Status of the FAIR-facility

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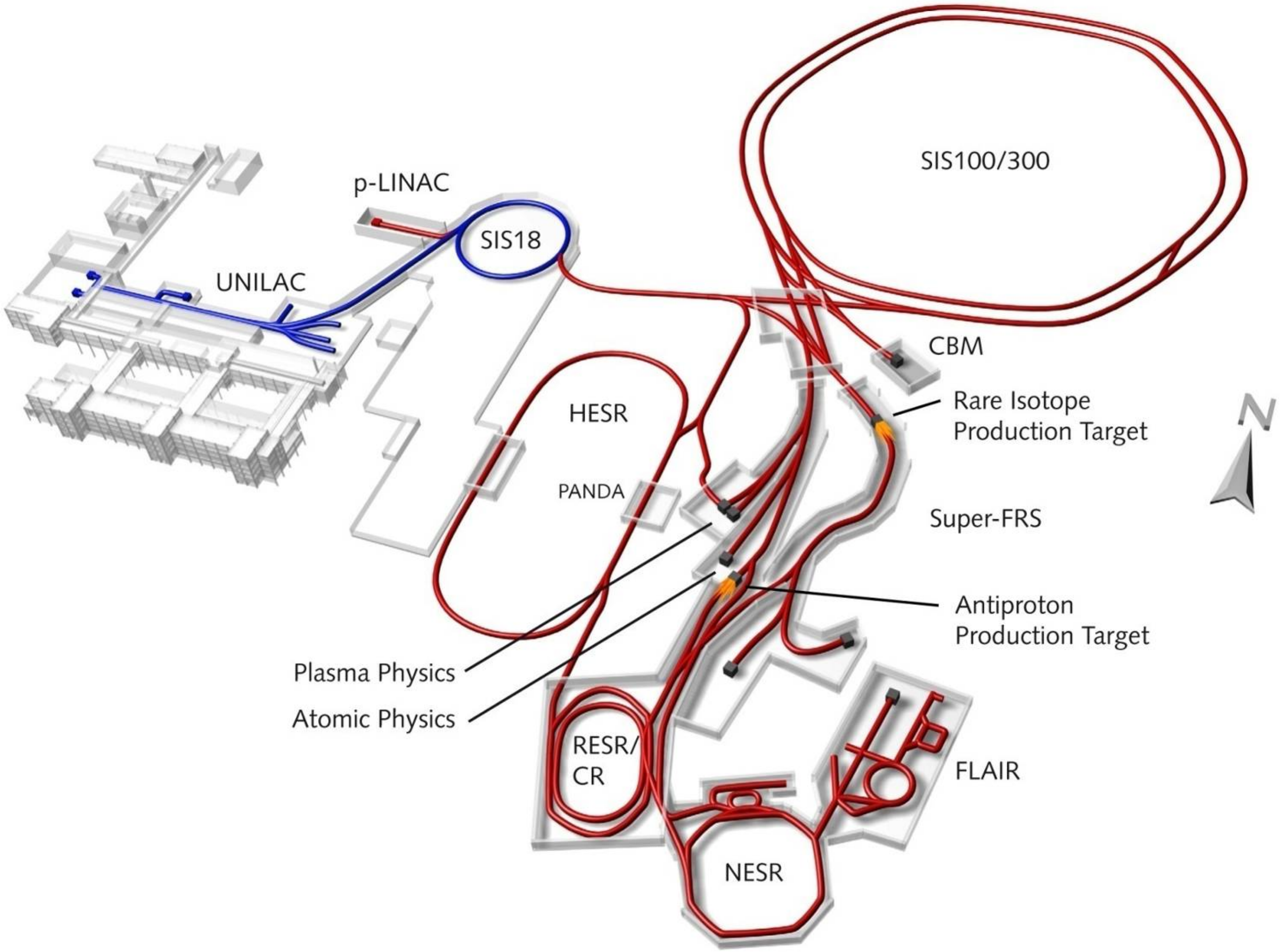
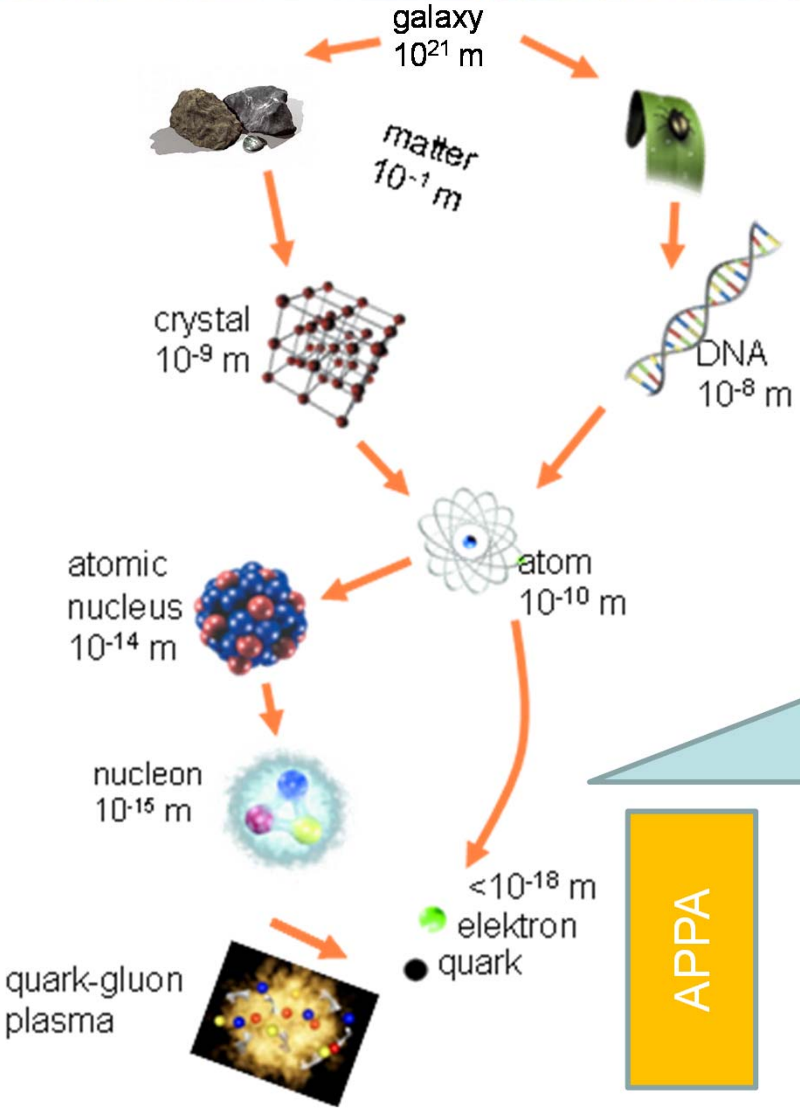
Outline

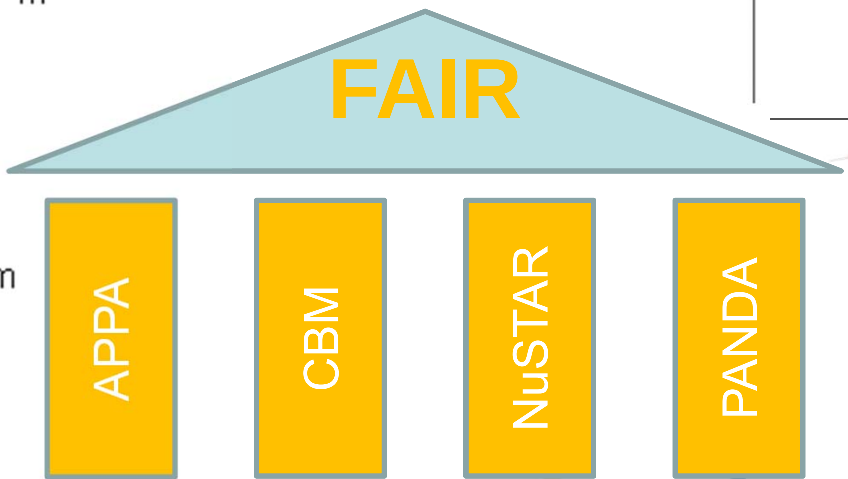
- Introduction to the FAIR project
- The FAIR injectors
  - UNILAC development program, p-Linac
  - SIS18 developments
- Challenges of the FAIR accelerators
  - Primary beam chain: SIS100
  - Super-FRS
  - Storage Rings
- Civil construction

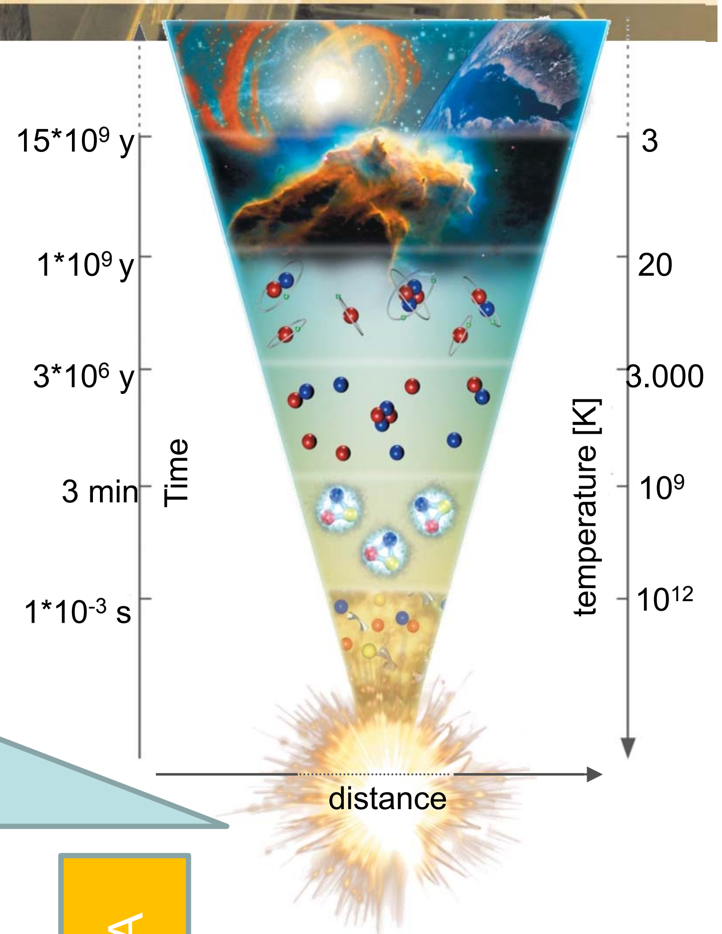
Facility for Antiproton and Ion Research - FAIR



FAIR physics programme

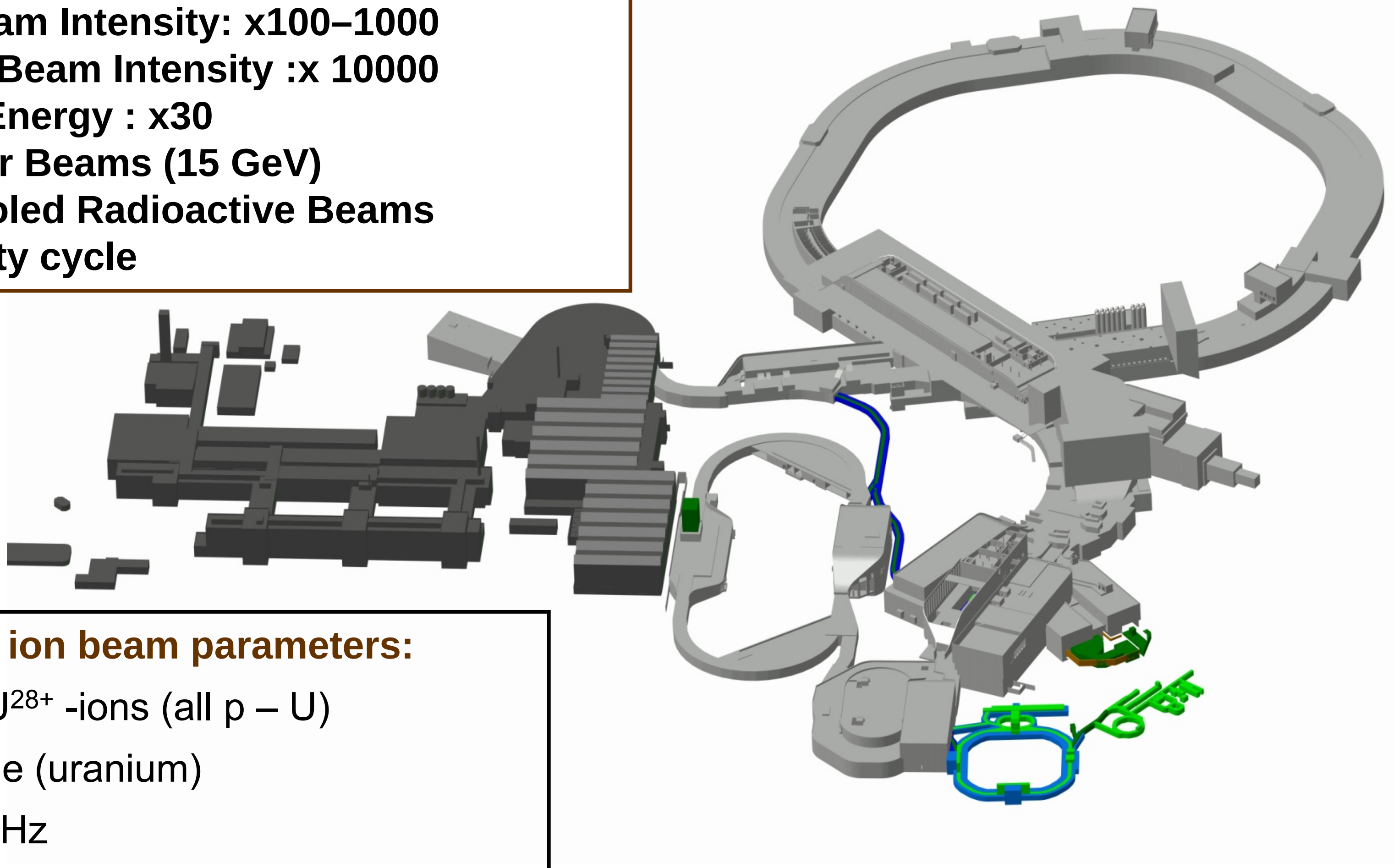






FAIR – Beam Parameters

- Primary Beam Intensity: x100–1000
- Secondary Beam Intensity :x 10000
- Heavy Ion Energy : x30
- Cooled pbar Beams (15 GeV)
- Intense Cooled Radioactive Beams
- Variable duty cycle



