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STATUS OF THE FAIR HEAVY ION SYNCHROTRON PROJECT SIS100

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Abstract

SIS100 is the main accelerator of the FAIR project. It is a worldwide unique heavy ion synchrotron dedicated to accelerate highest intensities of intermediate charge state heavy ion- and proton beams up to 100 Tm. From the technical point of view, most challenging issues are the fast ramped superconducting magnets and the acceleration of intense, intermediate charge state heavy ions beams. The latter required a unique lattice design (charge separator lattice) in combination with an ultra-high vacuum system based on distributed cryo-pumping with actively cooled magnet chambers, adsorption pumps and dedicated cryo-catchers for local suppression of gas desorption [1].

PROCUREMENT STATUS

The year 2014 was very much focused on completing, reviewing and finishing specifications and drawings for all kind of components. Finally, at the end of 2014, all contracts for the most demanding SIS100 components, the large series of superconducting magnets and RF systems, have been closed, which marks a major milestone in the project execution. This milestone corresponds to a bound value of about 50% of the SIS100 cost-book value. The last large in-kind contract regarding the quadrupole unit production has been successfully negotiated and closed with the Joint Institute for Nuclear Research (JINR, Dubna, Russia) and signed by the JINR, GSI and FAIR management at an official ceremony at JINR at 2015/02/20. This contract is accompanied by a number of contracts between GSI and JINR on quality assurance and magnet testing. Besides the major series with long production times, many other components have been tendered or contracted, e.g. the injection kicker system, the resonance sextupole magnets (awarded to DANFYSIK, Denmark) and the cryo-catcher system. The local cryogenics system will be delivered by the Wroclaw University of Technology (WrUT, Poland). The manufacturing design review for the first bypass line segment has been passed. The manufacturing design and preparation has been approved and the contract for the production of the bypass line has been awarded to the company KRIOSYSTEM, Poland.

BUILDING PLANNING

Detailed planning for the accelerator tunnel and the supply area (K0923A/T110) complex, including 3D DMU models of the accelerator and its technical infrastructure, has matured and is transitioning to execution planning, which will take place in 2015, see Figure 1. This will allow the finalization of the necessary building tendering documents and the start of the excavation in late 2015.

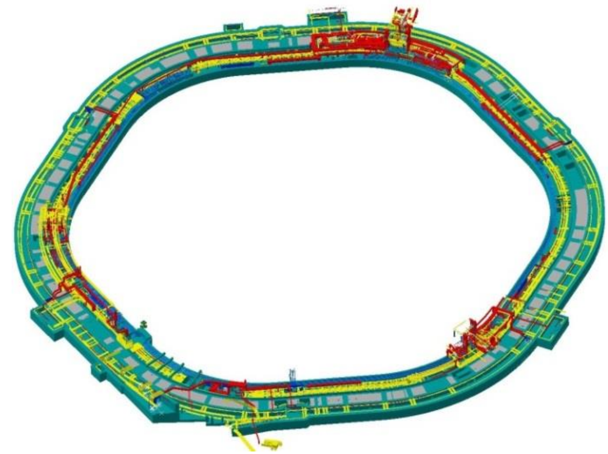

Figure 1: Design of T110, including the accelerator tunnel (outer tunnel) and the parallel supply tunnel (inner tunnel) with cable trays (yellow), cooling water supply lines (blue) and venting (red).

PROGRESS ON COMPONENT TENDERING AND DELIVERY

The first of the 109 superferric, 1.9 T dipole series magnets (FoS) [2] has already been delivered in June 2013 (Figure 2) and thoroughly tested under warm and cryogenic conditions. Although, the FoS dipole magnet has different to the previous prototype magnets, a completely new coil design and is operated at twice the electrical current, the quench training showed excellent behaviour. Nevertheless, the desired high beam currents allow only minimum mechanical errors in the series production of the yoke. Therefore, together with the manufacturer and the support by external experts, the production and welding process has been review and optimized. Meanwhile, significant progress in minimizing the deformation of the half yoke (before assembly) could be demonstrated by using a robot based laser welding. A new, mechanically further improved FoS yoke, providing the confidence in a high mechanical reproducibility of the series, will be produced and delivered until Q3/2015. In the frame of the side acceptance test of the FoS dipole, a number of precision measurement devices and technique could be developed, e.g. for high precision measurement of the inner magnet aperture (height, parallelism of pole surfaces, sag etc.), such that it will be able to release the

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series production after a shortened acceptance period. The FoS thin wall, actively cooled dipole vacuum chamber has been delivered by the company PINK and tested at warm and cold conditions. The manufacturing has been done with excellent results and the specified UHV properties were achieved. However, the cryogenic pumping properties of the He-cooling circuit, has to be improved. The cryo-pumping of the chambers is mandatory in order to minimize ionization beam loss at operation with low charge state heavy ions. Therefore, various new technologies are presently investigated to further improve the heat transfer between the cooling pipes and the chamber surface.

