A.6. Ion-Ion Collisions

A.6.1. Ion-Ion Collisions Involving Molecular Systems--*I. Reiser, I. Ali, I. Ben-Itzhak, K.D. Carnes, C.Y. Chen, C.L. Cocke and M. Stöckli*

The investigation of charge transfer in H_2^+ - He^{2+} collisions is extremely appealing because it allows us to study molecular processes in a true one-electron system. A molecular collision system that offers such unique features can only be implemented through ion-ion collisions. Traditional molecular collision systems, involving only one charged collision partner, can never be true one-electron systems. Our experimental data will provide a unique and stringent test for theoretical calculations. The energy range covered by our experiment (ranging from few to several keV) is well suited for semiclassical treatments [1].

The electron capture process that we are going to study, $H_2^+ + He^{2+} \rightarrow H^+ + H^+ + He^+$, is perfectly suited for the KSU ion-ion collision apparatus (see Fig. 1), which was designed to analyze and detect charged particles in both exit paths. The He^{2+} ions are produced in a 5 GHz ECR ion source and the H_2^+ ions are produced in an Oscillating Electron Ion Source (OEIS). Both ion beams are charge state analyzed by magnets before they enter the collision region where the two beams intersect each other at an angle of 90°. The beam overlap is verified by means of a vertically translated slit [2]. The reaction products are then separated from the parent ion beams by analyzing magnets and energy analyzed in an electric field before they are detected with 2D-position sensitive MCP detectors, one of which we equipped with a delay-line anode in order to observe both molecular fragments. The parent ion beams are collected in Faraday cups.

A low rest gas pressure at the collision region is indispensable in ion-ion collisions because of the low target density, which is given by the beam densities. For instance, typical particle densities in the ion beams are of the order 10^4 cm^{-3}. Through improved differential pumping, we reduced the rest gas pressure by a factor of five down to 2×10^{-10} Torr, or a background particle density of 7×10^6 cm^{-3}.

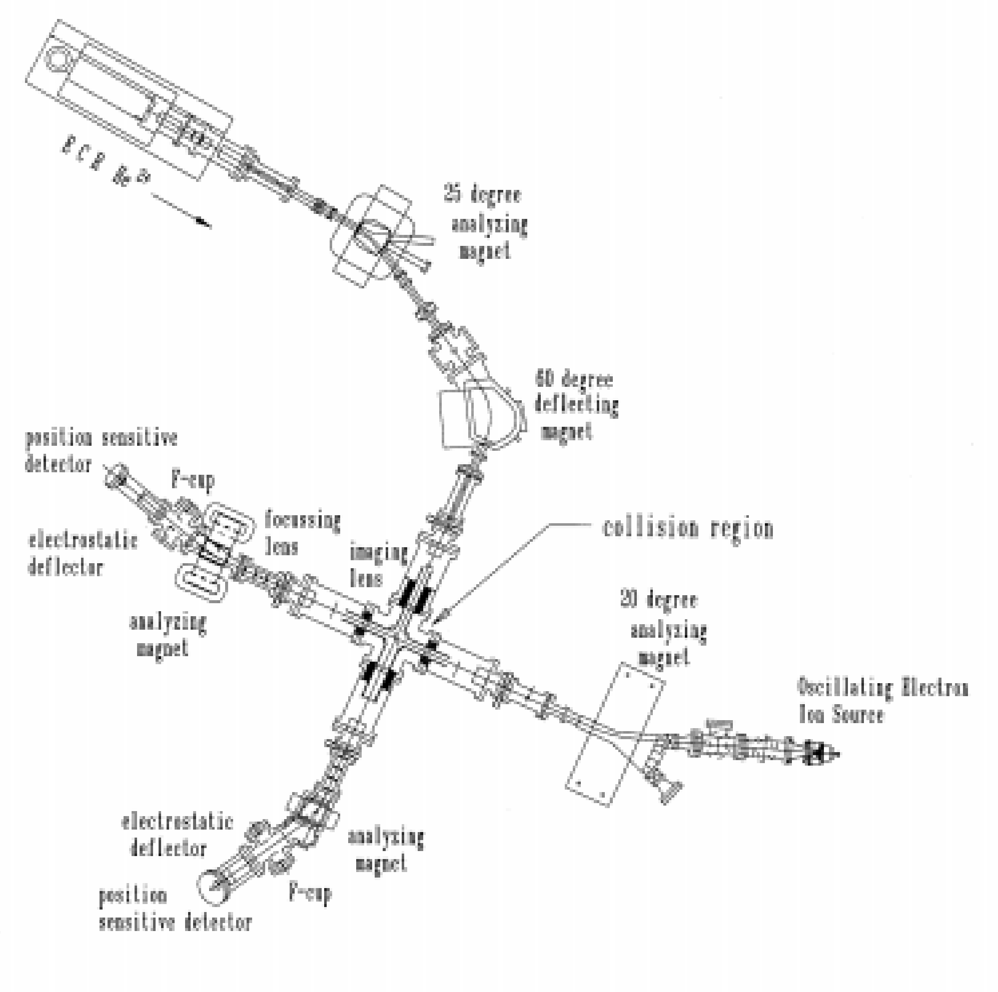

Figure 1. Overview of the KSU ion-ion collision facility.

