laser with an aperture to reduce the transverse nonlinear space charge forces. This is investigated in detail by optimizing the laser transverse profile at the Photoinjector Test facility at DESY in Zeuthen (PITZ), where photoinjector R&D is conducted for the E-XFEL and FLASH free electron lasers at DESY in Hamburg. In this contribution we present experimental results at high acceleration gradients (up to 60 MV/m) for both 250 pC and 500 pC. For a bunch charge of 500 pC an emittance reduction of about 30% compared to the commonly used transverse flat-top laser distribution was achieved.

WEPAB041 **Testing of the Milliampere Booster Prototype Cavity**

R.G. Heine *(KPH)*

The Milliampere Booster (MAMBO) is the injector linac for the Mainz

Energy-recovering Superconducting Accelerator MESA. MESA is a multi-turn energy recovery linac with beam energies in the 100 MeV regime currently designed and built at Institut für Kernphysik (KPH) of Johannes Gutenberg-Universität Mainz. The main accelerator consists of two superconducting Rossendorf type modules, while the injector MAMBO relies on normal conducting technolgy. The MAMBO RF cavities are bi-periodic pi/2 structures with 33 cells and 37 cells, respectively. In this paper we present the results of the commissioning and testing of a 13 cell prototype structure.

WEPAB042 **Linac-200: A New Electron Test Beam Facility at JINR**

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Commissioning of a new electron test beam facility Linac-200 comes to the end at JINR (Dubna, Russia). The core of the facility is a refurbished MEA accelerator from NIKHEF. The key accelerator subsystems including controls, vacuum, precise temperature regulation were redesigned or deeply upgraded. The facility provides electron beams with energy up to 200 MeV while the beam current varying smoothly from 40 mA down to almost zero (single electrons in a bunch). The main goal of the facility is providing test beams for particle detector R&D, studies of novel approaches to the beam diagnostics, and education and training of graduate and postgraduate students. The current status and operation parameters of the facility will be reported.

WEPAB043 **Consolidation and Future Upgrades to the CLEAR User Facility at CERN**

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The CERN Linear Electron Accelerator for Research (CLEAR) at CERN has been operating since 2017 as a dedicated user facility providing beams for a varied range of experiments. CLEAR consists of a 20 m long linear accelerator (linac), able to produce beams from a Cs_2Te photocathode and accelerate them to energies of between 60 MeV and 220 MeV. Following the linac, an experimental beamline is located, in which irradiation tests, wakefield and impedances tudies, plasma lens experiments, beam diagnostics development, and terahertz (THz) emission studies, are performed. In this paper, we present recent upgrades to the entire beamline, as well as the design of future upgrades, such as a dogleg section connecting to an additional proposed experimental beamline. The gain in performance due to these upgrades is presented with a full range of available beam properties documented.

WEPAB044 **Status of VHEE Radiotherapy Related Studies at the CLEAR User Facility at CERN**

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Despite the increase in interest in using Very High Energy Electron (VHEE) beams for cancer radiotherapy many unanswered questions in its development remain. The use of test facilities will be an essential tool used to solve these issues. The 200 MeV electron beam from the CERN Linear Accelerator for Research (CLEAR) has been used extensively, in collaboration with several research institutes, to perform dosimetry studies and explore potential applications of VHEE beams to radiotherapy, including the exploitation of the so called FLASH effect. In this paper, we present an overview of past studies with emphasis on the more recent results. We describe methods, techniques and equipment developed at CERN in this framework, and give an outlook on future activities.

WEPAB045 **European XFEL High-Power RF System - the First 4 Years of Operation**

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In 2016, the installation of the European XFEL was completed and its 26 RF stations started operation in 2017. Each RF station consists of a 10 MW-1.3 GHz-multibeam klystron, a HV pulse modulator and a waveguide system to supply the superconducting cavities and the normal-conducting electron gun with RF power. During commissioning and subsequent operation, the RF stations were closely monitored and causes of failures were investigated. For the optimisation of the RF systems, the various RF station failures were evaluated according to their impact on accelerator operation and the measures to eliminate them were prioritised accordingly. This report describes the operation experience and improvements of the high-power RF stations during the first 4 years of operation.

WEPAB046 **Conceptual Design of an Electron Accelerator for a Versatile THz Source at the European XFEL**

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The European XFEL has planned to perform pump-probe experiments by using its X-ray pulses and THz pulses. A promising concept to provide the THz pulses with a pulse repetition rate identical to that of the X-ray pulses is to generate them using a versatile accelerator-based THz source. This contribution presents conceptual design studies of a linear electron accelerator for the THz source. The accelerator beamline layout is based on the Photo Injector Test Facility at DESY in Zeuthen (PITZ) with an additional accelerator section and a chicane

bunch compressor. Beam dynamics simulations were performed in order to optimize the layout of the beamline and electron beam properties.

WEPAB047 **RF Design of a 12 GHz X-Band Coupled Cavity Linac for Medical Applications**

N.R.J. Roche *(The University of Manchester) R.M. Jones (UMAN)*

Novel electron beam therapies will require changes to the design rationale of the treatment machines, with increasing demand for compact acceleration and higher accelerating gradients. At Manchester work has been undertaken to deliver a linear accelerator capable of providing electron beams for Very High Energy Electron Radiotherapy. The beams are required to be low current and have energies exceeding 100 MeV. Here we present an RF design process for a high gradient 12 GHz coupled-cavity linear accelerating waveguide. Specifying the geometry of a side-coupled X-band structure to operate at high gradients presents distinct challenges, with the transversely positioned power coupling apertures particularly susceptible to localized field enhancements. An iterative optimization has been used to achieve suitable figures of merit, those being surface field ratios acceptable for reliable operation at accelerating gradients (~60 MV/m) and maximization of the shunt impedance.

WEPAB048 **Design of an Optical Cavity for Generating Intense THz Pulse Based on Coherent Cherenkov Radiation**

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We have been studying terahertz (THz) generation via Cherenkov radiation with high-quality electron beams from a photocathode rf (radio frequency) gun. In our early studies, we have succeeded in the generation of coherent Cherenkov radiation by controlling the tilt of the electron beam using an rf-deflector. For further enhancement, we are planning to stack the THz pulses in an optical cavity. Multi-bunch operation of the rf-gun will generate electron beams with a repetition rate of 119 MHz, and THz pulses as well. These pulses will be accumulated in the cavity for up to 150 pulses. In this conference, we report the design study of the enhancement cavity and discuss the performance of the THz source.

WEPAB050 **Conceptual Design of X-band 6 MeV Electron LINACs Using Dual-Beam Irradiation Method for Cancer Therapy**

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A linear accelerator using electron beam is widely used for X-ray source in cancer therapy. In recent years, a high-dose cancer therapy method with the support of precision imaging system such as CT and MRI is commonly applied to patients. This method focuses X-ray irradiation

only on cancer tumors, and reduces side effects on normal cells. However, conventional therapy machines have limitations in generating high-dose irradiation. To solve this problem, it is necessary not only to increase the X-ray dose-rate, but also to reduce the clinic time for patients. Korea Atomic Energy Research Institute has been developing a multiple-head cancer therapy machine which has two X-band (9.3GHz) 6 MeV Electron LINACs for X-ray source. The total length of the side-coupled RF cavity is about 40 cm, which makes it possible to implement a compact size LINAC station. In addition, two LINAC stations can be installed on a gantry body. Finally, a high X-ray dose-rate about 12 Gy/min by using dual-head irradiation can be obtained with volumetric irradiation. In this paper, we describe the conceptual design of an X-band 6 MeV LINAC system for a dual-beam irradiation method.

WEPAB051 **Beam Dynamics for a High Field C-band Hybrid Photoinjector**

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In this paper, we present a new class of a hybrid photoinjector in C-Band. This project is the effort result of a UCLA/Sapienza/INFN-LNF/SLAC/RadiaBeam collaboration. This device is an integrated structure consisting of an initial standing-wave 2.5-cell gun connected to a traveling-wave section at the input coupler. Such a scheme nearly avoids power reflection back to the klystron, removing the need for a high-power circulator. It also introduces strong velocity bunching due to a 90^{o} phase shift in the accelerating field. A relatively high cathode electric field of 120 MV/m produces a ~4 MeV beam with ~20 MW input RF power in a small foot-print. The beam transverse dynamics are controlled with a ~0.27 T focusing solenoid. We show the simulation results of the RF/magnetic design and the optimized beam dynamics that shows 6D phase space compensation at 250 pC. Proper beam shaping at the cathode yields a ~0.5 mm-mrad transverse emittance. A beam waist occurs simultaneously with a longitudinal focus of <400 fs rms and peak current >600 A. We discuss application of this injector to an Inverse-Compton Scattering system and present corresponding start-to-end beam dynamics simulations.

WEPAB052 **Development of an EO Sampling System for the Analysis of THz Waves Generated by Coherent Cherenkov Radiation**

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THz waves, located between microwaves and light waves, have transparency, directionality and fingerprint spectrum of specific materials.

Therefore, they are expected to be useful for various applications. We have been studying THz waves generation via Cherenkov radiation with electron beams from a photocathode rf-gun. In our early studies, we have succeeded in the generation of coherent Cherenkov radiation by tilted electron beams using an rf-deflector. Furthermore, we have generated quasi-monochromatic THz waves by spatially modulated electron beams and have succeeded in its measurement by bandpass filters. This study aims to obtain the THz wave form in time domain by electro-optic (EO) sampling, which is an useful detection system for obtaining the information of the electric field and the phase simultaneously with high S/N. In this conference, we report about our probe laser system, results of the time-domain spectroscopy measurement of THz waves by EO sampling, and future prospects.

WEPAB054 **Electromagnetic and Beam Dynamics Studies of the ThomX LINAC**

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ThomX is a new generation compact Compton source. The machine is composed of a 50/70 MeV injector linac and a storage ring where an electron bunch collides with a laser pulse accumulated in a Fabry-Perot resonator. The compact source, built at Irene Joliot-Curie Laboratory (IJCLAB) in the Orsay campus of Paris-Saclay University, is designed to produce a total flux of 10^{13} ph/s and a brightness of 10^{11} ph / (s.mm2.mrad2) in 0.1% of bandwidth with a tunable energy ranging from 45 keV to 90 keV on the X-ray beam axis. The photo-injector is composed of a homemade 2.5 cell photocathode RF-gun, placed between two solenoids. An energy of 5 MeV is reached with a 80 MV/m electric field gradient. During the commissioning phase, a 4.8 m S-band LIL section will be used to achieve a 50 MeV corresponding to a 45 keV X-ray energy. The LIL accelerating section is a quasi-constant gradient traveling wave structure. The energy gain in the section is 45 MeV, corresponding to an average effective accelerating gradient of 10 MV/m for an input RF power of 9 MW. Here we present the electromagnetic and beam dynamics studies of the ThomX LINAC.

WEPAB055 **Development of a Linac for Injection of Ultrashort Electron Bunches Into Laser Plasma Electron Accelerators**

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We are developing a C-band linac that produces ultrashort electron bunches as an injector for laser plasma accelerators. A plasma wave excited by a high intense ultrashort laser pulse has a wavelength of the order of 10 to 100 fs and transverse dimensions of the order of 10 to 100 um. To inject the bunch into a proper phase of the plasma wave, a length and transverse sizes of the bunch must be much smaller than the plasma wave structure. A laser triggered photo cathode electron RF-gun and a 2pi/3 mode traveling wave buncher with 24 cells

for ultrashort electron bunch production have been developed based on electron beam tracking simulations that show the bunch length is less than 10 fs with a charge of 100 fC at a focus on the plasma wave. The simulations also show that sufficiently small transverse sizes of the bunch at the focus can be obtained by a Q triplet. A highly accurate timing lower than the plasma wavelength (~10fs) is required for the synchronization between the electron bunch injection and the plasma wave excitation. An RF master oscillator with low SSB phase noise (-150dBc/Hz@10MHz) has been developed for the synchronization. We will report present development status.

WEPAB056 **Advanced Photoinjector Development at the UCLA SAMURAI Laboratory**

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UCLA has recently constructed SAMURAI, a new radiation bunker and laser infrastructure for advanced accelerator research. In its first phase, we will build a 30 MeV photoinjector with an S-band hybrid gun. Expansion options include addition of a 3-m S-band linac to produce 80 MeV beams, and a dogleg leading to a second beamline. In the next phase, we will upgrade to 300 MeV by introducing three 80-cm C-band cryogenic linacs with design accelerating gradient of 125 MV/m. With this beam, we will study the use of micro-bunching via IFEL to enable an EUV FEL generation from cryogenic undulators. The facility will also host experiments in 100-keV class X-ray generation via inverse Compton Scattering (ICS) and dielectric wakefield acceleration. Development of a cryogenic very high C-band NC RF gun is to take place in the facility in parallel. It is designed to operate at a peak cathode field of 250 MV/m, and produce 100 pC beams with the emittance as low as 50 nm. This extremely low emittance beam is the enabling technique behind the ultra-compact XFEL project that the SAMURAI lab intends to prototype. In this work we present the design of our accelerator systems and first applications.

WEPAB062 **Investigation of the Thomson Scattering Influence on Electron Beam Parameters in an Energy-Recovering Linear Accelerator on the Example of MESA.**

***C.L. Lorey**, K. Aulenbacher, A. Meseck (KPH)*

At the Johannes Gutenberg University (JGU) in Mainz, the Mainz Energy-recovering Superconducting Accelerator (MESA) is currently under construction. It is designed to deliver electron beams of up to 155 MeV. As it can be operated in an energy-recovery (ER) mode thus allowing for high repetition rate, it is a promising candidate for a high flux Thomson scattering based gamma source. This paper will provide a status update on the study of the impact of Thomson scattering on electron beam parameters and the underlying mechanics. Further, the implementation into a simulation code will be discussed.

WEPAB063 **Status of the Polarized Source and Beam Preparation System at MESA**

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The MESA Low-energy Beam Apparatus (MELBA) connects the DC photoemission source STEAM with the injector accelerator MAMBO. MELBA is capable of adjusting the longitudinal phase space for the requirements of the pre-acceleration by using a chopper and buncher while providing small transverse emittances. Measurements of the transverse phase space and longitudinal beam dimension taken at a test setup are presented. These results serve now for further improvements, e.g design changes in our corrector magnets. In addition, the revised MELBA will include two Wien filters and a solenoid for spin manipulation. A double scattering Mott polarimeter for spin diagnostics and a second source for the extraction of high bunch charges is foreseen using a branched off beam line. RF-synchronized laser diodes will be used with infrared wavelength as a driver for the spin-polarized photoemission. In this report we present the latest layout of MELBA and simulation results.

WEPAB064 **Front-to-End Simulations of the LHeC Energy Recovery Linac**

***K.D.J.A. André**, B.J. Holzer (CERN)*

The LHeC project aims to study the electron-proton deep inelastic scattering at the TeV energy scale with an innovative accelerator program. It exploits the promising energy recovery technology in order to collide an intense 50 GeV lepton beam with one hadron beam from the High Luminosity Large Hadron Collider (HL-LHC) in parallel to the hadron-hadron operation. The paper presents the studies that have been performed to assess the performance of the machine and the efficiency of the energy recovery process for different scalings of the ERL. The studies include emittance blow-up due to synchrotron radiation emission and beam-disruption created by the strong beam-beam force at the interaction point. The design principles of the ERL structure are discussed, including the particle detector bypass and the interaction region, and the results of the tracking simulations are presented, considering the complete multi-turn ERL process. Special attention is turned to the lepton beam emittance budget and the resulting energy recovery performance.

WEPAB065 **Studies of the Energy Recovery Performance of the PERLE Project**

***K.D.J.A. André**, B.J. Holzer (CERN) S.A. Bogacz (JLab)*

The Powerful Energy Recovery Linac for Experiments (PERLE) is an accelerator facility for the development and application of the energy recovery technique for an intense 500 MeV electron beam. The paper presents the studies that have been performed to assess the quality of the ERL lattice design and beam optics. The studies include the Coherent Synchrotron Radiation (CSR) emission and wakefields in the superconducting radio-frequency structures of the linacs. The lattice

design and optics principles of the ERL structure are discussed, involving the vertical deflection system and the 180° arcs. Finally, the results of the front-to-end tracking simulations that consider the complete multi-turn energy recovery process are presented.

WEPAB067 **High Duty Cycle EUV Radiation Source Based on Inverse Compton Scattering**

***R. Huang**, Q.K. Jia, C. Li (USTC/NSRL)*

ICS can obtain quasi-monochromatic and directional EUV radiation via a MeV-scale energy electron beam and a micron-scale wavelength laser beam, which enables a dramatic reduction in dimension and expense of the system, and makes it an attractive technology in research, industry, medicine and homeland security. Here we describe an EUV source based on high repetition ICS system. The scheme exploits the output from the laser-electron interaction between a MW-ps laser at MHz repetition-rate and a high quality electron beam with an energy of a few MeV at MHz repetition-rate.

WEPAB070 **Smart*Light: A Tabletop, High Brilliance, Monochromatic and Tunable Hard X-Ray Source for Imaging and Analysis**

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At Eindhoven University of Technology a tabletop Inverse Compton Scattering (ICS) source will be built and commissioned within the next year. This compact and affordable X-ray source will bridge the gap between conventional lab X-ray sources and synchrotrons. X-ray photon energies up to 40 keV will be generated which will find applications in fields as diverse as material science, cultural heritage and medical imaging. The physical basis is the ICS process in which photons from a laser pulse are bounced off a relativistic electron bunch, turning them into X-ray photons through the relativistic Doppler effect. X-band linear accelerator technology by the CLIC program from CERN will be used to accelerate the electron bunches to relativistic speeds and will keep the setup compact, monochromatic and easily tunable. An overview and status of the setup are given together with simulated properties of the electron bunches and X-rays. Measurements of the electron bunches along the first part of the beam line will be shown.

WEPAB071 **Design and Construction of an Intense Terahertz-Wave Source Based on Coherent Cherenkov Radiation Matched to Circle Plane Wave**

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National Institute of Advanced Industrial Science and Technology has been studied terahertz (THz) coherent radiation in collaboration with Nihon University and Kyoto University. We have been developed a coherent transition radiation (CTR) source with macropulse power of 1 mJ using a screen monitor in the parametric X-ray line at Laboratory

for Electron Beam Research and Application (LEBRA) in Nihon University. However, to obtain a THz-wave source with higher intensity, we have undertaken a development of a new THz-wave source based on coherent Cherenkov radiation (CCR) matched to circle plane wave. Bypassing an electron beam through a hollow conical dielectric having an apex angle equal to the Cherenkov angle, the wavefront of the CCR generated on the inner surface of the hollow conical dielectric matches on the basal plane. Therefore, it is possible to obtain a high-power beam that is easy to transport. We have already produced a hollow conical dielectric made of high-resistivity silicon and considered a position controller for the hollow conical dielectric. In this presentation, the status of the new THz-wave source will be reported.

WEPAB072 **Pax: A Plasma Driven Attosecond X-Ray Source**

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Plasma accelerators can generate ultra high brightness electron beams which open the door to light sources with smaller physical footprint and properties unachievable with conventional accelerator technology. In this work we show that electron beams from Plasma WakeField Accelerators (PWFAs) can generate coherent tunable soft X-ray pulses with TW peak power and duration of tens of attoseconds in a meter-length undulator. These X-ray pulses are an order of magnitude more powerful, shorter and can be produced with better stability than state-of-the-art X-ray Free Electron Lasers (XFELs). The X-ray emission in this approach is driven by coherent radiation from a pre-bunched, near Mega Ampere (MA) current electron beam of attosecond duration rather than the SASE FEL process starting from noise. This approach significantly relaxes the restrictive requirements on emittance, energy spread, and pointing stability which has thus far hindered the realization of a high-gain FEL driven by a plasma accelerator. We discuss the approach and progress towards the experimental realization of this concept at the FACET-II accelerator facility.

WEPAB073 **An Overview of the Radio-Frequency System for an Inverse Compton X-Ray Source Based on CLIC Technology**

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Compact inverse Compton scattering X-ray sources are gaining in popularity as the future of lab-based x-ray sources. Smart*Light is one such facility, under commissioning at Eindhoven University of Technology (TU/e), which is based on high gradient X-band technology originally designed for the Compact Linear Collider (CLIC) and its test stands located at CERN. Critical to the beam quality is the RF system which aims to deliver 10^{-24} MW RF pulses at repetition rates up to 1 kHz with a high amplitude and phase stability of <0.5% and <0.65° allowing it to adhere to strict synchronicity conditions at the interaction point. This

work overviews the design of the high power and low level RF systems for Smart*Light.

WEPAB074 **A Distributed Sextupoles Lattice for the ALBA Low Emittance Upgrade**

***G. Benedetti**, M. Carlà, U. Iriso, Z. Martí, F. Pérez (ALBA-CELLS Synchrotron)*

The first lattice studied in 2019 for the ALBA upgrade was a 7BA lattice with two dispersion bumps, for localised chromatic correction. That lattice had limited dynamic aperture and momentum acceptance. In 2020 we started to explore a different approach to find an MBA lattice with distributed chromatic correction that meets the same emittance goal with larger dynamic aperture and momentum acceptance. The choice of the number of bendings per cell, as well as the tuning of the magnet gradients, is carried out by developing a light weight solver that performs both the emittance and chromaticity optimisation of the arcs and the matching of the linear optics in the straight sections. We present the status of the storage ring upgrade studies, the performance of the new developed lattice, together with the issues related with the injection scheme.

WEPAB075 **Xenos: X-Ray Monte Carlo Simulation Code Suite**

***S. Humphries** (Field Precision)*

Xenos is an integrated 3D code suite for the design of X-ray sources and electron beam devices. The component programs run under all versions of Windows. This paper describes unique features of Xenos compared to other Monte Carlo packages: 1) representation of geometry and deposited dose on a finite-element mesh supported by an interactive mesh generator, 2) inclusion of full 3D electric and magnetic fields in Monte Carlo simulations, 3) an integrated user environment for input and output calculations (e.g., electron gun design, target heating, ...) and 4) extended parallel-computing support for high-accuracy solutions. Xenos employs the full capabilities of multi-core computers and allows parallel computations on an unlimited number of independent computers.

WEPAB076 **Development of Terahertz Source Based on Coherent Diffraction Radiation at ERL Test Accelerator in KEK**

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cERL in KEK is a test accelerator for development works of technologies related to Energy Recovery Linac (ERL) and CW-Superconducting accelerators. It can produce a low emittance and short bunch beam at a high repetition rate. This feature is suitable for producing a high average power terahertz (THz) coherent radiation. We have been developing a THz source based on Coherent Diffraction Radiation (CDR) at the straight section of cERL. In the scheme, a short bunch electron beam passing through a metal target with a small hole emits coherent radiation. For future applications, we have built a THz transport

system from the source to an experiment station at outside of the accelerator shielding. We will report the design and tuning procedure of the THz transport optics in beam experiments.

WEPAB077 **High Power Terahertz Cherenkov Free Electron Laser From a Waveguide With a Thin Dielectric Layer by a Near-Relativistic Electron Beam**

***W.W. Li**, T.L. He, Z.G. He, R. Huang, Q.K. Jia, S.M. Jiang, L. Wang (USTC/NSRL)*

Corrugated and dielectric structures have been widely used for producing accelerator based terahertz radiation source. Recently, the novel schemes of the sub-terahertz free electron laser (FEL) from a metallic waveguide with corrugated walls and a normal dielectric loaded waveguide driven by a near-relativistic (beam energy of a few MeV) picosecond electron beam were studied respectively. Such a beam is used for driving resonant modes in the waveguide, and if the pipe is long enough, the interaction of these modes with the co-propagating electron beam will result in micro-bunching and the coherent enhancement of the wakefield radiation. It offers a promising candidate for compact accelerator-based high power terahertz source which can be realized with relatively low energy and low peak-current electron beams. However the choices of the waveguide above is less effective in order to obtain high power with frequency around 1THz. In this paper, we propose to use the waveguide with a thin dielectric layer instead, and high power radiation (>~10 MW) around 1 THz is expected to obtain in the proposed structure according to the simulation results.

WEPAB079 **Optics Studies on the Operation of a New Wiggler and Bunch Shortening at the DELTA Storage Ring**

***B. Büsing**, P. Hartmann, A. Held, S. Khan, C. Mai, D. Schirmer, G. Schmidt (DELTA)*

The 1.5-GeV electron storage ring DELTA is a synchrotron light source operated by the TU Dortmund University. Radiation from hard X-rays to the THz regime is provided by dipole magnets and insertion devices like undulators and wigglers. To provide even shorter wavelengths, a new 22-pole superconducting 7-T wiggler has been installed. The edge focusing of the wiggler has a large impact on the linear optics of the storage ring. Measurements regarding its influence and simulations were performed. In addition, a second radiofrequency (RF) cavity has been installed to compensate the increased energy loss per turn due to the new wiggler. As a consequence of the higher RF power, the electron bunches are shorter compared to the old setup with only one cavity. In view of reducing the bunch length even more, studies of the storage ring optics with reduced momentum compaction factor were performed.

WEPAB080 **Near Threshold Pion Photoproduction on Deuterons**

V. Shastri, *V. Aswathi, S.P. Shilpashree (Christ University, School of Engineering and Technology)*

The study of photoproduction of mesons is a prime tool in understanding the properties of strong interactions. The only photoproduction reaction on deuteron with two-body final state is coherent pion photoproduction reaction. Several theoretical studies are being carried out on the pion photoproduction on deuterons since several decades. On the experimental side, the accelerator and detector technology has improved the developments. In the recent years, measurements of tensor analyzing powers associated with coherent and incoherent pion photoproduction are also being carried out at the VEPP-3 electron storage ring. In one of the recent measurements, Rachek et al. have observed discrepancy between theory and experiment at higher photon energies and have suggested for improvement of the theoretical models. In a more recent analysis, the role of D-wave component on spin asymmetries have been identified. In view of these developments, the purpose of the present contribution is to study coherent pion photoproduction on deuterons using model independent irreducible tensor formalism developed earlier to study the photodisintegration of deuterons.

WEPAB081 **The Broad-Band Impedance Budget in the Storage Ring of the ALS-U Project**

D. Wang, *K.L.F. Bane, R. Bereguer, T. Cui, S. De Santis, P. Gach, D. Li, T.H. Luo, T. Miller, T. Oliver, O. Omolayo, C. Steier, T.L. Swain, M. Venturini, G. Wang (LBNL)*

Design work is underway for the upgrade of the Advanced Light Source (ALS-U) to a diffraction-limited soft x-rays radiation source. Like other 4th-generation light source machines, the ALS-U multiple-bend achromat storage-ring (SR) is potentially sensitive to beam-coupling impedance effects. This paper presents the SR broad-band impedance budget in both the longitudinal and transverse planes. In our modeling we follow the commonly accepted approach of separating the resistive-wall and the geometric parts of the impedance, the former being described by analytical formulas and the latter obtained by numerical electromagnetic codes (primarily CST Studio software) assuming perfectly conducting materials. We discuss the main sources of impedance. Results of our analysis are the basis for the single bunch instability study and would feedback on the design of critical vacuum components.

WEPAB082 **Single Bunch Instability Simulations in the Storage Ring of the ALS-U Project**

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As the broad-band impedance modeling and the vacuum chamber design of the new Advanced Light Source storage ring (ALS- U) reach maturity, we report on progress in single-bunch collective effects stud-

ies. A pseudo-Green function wake representing the entire ring was earlier obtained by numerical and analytical methods. Macroparticle simulations using the computer code "elegant" and this wake function are used to determine the instability thresholds for longitudinal and transverse motion. We consider various operating conditions, such as without/with higher-harmonic RF cavities, zero/finite linear chromaticity, and without/with a transverse bunch-by-bunch feedback system. Results show enough margin for the broadband impedance budget when the single-bunch instability thresholds are compared with the design bunch charge.

WEPAB083 **Effect of Negative Momentum Compaction Operation on the Current-Dependent Bunch Length**

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New operation modes are often considered during the development of new synchrotron light sources. An understanding of the effects involved is inevitable for a successful operation of these schemes. At the KIT storage ring KARA (Karlsruhe Research Accelerator), new modes can be implemented and tested at various energies, employing a variety of performant beam diagnostics devices. Negative momentum compaction optics at various energies have been established. Also, the influence of a negative momentum compaction factor on different effects has been investigated. This contribution comprises a short report on the status of the implementation of a negative momentum compaction optics at KARA. Additionally, first measurements of the changes to the current-dependent bunch length will be presented.

WEPAB085 **Design of Various Booster Injectors for 4 GeV Synchrotron Light Source**

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Recently, preliminary studies have been performed to construct a 4 GeV Multi-Bend Achromat (MBA) based synchrotron light source in Korea. As a part of those studies, with ELEGANT code, we have designed booster-type injectors with various circumferences from 400 m to 800 m for the light source. After a long-period optimization, we can get a natural emittance of lower than 10 nm at a beam energy of 4 GeV and a circumference of shorter than 400 m. In this paper, we describe detailed design concepts and optimization results of our various booster-type injectors.

WEPAB086 **Design of Various MBA Based Storage Rings**

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In recent years, there have been many efforts to construct a new advanced synchrotron light source in Korea. As one of those efforts, we have designed Multi-Bend Achromat (MBA) based storage rings with various beam energies from 4 GeV to 6 GeV, various circumferences from 800 m to 1500 m, and various lattice structures with ELEGANT code. In this paper, we describe design concepts, optimization processes, design results of those various storage rings.

WEPAB087 **Observation of Undulator Radiation Generated by a Single Electron Circulating in a Storage Ring and Possible Applications**

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An experimental study into the undulator radiation, generated by a single electron was carried out at the Integrable Optics Test Accelerator (IOTA) storage ring at Fermilab. The individual photons were detected by a Single Photon Avalanche Diode (SPAD) at an average rate of 1 detection per 300 revolutions in the ring. The detection events were continuously recorded by a picosecond event timer for as long as 1 minute at a time. The collected data were used to test if there is any deviation from the classically predicted Poissonian photostatistics. It was motivated by the observation of sub-Poissonian statistics in a similar experiment. The observation could be an instrumentation effect related to low detection efficiency and long detector dead time. In our experiment, the detector (SPAD) has a much higher efficiency (65%) and a much lower dead time. In addition, we show that the collected data (recorded detection times) can be used to study the synchrotron motion of a single electron and infer some parameters of the ring. For example, by comparing the results of simulation and measurement for the synchrotron motion we were able to estimate the magnitude of the RF phase jitter.

WEPAB088 **Transverse Beam Emittance Measurement by Undulator Radiation Power Noise**

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Generally, turn-to-turn power fluctuations of incoherent spontaneous synchrotron radiation in a storage ring depend on the 6D phase-space distribution of the electron bunch. In some cases, if only one parameter of the distribution is unknown, this parameter can be determined from the measured magnitude of these power fluctuations. In this contribution, we report the results of our experiment at the Integrable Optics Test Accelerator (IOTA) storage ring, where we carried out an ab-

solute measurement (no free parameters or calibration) of a small vertical emittance (5|–|15 nm rms) of a flat beam by this new method, under conditions, when the small vertical emittance is unresolvable by a conventional synchrotron light beam size monitor.

WEPAB089 **Conceptual Design of Booster synchrotron for Siam Photon Source II**

S. Krainara, *S. Klinkhieo, P. Klysubun, T. Pulampong, P. Sudmuang (SLRI)*

A project on a 3.0 GeV Siam Photon Source II (SPS-II) has been started. The storage ring of SPS-II was designed to obtain an electron beam with a low-emittance below 1 nm-rad. The SPS-II injector mainly consists of a 150 MeV linac and a full-energy booster synchrotron. The booster synchrotron will be installed in the same tunnel as the storage ring, with a total circumference of 304.829 meters. The proposed lattice of the booster contains 40 modified FODO cells with combined function magnets. This lattice achieves a small beam emittance less than 10 nm-rad at 3 GeV, which can provide a high injection efficiency for top-up operation. The conceptual design for SPS-II booster synchrotron is presented in this work.

WEPAB090 **Higher Order Mode Damping for 166 MHz and 500 MHz Superconducting RF Cavities at High Energy Photon Source**

H.J. Zheng, *Z.Q. Li, F. Meng, N. Wang, H.S. Xu, P. Zhang, X.Y. Zhang (IHEP)*

Superconducting rf cavities have been chosen for High Energy Photon Source, a 6 GeV diffraction-limited synchrotron light source under construction in Beijing. The main accelerating cavity adopted a quarter-wave β=1 structure operating at 166 MHz while the third harmonic cavity utilized the single-cell elliptical geometry at 500 MHz for the storage ring. The high beam current (200 mA) requires a strong damping of higher order modes (HOMs) excited in the superconducting cavities. To meet the beam stability requirements, enlarged beam pipes with a diameter of 505 mm for the 166 MHz cavity and 300 mm for the 500 MHz cavity were chosen to allow all HOMs to propagate along the beam tubes and to be damped by beam-line absorbers. This paper presents the HOM damping scheme and the cavity impedance analysis results. In addition, power losses due to HOMs were also evaluated for various operation modes (high charge and high luminosity) of the HEPS.

WEPAB091 **Simulation Study of the Cornell Photoinjector for Use in MeV Energy Ultra Fast Electron Diffraction**

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We investigate the potential for producing extremely short pulses (10s of fs), low emittance bunches suitable for single-shot MeV energy ultrafast electron diffraction (UED) experiments in the Cornell Photoinjector. New injector settings are determined using Multi-objective Ge-

netic Algorithm optimization and include the effects of machine tolerances and the possible inclusion of pinholes for extracted the core charge of the electron suitable for diffraction.

WEPAB092 **Redesign of the Jefferson Lab -300 kV DC Photogun for High Bunch Charge Operations**

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Production of high bunch charge beams for the Electron-Ion Collider (EIC) is a challenging task. High bunch charge (a few nC) electron beam studies at Jefferson Lab using an inverted insulator DC high voltage photo-gun showed evidence of space charge limitations starting at 0.3 nC, limiting the maximum delivered bunch charge to 0.7 nC for the beam at -225 kV, 75 ps (FWHM) pulse width, and 1.64 mm (rms) laser spot size. The low extracted charge is due to the modest longitudinal electric field (Ez) at the photocathode as well as the beam loss. Thus, to reach the few nC high bunch charge goal, the existing photogun electrode and anode-cathode gap were modified. In addition, the anode aperture was shifted with respect to the beamline longitudinal axis to correct the beam deflection exerted by the non-symmetric nature of the inverted insulator photo-gun. This contribution discusses the electrostatic design of the modified photo-gun obtained using CST Studio Suite's electromagnetic field solver. Beam dynamics simulations performed using General Particle Tracer (GPT) with the resulting electrostatic field map obtained from the modified electrodes confirmed the validity of the new design.

WEPAB093 **Space Charge Effects in Low Energy Magnetized Electron Beams**

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Magnetized electron cooling is one of the major approaches towards obtaining the required high luminosity in the proposed Electron-Ion Collider (EIC). In order to increase the cooling efficiency, a bunched electron beam with a high bunch charge and high repetition rate is required. At Jefferson Lab, we generated magnetized electron beams with high bunch charge using a new compact DC high voltage photogun biased at -300 kV with bialkali-antimonide photocathode and a commercial ultra-fast laser. This contribution discusses how magnetization affects space charge dominated beams as a function of magnetic field strength, gun high voltage, and laser pulse width, and spot size in comparison with simulations performed using General Particle Tracer.

WEPAB094 **Towards Real-Time Programmable Photoinjector Laser Shaping**

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The next generation of augmented brightness X-ray free-electron lasers (XFEL), such as SLAC's LCLS-II, promises to address current challenges associated with systems with low X-ray cross-sections. A key component of XFELs is the photoinjector, which produces the electron beams (e-beams) whose phase-space will substantially determine the performance of the XFEL. Fast and active e-beam manipulation techniques and diagnostics are required to fully capitalize on this new generation of XFELs. We examine one possible solution for adaptive e-beam shaping using a hardware-based machine learning implementation of real-time photoinjector laser manipulation. Our presentation will provide an overview of this project, the five-year goals, and the work both completed and currently underway, in particular simulations of the system and hardware design for X-ray diagnostics. We anticipate this approach to not only enable active experimental control of X-ray pulse characteristics but could also increase the operational capacity of future e-beam sources and accelerator facilities.

WEPAB095 **Development of a Low-Emittance High-Current Continuous Electron Source**

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At the Eindhoven University of Technology a thermionic electron injector is being built, capable of supplying electron bunches at GHz repetition rates. The first part is a custom-built 100 keV thermionic source that generates a high current, low emittance continuous electron beam. Using a 1.5 GHz elliptical RF cavity operating at both the fundamental and the second harmonic mode, the continuous beam is chopped at a duty cycle of approximately 30% and with minimal loss of beam quality. Finally, an elliptical RF compression cavity, also using both the first and second harmonic mode, prepares the pulsed beam for injection into an X-band linear accelerator for use in an X-ray light source. With the high repetition rate, the average current of the injector is considerably improved as compared to photoemission based sources. Construction of the first part of the thermionic source has been completed and we report on the results of the initial performance tests.

WEPAB096 **RF Testbed for Cryogenic Photoemission Studies**

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Producing higher brightness beams at the cathode is one of the main focuses for future electron beam applications. For photocathodes operating close to their emission threshold, the cathode lattice tempera-

ture begins to dominate the minimum achievable intrinsic emittance. At UCLA, we are designing a radiofrequency (RF) test bed for measuring the temperature dependence of the mean transverse energy (MTE) and quantum efficiency for a number of candidate cathode materials. We intend to quantify the attainable brightness improvements at the cathode from cryogenic operation and establish a proof-of-principle cryogenic RF gun for future studies of a 1.6 cell cryogenic photoinjector for the UCLA ultra compact XFEL concept (UC-XFEL). The test bed will use a C-band 0.5-cell RF gun designed to operate down to 40K, producing an on-axis accelerating field of 120 MV/m. The cryogenic system uses conduction cooling and a load-lock system is being designed for transport and storage of air-sensitive high brightness cathodes.

WEPAB097 **Initial Nanoblade-Enhanced Laser-Induced Cathode Emission Measurements**

***G.E. Lawler**, J.I. Mann, J.B. Rosenzweig, V.S. Yu (UCLA) R.J. Roussel (University of Chicago)*

Nanostructured photocathodes offer a unique functionality not possible in traditional photocathodes, increasing beam brightness by reducing the effective emission area. Inspired by field emitter tips, we examine a possible extension for higher current operation, an extended nanoblade capable of producing asymmetric emittance electron beams. A full understanding of emission is necessary to establish the effectiveness of nanoblades as usable cathode for electron accelerators. Utilizing wet etching of silicon wafers, we arrive at a robust sample capable of dissipating incident laser fields in excess of 20 GV/m without permanent damage. Initial predictions and experiments from the nanotip case predict energies up to the keV scale from electron rescattering and fine features on the order of the photon quantum. We will present initial electron data from 800 nm Ti:S laser illumination and measurements of a focused 1 keV beam.

WEPAB098 **Cryogenic Component and Material Testing for Compact Electron Beamlines**

***G.E. Lawler**, N. Majernik, J.B. Rosenzweig (UCLA)*

Cryogenic regimes of operation are, for various reasons, highly advantageous for normal conducting accelerator structures. Liquid cryogen-based systems are costly to implement and maintain. As a result, developing cryogenic test facilities at a smaller more cost effective scale using cryo-coolers is attractive. Before real implementations of a cryocooler based beamline, a significant amount of information is necessary regarding the behavior and properties of various components and materials at cryogenic temperatures. Finding this information lacking for our particular beamline case and by extension similar electron beamlines, we endeavor to generate a thorough beamline-relevant material and component properties down to the range of a liquid nitrogen temperatures (77 K) and the nominal operating temperature of a modest Gifford-McMahon cryocooler (45 K).

WEPAB099 **Near-Threshold Nonlinear Photoemission From Cu (100)**
***C.J. Knill**, S.S. Karkare (Arizona State University) H.A. Padmore (LBNL)*
Photocathodes that have a low mean transverse energy (MTE) are crucial to the development of compact X-ray Free Electron Lasers (XFEL) and ultrafast electron diffraction (UED) experiments. For FELs, low MTE cathodes result in a lower requirement for electron energy when lasing at a defined energy, and for a defined electron energy result in lasing at higher energy. For UED experiments, low MTE cathodes give a longer coherence length, allowing measurements on larger unit cell materials. A record low MTE of 5 meV has been recently demonstrated from a Cu (100) surface when measured near the photoemission threshold and cooled down to 30 K with liquid Helium. For UED and XFEL applications that require a high charge density, the low quantum efficiency of Cu (100) near threshold necessitates the use of a high laser fluence to achieve the desired charge density. At high laser fluences the MTE is limited by nonlinear effects, and therefore it is necessary to investigate near photoemission threshold at these high laser fluences. In this paper we report on nonlinear, near-threshold photoemission from a Cu (100) cathode, and its effect on the MTE.

WEPAB100 **Heat Dissipation of Photocathodes at High Laser Intensities for a New DC Electron Source**
***M.A. Dehn**, K. Aulenbacher (IKP) K. Aulenbacher (HIM) K. Aulenbacher (GSI)*
Laser intensities of 1W or more are required to extract average beam currents of more than 10mA from photocathodes. Most of this laser power is converted into thermal load within the cathode and has to be dissipated to avoid excessive heating of the cathode and thus a significant reduction in lifetime. At Johannes Gutenberg-University Mainz, we are developing a new high current DC electron source operating at an energy of 100keV, where an efficient heat dissipation of the photocathode is achieved by a mechanical design of the supporting structure.

WEPAB101 **An Improved Model for Photoemission of Space Charge Dominated Picosecond Electron Bunches: Theory and Experiment.**
***S.M. Polozov**, V.I. Rashchikov (MEPhI) M. Krasilnikov (DESY Zeuthen)*
The emission of a short highly charged electron bunch in a radiofrequency photogun is discussed. The traditional space charge limited emission numerical model is extended by an introduction of positively charged ions arising in the cathode region and dynamically changing during the emission. Estimates on the time characteristics of the charge migrating process in the semiconductor region are given. The numerical results are compared with the results of other numerical models and with experimental observations at the Photo Injector Test facility at DESY in Zeuthen (PITZ).

WEPAB102 **Half-Metal Spin Filter for Highly Polarized Emission From GaAs Photocathodes**

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GaAs-based photocathodes are one of the major sources of spin-polarized electrons and are crucial for the upcoming Electron-Ion collider experiments which includes study of proton spin and spin parity violation in the standard model. The theoretical polarization limit in unstrained GaAs photocathodes is 50 % but only 35 % is routinely achieved in experiments. Spin selective filtering allows to boost the spin polarization beyond the 50 % theoretical limit. In this work, first-principle electronic calculations using standard Density Functional Theory are performed to predict possible Heusler alloy half-metal candidates to be used as spin-filter. Simulations are also performed to investigate the half-metallicity as function of the magnetic spin direction. Several devices are experimentally fabricated using dedicated Molecular Beam Epitaxy growth system. We implemented Quantum Efficiency and Polarization testing of these half-metal/GaAs heterostructures using a dedicated Mott polarimeter system. Photoemission can also be seen on magnetically switching the spin-filter direction accompanied by a change in sign of the asymmetry which is a qualitative proof of the spin-filtering effect.

WEPAB103 **Systematic Beam Parameter Studies at the Injector Section of FLUTE**

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FLUTE (Ferninfrarot Linac- und Test-Experiment) is a compact linac-based test facility for accelerator R&D and source of intense THz radiation for photon science. In preparation for the next experiments, the electron beam of the injector section of FLUTE has been characterized. In systematic studies the electron beam parameters, e.g., beam energy and emittance, are measured with several diagnostic systems. This knowledge allows the establishment of different operation settings and the optimization of electron beam parameters for future experiments.

WEPAB104 **Improving the Operational Lifetime of the CEBAF Photo-Gun by Anode Biasing**

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The operating lifetime of GaAs-based photocathodes in DC high voltage electron photo-guns is dominated by the ionization rate of residual beamline gas molecules. In this work, experiments were performed to quantify the improvement in photocathode charge lifetime by biasing

the photo-gun anode with a positive voltage, which repels ions generated downstream of the anode. The photo-cathode charge lifetime improved by almost a factor of two when the anode was biased compared to the usual grounded configuration. Simulations were performed using the particle tracking code General Particle Tracer (GPT) with a new custom element. The simulation results showed that both the number and energy of ions play a role in the pattern of QE degradation. The experiment results and conclusions supported by GPT simulations will be presented.

WEPAB105 **Simulating Electron Impact Ionization Using a General Particle Tracer (GPT) Custom Element**

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A new C++ custom element has been developed with the framework of General Particle Tracer (GPT) to simulate electron impact ionization of residual gas molecules. The custom element uses Monte-Carlo routines to determine both the ion production rate and the secondary electron kinetic energy based on user-defined gas densities and theoretical values for the ionization cross section and the secondary electron differential cross section. It then uses relativistic kinematics to track the secondary electron, the scattered electron, and the newly formed ion after ionization. The ion production rate and the secondary electron energy distribution determined by the custom element have been benchmarked against theoretical calculations and against simulations made using the simulation package IBSimu. While the custom element was originally built for particle accelerator simulations, it is readily extensible to other applications. The custom element will be described in detail and examples of applications at the Thomas Jefferson National Accelerator Facility will be presented for ion production in a DC high voltage photo-gun.

WEPAB106 **Study on Durability Improvement of Cs-Te Photocathode by Means of Alkali Halide protective films**

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We have been conducting basic and applied research for generating high quality electron beams, using 1.6 cell laser photocathode RF-gun. In our laboratory, Cesium Telluride (Cs-Te), one of the semiconductor photocathodes, is used as an electron source for accelerator experiments. This semiconductor photocathode is known for high quantum efficiency (Q.E.) about 5–10% and 3-month 1/e lifetime. High Q.E. photocathodes can reduce the power requirement of the laser system, and long lifetime photocathodes can decrease the maintenance frequency, contributing to an efficient experimental environment. For these reasons, high Q.E. and long lifetime photocathodes are neces-

sary in accelerator experiments. In order to produce robust photocathodes and extend the lifetime, we have conducted covering Cs-Te photocathodes with CsBr and CsI protective films. In this conference, we report the thickness dependency on the lifetime of Cs-Te photocathodes when we intentionally exposed oxygen gas to coated and non-coated Cs-Te photocathodes.

WEPAB107 **Design of an X-Band RF Photoinjector Within the Framework of the XLS-CompactLight Collaboration**

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The RF photoinjectors constitute the sources of high-brightness electron beams required by X-ray Free Electron Lasers. Within the framework of the Horizon 2020 CompactLight project, we propose a radio-frequency (RF) photoinjector based on a 5.6-cell RF gun in the X-band of frequency. The photoinjector design also includes an emittance-compensating solenoid, followed by two X-band traveling-wave structures to accelerate the beam out of the space-charge-dominated regime. The RF gun is intended to operate with a high gradient RF electric field at the cathode of 200 MV/m. The irises between cavity cells have been shaped to reduce the RF breakdown events. Thus, an assessment of RF breakdown risk for the RF gun is presented. Similarly, the multipactor analysis of the coaxial coupler of the RF gun is performed. Due to the high gradient RF fields, the temperature increase during the RF pulse along the device walls is estimated to ensure the heating is maintained within the limit for safe gun operation. Finally, the photoinjector has been optimized to fulfil the output electron beam quality parameter goals of the CompactLight project.

WEPAB108 **Evolution of QE Distribution of Cs_2Te Photocathodes in HZDR SRF gun-II**

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Since May 2014 SRF Gun-II has been installed at HZDR ELBE radiation centre as the second e^- source. It is now able to achieve an acceleration gradient of 8 MV/m which corresponds to 14.5 MV/m peak field on cathode surface. In 2016 two experiments with Cs_2Te failed, where the Mo substrate plugs were overheated in superconducting rf cavity. The reason is that different thermal expansion coefficient of Mo and Cu led to a bad thermal contact between the Mo plug and Cu holder. After that, pure copper is used as new substratum of Cs_2Te cathodes. Several Cs_2Te photocathodes on Cu plugs are prepared and simultaneously the vacuum of cathode transfer system is improved. Since May 2020, Cs_2Te photocathodes have been used again in the gun and generated totally 26.27 C in 10^{80} hours of beam time. In this contribution, we will present the long-term evolution of QE distribution of Cs_2Te

photocathodes with different thickness during SRF gun operation, and the possible reason for this phenomenon will be discussed too.

WEPAB109 **Initial Study of GaN Thin Films for Photocathodes Prepared by Magnetron Sputtering on Copper Substrates**

***M. Vogel**, X. Jiang, C. Wang (University Siegen) P. Murcek, J. Schaber, R. Xiang (HZDR)*

On the path for high brightness electron beams, Gallium Nitride (GaN) is one promising candidate for a photo-cathode material. In this contribution, we report on the continuation of the study to optimize the crystallization quality and crystallography of Mg-doped GaN samples on copper substrates that are synthesized by RF magnetron sputtering. SEM and XRD results show that the pretreatment methods and the sputtering conditions (temperature, sputtering power, and partial pressure of the reactive gas) can both affect the morphology and crystal quality of GaN films. The initial QE measurements of these samples are done in our newly build in-situ QE measurement system and the first results of QE analyses done at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) are presented in a dedicated contribution.

WEPAB110 **Solid-State Driven X-Band Linac for Electron Microscopy**

***A. Dhar**, E.A. Nanni, M.A.K. Othman, S.G. Tantawi (SLAC)*

Microcrystal electron diffraction (MicroED) is a technique used by scientists to image molecular crystals with cryo-electron microscopy (cryo-EM). However, cryo-EMs remain expensive, limiting MicroED's accessibility. Current cryo-EMs accelerate electrons to 200-300 keV using DC electron guns with a nA of current and low emittance. However at higher voltages these DC guns rapidly grow in size. Replacing these electron guns with a compact linac powered by solid-state sources could lower cost while maintaining beam quality, thereby increasing accessibility. Utilizing compact high shunt impedance X-band structures ensures that each RF cycle contains at most a few electrons, preserving beam coherence. CW operation of the RF linac is possible with distributed solid-state architectures that use 100W solid-state amplifiers at X-band frequencies. We present an initial design for a prototype low-cost CW RF linac for high-throughput MicroED producing 200 keV electrons with a standing-wave architecture where each cell is individually powered by a solid-state amplifier. This design also provides an upgrade path for future compact MeV-scale sources on the order of 1 meter in size.

WEPAB111 **Controlled Degradation by Oxygen Exposure in the Performance of a Ag (100) Single-Crystal Photocathode**

***L.A.J. Soomary**, C.P. Welsch (The University of Liverpool) L.B. Jones, T.C.Q. Noakes (STFC/DL/ASTeC)*

The search for high-performance photocathode electron sources is a priority in the accelerator science community. The surface characteristics of a photocathode define many important factors of the photoemission including the work function, intrinsic emittance, and quantum efficiency of the photocathode. These factors in turn define the

electron beam performance which is measurable as normalized emittance, brightness, and energy spread. Strategies for improving these parameters vary, but understanding and influencing the relevant cathode surface physics which underpin these attributes is a primary focus for the electron source community. As such, pure metal photocathodes and their performance at UV wavelengths are of interest as seen at the LCLS at SLAC and CLARA at Daresbury. We present performance data for an Ag (100) single-crystal photocathode under illumination at 266 nm wavelength, with known levels of surface roughness, using our Transverse Energy Spread Spectrometer (TESS) both at room and cryogenic temperatures. Crucially our data shows the effect of progressive degradation in the photo-cathode performance as a consequence of exposure to controlled levels of oxygen.

WEPAB112 **Performance Characterisation of a Cu (100) Single-Crystal Photocathode**

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The search for high performance photocathode electron sources is a priority in the accelerator science community. The surface characteristics of a photocathode define important factors of the photoemission including the intrinsic emittance, the quantum efficiency and the work function of the photocathode. These factors in turn define the electron beam performance which are measurable as emittance, brightness and energy spread. We have used ASTeC's Multiprobe (SAPI) to characterise and analyse photocathode performance using multiple techniques including XPS, STM, and LEED imaging, and their Transverse Energy Spread Spectrometer (TESS) to measure mean transverse energy (MTE). We present characterisation measurements for a Cu (100) single-crystal photocathode sample with data from SAPI confirming the crystallographic face and showing surface composition and roughness, supported by data from TESS showing the photocathode electron beam energy spread.

WEPAB113 **Stripline Kickers for Injection Into PETRA IV**

G. Loisch*, I.V. Agapov, S.A. Antipov, J. Keil, F. Obier (DESY) M.A. Jebramcik (CERN)*

PETRA IV is the planned ultralow-emittance upgrade of the PETRA III synchrotron light source at DESY, Hamburg. The current design includes an on-axis beam injection scheme using fast stripline kickers. These kickers have to fulfill the requirements on kick-strength, field quality, pulse rise-rate and a matched beam impedance. 3D finite element simulations in conjunction with Bayesian optimisation are used to meet these requirements simultaneously. Here, we will discuss the requirements on the PETRA IV injection kickers and the current design status.

WEPAB114 **FLASHforward: Beam-Quality Preserving Plasma Wakefield Acceleration at High Average Power**

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Beam-driven plasma-wakefield acceleration (PWFA) is one of the most promising candidates for reducing the footprint and boosting the energy of future photon science and high-energy physics facilities. Important milestones such as the demonstration of GV/m accelerating gradients with energy-transfer efficiency from drive to trailing beam on the 40% level have already been achieved. However, requirements to outperform the brilliance and luminosity of current machines, such as transverse beam-quality preservation and high repetition rates, have yet to be demonstrated. The FLASHForward project, housed at the free-electron laser facility FLASH at DESY, Hamburg is aiming to accelerate electron bunches in plasma with GV/m gradients whilst preserving the high brightness of the bunches provided by the FLASH accelerator. By exploiting the capability of the superconducting drive linac of accelerating trains of bunches with up to MHz bunch repetition rates, an increase of the average power of PWFA into the kW regime is targeted. This contribution will present an overview of the FLASHForward facility, highlighting recent results, ongoing work, and a roadmap towards its future goals.

WEPAB115 **Beam Preparation With Temporally Modulated Photocathode Laser Pulses for a Seeded THz FEL**

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The need for carrier-envelope-phase (CEP) stable THz pump pulses is recognized at many pump-probe experiments at the European XFEL. At the Photo Injector Test Facility at DESY in Zeuthen (PITZ), a proof-of-principle experiment of an accelerator-based THz FEL source is in preparation. Since the CEP stability of FEL pulses is not guaranteed in the SASE regime, a seeding scheme is needed. A common scheme for seeding is to drive the microbunching process with external laser pulses, which are power-limited in the THz range. Alternatively, a

pre-bunched beam, generated for example by applying a temporally modulated photocathode laser pulse, can be used to drive the FEL. The beam dynamics with such a seeding method are studied with ASTRA tracking code simulations with space-charge forces as well as experimentally. The results of these studies are shown and discussed.

WEPAB116 **Crystal-Based Extraction of Electron Beams From the DESY II Synchrotron**

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We propose a novel technique of crystal-based electron beam extraction at the DESY II synchrotron by using the channeling effect in a bent crystal. Though crystal-based beam collimation or extraction was successfully applied at several proton and heavy ion synchrotrons, such as U70, SPS, Tevatron and LHC, it has been never done with e^- beams. DESY II is a suitable synchrotron for design of the first experimental test of this extraction technique by the following reasons: 1. The e^- beam energy (6 GeV) lies in the energy range already tested in the experiments on channeling of electrons and is typical for electron synchrotrons existing in the world. 2. The upgrade of the Test Beam Facility consisting in the extraction of primary, and therefore, low-emittance and intense e^- beams into beam test area instead of the tertiary ones is an excellent motivation for these studies. 3. The extraction line including septum magnets already exists. We propose and simulate the experimental layout. We present the bent crystals of the new generation characterized experimentally at similar conditions. We show by simulations that the multi-turn extraction efficiency may exceed 15 %.

WEPAB117 **Injection Feedback for a Storage Ring**

***A. Moutardier**, C. Bruni, I. Chaikovska, S. Chancé, N. Delerue, E.E. Ergenlik, V. Kubytskyi, H. Monard (Université Paris-Saclay, CNRS/IN2P3, IJCLab)*

We report on an injection feedback scheme for the ThomX storage ring project. ThomX is a 50-MeV-electron accelerator prototype which will use Compton backscattering in a storage ring to generate a high flux of hard x-rays. Given the slow beam damping [in the ring], the injection must be performed with high accuracy to avoid large betatron oscillations. A homemade analytic code is used to compute, using the information provided by the ring's diagnostic devices, the corrections that need to be applied before the beam injection to achieve a beam position accuracy of a few hundred micrometers in the first beam position monitors (BPMs). The iterative feedback system has been tested using MadX simulations. Our simulations show that a performance that matches the BPMs' accuracy can be achieved in less than 60 iterations in all cases. Details of this feedback algorithm, its efficiency and the

simulations are discussed.

WEPAB118 **Loss Maps Along the ThomX Transfer Line and the Ring First Turn**

***A. Moutardier**, C. Bruni, I. Chaikovska, S. Chancé, N. Delerue, E.E. Ergenlik, V. Kubytskyi, H. Monard (Université Paris-Saclay, CNRS/IN2P3, IJCLab)*

We report on studies of the loss maps for particles travelling from the end of the ThomX's linac along the transfer line to the end of the ring first turn in preparation of the machine commissioning. ThomX is a 50-MeV-electron accelerator prototype which will use Compton backscattering to generate a high flux of hard x-rays. The accelerator simulation code MadX is used to simulate electrons' propagation and compute losses. These maps may be projected anywhere along the bunch path. This information is particularly relevant at the locations of the monitoring devices (screens, position monitors,...) where loss predictions will be compared with measurements. A way to display the aperture on visualization screens will also be discussed.

WEPAB119 **Beam Injection With a Pulsed Nonlinear Magnet Into the HALF Storage Ring**

***G. Liu**, W. Li, L. Wang, P.N. Wang (USTC/NSRL)*

The nonlinear optics of the HALF storage ring are well optimized to make it possible to inject the beam with the pulsed multipole injection scheme. In this paper, the injection scheme is studied with an innovatively designed pulsed nonlinear magnet. The layout and parameters of the injection system are well designed based on the acceptance analysis. The injection process is simulated with particle tracking is presented in this paper.

WEPAB120 **Upgrades to the Booster to Storage Ring Transfer Line at the Canadian Light Source**

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Investigations into the booster to storage ring transfer process identified non-linear fields in the booster extraction septum as the cause for the poor transfer efficiency. We found that by correcting the trajectory through the septum, the transfer efficiency improved substantially. This motivated an upgrade project to reliably control the trajectory through the septum and transfer line, to provide improved diagnostics and to implement a set of four horizontal scrapers to reduce the horizontal emittance of the beam before it reaches the storage ring.

WEPAB121 **Design and Simulation of Transparent Injection Upgrade for the CLS Storage Ring**

***P.J. Hunchak**, M.J. Boland (University of Saskatchewan) D. Bertwistle, M.J. Boland (CLS)*

The Canadian Light Source (CLS) synchrotron uses four fast kicker magnets to inject electrons into the storage ring from a 2.9 GeV booster

ring. The injection occurs over several turns of the stored beam, which is also perturbed by the injection kickers. The resultant oscillations of the stored beam can negatively affect beamline experiments, so it is desirable to implement an injection scheme which does not disturb the stored beam. Injection schemes of this type allow for transparent injection and are beneficial for planned top-up operations of the CLS storage ring. Many alternative injection techniques were examined as they apply to the CLS storage ring. Pulsed multipole magnets and a non-linear kicker (NLK) are the most viable options for integration with the current ring. Non-linear kicker designs are also being considered for the proposed CLS2 and studying the NLK in the limitations of the current machine provides insight to guide the work on the new machine. Simulation with the accelerator code ELEGANT shows the viability of the non-linear kicker design as developed at BESSY, MAX IV and SOLEIL for transparent injection at the CLS.

WEPAB122 **Development of Fast and Super-Fast Kicker System for SLS 2.0 Injection**

***M. Paraliev**, M. Aiba, S. Dordevic, C.H. Gough, A. Streun (PSI)*

Swiss Light Source plans a major upgrade to turn the existing Storage Ring (SR) into a modern diffraction-limited light source called SLS 2.0. As part of this project, the injection system has to be upgraded as well in order to ensure reliable and efficient injection in the reduced beam aperture. A 4 kicker bump and a new thin septum will ensure the conventional injection in the SR. To further minimize the perturbation of the stored beam during injection two new schemes are in development: "Fast" and "Super-fast" one. The "Fast" injection scheme should be able to ensure single-bunch off-axis top-up injection affecting only 10 to 20 SR bunches that are 2 ns apart. The "Super-fast" one should bring the perturbed bunches down to only one. In on-axis mode it should be able to inject a top-up bunch between two SR bunches with minimum disturbance of the adjacent ones. To do this a combination of special beam injection schemes and an extremely fast (ns) kicker system is required. We will discuss the status of the development, the problems, and the solutions for reaching such a challenging goal.

WEPAB123 **Multi-Bunch Resistive Wall Wake Field Tracking Via Pseudo-modes in the ALS-U Accumulator Ring**

***M.P. Ehrlichman**, S. De Santis, T. Hellert, S.C. Leemann, G. Penn, C. Steier, C. Sun, M. Venturini, D. Wang (LBNL)*

For the ALS-U project, particles will be injected from the booster to the accumulator ring utilizing an injection scheme that leaves the stored and injected particles with a non-trivial transient. This transient requires that multibunch feedback be masked for those buckets into which charge is injected. The masking significantly diminishes the damping capability of the multibunch feedback system. This problem is exacerbated by the large injection transient. The higher order resistive wall wake fields in the accumulator ring exceed the radiation damping time. To study whether the beam will remain multibunch sta-

ble during an injection cycle, a multibunch tracking simulation is used that simulates the multibunch feedback system and also pseudomode representation of resistive wall wake fields.

WEPAB124 **The Three Dipole Kicker Injection Scheme for the ALS-U Accumulator Ring**

***M.P. Ehrlichman**, T. Hellert, S.C. Leemann, G. Penn, C. Steier, C. Sun, M. Venturini, D. Wang (LBNL)*

The ALS-U light source will implement on-axis swap-out injection of individual trains employing an accumulator between the booster and storage rings. The accumulator ring design is a twelve period triple-bend achromat that will be installed along the inner circumference of the storage-ring tunnel. A non-conventional injection scheme will be utilized for top-off off-axis injection from the booster into the accumulator ring meant to accommodate a relatively narrow vacuum-chamber aperture while maximizing injection efficiency. The scheme incorporates three dipole kickers distributed over three sectors, with two kickers perturbing the stored beam and the third affecting both the stored and the injected beam trajectories. This paper describes this "3DK" injection scheme, how it was chosen, designed and optimized, and how we evaluated its fitness as a solution for booster-to-accumulator ring injection against alternate injection schemes.

WEPAB125 **Acceptance Analysis Method for the Scheme Design of Multipole Kicker Injection**

***P.N. Wang**, W. Li, G. Liu, L. Wang (USTC/NSRL)*

A pulsed multipole kicker has zero magnetic field at the center, consequently, this injection scheme can be transparent to the stored beam and users. In general, multipole kicker injection schemes are derived from the method of phase space analysis. In this paper, a new method of acceptance analysis based on multi-particles tracking is proposed. Using this method, we can quickly obtain multiple kicker injection schemes and easily make adjustments to them. The details of this method are presented and we apply it to the HALF storage ring as an example. A series of tracking simulations are carried out and results are also discussed.

WEPAB126 **Pulsed Wire Magnetic Field Measurement System for Short-Period Long Undulators**

***J.E. Baader**, S. Casalbuoni (EuXFEL)*

The pulsed wire method is an attractive option to measure the magnetic field in insertion devices, mainly for those with restricted access (e.g., small gaps, in-vacuum/cryogenic environments, etc.). Besides first and second field integrals, experiments have proved the feasibility of reconstructing the magnetic field profile. Undulators with a small gap and short period are - and are planned to be - used at diffraction-limited storage rings and free-electron lasers. This contribution outlines the pulsed wire system's requirements to perform magnetic field reconstruction in such undulators. We examine the main expected

limitations, particularly the dispersive, finite pulse-width, discretization error, and sag effects. Furthermore, we present the current status of developing the pulsed wire system at the European XFEL.

WEPAB127 **Accurate Measurements of Undulator Particle Beam Entrance/Exit Angles Using Improved Hall Probes and Calibration Process**

***I. Vasserman**, R.J. Dejus, Y. Piao, M.F. Qian, J.Z. Xu (ANL)*

The Advanced Photon Source Upgrade (APS-U) undulator requirements were changed from the first and second field integrals to the entrance and exit angles of the particle beam. This provides the user with the best radiation view angle by the storage ring closed orbit correction system. To satisfy such requirements we use improved Senis Hall probes and calibration process. In addition to the normal NMR calibration of the sensors, the calibration was further refined using stretch-coil integrals to make accurate measurements.

WEPAB128 **Recent Experience with Magnet Sorting for APS-U Hybrid Undulators**

***I. Vasserman**, R.J. Dejus, Y. Piao, M.F. Qian, J.Z. Xu (ANL)*

The quality of permanent magnets plays a particularly important role in undulator performance. Many different types of magnet sorting to enhance undulator performance have been carried out at different facilities. Meanwhile, progress in improving magnet quality has been made by different vendors. At the Advanced Photon Source (APS) we have assembled, measured, and analyzed over 14 new undulators of the same mechanical design, some of them with sorted magnets and some unsorted. The performance differences appear to be insignificant in meeting the tight APS Upgrade (APS-U) undulator requirements.

WEPAB129 **A New Method of Undulator Phase Tuning with Mechanical Shimming**

***M.F. Qian**, R.J. Dejus, Y. Piao, I. Vasserman, J.Z. Xu (ANL)*

We developed a new method for tuning the undulator phase errors by shimming the undulator gap profile mechanically. First, the phase errors of a device are calculated based on the initial field measurement; then the desired field strength modulation along the device length is derived from the phase errors; and finally, the gap profile is mechanically shimmed to produce the desire field strength modulation. The method has been successfully applied to the tuning of many new and reused APS Upgrade (APS-U) hybrid permanent magnet undulators. The method is especially effective for tuning the legacy undulators with large phase errors. For instance, an old 33-mm-period undulator with a 23 degree initial rms phase error largely due to radiation damage has been tuned to better than 3 degrees.

WEPAB130 **Experience with Algorithm-Guided Tuning of APS-U Undulators**

***M.F. Qian**, R.J. Dejus, Y. Piao, I. Vasserman, J.Z. Xu (ANL)*

The Advanced Photon Source (APS) is undergoing a major upgrade to its storage ring. The APS Upgrade (APS-U) project plans to build over 40 new hybrid permanent magnet undulators (HPMUs) and rebuild over 20 existing HPMUs. To meet the APS-U undulator requirements, the quality of the undulator magnetic field needs to be fine-tuned to the specifications. The traditional methods that depend on the tuning specialist experience are not desirable for tuning large quantities of undulators. We developed algorithms that automate the tuning of permanent magnet undulators. For tuning of the undulator trajectory and phase, the algorithms optimize the tuning parameters with differential evolution-based global optimization. The algorithms have been successfully applied to over 18 APS HPMUs. The results and experiences of the tuning are reported in detail.

WEPAB131 **Magnetic Tuning and Installation Modifications of U48 undulator for Delhi Light Source (DLS)**

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A compact THz radiation facility based on the principle of a prebunched Free Electron Laser, called Delhi Light Source (DLS) is at the final stage of commissioning at IUAC, New Delhi, India. For generation of THz radiation in DLS, an undulator with period length of 48 mm (U48), built by HZB and refurbished at DESY will be used. The magnetic tuning and the field measurements have been done on the U48 along with the design and installation of correction coils at the entrance/exit of the U48. In addition, horizontal and vertical ambient field correction coils were integrated into the magnet girders. A quadrupole correction coil along the vacuum chamber in order to mitigate the defocusing effect of the U48 on the electron beam has been designed. The current through all coils has been adjusted as a function of the gap by the new control system designed for the U48. In addition, an extruded aluminium vacuum chamber was designed and fabricated and will be aligned with the the undulator soon.

WEPAB132 **Towards a Superconducting Undulator Afterburner for the European XFEL**

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We propose to develop, characterize and operate a superconducting undulator (SCU) afterburner consisting of 5 undulator modules (1 module = 2 times SCU coil of 2 m length and 1 phase shifter) at the SASE2 hard X-ray beamline of European XFEL. This afterburner has the potential to produce an output of more than 10^{10} ph/pulse at photon energies above 30 keV. The project is divided into the production

of a pre-series prototype module and a small-series production of 5 modules. Central goals of this R&D activity are: the demonstration of the functionality of SCUs at an X-ray FEL, the set up of the needed infrastructure to characterize and operate SCUs, the industrialization of such undulators, and the reduction of the price per module. In this contribution, the main parameters and specifications of the pre-series prototype module (S-PRESSO) are described.

WEPAB133 **First Numerical Wakefield Studies of New In-Vacuum Cryogenic and APPLE II Undulators for BESSY II**

***M. Huck**, J. Bahrdt, A. Meseck (HZB) A. Meseck (KPH)*

While the new in-vacuum cryogenic undulator is in its last commissioning stages, a worldwide new in-vacuum APPLE II undulator is being designed and constructed for BESSY II storage ring. Besides the challenging mechanical design of these small-gap and short-period undulators, challenges arise due to interaction with the electron beam. Therefore, detailed studies of this interaction is required to minimize the adverse effects on beam dynamics and the device itself. For this purpose, the wakefield effects have been computed numerically for critical parts of these devices i.e. the RF-shields, flexible tapers and taper sections. A brief overview of simulation results and discussions are presented in this paper.

WEPAB134 **Experimental Studies of the In-Vacuum-Cryogenic Undulator Effect on Beam Instabilities at BESSY II**

***M. Huck**, J. Bahrdt, A. Meseck, G. Rehm, M. Ries, A. Schälicke (HZB)*

A new in-vacuum cryogenic permanent magnet undulator (CPMU17) has been installed in summer 2018 in the BESSY II storage ring at HZB. Such a small gap in-vacuum undulator device increases the impedance of the storage ring and can contribute to the instabilities that adversely affect the beam quality and the device itself. To identify and explore the effects of CPMU17 on the instabilities at BESSY II, grow-damp and drive-damp experiments have been conducted using the installed bunch-by-bunch feedback system. In this paper, the first results of the mode and gap analysis of these studies with a brief overview of other impedance studies will be presented.

WEPAB135 **Progress of the Development of a Superconducting Undulator as a THz Source for FELs**

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To produce radiation in the THz frequency range at X-ray Free Electron Lasers, undulators with large period length, high fields, and large gaps are required. These demands can be fulfilled by superconducting undulators. In this contribution, the actual requirements on the main parameters of such a superconducting undulator will be discussed and the progress of the design will be discussed. In addition, beam

impedance and heat load results obtained analytically as well as by large-scale wakefield simulations will be presented.

WEPAB136 **Experimental Studies of Interactions of Long CO_2 Laser Pulse With Plasma Using an Electron Beam as a Probe**

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Laser wakefield accelerators (LWFAs) can sustain accelerating gradients that greatly surpass those of conventional accelerators. Long (~ps) and intense (>TW) laser pulses have been employed in LWFAs to generate bright, hard X-rays which are of interest for imaging and diagnosing warm-dense matter. The CO_2 laser at the ATF facility of the Brookhaven National Laboratory is a unique source, which can generate 2 ps-long, multi-TW laser pulses in the mid- IR (9.2 um) regime. The properties of the laser-plasma interactions were characterized by imaging the plasma wakefields with the linac-produced short (150-250 fs) relativistic electron beam at ATF. The evolution of a self-modulated laser wake in an underdense plasma has been directly observed and analyzed. Experimental results as well as simulations exploring the properties of this regime will be presented.

WEPAB138 **Superconducting RF Gun With High Current and the Capability to Generate Polarized Electron Beams**

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High-current low-emittance CW electron beams are indispensable for nuclear and high-energy physics fixed target and collider experiments, cooling high energy hadron beams, generating CW beams of monoenergetic X-rays (in FELs) and gamma-rays (in Compton sources). Polarization of electrons in these beams provides extra value by opening a new set of observables and frequently improving the data quality. We report on the upgrade of the unique and fully functional CW SRF 1.25 MeV SRF gun, built as part of the Coherent electron Cooling (CeC) project, which has demonstrated sustained CW operation with CsK2Sb photocathodes generating electron bunches with record-low transverse emittances and record-high bunch charge exceeding 10 nC. We propose to extend the capabilities of this system to high average current of 100 milliampere in two steps: increasing the current 30-fold at each step with the goal to demonstrate reliable long-term operation of the high-current low-emittance CW SRF guns. We also propose to test polarized GaAs photocathodes in the ultra-high vacuum (UHV) environment of the SRF gun, which has never been successfully demonstrated in RF accelerators.

WEPAB139 **Beam Tracking Simulations for Stage 1 of the Laser-Hybrid Accelerator for Radiobiological Applications (LhARA)**

H.T. Lau *(Imperial College London)*

The Laser-hybrid Accelerator for Radiobiological Applications (LhARA) is a unique and flexible facility proposed for radiobiological studies. The first stage of LhARA consists of an intense laser source interacting with a thin foil target producing a large flux of protons with energies up to 15 MeV. Particles will propagate through a combination of plasma (Gabor) lenses and magnetic elements to an achromat arc delivering the beam vertically to an in-vitro end station. An end-to-end simulation from the laser source to the end station is required to verify the conceptual design of the beamline. The laser-plasma interaction is simulated with Smilei (a particle-in-cell code) to produce a two-dimensional (2D) distribution of particles. Whilst it is possible to simulate the laser-plasma interaction in three dimensions (3D), access to the computing resources needed to run highly resolved simulations was not available. A sampling routine will be described which samples the 2D distribution to generate a 3D beam. The Monte Carlo simulation programs BDSIM and GPT were used to track the beam. Results of the simulations will be shown and compared to the results of an idealized Gaussian beam.

WEPAB140 **Second Beam Test and Numerical Investigation of the Imperial College Plasma (Gabor) Lens Prototype**

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The design of the Laser-hybrid Accelerator for Radiobiological Applications (LhARA) is based on a series of plasma lenses to capture, focus, and select the energy of the ions produced in the laser-target interaction. A second beam test of the first plasma lens prototype, built at the Imperial College London, took place in October 2017 at the Ion Beam Centre of the University of Surrey. 1.4 MeV proton pencil beams were imaged 0.67m downstream of the lens on a scintillator screen over a wide range of settings. On top of the focusing effect, the electron plasma converted pencil beams into rings. The intensity of each ring shows a different degree of modulation along its circumference. Analysis of the results indicates non-uniformity and an off-axis rotation of the electron plasma. The effect on the beam is presented and compared to the results of a simulation of the plasma dynamics and proton beam transport through the lens. A particle-tracking code was used to study the impact of plasma instabilities on the focusing forces produced by the lens. The m = 1 diocotron instability was associated with the formation of rings from the pencil beams.

WEPAB141 **Preliminary Simulation of CERN's Linac4 H⁻ Source Beam Formation**

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Linac4 is the new (H-) linear injector of CERN's accelerator complex. This contribution describes the modelling activities required to get insight into H⁻ beam formation processes and their impact on beam properties. The simulation region starts from a homogeneous hydrogen plasma, the plasma then expands through the magnetic filter field. H⁻ ions and electrons are electrostatically extracted through the meniscus (line of separation between the plasma and the extracted beam) and eventually accelerated. The physics is simulated via the 3D PIC code ONIX. This code, originally dedicated to ITER's neutral injector sources, has been modified to match single aperture sources. A new type of boundary condition is described, as well as the field distribution and geometry of the standard IS03 and a dedicated proto-type of CERN's Linac4 H⁻ source. A plasma electrode prototype designed to provide metallic boundary conditions was produced and tested. This plasma electrode geometry enables Optical Emission Spectroscopy in the region closest to meniscus. A set of plasma parameters was chosen as input characterizing the plasma. Preliminary simulation results of beam formation region are presented.

WEPAB142 **Development of a Low Energy H⁻ Beamline for the ALPHA Antihydrogen Experiment**

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The ALPHA experiment at the CERN antiproton decelerator makes precision measurements of antihydrogen atoms, confined in a superconducting magnetic minimum trap. Recent measurements of antihydrogen's narrow 1S-2S transition have already provided unique, high-resolution tests of CPT symmetry and new physics beyond the standard model. The ALPHA collaboration has recently embarked on an ambitious upgrade programme, aimed at probing the spectra of both hydrogen and antihydrogen to the highest precision within the existing ALPHA atom trap. Key to this upgrade will be the addition of a low energy (~50 eV) hydrogen ion source that is compatible with ALPHA's existing charged particle beamlines. The PELLIS ion source, previously developed at JYFL, is a 5 keV filament-driven source that generates H⁻ beams with low emittances and currents of up to 50 uA. Here, we describe the design of a 2.2 m long electrostatic beamline to transport H⁻ ions from a PELLIS-type ion source into ALPHA's existing particle traps. We present extensive SIMION simulations that were used to develop the beamline, focusing on key components including a quadrupole switchyard and drift tube deceleration stage.

WEPAB143 **Sub-MeV Ion Generation by Standing Wave Excitation of Ionized Gases**

***Sz. Turnár**, G. Almasi, J. Hebling, Cs. Korpa, M.I. Mechler, L. Pálfalvi, Z. Tibai (University of Péece)*

Many ion acceleration techniques have been suggested and thoroughly studied in the last two decades. One of the promising techniques is the Coulomb explosion acceleration (CEA). Using CEA in clusters could result in symmetric acceleration if there are not any other significant mechanisms. We proposed a THz-driven accelerator scheme that is based on CEA in proton, deuterium and heavy water gas plasmas. Two counter-propagating THz pulses are focused to the ionized region of the gas jet. Following the ripping of the electrons from the gas plasmas by ultrafast standing waves, the Coulomb explosion accelerates the positive ions. According to our calculation, using 2 x 34 mJ THz pulses electrons and protons with 1.1 nC charge are accelerated up to 0.4 MeV and 0.1 MeV, respectively. The total energy of the particles is 0.7 % of the energy of the THz pulses. We examined the effect of the initial bunch charge, bunch size and shape on the final energy spectra and the directional distribution of the particles. Our presented technique is scalable from a few μm to a few thousand μm driving wavelengths and can be used for electron and heavy-ion acceleration.

WEPAB144 **A New Flux Concentrator Made of Cu Alloy for the SuperKEKB Positron Source**

***Y. Enomoto**, K. Abe, N. Okada, T. Takatomi (KEK)*

Flux concentrator (FC) is one of important device for positron source which translates position and momentum spread of the particles adiabatically to match them to the acceptance of the following section. To realize higher positron yield, higher magnetic field is desired. However, higher field by higher current generate stronger force on the coil. Since the gap between each turn of the coil is as narrow as 0.2 mm and the voltage across them is about as high as 1 kV at the design current, slight deformation of the coil cause discharge between the gap. To avoid such problem, a new FC made of Cu alloy which has 40 times higher yield strength than that of pure Cu was designed and tested. Finally, during summer shutdown in 2020, the old FC made of pure Cu was replaced by the new one made of Cu alloy in the KEK electron positron injector linac. The new one has been working stably at the design current, 12 kA, since Oct. 2020, and positron yield of 0.5 was realized. There were no discharge and other trouble till now.

WEPAB145 **GaN:Cs Photocathode for SRF Guns**

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Magnesium bulk cathodes and caesium telluride cathodes work routinely in SRF Gun II at ELBE. However, the particle accelerator community is always looking for new materials which can promise higher

quantum efficiency, longer lifetime and good vacuum stability, fast response time and low thermal emittance. III-V semiconductor has been considered as a potential candidate for next generation photocathodes for SRF gun at HZDR. P-type GaN on different substrate material is activated by a thin layer of caesium and illuminated at the same time by ultra-violet light. As a consequence of a negative electron affinity and photo effect, the generated photoelectrons enter into vacuum and are collected by a copper ring anode. The resulting photocurrent is detected during the activation process and stopped when a maximum photocurrent is reached. Quantum efficiency can be calculated from the photocurrent and its decay is tracked in the following days after activation. By a comparison of differences in substrate material, chemical pre-cleaning, thermal heat treatment and activation parameters (e.g. caesium-flux), the photocurrent, quantum efficiency and its decay is studied.

WEPAB146 **Normalized Intrinsic Emittance of Cold Emission Cathodes**
***M. Voin**, L. Schächter (Technion)*
We establish the normalized intrinsic emittance for cold emission cathodes, associated with the energy and angular spread of the emitted particles directly on the surface of the emitter for a given local field applied. While in principle we are motivated primarily by carbon-nanotube (CNT) cathodes, our approach is applicable to any type of cold cathode. Its essence relies on the evaluation of the initial momentum as the particles tunnel through the Schottky-Nordheim barrier based on the spectral radiance function. Next, the momentum distribution is integrated over the geometry, providing, along with well known Fowler-Nordheim current, an integral expression for the emittance. According to our theoretical results and based on experimental data for CNT emitters available in the literature, we predict that practical cold emission cathodes may provide a normalized intrinsic emittance comparable or even superior to that of conventional photoemission cathodes used in state-of-the-art electron sources.

WEPAB147 **Simulations of Nanoblade-Enhanced Laser-Induced Cathode Emissions and Analyses of Yield, MTE, and Brightness**
***J.I. Mann**, G.E. Lawler, J.B. Rosenzweig (UCLA) T. Arias, J.K. Nangoi (Cornell University)*
Laser-induced field emission of electrons from metallic nanotips has been well studied. Unfortunately, nanotips suffer low damage thresholds with enhanced fields around 10 GV/m. The nanoblade, akin to a nanotip extruded in one lateral dimension, may reach upwards of 40 GV/m due to its robust thermomechanical properties. This increased surface field promises brighter electron emissions. We perform simulations of strong-field emissions from metallic nanoblades via the 1-D time-dependent Schr¨odinger equation with effective Jellium and nonlinear collective image charge potentials, including the strong field gradients induced by the nanostructure. We measure spectra and yields and compare to recent experiments. Potential analytical

forms of image potential limited yield for a spectrally rich emission are presented. Calculations of mean transverse energy are provided as well as a prospective method of mitigation with the goal of increasing brightness.

