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CRYOPANELS IN THE ROOM TEMPERATURE HEAVY ION SYNCHROTRON SIS18

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Abstract

The FAIR complex at the GSI Helmholtzzentrum will generate heavy ion beams of ultimate intensities. To achieve this goal, medium charge states have to be used. However, the probability for charge exchange in collisions with residual gas particles of such ions is much higher than for higher charge states. In order to lower the residual gas density to extreme high vacuum conditions, 65% of the circumference of SIS18 are already coated with NEG, which provides high and distributed pumping speed. Nevertheless, nobel and nobel-like components, which have very high ionization cross sections, do not get pumped by this coating. A cryogenic environment at moderate temperatures, i.e. at 50-80 K, provides high pumping speed for all heavy residual gas particles. The only typical residual gas species, that cannot be pumped at this temperature is hydrogen. With an additional NEG coating the pumping will be optimized for all residual gas particles. The installation of cryogenic surfaces in the existing room temperature synchrotron SIS18 at GSI has been investigated. A prototype quadrupole chamber with cryogenic surfaces, first measurements, and simulations of the adapted accelerator are presented.

INTRODUCTION AND MOTIVATION

The FAIR-facility will provide high intensity heavy ion beams, with a goal of 1.25×10^{11} particles per pulse. To reach these intensities, medium charge states have to be used. The problem with these charge states is that the probability for charge exchanges with the residual gas particles, is much higher than for higher charge states. Ions with a different charge state will be deflected differently and will therefor hit the vacuum chamber wall at some point, see Fig. 1. At this position they will release gas particles via ion impact induced desorption processes into the vacuum chamber leading to a higher density of residual gas particles. Such, more charge exchanges happen and more ions will hit the vacuum chamber walls. This self-amplification process can evolve up to complete beam loss and is called dynamic vacuum [1].

In SIS18, the existing heavy ion synchrotron at GSI, several upgrade measures have been realized to reach high beam intensity [2]. To reduce the gas production by ionization beam loss, low desorption surfaces, so-called ion-catchers, have been installed. To suppress vacuum dynamics and to get to these high intensities, high pumping speed is still required. To lower the residual gas density to extreme high vacuum

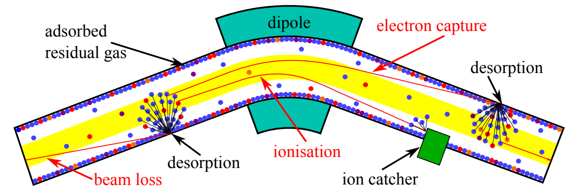

Figure 1: Principle of ionization loss and dynamic vacuum [1].

conditions, 65% of SIS18s vacuum chamber walls have been coated with NEG. This coating has a high pumping speed for light particles like hydrogen. These upgrades did lead to an improvement of the beam intensity [3]. However simulations of SIS18 show that the intensity goal for FAIR cannot be reached with the current setup [1]. To reach these high intensities, the density of the residual gas particles has to be reduced even further to extrem high vacuum conditions. Even though the NEG coating has a high pumping speed for light particles, nobel and nobel-like gases, like argon and methane do not get pumped by this coating [4]. These particles also have unfortunately a high cross section for charge exchanges with U^{28+} [5], see Fig. 2, and induce therefore high beam losses. One way these particles can be pumped, is by cryogenic surfaces below 77 K. Such, in combination with the already existing NEG coating, every residual gas component in SIS18 could get pumped efficiently.

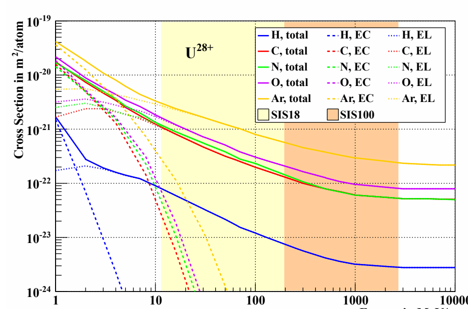

Figure 2: Cross sections for charge exchange for U^{28+} for different targets, distinguished for electron capture (EC), electron loss (EL) and total cross section. The energy regimes of SIS18 and SIS100 are marked [6].