Some SIS100 ion beam parameters:

Ion species : U^{28+} -ions (all p – U)

N: 5×10^{11} /cycle (uranium)

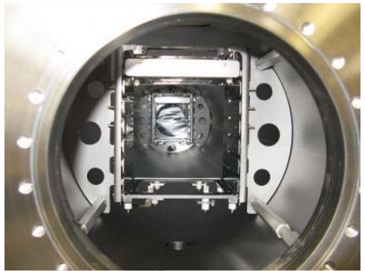
Rep. rate: 0.5 Hz

Energy : 400 – 2715 MeV/u for heavy ions

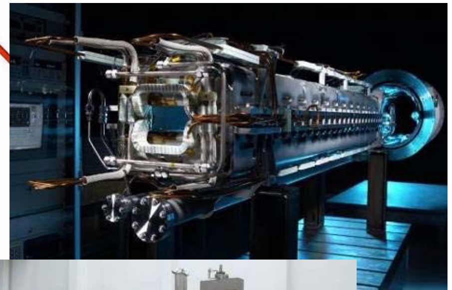
Pulse length : 30 – 90 ns

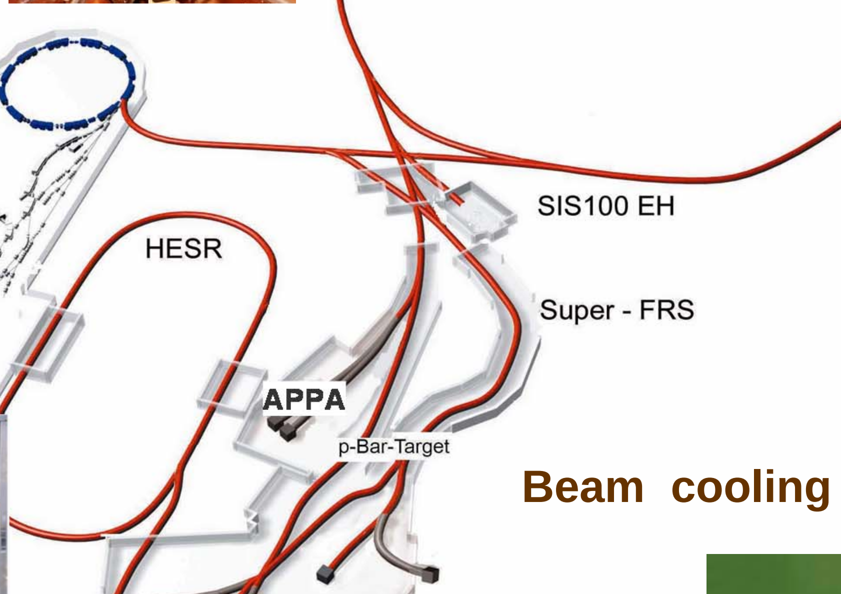
FAIR accelerator challenges

Diagnostic and XHV at highest intensities

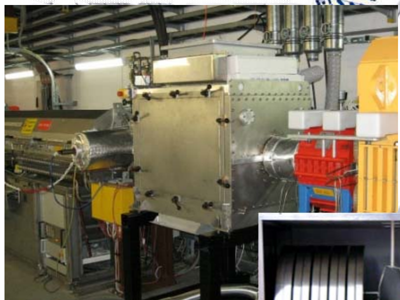


Superconducting magnets





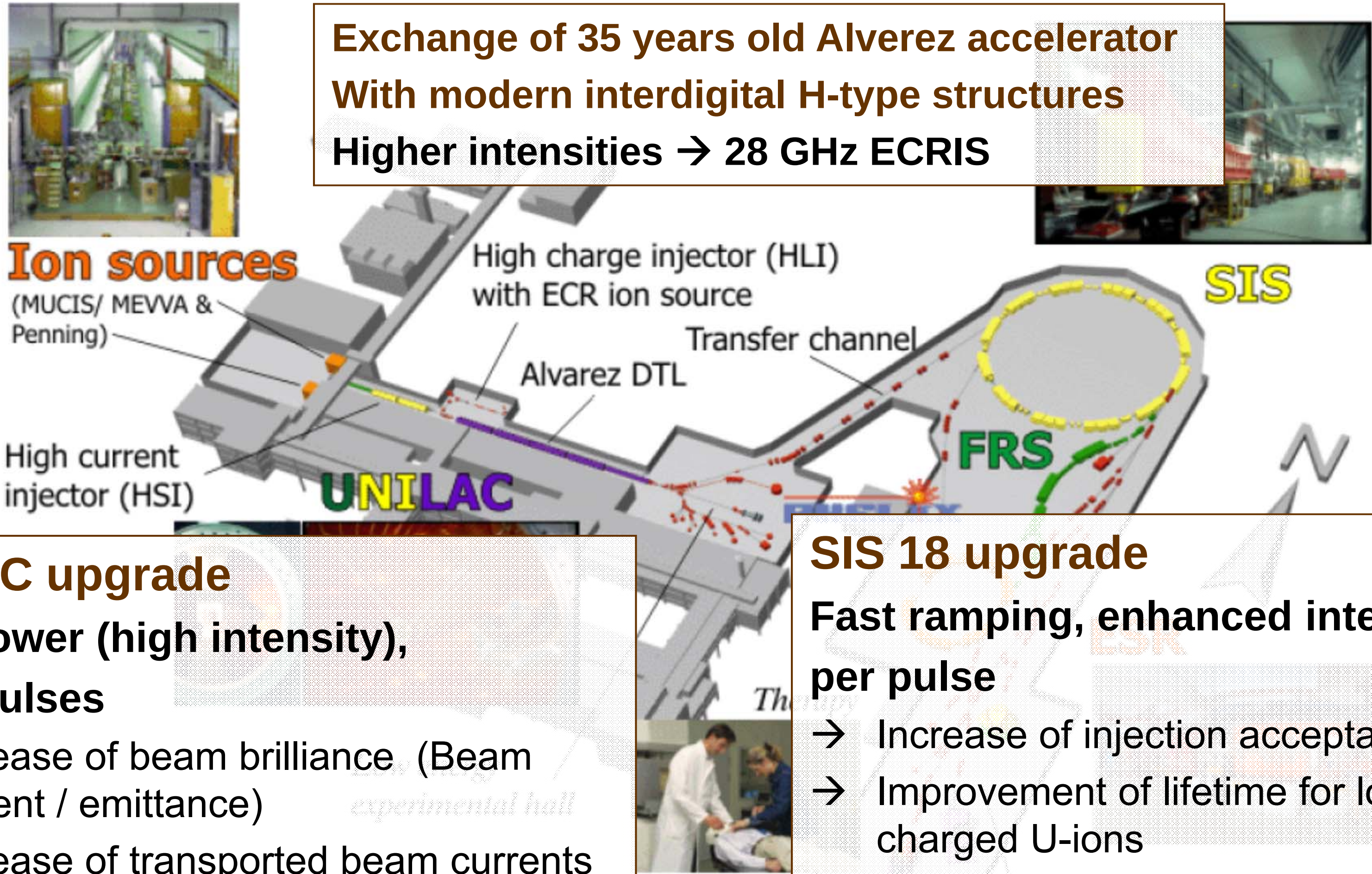
Rf-cavities



Beam cooling

The FAIR injectors

Preparing the Injector Chain



Exchange of 35 years old Alverez accelerator
With modern interdigital H-type structures
Higher intensities → 28 GHz ECRIS

UNILAC upgrade

High power (high intensity),
short pulses

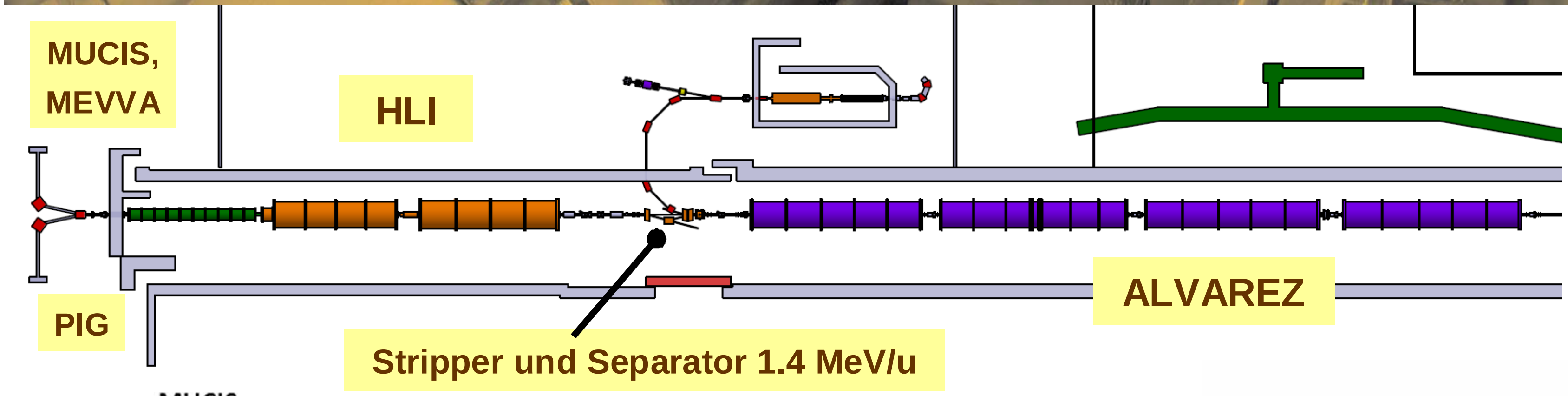
- → Increase of beam brilliance (Beam current / emittance)
- → Increase of transported beam currents
- → Improvements of high current beam diagnostics / operation

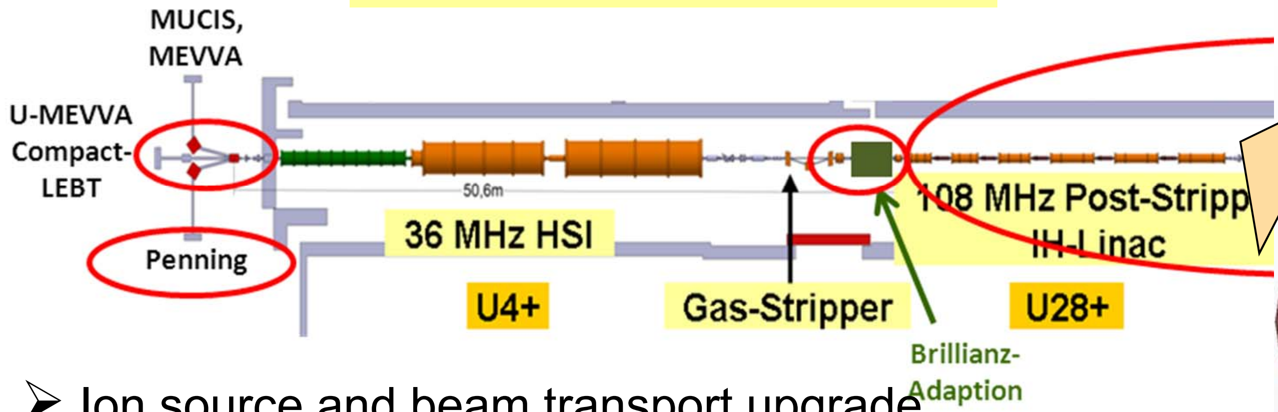
SIS 18 upgrade

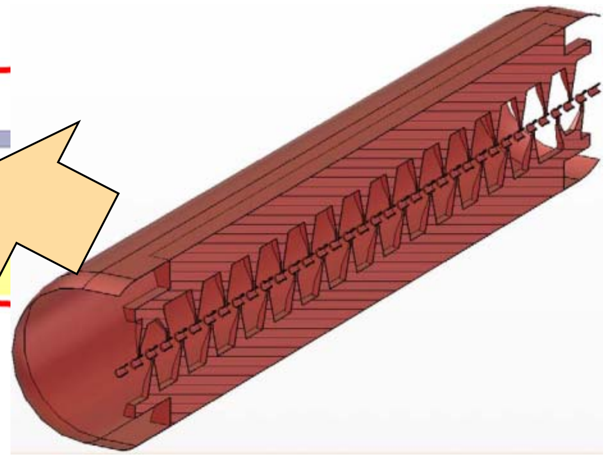
Fast ramping, enhanced intensity per pulse

