Zero-degree electron spectroscopy of highly-charged-ion–atom collisions in a storage ring

P-M Hillenbrand[1 *], S Hagmann[1], Y A Litvinov[1] and T Stöhlker[1,2,3]

[1]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany
[2]Helmholtz-Institut Jena, 07743 Jena, Germany
[3]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

Synopsis We show how electrons emitted under zero degree in collisions of highly charged ions with atoms are unique messengers of the underlying charge-transfer processes. We measured the continuum electron distribution for different collision processes using a magnetic electron spectrometer installed in a heavy-ion storage ring and compared our experimental results to individual theoretical calculations.

The energy distribution of emitted electrons is a prominent observable to study dynamical processes occurring in collisions of highly charged projectile ions with atomic targets. In these collisions, electrons emitted into the projectile continuum appear as well-known 'cusp electrons' in the laboratory frame, i.e., electrons ejected at zero degree with respect to the projectile beam, at velocities comparable to the projectile velocity. To this end, the spectroscopy of zero-degree electrons provides a highly sensitive tool to probe the energy and angular differential cross sections of charge-transfer processes.

Within the project presented here, we have extended the concept of zero-degree electron spectroscopy towards highly charged projectiles at near-relativistic collision energies. We used the experimental storage ring ESR at the heavy-ion accelerator facility GSI, which provides high luminosities of highly charged projectile beams under well-defined conditions. To measure the emitted electrons, we installed a dedicated magnetic electron spectrometer downstream from the supersonic gas-jet target.

Using the electron spectrometer in combination with detectors for emitted x rays and charge-exchanged projectiles, our studies of collision systems such as $U^{88+}(1s^2 2s^2) + N_2$ @ 90 MeV/u revealed three processes, each characterized by a unique shape of the electron cusp. In particular, the asymmetry of the measured electron energy distribution originating from a forward- or backward-enhancement of the populated electron continuum proves to be characteristic for the individual processes. Through the electron-loss-to-continuum (ELC) cusp, double-differential cross sections of projectile ionization can be measured even for the heaviest few-electron projectiles [1]. The electron-capture-to-continuum (ECC) is the non-radiative capture of a target electron into the projectile continuum, which is the dominant process at low collision energies [2]. Furthermore, at near-relativistic energies the new channel of radiative-electron-capture-to-continuum (RECC) opens up, which can be described as bremsstrahlung in inverse kinematics [3]. Each of these processes has been compared to their respective state-of-the-art theoretical calculations. Further studies include the ELC for multi-electron projectiles in collisions of U^{28+} with different gaseous targets [4].

These advanced experimental capabilities have recently motivated new theoretical studies that compare double-differential cross sections for proton- and electron-impact ionization of hydrogen-like highly charged ions [5]. The current status of the project and recent developments as well as future perspectives will be shown.

References

[1] Hillenbrand P-M *et al.* 2014 *Phys. Rev. A* **90** 042713
[2] Hillenbrand P-M *et al.* 2015 *Phys. Rev. A* **91** 022705
[3] Hillenbrand P-M *et al.* 2014 *Phys. Rev. A* **90** 022707
[4] Hillenbrand P-M *et al.* 2016 *Phys. Rev. A* **93** 042709
[5] Lyashchenko K N *et al.* 2018 *J. Phys. B* **51** 055204

*E-mail: p.m.hillenbrand@gsi.de