

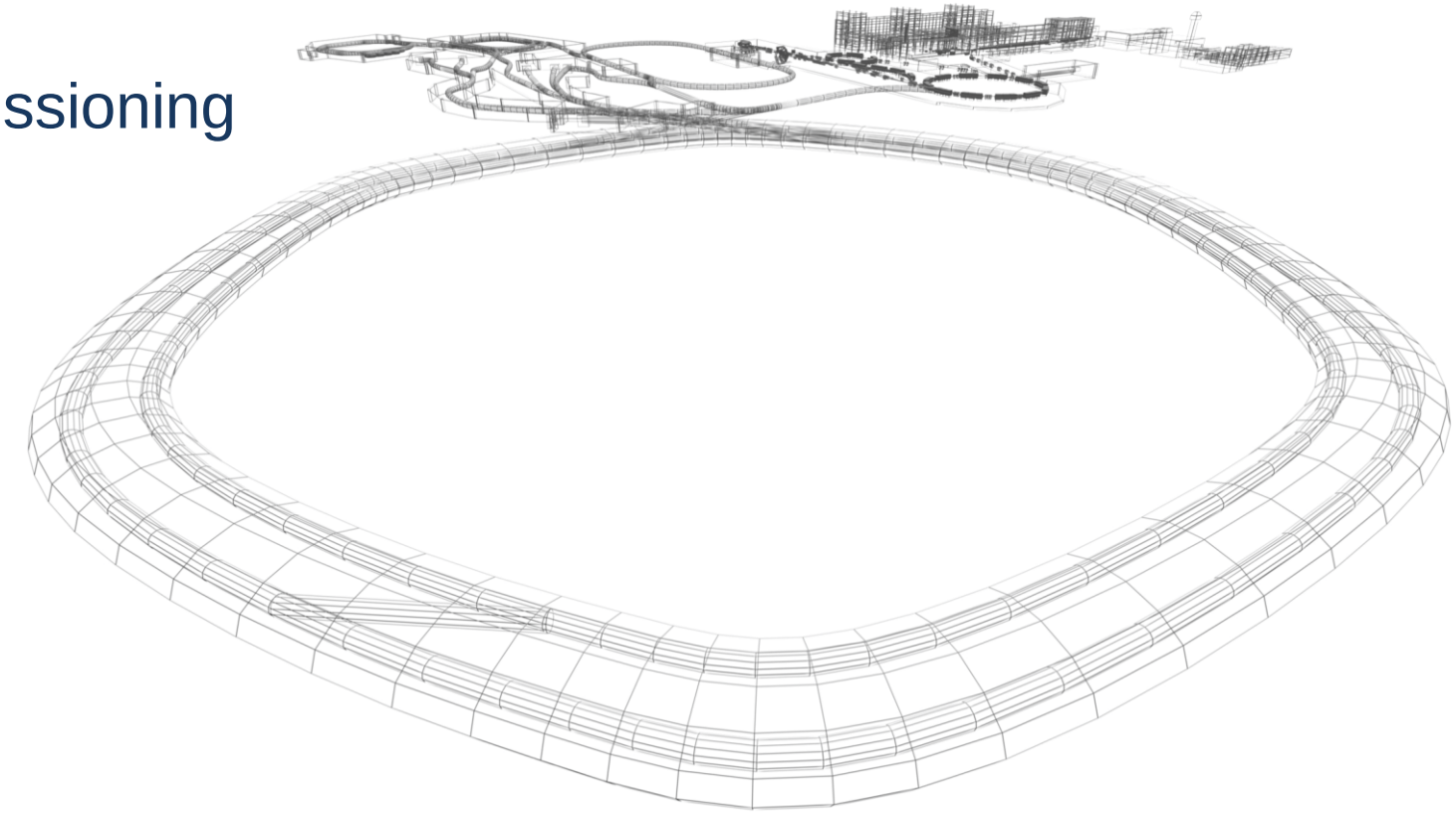
The SIS100 Accelerator at FAIR: Overview and Technical Contribution of IFJ PAN

Patricia Aguar Bartolome et al. – GSI Helmholtzzentrum fuer Schwerionenforschung GmbH

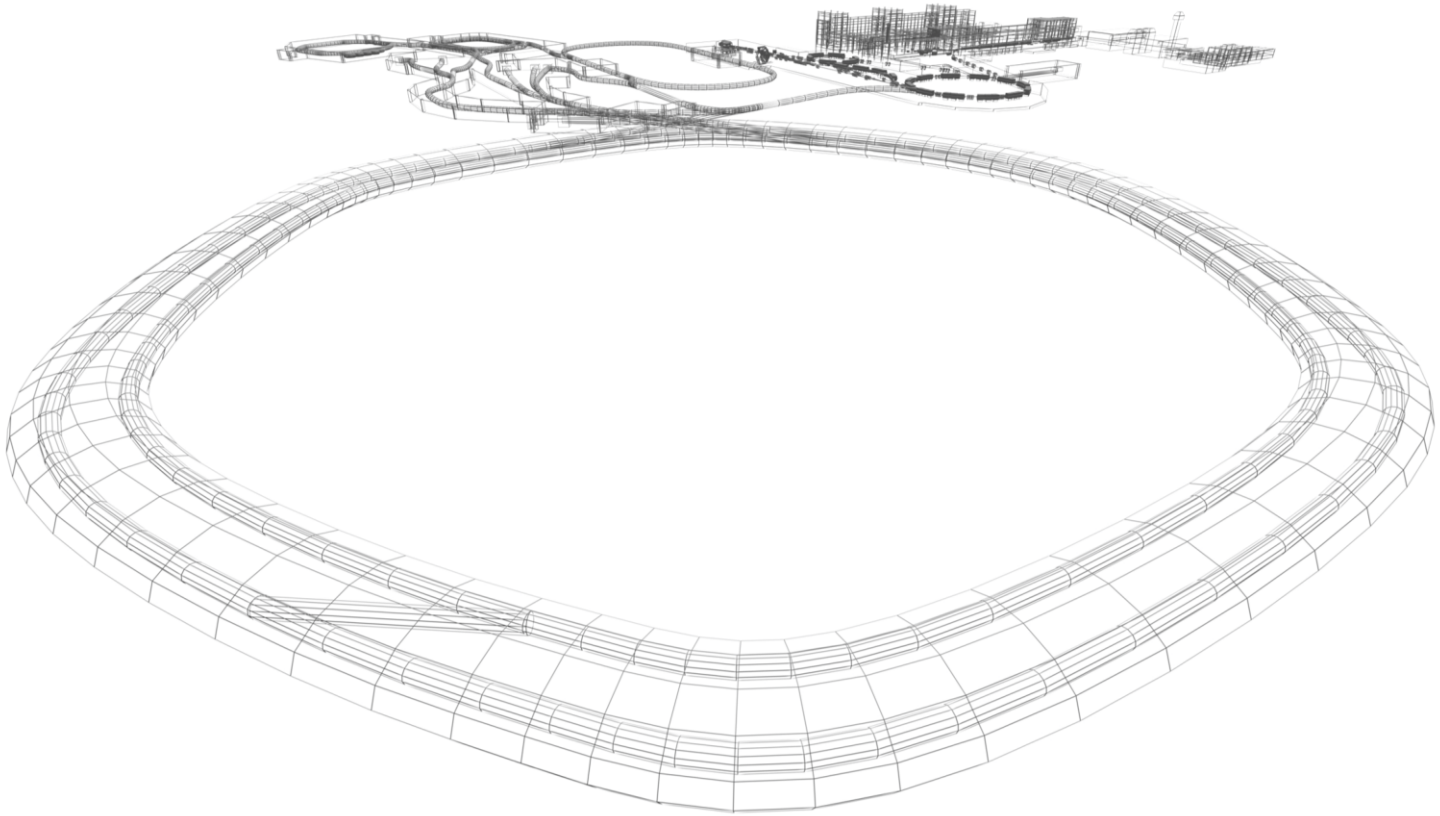
SPAS 2026 | Kraków | October 20-22

Outline

- Introduction to FAIR
- SIS100 overview
- SIS100 Installation & commissioning
- Summary



FAIR



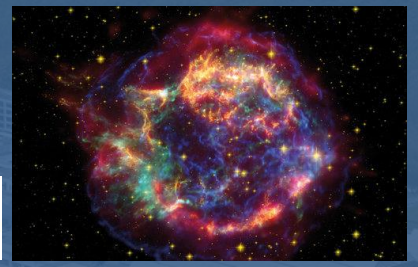
FAIR – Experimental program

NUSTAR

Nuclear Structure, Astrophysics and Reactions:

Stars and nuclei

(850 scientists)

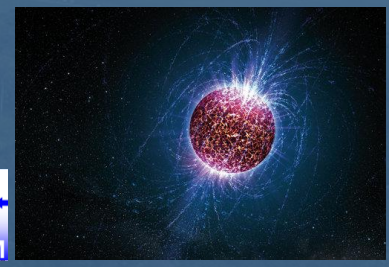


CBM

Compressed Baryonic Matter:

Inside a neutron star

(500 scientists)



APPA

Atomic, Plasma Physics and Applications:

From atoms to planets to cancer research

(720 scientists)





PANDA

Antiproton-annihilation at Darmstadt:

Hadron physics with antiprotons

(500 scientists)



https://www.gsi.de/en/researchaccelerators/fair

Graph: ion42/FAIR

FAIR – Civil construction

2 mil. m³
soil

5.000 family homes



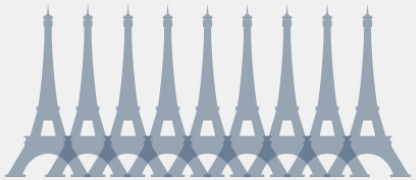
600.000 m³
concrete

8 times Frankfurt soccer stadium



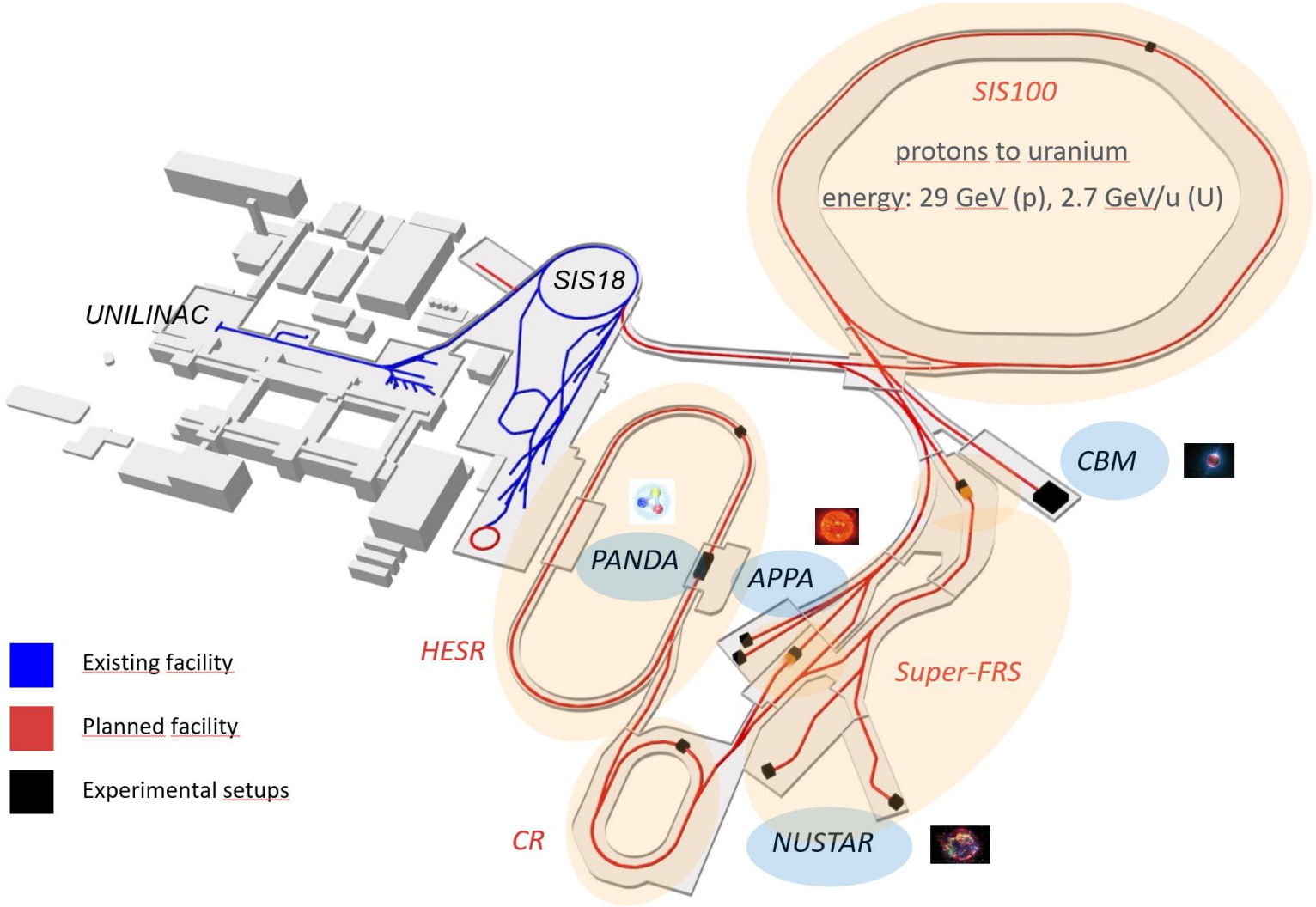
65.000 t
Steel

9 times Eiffel tower



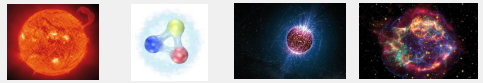


FAIR – The facility



SIS100 heavy –ion synchrotron
High intensity primary beams
Production targets
- exotic nuclei
- anti-protons

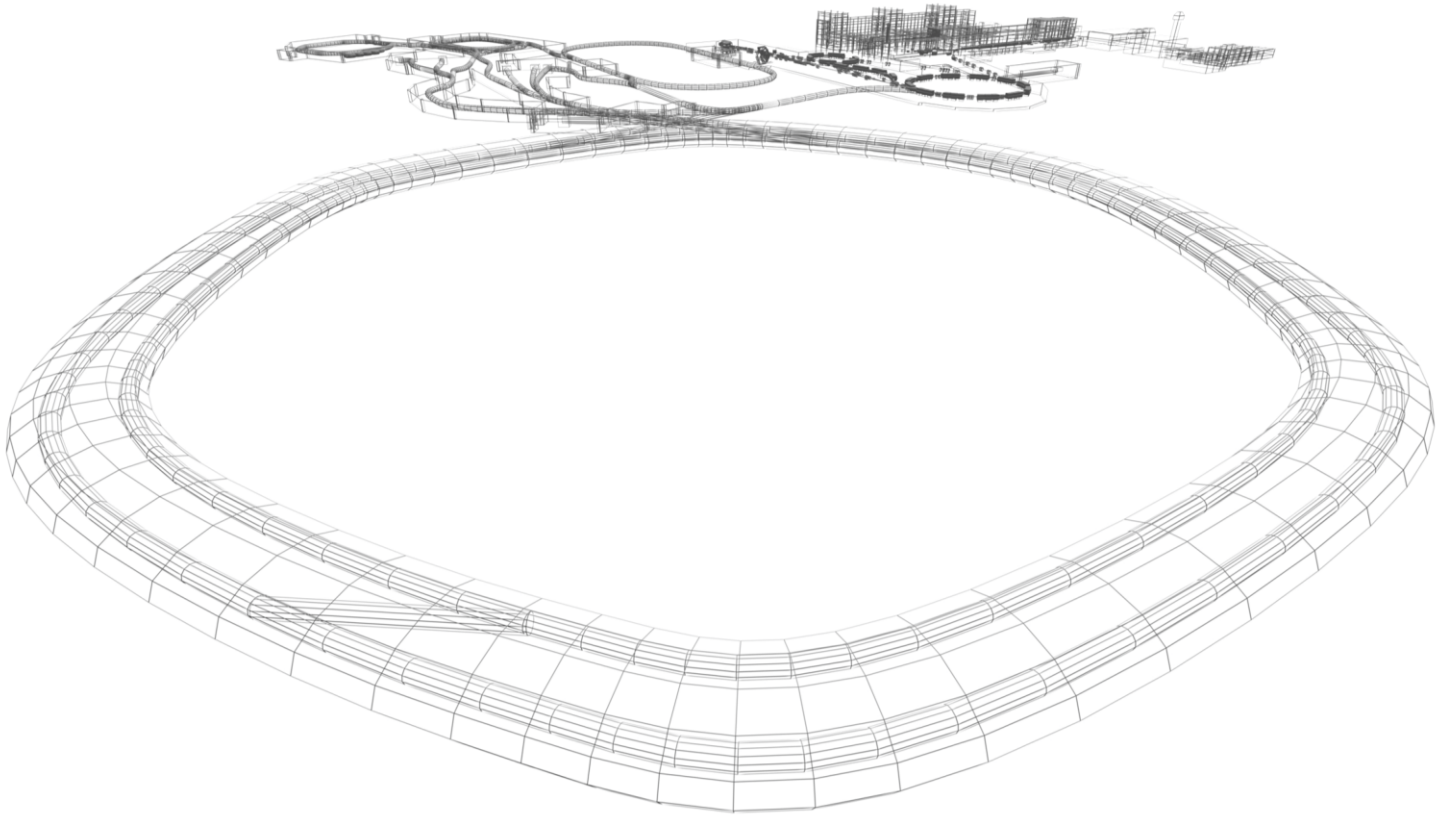
Super-Fragment Separator
In-flight separator for exotic nuclei
Rings
Collection and Storage
Experimental setups
Four main pillars



25 accelerator and experimental structures
Labs + operation and supply structures
SIS100 underground ring
Circumference of approx. 1100 m
Around 150.000 m² of total area

SIS100 = **S**chwer**i**onen**s**ynchrotron 100 [Tm] = Heavy Ion Synchrotron (beam rigidity) 100 [Tm]