WEPAB148 **RF Design of an X-band TM02 Mode Cavity for Field Emitter Testing**

Z. Li, *S.G. Tantawi (SLAC) S.V. Baryshev, T. Posos, M.S. Schneider (Michigan State University)*

Planar polycrystalline synthetic diamond with nitrogen-doping/ incorporation was found to be a remarkable field emitter. It is capable of generating a high charge beam and handling moderate vacuum conditions. Integrating it with an efficient RF cavity could therefore provide a compact electron source for RF injectors. Understanding the performance metrics of the emitter in RF fields is essential toward developing such a device. We investigated a test setup of the field emitter at the X-band frequency. The setup included an X-band cavity operating at the TM02 mode. The field emitter material will be plated on the tip of a insertion rod on the cavity back plate. Part of the back plate and the emitter rod are demountable, allowing for exchange of the field emitters. The TM02 mode was chosen such that the design of the demountable back plate does not induce field enhancement at the installation gap. The cavity were optimized to achieve a high surface field at the emitter tip and a maximum energy gain of the emitted electrons at a given input power. We will present the RF and mechanical design of such a TM02 X-band cavity for field emitter testing.

WEPAB149 **The RF Gun for the Siberian Circular Light Source "SKIF"**

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The Siberian Circular Light Source is a new medium-energy high brightness synchrotron light facility that is under construction on the Budker Institute of Nuclear Physics (BINP) in Russia, Novosibirsk. The accelerator facility is divided for convenience into three components; a 3 GeV storage ring, a full-energy booster synchrotron, and a 200 MeV injector linac with a thermionic gridded RF gun electron source. This paper describes the RF gun design and plans for operations.

WEPAB150 **Monotron Beam Break Up Instability Analysis**

V. Volkov, *V.M. Petrov (BINP SB RAS)*

New features of monotron beam break up (BBU) instability such as the typing of high order monopole modes (HOMs)in each cavity by two classes one of them are stable and other ones are unstable, HOM effective quality factor depending on average beam current, and normalized invariable threshold current individually characterizes each HOM are investigated in this article in detail.

WEPAB151 **Regenerative Beam Break Up Instability Analysis**
***V. Volkov**, V.M. Petrov (BINP SB RAS)*
New features of regenerative beam break up (BBU) instability such as the typing of high order dipole modes (HOMs)in each cavity by two classes, one of them are stable and other ones are unstable, HOM effective quality factor depending on average beam current, and normalized invariable threshold current individually characterizes each HOM are investigated in this article in detail.

WEPAB152 **Carbon Nanotubes as Cold Electron Field Emitters for Electron Cooling in the CERN Extra Low Energy Antiproton (ELENA) Ring**
***B. Galante**, G. Tranquille (CERN) O. Apsimon, C.P. Welsch (The University of Liverpool) J. Resta-López (IFIC)*
In ELENA electron cooling reduces the emittance of the antiproton beam allowing to deliver a high-quality beam to the experiments at the unprecedented low energy of 100 keV. To cool the antiproton beam at this low energy, the electron gun must emit electrons with as monoenergetic a distribution as possible. The currently used thermionic gun limits the cooling performance due to the relatively high transverse energy spread of the emitted electrons. Optimization is therefore being studied, aiming at developing a cold-cathode electron gun. This has led to the investigation of carbon nanotubes (CNTs) as cold electron field emitters. CNTs are considered the most promising field emitter material due to their high aspect ratio, chemical stability, and capability to deliver high current densities. To assess the feasibility of using such material operationally a full characterization is required, focussing on key parameters such as emitted current, emission stability, and lifetime. This contribution will present the status of ongoing experiments reporting on the conditioning process necessary to reach good stability over time and the emitting performance of different CNT arrays.

WEPAB153 **Temporally Shaped Ultraviolet Pulses for Tailored Bunch Generation in Wakefield Accelerators**
***T. Xu**, P. Piot (Northern Illinois University) S. Carbajo, R.A. Lemons (SLAC) P. Piot (ANL)*
Photocathode laser shaping is an appealing technique to generate tailored electron bunches due to its versatility and simplicity. Most photocathodes require photon energies exceeding the nominal photon energy produced by the lasing medium. A common setup consists of an infrared (IR) laser system with a 3ω frequency conversion to the ultraviolet (UV). In this paper, we present the numerical modeling of a temporal shaping technique capable of producing electron bunches with linearly-ramped current profiles for application to wakefield accelerators. Specifically, we show that controlling higher-order dispersion terms associated with the IR pulse provides some control over the UV temporal shape expanding on the technique. Possible experimental configurations are discussed and beam-dynamics simulation

of an electron-bunch shaping experiment at the Argonne Wakefield Accelerator described.

WEPAB154 **Low Emittance Electron Injector for Linear Colliders**

T. Xu, *P. Piot (Northern Illinois University) M. Kuriki (KEK) M. Kuriki (Hiroshima University, Graduate School of Science) P. Piot, J.G. Power (ANL)*

Two decades ago, the round-to-flat beam transform was proposed by Brinkmann *et al.* as a method to generate flat beams for linear colliders. Their studies demonstrated the scheme could produce a vertical emittance comparable to the ones achievable in, e.g., the ILC damping ring, albeit at a lower bunch charge. In this contribution, we further explore this method by combing a flat-beam transform with a transverse-to-longitudinal emittance-exchange beamline. We demonstrate that, with a spatio-temporally shaped electron bunch, one can achieve a low transverse emittance comparable with the current International Linear Collider design at the design charged of 3.2nC.

WEPAB155 **Generation and Transport of High Charge Magnetized Beams**

T. Xu, *P. Piot (Northern Illinois University) P. Piot (ANL)*

High charge magnetized beams have important implications in high-energy electron cooling. Magnetized beams are usually generated by immersing the cathode in a magnetic field and transported with rotation-invariant elements in the injector section. At higher energy, however, uncoupled elements like conventional dipole and quadrupoles are usually required. In this paper, we describe a method of transporting magnetized beam using round-to-flat and flat-to-round beam transform. A start-to-end simulation of the generation and transport of magnetized beam is described and a possible experiment at the Argonne Wakefield Accelerator is discussed.

WEPAB156 **Progress Towards Arbitrary Emittance Repartition in the 6D Phase Space**

T. Xu, *P. Piot (Northern Illinois University) G. Ha, P. Piot, J.G. Power, J.H. Shao, E.E. Wisniewski (ANL)*

A proof-of-principle experiment to demonstrate emittance repartitioning between the three degrees of freedom is currently in preparation at the Argonne Wakefield Accelerator. Beams with variable transverse emittance partition will be produced using a round-to-flat beam transform technique. A subsequent emittance exchange (EEX) beamline will then exchange the horizontal emittance with the longitudinal one, enabling full control over the emittance repartition within the 6D phase space. In this contribution, we report on the experimental generation of flat beams with adjustable emittance ratios. Additionally, start-to-end simulations of this repartitioning scheme are presented, and the expected performances are discussed.

WEPAB157 **Understanding the Growth Dynamics Cs-Sb Thin Films via In-Situ Characterization Techniques: Towards Epitaxial Alkali Antimonide Photocathodes**

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Alkali antimonide photocathodes, such as Cs3Sb, have attractive properties, such as low emittance and high quantum efficiency, which makes them excellent candidates for next-generation high-brightness electron sources. A large number of studies in literature focus on quantum efficiency and lifetime, and fewer report chemical and structural analysis, despite the latter ultimately determine the brightness at the photocathode. Epitaxial, single-crystalline films would allow to study the intrinsic properties of alkali antimonide photocathodes and to optimize them for maximum brightness, but this goal remains elusive. A strong limiting factor is the extreme air sensitivity, preventing ex-situ structural and chemical analysis. We report a study on the growth of Cs-Sb films via molecular beam epitaxy with reflection high-energy electron diffraction to monitor the growth in real time. The samples were characterized via in-situ ultraviolet photoelectron spectroscopy, x-ray photoelectron spectroscopy and scanning tunneling microscopy. Cs3Sb and CsSb phases can be stabilized on appropriate single crystal substrates, with the latter reproducibly resulting in atomically smooth surfaces.

WEPAB158 **Compact Terahertz-Powered Electron Photo-Gun**

***T. Kroh**, H. Cankaya, U. Demirbas, M. Fakhari, N.H. Matlis, M. Pergament, T. Rohwer (CFEL) R.W. Aßmann, H. Dinter, M.J. Kellermeier (DESY) M. Hemmer, F.X. Kärtner (Deutsches Elektronen Synchrotron (DESY) and Center for Free Electron Science (CFEL)) F.X. Kärtner (The Hamburg Center for Ultrafast Imaging, University of Hamburg)*

Novel accelerator concepts such as all-optical THz based compact accelerators promise to enable new science due to unique features such as reduced timing-jitter and improved space-charge broadening of the generated electron bunches. However, multi-keV electron photo-guns based on short single-cycle THz pulses for acceleration have not been demonstrated experimentally so far. Here, we present a modular THz-driven electron gun with both tunable interaction length and output orifice allowing optimization of the sub-mm interaction volume. First extraction of multi-keV electrons is demonstrated and the parameter space as well as resulting performance of the THz-driven gun by varying the timing of the two single-cycle THz pulses and the UV photo-excitation pulse are explored. Such compact gun prototypes are not only promising as injectors for compact THz-based LINACs but also as source for ultrafast electron diffraction experiments.

WEPAB159 **Fast Image Processing of Field Emission Micrographs**
***T. Posos**, S.V. Baryshev, M.S. Schneider (Michigan State University) O. Chubenko (Arizona State University) E. Jevarjian (MSU) J.H. Shao (ANL)*
Spatially resolving electron emission from field emission cathode surface is a crucial step to characterize and quantify emission uniformity and emission area, and therefore, beam brightness and current density. It is especially important for mm-wave/terahertz sources for which narrow beam is a must, or for miniaturized field emission devices where high current density is required. It is also important to compare theoretical and experimental results that can only be connected through using the electric field and current density. With these intentions, we developed a method which computes emission area given field emission micrographs in dc environment or number of active emission sites in rf environment. The algorithm produces fast and reliable results even if there is strong background glow. We processed micrographs of carbon nanotubes (CNTs) fiber cathodes under dc field and ultrananocrystalline diamond (UNCD) under rf field. Obtained results demonstrate deficiency of using Fowler-Nordheim (FN) law to describe non-metal emitters but, at the same time, allow to propose new hypotheses to overcome the existing deficiencies.

WEPAB160 **Optimizing Polarized Electron Source Using Machine Learning**
***S. Zhang** (JLab)*
Intense polarized electron beams have played a crucial role in the success of many high-energy and nuclear physics research and continue to be imperative tools required by future physics programs. In the meantime, the extremely challenging requirement set by some physics programs upon the polarized electron beams may be beyond what can be achieved by state-of-the-art techniques. In this paper, we propose and discuss possible approaches based on the Machine-Leaning technique to enhance the performance of polarized electron sources through fast and precise parameter control and optimization. We will provide some innovative considerations based on experience with the existing systems that could help the ongoing physics experiments and the design of future machines such as the Electron-ion Collider (EIC).

WEPAB161 **Photocathodes and Lasers for Generation of Multi-nC Polarized Electron Bunches**
***S. Zhang** (JLab)*
The electron-ion collider (EIC) imposes stringent requirements on its polarized electron beams, with 7nC of bunch charge and 85% polarization out of a high voltage (HV) DC gun and 400 MeV energy from the pre-injector. While similar bunch specifications were attempted for ILS at SLAC in the past, there are new opportunities for a much better design and performance as a result of the research and development in both photocathodes and lasers. This paper will present an analysis and discussion about technical changeless facing the EIC electron source and the possible approaches to generating the required elec-

tron bunches.

WEPAB162 **Improved Analytical Models for Photocathode Intrinsic Emittance**

T. Vecchione *(SLAC)*

Photocathodes are widely used in accelerator applications. This work derives new expressions for photocathode intrinsic emittance, a common performance metric, and validates the expressions by using them to fit published experimental data.

WEPAB163 **An X-Band Ultra-High Gradient Photoinjector**

S.V. Kuzikov*, S.P. Antipov, P.V. Avrakhov, E. Dosov, C.-J. Jing, E.W. Knight (Euclid TechLabs, LLC) G. Ha, G. Ha, C.-J. Jing, W. Liu, W. Liu, P. Piot, J.G. Power, J.G. Power, D.S. Scott, J.H. Shao, J.H. Shao, E.E. Wisniewski (ANL) C.-J. Jing (Euclid Beamlabs LLC) X. Lu (MIT/PSFC) X. Lu (SLAC) P. Piot (Fermilab) P. Piot, W.H. Tan (Northern Illinois University) E.E. Wisniewski (IIT)*

High brightness beams appealing for XFELs and UEM essentially imply a high current and a low emittance. To obtain such beams we propose to raise the accelerating voltage in the gun mitigating repealing Coulomb forces. An ultra-high gradient is achieved utilizing a short-pulse technology. We have designed a room temperature X-band 1,5 cell gun that is able to inject 4 MeV, 100 pC bunches with as low as 0.15 mcm normalized transverse emittance. The gun is operated with as high gradients as 400 MV/m and fed by 200 MW, 10 ns RF pulses generated with Argonne Wakefield Accelerator (AWA) power extractor. We report results of low RF power tests, laser alignment test results, and successful gun conditioning results carried out at nominal RF power.

WEPAB164 **Electrodeless Diamond Beam Halo Monitor**

S.V. Kuzikov*, S.P. Antipov, P.V. Avrakhov, E. Dosov, E.W. Knight (Euclid TechLabs, LLC) J.G. Power, J. Shao (ANL)*

Beam halo measurement is important for novel x-ray free-electron lasers which have remarkably high repetition rate and average power. We propose diamond as a radiation hard material that can be used to measure the flux of passing particles based on a particle-induced conductivity effect. Our diamond electrodeless monitor is based on a microwave measurement of the change in the resonator coupling and eigenfrequency. For measurements, we put a sensitive diamond sample in a resonator that intercepts the halo. By measuring the change in RF properties of the resonator, one can infer the beam halo parameters scanning across the beam to map its transverse distribution. In recent experiments we used a Vertical Beam Test Stand (VBS), delivered DC electron beam of the 20-200 keV energy with the current up to 50 μA, to characterize several diamond samples. We have designed and fabricated a scanning diamond monitor, based on an X-band resonator, which was tested at Argonne Wakefield Accelerator (AWA) with a multi-MeV electron beam.

WEPAB165 **Metamaterial Waveguide HOM Loads for SRF Accelerating Cavities**

S.V. Kuzikov *(Euclid TechLabs, LLC)*

Suppression of beam induced HOMs is necessary for most SRF accelerating cavities driven with high currents. One of the problems in design of a HOM load is that vacuum compatible materials with high enough imaginary part of the dielectric permittivity, which provides absorption, have also a high real part of the permittivity. This does not allow absorbing RF radiation at short distance and in broad frequency band. We propose considering artificial metamaterials where besides lossy dielectric pieces, an absorber with high magnetic permeability is included. In our proposal, we suggest composing a waveguide HOM load of a metamaterial consisted of well-known ceramic and ferrite plates placed periodically in a stack. Such a design provides low return losses, compactness and broad frequency range of the operation.

WEPAB166 **Concept of an Accelerator-Driven Neutron Source for the Production of Atmospheric Radiations**

P. Lee*, N.-W. Kang (Korea Atomic Energy Research Institute (KAERI)) M. Moon (KAERI)*

At the Korea Multi-purpose Accelerator Complex (KOMAC) of Korea Atomic Energy Research Institute (KAERI), we are studying an accelerator-driven neutron source for the production of white neutron beams that resemble the atmospheric radiations on the earth. In the concept of the neutron source, high-energy neutrons are generated by using a 200-MeV proton beam on a heavy-metal target in a target station, which is consisted of a target, moderator, reflector, and biological shields, and a part of the high-energy neutrons are guided in a forward direction to make neutron beams with the atmospheric-like energy spectrum. The conceptual design has 6 more thermal-neutron beamlines at the separation of 30 degrees for the fundamental research on neutron science. Here, we present the concepts of the target station and basic parameters regarding the neutron source.

WEPAB167 **Research of the Low Energy Beam Transport Line for Deuterium Ion Beam**

Q. Zhang *(INEST)*

An intense deuterium source, a low energy beam transport line (LEBT) and an accelerating tube have been developed for the DT neutron generator. The LEBT contains two solenoids and three drift sections, which transports a deuterium beam with 45 mA and 60 keV to the entrance of an accelerating tube at continuous-wave operation mode. Between the different accelerator sections, beam matching is one of the key methods for reducing beam losses and emittance growth. Therefore, this paper will study the optimum beam matching and reduce the beam losses and emittance growth in the theory and simulation. The results shows that optimizing the magnetic field of the solenoid lens can reduce the beam losses and enhance the beam quality at the entrance of the acceleration tube.

WEPAB168 **Beam Dynamics Simulation Code For Electrostatic Accelerator Based On PIC/MC Method**

Q. Zhang *(INEST)*

The increase of beam emittance due to the nonlinear space charge effect, the beam halo and the aberration caused by the applied electromagnetic field are all the frontier research topics of the high-current and low-energy accelerators, which are the key factors for beam loss control and high beam power achieved. In this paper, a three-dimensional electromagnetic particle-in-cell with Monte Carlo (PIC/MC) code is developed for the studying the beam optics. The code is applied to the electrostatic accelerator design. The simulation result is validated by TRACK and BEAMPATH, the results given by three codes are basically accordant with each other.

WEPAB169 **Towards Ultra-Smooth Alkali Antimonide Photocathode Epitaxy**

E.J. Montgomery *(Private Address) O. Chubenko, G.S. Gevorkyan, S.S. Karkare, P. Saha (Arizona State University) R.G. Hennig, J.T. Paul (University of Florida) C. Jing, S. Poddar (Euclid Beamlabs LLC) H.A. Padmore (LBNL)*

Photocathodes lead in brightness among electron emitters, but transverse momenta are unavoidably nonzero. Ultra-low transverse emittance would enable brighter, higher energy x-ray free-electron lasers (FEL), improved colliders, and more coherent, detailed ultrafast electron diffraction/microscopy (UED/UEM). Although high quantum efficiency (QE) is desired to avoid laser-induced nonlinearities, the state-of-the-art is 100 pC bunches from copper, 0.4 mm-mrad emittance. Advances towards 0.1 mm-mrad require ultra-low emittance, high QE, cryo-compatible materials. We report efforts towards epitaxial growth of cesium antimonide on lattice matched substrates. DFT calculations were performed to downselect from a list of candidate lattice matches. Co-evaporations achieving >3% QE at 532 nm followed by atomic force and Kelvin probe microscopy (AFM and KPFM) show ultra-low 313 pm rms (root mean square) physical and 2.65 mV rms chemical roughness. We simulate roughness-induced mean transverse energy (MTE) to predict <1 meV from roughness effects at 10 MV/m in as-grown optically thick cathodes, promising low emittance via epitaxial growth.

WEPAB171 **Feasibility Studies of Alkali Antimonide Photocathode Encapsulation Using RF Sputtering**

A. Liu *(Euclid TechLabs, LLC) M. Gaowei, E. Wang (BNL) S. Poddar (Euclid Beamlabs LLC)*

Alkali antimonide photocathodes are commonly used in high brightness photoinjectors because of their ultra-high quantum efficiency and relatively low requirements for growth. The biggest challenge of using the alkali antimonide photocathode is that it has an extremely stringent requirement on the vacuum. Consequently, the transportation of these photocathodes is eminently difficult. Furthermore, the photocathode lifetime is limited by the residual gas in the photoinjec-

tor. An efficient encapsulation can avoid damage to the photocathode in a poor vacuum and preserve lifetime. Euclid collaborates with BNL to encapsulate the photocathodes with thin-film coatings through RF sputtering, which can be easily configured to work with various facilities and produce photocathodes that are robust against poor vacuum. We are also developing a laser oscillator deposition enhancement system (LODES) to improve the coating without damaging the substrates. Results in the first stage of the project are presented, including density functional theory simulations, experimental results of our first BN coating results, preliminary photocurrent measurements of BN coated Cu (111) coupons, and so forth.

WEPAB172 **Recent Developments of the IDEAS-Halo Detector**
***A. Liu**, Y. Zhao (Euclid TechLabs, LLC) J.H. Shao (ANL)*
Euclid Techlabs has been designing and testing a cost-effective iris diaphragm beam halo/profile detector, which can be easily configured to work with various primary beam energies and sites. Besides working as a measurement device, it can also work as a controllable beam scraper/collimator. This novel iris diaphragm detector utilizes the current signal produced by the beam charge deposition on the moveable conductive iris blades, to accurately measure the beam distribution from the outlier to the beam core. In this paper, we discuss the recent developments of our iris diaphragm e-beam apparatus series (IDEAS)-halo detector, including its geometry upgrades and newest beam experiments done at the AWA cathode testbed (ACT) of Argonne National Laboratory.

WEPAB173 **Emissivity Enhancement and Protection of Tungsten for Production Targets Through Thin-Film Coatings**
***A. Liu**, B.T. Freemire, E.W. Knight (Euclid TechLabs, LLC) S. Poddar (Euclid Beamlabs LLC) D. Pushka (Fermilab)*
High energy physics experiments that are based on secondary particles produced by protons on target (POT) bombardment require careful, efficient cooling designs. High-temperature production targets suffer from creep deformation, oxidation, and delamination issues even in a vacuum environment, which significantly reduces the target lifetime. Some experiments rely on passive cooling through radiative heat transfer from the target to its surroundings, in order to avoid safety hazards introduced by active cooling. However, the emissivity, which describes an object's ability to radiate power, is generally very low for metals, for example Tungsten. This renders high beam power operations with untreated metal targets less practical. Euclid Techlabs, LLC has been testing and characterizing various materials for thin-film depositions for increasing the substrate emissivity and protecting it from oxidation. In this paper, we will present out latest work done on the thin-film coatings of Tungsten coupons and their enhanced properties, such as higher emissivity and higher tolerance against oxidation.

WEPAB174 **Study of the Electron Seeded Proton Self-Modulation Using FBPIC**

L. Liang, *G.X. Xia (The University of Manchester) A. Bonatto (Universidade Federal de CiÃªncias da SaÃºde de Porto Alegre)* ***L. Liang***, *G.X. Xia (Cockcroft Institute)*

In order to make a full use of the whole proton bunch to drive large amplitude plasma wakefields and suppress the uncontrolled growth of any possible instabilities at the head of the proton bunch, the AWAKE Run 2 experiment plans to use an electron bunch to seed the formation of the proton bunch self-modulation. Additionally, a density step in the plasma channel will be used to freeze the selfmodulation process to keep the wakefield amplitude. In this work, numerical simulations performed with FBPIC are used to investigate the electron seeded proton self-modulation and the effect of the plasma density step as well.

WEPAB175 **Simulation Study of Electron Beam Acceleration With Non-Gaussian Transverse Profile for AWAKE Run 2**

L. Liang, *G.X. Xia (The University of Manchester) J.P. Farmer (MPI-P)* ***L. Liang***, *G.X. Xia (Cockcroft Institute)*

In the physics plan for AWAKE Run 2, two known effects, beam loading the longitudinal wakefield and beam matching to the pure plasma ion channel, will be implemented for the better control of electron acceleration. It is founded in our study of beam matching that the transverse profile of the initial witness beam have a significant impact on its acceleration quality. In this paper, particle-in-cell (PIC) simulations are used to study factors that affect the acceleration quality of electron beams with different transverse profiles.

WEPAB176 **Beams of He^+ Acceleration by Heavy Ion Linear Accelerator and Injection Into Booster of NICA Project During Its First Run**

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Heavy Ion Linear Accelerator (HILAC) is designed to accelerate the heavy ions with ratio A/Z<=6.25 produced by ESIS ion source up to the 3.2 MeV for the injection into superconducting synchrotron (SC) Booster. HILAC was commissioned in 2018 using the carbon beams from Laser Ion Source (LIS). The project output energy was verified. Transmission could be estimated only for DTL structure because of the presence at the RFQ input the mixture of ions with different charge states extracted from laser-plasma. To estimate transmission through the whole linac the ion source producing the only species He^+ was designed. The beams of He^+ ions were used for the first run of SC Booster. The design of the helium ion source and results of the He^+ beam acceleration and injection are described.

WEPAB177 **Consideration of Triple-Harmonic Operation for the J-PARC RCS**

H. Okita *(JAEA/J-PARC) M. Furusawa, Y. Sugiyama (KEK) K. Hara, K. Hasegawa, M. Nomura, C. Ohmori, T. Shimada, F. Tamura, M. Yamamoto, M. Yoshii (KEK/JAEA)*

The wideband magnetic alloy (MA) cavities are employed in the J-PARC RCS. The dual-harmonic operation, in which each MA cavity is driven by superposition of the fundamental accelerating voltage and the second harmonic voltage, significantly improves the bunching factor and is indispensable for acceleration of the high intensity beams. The original LLRF control system was replaced with the new system in 2019, which can control the amplitudes of the higher harmonics as well as the fundamental and second harmonics. Therefore we consider to use additionally the third harmonic voltage for further improvement of the bunching factor during acceleration. By the triple-harmonic operation, the flat RF bucket can be realized with a higher synchronous phase and improvement of the bunching factor is expected. In this presentation, we describe the longitudinal simulation studies of the triple-harmonic operation. Also the preliminary test results are presented.

WEPAB178 **Non-Adiabatic Longitudinal Bunch Manipulation at Flattop of the J-PARC MR**

F. Tamura *(JAEA/J-PARC) C. Ohmori, Y. Sugiyama, M. Yoshii (KEK)*

The J-PARC MR delivers the high-intensity proton beams for the neutrino experiment. Eight bunches of high peak current are extracted by the extraction kickers, therefore the neutrino beam has a similar time structure. The new Intermediate Water Cherenkov Detector (IWCD) will be constructed for the future neutrino experiment and a low peak time structure is desired by the IWCD. Thus, we consider bunch manipulation at flattop of the MR for reducing the peak current. The manipulation requires a longer repetition period to extend the flattop. This reduces the output beam power. The manipulation should be quickly done to minimize the loss of the beam power. Also, the beam gap must be kept for the rise time of the extraction kicker. We propose a non-adiabatic bunch manipulation using the multiharmonic rf voltage. By using the neighbor harmonic of the accelerating harmonic, the first and eighth bunches can be decelerated and accelerated, respectively. After a certain period, the rf phase is flipped to pi for debunching. Thanks to the initial deceleration and acceleration, the beam gap for the kickers is kept. We present the concept and the longitudinal simulation result.

WEPAB179 **Recent status of J-PARC Rapid Cycling Synchrotron**

K. Yamamoto *(JAEA/J-PARC)*

The 3 GeV rapid cycling synchrotron (RCS) at the Ja-pan Proton Accelerator Research Complex (J-PARC) provides more than 500 kW beams to the Material and Life Science Facility (MLF) and Main Ring (MR). In

such a high-intensity hadron accelerator, even losing less than 0.1% of the beam can cause many problems. Such lost protons can cause serious radio-activation and accelerator component malfunctions. Therefore, we have been continuing a beam study to achieve high-power operation. In addition, we have also improved and maintained the accelerator components to enable stable operation. This paper reports the status of the J-PARC RCS over the last two years.

WEPAB180 **Design and Beam Dynamics Studies of a Novel Compact Recoil Separator Ring for Nuclear Research with Radioactive Beams**
J. Resta-López *(UVEG) A.P. Foussat, G. Kirby (CERN) I. Martel (University of Huelva) V. Rodin (The University of Liverpool) V. Rodin (Cockcroft Institute)*
The recent development of radioactive beam facilities has significantly expanded the capabilities for investigating the structure of the atomic nucleus and the nuclear interaction. For instance, the HIE-ISOLDE facility at CERN delivers presently the largest range of low-energy radioactive beam available worldwide. This energy range is ideal for the study of nuclear structure, low-energy dynamics and astrophysics by using nucleon transfer, Coulomb excitation and deep inelastic reactions. All these studies require an efficient and high-resolution recoil separator for the clear identification of medium and large mass reaction fragments. To meet these needs, we propose a versatile recoil separator for radioisotopes based on a compact storage ring, the Isolde Superconducting Recoil Separator (ISRS) formed of superconducting combined-function nested magnets with both, bending and focusing/defocusing functions. The ISRS is designed to operate in high momentum acceptance and isochronous modes. In this paper, we present the optics design and detailed beam dynamics studies for the performance characterisation.

WEPAB181 **New Opportunities in Low Energy Antiproton Research**
C.P. Welsch *(Cockcroft Institute)* ***C.P. Welsch*** *(The University of Liverpool)*
Experiments with low-energy antiprotons are at the cutting edge of science and offer unique opportunities to test some of the fundamental laws of physics. The experiments are, however, very difficult to realize. They critically depend on high-performance numerical tools that can model realistic beam transport and storage and also require advanced beam monitors and detectors that can fully characterize the beam. Finally, novel experiments need to be designed that exploit the enhanced beam quality that the new ELENA ring at CERN provides. This paper presents some selected findings from the pan-European AVA network's three scientific work packages. It shows results from studies into electron cooling at the new ELENA storage ring, research into carbon nanotubes as cold electron field emitters for electron cooling, and how antiproton-atom collision experiments can be optimized using GEANT4. Finally, the paper gives an overview of the network's interdisciplinary training program.

WEPAB183 **Big Data Techniques for Accelerator Optimization**
C.P. Welsch *(The University of Liverpool)* ***C.P. Welsch*** *(Cockcroft Institute)*
Accelerators and the experiments that they enable are some of the largest, most data-intensive, and most complex scientific systems in existence. The interrelations between machine subsystems are complicated and often nonlinear. The system dynamics involve large parameter spaces that evolve over multiple relevant time scales and accelerator systems. Any accelerator-based experiments and applications are almost always difficult to model. LIV. DAT, the Liverpool Centre for Doctoral Training in Data-intensive science, was established in 2017 as a hub for training students in Big Data science. The centre currently has 36 PhD students that are working across nuclear, particle and astrophysics, as well as in accelerator science. This paper presents results from R&D into betatron radiation models and beam parameter reconstruction for plasma acceleration experiments at FACET-II, simulations for MeV energy gain in dielectric structures driven by a CO_2 laser, and modelling of seeded self-modulation of long elliptical bunches in plasma. It also gives an overview of the training program offered to the LIV. DAT students.

WEPAB184 **Optimization of Medical Accelerators**
C.P. Welsch *(The University of Liverpool)* ***C.P. Welsch*** *(Cockcroft Institute)*
Between 2016 and 2020, 15 Fellows have carried out collaborative research within the 4 MEUR Optimization of Medical Accelerators (OMA) EU-funded innovative training network. Based at universities, research and clinical facilities, as well as industry partners in several European countries, the Fellows have successfully developed a range of beam and patient imaging techniques, improved biological and physical models in Monte Carlo codes, and also help improve the design of existing and future clinical facilities. This paper gives an overview of the research outcomes of this network. It presents results from tracking and LET measurements with the MiniPIX-TimePIX detector for 60 MeV clinical protons, a new treatment planning approach accounting for prompt gamma range verification and interfractional anatomical changes, and summarizes findings from high-gradient testing of an S-band, normal-conducting low phase velocity accelerating structure. Finally, it gives a brief over-view of the scientific and training events organized by the OMA consortium.

WEPAB185 **Target Bypass Beam Optics for Future High Intensity Fixed Target Experiments in the CERN North Area**
G.L. D'Alessandro*, D. Banerjee, J. Bernhard, M. Brugger, N. Doble, L. Gatignon, A. Gerbershagen, B. Rae, F.M. Velotti (CERN) S.M. Gibson (JAI)*
Several of the proposed experiments for operation at the K12 beam line would profit from significant beam intensity increase. Among those, there is the KLEVER experiment that would require an intensity

of 2x10^{13} protons per 4.8 s long spill. The main goal of the experiment is to measure BR(KL->pi0 nu nu) to test the Standard Model structure by itself, and in combination with results from NA62 for BR(K±>pi+ nu nu). NA62 could also profit from higher intensities, and could be run in a new configuration called NA62HI(gher intensity). In the current configuration the beam is transported from the SPS to the TT24 beamline. This beamline leads to the T4 target that attenuates the beam for P42. After T4 the beam is directed into the P42 beamline before impinging on the T10 target and creating the particles necessary for the experiment. Those are finally transported to the detector via K12. This paper presents the idea of partially bypassing T4 and changing the P42 beamline configuration in order to have a sufficiently small beam size at the T10 target for both KLEVER and NA62-HI. Optics studies are developed in MADX and the AppLE.py, software developed at CERN.

WEPAB186 **Studies for the K12 High-Intensity Kaon Beam at CERN**

***G.L. D'Alessandro**, D. Banerjee, J. Bernhard, M. Brugger, N. Doble, L. Gatignon, A. Gerbershagen, B. Rae, S. Schuchmann, F.W. Stummer, M.W.U. Van Dijk (CERN) S.T. Boogert, S.M. Gibson, L.J. Nevay (JAI)*

The NA62 experiment is a fixed target experiment located in the North Area of CERN and has as main goal the measurement of the branching ratio of the rare decay K±>pi+vv. The primary proton beam from the SPS accelerator interacts with the T10 beryllium target and the generated 75 GeV/c secondary particles, containing about 6% of positive kaons, are transported by the K12 beamline to the NA62 experiment. Studies in this paper present detailed simulations of the K12 beamline developed in both FLUKA and BDSIM codes, which reproduce the current configuration of K12 for the NA62 experiment. The beam optics parameters of K12 are studied in BDSIM and compared to MADX optics and tracking calculations. The models in FLUKA and BDSIM are used for beam studies and muon production at various locations along the beamline, and the parameters obtained from simulations are benchmarked against data recorded by the experiment. The impact of the Cherenkov kaon tagging detector (CEDAR) on the beam quality is calculated for two different gas compositions in view of a possible upgrade of the detector.

WEPAB187 **The ENUBET Multi Momentum Secondary Beamline Design**

***E.G. Parozzi**, N. Charitonidis (CERN) G. Brunetti, **E.G. Parozzi**, F. Terranova (Universita Milano Bicocca) A. Longhin, M. Pari, F. Pupilli (INFN- Sez. di Padova) A. Longhin, M. Pari (Univ. degli Studi di Padova) **E.G. Parozzi**, F. Terranova (INFN MIB)*

The aim of neutrino physics for the next decades is to detect effects due to CP violation, mass hierarchy, and search for effects beyond the Standard Model predictions. Future experiments need precise measurements of the neutrino interaction cross-sections at the ~GeV/c regime, currently limited by the exact knowledge of the initial neutrino flux on a ~10-20% uncertainty level. The ENUBET project is propos-

ing a novel facility, capable of constraining the neutrino flux normalization through the precise monitoring of the Ke3 (K±>e+pi0nu) decay products in an instrumented decay tunnel. ENUBET can also monitor muons from the two body kaon and pion decays (nu flux) and measure the neutrino energy with a 10% precision without relying on the event reconstruction at the neutrino detector. We present here a novel design based on a broad (4-8.5 GeV/c) momentum range secondary beamline, that widen the cross-section energy range that can be explored by ENUBET. In this poster, we discuss the target optimization studies and we show the early results on the new line's optics and the layout design. We discuss the expected performance of this line and the forthcoming activities.

WEPAB188 **New Method to Search for Axion-Like Particles Demonstrated With Polarized Beam at the COSY Storage Ring**
S. Karanth *(Jagiellonian University)*
The axion was originally proposed to explain the small size of CP violation in quantum chromodynamics. It might be a candidate for dark matter in the universe. Axions or axion-like particles (ALPs) when coupled to gluons induce an oscillating Electric Dipole Moment (EDM) along the nucleon's spin direction. At the Cooler Synchrotron (COSY) in Jülich, this principle was used to perform a first test experiment to search for ALPs using an in-plane polarized deuteron beam. If the spin precession frequency equals the EDM oscillation frequency, a resonance occurs that accumulates the rotation of the polarization out of the ring plane. Since the axion frequency is unknown, the beam momentum was ramped to search for a vertical polarization jump that would occur when the resonance is crossed. At COSY, four beam bunches with different polarization directions were used to make sure that no resonance was missed because of the unknown relative phase between the polarization precession and the EDM oscillations. We scanned a frequency window of about a 1-kHz width around the spin precession frequency of 121 kHz. This talk will describe the experiment and show preliminary results.

WEPAB189 **EIC Hadron Storage Ring Beamline Vacuum Studies**
D. Weiss*, M. Mapes, J.E. Tuozzolo, S. Verdú-Andrés (BNL)*
Ninety percent of the EIC hadron ring beamline is cold-bore comprising strings of interconnected 4.55 K RHIC superconducting (SC) magnets. The EIC operating specification requires shorter bunches and 3x higher intensity beams which are not appropriate for the present RHIC stainless steel cold-bore beam tube. The intensity and emittance of the hadron beams will degrade due to interactions with residual gas or vacuum instabilities arising from the expected resistive-wall (RW) heating, electron clouds, and beam-induced desorption mechanisms. Without strategies to limit RW heating, major cryogenic system modifications are needed to prevent SC magnet quenches. The SC magnet cold-bore beam tubes will be equipped with a high RRR copper clad stainless steel sleeve to significantly reduce RW heating and so

the effect on the SC magnet cryogenic heat load and temperature. A thin amorphous carbon film applied to the beam facing copper surface will suppress electron cloud formation. This paper discusses the vacuum requirements imposed by the EIC hadron beams and the plans to achieve the necessary vacuum and thermal stability that ensure acceptable beam quality and lifetime.

WEPAB190 **DC Break Design for a 2.45 GHz ECR Ion Source**
***M.S. Dmitriyev**, M.V. Dyakonov, S.A. Tumanov, M.I. Zhigailova (MEPhI)*
New 2.45 GHz Electron Cyclotron Resonance Ion Source (ECRIS) is under development at NRNU MEPhI. The transmission line is designed for transmitting the microwave power into the ECRIS. A DC break up to 80 kV was designed for the electrical insulation between the microwave supply system and the plasma chamber applied to high DC voltage. Current study considers the investigation results as well as the optimization of numerical simulations of the 2.45 GHz DC break with low losses and low emission into the surrounding space.

WEPAB191 **Magnet System for a Proton/helium ECR Ion Source**
***M.S. Dmitriyev**, K.G. Artamonov, M.V. Dyakonov, M.I. Zhigailova (MEPhI)*
The study of the magnetic system of ECRIS with operating frequency of 2.45 GHz for producing protons and double-charged helium ions has been carried out. The results of the numerical simulation of the ECRIS magnetic system based on permanent magnets have been performed. The possibility of shifting the ring magnets in both injection and extraction regions is considered to adjust maximum and minimum values of the axial distribution of a magnetic field in a plasma chamber. The possibility of shifting the bar magnets of the hexapole is shown to provide the adjustment of the radial magnetic field Brad at the chamber wall. Additional solenoids are introduced to the system for providing the required Binj and Bext adjustment and tuning the axial magnetic field distribution including the minimum on the axis Bmin. Furthermore, the magnetic system allows to switch the operation mode of the ECR source to the microwave mode.

WEPAB192 **Simulation Study on Double Diffuser for Loss Reduction in Slow Extraction at J-PARC Main Ring**
***R. Muto**, Y. Arakaki, T. Kimura, S. Murasugi, K. Okamura, Y. Shirakabe, M. Tomizawa, E. Yanaoka (KEK) A. Matsumura (Nihon Advanced Technology Co., Ltd)*
J-PARC (Japan Proton Accelerator Research Complex) Main Ring delivers slow-extracted 30 GeV proton beam to various nuclear and particle physics experiments. In the slow extraction the beam loss at the electrostatic septum (ESS) is inevitable, and the beam loss reduction is a key issue to realize the high-intensity beam delivery. We carried out simulation studies on the effectiveness of the beam diffusers at the upstream of the ESS for the beam loss reduction with various materials and dimensions of the diffusers. We found out that putting two

diffusers simultaneously on the beam was effective for the beam loss reduction, and the expected beam loss was 0.35 times as high as the operation without diffusers. According to the simulation results we installed the diffusers in the J-PARC Main Ring. We performed beam test with one diffuser and beam loss reduction of 60% was observed, which was in good agreement with the simulation results.

WEPAB193 **Optimization of the Hadron Ring Stripline Injection Kicker for the EIC**

***M.P. Sangroula**, C.J. Liaw, C. Liu, N. Tsoupas, B.P. Xiao, W. Zhang (BNL) X. Sun (ANL) S. Verdú-Andrés (Brookhaven National Laboratory (BNL), Electron-Ion Collider)*

The Electron-Ion Collider (EIC) at Brookhaven National Laboratory is a high luminosity, ($\sim 10^{34}$ $cm^{-2}s^{-1}$) accelerator facility colliding polarized electron beam with different ion species ranging from lighter nuclei (proton, deuterium) to heavier nuclei (gold, uranium). Design of a stripline injection kicker for the Hadron Storage Ring (HSR) of EIC for beams with the rigidity of ~ 81 T-m poses some technical challenges due to expected shorter bunch spacing and higher peak current of EIC. This paper focuses on the optimization of the EIC hadron ring injection kicker. Starting from the 2D cross-section design which includes the selection of electrodes shape, we describe the optimization of the kicker's cross-section. Then we discuss converting this 2D geometry to 3D by adding essential components for the stripline kicker and the 3D optimization techniques that we employed. Finally, we show simulation results for the optimized geometry including wakefields and Time Domain Reflection (TDR) from one feedthrough to another.

WEPAB194 **Feasibility of Using the Existing RHIC Stripline BPMs for the EIC**

***M.P. Sangroula**, C. Liu, M.G. Minty, P. Thieberger (BNL)*

The design of the Electron-Ion Collider (EIC) at Brookhaven National Laboratory (BNL) will utilize portions of the existing Relativistic Heavy Ion Collider (RHIC) for the EIC hadron ring. The EIC design calls for up to 10-times shorter ion bunches compared to the present RHIC operation. Higher single bunch peak currents will result in higher voltages to the output ports of the BPMs consequently producing more heating of the cryogenic signal cables connected to these output ports. Therefore, the existing stripline BPMs should be either upgraded or replaced with new ones. In this paper, we explore the potentially cost-effective approach by incorporating an RF-shielding piece into the existing BPMs as opposed to replacing them completely. Starting with the power delivered to the output ports, we present the proposed BPM modification with the RF-shielding piece. Then we discuss in detail the RF-shielding piece geometry including the dimension of RF slot and RF-fingers configuration. Finally, we present the optimization of the shielding piece and the mechanical tolerances required for its fabrication.

WEPAB195 **Design and Optimization of a Low-Frequency RF-Input Coupler for the IsoDAR RFQ**

***M.P. Sangroula**, J.M. Conrad, D. Winklehner (MIT) M. Schuett (BEVATECH)*

The Isotope Decay-At-Rest experiment (IsoDAR) is a proposed underground experiment which is expected to be a definitive search for sterile neutrinos. IsoDAR uses an especially designed low-frequency spilt-coaxial radio frequency quadrupole (RFQ) to accelerate H^{2+} ions directly from the ion source into the main cyclotron accelerator. This paper mainly focuses on the design and optimization of a low frequency (32.8 MHz) RF-input coupler for the IsoDAR RFQ. Starting with a basic design, we determine its appropriate position for this coupler in the RFQ. Finally, we optimized the design to lower the input power without compromising the coupling efficiency.

WEPAB198 **Beam Dynamics Design of a Synchrotron Injector With Laser-Accelerated Ions**

***M.Z. Tuo**, X. Guan, W. Lu, P.F. Ma, Y. Wan, X.W. Wang, Q.Z. Xing, H.J. Yao, S.X. Zheng (TUB)*

We present, in this paper, the beam dynamics design of a linac injector with laser-accelerated carbon-ions for a medical synchrotron. In the design, the initial transverse divergence is reduced by two apertures. The beam is focused transversely through a quadrupole triplet lens downstream the apertures. The output energy spread of the extracted beam at the exit of the injector is compressed from ±6% to ±0.6% by a debuncher and a bend magnet system to meet the injection requirement for the synchrotron. By changing the width of imaging slit of the bend magnet system, the beam with energy of 4±0.024 MeV/u is extracted, and the particle number per shot and transverse emittances of the beam at the exit of the injector can be regulated through adjusting the slit height. The dynamics design can pave the way for the future concept research of the synchrotron injector.

WEPAB199 **Study on the Important Technologies of 300MeV Upgrade for the CSNS Injection System**

***M.Y. Huang**, C.D. Deng, L. Kang, L. Liu, Y. Liu, X. Qi, S. Wang, Q.B. Wu, Y.W. Wu, S.Y. Xu, W.Q. Zhang, Y.L. Zhang (IHEP) J.X. Chen, T. Huang, H.C. Liu (IHEP CSNS)*

The China Spallation Neutron Source (CSNS-I) have achieved the design goal of 100kW beam power on the target in Feb., 2020. As the second phase of the CSNS, CSNS-II will achieve a beam power on the target of 500 kW. The injection energy of CSNS-II will be increased from 80 MeV to 300 MeV and the average beam current of the Linac will increase 5 times. Therefore, the injection system will require a complete upgrade. In this paper, the design scheme of the injection system for CSNS-II will be introduced. The key technologies of the upgrade injection system will be carefully analyzed and pre-developed, such as the pulse power supplies and their magnets, the special-shaped ceramic vacuum chambers, the main stripping foil, the stripped electron col-

lection, and so on.

WEPAB200 **Study on the Measurement and Residual Dose of the CSNS Stripping Foil**

M.Y. Huang, *L. Kang, S. Wang, Q.B. Wu, S.Y. Xu, Y.L. Zhang (IHEP) J.X. Chen, W.L. Huang, H.C. Liu (IHEP CSNS)*

In this paper, firstly, the application and service life of the main stripping foil for the China Spallation Neutron Source (CSNS) were introduced. The stripping efficiency of the main stripping foil have been measured and studied. Then, by using the codes FLUKA and ORBIT, the particle scattering of the main stripping foil has been simulated and the theoretical residual doses in the injection region caused by the foil scattering were obtained. By weekly measurement of the residual doses in the injection region, the actual residual doses near the main stripping foil were given. The residual doses comparison results have confirmed that the particle scattering of the main stripping foil is the most important source of the residual doses in the injection region.

WEPAB201 **8 GeV Proton Beam Commissioning and Extinction Measurement for the COMET Experiment at J-PARC Main Ring**

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The COMET (COherent Muon to Electron Transition) experiment, which searches the neutrinoless conversion of a muon to an electron in muonic atoms, utilizes a slow-extracted pulsed proton beam with 8 GeV from the J-PARC Main Ring (MR). This experiment requires an extremely clean pulsed beam. Specifically, an intensity ratio of leakage protons to the main pulsed beam, called EXTINCTION, must be less than 10^{-10}. This beam is critical in the pursuit of the highest level of sensitivity. The MR nominally accelerates the proton beam up to 30 GeV with 600 ns bunch intervals. Instead, the COMET requires the acceleration up to 8 GeV with 1.2 μs bunch intervals. It is essential that the extinction measurement with this customized MR operation. Although leakage protons were suppressed in the 2018 customized operation test, there were leakage protons after a bunch. The extinction did not satisfy the requirement in a case including all bunches. An extraction test in the improved operation is conducted with a new measurement setup in April 2021. The result of extinction measurement and the detailed description of the customized MR operation improved from the previous test will be presented.

WEPAB202 **Thermal Analysis of a Compact Split-Coaxial CW RFQ for the IsoDAR RFQ-DIP**

***D. Koser**, J.M. Conrad, D. Winklehner (MIT) H. Podlech, U. Ratzinger, M. Schuett (BEVATECH)*

The RFQ direct injection project (RFQ-DIP) for the neutrino physics experiment IsoDAR aims at an efficient injection of a high-current H^{2+} beam into the dedicated 60 MeV driver cyclotron. Therefore, it is intended to use a compact 32.8 MHz RFQ structure of the split-coaxial type as a pre-buncher. To determine the thermal elongation of the 1.4 m long electrode rods as well as the thermal frequency detuning of the RF structure at a maximum nominal power load of 3.6 kW, an extensive thermal and structural mechanical analysis using COMSOL Multiphysics was conducted. The water heating along the cooling channels as well as the properties of heat transfer from the copper structure to the cooling water were taken into account, which required CFD simulations of the cooling water flow in the turbulent regime. Here we present the methods and results of the sophisticated thermal and structural mechanical simulations using COMSOL and provide a comparison to more simplistic simulations conducted with CST Studio Suite.

WEPAB203 **RFQ Beam Dynamics Optimization Using Machine Learning**

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To efficiently inject a high-current H^{2+} beam into the 60 MeV driver cyclotron for the proposed IsoDAR project in neutrino physics, a novel direct-injection scheme is planned to be implemented using a compact radio-frequency quadrupole (RFQ) as a pre-buncher, being partially inserted into the cyclotron yoke. To optimize the RFQ beam dynamics design, machine learning approaches were investigated for creating a surrogate model of the RFQ. The required sample datasets are generated by standard beam dynamics simulation tools like PARMTEQM and RFQGen or more sophisticated PIC simulations. By reducing the computational complexity of multi-objective optimization problems, surrogate models allow to perform sensitivity studies and an optimization of the crucial RFQ beam output parameters like transmission and emittances. The time to solution might be reduced by up to several orders of magnitude. Here we discuss different methods of surrogate model creation (polynomial chaos expansion and neural networks) and identify present limitations of surrogate model accuracy.

WEPAB204 **Layout of the New Septum Magnets for Fast Extraction in J-PARC Main Ring**

***S. Iwata**, K. Ishii, H. Matsumoto, N. Matsumoto, Y. Sato, T. Shibata, T. Sugimoto (KEK)*

At J-PARC Main Ring (MR), we are pursuing to improve the beam power from 500 kW to 1.3 MW by reducing the repetition cycle from 2.48 to 1.16 seconds (1 Hz operation). Additionally, we are considering

the beam particles increasing by selecting a more optimal tune. The fast extraction (FX) equipment to the neutrino facility (NU) is needed to upgrade for the 1 Hz operation. We plan to replace most FX septum magnets with new ones in 2021. We report a layout of the FX line in confirmation of new beam optics and mention the beam loss during the fast extraction.

WEPAB205 **XiPAF Synchrotron Slow Extraction Commissioning**

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Xi'an 200 MeV Proton Application Facility (XiPAF) is a project to fulfill the need for the experimental simulation of the space radiation environment. It comprises a 7 MeV H^- linac, a 60–230 MeV proton synchrotron, and experimental stations. Slow extraction commissioning for 60 MeV proton beam in XiPAF synchrotron has been finished. After commissioning, the maximal experiment extraction efficiency with the RF-knockout (RF-KO) method can up to 85%. The reason for beam loss has been analyzed and presented in this paper. Besides, an experiment of multiple energy extraction has been conducted in XiPAF synchrotron. The proton beams of 3 different energies were successfully extracted in 1.54 s.

WEPAB207 **The New Primary Beam Transfer Lines for the CERN East Experimental Area**

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In the framework of the on-going renovation of the CERN East Experimental Area, the existing primary beamlines, as well as the secondary beamlines, have undergone a major overhaul. Optics for the primary beam has been adapted to serve the IRRAD and CHARM irradiation facilities as well as the two new production targets feeding the secondary beam lines T9, T10, and T11. In addition, a new dump destination will help to set-up the extraction from the CERN Proton Synchrotron, which delivers the primary proton beams of 24 GeV/c to the facility. Besides the layout change and new beam instrumentation, the renovation includes a new pulsed powering scheme with modern power converters and laminated magnets. The primary beams are planned to be commissioned in fall 2021.

WEPAB208 **Energy Sweeping Beam Extraction by the Septum Magnet Assisted With Charge Exchange for a Hadron Therapy**

***T.S. Dixit**, A. Shaikh (SAMEER) T. Adachi, T. Kawakubo, K. Takayama (KEK)*

An energy sweeping compact rapid cycling hadron therapy based on

a fast cycling induction synchrotron has been proposed by KEK and SAMEER as the next generation of hadron therapy machine. For energy sweep extraction, a C+5 beam is injected, captured and trapped in the barrier bucket. A fraction of the beam is continuously released from the barrier bucket by controlling the timing of barrier pulse generation. Released C+5 ions merge into the coasting beam and moves inwards with ramping of the guiding main magnets. Ions in the coasting beam eventually hit the carbon foil placed inside the beam chamber wall. As a result, C+5 is converted to C+6 and beam orbit is largely changed as it traverses through the downstream bending magnet. This notably facilitates C+6 beam extraction, resulting in a relatively small kick angle of the septum magnet. When the septum is excited in the same way as that of the main magnets, the extracted C+6 beam always places on the center of the irradiation beam line. LISE++ simulations demonstrated the charge exchange efficiency of almost 100 % for expected beam energy. The feasibility of the switching power supply for the septum magnet has been studied.

WEPAB209 **Review of Medical Accelerator Development at Sameer, India**

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At the Medical Electronics Division of SAMEER, R&D for the development of a 4 MeV energy electron linac for Cancer therapy was taken up in the late '80s. An S-band standing wave side coupled structure operating at pi/2 mode was developed for electron acceleration. The linac was integrated with other subsystems in collaboration with CSIO and PGIMER and the first machine was commissioned at PGI, Chandigarh in 1990. Thereafter, a lot of modifications like energy, dose rate, isocenter height etc. were made in the system, and later 4 more machines were commissioned in hospitals for treatment. More than 1,50,000 patients have been treated using SAMEER's 6 MeV oncology system. Subsequently, development of dual-mode and variable energy electron and photon output machines was undertaken. Two-photon energies of 6 and 15 MV and multiple electron energies starting from 6 to 18 MeV for treatment was offered from the linac. The electron energy variation was done using plunger mechanism in the side coupling cavity. This linac was successfully baked and RF tested for various parameters. This paper describes the experimental parameters achieved for both low and high energy dual-mode linac.

WEPAB210 **Beam Commissioning of the New 160 MeV H^- Injection System of the CERN PS Booster**

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A key component to meeting the brightness targets of the LHC Injectors Upgrade (LIU) project at CERN is the new 160 MeV H^- charge ex-

change injection system into the Proton Synchrotron Booster. This system has been in beam commissioning since December 2020, optimizing the beam production schemes for tailoring different beams to the respective user-defined brightness targets. In this paper, selected measurements from the beam commissioning period are presented, characterizing the system's flexibility to produce the required wide range of transverse emittances. The discussion focuses on the essential optimization of the injection set-up to minimize space charge driven emittance blow-up and injection errors. The results are completed by selected comparisons with multi-particle simulation models of the injection process.

WEPAB211 **Lattice Design of the PIP-II Beam Transfer Line (BTL) From LINAC to the Booster at Fermilab**

M. Xiao *(Fermilab)*

PIP-II beam transfer line (BTL) to transport the beam from PIP-II Linac to the Booster ring at Fermilab. The latest design eliminates rolling the dipoles in the beam line to cross over the Tevatron tunnel. Also redesigned is the lattice in the region of the Booster Injection to meet the request of the civil construction needs and accommodate the constrains of the Booster injection request. A beam line to the beam absorber (BAL) is designed based on the request from the results of Mars simulations and ANASYS calculation of the absorber. Simulations with dipole and quadrupole field errors for the Beam Transport Line (BTL) to the Booster, which provides the specifications for all the magnets and Power supplies, will be presented too.

WEPAB212 **Physics Studies for the LBNF Graphite Target Design**

J.J. Back *(University of Warwick)*

We present the simulated physics performance of the Long-Baseline Neutrino Facility (LBNF) graphite target that is being designed by the RAL High Power Targets Group for the Deep Underground Neutrino Experiment (DUNE). We first compare three conceptual cylindrical target design options as a function of target length (up to 2.2 m): downstream supported, two individual targets and an upstream-supported cantilever. Choosing the cantilever design as the baseline, we show the effect of widening the upstream inner conductor of the first focusing horn to provide extra space for supporting the target. We also give estimates of the expected performance of the 1.5 m prototype and 1.8 m production cantilevered targets. Furthermore, we show the effects of the main engineering updates made to the other two focusing horns since the DUNE TDR.

WEPAB213 **Optimization of Antiproton-Atom Collision Studies Using GEANT4**

V. Rodin*, N. Kumar, C.P. Welsch (The University of Liverpool)*
N. Kumar, ***V. Rodin****, C.P. Welsch (Cockcroft Institute)*

The interaction between antiprotons and hydrogen or helium atoms is a fundamental problem in many-particle atomic physics, attracting strong interest from both theory and experiments. Atomic collisions

are ideal to study the three and four-body Coulomb problem as the number of possible reaction channels is limited. Currently, only the total cross-sections of such interactions have been measured in an energy range between keV and a few MeV. This contribution investigates the discrepancies between different theories and available experimental data. It also describes a pathway for obtaining differential cross-sections. A purpose-designed experimental setup is presented and detailed Geant4 simulations provide an insight into the interaction between short (ns) antiproton bunches and a dense gas-jet target.

WEPAB214 **Realistic Simulations of Stray Field Impact on Low Energy Transfer Lines**

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Low energy (~100 keV) facilities working with antiprotons, heavy ions, or charged molecules may experience severe beam transport instabilities caused by field imperfections. For example, long (~10 m), unshielded beamlines will not be able to transfer particles due to the natural Earth magnetic field or stray fields from closely located experiments. Currently, only a limited number of simulation codes allow a simplified representation of such field errors, limiting capabilities for beam delivery optimization. In this contribution, a new simulation approach is presented that can provide detailed insight into 4D beam transport. It illustrates the impact of imperfections and stray fields on beam stability and quality through simulations of two antiproton experiments located in the Antimatter Factory (AD) at CERN in Geneva, Switzerland. Magnetic field imperfections are examined in two different ways, providing greater flexibility and an opportunity to benchmark all outcomes. Simulation performance is analyzed as a function of the level of detail and efficiency.

WEPAB215 **Simulation of Intra-beam Scattering in PyHEADTAIL**

***V. Rodin**, C.P. Welsch (The University of Liverpool) A. Oeftiger (GSI) **V. Rodin**, C.P. Welsch (Cockcroft Institute)*

High-intensity beams in low-energy synchrotrons are subject to space charge as well as intra-beam scattering (IBS). Accurate modelling of both effects becomes essential when the transverse emittances and minimum bunch length are determined through heating processes and resonances induced by machine errors. To date, only very few tools available to the general public allow to simultaneously study space charge and IBS in self-consistent simulations. In this contribution, we present our recent development of an IBS module for PyHEADTAIL, an open-source 6D multi-particle tracking tool, which already includes various 2.5D and 3D space-charge models based on the self-consistent particle-in-cell algorithm. A simulation example of high-intensity bunch rotation demonstrates the joint impact of applied heating effects. Our model is based on the Martini and Bjorken-Mitingwa theories. Benchmarks of our implementation against IBS

modules provided in the MAD-X and JSPEC codes are shown.

WEPAB216 **6D Simulations of PIP-II Booster Injection**
***J.-F. Ostiguy**, D.E. Johnson (Fermilab)*
The PIP-II superconducting linac will deliver 2 mA average H^- beam current at 800 MeV to the existing Booster synchrotron over a period of 0.55 ms (285 turns). As a result, the injected beam power will quadruple to 17 kW. Safe operation at the increased beam power implies careful attention to the origin, magnitude, and distribution of both controlled and uncontrolled losses. Uncontrolled losses are due to neutral ions in excited states stripped in downstream magnets and large angle scattered protons from parasitic foil hits. The relative magnitudes of these loss mechanisms is used to determine the optimal foil thickness. A transverse painting scheme involving closed orbit motion will be used to mitigate space charge effects and minimize parasitic foil hits. Using a detailed full 6D simulation of the injection process, we compute large angle scattering losses and compare results to back of the envelope estimates. We investigate possible impact of space charge on the emittance and beam distribution both during and at the conclusion of the injection period.

WEPAB217 **Linear Optics Measurement and Modeling of XiPAF Synchrotron**
***Y. Yang**, X.Y. Liu, H.J. Yao, W.B. Ye, S.X. Zheng (TUB) Z.M. Wang (NINT)*
Linear optics measurement and modeling have been carried out during the commission of XiPAF synchrotron, which is a compact ring operated at max energy of 60 MeV. Measurement results of linear optics for different energies will be presented. The optics have been modeled and corrected with LOCO (Linear Optics from Closed Orbits). New tracking algorithms with non-relativistic effects of low energy protons have been adopted in AT code to get the model response matrix accurately. The accuracy of the corrected model is limited by large BPM noise and limited measurement data. Nevertheless, the measured beta and dispersion function are in good agreement with the corrected model.

WEPAB218 **A Novel Design of Cyclotrons for Medical and Industrial Applications from 15 to 230 MeV**
***O. Karamyshev** (JINR)*
A novel design of normal conducting cyclotrons allows to make the cyclotron as compact as superconducting, but significantly easier and cheaper. The author presents 15 and 230 MeV proton cyclotrons as a proof-of-concept. The design is a hybrid of a 3 sector isochronous cyclotron and 6 harmonic acceleration.

WEPAB219 **Simulations of Novel Cyclotrons for Medical Application**
***O. Karamyshev** (JINR)*
Simulation techniques for new accelerators R&D.

WEPAB221 **H^0 Stark Stripping and Component Irradiation in Fermilab Booster**

***J.A. Johnstone**, D.E. Johnson (Fermilab)*

In foil stripping of H^- some fraction of the emerging neutral H^0 will be in excited states, which can then strip through the Stark effect in the magnetic field of the downstream orbit bump magnet. The resultant H^+ will experience a depleted net kick compared to protons emerging from the foil and will track on trajectories different from the nominal circulating beam. This will lead to irradiation of downstream machine components. An analysis of these processes is of particular importance looking forward to the much higher beam power of the Fermilab PIP-II era. This study investigates where these errant protons will be lost, how much power is deposited, and whether this will be a shielding concern.

WEPAB222 **Impedance Evaluation of Masks in the HEPS Storage Ring**

***N. Wang**, S.K. Tian, J.Q. Wang (IHEP) J.Q. Wang (University of Chinese Academy of Sciences)*

Masks are commonly used in photon light sources to protect sensitive elements from synchrotron radiations. In the ultra-low emittance rings, small aperture vacuum chambers are adopted in order to reach the very high gradient in the quadrupoles, while many masks are required due to the high radiation power density. Therefore, the impedance of the masks becomes one of the dominant contributors to the impedance budget. In this paper, the impedance is evaluated among different mask designs. Meanwhile, the impedance cross-talk between adjacent masks is discussed.

WEPAB224 **Update of the Transverse Proton Synchrotron Impedance Model**

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The CERN Proton Synchrotron (PS) was recently upgraded to allow reaching the ambitious performance goal of the High-Luminosity LHC Project. This upgrade is part of the LHC Injectors Upgrade project. The final part of the upgrade was performed during Long Shutdown 2 (LS2) to allow injection at higher energy from the PS Booster and a twofold increase in beam intensity and brightness. These changes must be considered in the PS impedance model. The effect on the impedance of the removal of obsolete injection equipment, changes of several accelerator components and new injection energy will be reviewed, as well as the wall impedance of the elliptic beam pipe, thanks to a newly developed code that allows taking into account both the ellipticity and the non-ultra-relativistic nature of the beam.

WEPAB225 **Transverse and Longitudinal Single Bunch Instabilities in FCC-ee**

***E. Carideo**, D. Quartullo, F. Zimmermann (CERN) D. De Arcangelis (Sapienza University of Rome) M. Migliorati, M. Zobov (INFN/*

LNF)

Improving the accuracy of the impedance model of an accelerator is important for keeping beam instabilities and power loss under control. Here, by means of the PyHEAD- TAIL tracking code, we first review the longitudinal mi- crowave instability threshold for FCC-ee by taking into ac- count the longitudinal impedance model evaluated so far. Moreover, we present the results of beam dynamics simula- tions, including both the longitudinal and transverse wake- fields due to the resistive wall, in order to evaluate the influ- ence of the bunch length on the transverse mode coupling instability. The results of the transverse beam dynamics are also compared with the Vlasov solver DELPHI.

WEPAB226 **Investigation of Vlasov Systems With a Certain Class of Linearly-Collective Hamiltonians**

***Ph. Amstutz**, M. Vogt (DESY)*

In many cases the Vlasov equation cannot be solved exactly due its inherent non-linearity arising from collective terms in the Hamiltonian. Based on the analysis of the Hamiltonian's dependence on the phase-space density and the requirement for self-consistency in this contribution a class of Hamiltonians is defined and characterized. For members of this class the corresponding expansion of the Vlasov equation terminates. The new, potentially non-autonomous, Hamiltonian of the resulting Liouville equation depends only on the initial condition of the phase-space density. Prominent members of this class are Poisson-type kick-Hamiltonians, which we show as an example. We expect these investigations to be a potential starting point for the analysis and conception of operator-splitting schemes or splitting-free methods for beam-dynamics simulation codes.

WEPAB227 **Mechanism of Longitudinal Single-Bunch Instability in the CERN SPS**

***I. Karpov** (CERN) M. Gadioux (UCD)*

Understanding the origin of beam instabilities is essential for reaching the highest performance of proton synchrotrons. In the present work, the Oide-Yokoya eigenvalue method of solving the linearised Vlasov equation was used to shed light on the mechanism of longitudinal single-bunch instability in the CERN SPS. In particular, semi-analytical calculations were done for the full longitudinal impedance model, taking into account the RF nonlinearity. The obtained results agree well with macro-particle simulations and are consistent with available beam measurements. For the first time, the instability has been interpreted as a coupling of radial modes within a single azimuthal mode, due to a strong potential-well distortion of the synchrotron-frequency distribution. To avoid this instability, a higher RF voltage is required at a given emittance. Thus, the instability mechanism is very different from the loss of Landau damping, which, in contrast, is mitigated by a lower RF voltage. This understanding also allowed us to optimise the RF voltage programmes during the acceleration cycle for high-

intensity bunches used in the AWAKE experiment at CERN.

WEPAB228 **Modelling and Counteracting Microbunching Instability in Spreader Lines of Radiofrequency and Plasma-Based Accelerators for Free-Electron Lasers**

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High energy radiofrequency and plasma-driven accelerators target electron beam brightness suitable for x-ray free-electron lasers. Microbunching instability can be enhanced during beam transport through the spreader line from the accelerator to the undulator, degrading the brightness of the accelerated beam and therefore reducing the lasing efficiency. We present a semi-analytical model of the instability, benchmarked with experimental data at the FERMI free-electron laser, in the presence of intrabeam scattering and beam heating. Strategies for minimization of the instability both in conventional and plasma-based accelerators are discussed.

WEPAB229 **Transverse Density Pileup and Pattern Formation in Dense Ultracold Electron Beamlets Under Coulomb Expansion**

A.J. Tencate*, K. Bhuyan, B. Erdelyi (Northern Illinois University)*

Dynamic Coulomb expansion of dense particle bunches can lead to transverse density shock-like propagation for nonuniform bunch distributions. Furthermore, under favorable circumstances, multiple bunches in close proximity can collide without crossing to form wheel-and-spoke patterns. This process has been observed experimentally for Rubidium ions, but not yet for electrons, where the dynamics occur over far shorter length scales. We simulate the interaction of electron bunches while varying the initial transverse temperature and density profiles to determine the thresholds that characterize this pattern formation. Additionally, we consider the effects of asymmetries and the impact of a low-density halo on the overall process. The simulations are conducted using a novel high-fidelity algorithm for collisional particle dynamics.

WEPAB230 **Simulation of Micro-Bunching in a SC-CW-XFEL**

M. Dohlus *(DESY)*

The possibility of expanding the European XFEL to CW operation is currently being investigated. Major changes for the beam dynamics come from the gun and the changed energy profile. This paper investigates micro-bunching effects for different working points of a SC gun followed by the bunch compresson system and SC accelerating sections. We calculate the stimulation by shot noise using three dimensional particle tracking with a high number of macro particles. SC and CSR fields are taken into account. There is a transition after few meters from the gun calculation to the tracking of the remaining system. Special attention is paid to the beam dynamics in the gun.

WEPAB231 **Theory of Space-Charge Driven Micro-Bunching Instability**

V. Litvinenko *(Stony Brook University) Y.C. Jing, J. Ma, I. Pinayev, G. Wang (BNL) I. Petrushina, Y.H. Wu (SUNY SB) K. Shih (SBU)*

In this paper, we present a unified theory of space-charge-driven micro-bunching instability occurring in charged particle beams including conventional micro-bunching instability and newly discovered Plasma-Cascade Instability. This instability is confirmed by 3D numerical simulations and observed experimentally. Such instability can be driven by variation of beam's density and/or particle's mobility. The micro-bunching instability can strongly amplify noise in the beam and drastically reduce its quality. Conversely, such instability can drive novel high-power sources of radiation or can be used as a broadband amplifier

WEPAB232 **Plasma-Cascade Instability**

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In this paper we describe a new micro-bunching instability occurring in charged particle beams propagating along a straight trajectory. The nature of these exponentially growing plasma oscillations gave the reason for its name: Plasma-Cascade Instability. Such instability can strongly amplify longitudinal micro-bunching originating from the beam's shot noise, even to the point of saturation. The resulting random density and energy microstructures can drastically reduce beam quality. Conversely, such instability can drive novel high-power sources of broadband radiation or can be used as a broadband amplifier. We discovered this phenomenon in a search for such amplifier in the Coherent electron Cooling scheme without separation of electron and hadron beams. In this paper, we present a brief analytical theory of this new phenomenon, detailed numerical studies, as well as the results of experimental demonstration as well as control of the longitudinal plasma-cascade instability.

WEPAB233 **Excitation of Micro-Bunching in Short Electron Bunches Using RF Amplitude Modulation**

T. Boltz*, E. Blomley, M. Brosi, E. Bründermann, B. Härer, A. Mochihashi, A.-S. Müller, P. Schreiber, M. Schuh, M. Yan (KIT)*

In its short-bunch operation mode, the KIT storage ring KARA provides picosecond-long electron bunches, which emit coherent synchrotron radiation (CSR) up to the terahertz frequency range. Due to the high spatial compression under these conditions, the self-interaction of the bunch with its own emitted CSR induces a wake-field, which significantly influences the longitudinal charge distribution. Above a given threshold current, this leads to the formation of dynamically evolving micro-structures within the bunch and is thus called micro-bunching instability. As CSR is emitted at wavelengths corresponding to the spatial dimension of the emitter, these small structures lead to an increased emission of CSR at higher frequencies. The instability is there-

fore deliberately induced at KARA to provide intense THz radiation to dedicated experiments. To further increase the emitted power in the desired frequency range, we consider the potential of RF amplitude modulations to intentionally excite this form of micro-bunching in short electron bunches. This work is supported by the BMBF project 05K19VKC TiMo (Federal Ministry of Education and Research).

WEPAB234 **Simulating Two Dimensional Coherent Synchrotron Radiation in Python**

***W. Lou**, Y. Cai, C.E. Mayes, G.R. White (SLAC)*

Coherent Synchrotron Radiation (CSR) in bending magnets poses an important limit for electron beams to reach high brightness in novel accelerators. While the longitudinal wakefield has been well studied in one-dimensional CSR theory and implemented in various simulation codes, transverse wakefields have received less attention. Following the recently developed two-dimensional CSR theory, we developed a Python code simulating the steady-state two-dimensional CSR effects. The computed CSR wakes have been benchmarked with theory and other simulation codes. To speed up computation speed, the code applies vectorization, parallel processing, and Numba in Python.

WEPAB235 **TMCI Theory of Flat Chambers Revisited**

***T.F. Günzel** (ALBA-CELLS Synchrotron)*

By accounting for the transverse impedance' quadrupolar component according to the work of R.Lindberg, no TMCI-instability can be observed in case of a pure horizontal resistive wall impedance of flat vacuum chambers. In order to study this effect more closely, TMCI-theory is reviewed and Lindberg's work is further developed by including the resonator model as impedance type. The theory is applied to the ALBA-impedance model for the calculation of horizontal TMCI-detuning and threshold. Moreover, a couple of example cases are presented including vertical TMCI-detuning and threshold. Results on both planes are compared to simpler descriptions which account for the quadrupolar impedance effect only by tune shift.

WEPAB236 **Complex Multi-Physics of Vlasov|–|Maxwell Dynamics**

***A.N. Fedorova**, M.G. Zeitlin (RAS/IPME)*

The multiscale variational/projection approach is proposed for modeling the complex collective behavior and the propagation of the intense charged particle beams described by different forms of Vlasov-Maxwell/Poisson equations. We construct representations for partition functions and dynamical variables in the framework of multiscale/multiresolution decomposition (non-Abelian Nonlinear Harmonic Analysis) with good convergence properties via the full tower of (nonlinear) high-localized basis eigenmodes of the underlying proper functional/Hilbert space. Such a description provides the full information about dynamical processes corresponding to complex collective behavior inside Vlasov-like evolutional systems. Numerical modeling shows the creation of different internal structures from generating modes, which are related to the stable/unstable type of

behavior and corresponding patterns (called waveletons) formation. In addition, the reduced algebraic structures provide the pure algebraic control of (meta)stability/unstability scenario: different patterns (chaotic or localized) are controlled in the space of parameters.

WEPAB237 **Non-Maxwellian Kinetics: Towards (Meta)Stable States Formation and Fusion**

M.G. Zeitlin*, A.N. Fedorova (RAS/IPME)*

The multiscale multiphysics approach is proposed for analysis and construction of (meta)stable states inside the full hierarchy of kinetic equations (BBGKY), i.e. some possible images for fusion-like patterns. It is based on the description of the complex part (non-Gaussian, non-Maxwellian) of collective dynamics inside of non-equilibrium ensembles. Our exposition is based on variational multiresolution approaches in the basis of polynomial tensor algebras of various localized bases within the properly selected functional spaces. We construct a representation for hierarchy of distribution functions and dynamical variables via the exact multiscale decomposition in high-localized nonlinear (eigen)modes. The corresponding cut-off of infinite hierarchy, reductions to finite dimensional subsets and accuracy of calculations are based on a new metric tensor structure of the whole Fock-like space of all partition functions. We demonstrate the existence of localized (meta)stable states with finite energy and minimum entropy in some subsets of the whole global configuration/phase space (waveleton patterns) considered as the possible image for confinement-like state in plasma physics.

WEPAB238 **Modeling Short Range Wakefield Effects in a High Gradient Linac**

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The interaction of charged beams with the surrounding accelerating structures requires a thorough investigation due to potential negative effects on the phase space quality. Indeed, the wakefields acting back on the beam are responsible for emittance dilution and instabilities, such as the beam break-up, which limit the performances of electron-based radiation sources and linear colliders. Here we introduce a new tracking code which is meant to investigate the effects of short-range transverse wakefields in linear accelerators. The tracking is based on quasi-analytical models for the beam dynamics which, in addition to the basic optics specified by the applied fields, include dipole wakefield forces and a simple approach to account for space-charge effects. Such features provide a reliable tool which easily allows to inspect the performances of a linac. To validate the model, a parallel analysis for a reference case is performed with well-known beam dynamics codes, and comparisons are shown. As an illustrative application, we dis-

cuss a study on alignment tolerances evaluating the emittance growth induced by misaligned accelerating sections.

WEPAB239 **Effect of Chromaticity and Feedback on Transverse Head-Tail Instability**

***V.V. Smaluk**, G. Bassi, A. Blednykh, A. Khan (BNL)*

The head-tail instability caused by the beam interaction with short-range wakefields is a major limitation for the single-bunch beam intensity in circular accelerators. The combined effect of the transverse feedback systems and chromaticity suppressing the instability is discussed. Theoretical and experimental studies of the head-tail instability and methods of its mitigation are reviewed. Results of experimental studies of the transverse mode coupling carried out at NSLS-II are compared with the theoretical model and numerical simulations.

WEPAB240 **Increasing the Single-Bunch Instability Threshold by Bunch Splitting Due to RF Phase Modulation**

***J.L. Steinmann**, E. Blomley, M. Brosi, E. Bründermann, A. Mochihashi, A.-S. Müller, M. Schuh, P. Schönfeldt (KIT)*

RF phase modulation at twice the synchrotron frequency can be used to split a stored electron bunch into two or more bunchlets orbiting each other. We report on time-resolved measurements at the Karlsruhe Research Accelerator (KARA), where this bunch splitting was used to increase the threshold current of the microbunching instability, happening in the short-bunch operation mode. Turning the modulation on and off reproducibly affects the sawtooth behavior of the emitted coherent synchrotron radiation.

WEPAB241 **Coupled Bunch Instabilities growth in the Fermilab Booster during the Acceleration Cycle**

***C.M. Bhat** (Fermilab)*

The Fermilab Booster is an RCS that accelerates proton beam from 400 MeV to 8 GeV at 15 Hz, with ~4.5E12ppBc, harmonic number 84, and gamma transition of 5.47. In an intermediate stage of the upgrade, the beam intensity will be increased by nearly 15% and during the forthcoming PIP-II era (cycle rate of 20Hz) by ~50%. In the current mode of operation, we have observed coupled bunch (CB) instabilities in the extracted beam. This issue is expected to become more serious as beam intensity is increased. We expect 83 modes of oscillations can contribute to these CB instabilities, some are more and some are less detrimental. Currently, we have a digital mode damper to mitigate prominent CB modes. We would like to understand at what time in the beam cycle a particular mode is going to originate and how much it contributes at a different time of the cycle. In this regard, we have collected wall current monitor data at multiple places in the beam cycle from injection to extraction and looked for the start of a particular mode of CB instability and its growth. In this paper, we present the results from this study and future plans to mitigate the CB instability in Booster.

WEPAB243 **Longitudinal Microwave Instability Study at Transition Crossing With Ion Beams in the CERN PS**

***A. Lasheen**, H. Damerau, A. Huschauer, B.K. Popovic (CERN)*

The luminosity of lead ion collisions in the Large Hadron Collider (LHC) was significantly increased during the 2018 ion run by reducing the bunch spacing from 100 ns to 75 ns, allowing to increase the total number of bunches. With the new 75 ns variant, three instead of four bunches are generated each cycle in the Low Energy Ion Ring (LEIR) and the Proton Synchrotron (PS) with up to 30% larger intensity per bunch. The beam was produced with satisfactory quality but at the limit of stability in the injectors. In particular, the minimum longitudinal emittance in the PS is limited by a strong longitudinal microwave instability occurring just after transition crossing. The uncontrolled blow-up generates tails, which translate into an unacceptably large satellite population following the RF manipulations prior to extraction from the PS. In this paper, instability measurements are compared to particle simulations using the latest PS impedance model to identify the driving impedance sources. Moreover, means to mitigate the instability are discussed.

WEPAB244 **Optimization and Machine Learning Applied to the RF Manipulations of Proton Beams in the CERN PS**

***A. Lasheen**, H. Damerau, S.C. Johnston (CERN)*

The 25 ns bunch spacing in the LHC is defined by a sequence of RF manipulations in the Proton Synchrotron (PS). Multiple RF systems covering a large range of revolution harmonics (7 to 21, 42, 84, 168) allow performing RF manipulations such as beam splitting, and non-adiabatic bunch shortening. For the nominal beam sent to LHC, each bunch is split in 12 in the PS. The relative amplitude and phase settings of the RF systems need to be precisely adjusted to minimize the bunch-by-bunch variations in intensity, longitudinal emittance, and bunch shape. However, due to transient beam-loading, the ideal settings, as well as the best achievable beam quality, vary with beam intensity. Slow drifts of the hardware may also affect beam quality. In this paper, automatized optimization routines based on particle simulations with intensity effects are presented, together with the first considerations of machine learning. The optimization routines are used to assess the best achievable longitudinal beam quality expected with the PS RF systems upgrades, in the framework of the LHC Injector Upgrade project.

WEPAB245 **A Possible Modification of Ceramic Chambers in the Injection Area at the RCS in J-PARC**

***Y. Shobuda**, K. Horino, J. Kamiya, K. Kotoku, T. Takayanagi, T. Ueno, T. Yanagibashi (JAEA/J-PARC)*

The J-PARC RCS is composed of ceramic chambers covered over copper stripes to suppress the eddy current on the chamber. The inductance, comprising the copper stripes and flanges, in combination with the capacitors makes an LCR electric circuit with the chamber and

can cause field modulation in the chamber. Though most chambers are not harmful at the RCS, the chambers at the injection area excite beam losses, because a trapezoid field pattern is excited to accumulate LINAC beam during the injection period. In this report, we consider several types of ceramic chambers to suppress the field modulation. One type is a ceramic chamber covered over copper stripes in parallel with damping resistors. Another is that covered over spiral copper stripes with only capacitors.

WEPAB246 **Influence of Different Beam Energies on the Micro-Bunching Instability**

***M. Brosi**, A.-S. Müller, P. Schreiber, M. Schuh (KIT)*

During the operation of an electron synchrotron with short electron bunches, the beam dynamics are influenced by the occurrence of the micro-bunching instability. This collective instability is caused by the self-interaction of a short electron bunch with its own emitted coherent synchrotron radiation (CSR). Above a certain threshold bunch current dynamic micro-structures start to occur on the longitudinal phase space density. The resulting dynamics depend on various parameters and were previously investigated in relation to, amongst others, the momentum compaction factor and the acceleration voltage. In this contribution, the influence of the energy of the electrons on the dynamics of the micro-bunching instability is studied based on measurements at the KIT storage ring KARA (Karlsruhe Research Accelerator).

WEPAB248 **Kurth Vlasov-Poisson Solution for a Beam in the Presence of Time-Dependent Isotropic Focusing**

***C.E. Mitchell**, K. Hwang, R.D. Ryne (LBNL)*

The well-known K-V distribution provides an exact solution of the self-consistent Vlasov-Poisson system describing an unbunched charged particle beam with nonzero temperature in the presence of time-dependent linear transverse focusing. We describe a lesser-known exact solution of the Vlasov-Poisson system that is based on the work of Kurth in stellar dynamics. Unlike the K-V distribution, the Kurth distribution is a true function of the phase space variables, and the solution may be constructed on either the 4D or 6D phase space, for the special case of isotropic linear focusing. Numerical studies are performed for benchmarking simulation codes, and the stability properties of a 4D Kurth distribution are compared with those of a K-V distribution.

