

FROM DESIGN TOWARDS SERIES THE SUPERCONDUCTING MAGNETS FOR FAIR

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Abstract

The Facility for Anti-proton and Ion Research (FAIR-project) is now under construction. The heavy ion synchrotron SIS100 and the Super Fragment Separator (Super-FRS) use mainly superferric magnets as beam guiding elements. We present the design status of the magnets next to the experience obtained on the first magnets which were produced for SIS100. Finally we give an overview of the preparation for the series production and testing of the cryomagnetic modules.

INTRODUCTION

The Facility for Anti-proton and Ion Research (FAIR-project) is procuring and testing its components. A significant fraction of the total investment is given by the superconducting accelerator magnets. These amount to 613 magnets: 415 for the heavy ion synchrotron SIS100 and 198 for the Super Fragment Separator (Super-FRS, see Table 1).

The SIS100 dipoles are procured by GSI Helmholtzzentrum für Schwerionenforschung mbH (GSI) and produced by Babcock Noell GmbH. All other superconducting magnets for SIS100 are build by the Joint Institute for Nuclear research (JINR) together with its industrial partners.

Along with the SIS100 magnets, the Super-FRS magnets are being designed and procured. The Super-FRS multiplets are being produced by ASG superconductors (ASG) while the Super-FRS dipoles are foreseen to be produced by an industrial partner supervised by the collaboration partner CEA, Saclay.

Table 1: FAIR Superconducting Accelerator Magnets, sf... Super Ferric

SIS100			Super-FRS		
magnet	type	#	magnet	type	#
dip.	sf	108	dip.	sf	24
quad.	sf	166	quad.	sf	80
chr. sex.	sf	42	sex.	sf	80
steerer	cos ϑ	83	steerer	cos ϑ	14
multipole corr.	cos ϑ	12			
inj. / extr. quad.	sf	4			
total		415			198

SIS100 DIPOLE

The First of Series (FoS) SIS100 dipole, the first component of the first awarded contract of the FAIR accelerator

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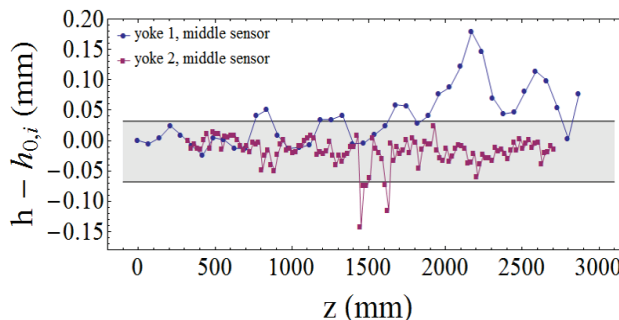


Figure 1: SIS100 dipole magnet gap height variation for the first and second yoke as measured along the transversal centre.

components, right from the beginning met the SIS100 machine requirements to a large extent [1], in particular:

- the first quench occurred close to nominal current, all other quenches were well above the nominal current; no significant detraining was observed between the different cycles.
- the AC losses were below the expected value, thus below 55 W for the triangular cycle ($B_{min} \rightarrow B_{max} \rightarrow B_{min}$ within 1 second; $B_{min} \approx 0.22 T$, $B_{max} \approx 1.9 T$).
- the high voltage of 3 kV has been achieved during the factory acceptance test.

Along all these tests, however, the field quality was found to be not quite matching the specification. Appropriate measurement systems based on tactile and capacitive sensors were developed [2], which allowed measuring the geometry of the magnet's coil position at room temperature and the magnets' gap at room temperature and at cryogenic temperatures. Here it was found that an improvement of the magnet's gap geometry should decrease the field deterioration to an acceptable level.

To achieve this goal the magnet yoke is now laser welded, a procedure optimized during a mock-up test. Furthermore the first magnet yoke had a gap at the back leg at room temperature, which should close during cool down. This gap was foreseen to compensate for the different contraction of the coil pack and the magnet yoke. Now the coil pack geometry was adapted in such a way that the magnet yoke can already be tightly closed at room temperature.

Based on these improvements a new magnet yoke was manufactured, whose geometry accuracy was significantly improved (see Fig. 1). During the associated cold tests a significantly reduced field deterioration were found; all

