UPDATE ON THE FAIR MACHINE INSTALLATION STATUS

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Abstract

The accelerator complex for the Facility for Antiproton and Ion Research (FAIR) is currently being built in Darmstadt, Germany. After the arrival of the cold box for the central cryogenic facility (CRYO2) in winter 2023, the installation of the accelerator components in the machine and supply tunnels started early 2024. Meanwhile the installation has moved forward. CRYO2 has been handed over to the commissioning team and the commissioning is in progress. The accelerator installation is ongoing in all parts of the beamlines of the High Energy Beam Transfer Lines (HEBT), the Super Fragment Separator (SFRS) and the Heavy Ion Synchrotron (SIS100). In parallel, the installation plans for the experiments (NUSTAR and CBM) are being developed and installation preparations are taking place. In this paper the status and challenges of the machine installation in those areas are presented and an outlook for the next steps towards realisation of the project phases for Early and First Science is given.

THE FAIR ACCELERATOR COMPLEX

The new Facility for Antiproton and Ion Research (FAIR) will consist of five main machines, the fast ramping heavy ion synchrotron SIS100 and the Super Fragment Seperator (SFRS), which are both designed based on superconducting magnets, and two storage rings, the collector ring (CR) and the high energy storage ring (HESR). The beam transfer between each of those machines is realised with a complex of normal conducting lines, the high energy beam transfer system (HEBT). The excisting accelerators from the GSI Helmholtz Centre for Heavy Ion Research (GSI) will serve as the injector for FAIR. In addition, a new high intensity proton linear accelerator is planned for injection into the GSI synchrotron SIS18.

Based on the beam from GSI and the five new machines, FAIR will allow researchers to perform a program of experiments with a unique range of ion types, extraction cycles and intensities. The main user collaborations with long term experimental installations at FAIR are NUSTAR, CBM, APPA and PANDA. Their research program as well as the key parameter of the FAIR machines are presented in [1] and [2].

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The realisation of the FAIR complex has been split into several stages, which are highlighted in Fig. 1. The building construction for the first stage First Science + is completed already, technical infrastructure installation is ongoing.

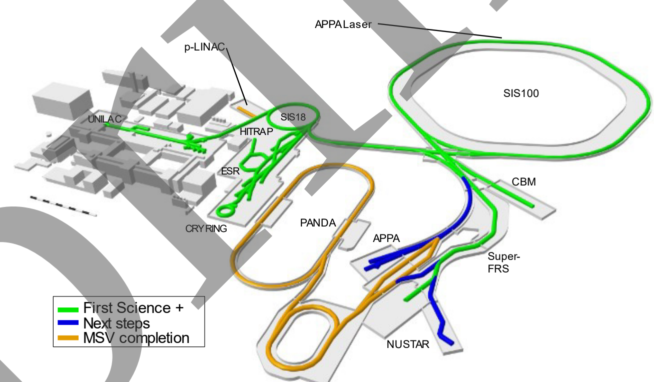

Figure 1: The GSI and FAIR facility with its stages of realisation [3].

MACHINE INSTALLATION AT FAIR

The machine installation activities are part of the FAIR sub-project "Site Management" (SMG) as shown in Fig. 2.

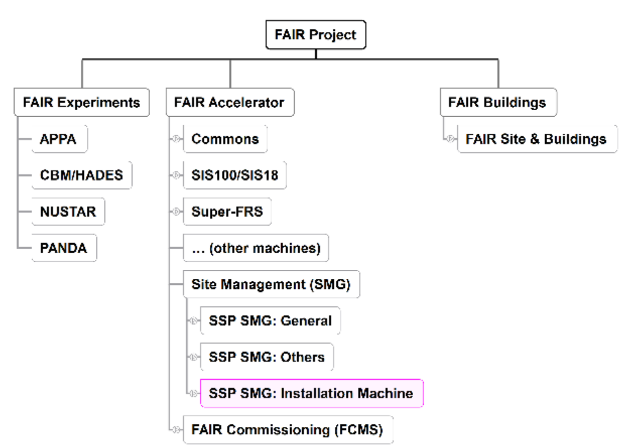

Figure 2: The machine installation within the FAIR project structure.

The machine installation project has been established with the mandate to support the machines and experiments in the pre-assembly and installation phase with a central team, managing the activities on the FAIR construction site and in the pre-assembly area at GSI. The focus (see Fig. 3) is set on the four topics of

- work execution, including work preparation and documentation,
- project management, including registration for access on site, resource management and more
- machine functionality, representing the responsibility of the machine subprojects in the installation and involving quality control
- and area coordination for the various active teams in the machine installation and the interface to the building and infrastructure responsibles.

For execution of the work, GSI personnel as well as external companies, collaboration partners (like IFJ PAN) and temporary workers have to be integrated in the processes on site.

