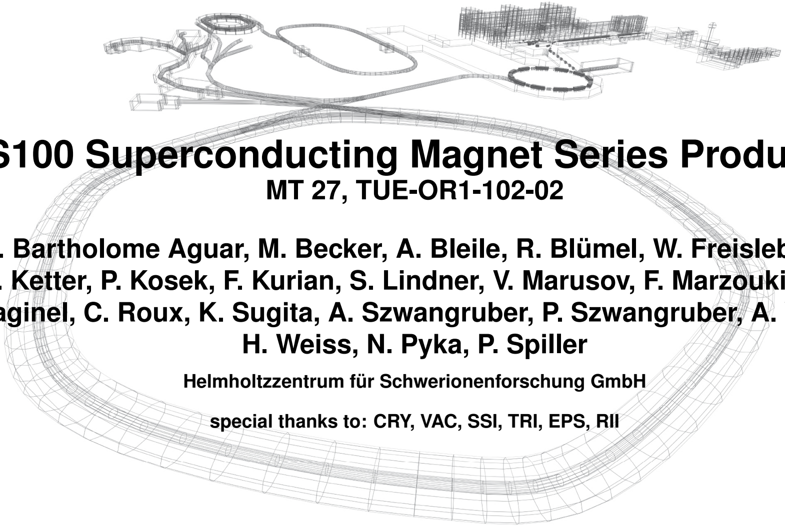


SIS100 Superconducting Magnet Series Production

MT 27, TUE-OR1-102-02

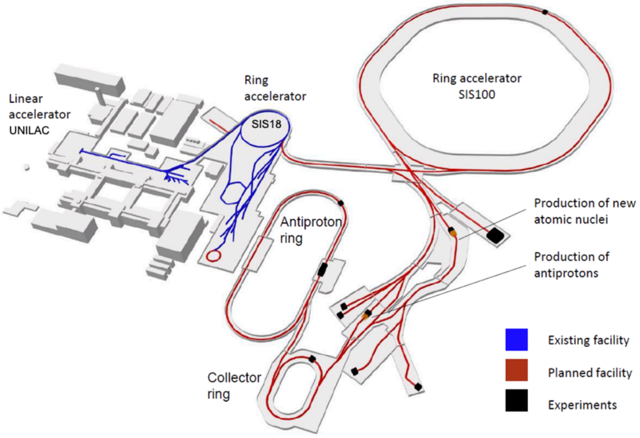
***T. Winkler*, P. Bartholome Aguar, M. Becker, A. Bleile, R. Blümel, W. Freisleben, M. Janke, F. Kaether, J. Ketter, P. Kosek, F. Kurian, S. Lindner, V. Marusov, F. Marzouki, J.P. Meier, S. Mohite, V. Raginel, C. Roux, K. Sugita, A. Szwangruber, P. Szwangruber, A. Waldt, A. Warth, H. Weiss, N. Pyka, P. Spiller**

Helmholtzzentrum für Schwerionenforschung GmbH

special thanks to: CRY, VAC, SSI, TRI, EPS, RII

Table of Contents

FAIR @ GSI



FAIR project member states

High intensity ion and antiproton beams for experiments in nuclear, atomic, plasma physics and material science.

Compared to the existing GSI facility

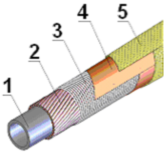
- Primary beam intensity: **x100**
- Secondary beam intensities: **x10000**
- Primary beam energies for U^{28+}: **x10**
- Antiproton production

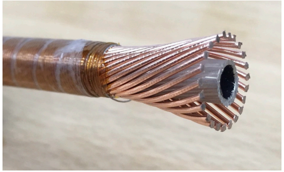
SIS100 Superconducting Magnets

SIS100 Magnet Types

In total SIS100 has 415 fast-ramped sc-magnets mounted in 193 modules. There are:

- 108 Dipole Modules
- 83 Quadrupole Doublet Modules
  - 83 Focusing Quadrupole
  - 83 Defocusing Quadrupole
  - 83 Nested Steerer
  - 42 Chromaticity Sextupole
  - 12 Multipole Corrector
  - 4 Low Current Quadrupole for injection and extraktion





SIS100 Cable

- 1 CuNi cooling tube
- 2 NbTi strand
- 3 CrNi wire
- 4 Kapton tape
- 5 Fibreglas tape

SIS100 Magnet Cooling

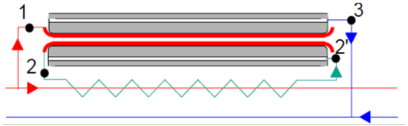
Helium Cooling Path

All magnets are connected in parallel to one supply line:

- 1 Helium is sub-cooled at Magnet entrance,
- 2 Helium exits coil in two-phase region,
- 2' Helium passes through recooler of supply line,
- 3 Helium exits the yoke.