SIS100

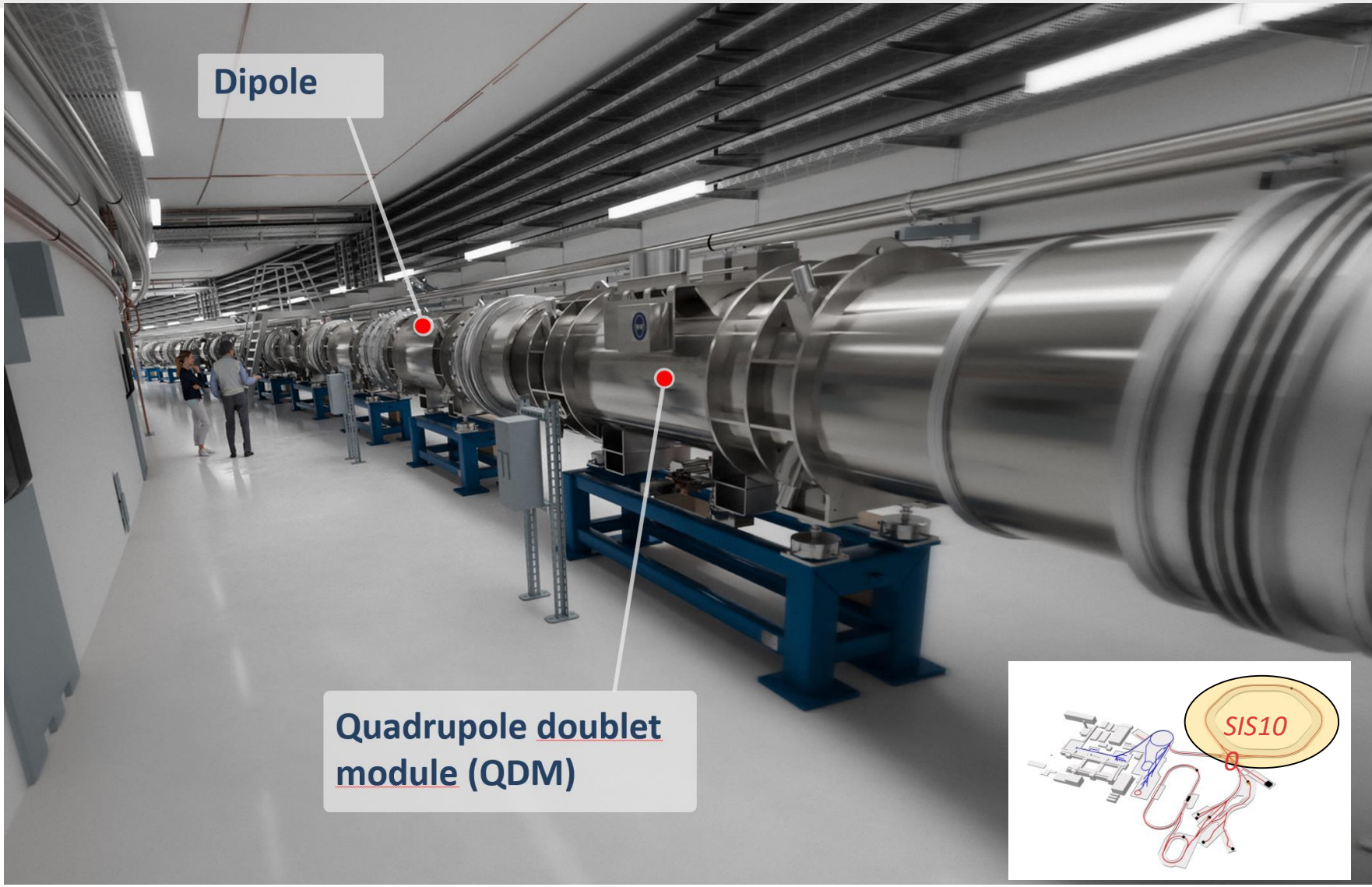


SIS100 – Heavy Ion Synchrotron

Heavy-ion synchrotron

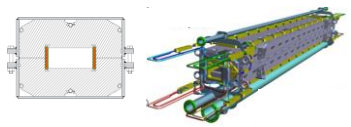
- primary beam acceleration at FAIR
- fast ramped SC magnets
- protons to uranium
- energy: 29 GeV (p), 2.7 GeV/u (U)
- number of ions per cycle:
  2.5×10^{13} (p) to 5×10^{11} (U^{28+})
- pulse length: 90 – 30 ns

Dipoles	108
Quadrupoles	166
Sextupoles	42
Steerer	83
Multipoles	12
Special quads	16
Total	**427**



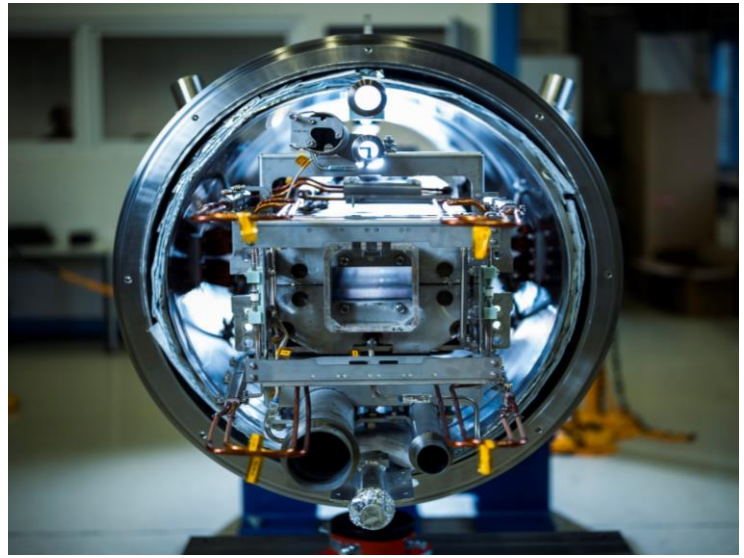
SIS100 – Heavy Ion Synchrotron

Dipoles



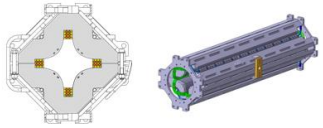
Features

- superferric magnet design
- nuclotron NbTi cable
- fast ramping
- two phase LHe cooling (forced flow)

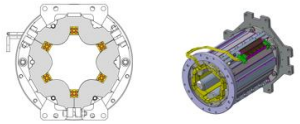


Quadrupole doublet modules (QDMs)

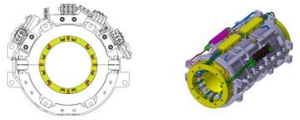
main quadrupoles (166)



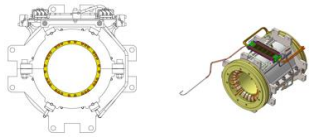
sextupoles (42)



multipoles (12) (B2, A3, B4)



steerers (83)



+ special quadrupoles (16)

quadrupole units (166 pcs.)

quadrupole + corrector + corrector

quadrupole doublet modules

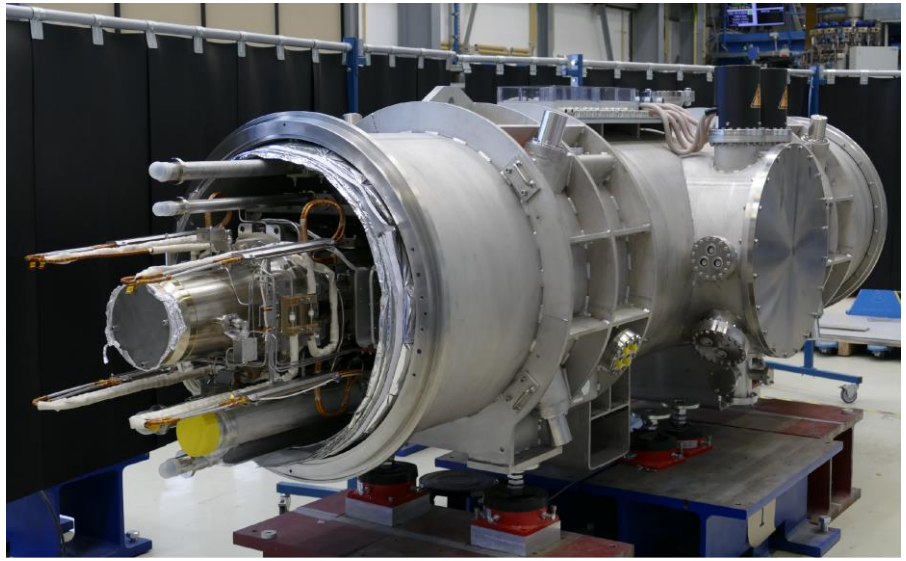
two units on common girder

together with other elements:
- beam chamber
- cryo catcher
- BPM
- cryo pump, roughing CWT