- → Increase of injection acceptance
- → Improvement of lifetime for low-charged U-ions
- → Increase of beam-intensity per time due to reduction of SIS18- cycle time

UNILAC modifications and the HE-linac



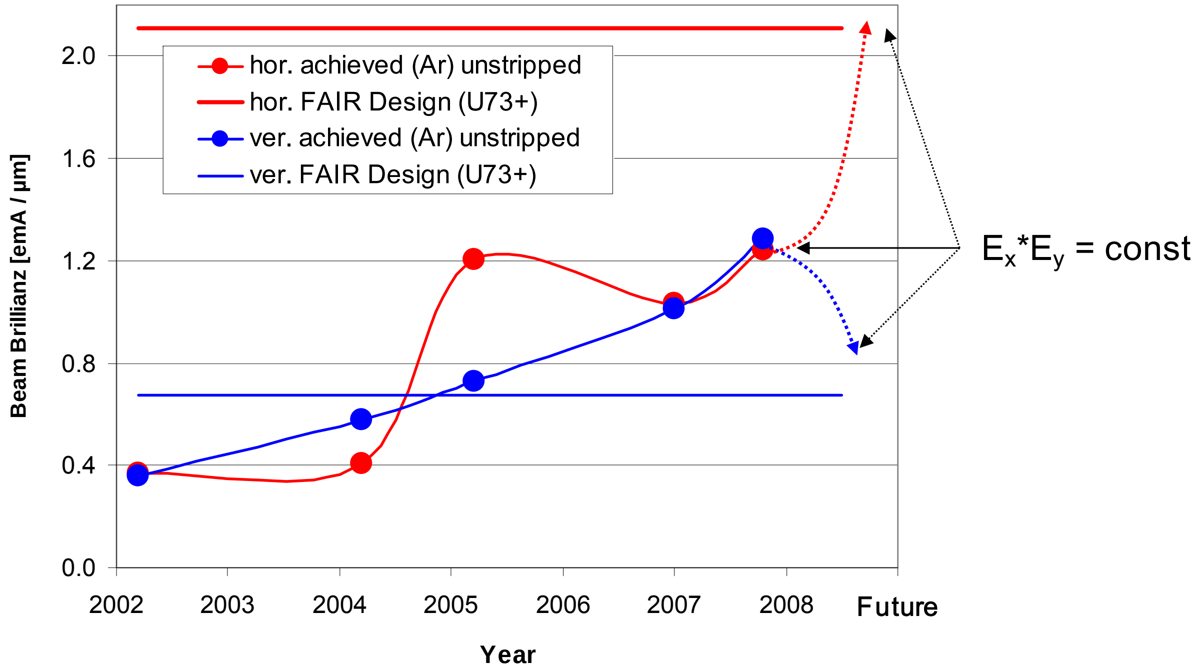




- Ion source and beam transport upgrade
- 4 Alvarez tanks, almost 40 years old → exchange by modern IH-structures
- Charge state stripper technology → higher charge states (high intensities)
- High intensity beam diagnostics

see also B. Schlitt et al., THPWO010 and L. Groening et al., TUPWA007

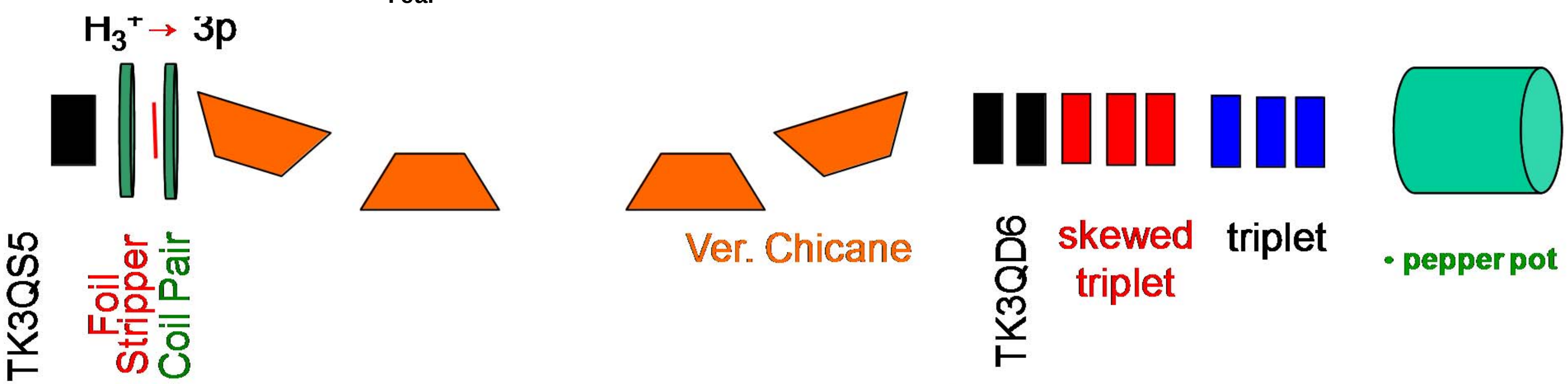
Emittance transfer



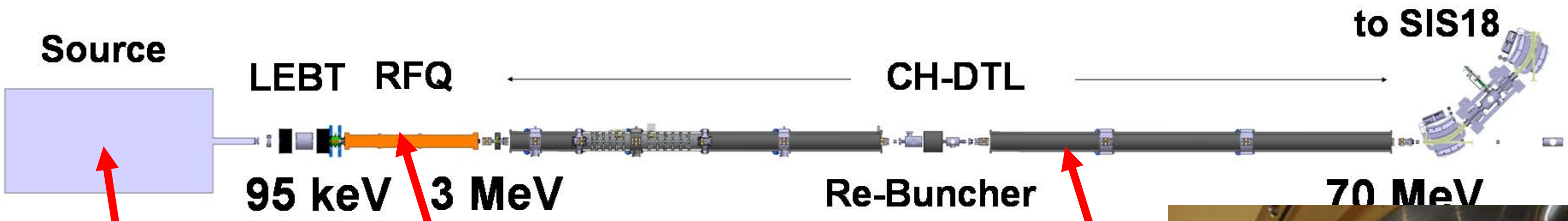
Emittance transfer via Eigen Emittance shaping

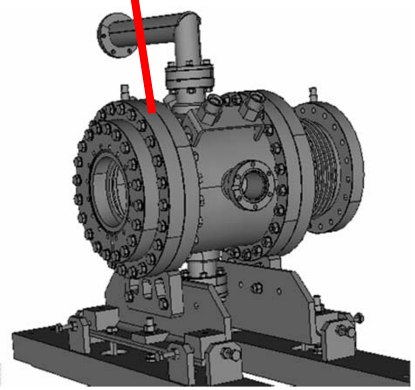
→Beam tailored to an optimized synchrotron injection

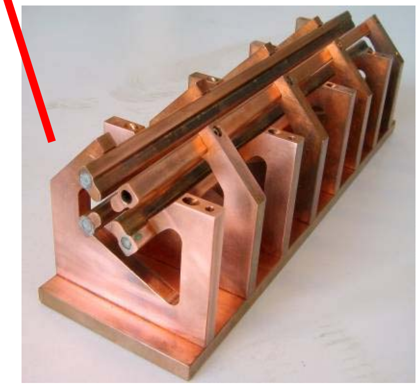
(see C. Xiao et al., TUPWO009)

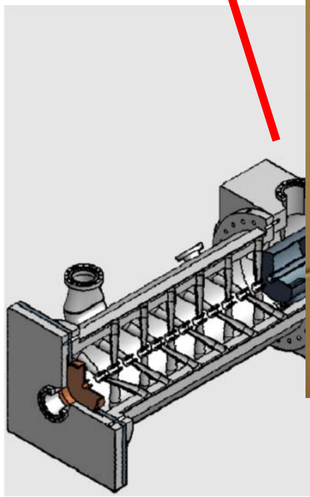


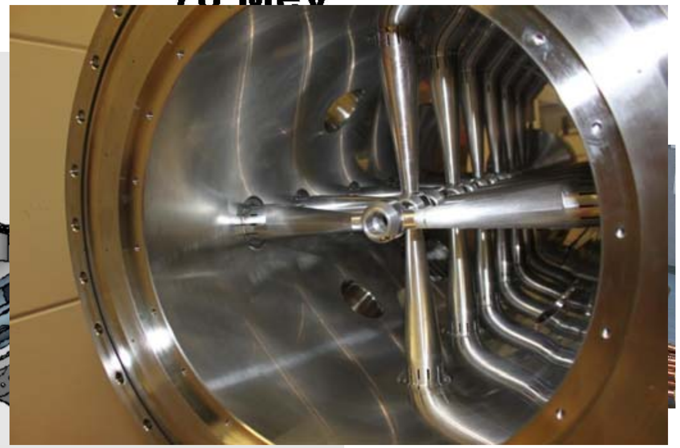
p-Linac overview

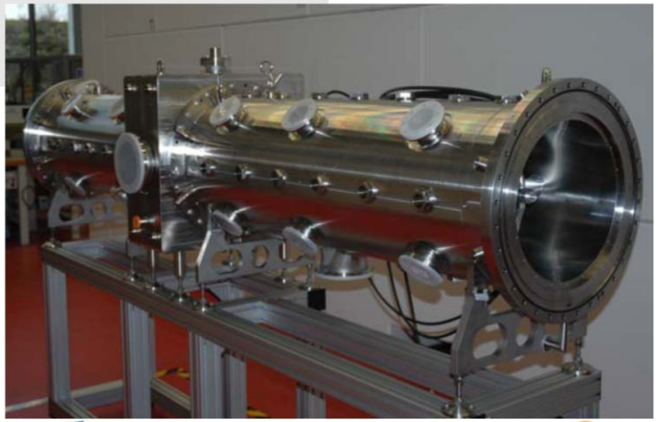










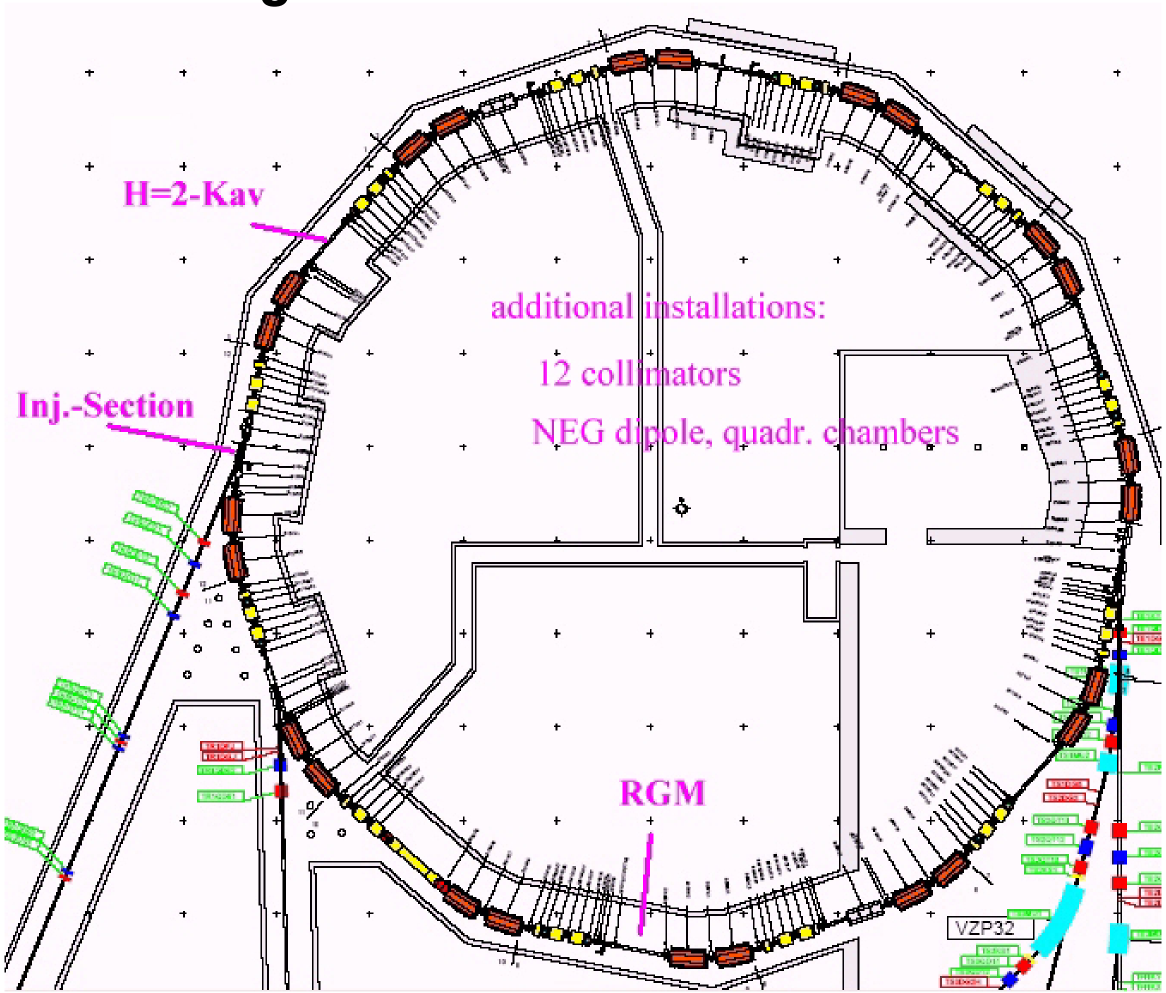


- ECR proton source & LEBT
- 4-rod RFQ, 325.224 MHz
- 6 accelerating cavities, 35 mA beam current

see also, R. Brodhage et al., THPWO014 & THPWO015
G. Clemente et al., THPWO008 & THPWO009

