

# THE HITRAP DECELERATOR PROJECT AT GSI - STATUS AND COMMISSIONING REPORT

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## Abstract

For injection into the ion trap facility HITRAP, the GSI accelerator complex has the unique possibility to provide beams of highly stripped ions and even bare nuclei up to Uranium at an energy of 4 MeV/u. The HITRAP facility comprises linear 108 MHz-structures of IH- and RFQ-type to decelerate the beams further down to 6keV/u for capturing the ions in a large penning trap for cooling purpose. The installation is completed except the RFQ.

During commissioning periods in 2007  $^{64}\text{Ni}^{28+}$  and  $^{20}\text{Ne}^{10+}$  beams were used to investigate the beam optics from the experimental storage ring extraction to the HITRAP double-drift-buncher system. In 2008 the IH-structure and the downstream matching section were examined with  $^{197}\text{Au}^{79+}$  beam. Comprehensive beam diagnostics were installed: Faraday cups, tubular and short capacitive pick ups, SEM grids, YAG scintillation screens, a single shot pepper pot emittance meter, and a diamond detector for bunch shape measurements. Results of the extensive measurements are presented.

available for a variety of attractive experiments in atomic physics. As presented in Fig.1 heavy ions are produced, accelerated, and stripped in the GSI accelerator complex and are stored, decelerated, and cooled in the ESR (Experimental Storage Ring) down to 4 MeV/u. After extraction from the ESR, the ions have to be further decelerated down to 6 keV/u by 108.408 MHz structures [2,3]. An IH drift tube cavity operating in the H11(0) mode reduces the ion energy to 0.5 MeV/u and a 4-rod RFQ [4] degrades it finally to 6 keV/u. Phase matching into the IH structure is prepared by a DDB (Double-Drift-Buncher combination) of  $\lambda/4$ -resonators whereof the second one works at 216 MHz. A third rebuncher of spiral type is located between the decelerator tanks. Finally a low power spiral type debuncher integrated into the RFQ tank at the beam exit end reduces the beam energy spread for efficient beam capturing in the super conducting penning trap. The linear decelerator as sketched in Fig. 1 is installed in the re-injection channel between ESR and SIS (Heavy Ion Synchrotron).

## INTRODUCTION

Within the HITRAP project (Heavy Ion Trap) [1] trapped and cooled highly charged ions up to  $\text{U}^{92+}$  will become

## STATUS OF INSTALLATIONS

Until September 2008 the HITRAP decelerator was being constructed except the RFQ tank. Magnet power

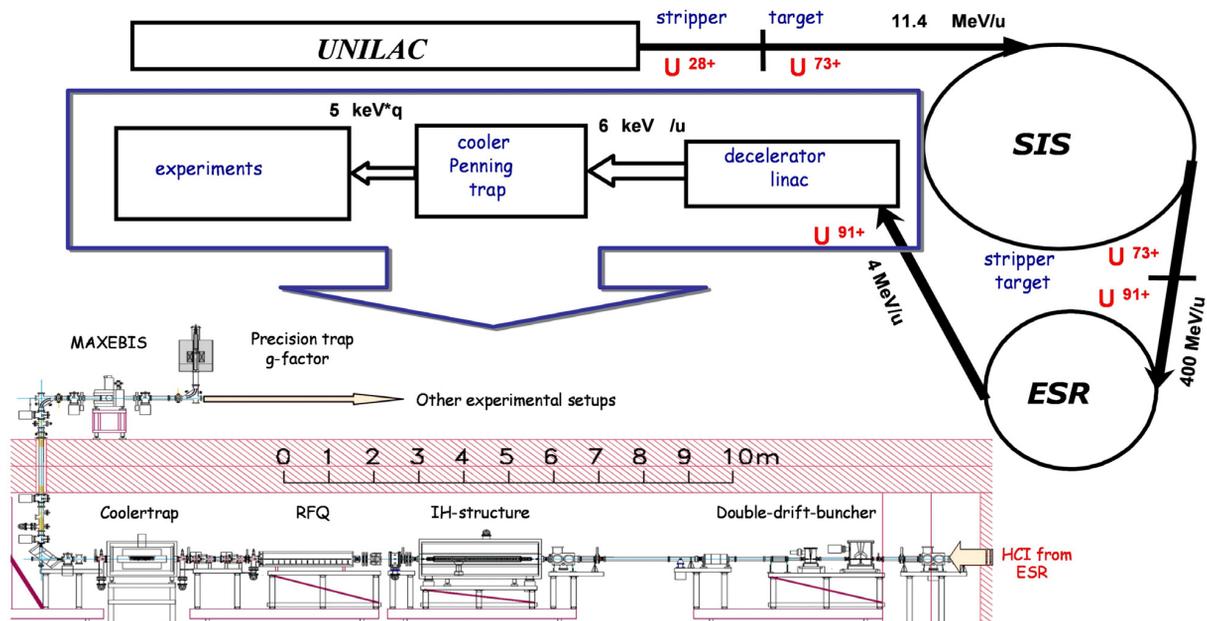


Figure 1: Production process of bare nuclei and HITRAP decelerator.

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converters and rf amplifiers are in operation as well as beam diagnostics and controls. The bunchers are fed by solid state amplifiers up to 5 kW power and could be commissioned without major problems. The decelerator cavities run by 200 kW tube amplifiers from GSI stock.

