THE VACUUM SYSTEM OF FAIR ACCELERATOR FACILITY

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Abstract

The FAIR accelerator complex consists of two superconducting synchrotrons (SIS100 and SIS300) with a circumference of 1083.6 m each, a high energy beam transport system (HEBT) with a total length of about 2.4 km and four storage rings (CR, RESR, HESR and NESR) [1]. Their length varies between 212 m and 574 m. For each of the subsystems different vacuum requirements have to be fulfilled. The vacuum system of SIS100 and SIS300 consists of cryogenic and bakeable room temperature sections, where a pressure in the low 10^{-12} mbar range is needed. For HEBT, also a combination of cryogenic and room temperature sections, a vacuum pressure of 10^{-9} mbar is sufficient. The storage rings will be operated in a pressure range from 10^{-9} mbar to 10^{-12} mbar, also some of them with cryogenic sections.

In this paper an overview of the preliminary vacuum layout of the synchrotron rings, the storage rings and the transfer beam lines will be given.

VACUUM SYSTEM OF SIS100/300

The vacuum system of the synchrotron rings SIS100 and SIS300 consists of the beam pipe vacuum and the cryostat insulation vacuum for operation of the superconducting magnets. The beam pipe vacuum system in addition is separated into an in-situ bakeable room temperature part and a cryogenic part, which operates at 4.2-15 K. To provide the required lifetime of the ion beam a vacuum pressure in the range of 10^{-12} mbar is required.

Beam Pipe Vacuum

The cryogenic vacuum system is divided into 6 large arc sections with a length of about 135 m long and 18 short straight sections with a length of 3 m for the quadrupole doublets. The arc (which is completely at cryogenic temperature) consists of 8 dipole doublets, two single dipoles, and 11 quadrupole doublets (SIS300: 10 dipole doublets and 10 quadrupole doublets). They all will be connected to one cryostat. The cold sections are separated by gate valves from the warm sections. This results in 8 valves per superperiod. The warm sectors have a length of about 9m. A schematic drawing of the vacuum layout of one superperiod of SIS100 is shown in Fig. 1.

In the cryogenic sections the cooling of the superconducting magnet coils will be advantageously used for pumping of the beam pipes. In the SIS100 dipoles and quadrupoles they will be cooled indirectly by means of cooling tubes attached on the outer circumference of the beam pipes, resulting in beam tube temperature of 4.2 to 15 K. Thus, the tube walls will operate at cryogenic temperatures as an expanded cold surface of an effective cryopump. At these low temperatures all gases except helium and partly hydrogen will be cryosorbed on the cold surface and the residual gas pressure in the cold beam tubes will be in the range of 10^{-12} mbar.

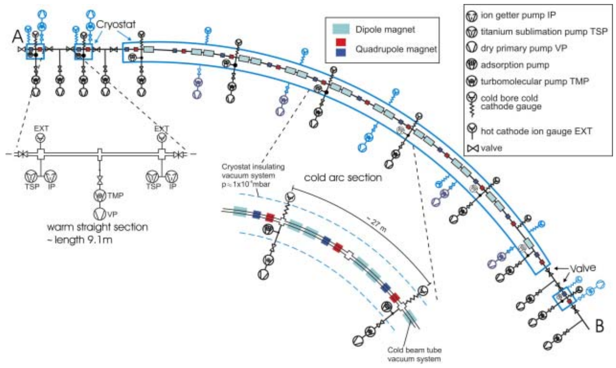

Figure 1: Schematic vacuum layout of one superperiod of SIS100.

In SIS300 the beam pipe in the magnets is part of the liquid helium cryostat of the superconducting magnet and has therefore a temperature of 4.2 K.

In both rings the six straight sections will be mainly at room temperature, except the three cold quadrupole doublets with their own cryostat.

A proper pre-pumping to a pressure of 10^{-4} mbar before cooling-down of the cryogenic sectors is foreseen to minimize the amount of pumped gas molecules on the cold beam pipe surfaces.

The room temperature vacuum sections will be a conventional, in-situ bakeable vacuum system. Depending on the space available in the straight section one or two pumping stations consisting of an ion getter pump and a titanium sublimation or NEG pump will be installed. In addition NEG coating of some vacuum chambers is foreseen. This getter coating of surfaces can be performed at GSI.

Commercial cold cathode gauges of inverted magnetron type with a very low pressure limit will be used to measure in the cryogenic vacuum sections and to control the beam tube valve interlocks. The gauges will be mounted on to the cold beam pipe by flexible conduits outside the ambient cryostat at intervals of approximately 25 to 30 m.

For the measurement of the total pressure in the warm vacuum sections a system of 48 calibrated hot cathode ion gauges (Extractor or BAG) (for redundancy reasons two per warm section) and 6 calibrated Residual Gas Analyzers (RGA) (one per superperiod) with high sensitivity and resolution will be installed.

