A.1.3. High Velocity Collisions: Kinematically Complete Measurements of the Single Ionization of He by Fast Protons and Highly Charged Ions--*A. Landers, M. Singh, P. Richard, C.L. Cocke, R. Unal, E. Wells, E. Edgu, I. Reiser*

When the COLTRIMS measurements of single ionization discussed above are carried to high velocity projectiles, several qualitative changes in the ionization mechanism take place. First, the process becomes less molecular and more perturbative in nature. Second, the momentum transfers to projectile, electron and recoil become very similar in magnitude, as opposed to the low velocity case where the momentum transfer between recoil and projectile is much larger than that to the electron. Finally, the heavy particle momentum transfers become quite small and challenge the experimenter to make a good measurement.

We have used a supersonic gas jet and imaging detectors in a COLTRIMS configuration to measure the single ionization of He by protons (1-5 MeV) and Cl^{+q} (0.47 MeV/u, q=5 and 10) in a kinematically complete experiment. These experiments are very complimentary to other electron-spectroscopic measurements being carried out in this laboratory. While they are not of high resolution, they concentrate nearly exclusively on the very soft electrons, which dominate the electron ionization total cross section. Furthermore, they provide the dependence of the electron momentum spectrum *on the transverse projectile momentum transfer*. This parameter is usually integrated over in both experiment and theory when dealing with soft continuum electron spectra.

The pulsed beam characteristics of the KSU LINAC and imaging detectors were used to provide the vector momenta of all three outgoing particles, giving us experimental control over the projectile (as well as recoil and electron) momentum transfer on an event-by-event basis. The longitudinal momentum transfer spectra are in agreement with previous singles electron data taken with conventional dispersive spectrometers. This comparison serves primarily as a test of the consistency of the two approaches to soft electron spectroscopy. The transverse momentum spectra allow the separate identification of photoionization-like (or “three body”) and binary-encounter-like (or “two body”) mechanisms in the ionization process. For example, for electrons with energies below 50 eV, where most of the total ionization cross section lies, the transverse momentum given to the electron is found to be very closely balanced by the transverse momentum carried away by the He^{+} recoil ion. The correlation between transverse electron and projectile momenta, which would indicate binary-encounter-like events, is found to be much

weaker over this electron velocity range. Figure 1 shows a plot of the transverse electron momentum plotted in the coordinate frame of the projectile momentum transfer or the recoil momentum transfer for 5 MeV H^+ on He. The correlation between projectile and electron momentum transfer is quite weak. This is because the reaction is dominated by the Bethe-Born large impact parameter region, and the spectrum is very similar to those that one obtains in photoionization with the polarization vector oriented vertically (direction of H^+). The middle figure shows a much stronger correlation between recoil and electron transverse momentum, while the lower figure shows the correlation between recoil and projectile momentum. This last momentum transfer occurs through the intermediary of the electron: direct Coulomb momentum transfer between recoil and projectile is negligible in this collision. The right hand column shows the corresponding first order Born approximation spectra.

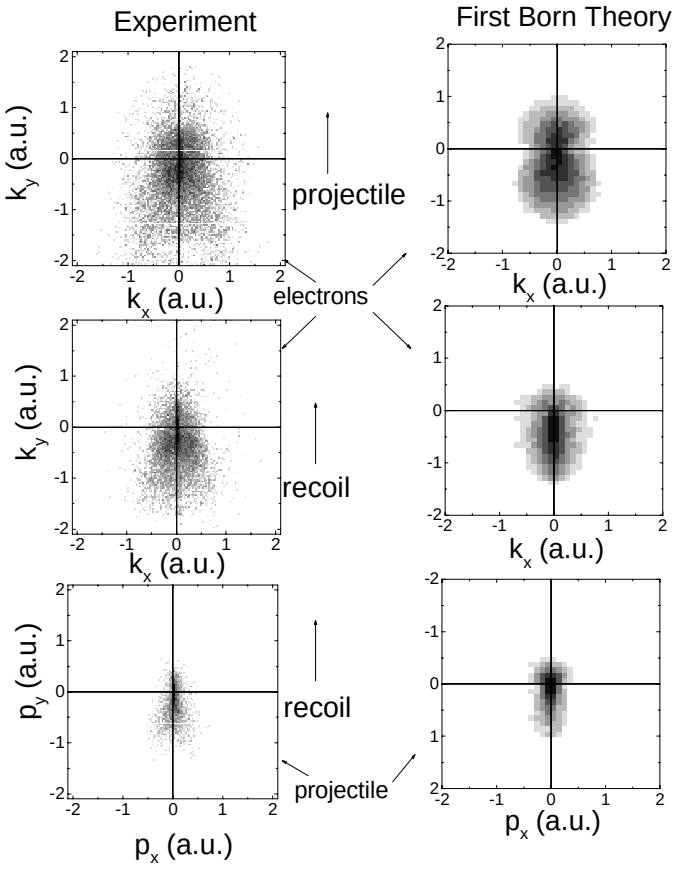

Figure 1. Left hand column: the top spectrum shows the transverse electron momenta from 5 MeV H^+ on He, with the projectile momentum vector defined as the positive vertical axis. The middle spectrum is the same, but the recoil vector is defined as the positive vertical axis. The lowest figure is the transverse projectile momentum vector, with the recoil momentum vector defined as the positive vertical axis. Right hand column: First Born calculations for the same three spectra.

The experimental results are in good agreement with first order Born approximation calculations for 5 MeV protons, as would be expected, since Z/v is small for this case and the perturbing influence of the internuclear scattering is small. A surprising observation is, however, that the photoionization-like dominance remains for the highly non-perturbative Cl^{10+} projectile as well, for which no reliable theoretical calculation is available. The results of these measurements are reported in the Ph.D. thesis of Allen Landers and in Publications #58 and 88.