SUPERCONDUCTING QUADRUPOLE MODULE SYSTEM FOR THE SIS100 SYNCHROTRON

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Abstract

The SIS100 heavy ion synchrotron, the core machine of the FAIR complex, uses fast ramped superconducting magnets. As for its ancestor, the Nuclotron operational at JINR Dubna since 1993, its superconducting magnets are based on iron dominated design and coils made of Nuclotron type cables. The SIS100 magnets differ from the Nuclotron magnets in the following points: they are longer, the beam aperture was enlarged and the field quality improved, its AC losses reduced. The coils have a lower hydraulic resistance and the operation current is doubled. These achievements were obtained in a R&D collaboration between JINR and GSI. Now in the realisation phase GSI will procure and test the SIS100 dipole magnets, while JINR together with GSI will finalise the design of the quadrupoles units (consisting of one quadrupole and one corrector), procure, test and assemble them into doublets. We report on the status of the project, the scheme of the JINR-GSI collaboration for developing and manufacturing the SIS100 quadrupole modules and the steps required to achieve the start of the series production.

INTRODUCTION

SIS100 is following the design of the Nuclotron, but its circumference was increased by a factor of about 4 that had several implications: the dipole magnet length was increased by a factor of about 2, the aperture was increased and a continuous triangular cycle demanded. Even though the AC losses occurring in the magnet were reduced by making a smaller end coil loop, replacing the ferritic brackets with a stainless steel version, which acted as a flux short path and thus created large losses, while the former two parts reduced the eddy currents and thus the AC losses due to the longitudinal B_z field component matching the original set target of 30% total loss reduction, the cable had to be redesigned to adjust the hydraulic resistance for the larger magnet, which now will provide ample cooling margin for the SIS100 magnets [1, 2]. This approach was then picked up for the NICA Booster and collider magnets [3] based on the common R&D conducted from 2002 until now. Further the field quality of the magnets was improved [4, 5, 6].

All that common interactions just naturally lead that GSI is now producing the SIS100 dipoles and JINR the quadrupole units of the SIS100 machine.

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THE SIS100 MAIN MAGNETS

The redesigned Nuclotron cable, necessitated by the cryogenic losses of the SIS100 dipole, is now also used for the quadrupole (see Fig. 1), which allows introducing the

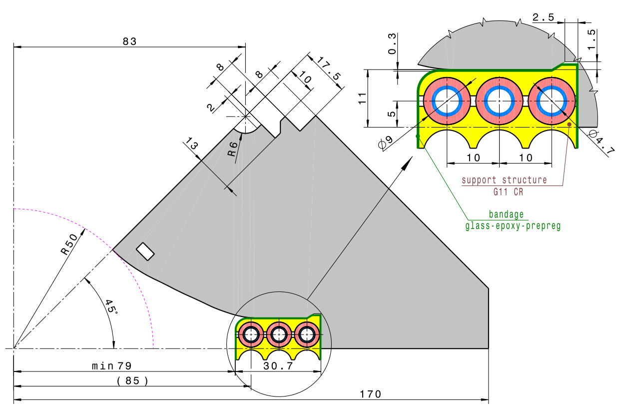

Figure 1: The 3-turn quadrupole magnet lamination design.

reinforcement coil support structure similar to the dipole and reusing the same components for the cable itself, the bus bars, the voltage breakers, soldering joints and current leads. Further low current quadrupoles are required for the extraction and injection section, which now can be produced using the same magnet yoke but using an adjusted low current Nuclotron type cable; the same as foreseen for the correctors. The 3 turn quadrupole design reduces further the types of various utilities as only one type of HTS current leads is required and only one type of bus bars and voltage breakers in the dipoles, quadrupole doublets, bypass lines, feed in lines, superconducting links, current lead boxes. Quench measurements of the dipole can be directly used for the quadrupole and only one single type of high current superconducting joints is needed.

QUADRUPOLE UNITS

The quadrupole units consist of a quadrupole on which one or two corrector magnets or a beam position monitor are mounted.

The corrector magnets are requested to be operated with low current (< 300 A) in order to reduce the heat leak from the copper current lead pair as each magnet is powered individually. Taking into account the advantage of Nuclotron type cables for fast ramped magnets, this design was adopted with individually insulated superconducting

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strands, as shown in Fig. 2. After the coil winding the stands are connected in series and the first and last of these strands are connected to the current lead pair.