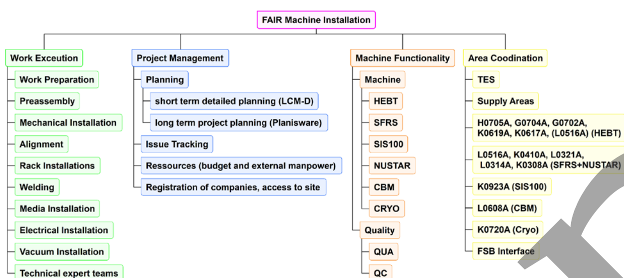

Figure 3: Fields of activities in the machine installation subproject.

The Workflow

The start and end of the machine installation in a certain area are evaluated in dedicated reviews. For each section of a machine or beamline the described process as shown in Fig. 4 is followed in parallel for the supply and beamline section.

In the installation readiness review a committee including the machine responsible, quality control, safety and the SMG team asses the presented state of work preparation. Checked is the readiness of

- the hardware - acceptance tests, open non-conformities,
- the technical documentation – drawings, electrical documentation, risk analysis, manuals and others,
- the work preparation – work instructions, hazard analysis, availability of material, transport paths and work space, time plans and definition of the scope of work,
- the status of the work area – infrastructure status, open works, cleanliness.

Prior to this review the work preparation team supports the executing groups and machine responsibles in the collection and development of all required instructions and material, which are summarized in so called "work binders".

During the installation, the progress is tracked constantly with respect to the full scope of work to reach the completion of machine installation. Generally, this includes all mechanical work and welding, vacuum closure and leak tests, connection and testing of media like cooling water and pressured air, electrical installations of cables and the grounding system, final completion of components and the connection to the cryogenic distribution. No power tests are planned within the installation, those are defined as the first step of commissioning. Feedback about the finished work is collected by filling the work binders and regular quality inspections are scheduled in the installation areas.

After the works are completed the installation documentation is finalized with reports, as-build information, remaining task and an overview of non-conformities. This set serves as an input for the commissioning team to prepare the next project phase.

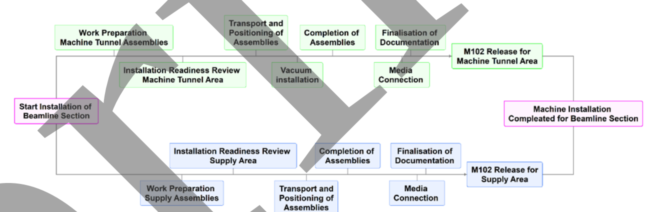

Figure 4: Overview of the installation process.

STATUS OF THE MACHINES

Currently the installation of the accelerator components is ongoing in the SFRS and SIS100, as well as in the beam transfer lines from GSI SIS18 to SFRS. Activities for the experiment installations in NUSTAR and the beam injection and extraction lines to and from SIS100 are about to start.

HEBT

The first section of the HEBT beamlines (see Fig. 5) is planned to be finished next month (June 2026). It is the connection to the extraction system of the GSI synchrotron SIS18.

Figure 5: HEBT beam transfer section close to the connection to GSI.

In this area, the installation management was challenging due to the location in the interface of both institutes GSI and FAIR. On the technical side, the transport of the beam line components across the building joint between the existing GSI building and the new FAIR transfer tunnel required the use of special hydraulic lifting tools (see Fig. 6), which have proven to be a well working solution.

Figure 6: Hydraulic transport system for lifting the beamline components over the building joint.

In the further sections of the transfer line the dependencies between the different installation stages and the interconnection of machines, which are located in separate buildings will define the main challenges. Fig. 7 gives an impression of the system of beam transfer lines in the so-called crossing building. In this area the bypass from GSI directly to SFRS, the injection into SIS100 and the extractions from SIS100 to SFRS or CBM as well as the corresponding beam dumps are located. The extraction line towards SFRS will be installed on a frame structure, which covers a hight difference of 7,5 m with an incline of 6,7° and a weight of about 20 t.

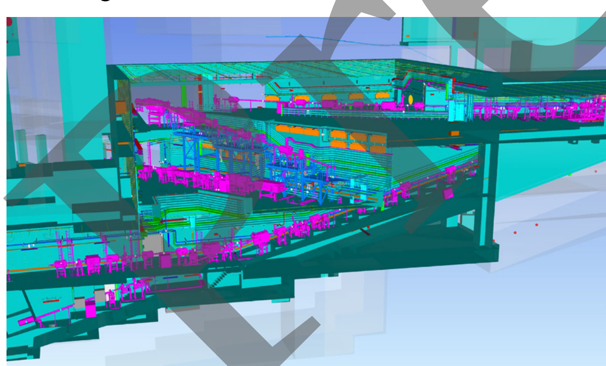

Figure 7: 3-D model view of the beam transfer lines in the crossing building.

SFRS and NUSTAR

The SFRS [4, 5] is spilt into three main installation areas, which are the pre-target, the target and the post-target area.

In the pre-target area, the installation of the local cryogenic distribution system is finished and the superconducting multiplets with a weight of approx. 60 t are transported with air cushions, positioned and connected to the cryogenic supply (see Fig. 8). The media and supply area installation continues in order to allow to run a first cold test in this area next year (2027).

