

ION CATCHER SYSTEM FOR THE STABILISATION OF THE DYNAMIC PRESSURE IN SIS18*

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Abstract

In synchrotrons operated with intermediate charge state heavy ion beams, intensity dependent beam losses have been observed. The origin of these losses is the change of charge state of the beam ions at collisions with residual gas atoms. The resulting m/q deviation from the reference beam ion leads to modified trajectories in dispersive elements, which finally results in beam loss. At the impact on the beam pipe, gas molecules are released by ion stimulated desorption which increase the vacuum pressure locally. In turn, this pressure rise will enhance the charge change- and particle loss process and finally cause significant beam loss within a very short time. In order to suppress and control the gas desorption process, a dedicated ion catcher system incorporating NEG coated surfaces and low-desorption rate materials has been developed and two prototypes were installed in SIS18. The design of the scraper and measured effect on the dynamic residual gas pressure are presented.

INTRODUCTION

The new accelerator facility FAIR at GSI relies on the existing SIS18 synchrotron as injector. Currently most of the experiments are performed with highly charged U^{73+} -beams. Higher intensities will be available by avoiding further stripping in front of SIS18 and accelerating low charged ions, which also raises the space charge limit. Therefore, U^{28+} has been selected as the reference ion for the FAIR project.

During machine experiments in SIS18, extremely fast and intensity dependent particle losses in connection with a very strong dynamic behavior of the residual gas pressure have been observed. The intensities were far below the space charge limit of the machine. The reason for the observed losses is a charge change of the beam particles, which finally degrades the vacuum by ion stimulated desorption. A quantitative treatment of these losses has been developed and implemented into the code "STRAHLSIM" [1].

In order to reduce the charge change induced beam losses, an upgrade of the SIS18 UHV system and the installation of a dedicated desorption catcher system has been planned. In the following, the most recent experimental results obtained with the catcher prototypes are summarized.

PROJECTILE IONISATION

Heavy ions change their charge state at collisions with residual gas atoms. Cross sections for electron capture can be described with Schlachter's formula [2]. A big uncertainty for simulations are still the projectile ionisation cross sections, especially at high energies. Detailed calculations for the electron loss cross sections of U^{28+} have been conducted recently by means of the relativistic LOSS-R code [3] and at the same time were measured experimentally in the ESR at GSI [4]. The LOSS-R calculations show that the cross sections slowly decrease with energy up to 2 GeV/u, as shown in figure 1.

For multiple ionisation, cross sections are mainly determined by heavy residual gas constituents, e.g. Argon. Therefore, in order to achieve sufficiently large beam life times, these residual gas components have to be removed from the vacuum system.

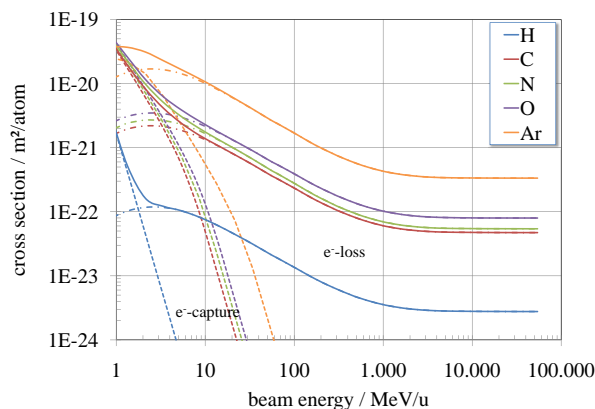


Figure 1: Calculated projectile charge change cross sections for collisions of U^{28+} -ions with various residual gas components.

ION IMPACT INDUCED DESORPTION

Particles with a trajectory modified by projectile ionisation will most probably hit the vacuum tube under grazing incidence. Thereby, depending on the projectile energy, molecules attached loosely to the wall's surface are desorbed at rates of $\eta_{\perp} \approx 5 \times 10^3 \dots 1 \times 10^6$ molecules/ion. If a beam ion hits the surface of the beam pipe or any other component under perpendicular angle of incidence, the desorption rate has been measured to be about $\eta_{\perp} \approx 1 \times 10^2 \dots 3 \times 10^3$ molecules/ion for energies of a few

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MeV/u. The desorbed gases consist to a large extent of CO and H₂.