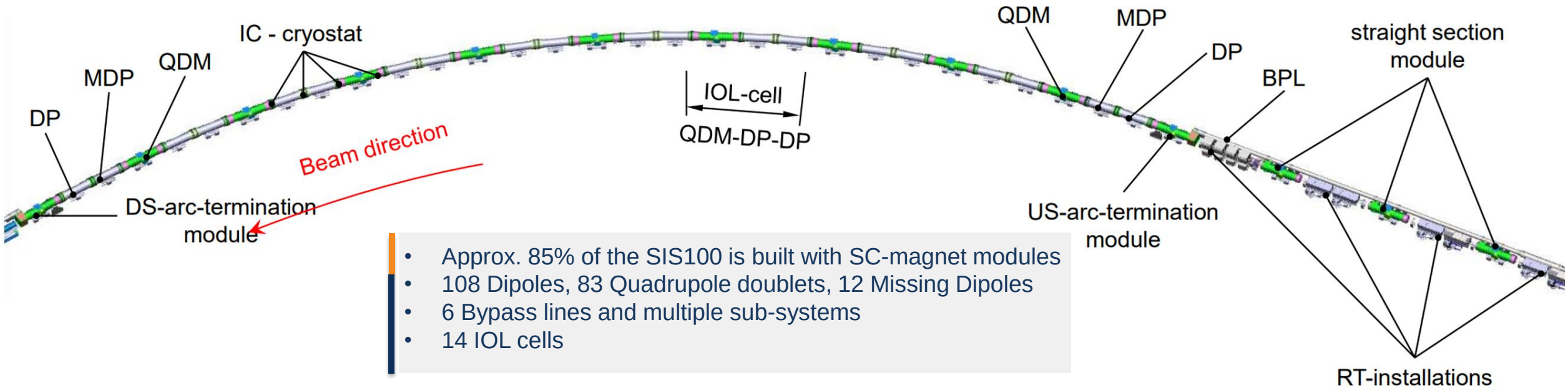
integration into common cryostat

configurations

11 types

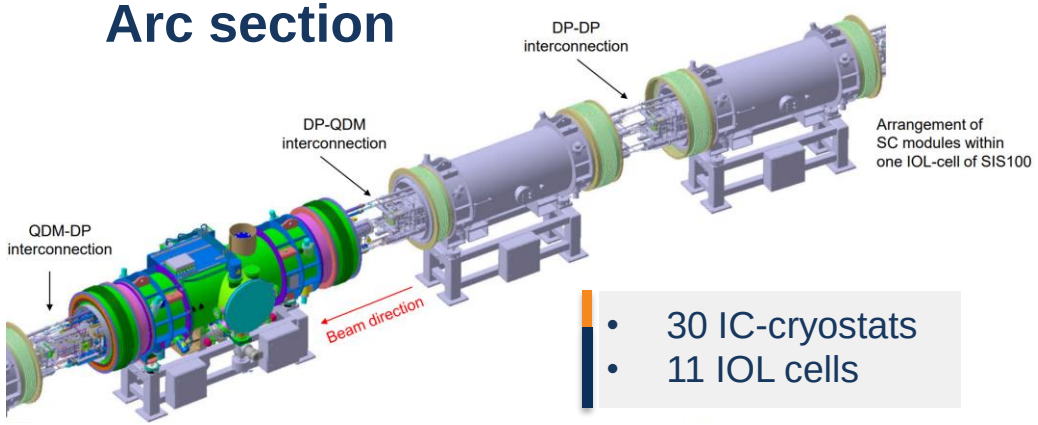


SIS100 – Overview of one Arc



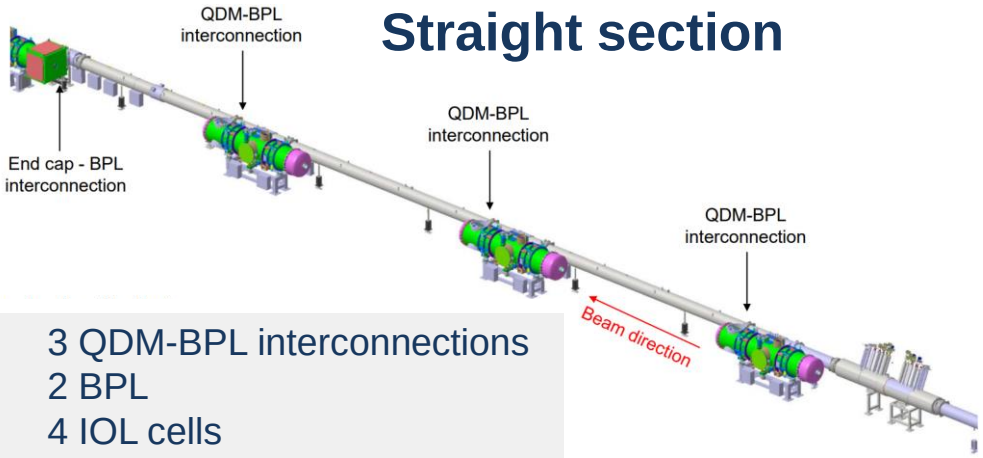
- Approx. 85% of the SIS100 is built with SC-magnet modules
- 108 Dipoles, 83 Quadrupole doublets, 12 Missing Dipoles
- 6 Bypass lines and multiple sub-systems
- 14 IOL cells

Arc section



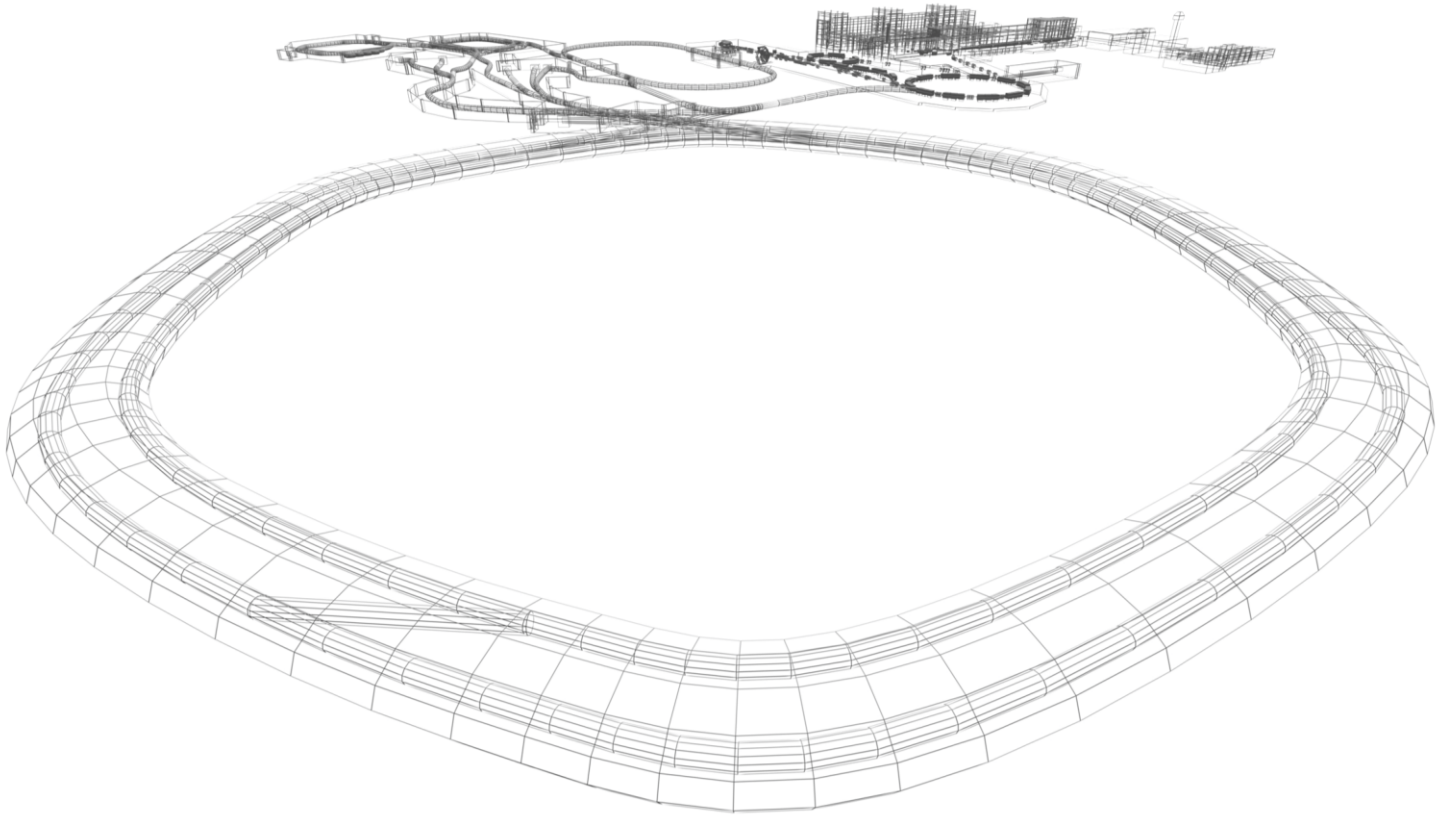
- 30 IC-cryostats
- 11 IOL cells

Straight section



- 3 QDM-BPL interconnections
- 2 BPL
- 4 IOL cells

SIS100 String Test



SIS100 String Test

SIS100 String: ion optical cell of SIS100

Crucial preparatory phase for the installation, commissioning and operation of the SIS100

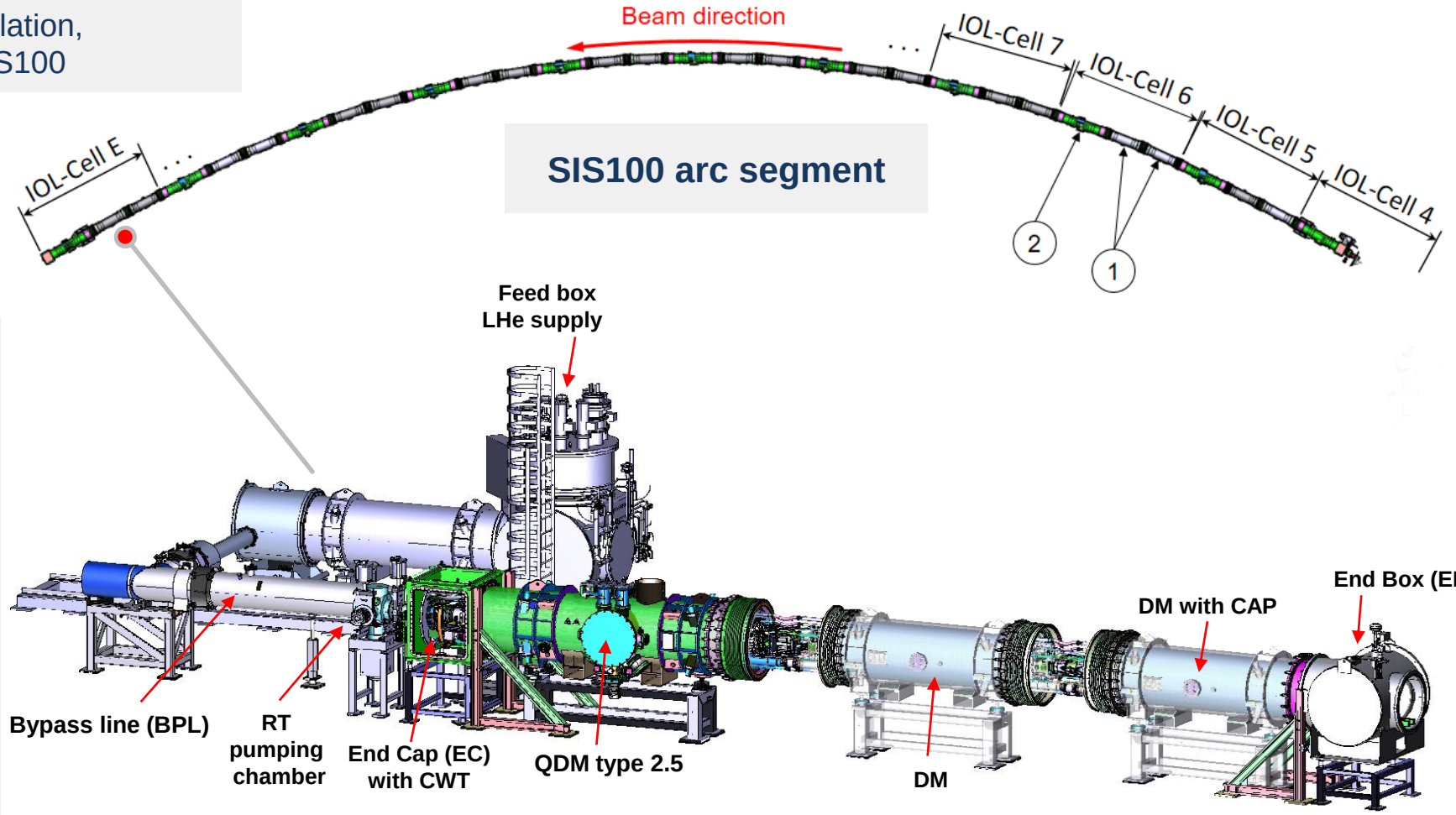
Assembly
- installation sequences
- interconnections / interfaces
- process description
- tool qualification

