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COMMISSIONING OF THE LOW ENERGY STORAGE RING FACILITY CRYRING@ESR

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Abstract

CRYRING@ESR is the early installation of the low-energy storage ring LSR, a Swedish in kind contribution to FAIR, which was proposed as the central decelerator ring for antiprotons at the FLAIR facility. An early installation opens the opportunity to explore part of the low energy atomic physics with heavy, highly charged ions as proposed by the SPARC collaboration but also experiments of nuclear physics background much sooner than foreseen in the FAIR general schedule. Furthermore, the ring follows in large parts FAIR standards, and is used to test the FAIR control system.

CRYRING@ESR has been installed behind the existing experimental storage ring ESR starting in 2013. It has a local injector that is used for commissioning. In November 2016 the commissioning of the storage ring started and a first turn was achieved. After a complete bake out cycle and substantial developments of control system, diagnosis and others, commissioning was continued in late summer 2017. Stored as well as accelerated beam has been achieved by now. The remaining step is to take the electron cooler into operation, which is planned for November this year.

INTRODUCTION

In Darmstadt, the facility for antiproton and ion research is being built. Based on the GSI accelerators for injection it will open up new areas of research with heavy ions and, new in Darmstadt, with antiprotons. When it comes to experiments with slow and stored heavy, highly charged ions and antiprotons, two collaborations, the Stored Particles Atomic Physics Research Collaboration - SPARC and the Facility for Low-Energy Antiproton and Ion Research - FLAIR, have been formed to move into one building complex, the FLAIR building.

The low energy storage ring LSR shall provide the highly charged ions and antiprotons at low energy at the FAIR facility for those two collaborations, SPARC and FLAIR. The LSR evolves from the heavy-ion storage ring CRYRING, which has been operated at the Manne Siegbahn Laboratory in Stockholm until 2010 [1]. The main-focus is on precision experiments, which requires low energy and well-controlled beam properties that is typically achieved by beam cooling. The LSR will be installed as intermediate step between the new experimental storage run NESR and the low energy facilities HITRAP and the ultra low energy storage ring USR. The LSR is a Swedish in-kind contribution to the FAIR facility in Darmstadt, i.e. part of the investment done by the Swedish physics community into the FAIR project.

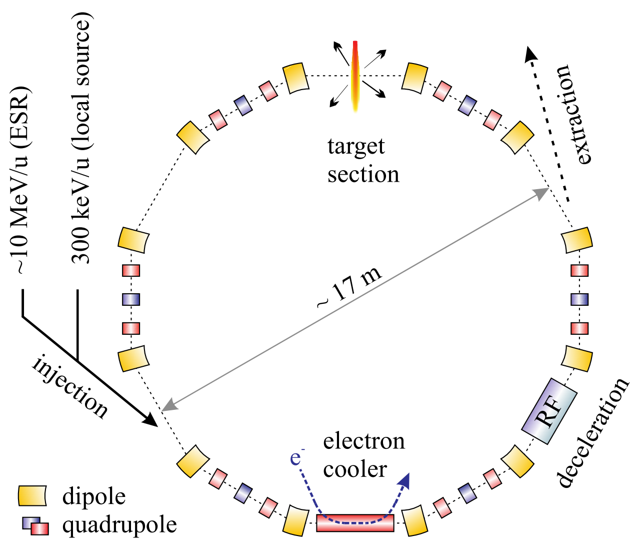

Figure 1: Schematic layout of CRYRING@ESR. The main components; injection, extraction, electron cooler, RF section, and the target section are indicated.

After careful cost evaluation a staged approach was put into place that does not include the NESR in its start version. However, contrary to the original plans the present storage ring at GSI, the ESR, will not be disassembled for component reuse but continue running. Consequently, instead of warehousing the ring components until installation at the Facility for Antiproton and Ion Research, FAIR, the immediate installation behind the existing Experimental Storage Ring, ESR [2, 3], has been proposed and worked out in detail by a Swedish-German working group. The estimated efforts for installation and operation of CRYRING at the ESR have been summarized in a report [4] published by that working group in 2012.

A schematic overview of the storage ring and its facilities is shown in Fig. 1. CRYRING as it is now installed behind the ESR can decelerate, cool and store heavy, highly charged ions from about 10 MeV/nucleon and antiprotons from about 30 MeV/nucleon down to a few 100 keV/nucleon. It provides a high performance electron cooler in combination with a gas jet target. It is equipped with it's own injector and ion source, to allow for standalone commissioning. For more detailed ring parameters see also Table 1.

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Table 1: Parameters for CRYRING@ESR

Description	**Value**
Circumference	54.17 m
Rigidity at injection	
protons/antiprotons	0.8 Tm
ions	1.44 Tm
Lowest Rigidity	0.054 Tm
Ramping rates	1.. 7 T/s

More details of the installation and ring characteristics can be found in the technical design report [1], earlier proceedings of this conference [5] and the most recent status report here [6].

STATUS OF COMMISSIONING

During the last year, i.e. in 2016/17, the ring has been taken stepwise into operation until stored beam was achieved.