The commissioning of the IH tank [5] including bead pull measurements and rf power conditioning was done in a rather short time. Fig. 2 shows the gap voltage distribution as calculated by MWS<sup>®</sup> (Micro Wave Studio) compared to the measured one. The drop corresponds to the position of the inner quadrupole triplet lens. The deviations cause an output energy 30 keV/u higher than the 500 keV/u design value. Final adjustment of the voltage distribution will be done later by undercut tuning. The overall effective deceleration voltage is 10.5 MV.

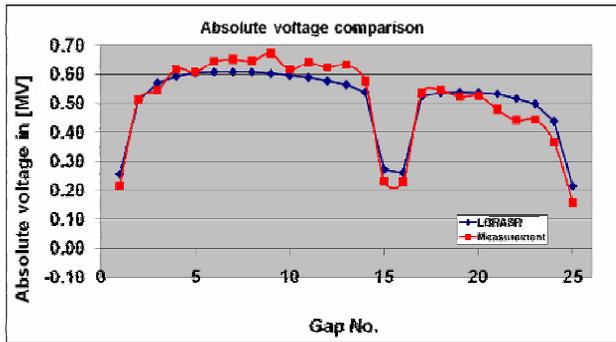


Figure 2: Measured (red) and calculated (blue) field distribution of the IH decelerator.

Table 1 shows the rf parameters of the IH structure. The measured values are very close to the calculated ones. The rf power consumption for the highest beam rigidity of mass/charge = 3 including 10 % reserve stays clearly below the limit of performance of the existing amplifiers.

Table 1: Parameters of the IH Decelerator Tank

Parameter	layout geometry calculated	actual geometry calculated	measured
f [MHz]	108.408	108.69	108.661
Z eff [MΩ/m]	263.3	264.9	270.2
rf-power [kW]	179.6	178.5	174.9
Q <sub>0</sub> (MWS)	21,948	22,163	22,529

Table 2: Measured RF Parameters of Bunchers and RFQ

Resonator	Q	Zeff [MΩ/m]	Ueff [kV]	required rf power [kW]
DDB 108 MHz	10,950	51.70	220.00	1.99
DDB 216 MHz	11,100	43.01	76.00	0.56
Re-buncher 108 MHz	5,300	28.60	105.00	1.92
RFQ 108 MHz	3,700	138.00	77.50	82.69
De-buncher 108MHz	2,700	15.50	0.40	0.00015

The RFQ tank is already placed in the HITRAP cave apart from the beam axis for high power rf conditioning. Table 2 summarizes measured properties of the bunchers and the RFQ and the resulting rf power consumption.

### COMMISSIONING MEASUREMENTS

The beam line from the ESR extraction to the HITRAP DDB section contains comprehensive beam diagnostics: Faraday cups, one tubular and two short capacitive pick-ups, three SEM grids, and four YAG scintillation screens. A single-shot pepper pot emittance meter [6] was used in the final temporary diagnostic setup containing also a diamond detector for pulse shape measurements.

In the first commissioning period in May 2007 the functionality of all components and controls was checked. The <sup>64</sup>Ni<sup>28+</sup> beam was transported through the DDB without rf operation as an acceptance test. Operational experience showed that two additional vertical steering magnets are necessary to improve the beam transmission through a diaphragm mounted to decouple the ESR vacuum of ~10<sup>-9</sup> Pa from the ~10<sup>-6</sup> Pa in the decelerator.

During the second commissioning period in August 2007 with a <sup>20</sup>Ne<sup>10+</sup> beam of 2 μA pulse current and 1.6 μs length the bunchers were in operation. No beam loss was measured up to the tubular pick-up behind the diaphragm. Negligible losses occurred at the narrow apertures of the buncher cavities. The capacitive pick-ups generated bunch signals according to the 108 MHz operating frequency (Fig. 3).

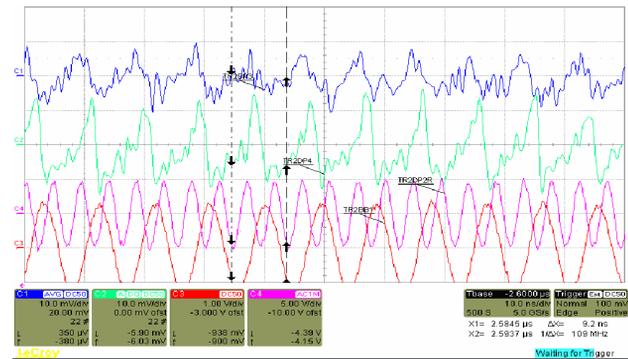


Figure 3: Top: two pick-up signals, bottom: rf signals of the 108 and 216 MHz bunchers.

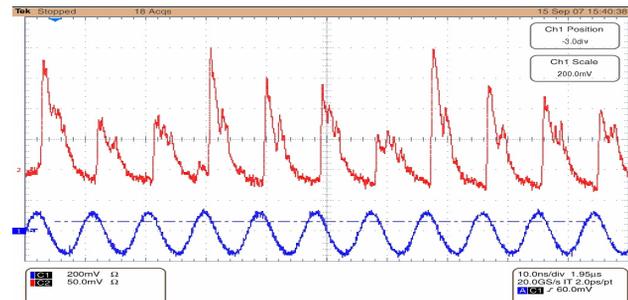


Figure 4: Top: 108 MHz bunches measured with the diamond detector, bottom: the 108 MHz reference signal.