SIS18 high current upgrade

SIS-Ring with modifications

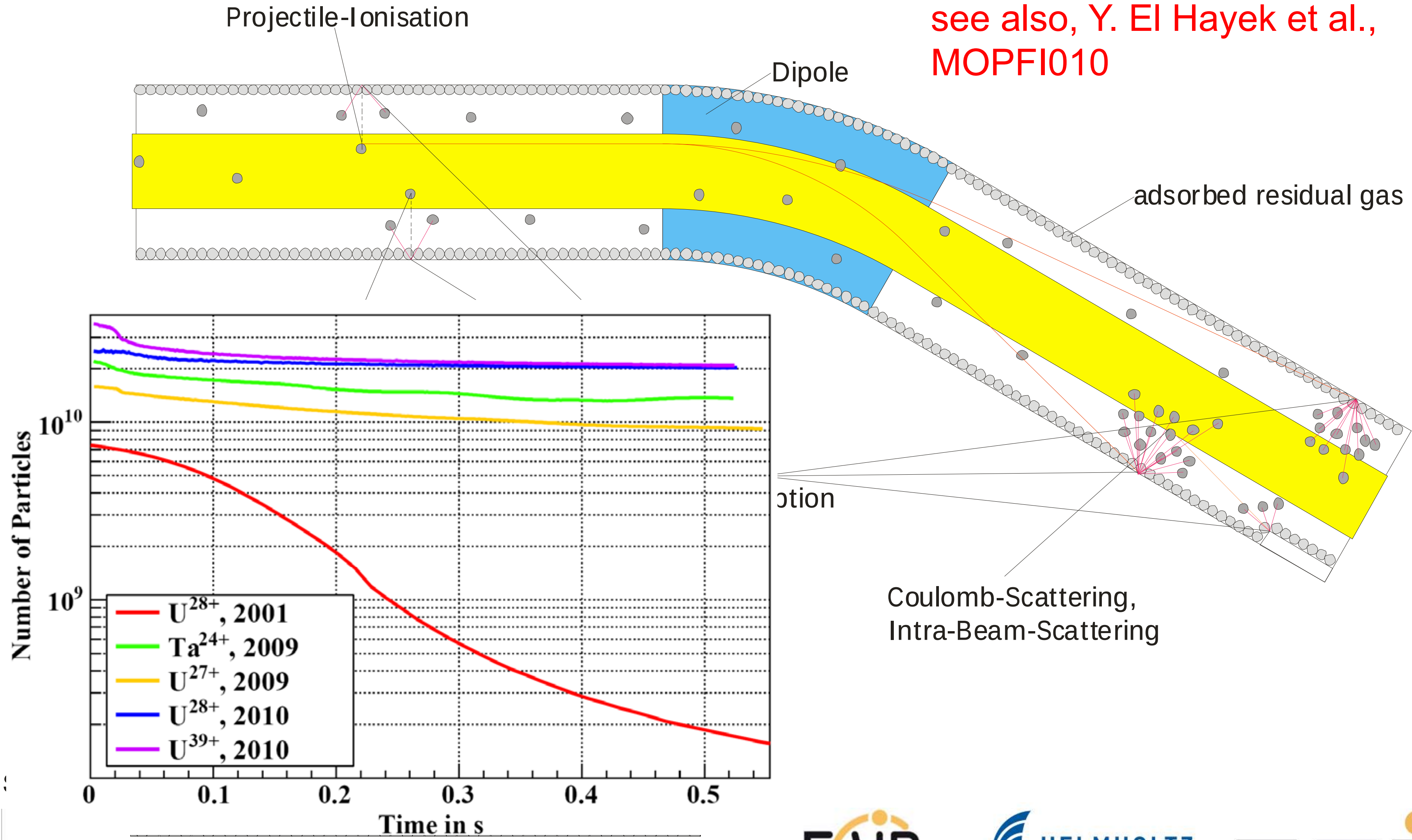


Main tasks:

- pulse power conn. finished (12 Tm fast ramping)
- new injection system finished
- Dynamic vacuum:
  - * UHV upgrade
  - * ion catcher system, collimators
  - * optimized beam diagnostics (RGM)
- Theoretical Investigations (and machine Exp.)
- Bunch compression

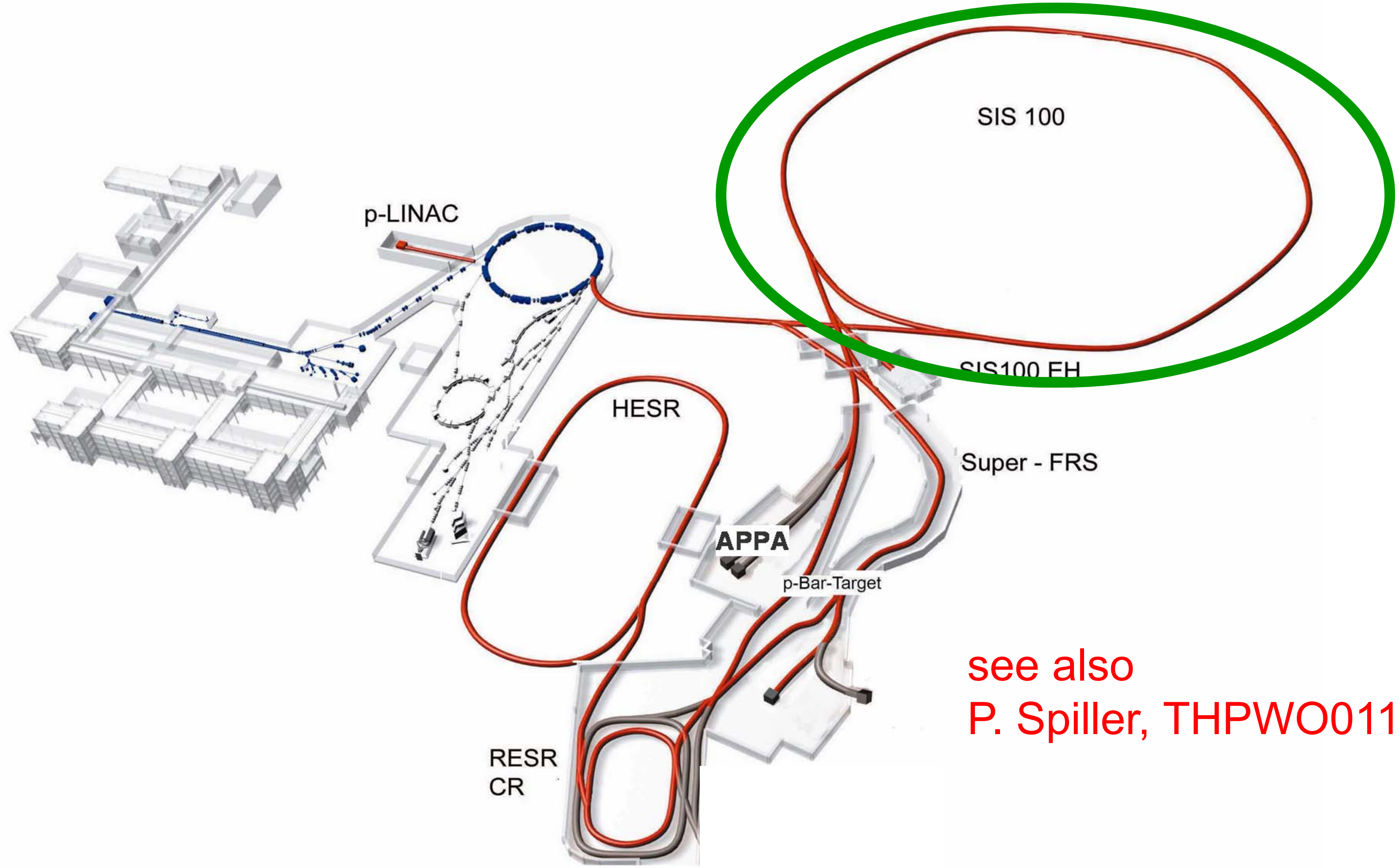
Dynamic Vacuum effect and collimation

see also, Y. El Hayek et al., MOPFI010



Challenges of the FAIR accelerators

SIS100 synchrotron

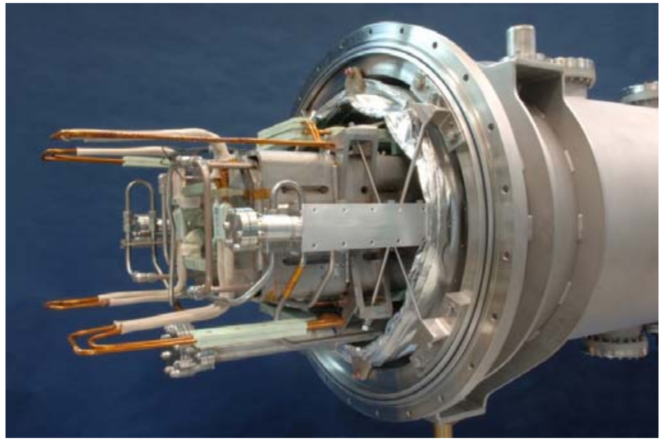


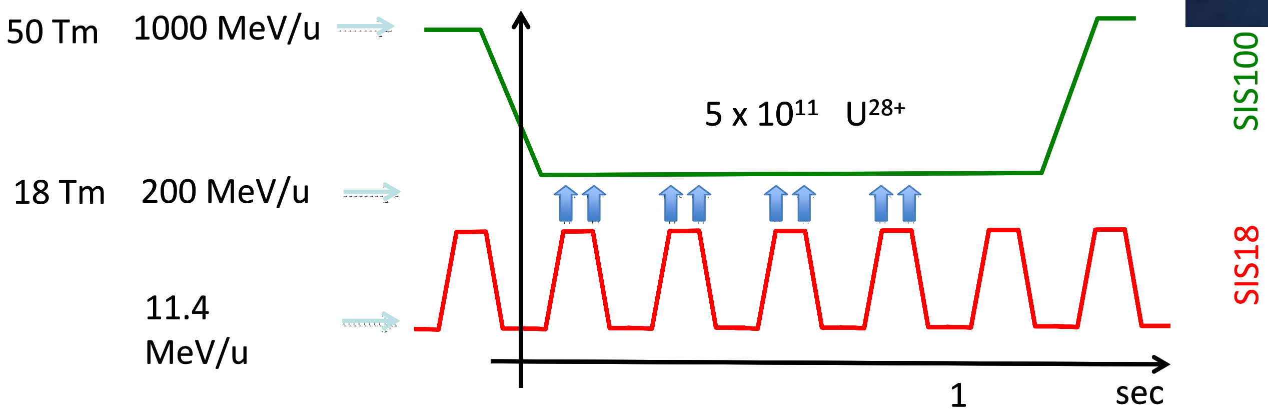
see also
P. Spiller, THPWO011

Challenges of the SC-magnets development for SIS100

Fast ramped magnets (synchrotrons)

- ➢ Dynamic load and AC heat losses
  Bρ= 100 Tm - Bmax= 1.9 T - dB/dt= 4 T/s
- ➢ High field quality, low multipole strength





