STATUS OF THE FAIR SYNCHROTRON PROJECTS

SIS18 UPGRADE AND SIS100

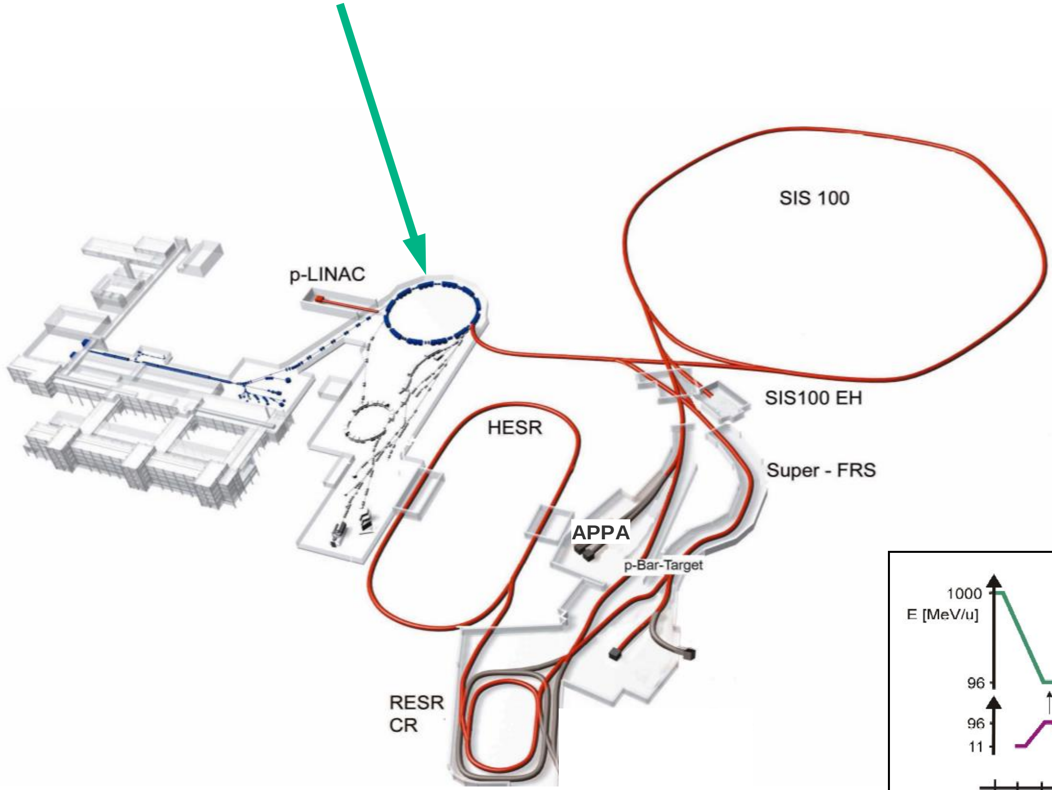
Peter Spiller

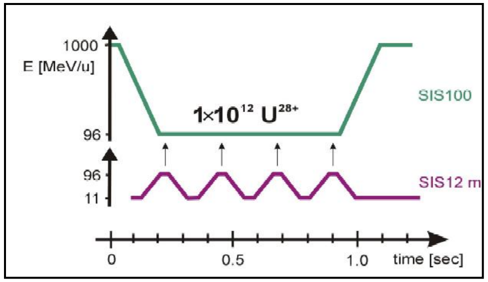
International Particle Accelerator Conference

June 2014

FAIR Construction Side

SIS18 Upgrade (Boosteroperation)





Booster Cycles

Low Charge State Heavy Ions

Existing and planned Heavy Ion Accelerators operated with low charge states worldwide

AGS Booster	BNL	5×10^{9}	Au^{31+}
LEIR	CERN	1×10^{9}	Pb^{54+}
NICA Booster	JINR	4×10^{9}	Au^{32+}
SIS18	**GSI/FAIR**	1.5×10^{11}	U^{28+}
SIS100	**FAIR**	6×10^{11}	U^{28+}

SIS18 served as a pilot facility for the development of

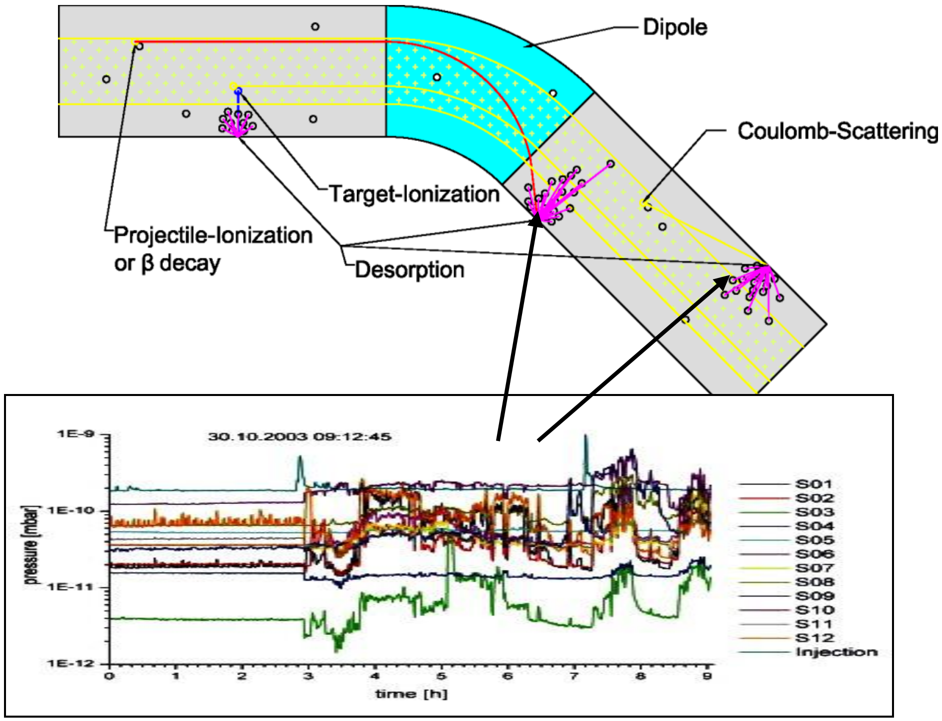
- new accelerator concepts
- new technologies and
- the understanding

... to overcome vacuum instabilities and ionization beam loss at high intensity heavy ion operation.

Ionization Beam Loss and Dynamic Vacuum determines

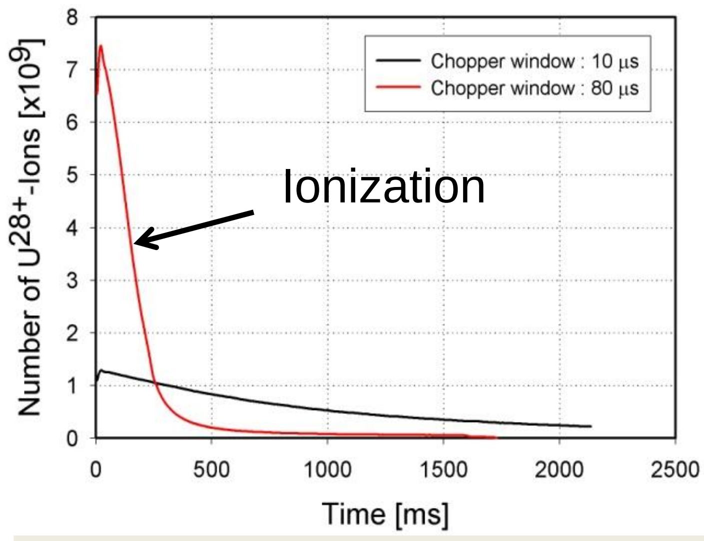
the system design and the accelerator technologies of SIS18 and SIS100

Ionization and Dynamic Vacuum



Static Dynamic

U^{28+}- operation in 2001

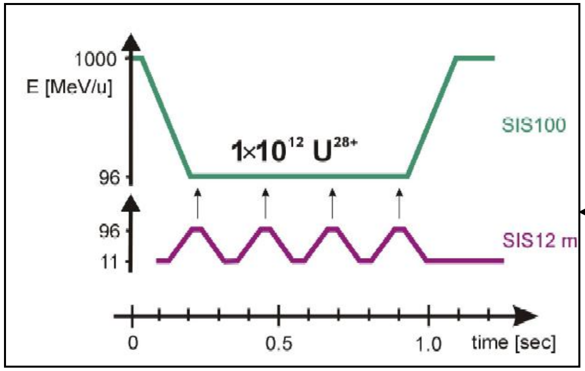


Main beam loss mechanism in SIS18 and SIS100 (far below the space charge limit)

- Life time of U^{28+} is significantly lower than of U^{73+}
- Life time of U^{28+} depends strongly on the residual gas pressure
- Ion induced gas desorption ($\eta \approx$ 10 000) generates local pressure bumps
- Beam loss increases with intensity (dynamic vacuum)

Requirements for SIS18

	Today	FAIR Booster	Today	FAIR Booster
Reference Ion	U^{73+}	U^{28+}	P	P
Maximum Energy	1 GeV/u	0.2 GeV/u	4 GeV	4 GeV
Maximum Intensity	4×10^{9}	1.5×10^{11}	5×10^{10}	2.5×10^{12}
Repetition Rate	0.3 - 1 Hz	2.7 Hz	0.3 – 1 Hz	2.7 Hz



Pressure Stabilization - Recipe

- Short cycle times, short sequences and short injection plateau

  Fast ramping (SIS18: 10 T/s, SIS100: 4 T/s)

  (power connection, power converters, Rf system,

  fast ramped (superconducting) magnets)

- XHV and huge pumping power

  (NEG-coating, cryo pumping - local and distributed)

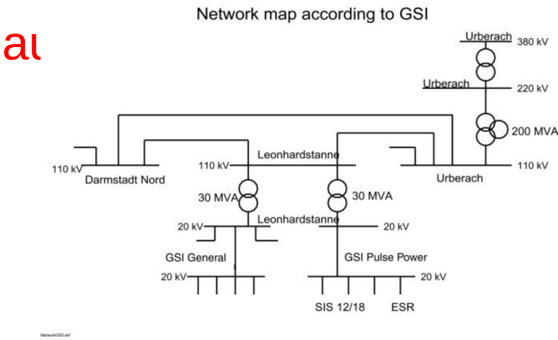
- Localizing beam loss and controle/suppression of desorption gases

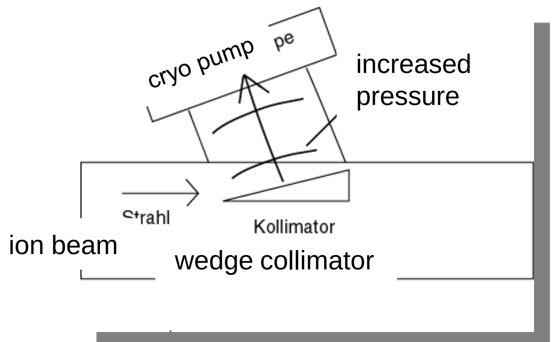
  (Ion catcher system with low desorption yield surfaces,

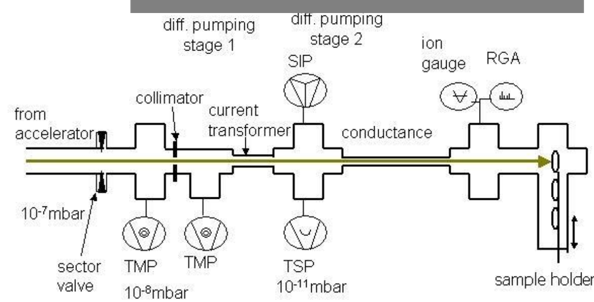
  Synchrotron optics and lattice design)

- Minimum „effective“ initial beam loss

  (TK halo collimation, low desorption yield surfaces)

