Internally cold ions in the Cryogenic Storage Ring

Oldřich Novotný for the CSR team

* Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Synopsis

We present first results from experiments on internally cold ions using the recently commissioned Cryogenic Storage Ring.

In last decades heavy ion storage rings have proven to be unique tools for investigating properties and reaction dynamics of atomic and molecular ions, in particular low-energy electron-ion collisions in merged beams [1]. The two most prominent advantages are 1) the long storage of the ions allowing relaxation of the internal ion states to the equilibrium with the black body radiation of the wall and 2) the ion beam phase-space cooling using an electron beam which prepares the ion beam target for experiments at high collision-energy resolution.

The black body radiation in the existing storage rings operated at room temperatures (300 K) became a limiting factor for these experiments. Even for small molecules, many rotational levels contributed to the reactions which compromised the comparison with theoretical calculations. Moreover, many low-temperature ion reactions are relevant for astrochemical models of the cold interstellar medium where the internal ion excitation drops down to $\sim 10$ K. This leaves ambiguities for data from 300 K storage rings, where many rotational states remain populated.

To resolve these limitations we have built the electrostatic Cryogenic Storage Ring (CSR) at the Max Planck Institute for Nuclear Physics, Heidelberg, Germany [2]. The ring is designed to store ion beams at energies up to 300 keV per unit charge, independently of ion mass. Cryogenic cooling of the whole beamline chamber leads to a low radiation field. Additionally, at 6K wall temperature reached, the cryo-pumping on the walls results in low residual gas densities ($< 140 \text{ cm}^{-3}$) and ion beam storage times of several hours.

The four straight sections of CSR house experimental setups (Figure 1). In the electron cooler the ion beam is merged with a cold photocathode-produced electron beam. With the electron energy spread of $\sim 1$ meV electron cooling of ions up to 160 u per unit charge is foreseen. The electron beam acts also as a target for experiments such as dissociative recombination of molecular ions and dielectronic recombination of highly charged atomic ions. From the corresponding counting and 3D-imaging detectors operated in the cryogenic environment we derive not only cross section but also the fragmentation dynamics and internal excitations of reactants and products. Another ion collision target is a laser beam oriented at crossed or grazing-angle geometry, accessing processes like photodissociation, photodetachment, etc. In a separate section, a beam of neutral atoms is merged with the stored molecular beam to probe ion-neutral collisions at low relative collision energies. A large variety of ion beams to be stored can be produced from specialized ion sources.

In the talk results from the first CSR experimental campaigns will be presented. We demonstrate functionality of the storage ring and some of the experimental tools, and present first physics results on investigating molecular and cluster ions. Special emphasis will be given to the internal ion cooling for positive and negative molecular ions [3]. Future upgrades will be discussed as well.

References


1E-mail: oldrich.novotny@mpi-hd.mpg.de