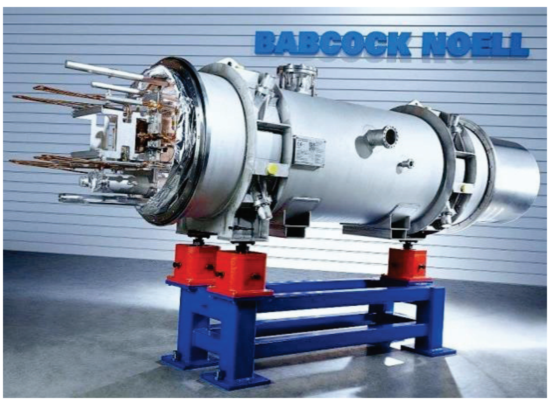

Figure 2: First of series (FoS) fast ramped, superferric SIS100 dipole magnet.

The s.c. quadrupole modules (83 pcs, see Figure 3) are technically and from the management point of view very demanding. On one side the different modules have a complex engineering design which is developed in collaboration with an industrial partner. Hereby, a design reference completed at GSI is being used as reference. On the other hand due to the international structure of FAIR, different parties (situated in different countries) are involved in the manufacturing and testing of the subcomponents and the modules as a whole. The quadrupole units (quadrupole magnet + corrector magnets) will be built at JINR, Dubna, whereas other components (vacuum chambers, cryo-catcher, BPM's, local current leads) are tendered by GSI. The integration of all components, including the manufacturing of all mechanical components, e.g. the common girder, the thermal shield and the cryostat will also be tendered by GSI. Whereas it is presently considered to perform the cold testing of the integrated module in Salerno, Italy. Currently, 80% of the specification work for the quadrupole units (quadrupole plus corrector magnet) and all manufacturing drawings for the quadrupole module type 2.5 FoS units are finished and are finally reviewed at JINR; the remaining 20% will be done when the external (industrialized) design work has been completed. The yoke steel (323 t in total) has been ordered at C.D. Wälzholz, Germany and the first lot will be delivered to JINR 04/2015. According to the present schedule, two FoS quadrupole units will be produced until the end of 2015. A critical item which has not been addressed so far is related to the design of the corrector magnets. The design is based on a new type of Nuclotron cable with insulated strands. The properties, especially the cooling at high ramp rates within the insulated strand Nuclotron cable has never been tested before. A first prototype sextupole magnet equipped with such a new cable, has been developed and build from BMBF collaboration funds, and will be tested for the first time in May 2015.

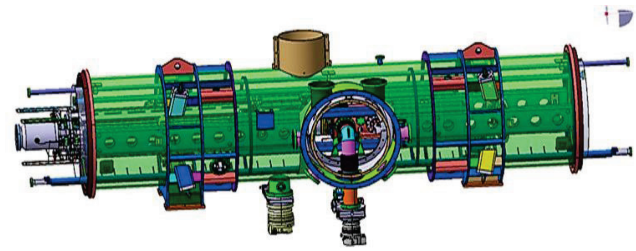
Figure 3: Manufacturing design of the quadrupole module type 2.5.

To suppress dynamics vacuum effects, each arc module is equipped with a cryogenic ion catcher. The cryocatcher tendering is nearly completed, bids do exist and the first round of negotiations with the bidders has started. Finally, smaller standardized components like voltage breakers and temperature sensors for the full quadrupole module series have been ordered by GSI in 2014, too.

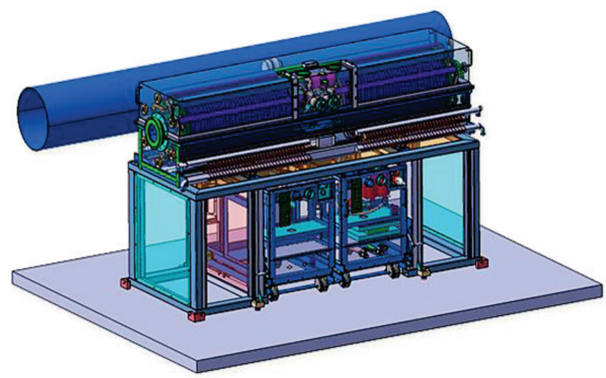
Figure 4: GSI design of the ferrite loaded acceleration cavity.