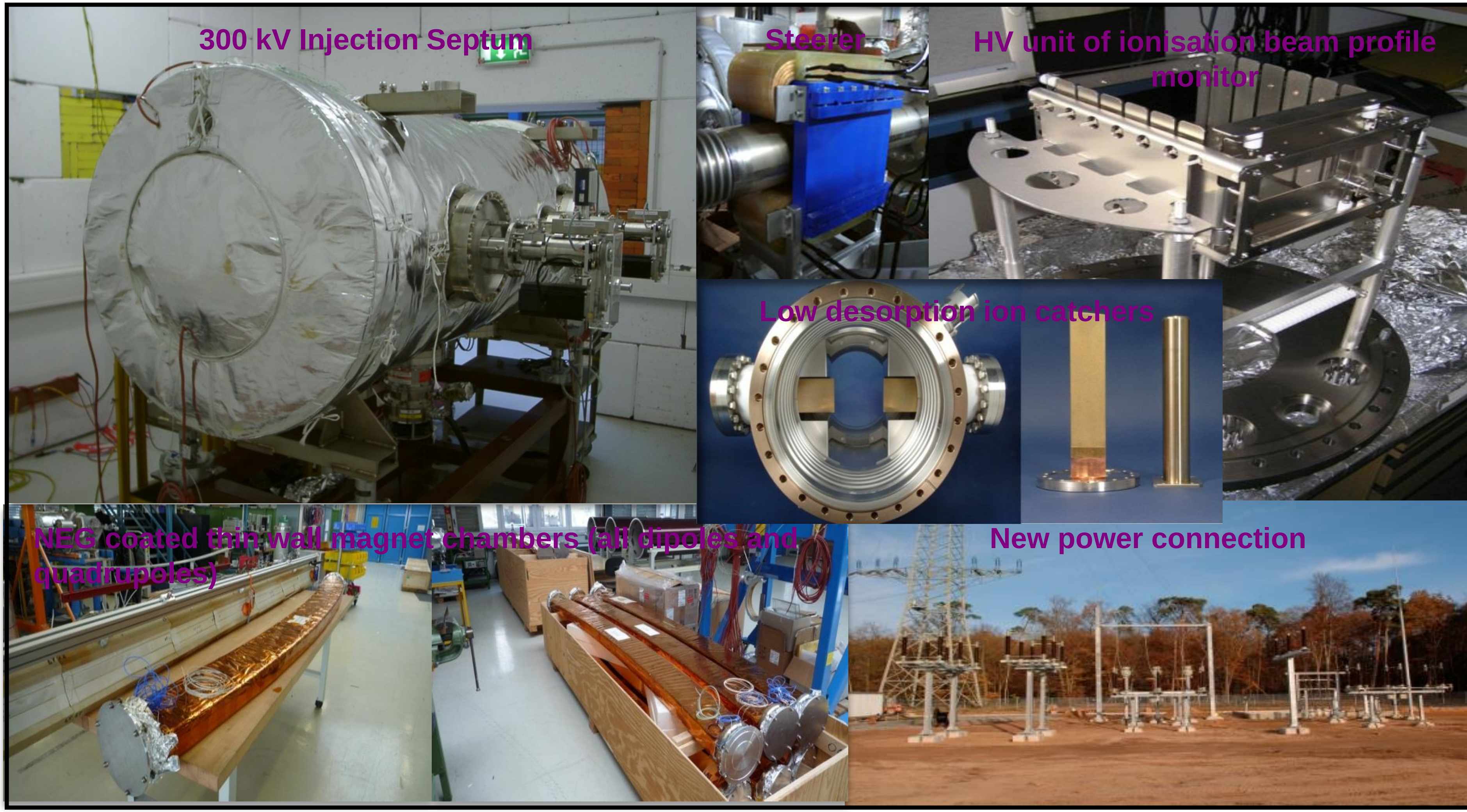




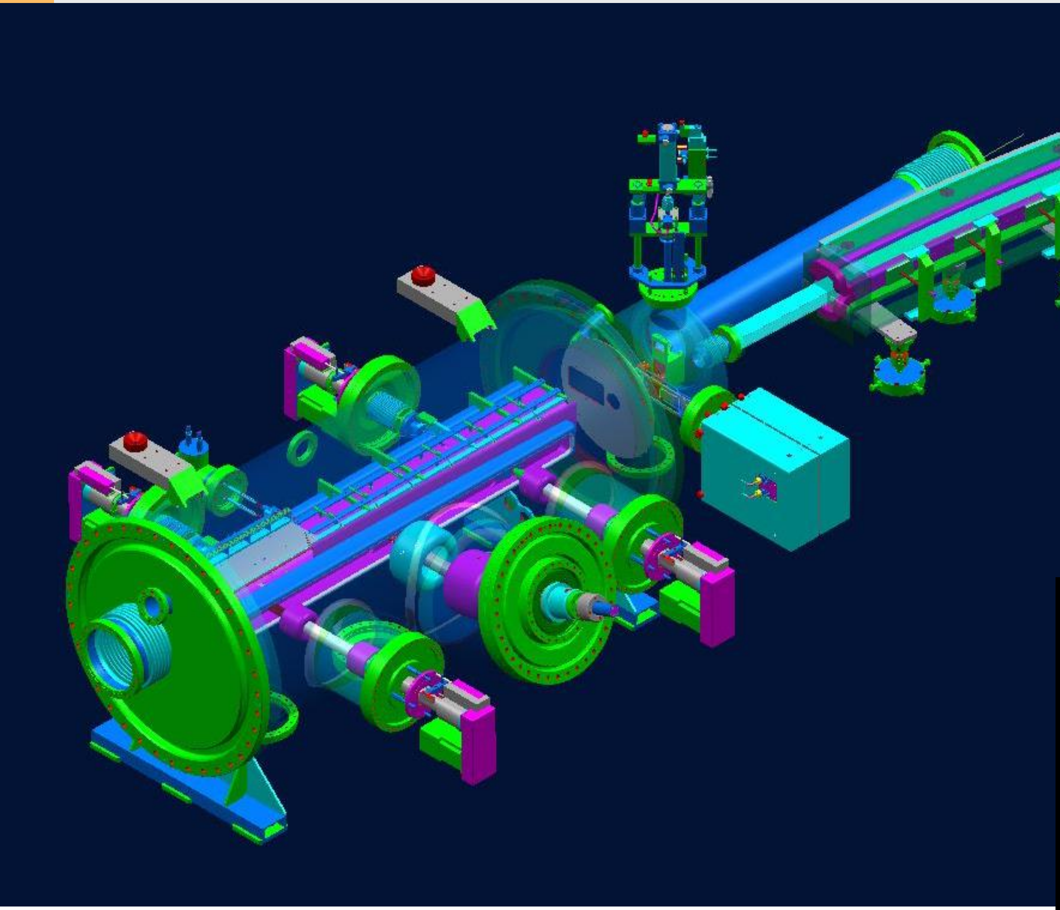


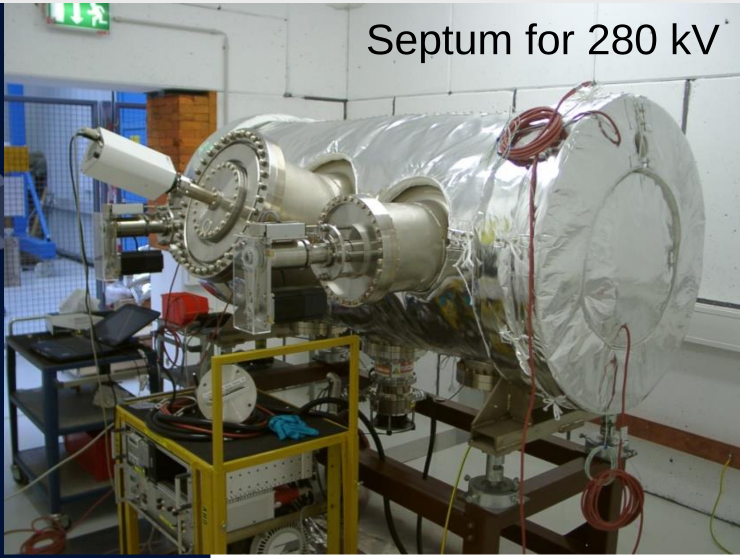
SIS18 Upgrade Program

Completed Developments and Procurements



Injection System Upgrade





- Increased acceptance
- Injection of U^{28+} at reference energy
- Protection of septum electrodes (1.5 MW beam power)
- Position and profile verification
- Aim for reduced gas production

Final design of the new injection system

Project completed

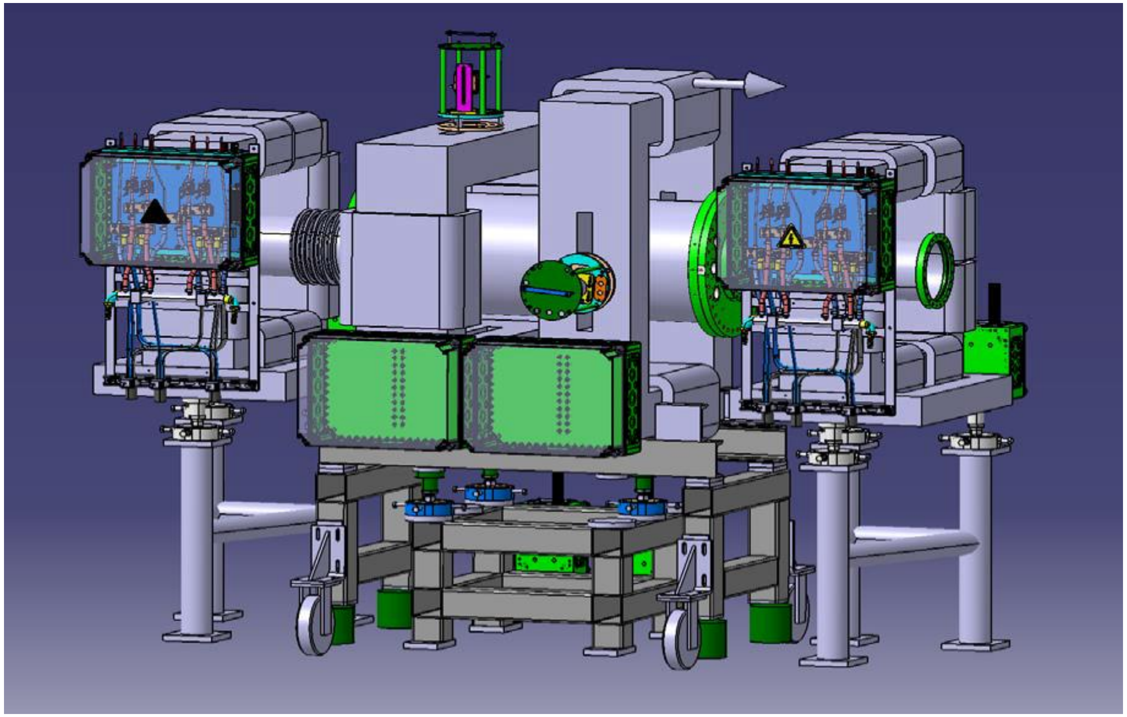
Bipolar Power Converter for Correction Coils

Replacement of unipolar power converter for horizontal corrections coils by bipolare power converter completed.

All power converters delivered and commissioned

Ionization Beam Profile Monitor

- Fast, turn-by-turn measurement, e.g. during injection process, of the transverse beam size.
- Magnetic and electric field for imaging of the ionized residual gas ions under the influence of strong beam space charge onto a phosphor screen.



IPM with magnet system

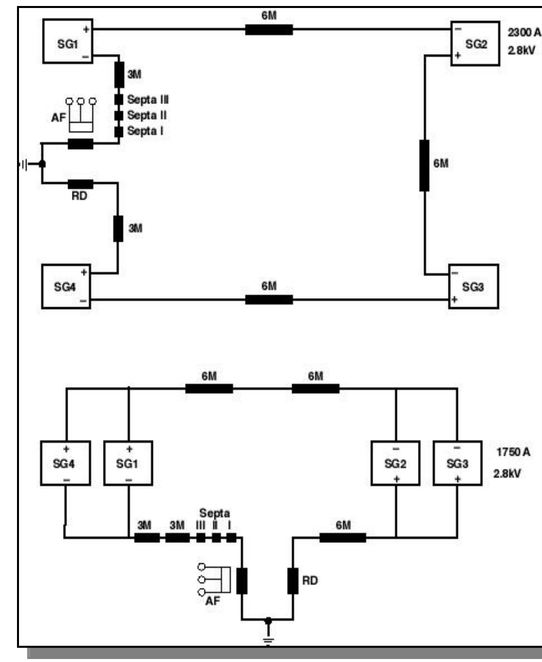
High voltage boxes and UHV tank delivered. Magnet system in tendering process.

Dipole Power Converter

High average beam intensity requires fast short cycle times with fast ramping.

- Shortening of cycle time (intermediate charge states)
- Higher repetition rate (booster operation 2.7)
- Increased average intensity (x 2-9)

Present Operation:
dB/dt = 1.3 T/s – 1/3 Hz



A. SIS18 Modus

B_{max}= 1.8 T - dB/dt = 4 T/s
I_{max} = 3500 A - V_{max} = 5.5 kV
2 groups each 2 parallel power converters
2 groups each 12 Dipole
$P_{\mathbf{max}}$ = +19/-17 MW

B. SIS12 Modus

B_{max} = 1.2 T - dB/dt = 10 T/s - I_{max} = 2300 A - V_{max} = 11.2 kV
4 in power converters in series supply 4 groups each 6 dipols
$P_{\mathbf{max}}$ = +26/-23 MW

(U^{73+} : E_{max} = 512 MeV/u)

Power converter upgrade for 10 T/s up to 18 Tm

New Dipole Power Converter

Fast ramping with 10 T/s up to 18 Tm (19kA/s up to 3500A)

Status:

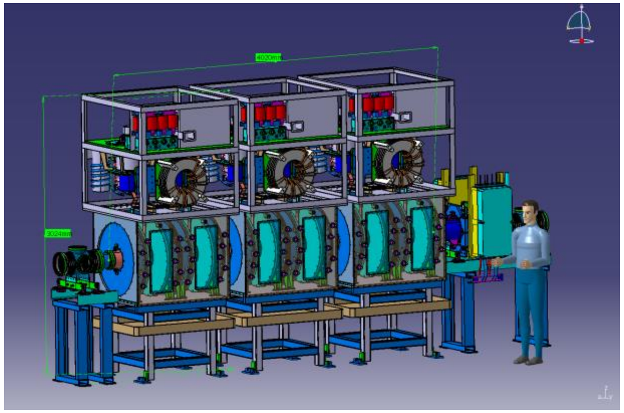
- Contract signed in December.2012 with GE (USA)
- Delivery of power grid filter unit mid of 2013 completed
- Scheduled final comissioning in 2016

New power grid filter
delivered mid of 2013

New MA Acceleration Cavities

- Sufficient Rf voltage for fast ramping with low charge state heavy ions
  U^{73+} acceleration with 4 T/s ($2x10^{10}$ ions)
  U^{28+} acceleration with 10 T/s ($1.5x10^{11}$ ions)

- Sufficient bucket area for minimum loss (50 kV)
  (30 % safety)