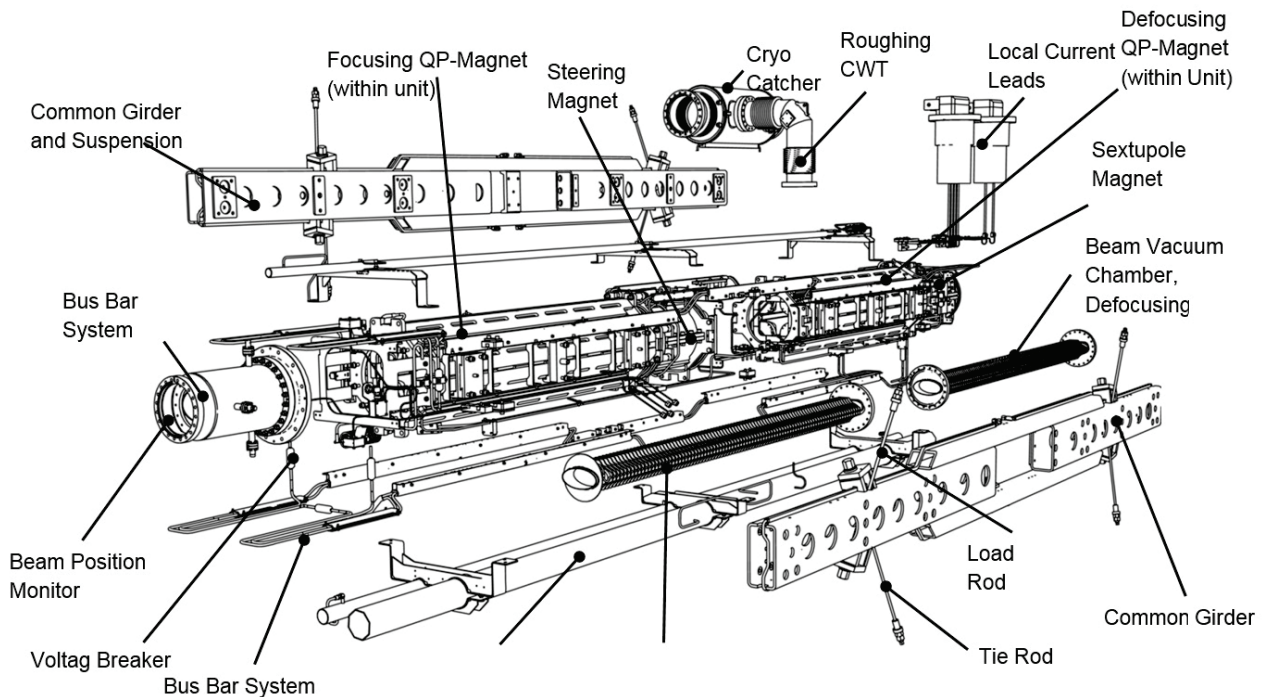


Figure 2: Components of the SIS100 quadrupole doublet cold mass.

other parameters met their previously achieved performance: e.g. the first quench occurred above nominal current and 16.07 kA have been reached ($\approx 90\%$ of short sample limit). Quench training has been stopped at this value as the magnet is now already required for providing a test bench for other components: e.g. magnetic field measurement systems commissioning and vacuum chamber tests.

Given the successful test of the SIS100 dipole magnet, some minor design adjustments are being discussed with the manufacturer and shall be soon agreed upon. Then the final design review for the SIS100 dipole series can be accepted. The remaining series magnets are then expected to be delivered by the end of the year.

SIS100 QUADRUPOLE UNITS

Except for the SIS100 main dipoles and the injection/extraction quadrupoles JINR is producing and testing all other superconducting SIS100 accelerator magnets namely, the main quadrupoles, chromaticity sextupoles, multipoles and steerers [3].

A SIS100 sextupole model magnet was built within a BMBF-JINR framework, which allowed a first test of a Nuclotron cable type with insulated strands; this test was passed successfully [4].

JINR has taken over the design made by GSI and adapted it to its internal production: i.e. the Nuclotron cable was changed from a dry to a wet technology. JINR has contracted two yoke manufacturers. Currently these are producing the lamination and then the first two yokes. First tests of these magnets are foreseen in Q1/2017.

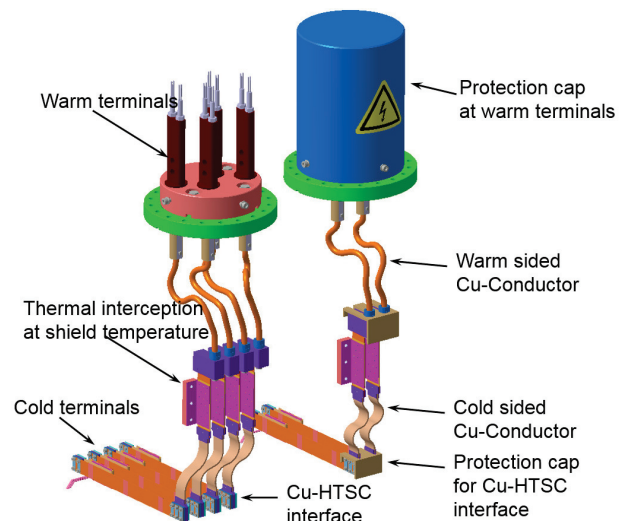


Figure 3: SIS100 local current leads.

