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From relativistic energies to zero: ion beam deceleration and experiments with slow HCI

HITRAP is a facility for deceleration of highly charged ions (HCI) produced by the GSI accelerator [1]. It consists of an IH-structure and an RFQ for deceleration down to several keV/q, as well as three beam bunchers and several beam transport sections. The linear deceleration stages reduce the ion energy from 4 MeV/u to 500 keV/u and to 6 keV/u respectively, resulting in a slow, but very hot ion bunch, following two non-decelerated bunches. Customized detectors are used to separate the energy components and optimize the deceleration process, while an electrostatic beamline guides the slow ions to a Penning-Malmberg trap. Finally, the ions are ejected towards various experiments.

The decelerator facility has made major progress recently. Last year, electron cooling was demonstrated with about 10^5 HCI produced by an EBIT, mixed with about 10^9 electrons. Depending on the energy, density and trap configuration, the ions transferred most of their energy to the electrons within a few seconds. Furthermore, during two commissioning campaigns, HCI produced by the GSI accelerator were decelerated from relativistic energies to essentially zero and captured in the ion trap –to our knowledge a unique procedure worldwide.

Based on this success, the first experiments with decelerated ions are planned. These include the irradiation of surfaces with slow HCI and the formation of nanometer-sized hillocks [2], scheduled for the beam time period of 2025. Properties of two-species ion Coulomb crystals have already been investigated in the SPECTRAP experiment [3]. In the future, this process will allow rapid cooling of highly charged ions. A new, similar approach involves mixing single HCIs with laser-cooled beryllium ions in a Paul trap [4]. The excitation is detected by quantum logic, which offers much higher sensitivity than classical fluorescence spectroscopy. The ultimate goal is to develop novel optical frequency standards based on HCIs. The goal and status of these and other experiments will also be presented.

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Primary author: ANDELKOVIC, Zoran (GSI Helmholtz Center for Heavy Ion Research GmbH)

Co-authors: Dr NEIDHERR, Dennis (GSI Helmholtz Center for Heavy Ion Research GmbH); Mr ZISIS, Dimitrios (IKP Darmstadt, Germany); Dr HERFURTH, Frank (GSI Helmholtz Center for Heavy Ion Research GmbH); Dr VOROBYEV, Gleb (GSI Helmholtz Center for Heavy Ion Research GmbH); Mr KÖDEL, Jonas (IKP Darmstadt, Germany); Dr STALLKAMP, Nils (GSI Helmholtz Center for Heavy Ion Research GmbH); Dr TROTSENKO, Sergiy (GSI Helmholtz Center for Heavy Ion Research GmbH); RAUSCH, Simon (TU Darmstadt); Dr FEDOTOVA, Svetlana (GSI Helmholtz Center for Heavy Ion Research GmbH); NÖRTERSHÄUSER, Wilfried (TU Darmstadt); Dr GEITHNER, Wolfgang (GSI Helmholtz Center for Heavy Ion Research GmbH)

Presenter: ANDELKOVIC, Zoran (GSI Helmholtz Center for Heavy Ion Research GmbH)