The Accelerator Facility of the Facility for Antiproton and Ion Research

P. Spiller on behalf of O. Kester
and FAIR@GSI
IPAC15, 5.5.15

FAIR Construction Side

FAIR Injector Facility
UNILAC, p-Linac and SIS18

Ion sources

CH cavities

p-Linac

SIS-18

UNILAC

SIS18

to SIS100

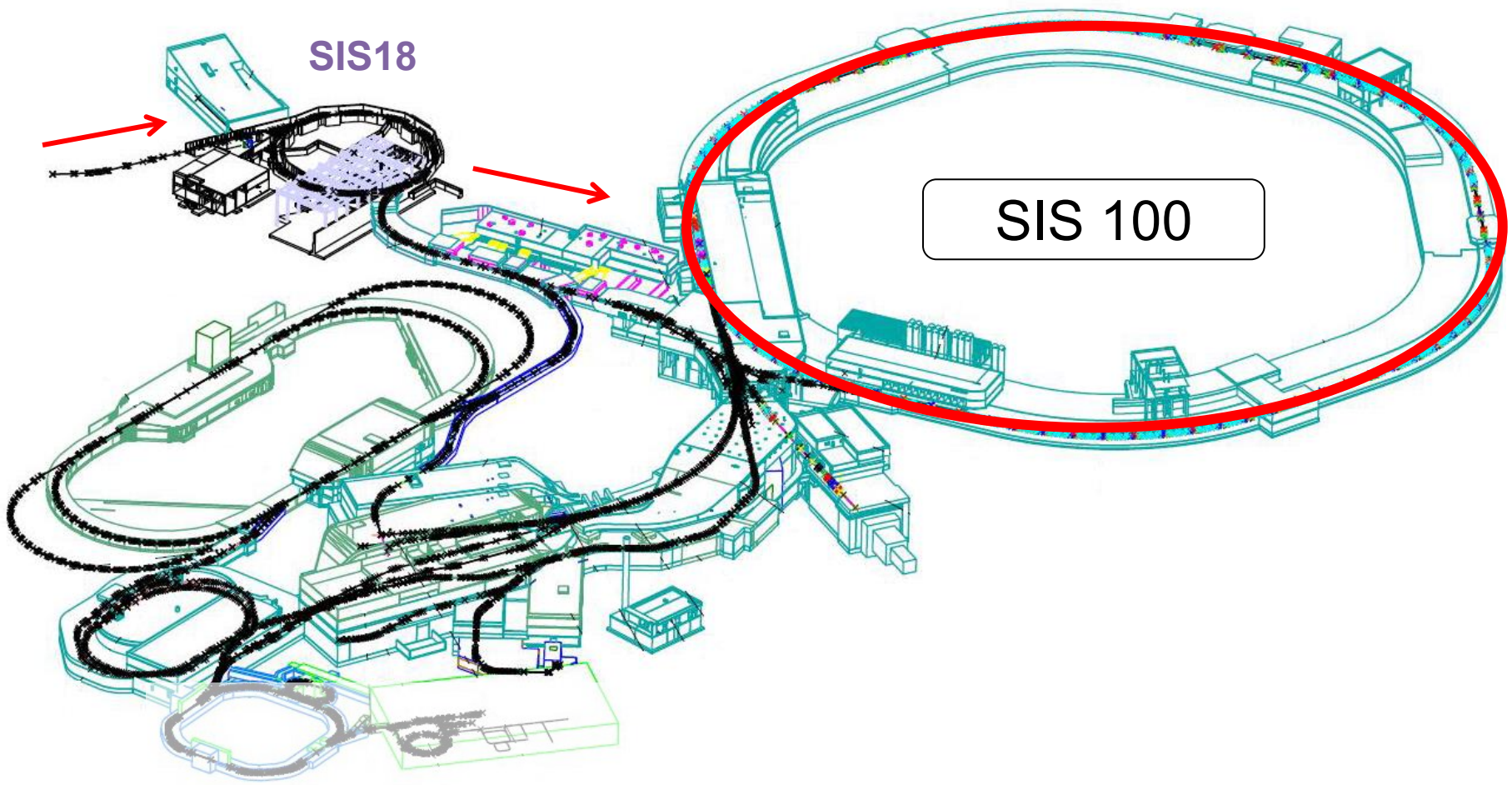
ESR

IH structure

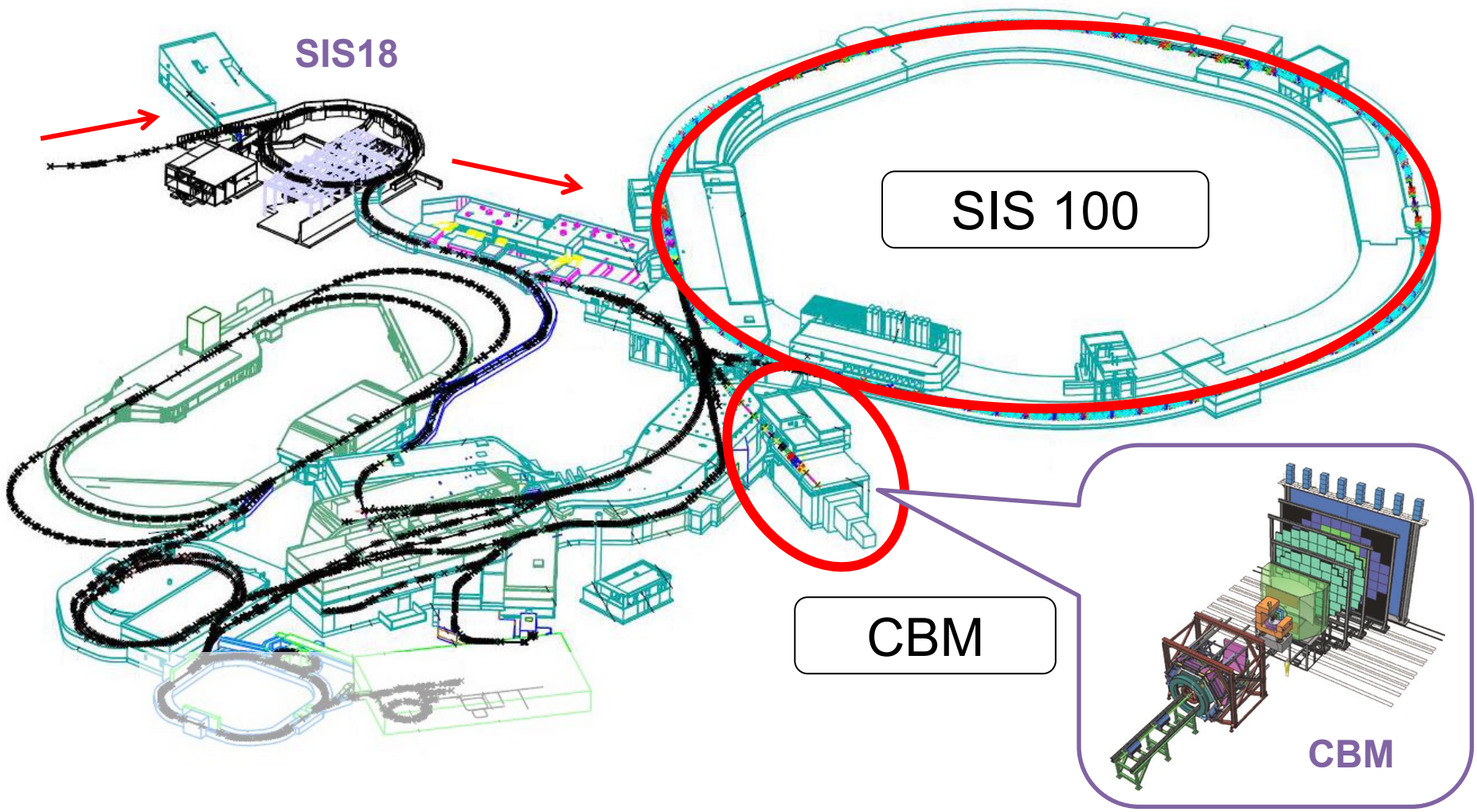
UNILAC world's highest beam power (MW) and beam currents (7 emA) for heavy-ions

SIS18 world's highest number of heavy-ions per cycle (> 10^{10})