WEPAB249 **Model of Curvature Effects Associated with Space Charge for Long Beams in Dipoles**

***C.E. Mitchell**, K. Hwang, R.D. Ryne (LBNL)*

For modeling the dynamics within a dipole of a bunch whose length is much larger than the vacuum pipe radius, it is typical to use a 2D (or 2.5D) Poisson solver, with arc length taken as the independent variable. However, sampled at a fixed time, the beam is curved, space charge is not truly 2D, and the usual cancellation between E and B contributions to the Lorentz force need not exactly hold. The size of these effects is estimated using an idealized model of a uniform torus

of charge rotating inside a toroidal conducting pipe. Simple expressions are provided for the correction of the electric and magnetic fields to first order in the reciprocal of the curvature radius.

WEPAB250 **Interplay Between Space Charge, Intra-beam Scattering, and Synchrotron Radiation Effects**

M. Zampetakis, *F. Antoniou, H. Bartosik, Y. Papaphilippou (CERN)* ***M. Zampetakis*** *(University of Crete)*

The objective of this research is to study the interplay of synchrotron radiation, intra-beam scattering, and space charge in the vicinity of excited resonances. In this respect, two modules were developed to simulate intra-beam scattering and synchrotron radiation effects and plugged into pyORBIT to be used together with its space charge module. Different regimes of synchrotron motion were used to study the response of the beam to a lattice resonance when space charge, intra-beam scattering and synchrotron radiation are present.

WEPAB251 **Beam Dynamics Optimization of LCLS-II HE Linear Accelerator Design**

J. Qiang *(LBNL) T.O. Raubenheimer, M.D. Woodley (SLAC)*

The LCLS-II-HE as a high energy upgrade of the high repetition rate X-ray FEL under construction at SLAC will provide great opportunities for scientific discovery by generating coherent, high brightness hard X-ray radiation. In this paper, we report on beam dynamics optimization of the LCLS-II HE linear accelerator design with a 100pC and a 20pC charge beam to attain high quality electron beam for X-ray FEL radiation. We also present preliminary results of beam dynamics optimization of a 100pC beam from a low emittance superconducting injector.

WEPAB252 **Transient Beam-Beam Effect During Electron Bunch Replacement in the EIC**

J. Qiang *(LBNL) M. Blaskiewicz, Y. Luo, C. Montag, F.J. Willeke, D. Xu (BNL) Y. Hao (FRIB)*

The high luminosity, high polarization electron-ion collider (EIC) will provide great opportunities in nuclear physics study. In order to maintain high polarization, the electron beam will be replaced every few minutes during the collider operation. This frequent replacement of electron beams can affect proton beam quality during the collision. In this paper, we report on the study of the transient effect of electron beam replacement on proton beam emittance growth through strong-strong beam-beam simulation. The effect of electron beam injection imperfection will be included in the study.

WEPAB254 **Design of a 10 MeV Beamline at the Upgraded Injector Test Facility for e-Beam Irradiation**

X. Li, *H. Baumgart, G. Ciovati (ODU) G. Ciovati, F.E. Hannon, S. Wang (JLab)*

Electron beam irradiation near 10 MeV is suitable for wastewater treatment. The Upgraded Injector Test Facility (UITF) at Jefferson Lab is a CW superconducting linear accelerator capable of providing an electron beam of energy up to 10 MeV and up to 100 uA current. This

contribution presents the beam transport simulations for a beamline to be used for the irradiation of wastewater samples at the UITF. The simulations were done using the code General Particle Tracer with the goal of obtaining an 8 MeV electron beam of radius (3-sigma) of ~2.4 cm. The achieved energy spread is ~74.5 keV. The space charge effects were investigated when the bunch charge is varied to be up to 1000 times and the results showed that they do not affect the beam quality significantly.

WEPAB255 **Simulation Studies on the Interactions of Electron Beam With Wastewater**

***X. Li**, H. Baumgart, G. Ciovati (ODU) G. Ciovati, F.E. Hannon, S. Wang (JLab)*

The manufactured chemical pollutants, like 1,4 dioxane and PFAS (per- and polyfluroralkyl substances), found in the underground water and/or drinking water are challenging to be removed or biodegraded. Energetic electrons are capable of mediating and removing them. This paper utilizes FLUKA code to evaluate the beam-wastewater interaction effects with different energy, space and divergence distributions of the electron beam. With 8 MeV average energy, the electron beam exits from a 0.0127 cm thick titanium window, travels through a 4.3 cm distance air and a second 0.0127 cm thick stainless water container window with 2.43 cm radius, and finally is injected into the water area, where the volume of water is around 75 cubic cm. The distribution parameters of the electron beam are from the GPT (General Particle Tracer) simulations for UITF (Upgraded Injector Test Facility) in Jefferson lab. By varying the distributions, several measurements including the dose (or energy deposition) distribution, electron fluence, photon fluence are scored and compared. Taking the comparisons into consideration, this paper is aiming to find better electron beams for the wastewater irradiation.

WEPAB256 **Three-Dimensional Space Charge Oscillations in a Hybrid Photoinjector**

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A new hybrid C-band photo-injector, consisting of a standing wave RF gun connected to a traveling wave structure, operating in a velocity bunching regime, has shown to produce an extremely high brightness beam with very low emittance and a very high peak current through a simultaneous compression of the beam in the longitudinal and transverse dimensions. A beam slice analysis has been performed in order to understand the evolution of the relevant physical parameters of the beam in the longitudinal and transverse phase spaces along the structure. A simple model for the envelope equation has been developed to describe the beam behavior in this particular dynamics regime that we term "triple waist", since all three dimensions reach a minimum con-

dition almost simultaneously. The model analyzes the transverse envelope dynamics at the exit of the hybrid photo-injector, in the downstream drift where the triple waist occurs. The analytical solutions obtained from the envelope equation are compared with the simulations, showing a good agreement. Finally, these results have been analyzed also in terms of plasma oscillation to obtain a further physical interpretation of the beam dynamics.

WEPAB257 **Matching of a Space Charge Dominated Beam into the Undulator of the THz SASE FEL at PITZ**

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The Photo Injector Test facility at DESY in Zeuthen (PITZ) is developing a THz SASE FEL as a prototype high repetition rate accelerator-based source for the THz-pumped, X-ray-probed experiments at the European XFEL. For the generation of THz pulses of mJ-level energy from SASE, an electron beam with a high charge (up to 4 nC) and high peak current (~200 A) will be injected into an LCLS-I undulator, which is currently being installed at the end of the photo-injector. The narrow vacuum chamber (11x5 mm) between the magnetic poles and the strong vertical focusing from the undulator, as well as the lack of beam diagnostics, have made it a challenge to match the space-charge dominated beam into the undulator without beam loss during the following transport. In this paper, boundary conditions of a matched electron beam will be discussed and the simulation and experimental study on our matching strategy will be presented.

WEPAB258 **Beam Dynamics Design of a 162.5 MHz Superconducting RFQ Accelerator**

***Ying. Xia**, H.P. Li, Y.R. Lu, Q.Y. Tan, Z. Wang (PKU) Y.R. Lu (IAP)*

Superconducting(SC) RFQ has lower power consumption, larger aperture and higher accelerating gradient than room temperature RFQ. We plan to design a 162.5MHz SC RFQ to accelerate the 30 mA proton beams from 35 keV to 2.5 MeV, which will be used as a neutron source for BNCT and neutron imaging project. At an inter-vane voltage of 180kV, the beam dynamics design was carried out with acceptable peak surface electric field, high transmission efficiency, and relatively short cavity length.

WEPAB259 **Impact of the Magnet Alignment and Field Errors on the Output Uniform Beam at the DONES HEBT line**

***C. Oliver**, A. Ibarra, J. Mollá, I. Podadera, R. Varela (CIEMAT) H. Dzitko (F4E) O. Nomen, D. Sánchez-Herranz (IREC)*

IFMIF-DONES will be a facility devoted to study the degradation of advanced materials for operation of fusion reactors. Motivated by the need of optimizing the neutron irradiation to the materials samples, the HEBT line of the deuteron DONES (DEMO Oriented Neu-

tron Source) accelerator is based on non-linear magnetic fields. By using octupoles and dodecapoles magnets, it is possible to shape the beam profile to achieve the demanded rectangular uniform distribution across the flat top of the beam profile, with high edge peaks in the horizontal direction. Special optics conditions are obtained with a proper setting of quadrupole magnets to minimize the x-y coupling. Additionally, the high beam power (5 MW, for a 125 mA, 40 MeV deuteron beam) in conjunction with the huge space charge makes challenging the HEBT line design to avoid non-controlled losses, except in the devoted scrapers. A comprehensive beam dynamics analysis has been made using TraceWin code. It includes extensive error studies to define tolerances and verify the robustness of the design with respect to magnet misalignment, power supply instabilities and injection parameters.

WEPAB262 **Damping Time Reduction with Longitudinal Gradient and Reverse Bends**

***Z.L. Ren**, Z.H. Bai, L. Wang, H. Xu, P.H. Yang (USTC/NSRL)*

Low emittance is a radical goal of the design of electron storage ring based light sources. In past years, longitudinal gradient bends (LGB) and reverse bends (RB) have been studied to achieve low emittance lattice. In the design of a low emittance storage ring, intra-beam scattering (IBS) is a non-ignorable source of emittance growth, and controlling the radiation damping times is required. Our recent study found that LGBs and RBs can not only decrease the emittance, but also introduce many other effects, such as the reduction of momentum compaction factor and damping time. In this work, we note that an opportune increase of phase advance can achieve lower damping time. Compared with homogeneous-bend (HOM) cells, a combination of LGBs and RBs in the theoretical minimum emittance (TME) like cells can reduce the damping time more effectively. However, LGBs alone are of rather limited gain.

WEPAB263 **Complex Unit Lattice Cell for Low-Emittance Synchrotrons**

***Z.L. Ren**, Z.H. Bai, L. Wang, H. Xu, P.H. Yang (USTC/NSRL)*

To reach the real diffraction-limited emittance, it is generally required to increase the number of bends in multi-bend achromat (MBA) lattices that are used in the designs of fourth-generation synchrotron light sources. For an MBA lattice with distributed chromatic correction, more bends mean much tighter space and much stronger magnets. Inspired by the hybrid MBA lattice concept, in this paper we propose a new lattice concept called complex unit lattice cell, which can save space and reduce magnet strengths. A 17BA lattice based on the complex unit cell concept is designed for a 3 GeV synchrotron light source with a circumference of 537.6 m, which reaches a natural emittance of about 21 pm·rad. Comparison is also made between this 17BA lattice and the 17BA lattice with distributed chromatic correction to demonstrate the merit of the complex unit cell concept.

WEPAB264 **Moga Optimization of Superconducting Longitudinal Gradient Magnet Based on NbTi Wire**

C. Chen, *Z.H. Bai, G.Y. Feng, Z.L. Ren, Zh.X. Tang, L. Wang, H. Xu (USTC/NSRL)*

Multi-bend achromat (MBA) lattices with unit cells are used in diffraction-limited storage ring (DLSR) designs. The longitudinal gradient bend (LGB) can reduce the horizontal emittance below the theoretical minimum of a given magnet structure, and generally, the horizontal emittance reduces with the peak field grows. Therefore superconducting longitudinal gradient bend (SLGB) can produce higher peak field value and quasi-hyperbolic field profile to minimize emittance at the location of radiation and generate better hard X-rays. NbTi conductor, rather than Nb_3Sn conductor, is selected to keep the design and the manufacturing of the SLGB magnet as simple as possible. In this paper, how the field profile of race-track type coil and solenoid coil change with their geometrical parameters are studied, and multiobjective genetic algorithm (MOGA) is used to optimize the SLGB structure considering Hefei Advanced Light Facility (HALF) lattice design demand and NbTi critical current.

WEPAB265 **Simulations of Cooling Rate for Coherent Electron Cooling With Plasma Cascade Amplifier**

J. Ma, *V. Litvinenko, G. Wang (BNL) V. Litvinenko (Stony Brook University)*

Coherent electron cooling (CeC) is a novel technique for rapidly cooling high-energy, high-intensity hadron beams. A plasma cascade amplifier (PCA) has been proposed for the CeC experiment in the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). The cooling rate of CeC experiment with PCA has been predicted in 3D start-to-end CeC simulations using code SPACE.

WEPAB266 **Simulation Studies of Plasma Cascade Amplifier**

J. Ma, *V. Litvinenko, G. Wang (BNL) V. Litvinenko (Stony Brook University)*

Plasma cascade amplifier (PCA) is an advanced design of amplifier for the coherent electron cooling (CeC) experiment in the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). Working principle of PCA is the new plasma cascade microbunching instability occurring in electron beams propagating along a straight trajectory. PCA is cost-effective as it does not require separating electron and hadron beams. SPACE, a parallel, relativistic 3D electromagnetic Particle-in-Cell (PIC) code, has been used for simulation studies of PCA.

WEPAB267 **Photoinjector Generation of High-Charge Magnetized Beams for Electron-Cooling Applications**

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The Electron-Ion Collider (EIC) to be built at Brookhaven National

Lab would greatly benefit from improved transverse phase space emittance on the Ion beam. One proposed solution is to employ Electron-Cooling to reduce the transverse phase space of the ion beam. The cooling rate for the electron-cooling method depends on the transverse emittance of the cooling electron beam and can benefit from using a beam with significant Canonical Angular Momentum (CAM) or sometimes called a magnetized beam. Using simulations and the 50-MeV photo-injector accelerator at the Fermilab Accelerator Science and Technology (FAST) facility we produce magnetized electron beams with comparable parameters that would be required for an EIC.

WEPAB268 **Modelling Dielectric-Lined Waveguides With WARP**
P. Piot *(Northern Illinois University)*
Dielectric-lined waveguides are ubiquitous tools for beam acceleration, manipulation, and radiation generation. These DLW structures are widely used owing to their relatively simple manufacturing yet the electromagnetic modes they support can be quite complex. In this contribution, we discuss the use of the finite-difference time-domain particle-in-cell method implemented in WARP to various applications of DLW structures including acceleration and radiation generation with a focus on cylindrical-symmetric and slab geometries.

WEPAB269 **Beam Dynamics and Experimental Tests of a Straight-Merger Concept**
P. Piot*, W.H. Tan, T. Xu (Northern Illinois University) S.V. Benson, J. Gubeli, A. Hutton, G.-T. Park, G.-T. Park, H. Wang (JLab) D.S. Doran, G. Ha, J.G. Power, E.E. Wisniewski (ANL) E.E. Wisniewski (Illinois Institute of Technology)*
Merging or splitting two or more bunches propagating collinearly in an accelerator beamline is sometimes necessary. For instance, in an energy-recovery linac, a low-energy "fresh" bunch is injected in a superconducting linac and accelerated using the field produced by a decelerating spent bunch. Devising configurations that minimize the phase-space degradations of the fresh bunch is a challenging problem. A recently proposed "straight merger" consists of a deflecting cavity with a superimposed dipole magnet. In this paper, we investigate the beam dynamics in such a merger configuration and present an experimental validation of the concept at the Argonne Wakefield Accelerator.

WEPAB270 **Characterization and Simulation of Optical Delay System for the Proof-of-Principle of Optical Stochastic Cooling at IOTA**
A.J. Dick*, P. Piot (Northern Illinois University) J.D. Jarvis (Fermilab) P. Piot (ANL)*
The Optical Stochastic Cooling (OSC) experiment at Fermilab's IOTA storage ring uses two undulators to cool the beam over many turns. The radiation emitted by electrons in the first undulator is delayed and imaged in the second undulator where it applies a corrective energy kick on the electrons. Imperfections in the manufacturing of the delay plates can lead to a source of error. This paper presents the experimental characterization of the absolute thickness of these delay plates

using an interferometric technique. The measured "thickness maps" are implemented in the Synchrotron Radiation Workshop (SRW) program to assess their impact on the delayed radiation pulse.

WEPAB271 **Numerical Modelling of the Optical Stochastic Cooling Experiment at IOTA**

***A.J. Dick**, P. Piot (Northern Illinois University) J.D. Jarvis (Fermilab) P. Piot (ANL)*

A proof-of-principle optical-stochastic cooling (OSC) experiment is currently in its commissioning phase at the Fermilab's IOTA ring. In support of this experiment, we recently implemented an OSC element in the ELEGANT tracking program. The model, based on a semi-analytic description of OSC, supports the simulation of a large number of macroparticles (10^4-10^6) over many turns (10^6). This paper showcases the simulation capabilities to investigate the beam dynamics in the presence of cooling (or self-interacting radiation field in general) and quantify the impact of various sources of error (e.g. transverse and phase jitter), guide data analysis.

WEPAB272 **Analysis of Multiple Coulomb Scattering of Muons in the MICE Liquid H_2 Absorber**

***G.T. Chatzitheodoridis** (USTRAT/SUPA)*

It is anticipated that high brightness muon beams will be used primarily in two types of accelerators, a muon collider and a neutrino factory. The primary challenge posed by using muons as the working particle of an accelerator physics system, and the reason it has not been used extensively in modern particle physics experiments, is its short lifetime (2.2μseconds at rest) and the relatively long cooling periods required by current cooling techniques. The Muon Ionization Cooling Experiment (MICE), is a multi-national accelerator physics initiative which has demonstrated Ionization Cooling (IC); a new, rapid beam-cooling technique suitable for the short-lived muon. The performance of IC depends on two key processes - energy loss due to collisional ionization, and Multiple Coulomb Scattering (MCS) - for which accurate models are crucial in parametrizing the method and enabling quantitative design of future muon accelerators. Experimental measurements of MCS of positive straight-track muons with momenta in the range 170-240 MeV/c in liquid H_2 are reported in this study.

WEPAB273 **Cooling and Diffusion Rates in Coherent Electron Cooling Concepts**

***S. Nagaitsev**, V.A. Lebedev (Fermilab) W.F. Bergan, E. Wang (BNL) G. Stupakov (SLAC)*

We present analytic cooling and diffusion rates for a simplified model of coherent electron cooling (CEC), based on a proton energy kick at each turn. This model also allows to estimate analytically the rms value of electron beam density fluctuations in the "kicker" section. Having such analytic expressions should allow for better understanding of the CEC mechanism, and for a quicker analysis and optimization of main

system parameters. Our analysis is applicable to any CEC amplification mechanism, as long as the wake (kick) function is available.

WEPAB274 **Numerical Study of Beam Dynamics in PITZ Bunch Compressor**

***A. Lueangaramwong**, Z. Aboulbanine, G.D. Adhikari, N. Aftab, P. Boonpornprasert, N. Chaisueb, G.Z. Georgiev, J. Good, C. Koschitzki, M. Krasilnikov, X. Li, O. Lishilin, D. Melkumyan, H.J. Qian, G. Shu, F. Stephan, G. Vashchenko, T. Weilbach (DESY Zeuthen) H. Shaker (CLS)*

A magnetic bunch compressor has been recently designed for an accelerator-based THz source which is under development at the Photo Injector Test facility at DESY in Zeuthen (PITZ). The THz source is assumed to be a prototype for an accelerator-based THz source for pump-probe experiments at the European XFEL. As an electron bunch is compressed to achieve higher bunch currents for the THz source, we investigate the beam dynamics in the bunch compressor by numerical simulations. A start-to-end simulation optimizer has been developed by combining the use of ASTRA, IMPACT-T, and OCELOT to support the design of the THz source prototype. Coherent synchrotron radiation effects degrade the compression performance for our study cases with bunch charges up to 4 nC and beam energy of 17 MeV at a bending angle of 19 degrees. Simulation and preliminary beam characteristic results will be presented in this paper.

WEPAB275 **Particle Motion Inside the CANREB Radiofrequency Quadrupole Cooler-Buncher**

***P.A. Harford**, F. Ames, M. Cavenaile, C.R.J. Charles, O.K. Kester, B.E. Schultz (TRIUMF)*

The ARIEL radiofrequency quadrupole cooler buncher (ARQB) as a part of TRIUMF's newly commissioned CANadian Rare isotope facility with Electron Beam ion source (CANREB) is essential for the preparation of radioactive isotope beams (RIB). We use SIMION version 8.1.1.32 to simulate coulomb interactions of the ions and collisions with the gas. This determines the effects of the total number of ions on the energy spread, transmission, and emittance after extraction. For 133Cs+1 at 30 and 60 keV, beam energies are typically hundreds-of-eV inside the ion guide with no gas. With gas, we find that collisional cooling efficiency is >60% approximately 1/3 through the ion guide, where beam energies drop to 10s of eV or less. When the ARQB deck potential approaches energies close to that of the beam, cooling reaches >90% about halfway into the ion guide, with a ~75% drop in ion velocity. As cooled beams exit the ion guide and continue through the beamline, space-charge effects again increase. Simulation results for 41K+1 at 3 MHz and 6 MHz will also be presented, along with results for incoming ion beams of lower energy (<10 keV).

WEPAB276 **Stochastic Cooling Study at the CR in the Time Domain**
M. Dolinska *(NASU/INR) C. Dimopoulou, A. Dolinskyy, O.E. Gorda (GSI) T. Katayama (Nihon University) L. Thorndahl (CERN)*
Special computer codes have been developed to calculate beam cooling in the time domain. The beam dynamics at the CR are studied under influence of stochastic cooling forces, which are treated turn by turn. In this paper three methods and algorithms are considered. The result of simulations is presented for the CR. The CR is a dedicated storage ring, which was designed special for fast cooling of secondary beams in frame of the FAIR project.

WEPAB277 **Transverse Emittance Change and Canonical Angular Momentum Growth in MICE 'Solenoid Mode' with Muon Ionization Cooling**
T.W. Lord *(University of Warwick)*
Emittance reduction of muon beams is an important requirement in the design of a Neutrino Factory or Muon Collider. Ionization cooling, whereby beam emittance is reduced by passing a beam through an energy-absorbing material, requires tight focusing in the transverse plane which is achieved in many designs using solenoid focusing. In solenoid focusing, the beam acquires kinetic angular momentum due to the radial field in the solenoid fringe. Cooling in 'flip' mode, where the beam-focusing solenoid field changes polarity at the absorber, has already been demonstrated in the Muon Ionization Cooling Experiment (MICE). In this mode the absorber is near to the field flip, so the kinetic angular momentum is zero at the absorber. 'Solenoid mode' cooling, where the field polarity does not change across the absorber leading to a beam crossing the absorber with significant kinetic angular momentum, has been considered for the final section of the muon collider design due to potentially stronger focussing that it enables. In this paper, we present the performance of MICE in 'solenoid mode'.

WEPAB278 **Beam-Beam Simulations for Lepton-Hadron Colliders: ALOHEP Software**
B.B. Oner *(Gazi University, Faculty of Arts and Sciences) B. Dagli, S. Sultansoy (TOBB ETU) B. Ketenoğlu (Ankara University, Faculty of Engineering)*
It is known that rough luminosity estimations for ll, lh, and hh colliders can be performed easily using nominal beam parameters. In principle, more precise results can be obtained by analytical solutions. However, beam dynamics is usually neglected in this case since it is almost impossible to cope with beam size fluctuations. In this respect, several beam-beam simulation programs for linear e^+e^- and photon colliders have been proposed while no similar open-access simulation exists for all types of colliders (i.e. linac-ring ep colliders). Here, we present the software ALOHEP (A Luminosity Optimizer for High Energy Physics), a luminosity calculator for linac-ring and ring-ring lh colliders, which also computes IP parameters such as beam-beam tune shift, disruption arising out of electromagnetic interactions. In addition, the pro-

gram allows taking crossing-angle effects on luminosity into account.

WEPAB279 **On Wire-Corrector Optimization in the HL-LHC and the Appearance of Special Aspect Ratios**
D. Kaltchev *(TRIUMF)*
For the two high-luminosity insertions of the Large Hadron Collider (HL-LHC) current bearing wire correctors are intended to mitigate the detrimental effect of long-range beam-beam interactions. With respect to finding the optimum longitudinal location of the wire, two special locations corresponding to the special values 2 and 1/2 of the beta-function aspect ratio have been previously shown to provide simultaneous cancellation of multiple two-dimensional Resonance Driving Terms. This paper attempts to explain the appearance of such special aspect ratios.

WEPAB280 **Two-Dimensional Beam-Beam Invariant With Applications to HL-LHC**
D. Kaltchev *(TRIUMF)*
Long-range beam-beam interactions represent the most severe limitation on the performance and achievable luminosity of circular collider. The paper presents a two-dimensional nonlinear Courant Snyder Invariant derived to first order in the beam-beam perturbation and based on the two-dimensional coefficients in the Fourier expansion of the Beam-beam Hamiltonian. Its validity in case of HL-LHC lattices with realistic beam-beam setup is verified with MadX tracking.

WEPAB281 **The Precision Laser Inclinometer**
B. Di Girolamo*, S. Vlachos (CERN) Ju. Boudagov, M.V. Lyablin (JINR)*
Earth surface movements, like earthquakes or human-produced (cultural) noise, can induce a degradation of the instantaneous luminosity of particle accelerators or even sudden beam losses. In the same way the presence of seismic and cultural noise limits the detection capabilities of interferometric antennas used for the observations of gravitational waves. This contribution discusses the importance of monitoring the effects of earth vibrations using a novel multi-purpose instrument, the Precision Laser Inclinometer (PLI). Few examples of recorded events are discussed along with ideas on PLI applications.

WEPAB282 **The Consolidation of the CERN Beam Interlock System**
R.L. Johnson*, C. Martin, T. Podzorny, I. Romera, R. Secondo, J.A. Uythoven (CERN)*
The Beam Interlock System (BIS) is a machine protection system that provides essential interlock control throughout the CERN accelerator complex. The current BIS has been in service since 2006; as such, it is approaching the end of its operational lifetime, with most components being obsolete. A second version of the Beam Interlock System, "BIS2", is currently under development and will replace the current system. BIS2 aims to be more flexible by supplying additional on-board diagnostic tools, while also improving the overall safety by adding more

redundancy. Crucially, BIS2 increases the number of critical paths that can be interlocked by almost 50%, providing an important flexibility for future additional interlocking requests. BIS2 will come into operation for the LHC in run 4 (2027) and will remain in operation until the end of the planned lifetime of HL-LHC. In this paper, we will focus on the Beam Interlock Controller Manager board (CIBM), which is at the heart of BIS2. Since this module works closely with many other systems that are similar in design to those in BIS1, we will compare how BIS2 improves upon BIS1, and justify the reasons why these changes were made.

WEPAB283 **CERN SPS Sprinkler System: A Customized Industrial Solution for a Non-Conventional Site**

A. Suwalska, *A. Arnalich, F. Deperraz, M. Munoz Codoceo, P. Ninin (CERN)*

Until 2018, the limited firefighting means in the SPS complex largely exposed it to the consequences of self-ignition or accidental fire. In 2015 the SPS Fire Safety project was launched with the objective of improving life safety and property protection by deploying a whole set of automatic actions to protect SPS in case of fire outbreak. If nothing was done, an unmanaged fire could be a threat to lives of those working underground and could mean losing a vast majority of the SPS machine and its equipment. In 2020, CERN has completed the consolidation of its SPS fire safety systems. Among these, a water based sprinkler system, following principles of standard industrial design but customized and tailor-made for SPS and its irradiated areas, is ready to operate. The system must take into account limitations related to the presence of fragile accelerator equipment, radioactive zones, integration constraints and comply with European norms, in particular EN12845. This paper presents the risk assessment, our experience from the planning and installation phase while discussing the custom-chosen and radiation tested equipment to end up with the lessons learned and outlook for the future.

WEPAB284 **Interlock System Upgrades at the CERN Accelerator Complex During Long Shutdown 2**

J.A. Uythoven, *A. Antoine, C. Martin, A. Mirana Fontan, R. Mompo, I. Romera, R. Secondo (CERN)*

The CERN accelerator complex stopped operation at the end of 2018 for the Long Shutdown 2 (LS2), allowing for the LHC Injector Upgrade program (LIU) and consolidation work to be accomplished. A gradual restart of the different accelerators is ongoing in 2021, culminating with the LHC foreseen to be back in operation early 2022. During LS2 a very large range of systems was modified throughout the accelerator complex. This includes the so-called Machine Interlock systems, which are at the heart of the overall machine protection system. This paper gives an overview of the Machine Interlock systems changes during LS2. It includes the installation of a Beam Interlock System (BIS) at the new linear accelerator LINAC4, at the PS-Booster and the installa-

tion of a new Injection BIS for the SPS synchrotron. New Safe Machine Parameter flags to protect the SPS transfer line mobile beam dumps against high intensity beams were put in place. The new Warm Magnet Controller (WIC) installations at LINAC4 the PS Booster and the different transfer lines and experimental areas are presented together with the modifications to the Power Interlock Controller protecting the LHC superconducting magnets.

WEPAB285 **High Resolution Arrival Time Measurement of the Seed Laser**

J.G. Wang, *H.X. Deng, L. Feng, C.L. Li, B. Liu (SARI-CAS) X.T. Wang, W.Y. Zhang (Shanghai Advanced Research Institute)*

The Shanghai soft X-ray Free-Electron Laser facility (SXFEL) is a fourth-generation linac-based light source, capable of producing X-ray pulses with a duration of tens of femtosecond. The seed laser for external seeding FEL, therefore, has tight requirements for relative arrival time to the electron bunch. To reach the required energy and wavelength for external seeding FEL, further optical amplification and frequency conversion is needed. These include reflection and propagation in different material and in air, in addition, also include the long laser transport beamline to the undulator, make the laser pulses arrival time influenced by environmental variation. To reach the required specification, high-resolution measurement of the laser arrival time is necessary. In this paper, we present a general concept for the measurement of the laser arrival time.

WEPAB286 **Design of the Laser-to-RF Synchronization at 1.3 GHz for the SHINE**

J.G. Wang, *H.X. Deng, L. Feng, C.L. Li, B. Liu (SARI-CAS) X.T. Wang, W.Y. Zhang (Shanghai Advanced Research Institute)*

A next-generation photo-science facility like Shanghai HIgh repetition rate XFEL aNd Extreme light facility (SHINE) is aiming to generate femtosecond X-ray pulses with unprecedented brightness to film chemical and physical reactions with sub-atomic level spatio-temporal resolution. To fulfill this scientific goal, high-precision timing synchronization is essential. The pulsed optical synchronization has become an indispensable scheme for femtosecond precision synchronization of X-ray free-electron lasers. One of the critical tasks of pulsed optical synchronization is to synchronize various microwave sources. For the future SHINE, ultralow-noise pulses generated by a mode-locked laser are distributed over large distances via stabilized fiber links to all critical facility end-stations. In order to achieve low timing jitter and long-term stability of 1.3 GHz RF reference signal for the accuracy Low-Level RF(RF) field control, an Electro-optical intensity Modulator (EOM) based scheme is being developed at SHINE. In this paper, we present the progress on the design of the optical part and the integrated electronics of the laser-to-RF synchronization.

WEPAB287 **Upgrade of the ELBE Timing System**

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At the ELBE accelerator center a superconducting linac is operated to drive manifold secondary radiation sources like two infrared FELs, a positron source and a THz facility. The machine uses two injectors as electron sources that are accelerated in the main linac. The user experiments demand a large variety of bunch patterns from single shot to macro pulsed and cw beam at up to 26 MHz repetition rate. At ELBE a new timing system is being developed based on the MRF hardware platform and the MRF Timing System IOC. It uses two masters and a scalable number of connected receivers to generate the desired pulse patterns for operating the machine and to control user experiments. The contribution will show the architecture of the timing system, the control interfacing and performance measurements acquired on the test bench.

WEPAB288 **A New Timing System for PETRA IV**

H. Lippek, *A. Aghababyan, K. Brede, H.T. Duhme, M. Fenner, U. Hurdelbrink, H. Kay, H. Schlarb, T. Wilksen (DESY)*

At DESY an upgrade of the PETRA III synchrotron light source towards a fourth-generation, low emittance machine PETRA IV is currently being actively pursued. The realization of this new machine implies a new design of the timing and synchronization system since requirements on beam quality and controls will significantly change from the existing implementation at PETRA III. As of now the technical design phase of the PETRA IV project is in full swing. For the timing system the design process of the overall system as well as the evaluation of individual components has been started as of last year. Given the success of the at DESY developed MicroTCA.4-based timing system for the European XFEL accelerator it has been chosen to serve as a basis for the PETRA IV timing system developement as well. We present first design ideas of the major timing system hardware component, a MicroTCA.4-based AMC for distributing clocks, triggers and further bunch-synchronous information within the accelerator complex and to user experiments. First steps of an evaluation process for designing the AMC hardware are briefly illustrated.

WEPAB289 **Machine Learning Based Spatial Light Modulator Control for the Photoinjector Laser at FLUTE**

C. Xu, *E. Bründermann, A.-S. Müller, M.J. Nasse, A. Santamaria Garcia, C. Sax, C. Widmann (KIT) A. Eichler (DESY)*

FLUTE (Ferninfrarot Linac- und Test-Experiment) at KIT is a compact linac-based test facility for novel accelerator technology and a source of intense THz radiation. FLUTE is designed to provide a wide range of electron bunch charges from the pC- to nC-range, high electric fields up to 1.2 GV/m, and ultra-short THz pulses down to the fs-timescale. The electrons are generated at the RF photoinjector, where the elec-

tron gun is driven by a commercial titanium sapphire laser. In this kind of setup the electron beam properties are determined by the photoinjector, but more importantly by the characteristics of the laser pulses. Spatial light modulators can be used to transversely and longitudinally shape the laser pulse, offering a flexible way to shape the laser beam and subsequently the electron beam, influencing the produced THz pulses. However, nonlinear effects inherent to the laser manipulation (transportation, compression, third harmonic generation) can distort the original pulse. In this paper we propose to use machine learning methods to manipulate the laser and electron bunch, aiming to generate tailor-made THz pulses. The method is demonstrated experimentally in a test setup.

WEPAB290 **Pointing Stabilization Algorithms Explored and Implemented With the Low Energy RHIC Electron Cooling Laser**
L.K. Nguyen *(BNL)*
The electron beam for the Low Energy RHIC electron Cooler (LEReC) at Brookhaven National Laboratory (BNL) is generated by a high-power fiber laser illuminating a photocathode, with a total propagation distance of 34 m separating the laser output and the photocathode. This propagation is facilitated by three independent laser tables that have varying responses to changes in time of day, weather, and season. Alignment drifts induced by these environmental changes are mitigated by an active "slow" pointing stabilization system found along the length of the transport, and this in-house system was commissioned as part of the full laser transport in 2019, as previously reported. In 2020, the system became fully operational alongside LEReC, the world's first electron cooler in a collider, and helped establish the transverse stability of the electron beam required for cooling. A summary of the different slow stabilization algorithms, which were continually refined during the run in order to achieve long-term center-of-mass stability of the laser spot on the photocathode to within 10 microns RMS, is provided.

WEPAB291 **The HIgh REsolution Hard X-Ray Single Shot Spectrometer (HIREX Spectrometer) as Feedback System for the SASE Beamlines of the European XFEL**
N.G. Kujala*, F. Dietrich, W. Freund, R.P. Gautam, J. Grünert, A. Koch, J. Laksman, J. Liu, Th. Maltezopoulos (EuXFEL)*
The European X-ray Free Electron Laser (EuXFEL) facility in Germany delivers pulses with femtosecond pulse lengths at repetition rates up to 4.5 MHz. There are three undulator beamlines: SASE1 and SASE2 provide hard X-ray FEL radiation, while SASE3 provides soft X-ray radiation. The X-ray photon diagnostics group provides reliable measurement devices and feedback systems for monitoring and controlling the properties of the FEL radiation which is created by the SASE process (Self Amplified Spontaneous Emission), whose stochastic nature gives rise to shot-to-shot fluctuations of the pulse energy and spectrum. In order to cover these variations, the HIgh REsolution hard X-

ray single shot spectrometer (HIREX spectrometer) has been installed in the SASE1 and SASE2 undulator beamlines as feedback system for machine optimization. The HIREX spectrometer is an online device, based on a bent diamond crystal as a dispersive element and a MHz-repetition rate strip detector. In this contribution we discuss the commissioning of the HIREX spectrometer with XFEL beam and present the spectral measurement applied in feedback for machine optimizing with a focus on self-seeding studies.

WEPAB292 **Application of Machine Learning to Predict the Response of the Liquid Mercury Target at the Spallation Neutron Source**
***L. Lin**, S. Gorti, J.C. Mach, H. Tran, D.E. Winder (ORNL)*
The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory is currently the most powerful accelerator-driven neutron source in the world. The intense proton pulses strike on SNS's mercury target to provide bright neutron beams, which also leads to severe fluid-structure interactions inside the target. Prediction of resultant loading on the target is difficult particularly when helium gas is intentionally injected into mercury to reduce the loading and mitigate the pitting damage on the target's internal walls. Leveraging the power of machine learning and the measured target strain, we have developed machine learning surrogates for modeling the discrepancy between simulations and experimental strain data. We then employ these surrogates to guide the refinement of the high-fidelity mercury/helium mixture model to predict a better match of target strain response.

WEPAB293 **The Trip Event Logger for Online Fault Diagnosis at the European XFEL**
***J.H.K. Timm**, J. Branlard, A. Eichler, H. Schlarb (DESY)*
The low-level RF (LLRF) system at the European XFEL, DESY, is of major importance for a high-performant and reliable operation. Faults here can jeopardize the overall operation. Therefore, the trip event logger is currently developped, - a fault diagnosis tool to detect errors online, inform the operators and trigger automatic supervisory actions. Further goals are to provide information for a fault tree and event tree analysis as well as a database of labeled faulty data sets for offline analysis. The tool is based on the C++ framework ChimeraTK Application Core. With this close interconnection to the control system it is possible not only to monitor but also to intervene as it is of great importance for supervisory tasks. The core of the tool consists of fault analysis modules ranging from simple ones (e.g., limit checking) to advanced ones (model-based, machine learning, etc.). Within this paper the architecture and the implementation of the trip event logger are presented.

WEPAB294 **LLRF Control and Synchronization System of the ARES Facility**
***S. Pfeiffer**, J. Branlard, F. Burkart, M. Hoffmann, T. Lamb, F. Ludwig, H. Schlarb, S. Schulz, B. Szczepanski, M. Titberidze (DESY)*
The linear accelerator ARES (Accelerator Research Experiment at SINBAD) is a new research facility at DESY. Electron bunches with a maxi-

mum repetition rate of 50 Hz are accelerated up to 155 MeV. The facility aims for ultra-stable sub-femtosecond arrival-times and high peak-currents at the experiment, placing high demands on the reference distribution and field regulation of the S-band RF structures. In this paper, we report on the current status of the RF reference generation, facility-wide distribution, and the LLRF systems of the RF structures.

WEPAB295 **Parameter Estimation of Short Pulse Normal-Conducting Standing Wave Cavities**

S. Pfeiffer, *J. Branlard, F. Burkart, M. Hoffmann, H. Schlarb (DESY)*

The linear accelerator ARES (Accelerator Research Experiment at SINBAD) is a new research facility at DESY. Electron bunches with a maximum repetition rate of 50 Hz are accelerated to a target energy of 155 MeV. The facility aims for ultra-stable sub-femtosecond arrival-times and high peak-currents at the experiment, placing high demands on the reference distribution and field regulation of the RF structure. In this contribution, we present the physical parameter estimation of key RF properties such as cavity detuning not directly measurable on the RF field decay. The method can be used as a fast monitor of inner cell temperature. The estimated properties are finally compared with the measured ones.

WEPAB296 **A Klystron Phase Lock Loop for RF System at TPS Booster Ring**

F.Y. Chang, *M.H. Chang, S.W. Chang, L.J. Chen, F.-T. Chung, Y.D. Li, M.-C. Lin, Z.K. Liu, C.H. Lo, Ch. Wang, M.-S. Yeh, T.-C. Yu (NSRRC)*

In TPS booster ring, the DLLRF is used to controlled the ramping gap voltage and also the energy saving module is applied to save power while the ring does not inject beam. But we occurred to have a problem of PI saturation due to a large phase change when the energy saving module working. The energy saving module switches the anode voltage of the klystron from high to low level to decrease the cathode current while the ring does not inject and do the opposite while the ring injects. This action causes a large phase change of the transmitter and leads the PI controller to work in the wrong direction. We add a klystron phase loop to solve this situation.

WEPAB297 **A Recent Upgrade on Phase Drift Compensation System for a Stable Beam Injection at J-PARC Linac**

E. Cicek, *Z. Fang, Y. Fukui, K. Futatsukawa (KEK) T. Hirane, S. Shinozaki (JAEA/J-PARC) Y. Sato (Nippon Advanced Technology Co., Ltd.)*

J-PARC linac, consisting of 324 MHz and 972 MHz acceleration sections, delivers H^- beam to the rapid cycling synchrotron (RCS). The drift in the beam injection momentum from linac to RCS was measured to be highly dependent on the humidity at the klystron gallery. Also, changes in both temperature and humidity strongly affect the rf field phase controlled within the digital feedback (DFB) system. To cope with this, a unique phase drift compensation system, namely the

phase drift monitor (PDM) system, is implemented in the MEBT2B1 station as the first step at the linac. However, the compensation of the drift correction could not be achieved directly since two different frequencies were used. The new PDM, which adapts the direct sampling method using the Radio Frequency System-on-Chip (RFSoC), will pave the way to ensure rf phase stability at all stations simultaneously. Here we present the effects of temperature and humidity on the rf field phase, along with performance and preliminary test results concerning the phase drift compensation.

WEPAB298 **Design of an Accurate LLRF System for an Array of Two-Gap Resonators**

***D.A. Liakin**, S.V. Barabin, T. Kulevoy, A.Y. Orlov (ITEP)*

A particle accelerator based on an array of two-gap resonators requires a control system, which is responsible for precise setup and stabilization of the phase and magnitude of the electromagnetic field in resonators. We develop a cost-effective LLRF system for the array of more than 80 resonators and three different operating frequencies. The design is based on proved solution used for 5-resonators accelerator HILAC (project NICA, Dubna). This paper gives an overview of the basic structure and some specific features of the developing LLRF control system.

WEPAB299 **Spallation Neutron Source Proton Power Upgrade Low-Level RF Control System Development**

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The Proton Power Upgrade (PPU) Project is approved for the Spallation Neutron Source at Oak Ridge National Laboratory and will double the proton beam power capability from 1.4 MW to 2.8 MW with 2 MW beam power available to the first target station. A second target station is planned and will utilize the remaining beam power in the future. The proton power increase will be supported with the addition of twenty-eight new superconducting cavities powered by 700 kW peak power klystrons to increase beam energy while increases to the beam current will be done with a combination of existing RF margin, and DTL HPRF upgrades. The original low-level RF control system has proven to be reliable over the past 15 years of operations, but obsolescence issues mandate a replacement system be developed for the PPU project. The replacement system is realized in a µTCA.4 platform using a combination of commercial off-the-shelf boards and custom hardware to support the requirements of PPU. This paper presents the prototype hardware, firmware, and software development activities along with preliminary testing results of the new system.

WEPAB300 **Python Based Tools for FRIB LLRF Operation and Management**

***S.R. Kunjir**, D.G. Morris, S. Zhao (FRIB)*

Some Python based tools have been developed at the Facility for Rare

Isotope Beams (FRIB) for the ease of operation and management of the low level radio frequency (LLRF) controllers. Utilizing the rich features in Python, some tasks can be easily applied to a whole segment, one type of cryomodule (CM), a specific cryomodule or individual cavities grouped by a complex custom query. The tasks include, for example, 1) testing interface connections between various sub-systems prior to an operational run; 2) setting, checking and saving/restoring parameters during and after an operational run; 3) updating LLRF controller firmware and software during maintenance. With these tools, routine manual tasks are streamlined to achieve significantly greater efficiency in terms of scalability, time, memory and network resources. Considering channel access security, beam on/off status etc., the strategy of choosing either input/output controller (IOC) or Python for the implementation of certain tasks is also discussed in the paper.

WEPAB301 **Design of an X-Band LLRF System for TEX Test Facility at LNF-INFN**

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In the framework of LATINO project (Laboratory in Advanced Technologies for INnOvation) funded by Lazio regional government, a TEst stand for X-band (TEX) is being commissioned at Frascati National Laboratories (LNF) of INFN. TEX is born as a collaboration with CERN, aimed at carrying out high power tests of X-band accelerating structure prototypes and waveguide components, and it is of paramount importance in view of the construction of EuPRAXIA@SPARC_LAB facility at LNF. In order to generate, manipulate and measure the RF pulses needed to feed the RF power unit (solid state ScandiNova K400 modulator, CPI 50 MW 50 Hz klystron) an X-band low level RF system has been developed, making use of a commercial S-band (2.856 GHz) Libera digital LLRF (manufactured by Instrumentation Technologies) with a newly designed up/down conversion stage and a reference generation/distribution system, which is able to produce coherent reference frequencies for the American S-band (2.856 GHz) and European X-band (11.994 GHz). In this paper the main features of such systems will be reviewed together with preliminary laboratory measurement results.

WEPAB302 **COSY Machine-Model Optimization**

***I. Bekman**, J.H. Hetzel (FZJ)*

Successful operation of a particle accelerator requires accompanying model calculations. The model helps in understanding the machine and predicts the impact of a change in the settings (e.g. current of magnetic elements). For the COoler SYnchrotron (COSY) at Research Center Jülich the accelerator simulation software MAD-X is used to model the machine. The model parameters are steadily being improved based on various manual adjustments and analytical studies,

however are hardly optimized all at once. This can be improved with machine learning methods. The model is used to predict measurable quantities, like Orbit Response Matrix (ORM) or betatron tunes. Several observables for different particle energies have been measured recently and the corresponding machine settings are available. We describe the effort to improve the agreement between measured and calculated ORMs and hence improve the agreement between model and (real) machine and report on the optimization using a multivariate algorithm (e.g. genetic algorithm). This facilitates the setup of COSY and will allow to perform high precision experiments e.g. a measurement of an electric dipole moment of deuterons at COSY.

WEPAB303 **Machine Learning Applied to Automated Tunes Control at the 1.5 GeV Synchrotron Light Source DELTA**
D. Schirmer *(DELTA)*
Machine learning (ML) driven algorithms are finding more and more use cases in the domain of accelerator physics. Apart from correlation analysis in large data volumes, low and high level controls, like beam orbit correction, also non-linear feedback systems are possible application fields. This also includes monitoring the storage ring betatron tunes, as an important task for stable machine operation. For this purpose classical, shallow (non-deep), feed-forward neural networks (NNs) were investigated for automated adjusting the storage ring tunes. The NNs were trained with experimental machine data as well as with simulated data based on a lattice model of the DELTA storage ring. With both data sources comparable tune correction accuracies were achieved, both, in real machine operation and for the simulated storage ring model. In contrast to conventional PID methods, the trained NNs were able to approach the desired target tunes in fewer steps. The report summarizes the current status of this machine learning project and points out possible future improvements as well as other possible applications.

WEPAB304 **Multi-Objective Multi-Generation Gaussian Process Optimizer**
X. Huang*, M. Song, Z. Zhang (SLAC)*
We present a multi-objective evolutionary optimization algorithm that uses Gaussian process (GP) regression-based models to select trial solutions in a multi-generation iterative procedure. In each generation, a surrogate model is constructed for each objective function with the sample data. The models are used to evaluate solutions and to select the ones with a high potential before they are evaluated on the actual system. Since the trial solutions selected by the GP models tend to have better performance than other methods that only rely on random operations, the new algorithm has much higher efficiency in exploring the parameter space. Simulations with multiple test cases show that the new algorithm has a substantially higher convergence speed and stability than NSGA-II, MOPSO, and some other recent preselection-assisted algorithms.

WEPAB305 **Teeport: Break the Wall Between the Optimization Algorithms and Problems**

***Z. Zhang**, X. Huang, M. Song (SLAC)*

Optimization algorithms/techniques such as genetic algorithm (GA), particle swarm optimization (PSO) and Gaussian process (GP) have been widely used in the accelerator field to tackle complex design/online optimization problems. However, connecting the algorithm with the optimization problem can be difficult, sometimes even unrealistic, since the algorithms and problems could be implemented in different languages, might require specific resources, or have physical constraints. We introduce an optimization platform named Teeport that is developed to address the above issue. This real-time communication (RTC) based platform is particularly designed to minimize the effort of integrating the algorithms and problems. Once integrated, the users are granted a rich feature set, such as monitoring, controlling, and benchmarking. Some real-life applications of the platform are also discussed.

WEPAB306 **Applying Machine Learning to Optimization of Cooling Rate at Low Energy RHIC Electron Cooler**

***Y. Gao**, K.A. Brown, P.S. Dyer, S. Seletskiy, H. Zhao (BNL)*

The Low Energy RHIC electron Cooler (LEReC) is a novel, state-of-the-art, electron accelerator for cooling RHIC ion beams, which was recently built and commissioned. Optimization of cooling with LEReC requires fine-tuning of numerous LEReC parameters. In this work, initial optimization results of using Machine Learning (ML) methods - Bayesian Optimization (BO) and Q-learning are presented. Specially, we focus on exploring the influence of the electron trajectory on the cooling rate. In the first part, simulations are conducted by utilizing a LEReC simulator. The results show that both methods have the capability of deriving electron positions that can optimize the cooling rate. Moreover, BO takes fewer samples to converge than the Q-learning method. In the second part, Bayesian optimization is further trained on the historical cooling data. In the new samples generated by the BO, the percentage of larger cooling rates data is greatly enhanced compared with the original historical data.

WEPAB307 **A Python Emittance Measurement Gui for the Lcls Control Room**

***A. Sihn** (Vanderbilt University)*

Emittance is an important beam property that describes the size and divergence of a particle beam. This is obtained by calculating a sigma matrix, drift matrix, and finding the Twiss parameters using matrices. Currently, this property is measured using a combination of standard diagnostics and MATLAB code first written when the Linac Coherent Light Source (LCLS) was being commissioned. To improve diagnostic measurements at the LCLS, a new emittance measurement graphical user interface (GUI) for the LCLS control room was designed. To keep up with current software, this code was written in Python as a resource

for future operators and engineers. The GUI loads, categorizes, and analyzes data from previous MATLAB measurements. It displays the measurements and saves related plots. Prior to development of the GUI, a correlation plot tool was coded in Python. This code takes in emittance measurements, calculates the average of the beam size for a certain magnet strength, and plots the correlation of the two variables. The correlation plot tool was added to the GUI as an option for users to see the relationship between the magnet strength and beam size of the data they are working with.

WEPAB308 **Measurement-Based Surrogate Model of the SLAC LCLS-II Injector**

L. Gupta *(University of Chicago) A.L. Edelen, C.E. Mayes, N.R. Neveu (SLAC)*

There is significant effort within particle accelerator physics to use machine learning methods to improve modeling of accelerator components. Such models can be made realistic and representative of machine components by training them with measured data. These models could be used as virtual diagnostics or for model-based control when fast feedback is needed for tuning to different user settings. To prototype such a model, we demonstrate how a machine learning based surrogate model of the SLAC LCLS-II photocathode injector was developed. To create machine-based data, laser measurements were taken at the LCLS using the virtual cathode camera. These measurements were used to sample particles, resulting in realistic electron bunches, which were then propagated through the injector via the Astra space charge simulation. By doing this, the model is not only able to predict many bulk electron beam parameters and distributions which are often hard to measure or not usually available to measure, but the predictions are more realistic relative to traditionally simulated training data. The methods for training such models, as well as model capabilities and future work are presented here.

WEPAB309 **Study and Design of the Appropriate High-Performance Computing System for Beamline Data Analysis Application at Iranian Light Source Facility**

A. Khaleghi*, M. Akbari (ILSF) H. Haedar, K. Mahmoudi (IKIU)*

Data analysis is a very important step in doing experiments at light sources, where multiple application and software packages are used for this purpose. In this paper we have reviewed some software packages that are used for data analysis and design at Iranian Light Source Facility then according to their processing needs, after taking in mind different HPC scenarios a suitable architecture for deployment of the ILSF HPC is presented. The proposed architecture is a cluster of 64 computing nodes connected through Ethernet and InfiniBand network running a Linux operating system with support of MPI parallel environment.

WEPAB310 **Study and Design of a High-Performance Computing Infrastructure for Iranian Light Source Facility Based on the Accelerator Physicists and Engineers' Applications Requirements**
K. Mahmoudi, *H. Haedar, A. Khaleghi (IKIU) M. Akbari, A. Khaleghi (ILSF) S. Mahmoudi (IUST)*
Synchrotron design and operation are one of the complex tasks which requires a lot of precise computation. As an example, we could mention the simulations done for calculating the impedance budget of the machine which requires a notable amount of computational power. In this paper we are going to review different HPC scenarios suitable for this matter then we will present our design of a suitable HPC based on the accelerator physicists and engineers' needs. Going through different HPC scenarios such as shared memory architectures, distributed memory architectures, cluster, grid and cloud computing we conclude implementation of a dedicated computing cluster can be desired for ILSF. Cluster computing provides the opportunity for easy and saleable scientific computation for ILSF also another advantage is that its resources can be used for running cloud or grid computing platforms as well.

WEPAB311 **Training of a Neural Network to Model the MYRRHA LEBT Using Multiple Data Sources**
M. Debongnie, *F. Bouly, J.-M. De Conto (LPSC) F. Davin (SCK•CEN) O. Kochebina (ACS)*
The MYRRHA (Multi-purpose hYbrid Research Reactor Reactor for High-tech Applications) linac has to meet very high reliability and stability requirements, i. e. during one operating cycle of 3 months a maximum of 10 beam trips longer than 3 seconds are allowed. To meet these requirements, multiple innovative solutions are planned such as redundancies and an optimized control system. This is especially the case for the tuning and control of the injector beam dynamics to minimize beam losses in the following elements of the linac. Here we present a potential solution by tuning a beam dynamics model of the MYRRHA low energy beam transport line based on neural network and supervised learning. The performances of a neural network trained using a combination of experimental and simulated data are presented and discussed.

WEPAB314 **TEX - an X-Band Test Facility at INFN-LNF**
S. Pioli, *D. Alesini, F.A. Anelli, M. Bellaveglia, S. Bini, B. Buonomo, S. Cantarella, F. Cardelli, G. Catuscelli, R. Ceccarelli, A. Cecchinelli, F. Chiarelli, P. Ciuffetti, R. Clementi, C. Di Giulio, E. Di Pasquale, G. Di Raddo, M. Diomede, A. Esposito, L. Faillace, A. Falone, G. Franzini, A. Gallo, S. Incremona, A. Liedl, D. Pellegrini, G. Piermarini, L. Piersanti, S. Quaglia, R. Ricci, L. Sabbatini, M. Scampati, G. Scarselletta, A. Stella, R. Zarlenga (INFN/LNF)*
We report the status of the development of an High Power RF Laboratory in X-Band called TEX (TEst-stand for X-Band). TEX is part of the LATINO (Laboratory in Advanced Technologies for INnOvation) initia-

tive that is ongoing at the Frascati National Laboratories (LNF) of the Italian Institute for Nuclear Physics (INFN) that covers many different areas focused on particle accelerator technologies. TEX is a RF test facility based on solid-state K400 modulator from ScandiNova with a 50MW class X-band (11.996 GHz) klystron tube model vkx 8311a operating at 50 Hz. This RF source will operate as resource for test and research programs such as the RF breakdown on RF waveguide components as well as high power testing of accelerating structures for future high gradient linear accelerator such as EuPRAXIA and CLIC. The high power testing will be performed in a dedicated brand-new bunker that has been recently built. RF system, vacuum controls and safety equipments are currently being installed. The first accelerating structure testing is scheduled by beginning 2022. In this document design and tests for all the sub-systems of the facility will be presented and discussed.

WEPAB315 **360 Degree Panoramic Photographs During the Long Shutdown 2 of the CERN Machines and Facilities**

***T.W. Birtwistle**, A. Ansel, S. Bartolome, B. Feral, G. Lacerda, A.-L. Perrot, J.F. Piñera Ovejero (CERN)*

Studies and preparation of activities are key to the success of short technical stops and longer shutdowns in CERN's accelerator complex. The 'Panorama' tool offers a virtual tour of our facilities, and thanks to integration with other CERN tools, further complementary information can be easily retrieved, including layout information, equipment detail, and a history of changes. The tool was used to support the preparation and the execution of works during the Long Shutdown 2. It helped to optimize machine (accelerator/decelerator) interventions and hence reduce potential radiation exposure, as well as to ease integration studies. Thanks to its user-friendliness, the tool is now also used for educational and outreach activities. The current instantiation of the 'Panorama' tool and related processes is presented, alongside the benefits that the tool can bring to the accelerator complex community. A particular focus is on the Long Shutdown 2. Future planned developments and improvements are also described.

WEPAB316 **Development of a New Online Model for the High-Energy Beam Transfer Lines at GSI**

***C. Heßler**, M. Ohlig, S. Reimann, M. Sapinski, P. Schütt (GSI)*

The high-energy beam transfer lines at GSI serve numerous experimental stations such as HADES, HTC and HTD as well as the fragment separator FRS and the storage rings ESR and CRYRING with a wide range of different heavy ion beams from the SIS18 synchrotron. The large amount of experiments carried out during beam times under different beam conditions require frequent changes of beam optics and beam steering in the transfer lines. In the past, the online model tool "Mirko Expert" was available for this purpose, which however is not compatible with the new control system intrastructure. Therefore, a new online model based on the MAD-X beam dynamics simulation

code and the JMad programming interface is under development in Java. This paper presents the concept and features of the new online model application, as well as possible future extensions. Efforts to overcome discrepancies in the present Mirko and MAD-X optics models are also discussed.

WEPAB317 **Online Model Developments for BESSY II and MLS**
***P. Schnizer**, J. Bengtsson, T. Birke, J. Li, T. Mertens, M. Ries, A. Schälicke, L. Vera Ramirez (HZB)*
Digital models have been developed over a long time for preparing accelerator commissioning next to benchmarking theory predictions to machine measurements. These digital models are nowadays being realized as digital shadows or digital twins. Accelerator commissioning requires periodic setup and review of the machine status. Furthermore, different measurements are only practical by comparison to the machine model (e.g. beam based alignment). In this paper we describe the architecture chosen for our models, describe the framework Bluesky for measurement orchestration and report on our experience exemplifying on dynamic aperture scans. Furthermore we describe our plans to extend the models applied to BESSY–II and MLS to the currently planned machines BESSY–III and MLS–II.

WEPAB318 **Prediction and Clustering of Longitudinal Phase Space Images and Machine Parameters Using Neural Networks and K-Means Algorithm**
***M. Maheshwari** (STFC/DL) D.J. Dunning, J.K. Jones, M.P. King, H.R. Kockelbergh, A.E. Pollard (STFC/DL/ASTeC)*
Machine learning algorithms were used for image and parameter recognition and generation with the aim to optimise the CLARA facility at Daresbury, using start-to-end simulation data. Convolutional and fully connected neural networks were trained using TensorFlow-Keras for different instances, with examples including predicting Longitudinal Phase Space (LPS) images with machine parameters as input and FEL parameter prediction (e.g. pulse energy) from LPS images. The K-means clustering algorithm was used to cluster the LPS images to highlight patterns within the data. Machine learning techniques can enhance the way large amounts of data are processed and analysed and so have great potential for application in accelerator science R&D.

WEPAB319 **OpenXAL Status Report 2021**
***N. Milas**, J.F. Esteban Muller, Y. Levinsen (ESS) T.V. Gorlov, A.P. Shishlo, A.P. Zhukov (ORNL)*
The Open XAL accelerator physics software platform is being developed through international collaboration among several facilities since 2010. The goal of the collaboration is to establish Open XAL as a multi-purpose software platform supporting a broad range of tool and application development in accelerator physics and high-level control (Open XAL also ships with a suite of general-purpose accelerator applications). This paper discusses progress in beam dynamics simulation, new RF models, and updated application framework along with

new generic accelerator physics applications. We present the current status of the project, a roadmap for continued development, and an overview of the project status at each participating facility.

WEPAB320 **RecCeiver-ETCD: A Bridge Between ETCD and ChannelFinder**
G. Jhang, *T. Ashwarya, A. Carriveau (FRIB)*
Managing EPICS Process Variables' (PVs) metadata, such as the host and the contact, is one of the important tasks for the operation of large-scale accelerator facilities with minimal downtime. Record Sychronizer (RecSync) provides a way to manage such crucial information in an EPICS Input-Output Controller (IOC). RecCeiver-ETCD is the server component of the RecSync-ETCD, or an extension of RecCeiver for ETCD. In the previous work, the client component of RecSync, or RecCaster, has been extended to RecCaster-ETCD to store the metadata into an ETCD key-value store. An important remaining step to the production use is to introduce a connection between ETCD and ChannelFinder, which is achieved by RecCeiver in the RecSync system. RecCeiver-ETCD plays the role of the original RecCeiver in the RecSync-ETCD system. RecCeiver-ETCD is designed to perform the specific operation, bridging the communication between ETCD and ChannelFinder. In addition, its simple implementation does not hold it down to ChannelFinder and makes it easy to extend RecCeiver-ETCD out to the other applications.

WEPAB321 **ALS-U Instrumentation Overview**
J.M. Weber, *J.C. Bell, M.J. Chin, S. De Santis, R.F. Gunion, S. Murthy, W.E. Norum, G.J. Portmann, C. Serrano (LBNL) W.K. Lewis (Osprey DCS LLC)*
The Advanced Light Source Upgrade (ALS-U) to a diffraction-limited storage ring with a small vacuum chamber diameter requires excellent orbit stability and a fast response orbit interlock for machine protection. The on-axis swap-out injection scheme and dual RF frequencies demand fast monitoring of pulsed injection magnets and a novel approach to timing. Recent development efforts at ALS and advances in PLLs, FPGAs, and RFSoCs that provide higher performance and mixed-signal integration can be leveraged for instrumentation solutions to these accelerator challenges. An overview of preliminary ALS-U instrumentation system designs and status will be presented.

WEPAB322 **Status of Digital BPM Signal Processor for SHINE**
L.W. Lai, *F.Z. Chen, Y.B. Leng, T. Wu, Y.M. Zhou (SSRF) J. Wan (SINAP)*
Digital signal processors that can handle 1MHz bunch rate BPM signal processing are under development for SHINE. Two different processors have been developed at the same time, including an intermediate frequency signal processor with a sampling rate higher than 500MHz, which can be used in general BPM applications; and a direct RF sampling processor, which can directly sample the C band cavity BPM signal without analog down-conversion modules and greatly simplifies

the cavity BPM system. This paper will introduce the design, development status, and performance evaluations of the processors.

WEPAB323 **High Performance DAQ Infrastructure to Boost Machine Learning for the Advanced Photon Source Upgrade**

***G. Shen**, N.D. Arnold, T.G. Berenc, J. Carwardine, E. Chandler, T. Fors, T.J. Madden, D.R. Paskvan, C. Roehrig, S.E. Shoaf, S. Veseli (ANL)*

It is well known that the efficiency of an advanced control algorithm like machine learning is as good as its data quality. Much recent progress in technology enables the massive data acquisition from a control system of modern particle accelerator, and the wide use of embedded controllers, like field-programmable gate arrays (FPGA), provides an opportunity to collect fast data from technical subsystems for monitoring, statistics, diagnostics or fault recording. To improve the data quality, at the APS Upgrade project, a general-purpose data acquisition (DAQ) system is under active development. The APS-U DAQ system collects high-quality fast data from underneath embedded controllers, especially the FPGAs, with the manner of time-correlation and synchronously sampling, which could be used for commissioning, performance monitoring, troubleshooting, and early fault detection, etc. This paper presents the design and latest progress of APS-U high-performance DAQ infrastructure, as well as its preparation to enable the use of machine learning technology for APS-U, and its use cases at APS.

WEPAB325 **Beam Closed-Orbit Correction Based on Lattice Server Middlelayer**

***C. Li** (USTC/NSRL)*

As an independent system software or service program to realize resource sharing among various software and technologies, Accelerator Middleware (Middle Layer) serves an important role in the accelerator control system. In the Hefei advanced light source pre-research project, according to its needs, the application research of Lattice Server middleware technology was carried out, and the Lattice Server middleware was developed. In order to verify the feasibility of the Lattice Server middleware software structure, a beam closed-orbit slow feedback correction based on the Lattice Server middleware was developed by using Python language, and the Hefei light source storage ring was used for the correction experiment. The results show that the Lattice Server middleware realizes the interaction between the upper physical application of the accelerator and the control system, and the beam closed orbit error is stable within the allowable range, which confirms the feasibility of the Lattice Server middleware software structure.

WEPAB326 **Beam Phase Detection in a Superconducting Cyclotron for Proton Therapy**

***Y. Yan**, K. Fan, H.J. Zhang (Huazhong University of Science and Technology, State Key Laboratory of Advanced Electromagnetic*

Engineering and Technology,) Z.Y. Mei (HUST)
A 250 MeV superconducting cyclotron (SCC250) for proton therapy is being developed at Huazhong University of Science and Technology (HUST), which requires high beam stability to ensure clinical requirements. However, the magnet iron temperature will increase during the operation due to the RF system's heat dissipation, eddy current effect, and beam loss, which will deteriorate the isochronism between the beam and the RF system leading to a degradation of beam quality. As the phase angle of beam pulses with respect to the rf voltage phase angle is most sensitive to the magnetic field change, the phase measurement system is essential for tuning the isochronous magnetic field and obtaining a high-quality beam. In this paper, the beam phase is detected using non-intercepting capacitive pick-up probes installed inside the cyclotron. Both the CST-studio and MATLAB are applied to simulate the process of beam phase detection. The phase measurement error can meet the requirement even under the severe RF-disturbance by using multi-stage filters, SSB mixer, phase calibration method.

WEPAB327 **Sheet Electron Probe for Beam Tomography**
***V.G. Dudnikov**, M.A. Cummings, G. Dudnikova (Muons, Inc)*
An electron beam probe has been successfully used for the determination of accelerated particle density distributions. However, the apparatus used for this diagnostic had a large size and complex design which limit the broad use of this diagnostic for tomography of accelerated bunches. We propose a new approach to electron beam tomography: we will generate a continuous sheet of electrons. As the ion beam bunches pass through the sheet, they cause distortions in the distribution of sheet electrons arriving at CCD device on the other side of the beam that is interpreted to give a continuous measurement of the beam profile. The apparatus to generate the sheet beam is a strip cathode, which, compared to the scanning electron beam probe, is smaller, has a simpler design and less expensive manufacturing, has better magnetic shielding, has higher sensitivity, higher resolution, has better accuracy of measurement and better time resolution. With this device, it is possible to develop almost ideal tomography diagnostics of bunches in linear accelerators and in circular accelerators and storage rings.

WEPAB328 **Rapid Surface Microanalysis Using a Low Temperature Plasma**
***V.G. Dudnikov**, M.A. Cummings, R.P. Johnson (Muons, Inc)*
There is a need for rapid, high-resolution (micron or sub-micron) scanning of surfaces of special nuclear materials (SNM) and surrogate materials to locate and identify regions of abnormalities. One technique that is commonly used to analyze the composition of solid surfaces and thin films is secondary-ion mass spectrometry (SIMS). SIMS devices are very complex and expensive. We propose to develop simpler, less expensive surface analysis devices, based on glow-discharge optical emission spectroscopy (GOES) that can provide excellent spa-

tial resolution. Ions from a plasma discharge sputtered atoms from the surface and the discharge electrons effectively excite and ionize the sputtered atoms. GOES uses the light emitted by the excited particles for quantitative analysis. In the GOES device, the ion flux is extracted from the gas-discharge plasma and focused to a micron size on the sample, providing very local sputtering and local elemental analysis. The radiation from the sputtered atoms is passed through an optical fiber to an optical spectrometer and recorded. To register the distribution of elements over the sample, the sample is scanned electromechanically.

WEPAB329 **LCLS-II Average Current Monitor**

***P. Borchard**, J.S. Hoh (Dymenso LLC)*

The LCLS-II project at SLAC is a high power upgrade to the existing free-electron laser facility. The LCLS-II Accelerator System will include a new 4 GeV continuous-wave superconducting linear accelerator in the first kilometer of the SLAC linear accelerator tunnel and supplements the existing low power pulsed linac. Average Current Monitors (ACMs) are needed to protect against excessive beam power which might otherwise cause damage to the beam dumps. The ACM cavities are pillbox-shaped stainless steel RF cavity with two radial probe ports with couplers, one radial test port with a coupler, and a mechanism for mechanically fine-tuning the cavity resonant frequency. The ACM RF cavities will be located at points of known or constrained beam energy and will monitor the beam current, a safety system will trip off the beam if the beam power exceeds the allowed value.

WEPAB330 **A Multirange Low Noise Transimpedance Amplifier for Sirius Beamlines**

***L.Y. Tanio**, F.H. Cardoso, M.M. Donatti (LNLS)*

In a typical synchrotron beamline, the interaction of photon beams with different materials generates free electric charges in devices such as ionization chambers, photodiodes, or even isolated metallic structures (e.g., blades, blocks, foils, wires). These free charges can be measured as electric current to diagnose the photon beam intensity, profile, position, or stability. Sirius, the new 3GeV fourth-generation Brazilian light source, may accommodate up to 38 beamlines, which combined will make use of hundreds of instruments to measure such low-intensity signals. This work reports on the design and test results of a transimpedance amplifier developed for low current measurements at Sirius' beamlines. The device presents low noise, high accuracy, and good temperature stability providing 5 selectable ranges (from 500pA to 7.3mA) to measure bipolar currents achieving femtoampere resolution under certain conditions. Considering low bandwidth applications, the results suggest noise performance comparable to commercial bench instruments. Additionally, the project definitions and plans for the development of a family of low current ammeters will be discussed.

WEPAB331 **Application of KALYPSO as a Diagnostic Tool for Beam and Spectral Analysis**

M.M. Patil, *E. Bründermann, M. Caselle, A. Ebersoldt, S. Funkner, B. Kehrer, A.-S. Müller, M.J. Nasse, G. Niehues, J.L. Steinmann, M. Weber, C. Widmann (KIT)*

KALYPSO is a novel detector capable of operating at frame rates up to 12 MHz developed and tested at the institute of data processing and electronics (IPE) and employed at Karlsruhe Research Accelerator (KARA) which is part of the Test Facility and Synchrotron Radiation Source KIT. This detector consists of silicon, InGaAs, PbS, or PbSe line array sensor with spectral sensitivity from 350 nm to 5000 nm. The unprecedented frame rate of this detector is achieved by a custom-designed ASIC readout chip. The FPGA-readout architecture enables continuous data acquisition and real-time data processing. Such a detector has various applications in the fields of beam diagnostics and spectral analysis. KALYPSO is currently employed at various synchrotron facilities for electro-optical spectral decoding (EOSD) to study the longitudinal profile of the electron beam, to study the energy spread of the electron beam, tuning of free-electron lasers (FELs), and also in characterizing laser spectra. This contribution will present an overview of the results from the mentioned applications.

WEPAB333 **Installation and Commissioning of the Sirius Vacuum System**

R.M. Seraphim, *R.O. Ferraz, H.G. Filho, G.R. Gomes, P.H. Lima, R.F. Oliveira, B.M. Ramos, T.M. Rocha, D.R. Silva, M.B. Silva (LNLS)*

The installation of the Sirius accelerators was completed in 2019. The vacuum installation of the booster took place in October 2018. The booster vacuum chambers were baked-out ex-situ and the vacuum pumps, gauges and valves were assembled prior to the installation in the tunnel. The vacuum installation of the storage ring took place from May to August 2019. The vacuum system of the storage ring is based on fully NEG-coated chambers and each sector was baked-out in-situ for NEG activation. The average static pressure in the booster is in the range of low 10^{-9} mbar. In the storage ring, 95% of the pressures are in 10^{-11} mbar range and 5% are in 10^{-10} mbar range. The first beam was stored in the storage ring in December 2019. The vacuum system has been performing well, and an effective beam cleaning effect has been observed for the NEG-coated chambers. At a beam dose of 70 A-h, the storage ring already achieved the design normalized average dynamic pressure of 3x10 12 mbar/mA. A summary of the installation and the commissioning status of the vacuum system will be presented.

WEPAB334 **Development of Diffusion Bonded Joints of AA6061 Aluminum Alloy to AISI 316LN Stainless Steel for Sirius Planar Undulators**

R.L. Parise, *O.R. Bagnato, R. Defavari, M.W.A. Feitosa, F.R. Francisco, D.Y. Kakizaki, R.D. Ribeiro (LNLS)*

LNLS has been commissioning Sirius, a 4th-generation synchrotron light source. The commissioning of the beamlines has been mainly

done by using planar undulator, which uses in-house built aluminum vacuum chambers with ultra-high vacuum tight bimetallic flanges. In order to manufacture these flanges, diffusion bonded joints of AA6061 aluminum alloy to AISI 316LN stainless steel were developed. Diffusion bonding was carried out at 400-500^{o}C for 45-60 min, applying a load of 9.8MPa in a vacuum furnace. Also, the surface preparation for Al and SS was investigated. SEM observation revealed that an 1-3 μm reaction layer was formed at the AA6061/Ni-plated interface. The intermetallic compound Al3Ni was identified in the reaction layer. The obtained Al/SS joints showed mean ultimate strength of 84 MPa, with the fracture occurring in the Al/reaction layer interface. Bake-out cycles followed by leak tests were carried out to validate the process and approve their use on the planar undulator vacuum chambers. Two undulators with Al/SS flanges have been installed and are under operation in the storage ring.

WEPAB335 **Aluminum Vacuum Chamber for the Sirius DELTA 52 Undulator**

***T.M. Rocha**, O.R. Bagnato, R.O. Ferraz, H.G. Filho, P.P.S. Freitas, G.R. Gomes, P.H. Lima, R.F. Oliveira, B.M. Ramos, F. Rodrigues, R.M. Seraphim, D.R. Silva, M.B. Silva (LNLS)*

Sirius is a 3 GeV fourth generation synchrotron light source under commissioning by the Brazilian Synchrotron Light Laboratory (LNLS). Delta Undulators with magnet vertical aperture of 13.6 mm, and period of 52.5 mm will be used for the generation of soft X rays to photoemission spectroscopy and X ray absorption experiments. Extruded aluminum vacuum chambers having small vertical aperture of 7.6 mm and horizontal aperture of 13 mm is proposed. This paper details the design and manufacturing processes of a complete chamber. Challenges regarding the TIG welding for aluminum and NEG coating for small aperture chambers will also be presented.

WEPAB336 **Aluminum Vacuum Chamber for the Sirius Commissioning Undulators**

***B.M. Ramos**, O.R. Bagnato, R.O. Ferraz, H.G. Filho, P.P.S. Freitas, G.R. Gomes, P.H. Lima, R.F. Oliveira, T.M. Rocha, F. Rodrigues, R.M. Seraphim, D.R. Silva, M.B. Silva (LNLS)*

Sirius is a 3 GeV fourth generation light source under commissioning by the Brazilian Synchrotron Light Laboratory (LNLS). Compact Linear Polarizing Undulators with magnet vertical aperture of 8 mm have been used for the commissioning of some beam lines. Extruded aluminum vacuum chambers having small vertical aperture of 6 mm and horizontal aperture of 40 mm, were built. This paper details the design and manufacturing processes of a complete chamber and its installation procedure at the storage ring. Challenges regarding the precision machining of the 0.5 mm wall thickness, TIG welding for aluminum, NEG coating for small apertures will also be presented.

WEPAB337 **Some Methods of Making Titanium Vacuum Chamber Act as Getter Pump for Uhv/xhv**

J. Kamiya, *T. Takano, H. Yuza (JAEA/J-PARC) K. Wada (Tokyo Electronics Co. Ltd.)*

The non-evaporable getter (NEG) coating has been developed in CERN to make a beam pipe act as a distributed vacuum pump by coating the getter materials with the ability to adsorb/absorb gas molecules on the beam pipe surface. The NEG coating materials used in the LHC are alloys of titanium, zirconium, and vanadium. In high-power beam accelerators, titanium has been used as the beam pipe chamber material due to its low radio activation characteristics. The ordinal titanium surface has no getter function because it is covered with a titanium oxide film. The new technique, which removes the titanium-oxide surface by some methods, such as baking or sputtering, has been investigated. The dependence of the surface oxide film and the getter characteristics on the baking temperature have been measured. Also, by sputtering the inner surface of the titanium chamber, clear evidence that shows the chamber acts as a vacuum pump has been obtained. Furthermore, the NEG coating on the pure titanium surface can suppress the rapid decrease of the sticking probability by the repeated air purge and reactivation.

WEPAB338 **Amorphous Carbon Coating in the SPS**

W. Vollenberg, *P. Chiggiato, P. Costa Pinto, P. Cruikshank, H. Moreno, C. Pasquino, J. Perez Espinos, M. Taborelli (CERN)*

Within the LHC Injector Upgrade (LIU) project, the Super Proton Synchrotron (SPS) needs to be upgraded to inject into the LHC higher intensity and brighter 25-ns bunch spaced beams. To mitigate the Electron Multipacting (E.M.) phenomenon, a well-known limiting factor for high-intensity positively charged beams, CERN developed carbon coatings with a low Secondary Electron Yield (SEY). During the 2016 & 2017 year-end technical stops, such coatings were deposited on the inner wall of the vacuum chambers of some SPS quadrupole and dipole magnets by a dedicated in-situ setup. A much larger scale deployment was implemented during the Long Shutdown 2 (2019-2020) to coat all beam pipes of focussing quadrupoles (QF) and their adjacent short straight sections. In this contribution, we remind the motivation of the project, and present the results and the quality control of the carbon coating campaign during the latter phase of implementation.

WEPAB339 **Beam-Induced Surface Modification of the LHC Beam Screens: The Reason for the High Heat Load in Some LHC Arcs?**

V. Petit, *P. Chiggiato, M. Himmerlich, G. Iadarola, H. Neupert, M. Taborelli, D.A. Zanin (CERN)*

All over Run 2, the LHC beam-induced heat load exhibited a wide scattering along the ring. Studies ascribed the heat source to electron cloud build-up, indicating an unexpectedly high Secondary Electron Yield (SEY) of the beam screen surface in some LHC regions. During the Long Shutdown 2, the beam screens of a low and a high heat load

dipole were extracted. Their inner copper surface was analysed in the laboratory to compare their SEY and surface composition. While findings on the low heat load beam screens are compatible with expectations from laboratory studies of copper conditioning and deconditioning mechanisms, an extremely low carbon amount and the presence of CuO (non-native surface oxide) are observed on the high heat-load beam screens. The azimuthal distribution of CuO correlates with the density and energy of electron impingement. Such chemical modifications increase the SEY and inhibit the full conditioning of affected surfaces. This work shows a direct correlation between the abnormal LHC heat load and the surface properties of its beam screens, opening the door to the development of curative solutions to overcome this critical limitation.

WEPAB340 **Pressure Simulations for the EIC Interaction Region**
M.L. Stutzman *(JLab)*
Background detector rates in the Electron Ion Collider depend in part on the pressure in the interaction region. Materials choice, synchrotron radiation induced desorption, conditioning time and pumping configuration all affect the pressure in the system. Simulations of the region using Synrad and Molflow+ coupled simulation codes will be presented for various configruations and conditioning times.

WEPAB341 **Injection and Extraction Kickers for the Advanced Light Source Upgrade Project (ALS-U)**
W.L. Waldron*, D.A. Dawson, S. De Santis, T. Oliver, C. Steier (LBNL)*
The Advanced Light Source upgrade project (ALS-U) at Lawrence Berkeley National Laboratory includes the construction of a new accumulator ring and the replacement of the existing storage ring. Both ferrite-loaded kickers and stripline kickers are used in the ALS-U design for injection, extraction, and decohering the beam before storage ring extraction. In the accumulator ring, the rise and fall time requirements are based on the single bunch revolution time of 608 ns which allows the use of ferrite-loaded kickers. The 10 ns spacing between bunch trains in the storage ring requires stripline kickers to meet the rise and fall time requirements. Both types of kickers are driven by solid-state inductive voltage adders using MOSFETs. Modeling and prototyping efforts have characterized the kicker impedance and beam-induced heating, and explored the effects of beam strike on electrodes.

WEPAB342 **Beam Induced Power Deposition in CERN SPS Injection Kickers**
M.J. Barnes*, O. Bjorkqvist (CERN) K. Kodama (KEK)*
The SPS injection kicker magnets (MKP) were developed in the 1970's, before beam power deposition was considered an issue and before any advanced tools for analysing beam coupling impedance were available in their current form. These magnets are very lossy from a beam impedance perspective, and the beam induced power deposition is

highly non-uniform. This is expected to be an issue during SPS operation with the higher intensity beams needed in the future for HL-LHC. There is an existing design, with serigraphy, that will mitigate the heating issues, which is presently being implemented on a prototype for test and measurement. Models have been developed to aid in predicting the safe operating regions until the upgraded MKPs are installed in the SPS: these are reported herein. A novel measurement technique is also presented to confirm the non-uniform power deposition in the ferrite yoke. Beam coupling impedance, power deposition, field rise time and field uniformity data are also presented for an upgraded, prototype, MKP.

WEPAB343 **Inductive Adder Prototype for FCC-HH Injection Kicker System**

***M.J. Barnes**, T. Kramer, D. Woog (CERN) H. De Gersem (TEMF, TU Darmstadt)*

The future circular collider (FCC) requires a highly reliable injection kicker system. Present day kicker systems often rely on thyratron-based pulse generators and a pulse forming network or line: the thyratron is susceptible to self-triggering. Hence, an alternative pulse generator topology, based on fast semiconductor switches, is considered for the FCC. One possibility is an inductive adder (IA). A prototype IA has been designed and built: the main challenges are the fast rise time, high output current, low system impedance and a 2.3 us pulse duration combined with low droop. This paper presents the results of measurements on the prototype IA where the rated output current and output voltage were achieved separately. Suggested improvements to the IA hardware are identified and proposals are presented that could help improve the kicker system performance.