Mechanical stability
- forces at cool-down and operation

Collective electrical behavior
- cross talk
- resistance

Cryogenics
- cooling time
- losses

Vacuum system
- beam and insulation vacuum



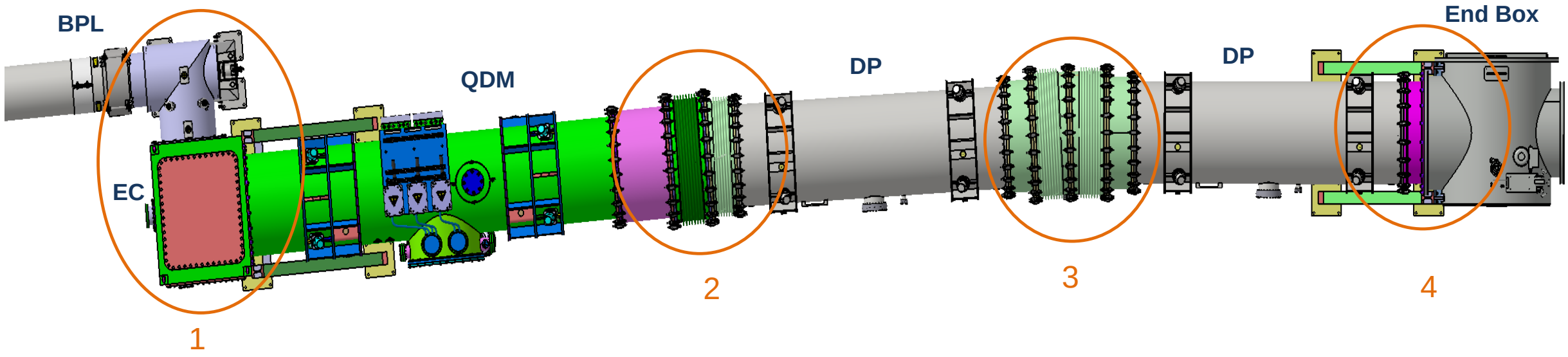
SIS100 String Test

SIS100 String: Four interconnection areas

1. Bypass line – End Cap
2. Quadrupole doublet – Dipole
3. Dipole – Dipole
4. Dipole – End Box

Multiple sub-systems interconnected

- Beam vacuum chambers
- He-process lines
- Thermal shields with MLI
- Insulation vacuum system



SIS100 String Test – Contribution of IFJ PAN

Assembly mainly carried out by IFJ PAN Kraków

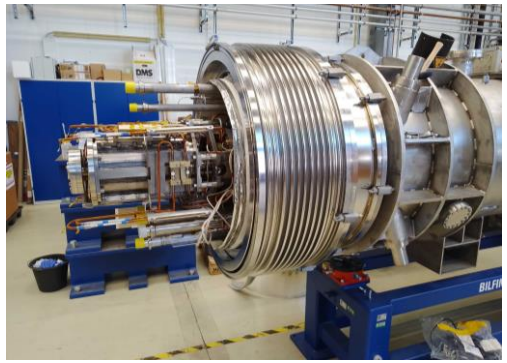
- Transport of components by **GSI**
- He-process lines interconnection by **KRIOSYSTEM** (Wrocław)

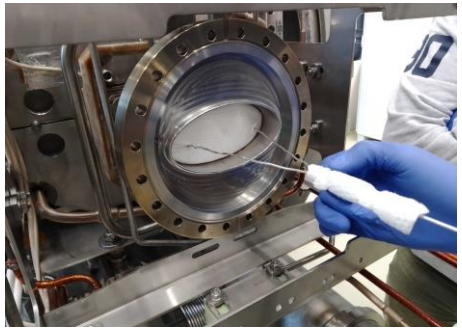
Assembly work started in July 2022

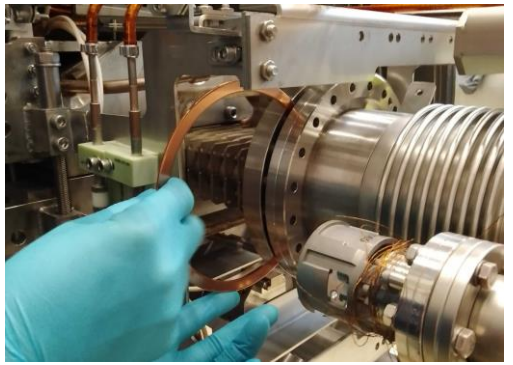
Key tasks

DM-DM & QDM-DM interconnections

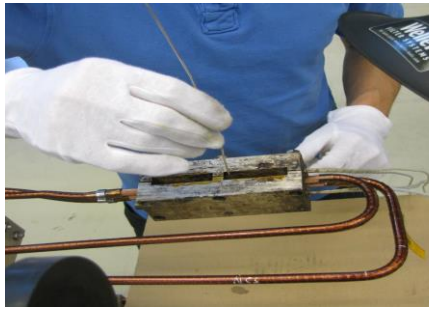
- Clean the beam-vacuum chambers (only for Dipoles)
- Installation of telescopic bellows
- Connection of the UHV system
- Beam line leak test
- Busbars soldering
- Installation of helium process lines stabilizers
- Installation of busbar clamps and fixation















SIS100 String Test – Contribution of IFJ PAN

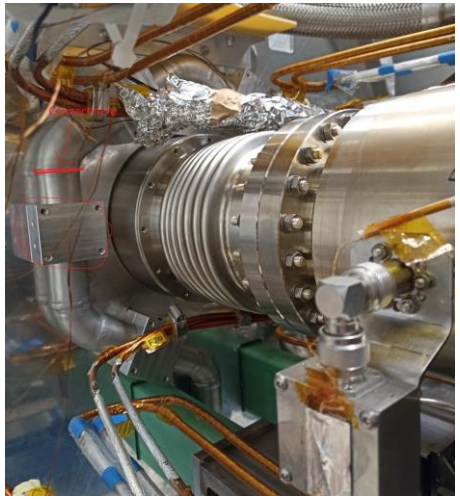
Key tasks

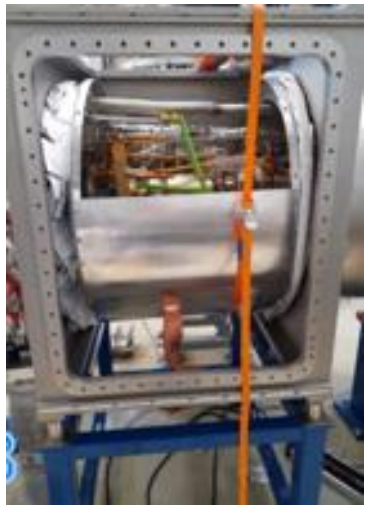
QDM-EC & EC-BPL assembly

- Connection of the UHV system
- Connection of BVCWT
- Busbars soldering
- Installation of busbar clamps and fixation

DM-End Box assembly

- Connection of the inner components
- Installation of supporting elements
- Busbars soldering
- Installation of busbar clamps and fixation








SIS100 String Test – Contribution of IFJ PAN

Key tasks

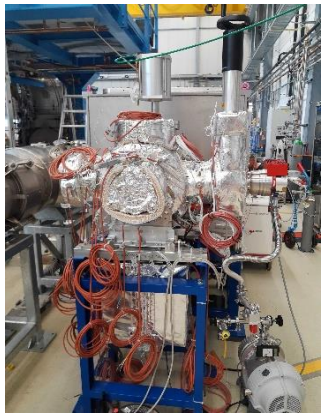
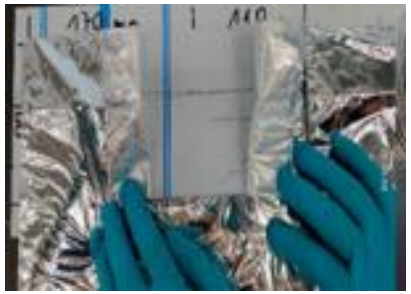
Pumping chamber installation

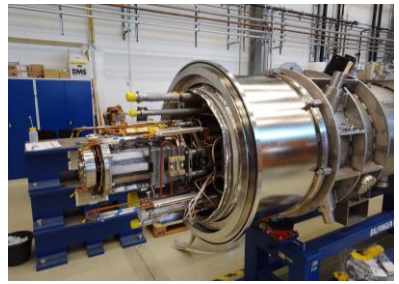
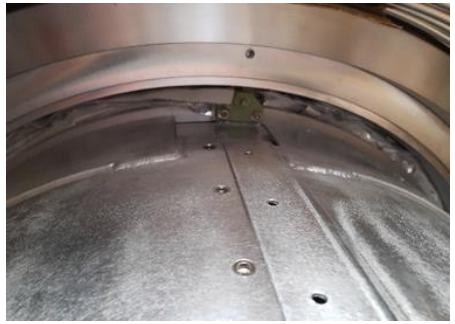
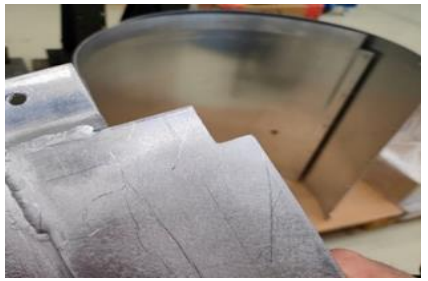
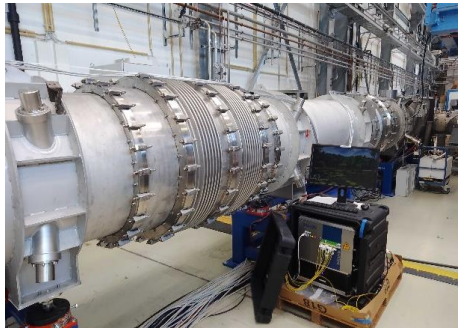
- Connection of the gate valve
- Assembly of vacuum equipment
- Installation of bakeout jackets

