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STATUS OF THE QUADRUPOLE DOUBLET MODULE SERIES MANUFACTURING

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Abstract

The 83 Quadrupole Doublet Modules (QDM) for the heavy-ion-synchrotron SIS100 of the FAIR project at GSI are highly integrated cryogenic modules containing multiple magnets. Each of eleven different QDM types consists of two units, where one unit consists of one quadrupole magnet as well as corrector magnets depending on the modules position in the accelerator Ion-Optical Lattice. Additionally, the QDMs contain cryogenic collimators, beam diagnostics, as well as cryogenic UHV beam pipes.

The modules contain parts from multiple suppliers increasing the logistics behinds the QDMs design further. We present the process of the module integration, give details on the current integration status and present an outlook on the timeline for the QDM integration planning.

FAIR

The Facility for Anti-Proton and Ion Research (FAIR) [1] is currently under construction at the site of GSI in Darmstadt, Germany. The facility will provide the possibility for research in the areas for experiments in nuclear, atomic, plasma physics as well as for material science activities.

The main work horse of the new research centre will be the heavy-ion synchrotron SIS100 with a maximum beam rigidity of 100 Tm. The accelerator will complement the existing accelerator installations at GSI, namely the SIS18 and the UNILAC.

SIS100 will improve the beam intensity up to a factor 100 over the existing infrastructure. It has a six-fold symmetric design, where each of the six sectors consists of a cold arc with superconducting magnets and a warm straight section with cold quadrupole doublet modules placed at defined distances according to the IOL.

QUADRUPOLE-UNIT

The cold arc has a regular cell layout with a sequence of dipole – dipole – quadrupole defocusing – quadrupole focusing. In SIS100 each QuadruPole-Unit (QP-Unit) is designed with one or two more devices attached to it.

The devices that can mounted either upstream of downstream of the main quadrupole can be, Fig. 1:

- a chromaticity sextupole (either vertical or horizontal),
- a combined nested steerer (horizontal and vertical),
- a multipole corrector magnet,
- special magnets such as gamma-t-jump quadrupole or low current quadrupoles
- beam position monitor

In total there are 17 different QP-unit types to be combined into 11 different QDMs types necessary for SIS100 to fulfil all requirements.

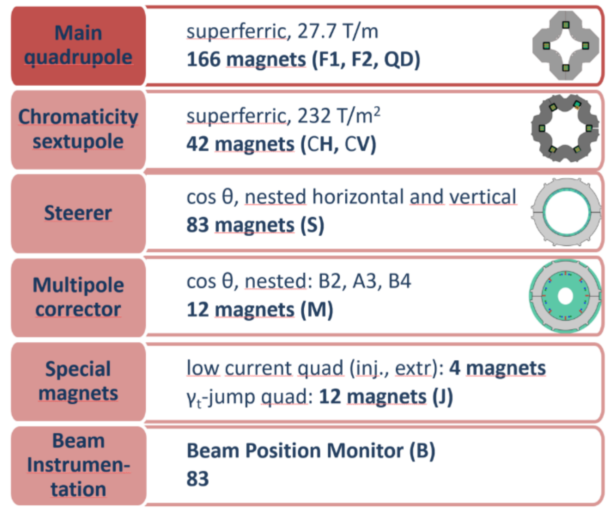

Figure 1: List of magnet types and devices.

QUADRUPOLE DOUBLET MODULE

The ion-optical lattice of SIS100 works with very small spaces between different modules, a feature that is enabled by the compact design of the QDMs [2-4]. Each QDM consists of two QP-Units, which are mounted on a common girder, with the beam chamber inserted in the QP-Unit. Between two units either a cryo-catcher or a drift tube is mounted. This position is also used in some modules to provide either roughing vacuum pumping possibilities or additional cryo-pumping capabilities on top of the cryo-pumping capabilities of the beam chamber to enable the ultra-high vacuum necessary for the operation of SIS100.

The different QDM types can be separated into four families depending on their position in SIS100 ion-optical lattice.

- Arc section modules
- Arc termination modules
- Straight section modules
- Special modules

The difference between the QDM types can be found in the cryostat and the helium supply connections.

The arc modules have a cryostat, open along the beam axis and are supplied with helium along the beam axis.

The arc termination modules have an open cryostat on one side, where the arc connects, on the other side an endcap is mounted where the helium supply is diverted towards the outside of the SIS100 ring, where the by-pass line connects to it.

