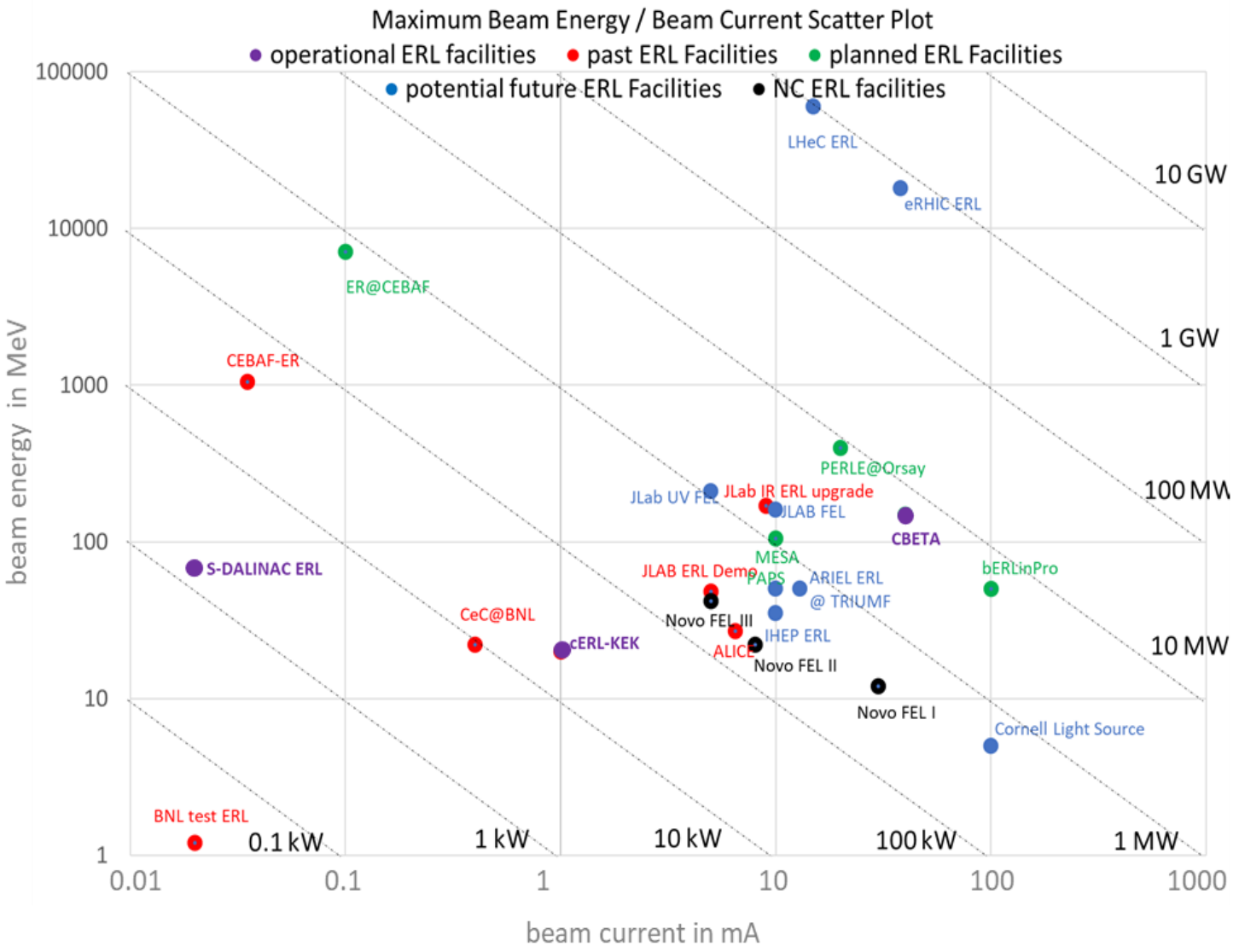
Report WG1: ERL Facilities

Members of WG1

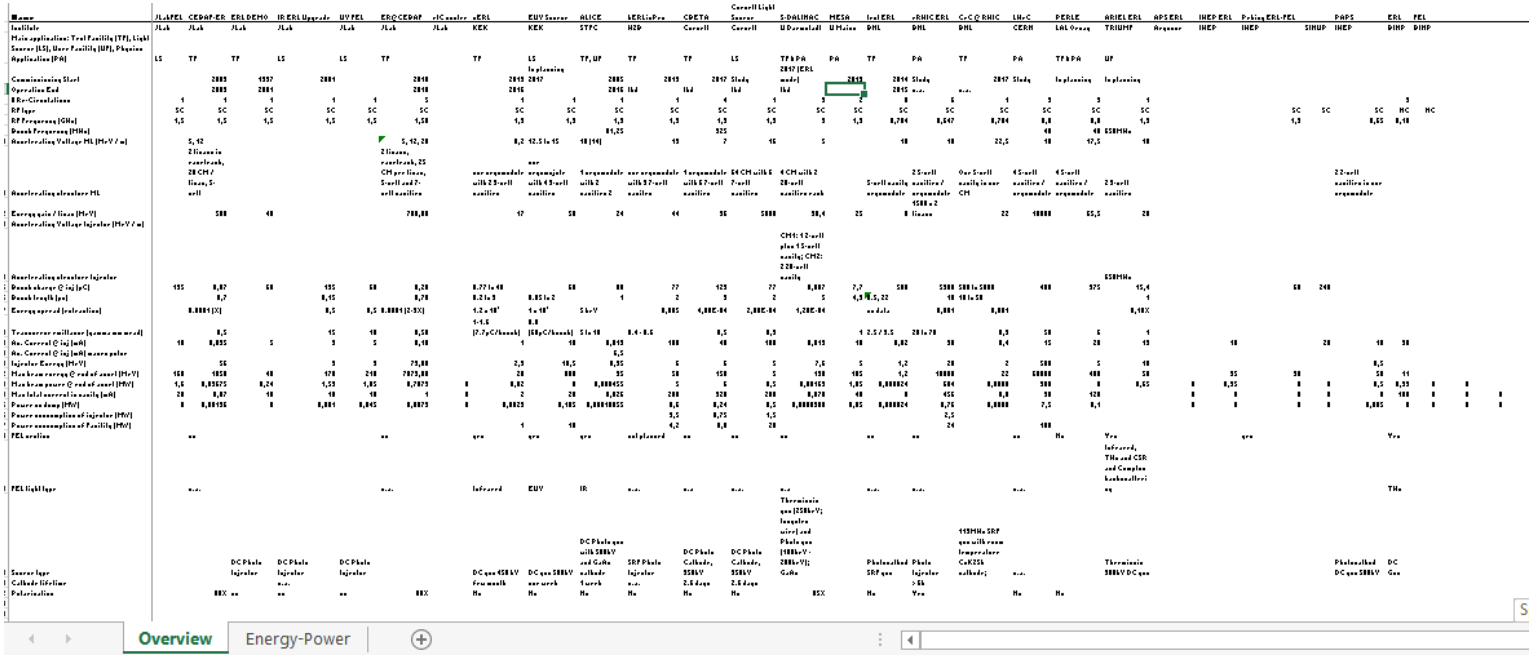
- Michael Abo-Bakr (HZB) (Convener)
- Michaela Arnold (S-DALINAC) (Convener)
- Walid Kaabi (LAL)
- Alexander Matveenko (HZB)
- Daniel Schulte (CERN)
- Nikolay Vinokurov (BINP)

ERL Landscape



F. Hug, ARIES Milestone Report MS28 – Parameter Database for Various ERL & Linac Facilities, (2019).

Facility Posters and Facility List



Overview | Energy-Power

Data up-to-date? Please check!