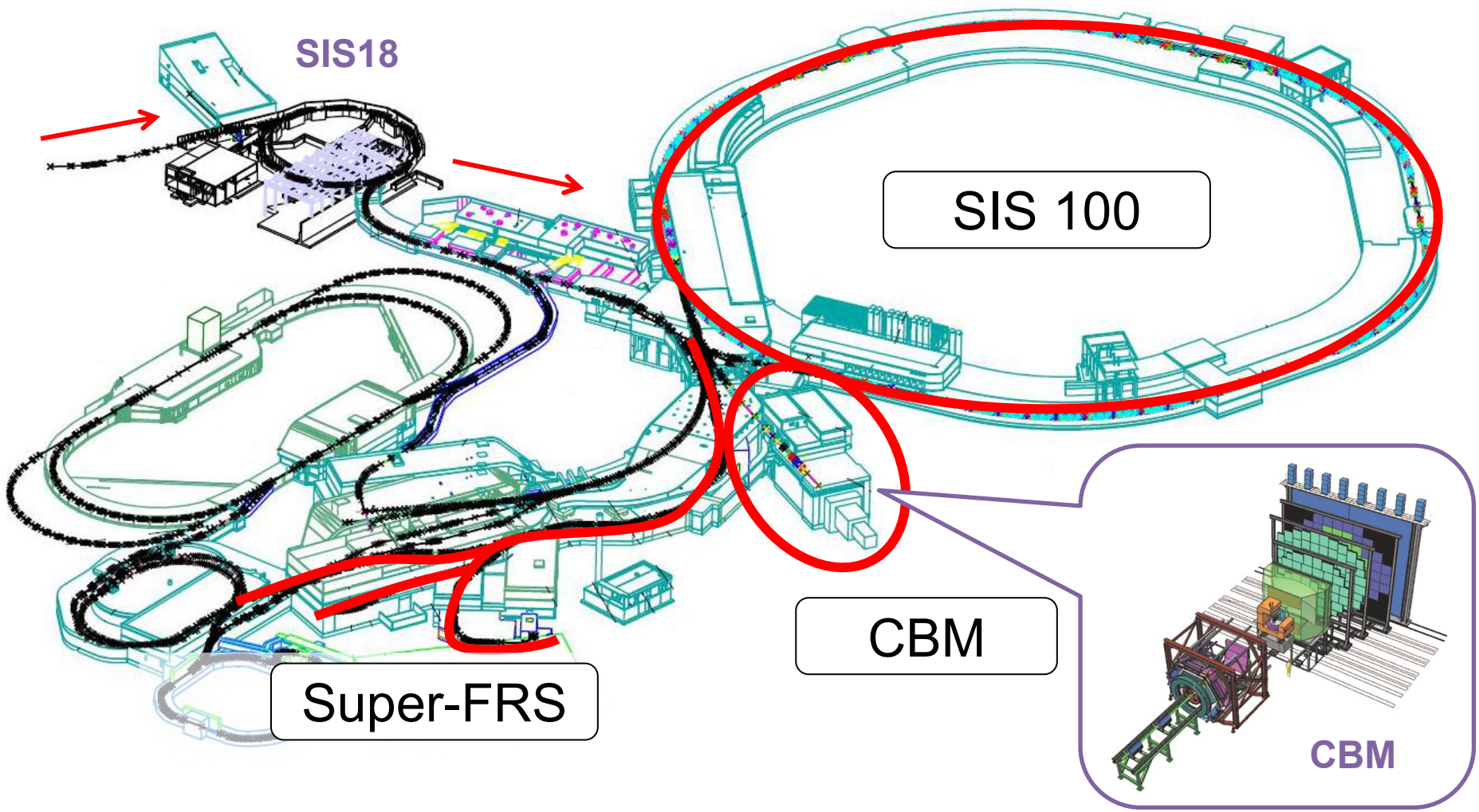
Heavy Ion Accelerator Chain



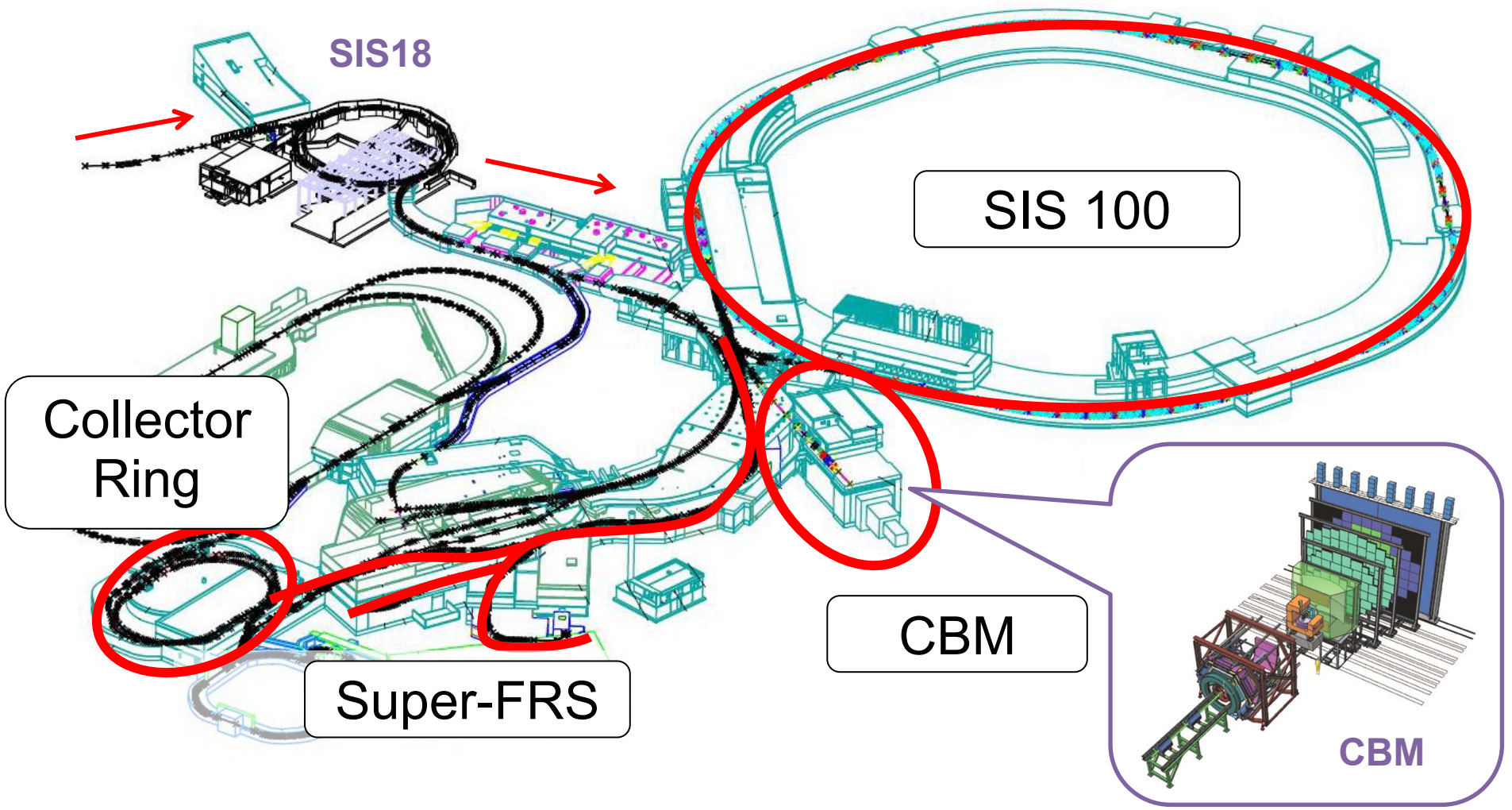
Heavy Ion Accelerator Chain



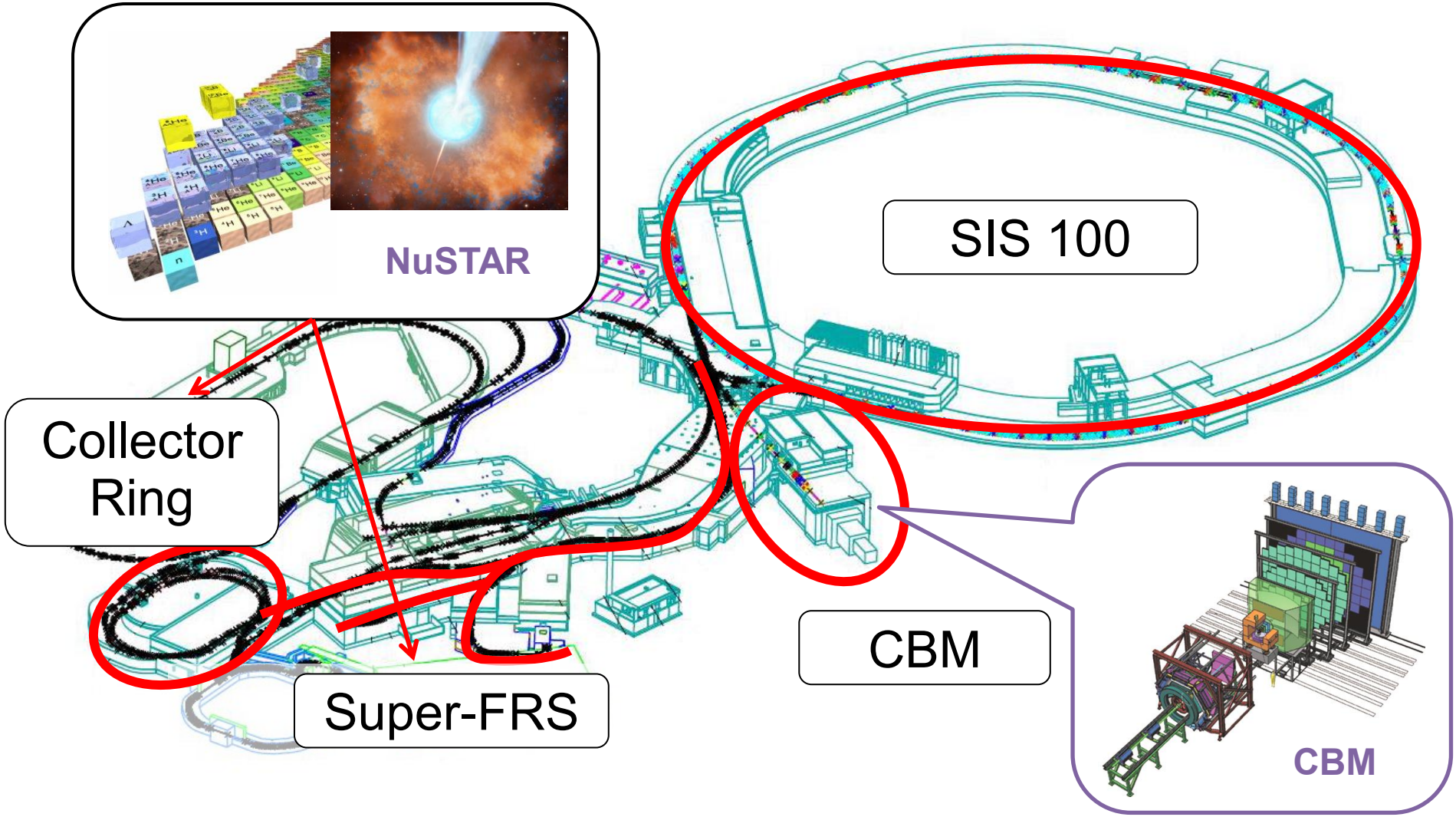
Heavy Ion Accelerator Chain



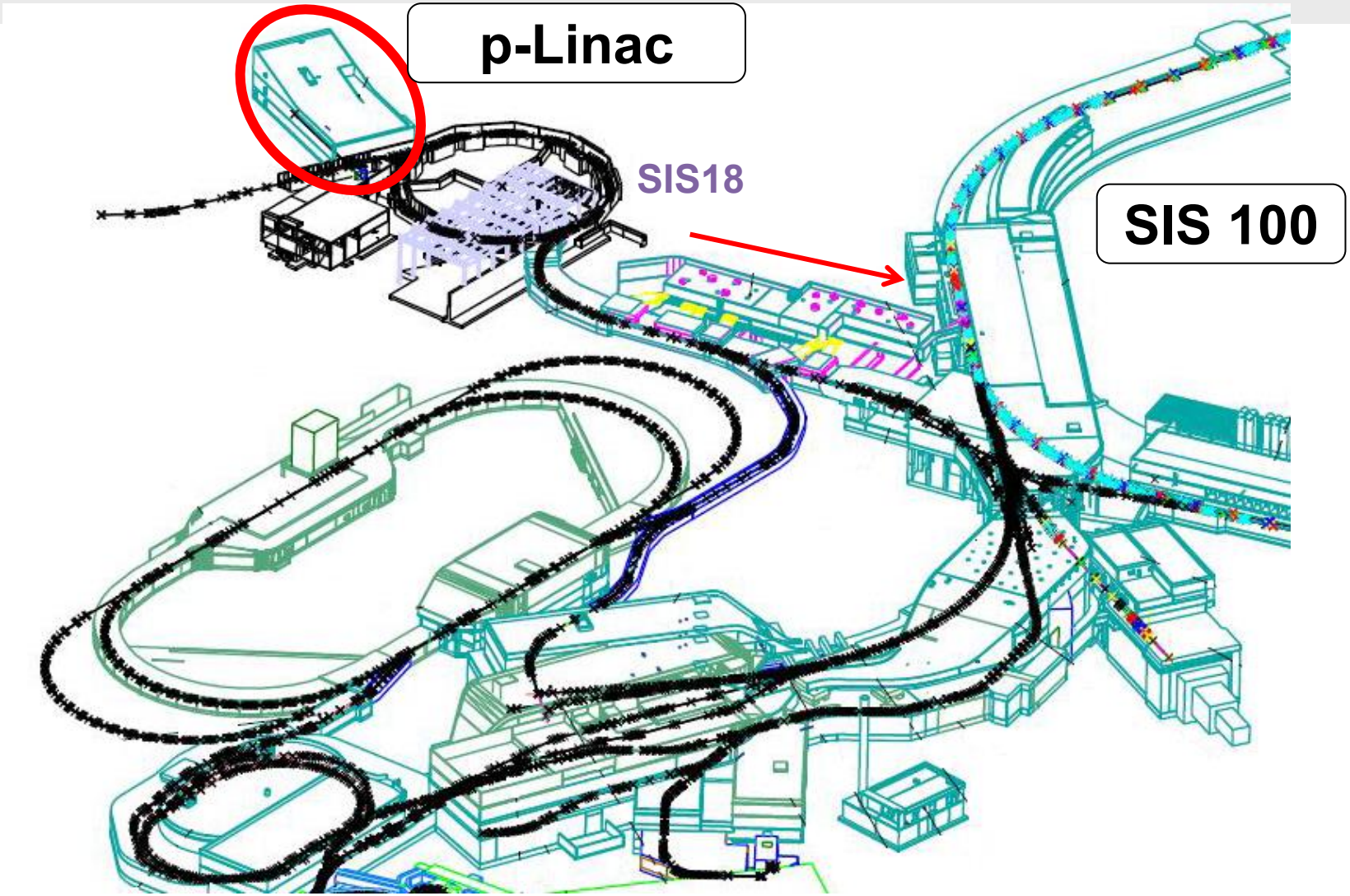
Heavy Ion Accelerator Chain



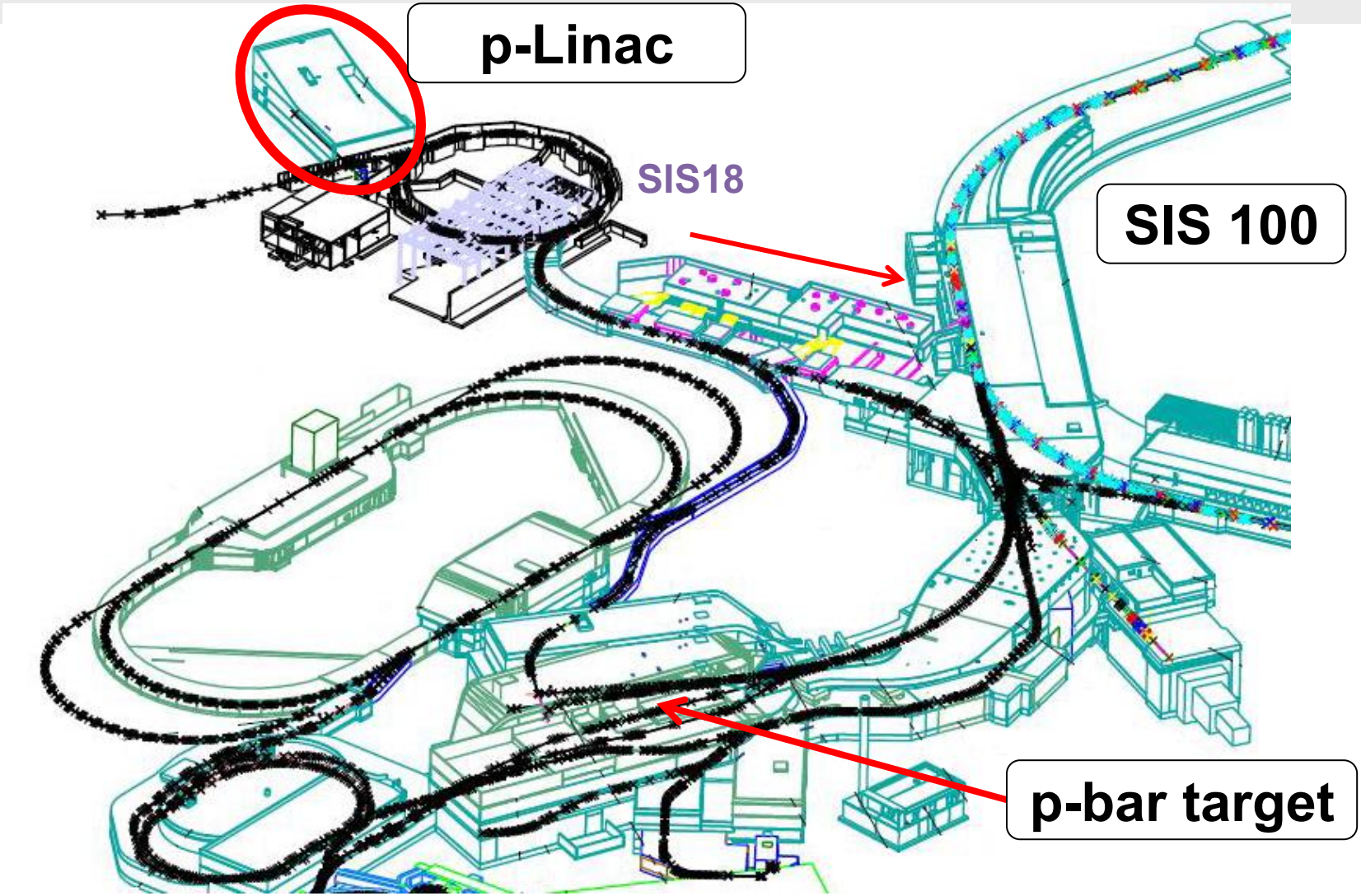
Heavy Ion Accelerator Chain



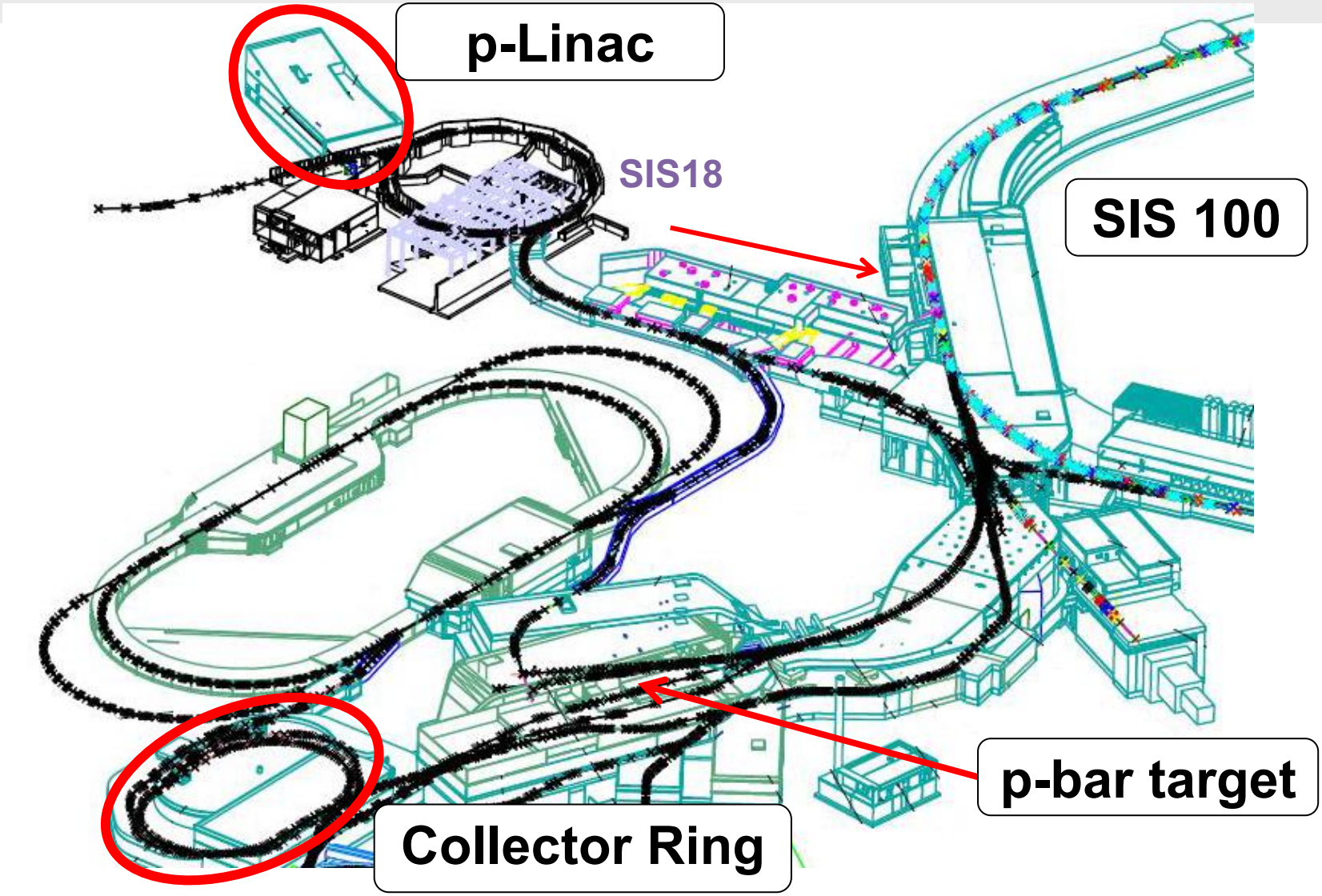
Anti Proton Accelerator Chain



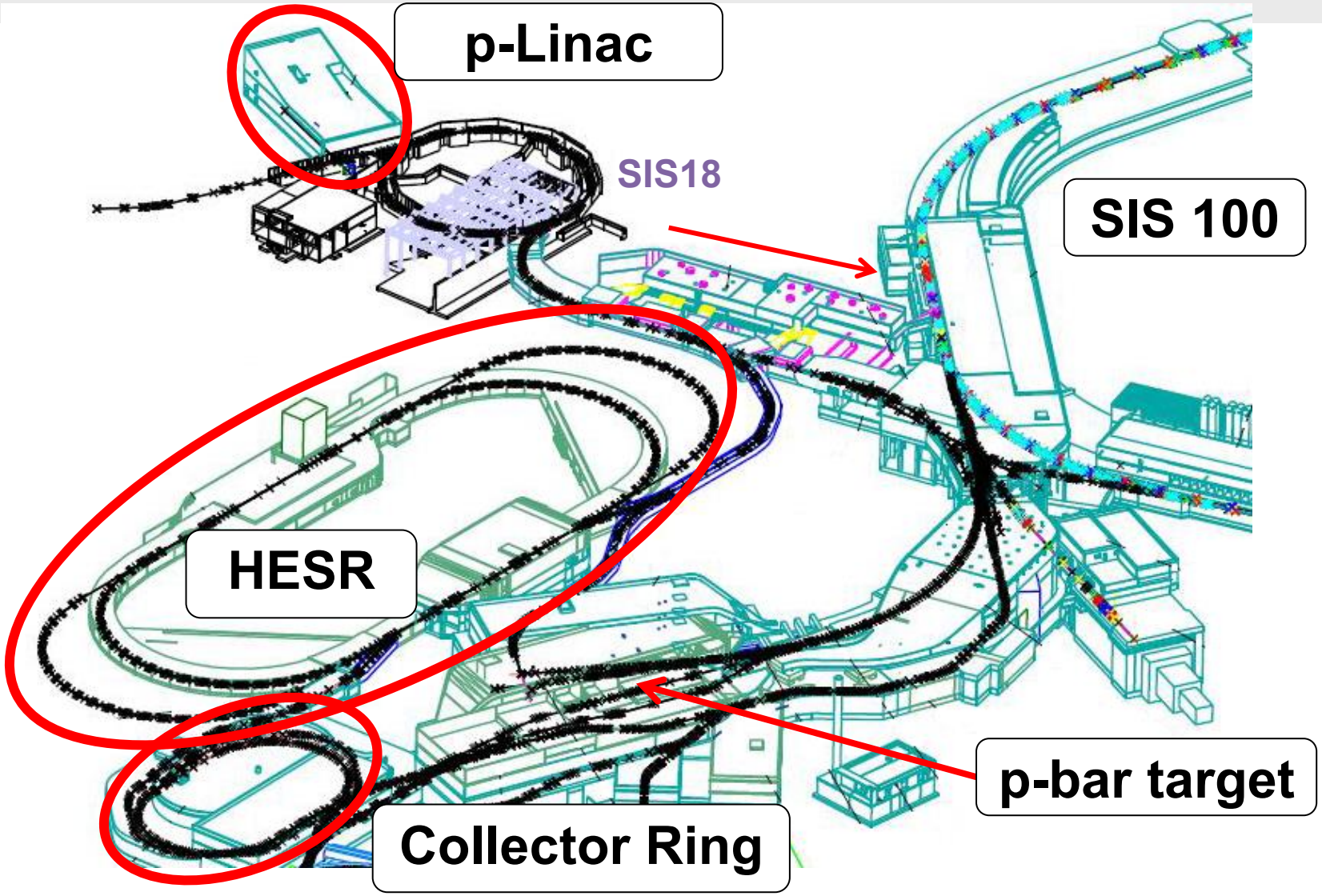
Anti Proton Accelerator Chain



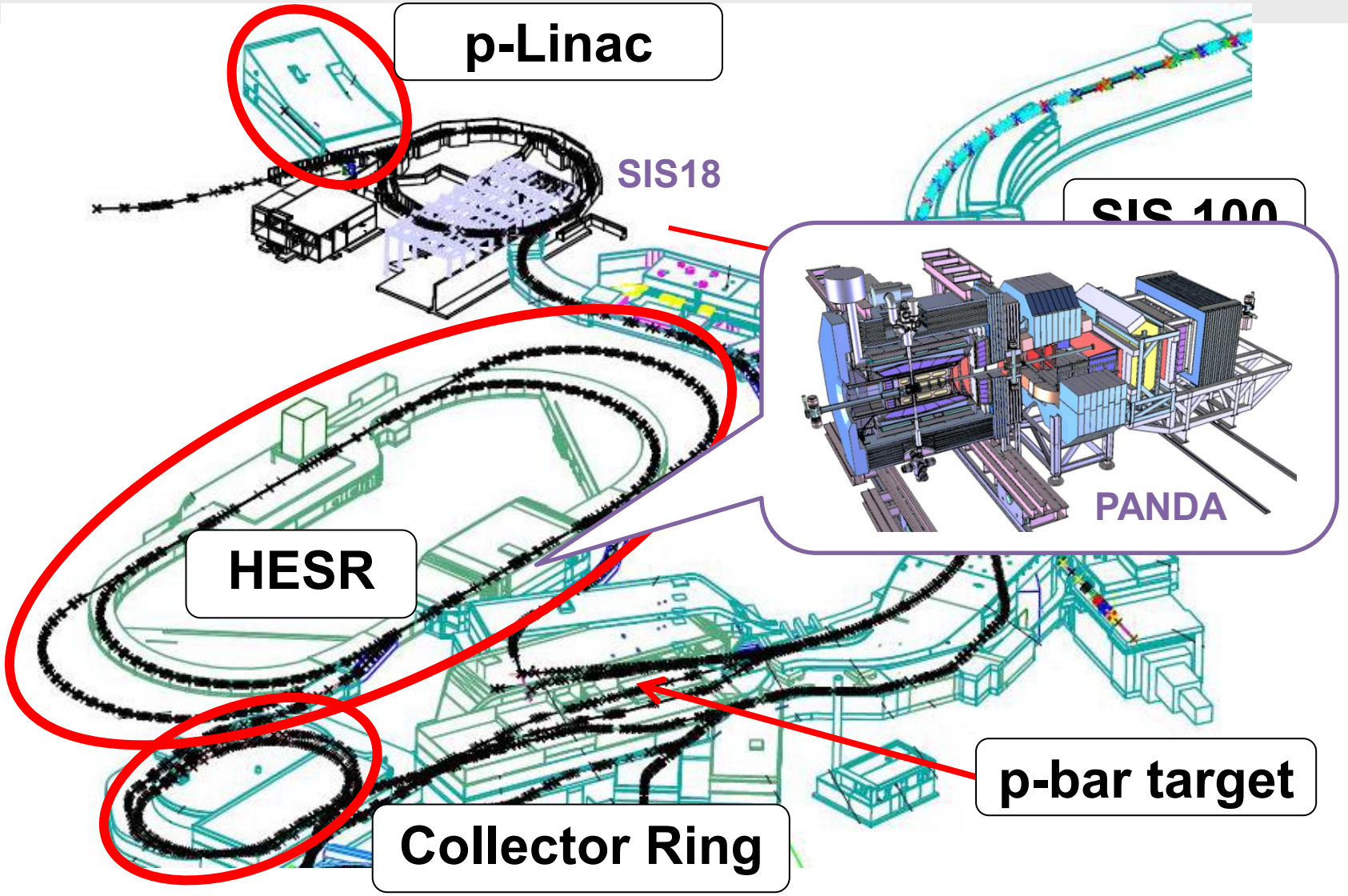
Anti Proton Accelerator Chain



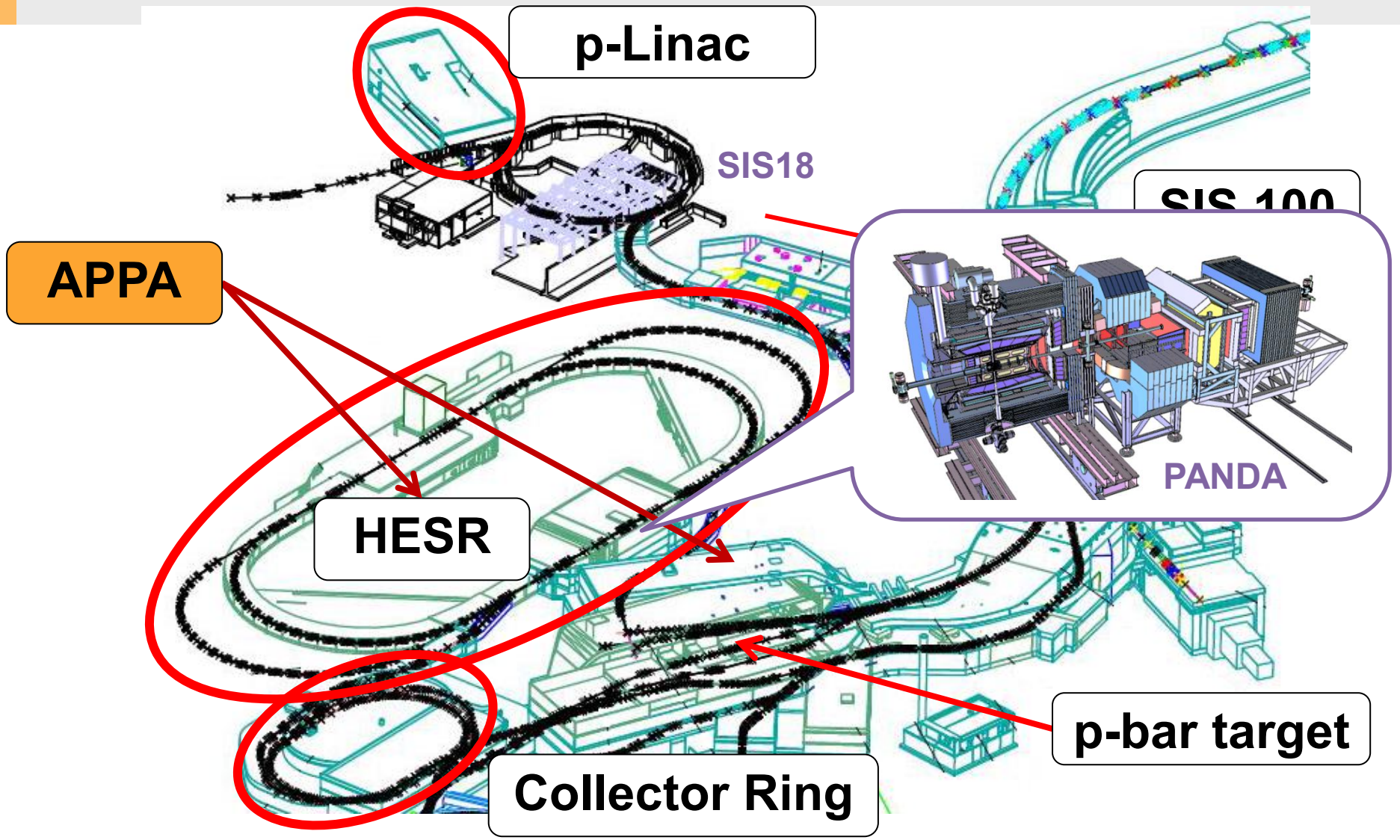
Anti Proton Accelerator Chain



Anti Proton Accelerator Chain



Anti Proton Accelerator Chain

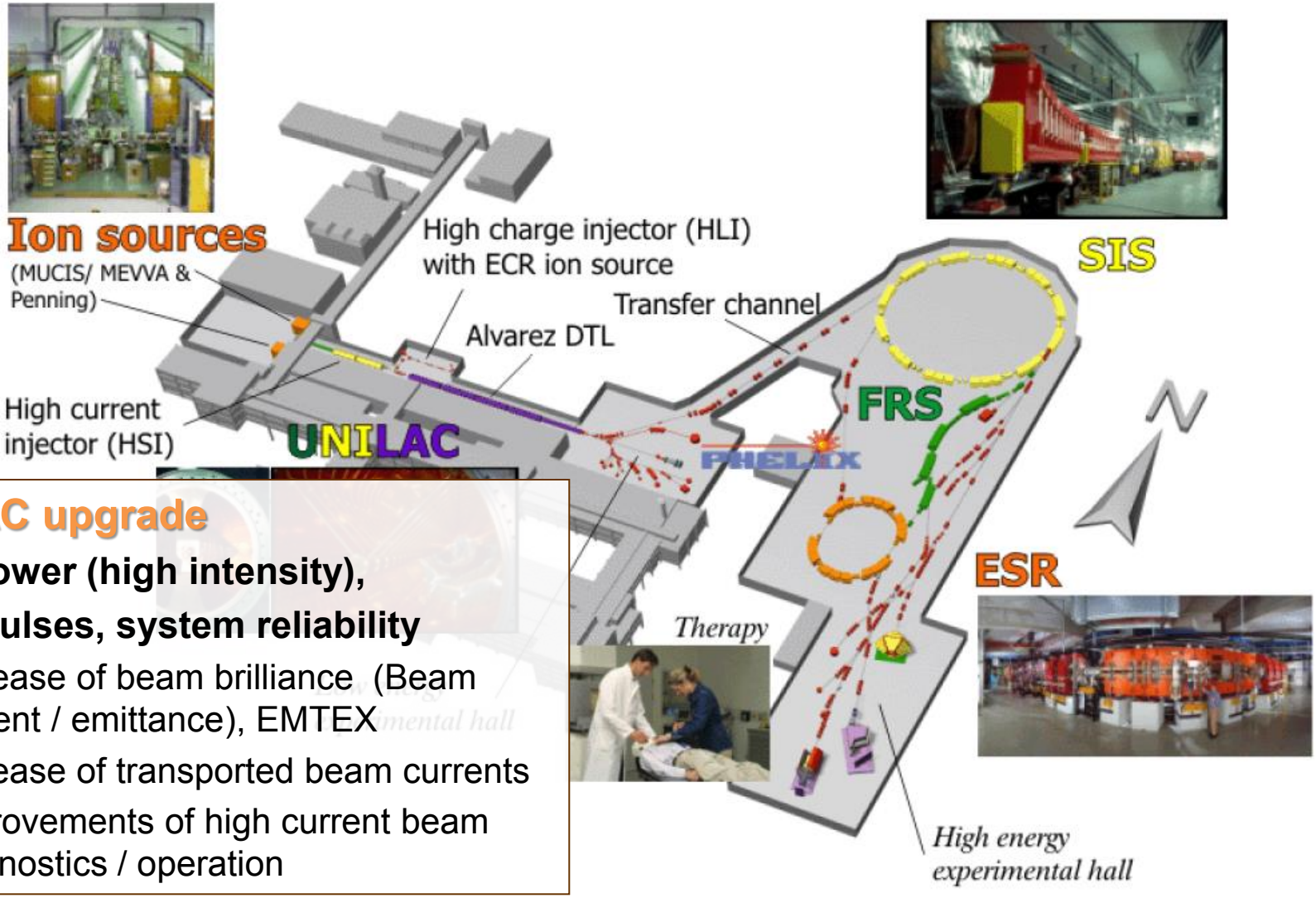


FAIR ACC Beam Performance

System parameter of the FAIR ring accelerators

	SIS18	SIS100	CR	HESR
Circumference [m]	216	1083	215	575
Max. beam magnetic rigidity [Tm]	18	100	13	50