SIMULATION OF U^{28+} IN SIS18 WITH CRYOGENIC SURFACES

To simulate the ionization loss and dynamic vacuum effects, StrahlSim is used. StrahlSim is an unique simulation code developed at GSI to simulate dynamic vacuum effects in circular accelerators. This code has been extended to in-

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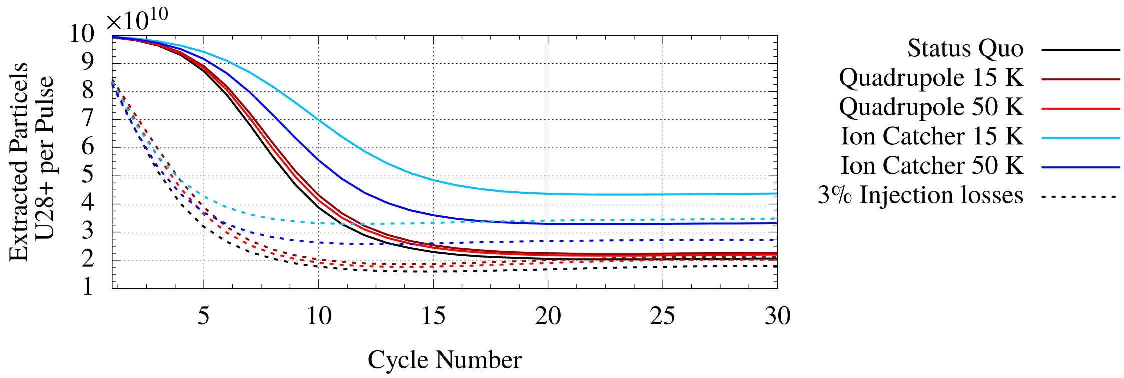

Figure 3: Results from simulations with cryogenic pipes in quadrupole chambers or ion catcher chambers at temperatures of 50 K and 15 K. More parameters are shown in Table 1. Dashed lines show simulations with 3% injection loss, solid lines show the case without injection loss.

clude the option of cryogenic surfaces in room temperature sections.

The simulations performed investigate the number of extracted particles and compare the status quo in SIS18 and different scenarios with cryogenic panels in room temperature. The simulated cryopanels correspond to two pipes with a diameter of 8 mm and the length of the used section. Cryogenic pipes were set up in different chamber types. The most interesting results were achieved by cryogenic pipes in quadrupole or ion catcher chambers. In Fig. 3 the results of these simulations are shown. The simulation parameters are written down in Table 1.

Table 1: Simulation Parameters for the Shown Simulations in Fig. 3

Injected particles	10^{11} U^{28+}
Ramprate	10 T/s
Cycle frequency	2.76 Hz
Break between cycles	25 ms
Temperature of pipes	50 K and 15 K
Injection losses	0% and 3%

Presented are the extracted particles of U^{28+} per pulse as a function of the cycle number for different scenarios. Comparing the black lines for the status quo to the blue line of the ion catcher chambers, Fig. 3 shows that the number of extracted particles with 0% injection losses have doubled if the pipes are cooled to 15 K (solid bright blue). Also the number of extracted particles which were injected with losses of 3% (dashed bright blue) would be much higher than without the pipes. In the ion catcher chamber the gas production is disproportionally higher than in other parts of the synchrotron. Additional pumping speed reduces the density of residual gas particles and thereby the ionization losses. However, comparing the red lines of the quadrupole chambers to the status quo does not show this effect. Regardless, the simulation with 3% (dark red) injection losses results in an interesting phenomenon. The extracted particles of the simulation with (dashed red) and without (solid red) ionization losses converge after many cycles. That means, if cryopanels are installed into the quadrupole chambers, the losses while the beam is injected do not affect the number of extracted particles.

PROTOTYPE TEST SETUP

To verify the simulation results of chambers with cryogenic pipes, a prototype quadrupole chamber is used. The structure of this prototype is similar to the set up of SIS18's quadrupole chambers. It is a thin walled chamber with one turbo molecular pump (TM) on one side, a sector gate valve allows to shut off the pump. On the other end, an ion getter (IG) pump is installed, Fig. 4. The thin walled chamber is divided by thicker parts (measuring chambers) to install gauges or similar devices. The whole set up is only 3 m long, the quadrupole chamber of SIS18 covers more than 4 m. To measure the pressure in the chamber, four gauges are installed at the setup.

Integrated into the chamber are two pipes with a diameter of 8 mm, which can be cooled independently or combined with liquid nitrogen or helium. On each pipe three sensors measure the temperature, Fig. 5.

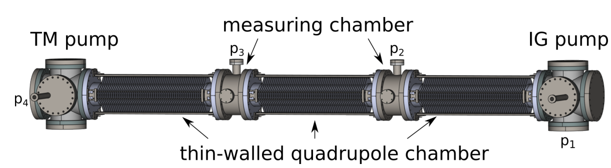

Figure 4: Sketch of the prototype quadrupole chamber with the positions of the pressure sensors p_x.