Cryostat Insulation Vacuum

In SIS100/SIS300 there will be 6 long cryostat insulation vacuum volumes (one per arc, each about 135 m long) and 18 short ones for the quadrupole doublets in the straight section.

To minimize the heat transfer from room temperature to the magnet's cold mass by gas convection, it is necessary to provide an insulating vacuum in the range of 10^{-6} mbar. The cryostats will be pumped down with mobile pumping stations consisting of a combination of a mechanical primary pump and a turbomolecular pump. After cool-down of the magnets the mobile pumping groups can be valved off and removed, since the cold mass of the magnets acts as an extended efficient cryopump, where all gases except He and H_2 are cryosorbed. Additional pumping speed has to be provided in the case of helium leak in the He interconnects. Fixed installed turbomolecular pumps help to detect helium leaks and provide local pumping provisions on these leaks until maintenance.

In the cryostat one has to monitor the pressure in three cases: while pump-down (for early leak detection), to guarantee a sufficient low pressure before cool-down and to locate leaks in the insulation vacuum. Hereby a range from atmospheric pressure down to 10^{-6} mbar has to be covered with the gauges.

HIGH ENERGY BEAM TRANFER LINES

For the vacuum system a combination of techniques used for the high energy beam transfer lines at the existing GSI, for SIS18 and for SIS100/SIS300 is foreseen. Also similar magnets like for CR and SFRS will be used. The vacuum system consists of cryogenic and room temperature parts. Some beam lines will be equipped with super ferric magnets with room temperature vacuum chambers. Most of the beam lines will operate at a pressure of 10^{-9} mbar. Only for beam lines directly connected to SIS100, SIS300, NESR and RESR a bakeout is necessary for differential pumping to the UHV systems of these machines.

The warm vacuum sections and the super-ferric sections with warm magnet chambers will be pumped with ion getter pumps. For pump-down a combination of turbo molecular pumps and dry roughing pumps, separated from the beam line vacuum by valves, is foreseen. In section where superconducting magnets will be installed, the cold beam pipes will be used for pumping.

The vacuum pressure in the warm sections will be measured with calibrated hot cathode ion gauges (Extractor or BAG) or wide-range ion gauges, depending on the required pressure range. No residual gas analyzers are foreseen in HEBT.

Commercial cold cathode gauges of inverted magnetron type with a very low pressure limit will be used to measure in the cryogenic vacuum sections.

A schematic drawing of the vacuum layout of HEBT can be found in Fig. 2.

Cryostat Insulation Vacuum

The vacuum of the 23 cryostats of HEBT has to be in the range of 10^{-6} mbar to minimize the heat transfer from room temperature cryostat walls to the superconducting coils of the magnets. They will be pumped down with turbomolecular pumps before the cold mass takes over pumping.

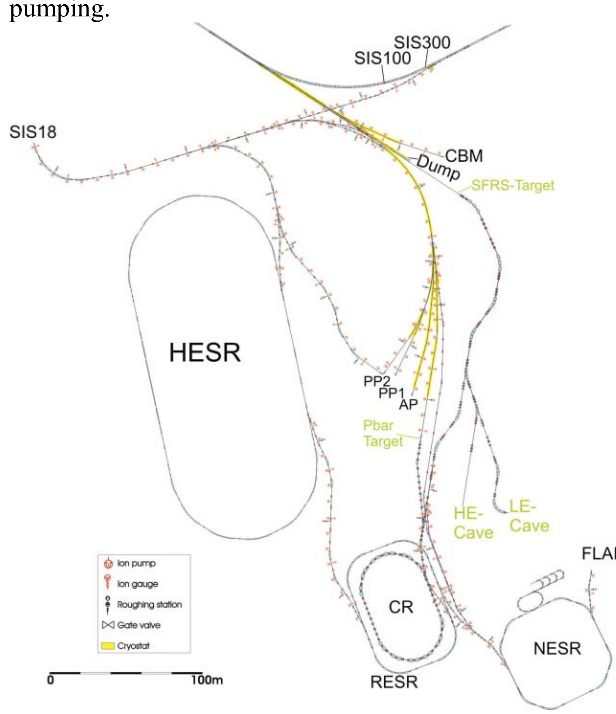

Figure 2: Schematic vacuum layout of HEBT.

COLLECTOR RING CR

As the requirements on storage time are comparatively moderate for the rare isotope beams, it is sufficient to keep the CR vacuum below a value of 10^{-9} mbar. The design of all vacuum components is straight forward following the specifications and techniques applied in the existing accelerator complex at GSI.

The residual gas atmosphere of the vacuum system must be completely free from hydrocarbons. Roughing will be provided by oil-free primary and turbomolecular pumps. For the ultrahigh vacuum regime a combination of titanium sublimation pumps and sputter ion pumps will be employed.

In CR super-ferric dipoles with warm vacuum chambers will be used. Therefore no cryogenic vacuum system is foreseen. The vacuum system will be divided into six vacuum sectors, separated by Viton sealed gate valves because of the limited radiation exposition. In addition six Viton sealed valves DN160CF are needed for the mobile roughing stations.