WEPAB344 **Studies for Mitigating Flashover of CERN-LHC Dilution Kicker Magnets**

***M.J. Barnes**, W. Bartmann, C. Bracco, L. Ducimetière, A.M. Loebner, V. Namora, V. Senaj (CERN)*

The LHC beam dump system is used for extracting beam from the LHC and, as such, is a safety critical system whose proper functionality must be assured. Dilution kicker magnets (MKBs) sweep the extracted beam over the cross-sectional area of a dump block as the energy density would otherwise be too high and damage the block. In 2018, a high voltage flashover occurred in a vertical MKB (MKBV) vacuum tank, during a beam dump, which resulted in non-ideal sweep of the beam over the block. The location of the flashover could not be identified during a subsequent inspection of the magnet. Hence, electrical field simulations have been carried out to identify potentially critical regions, to determine the most probable region of the flashover. One potentially critical region is a rectangular beam pipe (RBP) between the end of the tank and the MKBV magnet, whose purpose is to reduce plasma propagation to the adjacent tank in the event of a flashover. Mitigating measures were studied and are reported in this

paper.

WEPAB345 **Impedance and Thermal Studies of the LHC Injection Kicker Magnet Upgrade**

***M.J. Barnes**, O. Bjorkqvist, F. Motschmann (CERN)*

The bunch intensities of High Luminosity (HL) LHC are predicted to lead to heating of the ferrite yokes of the LHC injection kicker magnets (MKI), in their current configuration, to their Curie temperature. Hence, the MKIs are being upgraded to meet the requirements of HL-LHC, which is planned to start in the mid-2020s. The upgraded design features an RF damping ferrite loaded structure at the upstream end of each magnet, which will absorb a large portion of the beam induced power deposition of the magnet. The ferrite damper is cooled via a copper sleeve, brazed to the ferrite, and a set of water pipes. The thermal contact conductance (TCC) between ferrite and copper is very important, as are the properties of the ferrite. In this paper, we present measurements of the TCC and ferrite properties. This data is used to predict temperatures during operation of the LHC. In addition, a measurement and prediction is shown for the longitudinal impedance of the magnet. The models developed in this study will be benchmarked during run III of the LHC.

WEPAB346 **Electromagnetic Modelling of Kicker Magnets to Derive Equivalent Circuit Values**

***M.J. Barnes**, O. Bjorkqvist (CERN) L. Jensen, O.A. Nielsen (Aarhus University)*

An equivalent circuit model of a kicker magnet system is an invaluable tool for predicting the performance, studying possible modifications and for helping to diagnose faults. The frequency content of pulses associated with a ferrite loaded transmission line kicker magnet generally extend up to a few tens of MHz: hence, it is feasible to accurately model such a kicker magnet using lumped elements. This modelling technique is powerful since it in general has a run time several orders of magnitude shorter than a full wave electromagnetic simulation. In this paper, we determine values, including those of parasitic components, using modern simulation tools, for use in the lumped equivalent circuit models. In addition, the paper describes a method to simulate coupling between beam and the electrical circuit of a kicker magnet at relatively low frequencies: this allows one to use circuit analysis tools to study means of mitigating beam induced resonances.

WEPAB347 **Design, Construction and Testing of a Magnetic Probe for Fast Kicker Magnets**

***N. Ayala**, A. Ferrero Colomo, T. Kramer (CERN)*

The CERN PS injection kicker has been modified in the framework of the LHC Injector Upgrade (LIU) project to allow injecting proton beams with an energy of 2 GeV. One of the most important items of the system parameter validation is the measurement and analysis of the magnetic field in the magnet aperture. To meet the required measurement precision without compromising the magnet vacuum perfor-

mance, a dedicated magnetic probe has been designed, constructed and tested. The results are presented in this paper highlighting the mitigations of electrical, mechanical and vacuum complications. The paper concludes with an analysis of the probe performance during the first magnetic field measurements in the laboratory.

WEPAB348 **Injection and Extraction Systems of the SIS100 Heavy Ion Synchrotron at FAIR**

***I.J. Petzenhauser**, U. Blell, S. Heberer (GSI)*

The "Facility for Antiproton and Ion Research" (FAIR) is a new international accelerator complex, which is currently built in Darmstadt, Germany. Part of this complex is the SIS100 heavy ion synchrotron with a circumference of ~1086 m. To inject ions into the SIS100, an injection kicker system will we required. For fast extraction of the particle beam from the SIS100, an extraction kicker is used. This extraction kicker will be a bipolar system, this way it works as an emergency kicker at the same time. The fast kicker systems have to produce a current pulse >6 kA. To achieve this, energy storages are charged up to voltages >70 kV and are quickly discharged. The pulse durations vary from 0.5 us to 7 us, depending on the kicker type and the operation mode. Slow extraction of the ion beam will include an electrostatic septum, operating with voltages up to 160 kV. The requirements of these injection/extraction devices will be described in detail and the status of the projects will be presented.

WEPAB349 **Design of a Circular Waveguide TM01 Mode Launcher with Wire Loop Feed**

***A. Chittora** (BITS Pilani)*

In Accelerator technology, RF power couplers are important component to couple RF signal to travelling wave structure. Circular waveguide TM01 mode is one of the symmetric modes, that is suitable to use for RF coupling. TM01 mode launcher is used as an RF coupler in Accelerator technology. Design of a compact circular waveguide TM01 mode-launcher is presented in this paper. The design is based on the principle of magnetic field coupling between a wire loop and TM01 mode of circular waveguide. The mode launcher exhibits high efficiency and 3.1% bandwidth at 3.2 GHz frequency with both circular and elliptical loop. Performance of the mode launcher is experimentally verified and simulated S-parameters agree with the measured results. The mode launcher is of compact size and is suitable for efficient excitation of TM01 mode in circular waveguide and travelling wave structures. The launcher is also useful for cold testing of high power microwave antennas and Radars.

WEPAB351 **Requirements for an Inductive Voltage Adder as Driver for a Kicker Magnet With Short Circuit Termination**

***J. Ruf**, M.J. Barnes, T. Kramer (CERN) M. Sack (KIT)*

At CERN pulse generators based on Thyratron switches and SF6 gas filled pulse forming lines, used for driving kicker magnets, are to be replaced with semiconductor technology. Preliminary investigations

show the inductive voltage adder is suitable as a pulse generator for this application. To increase the magnetic field without raising the system voltage, a short-circuit termination is often applied to a kicker magnet. Because of the electrical length of a transmission line magnet, wave propagation needs to be considered. To allow for the wavefront reflected from the short-circuit termination back to the generator, a novel approach for an inductive adder architecture has been investigated. It is based on a modified generator interface, circulating the current back into the load, until the stored energy is absorbed at the end of the pulse. This approach allows for a smaller magnetic core size compared to a conventional design with a matched load. Moreover, it enables more energy-efficient operation involving smaller storage capacitors. This paper summarizes the conceptual design features and furthermore gives an overview of the parameter space for possible applications at CERN.

WEPAB352 **EMI Measurement for SXFEL Linac Klystron Modulator System**
Y.F. Liu *(SARI-CAS) L. Huang, J. Tong (SINAP)*
The purpose of this paper is to estimate the conducted and radiated Electromagnetic Interference (EMI) for subsystems in the SXFEL LINAC. A spectrum analyzer system with a wide frequency range of 9kHz to 3GHz was conducted to measure the EMI spectrum of pulse modulator and klystron system. The radiated EMI was tested by electric and magnetic field probe. A stray current was tested by wide frequency current transformer in order to measure the conducted current for kicker and septum systems. According to the experiment results, the stray current could flow through the other subsystems, and it might be affected the stability of other subsystems. Therefore reducing and eliminating the interference of EM waves will be a very important issue. At the end, measures to improve EMI performance are given.

WEPAB353 **Design and Commissioning of a Multipole Injection Kicker for the SOLEIL Storage Ring**
R. Ollier*, P. Alexandre, R. Ben El Fekih, L.S. Nadolski (SOLEIL)*
In third-generation synchrotron light sources, achieving an orbit distortion below 10% of the stored beam size is very challenging. The standard injection scheme of SOLEIL is made of 2 septa and 4 kicker magnets installed in a 12 m long straight section. Tuning the 4 kickers, to reduce perturbations, revealed to be almost impossible since it requires having 4 identical magnets, electronics, and Ti coated ceramic chambers. To reach the position stability requirement of the stored beam, a single pulsed magnet with no field on the stored beam path can replace the 4 kickers. Such a device, called MIK (Multipole Injection Kicker), was developed by SOLEIL and successfully commissioned in the MAX-IV 3-GeV ring as the key device used in the standard injection scheme for user operation, reducing the beam orbit distortion below 1 micron in peak value in both planes. A copy of the MIK has been installed in a short straight section of the SOLEIL storage ring, in January 2021. We report MIK positioning studies, the constraints of

the project, sapphire chamber coating challenges and the first commissioning results. The R&D MIK is a demonstrator for the injection scheme of SOLEIL upgrade as well.

WEPAB354 **A Low Jitter Cold Cathode Thyratron Driver**

***V. Popov**, S.F. Mikhailov, P.W. Wallace (FEL/Duke University)*

The injection/extraction kicker system is one of the key components of the Duke storage ring FEL which determines the efficiency and reliability of the light source operation. Pseudo-Spark Switches (PSS), also known as cold cathode thyratrons, are the critical components of the high voltage pulse generators for kickers. A set of new HV drivers which are used to trigger the PSSs with a wide band coaxial cable transformers have been designed based on the solid-state technology. The technical specifications for the HV driver include an adjustable pulse amplitude up to 2 kV with a 600 ns pulse width; a 10-90% pulse rise time of 20 ns; pulse timing jitter less than 1 ns and a repetition rate up to 20 Hz. The paper will present the driver schematic, photos, waveforms, and test results.

WEPAB355 **Series Production of the SIS100 Cryocatchers**

***L.H.J. Bozyk**, S. Ahmed, P.J. Spiller (GSI)*

The superconducting heavy ion synchrotron SIS100, which is the main accelerator of the FAIR-facility will be equipped with cryocatcher to suppress dynamic vacuum effects and to assure a reliable operation of high intensity heavy-ion beams. Subsequent to the successful validation of the prototype in 2011 as well as a First-of-Series cryocatcher, the series production of 60 cryocatcher modules meanwhile has been completed. It was released in 2018 after further design optimizations. Key findings from the series production and acceptance tests are presented as well. The First-of-Series cryocatcher has been integrated into the First-of-Series quadrupole module and has undergone several tests. These results are also illustrated in this report.

WEPAB356 **Proposal of an Alignment System for HALF: The Reference Network of Alignment**

***X. Li**, J.X. Chen, X.Y. He, W. Wang, Z.Y. Wang (USTC/NSRL) J.X. Chen, T. Luo (IHEP CSNS)*

As a fourth-generation light source based on the diffraction-limited storage ring, Hefei Advanced Light Facility (HALF) has higher requirements for magnets alignment in accuracy, efficiency, and reliability. In this paper, the Reference Network of Alignment (RNA) system is proposed to improve the magnetic axis alignment accuracy on the radial direction of the beamline. Herein, we mainly introduce the concept design and the theoretical analysis of the RNA system, which center on the novel fusion method of sensors. A simulation result shows that it is credible to assume the RNA system can achieve an alignment installation accuracy of 20 μm and a displacement monitoring accuracy of 10 μm.

WEPAB357 **A Method of Sag Compensation of Stretched Wire of WPS Based on HLS**

X. Li *(USTC/NSRL)*

In the Reference Network of Alignment (RNA) system, designed by the National Synchrotron Radiation Laboratory (NSRL), we set up a stretched wire as a straightness reference for Wire Positioning Sensors (WPS). The sag caused by gravity of stretched wire is an important factor that affects the accuracy of WPS measurement. In past applications, the sag of the stretched wire is calculated according a mathematical correction formula. This paper proposes a new method to compensate the sag by Hydrostatic Levelling Sensors (HLS).

WEPAB358 **Development of Low-Z Collimator for SuperKEKB**

S. Terui*, T. Abe, Y. Funakoshi, T. Ishibashi, H.N. Nakayama, K. Ohmi, D. Zhou (KEK) A. Natochii (University of Hawaii)*

Collimator jaws for SuperKEKB main ring, which is an electron-positron collider, installed to suppress background noise in a particle detector complex named Belle II. The collimators are successful to reduce backgrounds when the collimator was closed. But, in high current operations with 500 mA or more, jaws were occasionally damaged by hitting abnormal beams. This trouble is a low-frequency, which is once-a-commissioning period currently, but a high-consequence one because we are not able to apply high voltage on detectors in Belle II by high backgrounds. Low-Z collimator jaw, that is durable through hitting uncontrollable beam, have been designed due to protect important component as the solution of the trouble. The low-Z collimator jaws are installable in a present collimator chamber, have a pair of vertically opposed movable jaws. One pair of low-Z collimator jaws was installed. The paper is to describe what did we calculate and measure to make a low-Z collimator, how did we make a low-Z collimator, the impact of the installed low-Z collimator, mainly transverse mode coupling instability.

WEPAB359 **Report on Collimator Damaged Event in SuperKEKB**

S. Terui*, Y. Funakoshi, H. Hisamatsu, T. Ishibashi, K. Kanazawa, Y. Ohnishi, K. Shibata, M. Shirai, Y. Suetsugu, M. Tobiyama (KEK)*

Collimator jaws for SuperKEKB main ring, which is an electron-positron collider, installed to suppress background noise in a particle detector complex named Belle II. In high current operations with 500 mA or more, jaws were occasionally damaged by hitting abnormal beams. This trouble is a low-frequency, which is once-a-commissioning period currently, but high-consequence one because we are not able to apply high voltage on detectors in Belle II by high backgrounds. At this moment this jaw damage event occurs, we observed pressure burst near the collimator with the beam abort, there was no sign of beam oscillation indicating instability, and the beam intensity suddenly decreased a few turns before the abort. I predict that the cause of this jaw damage was that a sudden change of the beam energy by the collision with dust. In this paper, the explanation of the

observation result of this events and tracking simulation of beam colliding with dust are reported.

WEPAB360 **Silicon Crystals for Steering of High-Intensity Particle Beams at Ultra-High Energy Accelerators**

M. Romagnoni, *L. Bandiera, A. Mazzolari, A.I. Sytov (INFN-Ferrara)* ***M. Romagnoni*** *(Universita' degli Studi di Milano) M. Soldani (Università degli Studi di Ferrara)*

Super magnet dipoles employed to steer high energy particle beams are massive instruments requiring cryogenic cooling and featuring large energy consumption. A bent crystal has the potential in a few millimeters to deflect 100-1000 GeV particle beams as much as an hundreds-tesla magnetic dipole. Indeed, within the lattice of a crystal, large electric fields up to several GeV/cm are present. Positive charged particles can be efficiently channeled between two adjacent lattice planes, thus following their curvature. These features and the possibility to selectively affect only the portion of the beam intercepting the crystal led to the proposal of exploiting bent crystals for several purposes, such as the collimation of ions at LHC. In this scheme, the particles on the beam halo instead of being scattered by tens-centimeters long collimators are directly separated from the beam using a 4 mm long silicon crystal. The production of a bent crystal suitable for installation in the LHC beamline requires strict control over lattice features and bending apparatus. The results obtained by the years long research of the INFN research team in Ferrara are presented in this work.

WEPAB361 **New Generation CERN LHC Injection Dump - Assembly and Installation (TDIS)**

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During CERN's LS2, several upgrades were performed to beam intercepting devices in the framework of the HL-LHC Project. Upgraded equipment includes two internal beam dumps (TDIS) intended for machine protection located at the injection points from the SPS to the LHC. These two devices have been assembled, tested, and installed around LHC Point 2 and Point 8 and are currently ready to get commissioned with the beam. They are 5.8m-long, three-module-segmented vacuum chambers, with large aperture to accommodate the injected and circulating beam and equipped with absorbing materials, These comprise graphite and higher Z alloys that are embedded on sub-assemblies reinforced with back-stiffeners made of TZM. The current contribution covers three main matters. First, it details

the TDIS design and its key technical features. The second topic discussed is the outcome of an experiment where a prototype module was tested under high-energy beam impacts at CERN's HiRadMat facility. To conclude it is presented the return of experience from the pre-series construction, validation and installation in the LHC tunnel.

WEPAB362 **Radiate Collaboration Recent Results**

F. Pellemoine *(Fermilab)*

In the recent past, major accelerator facilities have been limited in beam power not by their accelerators, but by the beam intercepting device survivability. The beam intercepting devices (including targets, windows, etc) must endure thermal stress waves and high cycle fatigue due to high power pulsed beam. The increased beam power will create also significant challenges such as corrosion and radiation damage. The radiation-induced defects can cause harmful effect on the material and degrade their mechanical and thermal properties during irradiation, that can lead the failure and reduce drastically lifetime of any beam intercepting devices. In order to operate reliable beam-intercepting devices in the framework of energy and intensity increase for next-generation accelerators, the RaDIATE collaboration (Radiation Damage In Accelerator Target Environment) managed by Fermilab, brings together existing expertise from 14 international institutions to execute a coordinated strategy for high power targetry R&D. After presenting the high power targetry challenges, we will give an overview of RaDIATE R&D program in support of High Power Targetry development

WEPAB363 **Dynamic Response of Spallation Volume to Beam Raster on the European Spallation Source Target**

Y. Lee *(ESS)*

To achieve a desirably low beam intensity on the target, the European Spallation Source (ESS) adopted a beam raster system at the high beta beam transport part of the linac. The raster system paints the beam on the target with frequencies up to 40 kHz within the 2.86 ms beam pulse, to form a uniformly expanded beam footprint. While the beam raster reduces the time-averaged beam current density to a level that the 5 years of design lifetime of the target system can be achieved with a high operational reliability, it could potentially induce deleterious dynamic excitations in the spallation volume made of tungsten. The stress wavelets created by raster sweeps can be amplified if the sweep frequency is in tune with a resonance mode of the tungsten volume. This coherent interference of the wavelets could lead to a high dynamic stress in tungsten, posing a risk of premature failure of the target. In this paper, the dynamic response of the spallation volume of the ESS target to different beam raster frequencies has been analysed, using multi-physics simulations based on measured material data. Finally, a safe operational range of the beam raster frequency band is proposed.

WEPAB364 **Third-Generation CERN n_TOF Spallation Target: Final Design and Examinations of Irradiated Prototype**

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The new neutron spallation target for the CERN neutron Time-Of-Flight (n_TOF) facility is based on a nitrogen-cooled Pb core impacted by short high-intensity proton beam pulses. An extensive material characterization campaign has been carried out to define the constitutive behavior of lead and assess its response under pulsed proton beam irradiation. The activities carried out include a beam irradiation test in the CERN HiRadMat facility. The tests and inspections performed show a robust behavior of the core material during operation and prominent static hardening recovery already at room temperature.

WEPAB365 **CERN BDF Prototype Target Operation, Removal and Autopsy Steps**

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The Beam Dump Facility (BDF), currently in the study phase, is a proposed general-purpose fixed target facility at CERN. Initially will host the Search for Hidden Particles (SHiP) experiment, intended to investigate the origin of dark matter and other weakly interacting particles. The BDF particle production target is located at the core of the facility and is employed to fully absorb the high intensity (400 GeV/c) Super Proton Synchrotron (SPS) beam. To validate the design of the production target, a downscaled prototype was tested with the beam at CERN in 2018 in the North Area primary area in a dedicated test at 35 kW average beam power. This contribution details the BDF prototype target operation, fully remote removal intervention, and foreseen post-irradiation examination plans.

WEPAB366 **Towards the Last Stages of the CERN AD-Target Area Consolidation Project and Recommissioning Plans to Resume Operation**

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(CERN) J.C. Espadanal (LIP)
Antiprotons are produced at CERN at the Antiproton Decelerator (AD) Target Area by impacting 26 GeV/c proton beams onto a fixed target. Further collection, momentum selection, and transport of the secondary particles - including antiprotons - towards the AD ring is realised by a 400 kA pulsed magnetic horn and a set of magnetic dipoles and quadrupoles. A major consolidation of the area - in operation since the 80s - has taken place during the CERN Long Shutdown 2 (2019-2021). Among other activities, such upgrade included: (i) Installation of a new air-cooled target design and manufacturing of a new batch of magnetic horns, including a surface pulsing test-bench for their validation and fine-tuning (ii) Installation of a new positioning and maintenance system for the target and horn (iii) Refurbishment and decontamination of the Target Area and its equipment, (iv) Construction of a new surface service building to house new nuclear ventilation systems. This contribution presents an overview of such activities and lesson learnt. In addition, it provides the latest results from refractory metals R&D for the antiproton target and a summary of the recommissioning and optimization plans.

WEPAB367 **Bubble Generation in the SNS 2MW Mercury Target**
***C.N. Barbier**, M.P. Costa, K.C. Johns, D. Ottinger, F. Rasheed, B.W. Riemer, R.L. Sangrey, J.R. Weinmeister, D.E. Winder (ORNL)*
The accelerator at the Spallation Neutron Source is currently being upgraded to increase the proton beam power from 1.4 MW to 2.8 MW. About 2 MW will go to the first target station, while the rest will go to the future second target station. The first target station uses a mercury target. When the short proton beam pulse hits it, strong pressure waves are developed inside the mercury and the vessel itself, causing weld failures and cavitation erosion. The pressure wave can be significantly mitigated by injecting small helium bubbles into the mercury. SNS has been injecting helium since 2017 using small orifices but has met challenges in fabrication and operations with them. Thus, for the 2 MW target, swirl bubblers will be used to increase gas injection and improve reliability. A 2 MW prototypical target was built and tested in a mercury process loop available at Oak Ridge National Laboratory. Acrylic viewports on the top of the target were used to determine the bubble size distribution (BSD) generated by the swirl bubblers. It was found that the bubblers were not only capable of generating small bubbles but that the BSD was independent of gas injection rate.

WEPAB368 **Sigraflex® Studies for LHC CERN Beam Dump: Summary and Perspective**
***J.M. Heredia**, M. Calviani, R. Franqueira Ximenes, D. Grenier, K. Kershaw, A. Lechner, P.A. Muñoz, F.-X. Nuiry, A. Perillo-Marcone, V. Rizzoglio, C. Torregrosa (CERN) A. Alvaro (SINTEF) F. Berto, S. Solfiti (NTNU)*
The Large Hadron Collider (LHC) beam dump (TDE) is essential for safe and reliable operation of the collider. It absorbs particles ex-

tracted from the accelerator whenever required. The original design of the TDE dates from the mid 2000 and it is constituted of an eight-meter-long cylindrical stainless-steel tube, filled with low-Z carbon-based materials from different grades and densities. The Sigraflex®, an expanded low-density graphite, is employed in the middle section of the TDE core. Due to unexpected behaviour observed in the past LHC runs, several major upgrades were recently implemented in order for the TDE to be ready for LHC Run3 (2021-2024), where up to 555 MJ beam energy is expected to be dumped every few hours. According simulations, temperatures in the Sigraflex core will reach locally up to 1500°C in the regular dump cases, and above 2300°C for failure scenarios. The objective of this contribution is to summarize the LS2 hardware upgrades and the plan for the evaluation of the Sigraflex performance during LHC Run3. This work will also detail the last experimental and numerical findings applied to the Sigraflex®, and possible alternative materials for the future.

WEPAB369 **Status and Development of High Power Targetry Systems at FRIB**

***J. Gao**, W. Mittig, J. Wei (FRIB)*

The high-power target and beam dump systems are under development at the Facility for Rare Isotope Beams (FRIB) located at Michigan State University. FRIB will accelerate heavy ions up to Uranium with energies above 200 MeV/u. The 400 kW average beam power focused to 1 mm spot size is expected at the graphite target with 5000 RPM rotation speed. Downstream of the production target, over 300 kW of remaining primary beam power needs to be absorbed by a rotating water-cooled beam dump system. Due to the extremely high power density and radiation damage in the beamline vacuum, there are still remaining technical challenges in terms of materials, thermal expansion, and fluid turbulence. The FRIB linear accelerator has been commissioned with heavy-ion beams accelerated above 200 MeV/u, and during the next phase, the beam will be commissioned with the target systems. We summarize the status of high power targetry systems for early beam commissioning at FRIB. Besides, the testing results of angular contact ball bearings with an induction coil heating system and the new design of beam dump water-vacuum interface will be presented.

WEPAB370 **Study of an L-Band Linear Accelerator**

***J. Gao**, H.B. Chen, J.Y. Liu, J. Shi, H. Zha (TUB)*

We have studied an L-band linac based on a cheap industrial magnetron, which works at CW mode with 75kW averaged output-power. The designed energy-gain of electrons is 500keV. Low accelerating gradient was the dominant problem encountered during the structure design. We adopted a standing-wave structure with magnetically coupling and nose cones to increase the effective shunt impedance. A 7-cell design has been completed, of which the transverse dynamics and thermodynamics were simulated. Results showed that this accel-

erating structure could work stably at 59 C and 100 mA output beam current was achieved. This L-band design provided a cheap and efficient way to generate low-energy electrons for industrial irradiation processing.

WEPAB371 **Numerical Analysis on Nitrogen Injection Fire Extinguishing System in the Linac Area at TPS**

***J.-C. Chang**, W.S. Chan, Y.F. Chiu (NSRRC)*

The Linear accelerator (LINAC) of Taiwan Photon Source (TPS) could generate electrons to 150 MeV. The main subsystems including an electron gun, buncher, accelerating sections, vacuum system, and focusing and steering magnets are located in the LINAC area of 223.5 m2 and 3 m in height. We designed a nitrogen injection fire extinguishing system for the LINAC area and performed Computational Fluid Dynamic (CFD) simulation to analyse the fire extinguishing performance with and without fresh air supplied from the air conditioning system.

WEPAB372 **Design and Construction of Uninterruptible Paralleling Transfer Switches for an Emergency Power System in Taiwan Light Source**

***Y.F. Chiu**, W.S. Chan, K.C. Kuo, Y.-C. Lin (NSRRC)*

The ATS of an emergency power system in Utility Building II has operated over 18 years; in recent years the failure rate is gradually increasing because of aged components. To improve old switches, schemes of upgrading and developing new and efficient transfer switches have been conducted cautiously. A new device named an Uninterruptible Paralleling Transfer Switch (UPTS) is designed and implemented to replace an existing ATS to enhance the performance to meet the requirements of uninterrupted power transfer. The UPTS can uninterruptedly switch the grid power to emergency power of a backup generator during a planned utility power outage, and also exactly switch emergency power to the grid power uninterruptedly when the utility power is restored. If grid power is unexpectedly lost, UPTS acts like a typical ATS, automatically transferring power from a primary source to a backup source with switching duration a few seconds. A practical UPTS has been assembled and installed in Utility Building II and has performed well effectively to eliminate power-switching transients.

WEPAB373 **The Energy Management System in NSRRC**

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Taiwan has been suffering from a shortage of natural resources for more than two decades. As stated by the Energy Statistics Handbook 2019 of Taiwan, up to 97.90% of energy supply was imported from abroad. This kind of energy consumption structure is fragile relatively. Not mention to the total domestic energy consumption annual growth rate is 1.97% in twenty years. Either the semiconductor or the integrated circuit-related industry is developed vigorously in Taiwan. All the facts cause us to face the energy problems squarely. Therefore, an energy management system (EnMS) was installed in NSRRC

in 2019 to pursue more efficient energy use. With the advantages of the Archive Viewer - a utility supervisory control and data acquisition system in NSRRC, the data of energy use could be traced conveniently and widely. The model of energy use has been built to review periodically, furthermore, it provides us the accordance to replace the degraded equipment and alerts us if the failure occurs.

WEPAB374 **The Southern Hemisphere's First X-Band Radio-Frequency Test Facility at the University of Melbourne**

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The first Southern Hemisphere X-band Laboratory for Accelerators and Beams (X-LAB) is under construction at the University of Melbourne, and it will operate CERN X-band test stand containing two 12GHz 6MW klystron amplifiers. By power combination through hybrid couplers and the use of pulse compressors, up to 50 MW of peak power can be sent to any of 2 test slots at pulse repetition rates up to 400 Hz. The test stand is dedicated to RF conditioning and testing CLIC's high gradient accelerating structures beyond 100 MV/m. It will also form the basis for developing a compact accelerator for medical applications, such as radiotherapy and compact light sources. Australian researchers working as part of a collaboration between the University of Melbourne, international universities, national industries, the Australian Synchrotron -ANSTO, Canadian Light Source and the CERN believe that creating a laboratory for novel accelerator research in Australia could drive technological and medical innovation.

WEPAB375 **Development of a Compact Custom Linac Electron Accelerator: From Conception to Installation**

***B. Bouvry** (TRAD Tests & Radiations)*

A new compact LINAC electron accelerator device was installed at TRAD facility. This new custom device, with vertical configuration, allows performing electron irradiation in the energy range 1-4 MeV, with an approximate dose rate of $1.0{\cdot}10^{11}$ e-/cm^2/s at 4MeV, on materials and electronics devices. The irradiations can be performed under vacuum, to reproduce space conditions, under air or specific atmosphere (like Nitrogen or Argon) for nuclear field conditions. The device is also equipped with two thermal plates, to perform irradiations during thermal cycling (-170°C/+200°C). The maximum irradiation surface, with a 10% dose deposition homogeneity, is 30x30cm^2. In this study, we will present the steps of electron accelerator integration, and calculations performed with our own Monte Carlo code, RayXpert, based on GEANT4. We used it to define the best bunker configuration and dimensions in terms of radioprotection and for dose rate calculation for shielding. The calculations have been integrated into the authorization file for the French Agency for Nuclear Safety (ASN). First ex-

periments will be presented in this study, as well as an experimental-simulation results comparison.

WEPAB376 **The Inner Triplet String Facility for HL-LHC: Design and Planning**

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In the framework of the HL-LHC project, full-scale integration and operational tests of the superconducting magnet chain, from the inner triplet quadrupoles up to the first separation/recombination dipole, are planned in conditions as similar as possible to the final set-up in the LHC tunnel. The IT String includes all of the required systems for operation at nominal conditions, such as vacuum, cryogenics, warm and cold powering equipment, and protection systems. The IT String is intended to be both an assembly, and an integration test stand, and a full rehearsal of the systems working in unison. It will, closely reproducing the mechanical, electrical, and thermo-hydraulic interfaces of the final installation, as well as allowing a full rehearsal of the systems working in unison. This paper describes the conceptual design, the test stand's reference configuration, and the main goals. It also summarizes the status of the main activities, including the detailed design of the test infrastructure, procurement of main equipment, the baseline installation schedule, and major milestones. The first version of the experimental program and the associated planning are also presented.

WEPAB377 **Research on the Secondary Electron Yield and Surface Resistance of Laser Etched Stainless Steel**

***W.L. Zhang** (USTC/NSRL)*

Laser etching is a novel method to mitigate electron cloud (e-cloud) by reducing the surface secondary electron yield (SEY) in accelerators. After laser etching, the SEY of stainless steel reduces from 2.02 to 0.79 while the surface resistance increases significantly, which will affect the beam stability. Therefore, roughness tester and scanning electron microscope were used to find out the reason for the increase in resistance. The results indicate that the deep grooves and the nanoparticles attached to the surface can suppress the SEY but increase the roughness and resistance.

WEPAB378 **Near-Infrared Laser System for Dielectric Laser Acceleration Experiments at SINBAD**

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The technique of dielectric laser acceleration (DLA) utilizes the strong

field gradients generated by intense laser light near the surfaces of microscopic photonic structures, possibly allowing compact accelerator devices. We report on the infrared laser system at the SINBAD facility at DESY, where first DLA experiments with relativistic electrons preaccelerated by the ARES linear accelerator started in late 2020. We constructed a low-noise Holmium fiber oscillator producing pulses at a wavelength of 2050 nm, seeding a Ho:YLF regenerative amplifier. Pulses of 2 mJ and 2 ps duration from the amplifier are transported over a distance of about 30 m to the DLA interaction point. The laser system is synchronized to the accelerator by locking the laser repetition rate to an RF master oscillator using an all-digital phase-locked loop, giving a residual timing jitter of about 45 fs. The digital locking scheme allows precise shifting of the relative timing between laser pulses and electrons without need for a dedicated optical delay line. It is planned to lock the system to the UV photocathode laser by means of an optical cross correlator further to improve the locking performance.

WEPAB379 **Photocathode Laser Development for Superconducting X-ray Free Electron Lasers at DESY**

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Modern X-ray Free-Electron Lasers (XFEL) are a key tool to enable a variety of scientific research. Those large-scale machines rely on robust and reliable deep ultraviolet (DUV) laser sources to drive electrons from their RF photocathode gun. In this paper we present a new photocathode laser prototype, which offers more flexibility in duration and shape of the 257.5nm pulses for driving the CsTe Photocathodes of DESYs superconducting burst-mode FELs. The laser matches the FEL pulse structure, which are 800µs bursts at up to 4.5 MHz intraburst-rate with 10 Hz burst-repetition-rate. In a first version the system will offer variable DUV pulse durations, tunable from 1ps to 20ps to address different operational regimes of the XFEL. The laser system comprises a high-resolution spectral shaper with the option of generating flat-top DUV pulses for reducing electron-beam emittance at a later version. The laser is constructed in a hybrid Yb:fiber and Yb:YAG architecture. Our prototype delivers 180 uJ pulse energy at 1030nm and 1 MHz intraburst rate and we demonstrated conversion of 50µJ of the NIR beam to DUV, resulting 11.5µJ at 21ps (FWHM) and 6.15µJ at1.05ps (FWHM) pulse duration.

WEPAB380 **Measurements of Field Emission Induced Optical Spectra**

R.C. Peacock, *G. Burt (Lancaster University) S. Calatroni, W. Wuensch (CERN)*

Field emission induced optical spectra in a dc electrode system have been measured using a spectrometer and CCD camera system in order to gain insight into the nature of field emissions sites. Spectra were measured from between 2 ridged parallel copper electrodes with a gap ranging from 60µm to 100µm and a bias voltage of up to 8000V un-

der high vacuum conditions. A strong correlation between the light intensity of the spectra and the measured field emitted current was observed as a function of applied voltage. A characteristic broadband spectrum ranging from 550nm and 850nm wavelength was observed but there were important features which varied as a function of observation angle, polarity, and conditioning state and also with time. Possible causes of the optical spectra being considered include black body radiation, optical transition radiation and cathode luminescence of copper. Further experiments are ongoing with an improved optical setup to increase optical alignment for measurements with different materials of electrodes, developing further understanding of the cause of the optical spectra, to provide understanding into characteristics and evolution of emission sites.

WEPAB381 **Multipactor Simulations for MYRRHA Spoke Cavity: Comparison Between SPARK3D, MUSICC3D, CST PIC and Measurement**

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The multipactor effect can lead to thermal breakdown (quench), high field emission and limited accelerating gradient in superconducting accelerator devices. To determine the multipactor breakdown power level, multipactor simulations can be performed. The objective of this study is to compare the results given by different simulation codes with the results of vertical testing of SRF cavities. In this paper, Spark3D, MUSICC3D and CST Studio PIC solver have been used to simulate the multipactor effect in Spoke cavity developed within the framework of MYRRHA project. Then, a benchmark of these three simulation codes has been made. The breakdown power level, the multipactor order and the most prominent location of multipactor are presented. Finally, the simulation results are compared with the measurements done during the vertical tests.

WEPAB382 **Development of Automatic Measuring System of Pulling Sphere Method Based on Python**

***B.F. Wei** (USTC/NSRL)*

The perturbation theory shows that inserting a small metallic sphere into a resonant electromagnetic cavity can perturb its frequency, and the frequency change is dependent on the electromagnetic field at the position of the metallic sphere. According to this theory, we can measure the distribution of the electromagnetic field in the cavity. This article designs an automated measuring system to measure the longitudinal and horizontal distribution of the electromagnetic field, controlling the step motor to move the sphere, communicating the network analyzer and temperature sensor to measure frequency, calculating and visualizing the electromagnetic field distribution.

WEPAB383 **An Evolutionary Algorithm Approach to Multi-Pass ERL Optics Design**

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An Energy Recovery Experiment at CEBAF (ER@CEBAF) is aimed at demonstrating high energy, low current, multi-pass energy recovery at the existing 12 GeV CEBAF accelerator. The beam break-up instability, limiting the maximum beam current, can be controlled through minimizing beta functions for the lowest energy pass, which gives a preference to strongly focusing optics, e.g. a semi-periodic FODO lattice. On the other hand, one needs to limit beta function excursions, caused by under focusing, at the higher energy passes, which in turn favors weakly focusing linac optics. Balancing both effects is the main objective of proposed multi-pass linac optics optimization. Here, we discuss an optics design process for ER@CEBAF transverse optics using a genetic algorithm.

WEPAB384 **Design and Beam Dynamics of the Electron Lens for Space Charge Compensation in SIS18**

***S. Artikova**, D. Ondreka, K. Schulte-Urlichs, P.J. Spiller (GSI)*

An electron lens for space charge compensation is being developed at GSI to increase the ion beam intensities in SIS18 for the FAIR project. It uses an electron beam of 10A maximum current at 30keV. The maximum magnetic field on-axis is 0.6T, considerably higher than the field of the existing electron cooler. The magnetic system of the lens consists of solenoids and toroids. The toroids' vertical field component creates a significant horizontal orbit deflection in the circulating low rigidity ion beam. To correct this deflection, four correction dipoles have been introduced. As common for electron lenses, the high-power electron beam is not dumped at ground potential, but rather in a collector with a small bias potential with respect to the cathode. The present design foresees a collector at -27kV, leading to a power dissipation of 30kW, distributed over a large surface area by placing the collector in an appropriately shaped magnetic field of a pre-collector solenoid. This contribution reports on the design of the lens and presents the results of beam transport simulations for the electron beam (with space charge) and a representative ion beam, performed using the 3D CST STUDIO.

WEPAB385 **Beam Dynamic Analysis of RF Modulated Electron Beam Produced by Gridded Thermionic Electron Guns**

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A thermionic cathode gridded electron gun used in injectors for different types of circular and linear particle accelerators and for energy recovery configurations was studied. Both theory and numerical simulation were used to explore the relationship between the bunch charge and bunch length. The electron gun is based on a Pierce-type geom-

etry. It was initially designed using Vaughan synthesis followed by optimization using a 2D electron trajectory solver TRAK. After optimization, the grid in front of the cathode was inserted and the RF field was introduced through a coaxial waveguide structure. The complete gun was simulated using the PIC code MAGIC. High duty cycle operations at frequencies 1.5 GHz and 3.0 GHz, were investigated using different combinations of both the bias and the RF voltage applied between the cathode and the grid. The beam dynamics results from the PIC showed that a minimum bunch length of 10^6 ps could be achieved with a bunch charge of 33 pC when the driving RF frequency was 1.5 GHz. Operating at the higher RF frequency of 3GHz did not significantly reduce the bunch length. The normalized emittance of about 5.6 mm-mrad was demonstrated in PIC simulations.

WEPAB386 **Proton Beam Multiplexer Developments for the High Brilliance Neutron Source Project**

***M. Rimmler**, Th. Brückel, T. Gutberlet, U. Rücker (JCNS) O. Felden, R. Gebel, A. Lehrach, H. Soltner (FZJ)*

The High Brilliance neutron Source (HBS) project aims to develop a low energy accelerator-driven neutron facility enabling neutron fluxes at the corresponding instruments highly competitive to medium-flux fission-based research reactors. The full-fledged HBS facility features simultaneous operation of different neutron instruments, which subdivide into three target stations, each efficiently operated to supply different neutron pulse structures. This will be realized by different proton beam timing schemes distributed to the target stations in order to obtain the optimal balance between wavelength bandwidth and resolution of the time-resolved neutron spectrum extracted from the thermal or cold neutron moderator according to the requirement of the experiment. For this reason, a proton pulse distribution device, i.e. multiplexer, has to be developed. This contribution presents developments of a multiplexer test setup at the 45 MeV COSY injector JULIC at Forschungszentrum Jülich GmbH and concepts towards an implementation of such device into the final 70 MeV HBS framework. In this context, the top-level design of the beam transport from accelerator to target at HBS is presented.

WEPAB387 **Study of Failure Modes in Electron Linac-based X-ray Sources for Industrial Applications**

***K.P. Dixit**, G. Vinod (BARC)*

Electron linac-based X-ray sources (XRS) have an increased demand in industrial applications, mainly for their advantages of compactness and ease of use. In order to achieve reliable operation, it is necessary to have rugged components in the linac system. Hence, this study focusses on achieving high reliability design; also in formulating a preventive maintenance programme to optimise the availability and prognostic methods for performance monitoring of components. This paper investigates the failure modes in the important sub-systems of a 6 MeV electron linac, including electron gun, RF power source, vac-

uum system, x-ray target, control system, etc. Electron guns suffer from problems related to the filament heater damage and high voltage insulation failure. In the RF source, major components (line-type pulsed modulators, magnetrons, circulator and RF window) are studied to assess their life. Fault tree analysis of the individual sub-systems and the effect of individual failures on the linac down-time are studied. A few mitigation techniques used in practical systems are also discussed here.

WEPAB388 **Development of a Biologically Inspired Girder Design**
S. Andresen *(Alfred-Wegener-Institut)*
The PETRA IV project at DESY (Deutsches Elektronen Synchrotron) aims at upgrading the PETRA III synchrotron radiation facility to a unique synchrotron light source with an ultralow-emittance and diffraction limited up to X-rays of 10 keV. An optimization of the girder structure mainly supporting the magnets is essential to ensure a stiff machine and thus a stable particle beam. Therefore, an innovative, biologically inspired girder structure has been developed. Several structural elements were inspired by marine plankton organisms showing light, stiff, and vibration optimized structures. The girder development process is based on a topology optimization to disclose an optimum material distribution. The subsequently built beam-shell model combines biologically-inspired structural elements such has irregular honeycombs, smooth connections, branching structures, and torsional-rigid elements. A following cross section optimization revealed optimum cross section diameters and thicknesses for all beam and shell elements. The resulting optimized girder structure has been successfully fabricated using the casting technology.

WEPAB389 **Stability Analysis of CSNS Accelerator Control Network**
N. Ma *(IHEP CSNS)*
The first-level ground control network is the starting reference of the tunnel control network. It is used to monitor the geological stability of the installation area of the accelerator device, which directly affects the reliable operation of the accelerator device. Therefore, periodic monitoring is very necessary. Combining the ground network monitoring of China's spalled neutron source seven times from construction to stable operation, in this paper, the design of ground control network, point structure, monitoring schemes and methods, reliability analysis of data, and adjustment using elevation compensation surface are studied. During the process, the overall change trend of the CSNS ground network in recent years can be obtained, which can provide sufficient data and technical support for the operation of the accelerator device

WEPAB390 **High-Quality, Conformal Bellows Coatings Using Ultra-Fast HiPIMS With Precision Ion Energy Control**

***T.J. Houlahan**, I. Haehnlein, W.M. Huber, B.E. Jurczyk, I.A. Shchelkanov, R.A. Stubbers (Starfire Industries LLC)*

In this paper we demonstrate a replacement for traditional 'wet' chemical deposition processes using a vacuum, ionized physical vapor deposition (iPVD) process that results in a conformal metal film, capable of coating complex, convoluted parts that are common in modern particle accelerators (e.g., bellows, RF cavities). Results are presented for a process utilizing the combined deposition and etching that are achieved using ultra-fast high-power impulse magnetron sputtering (HiPIMS) coupled with precision control of the ion energy using a positive voltage reversal. This process results in a conformal film and has been used to coat both test coupons and full bellows assemblies. The resulting Cu films, which are 5-10 μm in thickness, exhibit excellent adhesion. Further, they have been shown to tolerate temperature extremes ranging from 77 K to a 400 C vacuum bakeout as well as extreme plastic deformation of the substrate without any buckling, cracking, or delamination.

WEPAB391 **Reserch on the Dynamic Response of the Stripping Foil System**

***L. Kang** (IHEP)*

The film stripping system is an important equipment in the high-current proton synchrotron, which directly affects the beam quality of the injected beam. The stripping film requires accurate positioning, and the general error is less than 0.5mm. The magnet in the injection area is mainly a strong pulse magnet, which will produce strong vibration and transmit to the peripheral equipment through the ground. In this paper, the finite element method is used to analyze the dynamic response of the membrane stripping equipment in the proton accelerator, and the modal analysis and harmonious response analysis of the system bracket are carried out, and the maximum displacement of the diaphragm caused by vibration is calculated with the result of harmonic response analysis as the load, and a reasonable structure is designed according to the calculation results.

WEPAB392 **Study of the Active Vibration Control System Base on Piezoelectric Driver**

***R.H. Liu**, J.X. Chen, H.Y. He, X.J. Nie, C.J. Ning, G.Y. Wang, A.X. Wang, J.B. Yu, Y.J. Yu, J.S. Zhang, D.H. Zhu (IHEP CSNS) L. Kang, L. Liu (IHEP)*

A parallel 6-DOF vibration isolation platform was built with piezoelectric ceramic actuators. And the NI Compact-RIO real-time control system and Fx-LMS adaptive filtering control algorithm were used for active vibration control. The secondary channel identification method and active vibration control algorithm were simulated, and the active vibration control system was built for experimental verification. The simulation and experimental results show that the designed active vibration control system has a good control effect on the low-frequency

micro-vibration at the range of 7 Hz to 50 Hz.

WEPAB393 **The Four Revolutions in Accelerators' History**
F. Zhao *(Private Address)*
Since particle accelerators were invented at the beginning of the 20th century, they have always been the frontier of physics development, and their technical level and application have also experienced many revolutions and changes. With the breakthrough and improvement of energy levels, new types of accelerators were continuing to appear. However, the academic circles have no clear definition of the several major innovations in the development of accelerators. Therefore, this article will elaborate on the four major technological breakthroughs in the development of accelerators, and call them the four revolutions in the history of accelerator development, in order to make a clear definition and discussion on the history of accelerator development.

WEPAB394 **Development of a New Interlock and Data Acquisition for the RF System at High Energy Photon Source**
Z.W. Deng*, J.P. Dai, H.Y. Lin, Q.Y. Wang, P. Zhang (IHEP)*
A new interlock and data acquisition (DAQ) system is being developed for the RF system at High Energy Photon Source (HEPS) to protect essential devices as well as to locate the fault. Various signals collected and pre-processed by the DAQ system and individual interlock signals from solid-state power amplifiers, low-level RFs, arc detectors, etc. are sent to the interlock system for logic decision to control the RF switch. Programmable logic controllers (PLC) are used to collect slow signals like temperature, water flowrate, etc., while fast acquisition for RF signals is realized by dedicated boards with down-conversion frontend and digital signal processing boards. In order to improve the response time, field programmable gate array (FPGA) has been used for interlock logic implementation with an embedded experimental physics and industrial control system (EPICS). Data storage is managed by using EPICS Archiver Appliance and an operator interface is developed by using Control System Studio (CSS) running on a standalone computer. This paper presents the design and the first test of the new interlock and DAQ for HEPS RF system.

WEPAB396 **First Measurements on Multipactor Study**
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Multipactor (MP) is an undesired phenomenon of resonant electron build up encountered on particle accelerators. It can induce anomalous thermal losses, higher than the Joule losses, inducing a decrease of the superconducting cavities quality factor, it can even lead to a cavity quench. On couplers, it can produce irreversible damages or generate a breakdown of their vacuum window. Multipactor may lead to Electron Cloud build up as well. The accelerator group at LPSC has de-

veloped a test bench dedicated to the multipactor studies. This paper presents the experimental set-up and its first measurements.

WEPAB397 **Design of the Two-Layer Girder for Accelerating Tube**

***X.J. Nie**, H.Y. He, L. Kang (IHEP) , J.X. Chen, L. Liu, R.H. Liu, C.J. Ning, A.X. Wang, G.Y. Wang, Y.J. Yu, J.S. Zhang, D.H. Zhu (IHEP CSNS) J.B. Yu (DNSC)*

An accelerating tube is one kind of important acceleration equipment of a linear accelerator. It is often made up of oxygen-free copper with a long tubular structure. It's easy to suffer from deformation. Based on support requirements, the reasonable structure of the girder was obtained. Four supporting blocks were installed on the top surface of aluminum profile with the uniform distribution along the beam direction. The support strength with static condition and different working conditions were checked by ANSYS simulation calculation to ensure the stable operation of the girder. The two-layer girder can be used as a reference for other similar slender part for its simple structure and reliable support.

WEPAB398 **A C-Band RFMode Launcher With Quadrupole Field Components Cancellation for High Brightness Applications**

***G. Pedrocchi** (Rome University La Sapienza) D. Alesini, F. Cardelli, A. Gallo, A. Giribono, B. Spataro (INFN/LNF) G. Castorina (AVO-ADAM) L. Ficcadenti (INFN-Roma) M. Migliorati, A. Mostacci, L. Palumbo (Sapienza University of Rome)*

The R&D of high gradient radiofrequency devices is aimed to develop innovative and compact accelerating stuctures based on new manufactoring techniques and materials in order to produce devices operating with the highest accelerating gradient. Recent studies have shown a large increase in the maximum sustained RF surface electric fields in copper structure operating at cryogenic temperature. These novel approaches allow significant performance improvements of RF photoinjectors. Indeed the operation at high surface fields results in considerable increase of electron brilliance. This requires high field quality in the RF photoinjector and specifically in its poweer coupler. In this work we present a novel power coupler for the RF photoinjector. The coupler is a compact C-band TM01 mode launcher with a fourfold symmetry which minimized both the dipole and the quadrupole RF field components.

WEPAB399 **Applications of the Local Observable in Future Optics Measurements**

***A. Wegscheider**, R. Tomás (CERN)*

Phase advances among four nearby beam position monitors in a circular accelerator can be used to calculate a local observable of quadrupolar lattice imperfections. This work explores the applicability of this local observable to two different circular accelerators: PETRA III, a synchrotron light source, and the LHC, a hadron collider as well as its upgrade project HL-LHC. MADX simulations for important optics settings are performed, showing that the local observable can detect

strong error sources. This is of particular interest in important regions of the accelerators like the LHC's interaction regions and PETRA III's experimental hall.

WEPAB400 **Forced Coupling Resonance Driving Terms**
***A. Wegscheider**, R. Tomás (CERN)*
At the LHC, coupling is routinely measured using forced oscillations of the beam through excitation with an AC-dipole. The driving of the particle motion has an impact on the measurement of resonance driving terms. Recent findings suggest that the current models describing the forced motion are neglecting a local effect of the AC-dipole, creating a jump of the amplitude of the resonance driving terms. This work presents a study of the improvement of coupling measurements for typical LHC optics as well as its upgrade project HL-LHC, by using the new model.

WEPAB401 **Study for Alternative Cavity Wall and Inductive Insert Material**
***C.E. Taylor**, A.M. Alexander, C.-F. Chen, E. Henestroza, E.-C. Huang, J.T.M. Lyles, P.K. Roy, J. Upadhyay (LANL) S. Biedron (University of New Mexico)*
The goal of this work was to develop a solution to the problem of longitudinal beam instability. Beam instability has been a significant problem with storage rings' performance for many decades. The proton storage ring (PSR) at the Los Alamos Neutron Science Center (LANCE) is no exception. To mitigate the instability, it was found that ferrite inductive inserts can be used to bunch the protons that are diverging due to the electron background. The PSR was the first to successfully use these inductive inserts to mitigate the instabilities. However, years later new machine upgrades facilitate shorter, more intense beams to meet the needs of researchers. The ferrite inserts used to reduce the transverse instabilities now induce a new longitudinal instability. Finemet was proposed as a replacement for the PSR Toshiba ferrite inserts because of its very stable magnet flux density. Yet in Japan, J-PARC has found complications with its use. This study investigates alternative magnetic materials for inductive inserts in particle beam storage rings, including the necessary engineering for maintaining the ideal temperature during operation.

WEPAB402 **Status and Progress of the High-Power RF System for High Energy Photon Source**
***P. Zhang**, T.M. Huang, J. Li, H.Y. Lin, Y.L. Luo, Q. Ma, W.M. Pan, F.C. Zhao (IHEP)*
High Energy Photon Source is a 6-GeV diffraction-limited synchrotron light source currently under construction in Beijing. Three types of high-power RF systems are used to drive the booster and the storage ring. For the booster ring, a total of 600-kW continuous-wave (CW) RF power is generated by six 500-MHz solid-state power amplifiers (SSA) and fed into six normal-conducting copper cavities. Concerning the storage ring, five CW 260-kW SSAs at 166 MHz and two CW 260-kW

SSAs at 500-MHz are used to drive five fundamental and two third-harmonic superconducting cavities respectively. The RF power distributions are realized by 9-3/16" rigid coaxial line for the 166-MHz system and EIA standard WR1800 waveguide for the 500-MHz one. High-power circulators and loads are installed at the outputs of all SSAs to further protect the power transmitters from damages due to reflected power although each amplifier module is equipped with individual isolators. The overall system layout and the progress of the main components are presented in this paper.

WEPAB403 **VAX Support for the HL-LHC Project: The Solution for a Modular and Remote Handling of Vacuum Components**

***M. Luque**, F. Sanchez Galan (CERN)*

The area between the quadrupole Q1 and the TAS absorber represents the interface between the LHC tunnel and the experimental caverns of CMS and ATLAS. A highly radioactive zone as well as narrow and crowded with service lines, cabling, and auxiliary elements which require inspections and maintenance. For the High Luminosity upgrade of the LHC, the vacuum components which mostly occupy this area today, are being re-organized in modules equipped with mechanisms adapted for remote control operation without human intervention, which are to be relocated in front of the TAS aiming to have low maintenance equipment that is accessible, when this is required, via remote handling through a robot. This is the goal of the development of the VAX support, an essential component equipped with the following different systems: guiding pins as reference for the positioning of the modules on v-seats and ball supports, Staubli connectors which permit the automated connection of electrical & pneumatical supply to the instrumentation on the modules in place, and an innovative system for connecting the beampipe guaranteeing the ultrahigh vacuum requirements.

WEPAB404 **TAS Alignment System: Reverse Engineering for the HL-LHC Project**

***M. Luque**, F. Sanchez Galan (CERN) N.S. Kristensen (Aarhus University)*

The inner triplet quadrupole absorbers (TAS) are in the interface between the LHC tunnel and the experimental caverns of ATLAS and CMS. Each TAS (one per IP side) consists of a Copper cylinder of 1,8 m in length and 0,5 m in diameter whose goal is to protect the triplets from collision debris leaving the interaction point. This absorber is equipped with an alignment system in order to adjust the position of the beampipe, if it is required after a survey campaign. The TAS will be replaced by the TAXS, a new absorber with identical shape but increased aperture. This is the opportunity of implementing improvements and modifications to a system which was designed and installed more than 20 years ago. The study starts by the idea of fully reproducing the alignment system on a 3D model which does not exist today. Through this process, it became for instance clear, that one cannot find

the exact replica of every mechanism in todays market and that it was designed in the United States without the use of European standards. The aim is to provide ideas to facilitate an eventual future replacement and to understand the origin of some difficulties encountered during the last operation.

WEPAB405 **Supercontinuum Generation for the Improvement of Pulse Radiolysis System**

***M. Sato**, Y. Kaneko, Y. Koshiba, M. Washio (RISE) K. Sakaue (The University of Tokyo, Graduate School of Engineering)*

Pulse radiolysis is one of the absorption measurement methods for investigating the fundamental, ultrafast process of radiation chemical reactions. Analytical light is transmitted simultaneously with the timing of electron beam irradiation, and its absorption by reactive species is detected. Since the target reactions arise in pico second time scale or even shorter, analytical light is required to have such duration. Besides, so as not to be buried in noise of the radiation source, the optical power of the analytical light must be high enough. Furthermore, it is desirable that the analytical light covers visible region because important absorptions caused by irradiation products such as hydrated electron, hydroxyl radical, or so exist in the region. We considered that the supercontinuum light generated from an ultrashort pulse laser is suitable as an analytical light because it has all these characteristics. In this study, we generate the second harmonic (775 nm) of an erbium fiber laser (1550 nm) as a seed laser for supercontinuum generation. In this presentation, we report the current situation of our laser system and prospects.

WEPAB406 **The Advantages of a Modular Solid-State Power Amplifier System for Particle Accelerators**

***M. Lau** (TRUMPF Huettinger) G. Baumann, R. Heilig, J. Weber (HBH Microwave GmbH)*

Industrialization of a product usually requires high expenditures on R&D. But the advantages of an industrialized microwave product directly result in its reliability and thus, for particle accelerators, in beam availability. Unfortunately, individual power levels and control interfaces are needed for the accelerators and different projects. Solid-state power amplifiers (SSPA) offer the advantage of good modularity and scalability to address individual needs. Based on this technology we are aiming to fuse the best of the two worlds, a highly flexible system by its modular design in combination with industrial reliability. Here we share insights into our development experience of modular, flexible, and software-controlled systems.

WEPAB407 **An Innovative Eco-System for Accelerator Science and Technology**

***C. Darve**, J.B. Andersen, S. Salman (ESS) B. Nicquevert, S. Petit (CERN) M. Stankovski (LINXS)*

The emergence of new technologies and innovative communication

tools permits us to transcend societal challenges. While particle accelerators are essential instruments to improve our quality of life through science and technology, an adequate ecosystem is essential to activate and maximize this potential. Research Infrastructure (RI) and industries supported by enlightened organizations and education, can generate a sustainable environment to serve this purpose. In this paper, we will discuss state-of-the-art infrastructures taking the lead to reach this impact, thus contributing to economic and social transformation.

WEPAB408 **Galactic Cosmic Ray Simulation Based on a 250 MeV Superconducting Cyclotron**

Z.Y. Mei *(HUST) K. Fan (Huazhong University of Science and Technology, State Key Laboratory of Advanced Electromagnetic Engineering and Technology,)*

Ground-based Galactic Cosmic Ray (GCR) Simulator has been widely used in space radiation research recently due to its accessibility and flexibility. As the space radiation inside a shielding vehicle is mainly contributed by protons (65%-75%) and light ions (10%-20%), a GCR Simulator using a single proton beam is viable to cover the space radiation research. A 250 MeV superconducting cyclotron is being developed at Huazhong University of Science and Technology (HUST-SCC250) for proton therapy, in collaboration with the China Institute of Atomic Energy (CIAE). We are planning to construct a GCR Simulator based on the cyclotron. An energy degrader is employed downstream to obtain a series of proton energies and to produce desired secondary particles for GCR simulating. This paper studies the secondary particle generation from the interactions between protons and the degrader materials. Both Monte Carlo codes FLUKA and Geant4 are employed for cross-validation that ensures the simulations correct. Results show that, by changing the thickness and material of the degrader, a highly similar particle field compared to GCR could be acquired, which meets the demands of GCR simulating.

WEPAB409 **Characteristic of Coherent Smith-Purcell Radiation From Ultrashort Relativistic Electron Bunch**

H. Qi*, K. Fan, C.-Y. Tsai (HUST)*

Advances in accelerator science and technology continue to reach shorter bunch lengths even down to femtosecond, paving a way to generate coherent radiation, which is taken as one of the most promising THz sources. After bunching in RF gun or dipoles chicane, relativistic electron bunches can emit coherent Smith-Purcell radiation, enhancing the radiation intensity greatly, when they pass above an aligned metal grating. To produce THz radiation for plasma diagnostic, researches on low energy electron bunches (3 MeV) and properties of Smith-Purcell radiation help to optimize the system parameters and extend the radiation frequency to 0-2.5 THz range. Simulations of the interaction between electron bunches and selected gratings show the components and intensity of radiation and frequency distribution in CST Particle Studio. The results are in accordance with the Smith-

Purcell radiation relation in farfield regime and indicate radiation distribution will change as the parameters of electron bunches differ.

WEPAB410 **Finite Element Analyses of Synchrotron Radiation Induced Stress in Beryllium Synch-Light Mirrors**

***Y. Lushtak**, Y. Li, A. Lyndaker (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)*

Mirrors made of high purity beryllium are used in particle accelerators to extract synchrotron radiation (SR) in the visible range for transverse and longitudinal particle beam profile measurements. Be is a high-strength, high thermal conductivity material. As a low-Z metal, it allows high-energy photons to penetrate the mirror body, so that majority of the SR power is dissipated, resulting in a significantly reduced thermal stress and distortion on the mirror surface. In this paper, we describe a Finite Element Analysis method of accurately simulating the SR-induced thermal stress on the beryllium mirrors at the Cornell Electron Storage Ring at various particle beam conditions. The simulations consider the energy dependence of X-ray attenuation in beryllium. The depth-dependent distribution of the power absorbed by the mirror is represented by separate heating zones within the mirror model. The results help set the operational safety limit for the mirrors-ensuring that the SR-induced thermal stress is below the elastic deformation limit and estimate the mirror surface distortion at high beam currents. The simulated surface distortion is consistent with optical measurements.

WEPAB411 **Ion Coulomb Crystals in Storage Rings for Quantum Information Science**

***K.A. Brown**, G.J. Mahler, T. Roser, T.V. Shaftan, Z. Zhao (BNL) A. Aslam, S. Biedron, T.B. Bolin, C. Gonzalez-Zacarias, S.I. Sosa Guitron (University of New Mexico) R. Chen, T.G. Robertazzi (Stony Brook University) B. Huang (SBU)*

We discuss the possible use of crystalline beams in storage rings for applications in quantum information science (QIS). Crystalline beams have been created in ion trap systems and proven to be useful as a computational basis for QIS applications. The same structures can be created in a storage ring, but the ions necessarily have a constant velocity and are rotating in a circular trap. The basic structures that are needed are ultracold crystalline beams, called ion Coulomb crystals (ICC's). We will describe different applications of ICC's for QIS, how QIS information is obtained and can be used for quantum computing, and some of the challenges that need to be resolved to realize practical QIS applications in storage rings.

WEPAB412 **Use of a Noise Iot Detection System to Measure the Environmental Noise in Taiwan Light Source**

***P.J. Wen**, S.P. Kao, S.Y. Lin, Y.-C. Lin (NSRRC)*

In the past, the method of general noise monitoring altered little; noise was still measured with a human hand-held mobile device, or the

measurement at fixed sites was made using traditional analogue data-storage equipment. In recent years, with the rapidly improved network transmission capabilities, the development of a small noise-detection IoT system allows the detection data to be transmitted wirelessly without need for human strength measurements, and records noise information. The statistics of subsequent noise data become a basis for analysis and improvement. Taiwan Light Source (TLS) beamlines have many vacuum pumps, cooling pumps, liquid-nitrogen pressure-relief systems, computer servers etc. that generate much noise. This study is expected to prepare for installation of noise detection. The system uses a noise-detection box to detect, to disclose louder locations, to collect noise data, to determine the source and type of noise source, and to provide information to reduce the noise of the working environment. The TLS noise-detection results find that the inner-ring area has less noise and are more stable than the outer ring area.

WEPAB416 **Industrialization Study of the Accelerating Structures for a 380 GeV Compact Linear Collider**

A. Magazinik *(Tampere University) N. Catalán Lasheras (CERN) S. Mäkinen (Tampere University of Technology) J. Sauza-Bedolla (Lancaster University)*

The LHC at CERN will continue its operation for approximately 20 years. In parallel, diverse studies are conducted for the design of a future large-scale accelerator. One of the options is the Compact Linear Collider (CLIC) who aims to provide a very high accelerating gradient (100 MV/m) achieved by using normal conducting radiofrequency (RF) cavities operating in the X-band range (12 GHz). Each accelerating structure is a challenging component involving ultra-precise machining and diffusion bonding techniques. The first stage of CLIC operates at a collision energy of 380 GeV with an accelerator length of 11 km, consisting of 21630 accelerating structures. Even though the prototypes have shown a mature and ready to build concept, the present number of qualified suppliers is limited. Therefore, an industrialization study was done through a technical survey with hi-tech companies. The aim is to evaluate current capabilities, to ensure the necessary manufacturing yield, schedule, and cost for mass production. This paper presents the results of the industrialization study for 12 GHz accelerating structures for CLIC 380 GeV, highlighting the principal challenges towards mass production.

WEPAB418 **The Power Supply System for 10 MeV and 20 kW Industry Irradiation Facility**

F.L. Shang*, L. Shang (USTC/NSRL)*

The 10 MeV and 20 kW industry irradiation facility (IIF) has been designed by National Synchrotron Radiation Laboratory (NSRL) for years. Modular design power supplies are employed for the latest version, depend on the performance of these power supplies with high precision and high stability, the operating reliability of the IIF has been greatly improved.

WEPAB419 **Analysis the Pulse Forming Scheme Applied to the Power Supply of Grid-Controlled Electron Gun**

F.L. Shang, *L. Shang (USTC/NSRL)*

The grid-controlled electron gun,with the advantages of mature technology,long working life,stable performance and flexible beam regulation,was widely applied in the industry irradiation facility. The power supply for grid-controlled electron gun includes:a DC filament power supply ,DC bias power supply and pulse extraction power supply. The pulse extraction power supply was the most important and difficult point in design. In this paper we discuss three schemes for pulse forming: pulse transformer,capacity coupling and MOSFET coupling. Firstly gave the schemes and simulate result,secondly presents the circuit of capacity coupling and MOSFET coupling,finally gave the actual measurement result.

WEIX01 **DOE's Office of Accelerator R&D and Production**
E.R. Colby *(OHEP/DOE) B.E. Carlsten (LANL) M. White (ANL)*
The Office of Accelerator R&D and Production (ARDAP) was formed in April 2020 in recognition of the central importance of accelerators and related technologies to the current and future scientific capabilities stewarded by the DOE Office of Science. ARDAP's mission is to understand and address accelerator science and technology gaps and accelerator component production gaps that may negatively impact future US accelerator-based physical science R&D priorities. The talk will include an overview of ARDAPs activities and how it coordinates accelerator activities with other programs within the Office of Science.

WEIX02 **Effective Software Collaboration Between Industry and National Labs**
D.L. Bruhwiler *(RadiaSoft LLC)*
The development and implementation of algorithms is a core competency of universities and research labs; however, the resulting codes can be difficult to use and expensive to maintain. Professional software developers could help to resolve the problem, but they are expensive to hire and difficult to retain. Retention difficulties and associated career pipeline problems are due in part to misaligned incentives. For example, making software sustainable and easy-to-use is orthogonal to publishing in academic journals and, perhaps more problematic, the scientific mission of national laboratories and university departments often does not motivate software developers and data scientists sufficiently to retain them. In contrast, software sustainability and ease-of-use are core competencies of software developers in industry. Hence, it is advantageous for national laboratories and universities to actively and routinely collaborate with industry. This more varied range of employment opportunities and internal institutional incentives will also offer possibilities for more varied career paths and, perhaps, better retention of talented individuals within the community.

WEIX03 **Collaboration Between Industry and Research Institutes: A Win-Win Approach in Large Research Projects**
P. Manini*, M. Campaniello, E. Maccallini, M. Mura, T. Porcelli (SAES Getters S.p.A.) M. Canetti, F. Gangini, C. Santini, T.F. Sinkovits (SAES RIAL Vacuum)*
Large research infrastructures and projects are progressively pushing the technological envelop to the limits. The need to increase performances of accelerators and experimental machines requires the adoption of innovative approaches, new materials and configurations as well as efficient and timely management of complex tasks. Manufacturability of reproducible serial products and component with high level technical specifications is key to deliver consistent and reliable

performances in the final experiment. In the present talk we report on the experience gathered by SAES Group working on research projects requiring the production of very demanding items. The industrial approach has resulted to be beneficial to improve the design of the products and provide stable performances. On the other hand, the interaction with the research Institutes has been extremely valuable to stimulate new ideas and to find technological solution to challenging problems. This has finally brought to an increase of the company product portfolio and a more competitive technology offer.

WEXA01 **Successful Crabbing of Proton Beams**
R. Calaga *(CERN)*
Many future particle colliders require beam crabbing to recover the geometric luminosity loss from the non-zero crossing angle at the interaction point. A first demonstration experiment of crabbing with hadron beams was successfully carried out with high energy protons. This breakthrough result is fundamental to achieve the physics goals of the high luminosity LHC upgrade project (HL-LHC) and the future circular collider (FCC). The expected peak luminosity gain (related to collision rate) is 65% for HL-LHC, and even greater for the FCC. Novel beam physics experiments with proton beams in CERN's Super Proton Synchrotron (SPS) were performed to demonstrate several critical aspects for the operation of crab cavities in the future HL-LHC including transparency with a pair of cavities, a full characterization of the cavity impedance with high beam currents and controlled emittance growth from crab cavity induced RF noise.

WEXA02 **Operational Electron Cooling in the Relativistic Heavy-Ion Collider**
A.V. Fedotov*, K.A. Drees, W. Fischer, X. Gu, D. Kayran, J. Kewisch, C. Liu, K. Mernick, M.G. Minty, V. Schoefer, H. Zhao (BNL)*
Since the invention of the electron cooling technique its application to cool hadron beams in colliders was considered for numerous accelerator physics projects worldwide. However, achieving the required high-brightness electron beams of required quality and cooling of ion beams in collisions was deemed to be challenging. An electron cooling of ion beams employing a high-energy approach with RF-accelerated electron bunches was recently successfully implemented at BNL. It was used to cool ion beams in both collider rings with ion beams in collision. Electron cooling in RHIC became fully operational during the 2020 physics run and led to substantial improvements in luminosity. This presentation will discuss implementation, optimization and challenges of electron cooling for colliding ion beams in RHIC.

WEXA03 **Physics and Technology Challenges in Generating High Intensity Positron Beams**
I. Chaikovska *(Université Paris-Saclay, CNRS/IN2P3, IJCLab)*
Positron sources are essential to the current and future lepton collider projects (ILC, CLIC, SuperKEKB, FCC-ee, etc.) with challenging critical requirements of high-beam intensity and low emittance necessary to achieve high luminosity. In the conventional positron-generation system, a possible scheme to increase the positron intensity is to increase the incident electron beam power (intensity and/or energy). However, the allowable heat load as well as the thermo-mechanical stresses in the target severely limit the allowable beam power of the incident electrons. The positron source community should consolidate the effort

and explore different methods of positron production, both classical techniques and especially novel ones, primarily for future high-energy physics applications requiring orders of magnitude higher intensity than what was demonstrated up to now, and for considering future hadronic applications (including the EIC) requiring both polarization and intensity. The studies should be focused on different source types, targets, capture approaches including the existing limitations and potential for polarized positron production identifying the main axes for future R&D.

WEXA04 **The RCS Design status for the Electron Ion Collider**

***V.H. Ranjbar**, M. Blaskiewicz, Z.A. Conway, D.M. Gassner, C. Hetzel, B. Lepore, H. Lovelace III, I. Marneris, F. Méot, C. Montag, J. Skaritka, N. Tsoupas, E. Wang, F.J. Willeke (BNL) J.M. Grames, J. Guo, F. Lin, V.S. Morozov, T. Satogata (JLab) D. Sagan (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)*

The design of the Electron-Ion Collider Rapid Cycling Synchrotron (RCS) to be constructed at Brookhaven National Laboratory is advancing to meet the injection requirements for the Electron Storage Ring (ESR). Over the past year activities are focused on developing the approach to inject two 28 nC bunches every second, up from the original design of one 10nC bunch every second. The solution requires several key changes concerning the injection and extraction kickers, charge accumulation via bunch merging and a carefully calibrated RF acceleration profile to match the longitudinal emittance required by the ESR.

WEXA05 **Solving for Collider Beam Profiles From Luminosity Jitter With Ghost Imaging**

***D.F. Ratner** (SLAC)*

Large accelerator facilities must balance the need to achieve user performance requirements while also maximizing delivery time. At the same time, accelerators have advanced data-acquisition systems that acquire synchronous data at high-rate from a large variety of diagnostics. Here we discuss the application of ghost-imaging (GI) to measure beam parameters, switching the emphasis from beam control to data collection: rather than intentionally manipulating the accelerator, we instead passively monitor jitter gathered over thousands to millions of events to reconstruct the target of interest. Passive monitoring during routine operation builds large data sets that can even deliver higher resolution than brief periodic scans, and can provide experiments with event-by-event information. In this presentation we briefly present applications of GI to light-sources, and then discuss a potential new application for colliders: measuring the transverse beam shapes at a collider's interaction point to determine both the integrated luminosity and the spatial distribution of collision vertices.

WEXA06 **Study of Pb-Pb and Pb-p Collision Debris in the CERN LHC in view of HL-LHC operation**

***M. Sabate-Gilarte**, R. Bruce, F. Cerutti, A. Lechner (CERN)*

For the first time, a full characterization of the Pb-Pb and Pb-p collision debris as well as its impact in terms of energy deposition in the long straight section (LSS) of CERN's Large Hadron Collider has been carried out. By means of Monte Carlo simulations with FLUKA, both inelastic nuclear interaction and electromagnetic dissociation were taken into account as source term for lead ion operation, while for Pb-p operation only nuclear interaction is of importance. The radiation exposure of detectors exclusively destined for ion beam runs is assessed, allowing drawing implications of their use. This work gave the opportunity for an unprecedented validation of simulation results against measurement of beam loss monitors (BLM) in the experimental LSS during ion operation. Pb-Pb operation refers to the 2018 ion run at 6.37 TeV per charge with a +160 microrad half crossing angle in the vertical plane at the ATLAS interaction point. Instead, Pb-p operation was benchmarked for the 2016 ion run at 6.5 TeV per charge with -140 microrad half crossing angle in the vertical plane at the same location.

WEXA07 **Beam background measurements at SuperKEKB/Belle-II in 2020**

***H.N. Nakayama**, T. Koga (KEK) K. Kojima (Nagoya University) A. Natochii, S. Vahsen (University of Hawaii)*

The SuperKEKB electron-positron collider began collision operation in 2018 and achieved the world-record luminosity of 2.4×10^{34} $cm^{-2}s^{-1}$ in June 2020. We pursue higher luminosity by squeezing beam sizes and increasing beam currents. Beam backgrounds induced by stray particles will also increase and might cause severe radiation damage to Belle II detector components and worsen the quality of collected physics data. To mitigate these backgrounds, we have carefully designed our interaction region and installed movable collimators in the machine. We present recent measurements of beam background at SuperKEKB. We have performed dedicated machine studies to measure each background component separately and found that beam-gas scattering and Touschek scattering in the positron ring are the dominant sources of background rates in Belle II. We also present the latest observations of injection background, which determines the timing of a required Belle II data acquisition trigger veto and therefore affects the integrated luminosity. We show the beam background extrapolation toward the expected higher-luminosity operation and our plans for further background mitigation.

WEXB01 **The ESS Elliptical Cavity Cryomodules production at CEA**
C. Madec *(CEA) C. Arcambal, S. Berry, A. Bouygues, G. Devanz, C. Mayri, P. Sahuquet, T. Trublet (CEA-DRF-IRFU) P. Bosland, E. Cenni, C. Cloué, T. Hamelin, O. Piquet (CEA-IRFU) P. Pierini (ESS)*
CEA in Kind contribution to the ESS superconducting LINAC includes 30 elliptical medium and high-beta cryomodules. CEA is in charge of the production of all the components (except the cavities delivered by LASA and STFC) as well as the assembly of the cryomodules and a few cryogenic and RF tests. The power couplers operating at a maximum power of 1.1MW on a 3.6ms pulse at 14Hz are conditioned at high RF power on a dedicated stand. The assembly of the cryomodules is performed at CEA by a private Company under the supervision of CEA. This paper presents the status of the cryomodules production and the infrastructure dedicated to this project at CEA Saclay.

WEXB02 **Upgrading J-PARC Accelerator for Hyper Kamiokande Project**
Y. Sato *(KEK)*
The Main Ring (MR) of J-PARC has supplied high-intensity proton beams for the T2K long-baseline neutrino oscillation experiment since 2010. The present beam power reaches 515 kW. To observe the CP violation in the lepton sector, more protons need to be delivered to the neutrino target. The project upgrading the beam power to 1.3 MW started in the MR, where hardware upgrades and beam dynamics improvements are scheduled to handle higher repetition and increase protons per pulse. The MR upgrade and the Hyper Kamiokande project, which has recently been approved and started construction, will open up a new phase of leptonic CP violation studies.

WEXB03 **The Multi-User Upgrade of the Superconducting Ion Linac, ATLAS**
B.M. Mustapha *(ANL)*
The recently approved multi-user upgrade of the superconducting ion linac, ATLAS, will enable simultaneous acceleration and delivery of two different ion beams to different experimental areas. In the initial phase, one stable, nearly continuous wave, beam from the ECR ion source and one pulsed radioactive beam from the EBIS charge breeder of the Californium Rare Isotope Beam Upgrade (CARIBU-EBIS) will be interleaved in time via an electrostatic deflector at injection, and accelerated through the first two sections of the linac. At that point, one of the beams is deflected via a pulsed switching magnet to a lower energy experimental area while the other is further accelerated through the third linac stage of ATLAS and delivered to a higher energy experimental area. Details of the proposed implementation and the expected gains from this upgrade will be presented. In addition to enhancing the ATLAS nuclear physics program, this upgrade will also increase the

availability of beam time for applications such as material irradiation, isotope production R&D, and radiobiology studies with ion beams. A brief overview and typical results from these applications will be presented.

WEXB04 **Commissioning of the Radioactive Ion Beam Transport System for ARIEL**

***S. Saminathan**, F. Ames, T.D. Angus, R.A. Baartman, P.E. Dirksen, K. Ezawa, M. Marchetto, M. Rowe, B.E. Schultz (TRIUMF)*

The ARIEL facility is being commissioned to triple the availability of radioactive ion beams with ISAC at TRIUMF. The ARIEL separator and front-end facility also referred to as radioactive ion beam (RIB) transport system, connects the two new ARIEL target stations to the existing ISAC facility. The RIB transport system acts as a switchyard, in excess of 200 meters of beamlines, for delivering two additional simultaneous beams from the two ARIEL target ion sources. The primary optical building blocks of the RIB transport system are the matching, periodic, order-reversing, low-beta-insertion, dogleg, and achromatic bend sections. These blocks consist of electrostatic optical elements such as quadrupole, bender, and steerer. The first phase of the ARIEL installation is completed, and commissioning is well underway. The paper will describe the recent commissioning and early operation results of the ARIEL RIB transport system.

WEXB05 **SPIRAL2 MEBT commissioning results with protons and helium**

***A.K. Orduz**, M. Di Giacomo, R. Ferdinand, B. Jacquot, O. Kamalou, J.-M. Lagniel, G. Normand, A. Savalle (GANIL) D. Uriot (CEA-IRFU)*

The SPIRAL2 injector includes a 5 mA proton-deuteron ECR source, a 1 mA ECR heavy ion source (up to A/Q =3) and a CW 0.73 MeV/u RFQ. It has been successfully commissioned using a diagnostic-plate in parallel with the superconducting linac installation. The green light has been obtained for the LINAC commissioning in July of 2019, starting with the Medium Energy Beam Transport (MEBT) commissioning with protons then with helium in 2020. The MEBT line and tuning process are described. The main experimental results are given, including the emittance and profile measurements which are compared with TraceWin simulations. RFQ output energy variation has been found due to an input energy error, its correction optimizing the source platform voltage is presented.

WEXB06 **Development of an APF IH-DTL in the J-PARC Muon g-2/EDM Experiment**

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H.Y. Yasuda (University of Tokyo)
An inter-digital H-mode drift-tube linac (IH-DTL) is under development in a muon linac at the J-PARC muon g-2/EDM experiment. It accelerates muons from 0.34 MeV to 4.3 MeV at an operating frequency of 324 MHz. The cavity can be miniaturized by introducing the alternative phase focusing (APF) method that enables transverse focusing only with an E-field. The APF IH-DTL cavity was modeled by a three-dimensional field analysis, and the beam dynamics were evaluated numerically. The beam emittance was calculated as 0.316pi and 0.189pi mm mrad in the horizontal and vertical directions, respectively. It satisfies the experimental requirement. Actually, the field error due to the fabrication errors and thermal expansion during operation causes an emittance growth. It was evaluated that the optimized tuners can suppress the emittance growth to less than 10%. In this paper, the detailed design of the APF IH-DTL including the tuner will be reported.

WEXB07 **Transverse Beam Profile Measurements From Extraction Losses in the PS**
***J.R. Hunt**, F. Cerutti, L.S. Esposito, M. Giovannozzi, A. Huschauer, G. Russo (CERN) G. Russo (Goethe Universität Frankfurt)*
During Multi-Turn Extraction (MTE) of continuous beams in the Proton Synchrotron (PS) at CERN, losses are generated on the blade of both the active and non-active septum during the rise time of the extraction kickers. Utilising pCVD Diamond detectors, secondary signal generated from these losses is measured. The high time resolution of these devices allows for insight into the detail of the horizontal beam distribution during extraction, and hence useful information such as the horizontal beam emittance may be computed. In this contribution, FLUKA simulations to relate the detector response to the beam impact conditions on the blades of the two septa are presented. The dependence on the beam angle, magnetic fringe field, and positioning of the detector is explored. Finally, realistic beam distributions are used to determine expected signal profiles at each septum.

WEXB08 **Beam Losses and emittance growth studies at the Record high space-charge dQ_SC in the Booster**
***V.D. Shiltsev**, J.S. Eldred, V.A. Lebedev, K. Seiya (Fermilab)*
Comprehensive studies of high intensity proton beams in the 0.4-8 GeV FNAL Booster synchrotron have revealed interesting nonlinear dynamics of the beam losses and emittance growth at the record high dQ_SC=0.6. We report the results of the studies and directions of further improvements to prepare the Booster to the era of even higher intensity operation with new 0.8 GeV PIP-II linac.

WEXC01 **Generation of High-Brightness Self-Seeded X-Ray Free Electron Laser**

C.-K. Min *(PAL)*

At the PAL-XFEL, we demonstrate substantially improved self-seeded XFEL performance, which promises to add another popular XFEL operation mode with up to ~mJ pulse energy at 9.7 keV (peak spectral brightness, 3.2×10^{35} photons s^{-1} mm^{-2} $mrad^{-2}$ $(0.1\%BW)^{-1}$) and wide tunability (3.5-14.6 keV). The machine is tuned to get stable seeding and its monochromatic amplification process and provide a stable amplitude (better than filtered SASE using DCM) and the time-bandwidth product is close to transform-limited. The suppression of μbunching instability using a laser heater is much more effective in this narrow spectral bandwidth compared to SASE mode with a broad spectrum. The benefit of this seeded XFEL is demonstrated in serial femtosecond crystallography experiments.

