ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEOBA01

STATUS OF THE FAIR SYNCHROTRON PROJECTS SIS18 AND SIS100

P. J. Spiller, R. Balss, A. Bleile, L. Bozyk, J. V. Ceballos, T. Eisel, E. Fischer, P. Forck, P. Hülsmann, M. Kauschke, O. Kester, P. Kowina, H. Kollmus, H. Klingbeil, A. Krämer, H. G. König, J. P. Meier, A. Mierau, C. Omet, D. Ondreka, N. Pyka, H. Ramakers, P. Schnizer, H. Welker and S. Wilfert, GSI, Darmstadt, Germany
D. Urner, FAIR, Darmstadt, Germany
H. G. Khodzibagiyan, JINR, Dubna, Russia
A. Illuk , WRUT, Wrocław, Poland

Abstract

A large fraction of the program to upgrade the existing heavy ion synchrotron SIS18 as injector for the FAIR synchrotron SIS100 has been successfully completed. With the achieved technical status, a major increase of the accelerated number of heavy ions could be reached. The now available performance especially demonstrates the feasibility of high intensity beams of medium charge state heavy ions with a sufficient control of the dynamic vacuum and connected charge exchange loss. Two further upgrade measures, the installation of additional magnetic alloy (MA) acceleration cavities and the exchange of the main dipole power converter, are presently being implemented. For the FAIR synchrotron SIS100, the procurement of all major components with long production times has been started. With the delivery and testing of several pre-series components, the phase of outstanding technical reserach and developments could be completed and the readiness for series production achieved.

SIS18 UPGRADE STATUS

UNILAC and SIS18 will serve as injectors for the new FAIR heavy ion synchrotron SIS100. To reach the desired performance and to assure long term availability, both accelerators require an extended upgrade. Major parts of the well-defined upgrade program for SIS18 have already been implemented. To accommodate dynamic vacuum effects, each magnet chamber and several standard beam pipes have been NEG coated. In addition, NEG panels have been installed in the injection- and extraction devices. Ion catchers with low desorption yield have been developed and are now used to suppress pressure bumps generated at the impact of stripped beam ions. A new injection system running at almost 250 kV was designed and manufactured to boost the injection energy for medium charge state heavy ions to 11.4 MeV/u. During the long shut down in 2013, all correction coils have been equipped with bipolar power converters and the first of three new MA Rf acceleration systems has been installed (figure 1). Beginning of 2014, the new MA Rf cavity has been commissioned and the full performance with a maximum gap voltage of 16 kV over the frequency range of 0.4 – 2.7 MHz has been reached. In the last machine development runs, all FAIR relevant Rf manipulations were demonstrated. The experiments have been conducted under control of the new LSA based set-value generation software. In the final stage, three of the new MA Rf acceleration cavities are required for the

- acceleration of the medium charge state, heavy ion U^{28+} with a ramp rate of 10 T/s,
- preparation of the SIS18 bunches for the transfer into the SIS100 buckets and
- generation of flat bunch profiles in a dual harmonic operation.

Figure 1: The first of three new MA acceleration cavities installed and commissioned in SIS18.

The last main upgrade measure, the replacement of the existing dipole power converters for fast ramping with 19 kA/s to 3.5 kA has been awarded to industry. Meanwhile, the first delivery of the new dipole power converter, a new power grid filter has been installed (Figure 2).

Figure 2: New power grid filter for SIS18.

The set-up of the power converter will be continued end of 2014 and completed in 2016. With the completion of a large fraction of the SIS18 upgrade program, major

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEOBA01

improvements have be achieved at the operation with medium charge state heavy ions. The operation with intense medium charge state heavy ions is one of the most challenging accelerator issues of the FAIR project. Since the first experiments in 2001, where more than 90 % of the beam has been lost within a few hundred milliseconds, the number of extracted ions could be enhances by three orders of magnitude. Figure 3 shows the development of beam intensity over the last decade [1].

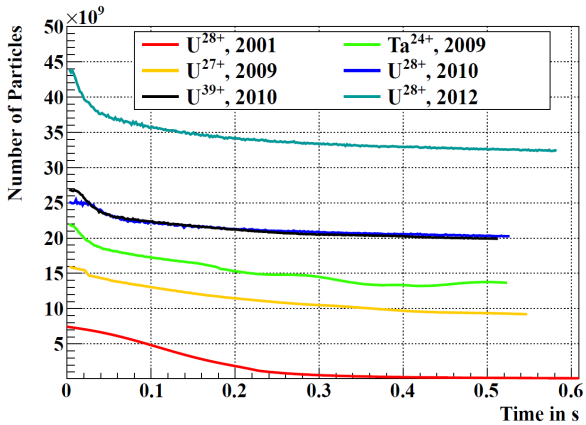

Figure 3: Progress in number of accelerated medium charge state heavy ions (U^{28+}) over the last decade.