Injection energy of protons or anti protons [GeV]	0.07	4	3	3
Final energy of protons or antiprotons [GeV]	4	29	3	14
Injection energy of heavy ions [GeV/u]	0.0114	0.2	0.74	0.74
Final energy of heavy ions U(28+) [GeV/u]	0.2	2.7		
Final energy of heavy ions U(/73+/92+) [GeV/u]	1	11	0.74 (92+)	0.2-4.9 (92+)
Max. beam intensity for protons or antiprotons /cycle	$5*10^{12}$	$2*10^{13}$	10^{8}	10^{10}
Max. beam intensity of U-ior /cycle	$1.5*10^{11}$	$4.5*10^{11}$	10^{8}	10^{8}
Required static vacuum pressure [mbar]	$< 10^{-11}$	$<5*10^{-12}$	$<10^{-9}$	$<10^{-9}$

GSI Accelerator Upgrade

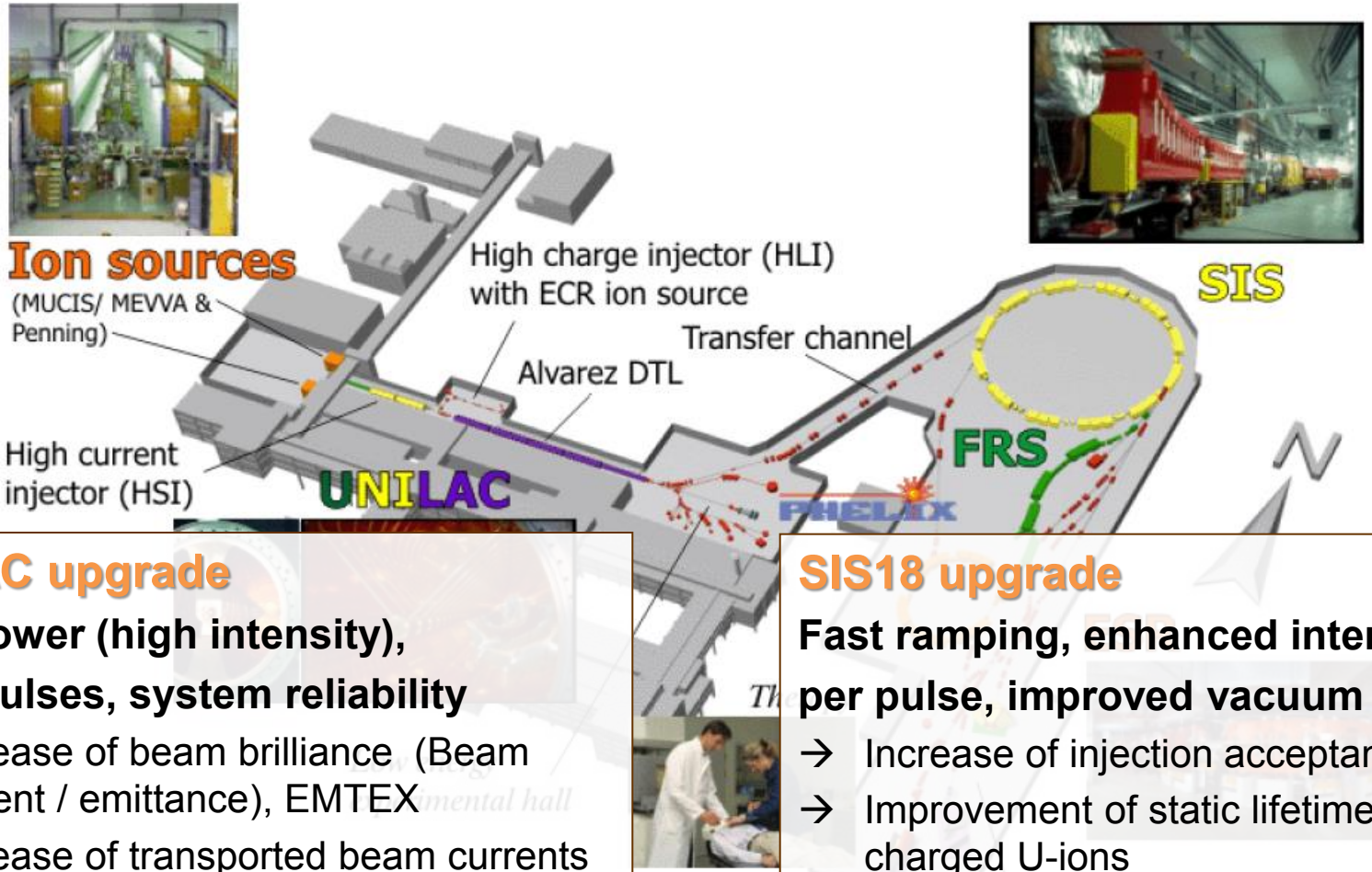


UNILAC upgrade

High power (high intensity), short pulses, system reliability

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

GSI Accelerator Upgrade



UNILAC upgrade

High power (high intensity), short pulses, system reliability

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

SIS18 upgrade

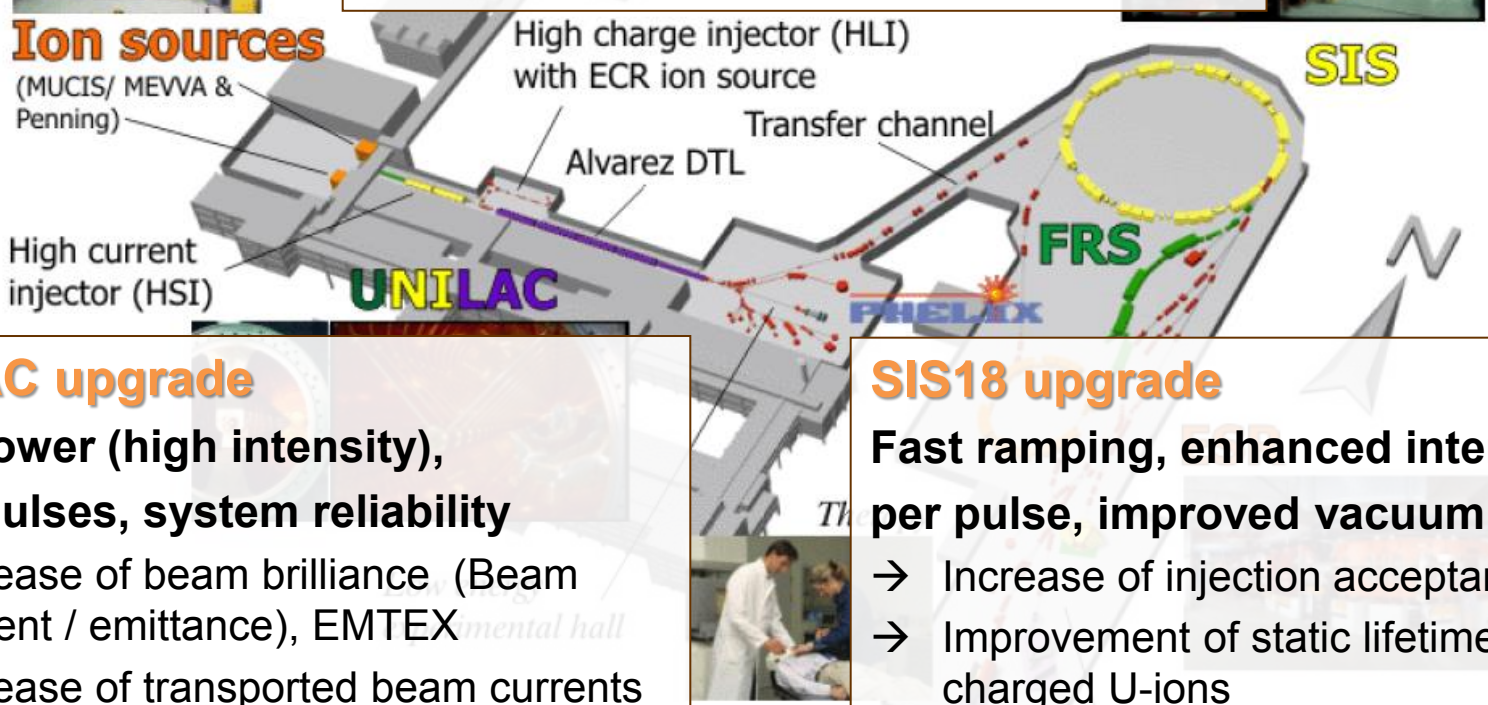
