# FAIR SIS100 – FEATURES AND STATUS OF REALISATION

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*Abstract*

SIS100 is a unique heavy ion synchrotron designed for the generation of high intensity heavy ion and Proton beams. New features and solutions are implemented to enable operation with intermediate charge state heavy ions and to minimize ionization beam loss driven by collisions with the residual gas. SIS100 aims for new frontiers and world-wide leading Uranium bam intensities. Most specific feature is the huge effort taken to stabilize the dynamics of the residual gas pressure and to suppress ion induced desorption. Fast ramped superconducting magnets have been developed and are in production with highest precision in engineering and field quality, matching the requirements from beams with high intrinsic space charge. A powerful equipment with Rf stations for fast acceleration, pre- and final compression, for the generation of barrier buckets and provision of longitudinal feedback shall allow a flexible handling of the ion bunches and matching to the user requirements.

## SIS18 – UPGRADE AND BOOSTER OPERATION

In order to prepare the existing heavy ion synchrotron SIS18 for the operation as fast cycling SIS100 injector, a technical upgrade has been conducted and almost completed. This upgrade program has been defined in the early project phase of FAIR [1]. It follows a recipe developed by GSI, to control the dynamic residual gas pressure during beam operation and involves almost all major technical subsystems [2]. Most of the upgrade program has been successfully implemented through the last decade. The still missing technical items will be completed in the course of 2017. This involves a) the completion of the new dipole power converter for fast, high precision, ramping with a ramp rate of 10 T/s, b) the commissioning of two of the three new MA (magnetic alloy) acceleration cavities, c) the manufacturing and installation of the IPM (ionization beam profile monitor) system and d) the manufacturing and installation of a new large bipolar dipole magnet for linking the existing facilities to the transfer line to SIS100. Part of the upgrade program, was a major effort to provide enhanced distributed pumping power in SIS18. In order to achieve this goal, all magnet chambers have been NEG coated and the bake-out system has been upgraded for temperatures up to 300 °C. In spite of the significantly enhanced pumping power, simulations on the dynamic vacuum evolution at high repetition rates do still indicate significant beam loss due to projectile ionization. Therefore, new options for further enhancing the distributed pumping, especially for the heaviest residual gas particles are under investigations. A study has been launched on integrating cryopanels into the room temperature vacuum chambers including possible supply scenarios. Cryogenic surfaces provide strong pumping power for heavy residual gas particles which determine the total cross sections for charge exchange processes. Since SIS18 will also be the driver for an important experimental program in the FAIR phase 0 further technical improvements, machine developments and maintenance measures are continuously conducted in parallel to the booster upgrade. E.g. a new high harmonic cavity is under preparation for smoothing the micro spill structure of slowly extracted beams [3].

## LINK EXISTING FACILITY – CIVIL CONSTRUCTION

Figure 1: To enhance the radiation shielding, the soil layer on the SIS18 tunnel is presently being enhanced.

In order to finalize the SIS18upgrade program and to enable the execution of major civil construction measures, the machine operation has been interrupted in 2017. To cope for the operation with significantly increased average beam intensities, beside the machine upgrade, the SIS18 tunnel construction is presently receiving a major modification. The corresponding civil construction project has been launched at the end of 2016 and shall be completed in January 2018. The project involves a) an enhancement of the soil shielding on top of the SIS18 tunnel, requiring a support structure to

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cover the additional load, b) a radioactive air management system, c) a fire protection system based on Nitrogen flooding, d) a reinforcement wall at the Northern arc of SIS18 and e) opening and modification of the Eastern building wall in the experimental hall, generating the interface to the FAIR tunnel 101. The underground pillars acting as foundation for the table are presently constructed (Fig. 1).

In order to serve the FAIR pulse power requirements, which are mainly determined by the operation of the two synchrotrons SIS18 and SIS100, a new transformer station is presently being setup. Although the operation of SIS18 requires a pulse power of 50 MW and SIS100 25 MW respectively, with the new transformer station, no further compensation measures for undesired reactions to the power grid are required. The new transformer station will be completed and commissioned beginning of 2018.