Will be available on ERL 2019 webpage

Facility Posters and Facility List

bERLinPro CBETA Novosibirsk ERL S-DALINAC MESA Facility List

Contribution: Talk

MOCOWBS01 *CBETA, a 4-turn ERL Based on SRF Linacs: Construction and Commissioning*

Invited Oral

Location WISTA: Bunsen Saal

Time Monday, 16-SEP-19 09:25 - 09:55

Speaker Georg H. Hoffstaetter - Cornell University (CLASSE) Cornell Laboratory for Accelerator-Based Sciences and Education

MOCOWBS02 *Compact ERL (cERL), Stable 1 mA Operation with a Small Beam Emittance at KEK*

Invited Oral

Location WISTA: Bunsen Saal

Time Monday, 16-SEP-19 09:55 - 10:25

Speaker Tsukasa Miyajima - High Energy Accelerator Research Organization

MOCOXBS02 *ERL Operation of S-DALINAC**

Invited Oral

Location WISTA: Bunsen Saal

Time Monday, 16-SEP-19 10:45 - 11:10

Speaker Norbert Pietralla - Technische Universitaet Darmstadt Institut fuer Kernphysik Fachbereich 05

MOCOXBS03 *Status of Novosibirsk ERL*

Invited Oral

Location WISTA: Bunsen Saal

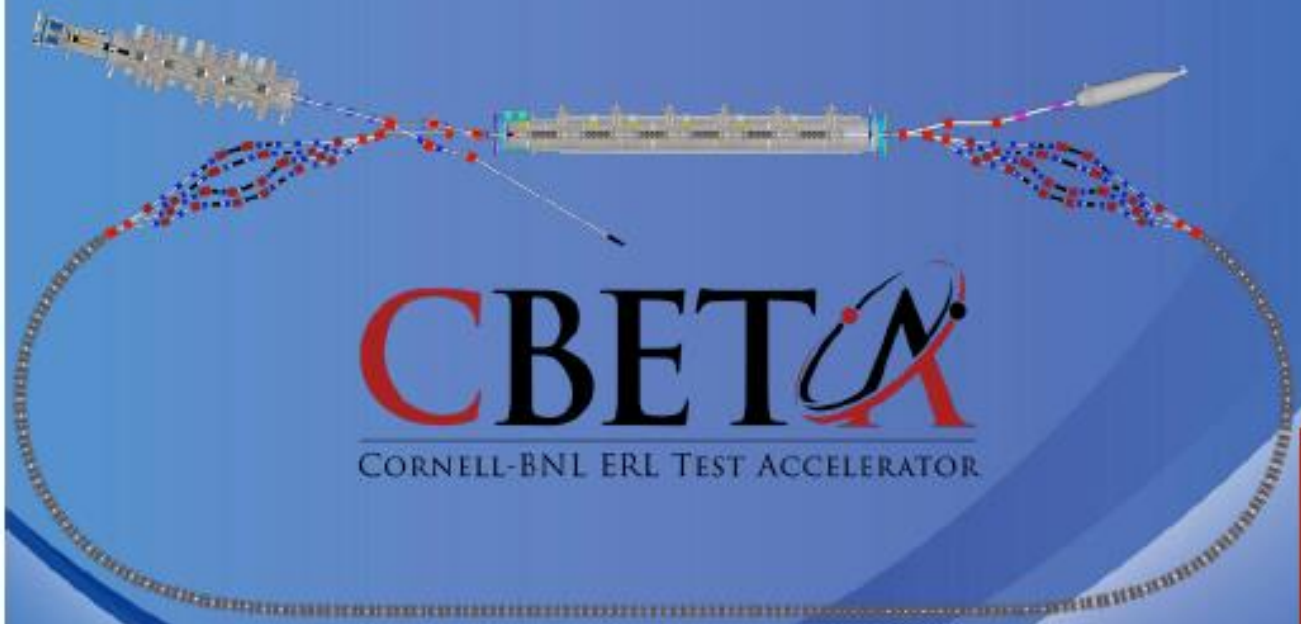
Time Monday, 16-SEP-19 11:10 - 11:35

Speaker Nikolay A. Vinokurov - Russian Academy of Sciences The Budker Institute of Nuclear Physics

CBETA at Cornell, the first 4-turn SRF Energy Recovery Linac with a single FFA return loop

Georg Hoffstaetter (Cornell)

For the CBETA collaboration team



CBETA

CORNELL-BNL ERL TEST ACCELERATOR

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

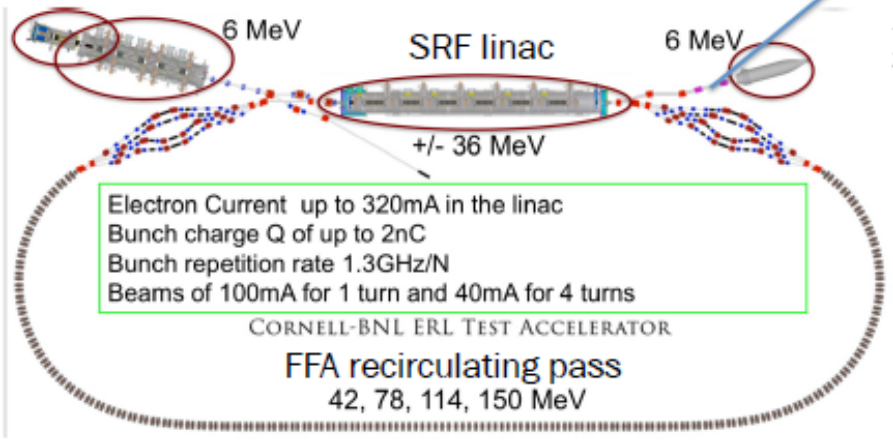
Office of Science

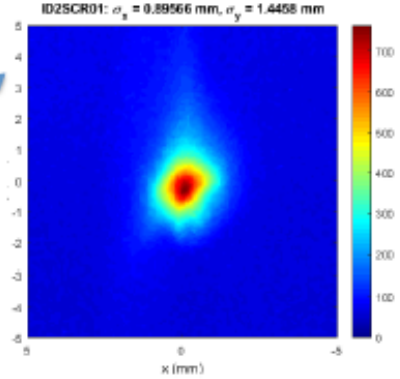
Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Cornell-BNL ERL Test Accelerator

CBETA

- At least 100 mA current will be needed for eRHIC hadron cooler (design limit for 1-turn CBETA)
- BNL and collaborators gained and demonstrated expertise in high-power ERLs
- Successful operation, including energy recovery in each cavity (June 24th, 2019).
- Full 4-turn construction is underway.