Final activities

- Installation of MLI around UHV system and helium process lines
- Installation of thermal shields
- Installation of MLI on the thermal shields
- Final closure of the telescopic bellows



SIS100 String Test – Contribution of IFJ PAN

Work preparation & test planning

Work plan

- relevant assembly and test steps

Work instructions

- procedures for the assembly – **13 documents**

Test instructions

- procedures for quality control – **5 documents**

Acceptance protocols – 7 documents

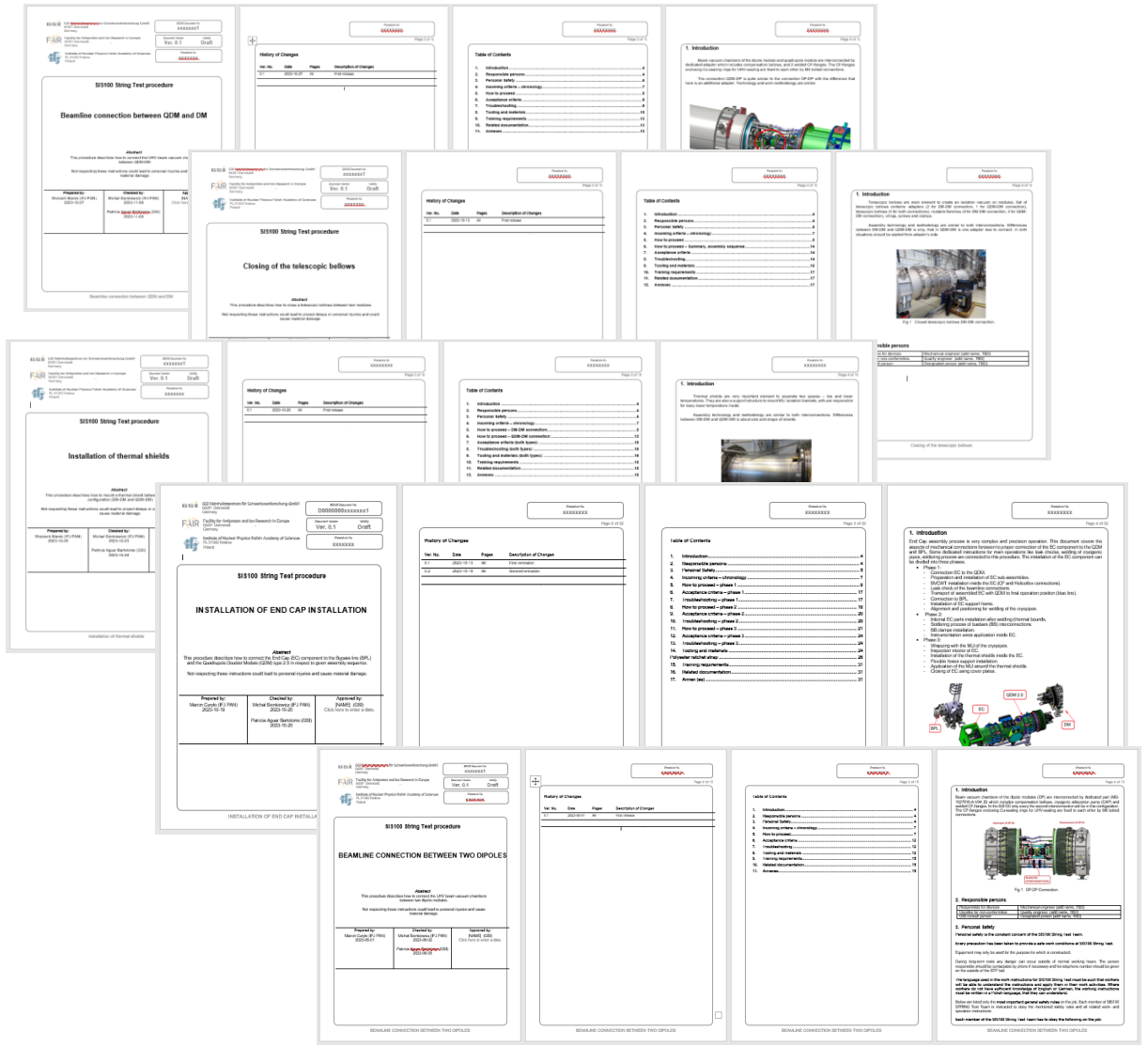
Non-conformity reports

Risk assessment

Lessons learned

- findings and recommendations

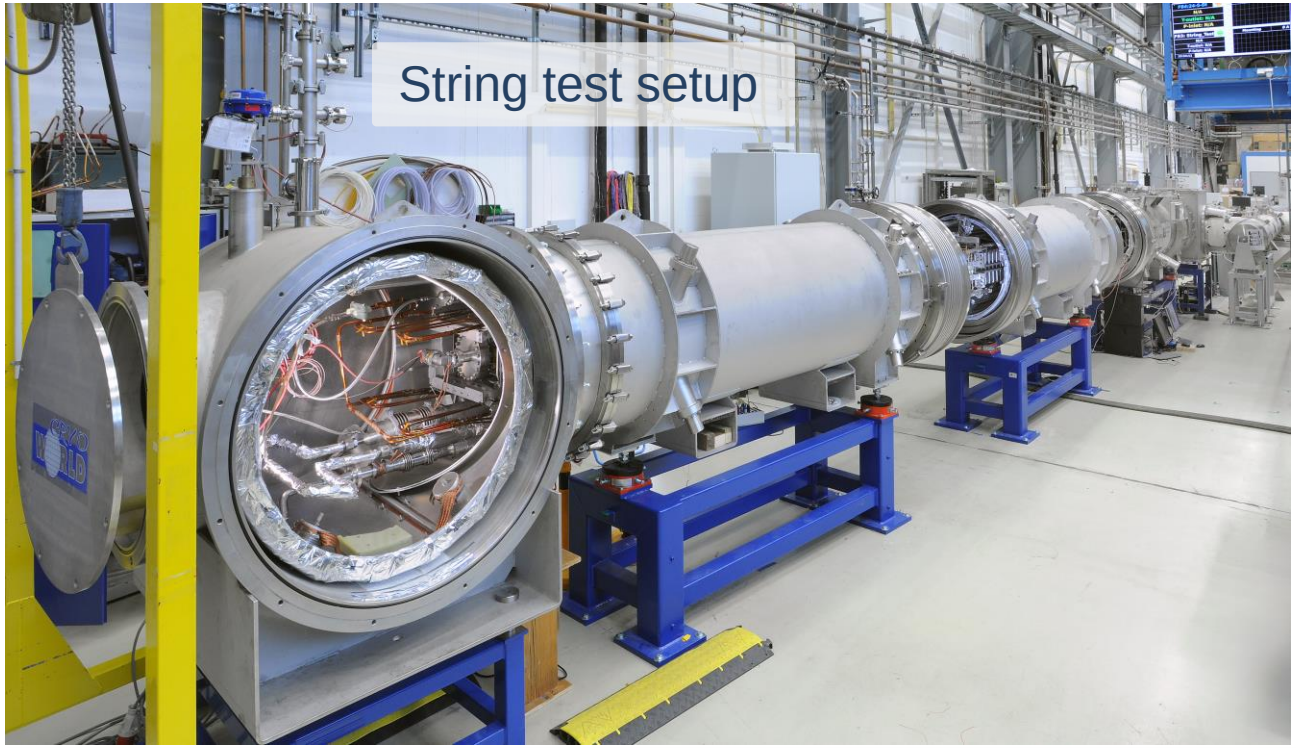
SIS100 String test documentation used in the SIS100 tunnel installation

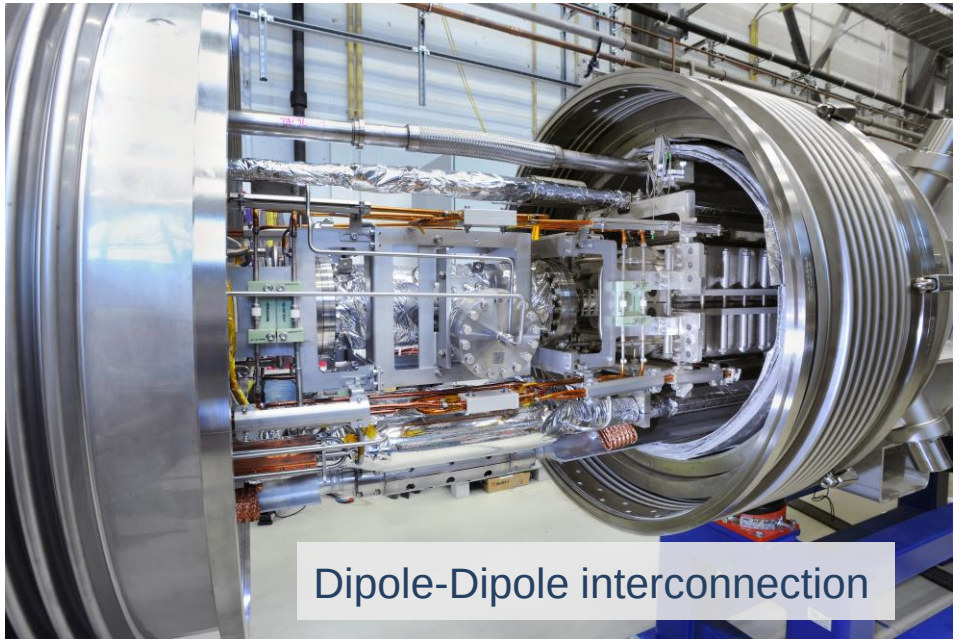


SIS100 String Test

Status

- Installation completed in October 2023
- Several cold runs with full magnet powering
- Experimental program completed (cross talk of main circuits, AC losses, quench study…)

