# Precise polarization studies of radiative electron capture

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The capture of electrons into bound states of ions is of significant importance for both experiment and theory in the fields of atomic and plasma physics as well as for astrophysics. The capture process is called radiative if it is accompanied by the emission of a photon that carries away the initial electron's kinetic energy and the binding energy of the final state it is captured into. If the initial electron is considered to be free, the capture process is referred to as radiative recombination (RR), being the time-reversal of the photoelectric effect, whereas the capture of a bound electron is called radiative electron capture (REC) [1].

The REC process is a prominent charge-changing process for fast, highly-charged ions interacting with dedicated target materials or with residual gas being present in the beamlines of accelerators and storage rings. Moreover, when low- to medium-$Z$ targets and heavy, highly-charged projectile ions are considered, the to-be-captured electrons can be treated as free particles having a momentum distribution equal to the one of the bound target states. This so-called impulse approximation reduces the REC description to the RR cross section convoluted with the incident electron momentum distribution. Consequently, both the REC and the RR process as well as the photoeffect can be treated within the same theoretical framework. Moreover, when compared to the photoeffect, the RR/REC process offers several experimental advantages, such as a more uniform emission pattern due to the partial cancelation of retardation and Lorentz transformation for a moving emitter system and the fact that x-rays, in contrast to electrons, can typically leave the target zone unaffected by secondary-collision effects. These facts motivated various REC measurements aiming for a deeper insight into the photoeffect while exploiting the advantageous experimental conditions present for the study of electron capture into fast, highly charged ions.

A first study of the linear polarization of REC photons was published in 2006 [2] where a $4 \times 4$ pixel Ge(i) detector was used for Compton polarimetry of x-rays emitted in collisions of bare uranium ions with a $N_2$ target at the experimental storage ring (ESR) of GSI. The experimental findings are presented together with theory values in figure 1a. Having only 16 pixels, the relatively low granularity of the detector resulted in a poor angular resolution of the Compton scattering distribution, which limited the experimental accuracy to an uncertainty between $\pm 5\,\%$ and $\pm 10\,\%$ with respect to the degree of linear polarization. The much higher granularity of a newly developed Si(Li) polarimeter [3](see figure 1b) enables more precise studies and this instrument was already applied in a series of test measurements also addressing the REC radiation [4,5]. Data analysis is still in progress and we expect an experimental uncertainty for these new polarization studies in the order of $\pm 1\,\%$ of the degree of linear polarization. With regard to future experiments at the new FAIR facility it is worth noting that while the existing ESR is limited to typical ion energies not higher than 400 MeV/u for beams of heavy ions, the planned high-energy storage ring (HESR) will reach up to approximately 5 GeV/u for bare uranium. With the extended energy range it will become possible to probe the cross-over effect in the degree of REC photon linear polarization which is predicted to occur at collision energies above 600 MeV/u and for forward emission angles, see the theory data for 800 MeV/u in figure 1a. In terms of the photoeffect this feature indicates that the initially bound electron is no longer preferentially ejected in the direction of the incident photon electric field vector, instead emission along the magnetic field vector is dominant.

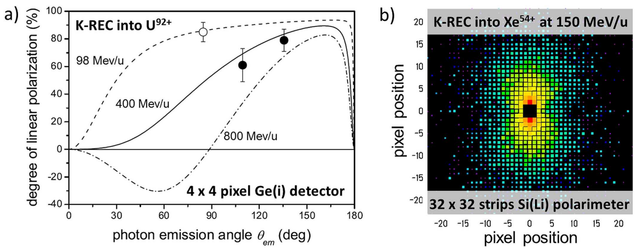


Figure 1: a) Degree of linear polarization of the radiative electron capture (REC) into the K-shell of bare uranium projectiles measured with a $4 \times 4$ pixel Ge(i) detector applied as a Compton polarimeter [2]. b) Position distribution of Compton scattered K-REC photons inside the Si(Li) polarimeter for the capture into bare xenon ions. Data analysis with respect to the degree of linear polarization is ongoing. The much higher granularity of the new detector is expected to enable significantly more precise measurements compared to the 16 pixel detector.

## References

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