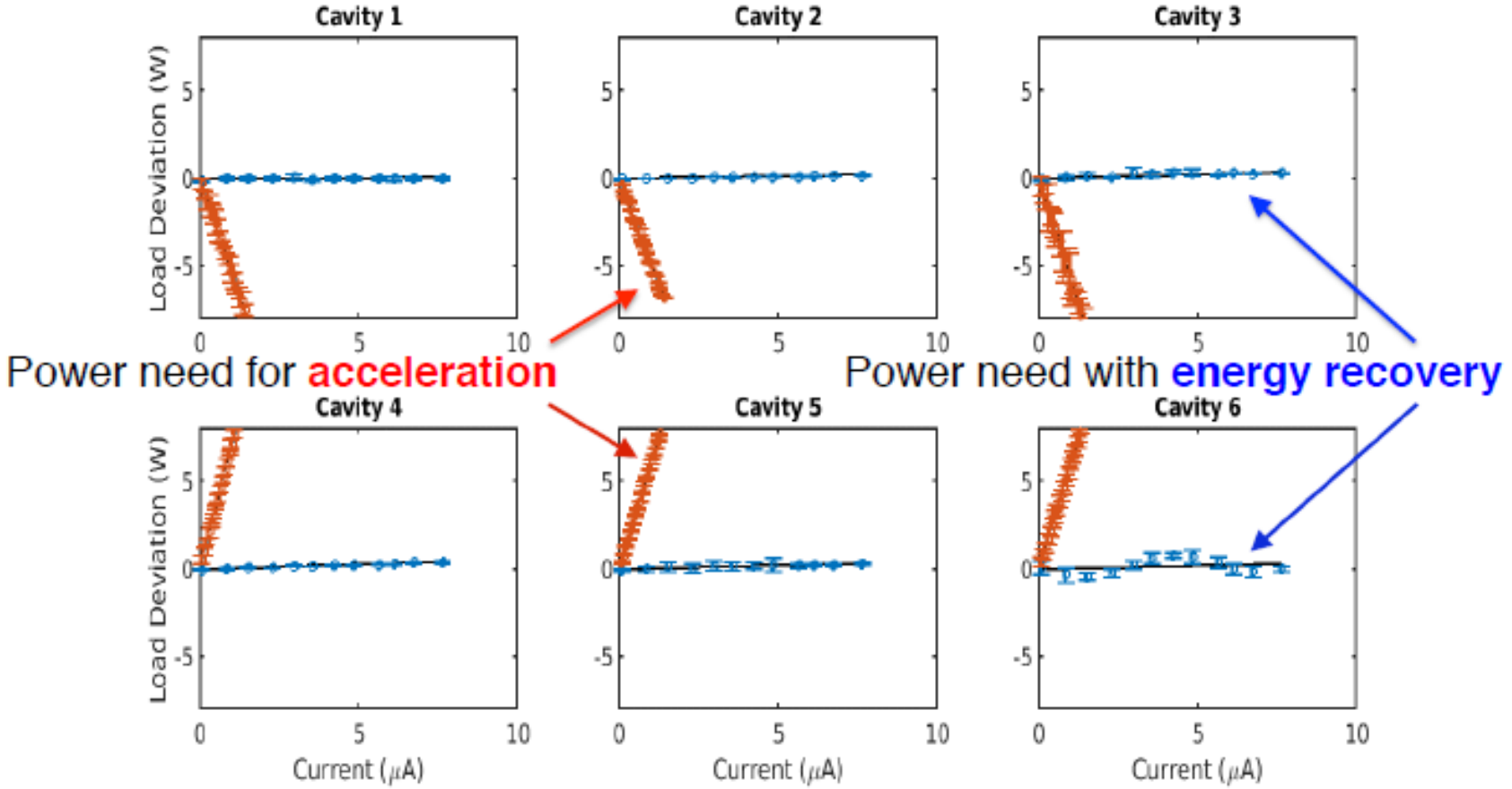


First energy-recovered beam spot @ CBETA

- Cornell DC gun
- 100mA, 6MeV SRF injector (ICM)
- 600kW beam dump
- 100mA, 6-cavity SRF CW Linac (MLC)

Energy Recovery in every cavity

- Transmission 99.6 ± 0.1% ; energy recovery > 99.8%
- Measured up to 8 μA
- Each cavity accelerates beam **without** receiving **external power** for it.



Compact ERL (cERL), Stable 1 mA Operation with a Small Beam Emittance at KEK

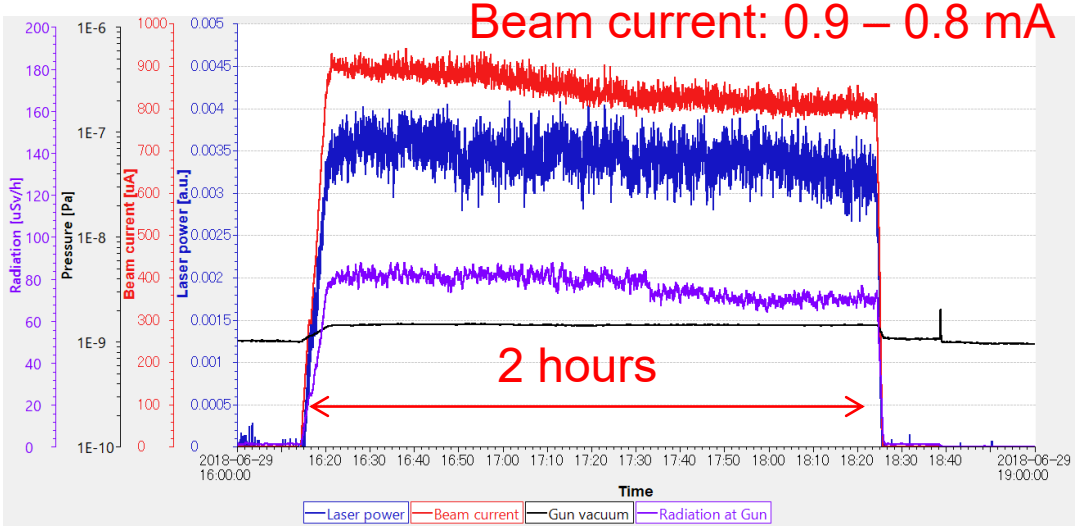
9:55-10:30, September 16, 2019
Workshop on Energy Recovery Linacs (ERL2019)
Helmholtz-Zentrum Berlin

Tsukasa Miyajima
KEK, High Energy Accelerator Research Organization
On behalf of cERL team

Compact ERL (cERL), Stable 1 mA Operation with a Small Beam Emittance at KEK

- In June 2018, we succeeded to CW 0.9 mA operation with recirculation loop energy 17.6 MeV after fine beam loss tuning. It is stable in 2 hours.

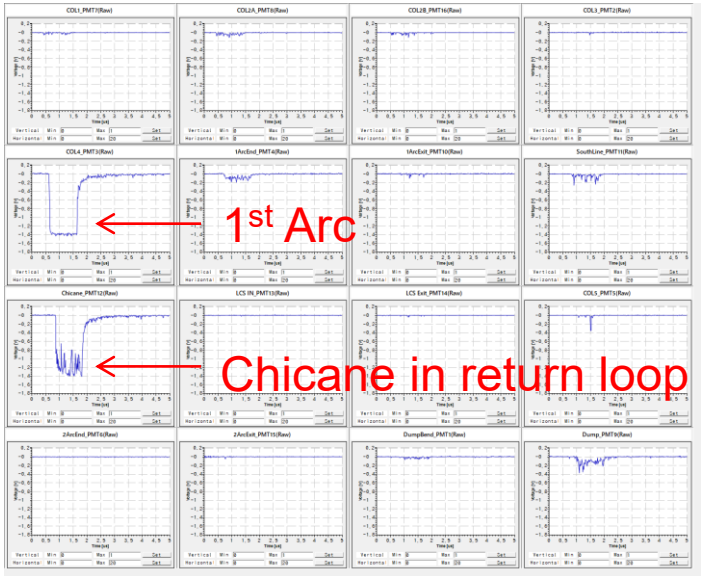
- To achieve stable CW operation, optics tuning and collimator tuning were very important.