Fast ramping, enhanced intensity per pulse, improved vacuum system

- → Increase of injection acceptance
- → Improvement of static lifetime for low-charged U-ions
- → Suppression of dynamic vacuum and ionization beam loss

GSI Accelerator Upgrade

Exchange of the 40 years old Alvarez accelerator with modern Rf- structures

Higher intensities (medium mass range)
→ 28 GHz ECRIS



UNILAC upgrade

High power (high intensity), short pulses, system reliability

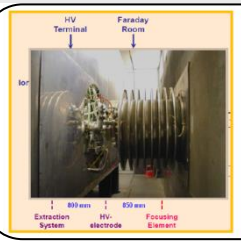
- → Increase of beam brilliance (Beam current / emittance), EMTEX
- → Increase of transported beam currents
- → Improvements of high current beam diagnostics / operation

SIS18 upgrade

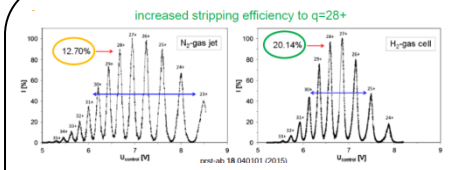
Fast ramping, enhanced intensity per pulse, improved vacuum system

- → Increase of injection acceptance
- → Improvement of static lifetime for low-charged U-ions
- → Suppression of dynamic vacuum and ionization beam loss