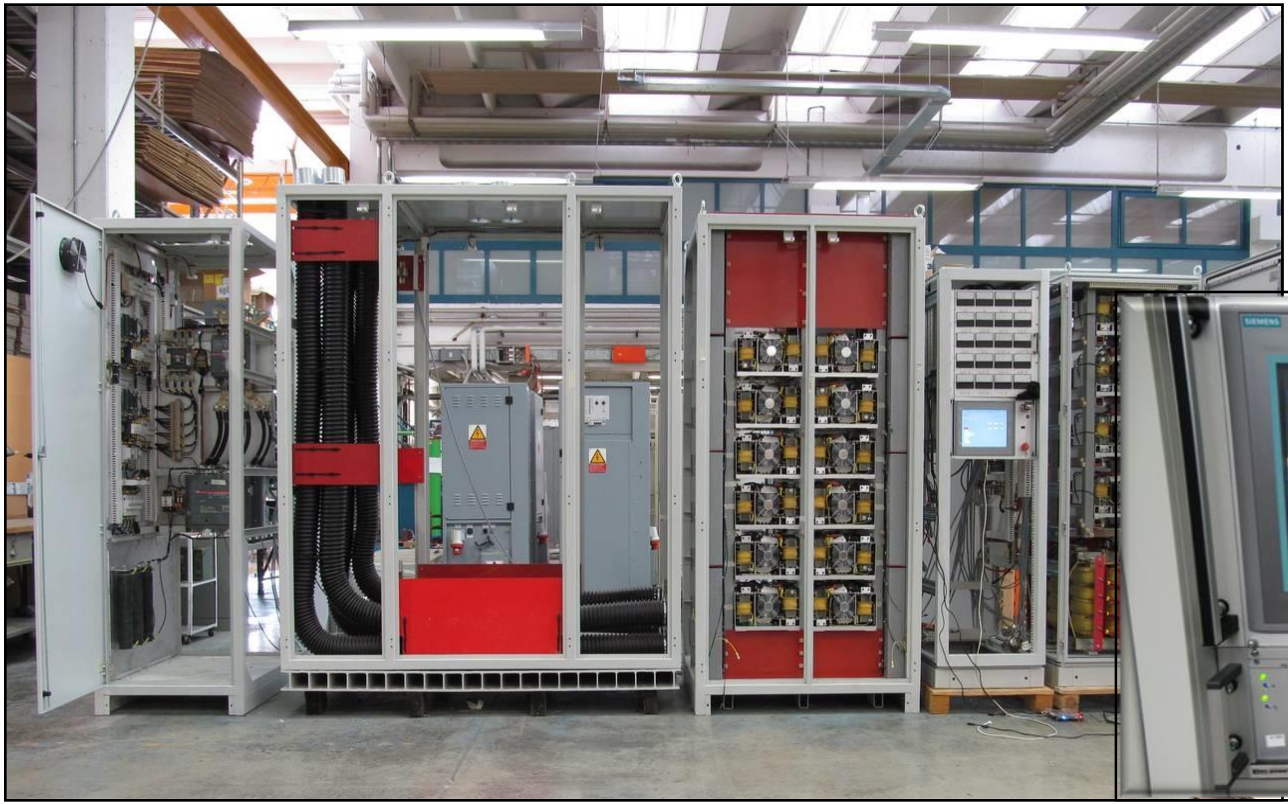
- Flat bunch profile (high Bf) for lower inc. tune shift
  two harmonic acceleration
  h=4 (existing cavity) and h=2 (new cavity)

- Compatibility with SIS100 Rf cycle

Supply Units for New Cavities

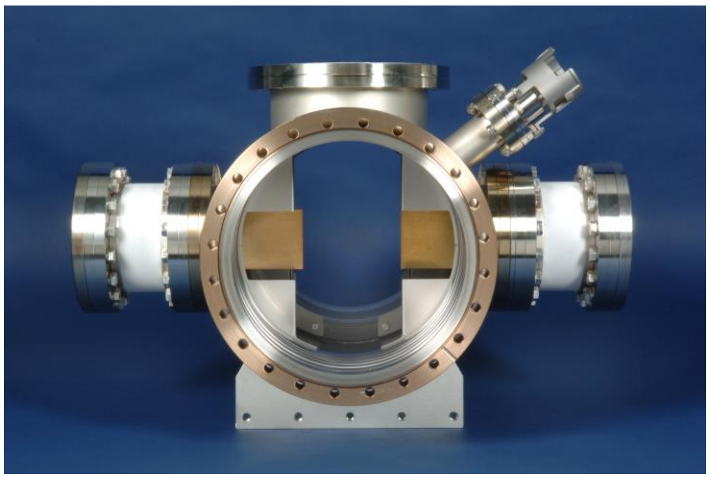
Status:

- First supply unit delivered by OCEM (*Italy*) in August 2012, and commissioned
- Second and third supply units delivered



UHV System upgrade

- Replacement of all dipole- and quadrupole chambers by new, NEG coated chambers
- Improved bake-out system for operation up to 300K
- Installation of low desorption ion catchers

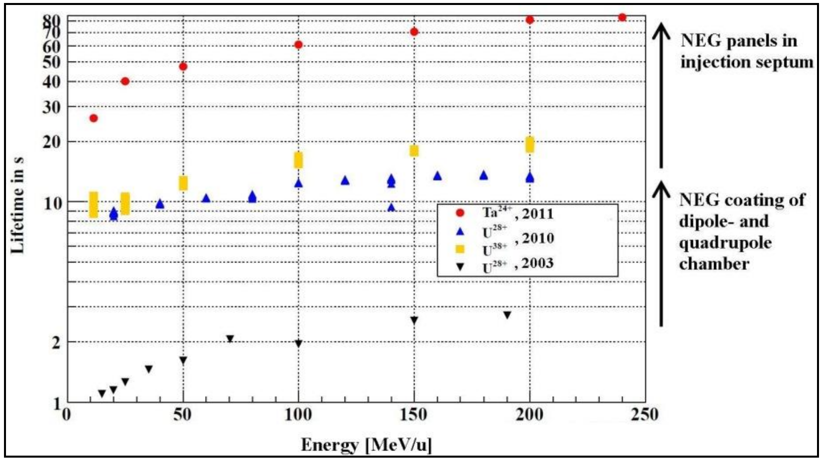


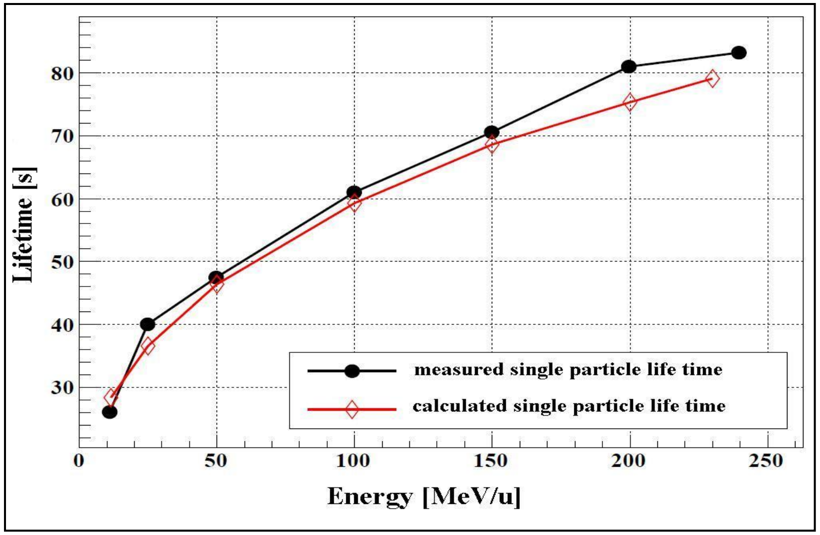
(Static) Single Particle Lifetime

As a result of the various upgrade stages, the beam lifetime could be continuously increased. These Figures showsthe measured lifetimes of intermediate charge state, heavy ions for different stages of the UHV system upgrade.

E.g. the measured lifetimes of intermediate charge state, heavy ions after NEG coating of the dipole- and quadrupole chambers and after inserting NEG panels in the injection septum.

After the installation of NEG panels in the injection septum, a perfect agreement has been achieved between the measured and expected beam lifetime and its energy dependence.

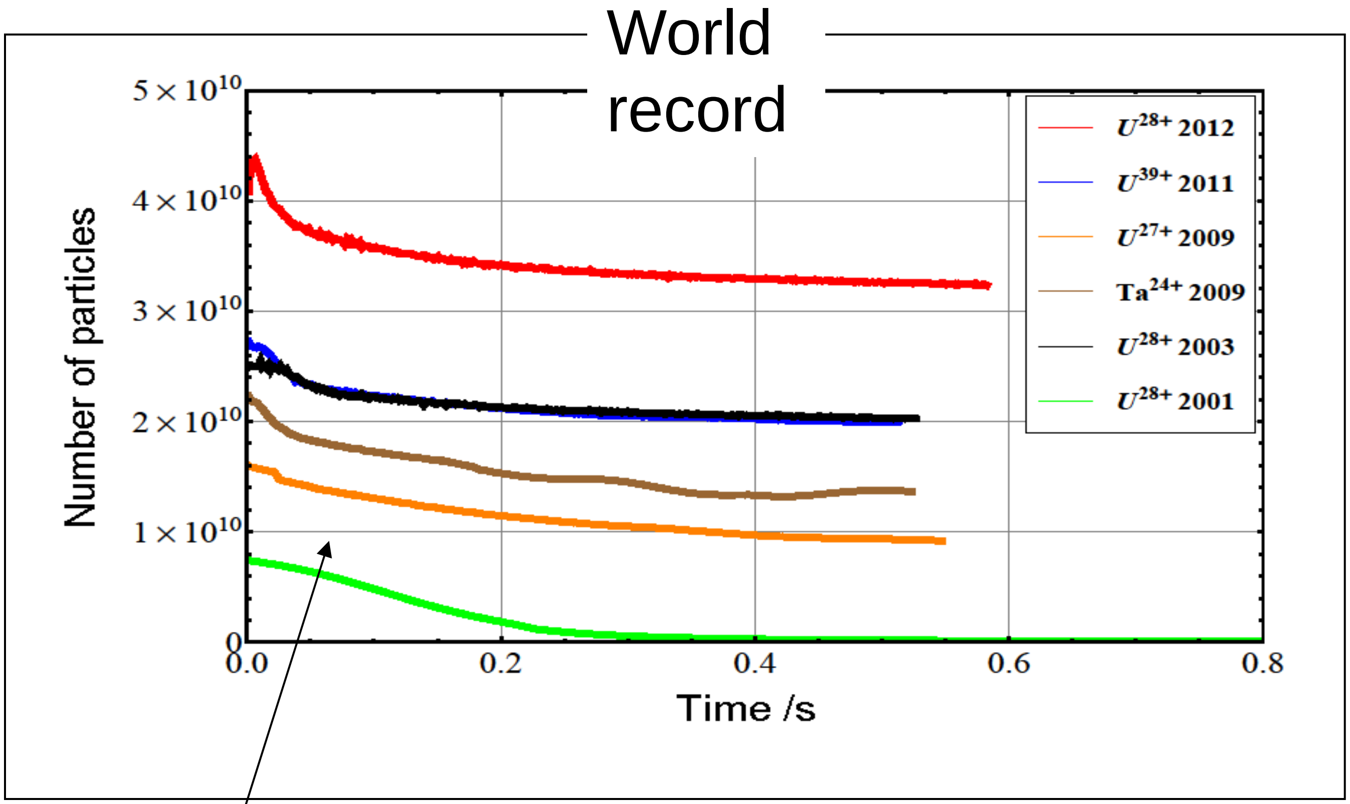




U^{28+} - Beam Intensity

World record intensity for intermediate charge state heavy ions.

The feasibility of high intensity beams of intermediate charge state heavy ions has been demonstrated.