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The straight section modules have closed form and have warm beam pipe connections on both sides. Helium is supplied by the by-pass line, which connects from the ring outside to the module.

There are two special modules in SIS100, one for the injection and one for the extraction. These modules have two additional quadrupole magnets for the injection and extraction, respectively. These modules are placed on the two arc ends of sector 5.

QDM MANUFACTURING CHAIN

Figure 2: Map for the QDM production.

The in-kind character of FAIR can be seen very well when plotting the travel of the different QDM parts on a map, see Fig. 2.

QP-Unit Production

The QP-unit production is an in-kind contribution from Russia to FAIR. The Joint Institute for Nuclear Research in Dubna, Russia, is producing the QP-units, and has subcontracted the yoke production to a company in Belarus. After manufacturing the QP-units, they are cold tested at JINR. The scope of these tests is to guarantee the full functionality of the QP-units before they are sent to Germany.

QDM Integration

The next steps are taking place at the facilities of Bilfinger Noell GmbH in Würzburg, Germany. The integrator is taking two QP-units and assembles the cold mass before integrating into the cryostat.

Besides the two QP-units, the cold mass of a QDM consist of other components which are procured by GSI and then supplied to the integrator for further assembly. The components supplied by GSI are the beam chamber, the cryo-catcher, beam position monitors, local current leads for the corrector magnets, cryo-sorption pumps and a roughing cold-warm-transition for the beam vacuum.

The integrator is procuring multiple additional parts, such as the common girder, the thermal shield and the cryostat and for the arc module also the telescopic connection bellows.

Alignment

One of the most critical steps in the integration is the alignment of the magnetic axes of the two QP-units and the alignment of the cold mass in the cryostat.

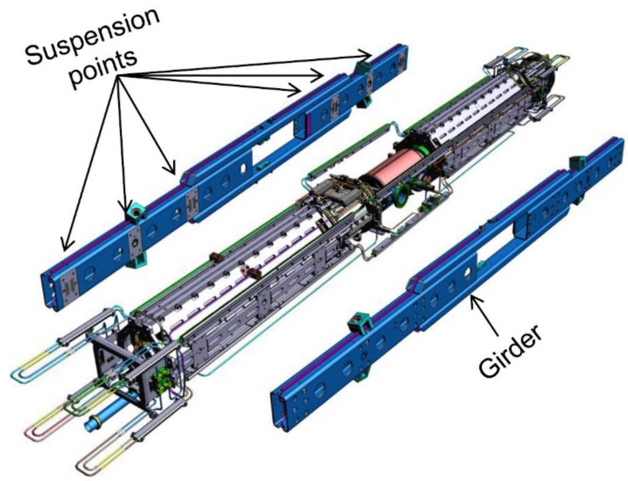

Figure 3: Alignment scheme for the QDM.

For the alignment of the two QP-units a special mounting system has been devised, such that deviations from the ideal axis can be compensated and the magnetic axes of the two QP-unis can be aligned, see Fig. 3. Each unit has 6 mounting points, placed in pairs along the beam axis. On the central mounting points, a ball plate and spacers can be mounted, on the other four mounting points, a dovetail joint together with angular plates and spacers is used.

With this system the following alignment performance can be achieved:

- 0.1 mm for translation
- 0.2 mrad for yaw
- 0.2 mrad for pitch
- 0.2 mrad for roll

This alignment system has the advantage that it allows for a very compact design with the least amount of mechanical connections from room temperature to low temperature, while still having the possibility to align the QP-units, at the cost of an increased difficulty to change the alignment after the integration.

QDM Testing

After successful integration of a module the factory acceptance tests take place to verify the room temperature properties of the module. A passed factory acceptance tests allows the shipment of the module to INFN Salerno in Italy, where the cold tests of the integrated module take place. This site acceptance test verifies the cryogenic properties of the module.

When passing the site acceptance tests the module is qualified for installation into the SIS100 tunnel at FAIR.

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The integration sequence allows for parallel work on the cold mass and the cryostat before the two parts are integrated together.

MANUFACTURING PLAN

The series integration of the QDM has started in January 2021 and the first series module will be delivered in June 2021. It is planned to start with the integration of the arc modules, followed by the arc termination modules. The last modules to be manufactured are the straight section modules. The integration of the special modules will be started at the same time as the arc termination modules but take longer due to the increased complexity of these two modules.

After a short learning curve the integration time per module is planned to be 6-8 weeks. The integration planning calls for a manufacturing rate of 3 Modules per month and allows for the SIS100 to be commissioned in 2025.

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