Figure 8: View of the SFRS pre-target area.

In parallel, the installation of the target area components starts with the placement of the target chamber. As shown in Fig. 9, the installation space within the iron shielding is extremely tight. At the 90 t normal conducting dipole, the free space right and left of the magnet is approx.3-4 cm. To support the positioning of the beamline components in this area, positioning pins have been placed in the floor.

Another challenge is the vacuum closure by pillow seals forcing requirements for the cleanliness of the area, which are challenging in the construction surrounding.

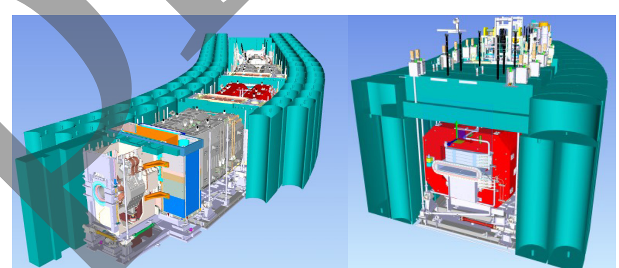

Figure 9: 3-D model view of the SFRS target area. Left: section view of the iron shielded area. Right: cross section at the 90 t normal conducting dipole.

The beam line structure of the post-target area basically follows the principle of the pre-target section. The first branch to be installed will be the branch towards the NUSTAR high energy cave. The vacuum chamber of the GLAD magnet of NUSTAR will be the first component transported into the cave this summer. For training reasons, lifting tests have been performed with this chamber recently (see Fig. 10).

SIS100 and CBM

The installation activities in SIS100 [6] can be spilt into the works in the arcs with the superconducting magnets and the straights with the superconducting quadrupoles and the warm sections with normal conducting magnets, RF systems, vacuum and beam diagnostic installations. A special installation to be mentioned is the laser cooling system in straight 3, which will be the first of its kind [7].

Figure 10: Lifting test of the GLAD vacuum chamber.

Meanwhile a great fraction of the SC dipoles is placed in the arcs and works on the interconnections are ongoing. Warm components have been placed in three of the five straights with the next one about to start. Straight 5 needs to stay clear to allow space for the installation of the extraction line. Transport of the first superconducting quadrupoles into the tunnel is planned for autumn this year (2026).

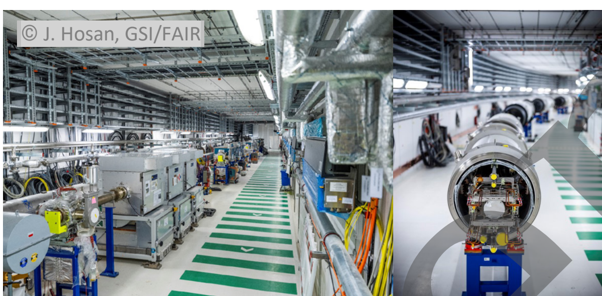

Figure 11: Views of the SIS100 beamline in a straight section (left) and an arc (right).

Additionally, the installation of the supply areas is well advanced. First power tests of the mains power supply planned for summer 2026.

Figure 11: Power supplies of the RF acceleration system in SIS100.

In terms of equipment installation, the transport of components with both large physical dimensions (for example the up to 13 m long cryogenic bypass line in Fig. 12) and heavy weight (23 t HEBT dipole) alongside the already placed components requires major planning efforts. For welding in the interconnections of the superconducting dipoles, welding tools have been modified to fit between the process pipes in the GSI workshop (in collaboration with the industrial provider) to allow orbital welding this tight space.

Further details about the status of the SIS100 installation are presented in [8].

Figure 12: Lifting of a 13 m long section of the cryogenic bypass line connecting the cryogenic components across the warm sections.

The work preparation for the CBM [9] experiment components has started just recently. The aim is to be prepared for a start of installation as soon as possible.

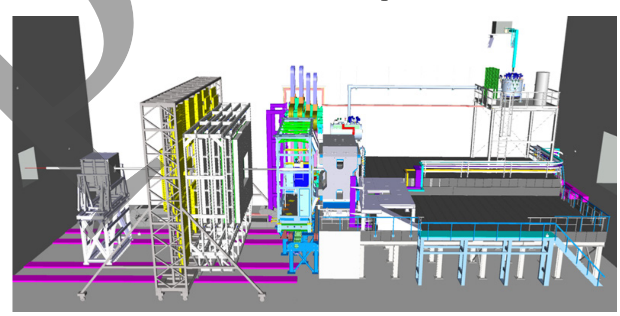

Figure 11: 3D model view of the planned set-up in the CBM cave.

SUMMARY

The activities for the installation of the accelerator and the experimental components of the FAIR complex have taken a great step within the last year. Installation is ongoing in all major parts of the machines and the first placement of experiment components is about to happen.

The project team is following a challenging schedule with the aim to allow start of beam line commissioning in June 2026 and gradually complete the installations for the beamline towards the NUSTAR high energy cave during 2027.

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