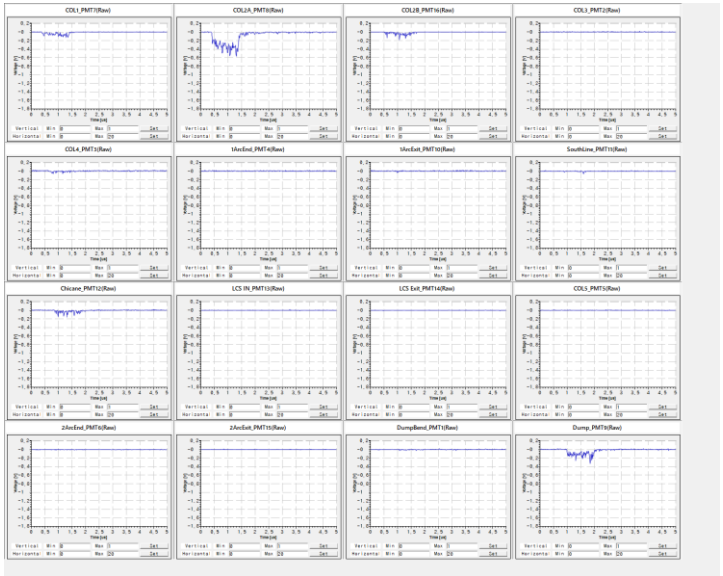
Gun voltage: DC 500 kV, Bunch charge: 0.77 pC

Los monitor signals

Before collimator tuning.



After collimator tuning.



- Beam performance:
  - The measured emittances were close to design values.
  - Energy recovery efficiency was 100% +/- 0.05 %.

Design emittance in recirculation loop

ε_{nx} = 0.34 mm mrad

ε_{ny} = 0.24 mm mrad

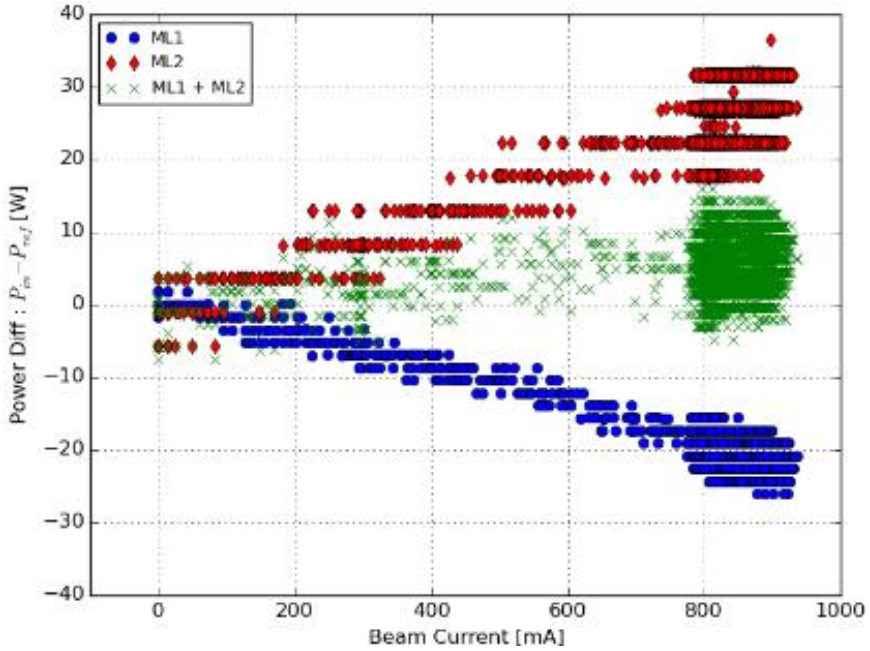
Measured emittance by Q-scan method

North straight section:

$(\varepsilon_{nx}, \varepsilon_{ny})$ = (0.29, 0.26) mm mrad

South straight section:

$(\varepsilon_{nx}, \varepsilon_{ny})$ = (0.42, 0.26) mm mrad



- Toward CW 10 mA operation
  - In 2019, we are improving the high voltage power supply of the DC gun.
  - Beam halo measurement to understand the mechanism
  - Estimation of Wake field caused by collimator
  - Cathode QE degradation for GaAs photocathode (Off center operation)
  - Reproducibility of beam loss tuning and collimator setting

ERL Operation of S-DALINAC

TECHNISCHE UNIVERSITÄT DARMSTADT

M. Arnold, T. Bahlo, M. Dutine, R. Grewe, J. Hanten, L. Jürgensen, J. Pforr, N. Pietralla, F. Schließmann, M. Steinhorst, S. Weih

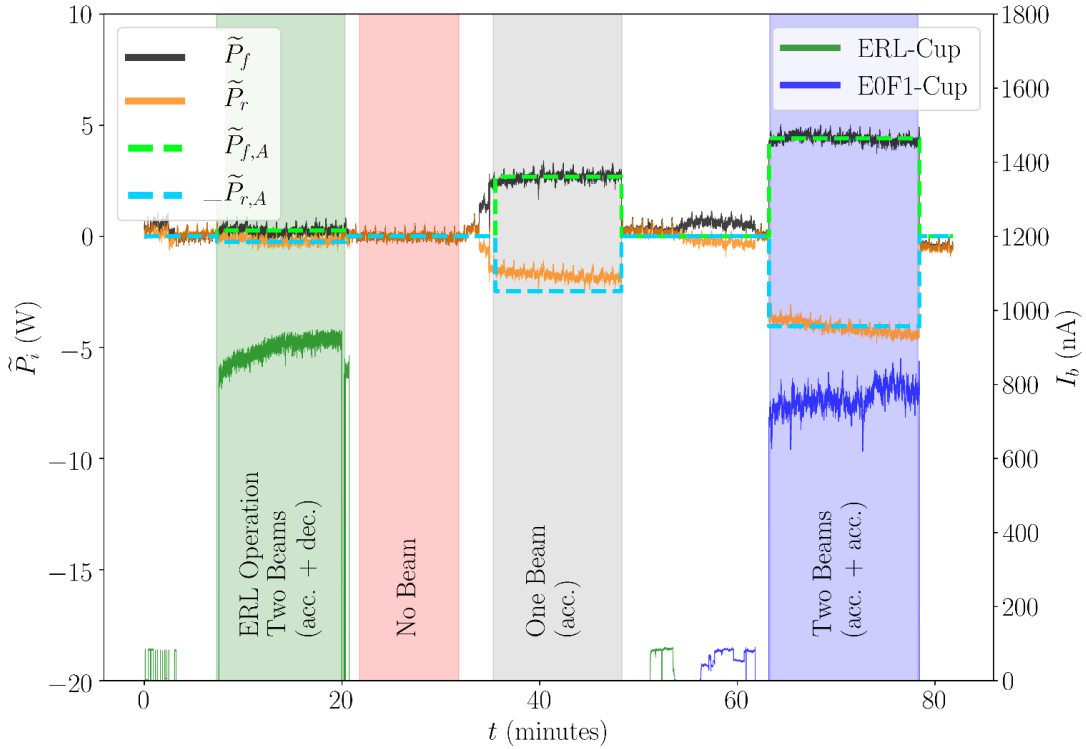
Picture: Jan-Christoph Hartung

ACCELENCE

Work supported by DFG through GRK 2128

Analytical Model Forward and Reverse Power

$$P_f = P_0 \frac{\left[\beta_{input} + (1 + \beta_{output} + \beta_{beam})\right]^2}{4\beta_{input}} \qquad P_r = P_0 \frac{\left[\beta_{in} - (1 + \beta_{output} + \beta_{beam})\right]^2}{4\beta_{input}}$$



- Curve-fitting to data in P_f
  - $\beta_{beam}=0$: to obtain β_{input}, β_{output} and P_0
  - $\beta_{beam}\neq 0$: to obtain $\beta_{beam,i}$ for each phase i
- Analytical prediction of P_r

M. Arnold et al., First Operation of the S-DALINAC as an Energy Recovery Linac, Phys. Rev. Accel. Beams, submitted (Sept. 2019).

