Forward-angle electron spectroscopy in ion-atom collisions studied at the ESR*

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The spectroscopy of electrons emitted in low-energy ion-atom collisions, in particular in forward direction parallel to the projectile ion beam, has been in the focus of research in atomic physics for several decades. These electrons populate low-lying continuum states of the projectile and, due to Lorentz transformation, are observed in the laboratory frame as electrons emitted under $\vartheta_e \approx 0^\circ$ with a velocity v_e similar to the projectile velocity $v_e \approx v_p$. Experimentally the spectroscopy of these so-called "cusp-electrons" benefits from enhanced energy resolution due to a reduced Doppler broadening.

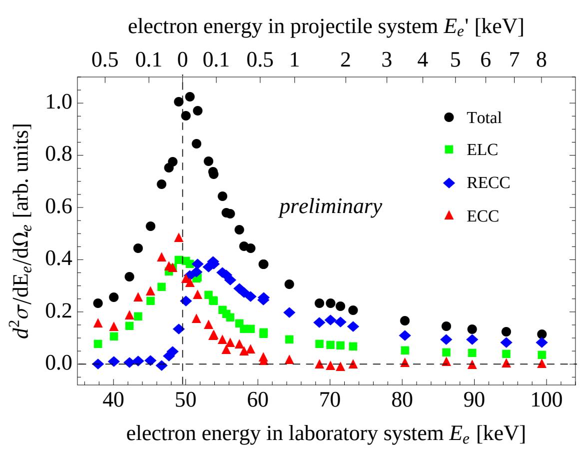

Figure 1: Energy distribution of forward emitted electrons originating from processes (a) – (c).

At GSI this field of research was extended to high-energy heavy-ion atom collisions. For this purpose collisions of beryllium-like U^{88+} projectile ions at 90 MeV/u colliding with a molecular gas-jet target of N_2 were studied at the ESR in a beam time in 2012. The energy distribution of cusp electrons emitted in these collisions was measured with a dedicated magnetic electron spectrometer located downstream the gas-jet target. Additionally five X-ray detectors were positioned around the target, and two particle detectors were used to detect projectile ions which had lost or captured one electron during a collision with the target (or the residual gas). Applying coincidence conditions between the electrons observed in the spectrometer and signals of one of the X-ray or particle detectors three different collision processes could be observed. Each of them resulted in an electron populating a low-lying continuum state of the projectile:

(a) The **electron loss to continuum** (ELC) corresponds to the ionization of a projectile electron into the projectile continuum during the collision with the target:

$$U^{88+} + N_2 \rightarrow U^{89+} + [N_2]^* + e^-.$$

(b) The **electron capture to continuum** (ECC) corresponds to the capture of a target electron into the projectile continuum, while the excess energy is carried away by the recoil of the generated target ion:

$$U^{88+} + N_2 \rightarrow U^{88+} + \left[N_2^+\right]^* + e^-.$$

(c) The **radiative electron capture to continuum** (RECC) corresponds to the capture of a target electron into the projectile continuum, while the excess energy is carried away by a photon:

$$U^{88+} + N_2 \rightarrow U^{88+} + \left[N_2^+\right]^* + e^- + \gamma.$$

Previously the RECC process (c) was for the first time observed unambiguously at GSI and experimentally proven to be equivalent to the high-energy endpoint of electron-nucleus bremsstrahlung studied in inverse kinematics [1]. Succeeding this pioneering experiment a high-resolution measurement of the processes (a) – (c) was performed in 2012, with a significantly improved experimental setup [2]. Whereas for low-energy projectiles used in former studies the cusp electron spectrum was dominated by ECC or ELC, it was proven within this experiment that at 90 MeV/u the cross sections of the three processes are comparably large, while the shapes of the electron energy distributions show significant differences (Fig. 1). Notably the opposite asymmetry of ECC and RECC gives a clear signature of the different underlying collision mechanisms. Comparison of the experimental results with various theoretical calculations is currently under way and soon to be published.

References

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