For the pressure measurement a system of 12 calibrated wide range ion gauges and 6 calibrated Residual Gas Analyzers with high sensitivity and resolution will be installed.

Cryostat Insulation Vacuum

To minimize the heat transfer from room temperature cryostat walls to the superconducting coils of the magnets through gas convection, it is necessary to provide a vacuum in the range of 10^{-6} mbar. The pump down is done with turbomolecular pumps. Only for the dipoles a cryostat is needed, as all other magnets are normal conducting.

ACCUMULATOR RING RESR

To meet the required beam lifetimes in RESR the pressure in the vacuum system must be below 10^{-10} mbar.

The pumping system for roughing consists of oil-free turbomolecular pumps in combination with dry mechanical primary pumps. For the ultrahigh vacuum regime a combination of titanium sublimation pumps and sputter ion pumps will be employed. In addition non-evaporable getter coating of the chambers is planned to increase the pumping speed.

The vacuum system of RESR will be divided into four vacuum sectors, i.e. the two straights and the two arcs, separated by DN250CF all-metal valves. Four all-metal valves DN160CF in addition are needed for the mobile roughing stations.

For bakeout of the RESR vacuum system a standard system will be used. It will consist of commercially available heating jackets providing a maximum temperature of up to 350°C, specially designed for each chamber. Thermocouples will be installed to monitor the temperatures while the bakeout procedure is controlled by a computer based unit.

The pressure will be measured with 12 calibrated hot cathode ion gauges (Extractor or BAG) (three per vacuum sector) and 4 calibrated Residual Gas Analyzers (one per vacuum sector).

NEW EXPERIMENTAL STORAGE RING NESR

As the NESR will be operated with ions and antiprotons at low energy, an ultrahigh vacuum better than 1×10^{-11} mbar is required. Therefore, the whole ring and all experimental installations inside the vacuum system must be bakeable to a minimum temperature of 300°C. The technology is identical with the one applied in the existing storage ring ESR.

The roughing of the vacuum system will be provided by a combination of oil-free primary mechanical and turbomolecular pumps. For the ultrahigh vacuum regime a combination of titanium sublimation pumps and sputter ion pumps will be employed. In addition non-evaporable getter coating of the chambers is possible, to increase the pumping speed when needed.

The vacuum system of NESR will be divided into eight vacuum sectors. They are separated by a DN250CF bakeable all-metal valve. In addition eight all-metal valves DN160CF are used for the mobile roughing stations. To protect the vacuum system in case of a leak two fast shutters are foreseen.

It is foreseen to operate the vacuum system at room temperature. This allows the use of a bakeout system which is similar to the one used in SIS18. It consists of commercially available heating jackets operating at temperatures of up to 350°C, specially designed and individually manufactured for each chamber, and a computer based unit for temperature control. The computer based control system was developed by GSI. To achieve the required specific outgassing rate of H_2 of 10^{-13} to 10^{-14} $mbar\cdot l\cdot s^{-1}\cdot cm^{-2}$ for stainless steel, bakeout for at least 24h at 300°C is necessary.

For the measurement of the total pressure a system of 16 calibrated hot cathode ion gauges and 8 calibrated RGAs (one per vacuum sector) with high sensitivity and resolution will be installed.

HIGH ENERGY STORAGE RING HESR

The vacuum layout of NESR was done by FZ Jülich [2]. The vacuum system consists of the beam pipe vacuum in the warm sections, in the cryogenic regions and the insulation vacuum within the cryostats of the superconducting magnets.

The cold sections have a total length of about 500m, the warm sections of about 74m.

The average residual gas pressure within the 574m long HESR beam pipe is required to stay below 10^{-9} mbar in order to minimise the probability for single scattering losses of the beam by residual gas interaction.

The warm sections will be the PANDA experimental section with its own vacuum system, the stochastic kicker tanks, the electron cooler region and the two injection sections. In each of these sections a system of oil-free turbomolecular pumps (with mechanical primary pumps for roughing) and ion getter pumps for pumping down will be used. Ti-sublimation pumps are foreseen roughly every 5m in the warm sections for vacuum preservation.

The beam pipe vacuum in the cryogenic sections of the HESR ring will be maintained by the cold vacuum pipe which is part of the magnet coil structure. So, only turbo-molecular pumps to generate the vacuum after a break of the vacuum system are useful. The number and length of separate cryostats and the number of cold-warm transitions with section valves is still part of the optimisation procedure.

Cryostat Insulation Vacuum

For the cryostats a vacuum of 10^{-6} mbar will be sufficient. As the design of the cryostats is not yet finished a final layout of the vacuum system cannot be presented.

CONCLUSION

A preliminary layout of the vacuum system of FAIR was done. Based on this a more detailed planning of all system components up to a technical drawing level is under way.

REFERENCES

[1] FAIR Baseline Technical Report, GSI 2006 unpublished

[2] http://www.fz-juelich.de/ikp/de/ikp_gg.shtml