FAIR MACHINE DEVELOPMENT CAMPAIGN

After a one year shut down in 2013, the machine operation of UNILAC and SIS18 has been continued beginning of 2014. Although, a large number of shifts were reserved for the physics program, the beam time has been intensively used for FAIR machine and device developments. The following developments could be conducted succesfully in the first half of 2014:

- Experiments on pumping and desorption from cryogenic surfaces. The data will be implemented in the dynamic vacuum code STRAHLSIM.
- Test operation with the new LSA based set-value generation system for flexible and parallel machine operation, e.g. with fast ramping up to 8 T/s.
- Beam instrumentation developments for in-ring diagnostics systems and for applications in the FAIR HEBT system, e.g. FLUKA based scaling of BLM signals, development of optical BIF based profile measurements, sensitive SQUID based current measurements, SEM grid and scintillation screen developments and testing of BBQ systems for incoherent tune measurements.
- Commissioning of new LLRF hardware for the FAIR ring Rf systems, e.g. a new calibration system for amplitude and frequency control.
- Rf manipulations, e.g. bunch merging, dual harmonic operations as required for the different FAIR operation modes of SIS18 and SIS100.

SIS100 PROJECT STATUS OVERVIEW

The start of the procurement of the long lead items, especially of components with large series, has been pushed in the last two years. The type of procurement depends on the inkind status of the relevant device. Devices which have been proposed as German in-kind contribution are tendered by GSI GmbH directly. Devices which are assigned as in-kind contributions of other international FAIR member states require in-kind contracts with the FAIR GmbH. Components which are not provided as in-kind contribution are directly tendered by the FAIR GmbH. Meanwhile, GSI has placed the orders for the main superconducting dipole series and the Rf bunch compression cavity series while FAIR has started the tendering process for the main Rf acceleration system. Contracting is planned for early summer 2014. The local cryogenics system for SIS100 has been assigned as a major in-kind contribution to the polish shareholder. To prepare the manufacturing, GSI has completed the design of the pre-series superconducting quadrupole module. The manufacturing and testing of the quadrupole units, consisting of the quadrupole magnets and the corrector magnets will be taken over by the JINR. The quadrupole modules will be manufactured in a close collaboration between GSI and the JINR. While JINR will manufacture the superconducting quadrupole units, GSI is responsible for the vacuum system, the BPMs and all mechanical parts of the modules and the cryostat system. GSI is also responsible for the integration of the quadrupole modules and the cold testing after assembly. Beside the pre-series quadrupole module, the manufacturing design for all other cryomagnetic moduls has been awarded to an industrial partner. Industrialization reduces the required time for completion and safes resources at GSI. For several other important machine and infrastructure systems the procurement and manufacturing has been started, e.g.

- the series dipole test facility, including the cryogenic plant, the local cryogenics and the power converter,
- the thin wall, actively cooled dipole chambers,
- the series of HTC current leads for the series test stands, the string test and the current lead box and
- the low loss superconducting wire with Copper-Manganese matrix.

Parallel to the procurements the existing test stand for superconducting magnets has been upgraded for testing of the new generation of superconducting SIS100 magnets. A new power converter and HTC current leads for the increased currents of up to 17 kA and ramp rates of up to 29 kA/s has been manufactured and commissioned.

THE FIRST OF SERIES (FOS) SUPERCONDUCTING DIPOLE MAGNET

After major decisions have been taken concerning the requirement for triangular machine cycles, the design of the main dipole magnets has been drastically changed [2]. The late change of major functional and structural components from the prototype to the first of series

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEOBA01

magnet represents a major project risk. The major difference between the prototypes and the FOS magnet is the transition from a two to a single layer coil with almost twice the maximum operation current. Meanwhile, the FOS dipole has been produced and delivered and is extensively tested since December 2013 [3].

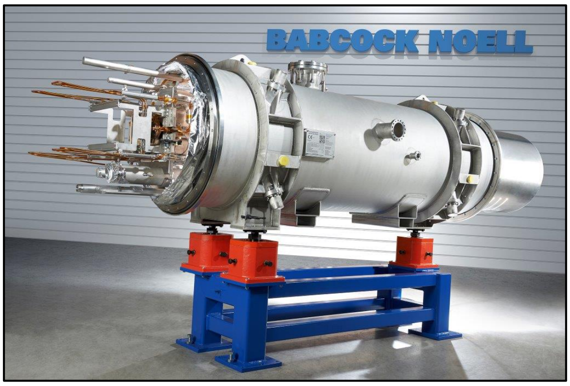

Figure 4: First of series (FOS), fast ramped superconducting SIS100 dipole magnet.

