MEDAUSTRON BEAM VACUUM SYSTEM: FROM SOURCES TO PATIENT TREATMENT ROOMS

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Abstract

The MedAustron beam vacuum system is a complex system integrating different technical solutions from the source to the patient treatment rooms. The specified vacuum performances combined with the challenging integration issues require technical compromise which will be presented in this poster. The status of the design of the vacuum system will be reviewed and the pending issues will be explained.

INTRODUCTION

MedAustron is an accelerator complex for protons and ions dedicated to hadron-therapy and research. It consists of up to four different primary particle sources, a LINAC to reach the injection energy of 7 MeV/u, a synchrotron and transfer lines, which direct the beams towards the experimental areas or the medical treatment rooms. The synchrotron delivers protons in an energy range from 60 to 250 MeV and carbon ions from 120 MeV/u to 400 MeV/u. For experimental purpose it will be possible to accelerate protons up to 800 MeV.

As in all particle accelerators, the particles will travel under vacuum to ensure the required beam lifetime and reduce the beam-gas scattering effects. However, as compared to particle accelerators for Physics, this medical accelerator has different operational and reliability requirements which impact the vacuum design and in particular its instrumentation and diagnostics.

The MedAustron accelerator seen from the beam vacuum side can be subdivided in 5 zones:

- The sources and Low Energy Beam Transfer (LEBT);
- The Medium Energy Beam Transfer (MEBT);
- The Synchrotron;
- The High Energy Beam Transfer (HEBT);
- The treatment rooms.

The Sources will be procured and delivered equipped with all vacuum pumps and instrumentation in order to avoid later unnecessary optimisations. A similar approach has been approved with the pumps and instrumentation of the IH tank in the LINAC.

The challenges with the MedAustron vacuum system are mainly focussed in three topics: integration of the pumping and instrumentation taking into account the density of beam instrumentation and diagnostics, the design of the dipole beampipes of the synchrotron and the injection and extractions in the synchrotron. The design of the vacuum components of the gantry and zones close to the treatment rooms are foreseen in a later stage.

VACUUM REQUIREMENTS AND CONSTRAINTS

General Considerations

All the equipment operated at room temperature shall fulfil the Ultra High Vacuum (UHV) requirements to achieve the required beam lifetime and avoid vacuum related effects such as beam losses, activation of material and damage to cables and to electronics, neutralisation of ions, etc.

In the LEBT, MEBT and HEBT, static pressures in the 10^{-6} Pa range (10^{-8} mbar) after 48 hours of pumping are required. The synchrotron is more demanding in terms of pressures; static pressures in the 5.10^{-7} Pa range (5.10^{-9} mbar) after 48 hours of pumping are required. To steer and control beams, an important amount of beam instrumentation and monitors, more than 100, will be foreseen. This contributes to space constraints and limitations on the maximum pumping speed which can be made available. This implies tighter outgassing rate specifications and recommendations to use metallic materials on all equipment installed in the beam vacuum.

Each beam or vacuum component will be leak tested and qualified regarding vacuum conformity prior to its installation in the accelerator e.g. total outgassing rate and residual gas composition. In case of non-conformities, alternative materials or design will be considered.

Reliability and Redundancy

The vacuum system is designed with built-in redundancy for the critical components. The malfunction of a single component of the vacuum system must not affect the availability of the machine for patient treatments. Where required, redundancy has been installed in order to avoid beam downtime.

The vacuum system design and manufacture is therefore based on standard components, well-mastered technologies and materials. Spares will be available to maximise machine availability in the event of a component failure.

Vacuum Sectorisation Layout

The vacuum sectorisation (see Figure 1) has been defined to allow the sequential installation and commissioning of the accelerator and to limit the beam downtime in case of a brutal vacuum failure. In the HEBT, the need to continue the operation with beams in case of problems with one of the transfer lines to the treatment rooms has resulted in additional sector valves, right after the dog-leg beampipes. Similarly, the sources and the strip foil monitor (downstream the IH tank) can be completely isolated for maintenance or repair purposes. The synchrotron has been subdivided in three vacuum sectors to reduce the pumping time and resources required during an intervention.

Pumping and Instrumentation Layout

The pumping and instrumentation layout (see Figure 2) has been defined according to the vacuum sectorisation and having in view to provide enough pumping and pressure gauges to monitor and interlock the vacuum system with the required redundancy. The permanent pumping will rely on ion pumps distributed all along the beam lines. In the LEBT, to cope with the gas load coming from the sources, a differential pumping by means of turbo molecular pumps is considered. In the synchrotron and in addition to ion pumps, NEG cartridges will be installed to fasten the recovery in case of vacuum venting to atmosphere.

The roughing in the Synchrotron and in the HEBT will be made using mobile turbo molecular pumping stations, available off the shelf in industry, connected to the roughing valves distributed all around the beam lines.