The RF acceleration system (14 pcs, 1.1...3.2 MHz, 20 kV, 30 kW beam power, see Figure 4 has been tendered by the FAIR GmbH and awarded to a consortium of RI(research instruments) and AMPEGON in 11/2014. The preparation of the manufacturing concept is currently done by the consortium. The conceptual design review (CDR) will take place Q1/2015. Driver amplifier, racks and LLRF procurements have been started at GSI. Furthermore, RI has meanwhile ordered the most critical components, the ferrite cores at Ferroxcube. In parallel to the acceleration cavities, the RF bunch compression system (9 pcs) has been tendered by GSI and awarded to the company AURION in 04/2014. The conceptual design review has meanwhile been successfully concluded. As last step before the start of production a final design review (FDR) is foreseen, which will take place in 03/2015 - the 1st device will be

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delivered in 07/2015. The technology of the SIS100 bunch compression cavities is based on the technology of the SIS18 bunch compression cavity [3] (see Figure 5). Both cavities contain MA (magnetic alloy) ring cores made from an amorphous magnetic alloy as inductive load. In this respect, the FAIR SIS100 project strongly benefits from the R&D conducted at GSI over the last decade on magnetic alloy materials and cavities.

Figure 5: SIS18 MA loaded bunch compression cavity.

The system design, including the integrated DMU drawings of the SIS100 injection straight section (sector 6) has been completed (see figure 6); as a result, the tendering of the injection kicker system (6 modules, 130 ns rise time, 7.5 mrad deflection angle) could be started. The procurement of the two magnetic injection septa will follow in Q2/2015.

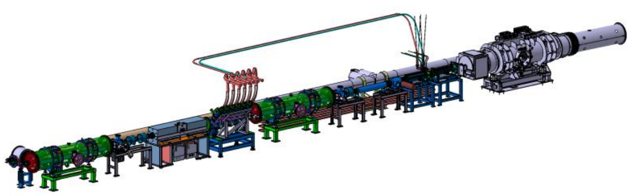

Figure 6: Layout of the SIS100 injection straight.

Most demanding from the point of mechanical engineering has been the design of the cryogenic injection- and extraction modules, comprising two lattice quadrupole magnets and two special quadrupoles for matching the injected beam. An end box, closing both ends of each of the six arcs, is linking the arc module to the bypass line. The bypass line is bridging the warm accelerator components in the straights and supplying the stand alone quadrupole modules in the straight. While the end box is designed at GSI, all local cryogenics components, including bypass lines, feed boxes and current lead boxes are designed at WRUT (Wroclaw University of Technology).

TEST FACILITIES FOR S.C. MAGNETS

In 2014, the existing prototype test facility (PTF) has been equipped with all missing infrastructure, e.g. 13 kA HTS current leads, new power converter, etc. to upgrade it for testing of the FoS dipole magnet. Furthermore, various devices for the qualification of the magnetic field have been developed, manufactured and used (e.g. warm and cold rotating coil probes, inductive coil probe assemblies, hall probe mappers). Cold rotating coils, meeting the requirements for precision measurements in curved magnets, are currently designed and built in collaboration with CERN. An in-kind contract has been closed with the Gdansk University of Technology (GUT) on the design and production of electrical integrity measurement equipment. For the series dipole magnet test facility (STF), a dedicated building has been constructed at GSI (Bldg. SH5). The cryogenic system, including feed boxes and test benches has been commissioned successfully (see Figure 7). The power converter for ramping the s.c. dipole magnets with 29 kA/s will be delivered in 04/2015.

Figure 7: Test facility for series dipole magnets at GSI.

The quadrupole unit testing will be performed at JINR, Dubna [4]. Here, an R&D contract between GSI and JINR has been closed in 12/2013. The cryo-plant at JINR has already been commissioned; measurement equipment will be designed by JINR in parallel to the construction of the first quadrupole units. Cold test of the full series of integrated quadrupole modules are considered to be important. Therefore, testing these modules at a magnet test facility in Salerno, Italy has been verified from the engineering point of view and considered as valuable. A common proposal between GSI and INFN has been set-up and is presently under approval. A reduced string-test is foreseen and will comprise two dipoles, one quadrupole module, the cryogenic bypass line, feedbox and current lead box. The space is preserved at the STF and the layout has been completed.

ACKNOWLEDGMENT

We are appreciating the joint, friendly and successful collaboration with all our international and industrial partners and would like to express our gratitude and thank all of them.

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