In a first step ions were transported from the ESR to CRYRING@ESR still in 2016. This is based on two assumptions that have been tested and validated on-line. First, fast extraction from the ESR had to be demonstrated using the existing kicker that was only designed for extraction into the reinjection beam line. To be able to use the existing kicker for extraction into the beam line towards CRYRING@ESR, a dedicated ion optic setup was developed and successfully tested [7].

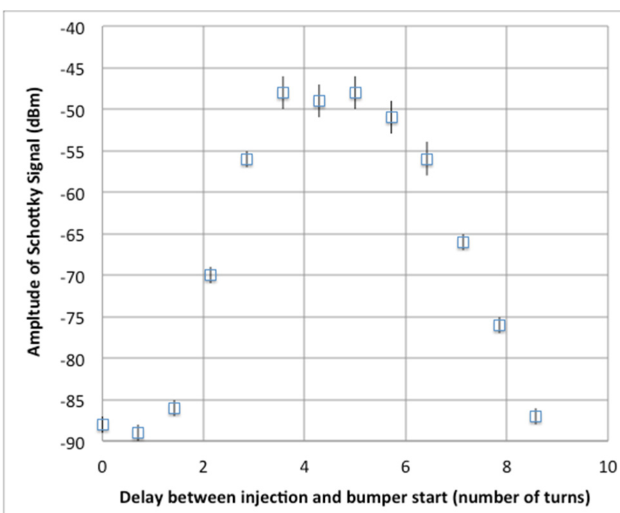

Figure 2: Present efficiency of the multiturn injection scheme. The amplitude of the Schottky noice signal is used as intensity monitor of the stored ion beam after injection at varying times after the bumper ramp start. This time is expressed in number of turns. One turn takes about 7 μs at injection energy.

The second challenge was that the existing sections of that beam line are designed for 10 Tm ion beams – some even for 14 Tm. Here it was successfully tested if the reminiscent magnetic field could be well enough controlled and understood to transport ions with a rigidity of only 0.8 Tm.

After the installation and commissioning of the local injector [6], this was used to deliver H_2^+ ions for the commissioning of the ring itself. Those ions are accelerated to 300 keV/nucleon and then injected with the newly designed [1] multi turn injection system into the ring. This system, a combination of a magnetic and an electrostatic septum together with a electrostatic bump should allow for injection of both, ions from the local injector with at most 300 keV/nucleon, and ions from the ESR with a rigidity of up to 1.44 Tm.

The result of one optimisation cycle is displayed in Fig. 2. The equivalent of about three turns can be injected with steady efficiency while more turns are only injected and stored with lower efficiency. Expected was from theoretical investigations on the new injection scheme an accumulated efficiency of about 70 % for ten turns [1].

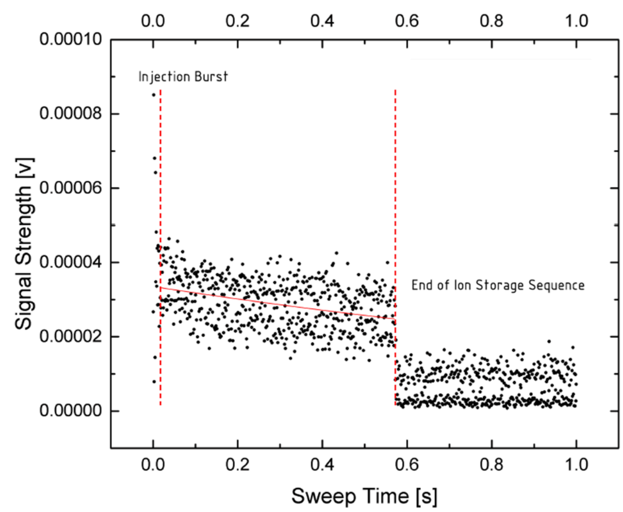

Figure 3: Storage time measurement using the Schottky noise signal. The moments in time when the ions are injected and dumped are marked with red dashed lines. The red line is an exponential fit to the data points that yields a storage time constant of 1.9(2) s.

Finally, stored beam has been achieved and the storage time constant has been measured (Fig. 3). For this the ion beam was injected, the Schottky noise signal recorded, and then the beam was dumped after about 0.7 s. The fit of an exponential to the data points yielded a storage time constant of 1.9(2) s. This storage time is dominated by the dissociation cross section of the hydrogen molecule over the scattering cross section with residual gas particles. The integrated residual pressure during the commissioning run was $8{\cdot}10^{-11}$ mbar, which was measured with a number of extractor type vacuum pressure gauges.

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SUMMARY AND FUTURE STEPS

Stored beam has been achieved, a major milestone on the way to the scientific applications with heavy, highly charged ions stored at low energy. The next steps are the commissioning of the electron cooler, the installation of first detectors and the installation and commissioning of the SPARC prototype gas jet target.

Eight experiment proposals have been evaluated positively by the GSI/FAIR general program advisory committee (GPAC) for the FAIR Phase Zero physics program. Those will be scheduled for the upcoming beam time period in 2018 and 2019.

ACKNOWLEDGEMENT

We would like to thank for the tireless support this project received from the expert groups at GSI. Also worth mentioning is the interest of the scientific community, foremost the SPARC collaboration that is the driving factor behind this installation. Last but not least the help by our Swedish colleagues who used to run this ring in Stockholm should be gratefully acknowledged.

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