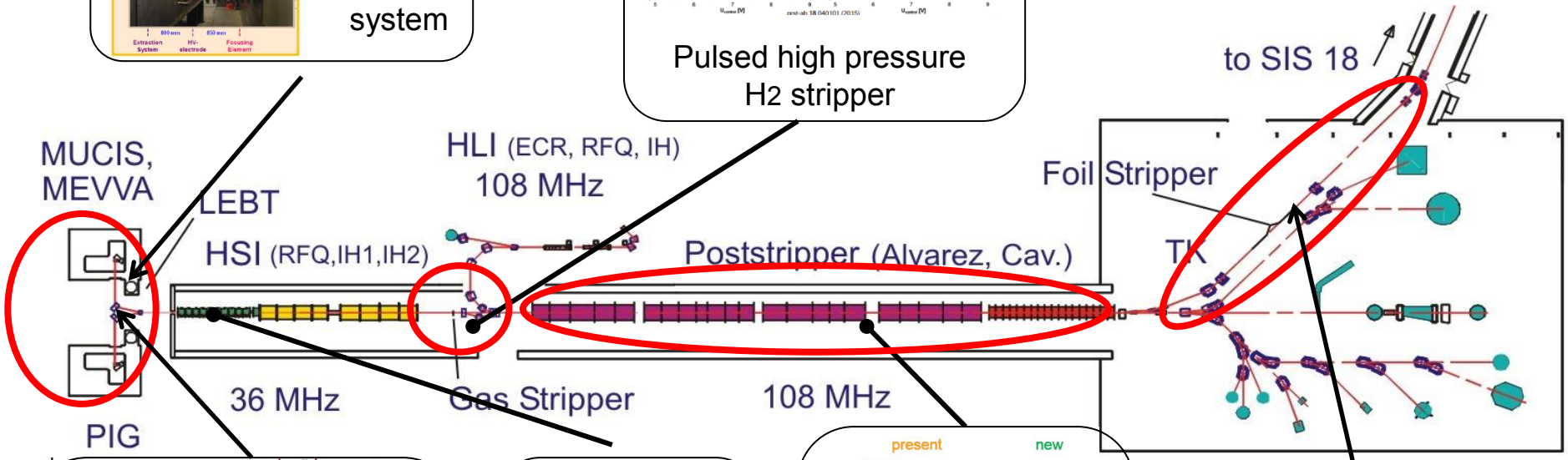
The UNILAC upgrade

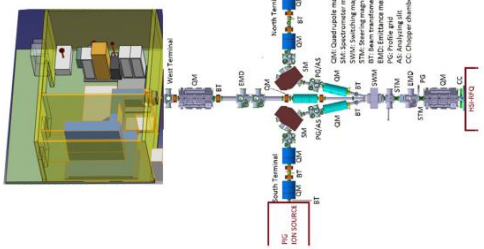


New source extraction system

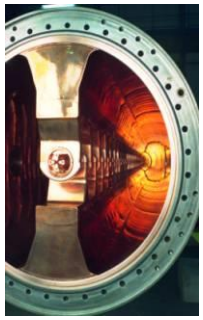


Pulsed high pressure H2 stripper

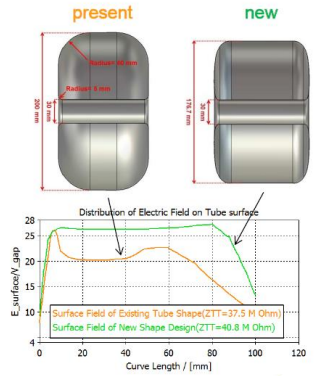




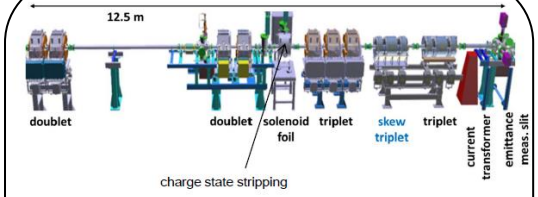
New terminal with compact LEBT under preparation



RFQ re-design

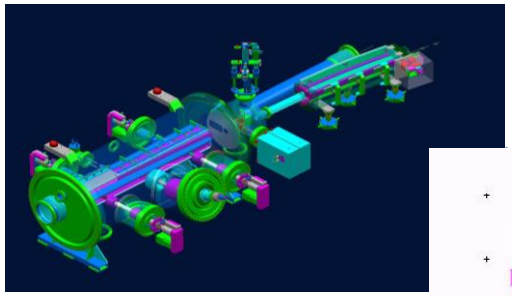


New Alvarez DTL



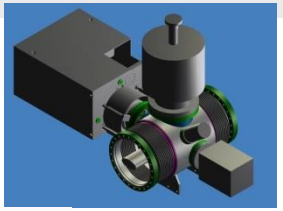
EMTEX: Emittance matching to SIS

SIS18 Upgrade Program

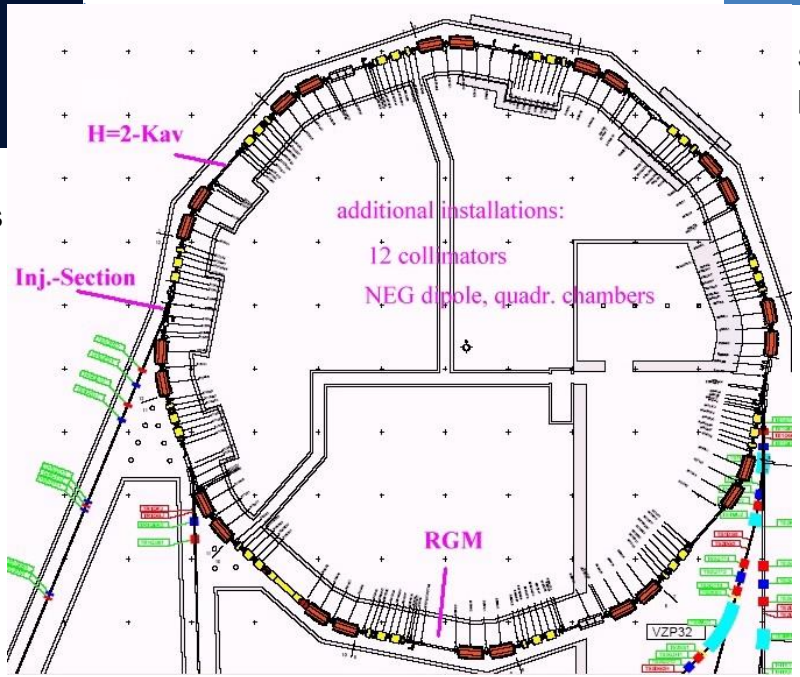


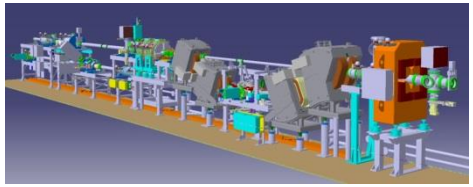
Injection system for low charged state heavy ions

Stabilization of dynamic vaccuum and minimization of ionization beam loss



Scrapers and NEG coating for pressure stabilization





Charge separator for higher intensity and high quality beams

Power grid connection

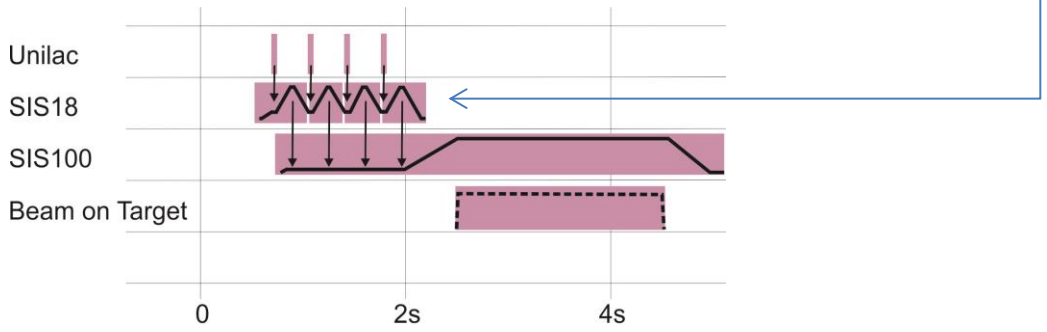
h=2 acceleration cavities for faster ramping

The SIS18 upgrade program: Booster operation with low charge state heavy ions

SIS18 Intensity Requirements for FAIR (SIS100 Booster)

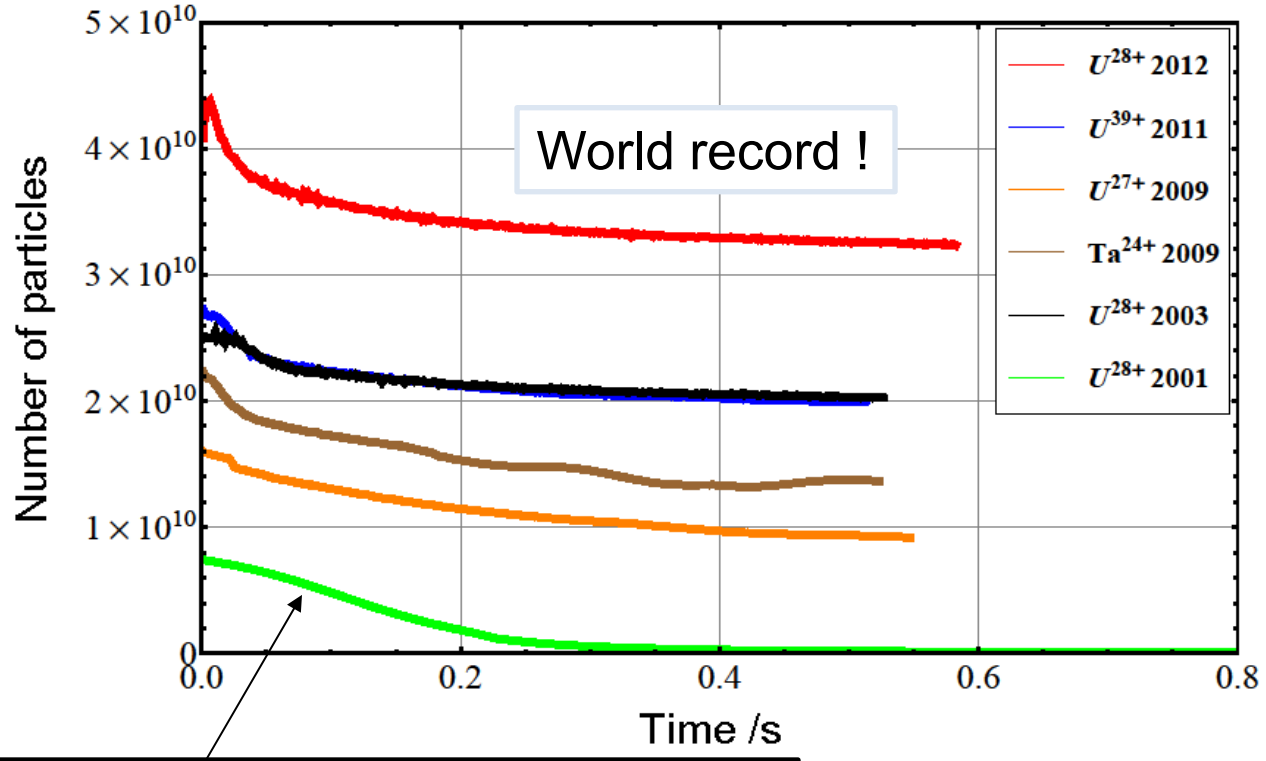
FAIR module (green paper)	Today	Module 0+1 (SIS100 + CBM, APPA)	Module 2 (Super-FRS, RIBs for NUSTAR)	Module 3 (pbar, CR, HESR, PANDA)
Reference ion	U^{73+}	U^{73+}	U^{28+}	U^{28+}
Maximum energy	1 GeV/u	1 GeV/u	0.2 GeV/u	0.2 GeV/u
Max. intensity / cycle	$4x10^{9}$	$2x10^{10}$	$1.25x10^{11}$ (*)	$1.25x10^{11}$
Repetition rate	0.3 – 1 Hz	1 Hz	1 Hz	2.7 – 4 Hz

(*) leads to $5x10^{11}$ at SIS100 injection



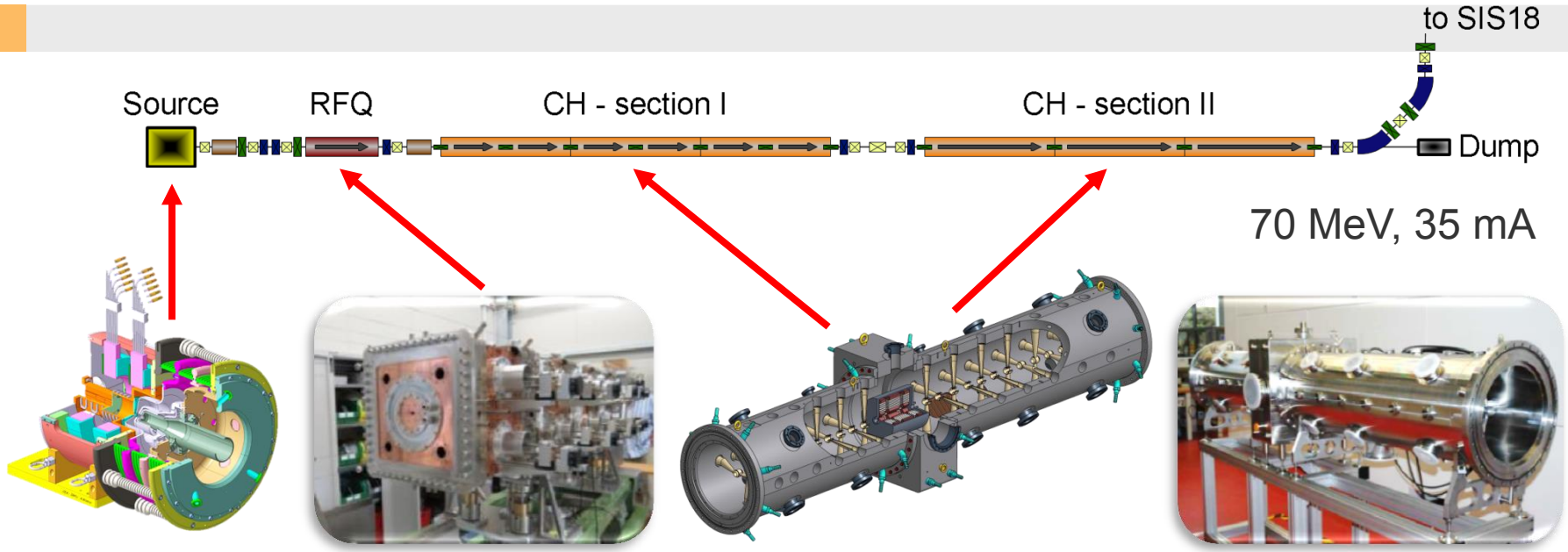
SIS18 Beam Intensity Progress

World record intensity per cycle for low charge state heavy ions has been achieved in SIS18.