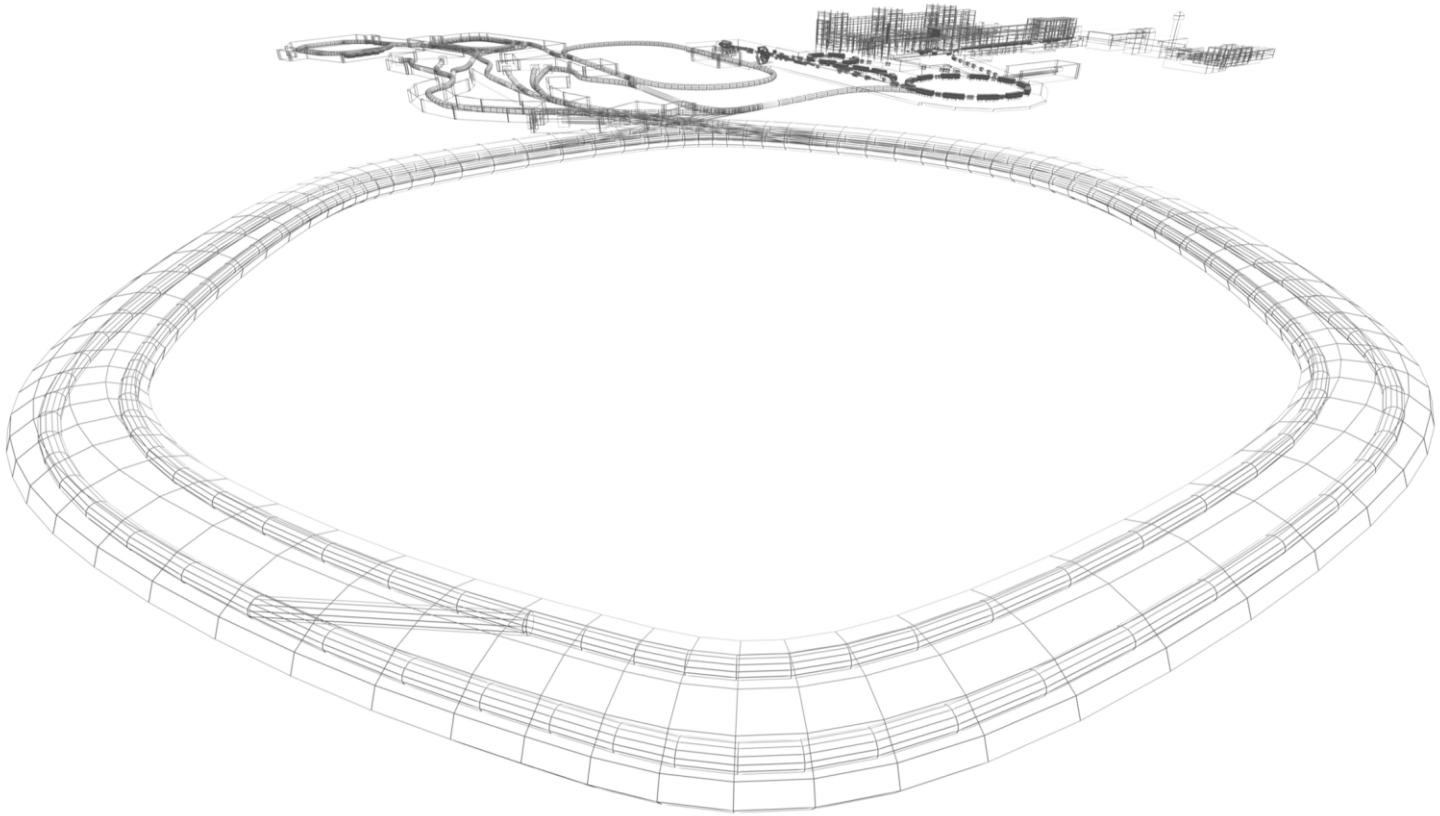




Currently

- 6th cold run: Endurance power test
- End of SIS100 String test in December 2026

SIS100 Installation



SIS100 Installation

Installation works

- civil construction completed in Q1.2024
- Dipole installation started subsequently and is ongoing







SIS100 Installation – Contribution of IFJ PAN

Installation mainly carried out by IFJ PAN Kraków

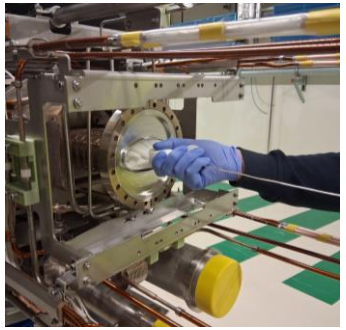
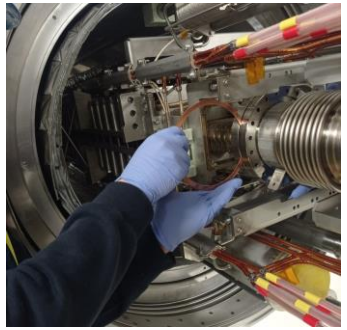
- Transport of components by **GSI**
- He-process lines interconnection by **GSI**

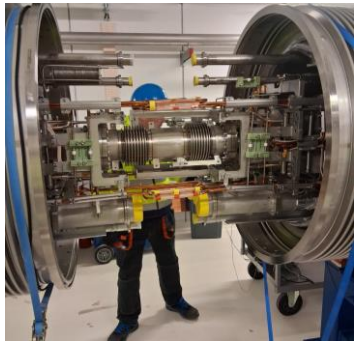
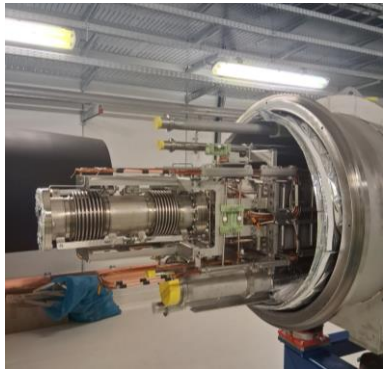
Assembly work started in April 2024

Installation works ongoing

Phase 1 of the Dipole-Dipole interconnection

- Transport of dipole modules
- Clean the beam-vacuum chambers
- Exchange of vacuum chamber holders
- Installation of telescopic bellows
- Connection of the UHV system
- Beam line leak test
- Busbars soldering
- Welding of helium process pipes (GSI)






SIS100 Installation – Contribution of IFJ PAN

Installation works upcoming

Phase 2 of the Dipole-Dipole interconnection

- Leak test of the welded helium process pipes
- Installation of helium process line stabilizers
- Installation of busbar clamps and fixation

QDM installation (on availability)

- Similar steps to the Dipole-Dipole interconnection

Final installation works

- Installation of MLI around UHV system and helium process lines
- Installation of thermal shields
- Installation of MLI on the thermal shields
- Final closure of the telescopic bellows

Installation of straight sections

- EC-QDM-BPL interconnections



SIS100 Installation

Arc 1, 2, 3, 4, 6

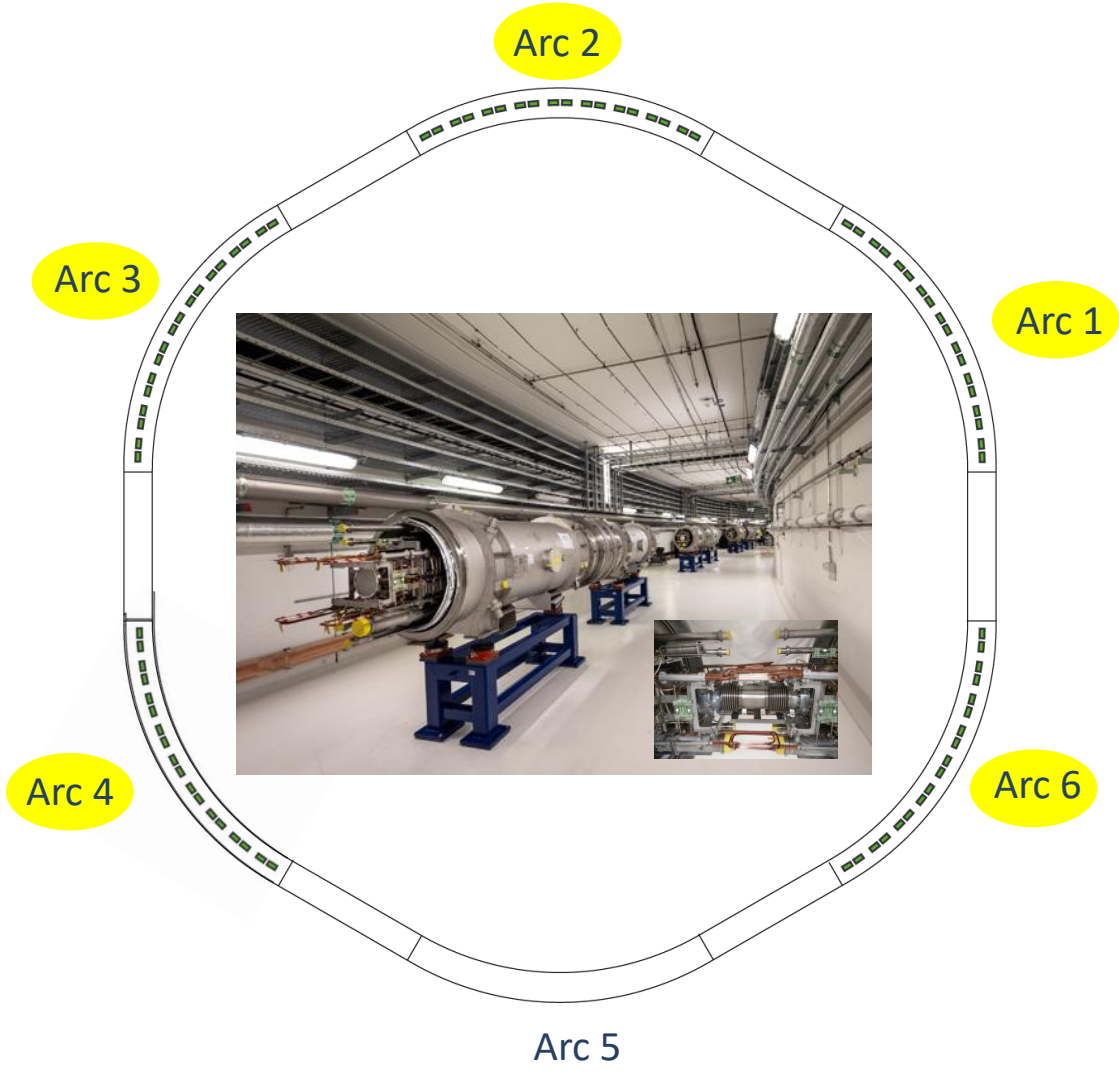
- Dipoles on position (roughly)
- Interconnections:
  - ✓ UHV connected
  - ✓ UHV Leak tested
  - ✓ Busbars soldered
  - ✓ Welding of process lines
  - ○ **ToDo**: Leak test of welded process lines