## SIS100 STATUS

Major progress has been achieved in contracting of new components for SIS100 and developing FOS (First of Series) devices towards readiness for series-production. After the successful manufacturing and cold testing of the FOS superconducting dipole magnet, the series production of 110 magnets has been released. The manufacturer, BNG, has just completed its move of the production line to a new dedicated building and released the series production of the steel for the yokes and the superconducting coils. Starting from August 2017, one s.c. dipole magnet will be delivered per week to GSI for cold testing. Therefore, the set-up of the team for series testing of the dipole magnets over the three years production time is presently a major issue. The manufacturing of the superconducting quadruple magnets in Dubna has progressed towards two integrated units, consisting of two quadruple magnets, a steerer and a sextupole magnet. In parallel, the preparation for cold testing of these units is progressing. The set-up of the dedicated NICA-FAIR superconducting magnet test facility could be completed end of November 2016. The commissioning of the test facility has been celebrated as an official ceremonial act. The production chain of superconducting units at JINR and the manufacturing and integration of the corresponding quadrupole modules is the critical path in the SIS100 schedule. Therefore, a major focus over the last year has been set onto the completion of the design of the cryogenic quadrupole modules and the preparation of the tendering for module production and integration. The design of the quadruple modules has been conducted together with industrial partners. The tendering of manufacturing and integration, which is one of the biggest technical efforts for the FAIR accelerators, could be launched recently. In parallel, possibilities for cold testing of the integrated modules have been evaluated. The status of design and manufacturing of the radiofrequency systems, used for acceleration and compression of the beam has been progressed well. After successful completion and testing of the FOS bunch compression cavity by the company AURION, the series production of the remaining eight cavities has been launched. In parallel, the company RI (Research Instruments) could complete the design and manufacturing of the FOS acceleration cavity. The cavity receives presently an intensive FAT (Factory Acceptance Test) including ramping with typical machine cycles (see Fig. 2). The nominal Rf gap voltage of 20 kV has already been achieved.

Figure 2: First of Series (FOS) SIS100 acceleration cavity at factory acceptance test at Research Instruments.

The procurement of several other SIS100 components has been launched. The goal is to complete the procurement according to functional sections. All major components of the injection system, the injections kicker modules and the injection septum magnets have been tendered and awarded. As next large system, the components of the extraction system shall be procured, starting with the electrostatic extraction septum in summer 2017. The so called local cryogenics system is one of the most complex and unique technical systems of SIS100. Especially the bypass lines, bridging the warm sections of SIS100, are demanding and differ from conventional cryogenic transfer lines by the integrated superconducting bus bar system. A FOS bypass line has been manufactured and delivered by the Wroclaw University of Technology as Polish in-kind contribution. Although the FOS bypass line has been accepted, the internal design had to be further improved for series production. The tendering process for the series production of the bypass lines has been launched by WUST (Wroclaw University of Science and Technology). In parallel to the bypass lines, the design of the overall local cryogenics system, including the end boxes, current feed boxes and feed-in boxes is progress very efficient. The local cryogenics system components are as well critical items in the overall SIS100 project schedule.

## THE DIFFERENCE TO PROTON SYNCHROTRONS

The desired operation with high intensity intermediate charge state heavy ions is the driver for significant technical differences between SIS100 and typical Proton synchrotrons. In order to enable such an operation, at first a new lattice structure had to be introduced. The SIS100 lattice has been optimized with respect to the distribution of projectiles lost after ionization by collisions with residual gas atoms. The so called charge separator lattice [4] provides 100% efficiency


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for an implemented ion catcher system. The specially developed, cryogenic ion catchers [5], which are installed at the major loss positions in the middle of the arc modules, dump ionized beam particles in a controlled manner. The goal is to minimize gas desorption and to inhibit desorbed gas from interaction with the revolving beam. In order to make use of extensive cryopumping, SIS100 has become a superconducting synchrotron. Besides the magnets itself, all magnet chambers are actively cooled by LHe. This generates surface temperatures of less than 15 K and builds up a system of powerful distributed pumps for heavy residual gas atoms and molecules. In addition, to provide sufficient pumping power for light atoms, e.g. for H and He, a large number of cryosorption pumps is foreseen.