WEXC02 **Enhanced Seeded Free Electron Laser Performance with a "Cold" Electron Beam**

G. Penco *(Elettra-Sincrotrone Trieste S.C.p.A.)*

In a seeded free-electron laser operating in high gain harmonic generation (HGHG) as FERMI, the harmonic conversion efficiency decreases at high harmonics and the quality of the pulses is increasingly affected by the electron beam phase space distortions. The lower the electron time-slice energy spread the higher harmonic of the seed is efficiently obtained. The optimization of the FERMI photoinjector and of some linac parameters has allowed a reduction of the relative slice energy spread to the level of few times of 10^5. With these new conditions, the FEL can be operated without the need for a laser heater to suppress micro-bunching instabilities and this "cold" beam has allowed the generation of extreme UV pulses with pulse energy exceeding 1 mJ, and with peak power of about 10 GW. We describe the electron beam characterization and the FEL performance improvement, including the extension of the range of harmonics of the seed which can be amplified, up to the twenty-fifth harmonic, i.e., 10 nm.

WEXC03 **Review of Superconducting Radio Frequency Gun**

R. Xiang *(HZDR)*

The success of proposed high power free-electron lasers (FELs) and energy recovery linac (ERL) largely depends on the development of the electron source, which requires the best beam quality and CW operation. An elegant way to realize this average brilliance is to combine the high beam quality of mature normal conducting radio frequency photoinjector with the quick developing superconducting radio frequency technology, to build superconducting rf photoinjectors (SRF guns). In last decade, several SRF gun programs based on different approaches

have achieved promising progress, even succeeded in routine operation at BNL and HZDR. In the near future SRF guns are expected to play an important role for hard X-ray FEL facilities. In this contribution, we will review the design concepts, parameters, and the status of the major SRF gun projects.

WEXC04 **Simulations of Beam Strikes on Advanced Photon Source Upgrade Collimators using FLASH, MARS, and elegant**

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Modeling of high-energy-density electron beams on collimators proposed for the Advanced Photon Source Upgrade (APS-U) storage ring (SR) is carried out with codes FLASH, MARS, and elegant. Code results are compared with experimental data from two separate beam dump studies conducted in the present APS SR. Whole beam dumps of the 6-GeV, 200 mA, ultra-low emittance beam will deposit acute doses of 30 MGy within 10 to 20 microseconds, leading to hydrodynamic behavior in the collimator material. Goals for coupling the codes include accurate modeling of the hydrodynamic behavior, methods to mitigate damage, and understanding the effects of the resulting shower downstream of the collimator. Relevant experiments, though valuable, are difficult and expensive to conduct. The coupled codes will provide a method to model differing geometries, materials, and loss scenarios. Efforts thus far have been directed toward using FLASH to reproduce observed damage seen in aluminum test pieces subjected to varying beam strike currents. Stabilizing the Eulerian mesh against large energy density gradients as well as establishing release criteria from solid to fluid forms are discussed.

WEXC05 **First Results Operating a Long-Period EPU in Universal Mode at the Canadian Light Source**

***W.A. Wurtz**, C.K. Baribeau, D. Bertwistle, M.J. Sigrist (CLS)*

The Quantum Materials Spectroscopy Centre beamline at the Canadian Light Source (CLS) requires photons with energies as low as 15 eV with circular polarization at the end station. This energy range is accomplished on the 2.9 GeV CLS storage ring using an elliptically polarizing undulator (EPU) with a 180 mm period, which we call EPU180. In order to realize circular polarized photons at the end station with this low energy, we must overcome two technical issues. First, the beamline optics distort the polarization of the light, so we compensate by providing light with a flattened, tilted polarization ellipse at the source point - a mode of operation known as universal mode. Second, the device has a strong effect on the electron beam due to dynamic focusing and is capable of reducing the injection efficiency to zero. We overcome this non-linear dynamic focusing using current strips adhered to the vacuum chamber. In this report, we present the first results with operating EPU180 in universal mode and we recover the dynamic aperture using the current strips.

WEXC06 **Eddy Current Effects on the Stored Beam Generated by the Pulsed Sextupole Magnet at KEK-PF**

H. Takaki, *K. Harada, Y. Kobayashi, C. Mitsuda, T. Nogami, T. Obina, R. Takai, T. Uchiyama (KEK) Y. Lu (Sokendai)*

The Photon Factory (KEK-PF) has been continuously developing new technologies for the top-up injection using the pulsed multipole magnets (PMM). We demonstrated beam injection with the PMM successfully at KEK-PF and operated for synchrotron user experiments with top-up injection in four years. One of the important issues to be solved in this injection is the effect of eddy currents on the stored beam generated in the PMM and its inner coating of the ceramic duct. The magnetic field of the PMM is designed so that it does not affect the stored beam, however, the eddy currents that occurred on the coating give an unwanted kick to the stored beam at the injection. In this paper, we report eddy current effects on the stored beam generated by the pulsed sextupole magnet.

WEXC07 **Nucleation of Single Crystal Photocathode on Atomically Thin Graphene Substrate Using Co-Deposition of Cesium Telluride**

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For the past decades, cesium telluride (CsTe) has been chosen as the electron source material for high bunch charge, high repetition rate superconducting radio frequency electron injectors. The application of cesium telluride photocathode has been reported by accelerators all over the world. Alkali based semiconductor photocathode material has always been vapor deposited thin films, with amorphous or very limited crystalline phases. The fragility of alkali-based photocathode partially comes from its disordered and unstable structure. The limited crystallinity also limits the quantum efficiency to improve. Therefore, growing large crystal or even single crystal of the alkali-based photocathode material is the goal of many scientific projects these days. Nucleation of cesium telluride crystalline phase was observed via co-deposition method on atomically thin graphene substrate, which is is a recognized sign of the first step of the formation of single crystal. In situ and operando X-ray characterization has been performed on this process and the results in the evolution of crystal structure, chemical stoichiometry as well as the surface morphology and quantum efficiency are reported.

THPAB001 **Reaching the Sub Per Mil Level Coupling Corrections in the LHC**
***E.J. Hoydalsvik**, T.H.B. Persson (CERN)*
The High Luminosity LHC (HL-LHC) is requiring sub per mil coupling correction, as defined by the closest tune approach. In this article, the current coupling correction strategy is analyzed in order to understand if it can robustly correct to these very low levels. The impact of realistic errors on the coupling correction is investigated with MAD-X simulations, including the influence of local coupling on the global coupling correction. Through simulations and measurements in the LHC, the effect of BPM noise on the coupling correction is analyzed.

THPAB002 **Lattice Design for BEPCII Upgrade**
***H. Geng**, W.B. Liu, Xing. Xing, C.H. Yu, Y. Zhang (IHEP)*
The Beijing Electron Positron Collider II (BEPCII) has achieved a series of achievements in high-energy physics study. Along with the deepening of the research, more important physics is expected in higher energy regions (>2.1 GeV). As the upper limit of BEPCII design energy is 2.1GeV, an urgent upgrade is required for BEPCII. To achieve a higher luminosity at higher energy, the number of RF cavities is expected to be doubled. In this paper, the lattice design for the upgrade of BEPCII is studied. The dynamic aperture tracking result shows that the lattice could meet the injection requirement of the BEPCII beam with a reasonable margin.

THPAB003 **Application of Generalized Gaussian Distribution in the Processing the Wire Scanner Data**
***H. Geng**, C. Meng, F. Yan, Y. Zhang, Y.L. Zhao (IHEP)*
Wire scanners are widely used for measuring beam emittance in both electron and hadron accelerators. Gaussian fitting is the most commonly used method in processing the wire scanner data. But in hadron machines, beams are normally not gaussian distribution due to the action of nonlinear forces such as space charge effect. Under these circumstances, there would be big deviations if the wire scanner data was still fitted with gaussian distributions. This paper introduces generalized Gaussian distribution in the processing the wire scanner data measured in the ADS injector-I. The results using different fitting method will be compared.

THPAB004 **Practical Challenges of the LHC Main Beam Dump Upgrades**
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The two Large Hadron Collider (LHC) beam dumps have to withstand arduous operating conditions and are essential for the safe and reliable

operation of the collider. During the LHC Long Shutdown 2 (2019-2020), extensive work was carried out to upgrade the dumps to cope with the more demanding future operating conditions of the LHC Run 3. The upgrades included modifications to the dump blocks, dump block supports and their lubrication, beam windows, the beam pipes leading to the dumps, and the nitrogen pressurization system of the dump blocks. A comprehensive instrumentation system was installed to monitor the behavior of the dumps. In addition, an internal endoscope inspection was performed on the ex-operational dumps to check their condition. Many of these operations had to be carried out in underground radiation areas, therefore the optimization of the dose-to-personnel according to the ALARA principle was an important consideration. The return on experience for these activities will be provided, including the critical tasks, unexpected events and lessons learned.

THPAB005 **CERN n_TOF Spallation Target Exchange: Preparation, Operations and Lessons Learned**

***J.M. Martin Ruiz**, O. Aberle, D. Boon, L. Buonocore, M. Calviani, H. Crossman, F. Dragoni, O. Fjeld, R. Franqueira Ximenes, S. Girod, J.L. Grenard, D. Grenier, J.F. Gruber, K. Kershaw, F. Pozzi, N. Roget, J. Vollaire (CERN)*

In the context of the n_TOF Facility consolidation project at CERN, the 2nd generation lead-based water-cooled spallation target has been removed from the target pit after 10-years of high-energy (20 GeV/c) beam operation, to be replaced by the 3rd generation version. The return on experience will be provided, including changes to the initial procedure, the critical tasks, unexpected events, and respective lessons learned. In particular, the dose -to-personnel optimization process via the ALARA radioprotection approach included the study of the handling and dismantling operations, often via mock-up trials and remote handling dry-runs. This contribution describes the preparations, summarizes the interventions, and presents the lessons learned from the target exchange. The status and prospects for Target#3 installation are also presented.

THPAB007 **Technology Spinoff and Lessons Learned From the 4-Turn ERL CBETA**

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The Cornell-BNL ERL Test Accelerator (CBETA) developed several energy-saving measures: multi-turn energy recovery, low-loss superconducting radiofrequency (SRF) cavities, and permanent magnets. With green technology becoming imperative for new high-power ac-

celerators, the lessons learned will be important for projects like the FCC-ee or new light sources, where spinoffs and lessons learned from CBETA are already considered for modern designs.

THPAB009 **A Hard X-Ray Compton Source at CBETA**

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Inverse Compton scattering (ICS) holds the potential for future high flux, narrow bandwidth x-ray sources driven by high quality, high repetition rate electron beams. CBETA, the Cornell-BNL Energy recovery linac (ERL) Test Accelerator, is the world's first superconducting radiofrequency multi-turn ERL, with a maximum energy of 150 MeV, capable of ICS production of x-rays above 400 keV. We present an update on the bypass design and anticipated parameters of a compact ICS source at CBETA. X-ray parameters from the CBETA ICS are compared to those of leading synchrotron radiation facilities, demonstrating that, above a few hundred keV, photon beams produced by ICS outperform those produced by undulators in term of flux and brilliance.

THPAB011 **Monte Carlo Driven MDI Optimization at a Muon Collider**

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A Muon Collider represents a very interesting possibility for a future machine to explore the energy frontier in particle physics. However, to reach the needed luminosity, beam intensities of the order of $10^9|--|10^{12}$ muons per bunch are needed. In this context, the Beam-Induced Background must be taken into account for its effects on magnets and detector. Several mitigation strategies can however be conceived. In this view, it is of crucial importance to develop a flexible tool that allows to easily reconstruct the machine geometry in a Monte Carlo code, allowing to simulate in detail the interaction of muon decay products in the machine, while being able to change the machine optics itself to find the best configuration. In this contribution, a possible approach to such a purpose is presented, based on FLUKA for the Monte Carlo simulation and on LineBuilder for the geometry reconstruction. Results based on the 1.5 TeV machine optics developed by the MAP collaboration are discussed, as well as a first approach to possible mitigation strategies.

THPAB012 **The Magnetic Compensation Scheme of the FCC-ee Detectors**

***M. Koratzinos**, K. Oide (CERN)*

A crucial part of the design of an FCC-ee detector is the minimisation of the disruption of the beam due to the presence of a large and powerful detector magnet. Indeed, the emittance blow-up of the few me-

ters around the interaction point (IP) at lower energies is comparable to the emittance introduced by the rest of the 100 km ring. Vertical emittance is the single most important factor in achieving high performance (luminosity, in this case) in a modern e^+ e^- storage ring such as the FCC-ee. The design adopted is the simplest possible arrangement that can nevertheless deliver high performance: two additional coils per IP side. The performance achieved is such that vertical emittance blow-up will not be a limiting performance factor even in the case of a ring with four experiments, and even in the most demanding energy regime, that of the Z running (about 45 GeV beam energy).

THPAB013 **Magnetic Measurements at Warm of the First FCC-ee Final Focus Quadrupole Prototype**

M. Koratzinos *(MIT) G. Kirby, M. Liebsch, C. Petrone (CERN)*

The first FCC-ee final focus quadrupole prototype has been designed, manufactured, assembled and tested at warm. The prototype is a single aperture quadrupole magnet of the CCT type. One edge of the magnet was designed with local multipole cancellation, whereas the other was left with the conventional design. An optimized rotating induction-coil sensor was used. A technique was developed to take into account field distortions due to the environment of the test and distinguish them from magnet effects, demonstrating an excellent field quality for the prototype.

THPAB014 **Matlab Simulations of the Helium Liquefier in the FREIA Laboratory**

E. Waagaard*, R.J.M.Y. Ruber, V.G. Ziemann (Uppsala University)*

We describe simulations that track a state vector with pressure, temperature, and gas flow through the helium liquefier in the FREIA laboratory. Most components, including three-way heat exchangers, are represented by matrices that allow us to track the state through the system. The only non-linear element is the Joule-Thomson valve, which is represented by a non-linear map for the state variables. Realistic properties for the enthalpy and other thermodynamic quantities are taken into account with the help of the Coolprop library. The resulting system of equations is rapidly solved by iteration and shows good agreement with the observed LHe yield with and without nitrogen precooling.

THPAB015 **Studies of the Imperfection in Crab Crossing Scheme for Electron-Ion Collider**

Y. Hao*, J.S. Berg, D. Holmes, Y. Luo, C. Montag (BNL) V.S. Morozov (JLab) J. Qiang (LBNL) D. Xu (FRIB)*

Crab crossing scheme is the essential scheme that accommodates large crossing angle without loss of luminosity in the design of Electron-Ion collider (EIC). The ideal optics and phase advances of the crab cavity pair are set to create a local crabbing bump in the interaction region (IR). However, there are always small errors in the actual lattice of IR. In this article, we will present the simulation and analytical studies on the imperfections in the crab crossing scheme in the EIC

design. The tolerance of the imperfection and the possible remedies can be concluded from these studies.

THPAB016 **Revisit of Nonlinear Dynamics in Henon Map Using Square Matrix Method**

***Y. Hao**, K.J. Anderson (FRIB) L.H. Yu (BNL)*

Henon map (2D or 4D) represents a thin lens sextupole in an otherwise linear lattice and had been well studied for many decades. We revisit the nonlinear properties of the Henon map with the aid of the square matrix method and Arnold theorem, including acquiring the resonance structure and amplitude-dependent frequency.

THPAB017 **The International Muon Collider Collaboration**

***D. Schulte** (CERN)*

A muon collider offers a unique opportunity for high-energy, high-luminosity lepton collisions and could push the frontiers of particle physics by providing excellent discovery reach with excellent precision. A scheme has been developed by the MAP collaboration. The updated European Strategy for Particle Physics recommended the development of an Accelerator R&D Roadmap for Europe and CERN Council has charged the LDG to develop it. LDG has initiated panels to provide input including one on the use of muon beams, in particular in view of a high-energy, high luminosity muon collider. A new international collaboration, is forming to develop a muon collider design and address the associated challenges, which are mainly due to the limited muon lifetime. The focus is on two energy ranges, around 3 TeV and above 10 TeV. Ambitious magnets, RF systems, targets and shielding are key for the design.

THPAB021 **Status of VEPP-5 Injection Complex**

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VEPP-5 injection complex is being put into operation as beam source of VEPP-2000 and VEPP-4 colliders at the end of 2016. Since then injection complex demonstrated maximum positron storage rate $1.7 \cdot 10^{10}$ e+/s and stable operation at the energy of 430 MeV. Latest operation results and prospects are presented.

THPAB022 **Possibilities for Upgrading to Polarized SuperKEKB**

***Z.J. Liptak**, M. Kuriki (HU/AdSM) J.M. Roney (Victoria University)*

The SuperKEKB accelerator is currently in operation in Tsukuba, Japan, with a planned long shutdown in 2026. Among the possible upgrades being considered during this period is the change to a polarized electron beam in the High Energy Ring. Such a change would

require modifications in the source generation and transport, geometrical and lattice variations to provide spin rotation, and polarimetry. A Polarized SuperKEKB Working Group has been formed from members of the Belle II experiment and the SuperKEKB accelerator team to investigate the possibilities and challenges of these modifications. This talk lays out the goals of the proposed upgrade, considers the necessary changes to the existing accelerator and their feasibility and lays out the physics motivation behind such an effort.

THPAB023 **Cornerstone of the Turkic Accelerator Complex (TAC) Project: Linac-Ring Type Super Charm Factory**

S. Sultansoy *(TOBB ETU) B. Ketenoğlu (Ankara University, Faculty of Engineering)*

Thirty years ago linac-ring type Charm-Tau factory (with positron ring-based synchrotron radiation facility) was proposed as a regional project for high energy physics. Here, region means Middle East, Balkans, Caucasus and Central Asia. In 1990s, estimated luminosity value of the proposed factory, namely 10^{34}cm^{-2}s^{-1}, was ten times higher than luminosity of conventional ring-ring type Charm-Tau factory proposals. After invention of crab-waist collision scheme, it was estimated that luminosity of conventional Charm-Tau factory may attain 10^{35}cm^{-2}s^{-1}. For this reason, energy recovery linac (ERL) option for the TAC Super Charm factory was proposed to achieve same-scale luminosity as conventional factory with crab-waist collisions. As for today, it should be emphasized that, main advantage of linac-ring type Super Charm Factory is the natural energy asymmetry, which is very important for investigation of charmed mesons properties such as CP-violation, oscillations and so on. In this presentation, main parameters of TAC Super Charm factory are discussed together with its physics search potential.

THPAB024 **LHC/FCC/SppC Based ep, eA, mu-p, mu-A, gamma-p, gamma-A and FEL gamma-A Colliders: Luminosity and Physics**

S. Sultansoy *(TOBB ETU)*

Construction of linear collider (or dedicated e-linac) tangential to energy frontier hadron colliders will give opportunity to explore multi-TeV center-of-mass energy scale in ep, eA, gamma-p and gamma-A collisions. Similarly, construction of muon collider (or dedicated mu-ring) tangential to energy frontier hadron colliders will give opportunity to handle multi-TeV energy scale in mu-p and mu-A collisions. These lepton-hadron and photon-hadron colliders will essentially enlarge physics search potential of the hadron collider's host laboratory both in SM and BSM phenomena. In addition, FEL gamma-A colliders will be powerful tool for nuclear spectroscopy. In this presentation main parameters of proposed colliders will be discussed, together with their physics search potential. Certainly, these machines have great potential in clarifying QCD basics, as well as new phenomena related to first two SM families.

THPAB025 **A Proposed Beam-Beam Test Facility COMBINE**

***E.A. Nissen**, G.A. Krafft (JLab) J.R. Delayen (ODU)*

The COmpact Machine for Beam-beam Interactions in Non-Equilibrium systems (COMBINE) is a proposed, dedicated, beam-beam test facility. The base design would make use of a pair of identical octagonal rings (2.5 meters per side) one rotated 180 degrees from the other, meeting at their common interaction point. These would be fed by an electron gun producing up to 125 keV electrons. The low energy will allow for beam-beam tune shifts commensurate with existing colliders, some linac-ring type systems, and will also allow for an exploration of the predicted effects of gear-changing, which would be performed using a variable pathlength scheme. The low energy, and small size will allow for cost effective research, simulation code benchmarking, as well as training opportunities for students.

THPAB026 **Final Booster Complex Design for the Jefferson Lab Electron Ion Collider**

***E.A. Nissen** (JLab)*

In this work we show the final iteration of the design for the booster complex of the Jefferson Lab EIC, which would have brought the ions from an energy (proton) of 150 MeV up to 12.1 GeV. This complex would have consisted of two figure-8 rings. The Low Energy Booster (LEB) which would have accelerated its protons from 150 MeV to 8 GeV, and has had its lattice tweaked to increase the effectiveness of chromaticity cancellations. The High Energy Booster (HEB) would have brought the 8 GeV protons up to 12.1 GeV. The HEB would in the tunnel that was designed for the collider rings, sitting on top of them. It has had a bypass around the interaction region added, as well as a cooling solenoid installed.

THPAB028 **Beam-Beam Related Design Parameter Optimization for the Electron-Ion Collider**

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The design luminosity goal for the Electron-Ion Collider (EIC) is 10^{34} $cm^{-2}s^{-1}$. To achieve such a high luminosity, the EIC design adopts high bunch intensities, flat beams at the interaction point (IP) with a small vertical β^*-function, and a high collision frequency, together with crab cavities to compensate the geometrical luminosity loss due to the large crossing angle of 25mrad. In this article, we present our strategies and approaches to obtain the design luminosity by optimizing some key beam-beam related design parameters. Through our extensive strong-strong and weak-strong beam-beam simulations, we found that beam flatness, electron and proton beam size matching at the IP, electron and proton working points, and synchro-betatron resonances arising from the crossing angle collision play a crucial role in proton beam size growth and luminosity degradation. After optimizing those paramet-

ers, we found a set of beam-beam related design parameters to reach the design luminosity with an acceptable beam-beam performance.

THPAB029 **Dynamic Aperture Evaluation for the Hadron Ring in the Electron-Ion Collider**

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The Electron-Ion Collider (EIC) is aiming at a design luminosity of 10^{34} $cm^{-2}s^{-1}$. To maintain such a high luminosity, both beams in the EIC need an acceptable beam lifetime in the presence of the beam-beam interaction. For this purpose, we carried out weak-strong element-by-element particle tracking to evaluate the long-term dynamic aperture for the hadron ring lattice design. We improved our simulation code SimTrack to treat some new lattice design features, such as radially offset on-momentum orbits, coordinate transformations in the interaction region, etc. In this article, we will present the preliminary dynamic aperture calculation results with β^*- function scan, radial orbit shift, crossing angle collision, and magnetic field errors.

THPAB030 **Optimizing Cooling for a 100 TeV Proton Antiproton Collider**

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We explore a $2{\cdot}10^{34}$ /(cm^2 s) luminosity, 100 TeV proton-antiproton collider in a 100 km circumference tunnel. Antiquarks are available at full energy rather than at partial energy via gluon splitting. The increased momentum acceptance (11 ± 2.6 GeV/c) in a Fermilab-like antiproton source is used with septa to collect 12x more antiprotons in 12 channels. Twelve stochastic cooling rings would be used in parallel to lower the normalized transverse emittance from 330 to 80 microns in 1.3 s. Phase rotation lowers the momentum spread from 2% to 0.1% in each ring. With smaller beams, the momentum in each ring can be ramped down to 3 GeV/c and the antiprotons still fit. All the antiprotons are then transferred to a single 3 GeV/c electron cooling ring. The transverse electron damping time for 80 micron, 3 GeV/c antiprotons is 11 s. The longitudinal damping time is 0.9 s. Space charge tune shift calculations indicate that this ring could store 100 hours of antiprotons (10^{15}) produced at the rate of 10^{13}/h. Intrabeam scattering is also an issue. Finally antiprotons are recycled during runs without leaving the collider ring by joining them to new bunches with synchrotron damping.

THPAB031 **Dump Line Layout and Beam Dilution Pattern Optimization of the Future Circular Collider**

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To avoid any damage to the beam dump target in the Future Circular

Collider, the beam will be swept over its surface using oscillating kickers in the x/y planes with a 90-degree phase difference, and an amplitude changing in time, creating a spiral pattern. The ideal pattern must have an increasing spiral pitch towards smaller radii to produce an even energy deposition density. We recommend the realization of the optimal pattern using two beating frequencies. This method enables a flat energy deposition density while only using simple independent damped oscillators. In this poster, we also present the study of the beamline optics and hardware that can realize the needed pattern. Two different possible hardware layouts were examined and optimized as well.

THPAB032 **Polarization Transport in the ERL-ERL FCC e^+ e^- Collider**
F. Méot, *V. Litvinenko, T. Roser (BNL)*
An alternative approach for the Future Circular electron-positron Collider uses energy recovery linac recirculation to mitigate the otherwise enormous power consumption needed to compensate 100 MW of beam energy losses by synchrotron radiation in a ring-ring design. This approach would also allow extending CM energy to 500 GeV (or above) for double Higgs production. An additional advantage of the ERL-ERL scheme is its allowing polarized e^+ e^- beam collision. A 100 km, 6250 cell, 220 GeV linear Fixed Field Alternating gradient (FFA) loop is subjected to polarized bunch transport simulations, including synchrotron radiation and polarization survival.

THPAB033 **Proper Simulation of the IRCMS FFA-Style Arc Optics a Fix to the Scalloping this Optics Causes**
F. Méot, *P.N. Joshi, N. Tsoupas (BNL) J.P. Lidestri (Columbia U. / BMI)*
The 60 degree, ~6 m long girder of the ion Rapid Cycling Medical Synchrotron (collaborative BNL/Best Medical International project) is comprised of 5 combined function (CF) sector dipoles (1/2F-D-F-D-1/2F) spaced by 4 short drifts, encompassed in a single coil. All dipoles share a common center at R=5.08 m, center as well of constant field arcs, in a similar way to FFA optics. Due to the small drifts the magnetic length of the 60 degree arc is <2piR/6, resulting in 10 mm closed orbit scalloping around the R=5.08 m reference arc. This is a prohibitive orbit excursion as the hyperbolic magnet gap has to accommodate a ±20 mm horizontal aperture vacuum pipe. Raytracing outcomes from a theoretical model are discussed and compared to observed scalloping using OPERA field maps. Filling-up the drifts between dipoles, to force the closed orbit on R=5.08, is the simplest fix to that scalloping and salvages the dipole gap profiles, the long coil and the girder. This however requires re-matching individual lengths of the 5 CF dipoles for proper optics. Results of momentum acceptance and dynamic aperture tracking, part of the iRCMS girder optimization strategy, are reported as well.

THPAB034 **Evaluation of Polarization Effects of Stochastic Processes in the EIC**

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The hadron beam parameters of the Electron-Ion Collider are approaching a regime where stochastic effects such as intra-beam scattering, beam-beam effect, and electron cooling, may play an important role in the beam polarization lifetime. Direct simulations of these effects are challenging because they require not only accurate beam and spin tracking but also accurate modeling of the stochastic effects. We use numerical tracking in Zgoubi and apply stroboscopic averaging to obtain the linear dependence of the invariant spin field direction on the phase space coordinates of interest. By folding it with the diffusion rates of those coordinates due to stochastic processes, we find an estimate of the polarization lifetime. We bench-mark this approach by applying it to the electron collider ring of the Electron Ion Collider where the behavior of the invariant spin field and the polarization lifetime due to synchrotron radiation are known from the well-validated electron codes, SLICK and SITROS. We discuss the application of this algorithm to stochastic effects beyond synchrotron radiation.

THPAB035 **Study of the Tolerances for Superconducting Undulators at the European XFEL**

***B. Marchetti**, S. Casalbuoni, V. Grattoni, S. Serkez (EuXFEL)*

European XFEL is investing in the development of superconducting undulators (SCUs) for future upgrade of its beamlines SCUs made of NbTi, working at 2K, with a period length of 15 mm and a vacuum gap of 5 mm allow covering a range between 54 keV and 100 keV for 17.5 GeV electron energy. The effect of mechanical errors in the distribution of K along the undulators is more relevant for working points at lower photon energy, which are obtained using a higher magnetic field in the undulator. In this article we investigate the effect of error distribution in the K-parameter for a working point at 50keV photon energy obtained injecting an electron beam with 16.5 GeV energy from the XFEL linear accelerator in a undulator line composed by SCUs with 1.58 T peak magnetic field.

THPAB036 **Superconducting Phase Shifter Design for the Afterburner at the European XFEL**

***V. Grattoni**, J.E. Baader, S. Casalbuoni (EuXFEL)*

At the European XFEL, a superconducting afterburner is under design for the SASE2 hard X-ray beamline. It will consist of 5 undulator modules. One module corresponds to two superconducting undulator (SCU) coils of 2 m length plus one phase shifter. Such an afterburner will enable photon energies above 30 keV. Superconducting (SC) phase shifters will be installed in each undulator module to keep the correct phase delay between the electron beam and photon beam. In this con-

tribution, we present the required SC phase shifter parameters to enable operation in the electron beam energy range 11.5-17.5 GeV. We also analyze different magnetic designs satisfying the calculated specifications.

THPAB037 **Insertion Devices Impact on Solaris Storage Ring Optics**
***G.W. Kowalski**, R. Panaś, A.I. Wawrzyniak (NSRC SOLARIS)*
Solaris storage ring is currently operating with three insertion devices. The IDs installed are the APPLE II type elliptically polarised undulators (EPU). The UARPES beamline is operating with the long period length EPU of 120 mm (EPU120) which has a significant impact on the linear optics and tune shift. The linear optics compensation of the EPU120 impact is realised by local adjustment of SQFO quadrupole/sextupole focusing gradient and defocusing gradient in the flanking dipoles. Two additional EPUs with period lengths of 58 and 46.6 mm are recently installed for next beamlines PHELIX and DEMETER, respectively and are under commissioning now. To reduce the impact of all undulators movement the additional correction coils are installed and the correction feedforward tables has been determined experimentally. Additionally to keep the tune at the nominal values the tune feedback is planned to be implemented. Within this presentation the effect of all existing insertion devices on the linear optics based on measurements and simulations to be discussed. Moreover the nonlinear effects, especially the impact on dynamic aperture of Solaris storage ring will be investigated.

THPAB038 **Three-Dimensional Positioning Method of Hall Probes in Magnetic Field Measurement**
***Z.Z. Wu**, J.Y. Chen, S.D. Zhou (SINAP) Q.G. Zhou (SSRF)*
A prototype of a superconducting undulator is being built for SHINE at SSRF. Compared with other types of undulators, low temperature and closed cabin are the particular attributes of superconducting undulators (SCUs). The length of the magnet of the SCU is 4 m and the gap is only 4 mm, which makes the design of the magnetic measurement system more difficult. A magnetic field measurement system was developed which is special for this prototype. We integrate three Hall probes, one temperature sensor and one corner cube reflector(CCR) on a sledge with the size of 120mm x 46mm x 3.8mm. The sledge is driven by an external device to move slowly through the gap, its real-time position is measured by a laser system when moving through the gap. In this paper, we focus on the layout of the Hall probes, CCR, and temperature sensor in the sledge, the three-dimensional positioning method of the Hall probes, the external drive device, and the positioning error of the three-dimensional positioning in the experiment.

THPAB040 **A Phase Shifter for Inline Undulators at the Advanced Photon Source Upgrade Project**

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Several undulator lines for the Advanced Photon Source Upgrade (APS-U) will consist of two inline undulators. In order to keep the undulators operating with optimal phasing over the full range of gaps, a phase shifter will be included between the undulators. A design has been developed for a phase shifter that will serve for a variety of undulator period lengths and gap ranges. The permanent-magnet phase shifter will use SmCo magnets to reduce the risk of radiation-induced demagnetization. The available space between the undulators is tight, so magnetic shields are placed between the undulators, the phase shifter, and the corrector magnet that is also located in the inter-undulator space. While these shields guard against magnetic cross-talk between the devices as the undulator and phase shifter gaps change, they do have an effect on the end fields of the devices. These end-field effects are examined and relevant tolerances are set and presented.

THPAB041 **Design of Photon Masks for the ILC Positron Helical Undulator**

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A long superconducting helical undulator is planned as baseline to produce polarized positrons at the International Linear Collider (ILC). To protect the undulator walls from synchrotron radiation, masks must be inserted along the undulator line. The power distribution deposited at these masks is studied in order to design the photon masks.

THPAB042 **Bending Radius Limits of Different Coated REBCO Conductor Tapes - an Experimental Investigation With Regard to HTS Undulators**

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Compact FELs require short-period, high-field undulators in combination with compact accelerator structures to produce coherent light up to X-rays. Likewise, for the production of low emittance positron beams for future lepton colliders, like CLIC or FCC-ee, high-field damping wigglers are required. Applying high-temperature superconductors in form of coated REBCO tape conductors allows reaching higher magnetic fields and larger operating margins as compared to low-temperature superconductors like Nb-Ti or Nb_3Sn. However, short undulator periods like 13 mm may require bending radii of the conductor smaller than 5 mm inducing significant bending strain on the superconducting layer and may harm its conducting properties. In this paper, we present our designed bending rig and experimental results for REBCO tape conductors from various manufacturers and

with different properties. Investigated bending radii reach from 20 mm down to 1 mm and optionally include half of a helical twist. To represent magnet winding procedures, the samples were bent at room temperature and then cooled down to T = 77 K in the bent state to test for potential degradation of the superconducting properties.

THPAB043 **Superconducting Undulator for CompactLight: Resistive Wall Wakefield Analysis**

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The CompactLight project is an advanced X-ray FEL light source, with high-frequency, high-gradient linacs and compact undulators. Lower electron energies give higher energy efficiency and a smaller environmental footprint. The extremely short bunch lengths (few fs) and narrow undulator gaps (4 mm) drastically increase the impact of resistive wall wakefields on the lasing process. The longitudinal resistive wall wakefield impedance is calculated in the framework of the surface impedance approach, in accordance with anomalous skin effect (ASE) theory. The dependence of the electron energy loss factor and the correlated energy spread of the bunch on the residual resistivity ratio (RRR) for both copper and aluminum is much higher for long (100 fs) than for ultra-short (6 fs) bunches. This is due to a known property of the longitudinal wakefield impedance - the field acting on a single particle traversing a resistive vessel does not depend on the conductivity of the vessel. The wakefields generated by the ultra-short bunch are already close to that of a single-particle regime and this leads to interesting consequences which are discussed in the present work.

THPAB045 **Design of a Short Period Helical Superconducting Undulator**

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Superconducting technology provides the possibility to develop short period, small bore undulators that can generate much larger magnetic fields than alternative technologies. This may allow an XFEL with optimised superconducting undulators to cover a broader range of wavelengths than traditional undulators. At STFC, we have undertaken work to design and build a prototype helical superconducting undulator (HSCU) module with parameters suitable for use on a future XFEL facility. This work includes the design of a full 2 m long undulator module, including an undulator with 13 mm period and 5 mm inner winding diameter, the supporting cryogenic and vacuum systems required for operation, and quadrupoles, phase shifters and correction magnets for use between undulator sections. We present here the magnetic and mechanical design of the HSCU. The choice of undulator parameters and their influence on the design is discussed. A turnaround scheme to allow continuous winding of the undulator without the need for superconducting joints is also presented. Techniques for winding the undulator are currently being investigated and a short prototype will soon be wound and tested.

THPAB046 **Status of Development of Superconducting Undulators at the Advanced Photon Source**

Y. Ivanyushenkov, *E.A. Anliker, E. Gluskin, Q.B. Hasse, H. Hu, M. Kasa, I. Kesgin, Y. Shiroyanagi (ANL)*

Superconducting undulators (SCUs) have been in user operation at the Advanced Photon Source (APS) since early 2013. The current portfolio of APS SCUs includes two planar undulators and a helical undulator. One of the planar undulators is planned to be replaced in the APS storage ring with an Nb_3Sn undulator, of the same period length and magnetic length, which is being developed. All these undulators will be removed because of the APS Upgrade (APS-U) project to give room for new SCUs - eight planar SCUs paired in four 4.8-m-long cryostats and a novel fast-switching undulator, SCAPE. A short description and status of the Nb_3Sn and APS-U superconducting undulators under development at the APS are presented.

THPAB047 **Status of Magnetic Measurement Benches for Insertion Device Characterization at MAX IV Laboratory**

M. Ebbeni, *M. Gehlot, M. Holz, H. Tarawneh (MAX IV Laboratory, Lund University)*

Insertion Devices (IDs) are the sole source of radiation used in all beamlines in MAX IV Laboratory with 14 IDs in operation of which 6 were built in-house. This paper shows the current capabilities and performance of the of the ID magnetic measurement systems, and the ongoing development work.

THPAB048 **Design and Fabrication Concepts of a Compact Undulator With Laser-Structured 2g-HTS Tapes**

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To produce small-scale high-field undulators for table-top free electron lasers (FELs), compact designs have been proposed using high temperature superconducting (HTS) tapes, which show both large critical current densities and high critical magnetic fields with a total tape thickness of about 50 µm and a width of up to 12 mm. Instead of winding coils, a meander structure can be laser-scribed directly into the superconductor layer, guiding the current path on a quasi-sinusoidal trajectory. Stacking pairs of such scribed tapes allows the generation of the desired sinusoidal magnetic fields above the tape plane, along the tape axis. Two practically feasible designs are presented, which are currently under construction at KIT: A coil concept wound from a single structured tape with a length of 15 m, which is a progression of a design that has been presented already in the past, as well as a novel stacked and soldered design, made from 25 cm long structured tapes, soldered in a zig-zag-pattern. In this contribution the designs are briefly recapped and the experimental progress is presented.

THPAB049 **Modeling the Magnetic Field of the LCLS-I Undulator for THz@PITZ**

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An accelerator-based THz source for pump-probe experiments at the European XFEL is under development at the Photo Injector Test Facility at DESY in Zeuthen (PITZ). For the proof-of-principle experiments an LCLS-I undulator is planned to be installed downstream of the PITZ accelerator. The fields of the undulator module 26 have been re-measured at DESY in Hamburg and the results are consistent with earlier SLAC measurements. A model for 3D field reconstruction based on the undulator magnetic measurements has been developed. It includes also a horizontal gradient of the vertical field. Tracking of the 17 MeV/c beam has revealed that the transverse gradient will lead to a significant off-axis trajectory in the horizontal plane. This offset has to be corrected with a steering coil, the design of which is also presented. The performance of the THz generation with the correction coil is discussed as well.

THPAB050 **Compact Hybrid Planar Permanent Magnet Undulator Design of APS-U 28-mm Period**

***M. Abliz**, M. Borland, J.H. Grimmer, J.S. Kerby, M. Ramanathan, A. Xiao (ANL)*

We report on the successful design of a compact 28-mm period hybrid planar permanent magnet (HPPM) undulator for the Advanced Photon Source Upgrade (APS-U) project. The design produces a peak field of 9750 G at a gap of 8.5 mm, with a pole width reduced to 35 mm as compared to the planar undulators currently in use at the Advanced Photon Source. The design includes a detailed investigation into the origin of the HPPM undulator demagnetization. We report on a finding of an optimization method that reduces the demagnetization field and increases the field at the gap center of the design. It includes an optimization of the pole edges to increase the field and decrease roll-off in the transverse direction. Further design optimizations include analyses of the mechanical assembly tolerances and comparison with the original design before building the device. Beam physics analyses included kick-map analysis, dynamic acceptance (DA), local momentum acceptance (LMA), and Touschek lifetime of this design were performed with the 42-pm lattice of the APS-U. Detailed magnetic design, effective field, field roll-off, magnetic force, and tracking results are reported.

THPAB051 **Vertical Septum Magnet Design for APS-U**

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The vertical injection scheme proposed for the APS Upgrade (APS-U) Project requires a challenging septum magnet that must meet

stringent beam physics, magnetic field leakage, and vacuum requirements. The current iteration of this magnet design includes an enlarged stored-beam chamber aperture of 9 mm x 12 mm and a reduction of the septum thickness to 1.5 mm. The enlarged aperture accommodates a non-evaporable getter (NEG)-coated stored beam chamber to better achieve the required vacuum. A prototype septum magnet has been built and measurements confirm the cancellation of a peak leakage field even though the value is six times larger than the design. The leakage field measured at the upstream (US) end cancels the downstream (DS) end as was expected by design. The measured and simulated leakage field and the stored beam trajectories are reported.

THPAB052 **Insertion Devices at the MAX IV 3 GeV Ring**

H. Tarawneh, *M. Ebbeni, M. Gehlot, M. Holz (MAX IV Laboratory, Lund University)*

Currently, there are 8 Insertion Devices (ID) installed and in operation and 2 new ones to be installed end of 2021 at the MAX IV 3 GeV storage ring. In this paper, the first commissioning results of the three newly installed IDs in 2020 will be described. The new IDs are one APPLE II for SoftiMAX beamline and two In-vacuum Undulators (IVU) for the DanMAX and CoSAXS beamlines. The mitigation scheme adopted to reduce undulator-like radiation from BALDER in-vacuum wiggler will be discussed. Two new IVUs with a period length of 17 mm and 18 mm for the ForMAX and MicroMAX beamlines will be installed during the winter shutdown of 2021-2022. Both IDs have 3 m lengths and a minimum gap of 4 mm. In this paper, the magnetic measurement results will be presented in terms of the achieved field quality and phase error.

THPAB053 **Magnetic Field Calculation of Planar SCUs Using Ansys Maxwell**

Y. Shiroyanagi, *E.A. Anliker, Q.B. Hasse, Y. Ivanyushenkov, M. Kasa, I. Kesgin (ANL)*

The Advanced Photon Source (APS) Upgrade includes a 4.8-m-long superconducting undulator (SCU) cryostat containing two 1.9-m-long, 16.5-mm-period planar NbTi undulator magnets. The magnetic and mechanical design of this magnet follows the design of the existing 1.1-m-long, 18-mm-period planar SCU that is currently in operation at the APS. Although OPERA is a reliable standard software tool for magnetic field calculations, ANSYS Maxwell 3D has the advantage of calculating a large and complex geometry. In this paper, first, the magnetic field map, including the peak field and end fields, is bench-marked against the magnetic measurement data of the existing planar SCU18-1. Then, corrector current optimization is presented for the 1.5-m-long, 21-mm-period planar SCU. Finally, a magnetic field model of a full-scale, 1.9-m-long planar SCU is presented.

THPAB054 **Measurement Results of the First Scape Prototype**
***M. Kasa**, E.A. Anliker, Q.B. Hasse, Y. Ivanyushenkov, I. Kesgin, Y. Shiroyanagi, E. Trakhtenberg (ANL)*
The SCAPE (SuperConducting Arbitrarily Polarizing Emitter) undulator is under development at the Advanced Photon Source (APS) as a part of the APS upgrade. SCAPE is comprised of four superconducting magnets which are arranged to create an on-axis undulator field that can be planar, elliptical, or circular. As a first step towards developing a full length device, a 0.5-meter long prototype was manufactured and assembled for testing in a liquid helium bath cryostat. A description of the mechanical assembly and subsequent measurement results of the first prototype will be presented in this paper.

THPAB055 **Reconstruction of Linear Optics Observables Using Supervised Learning**
***E. Fol**, H. Garcia, R. Tomás (CERN)*
In the LHC, most of the optical functions can be obtained from turn-by-turn beam centroid data. However, the measurement of such observables as β^* and the dispersion function require special dedicated techniques and additional operational time. In this work, we propose an alternative approach to estimate these observables using supervised machine learning, in case the dedicated measurements are not available but turn-by-turn data are. The performance of developed estimators is demonstrated on LHC simulations. Comparison to traditional techniques for the computation of beta-function will be also provided.

THPAB056 **Conceptual Design of a Multiple Period Staggered Undulator**
***I. Asparuhov**, J. Chavanne, G. Le Bec (ESRF)*
In staggered undulators, a ferromagnetic pole structure paired to a solenoid generates a sinusoidal field. Interest of such insertion devices has been studied for application to FEL systems in the end of the previous century. However, the concept has never been used in synchrotron radiation sources due to the undesirable magnetic effect of the solenoid on electron beam parameters in storage rings. Advent of fourth-generation low emittance light sources is foreseen to change this situation. Indeed, consequent electron beam transverse size and divergence reduction for such new storage rings give promise for a beam less sensitive to the presence of a longitudinal solenoidal field. Relating to this, a staggered concept can be an adequate design choice for short-period undulators producing high-energy photon flux. Such undulators would have a low K value a priori limiting their photon energy tunability. Considering integration of separate magnetic arrays of distinct periods in a solenoid to compose a global assembly can help suppress this possible drawback. Magnetic design and radiative performance of such an insertion device are presented.

THPAB057 **Goubau-Line Set Up for Bench Testing Impedance of In-Vacuum Undulator Components**

***P.I. Volz**, S. Grimmer, M. Huck, A. Meseck (HZB) A. Meseck (KPH)*

The worldwide first in-vacuum elliptical undulator, IVUE32, is being developed at Helmholtz Zentrum Berlin. The 2.5 m long device with a period length of 3.2 cm and a minimum gap of about 7 mm is to be installed in the BESSY II storage ring. It will deliver soft X-radiation to several beamlines. The proximity of the undulator structure to the electron beam makes the device susceptible to wakefield effects which can influence beam stability. A complete understanding of its impedance characteristics is required prior to installation and operation, as unforeseen heating of components could have catastrophic consequences. Since its complex structure makes numerical calculations, such as CST simulations, at high frequency very resource intensive, bench testing the device may proof invaluable. A Goubau-line is a single wire transmission line for high frequency surface waves with a transverse electric field resembling that of a charged particle beam out to a certain radial distance. This can be used to measure the impedance of vacuum chamber components. A concept optimized for bench testing IVUE32-components will be discussed and progress towards the test bench set up will be shown.

THPAB058 **Effect of Electron Density Profile on Laser Wakefield Acceleration**

***S. Kumar** (Indian Institute of Technology, Plasma Waves and Particle Acceleration Lab)*

Laser wakefield acceleration (LWFA) of charged particles is a promising tool to generate a much larger acceleration gradient than conventional accelerators. Ultrashort high-intensity laser pulses propagate in plasma drive relativistic plasma waves and plasma electrons are expelled due to radiation pressure creating ion cavity or bubble. The expelled plasma electrons get accumulated on the bubble's upper and lower surface and these electrons are self-injected from the tail of the bubble and accelerated to high energies. The advantage of this regime is that there is no need of injection of external bunch of electrons for acceleration. Here, we have investigated the effect of electron density profiles on laser wakefield injection. Uniform and trapezoidal electron density profiles have been studied and compared. The trapezoidal electron density profiles are found to result in much higher wakefield generation in comparison to the uniform density profile. We have presented our numerical simulation results like electron density, energy spectra of accelerated electrons. The numerical studies have been performed using particle-in-cell simulation code Smilei.

THPAB059 **Study on a Self-Resonating Optical Cavity for Laser-Compton Sources**

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Tokyo, Graduate School of Engineering) N. Sugawara, Y. Uesugi (Tohoku University, Institute of Multidisciplinary Research for Advanced Materials) T. Takahashi (Hiroshima University, Graduate School of Science)

Laser-Compton scattering (LCS) has been expected as a compact and high brightness X-ray source. Both electron beam and laser beam are required to be high brightness. As for lasers, optical enhancement cavity is an advantageous technique since it passively realizes high peak power at the interaction point. High finesse cavities composed of high reflective mirrors are required for high enhancement factor. One technical obstacle preventing from stable, high enhancement operation is the continuance of the resonant condition. Since the required precision of the cavity length is inversely proportional to the finesse, high enhancement factor and stability is a trade-off. To overcome this issue, we are testing a self-resonating laser system, which is a laser oscillator with a nested optical cavity. In this conference, we report the mode-locked, pulsed operation of our self-resonating laser system with the finesse of ~300.

THPAB060 **Dispersion Controlled Temporal Shaping of Photoinjector Laser Pulses for Electron Emittance Reduction in X-Ray Free Electron Lasers**

R.A. Lemons, *S. Carbajo, J.P. Duris, A. Marinelli, N.R. Neveu (SLAC) C.G. Durfee (Colorado School of Mines)*

Temporal shaping of photocathode excitation laser pulses is a long-sought-after challenge to tailor the phase-space of electrons. The temporal profile of lasers, typically up-converted from infrared to ultraviolet, have significant impact on the distribution and time-evolution of the collective electron bunches. Towards this end, we present a method combining efficient nonlinear up-conversion with simultaneous and adaptable temporal profile shaping through dispersion-controlled sum-frequency generation resulting in temporal profiles with sharp rise-fall times and flat top profiles. Using the LCLS-II photoinjector as a case study, we demonstrate a reduction in generated electron transverse emittance by upwards of 30% over conventionally implemented temporal profiles. Additionally, we discuss the ongoing experimental implementation of this method and preliminary results.

THPAB061 **Pulse-Burst CO_2 Laser for High-Brilliance Compton Light Sources**

I. Pogorelsky, *M.N. Polyanskiy, T.V. Shaftan (BNL)*

We propose a novel architecture for a mid-IR, high-repetition, kilowatt-class, CO_2 laser system operating in a pulse-burst regime and its implementation in In-verse Compton Scattering (ICS) sources of x-ray and gamma-ray radiation. Different types of particle accelerators are considered for conversion to such ICS sources, including energy recovery linacs and synchrotron storage rings. The expected ICS performance parameters are compared with earlier proposals where CBETA and DAΦNE accelerators have been paired with near-IR, mode-

locked solid-state lasers operating at a multi-megahertz repetition rate. A considerable increase in acting laser energy attainable in our CO_2 laser-based scheme, combined with an order of magnitude higher number of laser photons per Joule of energy allows maintaining a similarly high average flux of produced hard x-rays while the peak flux and brilliance will be raised by three to four orders of magnitude compared to aforementioned schemes based on near-IR lasers.

THPAB062 **Long-Wave IR Terawatt Laser Pulse Compression to Sub-Picoseconds**

***I. Pogorelsky**, M. Babzien, M.A. Palmer, M.N. Polyanskiy (BNL)*

We report an experiment and simulations on post-compression of 2 ps, 0.15 TW CO_2 laser pulses to 480 fs, ~0.25 TW by means of a self-phase modulation accompanied by a negative group dispersion in KCl and BaF2 optical slabs. In addition, down to 130 fs fine pulse structure, but at lower conversion efficiency, has been observed through self-compression in a bulk NaCl crystal. The obtained results surpass by far previous achievements in the ultra-fast long-wave IR laser technology

THPAB063 **Laser Transport System of Shanghai Laser Electron Gamma Source (SLEGS)**

***H.H. Xu**, G.T. Fan (SSRF)*

Shanghai Laser Electron Gamma Source (SLEGS), based on laser Compton scattering (LCS), as one of beamlines of Shanghai Synchrotron Radiation Facility (SSRF) in phase II, is under construction now. The technical design of its laser injection system has been implemented and optimized consecutively over the last few years. In order to inject the 10640 nm CO_2 laser into the interaction point from the laser hutch outside the storage ring's shielding, a laser transport system longer than 20 m using relay-imaging telescopes is designed. There are two operation mode in SLEGS. One is backscattering mode, which will make the laser and electron bunch collide at 180^o with flux higher than 10^7 gamma/s. The other mode is slanting mode, which mainly inherits the design used in the prototype. In this paper, a brief summary of the laser transport system is given. The system contains several modules to perform beam expansion, combining, monitoring and real-time adjustment. The design models, simulation study of the laser quality through the transporta-tion, and the experimental results are presented.

THPAB064 **LUMOS: A Visible Diagnostic Beamline for the Solaris Storage Ring**

***R. Panaś**, A. Curcio, A.I. Wawrzyniak (NSRC SOLARIS)*

LUMOS is a diagnostic beamline which operates in the visible region. It was installed in the Solaris storage ring during summer 2019. The first light was observed at the beginning of December 2019. During 2020 the beamline was commissioned and equipped with a streak camera setup. Currently, LUMOS allows to analyze far-field and near

field images of synchrotron light for transverse beam profile measurements. Moreover, using the streak camera setup, it is also possible to investigate the bunch length, the filling pattern and the longitudinal beam profile changes with respect to the different condition (ramping, 3rd harmonic cavities tuning, etc.). During the presentation the optical setup to be presented along with the measurements conducted with it.

THPAB065 **Experimental Verification of the Source of the Excessive Helical SCU Heat Load at APS**

***V. Sajaev**, J.C. Dooling, K.C. Harkay (ANL)*

Immediately after the installation of the Helical superconducting undulator (HSCU) in the APS storage ring, higher than expected heating was observed in the cryogenic cooling system. Steering the electron beam orbit in the upstream dipole reduced the amount of synchrotron radiation reaching into the HSCU and allowed the device to properly cool and operate. The simplest explanation of the excessive heat load was higher than expected heat transfer from the vacuum chamber to the magnet coils. However, modeling of the synchrotron radiation interaction with the HSCU vacuum chamber showed that Compton scattering could also result in synchrotron radiation penetrating the vacuum chamber and depositing energy directly into the HSCU coils. In this paper, we present experimental evidence that the excessive heat load of the HSCU coils is not caused by the heat transfer from the vacuum chamber but resulted from the synchrotron radiation penetrating the vacuum chamber.

THPAB066 **Ground Diffusion Measurement and Its Effect on APS-U Orbit Stability**

***V. Sajaev** (ANL)*

Spatial and temporal ground diffusion can be approximately described by the ATL law. Ground diffusion can have an important effect on the long-term stability of the accelerator alignment. To estimate the possible consequences of the ground diffusion on the APS Upgrade performance, the ground diffusion constant of the existing APS tunnel was measured using historical data of the orbit correction effort and then used to estimate the ground diffusion effect on the orbit stability of the APS Upgrade. In this paper, we will describe the diffusion constant measurement and present the estimations of the expected APS-U alignment and orbit stability.

THPAB067 **Simulation of the APS-U Orbit Motion Due to RF Noise**

***V. Sajaev** (ANL)*

APS Upgrade storage ring will keep the same rf system that is presently used at APS. This rf system has amplitude and phase noise dominated by the lines at 60, 180, and 360 Hz. APS presently operates with synchrotron frequency close to 2 kHz, which is far away from the rf noise frequencies, and still the rf system noise contributes over 2 micrometers rms into the horizontal orbit noise due to beam energy variation. APS-U will operate with a bunch-lengthening cavity, which will lower

the synchrotron frequency down to about 200 Hz. This could potentially lead to large orbit noise and other negative consequences due to energy variation caused by the rf system noise. In this paper, we will present simulations of the rf noise-induced orbit motion at APS and APS-U and define the rf amplitude and phase noise requirements that need to be achieved for APS-U operation.

THPAB068 **Denoising of Optics Measurements Using Autoencoder Neural Networks**

***E. Fol**, R. Tomás (CERN)*

Noise artefacts can appear in optics measurements data due to instrumentation imperfections or uncertainties in the applied analysis methods. A special type of semi-supervised neural networks, autoencoders, are widely applied to denoising tasks in image and signal processing as well as to generative modeling. Recently, an autoencoder-based approach for denoising and reconstruction of missing data has been developed to improve the quality of phase measurements obtained from harmonic analysis of LHC turn-by-turn data. We present the results achieved on simulations demonstrating the potential of the new method and discuss the effect of the noise in light of optics corrections computed from the cleaned data.

THPAB069 **Design Concepts for a High-Gradient C-Band Linac**

***T.B. Bolin**, S. Biedron, S.I. Sosa Guitron (University of New Mexico) J.R. Cary (Tech-X) M. Dal Forno (SLAC)*

During the last decade, the production of soft to hard x-rays (up to 25 keV) at XFEL facilities has enabled new developments in a broad range of disciplines. One caveat is that these instruments can require a large amount of real estate. For example, the XFEL driver is typically an electron beam linear accelerator (LINAC) and the need for higher electron beam energies capable of generating higher energy X-rays can require longer linacs; costs quickly become prohibitive, requiring state of art methods. One cost-saving measure is to produce a high accelerating gradient while reducing cavity size. Compact accelerating structures are also high-frequency. Here, we describe design concepts for a high-gradient, cryo-cooled LINAC for XFEL facilities in the C-band regime (~4-8 GHz). We are also exploring C-band for different applications including drivers for security applications. We investigate 2 different traveling wave (TW) geometries optimized for high-gradient operation as modeled with VSim software.

THPAB070 **An Ultra-Compact X-Ray Free-Electron Laser**

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Recent advances in high gradient cryogenic Cu structure RF research open the door to the use of surface electric fields between 250 and 500 MV/m. Such structures can enable a new generation of photoinjectors with brightness an order of magnitude beyond the state-of-the-art. Further, one may accelerate these beams to GeV scale in ~8 m. Such an injector, when combined with IFEL bunching techniques can produce multi-kA beams with 50 nm-rad emittances. These beams, when injected into short-period (1-10 mm) undulators enable ultra-compact X-ray FELs having university-scale-lab footprints. We discuss the design and performance of this compact XFEL, which promises photon-per-pulse production of a few percent of existing XFELs. In the context of a burgeoning project centered at UCLA to develop this instrument, we review implementation issues including collective beam effects, compact X-ray optics systems, and various technical challenges. To illustrate the potential of such a light source to fundamentally change the current paradigm of XFELs with their limited access, we examine transformative applications in biology, chemistry, materials, and atomic physics.

THPAB071 **Physics Goals of DWA Experiments at FACET-II**

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The dielectric wakefield acceleration (DWA) program at FACET produced a multitude of new physics results that range from GeV/m acceleration to the discovery of high field-induced conductivity in THz waves, and beyond, to a demonstration of positron-driven wakes. Here we review the rich program now developing in the DWA experiments at FACET-II. With increases in beam quality, a key feature of this program is extended interaction lengths, near 0.5 m, permitting GeV-class acceleration. Detailed physics studies in this context include beam breakup and its control through the exploitation of DWA structure symmetry. The next step in understanding DWA limits requires the exploration of new materials with low loss tangent, large bandgap, and improved thermal characteristics. Advanced structures with photonic features for mode confinement and exclusion of the field from the dielectric, as well as quasi-optical handling of coherent Cerenkov signals is discussed. Use of DWA for laser-based injection and advanced temporal diagnostics is examined.

THPAB072 **Laser Driven Plasma Particle Accelerators: Bringing GeV Ac-**

celerators Off the Shelf
N. Gupta *(LPU Punjab)*
Theoretical study on the generation of super thermal electrons by intense laser beams in hot dense plasmas during inertial confinement fusion (ICF) has been presented. In order to obtain uniform heating of the fuel pellet the irradiance over the beam cross section has been modelled by Cosh Gaussian (ChG) profile. Effect of self focusing of the laser beam on energy gained by the electrons has been investigated in detail. Following variational theory based on Lagrangian formulation and hydrodynamic uid model of plasma coupled differential equations governing the evolution of beam width of the laser beam and energy of the super thermal electrons have been obtained. It has been observed that the uniformity of the irradiance over the beam cross section enhances the energy of super thermal electrons considerably.

THPAB073 **Study of Seven-Bend-Achromat Lattice Option for Half**
J.H. Xu*, Z.H. Bai, Z.L. Ren, J.J. Tan, P.H. Yang (USTC/NSRL) Q. Zhang (INEST)*
A seven-bend-achromat (7BA) storage ring lattice design for Hefei Advanced Light Facility (HALF) with a beam energy of 2.2 GeV and a circumference of 388.8 m is presented. The 7BA lattice is designed with the combined function bends and reverse bends which has a natural emittance of about 67 pm·rad. Two lattice candidates with different tunes have been selected. One lattice has better nonlinear dynamic performance for off-axis injection. The other lattice provides lower beta functions at the center of straight sections. The results of these studies are discussed in this paper.

THPAB074 **ESRF-EBS: Implementation, Performance and Restart of User Operation**
J.-L. Revol*, P. Berkvens, J.-F. Bouteille, N. Carmignani, L.R. Carver, J.M. Chaize, J. Chavanne, F. Ewald, A. Franchi, L. Hardy, J. Jacob, G. Le Bec, I. Leconte, S.M. Liuzzo, D. Martin, J. Pasquaud, T.P. Perron, Q. Qin, P. Raimondi, B. Roche, K.B. Scheidt, R. Versteegen, S.M. White (ESRF)*
The European Synchrotron Radiation Facility - Extremely Brilliant Source (ESRF-EBS) is a facility upgrade allowing its scientific users to take advantage of the first high-energy 4th generation light source. In December 2018, after 30 years of operation, the beam stopped for a 12-month shutdown to dismantle the old storage ring and to install the new X-ray source. In December 2019, the first beam was stored and accumulated in the storage ring, allowing the vacuum conditioning and tuning to be started. The beam was delivered to beamlines in March 2020 for their commissioning. On 25 August, the user programme was restarted with beam parameters very close to nominal values. In this report, the milestones and key aspects of the return to user-mode operation are presented and discussed.

THPAB075 **Collective (In)stability Near the Coupling Resonance**
R.R. Lindberg *(ANL)*
We show how to treat transverse collective instabilities when operating in the vicinity of the coupling (or tune difference) resonance. We begin by defining the approximate independent degrees of freedom including both linear coupling and chromatic effects. We then show how the destabilizing force due to wakefields and the stabilizing chromatic effects can be described by a linear combination of the horizontal and vertical motion that depends upon how close one is to the resonance. The theory agrees well with tracking studies, and will be relevant for those next-generation storage rings that plan to operate near the coupling resonance to produce nearly round beams, including the multi-bend achromat upgrade for the Advanced Photon Source.

THPAB076 **Effects of Chromaticity and Synchrotron Emission on Coupled-Bunch Transverse Stability**
R.R. Lindberg *(ANL)*
We present a theory that can compute the transverse coupled-bunch instability growth rates at any chromaticity and for any longitudinal potential provided only that the long-range wakefield varies slowly over the bunch. The theory is expressed in terms of the usual coupled-bunch eigenvalues at zero chromaticity, and when the longitudinal motion is simple harmonic our solution only requires numerical root-finding that is easy to implement and fast to solve; the more general case requires some additional calculations but is still relatively fast. The theory predicts that the coupled-bunch growth rates can be significantly reduced when the chromatic betatron tune spread is larger than the coupled-bunch growth rate at zero chromaticity. Our theoretical results are compared favorably with tracking simulations for the long-range resistive wall instability, and we also indicate how damping and diffusion from synchrotron emission can further reduce or even stabilize the dynamics.

THPAB077 **Magnetic Shims Studies for APS-U Hybrid Permanent Magnet Undulators**
Y. Piao, *R.J. Dejus, M.F. Qian, I. Vasserman, J.Z. Xu (ANL)*
For the newly designed and fabricated APS Upgrade (APS-U) hybrid permanent magnet undulators (HPMUs), the development of magnetic shims has been critical to successfully tuning the undulators to meet the tight APS-U physics requirements. Different types of side and surface shims have been developed and applied for this purpose. The side shims are primarily used for trajectory tuning, and the surface shims are for phase and multipole tuning as well as trajectory tuning. Current design, applications, and measurement of the shims for the newly designed and fabricated APS28 (28 mm period) undulators are presented in this paper.

THPAB078 **SOLEIL Update Status**
L.S. Nadolski, *X. Delétoille, J.-F. Lamarre, A. Nadji (SOLEIL)*
SOLEIL is both a synchrotron light source and a research laboratory at

the cutting edge of experimental techniques dedicated to matter analysis down to the atomic scale, as well as a service platform open to all scientific and industrial communities. This French 2.75 GeV third generation synchrotron light source provides today extremely stable photon beams to 29 beamlines (BLs) complementary to ESRF. We report facility performance, ongoing projects and recent major achievements. Major R&D areas will also be discussed, and progress towards a lattice baseline for making SOLEIL a diffraction limited storage ring.

THPAB079 **Design Study on Beam Size Measurement System Using Synchrotron Radiation Interferometry for Low Beam Current**
***W. Li**, P. Liu, Y.K. Wu, J. Yan (FEL/Duke University)*
To enable reliable measurements of the small vertical size of the electron beam in the Duke Storage Ring, a measurement system is being developed using synchrotron radiation interference (SRI). By relating the transverse beam size to the transverse spatial coherence of synchrotron radiation from a dipole magnet according to the Van Cittert-Zernike theorem, the transverse beam size can be inferred by recording and fitting the interference fringe as a function of the characteristic features of the interference filter used. In this paper, the preliminary design of the SRI vertical beam size measurement system is described; related errors and optimizations are discussed; simulation results are presented. This system will be optimized to measure the electron beam size for low current operation down to about 100 ~ μA. It will be used as one of critical diagnostics for intrabeam scattering research at the Duke storage ring.

THPAB080 **Correcting the Magnetic Field Offsets Inside the Undulators of the EuXFEL Using the K-Monochromator**
***F. Brinker** (DESY) S. Casalbuoni, W. Freund (EuXFEL)*
Hard X-ray free-electron lasers (XFELs) generate intense coherent X-ray beams by passing electrons through undulators, i.e. very long periodic magnet structures, which extend over hundreds of meters. A crucial condition for the lasing process is the spatial overlap of the electrons with the electromagnetic field. Well-established electron beam-based procedures allow finding a straight trajectory for the electrons defined by the beam position monitors (BPM) between the undulators. A bending of the trajectory in between the BPMs cannot be seen by these methods. A general field offset inside the undulators has the effect that the synchrotron radiation is emitted at a different angle at the beginning and the end of the undulator which can result in a degradation of the FEL-gain especially for very short wavelengths. We report on how the spectral and spatial characteristics of the monochromatized radiation of a single undulator can be used to minimize the field offset in situ with the help of correction coils.

THPAB081 **High-Power Prototype Canon Coupler for APS-U Booster Cavities**

***G.J. Waldschmidt**, D.J. Bromberek, D. Horan, G. Trento, U. Wienands (ANL) T. Harada, H. Oikawa, H. Takahashi (CETD)*

The Advanced Photon Source Upgrade (APS-U) plans to achieve a beam capture efficiency above 90% at 17 nC bunch charge into the Booster. Due to large beam loading at injection, the 352-MHz Booster cavities will be significantly detuned necessitating effective-power handling much greater than the 100kW effective power rating of the present coupler. Canon Electron Tubes & Devices Co., Ltd. (CETD) has designed and built a compact coupler for the APS-U Booster using a high-power ceramic disk window design in addition to accommodating significant space restrictions and additional diagnostics and cooling requirements. The coupler design was modified from an existing 500MHz, 800kW coupler that has been in routine operation at KEKB. The APS-U coupler has been installed and tested in the high-power 352-MHz test stand at the APS. The details of the design and testing of the prototype coupler will be reported in this paper.

THPAB082 **Recent Operational Experience With Thermionic Rf Guns at the APS**

***Y. Sun**, M. Borland, G.I. Fystro, X. Huang, H. Shang (ANL)*

The electron beam at the Argonne Advanced Photon Source (APS) is generated from an S-band thermionic RF gun. There are two locations at the frontend of the linac where thermionic RF guns are installed |–| RG1 and RG2. Three so-called generation-III guns are available, two are installed at RG1 and RG2, one is a spare. In recent years, these guns are showing signs of aging after over a couple of decades of operations. RF trips started to occur, and we had to reduce the nominal operating rf power to alleviate the problem. In addition, beam generated by RG1 suffers from low transportation efficiency from the gun to the linac, and beam trajectory is unstable which results in charge instabilities. Recently, APS obtained a new type of prototype gun and it was beam commissioned in the linac. In this paper, we report our operational experience with these thermionic rf guns including thermionic-cathode beam extraction, gun front-end optimization for maximum charge transmission through the linac, linac lattice setup to match beam for injection into the Particle Accumulator Ring (PAR) and optimization for maximum PAR injection efficiency.

THPAB083 **Measurement of the Longitudinal Phase-Space of the APS Photo-Injector Beam**

***Y. Sun** (ANL)*

A S-band photocathode RF gun (PCG) is installed in the front end of the Argonne Advanced Photon Source (APS) liac. The high-brightness photoinjector beam can be compressed by a magnetic bunch compressor in the linac, and a 0.55 m long LOLA type S-band transverse-mode cavity (Tcav) is available at the end of the linac for beam diagnostics. Beam commissioning experience of the Tcav is reported in

this paper. The cavity RF conditioning and calibration are performed. There are existing YAG screens downstream of the Tcav as well as horizontally bending dipole magnet that can be utilized for beam longitudinal phase-space diagnostics. The Tcav kicks the beam in the vertical plane. Beam image on a flag downstream of the Tcav and dipole magnet contains the single-shot information of the longitudinal phase-space of the photo-injector beam. The longitudinal phase-space measurement of the compressed and non-compressed photoinjector beam is presented. Improvements of the measurement resolution are discussed, as the existing beam imaging system is not designed for longitudinal phase-space measurements.

THPAB084 **Propagation of Partially Coherent Radiation Using Wigner Functions**

***B. Nash**, J.P. Edelen, S.D. Webb (RadiaSoft LLC)*

Undulator radiation from synchrotron light sources must be transported down a beamline from the source to the sample. A partially coherent photon beam may be represented in phase space using a Wigner function, and its transport may use some similar techniques as is familiar in particle beam transport. We describe this process in the case that the beamline is composed of linear focusing and defocusing sections as well as apertures. We present a compact representation of the beamline map involving linear transformations and convolutions. We create a 1:1 imaging system (4f system) with a single slit on the image plane and observe the radiation downstream to it. We propagate a Gaussian beam and undulator radiation down this sample beamline, drawing parameters from current and future ultra low emittance light sources. We derive an analytic expression for the partially coherent Gaussian case including passage through a single slit aperture. We benchmark the Wigner function calculation against the analytical expression and a partially coherent calculation in the Synchrotron Radiation Workshop (SRW) code.

THPAB085 **Status of Insertion Device Tuning for the APS Upgrade**

***R.J. Dejus**, Y. Piao, M.F. Qian, J.M. TerHAAR, I. Vasserman, J.Z. Xu (ANL)*

The Advanced Photon Source Upgrade (APS-U) project is developing a multi-bend achromat (MBA) lattice at 6.0-GeV beam energy to replace the existing APS storage ring lattice operating at 7.0 GeV. One of the key components of the project is to design, fabricate, and install optimized insertion devices (IDs) for 35 beamlines. A plan was developed to standardize on four new undulator period lengths for 44 new undulators and to reuse 23 existing undulators with four more different period lengths. Early in the Upgrade project we anticipated there would be large challenges in meeting the tight fabrication and tuning schedules so that all undulators would be ready for installation in the upgraded storage ring prior to beam commissioning. With recent developments and techniques used in the magnetic measurement laboratory, we have successfully tuned many of the new and reused un-

dulators to demanding magnetic field requirements. We will report on the tools and techniques used and on results to date.

THPAB086 **Progress of the Hard X-Ray Self-Seeding Monochromator at SHINE**

***T. Liu**, C. Feng (SARI-CAS) K.Q. Zhang (SSRF)*

Hard x-ray self-seeding is one of the baselines at the SHINE project, which has been used successfully at the LCLS, SACLA, PAL-XFEL, and European-XFEL facilities. The crystal monochromator is the critical part of the hard x-ray self-seeding. At the SHINE project, the scheme design work of the monochromator is carried out. In this manuscript, we will introduce the progress of the scheme design from the basic physical design to preliminary technological design.

THPAB087 **Proposal of Fresh-Slice Based High-Power X-Ray Free-Electron Lasers for the SASE Beamline at the SXFEL User Facility**

***T. Liu**, H.X. Deng, C. Feng, Z. Qi (SARI-CAS) K.Q. Zhang (SSRF)*

Fully coherent X-ray radiation with ultra-short pulse length and high power is a strong demand for the SASE beamline at the SXFEL user facility. Since the SASE beamline includes the modulator segment and the small delaying chicanes between each undulator segment, some modes of SASE improvements are considered to operate such as enhanced SASE, high brightness SASE, and fresh slice based SASE. Simulation results show the infeasibility of the normal high brightness SASE due to the longitudinal dispersion of the small chicanes. While for the dechirper based fresh-slice multistage high-power SASE scheme, numerical simulations present that high-power x-ray FELs are generated and indicate the feasibility and validity of this proposal.

THPAB088 **Pre-FODO Design of the SASE Beamline at the SXFEL User Facility**

***T. Liu**, H.X. Deng, B. Faatz, C. Feng, D. Gu, B. Liu (SARI-CAS)*

The in-vacuum undulators with 16 mm period length and 4 mm gap are adopted for FEL at the SASE beamline of the SXFEL user facility. In order to minimize the radiation damage of the undulators, the FODO lattices should be arranged upstream of the undulator segments. A quasi pre-FODO is designed in the beamline, and the effects of the different undulator gap on the FODO matching are also considered for the soft x-ray FEL.

THPAB089 **Lattice Design for a Future Plan of UVSOR Synchrotron**

***E. Salehi**, M. Katoh (UVSOR) M. Katoh (HSRC)*

UVSOR is a 750 MeV synchrotron light source with a moderately small emittance of about 17nm. We surveyed the periodic solutions by drawing a tie diagram and mapped the emittance and the dynamic aperture on the tune diagram. The aim of this work is to search for a possible low emittance solution without a major change of the lattice. Although, we could not find a solution which has a drastically small emittance, we have found a few solutions which has a significantly smaller emittance than present value. They may be useful for some special low

emittance operation modes dedicated to developments on new light sources technologies and their applications.

THPAB090 **Progress with the Diamond-II Storage Ring Lattice**
***H. Ghasem**, I.P.S. Martin, B. Singh (DLS)*
Building on the CDR proposal for the Diamond-II storage ring, a number of changes have been implemented to improve the performance of the lattice. Firstly, anti-bend magnets have been utilized to provide additional control over the dispersion function, and an improved symmetrization in the phase advance between the sextupoles was found to be beneficial for the dynamic aperture. Furthermore, the longitudinal variable bends have been tailored to reduce the emittance and have had transverse gradient added to improve the optics control in the mid-straights. In the absence of IDs, the current design provides 161 pm electron beam emittance, reducing to 139 pm once all effects are taken into account. The dynamic aperture is large enough to support an off-axis injection scheme using a nonlinear kicker and has a lifetime greater than 4 h. In this paper, the main parameters and magnet specifications for the Diamond-II lattice are provided. The related linear and non-linear beam dynamics issues are discussed, along with the impact of IDs.

THPAB095 **Development of the Prototype Magnets for HEPS Booster**
***W. Kang**, Y. Chen, X.W. Dai, Y.Q. Liu, J.X. Zhou (IHEP) C.D. Deng (DNSC) L. Liu, Y.J. Yu (IHEP CSNS)*
The High Energy Photon Source (HEPS) is a kilometre-scale, ultralow-emittance storage ring light source built in Beijing, China. Its accelerators include Linac, Booster and Storage Ring. The Booster is a synchrotron operating at a frequency of 1Hz. Unlike the magnets of the Storage Ring, all magnets of the Booster will work at dynamic mode, the field of the magnets will change with the beam energy. In this paper, the design, fabrication and test results of the prototype magnets for the Booster is presented, especially the dynamic properties of the magnetic field.

THPAB097 **Towards Arbitrary Pulse Shapes in the Terahertz Domain**
***C. Mai**, B. Büsing, A. Held, S. Khan, D. Krieg (DELTA)*
The TU Dortmund University operates the 1.5-GeV electron storage ring DELTA as a synchrotron light source in user operation and for accererator physics research. At a dedicated beamline, experiments with (sub-)THz radiation are carried out. Here, an interaction of short laser pulses with electron bunches is used to modulate the electron energy which causes the formation of a dip in the longitudinal electron density, giving rise to the coherent emission of radiation between 75 GHz and 6 THz. The standard mode of operation is the generation of broadband radiation. However, more sophisticated energy modulation schemes were implemented using a liquid-crystal phase modulator. Here, a modulation of the spectral phase of the laser is used to control the spectral shape of the THz pulses. The resulting THz spectra

have a relative bandwidth of about 2 %. Measurement results from the different THz generation schemes are presented.

THPAB098 **Design and Construction Progress of ALS-U, the Soft X-Ray Diffraction Limited Upgrade of the Advanced Light Source**

***C. Steier**, K. Chow, R.M. Leftwich-Vann, D. Leitner, W.J. Pearce, D. Robin, M. Venturini, S.P. Virostek, W.L. Waldron (LBNL)*

The ALS-U project to upgrade the Advanced Light Source to a multi bend achromat lattice received CD-3a approval in 2019 allowing the start of construction for the accumulator ring. The ALS-U storage ring recently entered the final design phase. ALS-U promises to deliver diffraction-limited performance in the soft x-ray range by lowering the horizontal emittance to about 70 pm rad resulting in two orders of magnitude brightness increase for soft x-rays compared to the current ALS. The design utilizes a nine bend achromat lattice, with reverse bending magnets and on-axis swap-out injection utilizing an accumulator ring. This paper presents recent design progress of the accelerator, as well as results of prototype testing and the status of the manufacturing of the accumulator.

THPAB099 **Microscopic Space-Charge Effects in an Ultra-High Brightness FEL Injector**

***O. Camacho**, R. Robles, J.B. Rosenzweig (UCLA) S.B. van der Geer (Pulsar Physics)*

Here we present simulation studies of the impact of short-range Coulomb interactions on the performance metrics of an ultra-high brightness RF photoinjector. These so-called microscopic effects, such as intrabeam scattering and disorder-induced heating, are ignored by the mesh-based space-charge algorithms employed in typical injector simulations on account of their relatively small impact on metrics such as the emittance and energy spread. However, for the cryo-injector recently proposed at UCLA, the ultra-high brightness of the baseline design enhances the relative strength of microscopic effects, thereby demanding a more thorough evaluation of their impact. We use the Barnes-Hut algorithm as implemented in the General Particle Tracer code to examine the impact of these effects on a scaled design chosen to preserve the relevant physics while alleviating computational burdens.

THPAB102 **Rapid Helicity Switching of Compton Gamma-Ray Beams at HIGS**

***J. Yan**, P. Liu, S.F. Mikhailov, V. Popov, Y.K. Wu (FEL/Duke University) H. Hao (ORNL RAD)*

At the High-Intensity Gamma-ray Source (HIGS), using an oscillator Free-Electron Laser (FEL) with two helical undulators of opposite helicities, we have demonstrated great flexibility in generating gamma-ray beams of various polarizations, from the linear polarization with a rotational direction to two circular polarizations of opposite helicities. Here, we report our development of fast helicity switching of a circularly polarized gamma-ray beam using the same FEL. First, we realized

helicity switching of the FEL beam by alternately producing lasing of one helical undulator while preventing the other undulator from lasing. The lasing of each undulator can be stopped by slightly detuning its undulator current (a few percent) so that a high switching rate up to 10 Hz can be achieved. By colliding an electron beam with such an FEL beam, a Compton gamma-ray beam with its helicity switched, in the same manner, is produced. The measured gamma-ray beam profiles and energy spectra for the two helicities are shown to be highly consistent. This gamma-ray operational mode opens up new opportunities for the exploration of various helicity-dependent nuclear processes.

THPAB103 **Nitrogen Purged Optical Diagnostic System for VUV FEL Operation**

***J. Yan**, S.F. Mikhailov, V. Popov, G. Swift, P.W. Wallace, Y.K. Wu (FEL/Duke University)*

At the Duke FEL facility, we operate a storage ring FEL in the VUV wavelength range, routinely around 190 nm and more recently around 175 nm. To facilitate the VUV FEL operation, we have developed a dedicated optical system to characterize the FEL beam. To reduce the beam loss in the air, the extracted FEL beam is transported and measured in a nitrogen-purged diagnostic system. The VUV diagnostic system is developed to use a minimum number of optic elements and measurement instruments which are compatible with the VUV operation. It enables the measurement of several essential FEL beam properties, including the FEL power, transverse beam profile, and radiation spectrum. This paper presents the overall layout of the diagnostic system and choices of VUV optics and detectors. This diagnostic system has been essential for our FEL research and operation below 200 nm, including the recent FEL lasing work from 180 nm to 169 nm.

THPAB104 **Magnetic Error Effects of the Storage Ring for the Southern Advanced Photon Source**

***J. Chen**, Y. Jiao, X. Liu, S. Wang (IHEP)*

There are various magnetic errors in the actual accelerator, which will significantly affect the beam quality and machine performance. The diffraction-limited storage ring (DLSR) of Southern Advanced Photon Source (SAPS) will use a large number of ultra-high gradient quadrupoles and sextupoles, which, in turn, leads to the tight tolerance of beam parameters to magnetic errors. Based on a preliminary designed storage ring lattice of the SAPS, the influence of various magnetic errors on lattice parameters has been evaluated.

THPAB105 **Alignment of Neutron Guide for Multi-Physics Instrument of CSNS**

***Z.Y. Ke**, Z.Q. He, B. Li, T. Luo, N. Ma (IHEP CSNS) L. Dong, L.L. Men, X.L. Wang (IHEP) J. Liang, T. Wang (DNSC)*

Multi-Physics Instrument (MPI) is the first cooperation instrument of China Spallation Neutron Sources (CSNS), and also the first total-scattering neutron instrument in China. The alignment precision of the neutron guide, which is one of the important components of the

MPI, directly affects the neutron flux and thus the performance of the instrument. In view of the special structure and installation method of the neutron guides of MPI, an alignment scheme combining laser tracker and measuring arm is adopted to fiducilize and pre-alignment the neutron guide precisely, which will ensure the accuracy and reliability of alignment of the neutron guide, also greatly improve the efficiency of the measurement, and the excellent neutron flux test results of MPI confirmed the feasibility of the new alignment method.

THPAB106 **Optimization of a High Bunch Charge ERL Injection Merger for PERLE**

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Delivery of high charge electron bunches into the main loop of an ERL (energy recovery linac) while preserving the emittance is challenging. This is because at the typical injection momentum, space charge forces still have a significant effect on the beam dynamics. In this work we consider the design of the merger for PERLE, an ERL test facility to be based at IJCLab in France. Previous simulations have shown that the baseline DC gun based injector can achieve the required emittance at the booster linac exit. The quality of the 500 pC bunches must then be preserved with space charge through the merger at total beam energy of 7 MeV keeping the emittance below 6 mm mrad. The beam dynamics in the merger were simulated using the code OPAL and optimised using a genetic algorithm. Three possible merger schemes were investigated. The goal of the optimisation was to minimise the emittance growth while also achieving the required Twiss parameters to match onto the spreader at the main linac exit. A three dipole solution is then examined in more detail.