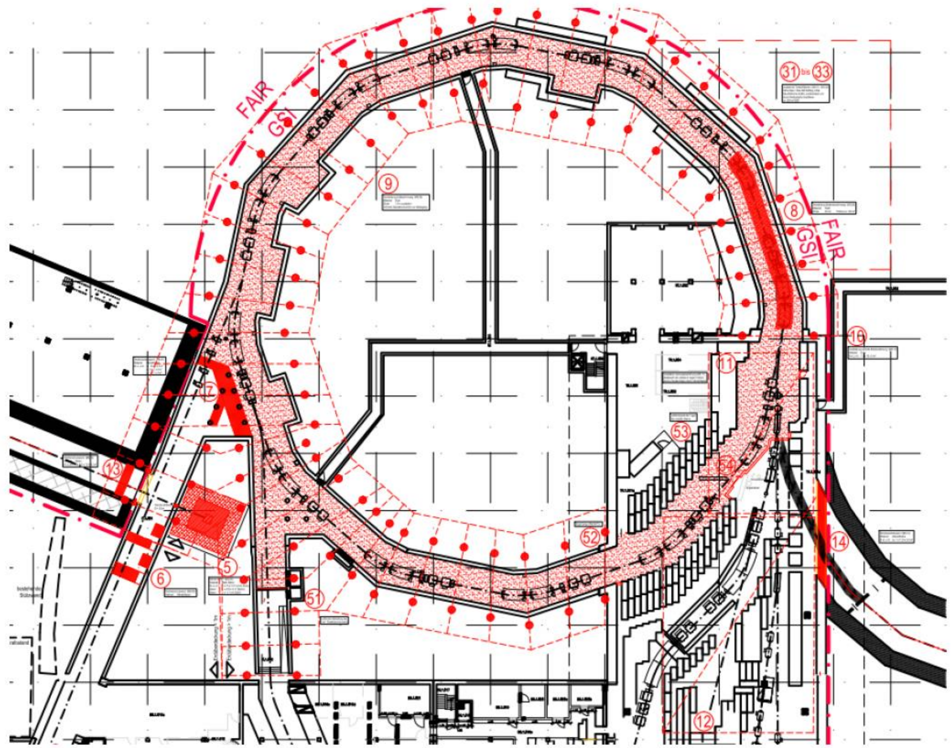


2001 FAIR conceptual design report (FAIR proposal)

SIS18 Civil Construction

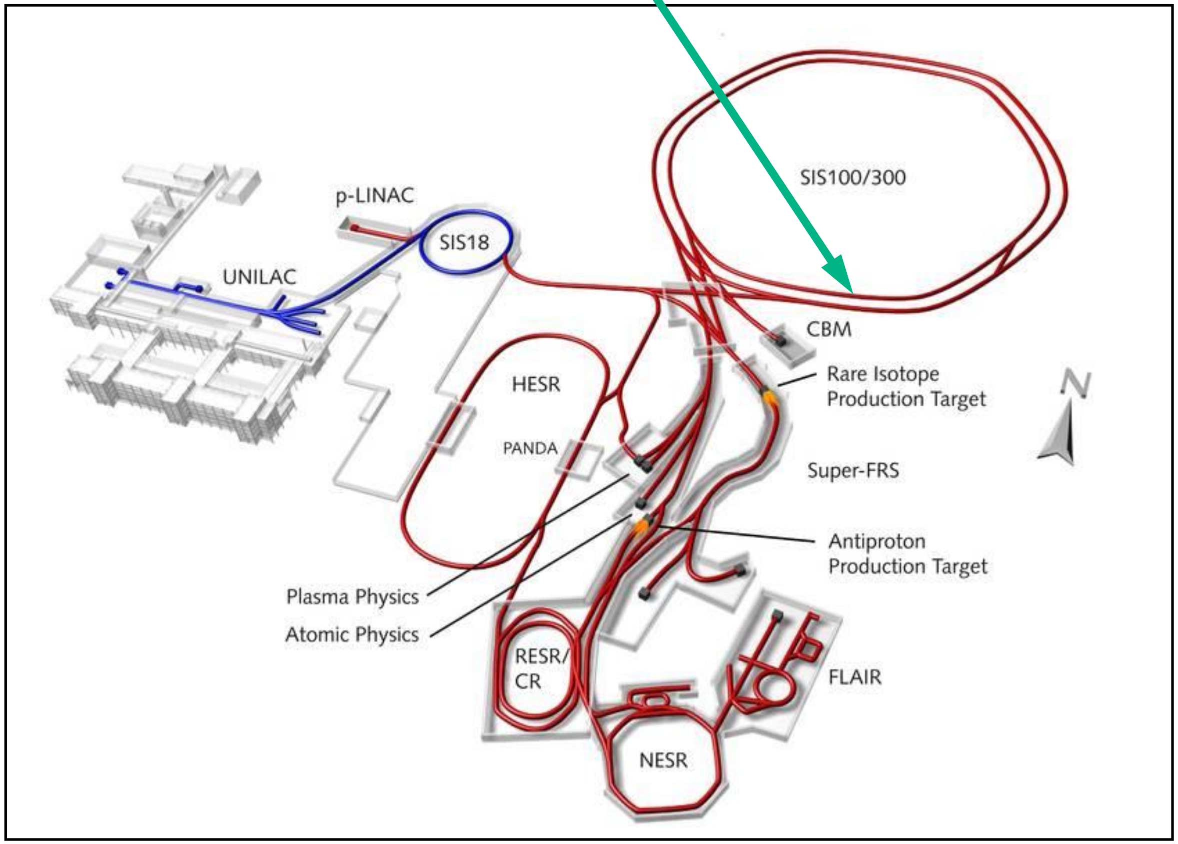
Link existing facility –
civil construction comprises:

- the beam dump for the proton linac
  in the transfer channel
- the shielding enhancement by means of a table construction on top of the existing tunnel
- othe radiation protection measures
  e.g. steel plates below extraction system
- underpressure generation in the tunnel
  (treatment of radioactive air)
- link to the FAIR tunnel 101



After the completion of the civil construction measures
a complete re-aligment of SIS18 will be needed.

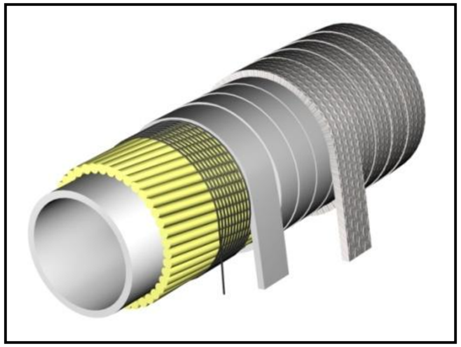
SIS100

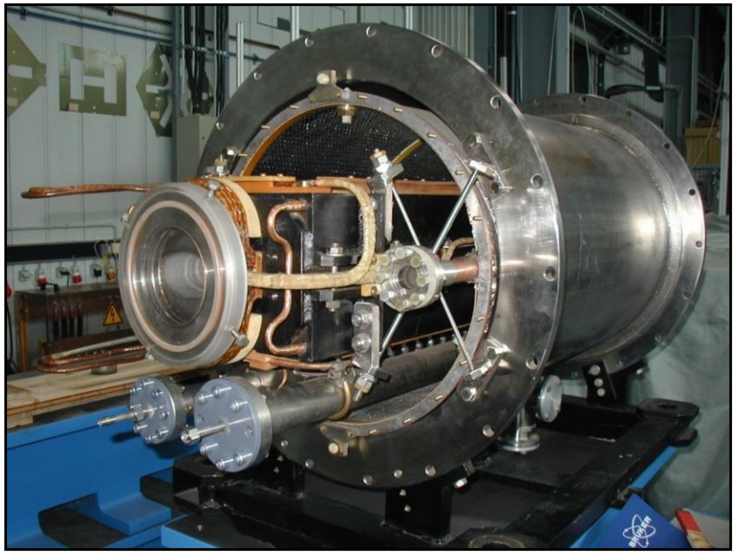


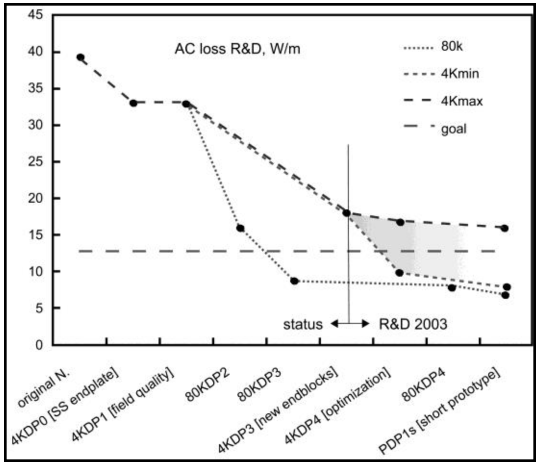
SIS100/300
p-LINAC
SIS18
UNILAC
CBM
HESR
Rare Isotope
Production Target
PANDA
Super-FRS
Antiproton
Production Target
Plasma Physics
Atomic Physics
RESR/
CR
FLAIR
NESR
N

Fast Superconducting Magnets

Window frame magnet with superconducting coil







Nuclotron Cable **Nuclotron Dipole in Cryostat**

Main R&D goal: **Reduction of AC losses during ramping by improved iron yoke design**

40 W/m > 13 W/m **B_{max}= 1.9 T** **dB/dt= 4T/s**

FOS Dipole Magnet

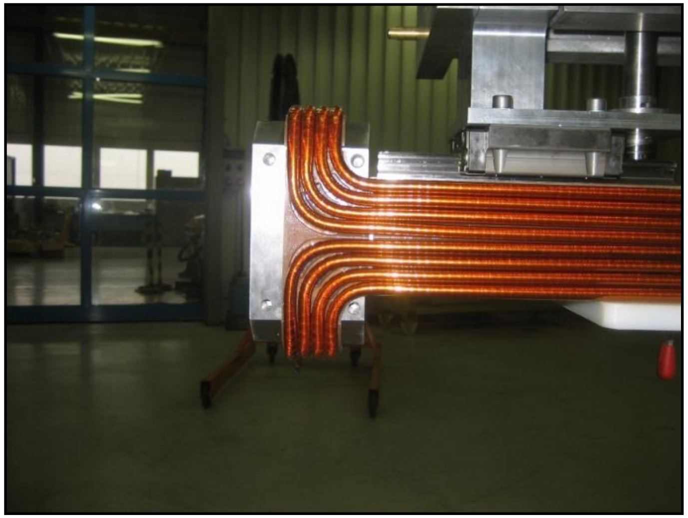
Status: (109 pieces required)

• Contract signed (end of 2011)

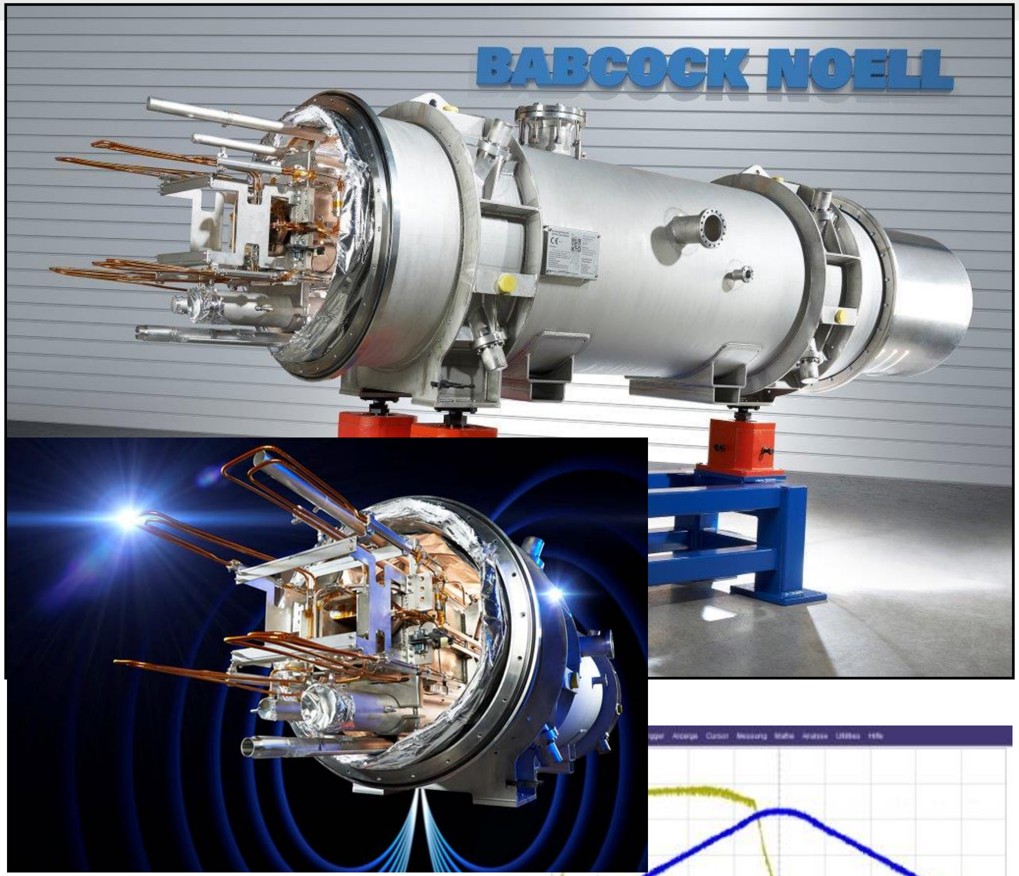
• Production by BNG (*Germany*) started

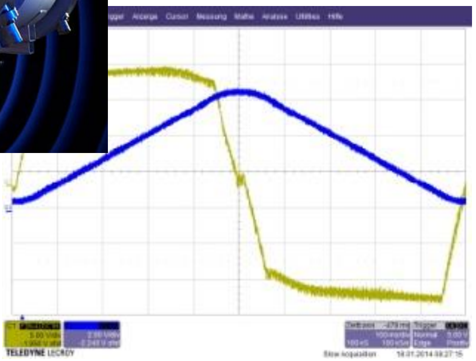
• Delivery of FOS dipole: 06.2013

• Steel procurement and cable production released



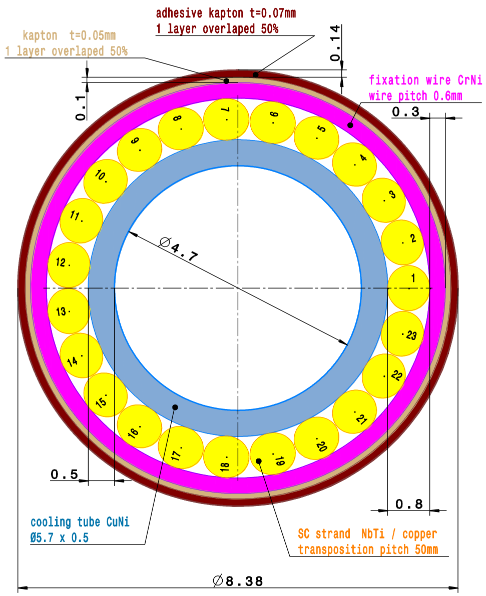
Coil head of pre-series dipole magnet



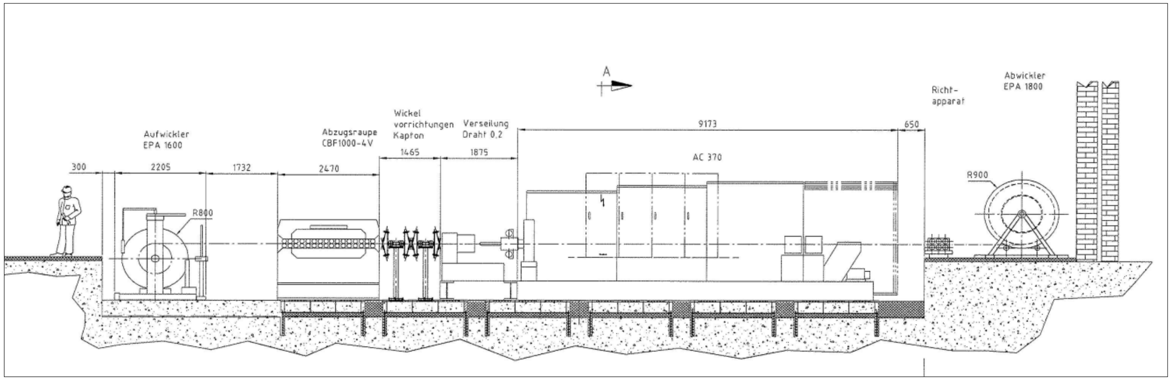


4 T/s triangular cycle reached

Nuklotron Cable Production at BNG



BNG is the only provider for a Nuklotron type s.c. cable beside JINR (Russia)