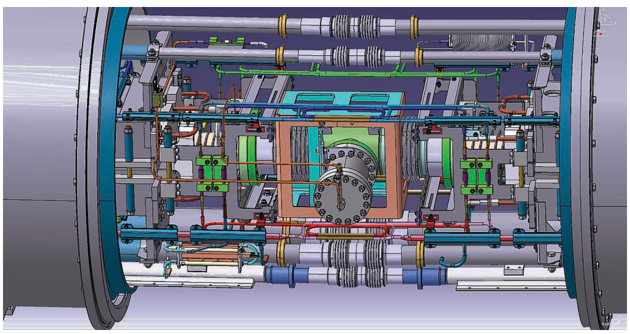

Figure 3: Cryosorption pump installed inbetween two dipole magnets.

The cryosorption pumps are installed between all dipole pairs (Fig. 3) and in the straight section quadrupole modules. Since the magnet chambers are inductively heated by the magnet cycle, the surface temperatures varies between 8 and 15 K and may exceed the temperatures of the adsorption isotherms for an effective condensation of light residual gas atoms. The surface temperature of the cryocatcher chambers however, is constant and sufficiently low. Together with the cryosorption pumps, a reliable system for powerful pumping for light atoms is build up. In case of any release of cryosorped light particles from the magnet chambers, a redistribution takes place from a) the dipole chamber to the cryosorption pumps and b) from the quadrupole chambers to the cryocatcher surfaces (Fig. 4). This may appear after reaching a high surface coverage in combination with inductive chamber heating.

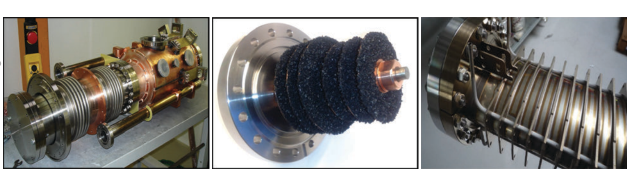

Figure 4: Cryogenic pumping of the UHV system in SIS100. Left a cryocatcher, in the middle a cryosorption pump and right a cryogenic magnet chamber.

The cooling circuit for the beam vacuum chamber, the cryosorption pumps and the cryocatchers are supplied by a separate auxiliary supply header (Fig. 5). This system can be switched off independently from the magnet cooling circuit. Thereby, in case of saturation, bound particles can be released from the surface and full pumping power can be recreated.

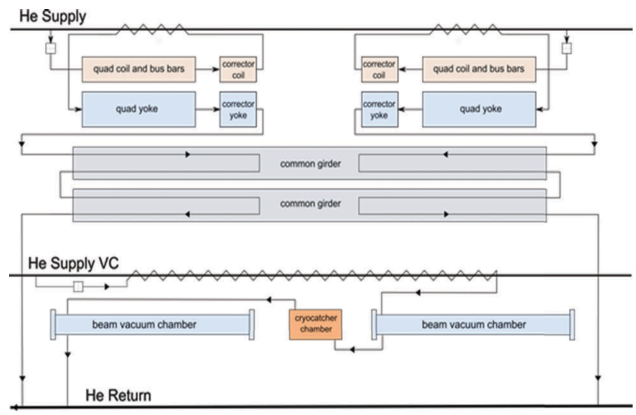


Figure 5: The cooling of the cryogenic UHV pumping system is provided by an independent supply header.

By means of a dedicated test stand, the pumping properties of cryogenic surfaces have been studied extensively [6]. Sticking coefficients and sojourn time of light atoms on cryogenics surfaces have been measured at different temperatures and surface coverages. The results were implemented in the STRAHLSIM code and have been used for more precise predictions on ionization beam loss and dynamic vacuum. The cryogenic pumping in the cold section is supported by a system of powerful conventional pumps combined with NEG coating and NEG panels in the straight room temperature sections.

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