The physics behind the desorption process itself is meanwhile quite good understood. Detailed investigations have been performed by the GSI UHV group using an ERDA (elastic recoil detection analysis) technique [5]. It could be shown that the lowest measured desorption rate of $\eta_{\perp} \approx 25 \dots 80$ molecules/ion are reached with a pure Gold surface. The measured desorption rate depends on thermal treatment and history [6]. The measurements have been conducted at the HLI (high charge state injector) in GSI under perpendicular angle of incidence with a dE/dx normalized for 11.4 MeV/u U²⁸⁺-ions.

CATCHER SYSTEM FOR IONISATION BEAM LOSS

SIS18 is currently being upgraded for the operation with highest beam intensities required for the FAIR project. For this purpose, the dynamics of the residual gas pressure has been studied with STRAHLSIM. It has been shown that beside reducing the injection losses and increasing the ramp rate, a large distributed pumping speed and an effective catcher system are required for the minimization of beam losses.

Injection losses produce a very high pressure bump in the range of several orders of magnitude during a few μ s. This pressure bump has to be removed by the UHV system as fast as possible. For this purpose, NEG coating of the dipole and quadrupole chambers is foreseen to increase the distributed pumping speed by a factor of 100. For the control of the charge change generated beam losses of U²⁸⁺ and to confine the desorbed gases, a dedicated catcher system will be installed in each section of SIS18.

As the static beam lifetime can always be enhanced by a lower residual gas base pressure, the dynamic pressure can be stabilized by the stronger pumping and the dedicated ion catcher system. Catchers can be designed such that they control most of the ionized particles and confine the produced desorption gases. It is essential to prevent the desorbed gases from reaching the beam axis and to minimize the charge change rate. Due to the SIS18 triplet lattice, the catcher system could be built such that it does not reduce the acceptance of the machine.

Two prototypes of the ion catcher system have been developed and installed during the winter shutdown 2007/2008 in two sections of SIS18 (S02 and S03). As shown in figure 2, the catcher consists of two transversally movable copper beam absorbers, coated with a few 100 nm Gold and an underlying diffusion barrier made of Nickel. To prevent the desorption gases from reaching the beam axis, the absorber is enclosed by a secondary chamber. To achieve a high pumping speed near by the absorbers, both primary and secondary catcher chambers have been coated with TiZrV-NEG at GSI.

During machine experiments with U²⁸⁺-beams in February 2008, the qualitative behavior of the projectile

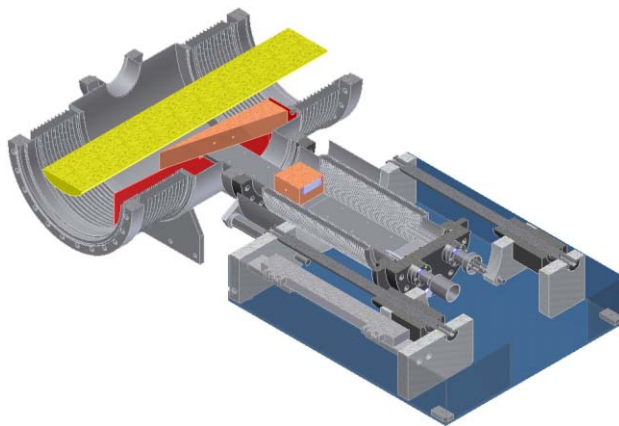


Figure 2: Horizontal cut through the installed SIS18 ion catcher prototype. Yellow: beam, red: secondary chamber, brown: beam absorbers.

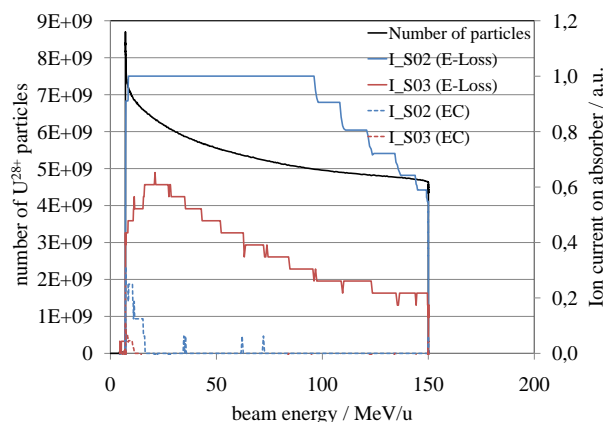


Figure 3: Measured ion currents on absorbers as a function of energy. Dotted: beam loss by electron capture, solid: beam loss by electron loss.

ionisation cross sections vs. energy have been confirmed by measuring the ion current onto the beam absorbers. For these measurements, the absorbers have been positioned left and right of the beam axis. Thereby it was possible to measure directly the ion current of U²⁷⁺ on the outer side and U²⁹⁺ on the inner side of the ring. As can be seen from figure 3 and figure 1, the measured ion currents for both ionisation and electron loss have a similar dependence on energy as the cross sections calculated by the relativistic LOSS-R code. The measured ion currents have amplitudes proportional to the amount of ionisation, i.e. proportional to the residual gas pressure in the section before the catchers. This observation is the first direct prove that projectile ionisation is indeed the driving process of the observed strong beam loss.