THPAB107 **Update on Simulation Studies for the FLASH2020+ Seeded Beam Line**

S. Ackermann, *P. Niknejadi, G. Paraskaki, L. Schaper (DESY) W. Hillert, D. Samoilenko (University of Hamburg, Institut für Experimentalphysik) F. Pannek (University of Hamburg)*

The FLASH2020+ project includes the aim to extend the range of possible experiments at the FLASH Free-Electron Laser facility in Hamburg by offering one photon beamline delivering externally seeded radiation pulses with variable polarization at MHz repetition rates. For the shortest fundamental wavelength foreseen, a method manipulating the longitudinal electron phase-space distribution called Echo-Enabled Harmonic Generation will be applied. In this contribution, methods of optimizing the radiation output of the seeded FEL in simulation together with the results of those optimizations are presented. The impact of different undulator lengths is shown, as well as results from tapering optimization and a possibility to generate superradiant radiation pulses of femtosecond duration.

THPAB108 **Linear Accelerator of a New Synchrotron Light Source SKIF**
A.E. Levichev, *A.V. Andrianov, M.V. Arsentyeva, A.M. Barnyakov, V.G. Cheskidov, O.I. Meshkov, D.A. Nikiforov, O.A. Pavlov, I.L. Pivovarov, S.L. Samoylov, A.M. Semenov, S.V. Shiyankov, V. Volkov (BINP SB RAS) X.C. Ma (BINP) A.M. Semenov (BINP & NSTU)*
A new synchrotron light source SKIF of the 4th generation is under construction at Budker Institute of nuclear physics (Novosibirsk, Russia). It consists of the main ring, the collector ring, and the linear accelerator. This paper presents the design of the linear accelerator. It is expected to provide electron beams with an energy of 200 MeV. The construction of the linear accelerator is discussed. A description of the linear accelerator's main elements is presented.

THPAB111 **TerRa@BriXSino, a TeraHertz FEL Oscillator Driven by a MHz-class ERL**
V. Petrillo *(Universita' degli Studi di Milano) A. Bacci, I. Drebot, M. Opromolla, M. Rossetti Conti, L. Serafini (INFN-Milano)*
The CW ERL BriXSino drives an FEL Oscillator operating in the TeraHertz range and delivering high average power and high coherence radiation. Start-to-end simulations of the emission process from the cathode to the radiation users are performed, demonstrating the possibility of obtaining a flexible, highly tunable, and powerful tool for biomedical, security, and cultural heritage applications.

THPAB112 **Current Status of UVSOR-III**
M. Fujimoto, *K. Hayashi, M. Katoh, A. Minakuchi, H. Ota, E. Salehi, Y. Taira, J. Yamazaki (UVSOR)* ***M. Fujimoto***, *Y. Taira (Sokendai - Okazaki) M. Katoh (HSRC)*
UVSOR-III is the 750 MeV synchrotron light source of the Institute for Molecular Science in Japan. The first light was in 1983. Since major upgrades in 2012, it has been operated in top-up injection mode with a beam current of 300 mA and the beam emittance of 17 nm-rad. Fourteen beamlines, mainly six undulators, are providing high brilliance light in VUV to soft X-ray region. In addition, recently it has constructed to routinely use gamma-ray by laser Compton scattering with injecting laser pulses synchronized to the electron bunch. In the development of light source, using a beamline dedicated for R&D, novel researches have been conducted, generation of an optical vortex or vector beams from undulator, control of the quantum state in atoms, and development of the gamma-ray applications.

THPAB113 **The Extended Operative Range of the LNF LINAC and BTF Facilities**
L.G. Foggetta, *M. Belli, B. Buonomo, F. Cardelli, R. Ceccarelli, A. Cecchinelli, R. Clementi, D. Di Giovenale, C. Di Giulio, G. Piermarini, L.A. Rossi, S. Strabioli, R. Zarlenga (INFN/LNF)*
In 2020 the INFN-LNF LINAC and BTF have performed long-term runs for test beams and fixed-target experiments. The scientific needs of

these items have been leading our groups to continuous improvements of the LINAC operative range both in pulse time at maximum energy and on the minimum transported energy, until the reset to DAΦNE injections at the beginning of 2021. We will also show the BTF recent developments in the transported beams and the second line installation.

THPAB114 **Conception and Main Components of the SRS SKIF Vacuum System**

A.A. Krasnov, *V.V. Anashin, A. Bainazarova, L.L. Belova, G.A. Gusev, V. Kuzminykh, A.E. Levichev, A.E. Levichev, O.A. Pavlov, P.A. Piminov, A.M. Semenov, S.V. Shiyankov, S.V. Sinyatkin, A.A. Zhukov, A.N. Zhuravlev, A.N. Zhuravlev (BINP SB RAS)* ***A.A. Krasnov***, *A.E. Levichev (NSU) A.M. Semenov (BINP & NSTU)*

The article gives a brief description of the vacuum system concept for the future low emittance Synchrotron Radiation Source SKIF (Novosibirsk, Russia). The main attention is paid to the compromise use of combined lumped pumps together with distributed pumping based on non-evaporated getter coating (NEG). The time required for conditioning the storage ring beam pipe is estimated. Options for low impedance designs of the beam pipe and main components are considered.

THPAB115 **XUV and Soft X-Ray External Seeding at FLASH: Activities and Future Plans**

L. Schaper, *S. Ackermann, E. Allaria, T. Lang, M.M. Mohammad Kazemi, P. Niknejadi, G. Paraskaki, S. Schreiber, M. Tischer, P. Vagin, J. Zemella (DESY) W. Hillert, F. Pannek, D. Samoilenko (University of Hamburg, Institut für Experimentalphysik)*

The currently existing external seeing infrastructure at FLASH called Xseed has recently been upgraded to EEHG capability via the installation of a new chicane. The now installed hardware allows for significantly increased flexibility in experiments and also serves as a testbed for the FLASH2020+ project. In the latter a major upgrade of FLASHs primary beamline will expand its capabilities, resulting in the first fully externally seeded high repetition rate XUV and soft X-ray FEL for users with radiation properties tailored to future experiments. Together with an energy upgrade of the linac to 1.35 GeV and by using AppleIII-type undulators this will allow for the generation of coherent temporally short and spectrally narrow FEL radiation with variable polarisation at an accessible wavelength down to 4nm.

THPAB117 **Preliminary Design Studies of a New L Band RF Gun for Higher Duty Cycle Operation**

G. Shu, *H.J. Qian (DESY Zeuthen)*

The high brightness electron source of the European XFEL is based on a 10 Hz L band 1.6 cell normal conduction rf gun operating in long pulse mode (650 µs). A new rf gun aiming for 1 ms pulse length is designed with enhanced water cooling, and more x-ray pulses are expected if the ~50% increase of duty cycle is successful. In this paper,

a 2.4 cell rf gun with a reentrant cathode cell is studied, aiming for an even higher duty factor and lower peak rf power, which benefits the rf system stability and reduces the pulsed heating effect of the gun. The input peak rf power was reduced by 50% and the average RF heating density is reduced by a factor of ~3, while the beam brightness was maintained. Both the rf design and beam dynamics studies will be presented in this paper.

THPAB119 **Many-Objective Beam Dynamics Optimization for High-Repetition-Rate XFEL Photoinjector**

***Z.H. Zhu**, J.W. Yan (SINAP) D. Gu (SARI-CAS) Q. Gu (Shanghai Advanced Research Institute)*

SHINE, as the first hard x-ray free-electron-laser (FEL) facility in China, is design to provide high-brightness FEL lasing under high-repetition-rate operation. In order to drive x-ray FEL pulses with high qualities, the photoinjector section is deployed to provide the specified electron beam with low transverse emittance and high brightness. Normally the multi-objective optimization algorithm is employed in the injector beam dynamics design. In this paper, the many-objective optimization algorithm NSGA-III is introduced to the injector physical design for optimizing the 4 detailed beam quality properties using 17 variables for the first time. The results of the optimization are presented and the correlations are analyzed. This approach can provide guidance for further physical research as well as improve the beam dynamics optimization efficiency.

THPAB120 **Beam on Demand for High-Repetition-Rate X-Ray Free-Electron Lasers**

***Z. Zhang**, Y. Ding, Z. Huang (SLAC)*

High-repetition-rate (HRR) free-electron lasers (FELs) with multiple undulator beamlines will advance the frontiers of X-ray science significantly from the remarkable success of existing X-ray FEL facilities. The wide-ranging requirements for the photon properties from multiple beamlines are extremely challenging to satisfy by the same electron beam from a single superconducting radio-frequency (SRF) accelerator. To realize the full potential of an HRR FEL facility, a new emerging concept of "beam on demand" is proposed here. The concept is based on advanced beam dynamics and radio-frequency (RF) techniques to provide beam properties tailored to each undulator line at the desired repetition rate. The beam properties that will be pursued in this proposal include, but are not limited to, beam energy, bunch charge, bunch length, beam current, and its profile. The realization of "beam on demand" will allow optimization of photon properties of individual beamlines to maximize their performance and drastically improve the multiplexing capabilities of Linac Coherent Light Source II and its high-energy upgrade.

THPAB121 **Plasma Muon Beam Cooling for HEP**

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Ionization cooling has the potential to shrink the phase space of a muon beam by a factor of 10^6 within the muons' short lifetime (2.2 μs) because the collision frequency in a cooling medium is extremely high compared to conventional beam cooling methods. It has been realized that ionization cooling inherently produces a plasma of free electrons inside the absorber material, and this plasma can have an important effect on the muon beam. In particular, under the right circumstances, it can both improve the rate of cooling and reduce the equilibrium emittance of the beam. This has the potential to improve the performance of muon facilities based on muon cooling; in particular a future muon collider. We describe how this project will integrate Plasma muon beam cooling into both the basic Helical Cooling Channel (HCC) and extreme Parametric-resonance Ionization Cooling (PIC) techniques. This potentially whole new approach to muon cooling has exciting prospects for significantly reduced muon beam emittance.

THPAB122 **Beam Profile Measurement of the MEVVA Ion Source at KOMAC**

***S.H. Lee**, H.S. Kim, H.-J. Kwon (Korea Atomic Energy Research Institute (KAERI)) Y.-S. Cho (KAERI)*

KOMAC (Korea Multi-purpose of Accelerator Complex) has developed a metal ion beam facility based on MEVVA (Metal Vapor Vacuum Arc) ion source. The MEVVA ion source can generate plasma of most metal ion species because it uses vacuum arc discharge characteristics. We have extracted various metal ion beams using the MEVVA ion source such as noble metal, rare earth metal, high melting point metal, and semi-metal and we will continue to try a wider variety of metal ion beam extraction. The facility has a vertical configuration, which means the ion source is located at the top, the irradiation chamber located at the bottom, and the beam is transported from the top to bottom direction. Recently, the beam characteristics are under measurement. One of the important beam parameters is the beam profile and a multi-wire beam profile monitor was developed and its data processing method was implemented too. And the dependence of beam profile with the extraction condition was compared and analyzed. In this paper, the beam profile monitor and its measurement results are discussed.

THPAB123 **Pytomic: A Python Tool for Polarized Atomic Beam Tracking**

***J.L. Martinez Marin** (ANL)*

Pytomic is a new tool for the simulation and analysis of atomic beams through magnetic systems. It is written in Python and based on the same fundamentals as other particle tracking codes but for atomic beams instead of charged beams. In this case, the manipulation and control of neutral atomic beams is via a force due to the spin interacting with a magnetic field gradient. An object-oriented tool was developed to aid in the design of a beamline through the manipulation of

modular elements. The Python language allowed for a smooth implementation and kept the code clear and simple. The primary purpose of developing this code was to have a tool to design, simulate, and optimize a Breit-Rabi Polarimeter to measure the polarization of an atomic beam. Therefore, different set-ups with different magnets need to be simulated and optimized for direct comparison. In addition to simulation and tracking modules, a new data analysis module was developed to be able to quickly analyze simulation results, gaining insight from each iteration of the simulation, leading to an efficient and rapid design process. Example applications to design polarimeters for atomic beams will be presented.

THPAB124 **Application of the FFA Concept to a Muon Collider Complex**

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Muon collider complex is one of the places where the concept of fixed field alternating gradient (FFA) optics can be applied with great benefits. Vertical excursion FFA (vFFA) provides the isochronous condition for the ultra-relativistic muon beams after pre-acceleration. Together with the fixed transverse tune, it will be an ideal accelerator of short-lived muon beams with no time variation of magnetic fields and RF frequency. Novel collider ring optics is a design based on skew quadrupole after extracting essential functions from vFFA. That enables control of the momentum compaction factor. Neutrinos from the continuing decay of muons are spread out with orbit wiggling in the vertical direction as well as horizontal. The paper discusses the underline principle and describes some design examples.

THPAB126 **Operational Experience and Characterization of a Superconducting Transverse Gradient Undulator for Compact Laser Wakefield Accelerator-Driven FEL**

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A 40-period superconducting transverse gradient undulator (TGU) has been designed and fabricated at Karlsruhe Institute of Technology (KIT). Combining a TGU with a Laser Wakefield Accelerator (LWFA) is a potential key for realizing an extremely compact Free Electron Laser (FEL) radiation source. The TGU scheme is a viable option to compensate the challenging properties of the LWFA electron beam in terms of beam divergence and energy spread. In this contribution, we report on the operational experience of this TGU inside its own cryostat and show the current status of the TGU and the further plan for experiments. This work is supported by the BMBF project 05K19VKA PlasmaFEL (Federal Ministry of Education and Research).

THPAB129 **Beam Dynamics Simulations in a High-Gradient X-Band Photoinjector**

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A high-gradient X-band (11.7-GHz) photoinjector was recently developed by Euclid Techlabs and is in its commissioning phase at the Argonne Wakefield Accelerator (AWA). This contribution discuss the beam-dynamics modeling of the photoinjector system comprising an RF gun and linac section. We especially discuss beam-dynamics optimization of setup for an integrated proof-of-principle experiments. We also discuss the use of such a photoinjector as a witness-bunch source for a future high-gradient collinear-wakefield accelerator experiments at the AWA.

THPAB130 **Design of a Very Low Energy Beamline for NA61/SHINE**

***C.A. Mussolini**, N. Charitonidis (CERN) P. Burrows (JAI) P. Burrows (Oxford University, Physics Department) Y. Nagai (Colorado University at Boulder) Y. Nagai (ELTE) E.D. Zimmerman (CIPS)*

A new, low-energy beamline branch is currently under consideration for the H_2 beamline at the CERN North Area. This new branch would extend the capabilities of the current infrastructure enabling the study of particles in the very low, 1-13 GeV/c, momentum range. The design of this new beamline involves various stages. Firstly, a study of the secondary targets to maximise the yield of secondary hadrons. Secondly, the development of high acceptance transverse optics with high momentum resolution on the order of a few %. Finally, we discuss the first considerations on instrumentation to enable particle identification and background rejection. The first experiment to profit from this new line could be NA61/SHINE, but other possible future fixed target experiments or test-beams installed in the downstream zones could also use the low-energy particles provided. The aim is to arrive at a complete design of this branch by the end of 2021, which, pending the approval of the CERN scientific committees, could be envisaged for construction after 2024. This timescale is compatible with requests for measurements by various large international collaborations, in the next 10-year horizon.

THPAB131 **Spatio-Temporal Measurements of THz Pulses**

***G.A. Hine** (ORNL)*

The 3D characterization of single-cycle Terahertz (THz) pulses in its transverse and temporal dimensions is presented. The high fields and short wavelengths of THz pulses make them an intriguing prospect for novel accelerator technologies. Effective application for free-space THz pulses requires high beam quality and concomitant measuring techniques. The combination of conventional electro-optic sampling to measure the temporal profile and detectors like microbolometer focal plane arrays to measure the transverse profile does not capture the correlations that can arise in single-cycle THz pulses. To capture these

correlations, a modified version electro-optic sampling using a CCD is implemented. THz pulses generated by optical rectification in organic crystals are measured using this technique and their spatiotemporal correlations characterized.

THPAB134 **Development and Analysis of Software for the Numerical Simulation of Field Emission Electron Sources**

***N.S. Kakorin**, K.A. Nikiforov (Saint Petersburg State University) N.V. Egorov (St. Petersburg State University)*

The open-source DAISI C++ package (Design of Accelerators, optImizations and SImulations) is extended with the ability to simulate the operation of electron sources in the field emission mode, with the user-defined initial distribution of emitted electrons velocities, as a model parameter, and with the automated calculation of current-voltage characteristics. Particles injection scheme is suggested. Computational experiments are performed for silicon carbide field emission electron source nanostructure with bimodal energy spectrum, revealed from experimental study, and comparative analysis with Maxwell distribution is presented.

THPAB135 **Operation of the Nitrogen Doped Ultra Nano-Crystalline Diamond ((N)UNCD) Field Emission Cathodes Beyond Child-Langmuir Bright Beams**

***M.S. Schneider**, S.V. Baryshev, T. Nikhar (Michigan State University) H.L. Andrews, D. Kim, K.E. Nichols, E.I. Simakov (LANL) J.H. Shao (ANL)*

For development of an FE injector that can operate under high gradients and produce bright beams without disruption, measurements of (N)UNCD were carried out at the Argonne Cathode Test-stand. Operation at 100 MV/m surpassing the AWA's previous record of 100 nC/pulse with a new record of 300 nC/pulse was demonstrated. Insights and data analysis from field emission conditioning parameters, in situ imaging analysis, and custom beam dynamics using the platform called FEmaster enabled new evidence that a high gradient high charge operation of field emission cathode can surpass the Child Langmuir 1D limit. This high field operating regime is termed space-charge dominated Fowler-Nordheim (SCFN). Output charge surpassing 1D Child Langmuir limit was be explained by UNCD's surface inhomogeneity of UNCD requiring 2D consideration of space charge physics. Output beam brightness near 10^{15} A/m^{2}rad^2 is estimated for the given experimental conditions, and brightness near 10^{16} A/m^{2}rad^2 is possible to further high gradient of C-band injectors. Our technology could pave a path to produce bright field emission beams comparable to its photoemission counterparts.

THPAB136 **A Field Emission Initial Particle Distribution Freeware for Advanced Beam Dynamics Simulations Based on Fowler- Nordheim Equations for High Gradient Accelerators**

***M.S. Schneider**, S.V. Baryshev (Michigan State University)*

Field emission electron sources are poised to be the cathode of choice

for the next generation of high gradient and high-frequency injectors. This presents the question of how to properly model these sources in an rf injector environment. This led to the development of FEgen as part of the FE master series comprehensive field emission diagnostics and modeling toolkit. FEgen is a freeware open-source software that creates initial field emission distributions based on Fowler Nordheim equations both in the pulse power and RF environments. Which can be directly imported into being modeling software such as ASTRA, IMPACT-T, and GPT which currently do not have any built-in field emission modeling capabilities. FEgen modular design is an improvement over costly PIC codes like Michelle and VSim due to its ease-of-use. It can be customized for a variety of different scenarios which cannot be done with these proprietary codes. FEgen allows for the modeling of grid and custom pattern of emission which is been shown to match recent experimental measurements, with preliminary work towards development beyond Fowler Nordheim using nonplanar geometries.

THPAB137 **FEbeam: A Comprehensive Field Emission Data Processing for Field Emission and Breakdown Analysis in RF Environment**
***M.S. Schneider**, S.V. Baryshev (Michigan State University) J.H. Shao (ANL)*
As the ubiquity of field emission sources becomes more prevalent in that a variety of cathode materials and geometries are being tested or used, an easy-to-use data processing pipeline FEbeam was developed, and it is a part of the FEmaster platform. This algorithm processes and converts raw data to the standard format enabling further physics interpretation: combining 17 different subroutines, it processes the raw waveforms obtained from the bidirectional coupler and Faraday cup into the final field emission parameter space, Fowler-Nordheim (FN) and Millikan coordinates. FEbeam's modular design also allows for direct interfacing with FEpic, an image processing software to determine the number of emitters from images that can be obtained in situ at AWA's ACT facility, while providing postprocessing analysis options. FEbeam was originally designed for ACT but can be extended for use in any RF system with ease. This algorithm also uses a knee point selection to search if cathode emission behavior diverge from FN law. Thus, FEbeam is a useful tool enhancing the ease of development for the next generation of field emission injectors.

THPAB138 **FEbreak: A Comprehensive Diagnostic and Automated Conditioning Interface for Breakdown Analysis and Dark Current Effects**
***M.S. Schneider**, S.V. Baryshev (Michigan State University) R.L. Fleming, D. Gorelov, J.W. Lewellen, E.I. Simakov (LANL)*
As the next generation of accelerator technology pushes towards being able to achieve higher and higher gradients there is a need to develop high-frequency structures that can support these fields. The conditioning process of the structures and waveguides to high gradient is a

labor-intensive process, its length increases as the maximum gradient is increased. This results in the need to automate the conditioning process. This automation must allow for high accuracy calculations of the breakdown probabilities associated with the conditioning process which can be used to instruct the conditioning procedure without the need for human intervention. To automate the conditioning process at LANL's high gradient C-band accelerator test stand we developed FEbreak that is a breakout probability and conditioning automation software that is a part of the FEmaster series. FEbreak directly interfaces with the rest of FEmaster to automate the data collection and data processing to not only analyze the breakdown probability but also the dark current effects associated with these high gradient structures.

THPAB139 **Simulations of Particle Beam-Driven Wakefields in Carbon Nanotube Arrays**

***A. Perera**, C. Bontoiu, V. Rodin, C.P. Welsch, M. Yadav (The University of Liverpool) C. Bontoiu, V. Rodin, C.P. Welsch, M. Yadav (Cockcroft Institute) J. Resta-López (IFIC) A.A. Sahai (CU Denver) M. Yadav (UCLA)*

The use of nanostructures for particle acceleration is attracting renewed interest due to the possibility of TV/m accelerating gradients. Newly proposed sub-micron, near-solid beams, such as at FACET-II, have opened the possibility of exciting wakefields in previously inaccessible regimes in these high-electron-density (10^{29} m^{-3}) structures. In this work, we examine particle-beam-excited wakefields in both weakly perturbative (with conventional beams) and strongly non-linear (with near-solid beams) regimes using 3D particle-in-cell simulations. The acceleration efficiency of such schemes for various beam configurations is evaluated. We characterize the effects of transverse wakefields on the phase space of a witness beam, such as due to spatial asymmetry and beam misalignment.

THPAB140 **Modelling Seeded Self Modulation of Long Elliptical Bunches in Plasma**

***A. Perera**, O. Apsimon, C.P. Welsch (The University of Liverpool) O. Apsimon, C.P. Welsch (Cockcroft Institute) J. Resta-López (IFIC)*

The stability of particle bunches undergoing seeded self-modulation (SSM) over tens or hundreds of meters is crucial to the generation of GV/m wakefields that can accelerate electron beams as proposed for use in several high energy plasma-based linear colliders. Here, 3D particle-in-cell simulations using QuickPIC are compared to an analytical model of seeded self-modulation (SSM) of elliptical beam envelopes using linear wakefield theory. It is found that there is quantitative agreement between simulations and analytical predictions for the envelope in the early growth of the SSM. A scaling law is derived for the reduction of the maximum overall modulation growth rate with aspect ratio and is found to match well with simulation.

THPAB141 **Novel Design of a HVDC Magnetized Electron Source**

***O.H. Rahman**, J. Skaritka, E. Wang (BNL)*

The hadron beam in EIC is flat with a transverse size ratio of about 1:3. The cooling rate of the hadron beam can be maximized if the electron beam from the strong hadron cooler fully overlaps with the hadron beam. Therefore, generating a flat electron beam is essential. The most efficient way to generate a flat electron beam is to produce a magnetized beam first, and then convert it to flat to the desired transverse size ratio. Using a Magnetized electron beam is a promising way to cool high-energy hadrons. One of the major challenges in producing magnetized beams is fine-tuning the longitudinal magnetic field on the cathode surface and maintaining the desired field uniformity over the emission area. In this paper, we discuss the design of a novel high voltage DC gun capable of fine-tuning the B field on the cathode. This is achieved by installing a permanent magnet inside the cathode puck, with a solenoid field at the front of the cathode. We show magnetostatic simulation to prove the feasibility of this idea. We also show preliminary beam dynamics simulations showing emittance from the gun as the permanent magnet and solenoidal fields are tuned for minimum emittance.

THPAB142 **Optical and Surface Characterization of Alkali-Antimonide Photocathodes**

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Alkali-antimonides, characterized by high quantum efficiency and low mean transverse energy in visible light, are excellent electron sources to drive x-ray free electron lasers, electron cooling and ultrafast electron diffraction applications etc. Existing studies of alkali-antimonides have focused on quantum efficiency and emittance, but information is lacking on the fundamental aspects of the electronic structure, such as the energy gap of the semiconductor and the density of defects as well as the overall nano-structure of the materials. We are, therefore, conducting photoconductivity measurements to measure fundamental semiconductor properties as well as using atomic force microscope (AFM) and kelvin probe force microscope (KPFM) to measure the nanostructure variations in structure and surface potential.

THPAB143 **M2 Experimental Beamline Optics Studies for Next Generation Muon Beam Experiments at CERN**

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In the context of the Physics Beyond Colliders Project, various new experiments have been proposed for the M2 beamline at the CERN North Area fixed target experimental facility. The experiments include MUonE, NA64μ, and the successor to the COMPASS experiment, tentatively named AMBER/NA66. The AMBER/NA66 collaboration pro-

poses to build a QCD facility requiring conventional muon and hadron beams for runs up to 2024 in the first phase of the experiment. MUonE aims to measure the hadronic contribution to the vacuum polarization in the context of the (gμ-2) anomaly with a setup longer than 40 m and a 160 GeV/c high intensity, low divergence muon beam. NA64μ is a muon beam program for dark sector physics requiring a 100 - 160 GeV/c muon beam with a 15-25 m long setup. All three experiments request similar beam times up to 2024 with compelling physics programs, which required launching extensive studies for integration, installation, beam optics, and background estimations. The experiments will be presented along with details of the studies performed to check their feasibility and compatibility with an emphasis on the updated optics for these next-generation muon beam experiments.

THPAB145 **Cold Test of a Novel S-Band 1.6 Cell Photocathode RF Gun**
***Zh.X. Tang**, S.X. Dong, Y.J. Pei, B.F. Wei (USTC/NSRL)*
The photocathode RF gun is one of the most critical components for high quality electron beam sources. The asymmetric multi-pole field contributes to the transverse emittance growth and degrades the beam quality. In order to overcome the problem, we propose a novel rotationally symmetric 1.6 cell RF gun to construct the symmetric field in this paper. The concrete proposal is that a coaxial cell cavity with a symmetrical distribution of four grooves is concatenated to the photocathode end of the traditional 0.6 cell cavity to form the novel 0.6 cell cavity. Through the detailed design study, the profile of the RF gun is optimized to improve the shunt impedance and mode separation and make the surface peak electric field at the photocathode end. Considering the filling time, a coupling slot is designed to couple input power into the RF gun. The RF cavity is machined by numerical control machine tool, and the tuning and low power RF measurement are carried out. The experimental results are consistent with the simulation results.

THPAB146 **Preliminary Study of Femtosecond Electron Source Based on THz Acceleration and Field Emission**
***Zh.X. Tang**, G. Feng, B.F. Wei (USTC/NSRL)*
In this paper, we propose a novel electron gun based on THz acceleration and field emission to generate femtosecond electron bunches. The field emission cathode is placed in the center of the cavity, and the standing wave field is established in the cavity to achieve the field emission conditions and extract the electron beam. Because the period of THz band is about picosecond, the femtosecond bunch is formed by controlling the field strength and the pulse width of the extracted beam. We analyzed the feasibility of field emission and the length of the pulse beam. The surface peak field intensity of the structure of the cavity with different emitters are simulated by CST software.

THPAB147 **Study of 500 MHz HOM RF Cavity**
***Zh.X. Tang** (USTC/NSRL)*
In this paper, we study the microwave characteristics of 500 MHz RF

cavity, including the optimization of cavity structure, the simulation design of high-order mode (HOM) absorption structure and the design of coupler. The cavity structure is simulated by CST. The absorption waveguide is designed and optimized. The coupler is designed.

THPAB149 **Testing Laser Driven Plasma Injector for EuPRAXIA**

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Laser-driven wakefields in plasmas are able to provide electron beams in the 100-300 MeV range, suitable as an injector for a successive plasma stage, as envisaged in the EuPRAXIA conceptual design. Reproducibility of electron beam parameters is vital for this application. An experiment investigating the influence of laser parameters on controlling electron beam properties for tailored plasma profiles was conducted using the 100TW-class laser at the Lund Laser Centre. The drive laser's parameters - including energy, spectrum, wavefront, and pointing fluctuations - were characterized on every shot in order to delineate the driver effects from those induced by the plasma. Using the ELISA gas cell with nitrogen-doped hydrogen gas at varying concentrations for ionization-assisted injection, the plasma profile was optimized for a specific set of laser parameters and accelerated electron properties. Optimization methods and results will be discussed alongside electron beam measurements as an example for laser wakefield injectors and the control which can be achieved.

THPAB150 **AWA: A Test Facility for Advanced Acceleration Concepts and Beam Control**

***J.G. Power**, D.S. Doran, G. Ha, C.-J. Jing, W. Liu, P. Piot, C. Whiteford, E.E. Wisniewski (ANL) C.-J. Jing (Euclid TechLabs, LLC) X. Lu, P. Piot (Northern Illinois University)*

The upgraded AWA (Argonne Wakefield Accelerator) test facility at ANL was commissioned in 2015 and has been operating since. The facility possesses three RF photoinjectors: a 65 MeV drive beamline with the world's high charge photoinjector (100 nC bunches and 600 nC trains), (ii) a 15 MeV witness beamline and (iii) a 2 MeV beamline, the Argonne Cathode Test-stand as well as flexible experimental switchyard. AWA scientists, in partnership with collaborators from universities and other laboratories, carryout research in two primary areas: advanced acceleration concepts (AAC) and beam control. AAC research develops high-gradient and high-efficiency acceleration including both structure wakefield acceleration (SWFA) and plasma wakefield acceleration (PWFA). Beam control includes an active beam manipulation program to create tailored transverse and longitudinal bunch shapes using the

world's only operating emittance exchanger as well as work on electron cooling. The AWA facility has a number of near-term upgrades underway to improve the beam quality and stability, add new shaping capabilities as well as a long-term path to upgrade the energy called AWA-II.

THPAB151 **The Advantage of Cold Electron Source in Electron Diffraction**
***J. Liu**, H. Luo (SWUST)*
In this paper, a model for discussing the influence of transverse coherence of electron beams on electron diffraction is established. With reference to Fedele's thermal-wave model, the transverse coherence length is introduced into this model to characterize the transverse coherence of electron beams. The simulation results show that the transverse coherence of electron beams has a significant influence on electron diffraction, and the cold electron source with high transverse coherence has an obvious advantage in electron diffraction.

THPAB152 **Fabrication and Testing of the Corrugated Waveguide for a Collinear Wakefield Accelerator**
***A.E. Siy**, N. Behdad (UW-Madison) M.G. Fedurin, K. Kusche (BNL) W.G. Jansma, S.H. Lee, A. Nassiri, S.S. Sorsher, K.J. Suthar, E. Trakhtenberg, G.J. Waldschmidt, A. Zholents (ANL)*
Significant progress has been made in the past year at Argonne National Laboratory in the development of a compact wakefield accelerator based on a corrugated waveguide with a 2-mm ID and fine corrugations on the wall. The fabrication process of 10-cm long corrugated waveguide structures has been established and the high quality of the final product has been confirmed by precision metrology. These results are described. Several samples were tested using the electron beam at Brookhaven National Laboratory's Accelerator Test Facility. Measurements included a characterization of the wakefield, a determination of frequency for the fundamental longitudinal mode of Cerenkov radiation and three higher frequency transverse modes, and a determination of the fundamental mode group velocity. The results were found to be in excellent agreement with design values calculated using CST Microwave Studio. Both the experimental results and calculations are described. Plans for continued experimental characterization of the corrugated waveguide-based wakefield accelerator will be presented.

THPAB153 **Design, Construction and Tests of the Cooling System With a Cryocooler for Cavity Testing**
***P. Pizzol**, J.W. Lewellen, E.R. Olivas, E.I. Simakov, T. Tajima (LANL)*
Cryogenically cooled normal-conducting cavities have shown higher gradients than those operated at room temperature. We are constructing a compact cooling system with a cryocooler to test C-band normal-conducting cavities and 1.3 GHz superconducting cavities. This paper describes the design, construction, and cooling test results as well as some low-power cavity Q measurement results.

THPAB154 **Gentle and Extreme Ion Motion in Plasma Accelerators and the E-314 Experiment at FACET-II**

***C.E. Hansel**, W. An, P. Manwani, W.B. Mori, J.B. Rosenzweig (UCLA) M. Yadav (The University of Liverpool)*

Ion motion presents a significant challenge for future plasma-based linear colliders. For gentle ion motion where the flow is laminar, a nonlinear perturbation is introduced to the linear focusing fields inside the bubble. We present a new simple numerical model for laminar ion motion and compare it to Particle-In-Cell (PIC) simulations. For more extreme ion motion, ions collapse into a thin filament within the volume of the beam and generate strong nonlinear focusing fields. We analytically investigate this beam-ion quasi-equilibrium as well as discuss the matching of the beam to the nonlinear focusing fields. Finally, we discuss and present PIC simulations for the upcoming E-314 experiment at FACET-II which will experimentally demonstrate ion motion.

THPAB155 **Strong Quadrupole Wakefield Based Focusing in Dielectric Wakefield Accelerators**

***W.J. Lynn**, G. Andonian, N. Majernik, J.B. Rosenzweig (UCLA)*

We propose here to exploit the quadrupole wakefields in an alternating symmetry slab-based dielectric wakefield accelerator (DWA) to produce second-order focusing. The resultant focusing is found to be strongly dependent on longitudinal position in the bunch. We analyze this effect with analytical estimates and electromagnetic PIC simulations. We examine the use of this scenario to induce beam stability in very high gradient DWA, with positive implications for applications in linear colliders and free-electron lasers.

THPAB156 **Built-in Thermionic Electron Source for an SRF Linacs**

***I.V. Gonin**, S. Kazakov, R.D. Kephart, T.N. Khabiboulline, T.H. Nicol, N. Solyak, J.C.T. Thangaraj, V.P. Yakovlev (Fermilab)*

The design of a thermionic electron source connected directly to a superconducting cavity, the key part of an SRF gun, is described. The results of beam dynamics optimization are presented which allow lack of beam current intercepting in the superconducting cavity. The electron source concept is presented including the cathode-grid assembly, thermal insulation of the cathode from the cavity, and the gun resonator design. The cavity thermal load caused by the gun is analyzed including the static heat load, black body radiation, backward electron heating, etc.

THPAB157 **Studying X-Ray Spectra of the SIS18 Electrostatic Septa to Measure Their Electric Field**

***B. Gålander**, E. Kozlova, D. Ondreka, A. Sokolov, P.J. Spiller, J. Stadlmann (GSI)*

The synchrotron SIS18 at GSI uses resonant extraction for slow beam extraction on the order of seconds. For some time, there has been an unexplained discrepancy of the slow extraction with a lower extraction efficiency than expected at the highest beam energies. Recent machine studies have indicated that the deflection by the electrostatic septum

might be less than the nominal 2.5 mrad, leading to increased losses at the magnetic septum. In this paper, we pursue an idea to directly measure the voltage of the electrode gap by utilizing the fact that dark current electrons accelerated in the gap of the electrostatic extraction septum generate Bremsstrahlung X-rays when hitting the anode. The high-energy cut-off of the X-ray spectra then corresponds to the voltage of the electrode gap. Measurements of the X-ray spectra at the extraction septum of SIS18 have been performed using a solid-state CdTe detector. This technique provides an in-situ measurement of the voltage applied to the electrostatic extraction channel and has proven to be a useful diagnostics tool.

THPAB158 **Beam Collimation in the PIP-II Linac to Booster Transfer Line**
***D.E. Johnson**, J.-F. Ostiguy, M. Xiao (Fermilab)*
The new PIP-II superconducting linac will deliver a 2 mA average H^- beam to the existing Booster synchrotron. The injected beam is accumulated by charge exchange over approximately 300 turns; phase space painting is used to mitigate space charge effects. To limit the power load on the internal waste beam absorber from the transverse tails of the H^- distribution missing the foil, the beam will be collimated in both planes in the linac to Booster transfer line using compact collimators of a novel design. Both the number of parasitic hits and the fraction of the beam missing the foil are sensitive functions of the H^- beam centroid position with respect to the edge of the foil. The positioning of the collimation is constrained by the availability of suitable space in the transfer line lattice, by specifics of the collimator design, by the phase space orientation at the collimator, and by the betatron phase advance to the foil needed to achieve proper orientation of the spatial distribution at the injection point. In this contribution, we describe the procedure by which collimator positions were optimized. We then discuss the expected performance of the overall system.

THPAB162 **New Simulation Tools for 3D Modeling of the Microbunced Electron Cooling Concept**
***I.V. Pogorelov**, D.L. Bruhwiler, C.C. Hall (RadiaSoft LLC) G. Stupakov (SLAC)*
The development of the next-generation polarized electron-ion collider (EIC) is a high priority for the nuclear physics community. Because reaching the required cooling times at collision energies is challenging with conventional electron cooling, it is important to explore cooling schemes that are based on fundamentally different techniques such as microbunched electron cooling (MBEC). Regular PIC simulations in the parameter regime of the EIC cooling system would require a prohibitively large number of particles to resolve the ion-imprinted modulation. We developed and implemented in Warp an approach based on two perturbative techniques, the beam-frame δf method and a variant of the distribution difference (DD) technique. To model the dynamics of the ion-seeded modulation in the MBEC chicanes, we developed a novel approach that combines the DD and quiet start

techniques with analysis of correlations between the divergence of DD trajectories and their location within the e-beam. We have also prototyped in Warp the computation of the time-dependent 3D wakefield in the MBEC kicker. We present the initial results of simulations in the parameter regime of the EIC cooler.

THPAB163 **Design for Heavy Ions Linac**

***A.I. Semennikov**, G. Kropachev, T. Kulevoy, D.N. Selesnev, A. Sitnikov (ITEP)*

The new linac for A/Z = 8, output energy 4 MeV/u, and 10 mA current is under development at NRC Kurchatov Institute-ITEP. The linac consists of Radio-Frequency Quadrupole (RFQ) with operating frequency 40 MHz and two sections of Drift Tube Linac (DTL) with operating frequency 80 and 160 MHz, correspondently. The paper presents the design of RFQ, QWR, and IH structures for linac. Analyses of applying for constructing materials, mechanical deformations, machining technology are given in the article also.

THPAB164 **Beam Loss Analysis and Electrostatic Deflector Design for a 250 MeV Superconducting Cyclotron**

***H.J. Zhang**, K. Fan, Y. Yan (Huazhong University of Science and Technology, State Key Laboratory of Advanced Electromagnetic Engineering and Technology,) Z.Y. Mei (HUST) Y.-N. Rao, L.G. Zhang (TRIUMF)*

A superconducting cyclotron-based proton therapy facility is under development at Huazhong university of science and technology (HUST). An electrostatic deflector (ESD) is employed as one of the key components for the beam extraction from the superconducting cyclotron. Due to the narrow orbit separation, a fierce interaction between the proton beam and the deflector septum is expected, which will deposit significant beam energy on the deflector and produce secondary particles resulting in excess heat accumulation and radiation effect. This paper investigates the beam loss on the deflector septum using the particle tracking code CYCLONE. The optimal electrostatic deflector design, including optimization of structure and material, is introduced in detail. Thermal analysis based on fluid dynamics (CFD) of ANSYS has been performed to investigate the thermal and mechanical effects on the deflector.

THPAB165 **5 MW Beam Power in the ESSnuSB Accumulator: A Way to Manage Foil Stripping Injection at 14Hz Linac Pulse Rate**

***H. Schönauer** (CERN) , Y. Zou (Uppsala University)*

In the past, the scenario for foil stripping consisted of splitting a linac pulse into 4 rings, or 3 or 4 intermediate pulses, and one ring. At present, the scenario, in view of laser stripping, consists of one ring, one pulse, split into four batches. Conventional stripping geometry would lead to foil evaporation under this beam load. One way out appears to be replacing the standard corner foil by a single-edge foil rotated to about 45deg. The tilted foil allows moving the injection point together with the painting bumps along the foil edge, distributing the

deposited beam power over a larger foil area. Simulation results obtained with the same tools as in the past scenarios are presented. They show peak foil temperatures, which compare with the best results obtained from the past scenarios.

THPAB167 **Technical Design of an RFQ Injector for the IsoDAR Cyclotron**
***H. Höltermann**, D. Koser, B. Koubek, H. Podlech, U. Ratzinger, M. Schuett (BEVATECH) J.M. Conrad, D. Winklehner (MIT)*
For the IsoDAR (Isotope Decay-At-Rest) experiment, a high intensity (10 mA CW) primary proton beam is needed. To generate this beam, H^{2+} is accelerated in a cyclotron and stripped into protons after extraction. An RFQ, partially embedded in the cyclotron yoke, will be used to bunch and axially inject H^{2+} ions into the main accelerator. The strong RFQ bunching capabilities will be used to optimize the overall injection efficiency. To keep the setup compact the distance between the ion source and RFQ can be kept very short as well. In this paper, we describe the technical design of the RFQ. We focus on two critical aspects: 1. The use of a split-coaxial structure, necessitated by the low frequency of 32.8 MHz (matching the cyclotron RF) and the desired small tank diameter; 2. The high current, CW operation, requiring a good cooling concept for the RFQ tank and vanes.

THPAB168 **Optics Measurement by Excitation of Betatron Oscillations in the CERN PSB**
***E.H. Maclean**, F. Antoniou, F. Asvesta, H. Bartosik, C. Bracco, J. Dilly, E. Fol, H. Garcia Morales, M. Hofer, J. Keintzel, M. Le Garrec, T.E. Levens, L. Malina, T.H.B. Persson, T. Prebibaj, E. Renner, P.K. Skowroński, F. Soubelet, R. Tomás, A. Wegscheider, L. van Riesen-Haupt (CERN)*
Optics measurement from analysis of turn-by-turn BPM data of betatron oscillations excited with a kicker magnet has been employed very successfully in many machines but faces particular challenges in the CERN PSB where BPM to BPM phase advances are sub-optimal for optics reconstruction. Experience using turn-by-turn oscillation data for linear optics measurements during PSB commissioning in2021 is presented, with implications for the prospect of such techniques in the PSB more generally.

THPAB169 **A Mechanism for Emittance Growth Based on Non-Linear Islands in LHC**
***E.H. Maclean**, M. Giovannozzi, T.H.B. Persson, R. Tomás (CERN)*
Landau octupoles are used in the LHC to prevent coherent instabilities of the circulating beam. The reduction of their strength occurring during the energy ramp can transport particles in nonlinear islands to larger amplitude. This has the potential to lead to emittance growth and to beam-losses. Beam-based studies and simulations of emittance growth during Landau octupole ramps performed in the LHC are presented to explore this mechanism in more detail.

THPAB170 **RF Deflector Design for Rapid Proton Therapy**
***E.J.C. Snively**, G.B. Bowden, V.A. Dolgashev, Z. Li, E.A. Nanni,*

D.T. Palmer, S.G. Tantawi (SLAC)

Pencil beam scanning of charged particle beams is a key technology enabling high dose rate cancer therapy. The potential benefits of high-speed dose delivery include not only a reduction in total treatment time and improvements to motion management during treatment but also the possibility of enhanced healthy tissue sparing through the FLASH effect, a promising new treatment modality. We present here the design of an RF deflector operating at 2.856 GHz for the rapid steering of 150 MeV proton beams. The design utilizes a TE11-like mode supported by two posts protruding into a pillbox geometry to form an RF dipole. This configuration provides a significant enhancement to the efficiency of the structure, characterized by a transverse shunt impedance of 68 MOhm/m, as compared to a conventional TM11 deflector. We discuss simulations of the structure performance for several operating configurations including the addition of a permanent magnet quadrupole to amplify the RF-driven deflection. In addition to simulation studies, we will present preliminary results from a 3-cell prototype fabricated using four copper slabs to accommodate the non-axially symmetric cell geometry.

THPAB171 **mm-Wave Linac Design for Next Generation VHEE Cancer Therapy Systems**

***E.J.C. Snively**, K.C. Deering, E.A. Nanni (SLAC)*

Direct electron therapy offers an attractive method for providing the high dose rates necessary for FLASH radiation therapy, a new treatment modality with the potential for enhanced healthy tissue sparing. Direct electron therapy has been limited by the low beam energies, up to 20 MeV, provided by today's medical linacs, restricting the achievable dose depth to superficial tumors. Very High Energy Electron (VHEE) therapy could reach deep-seated tumors throughout the body. A clinically viable VHEE system must provide electron energies of around 100 MeV in a compact footprint, roughly 1 to 2 meters, with modest power requirements. We investigate the development of mm-wave linacs to provide the necessary beam energies on the sub-meter scale, taking advantage of the favorable scaling of high-frequency operation to support gradients well above 100 MeV/m. We discuss the design parameters necessary for high-efficiency structures, with shunt impedance on the order of 1 GOhm/m, producing high gradients with only a few megawatts of power. We present simulations of cavity performance in the mm-wave operating regime, with an emphasis on compatibility with the requirements of VHEE therapy.

THPAB172 **Bunch Luminosity Variations in LHC Run 2**

***I. Efthymiopoulos**, S.D. Fartoukh, G. Iadarola, N. Karastathis, S. Papadopoulou, Y. Papaphilippou (CERN)*

The LHC is designed to collide intense bunches of protons with tightly defined conditions, aimed to maximize the delivered recorded integrated luminosity to the experiments. One of these conditions is the maximum level of bunch-to-bunch fluctuation in the luminosity, in

particular when levelling at maximum acceptable event rate at the experiments. Analysis results of the bunch-to-bunch luminosity variations in LHC Run 2 are presented here. In particular, the observed correlations with the LHC filling pattern that can enhance the effects introducing bunch-dependent losses or emittance blow-up from injection to collisions are discussed. In Run 2 conditions, bunch-by-bunch luminosity fluctuations reached 10% at the start of collisions and gradually increased with time, without affecting the experiments as the luminosity was not levelled. Projections for Run 3 and HL-LHC operation are discussed along with envisaged mitigation measures.

THPAB173 **Fundamental Study on Electromagnetic Characteristics of Half-Wave Resonator for 200 MeV Energy Upgrade of KOMAC Proton Linac**

J.J. Dang, *Y.-S. Cho, H.S. Kim, H.-J. Kwon, S. Lee (Korea Atomic Energy Research Institute (KAERI))*

A superconducting linac has been developed at KOrea Multi-purpose Accelerator Complex (KOMAC). A goal of the SRF linac is to increase proton beam energy from 100 MeV to 200 MeV. 350 MHz medium beta half-wave resonator (HWR) should provide 3.6 MV accelerating voltage to achieve the energy upgrade. An electromagnetic (EM) analysis on the parametrically designed HWR cavity was conducted. The cavity design was optimized to reduce a peak electric field and a peak magnetic field while satisfying the required acerating voltage. In addition, a mechanical-EM coupled simulation was conducted to estimate a helium pressure sensitivity. Also, Lorentz force detuning was simulated. The design is being optimized to minimize the frequency detuning due to the helium pressure and Lorentz force.

THPAB174 **T-BMT Spin Resonance Tracker Code for He3 With Six Snakes**

V.H. Ranjbar, *H. Huang, Y. Luo, F. Méot, V. Ptitsyn (BNL) G.H. Hoffstaetter, D. Sagan (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) F. Lin, V.S. Morozov (JLab)*

Polarization lifetime for He3 using two and six snakes are studied using the T-BMT Spin Resonance Tracker code. This code integrates a reduced spinor form of the T-BMT equation including only several spin resonances and the kinematics of synchrotron motion. It was previously benchmarked against RHIC polarization lifetime under the two snake system.

THPAB175 **NuSTORM Accelerator Challenges and Opportunities**

C.T. Rogers, *J.-B. Lagrange (STFC/RAL/ISIS) N. Gall (CERN) J. Pasternak (STFC/RAL) J. Pasternak (Imperial College of Science and Technology, Department of Physics)*

The nuSTORM facility uses a stored muon beam to generate a neutrino source. Muons are captured and stored in a storage ring using stochastic injection. The facility will aim to measure neutrino-nucleus scattering cross-sections with uniquely well-characterized neutrino beams;

to facilitate the search for sterile neutrino and other Beyond Standard Model processes with exquisite sensitivity, and to provide a muon source that makes an excellent technology test-bed required for the development of muon beams capable of serving as a multi-TeV collider. In this paper, we describe the latest status of the development of nuSTORM, the R&D needs, and the potential for nuSTORM as a Muon Collider test facility.

THPAB176 **Studies on Beam Collimation System for the ESSnuSB Accumulator**

***Y. Zou**, M. Olvegård (Uppsala University)*

The ESSnuSB, a neutrino facility based on the European Spallation Source, aims at measuring, with precision, the charge-parity (CP) violating lepton phase at the 2nd oscillation maximum. The ESS linac will have to be upgraded to provide an additional 5 MW beam for the ESSnuSB to produce an unprecedented high-intensity neutrino beam. An accumulator ring is employed to compress the 2.86 ms long pulse from the linac to around 1.5 μs in order to satisfy the target requirements and improve the physics performance. In the operation of a high-intensity proton accumulator, the most important issue is to minimize the uncontrolled beam loss to reduce component activation to make hands-on maintenance possible. For this purpose, a two-stage collimation system is designed, which consists of a thin scraper to scatter halo particles and secondary collimators to absorb those scattered particles. Phase advances between scraper and secondary collimators, together with the material, the thickness of collimators, have been detailed studied and numerical simulations have been performed to evaluate the performance of the collimation system. This paper presents the design of the collimation system.

THPAB177 **Simulation Model Improvements at the Cooler Synchrotron COSY Using the LOCO Algorithm**

***A. Lehrach**, V. Poncza (FZJ) **A. Lehrach**, V. Poncza (RWTH)*

The JEDI (Jülich Electric Dipole moment Investigations) collaboration is searching for Electric Dipol Moments (EDMs) of charged particles in storage rings. In a stepwise approach, a first direct deuteron EDM measurement was performed at the Cooler Synchrotron COSY and design studies for a dedicated proton EDM storage ring are underway. In an experiment with a polarized beam in a storage ring, an EDM leads to a vertical polarization buildup. However, the vertical polarization component is also induced by systematic effects such as magnet misalignments. To investigate systematic effects individually and to support data analysis, a realistic simulation model of the storage ring is needed. In this paper, the development of such a model based on the Bmad software library is presented. Furthermore, various systematic effects and their impact on the spin motion in COSY are investigated and quantified by means of beam and spin tracking simulations.

THPAB178 **The SIS100 Extraction and Emergency Kicker Magnet System**

***J.H. Hottenbacher**, K. Dunkel, M. Eisengruber, M. Osemann,*

A. Padvi, C. Piel (RI Research Instruments GmbH) S. Heberer, I.J. Petzenhauser (GSI)

The extraction and emergency kicker system for SIS100 is a bipolar kicker system that allows for an in-situ choice between two directions: extraction to the experiments or to the beam dump. For that, both magnet ends are connected to a PFN each which are being charged simultaneously up to 80kV continuously. Due to the static HV operation, different to usually in other pulsed kicker systems, not only displacement current is flowing in the ferrite material. After less than 1s, the ferrite material is nearly field-free and the E-field is concentrated in the surrounding ceramic magnet clamp mechanism. As the field is further concentrated in gaps between ceramic and metallic parts, the HV layout of the magnet is a critical design task. As a magnetic field homogeneity of ±1% is required, special shaping of the coil is required as found during iterative 3D field simulations. The kicker chamber is designed to operate at a pressure level of $3{\cdot}10^{-11}$ mBar. As one 3 meter-chamber contains 3.5 m^2 ferrite surface, careful vacuum heat treatment of the ferrite is required to reach this pressure level. The paper will describe design principles for HV and UHV and effects found by 3D modeling.

THPAB179 **Commissioning of PIP2IT Superconducting Linac at Fermilab**

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PIP-II Injector Test (PIP2IT) facility is a full-scale prototype of the low energy end of the PIP-II linac driver, designed to accelerate a 2 mA H^- beam to an energy of 20 MeV. PIP2IT comprises the room temperature front end and prototypes of the first two PIP-II superconducting cryomodules, half-wave-resonator, and single-spoke-resonator cryomodules. The facility serves as a testbed for PIP-II technologies, most importantly SRF, significantly reducing project technical risks, and provides an opportunity to gain experience with beam commissioning that will be used later to commission PIP-II. Some PIP2IT components are contributions from international partners, who also lend their expertise to the accelerator project. In this paper, we discuss our experience with the commissioning of PIP2IT system and present commissioning results.

THPAB180 **Simulation of 4D Emittance Measurement at the Spallation Neutron Source**

A.M. Hoover *(UTK) N.J. Evans (ORNL RAD)*

Similar to the KV distribution, the Danilov distribution has an elliptical shape and uniform density in the transverse plane and maintains these properties under any linear transport. Efforts are underway at the Spallation Neutron Source (SNS) to paint a Danilov distribution in the accumulator ring. After the beam has been painted, the level to

which it approximates an ideal Danilov distribution must be quantified. One way to do this is to measure the four-dimensional emittance, which is ideally zero due to linear relationships between the phase space variables. To measure this emittance, we will utilize a standard method of reconstructing the covariance matrix using various optics settings in conjunction with beam profile measurements. We present the results of preliminary simulations which aim to optimize this measurement scheme for the SNS Ring to Target Beam Transport (RTBT) line.

THPAB181 **AI/ML Developments for the ATLAS Ion Linac Facility**

B.M. Mustapha, *B.R. Blomberg, C. Dickerson, J.L. Martinez Marin, C.E. Peters (ANL)*

ATLAS is a DOE/NP User Facility for the study of low-energy nuclear physics with heavy ions. It operates ~6000 hours per year. In addition to delivering any stable beam from proton to uranium, the facility also provides radioactive beams from the CARIBU source or via the in-flight radioactive ion separator, RAISOR. The facility uses 3 ion sources and services 6 target areas at energies from ~1-15 MeV/u. To accommodate the large number and variety of approved experiments, ATLAS reconfigures once or twice per week over 40 weeks of operation per year. The startup time varies from ~12-48 hours depending on the complexity of the tuning, which will increase with the upcoming Multi-User Upgrade to deliver beam to two experimental stations simultaneously. DOE/NP has recently approved a project to use AI/ML to support ATLAS operations. The project aim is to significantly reduce the accelerator tuning time and improve machine performance by developing and deploying artificial intelligence methods. These improvements will increase the scientific throughput of the facility and the quality of the data collected. Our recent developments and future plans will be presented and discussed.

THPAB182 **DC-280 Cyclotron for Factory of Super Heavy Elements Experimental Results**

V.A. Semin, *S.L. Bogomolov, K. Gikal, G.G. Gulbekyan, I.A. Ivanenko, I.V. Kalagin, N.Yu. Kazarinov, V.I. Mironov (JINR) L.A. Pavlov (JINR/FLNR)*

The DC280 is the high current cyclotron with design beam intensities up to 10 pμA for ions with energy from 4 to 8 MeV/nucleon. It was developed and created at the FLNR JINR. The first was extracted from the cyclotron on January 17, 2019. Experiments on acceleration of ^{12}C, ^{40}Ar, ^{48}Ca, ^{48}Ti, ^{52}Cr and ^{84}Kr beams production were carried out. The following intensities of accelerated beam have been achieved: 10 pμA for $^{12}C^{+2}$; 9,2 pμA for $^{40}Ar^{+7}$; 7,1 pμA for $^{48}Ca^{+10}$; 1,0 pμA for ^{48} Ti^{+10}; 2,4 pμA for $^{52}Cr^{+10}$ and 1.43 pμA for $^{84}Kr^{+14}$. The accelerator has worked more than 9000 hours. The work of accelerator was stable and high efficiency. The total acceleration efficiency from ion source to transport channel was about 46%.

THPAB183 **New Longitudinal Beam Production Methods in the CERN Proton Synchrotron Booster**

S.C.P. Albright, *F. Antoniou, F. Asvesta, H. Bartosik, C. Bracco, E. Renner (CERN) E. Renner (TU Vienna)*

As part of the LHC Injectors Upgrade (LIU) project, significant improvements were made to the CERN Proton Synchrotron Booster (PSB) during the 2019/2020 long shutdown, including a new Finemet-based wideband RF system, renovated longitudinal beam control, and a new magnetic cycle. To meet the requirements of the diverse experimental program, the PSB provides beams with intensities spanning three orders of magnitude and a large range of longitudinal emittances. To maximize the brightness, in particular for the LHC beams, the voltages at low energy are designed to reduce the impact of transverse space charge using a second RF harmonic in bunch lengthening mode. At high energies, the risk of longitudinal microwave instability is avoided by optimizing the longitudinal distribution to raise the instability threshold. RF phase noise is applied to provide controlled longitudinal emittance blow-up and to shape the longitudinal distribution. This paper discusses the design of the RF functions used to meet the beam specifications, whilst ensuring longitudinal stability.

THPAB185 **Solution to Beam Transmission Decline in the CSNS Linac OPERATION Using Measurements and Simulations**

J. Peng, *M.T. Li, X.H. Lu, X.B. Luo (IHEP CSNS) Y.W. An, S. Fu, L. Huang, M.Y. Huang, Y. Li, Z.P. Li, S. Wang, S.Y. Xu, Y. Yuan (IHEP)*

The CSNS linac operation at its design average power currently. However, the beam transmission is declining and the beam loss is increasing during the operation. With simulations and experiments, we found there is a long longitudinal tail exist in the beam bunch output from the RFQ. And this tail caused the beam loss in the following linac. After inhibition of the longitudinal tail in the beam bunch, the beam transmission in operation can keep stable.

THPAB186 **Several Commonly Proton Linac Beam Dynamic Simulation Code**

X.Y. Feng, *J. Peng (IHEP CSNS)*

CSNS-II project design a linac accelerates 40 mA H^- beam from 3.8 MeV to 300 MeV, which should not only overcome the space-charge effect at low energy but also have high efficiency at high energy. Therefore, lots of simulation studies should be done on a variety of codes. Each of them has its own characteristics. For example, MAD can easily match quadrupole fast while it couldn't do the multiparticle calculation. This paper will introduce some common and efficient code used to design linac and study beam dynamic performance.

THPAB187 **Determination of Required Tolerances and Stop Band Width for Cells Manufacturing and Tuning in Compensated High Energy Accelerating Structures**

***I.V. Rybakov**, V.V. Paramonov (RAS/INR)*

The required value of the spread for accelerating field distribution comes from the beam dynamics conditions and for cavities in high energy hadron linacs is ~1%. The standard deviation of the accelerating field distribution depends on the spread in frequencies of accelerating and coupling cells, stop bandwidth and deviations in coupling coefficients. The deviations in frequencies for accelerating, coupling cells, coupling coefficients, are directly related to tolerances manufacturing tolerances for cells. The stop bandwidth should be adjusted with cell tuning. Relations between the standard deviation of field distribution and deviations in cells parameters are known. Together with the relation between deviations in cells dimensions and cells parameters recommendations for cells manufacturing tolerances could be obtained. In relation to the coupling coefficient of compensated accelerating structures (ACS, SCS, CDS, DAW) for high-energy parts of linacs some recommendations for the determination of optimal manufacturing tolerances and acceptable stopband are presented.

THPAB188 **Self-Consistent Modeling of Coherent Synchrotron Radiation From Electron Beams in Bunch Compressors**

***C.-K. Huang**, B.E. Carlsten, G.A. Dilts, R. Garimella, T.J. Kwan, F.Y. Li, H.N. Rakotoarivelo, R.W. Robey (LANL)*

The self-consistent nonlinear dynamics of a relativistic particle beam interacting with its complete self-fields is a fundamental problem underpinning many of the accelerator design issues in high brightness beam applications, as well as the development of advanced accelerators. Particularly, synchrotron radiation-induced effects can lead to collective beam instabilities and emittance growth. We are developing a novel Lagrangian method for the calculation of the particles' radiation near-fields on adaptive meshes, which are then interpolated onto a global mesh. This method allows simulation of radiation co-propagation and interaction with the beam at greatly reduced errors. Multiple levels of parallelisms inherent in this method are implemented in our code CoSyR to enable at-scale simulations of the nonlinear beam dynamics on modern computing platforms using MPI, multi-threading, and GPUs. CoSyR has been benchmarked with other coherent synchrotron radiation models and used to evaluate the transverse and longitudinal effects on the beam. Beam optics designs proposed for the mitigation of beam brightness degradation in a magnetic compressor are also investigated and discussed.

THPAB189 **New Techniques to Compute the Linear Tune**

***G. Russo**, M. Giovannozzi (CERN) G. Franchetti (GSI)*

Tune determination in numerical simulations is an essential aspect of nonlinear beam dynamics studies. In particular, because it allows probing whether an initial condition is close to resonance, and it en-

ables assessment of the stability of the orbit, i.e. whether the motion is regular or chaotic. In this paper, results of recently developed techniques to obtain accurate tune computation from numerical simulation data are presented and discussed in detail.

THPAB190 **Optimising and Extending a Single-Particle Tracking Library for High Parallel Performance**

M. Schwinzerl, *H. Bartosik, R. De Maria, G. Iadarola, K. Paraschou (CERN) A. Oeftiger (GSI)* ***M. Schwinzerl*** *(KFUG/IMSC)*

SixTrackLib is a library for performing beam-dynamics simulations on highly parallel computing devices such as shared memory multi-core processors or graphical processing units (GPUs). Its single-particle approach fits very well with parallel implementations with reasonable baseline performance, making such a library an interesting building block for various use cases, including simulations covering collective effects. We describe optimizations to improve their performance on SixTrackLib's main target platforms and the associated performance gains. Finally, we outline the implemented technical interfaces and extensions that allow SixTrackLib to be used in a wider range of applications and studies.

THPAB191 **Physics-Enhanced Reinforcement Learning for Optimal Control**

A.N. Ivanov, *I.V. Agapov, A. Eichler, S. Tomin (DESY)*

We propose an approach for incorporating accelerator physics models into reinforcement learning agents. The proposed approach is based on the Taylor mapping technique for simulation of the particle dynamics. The resulting computational graph is represented as a polynomial neural network and embedded into the traditional reinforcement learning agents. The application of the model is demonstrated in a nonlinear simulation model of beam transmission. The comparison of the approach with the traditional numerical optimization as well as neural networks based agents demonstrates better convergence of the proposed technique.

THPAB192 **Continuous Beam Dynamics Simulation in COMSOL Multiphysics**

D. Popov, *O. Karamyshev, I.D. Lyapin, V. Malinin (JINR/DLNP)*

The classic way of beam dynamics simulation in a cyclotron is to separate it into many different stages from the ion source to the extraction (or even further), this was absolutely necessary to fit the calculations into any reasonable time in a cost of influence of some operation devices from one stage, on beam dynamics of another (next or previous mostly) stage. We've managed to perform beam dynamics from ion source through a solenoid to the center region in a single model in COMSOL, using several fields simultaneously: external magnetic (the magnet), calculated magnetic (the solenoid) and alternating and stationary electric fields in the center region.

THPAB193 **New CYCLOPS-Based Cyclotron Code for Field Map Evaluation and Beam Dynamics**

***V. Malinin**, D. Popov (JINR/DLNP)*

The goal of the code, presented in this poser is to reduce calculation time, required to evaluate field maps during cyclotron magnet design or shimming. Here we focus on our modification of CYCLOPS code, responsible a for finding closed orbits and calculating the focusing properties of the magnetic field. The original CYCLOPS procedure finds closed orbits with an iterative scheme, where every orbit has to be calculated one after another. The new algorithm, presented in this poster, allows to perform searches for every orbit in parallel. It is developed as a part of a larger code, called CORD (Closed ORbit Dynamics) which is briefly addressed in this poster.

THPAB194 **Simulating Point-to-Point Interactions in High Brightness Photoelectron Beamlines for Ultrafast Electron Diffraction**

***M.A. Gordon**, Y.K. Kim (University of Chicago) J.M. Maxson (Cornell University) S.B. van der Geer (Pulsar Physics)*

Spatial and temporal resolution of electron diffraction and microscopy techniques can typically not exceed the quality of the electron source. For this reason, ultra-high brightness photocathodes have been actively sought, and found, over the past decades. This however poses a new challenge: Maintaining the increased phase-space density throughout the entire device. Most beam dynamics simulation codes approximate detrimental Coulomb interaction with a mean-field space charge approach. While this approximation is sufficient in traditional beams with large temperature, for cold dense beams, the failure of Debye screening leads to the rise of the Boresch effect and disorder induced heating, which can significantly impact beam quality. In this contribution we introduce two numerical methods implemented in the General Particle Tracer (GPT) code to calculate the effects of the photocathode image charge when using a point-to-point interaction model. With these methods we simulate the effects of stochastic Coulomb interactions on two high brightness photoemission beamlines designed for single-shot ultrafast electron diffraction: one using a 200 keV gun, and the other using a 5 MeV gun.

THPAB195 **Start-to-End Code Integration, Code Coupling and Rapid Benchmarking**

***D.L. Bruhwiler**, D.T. Abell, E. Carlin, N.M. Cook, J.P. Edelen, C.C. Hall, M.V. Keilman, P. Moeller, R. Nagler, B. Nash, S.D. Webb (RadiaSoft LLC)*

A community initiative in the late 1990s to establish a common lattice file description for particle accelerator codes, deemed at the time to be long overdue and a high priority, was unsuccessful. The problem remains unsolved, in spite of subsequent initiatives over the past 20 years. The open source Sirepo framework and associated scientific gateway provides a practical solution, which avoids the political difficulty of requiring widespread agreement on naming conventions and

allows the many code development teams to proceed with their work. In Sirepo, lattice and other configuration data is stored via simple JSON structures, encapsulating the minimal information required for each code. This declarative programming approach enables the development and sustainable maintenance of code for input file translation. Supported particle accelerator codes include MAD-X, elegant, OPAL, Synergia and Zgoubi. We explain how the Python libraries of Sirepo can be used and extended by the community.

THPAB197 **Enhancing Efficiency of Multi-Objective Neural-Network-Assisted Nonlinear Dynamics Lattice Optimization via 1-D Aperture Objectives & Objective Focusing**

***Y. Hidaka**, D.A. Hidas, F. Plassard, T.V. Shaftan, G.M. Wang (BNL)*

Mutli-objective optimizers such as multi-objective genetic algorithm (MOGA) have been quite popular in discovering desirable lattice solutions for accelerators. However, even these successful algorithms can become ineffective as the dimension and range of the search space increase due to exponential growth in the amount of exploration required to find global optima. This difficulty is even more exacerbated by the resource-intensive and time-consuming tendency for the evaluations of nonlinear beam dynamics. Lately the use of surrogate models based on neural network has been drawing attention to alleviate this problem. Following this trend, to further enhance the efficiency of nonlinear lattice optimization for storage rings, we propose to replace typically used objectives with those that are less time-consuming and to focus on a single objective constructed from multiple objectives, which can maximize utilization of the trained models through local optimization and objective gradient extraction. We demonstrate these enhancements using a NSLS-II upgrade lattice candidate as an example.

THPAB198 **Commissioning of Current Strips for Elliptically Polarizing Undulators at NSLS-II**

***Y. Hidaka**, O.V. Chubar, T. Tanabe (BNL) C.A. Kitégi (SOLEIL)*

Most of the Elliptically Polarizing Undulators (EPUs) at NSLS-II are equipped with current strips (or flat wires), attached to their vacuum chambers. These strips compensate the dynamic field integrals of the EPU to minimize undesirable nonlinear beam dynamics effect that can lead to reduction in injection efficiency and beam lifetime. For each EPU, we measured the field integrals of the insertion device alone, the current strips alone, and both, while creating horizontal bumps of different amplitudes at the straight section to assess the effectiveness of the compensation provided by the design current values for the strips. The commissioning results of these current strips are reported in this article.

THPAB199 **Studies of Longitudinal Beam Losses at LHC Injection**

***L.E. Medina Medrano**, T. Argyropoulos, R. Calaga, H. Timko (CERN)*

Due to higher beam intensities, the required rf power in the High-Luminosity LHC (HL-LHC) era is expected to be at the limit of the available rf power. To mitigate potential limitations of the rf system, the injection voltage can be reduced at the expense of beam losses. In this paper, the average and bunch-by-bunch losses are estimated from Run 2 beam intensity measurements in the SPS before extraction and in the LHC after injection. Macro-particle simulations are performed with CERN's Beam Longitudinal Dynamics code to reproduce the observed SPS-to-LHC capture and LHC flat-bottom losses. First estimates of injection losses for the HL-LHC at different injection voltages and injection energy errors are discussed.

THPAB200 **Cavity Control Modelling for SPS-to-LHC Beam Transfer Studies**

***L.E. Medina Medrano**, T. Argyropoulos, P. Baudrenghien, H. Timko (CERN)*

To accurately simulate injection losses in the LHC and the High-Luminosity LHC era, a realistic beam distribution model at SPS extraction is needed. To achieve this, the beam-loading compensation by the SPS cavity controller has to be included, as it modulates the bunch positions with respect to the rf buckets. This dynamic cavity control model also allows generating a more realistic beam halo, from which the LHC injection losses will mainly originate. In this paper, the implementation of the present SPS cavity controller in CERN's Beam Longitudinal Dynamics particle tracking code is described. Just like in the machine, the feedback and feedforward controls are included in the simulation model, as well as the generator-beam-cavity interaction. Benchmarking against measurements of the generated beam distributions at SPS extraction are presented.

THPAB201 **A Machine Learning Technique for Dynamic Aperture Computation**

***B. Dalena**, M. Ben Ghali (CEA-IRFU)*

Currently, dynamic aperture calculations of high-energy hadron colliders are performed through computer simulations, which are both a resource-heavy and time-costly processes. The aim of this study is to use a reservoir computing machine learning model in order to achieve a faster extrapolation of dynamic aperture values. A recurrent echo-state network (ESN) architecture is used as a basis for this work. Recurrent networks are better fitted to extrapolation tasks while the reservoir echo-state structure is computationally effective. Model training and validation is conducted on a set of "seeds" corresponding to the simulation results of different machine configurations. Adjustments in the model architecture, manual metric and data selection, hyperparameters tuning and the introduction of new parameters enabled the model to reliably achieve good performance on examining testing

sets.

THPAB202 **Problem and Solution with the Longitudinal Tracking of the ORBIT Code**

L.H. Zhang, *J.Y. Tang (IHEP) Y.K. Chen (IHEP CSNS)* ***L.H. Zhang*** *(University of Chinese Academy of Sciences)*

The ORBIT code has been widely used for beam dynamics simulations including injection and acceleration in high-intensity hadron synchrotrons. When the ORBIT's 1D longitudinal tracking was employed for the acceleration process in CSNS/RCS, the longitudinal emittance in eV-s was found decreasing substantially during acceleration, though the adiabatic condition is still met during this process. This is against the Liouville theorem that predicts the preservation of the emittance during acceleration. The recent machine study in the accelerator and the simulations with a self-made code demonstrate that the longitudinal emittance is almost invariant, which further indicates that the ORBIT longitudinal tracking might be incorrect. A detailed check-over in the ORBIT code source finds that the longitudinal finite difference equation used in the code is erroneous when applied to an acceleration process. The new code format PyORBIT has the same problem. After the small secondary factor is included in the code, ORBIT can produce results keeping the longitudinal emittance invariant. This paper presents some details about the study.

THPAB203 **Update of the RF-Track Code**

A. Latina *(CERN)*

During the last couple of years, the RF-Track particle tracking code has seen a tremendous increase in the number of its applications: medical linacs, compact injector electron guns, and positron sources are among the main ones. Following a work of consolidation of its internal structure, new simulation capabilities have been introduced, together with several new effects: arbitrary orientation of elements in space, full element overlap, short- and long-range wakefields, and laser-beam interaction through Compton scattering are the most significant ones. In this paper, some of these new features are presented and discussed.

THPAB204 **End-to-End RMS Envelope Model of the ISAC-I Linac**

O. Shelbaya, *R.A. Baartman, O.K. Kester (TRIUMF)*

A full end-to-end simulation of the ISAC-I linear accelerator has been built in the first order envelope code TRANSOPTR. This enables the fast tracking of rms sizes and correlations for a 6-dimensional hyperellipsoidal beam distribution defined around a Frenet-Serret reference particle frame, for which the equations guiding envelope evolution are numerically solved through a model of the machine's electromagnetic potentials. Further, the adopted formalism enables the direct integration of energy gain via time-dependent accelerating potentials, without resorting to transit-time factors.

THPAB205 **On-Line Retuning of ISAC Linac Beam With Quadrupole Scan Tomography**

***O. Shelbaya**, R.A. Baartman, P.M. Jung, O.K. Kester, S. Kiy, T. Planche, Y.-N. Rao, S.D. Rädel (TRIUMF)*

The method of tomographic reconstruction has been in use at TRIUMF and elsewhere for several years, allowing for the beam diagnostic extraction of elements of the beam matrix on-line. One of the more recent applications of the technique at ISAC consists of using the measured density distribution as the input parameters for a real-time tune re-computation. This technique is advantageous since it does not require installation of dedicated emittance meters, but can instead be carried out with existing position monitors. Instead of requiring an operator to manually re-tune quadrupoles in a matching section, which can be time consuming, the technique allows for a fast and reproducible means to precisely control the beam and can be proceduralized for use by operators tuning the machine.

THPAB206 **Validating PyORBIT for Modeling Beam Dynamics in the IOTA Ring**

***R. Li** (UW-Madison/PD) J.-F. Ostiguy, T. Sen (Fermilab)*

The Integrable Optics Test Accelerator (IOTA) ring is a new Fermilab facility dedicated to beam physics experiments, currently operating with 150 MeV electrons. Space charge effects are expected to be significant when it operates with 2.5 MeV protons. In this contribution, we present results of a suite of validation tests of PyORBIT, a PICstyle space charge code. Single particle dynamics of quasiintegrable optics using an octupole string in IOTA is compared with MADX, and shown to be in good agreement. Requirements for the convergence of space charge computations are systematically established and when possible, tests involving space charge are compared with theoretical predictions.

THPAB207 **Beam Dynamics Simulation About the Dual Harmonic System by PyORBIT**

***H.Y. Liu**, X.Y. Feng, L. Huang, M.T. Li, X.H. Lu (IHEP CSNS) S. Wang, S.Y. Xu (IHEP)*

The space charge effect is a strong limitation in high-intensity accelerators, especially for low- and medium-energy proton synchrotrons. And for CSNS-II, the number of particles in the RCS is $3.9{\cdot}10^{13}$ ppp, which is five times of CSNS. To mitigate the effects of the strong space charge effect, CSNS-II/RCS (Rapid Cycling Synchrotron) will use a dual harmonic system to increase the bunching factor during the injection and the initial acceleration phase. For studying the beam dynamics involved in a dual harmonic RF system, PyORBIT is used as the major simulation code, which is developed at SNS to simulate beam dynamics in accumulation rings and synchrotrons. We modified parts of the code to make it applicable to the beam dynamic in RCS. This paper includes the major code modification of the Dual Harmonic RF system and some benchmark results. The preliminary simulation results

of the dual-harmonic system in CSNS-II/RCS simulated by the particle tracking code PyORBIT will also be discussed.

THPAB208 **LCLS-II Photoinjector Optimization Using Measured Transverse Laser Profiles**

***L. Berens**, N.R. Neveu (SLAC) L. Gupta (University of Chicago)*

An upgrade to the Linac Coherent Light Source (LCLS) is currently under construction (LCLS-II). Simulations of the photoinjector are used to better understand and predict beam quality under different operating conditions. These simulations, however, do not currently account for the transverse laser profile at the photocathode. We present results on using transverse laser profiles from Virtual Cathode Camera (VCC) images to optimize LCLS-II photoinjector simulations. We have used these VCC images as initial transverse particle distributions for ASTRA photoinjector simulations, as opposed to ideal particle distributions. We also present preliminary hyperparameter settings for optimization of the emittance and bunch length using NSGA-II.

THPAB209 **Tracking Complex Re-Circulating Machines With PLACET2**

***R.A.J. Costa**, A. Latina (CERN)*

We present the latest version of the multi-particle tracking package PLACET2. This software was designed to track multiple electron bunches through re-circulating machines with complex topologies, such as the recombination complex of the Compact Linear Collider (CLIC), energy-recovery linacs such as the Large Hadron-Electron Collider (LHeC), racetracks and others. This update also expands the capabilities of PLACET2 to track heavier particles such as muons. In addition to simulation, PLACET2 was also developed to allow beamline optimization scans, evaluating beam properties and tuning the beamline parameters at runtime either standalone or accessing the optimization tools present in the Octave and Python packages, with which it interfaces. This paper presents and benchmarks PLACET2's latest features, such as coherent and incoherent synchrotron radiation, long and short wakefields and power extraction.

THPAB210 **Extrapolated Range for Low Energy Electrons (< 1 keV)**

***C. Inguimbert**, M.B. Belhaj, Q. Gibaru (ONERA) Q. Gibaru, D. Lambert, M. Raine (CEA) Q. Gibaru (CNES)*

The Secondary Electron Emission (SEE) process plays an important role in the performance of various devices. Mitigating the multipactor phenomenon that may occur in radio-frequency components is a concern in many fields such as space technologies or electron microscopy. SEE is also a concern in the accelerator physics community, where the beam lines stability can strongly be affected by this phenomenon. In that scope, the escaped depth and thus the range of emitted electrons is of great interest. Our goal, by means of simulations is to provide a better knowledge of SEE. We have developed a Monte Carlo electron transport code for low energy electrons [~eV, ~10keV], that is part of the Dec. 2020 release of GEANT4. It has been used to study the practical range of low energy electrons. Our goal is to formulate, below ~10

keV, an analytic range vs. energy expression, and to relate it to fundamental physcial parameters such as the mean free paths of electrons in matter. The goal is to provide simple practical extrapolated range formula that can help to understand SEE phenomenon.

THPAB211 **Monte Carlo Simulation of 3D Surface Morphologies for Secondary Electron Emission Reduction**

***Q. Gibaru**, M.B. Belhaj, C. Inguimbert (ONERA) **Q. Gibaru**, M. Raine (CEA) **Q. Gibaru** (CNES)*

Low energy electrons of few tens of eV may cause Multipactor breakdowns in waveguides driven by the Secondary Electron Emission Yield (SEY) of the walls. This risk is lowered by using low emissive surfaces and this topic has been studied experimentally and with numerical simulations. The dependence of the SEY on surface properties is well known. Surface morphology has been widely used to reduce the SEY by forming roughness patterns on the surface. All patterns do not have the same efficiency so their analysis in terms of SEY is relevant. Monte-Carlo simulation codes can be used to study the processes behind the SEY. The MicroElec module of GEANT4 has recently been extended with more materials and processes and validated with experimental data for SEY calculations. In this work, simulation results are shown for a bulk sample capped with different roughness patterns. The effects of the shape parameters on the SEY are studied for typical dimensions between 20 µm and 100 µm. The results are checked with experimental SEY measurements on samples with similar roughness patterns.

THPAB212 **Very Thin a-C Film as e^- Cloud Suppressor**

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The interaction of particles (electrons, photons, ions) with a surface produces the emission of secondary electrons. In accelerators, the synchronization of emitted electrons with the passing beam gives rise to a resonant phenomenon called "e-cloud effect" (ECE). ECE can affect accelerator performance, inducing vacuum pressure rise, emittance growth, beam instabilities, etc. The ratio between the number of emitted electrons and the number of electrons hitting the surface is called secondary electron yield (SEY). The reduction of SEY around unity or below is at the base of the ongoing research for the mitigation of the e-cloud phenomena. Carbon coating has been proposed as an ECE mitigator having the desired SEY. Amorphous Carbon's high resistivity may impact the available impedance budget. It is, therefore, essential to reduce the coating thickness as much as possible, still granting SEY reduction. Here we report a combined study on a prototypical system of amorphous carbon (a-C) deposited on clean Cu. The data show that a remarkably thin a-C film (8-10 nm) is enough to reduce the SEY below unity and still be compliant with the most stringent impedance requirements.

THPAB214 **Recent BDSIM Related Developments and Modeling of Accelerators**

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Beam Delivery Simulation (BDSIM) is a program based on Geant4 that creates 3D radiation transport models of accelerators from a simple optical description in a vastly reduced time frame with great flexibility. It also uses ROOT and CLHEP to create a single simulation model that can accurately track all particle species in an accelerator to predict and understand beam losses, secondary radiation, dosimetric quantities and their origin. BDSIM provides a library of scalable generic geometry for a variety of applications. Our Python package, Pyg4ometry, allows rapid preparation and conversion of geometries for BDSIM and other radiation transport simulations including FLUKA. We present a broad overview of BDSIM developments related to a variety of experiments at several facilities. We present a model of the forward experiment FASER at the LHC, CERN where the geometry is composited from multiple sources using Pyg4ometry. The analysis of particle history is presented as well as production mechanisms. We also present the application of recently introduced laser interactions in Geant4 to Compton photons from a laserwire diagnostic at the ATF2.

THPAB215 **Study of the Transfer and Collimation of Low-Energy Ion Beams in the T8 Beamline of the CERN East Experimental Area**

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Due to the increasing demand for ion beams in the CERN East Area irradiation facility CHARM, a study for transfer and collimation of low energy beams in the order of hundreds of MeV/c has recently been started. A modification of the standard optics with the inclusion of an acceptance collimator is envisaged that would allow for control of the extracted intensity. The new collimator would be able to limit the emittance in both horizontal and vertical planes with the aim of reducing the intensity of the extracted beam by about two to three orders of magnitude. If the feasibility of low energy ions can be established, an additional degrader would allow for more flexibility in the beam characteristics, in particular adjusting the energy without the need for changes in the upstream accelerators, and with a potential to reach even lower energies with such a setup.