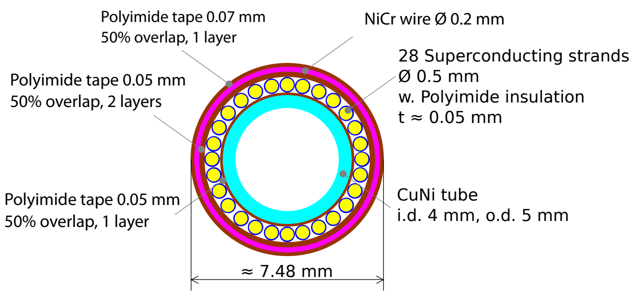

Figure 2: The cable of the corrector magnets.

The steering magnet (Fig. 3(a)), which contains a vertical and a horizontal dipole coil, and the multipole corrector magnet (Fig. 3(b)), which contains a quadrupole, a sextupole and a octupole coil, are designed as $\cos\theta$ type magnet. The chromaticity sextupole magnet (Fig. 3(c)) is a superferric type. As first pre-series corrector the chromaticity sextupole magnet is being built in collaboration between GSI and JINR. GSI has made the conceptual detailed magnet design and JINR finalised the iron lamination shape and manufactured the yoke (Fig. 4). The final design of the coil was made by GSI and the manufacturing will be completed, tested and assembled by JINR. This magnet will be integrated into the first quadrupole unit and then assembled into the first quadrupole doublet.

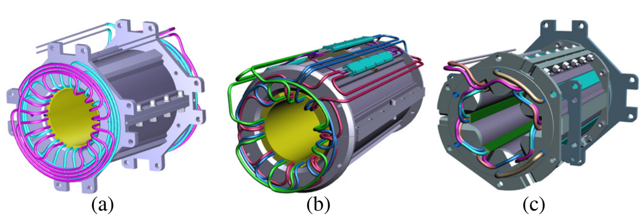

Figure 3: Sketch of the different corrector magnets: a. . . steerer, b. . . multipole corrector, c. . . chromaticity sextupole.

In parallel the design of the cable for the correctors is further improved. A substitute of the CrNi wire is investigated (e.g. Kevlar or carbon tape), which is considered to be less likely to break the insulation of the strands than the hard metal CrNi wire.

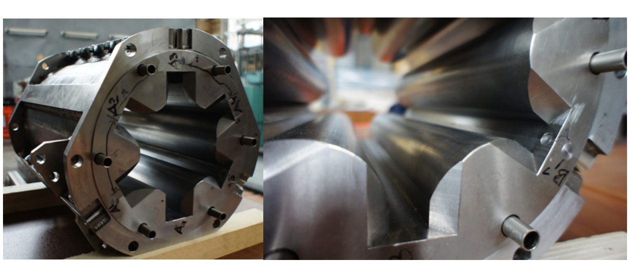

Figure 4: The sextupole yoke.

The quadrupole magnets and corrector magnets are mounted as one common magnetic and hydraulic unit. The different unit types are listed in Table 1. One of the units is displayed in Fig. 5.

Table 1: The different quadrupole units. QD. . . defocusing quadrupole; QF1. . . focusing quadrupole, family 1; QF2. . . focusing quadrupole, family 2; CH. . . horizontal chromaticity sextupole; CV. . . vertical chromaticity sextupole; ST. . . steering dipole; BPM. . . beam position monitor. ←. . . upstream →. . . downstream

type	quantity	contents	position
1	12	QD	←
2	23	QD +BPM	←
3	24	BPM+ QD	←
4	24	CV + QD	←
5	6	ST +QF1	→
6	17	ST +QF2	→
7	18	ST +QF1+BPM	→
8	18	ST +QF2+BPM	→
9	12	ST +QF1+ CH	→
10	12	ST +QF1+ CH	→

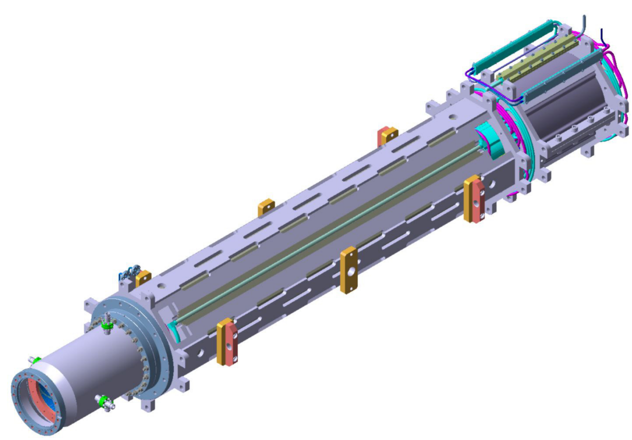

Figure 5: One of the quadrupole units consisting of a BPM (on the left), a quadrupole (in the middle) and a steerer.