The test program comprises electrical, hydraulic and mechanical qualification measures. Of major importance was the succesful quench training and the demonstration of continous fast ramping with 4 T/s in triangular cycles. The measured AC loss during fast ramping has kept significantly below the expected values. This positive result relaxes the overall AC load and the requirements for the cryogenic system. Since February 2014 the field quality is being investigated by means of rotating coils probes, field mappers and stretched wires. First results indicate and confirm the small tolerances for mechanical errors. In order to minimize the random error, additional quality assurance strategies will be implemented for the series production on the manufacturer side.

SIS100 VACUUM SYSTEM

For stable operation of SIS100 with intense beams of medium charge state heavy ions, the SIS100 UHV system plays an extraordinary role [4] [5]. The requirement for a static residual gas pressure of less than $5x10^{-12}$ mbar and for stabilizing the dynamic pressure during high current operation, was the main reason for making use of superconducting magnets. In combination with fast ramping and short cycle times, the integral cross section for ionization of the medium charge state heavy ions can be kept sufficiently small. Cryogenic surfaces provide several advantages for the UHV system: a) a huge pumping power per meter length, b) sufficient distribution over the circumference (which is essential in a conductance limited system), and c) the possibility to recover at any time and arbitrary often. However, the fast ramping of the magnets induces eddy currents in the vacuum chamber wall which increase the wall temperature [6]. Therefore, ceramically insulated cooling pipes must be attached to the chamber wall for cooling and stabilization of the wall temperature to less than 12 K. In order to be able to recover the vacuum chambers independently from the magnet cooling circuit, an additional auxiliary cooling circuit is foreseen. The ceramic coating of the cooling pipes of the magnet chambers has been specified to resist multiple shock-cooling cycles without peeling and degradation of the insulation. The first full size dipole chamber with a wall thickness of 0.3 mm has been delivered to GSI (figure 5) and will be tested according to the specifications.

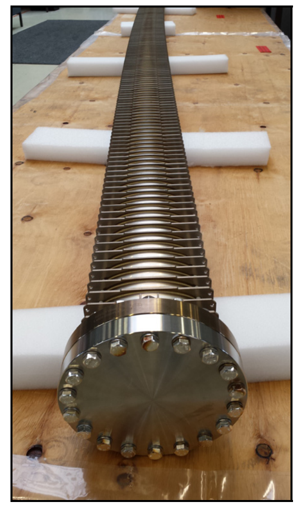

Figure 5: The first thin wall, LHe-cooled dipole chamber.

Although the cross section for ionization is orders of magnitudes smaller, the partial pressure for Hydrogen has also to be restricted to less than 10^{-10} mbar. For the H-pumping, adsorption pumps will be installed in the middle of each dipole pair and in addition in each quadrupole module in the straights. Special measures have to be taken to prevent pressure bumps due to unavoidable beam loss at slow extraction. Beam ions, stripped in the septum wires are immediately lost in the following quadrupole doublet. Therefore, downstream the electrostatic septum, the superconducting quadrupole units will be replaced by radiation hard normalconducting quadrupole magnets. The design of these figure of eight quadrupole magnets allows the installation of a dedicated star-shaped vacuum chamber with attached antichamber. Beam loss at slow extraction will be dumped in this anti-chamber and the pressure dynamics will be controlled by NEG panels.

UPCOMING PROCUREMENTS

The tendering of main technical systems for SIS100 will be continued in 2014. Of special importance are the production of the pre-series quadrupole units at JINR and the preparation of the manufacturing of the mechanical components and their integration into quadrupole modules. The tendering for the last major Rf system, the barrier bucket system, will also be released on short term.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEOBA01

REFERENCES

[1] P. Spiller et al., Proc. of IPAC2011 (2012).
[2] E. Fischer et al., IEEE Transact. on appl. supercon. Vol. 24, No.3, (2014).
[3] W. Walter et al., IEEE Transact. on appl. supercon. Vol. 24, No.3, (2014).
[4] P. Puppel et al., Proc. of IPAC2011 (2012).
[5] E. Fischer et al., Proc. of IPAC2010 (2011).
[6] S. Wilfert et al., GSI Scientific Report2009 (2010).