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Preparation of the Superconducting Magnet String Test for SIS100 Synchrotron

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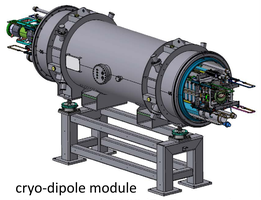
Introduction — The new international accelerator facility FAIR (Facility for Antiproton and Ion Research) is currently under construction in Darmstadt, Germany.

The core component of the complex is the heavy ion synchrotron SIS100 which utilizes 417 superconducting magnets. The SIS100 machine is supplied with two phase helium (4.5 K , 1.5 bar). All cryo-modules are tested at ambient (300 K) and at operating (4.5 K) conditions during comprehensive acceptance tests either at the contractor's or at GSI side.

Besides the testing of standalone modules, the SIS100 magnet string will be assembled and tested at GSI. The string will be built-up of a number of the main cryo-magnetic components such as dipole- and quadrupole modules and the most crucial local cryogenic parts, such as a by-pass line piece. A wide spectrum of tests will be performed in order to evaluate the interaction of the main components during cool down, warming up and during powering at operational conditions.

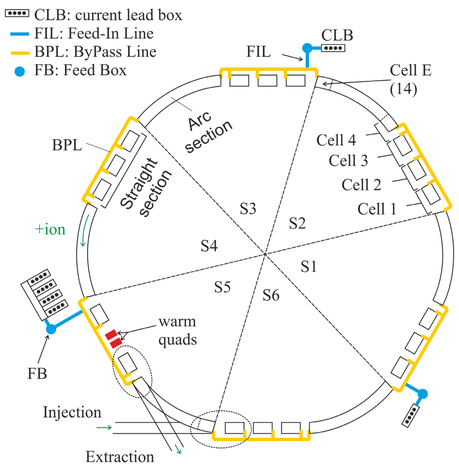
SIS100 synchrotron - heavy ion synchrotron:

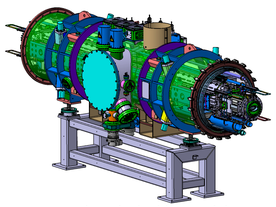
- **beam rigidity 100[Tm]**
- **circumference 1083.6 m**
- **fast ramped machine 4Ts^{-1} → 27.5 kAs^{-1} (1Hz)**
- **417 sc-magnets assembled in**
- **over 190 cryo-magnetic modules**
- **over 60 local cryo components**



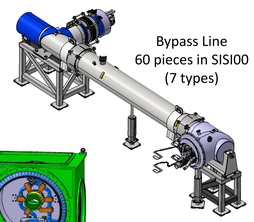
cryo-dipole module
108 pieces in SIS100 (Di, Do- types)

Simplified cryogenic lay-out of the SIS100

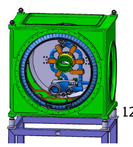




cryo-quadrupole doublet module
83 pieces in SISI00 (12 types)



Bypass Line
60 pieces in SISI00
(7 types)



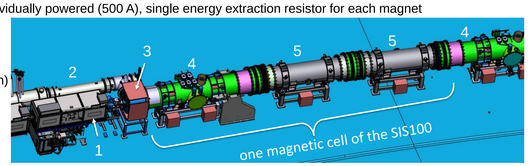
End Cap
12 pieces in SISI00
(3 types)

Electrical system of the SIS100:

- 4 main high current (11-13 kA) circuits
  - Dipole (DP) circuit: 108 magnets connected in series, 2 power converters, 12 energy extraction resistors
  - Quad. defocusing (QD) - 83 magnets connected in series, power converter, 4 energy extraction resistors
  - Quad. focusing 1 (F1): 36 magnets connected in series, power converter, 2 energy extraction resistors
  - Quad. focusing 2 (F2): 47 magnets connected in series, power converter, 2 energy extraction resistors
- 7 chromaticity sextupole circuits (CS): In total 42 magnets. Each circuit - 6 magnets connected in series (300 A). 2 energy extraction resistors pro circuit
- 83 steering magnets (nested horizontal, vertical coils). Individually powered (300A), single energy extraction resistor for each coil
- 12 multipole correctors (nested b_2, a_3, b_4 coils). Individually powered (300 A), single energy extraction resistor for each coil
- 4 injection/extraction quadrupoles. Individually powered (500 A), single energy extraction resistor for each magnet

A part of the SIS100 structure:

1 – RF cavity (warm part of the straight section)
2 – cryogenic bypass line (BPL)
3 – end cap
4 – cryo quadrupole doublet module
5 – cryo dipole module



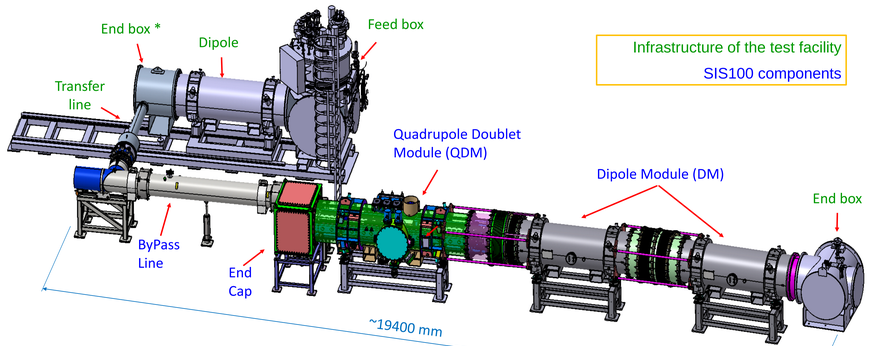
SIS100 string at the GSI test facility

String configuration – arc section cell of the SIS100 + most critical local cryogenic components

