Fast Ion Beams Stored in Cryogenic Low-Density Environment: Collision Experiments and Low-Energy Internal Excitations

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Internal structures and excitations of atomic, molecular and cluster ions are sensitively probed by their collisions and reactions. An important class of these reactions – such as ion–neutral reactions, dissociative recombination with electrons, or electron emission from molecular and cluster anions – leads to neutral products. These products are difficult to access with stationary targets. However, fast ion beams offer powerful single-particle detection methods by which neutral daughter products can be observed. The use of these efficient detection methods on the binary interactions of stored and possibly state-controlled particles is a main motivation behind the development of storage rings for atomic, molecular and cluster ions. In particular, electrostatic storage rings [1, 2] were developed for complex, heavy ionic species with energies in the multi-keV range.

Both the ion storage conditions and the control over the internal ionic excitations can be much improved by setting up cryogenic electrostatic storage rings. Devices of this type recently started operation at three laboratories world-wide [3, 4, 5]. In this talk, we present the Cryogenic Storage Ring (CSR) realized at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany [5]. It is built to accept ion beams (cations and anions) of kinetic energy up to 300 keV per ionic charge and stores these ions on a 35 m long closed orbit. The ion orbit encompasses four 2 m long, field-free straight sections for collision experiments. The ion energy is high enough to enable experiments with a merged electron beam at matched electron and ion velocities, even for polyatomic molecules. Correspondingly, it is envisaged that phase-space cooling of such molecular ion beams will be possible (envisaged mass limit $\sim$160 u per ionic charge). Multi-particle coincidence detectors operated downstream of the merged-beam zones offer the detection of neutral products and to include them in the analysis of the collision kinematics.

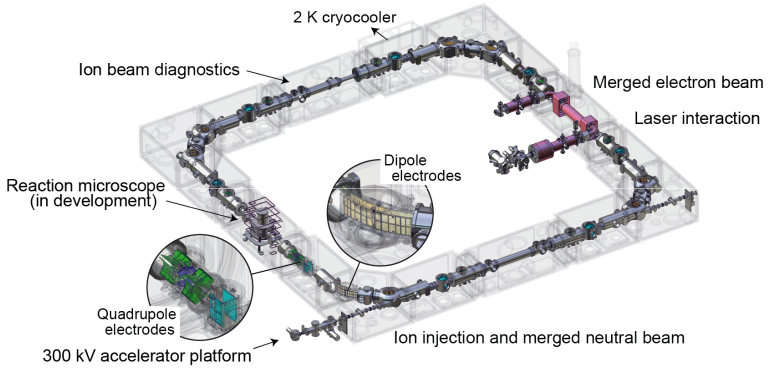

Fig. 1: Overview of the Cryogenic Storage Ring CSR (closed orbit circumference: 35 m).

The CSR was operated successfully at vacuum chamber temperatures of 6 K and ion beam storage time constants up to 45 min [5]. Moreover, it was used for experiments on resonant photodissociation of cations (CH^+ [6]) and near-threshold photodetachment of anions (OH^- [7]). In both cases, the rotational levels radiatively cooled towards a population dominated by $J = 0$. Photodissociation and photodetachment cross-sections as well as radiative lifetimes were investigated on the rotationally cold ions, stored in empty space without buffer gas over times of up to 20 min. Presently, merged-beams reaction zones with electrons and neutral atoms are taken into operation. The talk will present the performance of the CSR, results of first experiments at the facility and the progress of recent experiments using laser and merged particle beam interactions.

References

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