RF Measurements - Power

Operation	Mean Beam Power in W
No Beam	0.00 ± 0.01
One Beam (acc.)	4.51 ± 0.16
Two Beams (acc. + acc.)	8.59 ± 0.01
ERL (acc. + dec.)	0.45 ± 0.03

RF-recovery effect:

$$\varepsilon_{RF} = (90.1 \pm 0.3)\%$$

Value and uncertainty take correlations between fit parameters into account.

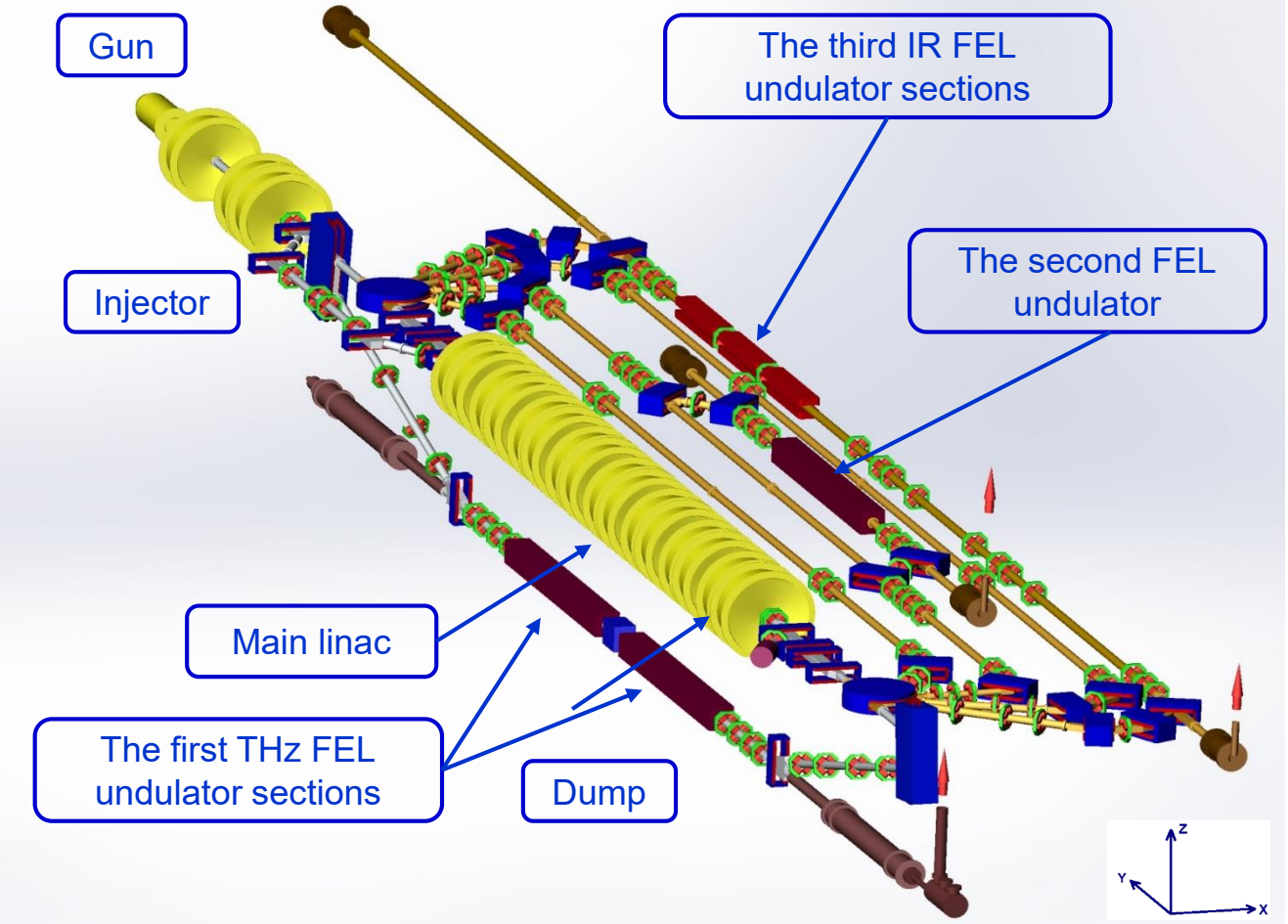
Beam-recovery efficiency:

$$\varepsilon_{b,max} = 88.9\%$$

M. Arnold et al., First Operation of the S-DALINAC as an Energy Recovery Linac, Phys. Rev. Accel. Beams, submitted (Sept. 2019).

Status of Novosibirsk ERL

N. A. Vinokurov
Budker Institute of Nuclear Physics SB RAS
Novosibirsk, Russia



All three laser systems of the NovoFEL facility are now in operation covering the wavelength range from 8 to 240 micron.

11 workstations are in operation and more two are under construction.

The workstations are well equipped with instrumentation which is available to users.

We invite researchers to apply for beam time to perform experiments at the NovoFEL.

MOCOXBS03

Novosibirsk FEL Facility Based on Non-suprconducting Multiturn ERL

- The Novosibirsk ERL is the first multiturn ERL in the world.
- normal-conductive 180 MHz accelerating system
- DC electron gun with the grid thermionic cathode
- three operation modes of the magnetic systema
- a rather compact (6×40 m^2) design.
- The facility has been operating for users of terahertz radiation since 2004.

FEL #	1	2	3
Energy, MeV	12	22	42
Current, mA	30	10	3
Wavelength, μm	90-240	37-80	8-11
Radiation power, kW	0.5	0.5	0.1
Electron efficiency, %	0.6	0.3	0.2
Pulse repetition rate, MHz	5.6 or 11.2	7.5	
Peak power, MW	1	1	

These two FELs (1+2) are the world's most powerful (in terms of average power) sources of coherent narrow-band (less than 1%) radiation in their wavelength ranges.