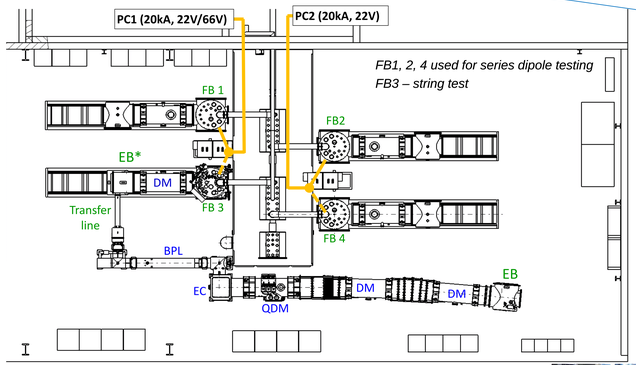
Main goals of the string test:

- verification of different interfaces and interconnections regarding fitting and mountability
- choosing appropriate tools for installation of the component in the tunnel
- preparation of the work instructions for the installation of the SIS100
- insulation vacuum stability and performance of the UHV components
- cooling down behaviour, functionality of parallel cooling channels and local cryo-components
- electrical issues – cross-talk between live circuits, degradation of insulation resistance
- testing of new quench detectors and cabling
- testing of the slow control system

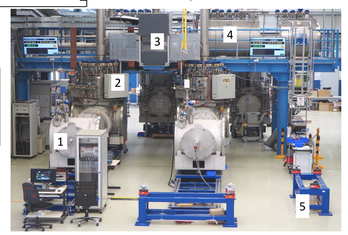
Arrangement of the string at the test facility



Infrastructure of the test facility
SIS100 components



Test benches for sc-magnets:
1- end box, 2 - feed box,
3 - distribution box, 4 - power switch,
5 - preparation bench



Start of the string assembly ~ March 2020

Simultaneously with the SIS100 String:
SAT for series dipole magnets (remaining 40 pieces) and
SAT FoS Quadrupole Doublet module will be performed.

Detailed information about SIS100 series dipole and FoS Quadrupole testing will be given in:

Thu-Af-Or22-06: Status of the SIS100 Dipole Magnet Production and Testing

Thu-Af-Or22-05: FAIR's first SIS100 Accelerator Quadrupole Doublet Module – Manufacturing Update and Test

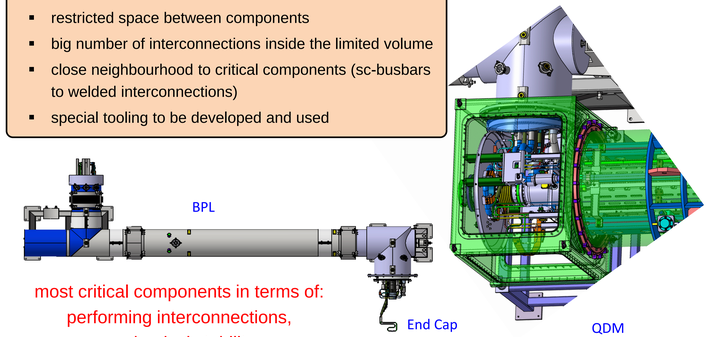
Challenges of interconnections between cryo components of the SIS100

Interconnection types:

- bolted (spec. KF, CF) for cryostat-cryostat and UHV components ~ 600 in SIS100 (for cryo-components)
- bolted for thermal shield – thermal shield interconnections ~ 400 in SIS100
- welded connections for LHe – process lines (up to 20 bar operational pressure) ~ 1300 in SIS100
- soldered – sc-joints for sc-busbars ~ 2200 in SIS100

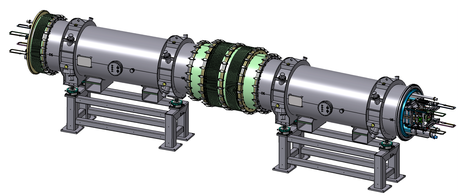
Challenges:

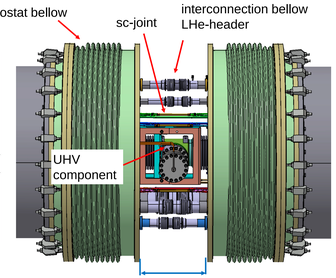
- restricted space between components
- big number of interconnections inside the limited volume
- close neighbourhood to critical components (sc-busbars to welded interconnections)
- special tooling to be developed and used



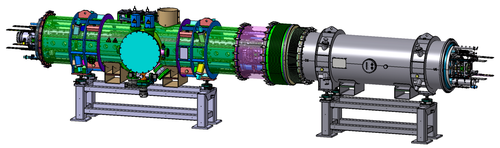
most critical components in terms of:
performing interconnections,
mechanical stability,
electrical cross talk

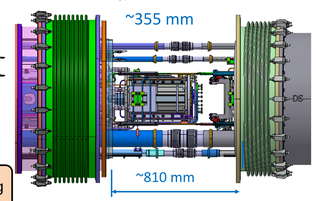
DM – DM interconnections





QDM – DM interconnections





Summary - The chosen configuration of the SIS100 string enables broad spectra of tests to verify important aspects for installation and operation of SIS100. Special attention will be brought to the functionality of the ultra-high vacuum system and its performance. Moreover, the quench detection system and the power converter control will be verified on the string. Besides the tests relevant to the SIS100 operation, the string will provide an ideal scenario to develop the processes for the future machine assembly, e.g. sc-circuits interconnection, process pipes welding.

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