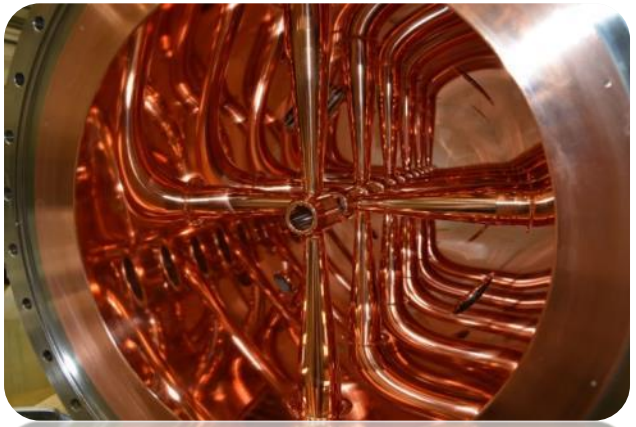
2001 FAIR conceptual design report (FAIR proposal)

The Proton-LINAC

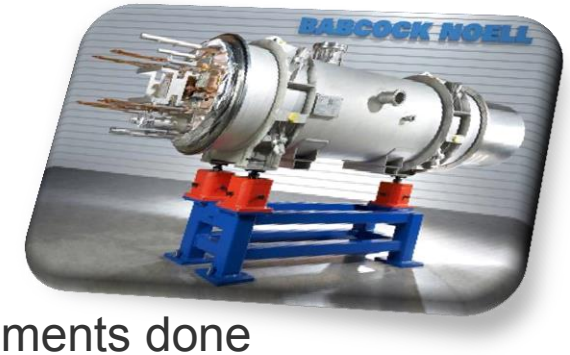


H+: 70 mA at 70 MeV

- Status:
  - Ion source and LEBT ready in Summer 2015
  - First prototype cross bar (CH) cavity ready for power tests
- Critical items:
  - RFQ Design and procurement
  - CH cavities procurement & production follow-up
  - Design of the 325 MHz Modulators



Synchrotron SIS100

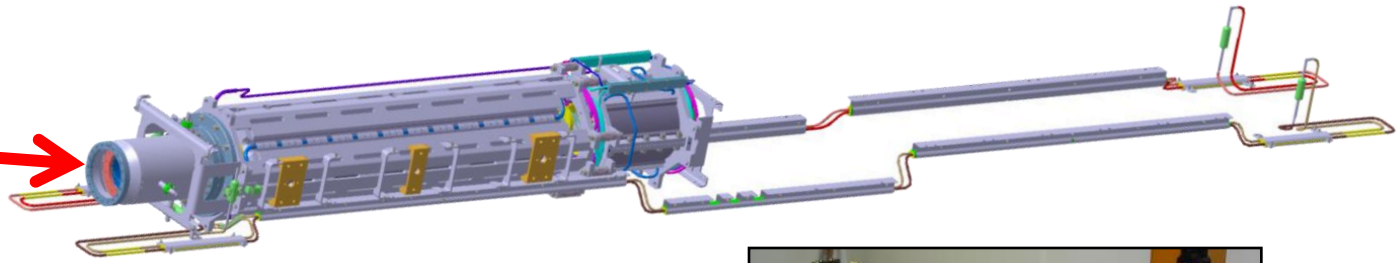


- Status:
  - 50% of the SIS100 budget bound in contracts
    all major components ordered
    system engineering of SC-magnets nearly completed
  - Accurate mechanical (µm) and magnetic field measurements done
    → production of First of Series (FoS) Dipole was not according to the specs
    → New production for the yoke is on the way
  - All major RF-systems are ordered (bunch compressor, ferrite cavities)

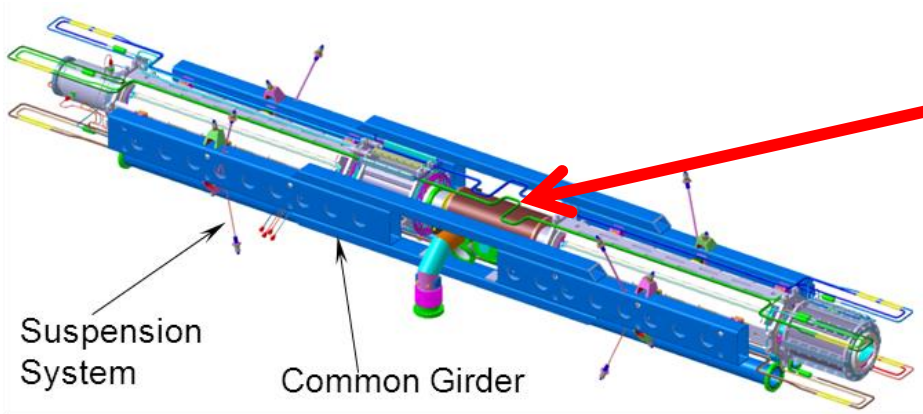
- Critical items:
  - Quadrupole units for the SIS100 Quadrupole Doublet modules production and testing in Dubna until Q1/2020
    → integration into modules tendered by GSI
    → Cold test of modules

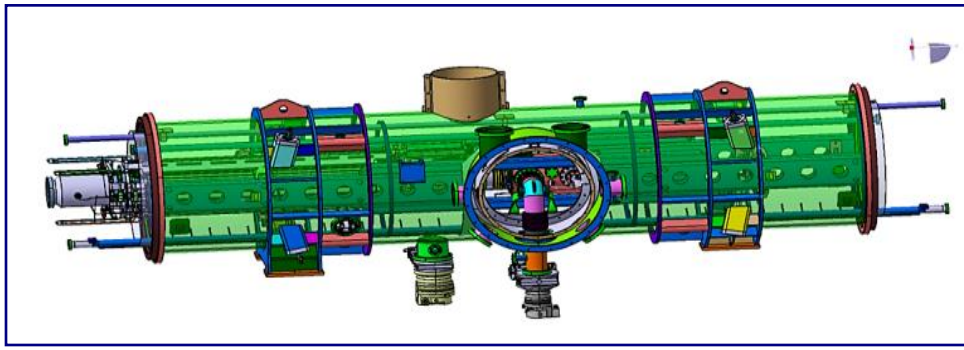
S.C. Quadrupole Modules

Quadrupole units comprise quadrupoles, sextupoles, steerer and BPMs



Arc modules contain cryo-catcher





Quadrupole units installed on a common girder

Inkind- and R&D contracts signed with JINR

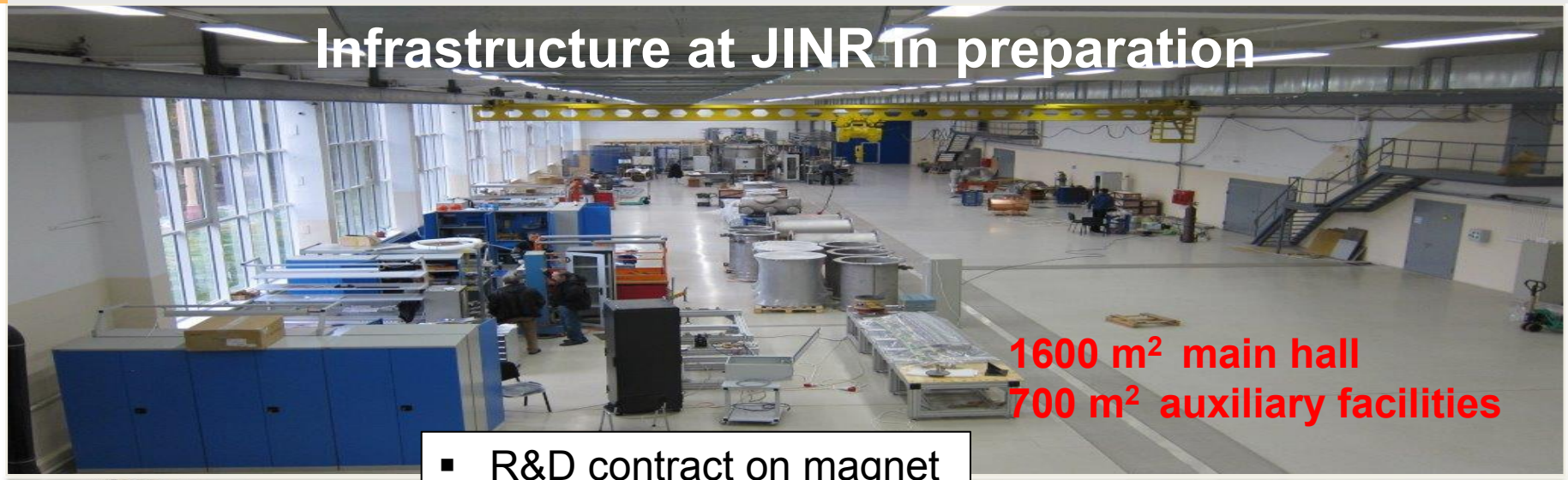
Series Dipole Test Facility at GSI

- Civil construction including media supply is ready
- Cryo components are installed
- STF ready for testing in spring 2015
- SAT ongoing: Cold Box and distribution system cold. LHe buffer is filled.

1.5 kW@4 K cold box

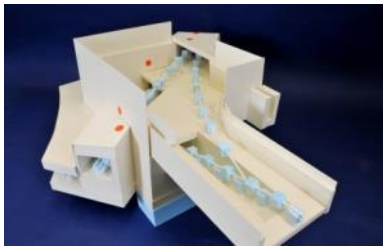
450 kW compressor

SIS100 Quadrupole Testing at JINR



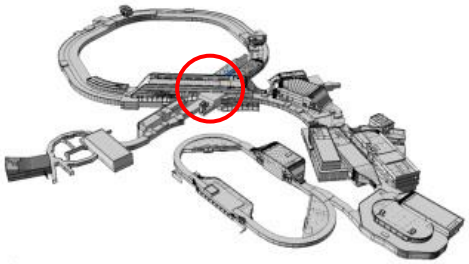
- R&D contract on magnet test facility signed.

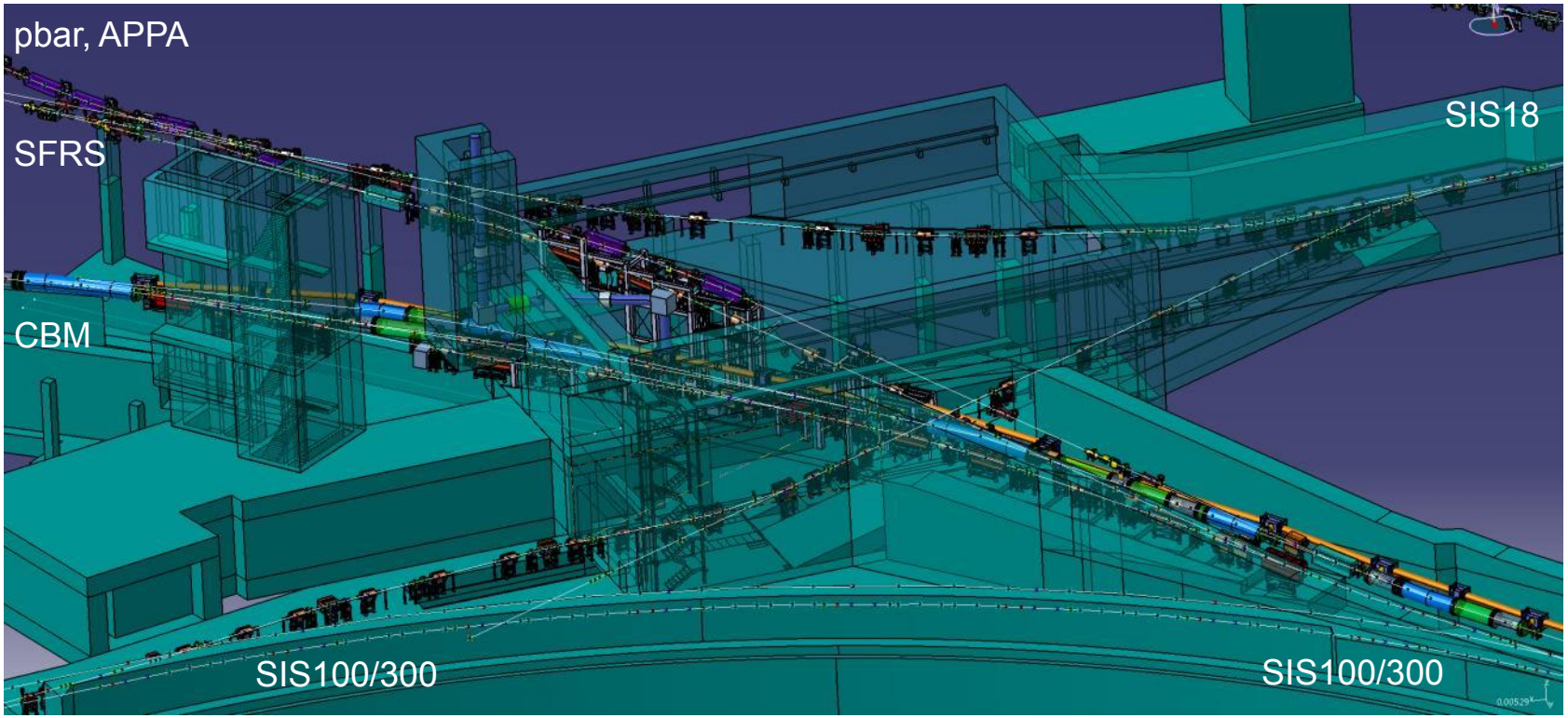
System Design HEBT



Central Transfer Building H0705A

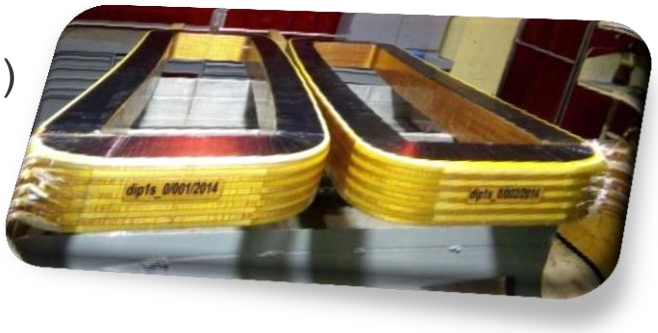
- branching and crossing point for 8 beam lines (full version)
- several beam lines inclined
- components of many other beam lines are transported through this building