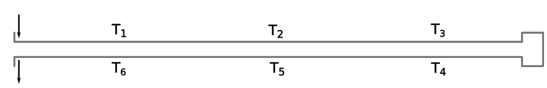

Figure 5: Sketch of the intalled pipes with the positions of the temperature sensors T_x. The direction of the flow is marked.

Measurements

In Fig. 6, a longtime measurement with cooling over six hours and the following warm up is shown. The pipes were both cooled with liquid nitrogen at a temperature of

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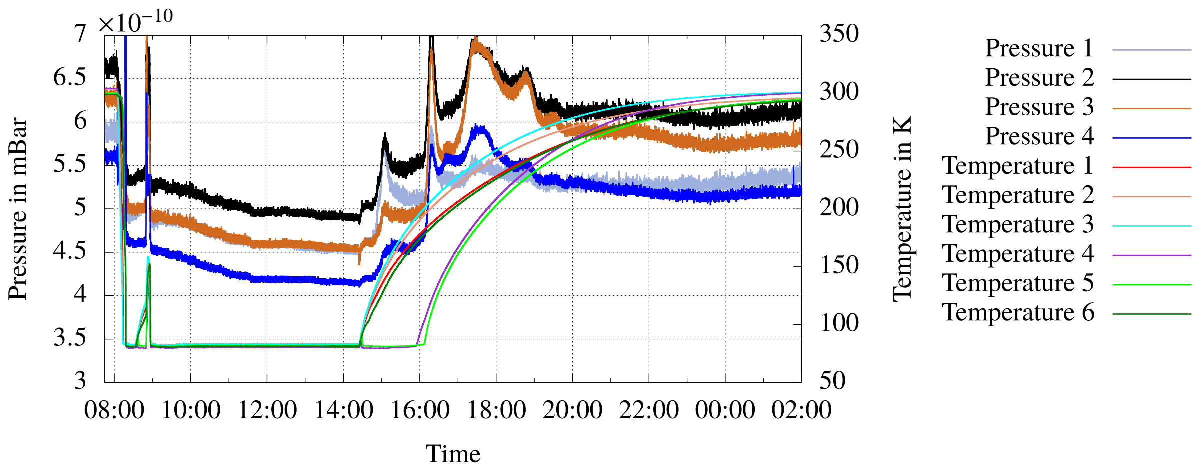

Figure 6: Longtime measurement with both pipes cooled to ≈80 K. The position of the sensors can be seen in Figs. 4 and 5.

≈80 K. The temperature remains stable, while the pressure still decreases.

In Fig. 7, the pressure profile over the chamber is shown. Although the temperature is to high too pump most of the residual gas species effectively, the pressure in the set up is reduced by a factor 1.5 and more homogeneous over the entire chamber.

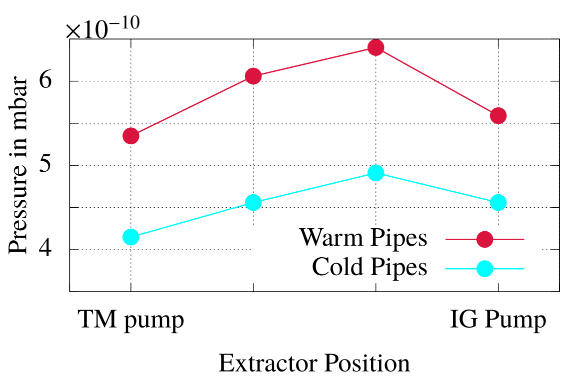

Figure 7: Pressure profile over the chamber, with warm pipes (300 K) and cold pipes (80 K).

Planned Measurements

In the following, different planned measurements are listed:

- Static pressure for different operation modes: with and without cooling with liquid nitrogen or helium, both before and after NEG-coating of the inner surfaces
- Influence of the temperature of the surfaces
- Simulation of dynamic vacuum effects by a gas inlet system with a fast dosing valve
- Capacity and saturation effects of the cryogenic surfaces
- Long term evolution of the residual gas composition
- Heat input from the vacuum chamber walls on the cryogenic surfaces.

SUMMARY AND OUTLOOK

To reach the FAIR intensity goal, different upgrades were integrated in the SIS18. Nevertheless, it could be shown that the intensity goals will not be reached. Simulations show that cryogenic surfaces in SIS18 can increase the extracted particles. These surfaces are most effective in sections of SIS18 with high gas desorption. First measurements with a prototype quadrupole chamber have shown that using cryogenic pipes leads to a reduced and more homogeneous pressure. To verify these results futher measurements are planned later this year.

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