R&D Goals

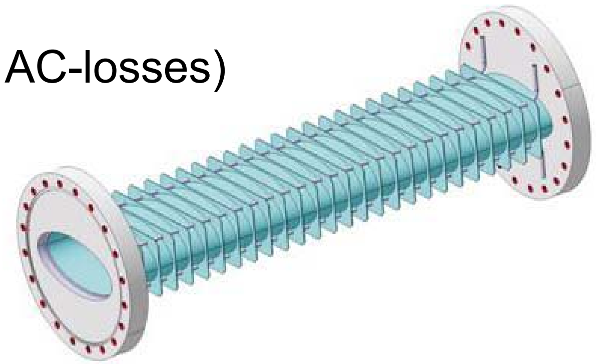
- Reduction of eddy / persistent current effects
- Guarantee of long term mechanical stability (≥ $2*10^8$ cycles)
  (mechanical stress →coil restraint)

see also
St. Sattler et al.,
MOODB101

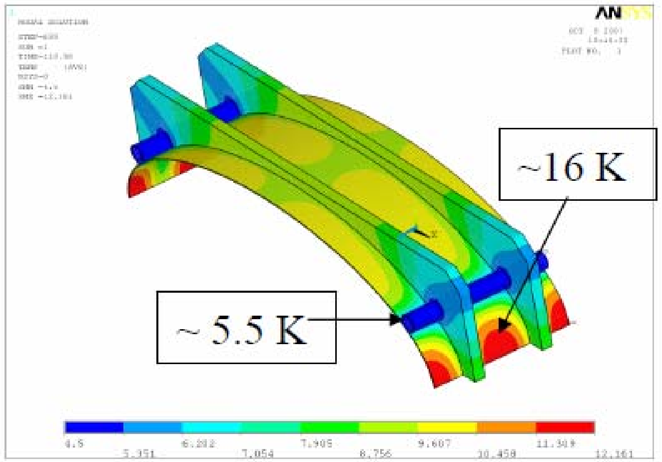
Dipole vacuum chamber

Curved thin wall (0.3 mm) chamber

- elliptical cross section
- wall thickness: 0.3 mm (minimize AC-losses)
- chamber reinforced by ribs



Eddy currents and according losses

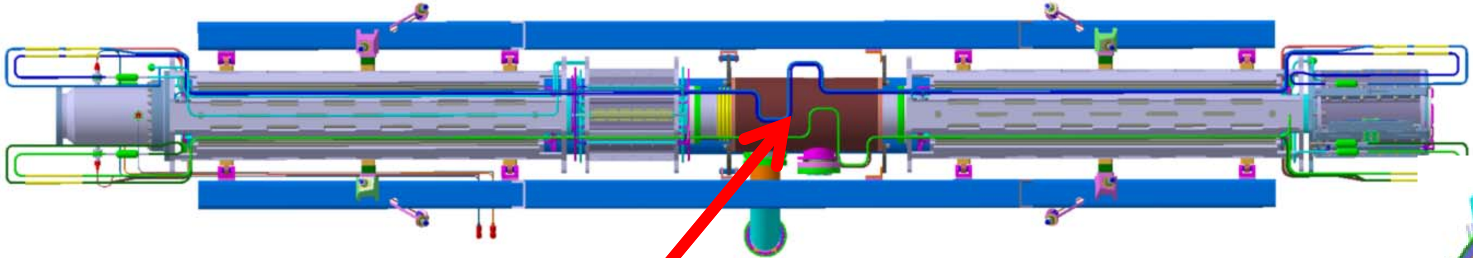


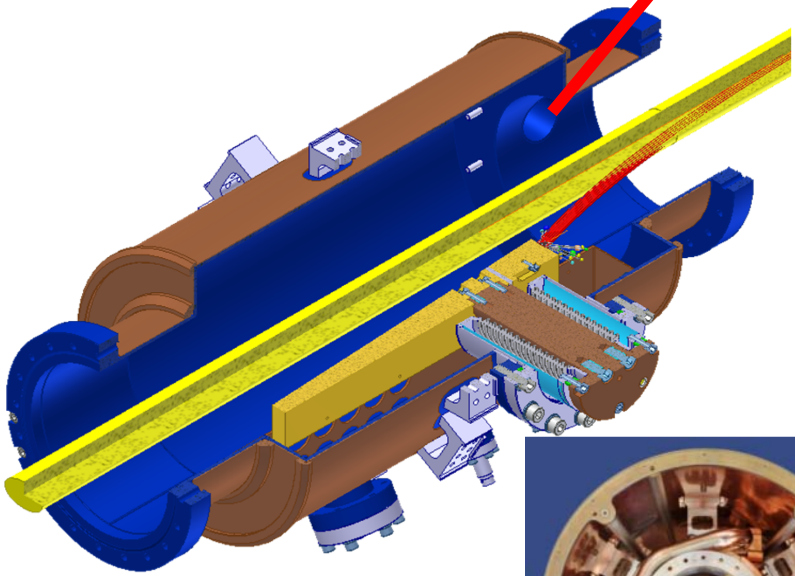
Big problem:

Without cooling→ due to the fast magnet ramping eddy currents heat the chamber wall to temperatures >80K

The demand is due to outgasing <20 K

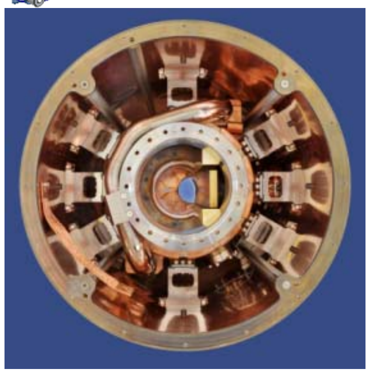
SIS100 quadrupole doublet modules





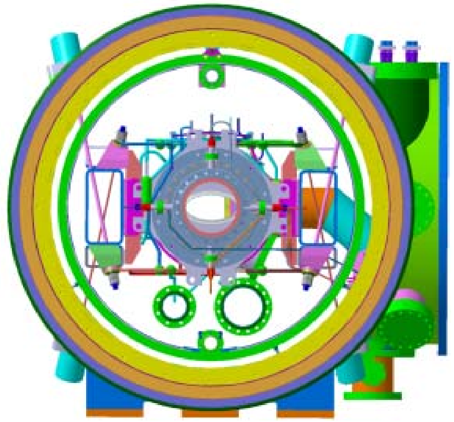
SIS100 cryo catcher

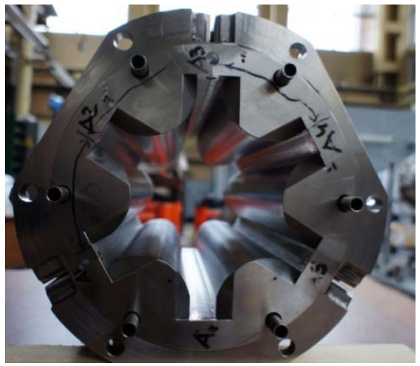
(prototype tested)

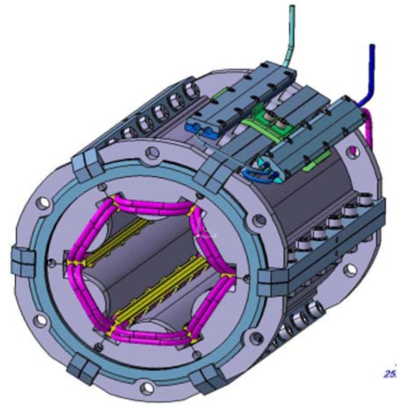


SIS100 sextupole

→ Dubna prototype

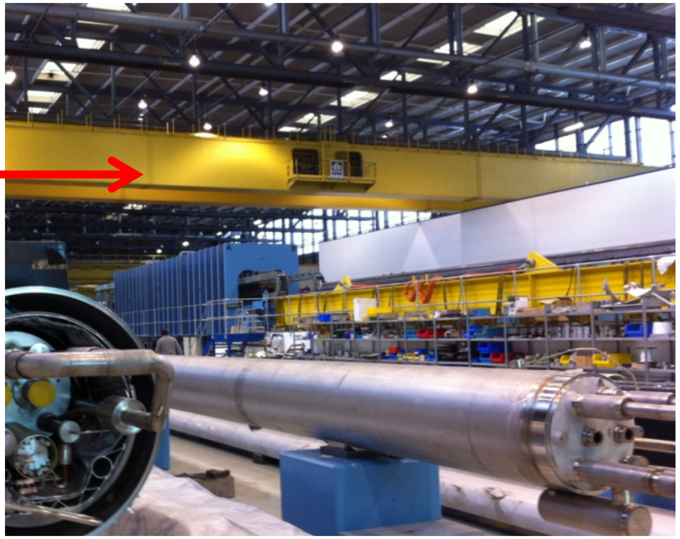


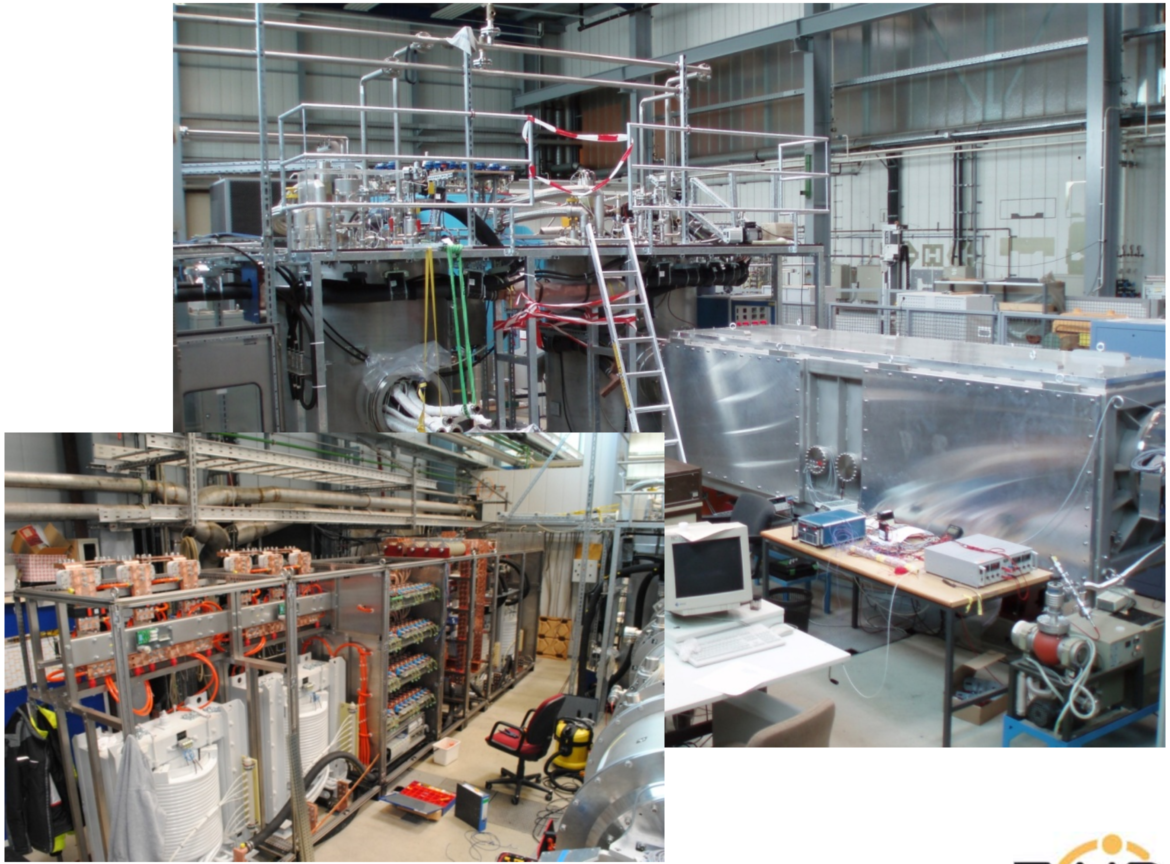




Magnet testing facilities

- Testing of SIS100 Dipoles and prototypes at GSI
- Testing of SIS100 quadrupole units at Dubna
- Testing of Super-FRS magnets at CERN