Pressure reading will be provided by means of Pirani gauges for the high pressure, cold cathode gauges for the UHV system as well as by the current of the ion pumps. Only passive gauges, i.e. no electronic on the head of the gauges, are considered to avoid problems with the radiation. Both the gauges and ion pumps will be used as trigger for the vacuum interlocks.

Vacuum Engineering Issues

The design of the MedAustron vacuum system was made considering the use of industrial standard flanges and gaskets. Conflat® flanges with a metallic copper gasket are preferred whenever possible for the beam vacuum pipes since providing the highest reliability in terms of leak tightness and lifetime. Conical flanges coated with enamel will be used in the synchrotron to isolate electrically each dipole avoiding perturbation induced by the Eddy currents during the fast cycling of the magnets. Exceptions exist for the beam instrumentation which requires the use of rectangular flanges in order to optimize the space available.

The beampipes and pumping ports have standard designs since they shall not fulfill any specific impedance or higher order modes (HOM) requirements. This is not the case for the synchrotron dipole beampipes. To avoid

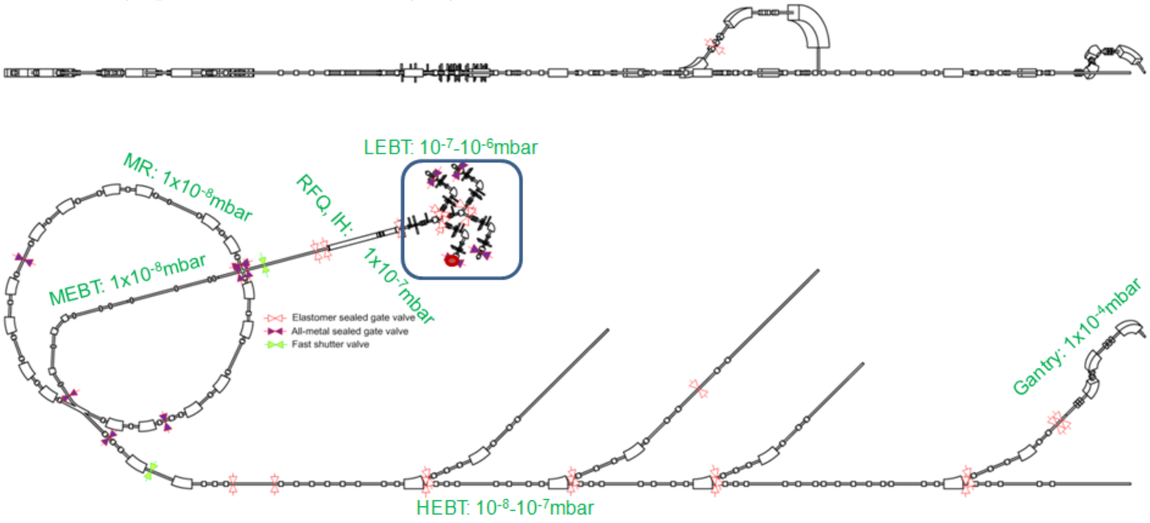

Figure 1: Vacuum sectorisation layout.

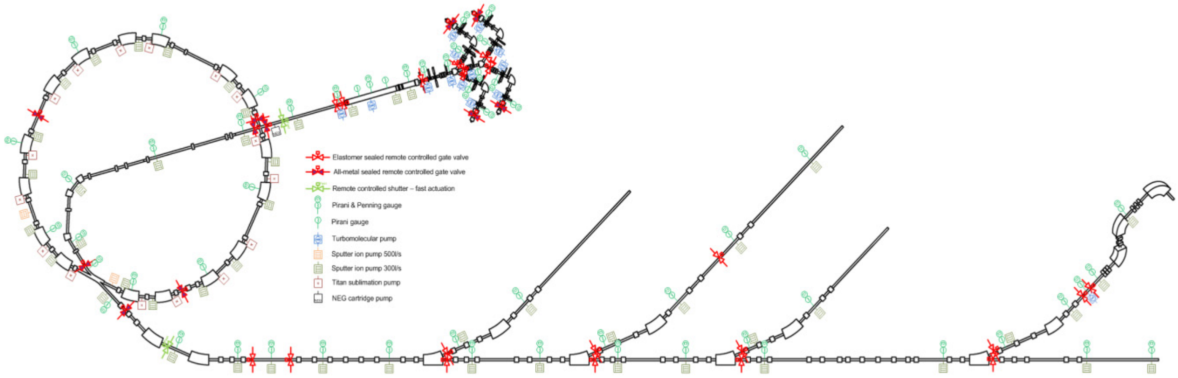

Figure 2: Pumping and instrumentation layout.

huge eddy current and perturbations of the magnetic fields during the fast ramping of the dipoles, the beampipe was specified to have a thickness of 0.4 mm maximum. After considering the manufacturing from a bulk as made for CNAO medical accelerator and the use of rips to reinforce a thin formed beampipe, it was finally decided to go for a corrugated beampipe (Figure 3 and 4) similar to the one used for the CERN Proton Synchrotron (PS). To decrease the electrical conductivity, Inconel is used instead of stainless steel. However, their use need careful positioning and holding of the beampipes inside the dipole bore to avoid deformations and displacements once put under vacuum. In addition and resulting from space constraints, two pumping ports to hold the ion pumps and NEG cartridges are welded at each end of the corrugated chambers. The beampipe supports, attached to the dipole bore, support weights and induced forces.