SIS100 QUADRUPOLE DOUBLETS

All superconducting magnets, except the SIS100 dipole magnets, are installed in quadrupole doublet modules (QDM) (see Fig. 2 [3, 5]) together with the cryo collimators and beam position monitors. The different corrector magnets are individually powered at low currents (below 300 A). These are connected with low current HTS-current leads at dedicated ports of the SIS100 quadrupole doublets. Different test setups of HTS current leads were made and a suitable solution was found (see Fig. 3). It is made in such

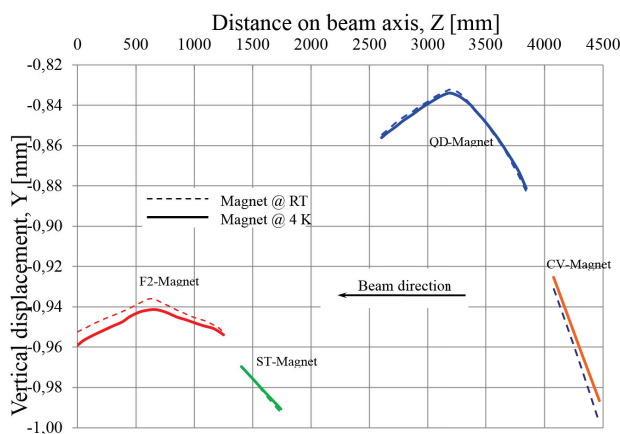


Figure 4: Expected magnet axes stability of the QDM during cool down.

a way that it can be easily assembled: Tests showed that a current of up to 250 A could be reached.

The magnet units are assembled on a common girder (see Fig. 2) and are cooled in parallel channels. The axes of the magnets is expected to change less than 0.01 mm during cool down (see Fig. 4 [5]). The tendering for the quadrupole doublet integration will be opened soon.

SUPER-FRS MAGNETS

The Super-FRS multiplet magnets have been awarded to ASG, who delved immediately into the magnetic and mechanical design. Here it was identified that the field quality of the main quadrupoles was difficult to reach, especially for the electrical steel available on the market. Here in collaboration a lamination design was found that is able to reach the field quality over the whole operation range.

Along to these improvements the overall mechanical and electrical design was made including the assembly of the overall units. Aside to that all different manufacturing and logistic issues are planned; including the transport to CERN for testing and then to GSI.

The dipoles are designed and now shall be tendered as soon as the collaboration with CEA Saclay is established.

TESTING

Testing the superconducting magnets is split up in three different sites [6]. GSI has started the built up of its series test facility (STF) including the cryo-infrastructure with 4 test benches, the power converters and the measurement systems. The cryo infrastructure is ready, the first power converter is functional and ready; the second power converter is currently being commissioned.

The first pair of HTS high current current leads has been delivered and tested [7]; a second pair has arrived and is being commissioned. Further quench detection systems from Karlsruhe Institute of Technology have been procured, tested and are being installed. Partly it was already used for the HTS current leads test.

Magnetic measurement will be based on a rotating coil probe shaft. Here a collaboration with CERN was established. CERN is producing the coil probes and coil probe shafts. GSI is procuring and assembling the micro rotation units, which have been designed by CERN.

The SIS100 quadrupole units will be tested by JINR. JINR has built up its tests station, which is shared between the FAIR and NICA projects. All three satellite refrigerators are being installed. Power converters and measurement systems follow. A first test for FAIR will be the second cold test of the SIS100 sextupole model magnet including magnetic measurement.

The Super-FRS magnet will be tested at CERN [8]. The test facility is currently being built up and will be commissioned by the end of this year. It will provide three different test benches which have to run in synchronised operation. Appropriate magnetic measurement systems have been developed [9].

CONCLUSION

The construction phase of the SIS100 accelerator for FAIR has started. The yoke production of the main dipole has been optimized and the magnet with the newly manufactured yoke has been tested; an improved yoke gap geometry along with an improved field quality was found. Its series production will be released soon.

The quadrupole units design has been finished and the manufacturing phase for the first of series magnets was started in 2015. As first corrector model magnet a chromaticity sextupole, using the low current Nuclotron cable with insulated strands, has been built and successfully tested. This validates the low current Nuclotron cable next to the corrector design and confirms that the design of the SIS100 corrector magnets is sound. Based on these achievements the production of the series magnets of the SIS100 quadrupole units at JINR/Dubna is planned for 2017. The integration work of the quadrupole units into cryogenic doublet modules will be tendered in 2016 and should start beginning of 2017.

The Super-FRS-Dipoles are currently redesigned and prepared for tendering by Irfu, CEA/Saclay. The Super-FRS Multiplet contract was awarded to ASG and the practical work is started.

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