Arc 5

- Dipoles on position (roughly)

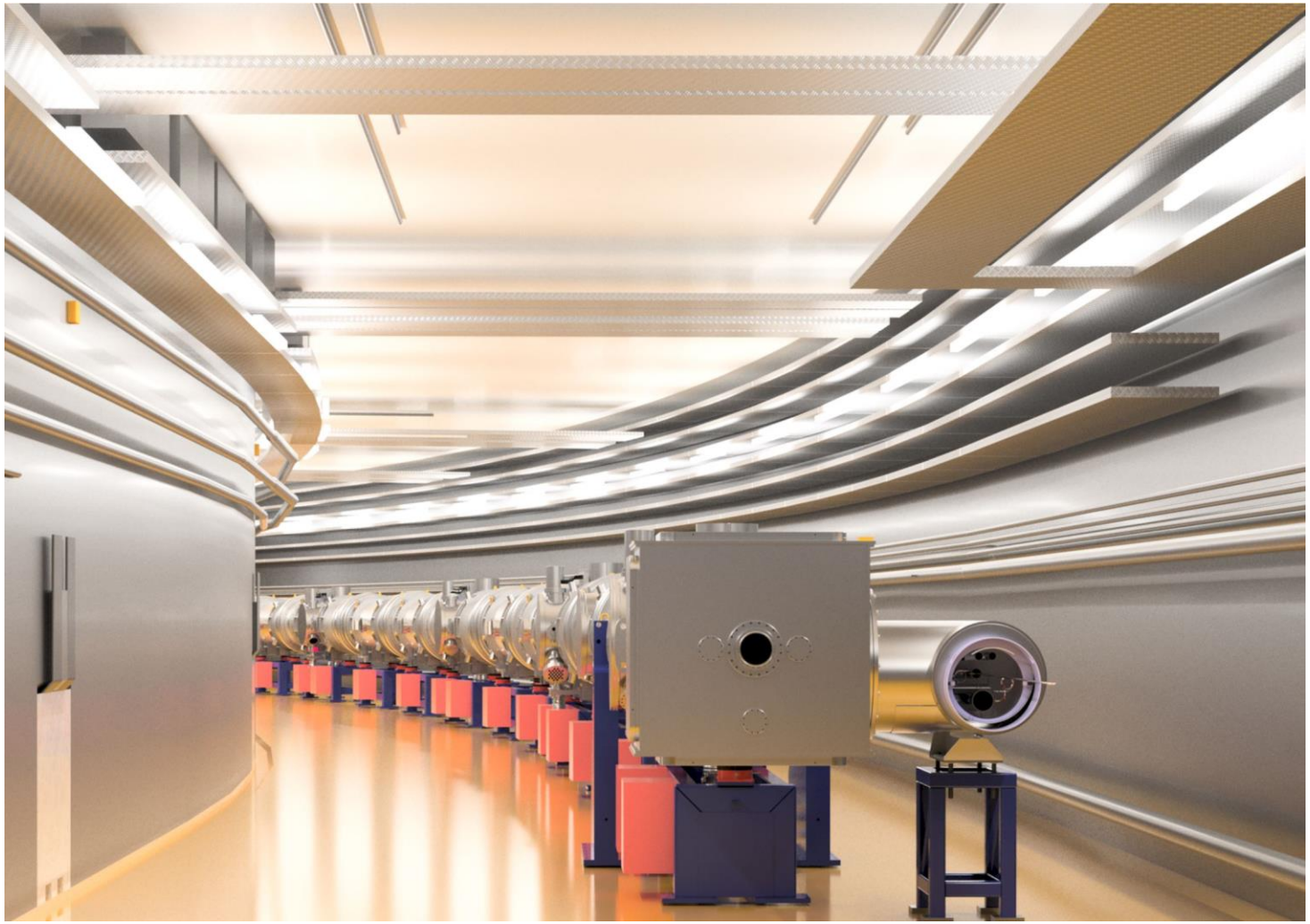
In parallel: installation of cavities , local cryogenics, …

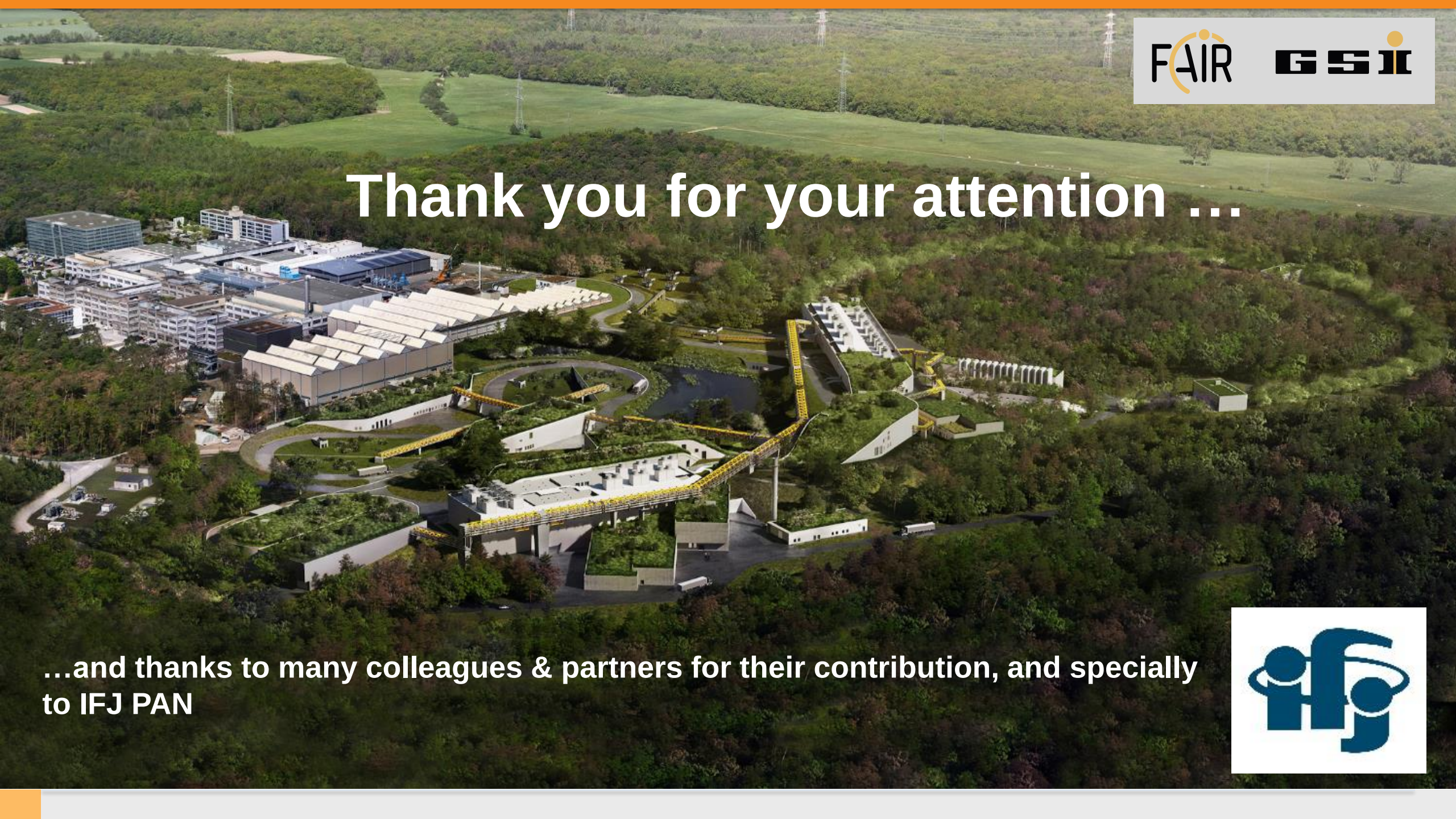
GOAL: commissioning with beam in 2028



Summary

- SIS100 is a key high-intensity synchrotron designed to accelerate beams from protons to uranium.
- The superconducting magnet system presents significant technical and integration challenges.
- The String Test validated the assembly procedures and the interconnected systems, preparing for tunnel installation.
- IFJ PAN has made a substantial contribution to the String Test and the accelerator installation.
- Dipole installation is ongoing and QDM installation is planned from December 2026.
- **Next milestone:** Commissioning with beam targeted for 2028





Thank you for your attention …

…and thanks to many colleagues & partners for their contribution, and specially to IFJ PAN