Contribution: Talk

MOCOXBS04 *The bERLinPro Project - Status and Perspectives*

Invited Oral

Location WISTA: Bunsen Saal

Time Monday, 16-SEP-19 11:35 - 12:00

Speaker Andreas Jankowiak - Helmholtz-Zentrum Berlin für Materialien und Energie GmbH Elektronen-Speicherring BESSY II

MOCOXBS05 *The MESA ERL Project*

Invited Oral

Location WISTA: Bunsen Saal

Time Monday, 16-SEP-19 12:00 - 12:25

Speaker Florian Hug - Johannes Gutenberg University Mainz Fachbereich Physik Institut für Kernphysik

MOCOYBS01 *PERLE: A High Power Energy Recovery Facility at Orsay*

Invited Oral

Location WISTA: Bunsen Saal

Time Monday, 16-SEP-19 14:00 - 14:25

Speaker Walid Kaabi - Laboratoire de l'Accélérateur Linéaire CNRS/IN2P3 Université Paris-Saclay

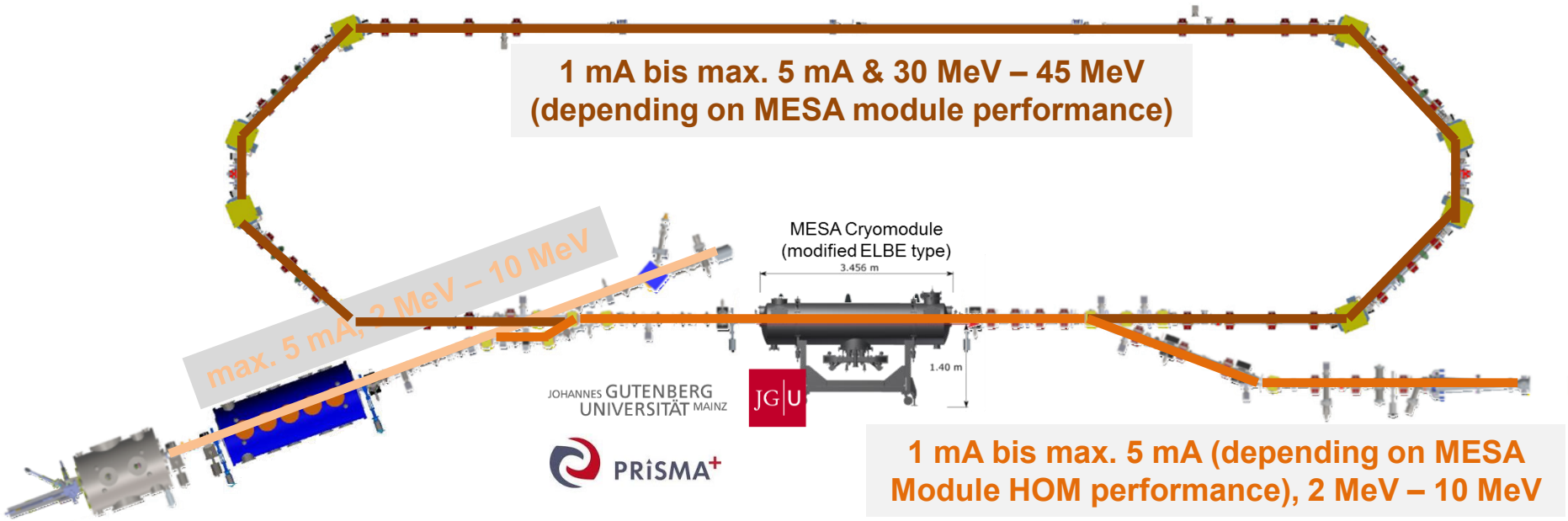
The Berlin Energy Recovery Linac Project

bERLinPro - Status, Plans, Future Opportunities
Summary slides

Andreas Jankowiak
on behalf of the bERLinPro project team
Helmholtz-Zentrum Berlin

63rd ICFA Advanced Beam Dynamics Workshop
on Energy Recovery Linacs – ERL´19
HZB / Berlin, 16.09.2019

Present planning – no contingency / still many uncertainties



06/2020 Gun1 cool down and RF commissioning (no beam tests)

10/2020 start installation of re-circulator vacuum (to be finished 03/2021)

12/2020 booster module installed

01/2021 MESA module installed (collaboration JGU Mainz, 2 x 9 cell)

06/2021 First beam possible, with subsequent re-circulation + recovery

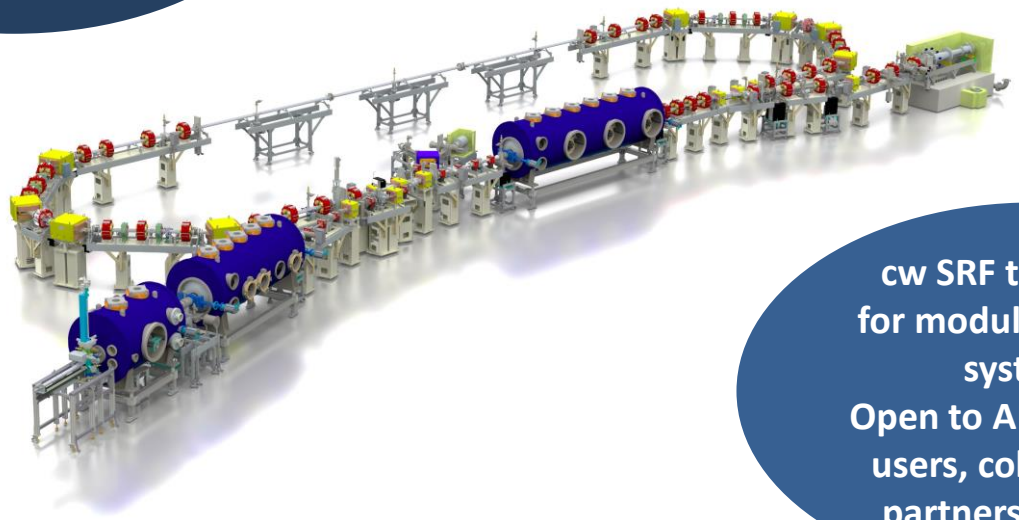
Re-circulation test period limited, as MESA module back to Mainz 07/2022 and start of VSR module tests in bERLinPro hall ca. 09/2022. Funding for 2000 h / a of operation secured till end of 2022.

bERLinPro as an R&D test facility in the future from 2022

To be able to secure HZB support for further operation of bERLinPro beyond 2022 we need to define possible applications and the strong interest of the community must be demonstrated.

THz pilot facility, High quality, high power radiation schemes (THz, X-rays, e- pump/probe)

Exotics
Dark matter search
Isotope production
EUV facility tests



cw SRF test facility for modules, cavities, systems. Open to ARD, external users, collaboration partners, industry.

ERL / Gun test accelerator, test bed for undulators, impedance tests, …

Teaching and education

STATUS OF THE MESA PROJECT

Cluster of Excellence
PRISMA+
Precision Physics,
Fundamental Interactions
and Structure of Matter