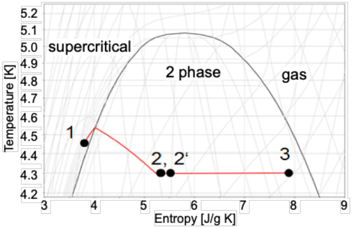
The beam pipe is cooled with a independent circuit, using a similar approach.

Magnet cooling and beam pipe cooling use the same common return line.



Cooling scheme of SIS100 dipole:

1 – coil inlet, 2 – coil outlet,
2´ – re-cooler outlet / yoke inlet, 3 – yoke outlet



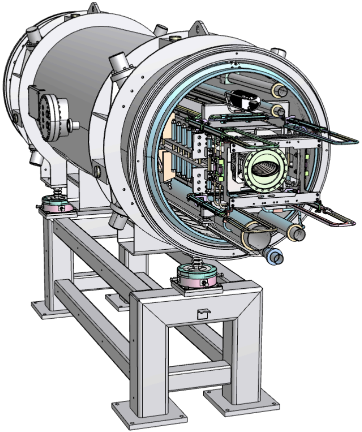
SIS100 Dipole Module Design and Production

Dipole Timeline

- First dipol delivered: Q3-2017
- Last dipol delivered: Q4-2020
- Last dipol tested: Q1-2021

SIS100 Dipol Functional Requirements

- B_{max} = 1.9 T
- $dB/dt = 4\,\mathrm{T\,s^{-1}}$
- $\Delta B/B < \pm 6$ units
- Bending angle $1\frac{1}{3}$ deg
- Magnetic length 3.062 m

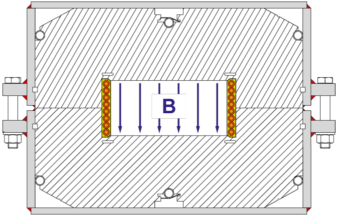


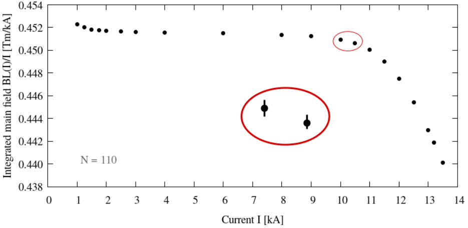
SIS100 Dipole Module Testing - Mechanical

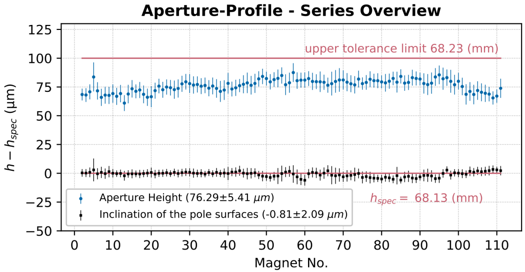
Dipol Gap Geometry

- Required precision: $68.13^{+0.10}_{-0.0}$ mm,
- Manufacturing precision well within specification,
- Tilt of pole shoes negligible.

$$B \approx \frac{IN\mu_0}{h}$$



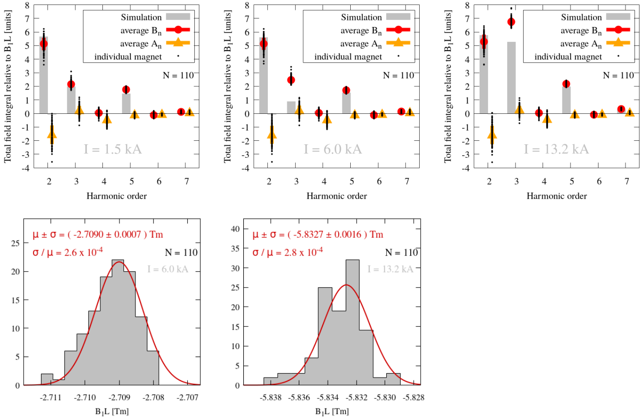




SIS100 Dipole Module Testing - Magnetic

Test Results

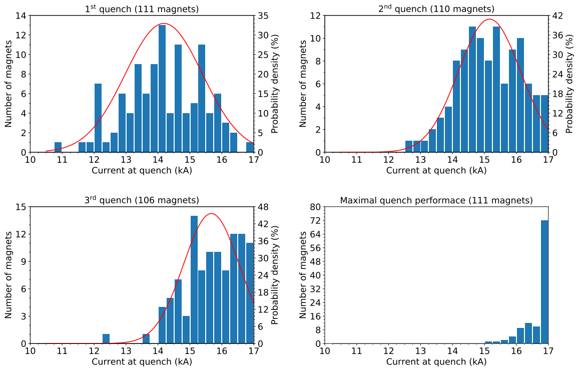
- Magnetic field data have been measured for all 110 dipoles
- Data shows good agreement with simulations, except for b_3 and a_2,
- b_3 and a_2 deviations are systematic and can be compensated,
- no need for magnet sorting for accelerator installation,
- Magnetic data used for beam dynamic model of SIS100.