New series test facility at GSI

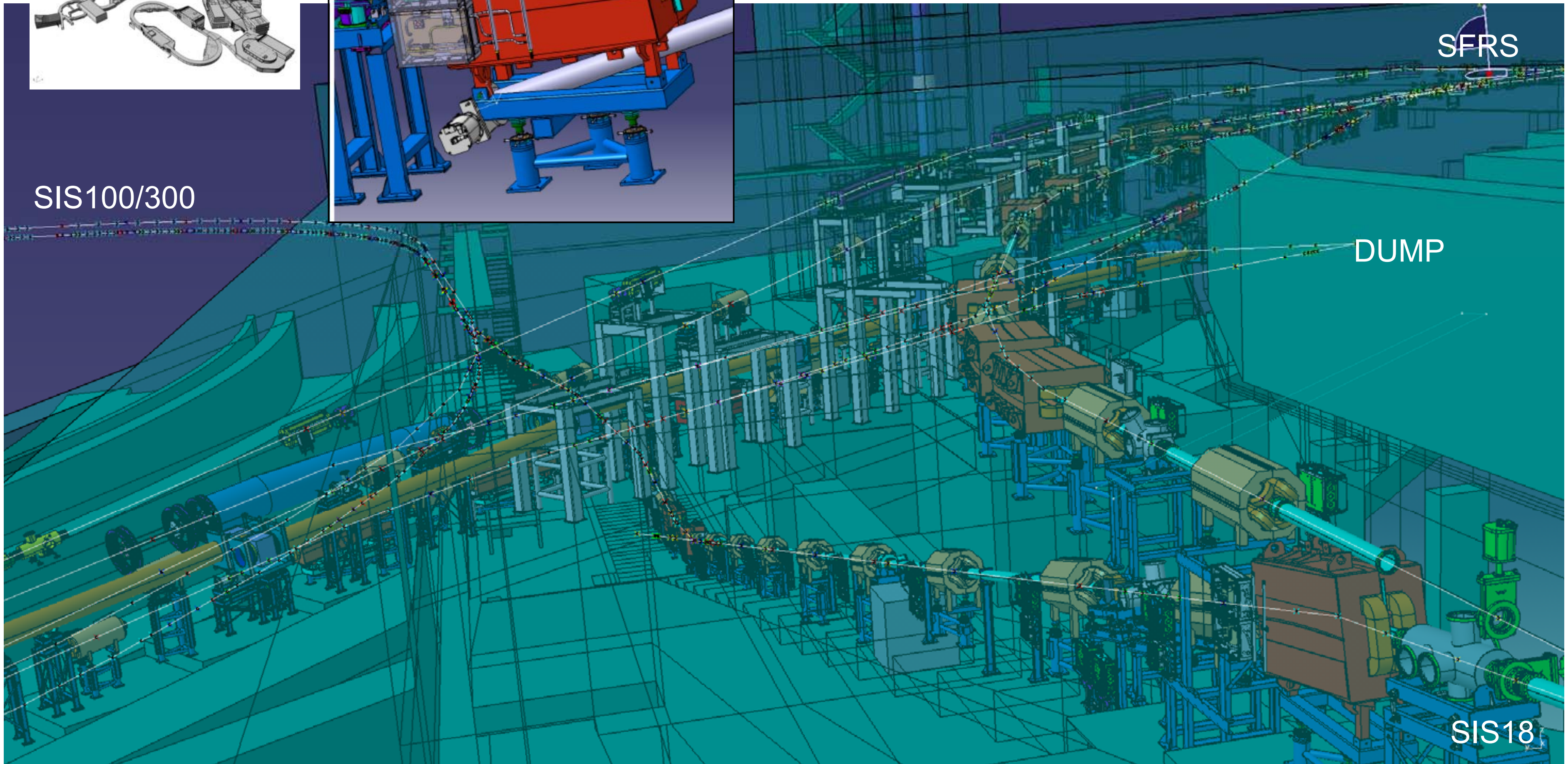
→ 2 kW cryo plant, new building

upgrade of test facility with a 20 kA power converter

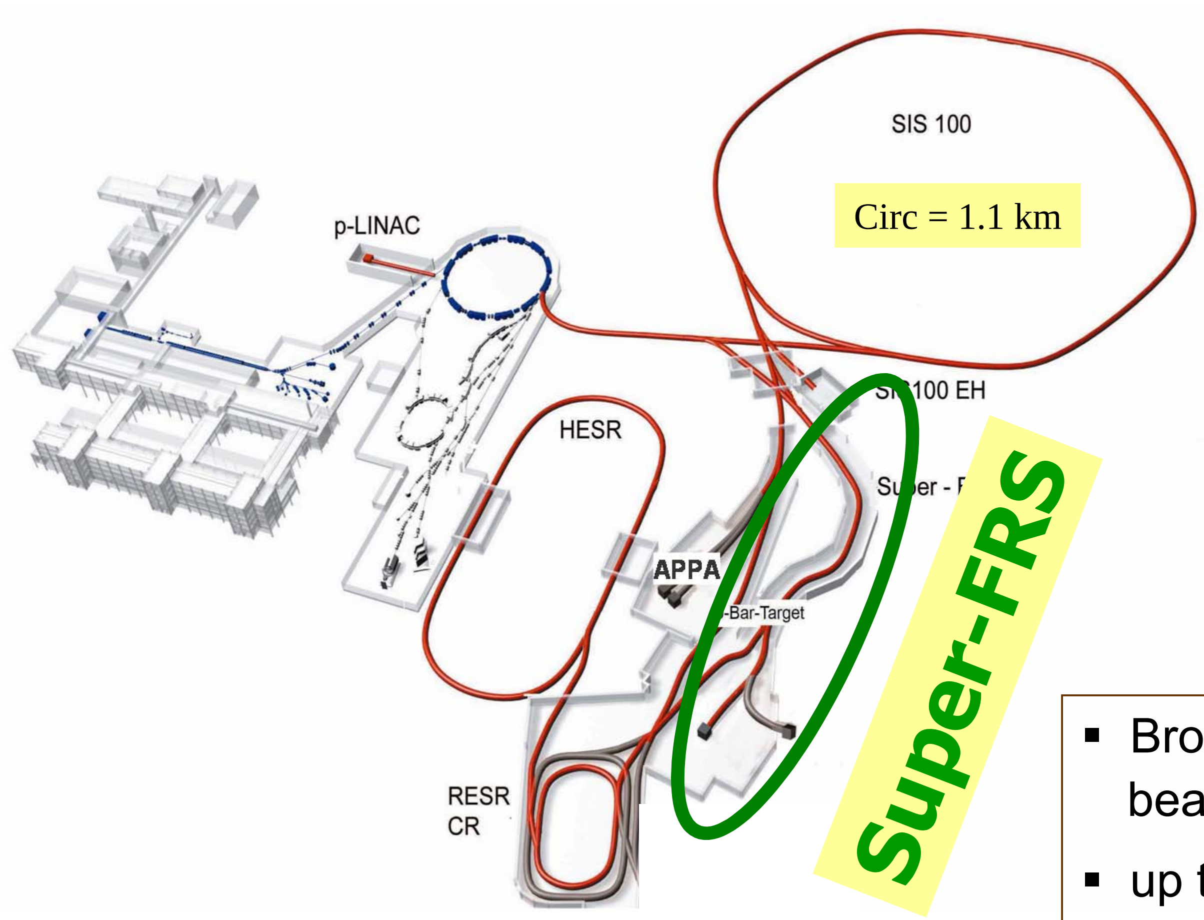
preparation of string test area

HEBT system lay-out of transfer lines

Production of HEBT magnets → Efremov St. Petersburg



Super-Fragment Separator at FAIR



Primary Beams

- **$3 \cdot 10^{11}$ $^{238}U^{28+}$/s (Slow extr.)** @ 1.5 GeV/u
- **$4 \cdot 10^{11}$ $^{238}U^{28+}$ (pulsed)** @ 1 GeV/u
- factor **100** in intensity over present

Secondary Beams

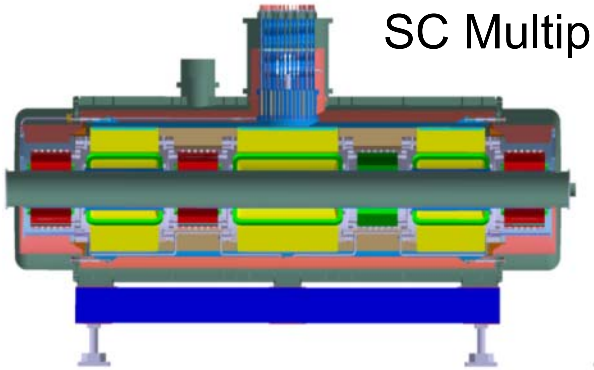
- Broad range of radioactive beams up to **1.5 GeV/u**
- up to **factor 10 000 in intensity** over present

Developments for the Super-FRS

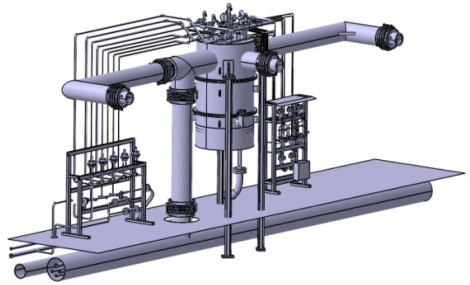
Remote Handling

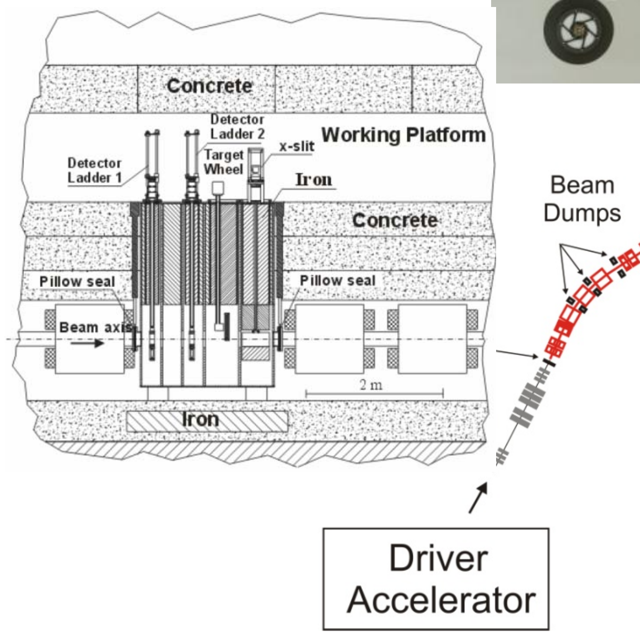
Target

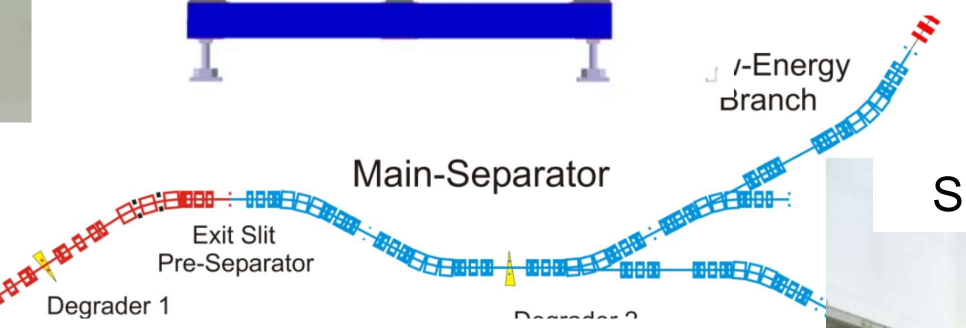
SC Multiplets



Local Cryogenics

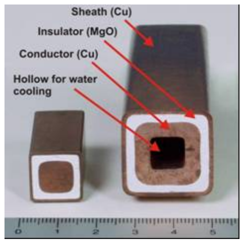




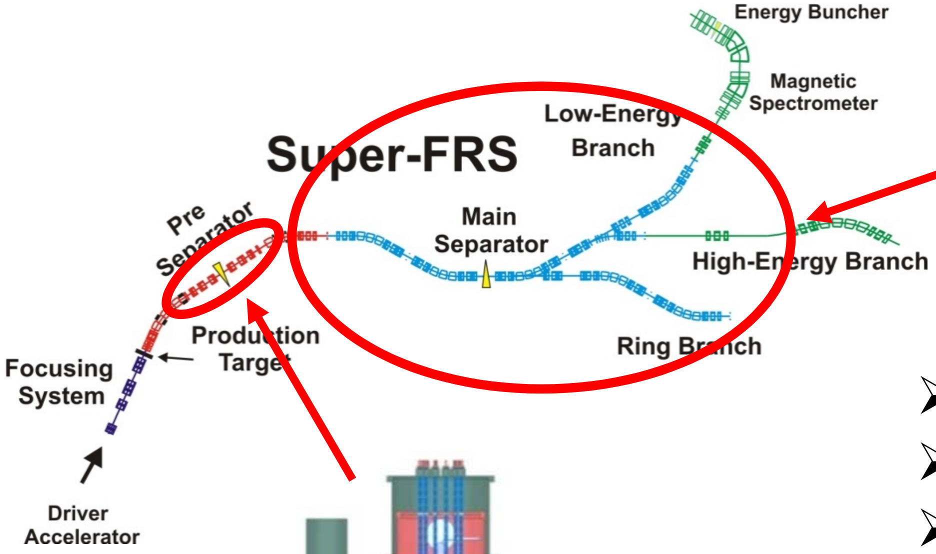


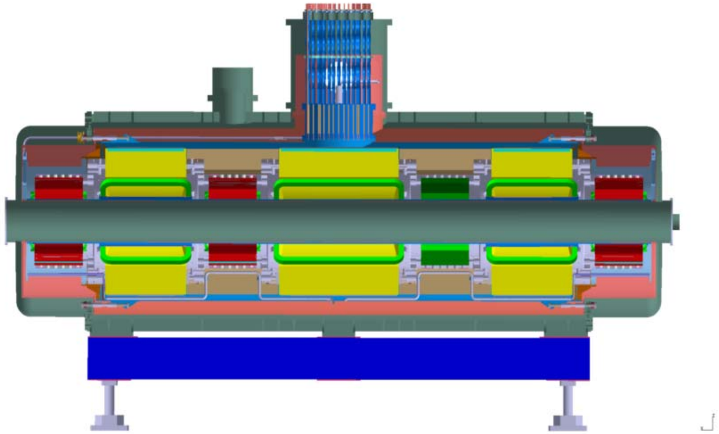
SC Dipoles

Radiation Resistant Magnets

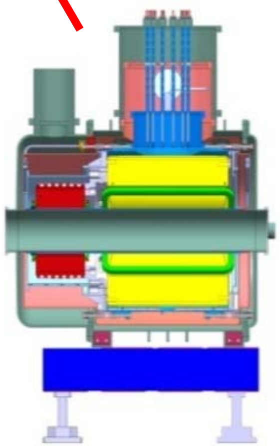


Super-FRS Superferric Multipletts





- 24 multiplets (7 m long)
- Quadrupol triplet
- up to 3 sextupoles and 1 steerer
- Octupole coils in short quadrupoles