ACCELENCE

ARIES

Florian Hug
for the MESA group

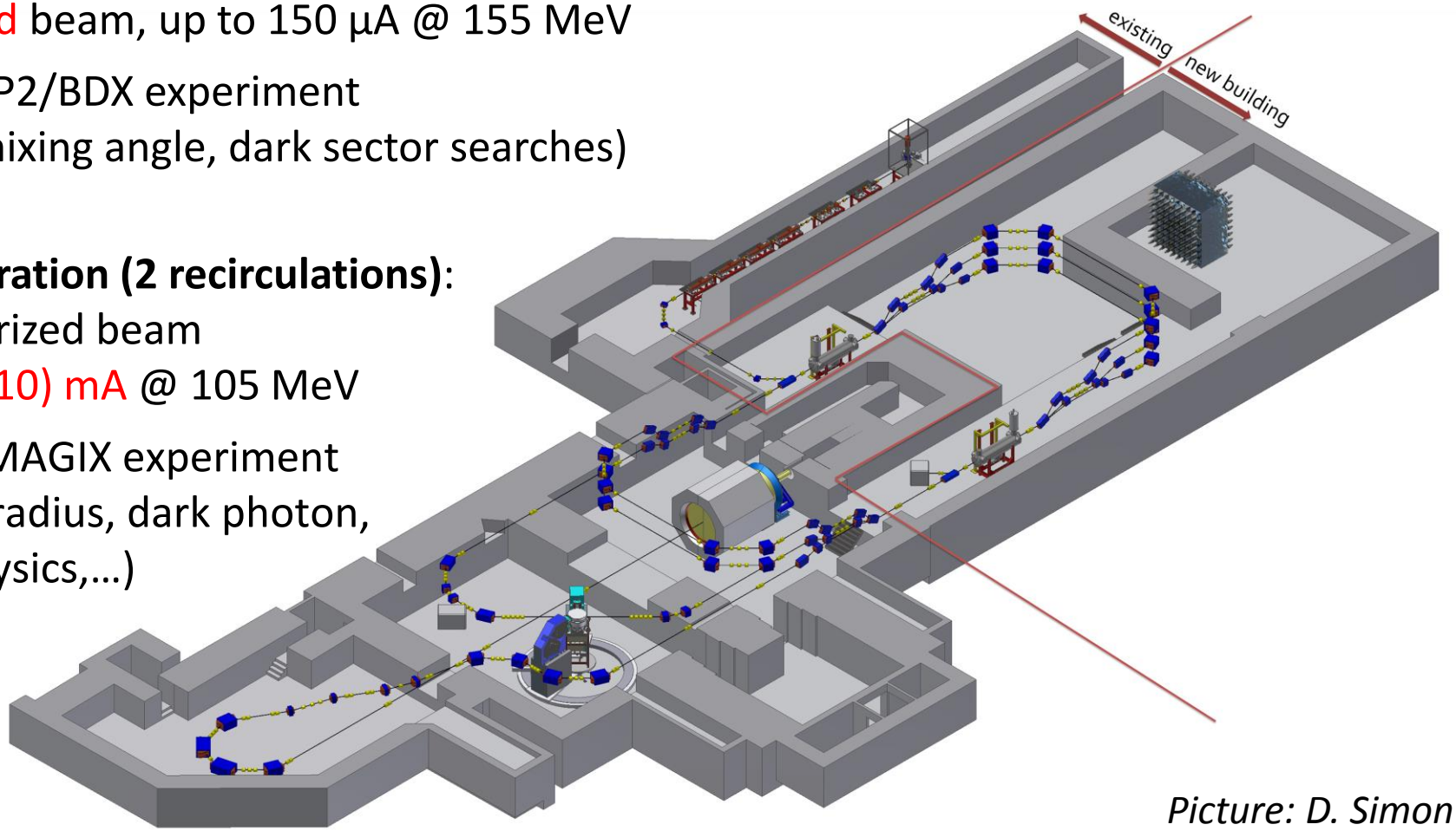
ERL Workshop 2019
HZB Berlin

The MESA ERL Project

Double sided recirculation design with normal-conducting injector and superconducting main linac running at different operation modes

- **External beam operation (3 recirculations)**:
  polarized beam, up to 150 µA @ 155 MeV
  serving P2/BDX experiment
  (weak mixing angle, dark sector searches)

- **ERL-operation (2 recirculations)**:
  (un)polarized beam
  up to 1 (10) mA @ 105 MeV
  serving MAGIX experiment
  (proton radius, dark photon,
  astrophysics,…)



Picture: D. Simon

Accelerator parts and Timeline

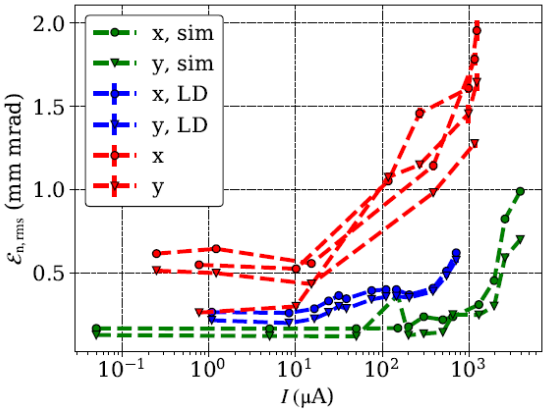
- Construction of the extended MESA until **2021.** Construction of the main linac in **2022.** Commissioning of injector in **2021,** first beam to experiments in **2023**

- **Until now:** Successful tests of SRF module (left), NC injector cavity prototype and amplifier (middle) and low energy injection (source, beam transport)

Cryomodule (2 XFEL Cavities @ 12.5 MV/m)

F. Hug, T. Stengler

R. Heine



C. Matejcek, K. Aulenbacher & S. Friederich, IPAC 2019

Energy Recovery Linacs Workshop- ERL 2019

Berlin, 15th-20th September 2019

bERLin 2019

PERLE : A High Power Energy Recovery Facility at Orsay

On behalf of the PERLE Collaboration

Walid KAABI-LAL/CNRS

PERLE

cnrs IN2P3 Les deux infinis

CERN

Jefferson Lab

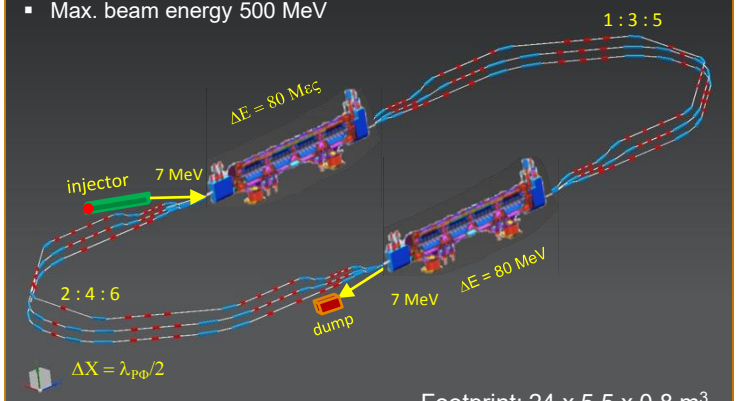
Science & Technology Facilities Council

Daniel Institute of Nuclear Physics

University of Liverpool

PERLE: A High Power Energy Recovery Facility at Orsay

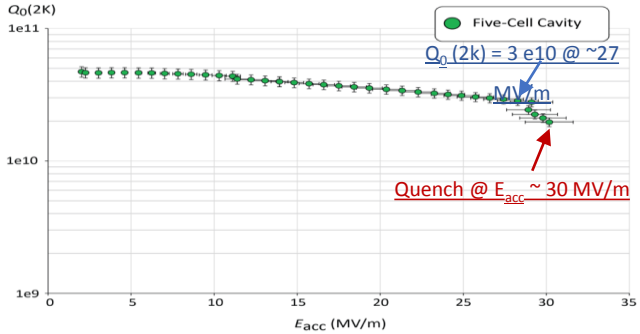
- 2 Linacs (Four 5-Cell 801.58 MHz SC cavities)
- 3 turns (160 MeV/turn)
- Max. beam energy 500 MeV



