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Electron- and Proton-Impact Excitation in Stored Hydrogenlike Uranium Ions

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Synopsis The projectile excitation of high-Z ions has been investigated in relativistic ion-atoms collisions by observing the subsequent x-ray emission. Within this experiment information about the population of the magnetic sublevels has been obtained via an angular differential study of the decay photons associated with the subsequent de-excitation process. In addition, we have observed for the first time the effect of electron-impact excitation in a heavy highly charged ion undergoing a collision with a neutral atom.

Electron-impact excitation (EIE) of bound electrons is one of the most fundamental processes and leads to the specific formation of spectral lines. In particular, it is responsible for the vast majority of x-ray radiation produced in high energy density physics experiments and at laboratory fusion devices. In addition, QED effects are predicted to affect the EIE process through the generalized Breit interaction [1]. Most EIE measurements have thus far only been performed at electron beam ion trap facilities with low- to mid-Z ions [2] because the heaviest highly charged ions cannot easily be produced. To study EIE in the highest-Z few electron ions an accelerator facility with a large number of ions is needed. However, because the impact excitation cross-sections for heavy highly charged ions (i.e. hydrogenlike uranium) are typically under one barn and the proton-impact excitation rate for a stored highly charged ion scales as Z^2 (while the EIE rate only scales as Z), the only excitation studies that have thus far been performed have used multi-proton gases or solids in an effort to have a reasonable intensity of photons recorded [3].

In a recent experiment at GSI, we looked for EIE effects in relativistic collisions between H-like uranium ions and hydrogen and nitrogen targets. At energies of 100, 220 and 400 MeV/u, x-ray spectra from uranium ions were recorded to investigate the produced excitation lines 1s $\rightarrow$ $2p_{3/2}$ Lyman-α_1 and1s $\rightarrow$ $2p_{1/2}$ Lyman-α_2. This allowed for investigation of regions below, at, and above the EIE threshold of $\sim$ 200 MeV/u. We used four high purity solid state germanium detectors for angular differential measurement.

The effect of EIE can be seen by looking at the ratio of the number of counts in the Lyman-α_1/ Lyman-α_2 spectral lines produced by both excitation processes. For collisions with nitrogen gas atoms, the excitation process is mainly due to the protons in the target atom. However, for collisions with hydrogen gas atoms both the proton and the electron contribute to the excitation equally. From a comparison between these two collision systems, electron- and proton-induced excitation can be disentangled. In addition, energy specific relative and total electron- and proton-impact excitation cross sections and alignment parameters (described in more detail in reference [4]) have been measured.

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