7 short multiplets (2.6 m)

- iron dominated, cold iron (up to 37 tons)
- warm beam pipe (38 cm inner diameter)

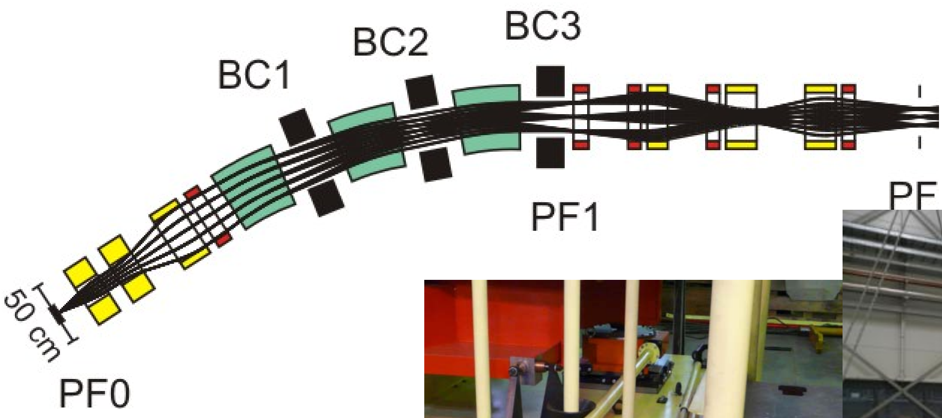
H. Müller et al., THPME005

Radiation Resistant Dipole

Prototype Production

High-radiation level
→ Normal conducting

Super conducting



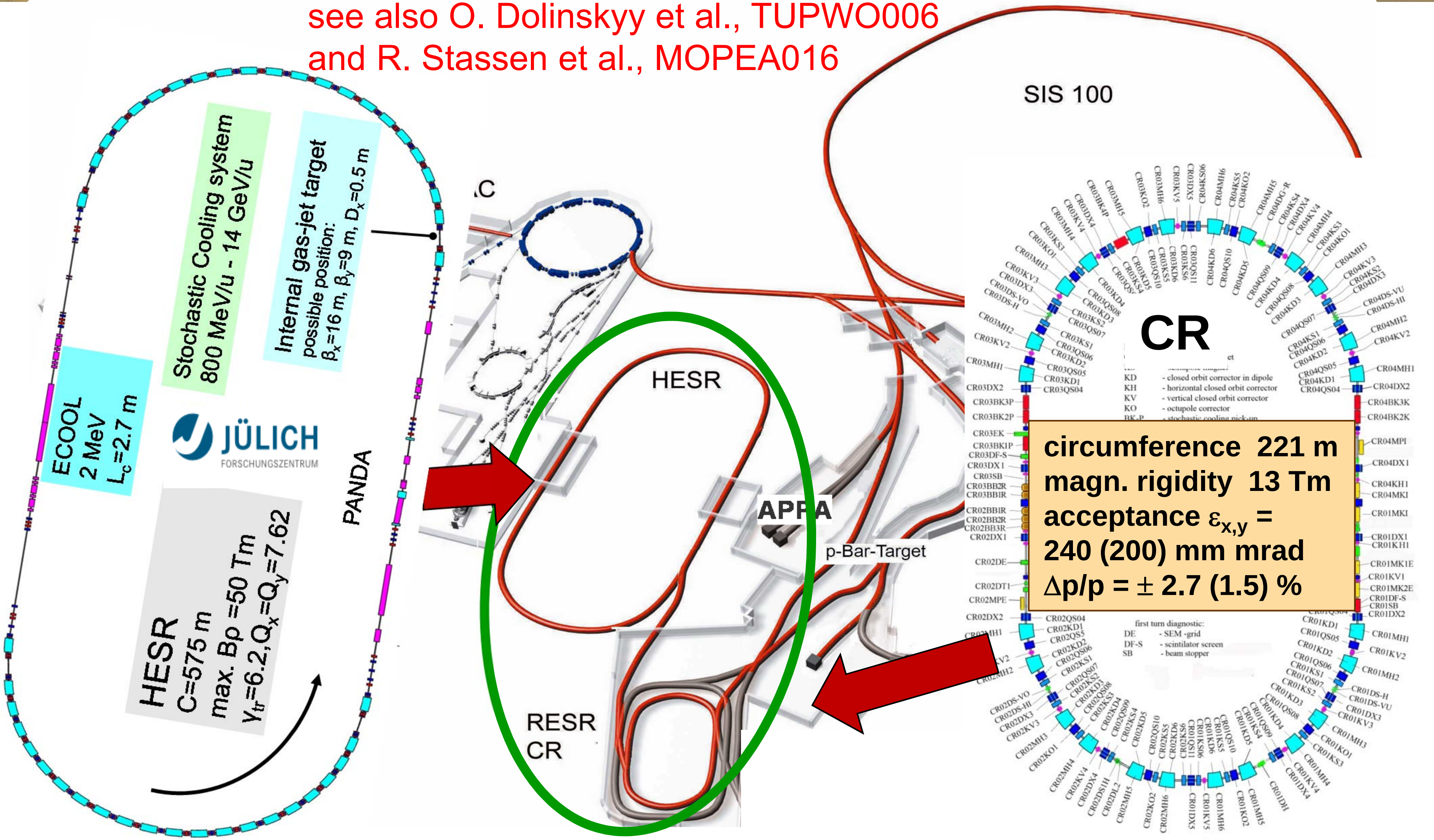
- Developed with BINP, Novosibirsk
- Normal conducting magnets using **M**ineral **I**nsulating **C**able
- $\rho = 12.5$ m, $\phi = 11°$, $B_{max} = 1.6$ T, 95 tons
- Remote connectors and alignment