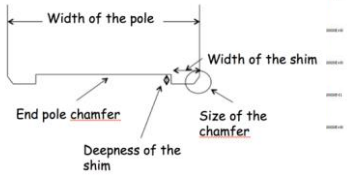
Footprint: 24 x 5.5 x 0.8 m^3

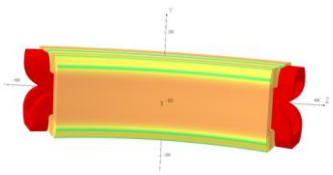
Target Parameter	Unit	Value
Injection energy	MeV	7
Electron beam energy	MeV	500
Normalised Emittance $\gamma\varepsilon_{x,y}$	mm mrad	6
Average beam current	mA	20
Bunch charge	pC	500
Bunch length	mm	3
Bunch spacing	ns	25
RF frequency	MHz	801.58
Duty factor		CW

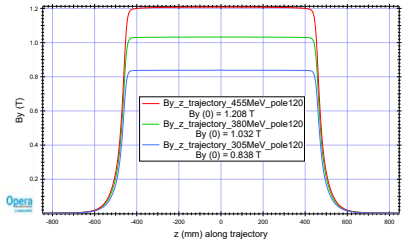
❑ 1st SRF cavity fabrication and test:

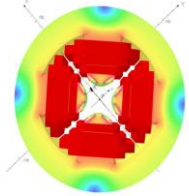


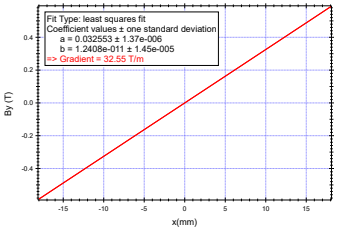
❑ Arc optics optimisation:

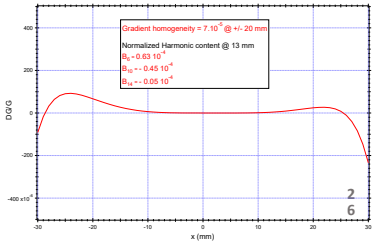






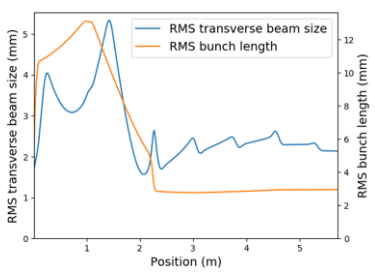


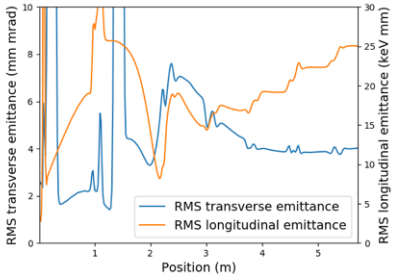


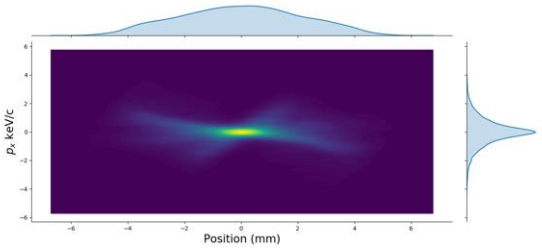


PERLE: A High Power Energy Recovery Facility at Orsay

❑ Electron source and injector optimisation:



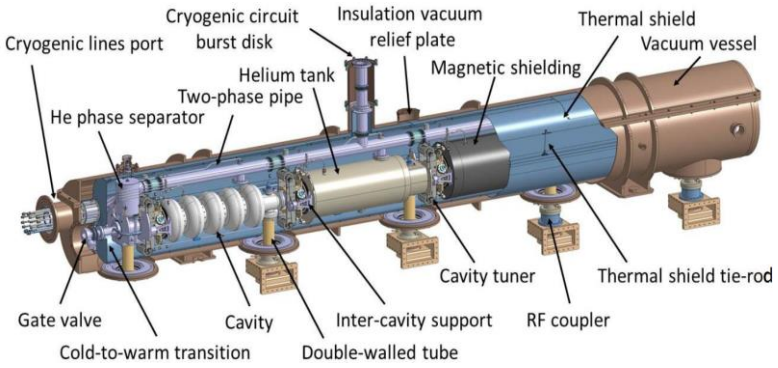




Achieved bunch parameters	
Transverse emittance/ mm mrad	4.0
Longitudinal emittance/ keV mm	25.1
Bunch length/ mm	3.0
Energy/ MeV	7.0

=> The PERLE injector is capable of achieving the specification at the booster exit. The possibility of improving the bunch distributions and longitudinal phase space will be investigated (linearizing the longitudinal phase space)

❑ SPL cryomodule adaptation for PERLE:



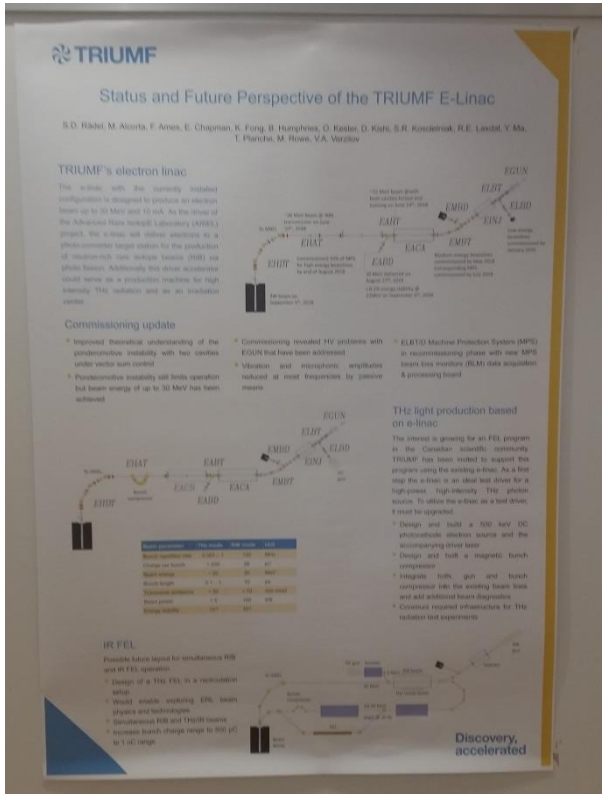
First results:

- ✓ Thermal and magnetic shielding are well sized for PERLE operation parameters. Their design could be modified if needed.
- ✓ Vacuum vessel could be reused without refurbishing
- ✓ Input coupler designed for SPL cavity could be easily adapted to meet PERLE requirement
- ✓ Further studies will define if Cryogenic lines have to be adapted
- ✓ Space liberated due to cavity frequency difference give a little margin for auxiliaries integration.

Pending issue:

- HOM study to define the design and the number of HOM couplers to be used for PERLE cavities.

Contribution: Poster



- SRF linac
- Max. energy 30 MeV
- Max. current 10 mA
- Low beam power commissioning in summer 2018 (25 MeV)

- Driver for ARIEL (Advanced Rare Isotope Laboratory) project
  - Rare isotope beams
  - THz radiation possible

- Upgrade could be recirculation and thus ERL

WEPNEC01 *Status and Future Perspective of the TRIUMF E-Linac*

Poster

Location Newton-/Einstein Cabinet

Time Wednesday, 18-SEP-19 14:00 - 06:00

Presenter Stephanie Diana Rädel - TRIUMF Canada's National Laboratory for Particle and Nuclear Physics

Thanks to all contributions and discussions!