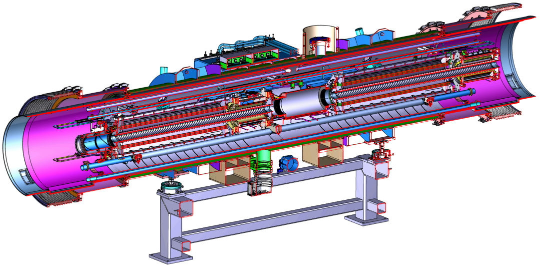
SIS100 Dipole Module Testing - Electrical

Quench Performance

- Excellent quench performance: 80%, 97%, 99% out of 111 tested magnets exceeded the I_n at the 1st, 2nd and 3rd training quench, respectively.
- 65% of all dipoles withstood an applied current of 16.9 kA without quenching,
- Very stable DC and AC (2-28 $kA\,s^{-1}$) operation of all tested dipoles.



SIS100 Quadrupole Doublet Module



SIS100 QP Unit Functional Requirements

- $B_{max} = 27.77\,\mathrm{T\,m^{-1}}$
- $dB/dt = 58\,\mathrm{T\,m^{-1}\,s^{-1}}$
- $\Delta B/B < \pm 6$ units
- Magnetic length 1.264 m

QDM Timeline

- FoS units delivered: Q3-18
- FoS module delivered: Q4-19
- Series production released: Q1-21
- 1st Module delivered: Q3-21
- End of module production: Q2-24

Delivery Status

- 18 QP-Units delivered
- 1 QDM delivered
- 2 more QDM in 21

SIS100 Quadrupole Doublet Module - Map

From Production to Installation

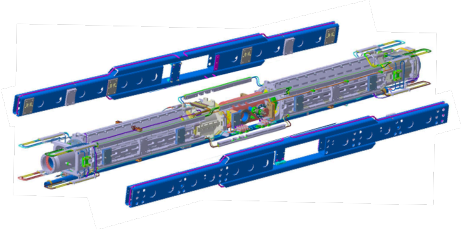
- QP unit production at JINR, Russia
- QP unit testing at JINR, Russia
- QDM integration at Bilfinger Noell, Germany
- QDM testing at INFN/Salerno
- QDM installation at GSI

Other Mayor Components

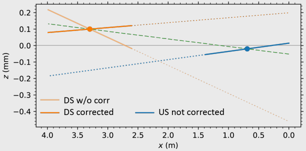
- Cryo Collimator from Pfeiffer, Germany
- Beam Pipe from Research Instruments, Germany
- Beam Position Monitor from Kyocera, Germany

SIS100 Quadrupole Unit Alignment

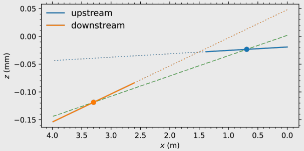
- One QDM contains two QP Units on one common girder,
- The two QP units can be adjusted independently in steps of 0.2 mrad for yaw and pitch;
- The common girder is positioned in the cryostat such that lateral translation errors are corrected.



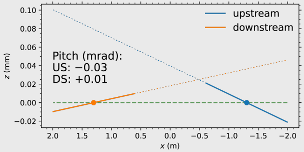
Calculation of ideal setup of shims.



Measurement mounted on girder



Calculcation of "best" girder positioning



Summary and Outlook

Summary

- All 108 dipole modules have been successfully manufactured and tested.
- The mechanical and electrical quality of the dipole modules is very good.
- Series production of quadrupole units is well under way.
- QDM series production has started and the first modules have been delivered.
- QP unit alignment on common girder is non-trivial, proof of principle successful

Outlook

- Current planning foresees the production of QDMs until Q2-24.
- Manufacturing rates of QDMs will have to increase considerably to meet this date.
- Logistics and timing around the QDM involves multiple partners and will be the challenge to solve.
- QDM test program has started and will be the final quality milestone.

Thank you very much for your attention!