THPAB216 **Increased Transverse Instability Threshold in the IOTA Storage Ring Due to Octupoles**

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The IOTA ring is designed to suppress instabilities via the octupole magnets and a special non-linear magnet. The goal of the experiment is to demonstrate the suppression of coherent transverse beam instabilities in the IOTA ring by using the non-linear response of the octupole strings. A transverse beam feedback system (damper) was implemented to provide a controlled method to mimic a coherent beam instability. Traditional dampers are negative feedback systems used for suppressing beam oscillations resulting from coherent beam instabilities. For this experiment, the phase of the feedback is shifted by 180 to produce positive feedback or anti-damping to produce instability.

THPAB217 **Lightsource Unified Modeling Environment (Lume), a Start-to-End Simulation Ecosystem**

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SLAC is developing the Lightsource Unified Modeling Environment (LUME) for efficient modeling of X-ray free electron laser (XFEL) performance. This project takes a holistic approach starting with the simulation of the electron beams, to the production of the photon pulses, to their transport through the optical components of the beamline, to their interaction with the samples and the simulation of the detectors, and finally followed by the analysis of simulated data. LUME leverages existing, well-established simulation codes, and provides standard interfaces to these codes via open-source Python packages. Data are exchanged in standard formats based on openPMD and its extensions. The platform is built with an open, well-documented architecture so that science groups around the world can contribute specific experimental designs and software modules, advancing both their scientific interests and a broader knowledge of the opportunities provided by the exceptional capabilities of X-ray FELs.

THPAB219 **Beam Dynamics in CeC Accelerator**

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Coherent electron Cooling (CeC) has the potential to substantially reduce the cooling time of the high-energy hadrons and hence to boost luminosity in high-intensity hadron-hadron and electron-hadron colliders. Recent development in CeC cooling theory requires the accelerator to deliver high-quality electron bunches with low beam noise. In this paper, we present our design of the CeC accelerator to achieve the electron beam requirements and compare our findings with the

experimental observations.

THPAB220 **Multibunch Studies for LCLS-II High Energy Upgrade**
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The Linac Coherent Light Source (LCLS) X-ray free-electron laser at SLAC is being upgraded to LCLS-II with a superconducting linac and 1 MHz bunch repetition rate. The proposed high-energy upgrade (LCLS-II-HE) will increase the beam energy from 4 to 8 GeV, extending the reach of accessible X-ray photon energies. With the increased repetition rate and longer linac of LCLS-II-HE, multi-bunch effects are of greater concern. We use recently introduced capabilities in the beam transport code ELEGANT to study dipole and monopole beam breakup effects for LCLS-II HE beam parameters. The results indicate that resonant dipole kicks have steady-state settle times on the order of 500 bunches or less and appear manageable. We also consider a statistical variation of the cavity frequencies and transverse offsets of cavities and quadrupoles. Resonant emittance growth driven by monopole kicks is found to be disrupted by frequency variation between cavities.

THPAB221 **Multi-Objective Optimization With ACE3P and IMPACT**
D.A. Bizzozero, *J. Qiang (LBNL) L. Ge, Z. Li, C.-K. Ng, L. Xiao (SLAC)*
Photo injector design is an important consideration in the construction of next-generation accelerators. In current injector optimization, components (e.g. RF cavities) are individually shape-optimized for performance subject to requirements such as peak surface field, shunt impedance, and resonant frequency. Once these component shapes are determined, beam dynamics simulations optimize the injector lattice by adjusting parameters such as the amplitude and phase of the driving fields. However, this form of beam dynamics optimization is restricted by the fixed geometry and field profile of the components. To optimize accelerator design more generally, a coupled optimization of the cavity shape and beam parameters is required. For this coupled optimization problem, we have created an integrated ACE3P-IMPACT workflow. Within this workflow, component geometries are adjusted, field modes are computed with Omega3P (a module in the ACE3P suite), and beam dynamics are simulated with IMPACT-T. This workflow is encapsulated into a multi-objective optimization algorithm using the DEAP and libEnsemble Python libraries to yield a Pareto-optimal set of solutions for a simple injector model.

THPAB222 **Transverse Impedance Coaxial Wire Measurement in an Extended Frequency Range**
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The low energy accelerators are tend to have some instabilities especially the beam coupling impedances which comes from the interaction between the beam and accelerator components. As long as the

longitudinal impedance are important, transverse impedance determination is crucial for determine the instabilities which will affect the working efficiency of the accelerators. However due to their small amplitudes and measurement setup configuration they are hardly measurable especially in wide frequency ranges. We developed a specific setup for small diameter pieces (28-40mm) for moving and two wire transverse impedance measurements. The dipolar and quadrupolar impedance measurement even with a few Ω level up to 6 GHz for the bellows of ThomX will be presented. Also the comparison with electromagnetic simulations have been performed and can be seen for dipolar impedance measurements.

THPAB223 **Energy Compression System Radio Frequency Design at the Canadian Light Source**

***E.J. Ericson**, D. Bertwistle, M.J. Boland (CLS)*

The Canadian Light Source (CLS), Canada's only synchrotron light source, is considering a linear accelerator (LINAC) upgrade. As a result, the radio frequency (RF) structure in the downstream Energy Compression System (ECS) needs to be redesigned. In this paper, we describe the design process followed to determine the geometry of the RF structure cells and coupler.

THPAB224 **The Correction of Time-Dependent Tune Shift by Harmonic Injection**

***X.H. Lu** (IHEP CSNS) J. Chen, S. Wang, S.Y. Xu (IHEP)*

In the Rapid Cycling Synchrotron(RCS) of China Spallation Neutron Source(CSNS), transverse painting injection is employed to suppress the space-charge effects. The beta-beating caused by edge focusing of the injection bump magnets leads to tune shift. A new method based on the harmonic injection is firstly introduced to correct the time-dependent tune shift caused by the edge focusing effect of the chicane bump magnets in RCS. The simulation study was done on the application of the new method to the CSNS/RCS, and the results show the validity and effectiveness of the method.

THPAB225 **Precise Control of Three-Dimensional Beam Trajectory by an Active Shield Steering Magnet in the Solenoid Fringe Field**

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A new fundamental physics experiment, the J-PARC muon g-2/EDM experiment, is in progress to explore beyond the standard model of elementary physics. To realize a very precise measurement of the muon spin precession frequency in the level of sub-ppm, the relativistic energy of the muon beam is injected into a precisely adjusted storage magnet of sub-ppm uniformity by applying medical MRI magnet technologies. One of the major technical keys of this experiment is to perform a three-dimensional spiral injection scheme. In this presentation, how to control and guide the relativistic muon beam into a compact storage orbit of 0.66 m diameter, is discussed. A conceptual de-

sign of beam steering devices, which contains an active shield magnet that allows us to apply fine-tuning of the beam trajectory without disturbing the 3-T magnetic field in the beam storage volume, is also discussed, as well as a prototype production at the test bench.

THPAB226 **Beam Dynamic Simulations of HUST Proton Therapy Beamline Using BDSIM**

***X. Liu**, Q.S. Chen, Y.C. Liao, B. Qin, W. Wang (HUST)*

Proton therapy is now recognized as one of the most effective radiation therapy methods for cancers. A proton therapy facility with two gantry treatment rooms and one eye treatment room is under development in HUST (Huazhong University of Science and Technology). To mimic the real beam conditions in the debugging and operation, we construct an accurate beam dynamic model of the beamline using BDSIM code, which can simultaneously simulate the magnetic beam transport and particle-matter interactions. The preliminary simulation results are also presented in this paper.

THPAB227 **MACH-B: Fast Multipole Method Approaches in Particle Accelerator Simulations for the Computational and Intensity Frontiers**

***M.H. Langston**, R. Lethin, P.D. Letourneau, J. Wei (Reservoir Labs) M.J. Morse (Courant Institute of Mathematical Sciences, New York University)*

The MACH-B (Multipole Accelerator Codes for Hadron Beams) project is developing a Fast Multipole Method (FMM)-based tool for higher fidelity modeling of particle accelerators for high-energy physics within the next generation of Fermilab's Synergia simulation package. MACH-B incorporates (1) highly-scalable, high-performance and generally-applicable FMM-based algorithms to accurately model space-charge effects in high-intensity hadron beams and (2) boundary integral approaches to handle singular effects near the beam pipe using advanced quadratures. MACH-B will allow for more complex beam dynamics simulations that more accurately capture bunch effects and predict beam loss. Further, by introducing an abstraction layer to hide FMM implementation and parallelization complexities, MACH-B removes one of the key impediments to the adoption of FMMs by the accelerator physics community.

THPAB228 **Study on Laser Modulator for Electron Beam Density Modulation**

***K. Kan**, M. Gohdo, J. Yang, Y. Yoshida (ISIR)*

Ultrashort electron beams are essential for light sources and time-resolved measurements. Laser modulation using an undulator and pulsed near infrared light is expected for attosecond density modulation of electron beam. In this study, simulation of laser modulation using undulator with period length of 6.6 mm and optical pulse with a wavelength of 800 nm was performed by ELEGANT code. Simulation results of laser modulation for electron beam with an energy of 32.5 MeV will be presented from a view point of the density modulation.

THPAB229 **Energy-Binning Fast Multipole Method for Electron Injector Simulations**

***S.A. Schmid**, H. De Gersem, E. Gjonaj (TEMF, TU Darmstadt)*

In a high brilliance electron injector, small beam energy and large charge density give rise to strong space charge effects. Furthermore, a large relative energy spread during the beam generation modifies the space charge interaction between different regions of the particle bunch. Therefore, modeling the phase space evolution in an electron injector requires a numerically efficient particle tracking code that can handle space charge interactions of spatially and energetically strongly inhomogeneous particle distributions. We implemented an energy-binning scheme for a meshless fast multipole method (FMM). The energy-binning approximates the momentum distribution of the beam by assigning particles to adaptive tree structures defined at different Lorentz frames. Based on the tree structures, the FMM computes a hierarchical approximation for the space charge interaction of the particle bunch. We use the energy-binning FMM to simulate the beam generation in the photoinjector of the European XFEL developed at DESY-PITZ. Furthermore, we present numerical convergence and performance studies and compare the simulation results to direct particle-particle methods.

THPAB230 **Design of Split Permanent Magnet Quadrupoles for Small Aperture Implementation**

***I.I. Gadjev**, G. Andonian, T.J. Campese, M. Ruelas (RadiaBeam) C.C. Hall (RadiaSoft LLC)*

Permanent magnet quadrupoles are ideal for strong focusing in compact footprints. Recent research in the use of permanent magnet based quadrupole magnets has enabled very high-gradient uses approaching 800T/m in final focus systems. However, in order to achieve high quality field profiles with strong fields, small diameter bore magnets must be used necessitating in vacuum operation, or very small beampipes. For small beampipe geometry, we have developed a hybrid-permanent magnet quadrupole, with steel and permanent magnet wedges, that is able to maintain high quality fields but also readily machinable in a separable design. The split design allows for accurate and reproducible reconfiguration on a beam pipe. In this paper, we will discuss the design, engineering, fabrication and first measurements of the split permanent magnet quadrupole.

THPAB231 **A Novel Longitudinal Injection Scheme for the Diffraction Limit Storage Ring**

***K. Wang** (SARI-CAS)*

The on-axis injection scheme has been proposed with the consideration of the small dynamic aperture. The conditional on-axis injection schemes include the swap-out injection and the longitudinal injection. The former uses an accumulation ring for the beam accumulation so that additional implements are needed and the injection efficiency may be decreased with complex injection strategies. The latter

uses a short-pulse kicker to kick the injected beam into the storage ring in the longitudinal phase space separated from the stored beam, which needs a challenging ns-order pulsed kicker.

THPAB232 **Study of Nonlinear Properties of ESR via Tune Scans**
G. Franchetti *(GSI)*
The ESR storage ring at GSI is a key accelerator for the FAIR phase zero. This phase requires several highly specialized beam manipulations, which range from beam storage to deceleration of several ion species with the ultimate goal to provide intense highly charge ions to CRYRING. This plan will bring the ESR storage ring into a unique unexplored regime of accelerator operations where nonlinear dynamics, IBS, cooling, and high intensity will all become strongly interdependent. It is, therefore, necessary to acquire the best knowledge of the machine starting from its nonlinear dynamics properties. In this work, we present the development of a strategy to be used in the ESR, in which tune scans are used to explore the nonlinear properties of the accelerator. This approach is discussed with the help of simulations.

THPAB233 **Could "Flakes" of Neutral Paramagnetic or Dipolar Molecules Explain Beam Losses in the LHC?**
G. Franchetti *(GSI) F. Zimmermann (CERN)*
"Flakes" of neutral water or oxygen molecules carrying an electric or magnetic dipole moment can be attracted and trapped by the electromagnetic field of the circulating LHC proton beam. The possible presence of such flakes in the vacuum system could explain beam losses and beam instabilities encountered during the 2017 and 2018 LHC runs, and the observed effect of an external magnetic field.

THPAB235 **Detailed Electromagnetic Characterisation of HL-LHC Low Impedance Collimators**
A. Kurtulus*, C. Accentura, N. Biancacci, F. Carra, F. Caspers, N. Chitnis, F. Giordano, R. Illan Fiastre, S. Joly, I. Lamas Garcia, L. Mourier, E. Métral, S. Redaelli, B. Salvant, W. Vollenberg, C. Vollinger, C. Zannini (CERN)*
The High Luminosity Large Hadron Collider (HL-LHC) project will upgrade the LHC machine to allow operation with increased luminosity for the experiments. In order to achieve this goal, different operational parameters of the machine need to be pushed beyond the present design values, including the stored beam energy. One of the main challenges related to the achievement of the upgraded performance is the beam collimation system and its contribution to the overall machine impedance budget. In this perspective, new low impedance collimators have been designed, fabricated, and installed in the LHC. In this study, we will present their detailed electromagnetic (EM) characterization by means of radio frequency (RF) measurements and EM simulations.

THPAB236 **First Order Analytic Approaches to Modelling the Vertical Excursion Fixed Field Alternating Gradient Accelerator**

M.E. Topp-Mugglestone, *S.L. Sheehy (JAI) J.-B. Lagrange, S. Machida (STFC/RAL/ISIS)*

Whilst the Vertical Excursion Fixed Field Alternating Gradient Accelerator (VFFA) remains a promising solution to a number of problems at the frontiers of accelerator physics, the optics of this type of machine are still poorly understood. Current designers are forced to rely on brute-force numerical tracking codes, with optimisation dependent on time-consuming parameter scans. With an aim to both improve understanding of this machine, as well as to develop tools for rapid design and optimisation of VFFA lattices, first steps towards an analytic approach based on a linearised Hamiltonian formalism have been developed.

THPAB237 **Controlling Systematics in the Search of Electric Dipole Moment With the Storage Ring Using Different Methods**

A. Aggarwal *(Jagiellonian University, Marian Smoluchowski Institute of Physics, Astronomy and Applied Computer Science)*

Measurement of p/d EDM using storage rings was proposed up to the accuracy of 10^{-29} e-cm; it is necessary to consider effects that could mimic EDM signal. Elements of storage rings have complex fields, so field gradients are present. Therefore, the magnetic dipole moment and electric quadrupole moment interaction with fields and their gradients must be considered. BMAD software was modified by all the above effects and a full T-BMT equation (with field gradients) are introduced. Preliminary calculations are done for the quasi-frozen spin method. Precursor experiment using COSY storage ring aims precision of 10^{-19} e-cm. The main source of systematic error is storage ring magnets misalignment which mimics EDM signal. Method of Fourier analysis of vertical spin time dependence was developed to distinguish between EDM and misalignments signals. Magnet misalignment affects not only spin precession but also particle orbit. Steerer dipole magnets are used for orbit correction, it affects spin precession also. To investigate steerer effects on spin behavior the standard kickers were replaced by the dipole magnets. Using the Fourier method it is possible to reach 10^{-19} e-cm accuracy of EDM

THPAB238 **An Overview of the Collective Effects and Impedance Calculations for the EIC**

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A new high-luminosity Electron-Ion Collider (EIC) is being designed at Brookhaven National Laboratory (BNL). Stable operation of the electron beam at an average current of 2.5A within 1100 bunches with a 7mm bunch length is one of the challenging tasks in achieving an electron-proton luminosity of 10^{33}-1034 cm^{-2} ses^{-1} range. Beam in-

duced heating, short-range and long-range wakefield analysis is discussed for some of the vacuum components of the electron storage ring (ESR), the hadron storage ring (HSR), and the rapid cycling synchrotron (RCS) and as well as the impact of the collective effects on the beam stability.

THPAB239 **Impedance Optimization of the EIC Interaction Region Vacuum Chamber**

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The interaction region chamber has a complex geometry at the crossing location of electron and proton beam pipes. In the direction of the electron beam, the pipe is designed in a way to avoid joints with cavity characteristics. The horizontal slot on the upstream side and the tapered transition on the downstream side are applied to minimize the IR chamber contribution to the total impedance of the electron ring and to avoid generating Higher Order Modes and heating-related issues. The synchrotron radiation mask is included to protect the IR chamber from synchrotron radiation without significant aperture reduction. In the direction of the proton beam, the main area for optimization is the transition area right after the detector.

THPAB240 **Combined Effect of IBS and Impedance on the Longitudinal Beam Dynamics**

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The horizontal/vertical emittances, the bunch length, and the energy spread increase have been studied in the NSLS-II as a function of a single bunch current. The monotonic growth of the horizontal emittance dependence and the energy spread dependence on the single bunch current below the microwave instability threshold can be explained by the Intrabeam Scattering Effect (IBS). The IBS effect results in an increase in the bunch length and the microwave instability thresholds. It was observed experimentally by varying the vertical emittance. To compare with experimental data, particle tracking simulations have been performed with the ELEGANT code including both IBS and the total longitudinal wakefield calculated from the 3D electromagnetic code GdfidL. The same particle tracking simulations have also been applied for the APS-U project, where IBS is predicted to produce only a marginal effect.

THPAB241 **Examination of Semi-Analytic Model for Mode Coupling Instabilities**

M.A. Balcewicz*, Y. Hao (FRIB) M. Blaskiewicz (BNL)*

A semianalytic model for studying beams at high SC tune shift is shown. It is a generalization of SWM/ABS for an arbitrary number of longitudinal phase space cycles, yielding more realistic longitudinal

physics. The consequences of this generalization are explored; model is benchmarked against TRANFT and analytical methods.

THPAB242 **A Novel Method to Remove Timestep Limitation in Boosted Frame Simulations of Plasma Accelerators**
O. Shapoval, *R. Lehé, M. Thevenet, J.-L. Vay, E. Zoni (LBNL)*
The Lorentz-boosted frame technique can successfully speed up plasma acceleration (LWFA or PWFA) simulations with the electromagnetic particle-in-cell (PIC) method by orders of magnitude. The speedup can however be hampered if the time step of the simulation becomes limited by the Courant (aka CFL) condition when the simulation grid cell size becomes smaller in the transverse direction than in the longitudinal direction in the boosted frame of the simulation. We present a novel method that extends the Galilean PSATD algorithm to overcome this limitation while preserving accuracy, as well as stability with regard to the numerical Cherenkov instability (NCI). The details of the method will be discussed and its applications to the modeling of plasma accelerators will be presented.

THPAB243 **Optimizing Mu2e Spill Regulation System Algorithms**
A. Narayanan *(Northern Illinois University) K.J. Hazelwood, M.A. Ibrahim, V.P. Nagaslaev, D.J. Nicklaus, P.S. Prieto, B.A. Schupbach, K. Seiya, R.M. Thurman-Keup, N.V. Tran (Fermilab) H. Liu, S. Memik, R. Shi, M. Thieme (Northwestern University)*
A slow extraction system is being developed for the Fermilab's Delivery Ring to deliver protons to the Mu2e experiment. During the extraction, the beam on target experiences small intensity variations owing to many factors. Various adaptive learning algorithms will be employed for beam regulation to achieve the required spill quality. We discuss here preliminary results of the slow and fast regulation algorithms validation through the computer simulations before their implementation in the FPGA. Particle tracking with sextupole resonance was used to determine the fine shape of the spill profile. Fast semi-analytical simulation schemes and Machine Learning models were used to optimize the fast regulation loop.

THPAB244 **Design of Interdigital H-Mode Re-Buncher at KOBRA Beamline**
Y. Lee, *E.-S. Kim (KUS)*
KOrea Broad acceptance Recoil spectrometer & Apparatus (KOBRA) is an experimental facility for low energy nuclear physics in the heavy ion accelerator complex RAON. Two re-buncher systems at KOBRA beamline are required to longitudinally focus the $40Ar^{9+}$ with 27MeV/u. The normal conducting IH resonator with seven-gap as the re-buncher structure was chosen because of the reduction in the risk of particulate contamination and total power consumption. In this paper, the detailed design results of the 162.5 MHz IH re-buncher cavity will be presented.

THPAB245 **A Simulation Study of Beam Pipe Eddy Current Effects on Beam Optics**

***T. Asami**, T. Koseki (The University of Tokyo, Graduate School of Science) S. Igarashi, T. Koseki, Y. Kurimoto, Y. Sato (KEK)*

In synchrotrons, fast changes of magnetic field induce eddy currents at the wall of beam pipes. The eddy currents cause a phase delay between excitation currents of the magnets and the magnetic field. The undesired magnetic field affected by eddy currents might be a serious obstacle in controlling beam optics precisely. In fact, in the operation of a high-intensity proton synchrotron J-PARC MR, the largest beam loss is observed at the beginning of acceleration when the magnetic field starts to vary in time. Therefore, it is important to estimate and understand the effects of eddy currents on beam optics. In this study, we have calculated the effect of eddy currents on magnetic field for some magnets in J-PARC MR, using electromagnetic simulation software. In this paper, we would like to report the details and results of the simulation.

THPAB246 **Resolution Optimization for Bunch Charge Measurement in SXFEL**

***N. Zhang**, S.S. Cao, J. Chen, L.F. Hua (SSRF)*

ICT is an important routine for bunch charge measurement in the linac accelerator. There are totally 7 ICTs installed in Injector, Main accelerator, and Undulator sections in the SXFEL project, but the resolution of acquired raw signal from ICTs was not optimized as expected, because of ground-disturbing and high-frequency noise coupling from unknown sources. The amplitude of TM010 mode was employed for bunch charge measurement with a higher resolution, which was introduced from reference cavities of BAM/CBPM. The calibration of TM010 amplitude by ICT and resolution evaluation would be discussed in the paper.

THPAB247 **A Novel Electromagnetic Design for the Cavity BPM in HUST-PTF**

***J.Q. Li**, Q.S. Chen (HUST) K. Fan (Huazhong University of Science and Technology, State Key Laboratory of Advanced Electromagnetic Engineering and Technology,)*

A dedicated proton therapy facility is being developed at Huazhong University of Science and Technology (HUST-PTF). The proton beam current varies from 0.4 to 5 nA to meet the clinical requirement. High precision beam diagnostic devices are essential. However, the extremely low beam intensity is a great challenge to non-destructive beam position detection. Ionization champers can precisely monitor proton beam parameters, but it will cause beam scattering worsening beam quality, limiting their applications. To overcome this difficulty, we design a non-destructive BPM based on a dielectric-filled rectangular cavity. The cavity works in fundamental mode, and its working frequency of 146 MHz matches the second harmonic of the proton pulse rate. The output position signal with respect to different proton beam

energy has been studied and optimized thoroughly using CST code. A lock-in amplifier is proposed to improve the signal-to-noise ratio to maintain the high beam position resolution. The design studies results show that the dielectric-filled rectangular cavity is a potential candidate for non-destructive beam position detection in HUST-PTF.

THPAB248 **R&D of EOTD Bunch Length Monitor for SXFEL**
***L.F. Hua**, R.X. Yuan (SSRF)*
As one of the online single-shot and non-destructive methods with high resolution, Electro-optical (EO) techniques have been wildly used in Free Electron Laser to measure the longitudinal bunch profile. A bunch length monitor with 100 fs resolution is required for Shanghai soft Xray FEL (SXFEL) facility. The solution based on EOTD has been developed and tested during the past year. This paper will introduce the whole design according to SXFEL condition and its current progress.

THPAB249 **X-ray Beam Position Monitor (XBPM) Calibration at NSRC Solaris**
***M. Waniczek**, A. Curcio, G.W. Kowalski, R. Panaś, A.I. Wawrzyniak (NSRC SOLARIS)*
During the installation of Front-ends in sections 4th (XMCD beamline frontend) and 6th (PHELIX beamline frontend) at National Synchrotron Radiation Centre Solaris (NSRC Solaris), two units (one for each front end) of X-ray Beam Position Monitors (XBPM) have been installed as a diagnostic tool enabling for measurement of photon beam position. Hardware units of XBPM were manufactured, delivered, and eventually installed in Solaris by FMB Berlin. In order to get readouts of beam position from XBPM units, Libera Photon 2016 controller has been used as a complementary electronic device. Since XBPM units are supposed to be used along with the insertion device, an on-site Libera calibration was necessary. Libera's calibration required few iterations of scans involving gap and phase movement of insertion devices at the 4th and 6th sections of the Solaris ring. The main focus was put on the derivation of Kx, and Ky coefficients. The content of this document describes step by step the procedure of Libera's Kx, Ky coefficients value derivation at NSRC Solaris.

THPAB250 **Fire Detection System Reliability Analysis and Operational Data-Based Framework**
***M.M.C. Averna**, G. Gai (CERN)*
This paper describes a framework developed at CERN, conducting reliability analysis of Safety-Critical Systems (Fire detection and Alarms) based on operational data. It applies Fault-Tree Analysis on maintenance-related data, categorized based on the component on failure. This framework, a tool implemented in Python, accounts for Fire Detection components installed in tunnels and surface buildings (control panels, detectors, etc) and safety functions triggered upon detection (evacuation, alarms to the CERN Fire Brigade, compartmentalization, electrical isolation, etc). The usefulness of the results of

this type of analysis is twofold. Firstly, the results are a supporting tool for estimating the yearly availability of Fire Detection Systems in critical facilities, crucial in Capital and Operational Expenditure identification. Additionally, this approach refines the frequency analysis as part of quantitative fire risk assessments performed in the context of the FIRIA (Fire-Induced Radiological Integrated Assessment) Project, launched by CERN in 2018 and aiming at assessing the risk of fire events in experimental facilities with potential radiologic consequences to the public.

THPAB251 **Efficient Terahertz Generation by Tilted-Pulse-Front Pumping in Lithium Niobate for the Split-Ring Resonator Experiment at FLUTE**

***M. Nabinger**, E. Bründermann, S. Funkner, B. Härer, A.-S. Müller, M.J. Nasse, G. Niehues, R. Ruprecht, J. Schaefer, T. Schmelzer, N.J. Smale (KIT) M.M. Dehler, R. Ischebeck, M. Moser, V. Schlott (PSI) T. Feurer, M. Hayati, Z. Ollmann (Universität Bern, Institute of Applied Physics)*

A compact, longitudinal diagnostics for fs-scale electron bunches using a THz electric-field transient in a split-ring resonator (SRR) for streaking will be tested at the Ferninfrarot Linac- Und Test- Experiment (FLUTE). For this new streaking technique, intensive THz pulses are required, which will be generated by laser-based optical rectification. We present a setup for generating THz pulses using tilted-pulse-front pumping in lithium niobate at room temperature. Excited by an 800 nm Ti:Sa pump laser with 35 fs bandwidth-limited pulse length, conversion efficiencies up to 0.027% were achieved. Furthermore, the status of the SRR experiment is shown.

THPAB252 **Machine Learning for Improved Availability of the SNS Klystron High Voltage Converter Modulators**

***G.C. Pappas** (ORNL RAD) D. Lu (ORNL) M. Schram (JLab) D.L. Vrabie (PNNL)*

Beam availability has increased at the SNS, however, the targeted availability is greater than 95 %, while the SNS has failed to meet lower targets in the past. The HVCM used to power the linac klystrons have been one source of lost beam time and was chosen to explore using AI/ML techniques to improve reliability. Among the possibilities being explored are automating the tuning of HVCMs and predicting component failures such as capacitor aging, rectifier assemblies containing hundreds of diodes, and insulating oil degradation. The methodology pursued includes data cleaning, de-noising, post-analysis data labeling, and machine learning model development. We explore using Long Short-Term Memory and autoencoders for anomaly detection and prognostication used to schedule maintenance. We evaluate the use of model regularizers and constraints to improve the performance of the model and investigate methods to estimate the uncertainty of the models to provide a robust prediction with statistical interoperability. This paper describes the operational experience and known

failures of the HVCMs and the proposed ML methodology and the preliminary results of training the AI/ML algorithms.

THPAB253 **Commissioning of GSI Data Archiving and Retrieving**
M. Bai, *R. Bär, J. Fitzek, W. Geithner, F. Herfurth, V. Rapp (GSI) A. Debenjak, J. Strnisa (Cosylab)*
While the FAIR accelerators are still under construction, the FAIR controls have been implemented throughout the GSI circular accelerators including the beamlines. Hence, the FAIR data archiving is now available for the GSI accelerator operation to log critical and essential system as well as beam performance data. In order to assist the extraction of the logged data from the FAIR Archiving system, GSI and CosyLab co-developed a GUI application, i.e. Data Archiving ViEwer (D.A.V.E). In this paper, the functionality and design will be reported. The results from the latest commissioning with beam will also the presented.

THPAB255 **An Electro-Optic Sampling Beam Position Monitor**
K.D. Hunt-Stone, *R. Ariniello, C.E. Doss, V. Lee (CIPS) M.D. Litos (Colorado University at Boulder)*
Beam-driven plasma wakefield accelerators (PWFAs) utilize a two bunch electron beam structure propagating through plasma where the leading drive bunch creates a wakefield in a plasma resulting in an exceptionally strong longitudinal electric field that accelerates the trailing witness bunch. Two critical parameters for experimental success are the longitudinal separation of the electron bunches, where the accelerating gradient is sensitive to ~10 fs changes, and the transverse separation of the two bunches, where the witness bunch's transverse emittance is sensitive to ~1-micron offsets. We present an electro-optic sampling beam position monitor (EOS-BPM) capable of diagnosing these parameters at the required resolution. Simulation work utilizing a realistic electron beam profile for upcoming experiments at SLAC national laboratory shows that EOS-BPM is capable of providing these critical measurements at the required sensitivity. Preliminary experimental data from the first EOS-BPM deployed at SLAC's FACET-II user facility gives proof-of-concept for the detector.

THPAB256 **Analysis of Multi-Bunch Instabilities at Alba Using a Transverse Feedback System**
U. Iriso, *T.F. Günzel (ALBA-CELLS Synchrotron)*
Since 2015 Alba is equipped with a transverse bunch by bunch feedback system, which not only damps the transverse coupled bunch instabilities in the machine but also allows the characterization of the multi-bunch instabilities of the storage ring. This characterization is produced by an internal sequence, which is programmed to excite and measure the growth and damping rates of each of the multi-bunch modes. This paper describes the measurement technique, presents the studies carried out to characterize the machine and different movable systems like the scrapers or in-vacuum undulators. Results are compared with the transverse impedance spectra obtained from computer simulations.

THPAB257 **Fast Orbit Corrector Power Supply in MTCA.4 Form Factor for Sirius Light Source**

***A.F. Giachero**, G.B.M. Bruno, L.M. Russo, D.O. Tavares (LNLS)*

A new fast orbit feedback (FOFB) hardware architecture has been pursued at Sirius. The fast corrector magnets' are fed by power supply modules which are placed in the same MicroTCA.4 crates where the BPM digitizers and FOFB controllers are located. Each channel is made of a 3-Watt linear amplifier whose output currents are digitally controlled by the same FPGA where the distributed orbit feedback controller is processed. The amplifier is specified to reach up to 10 kHz small-signal bandwidth on a 3.5 mH inductance magnet and ±1 A full scale, which translates to 30 urad deflection on Sirius' 3 GeV beam. Such a high level of integration aims at minimizing the overall latency of the FOFB loop while leveraging the crate infrastructure, namely electronics enclosure, DC power, cooling, and hardware management support already provided by the MTCA.4 crates. The fast corrector power supply channels are placed on Rear Transition Modules (RTMs) which are attached to the front AMC FPGA module where the FOFB controller is implemented. This paper will describe the main design concepts and report on the experimental results of the first prototypes.

THPAB258 **Status of Time-Domain Simulation for Fast Orbit Feedback System at the HEPS**

***Y. Wei**, Z. Duan, X.Y. Huang, Y. Jiao (IHEP)*

High Energy Photon Source (HEPS) is a complex designed at ultra-low emittance. A fast orbit feedback system is proposed to meet the requirement of beam orbit stability at the sub-micron level. In this paper, we present our work on setting up an orbit feedback process combined with noise model, system modeling, and particle tracking in the time domain. RF phase parameter is adjusted together with fast correctors to mitigate the orbit fluctuation due to energy vibration. The preliminary results are shown here. By the following optimization, we hope to provide an effective tool to specify and configure the FOFB system with the simulation.

THPAB259 **High Level Applications for Sirius Accelerators Control**

***A.C.S. Oliveira**, M.B. Alves, L. Liu, X.R. Resende, F.H. de Sá (LNLS)*

Sirius is a 4th generation 3 GeV synchrotron light source that has just finalised the first commissioning phase at the Brazilian Center for Research in Energy and Materials (CNPEM) campus in Campinas, Brazil. The large number of process variables and large complexity of the subsystems in this type of machine requires the development of tools to simplify the commissioning and operation of the accelerators. This paper describes some of the high level control tools developed for the accelerators commissioning and future operation.

THPAB260 **Detection and Classification of Collective Beam Behaviour (i.e. Collective Beam Instabilities) in the LHC**

***L. Coyle**, F. Blanc, T. Pieloni, M. Schenk (EPFL) X. Buffat, M. Solfaroli Camillocci, J. Wenninger (CERN) E. Krymova, G. Obozinski (SDSC)*

Collective instabilities can lead to a severe deterioration of beam quality, in terms of reduced beam intensity and increased beam emittance, and consequently a reduction of the collider's luminosity. It is therefore crucial for the operation of the CERN's Large Hadron Collider to understand the conditions in which they appear in order to find appropriate mitigation measures. Using bunch-by-bunch and turn-by-turn beam amplitude data, courtesy of the transverse damper's observation box (ObsBox), a novel machine learning based approach is developed to both detect and classify these instabilities. By training an autoencoder neural network on the ObsBox amplitude data and using the model's reconstruction error, instabilities and other phenomena are separated from nominal beam behaviour. Additionally, the latent space encoding of this autoencoder offers a unique image like representation of the beam amplitude signal. Leveraging this latent space representation allows us to cluster the various types of anomalous signals.

THPAB261 **NuMI Beam Monitoring Simulation and Data Analysis**

***Y. Yu** (IIT) P. Snopok (Illinois Institute of Technology) D.A. Wickremasinghe, K. Yonehara (Fermilab)*

With the Main Injector Neutrino Oscillation Search (MINOS) experiment decommissioned, muon and hadron monitors became an important diagnostic tool for the NuMI Off-axis ν_μ Appearance (NOvA) experiment at Fermilab to monitor the Neutrinos at the Main Injector (NuMI) beam. The goal of this study is to maintain the quality of the monitor signals and to establish correlations with the neutrino beam profile. And we carry out a systematic study of the response of the muon monitors to the changes in the parameters of the proton beam and lattice parameters. We report here on the progress of the beam data analysis and comparison with the simulation results.

THPAB262 **Using Machine Learning Techniques for Optimizing Production at the Facility for Rare Isotope Beams**

***S.M. Lidia**, Y. Hao, T. Maruta, A.S. Plastun, T. Zhang (FRIB) S. Biedron (Element Aero)*

The Facility for Rare Isotope Beams will begin user operations in late 2021. As an intensity-frontier facility for heavy ions, many challenges exist to maintain high scientific productivity and facility reliability. Employing machine learning techniques will be critical in several areas: (i) establishing new tunes and operating modes of the linac and transport lines that demand multi-charge state operation and fast turnaround times for experiments; (ii) creating virtual diagnostics to observe longitudinal and transverse distributions at lattice matching points; (iii) predicting and monitoring performance of the high power

beam target and final focus optics; (iv) analysis of the beam loss monitor network response for machine protection; and (v) establishing agents and procedures to assist with tuning the rare isotope fragment separator. We discuss the utilization of multiple techniques in supervised and unsupervised learning, anomaly detection, and principal component analyses. Considerations of training methods, as well as distributed and edge computing will also be addressed.

THPAB263 **Wave Optics Simulation for Performance of Soft X-Ray Nanoprobe Beamline**

K.R. Tian *(Ward Melville High School)*

Wave optic simulations allow scientists to observe how beamline properties, specifically degree of coherence and intensity, perform while changing specific parameters. The Soft X-ray nanoprobe Beamline under development at the National Synchrotron Light Source II in Brookhaven National Laboratory aims to have resolution better than 10 nm using zone plate and lensless coherent imaging techniques; it offers flexible tradeoffs between flux and resolution to enable a wide variety of scanning and coherent imaging techniques over a wide energy range. In order to accurately simulate the performance of the SXN, the online Synchrotron Radiation Workshop (SRW) Sirepo computer code was used to change the position of the zone plate center and the energy bandwidth to observe the effect on the beamline's degree of coherence and intensity. The results indicate that the beamline can make a fully coherent beam for the zone plate from a 0 - 800 μm shift, but over a 1 mm shift the beam is no longer fully coherent. The results indicate that for the 0.1 eV energy bandwidth the error bar reaches 1% when over 10,000 particles are used, and becomes 0.5% when over 15,000 particles are used at 0 eV.

THPAB264 **FOFB System Upgrade to ZynqMP FPGA with Fast ORM Measurement**

S. Chen*, Y.E. Tan (AS - ANSTO)*

The FOFB processor has been ported from a Vertex 6 FPGA to a ZynqMP SoC (System on Chip) to provide additional resources to include a system to inject sinusoidal and pink noise through the feedback loop. The amplitude, duration, phase, and frequency of sinusoidal, amplitude, and duration of pink noise are user-programmable.

THPAB265 **New RF BPM Electronics for the 560 Beam Position Monitors of the APS-U Storage Ring**

P. Leban*, L. Bogataj, M. Cargnelutti, U. Dragonja, P. Paglovec (I-Tech) A.R. Brill, J. Carwardine, W.X. Cheng, N. Sereno (ANL)*

Within the upgrade of the APS storage ring to a multi-bend achromat lattice, 560 RF Beam Position Monitors will be required. The projected beam sizes are below 10 microns in both horizontal and vertical planes, putting stringent requirements on the BPM electronics resolution, long-term stability, beam current dependency, and instrument reproducibility. For the APS-U project, the Libera Brilliance^{+} instrument has been upgraded in technology and capabilities, including the

independent multi-bunch turn-by-turn processing and an improved algorithm to further reduce the crossbar-switch artifacts. More than 140 instruments, equipped with 4 BPM electronics each, are being delivered to Argonne National Laboratory, consisting of the largest scale production for Instrumentation Technologies. In this contribution, the extensive test conditions to which the instruments were exposed and their results will be presented, as well as the beam-based long-term drift measurements with different fill patterns.

THPAB266 **Accurate Uncertainty Quantification for Active Learning for Parameter Tuning in Particle Accelerators**

S. Zhao, *S. Ermon, D.F. Ratner (Stanford University) , A.A. Mishra, D.F. Ratner (SLAC)*

Particle accelerators have found uses in various medicine, industrial and scientific applications. To cater to the needs of these diverse applications, the controllable settings of the accelerators need to be optimized to engender the required beam shape, energies, etc. Presently, this process relies on manual tuning and simplified analytic relations, which is often inefficient and can fail to find the optimal parameter settings. Active learning can automatically optimize accelerator parameters but requires a surrogate prediction model with accurate uncertainty estimation. In this investigation, we utilize conformal prediction and calibration techniques to provide accurate uncertainty estimation for existing prediction models such as deep networks. This leads to improved active learning performance. Based on tests on the SPEAR3 storage ring, we show that our algorithm requires fewer trials compared to traditional tuning approaches and leads to robust parameter settings. Additionally, we illustrate that this framework exhibits efficacy for different accelerator designs and settings.

THPAB267 **Reliable Uncertainty Estimation for Deep Learning in Particle Accelerator Problems**

A.A. Mishra, *A.L. Edelen, C.E. Mayes (SLAC)*

With the advent of increased computational resources and improved algorithms, machine-learning-based models are being increasingly applied to complex problems in particle accelerators. However, such data-driven models may provide overly confident predictions with unknown errors and uncertainties. For reliable deployment of machine learning algorithms in high-regret and safety-critical systems such as particle accelerators, we also need interval estimates that reflect the uncertainty in predictions. We evaluate Bayesian Neural Networks as an approach that can provide accurate predictions along with reliably quantified uncertainties for particle accelerator problems. We select problems across different designs of linac-based accelerators. Furthermore, the problems span diverse data volumes and varying dimensionalities of data formats, for instance, scalar predictions as well as high-dimensional image outputs. It is found that Bayesian Neural Networks provide accurate predictions of the mean along with reliable and calibrated estimates of predictive uncertainty across the test cases.

THPAB268 **Hierarchical Intelligent Real-Time Optimal Control for LLRF Using Time Series Machine Learning Methods and Transfer Learning**

R. Pirayesh, *S. Biedron, S. Biedron, J.A. Diaz Cruz, M. Martinez-Ramon (University of New Mexico) J.A. Diaz Cruz (SLAC)*

Machine learning (ML) has recently been applied to Low-level RF (LLRF) control systems to keep the voltage and phase of Superconducting Radiofrequency (SRF) cavities stable within 0.01 degree in phase and 0.01% amplitude as constraints. Model predictive control (MPC) uses an optimization algorithm offline to minimize a cost function with constraints on the states and control input. The surrogate model optimally controls the cavities online. Time series deep ML structures including recurrent neural network (RNN) and long short-term memory (LSTM) can model the control input of MPC and dynamics of LLRF as a surrogate model. When the predicted states diverge from the measured states more than a threshold at each time step, the states' measurements from the cavity fine-tune the surrogate model with transfer learning. MPC does the optimization offline again with the updated surrogate model, and, next, transfer learning fine-tunes the surrogate model with the new data from the optimal control inputs. The surrogate model provides us with a computationally faster and accurate modeling of MPC and LLRF, which in turn results in a more stable control system.

THPAB269 **Compton Spectrometer for FACET-II**

B. Naranjo, *G. Andonian, A. Fukasawa, W.J. Lynn, N. Majernik, J.B. Rosenzweig, Y. Sakai, O. Williams, M. Yadav, Y. Zhuang (UCLA)*

We present the design of a Compton spectrometer for use at FACET-II. A sextupole is used for magnetic spectral analysis, giving a broad dynamic range (180 keV through 28 MeV) and the capability to capture an energy-angular double-differential spectrum in a single shot. At low gamma energies, below 1 MeV, Compton spectroscopy becomes increasingly challenging as the scattering cross-section becomes more isotropic. To extend the range of the spectrometer down to around 180 keV, we use a 3D-printed tungsten collimator at the detector plane to preferentially select forward-scattered electrons at the Compton edge.

THPAB270 **Pair Spectrometer for FACET-II**

B. Naranjo, *G. Andonian, A. Fukasawa, N. Majernik, M.H. Oruganti, J.B. Rosenzweig, Y. Sakai, O. Williams, M. Yadav (UCLA)*

We present the design of a pair spectrometer for use at FACET-II, where there is a need for spectroscopy of photons having energies up to 10 GeV. Incoming gammas are converted to high-energy positron-electron pairs, which are then subsequently analyzed in a dipole magnet. These charged particles are then recorded in arrays of acrylic Cherenkov counters, which are significantly less sensitive to background x-rays than scintillator counters in this case. To reconstruct energies of single high-energy photons, the spectrometer has a sensitiv-

ity to single positron-electron pairs. Even in this single-photon limit, there is always some low-energy continuum present, so spectral deconvolution is not trivial, for which we demonstrate a maximum likelihood reconstruction. Finally, end-to-end simulations of experimental scenarios, together with anticipated backgrounds, are presented.

THPAB271 **Jefferson Lab LLRF 3.0 Development and Tests**
***T.E. Plawski**, R. Bachimanchi, H. Higgins, C. Hovater, J. Latshaw, C.I. Mounts, D.J. Seidman, J. Yan (JLab)*
The Jefferson Lab LLRF 3.0 system is being developed to replace legacy LLRF systems in the CEBAF accelerator. The new design builds upon 25 years of design and operational RF control experience, and our recent collaboration in the design of the LCLSII LLRF system. The new cavity control algorithm is a fully functional phase and amplitude locked Self Exciting Loop (SEL). This paper discusses the progress of the LLRF 3.0 hardware design, FPGA firmware development, User Datagram Protocol (UDP) operation, and recent LLRF 3.0 system tests on the CEBAF Booster cryomodule in the Upgrade Injector Test Facility (UITF).

THPAB272 **Validation of Two Rebuncher Cavities Under High Beam Loading for LIPAc**
***D. Gavela**, I. Podadera, F. Toral (CIEMAT) I. Moya (Fusion for Energy) F. Scantamburlo (IFMIF/EVEDA)*
Two re-buncher cavities were installed at the Medium Energy Beam Transport line of the LIPAc accelerator, presently being commissioned at Rokkasho (Japan). They are IH-type cavities with five gaps providing an effective voltage of 350 kV at 175 MHz for a nominal operation of 125 mA CW deuterons at 5 MeV. After full conditioning and beamline integration in Europe, the cavities were installed in the accelerator with special care given to the alignment with respect to the rest of the components. The RF line, cooling circuits, and instrumentation were also mounted. The cavities were operated with an FPGA-based LLRF system. A re-conditioning of the cavities was performed in the first place, followed by tests with a pulsed beam with increasing currents. A maximum pulsed beam current of 100 mA was reached while operating the buncher cavities, under which they reached voltages up to 340 kV and 260 kV respectively. As expected, the beam loading was significant, leading to a series of difficulties and required strategies for a good operation that are discussed in this paper. The effect on the beam dynamics, measured by beam position monitors downstream of the bunchers is also discussed.

THPAB273 **Spectral Reconstruction for FACET-II Compton Spectrometer**
***Y. Zhuang**, B. Naranjo, J.B. Rosenzweig, M. Yadav (UCLA)*
The Compton spectrometer under development at UCLA for FACET-II is a versatile tool to analyze gamma-ray spectra in a single shot, in which the energy and angular position of the incoming photons are recorded by observing the momenta and position of Compton scattered electrons. We present methods to reconstruct the primary spec-

trum from these data via machine learning and the EM Algorithm. A multi-layer fully connected neural network is used to perform the regression task of reconstructing both the double-differential spectrum and the photon energy spectrum incident with zero angular offset. We present the expected performance of these techniques, concentrating on the achievable energy resolution.

THPAB274 **Short Pulsed Beam Extraction in KURNS FFA**
***T. Uesugi**, Y. Ishi, Y. Kuriyama, Y. Mori (Kyoto University, Research Reactor Institute)*
Aiming the rms length of ~10 ns, short-pulsed beam extraction is tried in FFA Accelerator at KURNS. A bunched beam at flat top energy was shortened by means of bunch rotation after adiabatic damping and then trimmed with the rising edge of the extraction kicker.

THPAB275 **Hollow Electron Gun Tests at Electron Beam Test Stand**
***S. Sadovich**, A. Rossi (CERN)*
The electron beam test stand at CERN aims at studying electron beam dynamics and testing components for the HL-LHC Hollow Electron Lenses, in particular the electron gun and anode modulator, the collector, and the electron beam diagnostics (beam position monitor and beam gas curtain monitor). This paper presents an overview of the electron beam test stand and the first experimental results obtained during commissioning. The measured electron beam profile and electron current as a function of the filament temperature and gun extraction voltage are compared with simulations performed with CST.

THPAB276 **X-Ray Double Slit Interferometer Progress at CLS**
***N.A. Simonson**, Y. Yousefi Sigari (University of Saskatchewan) M.J. Boland (CLS)*
The Canadian Light Source (CLS) is a 3rd generation synchrotron that is used to produce extremely bright synchrotron light that can be used for research. The light at the CLS is produced by an electron storage ring that has an emittance of 20 nm. A 4th generation synchrotron (CLS2) is planned which will reduce the emittance to less than 1 nm and thus reduce the transverse beam size significantly, making it very challenging to measure. A double slit interferometer can be used to measure small transverse beam sizes, as first described by Mitsuhashi. An x-ray double slit interferometer will be designed and tested at the current CLS with the goal of using this setup at CLS2.

THPAB278 **Frequency Response Analysis of SiO_2 Thin Film in Iris Diaphragm Electron-Beam Apparatus Series**
***J.R. Callahan**, A. Liu, Y. Zhao (Euclid TechLabs, LLC)*
Euclid Techlabs has been designing and testing a cost-effective iris diaphragm beam halo/profile detector that can be configured to measure various beam energies. Some of the device parts include four iris blades which consist of sputtered SiO_2 thin films that insulate the blades where they come into contact with one another. These iris blades are opened and closed through actuation to allow most of the

electron beam to pass through a gap between the blades with the outer edges of the beam contacting the iris blades. Electron beam profiles are measured when the beam strikes the iris blades which then transmit a signal characterizing the beam properties. In order to better understand the insulation properties of these thin films, the response of an electric signal across the thin film at various frequencies must be measured and analyzed. Understanding the frequency response of SiO_2 thin films will provide valuable insight into the sensitivity and function of the iris diaphragm beam halo/profile detector.

THPAB279 **Adaptive Neural Network Based Online Modeling and Model-based Control for SLAC's Accelerators**

***A.L. Edelen**, C. Emma, J.R. Garrahan, A. Hanuka, C.E. Mayes, A.A. Mishra, N.R. Neveu, B.D. O'Shea, H.H. Slepicka (SLAC) L. Gupta (University of Chicago)*

The controllable settings of particle accelerators are adjusted online to fulfill requests for custom beam characteristics. Physics-based simulations can aid this process, but these are often too computationally intensive to execute online and may not capture the empirical accelerator behavior accurately enough for reliable use in control. In addition, myriad sources of uncertainty complicate the modeling process. Models based on machine learning can help circumvent these limitations, but they can be challenging to use in practice for large or frequently varying parameter spaces. Here we describe recent results from SLAC in using neural network surrogate models for online prediction of accelerator responses, rapid online optimization, and online model adaptation to machine changes. We describe our results for present challenges, including combining both measured data and data from physics simulations, reliability of online retraining, and uncertainty estimation for widely varying parameter spaces. Finally, we describe an open-source software framework for easy deployment of new models on the EPICS control system, including auto-generation of control room GUIs from model metadata.

THPAB280 **Simulate an Optical System for Measuring Beam Size With Python**

***S.S. Jin**, B.G. Sun (USTC/NSRL)*

In the storage ring, the beam emittance is one of the important parameters to measure the beam quality. The emittance can be obtained by measuring the beam size and combining the Twiss parameters. In the fourth-generation light source, the beam size is very small, it is necessary to develop a high-resolution beam-size measurement system. The optical-based measurement scheme has its advantages due to its non-destructive, good real-time performance, and high resolution. In summary, the topic is to measure the beam size based on optical design schemes, including synchrotron imaging systems, synchrotron interference systems, etc. We use Python code to simulation the optical system and get the appropriate final results.

THPAB281 **Online Model for the CLARA Accelerator at Daresbury Laboratory**

M.P. King, *A.D. Brynes, H.M. Castañeda Cortés, J.K. Jones, B.D. Muratori, T.H. Pacey (STFC/DL/ASTeC)*

We present an initial version of an online model for CLARA at Daresbury Laboratory. The online model is a PyQT5-based GUI providing an interface to the Python SimFrame optimization package. The GUI integrates particle tracking in multiple codes, plotting of various common accelerator quantities, and multi-dimensional parameter scanning. A database backend supplies historical results and allows sections of earlier runs to be re-used, speeding up analysis. The paper will detail the ideas behind the online model, together with the programs used. A logical approach to accelerator optimization through parameter scanning is detailed, giving an improved physical insight together with the possibility to make practical compromises whenever needed. Examples of applications on the CLARA accelerator, and some initial comparisons between the model and measurements, will also be discussed.

THPAB282 **Optimization Design of Four-Point Vibration Isolation Support for Spallation Neutron Source Vibration Magnet**

J.S. Zhang, *J.X. Chen, H.Y. He, L. Liu, R.H. Liu, C.J. Ning, G.Y. Wang, A.X. Wang, J.B. Yu, Y.J. Yu, D.H. Zhu (IHEP CSNS) L. Kang (IHEP)*

Chinese spallation neutron source (CSNS) RCS of the dipole magnets by 25 Hz sinusoidal alternating current (AC) with dc bias field, because the magnet will produce eddy current effect caused by the vibration, this safe and reliable operation of the long-term impact of magnets, so need to CSNS/RCS dipole magnets, a support system for dynamic characteristic research and the performance of vibration isolation design. The mechanical model of ac dipole magnet and support system is first established, and ANSYS theoretical modal analysis and experimental modal verification are carried out. On this basis, vibration isolation parameters of the four-point support system are studied. The theoretical analysis and the experimental results of modal parameters are consistent, which shows that the ANSYS analysis model is correct and reliable. The dynamic system parameter design method established in this paper can be applied to various equipment of AC power accelerator. The final experimental verification shows that the total displacement amplitude of the isolator to the Y direction of the magnet on the magnetic support decreases by 62.3%.

THPAB283 **3D Radiation Tolerant Diamond Detector for High-Rate Charged Particle Tracking**

I.V. Ponomarev *(Euclid TechLabs, LLC)*

The particle collision rates in future HEP experiments will be one order of magnitude higher, imposing severe radiation tolerance on the performance of the tracking detectors which is already pushing technology. We addressed the current limitations by developing a diamond

detector technology based on 3D conducting structures that combines the inherent advantages of diamond material (high radiation tolerance and thermal conductivity, very short charge collection time, low leakage currents) with advanced 3D femtosecond laser writing capabilities of micrometer-scale conductive graphitic structures fabrication inside bulk diamond substrates. This technology allows the creation of arbitrary 3D geometries for electrodes embedded inside the insulating diamond. Moreover, the electrodes and wiring can be optimized for a specific application. For example, sub-surface wiring allows the relocation of surface high voltage (HV) connections inside the insulating diamond matrix providing HV immunity. Multiple column connections inside the material can also improve the electric field distribution inside cells and readout channel resistances improving space and time resolutions.

THPAB284 **Analytical and Numerical Characterization of Cherenkov Diffraction Radiation as a Longitudinal Electron Bunch Profile Monitor for AWAKE Run 2**

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In this paper, CST simulations of the coherent Cherenkov Diffraction Radiation with a range of parameters for different dielectric target materials and geometries are discussed and compared with the theoretical investigation of the Polarization Current Approach to design a prototype of a radiator for the bunch length/profile monitor for AWAKE Run 2. It was found that the result of PCA theory and CST simulation are consistent with each other regarding the shape of the emitted ChDR cone.

THPAB285 **A Low Frequency Vibration Sensor Using Capacitive and Optical Measurement**

***A. Dominjon**, B. Aimard, G. Balik, L. Brunetti, M. Serluca (IN2P3-LAPP) B. Caron (SYMME)*

In particle physics, vibration mitigation is a critical issue for many experiments. In this context, the R&D accelerator group at LAPP developed a dedicated sensor for future colliders like CLIC (Compact Linear Collider) or FCC-ee to optimize the collision condition at the interaction point. For example, CLIC specifications require stabilization of the final focus quadrupole motion to a value of 0.2 nm RMS at 4 Hz. Using our homemade sensors and an active vibration control system, we manage to damp the ground motion by a ratio of 10 in the 3-70 Hz frequency range leading to an RMS value of 0.26 nm at 4 Hz. This result, presented in IPAC17, validates the principle of the developed sensor but shows as well that the performance boundary is the measurement done by a capacitive gauge of the internal mass differential motion. To overcome this technical limit, a simultaneous comparison test in the sensor is performed with three optical measurements:

one optical encoder and two interferometers (one single-pass and one multi-pass). The aim is to determine the most adapted technology for such vibration inertial sensors dedicated to the CLIC sub-nanometer vibration active control.

THPAB286 **Quadrupole Focusing Lenses for Heavy Ion Linac**
***T. Kulevoy**, A.V. Kozlov, G. Kropachev, D.A. Liakin, O.S. Sergeeva, V.S. Skachkov, V. Skachkov, Yu. Stasevich (ITEP)*
Simulation results of pulsed current electromagnet quadrupoles with integral of the magnetic field gradient up to 7 T are presented. Magnets for the DTL and MEBT focusing channels are designing for the heavy-ion linac in Institute for Theoretical and Experimental Physics (ITEP - NRC "Kurchatov Institute"). Appropriate conditions which promise getting the magnetic lens parameters required at restrictions on the overall length <130 mm as well as on the beam aperture >45 mm are defined. It is shown that the channel acceptance to beam emittance ratio desired not less than 3 can be provided by conventional low-carbon steel up to a magnetic aperture of 50 mm in diameter while beyond this size permendur is out of competition. Some aspects of the pulsed power supply system are considered and main parameters of the pulse current generator (PCG) are given.

THPAB287 **Providing Computing Power for High Level Controllers in MicroTCA-based LLRF Systems via PCI Express Extension**
***P. Nonn**, A. Eichler, S. Pfeiffer, H. Schlarb, J.H.K. Timm (DESY)*
It is possible to connect the PCIe bus of a high performance computer to a MicroTCA crate. This allows the software on the computer to communicate with the modules in the crate, as if they were peripherals of the computer. This article will discuss the use of this feature in respect to accelerator control with a focus on High Level Controllers.

THPAB289 **Design and Manufacture of Solenoid Center Deviation Measurement Device**
***X. Wu** (IHEP)*
The solenoids are widely used both in conventional magnets and superconducting magnets in particle accelerators. The longitudinal fields along the longitudinal direction of the solenoids are usually measured with the Hall probe measurement system. However, in some cases, the deviation between the magnetic center and mechanical center of the solenoid is another important parameter and has to be measured accurately. In this paper, a device is designed and developed to measure the center deviation of the solenoid, which can be both used in conventional magnets and superconducting magnets. After the device is finished, some tests are made in the solenoid to check whether the data is correct. For the numerical simulation and analysis of the magnetic field inside the solenoid, the TOSCA code was chosen right from start. The results of the analysis are compared to the result of the tests.

THPAB290 **Evolution of the LHC Beam Screen Surface Conditioning Upon Electron Irradiation**

***S. Bilgen**, S. Della-Negra, D. Jacquet, B. Mercier, I. Ribaud, G. Sattonnay (Université Paris-Saclay, CNRS/IN2P3, IJCLab) V. Baglin (CERN)*

For the vacuum scientists and the accelerator community, finding solutions to mitigate pressure rises induced by electron, photon, and ion desorption, and also beam instabilities induced by ion and electron clouds is a major issue. Moreover, it is worth noting that the OFE copper beam screen of the LHC is initially cleaned with standard industrial processes, leading to residual chemical contamination. Along the time, changes in the surface chemistry of vacuum chambers are observed during beam operations, leading to modifications of outgassing rates, stimulated desorption processes, and secondary emission yields (SEY). The impact of ions on molecule desorption and electron production was investigated to identify their influence on the global pressure rises and to quantify the ion conditioning effect on copper surfaces: (i) SEY evolution was measured to understand the changes of surface conditioning upon particle irradiation; (ii) surface chemistry evolution after electron irradiation was investigated by both XPS and TOF-SIMS analyses using the ANDROMEDE facility at IJCLab. Finally, the relationship between surface chemistry and the conditioning phenomenon will be discussed.

THPAB291 **DYVACS(DYnamic VACuum Simulation) Code: Gas Density Profiles in Presence of Electron Cloud in the LHC**

***S. Bilgen**, B. Mercier, G. Sattonnay (Université Paris-Saclay, CNRS/IN2P3, IJCLab) V. Baglin (CERN)*

The computation of residual gas density profiles in particle accelerators is an essential task to optimize beam pipes and vacuum system design. In a hadron collider such as the LHC, the beam induces dynamic effects due to ion, electron, and photon-stimulated gas desorption. The well-known VASCO code developed at CERN in 2004 is already used to estimate vacuum stability and density profiles in steady-state conditions. Nevertheless, some phenomena are not taken into account such as the ionization of residual gas by the electron clouds and the evolution of the electronic density related to the electron cloud build-up. Therefore, we propose an upgrade of this code by introducing electron cloud maps to estimate the electron density and the ionization of gas by electrons leading to an increase of induced desorption. The pressure evolution computed with DYVACS reproduces with good accuracy the experimental pressure recorded in the VPS beam pipes sector of the LHC from the proton beam injection to the stable beam period. Additionally, DYVACS can also be used as a predictive tool to compute the pressure evolution in the beam pipes for Future Circular Colliders (FCC-hh or -ee).

THPAB292 **Dynamic Pressure in the LHC: Detection of Ions Induced by Ionization of Residual Gas by the Proton Beam and by the Electron-Cloud**

***S. Bilgen**, B. Mercier, G. Sattonnay (Université Paris-Saclay, CNRS/IN2P3, IJCLab) V. Baglin (CERN)*

Ultra-High Vacuum is an essential requirement to achieve design performances and high luminosities in high-energy particle colliders. Consequently, the understanding of the dynamic pressure evolution during accelerator operation is fundamental to provide solutions to mitigate pressure rises induced by multiple effects leading to beam instabilities. For the LHC, the appearance of instabilities may be due to the succession of several phenomena: (i) the induced desorption of gases adsorbed on the surfaces leading to pressure rises; (ii) the creation of secondary particles (ions, electrons); (iii) the production of the so-called Electron Cloud build-up by multipacting effect. This work aims to investigate some fundamental phenomena which drive the dynamic pressure in the LHC, namely the effects induced by electrons and ions interacting with the copper surface of the beam screens. Electron and ion currents, as well as pressure, were recorded in situ in the Vacuum Pilot Sector (VPS) located on the LHC ring during the RUN II. By analyzing the results, more ions than expected were detected and the interplay between electrons, ions, and pressure changes was investigated.

THPAB294 **The Vacuum System of Booster at HEPS**

***P.C. Wang** (USTC/NSRL)*

The High Energy Photon Source(HEPS) is being constructed in Beijing. It contains a kilometer-scale storage ring based light source, with an emittance of less than 60 pm.rad, The light source consists of a 500MeV linac, a 500MeV low energy transport line, a 500MeV to 6GeV booster synchrotron, two 6GeV transport lines, a 6GeV ultra-low emittance storage ring and beamlines, and experimental stations. The Booster section with a total length of about 454 meters is an important part of the accelerator. This paper introduces the Booster vacuum system, including vacuum layout design, physical requirements, vacuum parameters, key equipment, etc; At present, All non-standard vacuum designs have been completed and production has begun, and standard vacuum equipment has also been purchased. The installation is expected to start in March 2022.

THPAB295 **Application of CMM Technology in Accelerator Magnet Detection**

***S. Li**, F.S. Chen, C.D. Deng, W. Kang, Y.Q. Liu, X. Wu, Y.W. Wu (IHEP)*

Accelerator magnet is one of the most difficult equipment in accelerator hardware system. With the improvement of physical requirements, more and more high technical requirements are put forward for magnets. This paper mainly introduces the new application of three coordinate measurement technology in the detection of accelerator mag-

net, and introduces the working process of CMM in the detection of accelerator magnet polar profile.

THPAB296 **The SNS Normal Conducting Linac RF System Design for the Proton Power Upgrade Project**

***J.S. Moss**, M.T. Crofford, S.W. Lee, G.D. Toby (ORNL) M.E. Middendorf (ORNL RAD)*

The Proton Power Upgrade (PPU) project at the Spallation Neutron Source will double the available proton beam power from 1.4 to 2.8MW by increasing the beam energy from 1.0 to 1.3GeV and the beam current from 26 to 38mA. The increase in beam current resulted in the need to redesign the existing normal conducting linac (NCL) RF Systems. High-power testing of the existing NCL RF Systems configured to accelerate PPU-level beam provided the data used to make the final design decisions. This paper describes the development and execution of those in-situ tests and the subsequent results.

THPAB298 **Cryogenic and Mechanical Analyses for 3.9 GHz Cavity in SHINE**

***Y.W. Huang** (ShanghaiTech University) J.F. Chen, Y. Liu, D. Wang, L. Yin (SARI-CAS)*

The Shanghai HIgh repetition rate XFEL aNd Extreme light facility (SHINE), is under construction in Shanghai. The SHINE accelerator is designed to deliver an electron beam to 8 GeV based on a superconducting (SC) RF Linac, applying six hundred 1.3 GHz cavities and sixteen 3.9 GHz cavities. In order to accommodate CW operation, the SHINE 3.9GHz cavity has been first designed to meet the cryogenic capability of carrying the RF power dissipated on the cavity wall to the Superfluid Helium (SHe) surface in the helium 2-phase pipe. Secondly, the bare cavity has been mechanically analyzed in terms of stiffness, pressure sensitivity, different vibration mode (longitudinal and transverse), different pressure load case,s and so on. This paper will address the above issues to give the SHINE cryogenic and mechanical design for a 3.9 GHz cavity.

THPAB300 **Structure Design and Motion Analysis of 6-DOF Sample Positioning Platform**

***G.Y. Wang**, J.X. Chen, L. Liu, R.H. Liu, C.J. Ning, A.X. Wang, J.B. Yu, Y.J. Yu, J.S. Zhang (IHEP CSNS) L. Kang (IHEP)*

with the development of synchrotron radiation (SR) light source technology, in order to meet the requirements of sample positioning platform of some beamline stations, such as adjusting resolution at the nanometer level and having larger sample scanning distance, a six degree of freedom positioning platform based on spacefab structure was developed. The key technologies such as coordinate parameter transformation, kinematics analysis, and adjustment decoupling algorithm of 6-DOF pose adjustment system of SpaceFAB positioning platform are mainly studied. A 6-DOF platform driven by a stepping motor is designed and manufactured. The control system of the 6-DOF Platform Based on bus control is developed, and the adjustment accuracy

is tested. The repeated positioning accuracy of the platform in three directions is 0.019 mm, and that of rotation is 0.011 ^{o} in three directions. The test results verify the correctness of the theoretical analysis of SpaceFAB structure and the rationality of mechanism design. The research on the platform motion algorithm and control system has important reference value for the follow-up research of large stroke nano-6-dof positioning platform.

THPAB303 **Development of the High-Voltage Power System for High-Efficiency Klystron Research**

***J.D. Liu**, X.P. Li (IHEP)*

In order to meet the requirements of CEPC high-efficiency klystron research, a set of high-power high-voltage power systems in continuous wave mode is developed. The new system is based on PSM topology. The design target is up to 130kV, the power level is 2.6MW, and both continuous wave mode and pulse mode are taken into account. In pulse mode, the minimum pulse width is 500us, and the pulse width is continuously adjustable. This article describes the development of a high voltage power system.

THPAB304 **Development of High-Power Test Platform for S-Band Applications at IHEP**

***J.D. Liu**, Z.S. Zhou (IHEP)*

In order to meet the requirement of high-power conditioning environments in projects such as High Energy Photon Source (HEPS), Beijing Electron Positron Collider (BEPCII), and Circular Electron Positron Collider (CEPC). According to the needs of linear accelerators with different frequencies (2856MHz/2998MHz) and different power levels (45MW/50MW/65MW/80MW) klystrons, accelerator structure and high-power microwave devices, a set of modulators with a maximum power of more than 200MW has been developed, which could meet the task requirements of different projects. According to the test results of different klystron load tests, the pulse cable and wiring can be adjusted to meet the conditioning needs of different types of klystrons. The repetition frequency and pulse flatness meet the test requirements. The long-term running time verifies its reliability.

THPAB305 **Solid-State Pulsed Power System for Positron Source Flux Concentrator Driver**

***J.D. Liu**, X.P. Li (IHEP)*

A prototype of an all-solid-state high-current pulse power supply is designed to drive the positron source magnetic flux Concentrator. The experimental results show that the prototype obtains a relatively ideal half-sine pulse waveform, which can provide a pulse current with a peak value of 15 kA and a repetition frequency of 50 Hz. Based on distributed magnetic field measurement, it generates a peak magnetic field of up to 6.2T, which can meet the requirements of CPEC positrons source. This paper describes the design and results of testing the solid-state Pulsed power system.

THPAB306 **Application of Machine Learning in Orbital Correction of Storage Ring**

R.C. Li *(SINAP) B.C. Jiang (Shanghai Advanced Research Institute) C.L. Li, K. Wang (SARI-CAS) Q.R. Mi, Q.L. Zhang, Z.T. Zhao (SSRF)*

The synchrotron light source is one of the most powerful tools in modern science and technology. Shanghai Synchrotron Radiation Facility (SSRF), located in Shanghai, China, is an advanced 3.5GeV 3rd-generation medium energy light source. The 3rd-generation synchrotron radiation light source will provide high brilliant and high stable synchrotron radiation to fulfill the advanced experimental conditions in frontier research. To achieve high stable radiation, it is important to have a high stable beam orbit. This paper uses a machine learning method to control and feedback the orbit. This neural network-based orbit correction method, which doesn't rely on the response matrix, can establish a nonlinear mapping relationship between correctors and the orbit distortions and perform continuous online retraining. This new method can significantly improve the orbit stability of SSRF.

THPAB307 **Behavior of Ironless Inductive Position Sensors in Close Proximity to Each Other**

N.J. Sammut*, A. Grima (University of Malta, Information and Communication Technology) Dr. DI CASTRO, A. Masi (CERN)*

Safety critical systems like the collimators of the Large Hadron Collider require transducers which are immune to interference from their surroundings. The ironless inductive position sensor is used to measure the position of collimator jaws with respect to the beam and is designed to be immune to external DC or slowly changing magnetic fields. In this paper we investigate whether frequency separation is required when multiple ironless inductive position sensors are used and whether two or more sensors at the same frequency results in cross-talk. Numerical simulations and experiments are conducted to study the magnetic field behaviour of the sensors, their interference with each other and the impact of this interference on the position reading. Finally, this paper defines guidelines on safe operation of the ironless inductive position sensor in the aforementioned conditions.

THPAB308 **Composition and Error Analysis of NEG Coating Pipe Pumping Speed Online Measuring System**

X.Y. Sun *(DNSC)*

In the diffraction-limited synchrotron light sources, the diameter of the pipe is required to be very small, and the discrete vacuum pump cannot meet the vacuum requirements, and a layer of NEG film needs to be coated on the inner wall of the pipe. In order to obtain the sticking probability of NEG coating pipe online in the experiment, a pumping speed test system was built. By solving the differential equation method, the analytical mathematical relationship between the pressure ratio at both ends of the pipes of different shapes and the stick-

ing probability is obtained and compared with the Monte-Carlo simulation results, and the uncertainty of the entire test system is given. When the viscosity coefficient is less than 0.1, the mathematical relationship is closer to the Monte-Carlo simulation result. Finally, by collecting data from the vacuum gauge, the function of online calculation of the pipeline pumping speed is realized.

THPAB309 **New Working Tune Feedback System for TLS**
***S.J. Huang**, Y.K. Lin, Y.-C. Lin (NSRRC)*
TLS storage ring has two sets of working tuning feedback systems: one is used to correct the working tune deviation caused by insertion device U90; another system uses a local trim coil to correct the working tune deviation caused by all insertion devices. This article describes a new working tune feedback system in TLS that can correct the working tune effectively back to the required conditions for operation; the two existing feedback systems do not cause problems. We can both avoid increasing the local radiation dose and decreasing the injection efficiency.

THPAB310 **Automatic Correction System of TLS Booster Linac Klystron Modulator**
***S.J. Huang**, Y.K. Lin (NSRRC)*
The aim of this article is to analyse the performance output of the klystron modulator, which is based on the observation of the output voltage and current performance of the linear-accelerator klystron modulator; we modify the operating-point parameters based on those results or assess whether the klystron needs to be replaced. For this purpose, we collect the observation data of the klystron performance; we then develop a program to adjust automatically the high-voltage setting of the klystron to ensure that the storage current maintains beam current 360 mA in the top-up mode operation.

THPAB311 **Using Linear Regression to Model the Parameters of the Flat Wire in TLS-EPU56**
***S.J. Huang**, Y.H. Chang, T.Y. Chung (NSRRC)*
Although a theoretical calculation might predict the set currents of the flat wires, which are used to compensate the deviation in the Betatron tune caused by the elliptically polarized undulator (EPU), those set currents must still be tuned in reality. To approach this reality, a strategy of Machine Learning was adopted, which included collecting real-condition data and using a linear-regression model to adjust the parameters of the flat wires. After training the model, the predictions in variables tune x, tune y and beam size x were compared with the required amount of correction of the EPU at various gaps and phases. To prove the feasibility of this method, a test was performed under the real conditions of accelerator Taiwan Light Source (TLS).

THPAB312 **The Applications of the Light Pulse Measurement System Based on Streak Camera in HLS II**

***P. Lu**, B.G. Sun, J.G. Wang, F.F. Wu, Y.K. Zhao, T.Y. Zhou (USTC/NSRL)*

The dual-axial scan streak camera plays an important role in the super-fast optical measurement and the beam diagnosis of the accelerators. The development of the synchrotron light measurement system based on the streak camera provides an effective tool and research platform for accelerator physics research and super-fast optical measurement. In this paper, the hardware architecture of this measurement system by virtue of the streak camera is described. And the experimental researches are simultaneously performed, including the bunch lengthening effect, the bunch length as a function of RF gap voltage, the potential-well distortion, the longitudinal beam oscillations, and the beam statuses during the injection in HLS-II. Moreover, the experiments of the RF phase modulation on the beam lifetime and longitudinal beam dynamics of the bunch are carried out. And the measured results show that the effect of RF phase modulation can affect the equilibrium particle distribution and effectively improve the beam lifetime.

THPAB313 **Status of Drive Laser Systems for Shanghai Soft X-Ray Free Electron Laser**

***L. Feng**, C.L. Li, B. Liu (SARI-CAS) X.T. Wang, W.Y. Zhang (Shanghai Advanced Research Institute)*

In this paper, we introduce the design and layout of the drive laser of Shanghai Soft X-ray Free Electron Laser (SXFEL). It is known that the temporal and spatial distribution of the drive laser is crucial for high-quality electron beams. The drive laser provides the laser pulse of 266nm wavelength and 8ps pulse duration for the photocathode, as well as 400nm wavelength, 2-20ps tunable pulse duration for the laser heater. For this purpose, there are mainly four parts in such system, including a third-harmonic generation device, pulse stretcher, image transmitted system, and laser optical module for laser heater. Finally, the measured results of the electron beam under this drive laser system are presented and discussed.

THPAB314 **Development of the Femtosecond Timing Distribution System for the Shanghai Soft X-Ray FEL**

***L. Feng**, C.L. Li, B. Liu, J.G. Wang (SARI-CAS) X.T. Wang, W.Y. Zhang (Shanghai Advanced Research Institute)*

High accuracy timing and synchronization system on femtosecond timescale play an important role for free-electron laser projects such as Shanghai Soft X-ray free-electron laser facility (SXFEL), and future Shanghai high repetition rate XFEL and Extreme light facility (SHINE). To meet the high precision synchronization requirements for both facilities, an optical-based timing distribution system is absolutely necessary. Such a system distributes the laser pulse train from a locked optical master oscillator through the fiber links, which stabilized by a

balance optical cross-correlator based on a periodical-poled KTiOPO4 crystal. In this paper, the recent progress and experimental results of SXFEL and SHINE timing distribution system will be reported.

THPAB315 **A New Wire Position Sensor in the Reference Network for Alignment**

***T. Luo**, Z.Q. He, Z.Y. Ke (IHEP CSNS) L. Dong (IHEP) X.Y. He (USTC/NSRL) J. Liang, T. Wang (DNSC)*

Wire Position Senor (WPS) is one of the core high precision alignment sensors in the reference network of alignment "RNA" for the future light source. However, the accuracy of WPS based on binocular vision technology is determined heavily by the calibration and worsens with the environment. This paper presents a new self-calibration WPS that utilizes precision machining to ensure binocular camera orthogonality and achieves its high precision and high reliability with real-time self-calibration and binocular data verification of wire's measurement. Also, the new WPS has great measurement range extension and application prospect for the non-linear accelerator.

THPAB316 **Performance of a 250 kW 202.5 MHz Solid State Amplifier for the ISIS LINAC**

***R.J. Patrick** (TMD Technologies) M. Keelan (STFC/RAL) G.B. Sharkov (NIITFA)*

To investigate long-term sustainability and efficiency options for the STFC-Rutherford Appleton Laboratory ISIS Linac RF systems, the tetrode stage of tank 4 was replaced with a 250 kW solid-state RF amplifier, Developed by SC Rosatom and supplied by TMD Technologies Ltd. The solid-state amplifier was in operation on user cycle 2020/03 for over 600 hours and further operation is planned for 2021/01. The paper describes the SSA design, its features, and performance during tests and user cycle operations, based on matched load measurements and analysis of SSA telemetry data gathered during the user cycle.

THPAB317 **Experiment and Simulation Study on the Capture and Acceleration Process of XiPAF Synchrotron**

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The beam commissioning of the capture and acceleration process on the XiPAF (Xi'an 200MeV Proton Application Facility) synchrotron has been carried out. The efficiency of the experiment results has been compared with the simulation results. At present, the efficiency of the capture process with single-harmonic is about 73%, and the acceleration efficiency is about 82%, and the simulation results are 77% and 96% without space charge effect, respectively. In order to improve efficiency, dual-harmonic was used during the capture and acceleration process. During the experiment, the capture efficiency was increased by 5%, and the acceleration efficiency was increased by 4%. The capture efficiency decreases with the increase of the maximum RF voltages. We analyzed the reasons for the decrease in capture efficiency.

In the next step, further verification will be carried out through experiments under different conditions.

THPAB318 **Uniformization of the Transverse Beam Profile With Nonlinear Magnet**

Y. Li, *X. Guan, X.Y. Liu, X.W. Wang, Q.Z. Xing, Y. Yang, H.J. Yao, W.B. Ye, S.X. Zheng (TUB) Y. Yang (NINT)*

The beam generated after slow extraction of the synchrotron is always not uniform and asymmetrical in transverse distribution. In practice, radiation therapy or radiation irradiation requires a high degree of uniformity of beam spot. Therefore, it is necessary to adjust the beam distribution with a nonlinear magnet and other elements on the transport line from synchrotron ring to beam target station. Nonlinear magnet has high requirements on beam quality. Before passing through the nonlinear magnet field, the beam center can be adjusted by taking advantage of the gradient change distribution of the nonlinear magnet's transverse field map to achieve uniform distribution at the target station. As an example, we use the parameters of heavy ions of XiPAF (Xi'an 200MeV Proton Application Facility) to simulate the beam transport from synchrotron ring to beam target station.

THPAB319 **RF Power Generating System for the Linear Ion Accelerator**

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An RF power supply system based on solid-state amplifiers has been developed for the linear accelerator of heavy ions. The report contains information on the characteristics and composition of the system, presents the LLRF structure for RFQ and DTL sections.

THPAB320 **ALD-Based NbTiN Studies for SIS R&D**

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Superconductor-Insulator-Superconductor multilayers improve the performance of SRF cavities providing magnetic screening of the bulk cavity and lower surface resistance. In this framework NbTiN mixtures stand as a potential material of interest. Atomic layer deposition (ALD) allows for uniform coating of complex geometries and enables tuning of the stoichiometry and precise thickness control in sub-nm range. In this talk, we report about NbTiN thin films deposited by plasma-enhanced ALD on insulating AlN buffer layer. The deposition process has been optimized by studying the superconducting electrical properties of the films. Post-deposition thermal annealing studies with varying temperatures, annealing times, and gas atmospheres have been performed to further improve the thin film quality and the superconducting properties. Our experimental studies show an increase in Tc by 87.5% after thermal annealing and a maximum Tc of 13.9 K has been achieved for NbTiN of 23 nm thickness. Future steps include lattice characterization, using XRR/XRD/EBSD/PALS, and SRF measurements to obtain Hc1 and the superconducting gap.

THPAB321 **CERN n_TOF Facility Status and Upgrades**

***O. Aberle**, A.P. Bernardes, M. Calviani (CERN)*

The n_TOF Facility at CERN is a world-class installation currently exploited by the n_TOF International Collaboration to carry out cutting-edge neutron-induced capture, fission, and charged-particle cross-section measurements as well as multidisciplinary measurements with neutrons. Two class A laboratories hosting the experiments, located about 200 m downstream and 20 m above the spallation area respectively, receive the neutrons produced by a lead spallation target. The new generation target shall guarantee the physics performances of the installation and solve some operational issues identified during past operation. An overview will be provided on the new and unique spallation target design, using as cooling medium N_2 gas, which will be installed during 2021 in the context of CERN's Long Shutdown 2 (LS2), and which will guarantee the operation of the n_TOF facility until the 2030s. Together with the new target, its side shielding has been transformed into mobile shielding offering the opportunity to implement additional irradiation possibilities for material testing and radiation to electronics studies. This new feature, named the NEAR station, will be described in detail.

THPAB322 **Transient Beam Loading in the CBETA Multi-turn ERL**

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The Cornell-BNL ERL Test Accelerator (CBETA) is the first superconducting multi-turn ERL that has been commissioned at Cornell University in a low current mode. In this paper, we first discuss a new model of beam loading which is valid for the low injection energies used in CBETA. Using this model, we explore the effect of bunch patterns, beam turn-on, and turn-off transients on the fundamental mode of the 7-cell SRF cavities used in the main linac. In particular, we examine the operational constraints on the rf system at the design current of 40 mA.