Development at BINP

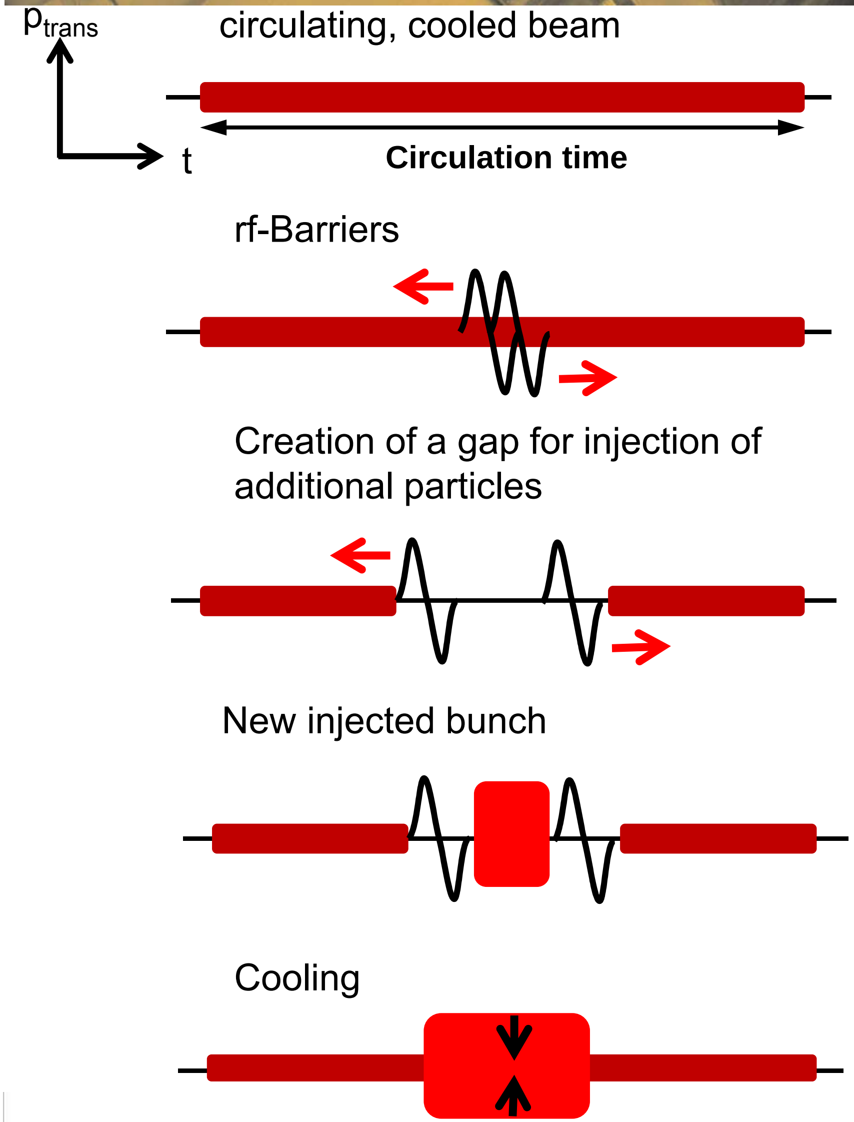
Installation at GSI

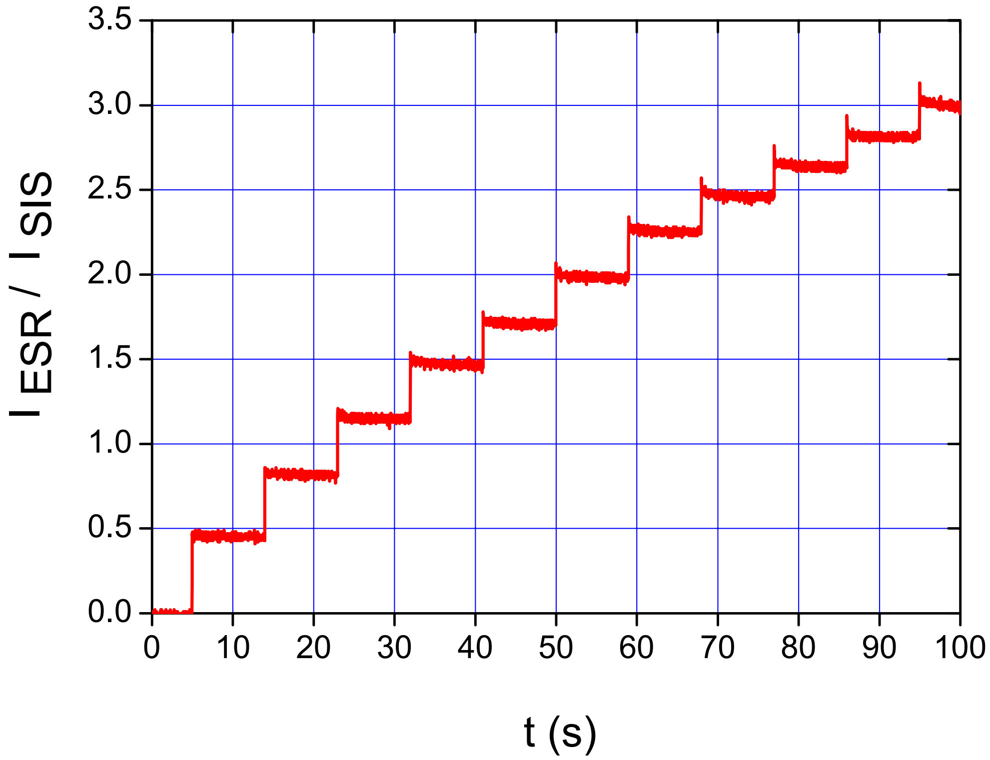
The FAIR storage rings

see also O. Dolinskyy et al., TUPWO006
and R. Stassen et al., MOPEA016



Stacking of particles in the FAIR storage rings

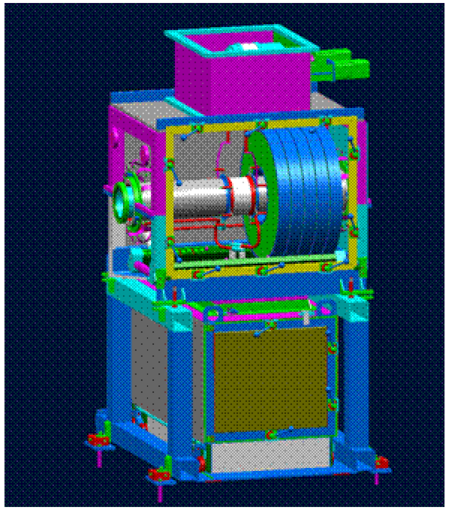


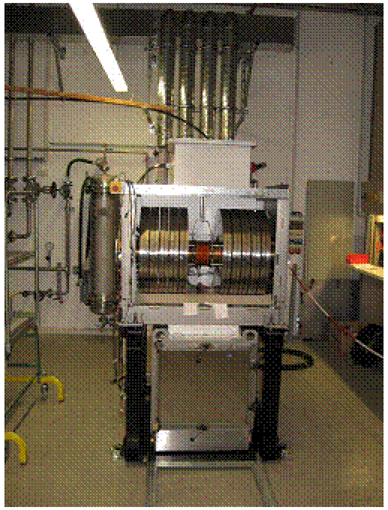


see also F. Nolden et al., MOPEA013

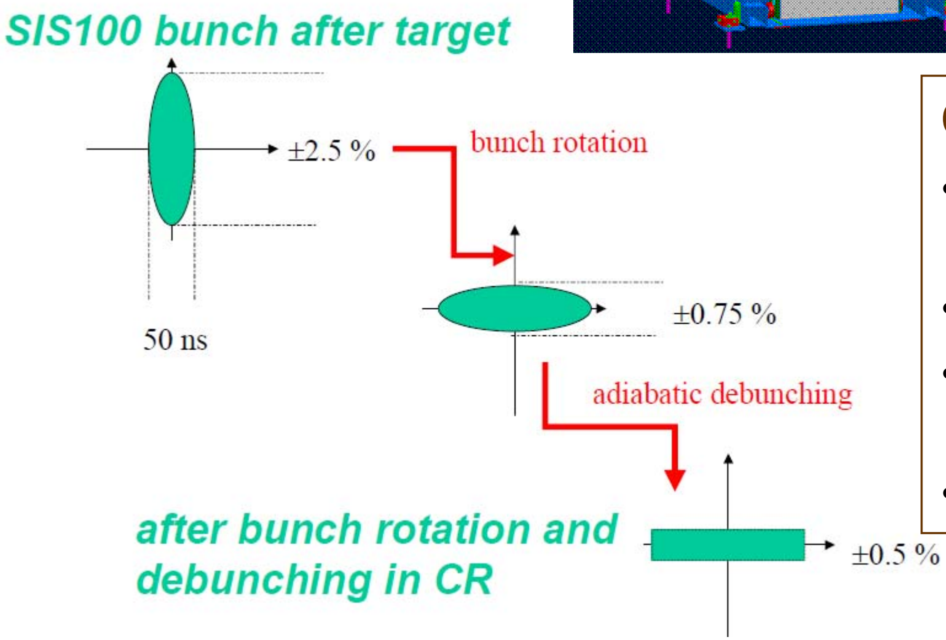
MA- ring core cavities: Bunch compression in SIS100 and Fast bunch rotation in the CR

Gap voltage 40 kV
Length 1 m
Rotation time ~ 100 μs





see also S. Schäfer et al., THPEA003



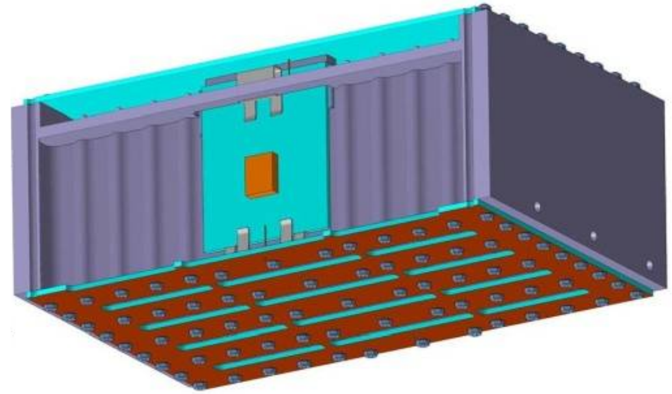
Challenges:

- Short bunch from SIS100 (50 ns)
  → bunch compression
- For stochastic cooling de-bunching required
- High voltage (200 kV) required for fast rotation
- Advanced low level rf system

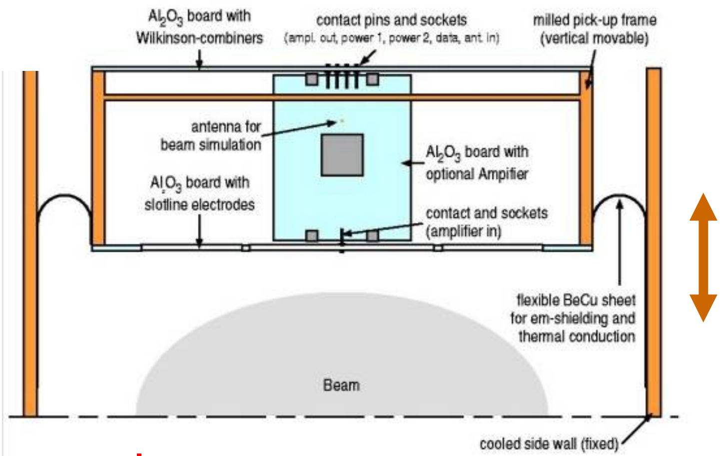
Stochastic Cooling development

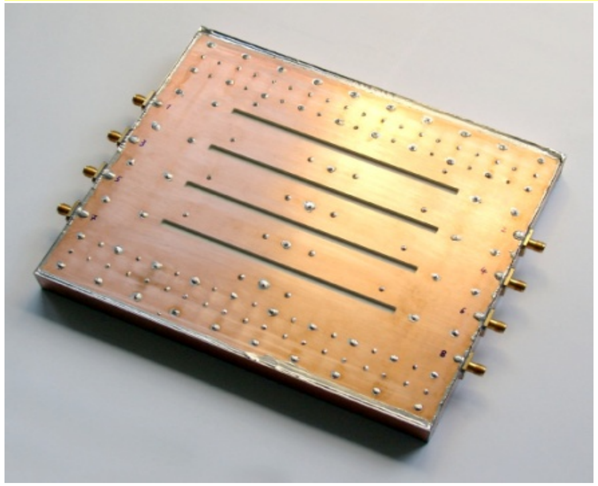
Challenges:

- 2 GHz band (specs for power ampl. are ready)
- UHV conditions and 20 K temperature level
- Mounted on movable feedthroughs
  → synchronous operation of lin. motor drives
- Numerical code under development



CR: fast stochastic cooling (1-2 GHz) of antiprotons (10 s) and RIBs (1.5 s)



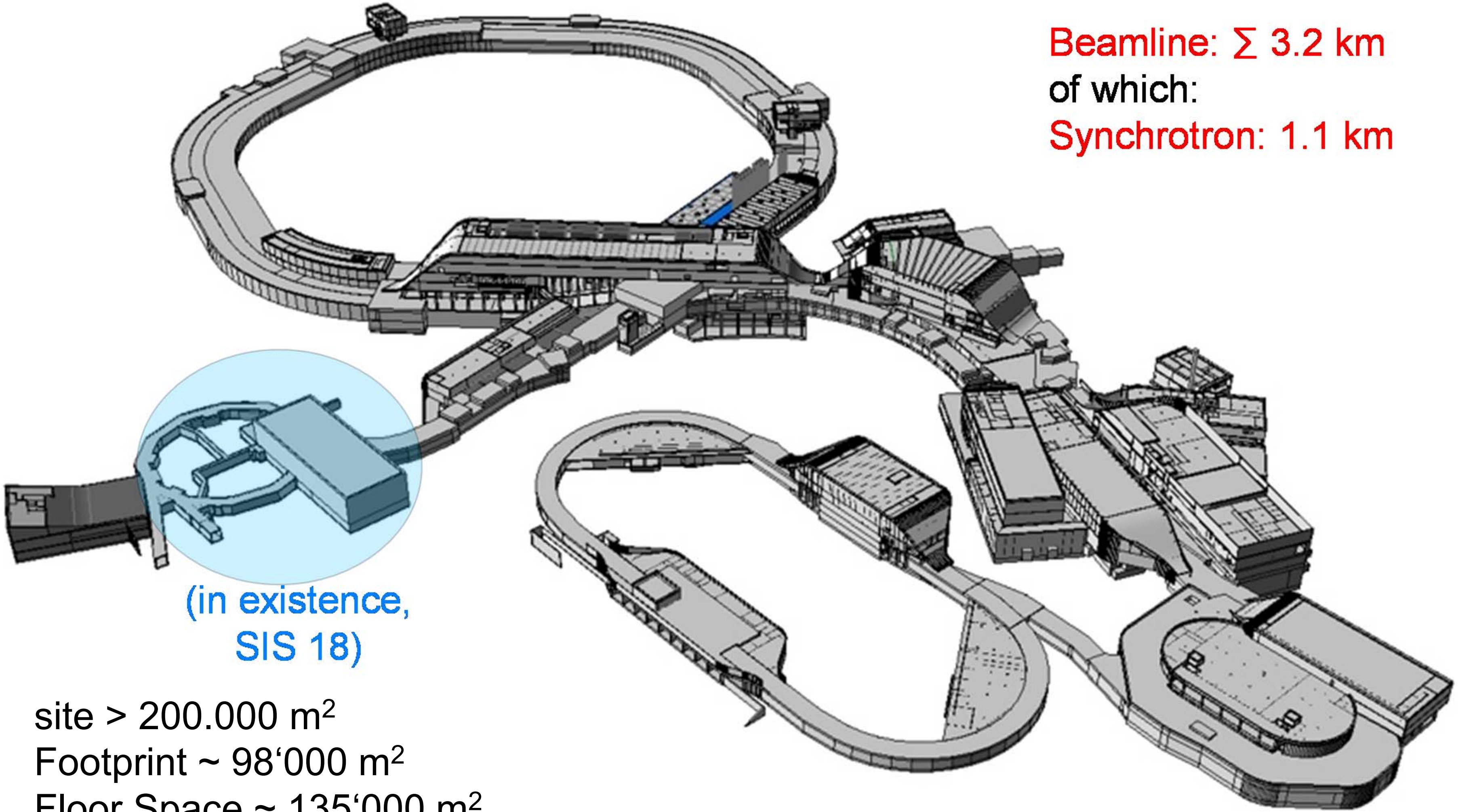


prototype electrode (ß = 0.83-0.97)

see also
M. Dolinska et al., MOPWO061

FAIR civil construction

FAIR Site and Buildings



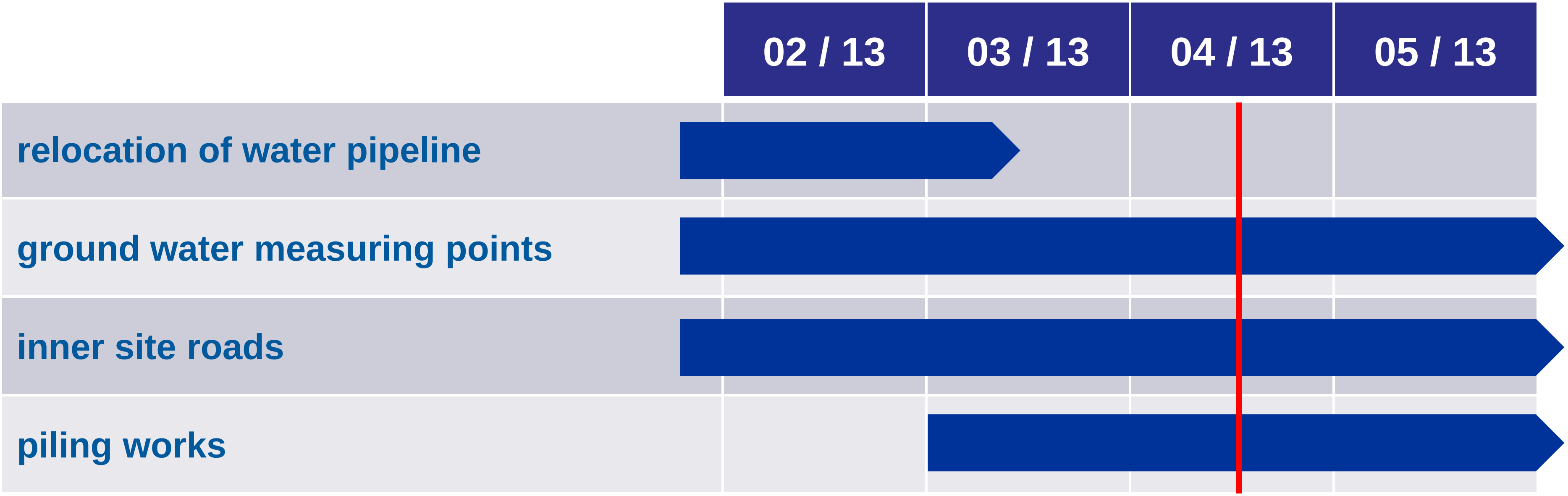
Beamline: $\sum$ 3.2 km
of which:
Synchrotron: 1.1 km

site > 200.000 m^2
Footprint ~ 98‘000 m^2
Floor Space ~ 135‘000 m^2
(Cubature ~ 1‘049‘000 m^3)

FAIR — HELMHOLTZ ASSOCIATION GSI

The FAIR project is moving forward

Status of preliminary works / construction works



Status of piling works

- about 10 holes drilled
  (1.5 m diameter, 60 m deep)
- holes concrete-lined
- testing of core iron systems

http://www.fair-center.eu/construction/webcam.html

- Civil construction is moving forward
- Master schedule of accelerator ready
- Procurement of components for SIS100, HEBT and CR started ~100 M€