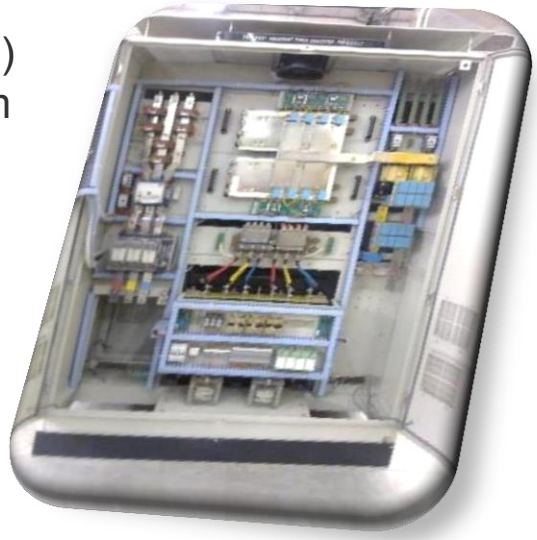




High Energy Beam Transport - HEBT

- Status:
  - Three batches → Batch 1: EFREMOV Institute (magnets) and Budker Institute (vacuum chambers)
    Batch 1 – production of first pre-series dipole magnet running (coil produced, laminations punched), will be finished in May 2015
  - Batch 2 specifications released, Batch 3 specifications available shortly, contract negotiations
  - First In-kind contract with India (Bose Institute, producer ECIL) for quadrupole power converter (78 pieces) of 18/13 Tm beam lines signed
  - Contract of Slovenian in-kind (HEBT Beam Instrumentation – DAQ, pneumatic drives and controls) signed
  - Provider of 65 diagnostics vacuum chambers is currently selected by Bose Institut (India)





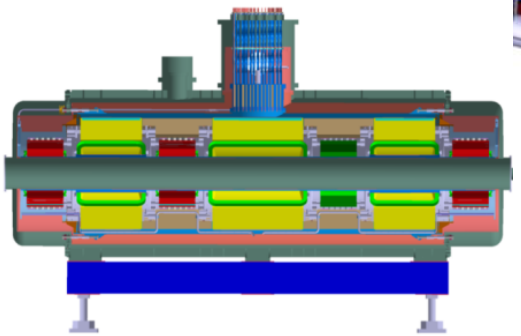
- Critical items:
  - Magnet production and vacuum chamber (magnets and diagnostics)
  - QA of production in India

Super-Fragment Separator

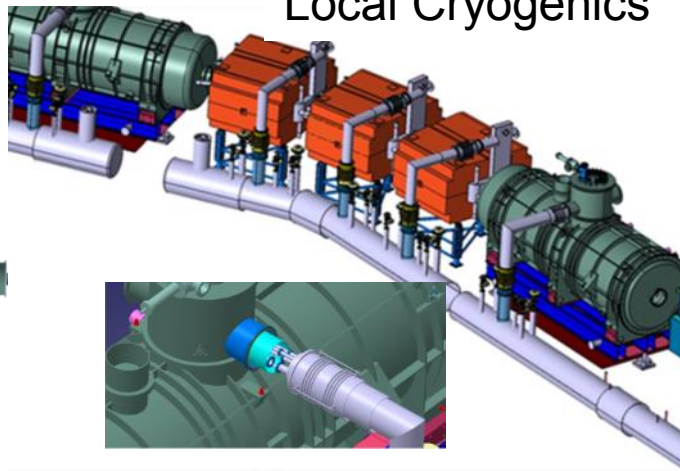
Remote Handling

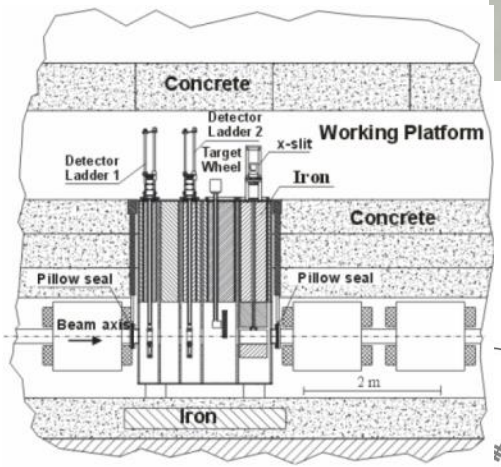
Target

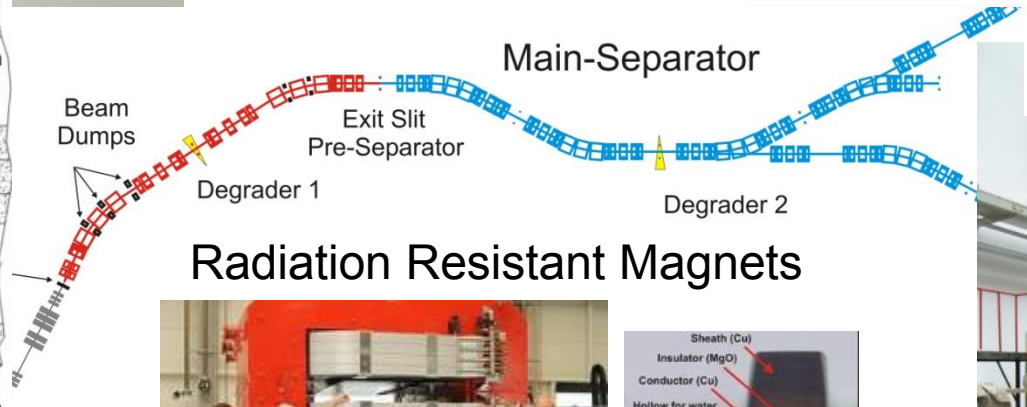
SC Multiplets



Local Cryogenics

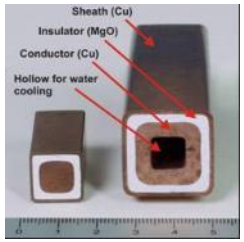






Driver Accelerator

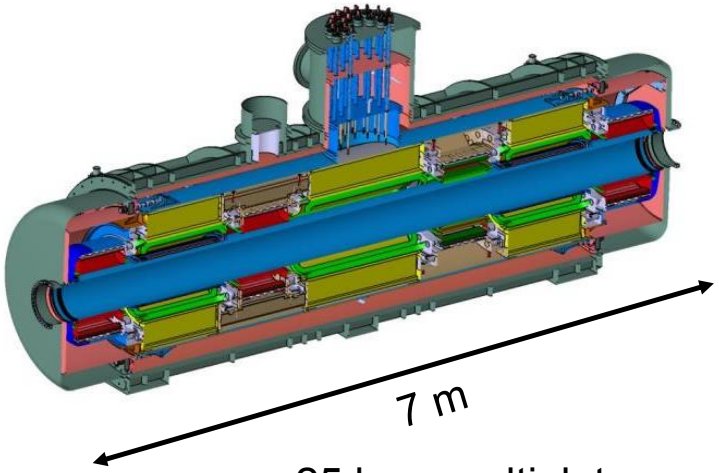
Radiation Resistant Magnets



SC Dipoles

Super-Fragment Separator

- Status:
  - Multiplets → negotiation with companies
    Order in Q1/2015
  - Target chamber & plug inserts
    German in-kind in collab. with KVI-CART
  - Target wheel & plug inserts
    → German in-kind in collaboration with KVI-CART

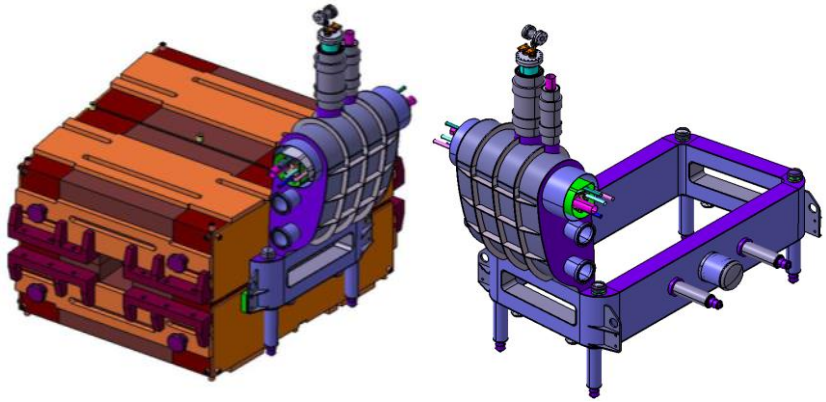


25 long multiplets
8 short multiplets

- Critical items:

  Dipole magnet design and procurement.
  → Collaboration agreement with CEA/Saclay on detailed design & Technical follow-up

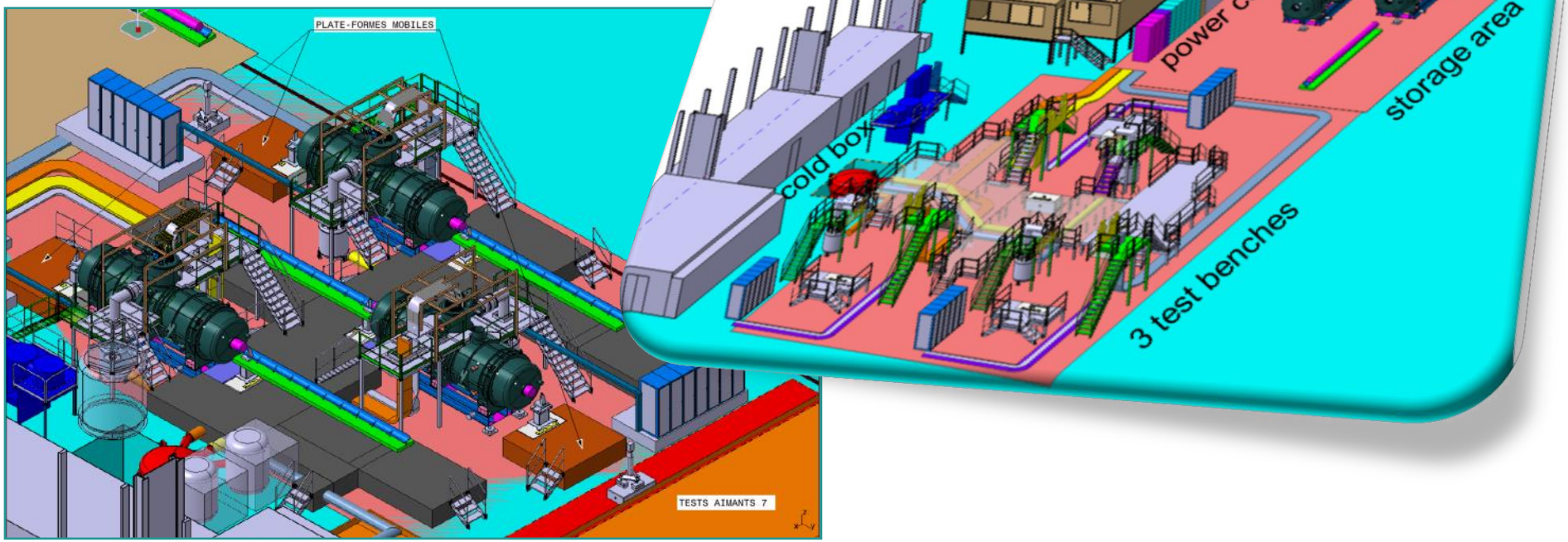
  Tender by FAIR starting Q2/2015
  First of Series ready for testing: Q4/2016
  Series production & testing:
  Q1/2017 – Q4/2019



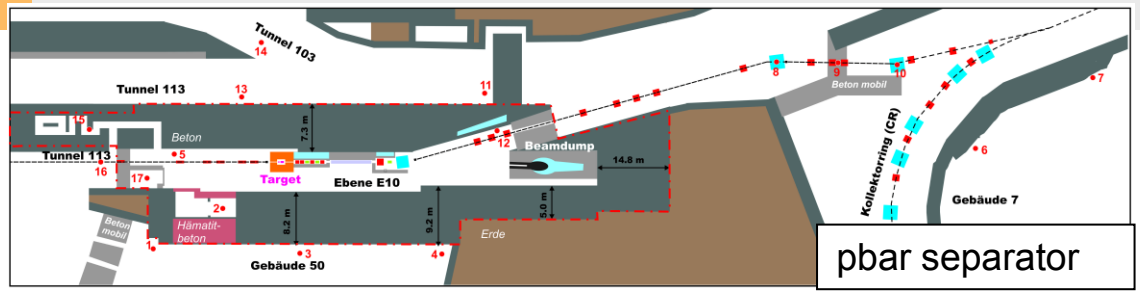
CEA revised SC dipole design

Magnet Testing Super-FRS at CERN

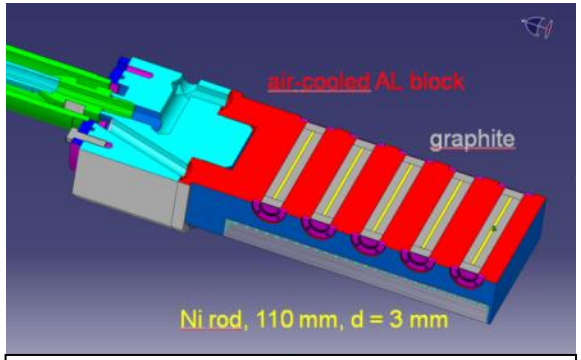
- Layout of planned test facility at CERN (building 180) ready
- Cryogenic-infrastructure with 2 pre-cooler
- CERN Controls and data acquisition
- 3 test benches in Q3/2016
  cooling and test time ~45 days/unit