THPAB324 **PIP-II 800 MeV Proton Linac Beam Pattern Generator**

***H. Maniar**, B.E. Chase (Fermilab) J.E. Dusatko (SLAC) S. Khole (BARC) D. Sharma (RRCAT)*

The PIP2 IT Beam Pattern Generator is the system that synchronizes beam injection and the RF systems between the PIP2 LINAC to the Booster. The RF frequencies of these two accelerator systems are not harmonically related. Synchronization is accomplished by controlling two MEBT Beam Choppers, which select 162.5MHz beam bunches from the LEBT and RFQ to produce an appropriate reduced beam bunch pattern that enables bucket-to-bucket transfer to the Booster RF at 46.46MHz (84th harmonic). This chopping pattern also reduces the beam current to an average of 2mA over the Booster injection, matching the Linac nominal beam current. The BPG also generates the RF frequency/phase reference which the Booster will phase lock

to during injection. The BPG is fully programmable, allowing for arbitrary beam patterns with adjustable timing parameters, having a fine adjustment resolution of 38ps. The latter is accomplished using digital signal processing techniques. This paper discusses the design of the BPG, its construction, test results, and operational experience after being integrated into the PIP2 IT test accelerator and concludes with a discussion of the system's performance and future plans.

THPAB325 **Surface Defects in Nb Used in SRF Technology: Their Nature and Implications**

A. Cano, *D. Bafia, A. Grassellino, M. Martinello (Fermilab)*

Niobium is the material of choice for SRF technology used in particle accelerators. Under operation conditions, the RF penetration deep is about 40 nm, and from this fact, the local chemical composition and structural defects in that near-surface region are relevant for the cavity's performance. Different surface treatments have been evaluated in the past in order to improve the cavity quality factor (Q_0), among them N-doping under moderate temperature baking, which results in a significant increase for the value of Q_0, up to three times. The nature of such quality factor improvement is not yet understood. Since a decrease for the structural defects in the near-surface region results in a better cavity performance, in this study we are evaluating the effect of the N-doping treatment followed by electropolishing etching on the chemical composition and structure of that material region, from spectroscopic data and electron microscope images. The results herein discussed shed light on the possible nature of the observed better cavity performance for the cavity when it is submitted to that treatment.

THPAB326 **Material Engineering of ALD-Deposited Multilayer to Improve the Superconducting Performances of Rf Cavities Under Intense RF Fields**

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We are exploring an original approach to improve the performance of bulk Niobium RF cavities through surface engineering with ALD superconducting multilayer capable of screening efficiently the magnetic fields and therefore inhibiting vortices penetration in Niobium SRF cavities. As a first step for the multilayer, we aim at replacing the deleterious niobium native oxide with a clean interface between an insulator synthesized by ALD (Al2O3, Y2O3, and MgO) and the Niobium metal. To that end, I will present the results obtained on both flat niobium samples and 1.3 GHz elliptical cavities. Our study shows that ALD deposited films are in fact a good diffusion barrier, resist thermal treatments, and reduce significantly the presence of the niobium native oxide on the surface. RF test on ALD coated cavities shows already

a slight improvement of the superconducting performances. In parallel, we started synthesizing superconducting NbTiN alloys by ALD. I will present preliminary results on the superconducting properties of NbTiN films grown on AlN by ALD with various compositions on Nb substrates.

THPAB327 **Novel Method of Magnet Ripple Reduction in XiPAF Ring**
H.J. Zeng *(TUB)*
In this paper, the magnet equivalent circuit of AC small-signal and its corresponding ripple transfer function is established. Based on this model, the mechanism of zero flux in active and passive filtering structures is analyzed completely, and the influence of different component parameters on low-pass filtering and input signal integrity is studied by the analytical calculation method of the transfer function. A passive frequency selection filtering structure at the magnet end is proposed to reduce the ripple by more than 20 dB with small size, anti-radiation, and low cost.

THPAB328 **Tapered Modular Quadrupole**
Y.Z. Shao*, G.E. Lawler, B. Naranjo, J.B. Rosenzweig (UCLA)*
At UCLA's SAMURAI Laboratory, there will be a need for beam optics to accommodate operation over a range of beam energies. We present a modular quadrupole design that, in addition to satisfying this requirement, incorporates interchangeable tapered end-pieces for mitigation of higher-order aberrations. The design progresses in an iterative fashion, whereby the tapered shapes, generated algorithmically, are fed into a field solver, and then the aberrations of the resulting particle trajectories are calculated and minimized.

THPAB329 **Performance Optimization of Medium-Beta 644 MHz Cavities for Michigan State University's Facility for Rare Isotopes Beams Energy Upgrade**
K.E. McGee*, S.H. Kim, P.N. Ostroumov (FRIB) G.V. Eremeev, M. Martinello, A.V. Netepenko, T.J. Ring (Fermilab) M.P. Kelly, T. Reid (ANL)*
We present the first study of high-Q RF surface treatments for medium-beta SRF elliptical cavities designed for Michigan State University's Facility for Rare Isotope Beams (FRIB) energy upgrade linac. Two prototype β = 0.65 644 MHz 5-cell elliptical SRF cavities were fabricated and previously used to test the high-Q performance of Electropolishing, Electropolishing + 120C baking, BCP+120C baking. The cavities were then "Reset" and (2/0) N-doped at Fermi National Accelerator Laboratory in the first study of N-doping in medium-beta SRF elliptical cavities. Due to N-doping, we find that the BCS resistance is improved by nearly a factor of 3 at 17.5 MV/m accelerating gradient, which is the first experimental proof in the world for this particular type of cavity operated at 644 MHz. We present the results of this first N-doping study, as well as the results of EP cathode improvement and other recommendations for future iterations in the ~650 MHz N-doping parameter space for CW linac applications.

THPAB331 **High-Power Test of a Highly Over-Coupled X-Band RF Gun Driven by Short RF Pulses**

***J.H. Shao**, D.S. Doran, W. Liu, J.G. Power, C. Whiteford, E.E. Wisniewski (ANL) C.-J. Jing, S.V. Kuzikov (Euclid TechLabs, LLC) X. Lu, P. Piot, W.H. Tan (Northern Illinois University)*

Beam brightness, a key figure of merit of RF photocathode guns, can be improved by increasing the cathode surface field which suppresses emittance growth from space charge. The surface field in normal-conducting structures is mainly limited by RF breakdown and it has been experimentally discovered that RF breakdown rate exponentially depends on RF pulse length. A highly over-coupled 1.5-cell X-band photocathode gun has been developed to be powered by 9 ns RF pulses with 3 ns rising time, 3 ns flat-top, and 3 ns falling time generated by an X-band metallic power extractor. In the recent experiment at Argonne Wakefield Accelerator facility, cathode surface field up to 350 MV/m with a low breakdown rate has been obtained under 260 MW input power. Strong beam loading from dark current was observed during RF conditioning and it quickly recovered to a negligible level. Detailed high-power test results and data analysis will be reported in this manuscript.

THPAB332 **Development of a Pair of 182 GHz Two-Half Power Extractor and Accelerator for Short Pulse RF Breakdown Study**

***J.H. Shao**, J.G. Power (ANL) R.B. Agustsson, S.V. Kutsaev, A.Yu. Smirnov (RadiaBeam)*

High-frequency structures are favorable in structure wakefield acceleration for their strong beam-structure interaction. Recent progress of advanced fabrication technologies, such as high-precision two-half milling and additive machining, has enabled experimental research of mm-wave/THz structures. In this work, we have designed a pair of 182 GHz two-half power extractors and a single-cell accelerator for a short pulse RF breakdown study. When driven by a 182 GHz 4-bunch train with 4 nC total charge and 0.3 mm RMS bunch length, the power extractor is simulated to generate 0.5 ns 8 MW RF pulses and the corresponding gradient in the single-cell accelerator reaches 1 GV/m. RF design and mechanical design of the proof-of-concept structures will be reported in this manuscript.

THPAB334 **Modification of the 3.9 GHz Cavity Design for SHINE**

***Y.X. Zhang**, J.F. Chen, D. Wang, J.N. Wu (SARI-CAS) X. Huang, Y. Zong (SINAP) Y.W. Huang (ShanghaiTech University) J. Rong (SSRF)*

The Shanghai HIgh-repetition-rate XFEL aNd Extreme light facility (SHINE) under construction is designed to be one of the most advanced high-repetition-rate FEL facilities in the world. The Linac includes two 3.9 GHz cryomodules. Based on the design and experience of 3.9 GHz cavities gained in E-XFEL and LCLS-II projects, we optimize the 3.9 GHz cavity design for SHINE to adapt CW mode operation. In this paper, we present a redesign of the SHINE 3.9 GHz cavity, which

includes the RF design and some mechanical simulations.

THPAB335 **Optical Phase Space Mapping Using a Digital Micro-Mirror Device**

***M. Vujanovic**, C.P. Welsch, J. Wolfenden (The University of Liverpool) A.L. Kippax (Cockcroft Institute)*

Optical transition radiation (OTR) is routinely used to measure transverse beam size, divergence , and emittance of charged particle beams. Presented here is an experimental method, which uses micro-mirror device (DMD) to conduct optical phase space mapping (OPSM). OPSM will be a next step and significant enhancement of the measurements capabilities of an adaptive optics-based beam characterization system. For this measurements, a DMD will be used to generate a reflective mask that replicates the double slit. Since the DMD makes it possible to easily change the size, shape and position of the mask, the use of the DMD will greatly simplify OPSM and make it more flexible, faster and more useful for diagnostics applications. The process can be automated and integrated into a control system that can be used to optimize the beam transport.

THPAB336 **Novel Magnetron Operation and Control Methods for SC Accelerators**

***G.M. Kazakevich**, R.P. Johnson (Muons, Inc) T.N. Khabiboulline, G.V. Romanov, V.P. Yakovlev (Fermilab)*

High power magnetrons designed and optimized for industrial heating, being injection-locked, have been suggested to power superconducting RF cavities for accelerators due to lower cost and higher efficiency. However, standard operation methods do not provide high efficiency with wideband control suppressing microphonics. We have developed and experimentally verified novel methods of operating and controlling the magnetron that provide stable RF generation with higher efficiency and lower noise than other RF sources. By our method the magnetrons operate with the anode voltage notably lower than the self-excitation threshold improving its performance. This is also a promising way to increase tube reliability and longevity. A magnetron operating with the anode voltage lower than the self-excitation threshold, in so-called stimulated coherent generation mode has special advantage for pulse operation with a gated injection-locking signal. This eliminates the need for expensive pulsed HV modulators and additionally increases the magnetron RF source efficiency due to absence of losses in HV modulators.

THPAB337 **Resonance Control System for the Fermilab PIP-II IT HWR Cryomodule**

***P. Varghese**, B.E. Chase, H. Maniar, D.J. Nicklaus, S. Sankar Raman (Fermilab) L.R. Doolittle, S. Paiagua, C. Serrano (LBNL)*

The HWR (half-wave-resonator) cryomodule is the first one in the superconducting section of the PIP-II LINAC project at Fermilab. PIP-II IT is a test facility for the project where the injector, warm front-end, and the first two superconducting cryomodules are being tested.

The HWR cryomodule comprises 8 cavities operating at a frequency of 162.5 MHz and accelerating beam up to 10 MeV. Resonance control of the cavities is performed with a pneumatically operated slow tuner which compresses the cavity at the beam ports. Helium gas pressure in a bellows mounted to an end wall of the cavity is controlled by two solenoid valves, one on the pressure side and one on the vacuum side. The resonant frequency of the cavity can be controlled in one of two modes. A pressure feedback control loop can hold the cavity tuner pressure at a fixed value for the desired resonant frequency. Alternately, the feedback loop can regulate the cavity tuner pressure to bring the RF detuning error to zero. The resonance controller is integrated into the LLRF control system for the cryomodule. The control system design and performance of the resonance control system are described in this paper.

THPAB338 **Performance of the LLRF System for the Fermilab PIP-II Injector Test**

***P. Varghese**, B.E. Chase (Fermilab)*

PIP-II IT is a test facility for the PIP-II project where the injector, warm front-end, and the first two superconducting cryomodules are being tested. The 8-cavity half-wave-resonator (HWR) cryomodule operating at 162.5 MHz is followed by the 8-cavity single-spoke resonator(SSR1) cryomodule operating at 325 MHz. The LLRF systems for both cryomodules are based on a common SOC FPGA-based hardware platform. The resonance control systems for the two cryomodules are quite different, the first being a pneumatic system based on helium pressure and the latter a piezo/stepper motor type control. The data acquisition and control system can support both CW and Pulsed mode operations. Beam loading compensation is available which can be used for both manual/automatic control in the LLRF system. The user interfaces include EPICS, Labview, and ACNET. Testing of the RF system has progressed to the point of being ready for a 2 mA beam to be accelerated to 25 MeV. The design and performance of the field control and resonance control system operation with beam are presented in this paper.

THPAB339 **Innovative Compact RF Chopping System**

***M. Popovic**, G.M. Kazakevich (Muons, Inc)*

An innovative, compact RF chopping system is proposed that can reduce a bunched ion beam frequency from about 100 MHz to about 20 MHz at roughly 500 keV/u. The system should be capable of operating near SRF cryomodules and can dump up to 500 W heavy ion beam power. This highly compact RF Chopping System is achieved by using ferrite-loaded accelerating cavities as a deflecting system. Additional deflection can be achieved using DC biasing one or both electrodes. The system can be designed as a fixed frequency kicker or it can be fast tuned (~10ms) to the desired frequency. The system can be operated at a single frequency or it can include a second harmonic in a space shorter than 0.4 m. The removed beam can be dumped into one or two

dumps. In addition to the application to FRIB's needs, this system and method could be applied to other accelerator applications that have similar needs.

THPAB340 **Sub-Nanosecond Switching of HV SIC MOS Transistors for Impact Ionisation Triggering**

***V. Senaj**, T. Kramer, A.A. del Barrio Montañés (CERN) M. Sack (KIT)*

Pulse generators with multi kV/kA pulses are necessary for the particle accelerator environment for beam transfer magnets. Traditionally these generators are using thyratrons - until recently the only switches capable of switching such pulses within tens of ns. There is a strong demand to replace thyratrons with semiconductor switches to avoid their future obsolescence. Very promising candidates are components from the family of fast ionization dynistors triggered by impact ionization. Their sub-nanosecond switching time and extreme current densities can provide performances superior to that of thyratrons. Recent investigations showed that impact ionization triggering is feasible also in cheap industrial thyristors. The main issue is the generation of triggering pulses with slew rates in the multi kV/ns region and with the required output current for charging the parasitic capacitance of the thyristor. We present an approach of generating > 1 kV/ns pulses by ultra-boosted gate driving of HV SiC MOS transistors. We found that the MOS lifetime under these extreme triggering conditions can still reach more than 10^8 pulses, enough for kicker generator applications.

THPAB341 **TiN Metalizing and Coating for Multi-Megawatt RF Vacuum Windows**

***M.L. Neubauer** (Muons, Inc)*

Coatings on microwave windows and high-voltage ceramics are required to eliminate secondary electron emission (SEE), which initiates multipactoring discharge causing local heating and ceramic failures due to cracking and loss of vacuum. The region surrounding the triple junction (ceramic+metal+vacuum) is the primary source of free electrons and in microwave windows and high-voltage ceramics. This region is located at the metalizing and braze joint of the ceramic support structure making the vacuum seal. On very large microwave windows typically at low frequencies, this critical region is difficult to coat by the traditional techniques of sputter coating anti-multipactoring titanium nitride or other materials. The novel processes proposed here include a means for applying and controlling the thickness of titanium nitride both in the metallizing (controlling the source) and on the surface of the window, eliminating SEE and the multipactoring discharge.

THPAB342 **RF Power Source for IRFEL Facility at NSRL**

***L. Shang**, Y. Lu, F.L. Shang (USTC/NSRL)*

The new Infrared Free Electron Laser (IRFEL) facility which is based on electron Linac has been constructed and commissioned at NSRL. The facility which is jointly proposed by Xiamen University and the University of Science and Technology of China will deliver IR radiation in the

wavelength range of 2.5 to 200 micron for applications of energy chemistry. The electron Linac is designed to operate at the energy of 20 to 60 MeV with a bunch charge of 200pC. Two 30 MeV S-band RF sources are required to provide power to both the buncher system and the accelerator structures. The long pulse RF power source with an RF pulse width of 13.5us is quite different from the existing RF powers. This paper presents the design of the power source and the considerations to achieve repeatability of 0.1% and pulse flatness of 0.3%.

THPAB343 **Test Results of the Prototype SSR1 Cryomodule for PIP-II at Fermilab**

D. Passarelli, *J. Bernardini, C. Boffo, B.M. Hanna, S. Kazakov, T.N. Khabiboulline, A. Lunin, J.P. Ozelis, M. Parise, Y.M. Pischalnikov, V. Roger, B. Squires, A.I. Sukhanov, G. Wu, V.P. Yakovlev, S. Zorzetti (Fermilab) C. Contreras-Martinez (FRIB)*

A prototype cryomodule containing eight Single Spoke Resonators typs^{-1} (SSR1) operating at 325 MHz and four superconducting focusing lenses has been successfully assembled and cold tested in the framework of PIP-II project at Fermilab. The performance of cavities and focusing lenses along with test results of other cryomodule's key parameters are presented in this contribution.

THPAB344 **Magneto-Optical Trap Cathode for High Brightness Applications**

V.S. Yu, *C.E. Hansel, G.E. Lawler, J.B. Rosenzweig (UCLA) J.I. Mann (PBPL)*

Electron bunches extracted from magneto-optical traps (MOTs) via femtosecond photo-ionization and electrostatic acceleration can have significantly lower transverse emittance than emissions from traditional metal cathodes. Such MOT cathodes, however, have two drawbacks: the need for multiple trapping lasers and the limit to ~MV/m fields. Designs exist for MOTs which only require one trapping laser. Our RF simulations in High-Frequency Structure Simulator (HFSS) indicate that the cone MOT is the only one compatible with high gradient RF cavities. We present the combination of the two, an RF cavity with a cone-MOT as part of its geometry. It only requires one trapping laser and can use much higher fields. The geometry of the chamber is compatible with a wide range of MOT species, which allows the search for one which is compatible with copper cavities.

THPAB345 **Fiducialization the NICA Booster Superconducting Quadrupole Doublet Magnets Using Vibrating Wire Technique**

T.A. Parfylo, *M.A. Kashunin, S.A. Kostromin, V.A. Mykhailenko (JINR/VBLHEP) V.V. Borisov, H.G. Khodzhibagiyan, B.Yu. Kondratiev, M.M. Shandov (JINR)*

Within the NICA (Nuclotron-based Ion Collider fAcility) project, at the end of 2020, the assembly was completed and a new superconducting booster synchrotron was successfully put into operation at the Veksler and Baldin Laboratory of High Energy Physics (VBLHEP) JINR. Booster's magnetic system includes 24 superconducting doublets of

quadrupole magnets. Each doublet is set to the calculated beam trajectory. The positions of the magnetic axes of the doublets are determined, which are necessary for their correct installation. The vibrating wire method was used to determine the position of the magnetic axes of the doublets. A new measuring system was developed and manufactured at VBLHEP. The positions of the magnetic axes at ambient temperature are determined. The article presents the design of the measuring system, the method for determining the magnetic axis of the superconducting quadrupole doublets of the booster, and the measurement results.

THPAB346 **Development of a 12 MeV Standing Wave Linac for Intraoperative Radiotherapy**
P. Wang *(TUB)*
We developed a 12 MeV standing wave linac for intraoperative radiotherapy.

THPAB347 **Status of Sirius Storage Ring RF System**
A.P.B. Lima*, D. Daminelli, R.H.A. Farias, F.K.G. Hoshino, F.S. Oliveira, R.R.C. Santos, M.H. Wallner (LNLS)*
The design configuration of the Sirius Light Source RF System is based on two superconducting RF cavities and eight 60 kW solid state amplifiers operating at 500 MHz. The current configuration, based on a 7-cell room temperature cavity, was initially planned for commissioning and initial tests of the beamlines. However, it will have to remain in operation longer than planned. Sirius has been operating in decay mode for beamline tests with an initial current of 70 mA. We present an overview of the first-year operation of the RF system and the preparations for the installation of the two superconducting cavities, which is expected to take place in 2023.

THPAB348 **INFN-LASA for the PIP-II LB650 Linac**
R. Paparella*, M. Bertucci, M. Bonezzi, A. Bosotti, A. D'Ambros, A.T. Grimaldi, P. Michelato, L. Monaco, D. Sertore (INFN/LASA) C. Pagani (Università degli Studi di Milano & INFN)*
INFN joined the international effort for the PIP-II project at Fermilab and it's going to contribute to the low-beta section of the PIP-II proton linac. In particular, INFN-LASA is finalizing its commitment to deliver in kind the full set of the LB650 cavities, namely 36 plus spares 5-cell cavities at 650 MHz and geometrical beta 0.61. All cavities, designed by INFN-LASA, will be produced and surface treated in industry, qualified through vertical cold test, and delivered as ready for string installation. This paper reports the status of INFN's contribution to PIP-II and of ongoing activities toward the experimental qualifications of infrastructures and prototypes.

THPAB349 **Convolutional Neural Network-Based Modeling of an Ultrafast Laser**
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of Naval Research Project) S. Biedron (Element Aero) M. Burger, J. Murphy (NERS-UM) K.M. Krushelnick, A.G.R. Thomas (University of Michigan) Y. Ma (IHEP) Y. Ma (Michigan University)
The applications of machine learning in today's world encompass all fields of life and physical sciences. We try to adopt, implement, and execute a machine learning-based algorithm in the context of laser physics and particle accelerators. More specifically, a neural network-based optimization algorithm has been developed that offers enhanced control over an ultrafast femtosecond laser in comparison to the traditional PID-based controls. Moreover, the neural network, which in this case was a feed-forward neural network (FFNN), was used to demonstrate the back propagation control system to model the relationship between acousto-optic programmable dispersive filters. For this work, we use the low-jitter DAZZLER input parameters to produce an optimized Temporal Full-width half Maximum (Temp-FWHM) as output. The development of the model, including the laser control and parameter selection along with training and testing of the algorithm was performed. This opens a new potential of utilizing machine learning and even deep learning techniques to improve the performance of several different lasing and accelerator systems.

THPAB351 **INFN-LASA Experimental Activities on PIP-II Low-Beta Cavity Prototypes**

***M. Bertucci**, A. Bosotti, A. D'Ambros, A.T. Grimaldi, P. Michelato, L. Monaco, C. Pagani, R. Paparella, D. Sertore (INFN/LASA) A. Gresele (Ettore Zanon S.p.A., Nuclear Division)*
This paper reports on the first results obtained by INFN-LASA on PIP-II low-beta cavity prototypes. The goal of this activity was to validate the reference surface treatment based on Electropolishing as a bulk removal step. The cavity treatment procedures are here presented together with the strategy used for their optimization. The experimental results of cavity cold tests for a single cell prototype are presented and discussed. Having this cavity achieved the requested performance, the baseline procedure is considered as validated and a plan for a future high-Q cavity surface treatment is proposed.

THPAB352 **Computer Vision Techniques Used to Monitor the Alignment of Cavities and Solenoids in the PIP-II Prototype SSR1 Cryomodule**

***S. Zorzetti**, J. Bernardini, D. Passarelli (Fermilab)*
The alignment of the SRF PIP-II string components is studied as the acceptable beam deflection, offset and defocusing, which may otherwise cause beam loss. Simulations and measurements established that the maximum deviation of the beam pipe from the reference orbit should not exceed a small fraction of the beam aperture. To observe the translations and rotations of each single component within the cryomodule, optical instruments (H-BCAM) surveying highly reflective targets, installed in the internal assembly of the module were used. The alignment monitoring concept for the PIP II SSR1 prototype cryomodule,

along with relevant measurements of the components' position monitoring during coldmass cooldown is presented in this contribution. This development paves the way to new computer vision applications in the field of cryomodule assemblies in cleanroom environment, in which robotically-assisted operations have the potential to dramatically reduce the risk of chemical and particulate contamination.

THPAB353 **Approaches Using Artificial Intelligence Towards Storage Ring Quantum Computers**

***S.D. Scott**, A. Aslam, S. Biedron, T.B. Bolin, M. Martinez-Ramon (University of New Mexico) K.A. Brown (BNL) S. Sosa (ODU)*

Particle-beam storage rings are a recent approach to constructing a quantum computer, where the storage ring forms the ion trap. Compared to a conventional ion trap, a storage ring quantum computer has the potential to be scalable. An initial calculation of the equilibrium position of the ions is generally required. Computation time for the 1-D ion equilibrium position grows quickly with the number of ions, such that the computation time becomes impractical. Recent research in the calculation of the equilibrium position makes use of a parameterized model to describe the inter-ion spacing in the equilibrium configuration. An artificial neural network was then trained to quickly estimate the model parameters given a target number of ions. In this paper, we will build on this previous research by exploring the application of alternate neural network architectures to improve the estimation of the model parameters.

THPAB354 **Deployment and Commissioning of the CERN PS Injection Kicker System for Operation With 2 GeV Beams in Short Circuit Mode**

***T. Kramer**, N. Ayala, J.C.C.M. Borburgh, P.A.H. Burkel, E. Carlier, L. Ducimetière, L.M.C. Feliciano, A. Ferrero Colomo, M.A. Fraser, L.A. Govertsen, R. Noulibos, S. Pavis, L. Sermeus (CERN)*

Within the framework of the LHC Injector Upgrade (LIU) project, the feasibility and design of an upgrade of the existing CERN PS proton injection kicker system have been outlined in previous publications already. This paper describes the adjustments of final design choices, testing, and deployment as well as the validation and commissioning of the new 2 GeV injection kicker system. The upgrade pays particular attention to the reduction of pulse reflections unavoidably induced by a magnet in short circuit mode configuration whilst keeping a fast 10^4 ns rise and fall time. An adopted thyratron triggering system to reduce jitter and enhance thyratron lifetime is outlined. Additionally, improvements to the magnet entry box and the suppression of SF6 gas in the magnet connection box and the associated pulse transmission lines are discussed.

THPAB355 **L-CCD System for Monitoring Linear Parts in Accelerator**

***X.Y. He** (USTC/NSRL) J.X. Chen (IHEP CSNS)*

The newly proposed key project in China, Hefei Advance Light Facility (HALF), mainly has three parts, e.g. a 140m line accelerator, a 50m

transport line, and a storage ring with 480m Circumference. During the R&D stage of the project, a new displacement monitoring system has been designed to real-time measure the displacement of some key points along the linear of the laser Based on Laser and CCD sensors. The displacement may be caused by the slow movement of the floor or the mechanical girds or the online units. During the R&D stage, measuring distance is required for 40m, which will be able to be expanded to 100m for actual use. Among the 40m linear parts, 2 CCD detectors are inserted at intervals of 10meters. In the two directors on the plane vertical to the laser line, the measurement accuracy would be higher than 10μm.

THPAB356 **Progress and Status on Civil Construction of the SIS100 Accelerator Building**

M. Draisbach, *N. Pyka, P.J. Spiller (GSI) J. Blaurock, M. Ossendorf (FAIR)*

Besides the accelerator machine itself, civil construction of the accelerator ring tunnel building in the northern area of the FAIR campus is a core activity of the rapidly progressing FAIR project. It will facilitate and supply the future SIS100 accelerator at 17m underground level and has been growing continuously and according to schedule since groundbreaking in 2017. This contribution presents the current status of the civil construction progress and gives an optimistic forecast for the preparation of machine installation.

THPAB358 **Application of Zone Plate Irradiated by Laser to Realize Foundation Settlement Monitoring and Alignment Reference Line Correction in SHINE Project**

T. Lan, *P.C. Dong, M.D. Feng, Z.Q. Jiang, X.T. Wang, D. Yuan (Shanghai Advanced Research Institute)*

When the collimated parallel laser beam irradiates the zone plate, a bright spot will be formed on its main focal plane. When the zone plate moves perpendicular to the laser beam, the position of the bright spot will also move. Therefore, the displacement of the zone plate can be obtained by measuring the displacement of the spot. If multiple zone plates are arranged along the beam direction, the displacement monitoring of multiple positions can be realized. At the same time, when the centers of each bright spot coincide, the centers of all zone plates are on the same line, so a virtual alignment reference line is obtained. Based on this principle, we built a prototype device in the SHINE project to monitor the foundation settlement of the undulator section and provide correction parameters for the alignment network. The light source is a semiconductor laser with a wavelength of 405nm, which is collimated to a nearly parallel beam through a lens group. The laser beam passes through a vacuum pipe with a total length of 100m. Five zone plates are arranged in the pipe with a spacing of 20m. After calibration, the displacement measurement accuracy of each zone plate can reach ±0.02mm.

THPAB359 **Simulations of the Stage 2 FFA Injection Line of LhARA for Evaluating Beam Transport Performance**

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A new, novel facility for radiobiological research, the Laser-hybrid Accelerator for Radiobiological Applications (LhARA), has recently been proposed. LhARA will be a two-stage facility with the first stage employing laser-target acceleration to produce intense proton bunches of energies up to 15 MeV. The second stage will accelerate the beam in an FFA ring up to 127 MeV. Optimal performance of stage 2, however, will require an emittance reduction of the stage 1 beam due to the FFA's nominal dynamical acceptance. Here, we demonstrate a new optical configuration of LhARA's stage 1 lattice that will provide this reduced emittance. The profile of the laser-target generated beam is far from an ideal Gaussian, therefore two start-to-end Monte Carlo particle tracking codes have been used to model beam transport performance from the laser-target source through to the end of the stage 2 FFA injection line. The Geant4-based Beam Delivery Simulation (BDSIM) was used to model beam losses and the collimation that is crucial to LhARA's energy selection system, and General Particle Tracer (GPT) was used to model the space-charge effects that may impact performance given the emittance reduction.

THPAB360 **A Dose Verification Tool of the Proton Therapy Treatment Plan Using TOPAS**

W. Wang*, X. Liu, B. Qin, Z.Y. Yang (HUST)*

Owing to the Bragg Peak (BP) in depth-dose distribution, Proton therapy (PT) has attracted much attention in recent years. Dose validation is indispensable and crucial before the treatment. In this paper, we proposed an independent dose verification tool by using TOPAS v3.4, and presents verification results for 85 prostate patients. A full-beam delivery model in the nozzle was firstly built in TOPAS. CT images and treatment plans from the treatment planning system (TPS) were then fed into this model. From the result of the gamma analysis, two doses from the TPS and the Monte Carlo simulation show a good agreement with the gamma passing rate exceeding 95%.

THPAB364 **Mu*STAR: A System to Consume Spent Nuclear Fuel While Economically Generating Nuclear Power**

R.P. Johnson*, R.J. Abrams, M.A. Cummings, S.A. Kahn, J.D. Lobo, T.J. Roberts (Muons, Inc)*

Mu*STAR is a superconducting-accelerator driven, subcritical, molten-salt reactor designed to consume the spent nuclear fuel (SNF) from today's commercial fleet of light water reactors. In the process of doing so it will: 1. generate electricity in a cost-competitive manner, 2. significantly reduce the waste-stream volume per Gigawatt-hour generated, 3. greatly reduce the radio-toxic lifetime of the waste stream. As many states and countries now prohibit licensing of new nuclear plants until a national strategy has been established for the long-term

disposal of their nuclear waste, Mu*STAR can be an important enabler for new nuclear facilities. This is especially important in the light of climate change, as nuclear energy is the only carbon-free technology for a base-load generation that is readily expandable.

THPAB365 **Comparision between NDP and SIMS Analytical Methods to Determine the 10-B and 6-Li Depth Profiles**

S.M.T. Hoang *(Thu Dau Mot University, Tuan Hoang)*

In this study, the comparison of the analytical results between SIMS (Secondary-ion mass spectrometry) and NDP (Neutron Depth Profiling) methods has been carried out with LiCoO2 and BSi samples. The NDP is an analytical method that can analyze the component nuclide concentration versus depth distribution in a sample by detecting the charged particles emitted after the neutrons are absorbed. The 10B and 6Li depth profiles in the BSi and LiCoO2 samples were also analyzed by using a CAMECA IMS 7f SIMS instrument at the National Nanofab Center (Republic of Korea). The results from NDP analysis have been performed at the CN-NDP system (HANARO, Republic of Korea). In comparison results for the samples, the peak depth, peak concentration, and total dose of the NDP results are consistent with the SIMS results to within 2, 6, and 11 %, respectively. The NDP is useful for analyzing light elements with high neutron cross-sections for particle-producing reactions.

THPAB366 **Microscope Tuning With Machine Learning Based Emittance Measurement and Gaussian Process Optimization**

C.Y. Zhang*, Z. Baraissov, J.M. Maxson, D.A. Muller (Cornell University) C.J.R. Duncan (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) A.L. Edelen, A. Hanuka (SLAC)*

Modern scanning transmission electron microscopes (STEM) use an aberration corrector containing a series of multipole magnets to generate an ideal spherical wavefront, which enables a sub-Angstrom size electron probe. The conventional aberration corrector tuning is time-intensive and requires human interaction about every half minute. A new scheme for aberration corrector alignment using tools borrowed from the accelerator community is reported, includes both new ways of conducting the aberration measurement and aberration corrector control. For the measurement, we adopted emittance as the metric of the beam quality and predict the emittance from Ronchigrams using a convolutional neural network (CNN) that was trained and tested on simulations, and is robust under different experimental conditions. For the aberration correction, Bayesian optimization with a Gaussian Process (GP) has been applied to adjust multipole magnet settings in the aberration corrector and minimize the emittance. The GP-based optimization has been tested and is able to minimize the emittance on a general particle tracer (GPT) simulation that simulates the probe after aberration corrector.

THPAB367 **Femtosecond Mid-IR Excitation Capabilities for MeV Ultrafast Electron Diffraction Measurements**

M. Babzien, *M.G. Fedurin, R. Kupfer, J.J. Li, M.A. Palmer, J. Tao (BNL)*

The use of pump-probe time-resolved ultrafast electron diffraction (UED) has continued to demonstrate the complementary nature of the technique alongside X-ray diffraction for studies of dynamic solid-state and gas-phase materials. At the Brookhaven UED facility, recently expanded capabilities including increased repetition rate have provided higher throughput and increased resolution. We report on the latest development of the Brookhaven UED facility, the installation of an optical parametric amplifier (OPA) for the generation of tunable ultrafast optical pulses spanning the wavelength range from 1-11 microns. This will enable a much broader range of materials to be studied, including molecular species with mid-IR transitions that are not easily pumped by near-IR Ti:Sapphire lasers. The resulting increase in accessible materials will drive greater productivity, and also enable dual-excitation experiments where different pumping mechanisms are excited by two laser wavelengths with variable timing relative to the electron probe. In addition to the latest capabilities of the facility, the first results from mid-IR excitation experiments will be presented.

THPAB369 **Research and Design of an X-band 100-MeV Compact Electron Accelerator for Very High Energy Electron Therapy in Tsinghua University**

X. Lin, *H.B. Chen, J. Shi, C.-X. Tang, H. Zha, L.Y. Zhou (TUB)*

A 100-MeV Compact Electron Accelerator scheme based on the Tsinghua X-band (11.424 GHz) High Power Test stand (TPot-X) was proposed for Very High Energy Electron (VHEE) radiotherapy. A pulse compressor with correction cavity chain was designed to compress the 50 MW, 1500 ns microwave pulse from the X-band klystron to 120 MW, 300 ns. The acceleration system consists of 3 parts, a buncher which bunches and boosts the electron from a thermionic cathode gun to 8 MeV, and two accelerating structure which further boost the electron energy to 100MeV. The detailed design and consideration are presented in this article.

THPAB372 **SABINA: a Research Infrastructure at LNF**

L. Sabbatini, *D. Alesini, M.P. Anania, M. Bellaveglia, A. Biagioni, B. Buonomo, S. Cantarella, F. Cardelli, E. Chiadroni, G. Costa, G. Di Pirro, F. Dipace, A. Esposito, M. Ferrario, M. Galletti, A. Gallo, A. Ghigo, L. Giannessi, A. Giribono, S. Incremona, L. Pellegrino, L. Piersanti, R. Pompili, R. Ricci, J. Scifo, A. Stecchi, A. Stella, C. Vaccarezza, A. Vannozzi, S. Vescovi, F. Villa (INFN/LNF) A. Cianchi (Università di Roma II Tor Vergata) A. Cianchi (INFN-Roma II) A. Doria, A. Petralia (ENEA C.R. Frascati) L. Giannessi (Elettra-Sincrotrone Trieste S.C.p.A.) S. Lupi (Sapienza University of Rome) S. Macis (La Sapienza University of Rome)*

V. Petrillo (Universita' degli Studi di Milano) V. Petrillo (INFN-Milano)

SABINA (Source of Advanced Beam Imaging for Novel Applications) is a project aimed at the enhancement of the SPARC_LAB research facility. This enhancement is carried out through the following actions: first, the increase of the uptime through the consolidation of technological systems and the replacement of some critical equipment in order to limit the number and extent of faults; then, the improvement of the accelerator performances, by replacing some devices with updated ones. The effect will be greater reliability of the accelerator, which will allow it to be opened as a facility for external users, both industrial and scientific, with the goal of increasing the competitiveness of industries in a broad range of technological areas and enhancing collaborations with research institutions. The two user lines that will be implemented are a power laser target area and a THz radiation line, by using a dedicated undulator. The undulator and the THz line are also described in other contributions to this conference. A brief description of the project and potential exploitations are reported.

THXX — Thursday Combined Oral Session

THXX01 **The Path to High Power FELs**
N.R. Holtkamp *(SLAC)*
The presentation will give an overview of the achievements of major FEL facilities around the world. Followed by a discussion of plans to improve and/or increase brightness, spectral cleanliness, peak power, energy per pulse, and photon energy reach. The presentation will attempt to define the term "High Power" in the context of where future developments should go and what other high power systems are necessary to support maximum science output.

THXX02 **High Power Proton Sources for Neutrino Science**
E. Pozdeyev *(Fermilab)*
Neutrinos can hold keys to fundamental physics questions such as the origin of matter, the relationship between nature's forces, formation of the most extreme objects in galaxies, and how we come to exist at all. Accelerator-based neutrino facilities provide platforms that enable comprehensive studies of neutrinos and their properties. In this paper, we discuss high-power proton accelerators for neutrino science and describe their parameters, features, and critical technologies.

THXA01 **Beyond RMS: Understanding the Evolution of Beam Distributions in High Intensity Linacs**
K.J. Ruisard*, A.V. Aleksandrov, S.M. Cousineau, A.P. Shishlo, A.P. Zhukov (ORNL)*
Understanding the evolution of beams with space charge is crucial to design and operation of high intensity linacs. While the community holds a broad understanding of the mechanisms leading to emittance growth and halo formation, there is outstanding discrepancy between measurements and beam evolution models that precludes prediction of halo losses. This may be due in part to insufficient information of the initial beam distribution. This talk will describe work at the SNS Beam Test Facility to directly measure the 6D beam distribution. Full-and-direct 6D measurement has revealed hidden but physically significant dependence between the longitudinal distribution and transverse coordinates. This nonlinear correlation is driven by space charge and reproduced by self-consistent simulation of the RFQ. Omission of this interplane correlation, common when bunches are reconstructed from lower-dimensional measurements, degrades downstream predictions. This talk will also describe the novel diagnostics supporting this work. This includes ongoing improvements to efficiency of the 6D phase space measurement as well as recent achievement of six orders of dynamic range in 2D phase space.

THXA02 **Overview of the Micro-Bunching Instability in Electron Storage Rings and Evolving Diagnostics**
M. Brosi *(KIT)*
The micro-bunching instability is a longitudinal instability that leads to dynamical deformations of the charge distribution in the longitudinal phase space. It affects the longitudinal charge distribution, and thus the emitted coherent synchrotron radiation spectra, as well as the energy distribution of the electron bunch. Not only the threshold in the bunch current above which the instability occurs, but also the dynamics above the instability threshold strongly depends on machine parameters, e.g., natural bunch length, accelerating voltage, momentum compaction factor, and beam energy. All this makes the understanding and potential mitigation or control of the micro-bunching instability an important topic for the next generation of light sources and circular e^+/e^- colliders. This presentation will give a review on the micro-bunching instability and discuss how technological advances in the turn-by-turn and bunch-by-bunch diagnostics are leading to a deeper understanding of this intriguing phenomenon.

THXA03 **Simultaneous Top-Up Injection Into Four Storage Rings at SuperKEKB**
M. Satoh *(KEK)*
The injector linac at KEK is being upgraded for SuperKEKB, where

ten-times smaller emittance and five-times larger current in injection beam are required as compared to KEKB. An RF gun and damping ring were built to generate low emittance beams for the SuperKEKB electron (HER) and positron (LER) beams, respectively. A pulse-to-pulse beam modulation scheme for delivery of beam to the 7 GeV HER and 4 GeV LER, as well as to the 2.5 GeV Photon Factory (PF) ring and the and 6.5 GeV PF-AR ring, has been successfully developed, and simultaneous top-up injections are carried out during SuperKEKB Phase III commissioning. The linac upgrades needed for these simultaneous top-up injections are reported here.

THXA04 **Microbunching Instability in the Presence of Intrabeam Scattering for Single-Pass Accelerators**

C.-Y. Tsai *(HUST) W. Qin (Lund University)*

Intrabeam scattering (IBS) has long been studied in lepton or hadron storage rings as a slow diffusion process, while the effects of IBS on single-pass or recirculating electron accelerators have drawn attention only in the recent two decades due to the emergence of linac-based or ERL-based 4th-generation light sources, which require high-quality electron beams during the beam transport. Recent experimental measurements indicate that in some parameter regimes, IBS can have a significant influence on microbunched beam dynamics. Here we develop a theoretical formulation of microbunching instability (MBI) in the presence of IBS for single-pass accelerators. We start from the Vlasov-Fokker-Planck (VFP) equation, combining both collective longitudinal space charge and incoherent IBS effects. The linearized VFP equation with the corresponding coefficients is derived. The evolutions of the phase space density and energy modulations are formulated as a set of coupled integral equations. The formulation is then applied to a simplified single-pass transport line. The results from the semi-analytical calculation are compared and show good agreement with particle tracking simulations.

THXA05 **A Fast Method of 2D Calculation of Coherent Synchrotron Radiation Wakefield in Relativistic Beams**

J. Tang*, Z. Huang, G. Stupakov (SLAC)*

Coherent Synchrotron Radiation (CSR) is regarded as one of the most important reasons that limit beam brightness in modern accelerators. CSR wakefield is often computed in a 1D assuming a line charge, which can become invalid when the beam has a large transverse extension and small bunch length. On the other hand, the existing 2D or 3D codes are often computationally inefficient or incomplete. In our previous work we developed a new model for fast computation of 2D CSR wakefield in relativistic beams with Gaussian distribution. Here we further generalize this model to achieve self-consistent computation compatible with arbitrary beam distribution and nonlinear magnetic lattice with particle tracking. These new features can enable us to perform realistic simulations and study the physics of CSR beyond 1D in electron beams with extreme short bunch length and high peak cur-

rent.

THXA06 **The Effect of Beam Velocity Distribution on Electron-Cooling at Elena**

***B. Veglia**, A. Farricker, C.P. Welsch (The University of Liverpool)*
*A. Farricker (UMAN) **B. Veglia**, C.P. Welsch (Cockcroft Institute)*

ELENA is a novel storage ring at CERN, designed to deliver low energy, high-quality antiprotons to antimatter experiments. The electron cooler is a key component of this decelerator, which counters the beam blow-up as the antiproton energy is reduced from 5.3 MeV to 100 keV. Typical numerical approximations on electron cooling processes assume that the density distribution of electrons in analytical form and the velocity distribution space to be Maxwellian. However, it is useful to have an accurate description of the cooling process based on a realistic electron distribution. In this contribution, BETACOOL simulations of the ELENA antiproton beam phase space evolution were performed using uniform, Gaussian, and "hollow beam" electron velocity distributions. The results are compared with simulations considering a custom electron beam distribution obtained with G4beamline. The program was used to simulate the interaction of an initially Gaussian electron beam with the magnetic field measured inside the electron cooler interaction chamber. The resulting beam lifetime and equilibrium parameters are then compared with measurements.

THXA07 **Driven 3D beam oscillations for optics measurements in synchrotrons**

***L. Malina**, J.M. Coello de Portugal, H. Timko, R. Tomás (CERN)*

Optics measurements in storage rings employ turn-by-turn data of transversely excited beams. Traditionally, to measure chromatic properties, the relative momentum is changed step-wise, which is time-consuming and almost impractical during the energy ramp. We present an optics measurement method based on adiabatic simultaneous 3-dimensional beam excitation, which is more time-efficient and well fitted for the energy ramp. This method was successfully demonstrated in the LHC utilising AC-dipoles in combination either with a slow RF-frequency modulation or a driven RF-phase modulation close to the synchrotron frequency. Faster longitudinal oscillations improve the accuracy of optics parameters inferred from the synchro-betatron sidebands. This paper reports on the experimental demonstration of optics measurements based on 3D driven beam excitations and the plans for LHC Run 3.

THXB01 **3D Tracking of a Single Electron in IOTA**

***A.L. Romanov**, S. Nagaitsev, J.K. Santucci, G. Stancari, A. Valishev (Fermilab) N. Kuklev, I. Lobach (University of Chicago)*

High-resolution observations of single-particle dynamics have potential as a powerful tool in the diagnostics, tuning and design of storage rings. We are presenting the results of experiments with single electrons that were conducted at Fermilab's IOTA ring to explore the feasibility of this approach. A set of sensitive, high-resolution digital cameras was used to detect the synchrotron radiation emitted by an electron, and the resulting images were used to reconstruct the time evolution of oscillation amplitudes in all three degrees of freedom. From the evolution of the oscillation amplitudes, we deduce transverse emittances, momentum spread, damping times, beam energy and estimated residual-gas density and composition. To our knowledge, this is the first time that the dynamics of a single particle in a storage ring has been tracked in all three dimensions. We discuss farther development of a single particle diagnostics that may allow reconstruction of its turn-by-turn coordinates over macroscopic periods of time facilitating ultra-precise lattice diagnostics and direct benchmarking of tracking codes.

THXB02 **Beam Arrival Stability at the European XFEL**

***M.K. Czwalinna**, J. Kral, B. Lautenschlager, J. Müller, H. Schlarb, S. Schulz, B. Steffen (DESY) R. Boll, H. Kirkwood, J. Koliyadu, R. Letrun, J. Liu, F. Pallas, D.E. Rivas, T. Sato (EuXFEL)*

Free electron laser facilities, such as the European XFEL, make increasingly high demands on the longterm temporal stability and uniformity of the electron bunches, as pump-probe experiments meanwhile aim for timing stabilities of few femtoseconds residual jitter only. For a beam-based feedback control of the linear accelerator, electro-optical bunch arrival-time monitors are deployed, achieving a time resolution better than 3 fs. In a first attempt, we recently demonstrated a beam-based feedback system, reducing the arrival time jitter of the electron bunches to the 10 fs level with stable operation over hours. For pump-probe experiments it is crucial to equally verify this new level of precision in the FEL pulse arrival time with independent methods. In this work, we are discussing first results from examining the facility-wide temporal stability at the European XFEL, with attention to the contributions of various sub-systems and on the different time scales.

THXB03 **High Precision RF Control: from Particle Accelerators to Quantum bits**

***G. Huang** (LBNL)*

Superconducting circuit quantum bit (qubits) is one of the leading implementation of a quantum computer. The qubits are controlled

and read by 4-8 GHz RF pulses. High precision FPGA based RF control technique has been widely used in the various particle accelerator subsystems, including the cavity field control (LLRF) system and timing/synchronization system. Based on the technique developed from the accelerator control, we are developing an open source qubit control system. The prototype module is tested with the superconducting qubits and demonstrated the single and two qubits gate operation with good fidelity and multi-module synchronization is under development.

THXB04 **Non-Invasive Dispersion Function Measurement during Light Source Operations**

***B. Podobedov**, Y. Hidaka (BNL)*

We implemented a completely parasitic measurement of lattice dispersion functions in both horizontal and vertical planes, which is fully compatible with light source user operations. The measurement is performed by applying principle component analysis and adaptive filtering to very small residual orbit noise components introduced by the RF system and detected in the beam orbit data, sampled at 10 kHz. No changes in RF frequency are required. The measurement, performed once a minute, was shown to be robust and immune to changes in the beam current, residual orbit noise amplitude and frequency content as well as other factors. At low current it was shown to provide similar accuracy to the traditional method (which shifts the 500 MHz RF frequency by ±500 Hz). In this paper we will explain our measurement technique and present typical dispersion function stability achieved during NSLS-II operations.

THXB05 **Inverse orbit response matrix measurements: a possible online tool for optics control in Storage Rings**

***Z. Martí**, G. Benedetti, U. Iriso, E. Morales (ALBA-CELLS Synchrotron)*

We propose a novel technique to measure the linear optics in storage rings based on the acquisition of the inverse orbit response matrix (iORM). The iORM consists in the orbit correctors magnets (OCM) strength changes needed to produce a local orbit variation in each beam position monitor (BPM). This measurement can be implemented by introducing sequentially small changes in the BPM offsets and logging the OCM setting variations when the orbit correction is running. Very high precision and accuracy in the OCM set-points is required which poses a considerable challenge. Since the orbit feedback (FOFB) is kept running, the iORM could potentially be acquired in parallel to users storage ring operation. Since the iORM is very linear and local, optics perturbations could be easily diagnosed online. This paper introduces the iORM measurement concept and presents the progress of these studies at ALBA, where the implementation of this technique is limited by hysteresis effects in the OCM and the FOFB performance.

THXB06 **Results of the First Alignment Run for Sirius**

***R. Junqueira Leão**, R. Oliveira Neto (CNPEM) H. Geraissate, F. Rodrigues, G.R. Rovigatti de Oliveira (LNLS)*

It is widely known that the position of particle accelerator components is critical for its performance. For the latest generation light sources, whose magnetic lattice is optimized for achieving very low emittance, the tolerable misalignments are in the order of a few dozens of micrometers. Due to the perimeter of these machines, these requirements push the limits of large-volume dimensional metrology and associated instruments and techniques. Recently a fine alignment campaign was conducted following the pre-alignment performed during the installation phase. To conform with the strict absolute and relative positioning tolerances, metrology good practices were followed, and several 3D metrology procedures were developed. Also, to improve positioning resolution, high rigidity translation devices were manufactured. Finally, the special target holders designed as removable fiducials for Sirius magnets were revisited to assure maximum reliability. Data processing algorithms were implemented to evaluate the alignment results in a robust and agile manner. This paper will present the final positioning deviations for Sirius magnets with an expression of the estimated uncertainty.

THXB07 **Coherent Radiation From Inverse Compton Scattering Sources by Means of Particle Trapping**

***A. Fallahi** (ETH Zurich, Photonics Laboratory)*

Inverse Compton scattering (ICS) sources are one of the promising compact tools to generate short wavelength radiation from electron beams based on the relativistic Doppler effect. Nonetheless, these sources suffer from a few shortcomings such as incoherent radiation and low-efficiency in radiation generation. This contribution presents a novel scheme based on the scattering of an optical beam from a trapped electron beam inside an optical cavity. Inverse-Compton scattering off both free and trapped electrons are simulated using a full-wave solution of first-principle equations based on FDTD/PIC in the co-moving frame of electron beams. It is shown that the strong space-charge effect in low-energies is the main obstacle in acquiring coherent gain through the ICS mechanism. Subsequently, it is shown that by trapping the electron beam to the high-intensity spots, the space-charge effect is compensated, and additionally, the ultrahigh charge density enables high FEL-gain at trapping spots, thereby augmenting the coherence of the output radiation and concurrently increasing the source efficiency by three orders of magnitude.

THXC01 **Transformative Technology for FLASH Radiation Therapy**
C. Johnstone *(Fermilab)*
Cancer therapies include surgery, radiation therapy, chemotherapy, and immunotherapy. The prevailing method creates a physical dose differential between tumors and normal tissue, with treatment limited by normal tissue toxicity and patients experiencing acute side effects. Recently, a different paradigm for increasing the therapeutic index of radiation therapy has emerged, supported by preclinical research based on the FLASH radiation effect. FLASH radiation therapy (FLASH-RT) refers to novel radiation techniques delivering therapeutic radiation doses with ultra-high dose rates. Experimental studies have shown that normal tissues seem to be universally spared by FLASH-RT, whereas tumors are not. The dose delivery conditions are not fully characterized, but it is estimated that doses (>10 Gy) delivered in >100 ms produce optimal sparing effects. There are many technical challenges for the accelerator communities to create and monitor the required dose rates with novel and compact accelerators and fast large-area monitors for FLASH-RT, to ensure safe and reproducible beam delivery. This presentation reviews current R&D in the FLASH effect and promising innovative beam technologies.

THXC02 **Enhancing Particle Beam Therapy Through the Use of Mixed Ion Beams**
S. Jolly *(UCL)*
Particle beam therapy treatment with protons and light ions provides significant improvements over conventional X-ray radiotherapy due to the Bragg peak. However, the improved dose conformity of particle therapy requires a corresponding improvement in the accuracy of dose delivery to prevent underdosing of the tumour and overdosing of the surrounding healthy tissue. In vivo measurements of dose delivery have proved challenging: real-time systems for measuring delivered dose have yet to be realised. One possibility for ion therapy systems is through Helium-Carbon mixing. By diluting the Carbon treatment beam with a small quantity of Helium ions and accelerating to the same energy per nucleon, a diagnostic signal can be obtained: with a negligible increase to the delivered dose, the Helium beam exits the patient, providing diagnostic information on the tissue being treated and thereby providing real-time information on the position and range accuracy of the delivered dose. This talk describes the background to ion beam therapy and gives insight into experiments carried out to realise clinical Helium-Carbon mixing. The challenges for future systems are also discussed.

THXC03 **Evolution of the High-Power Spallation Mercury Target at the SNS**

D.E. Winder *(ORNL)*

The Spallation Neutron Source (SNS) began operation in 2006 and first operated at its full 1.4 MW power in 2013. Targets, which receive the pulsed proton beam, were a limiting factor for reliable full power operation for several years. Reaching reliable target operation at 1.4 MW required not only changes to the target design but also support and coordination across the entire SNS enterprise. The history and some key lessons learned are presented.

THXC04 **Neutrons for Today and Tomorrow - the HBS Project for Compact Accelerator Based Neutron Sources**

T. Gutberlet *(JCNS)*

Accelerator-driven neutron sources with high brilliance neutron provision present an alternative to classical neutron sources of fission reactors and spallation sources to provide scientists with neutrons to probe the structure and dynamics of matter. The Jülich Centre for Neutron Science has started a project to develop, design and demonstrate compact accelerator-driven high-brilliance neutron sources (HBS) as an efficient and cost-effective alternative to current low- and medium-flux reactor and spallation sources. The HBS will consist of a high current proton accelerator, a compact neutron production and moderator unit, and an optimized neutron transport system to provide thermal and cold neutrons with high brilliance. The project offers the construction of a scalable neutron source ranging from university based neutron laboratory to a full user facility with open access and service. Embedded within international collaboration with partners from Germany, Europe and Japan the Jülich HBS project will offer flexible solutions to the scientific. We will describe the current status of the project, the next steps, milestones, and the vision for the future neutron landscape in Europe.

THXC05 **Simulation of imaging using accelerated muon beams**

M. Otani *(KEK) H.M. Miyadera (LANL) T. Shiba (Japan Atomic Energy Agency)*

Muons are elementary particles with strong penetrating power and cosmic-ray muons have been utilized to see through large structures such as the pyramids. Recently, we have succeeded in accelerating muons using a radio-frequency accelerator, opening the door to new imaging techniques using accelerated muon beams. Currently, imaging with cosmic-ray muons is limited in imaging time and resolution by their intensity and energy fluctuations. The muon beams can have high intensity and monochromatic energy, allowing for better resolution imaging in less time. In this poster, imaging of spent nuclear fuel in casks using cosmic rays and muon beams, as well as imaging in other cases, will be evaluated and compared.

THXC06 **Design and Measurements of an X-Band 8 MeV Standing-Wave Electron Accelerator**

***F. Liu**, H.B. Chen, J. Shi, C.-X. Tang, H. Zha (TUB)*

X-band low-energy electron linear accelerators are attractive to industrial and medical applications due to the compact size. In this work we present tests of an 8 MeV X-band accelerator for industrial use. It adopts the coaxial coupling standing wave structure working at 9300 MHz. The accelerator length is 50 cm including the cavity, thermal gun, and electron window. Dedicated bunching cells are designed to reduce the energy spread. In the high power tests, the accelerator was able to generate the electron beam with RMS energy spread less than 1% (beam energy: 8.1 MeV, peak current: 45 mA). Combining features of compact size and the low energy spread, this X-band accelerator design is valuable for various applications.

THXC07 **Adaptive Control of Klystron Operation Parameters for Energy Saving at Storage Ring of TPS**

***T.-C. Yu**, F.Y. Chang, M.H. Chang, S.W. Chang, L.J. Chen, F.-T. Chung, Y.D. Li, M.-C. Lin, Z.K. Liu, C.H. Lo, Ch. Wang, M.-S. Yeh (NSRRC)*

To satisfy maximum beam current operation in the storage ring of TPS, the operation parameters of both RF transmitters are set to be able to generate its maximum RF power in daily operation. Under such condition, the klystrons can deliver any power below 300kW at constant AC power consumption which is about 520-530 kW. Hence, the AC power usage is independent of the required RF output power. To best utilize the available AC power based on the required RF power, an adaptive control methodology is proposed here for changing the operation parameters of the klystron, cathode voltage and anode voltage, according to the present RF power. The corresponding operation parameters are applied by the prior tested table which maps the operation parameters with the saturation RF power. The test results show that the saved energy can be 47% to 10% from 30mA to 400mA for each RF plant when comparing to constant operation parameters.

FRXA01 **Full Energy On-Demand Beam Injection from SACLA into the SPring-8 Storage Ring**

H. Maesaka*, T. Fukui, T. Hara, T. Hiraiwa, T. Inagaki, E. Iwai, H. Tanaka, K. Togawa (RIKEN SPring-8 Center) H. Dewa, T. Fujita, K. Fukami, N. Hosoda, A. Kiyomichi, M. Masaki, S. Matsubara, T. Ohshima, M. Oishi, K. Soutome, S. Takano, T. Watanabe (JASRI/SPring-8) C. Kondo (JASRI)*

The beam injector for the SPring-8 storage ring (SR) was switched from the booster synchrotron to the SACLA linac, a driver for X-ray free-electron laser (XFEL). The low-emittance beam from SACLA (~100 pm rad, 8 GeV) is delivered to the SR through a 600m-long beam transport line. This low-emittance beam can be applied to the new low-emittance storage ring after the SPring-8 upgrade planed in the coming years. The shutdown of the booster synchrotron and 1-GeV linac saves energy consumption and operation cost. To provide the electron beam injected to the SR on demand for the top-up injection during the XFEL operation, the SACLA linac must be synchronized to the desired bucket of the SR, the beam energy and route must be switched shot-to-shot, and the XFEL performance must not be degraded. We developed a precise synchronization system, on-demand beam route and parameter switching system, a pulsed magnet for the switchyard, isolated bunch purification system, etc. In this presentation, we will show the design and performance of each component for the beam injection and the results from beam commissioning of the accelerator and transport line.

FRXA02 **Advances in Beam Stability in Low-Emittance Synchrotron Light Sources**

G.M. Wang *(BNL)*

The evolution and maturation of user applications at low-emittance light sources is driving new, more stringent requirements for electron beam stability in the source points. Long high-spatial-resolution, nano-focus, and high-energy-resolution beamlines demand that the beam orbit and envelope in their insertion devices are stabilized to a small degree of the beam size. At the same time, the capabilities of modern electronics have been advancing rapidly in the past decade, enabling revolutionary developments in broad-bandwidth feedback systems for every dimension of beam dynamics. In addition, synergies between modern beamline and accelerator controls have opened up a pathway to develop and test the first fully integrated feedback system that can counteract drifts and vibrations, allowing us to meet these tight stability requirements. In this presentation we will discuss the stability requirements for premier instruments at NSLS-II and summarize our recent developments in this area.

FRXA03 **Harmonic Rf Cavities and Instabilities in Electron Storage Rings**

M. Venturini *(LBNL)*

Higher-harmonic rf cavities (HHC) are employed in several storage-ring light sources to lengthen the bunches and increase Touschek lifetime; their use is gaining further popularity in the new-generation machines as stronger intra-beam particle scattering is the unavoidable price to pay for higher brightness. Historically, HHCs were first introduced as a way to control certain collective instabilities. While often dubbed as "Landau cavities" (with reference to the damping potentially associated with the HHC-induced synchrotron-oscillation frequency spread), their effect on beam stability is, in fact, not necessarily always beneficial. Whether the HHCs help stabilize a beam, aggravate existing instabilities, or introduce new ones, is a complicated matter that depends on various circumstances. With focus on normal-conducting passive HHCs this talk will present some recent progress and revisit some older results on instability collective-mode theory illustrating aspects of the complex impact that HHCs have on beam dynamics. We will also review some open problems, making the case for the need of further theory development beyond conventional mode analysis.

FRXA04 **Commissioning results of LCLS-II MHz repetition rate electron source**

F. Zhou*, C. Adolphsen, A.L. Benwell, G.W. Brown, D. Dowell, M.P. Dunning, S. Gilevich, K. Grouev, B.T. Jacobson, X. Liu, A. Miahnahri, J.F. Schmerge, T. Vecchione (SLAC) G. Huang, F. Sannibale (LBNL)*

A 4 GeV 1.3 GHz superconducting linac is being constructed at SLAC as part of the X-ray free electron laser project (LCLS-II). The first 3-meter of the electron source that includes a normal conducting 185.7MHz CW RF gun, 2-cell 1.3 GHz CW RF buncher, and a loadlock system for cathode changes was designed and built by LBNL based on their experience with similar one for advanced photo-injector experiment program. The electron beam is designed to operate at a high repetition rate, up to 1 MHz. Since summer of 2018 we started LCLS-II injector source commissioning immediately after the major installation completion. This paper presents major commissioning results including achievements of ultra-high vacuum, RF processing to CW nominal power, dark current characterization and mitigation, and high-brightness electron beam measurements.

FRXA05 **Record High Extraction Efficiency of Free electron Laser Oscillator**

H. Zen*, H. Ohgaki (Kyoto University) R. Hajima (QST)*

The highest extraction efficiency (9.4%) of a free electron laser (FEL) oscillator has been achieved at the mid-infrared FEL facility of Kyoto University. Because of the interaction between the electron beam and FEL electromagnetic field, a maximum electron energy decrease of

16% was observed. The measured energy decrease was consistent with the measured FEL spectrum. An FEL micro-pulse energy of approximately 100 micro-J with micro-pulse duration of 150 fs was observed. This result is an important milestone for the high-extraction-efficiency FEL oscillator and will contribute to the strong-field physics of atoms and molecules.

FRXA06 **Mitigation of Beam Instabilities in the Echo-Enabled Harmonic Generation Beamline for FLASH2020+**

***F. Pannek**, W. Hillert, D. Samoilenko (University of Hamburg, Institut für Experimentalphysik) S. Ackermann, E. Allaria, P. Niknejadi, G. Paraskaki, L. Schaper (DESY) M.A. Pop (MAX IV Laboratory, Lund University)*

With the FLASH2020+ upgrade, one of the beamlines of the free-electron laser FLASH at DESY will be based on the Echo-Enabled Harmonic Generation (EEHG) seeding scheme and provide high-repetition-rate, coherent radiation down to 4 nm. To reach this wavelength, it is necessary to imprint intricate structures on the longitudinal phase space of the electron bunch at a very high harmonic of the seed laser wavelength, making the scheme potentially vulnerable to beam instabilities. Part of the beamline is a strong chicane, which is necessary to create the dispersion required by EEHG. Resulting effects such as Coherent Synchrotron Radiation (CSR) can be very detrimental for the bunching process and have to be taken into account already in the design of the beamline to ensure optimum FEL performance. We investigate and propose possible mitigation solutions to such instabilities in the FLASH2020+ parameter range.

FRXA07 **Ringdown Measured in a Four-Bounce, 20 Meter Hard X-Ray Cavity**

***J.P. MacArthur**, Z. Huang, J. Krzywiński, G. Marcus, R.A. Margraf, T. Sato, D. Zhu (SLAC)*

A cavity-based hard x-ray free-electron laser (CBXFEL) could produce fully coherent pulses with a bandwidth several orders of magnitude below the intrinsic bandwidth of SASE. A cavity-based FEL is not a new concept - the first FEL was an oscillator operating at 3.4 um - but single-pass amplification of spontaneous radiation was the fastest path to gigawatt x-ray powers. One unproven component of a CBXFEL is a stable, high reflectivity cavity. To address this deficit we present ring-down measurements in a 20 m round-trip cold cavity operating at 9.8 keV. The cavity is composed of four strain-relief-cut diamond 400 Bragg mirrors and a transmission grating for in/out-coupling. It is a testbed for alignment protocols and component performance under realistic experimental conditions like source instability, optics imperfections, and thermal drift.

FRXB01 **The Progress of the In-Vacuum Superconducting Undulator Prototype for SHINE Project**

Q.G. Zhou *(SSRF)*

The superconducting undulator can generate the highest peak field with the short period length and give the desirable K value, thus producing the high-intensity high-energy radiation photons. The Shanghai High Repetition rate XFEL and Extreme Light (SHINE) facility will use 40 superconducting undulators with 4m long for each to produce the vertically polarized photons with energy of 10keV-25keV. The period length of undulators is 16mm, the magnetic gap is 5mm and the peak field is 1.58T. Each undulator contains 504 vertical racetrace coils made of NbTi wires which are wound on 504 active poles. A 65K shielding is designed to reduce the thermal radiation from the vacuum chamber. The cooling of the magnet is forced by the liquid helium pipes which are installed in the middle of the magnet yoke surface and the sides of the gap in the direction of the electron beam. There is no beam vacuum chamber due to the small magnetic gap. A prototype of 4m long is being manufactured before the mass production and will be finished this year. The paper will describe the design parameters, the configuration of the prototype and the test plan of this year.

FRXB02 **Development of 36 GHz RF Systems for RF Linearisers**

A. Castilla*, G. Burt (Lancaster University) M. Behtouei, B. Spataro (INFN/LNF) G. Burt (Cockcroft Institute) J.C. Cai,* ***A. Castilla****, A. Latina, X. Liu, I. Syratchev, X.W. Wu, W. Wuensch (CERN) J.C. Cai,* ***A. Castilla*** *(Cockcroft Institute, Lancaster University) A.W. Cross, L. Zhang (USTRAT/SUPA) L.J.R. Nix (University of Strathclyde)*

As part of the deign studies, the CompactLight project plans to use an injector in the C-band. Which constitutes a particular complication for the harmonic system in charge of linearising the beam's phase space, since it means its operation frequency could be higher than the standard X-band RF technologies. In the present work, we investigated a 36 GHz (Ka-band) as the ideal frequency for the harmonic system. A set of structure designs are presented as candidates for the linearizer, based on different powering schemes and pulse compressor technologies. The comparison is made both in terms of beam dynamics and RF performance. Given the phase stability requirements for the MW class RF sources needed for this system, we performed careful studies of a Gyro-Klystron and a multi-beam klystron as potential RF sources, with both showing up to 3 MW available power using moderate modulator voltages. Alternatives for pulse compression at Ka-band are also discussed in this work.

FRXB03 **MgB_2 Based High-Current Power Transmission Lines for the HL-LHC Magnets: From Concept to Prototype Validation**
A. Ballarino *(CERN)*
The powering of the HL-LHC magnets requires transferring multiple large quasi-DC currents from the power converters, located in new radiation-free underground galleries, to the magnets. Superconducting power transmission lines based on MgB_2 superconductor, called Superconducting Links, ensure the electrical transmission from the current leads, near the power converters, to the magnets in the LHC main tunnel. They span a physical distance of up to about 120 metres, snaking through a complex underground environment that includes a vertical path of about 10 metres, and transfer DC currents totalling up to 120 kA at temperatures of up to 25 K. This paper summarizes the development done in order to conceive, construct and industrialize cold powering systems including 100 kA Superconducting Links. The systems, which are cooled by the forced flow of helium gas, incorporate HTS REBCO based current leads and Nb-Ti terminations for the connection to the magnets' busbars. Demonstrator cold powering systems were recently constructed and tested at CERN in nominal and transient conditions representative of the final operation modes. The results from these tests are also presented and discussed.

FRXB04 **Newly Development of Ceramics Chamber with Integrated Pulsed Magnet for Super Narrow Bore in KEK-PF**
C. Mitsuda*, K. Harada, Y. Kobayashi, S. Nagahashi, T. Nogami, T. Obina, R. Takai, H. Takaki, T. Uchiyama, A. Ueda (KEK) K. Hamaji, K. Iwamoto, A. Sasagawa, A. Yokoyama (KYOCERA Corporation) Y. Lu (Sokendai)*
Ceramics chamber with integrated pulsed magnet (CCiPM) is a new air-core type magnet that has a plan to be used as a multipole injection magnet, a dipole injection kicker, and a fast correction kicker in the next-generation light source. The magnet coils are implanted completely into the thickness of cylindrical ceramic and integrated with ceramic structurally. The first CCiPM was developed for an internal diameter of 60 mm as a magnet bore to establish the basic production techniques. The technique has been enhanced to realize narrower bore over 3 years, and finally, the achieved internal diameters were 40 and 30 mm in newly developed CCiPM. These super small bores have an expectation to conform to the size of the vacuum beam duct in the ring of a future light source. New CCiPMs are under the off-line test to confirm the vacuum durability, electrical characteristics, and magnetic performance, and the beam test for the CCiPM with 30 mm diameter has also proceeded in parallel. The points of production technique and the recent results of the off-line test will be presented in this conference.

FRXB05 **Muon Ionization Cooling Experiment: Results & Prospects**

C.T. Rogers *(STFC/RAL/ISIS)*

A high-energy muon collider could be the most powerful and cost-effective collider approach in the multi-TeV regime, and a neutrino source based on decay of an intense muon beam would be ideal for measurement of neutrino oscillation parameters. Muon beams may be created through the decay of pions produced in the interaction of a proton beam with a target. The muons are subsequently accelerated and injected into a storage ring where they decay producing a beam of neutrinos, or collide with counter-rotating antimuons. Cooling of the muon beam would enable more muons to be accelerated resulting in a more intense neutrino source and higher collider luminosity. Ionization cooling is the novel technique by which it is proposed to cool the beam. The Muon Ionization Cooling Experiment collaboration constructed a section of an ionization cooling channel and used it to provide the first demonstration of ionization cooling. Here the observation of ionization cooling is described. The cooling performance is studied for a variety of beam and magnetic field configurations. The outlook for muon ionization cooling demonstrations is discussed.

FRXB06 **Direct response time measurements on semiconductor photocathodes**

G. Loisch*, M. Groß, D.K. Kalantaryan, C. Koschitzki, M. Krasilnikov, X. Li, O. Lishilin, D. Melkumyan, R. Niemczyk, A. Oppelt, H.J. Qian, F. Stephan, G. Vashchenko, T. Weilbach (DESY Zeuthen) Y. Chen, S. Lederer (DESY) L. Monaco, D. Sertore (INFN/LASA) R. Valizadeh (STFC/DL/ASTeC)*

Semiconductor photocathodes like Cs_2Te enable stable electron sources with high photon to electron conversion rate (quantum efficiency, QE) for high brightness photoinjectors. Besides QE, work function and vacuum stability, bunch lengthening is a key figure of merit for these sources, resulting from UV photon penetration into the semiconductor and scattering of excited electrons before emission. These processes and their statistical variation lead to a delay, as well as to lengthening of the extracted electron bunch w.r.t. the incident laser pulse, often referred to as "response time". Thus far, no direct measurement of the response time of Cs_2Te, one of the most widely used cathode materials, has been reported. As such a measurement is crucial for photocathode laser based bunch shaping, short bunch applications, emission modeling and for evaluating new cathode materials like CsKSb, a measurement procedure has been established at the photoinjector test facility at DESY in Zeuthen (PITZ) to measure longitudinal bunch shape variation due to cathode emission effects. Here, we introduce the method and show first results on direct cathode response measurements of Cs_2Te cathodes.

FRXB07 **Injector Optimization for the IR-FEL Operation at the Compact ERL at KEK**

***O.A. Tanaka**, N. Higashi, T. Miyajima (KEK)*

The Compact Energy Recovery Linac (cERL) at KEK is a test accelerator to develop ERL technologies and to operate with a high average beam current and a high beam quality. cERL consists of a photoinjector, a main linac for energy recovery, a recirculation loop and a beam dump. A recent upgrade of the cERL to the middle Infrared Free Electron Laser (IR-FEL) imposed new conditions to maintain beam parameters. Therefore, the injector should be optimized to meet the following requirements at the exit of the main linac. The rms bunch length should be 2 ps, the rms longitudinal emittance should be kept the least, and simultaneously the rms transverse emittance should be kept less than 3 c mm mrad. In this work we describe the strategy and results of the injector optimization to achieve the better performance of the cERL-FEL.

FRXC01 **Superconducting Radio-Frequency Cavity Fault Classification Using Machine Learning at Jefferson Laboratory**

***C. Tennant**, A. Carpenter, T. Powers, L.S. Vidyaratne (JLab) K.M. Iftekharuddin, M. Rahman (ODU) A.D. Shabalina (STFC/DL)*

We report on the development of machine learning models for classifying C100 superconducting radiofrequency (SRF) cavity faults in the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab. Of the 418 SRF cavities in CEBAF, 96 are designed with a digital low-level RF system configured such that a cavity fault triggers recordings of RF signals for each of eight cavities in the cryomodule. Subject matter experts analyze the collected time-series data and identify which of the eight cavities faulted first and classify the type of fault. This information is used to find trends and strategically deploy mitigations to problematic cryomodules. However, manually labeling the data is laborious and time-consuming. By leveraging machine learning, near real-time - rather than postmortem - identification of the offending cavity and classification of the fault type has been implemented. We discuss the performance of the machine learning models during a recent physics run. We also discuss efforts for further insights into fault types through unsupervised learning techniques and present preliminary work on cavity and fault prediction using data collected prior to a failure event.

FRXC02 **Non Invasive Bunch Length Measurements Exploiting Cherenkov Diffraction Radiation**

***S. Mazzoni**, M. Bergamaschi, R. Corsini, A. Curcio, W. Farabolini, D. Gamba, L. Garolfi, A. Gilardi, R. Kieffer, M. Krupa, T. Lefèvre, E. Senes, M. Wendt (CERN) A. Curcio (NSRC SOLARIS) C. Davut, G.X. Xia (UMAN) W. Farabolini (CEA-DRF-IRFU) K.V. Fedorov, P. Karataev, K. Lekomtsev, C. Pakuza (JAI) K.V. Fedorov, A. Potylitsyn (TPU) J. Gardelle (CEA) P. Karataev (Royal Holloway, University of London) T.H. Pacey, Y.M. Saveliev (STFC/DL/ASTeC) A. Schloegelhofer (TU Vienna) E. Senes (Oxford University, Physics Department)*

Cherenkov Diffraction Radiation (ChDR) refers to the emission of broadband electromagnetic radiation which occurs when a charged particle propagates at relativistic speed in the vicinity of a dielectric material. At variance with the better-known Cherenkov radiation, ChDR is a non-invasive technique, that is the particle beam does not impinge on the dielectric radiator. ChDR also possesses other interesting features like a relatively high light yield, a broadband spectrum of emission and the emission at a relatively large angle with respect to the beam trajectory. Due to its potential, CERN initiated over the last few years several studies on ChDR-based diagnostics techniques. In this

contribution I will focus on the exploitation of ChDR for non-invasive bunch length measurement, from proof of principle tests performed at the CLEAR facility at CERN and CLARA at Daresbury laboratory to current developments for experiments and facilities such as AWAKE and FCC

FRXC03 **Modern Ultra-Fast Detectors for Online Beam Diagnostics**
***M.M. Patil**, E. Bründermann, M. Caselle, A. Ebersoldt, S. Funkner, B. Kehrer, A.-S. Müller, M.J. Nasse, G. Niehues, J.L. Steinmann, W. Wang, M. Weber, C. Widmann (KIT)*
Synchrotron light sources operate with bunch repetition rates in the MHz regime. The longitudinal and transverse beam dynamics of these electron bunches can be investigated and characterized by experiments employing linear array detectors. To improve the performance of modern beam diagnostics and overcome the limitations of commercially available detectors, we have at KIT developed KALYPSO, a detector system operating with an unprecedented frame rate of up to 12 MHz. To facilitate the integration in different experiments, a modular architecture has been utilized. Different semiconductor microstrip sensors based on Si, InGaAs, PbS, and PbSe can be connected to the custom-designed low noise front-end ASIC to optimize the quantum efficiency at different photon energies, ranging from near-UV, visible, and up to near-IR. The front-end electronics are integrated within a heterogeneous DAQ consisting of FPGAs and GPUs, which allows the implementation of real-time data processing. This detector is currently installed at KARA, European XFEL, FLASH, Soleil, DELTA. In this contribution, we present the detector architecture, the performance results, and the ongoing technical developments.

FRXC04 **Time-Resolved H^- Beam Emittance Measurement at the SNS Linac Using a Laser Comb**
***Y. Liu**, A.V. Aleksandrov, C.D. Long (ORNL)*
We proposed and demonstrated a novel technique to measure time-resolved transverse emittances of the hydrogen ion (H-) beam in a 1-GeV high-power accelerator. The measurement is performed in a non-intrusive manner by using laser comb - laser pulses with controllable multi-layer temporal structure generated from a fiber-based master laser oscillator and diode-pumped solid-state laser amplifiers. The technique has been applied to the transverse emittance measurement of 1-GeV H^- beam at the Spallation Neutron Source (SNS) high energy beam transport (HEBT). More than 20 time-resolved emittances have been simultaneously measured within a macro-pulse, a single mini-pulse, or a single bunch of the 1.4-MW neutron production H^- beam from one measurement.

FRXC05 **Gas Jet In-Vivo Dosimetry for Particle Beam Therapy**

***J. Wolfenden**, N. Kumar, A. Salehilashkajani, C.P. Welsch, H.D. Zhang (The University of Liverpool) N. Kumar, A. Salehilashkajani, C.P. Welsch, **J. Wolfenden**, H.D. Zhang (Cockcroft Institute)*

Medical applications of charged particle beams require a full online characterisation of the beam to ensure patient safety, treatment efficacy, and facility efficiency. In-vivo dosimetry, measurement of delivered dose during treatment, is a significant part of this characterisation. Current methods offer limited information or are invasive to the beam, meaning measurements must be done offline. This contribution presents the development of a non-invasive gas jet in-vivo dosimeter for treatment facilities. The technique is based on the interaction between a particle beam and a supersonic gas jet curtain, which was originally developed for the high luminosity upgrade of the large hadron collider (HL-LHC). To demonstrate the medical application of this technique, an existing HL-LHC test system with minor modifications will be installed at the University of Birmingham's 35 MeV proton cyclotron, which has properties comparable to that of a treatment beam. This contribution presents the design and development of this test setup, plans for initial benchmarking measurements, and plans for a future optimised medical accelerator gas jet in-vivo dosimeter.

FRXC06 **Development of the prototype of the Cavity BPM system for SHINE**

***J. Chen**, Y.B. Leng, R.X. Yuan (SSRF) S.S. Cao (SINAP) L.W. Lai (SARI-CAS)*

The Shanghai high repetition rate XFEL and extreme light facility (SHINE) under construction is designed as one of the most advanced FEL facilities in the world, which will produce coherent x-rays with wavelengths from 0.05 to 3 nm and maximum repetition rate of 1MHz. In order to achieve precise, stable alignment of the electron and photo beams in the undulator, the prototype of the cavity beam position monitors (CBPM) including C-band and X-band have been designed and fabricated for the SHINE. And the requirement of the transverse position resolution is better than 200 nm for a single bunch of 100 pC at the dynamic range of ±100 μm. In this paper, we present the design of the cavity with high loaded Q and the RF front-end with low noise-figure, adjustable gain, single-stage down-conversion and phase-locked with reference clock, and also described the structure and specifications of the home-made data acquisition (DAQ) system. The construction of the experiment platform and preliminary measurement result with beam at Shanghai Soft X-ray FEL facility (SXFEL) will be addressed as well.

FRXC07 **Uncertainty Quantification for Virtual Diagnostic of Particle Accelerators**

***A. Hanuka**, O.R. Convery (SLAC) Y. Gal (Oxford University Press (Oxford Electronic Publishing)) L. Smith (University of Oxford)*

Current diagnostic tools for characterizing a system are often costly, limited and invasive, i.e. interrupt the system's normal operation. A Virtual Diagnostic (VD) is a computational tool based on deep learning that can be used to predict the diagnostic output. For practical usage of VDs, it is necessary to quantify the prediction's reliability, namely the uncertainty in that prediction. In this paper, we applied an ensemble of neural networks to create uncertainty and explore various ways of analyzing prediction's uncertainty using experimental data from the Linac Coherent Light Source particle accelerator at SLAC National Laboratory. We aim to accurately and confidently predict the longitudinal properties of the electron beam as given by their phase-space images. The ability to make informed decisions under uncertainty is crucial for reliable deployment of deep learning tools on safety-critical systems as particle accelerators.

FRXX — Closing Plenary

FRXX01 **My View on the 5 Most Beautiful Formulae in Accelerator Physics**

K. Yokoya *(KEK)*

Nowadays, projects using accelerators are becoming larger and larger in scale. More and more accurate designs of the entire accelerator systems and components are being demanded. Accordingly, detailed computer simulations are indispensable. On the other hand, in the past, most works have been done using analytic formulae with simple numerical estimation. They are still in the basis of designs. The extraordinary title of the this was given by the organizers. I would like to select a few of such formulae and explain the history.

FRXX02 **Accelerator Needs for Materials Research: Opportunities for Synergistic Collaboration**

J.L. Sarrao *(LANL)*

The particle accelerator and materials research communities have long enjoyed a synergistic relationship, dating back at least to the first studies of materials using synchrotron radiation produced at particle accelerators. At present a new generation of advanced synchrotrons and x-ray free electron lasers are emerging. These advances are coincident with a push in materials research to understand phenomena at unprecedented length and time scales, including a focus on the mesoscale properties of materials. Further, photons are not the only accelerator-produced particle of interest to materials research, both as a probe and as a means of generating perturbed states of matter. This presentation will not only reprise recent progress but also speculate about future opportunities.

FRXX03 **Amazonia and Climate Change: A Complex Relationship Critical for Our Future**

P. Artaxo *(USP)*

PLEASE ADD ABSTRACT

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