Single Ionization of Helium by Fast Proton Impact

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Synopsis: We measured single ionization of helium for proton impact at energies between 0.5 and 2 MeV. The electron angular distributions will be discussed in the context of the heavily debated influence coherence length.

The most simple ion-impact experiment is single ionization, induced by a fast ion and small perturbation. These are well described by a calculation in the First Born approximation (FBA). In the angular distribution of the emitted electron a pronounced peak between the forward (directly) emitted electron and the backward emitted electrons (scattered at the target nucleus), is expected in these experiments and has been seen in ($e,e'\gamma$) experiments. For a long time similar results were also expected for the impact of fast ions. The deviations were attributed to insufficient resolution. A collision experiment with C$^{6+}$ projectiles at 100 MeV/u [1], impacting on a helium target, showed that the node was mostly filled, but not symmetrically. This started an ongoing discussion from experimental problems, a lack of theoretical description or new physics. 15 years later, the issue is still not solved and two explanations remained: insufficient momentum resolution and the influence of transversal beam coherence. According to [2] the macroscopic geometrical preparation of the beam, e.g. its divergence, should influence the microscopic scattering behavior and therefore for example the electron’s angular distribution.

Therefore we investigated p+He collisions at impact energies from 0.5 to 2 MeV, produced by a Van-de-Gaaff accelerator. We used the COLTRIMS reaction microscope technique [3] and optimized the imaging spectrometer for the highest momentum resolution. We measured the momentum vectors of all emitted particles in coincidence. At 1 MeV impact energy (see Figure 1) we observed a pronounced minimum between the binary and recoil peak. The electron angular distribution is well reproduced by calculations in the FBA (calculations differ how the initial state is described). The experimentally forward bend angular distributions are due to post collision effects. To shine light on the discussion on beam coherence effects, we manipulated investigated the electron angular distributions for various beam divergence parameters, either by different collimation (1 MeV) or by utilizing an electro static quadrupole lense (2 MeV).

Figure 1. Electron emission angle in the scattering plane for 1 MeV p+He, E$_p$=6.5±3.5 eV, q=0.75±0.25 au; experiment (green dots), FBA calculation (black dashed line), JFBA (blue dotted line) and CFBA (red line).

References
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