The injection-extraction chamber in the Synchrotron is also an example of a complex design. Indeed, it has to allow beams coming from the MEBT to get injected in the synchrotron, then allow them to circulate and finally provide the path for their extractions to the HEBT.

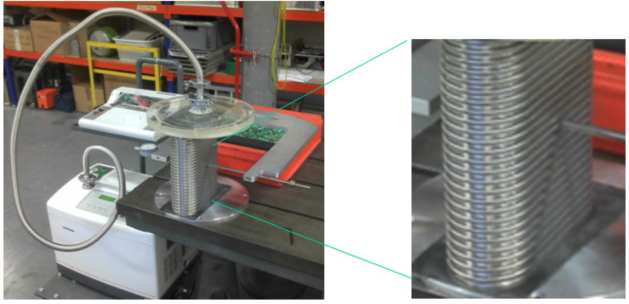

Figure 3: Prototype segment of a corrugated beampipe (CERN Proton Synchrotron - PS).

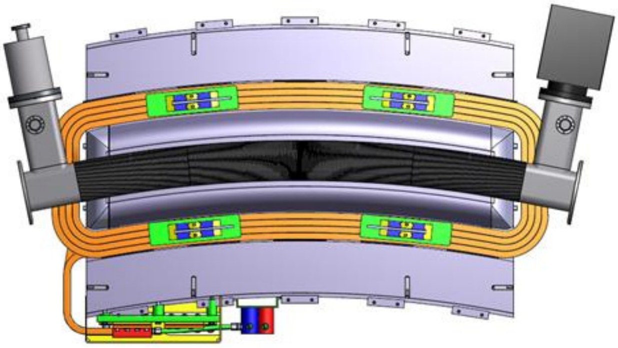

Figure 4: Dipole of the Synchrotron with its vacuum beampipe.

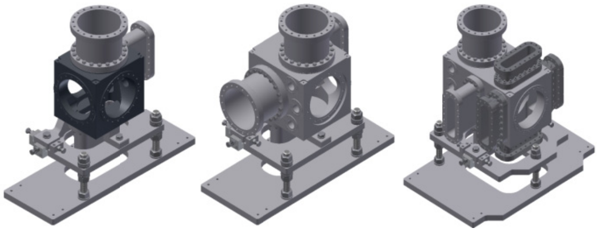

Figure 5: Beam instrumentation vacuum tanks.

The beam instrumentation tanks (Figure 5) house the instrumentation and diagnostics to steer and qualify the beams. These tanks have complex shapes since, for space reasons, they must house several type of instrumentation for the vertical and horizontal planes.

Vacuum Controls, Monitoring and Interlocks

The vacuum system is designed to control and to monitor the vacuum equipment such as gauges, valves and pumps. The system is divided into a supervision and a frontend control system. Via the supervision system, the user can have remote control to the vacuum equipment and is able to see their physical status.

A monitoring of the vacuum system is required in every vacuum sector of the machine to verify the vacuum level before opening the valves and for protection purposes by triggering the closure of the sector valves in case of a sudden increase of the pressure. To minimise false triggering of the closing of the sector valves and the subsequent impact on the operation of the accelerator, several signals (2 or 3) will be combined to generate an interlock. This manipulation will be made at the vacuum front-end chassis. Some equipment requires pressure interlocks to operate or for their protections: kickers, RF cavities, electrostatic septa, etc. For these equipments and on demand, appropriate hardware or software pressure signals are provided with some redundancy to avoid false alarms or stoppages in case of failure of a pressure gauge or pump.

CLOSING REMARKS

The procurement of standard components is progressing according to schedule. The major contracts are being placed e.g. pumps, instrumentation, flanges, beam instrumentation tanks for the LEBT, dipole chambers for the Synchrotron, vacuum valves as well as all vacuum components required to assemble the Injector test bench.

The full integration of the accelerator vacuum system is expected to be completed by November and all procurements by end of 2012.

The installation will follow the beam path from the sources to the treatment rooms. In case of work stoppage due to the unavailability of components, the teams will be temporarily rerouted to the installation of the HEBT.

REFERENCES

[1] "MedAustron - Project overview and status", M. Benedikt, A. Wrulich,, Eur. Phys. J. Plus (2011) 126: 69.