Instrumentation for Electron-Ion Recombination Experiments at the CSR

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Electron cooler storage rings have been established as ideal environments to study recombination processes between free electrons and atomic or molecular ions [1]. Dielectronic recombination cross sections for atomic ions govern the ionisation balances of photoionised astrophysical plasmas [2]. Dissociative recombination (DR) of molecular ions is an exothermic process of significant relevance to the chemical evolution of cold interstellar clouds [3].

Scientific progress towards ions of lower and lower charge-to-mass ratios has led the present generation of electron cooler storage rings to practical limits. The Cryogenic Storage Ring (CSR), presently under construction at the Max-Planck Institute for Nuclear Physics [4], is designed to become the future platform for precision recombination experiments. It will be the first storage ring to combine the proven advantages of traditional cooler storage rings with those of compact electrostatic storage devices, allowing precise low-energetic recombination experiments on ionic species of very low charge-to-mass ratios (down to 1/160 e/u). The 10-K-cold beam line of the CSR provides an environment of extremely low residual gas density and infrared radiation background.

We present the electron cooler of the CSR [5], the key ingredient to low-energy electron-ion collision experiments. The cooler will employ a novel parallel-beams merging scheme in order to minimise disturbances of the ion trajectory in the storage ring. The electron beam will be produced using cryogenic GaAs (Cs,O) photocathodes. Experiments have shown that with this device stable electron beams can be generated down to mean kinetic electron energies of 1 eV.

For experiments on recombination of atomic or molecular ions, the electron cooler will be backed by a set of counting and imaging detectors. Mobile counters based on secondary electron generation at converter electrodes will be used after the CSR bending elements to detect rigidity-changed particles, such as recombination products of multiply-charged ions or charged fragments from molecular ion breakups. Neutral fragments, typically emerging from DR of singly-charged molecular ions, will be recorded by large-area MCP detectors equipped with delay-line readout anodes that allow fully momentum-resolved reconstruction of breakup geometries. Thanks to the low emittance of the ion beam after electron cooling, neutral fragment masses can be identified by statistical analysis of the fragmentation opening cones on the MCP detector [6].

At present, no off-the-shelf detector solution can provide direct particle mass resolution at the low beam energies found at the CSR. However, a large-area metallic magnetic calorimeter (MMC) detector is currently in development at the Kirchhoff Institute for Physics (KIP) in Heidelberg. The micro-calorimeter has a diameter of 36 mm and is 16-fold radially segmented. According to simulations of the detector performance, an energy resolution down to a few hundred eV can be expected, combined with near-unity detection efficiency and good radial resolution (in the order of a mm) along each calorimeter segment. Construction and testing of a detector prototype as well as the planning of its implementation at the CSR are currently under way.

Together with the aforementioned key technologies, we present possible future benchmark experiments on electron-ion recombination to be performed after commissioning of the CSR.

References

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