QUADRUPOLE CRYOMODULES

The SIS100 machine is based on a doublet lattice using the main bending dipoles as spectrometers to deflect any wrong ions on a cryo collimator positioned between the two quadrupoles. Thus two quadrupole units (see also Table 1), which consist of one focusing and one defocusing quadrupole with a corrector, steerer, or beam position monitor mounted on them, and a cryocollimator are assembled to one doublet (see Figure 6). Further at the beginning and the end of the arc a multipole corrector magnet is mounted in the (nearly) dispersion free area. This assembled com-

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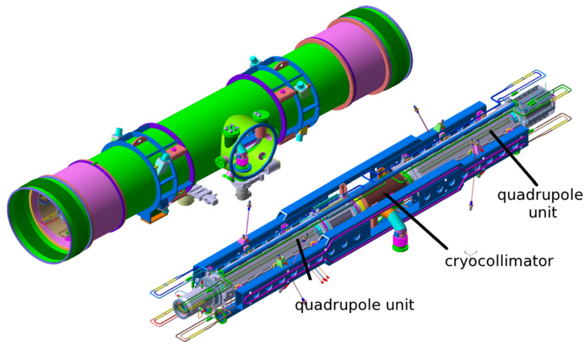

Figure 6: The doublet cryostat (above) and all the components mounted on the common girder.

plex is then inserted in the cryostat. This doublet design has been developed by GSI. Breakage of the cryostat vacuum is an incident which needs to be foreseen in the design of cryo components; thus such a test will be performed with the prototype doublet in Dubna. A failure of this test can be remedied reverting to single units as already used at the Nuclotron.

PROCUREMENT AND TESTING

The doublet is manufactured in the following way:

- the quadrupoles with their corrector magnets are manufactured and these units are tested at cold including the measurement of the magnetic field, its axis and homogeneity. These work packages are executed at JINR. This cold test at this stage is mandatory as the full aperture of the magnets is not accesible after the vacuum chamber has been installed.
- After warm up the vacuum chambers are installed into the unit and the end flange welded on them. If required a BPM is installed on the quadrupole magnet.
- All components are mounted on a common girder and their mutual alignment checked.
- Finally the girder and the thermal shield are mounted inside the cryostat and aligned in the module.

At last this module is made ready for shipping.

Collaboration GSI–JINR for FAIR

The fabrication and testing of these modules will be a collaboration effort (see Table 2). Components manufactured by GSI and its subcontractors and components manufactured by JINR and its subcontractors will finally be integrated at JINR and shipped to GSI as a major contribution of the biggest German partner in the FAIR project. This collaboration also shares the manufacturing responsibility: JINR for the units and the components of the module, GSI for the vacuum chambers, cryo-collimators and beam position monitors; GSI for the doublet functionality, module safety and integration concept. JINR has started with the preparation of a hall.

Table 2: The quadrupole module components and their delivery.

GSI	JINR
doublet design	cables
wires	quadrupoles
vacuum chambers	chromaticity sextupoles
cryo-collimators	steerers
beam position monitors	multipoles
voltage breakers	girders
doublet warm test	unit testing
magnetic measurement consulting	integration and assembly of the doublet

In this hall the test benches capable of testing SIS100 and NICA magnets will be installed. Given the similarity of the magnets the infrastructure of the hall will be shared between the two projects.

CONCLUSION

The SIS100 is now in the procurement phase with the start of the dipole series production. The integration of the already designed modules is now detailed. The quadrupole and corrector magnets will follow swiftly in a joint GSI-JINR collaboration starting 2013. The design of the doublets is being made by GSI. The units (quadrupole plus associated correctors) will be manufactured and tested by JINR. Finally the doublets will be assembled at JINR and shipped to GSI ready for installation following the joint proposal which was accepted by the FAIR council.

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