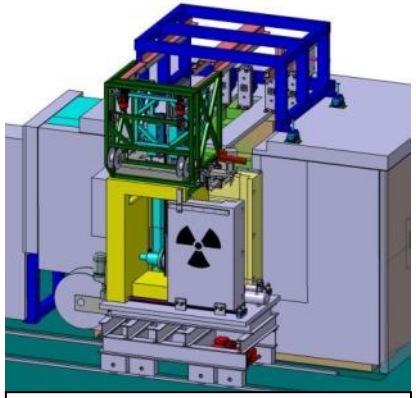
The pbar Target and Separator



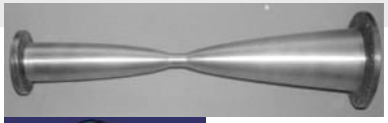
pbar separator

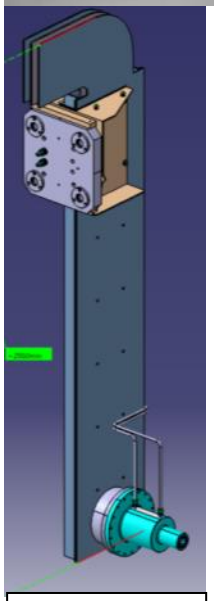


target

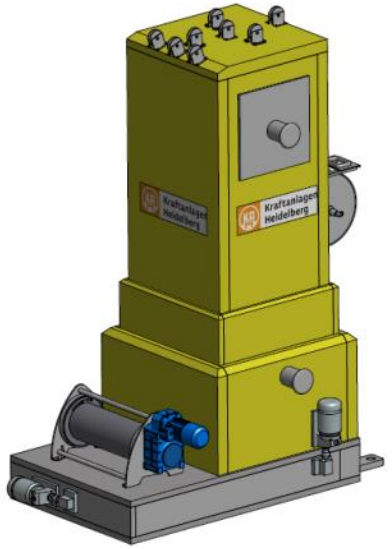


target station (250t) with remote handling





magnetic horn

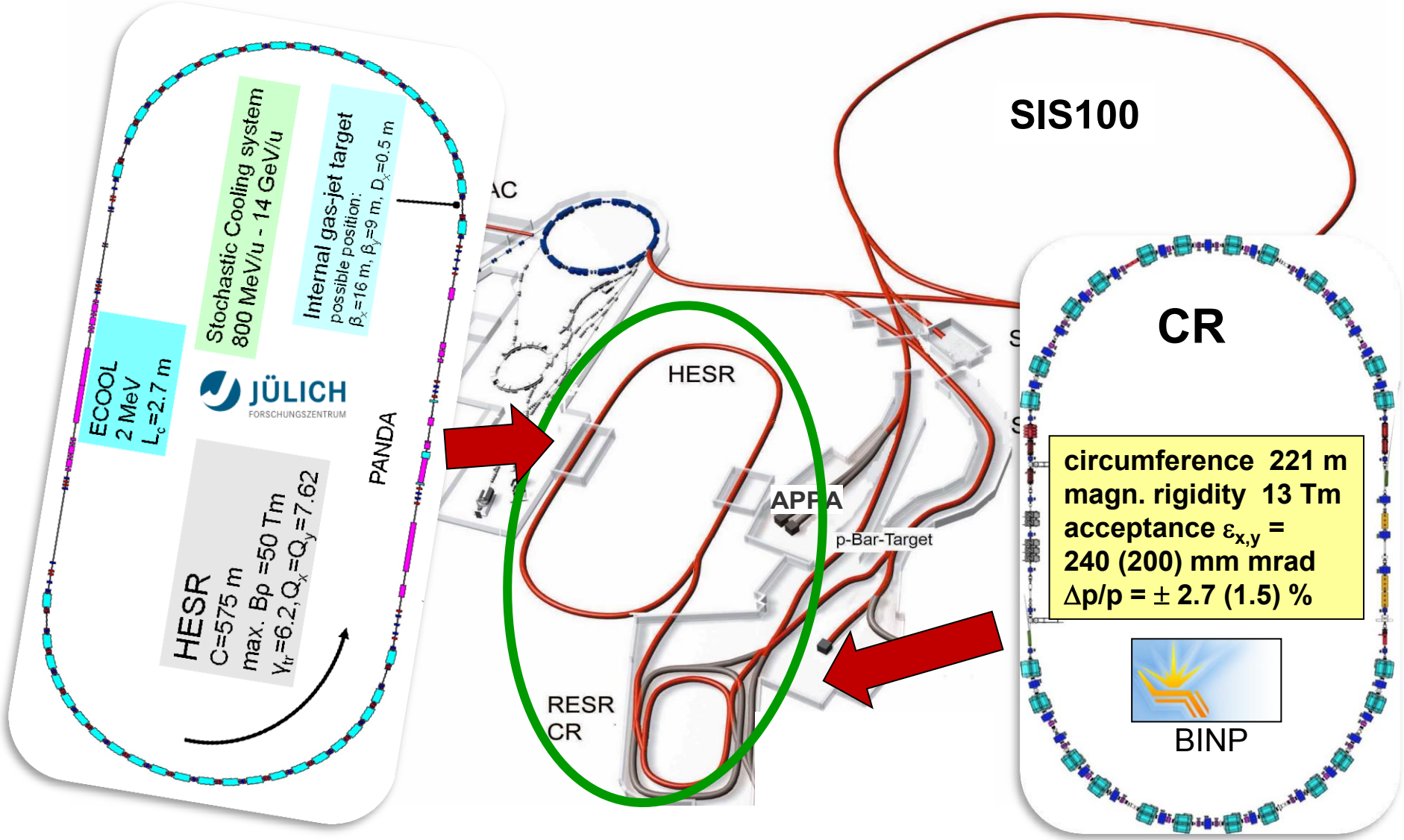


shielding flask (25 t)

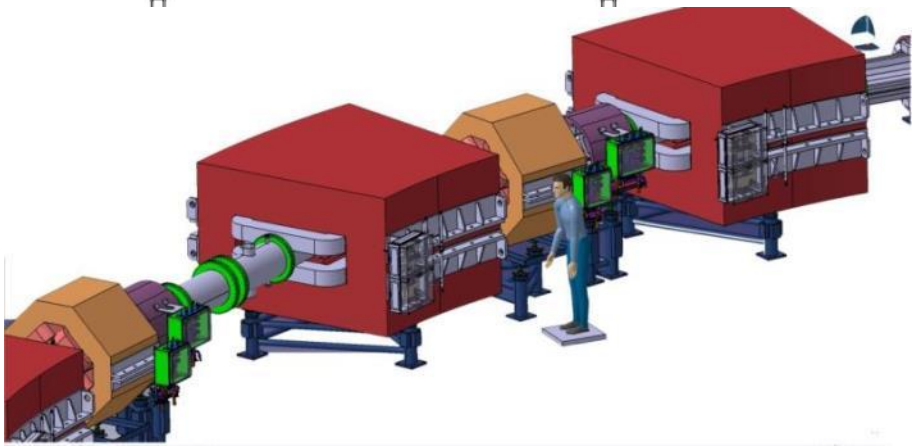
- Status:
  - Detailed concept for handling of activated components finished. Positive response from authorities. Draft specification for magnetic horn system available. Tendering of detailed system design study.
  - Draft specifications for most magnets available (BINP)
- Critical items:
  - Magnetic horn pulser (400 kA), switches (semi-conductors).
  - Magnets, however most magnets are CR-type. The first magnets of the series can be used for pbar.

K. Knie

The FAIR Storage Rings

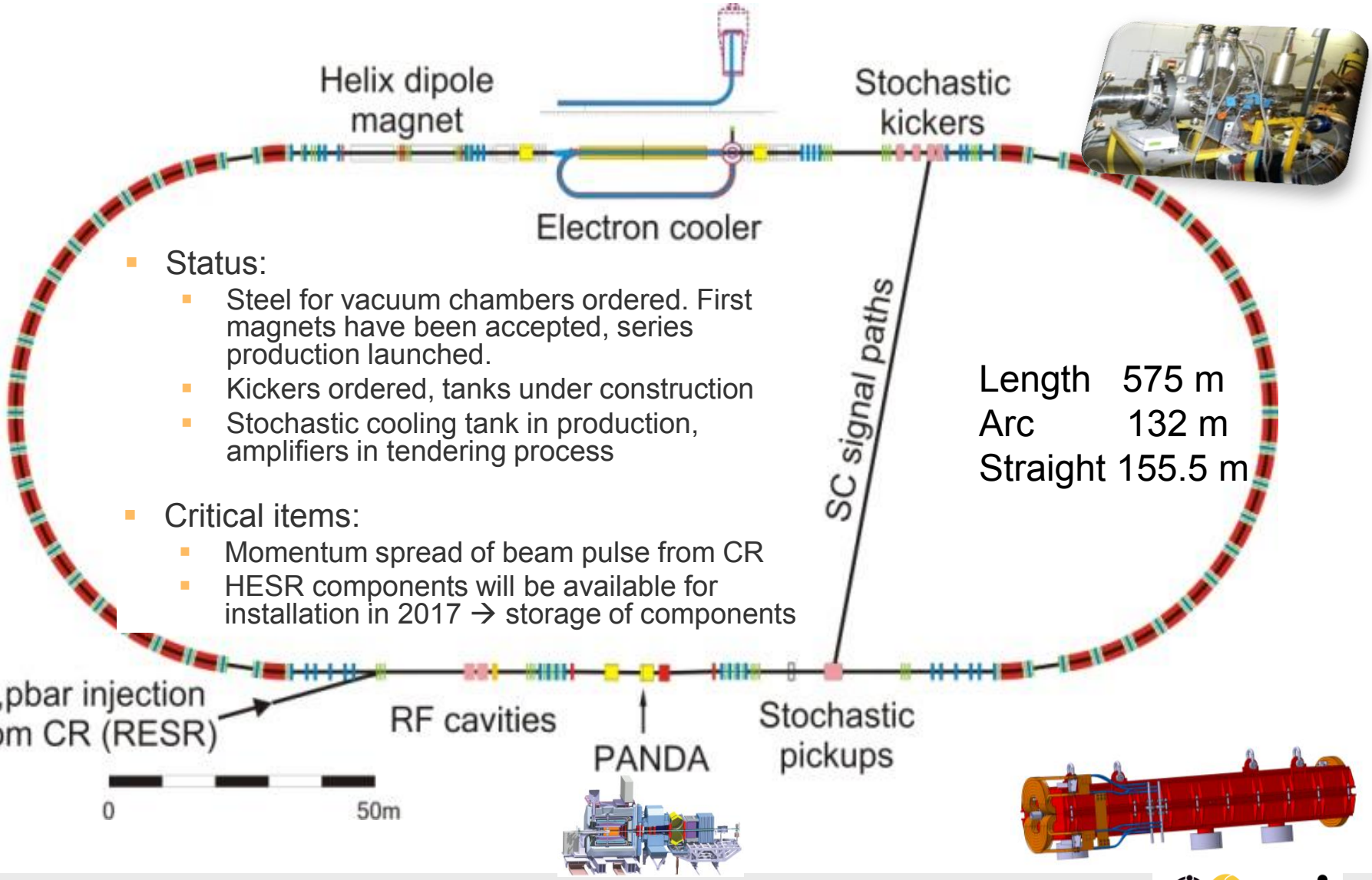


Large Aperture Storage Ring CR



- Status:
  - Technical supervision of CR → Budker Institute
  - CR-Rf system (debuncher cavities) under construction
  - Pick up tank prototype of stochastic cooling system available
- Critical items:
  - Dipole magnets, specs ready, but In-kind contract not yet ready
  - No system design freeze yet

The High Energy Storage Ring HESR

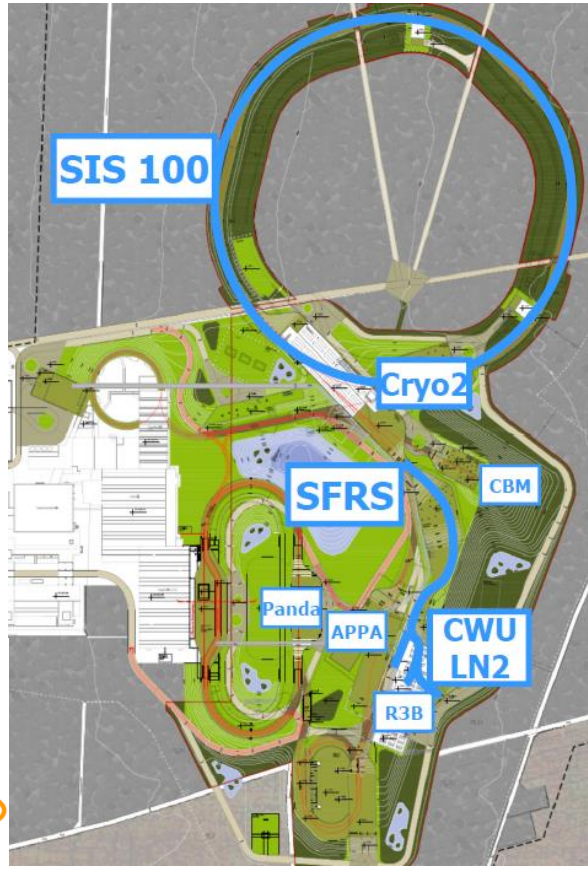


- Status:
  - Steel for vacuum chambers ordered. First magnets have been accepted, series production launched.
  - Kickers ordered, tanks under construction
  - Stochastic cooling tank in production, amplifiers in tendering process
- Critical items:
  - Momentum spread of beam pulse from CR
  - HESR components will be available for installation in 2017 → storage of components

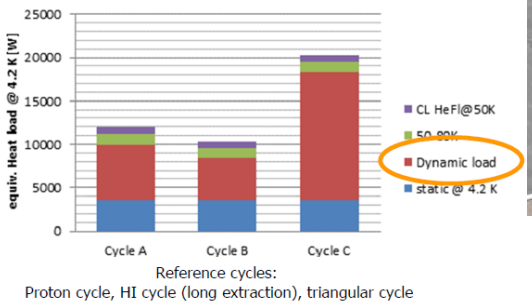
Length 575 m
Arc 132 m
Straight 155.5 m

Status Cryogenic Supply and Distribution

- Status:
  - Two industry studies successfully performed by Linde and Air Liquide
    - confirmation on space and budget requirements
    - confirmation on time scheduling
    - no technical risks on the cryo plants observed
  - Start configuration for the cryogenic supply for SIS100 and Super-FRS
  - Specifications for a 25 kW common plant and a cool down unit are in preparation (to 90 % completed)
  - Technical study on the distribution system of SIS100 successfully performed
    - reliable statements on prize and delivery time



- Critical items:
  - Civil construction building milestones (commissioning, warranty)
  - Reliability on heat loads
  - Requirements and operation are dominated by dynamic load



Reference cycles:
Proton cycle, HI cycle (long extraction), triangular cycle

picture from Linde KT