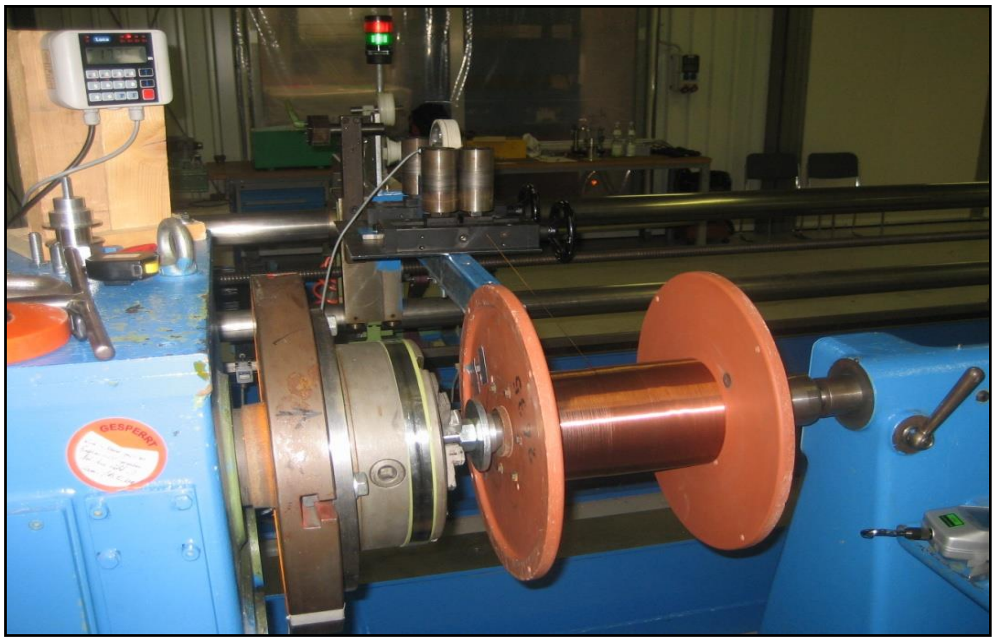
Low Loss Superconducting Wire

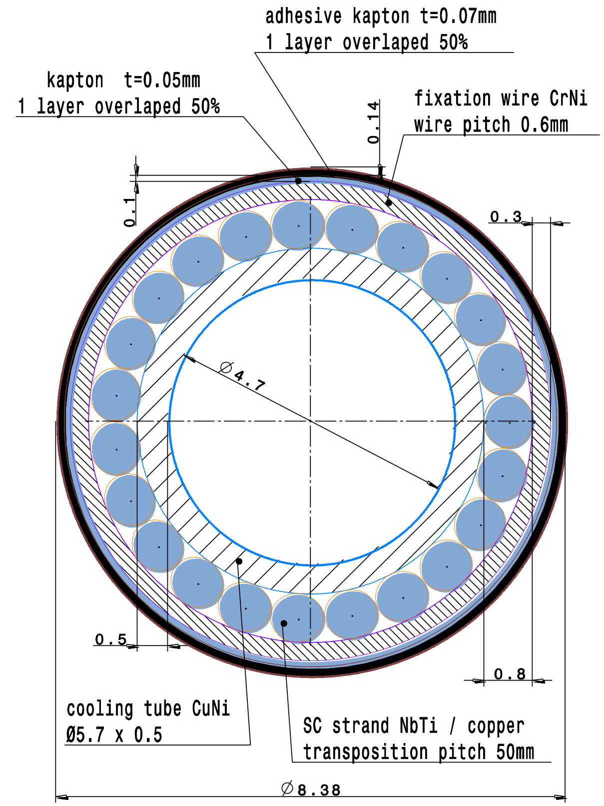
S.c. filaments in a Copper Manganese matrix

Status:

Contract signed with Luvata (*Finnland*)

First billet delivered – series production released



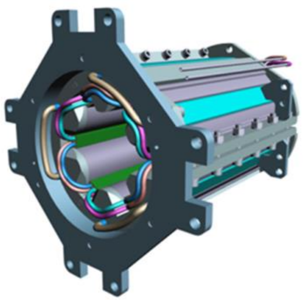


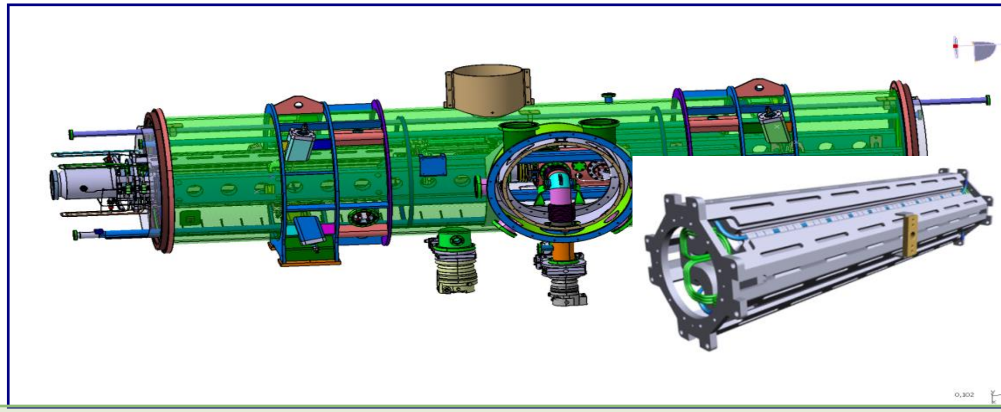
Production of the superconducting cable for the pre-series dipole at BNG

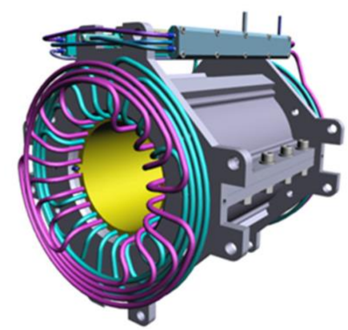
Superconducting Nuklotron cable

S.C. Quadrupole Modules

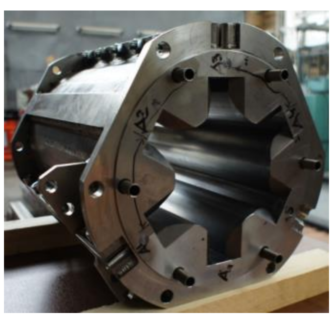
- Manufacturing design of pre- series module, completed by GSI design department
- Design service contract for overall cryomagnetic quadrupole module system signed and progressing
- Inkind contracfor the production of quadrupole units with JINR (*Russia*) under preparation

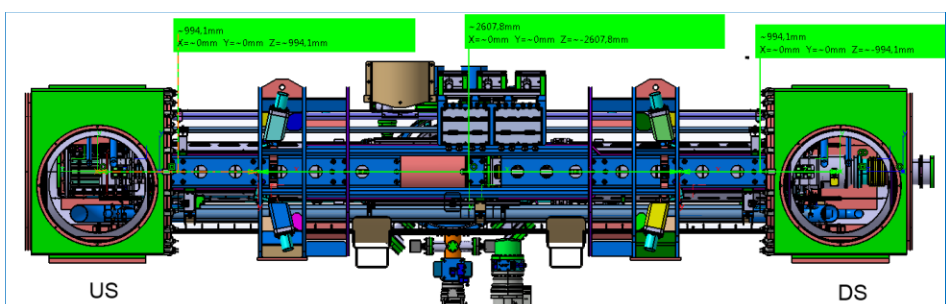






Design of pre-series modul and components by GSI Design Office

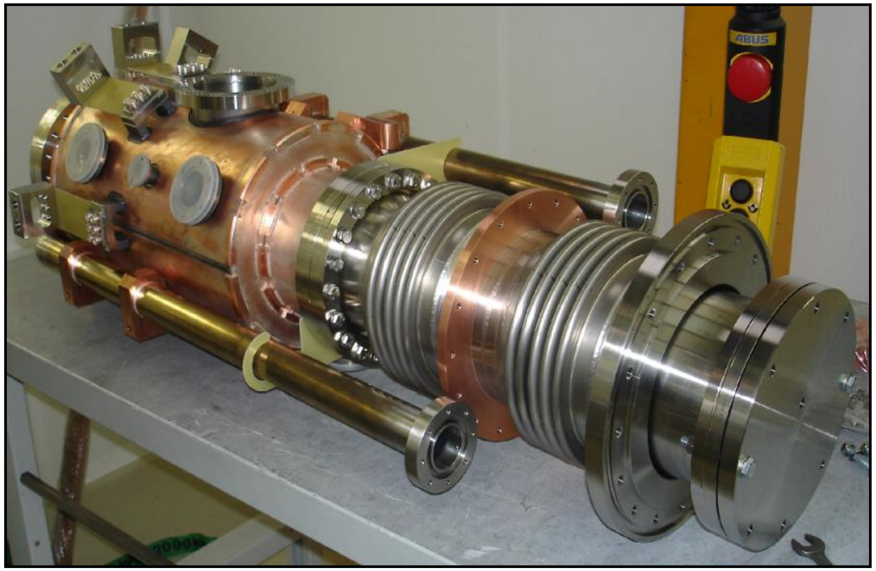




Design of QM module including end boxes (link to local cryogenics)

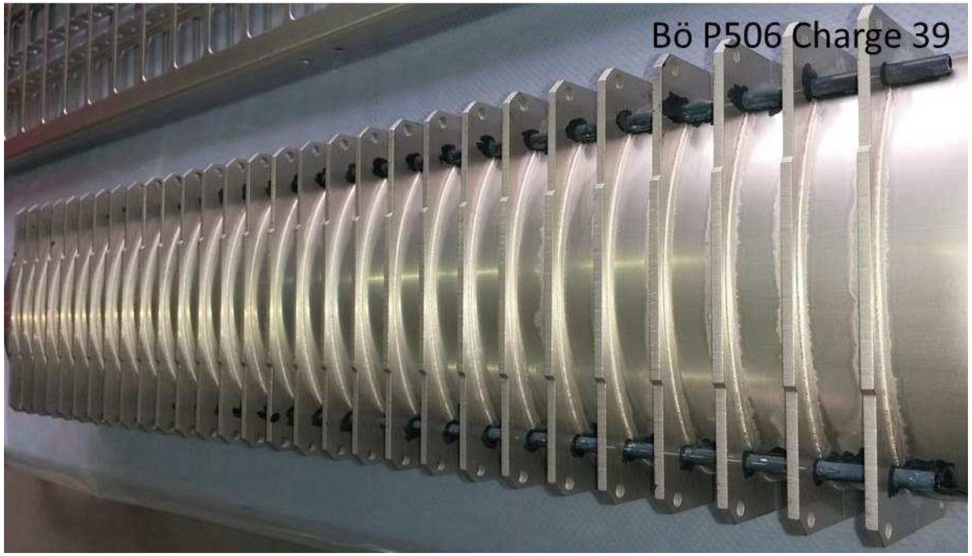
SIS100

Cold BPM and Cryocatcher



Pre-Series Cryogenic Beam Position Monitor (BPM)	Pre-Series Cryo-Catcher

Thin-wall LHe-cooled chambers



Successful production of chamber segments made of special stainless steel grade Bö P506

(120 pieces required)

Status:

- Tender on pre- series and 119 pcs. series chambers placed in 2012
- Delivery of the FOS chamber in May 2014

Associated procurements:

- Special stainless steel (Böhler steel P506) for all dipole and quadrupole magnet chambers

Current status:

- special stainless steel grade P506 for chamber production was delivered in August 2013 and transferred to chamber manufacturer in Oct. 2013
- LHe-cooling tubes made of special stainless steel grade ES 2374; Current status: 75% of the order is already delivered to GSI

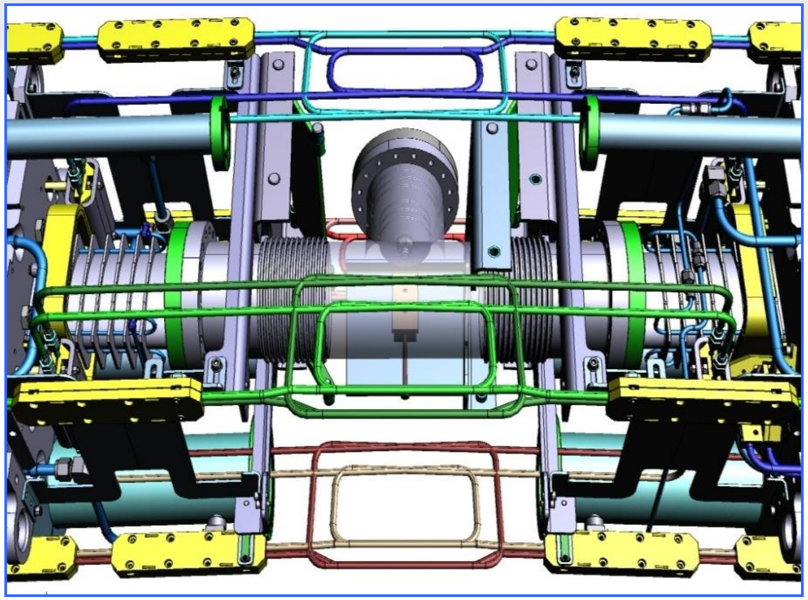
Special UHV Equipment

SIS 100 Adsorption Pumps

(60 pieces)