In order to reduce the active path length, during which products from rest gas collisions are observed on the detectors, the collision region is held on an electric potential. The downstream electrostatic analyzers then energy-select only those collision products emerging from the collision region, which is shorter by an order of magnitude than the beam path through the entire beam line. The true ion-ion collision events are then identified by establishing a time coincidence between two particles impacting on each detector.

In order to check the performance of the apparatus and test the electronics, we measure resonant charge transfer in a kinematically similar collision system, $He^{+} + He^{2+} \rightarrow He^{2+} + He^{+}$. Total cross sections for this collision system have been previously measured in the energy range between 1.775 keV and 15.225 keV [3,4].

We have observed the He^+ - He^{2+} time-coincidence peak with the multi-hit detector at the CM-collision energy of E_{cm} = 4 keV. The coincidence spectrum and the related He^{2+} position spectrum observed with the multi-hit detector are shown in Fig. 2. Note that for test purposes we do not intend to improve the signal to noise ratio by setting software gates on the detector positions, a procedure used in the previous experiment [3]. During the testing we want to ensure that a time-coincidence peak is emerging under the exact same conditions as for the molecular experiment, where the fragments are covering most of the detector surface. The position of this coincidence peak in the time spectrum gives us a reference point for the molecular experiment. Once we observe the He^+ - He^{2+} time-coincidences, we switch to the molecular ion beam. At first we chose to use a D_2^+ beam, which has the same magnetic and electric rigidity as a He^+ beam. Due to kinematics, the reaction products also conserve this similarity (see Section A.5.1 in proposal).

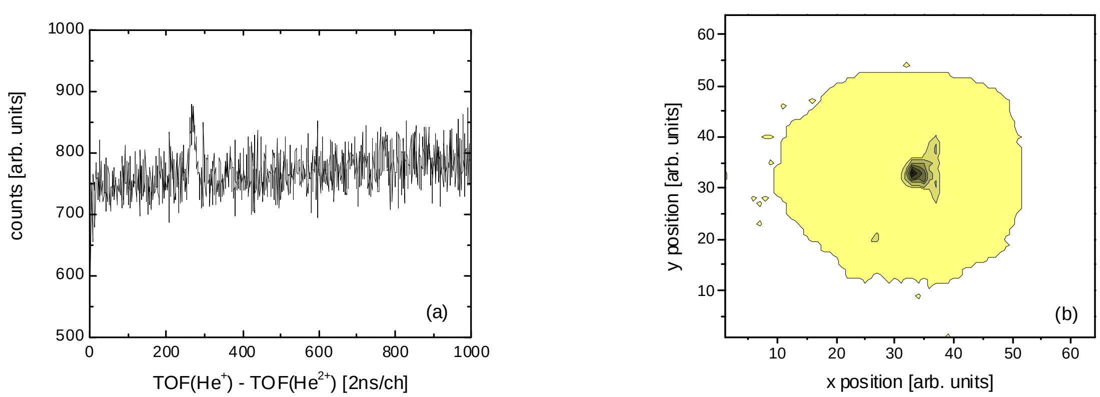

Figure 2: (a) Coincidence spectrum of He^+ - He^{2+} collisions. The coincidence peak has a FWHM of 30ns. (b) Position spectrum of the He^{2+} ions recorded with the delay-line anode.

Unfortunately, when using a D_2^+ ion beam, we observe a much higher count rate on the detector than if we used a He^+ ion beam of the same intensity. We attribute this background (BG) to slit scattering and the high cross section for Collision Induced Dissociation (CID) of molecular ions, as opposed to ionization which gives rise to the He^{2+} background with a very small cross section at keV energies. This limits the D_2^+ beam current, which hurts our signal-to-noise ratio (in ion-ion collisions, $S/N \propto \sqrt{I_1 I_2}$, where I_1, I_2 are the beam currents). To circumvent this problem, we placed a small disk in front of the detector to block D^+ from rest gas collisions. The true events are little affected by this measure since the projection of the Coulomb sphere onto the detector results mainly in a ring with vanishing intensity per unit area at its center.

Since most of the BG processes give rise to only one charged molecular fragment, we select fragments originating from a Coulomb exploded molecule by requiring two D^+ impacting on the detector within the physical flight time spread, which is about 200 ns for an explosion energy of 20 eV. With the pulse pair resolution of the D^+ detector of about 15 ns, we were able to implement a self-coincidence scheme and record only D^+ - D^+ time coincidences for which the difference in flight time was less than 500 ns. The two particle coincidence scheme that we used to detect He^+ - He^{2+} time coincidences is not applicable here because of the width of the He^+ - D^+ coincidence peak due to the Coulomb explosion. With this setup, we recently obtained preliminary data that shows an indication of D^+ - D^+ time coincidences.

One aspect that we are going to investigate further is the distortion of the Coulomb sphere by the ion optics. We have carried out simulations of the ion trajectories with SIMION that show that we are able to collect molecular fragments with large scattering angles as produced in a Coulomb explosion. To reinforce those results, we installed electrostatic deflectors at the collision center, so that we can probe the imaging properties of our apparatus directly with a D^+ beam. In addition to mapping out our apparatus, we also hope to gain more insight as to the origins of the high D^+ background during the coming months.

References

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