The measured and gas specific corrected pressures in the catcher chamber together with the average pressure of SIS18 are shown in figure 4. Under beam loading, the average pressure in SIS18 raises due to ion stimulated desorp-

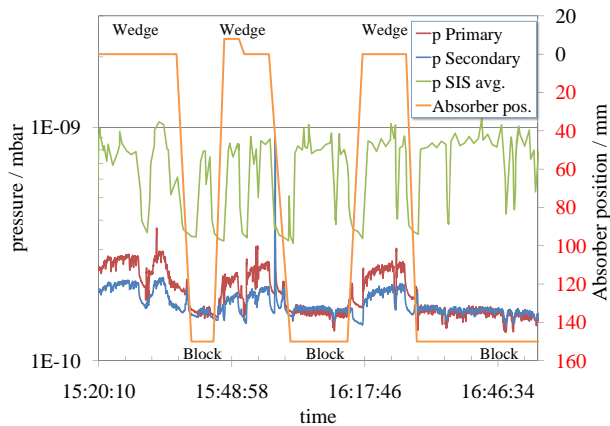


Figure 4: Measured residual gas pressures in the catcher chamber and the whole SIS18.

tion from 3.3×10^{-10} mbar to about 1×10^{-9} mbar. The pressure rise in the catcher chamber itself decreases significantly when the absorber block is moved to its designated position.

From the measured pressure rise, the effective, for the beam visible desorption rate of the wedge shaped absorber was calculated to be $\eta_{\perp} \approx 278$ mol/ion and for the block shaped absorber $\eta_{\perp} \approx 55$ mol/ion. These values are quite close to the measured desorption rates at the ERDA test stand. Therefore, the low desorption rate Gold coating works exactly as intended only for perpendicular angle of incidence. After approval of the catcher prototypes, a series of 10 catchers will be installed together with 6 NEG coated quadrupole chambers in the shutdown end of 2008. Since two of the 12 SIS18 sections are blocked by accelerator installations, the efficiency of the overall system will be reduced by a few percent.

U^{28+} beam intensities

The successive optimizations during the ongoing SIS18 machine development program have pushed the number of extracted U^{28+} -particles in comparison to 2001. The highest measured number of extracted particles is now about 8×10^9 , as can be seen in figure 5. As the upgrade is still progressing, the U^{28+} -experiments have been conducted with only half of the dipole magnet chambers replaced by NEG coated chambers (which is about 7 % of the ring's circumference) and with two prototype ion catchers installed. The maximum transmission was achieved at a ramp rate of $\dot{B} = 7$ T/s.

Major improvements have been reached by a new closed orbit correction scheme [7] and 10 s long pumping breaks between the machine cycles. The fact that the last measure improves the number of extracted particles by more than 10-13 % indicates that the observed losses are strongly dependent on pressure and not driven by other high-current effects such as resonances or longitudinal or transversal instabilities.

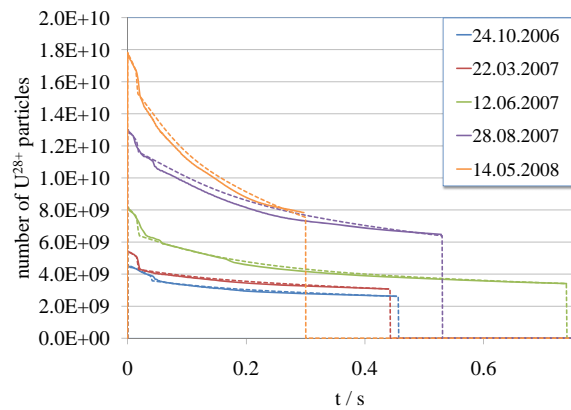


Figure 5: Measured (solid lines) and calculated (dotted lines) time dependent number of U^{28+} -particles in SIS18.

CONCLUSIONS

Both the UHV upgrade with the NEG coated chambers and the dedicated catcher prototypes show the intended stabilization of the dynamic vacuum in SIS18. Furthermore, it could be shown that the main upgrade measures have to be accompanied by a precise machine setting to avoid pressure bumps by systematic beam losses.

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