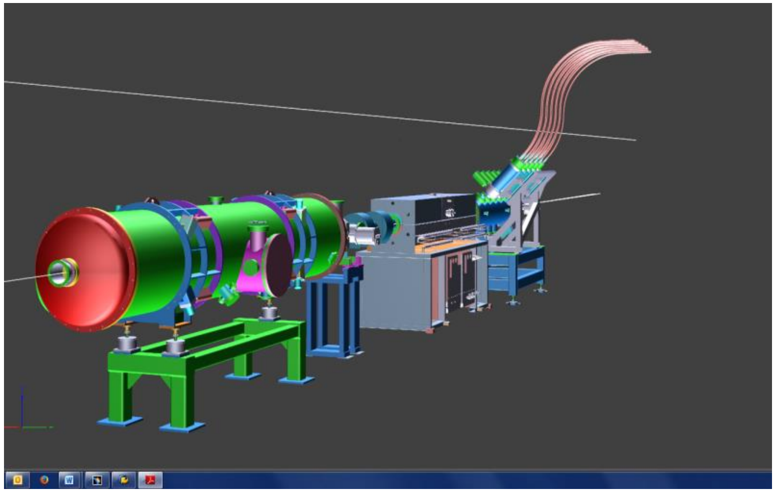
Status:
Procurement in preparation

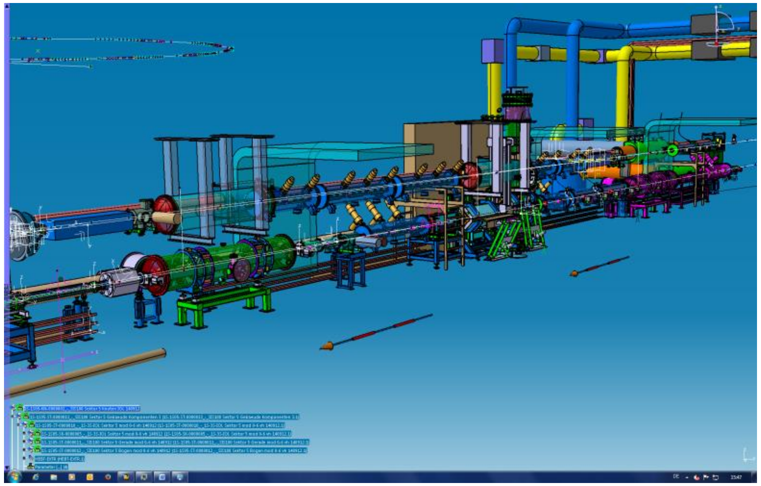
Adsorption pump produced at KIT, Karlsruhe

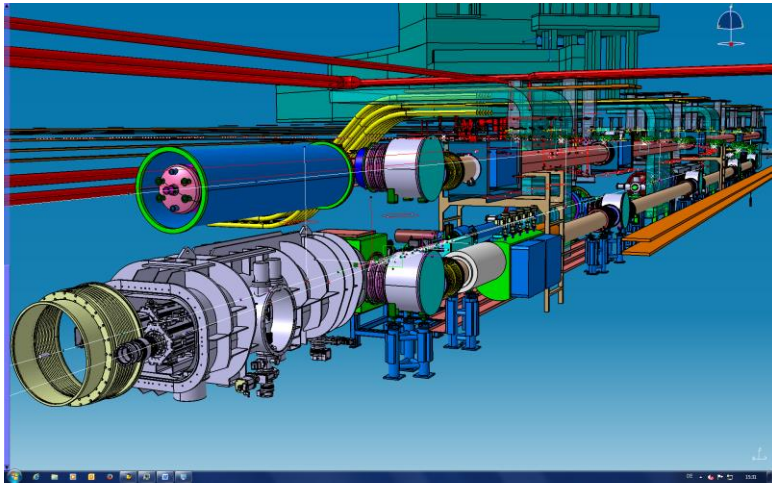


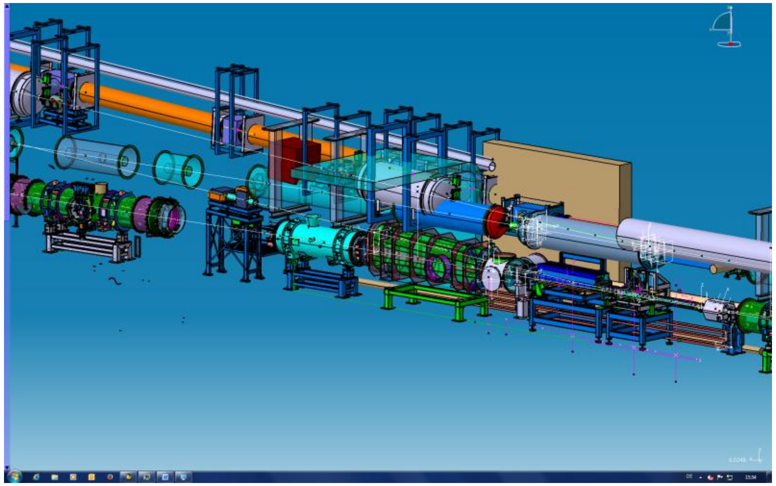
Partial pressure of H < 10^{-10} mbar

DMU and Industrialized Design





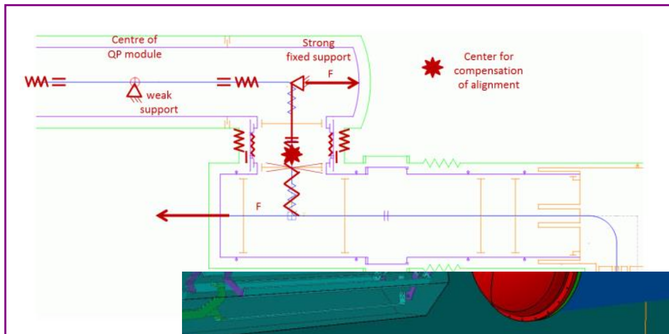


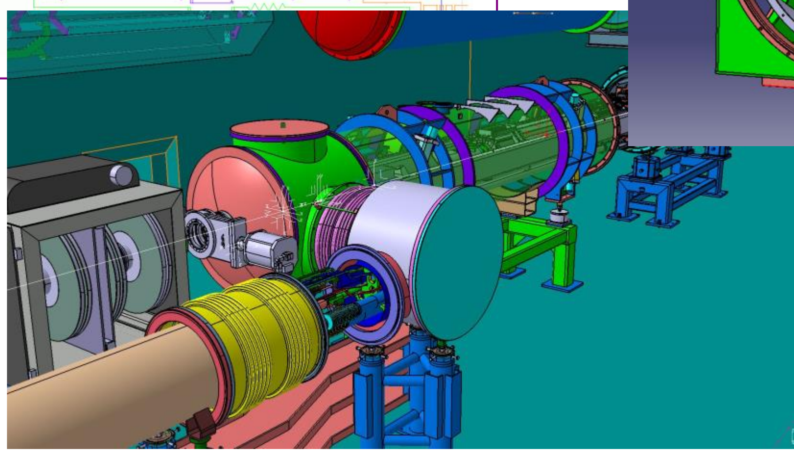


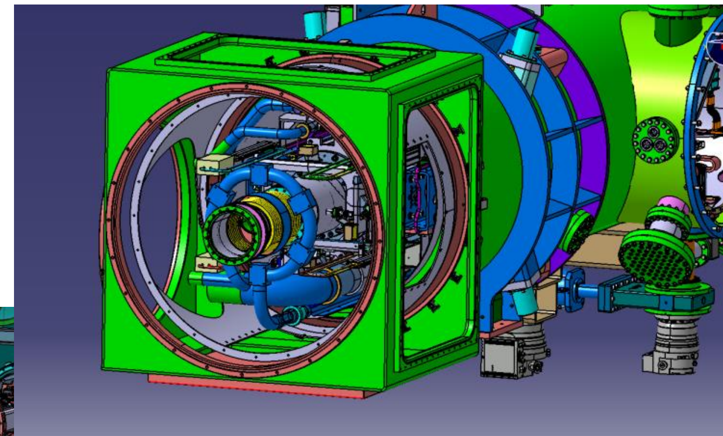
Local Cryogenics System

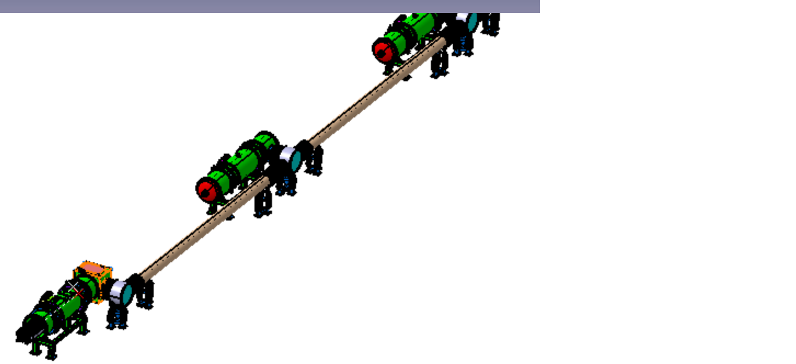
Status:

- First in-kind contract signed with polish shareholder.
- Manufacturing design of bypass line and interface connection boxes/end box started with WUT





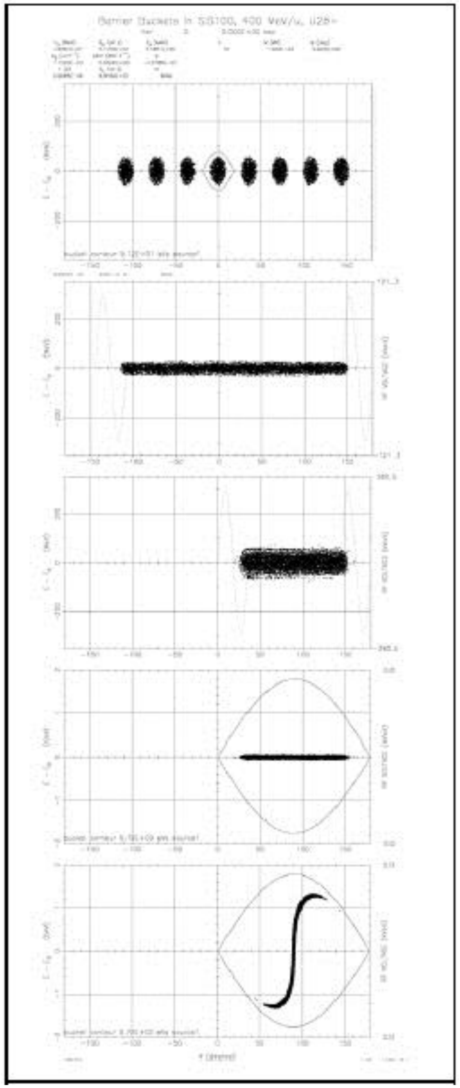




Design of interface between bypass line and cryomagnetic system

Targets and Secondary Beams

Short pulses for optimum target matching and fast cooling in CR



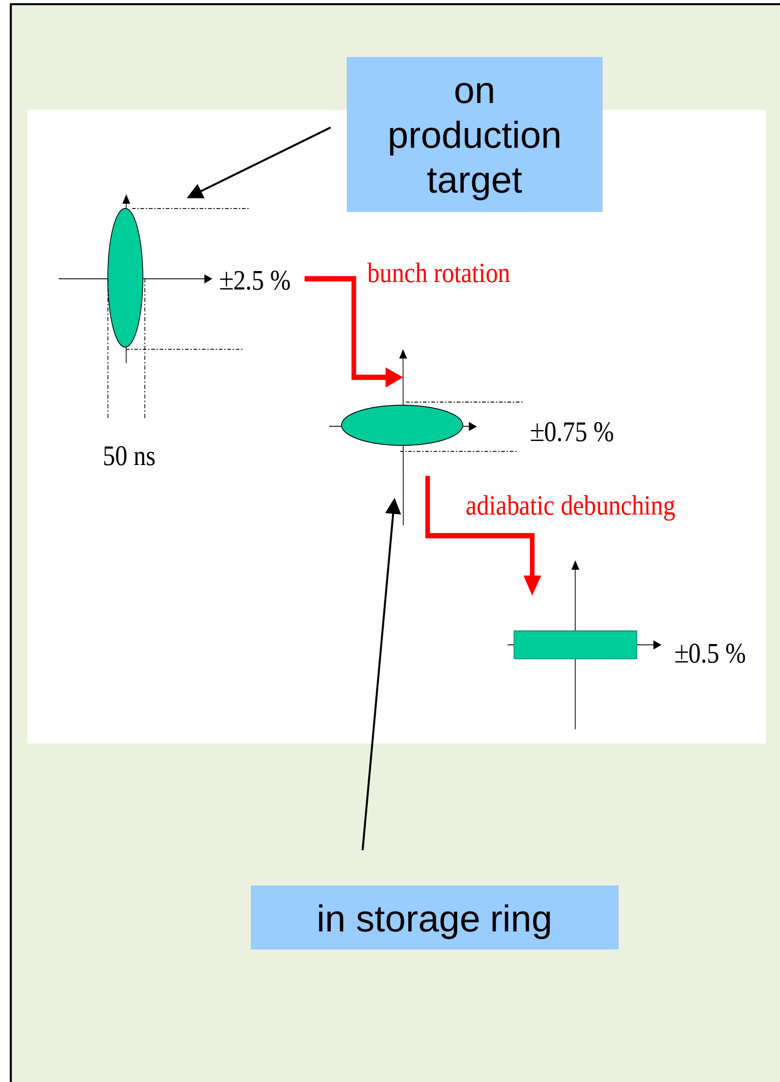
Major bunch manipulations are required in the FAIR synchrotrons and storage rings:

- Acceleration

  (single and dual harmonic)
- Bunch Merging
- Batch compression
- Fast compression

  (rotation of phase space)
- Fast decompression

  (debunching)

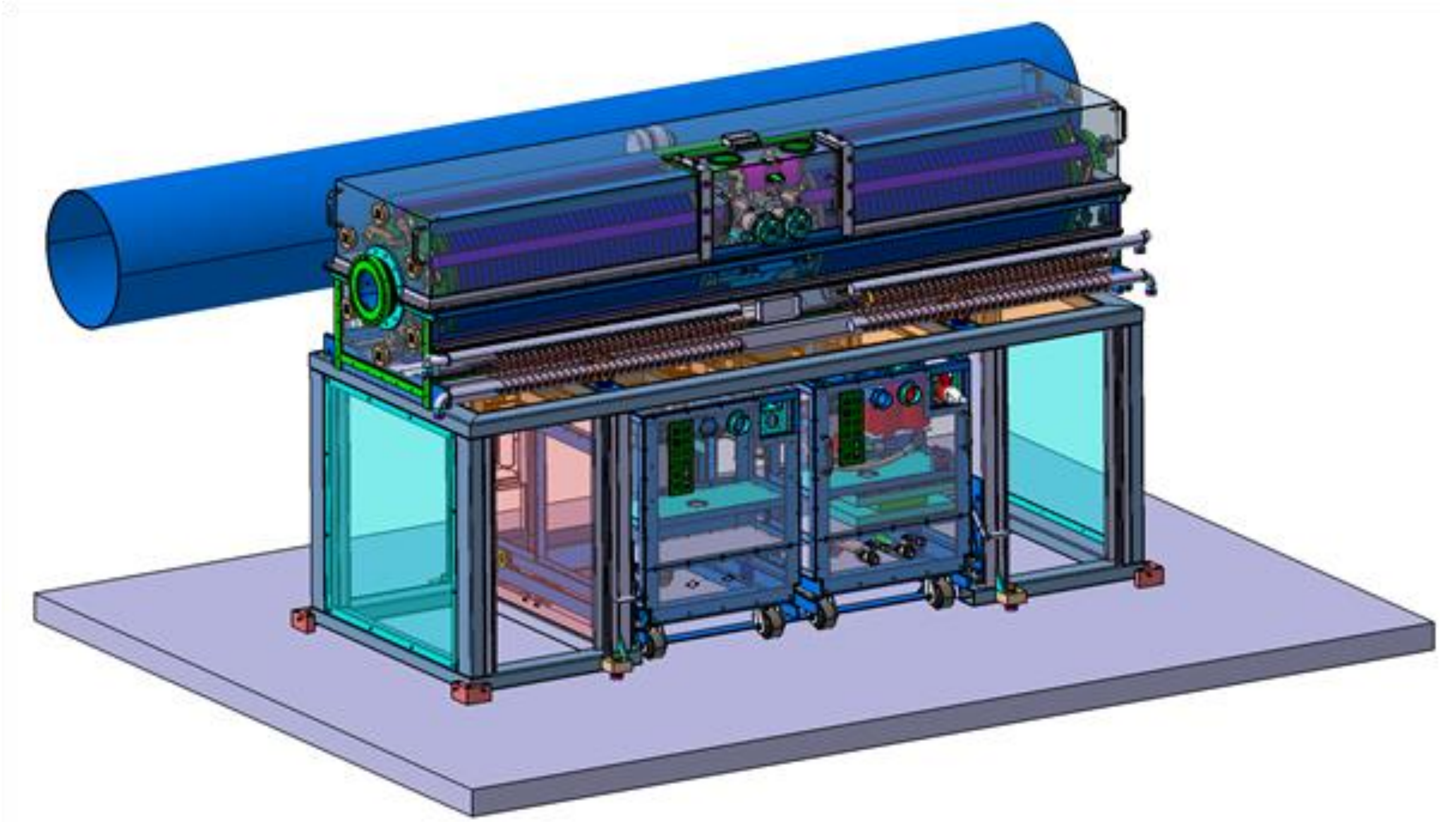


Acceleration Rf Cavities

Status: (14 pieces required)

Tendering negotiations for cavity and supply units running.

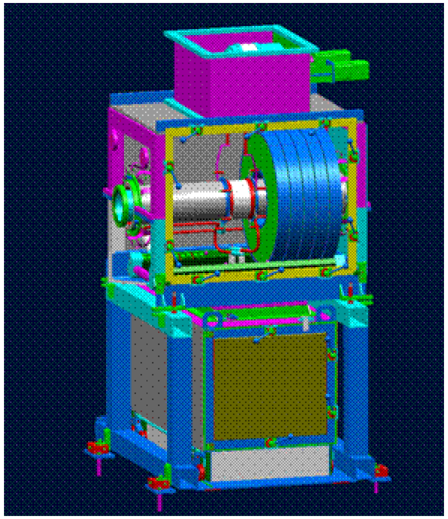
Procurement via FAIR GmbH. Procurement of standardized components prepared by GSI

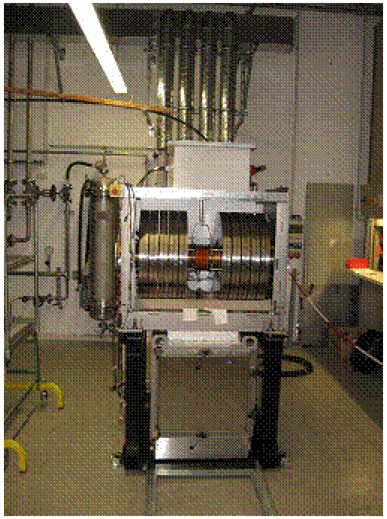


Ferrit loaded acceleration cavities: V_0= 20 kV f_0= 1.1 – 3.2 MHZ

Status:

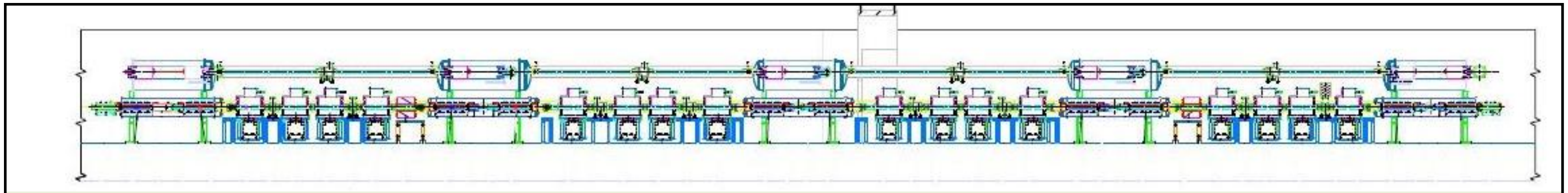
Contract signed (9 pieces)





SIS18 Bunch Compressor Cavity

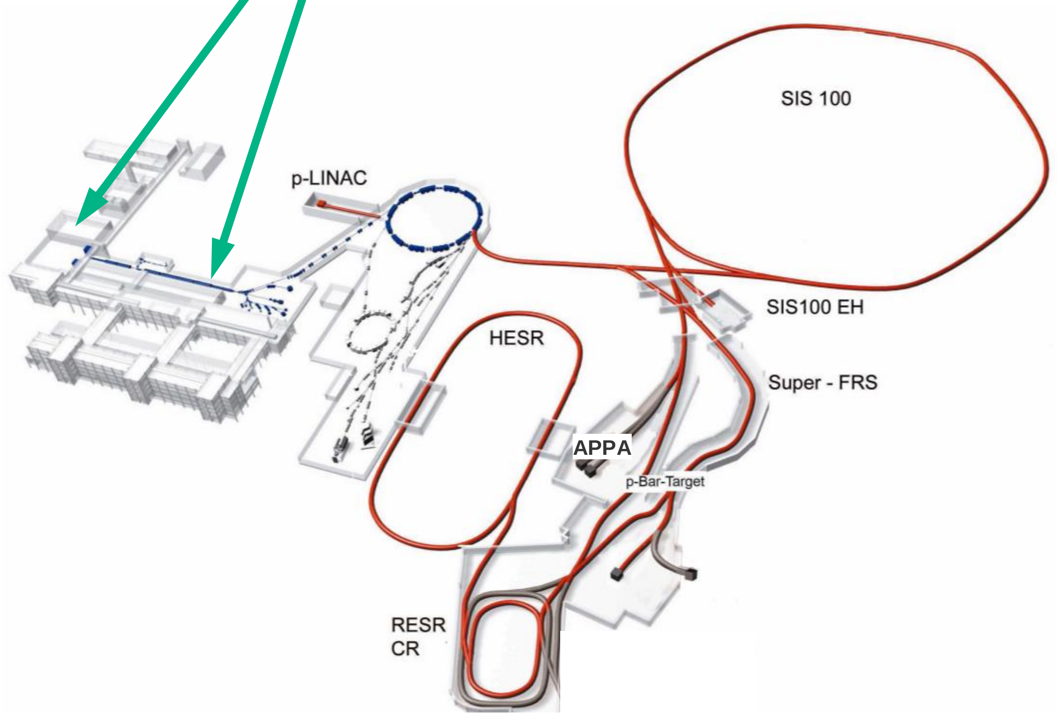
FAIR benefits from 10 years development of MA cavities for SIS18.



Installation of sixteen Rf cavities in one straight of SIS100

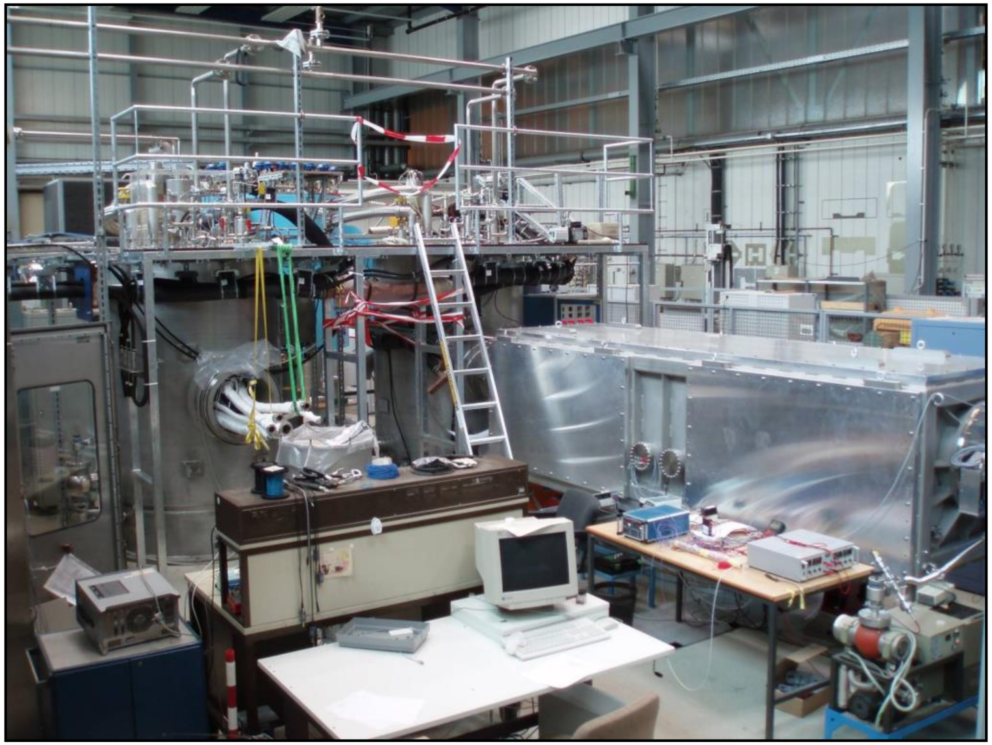
MA loaded bunch compression cavities: V_0= 40 kV f_0= 0.3 – 0.6 MHZ

Superconducting Magnet Testing



S.C. Magnet Testing

- SIS100 dipole units will be tested at GSI
- SIS100 quadrupole units will potentially be tested at JINR (contracts under preparation)
- Super-FRS magnets potentially tested at CERN (contract signed)



Existing Test Stand for Superconducting Magnets at GSI

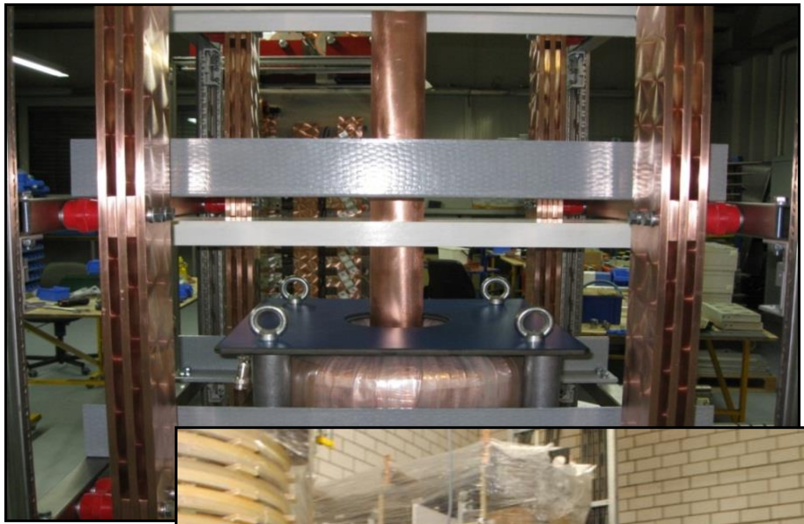
20 kA Power Converter Upgrade

20 kA – 29 kA/s

Status:

Power Converter delivered, commissioned

and in operation



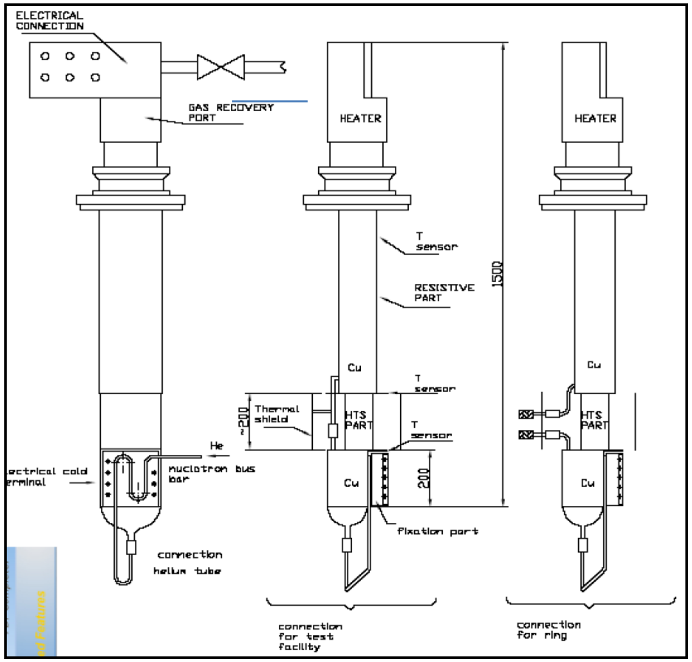
HTC Current Leads

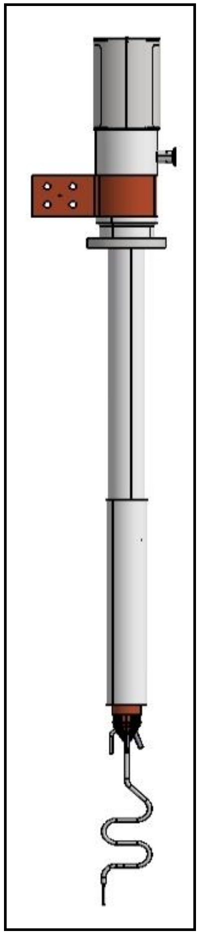
17 kA / 29 kA/s

Status: (22 pairs required)

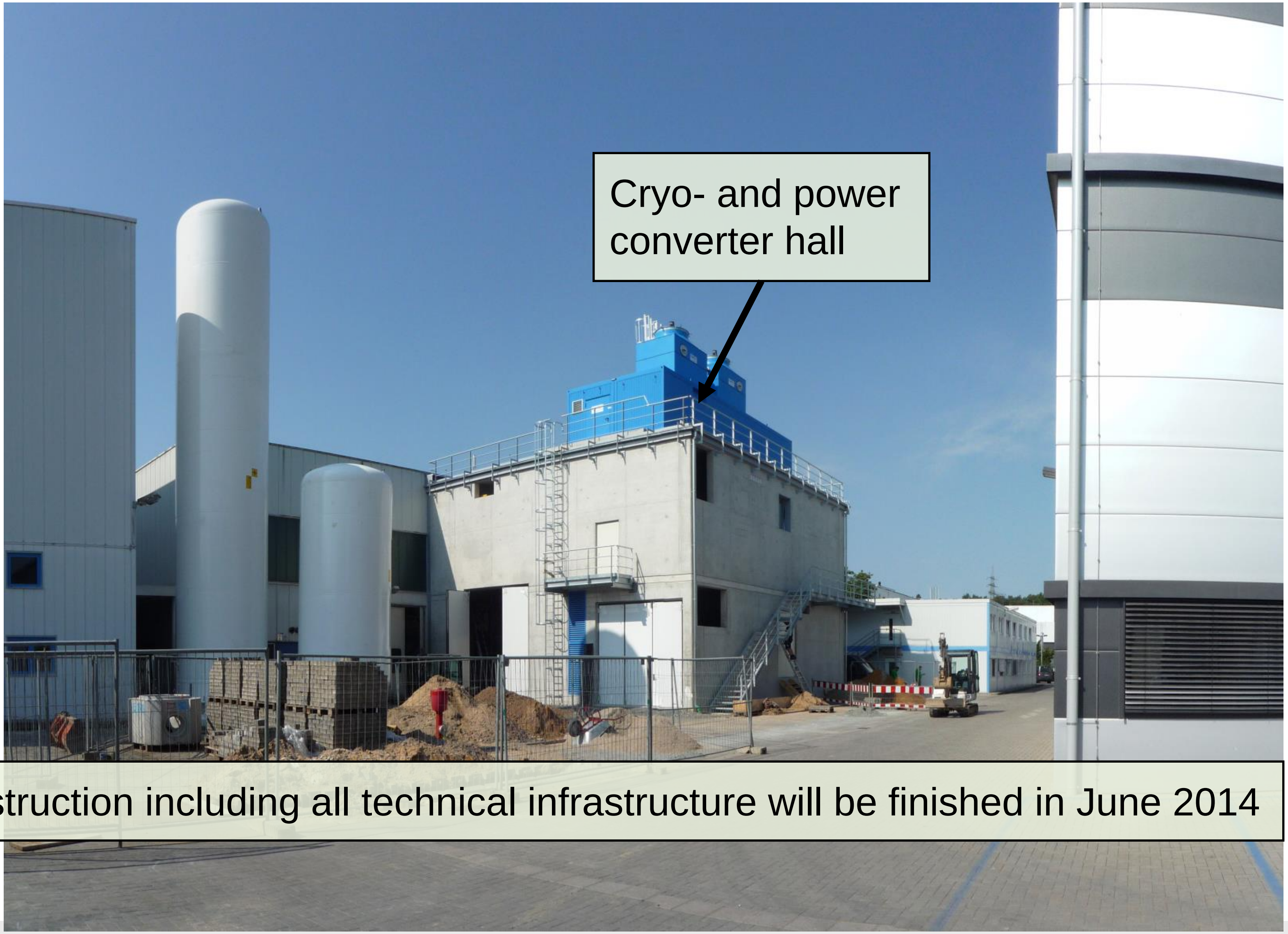
Delivery of 1st pair type October 2013. Order placed for all HTS current lead of the series test stand, the reference string and the SIS100 lead box.

S.c. strands at the cold terminal connected to the HTS parts





S.C. Dipole Series Test Facility



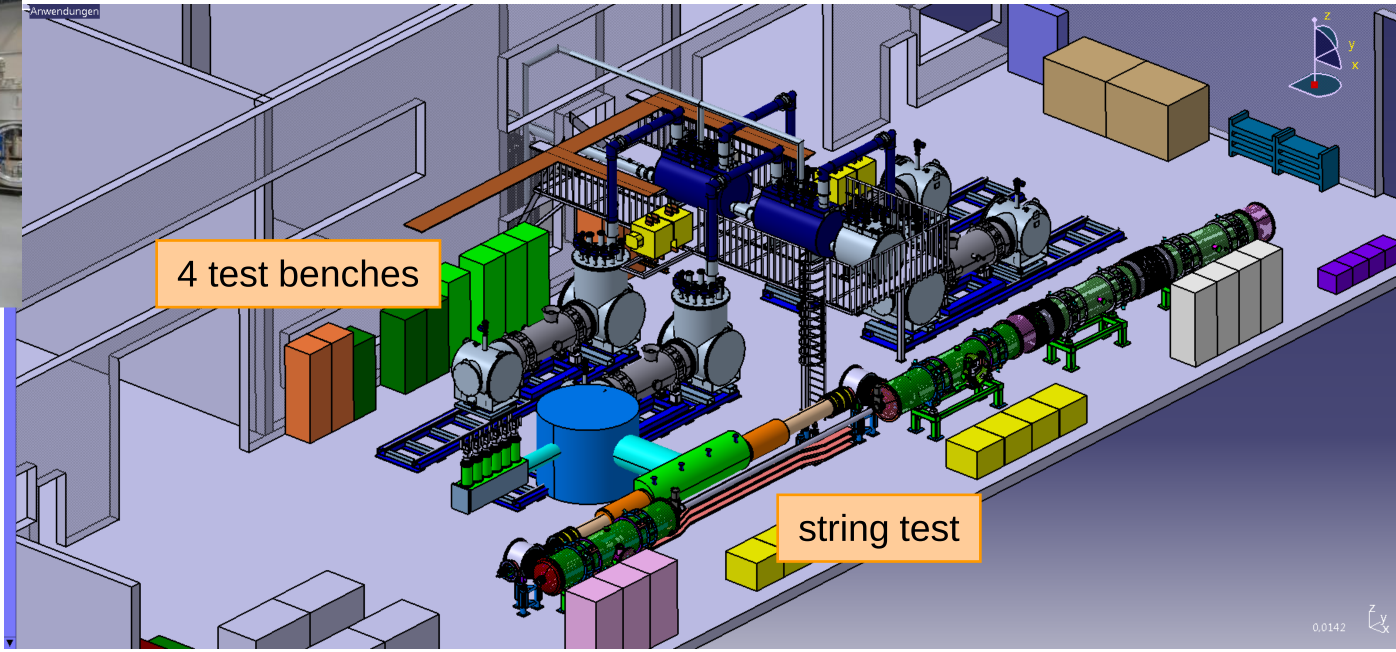
Civil Construction including all technical infrastructure will be finished in June 2014

S.C. Dipole Series Test Facility

Cryogenic Plant (compressor, liquefier incl. distribution to the feed boxes)

Status: Contract signed with Linde (*Germany*)

Feed-box manufacturing at Cryoworld



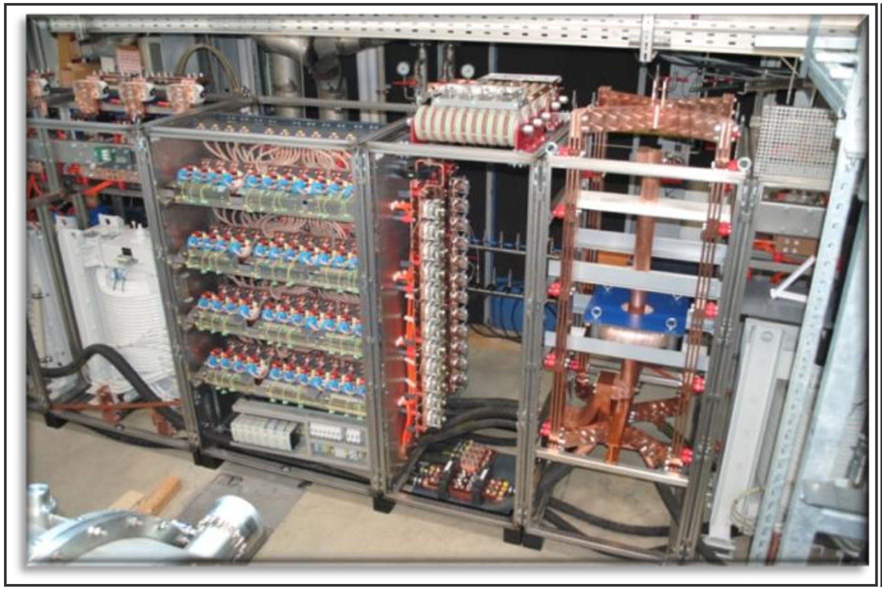
700 m^2 testing area in SH5

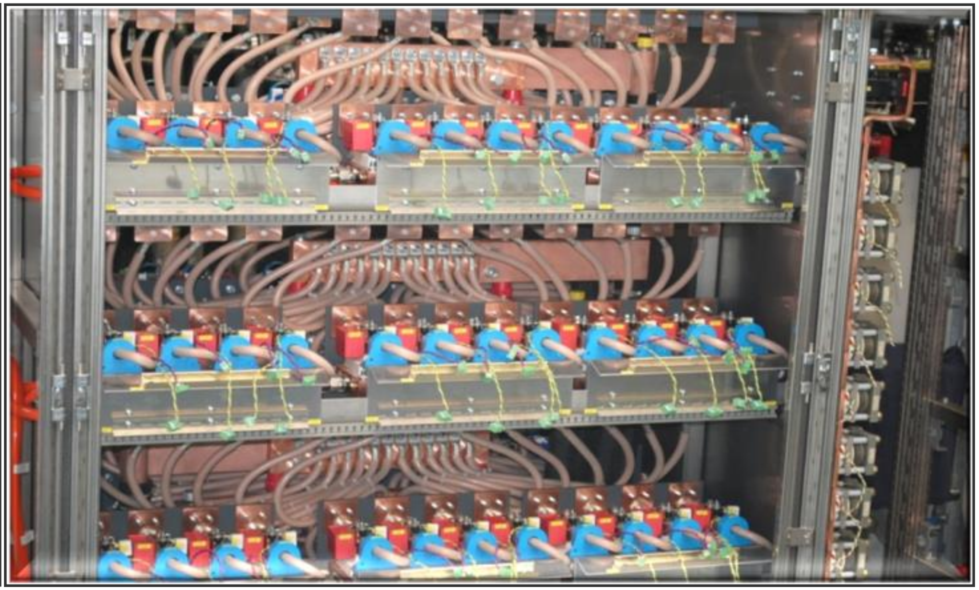
20 kA / 29 kA/s

(Testing of the Series SIS100 Dipole Magnets)

(Sum for 2 pieces)

Status: Delivery planned for end of 2014





Quadrupole Unit Testing

Preparation for tests at JINR

MoU on magnet testing signed

S.c. Magnet Testing

Summary

- GSI has reached and demonstrated, the feasibility for acceleration of high intensity low charge state heavy ion beams with the existing UNILAC and SIS18.

- GSI has conducted successfully major R&D on accelerator key components providing surpassing and unique performance not only for FAIR, but also for the next generation of particle accelerators world wide.

- Procurement of major technical systems, components and facilities for FAIR has been started involving industry and public laboratories in Germany, Europe and the main FAIR member states.

- Further procurements planned for 2014 according to the project schedule.