Towards a fast calculator for the radiation characteristics of radiative recombination and radiative electron capture

G. Weber[*1,2], *H. Ding*[2,3], *M. O. Herdrich*[2,3], and *A. Surzhykov*[2]
[1]GSI, Darmstadt, Germany; [2]Helmholtz Institut Jena, Germany; [3]IOQ, FSU Jena, Germany

The radiative capture of free electrons (radiative recombination, RR) and bound electrons (radiative electron capture, REC) are among the most important charge changing processes for fast, highly-charged ions passing through matter. In particular for ongoing highly-charged ion studies at the ESR and for future experimental campaigns planned at the CRYRING@ESR and the high-energy storage ring (HESR) of the FAIR facility, precise knowledge of REC characteristics in a broad range of collision energies from about 1 MeV/u up to 5 GeV/u is highly desirable. 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 approximation reduces the REC description to the RR cross section folded with the incident electron momentum distribution. Consequently, both the REC and the RR processes, as well as the photoeffect (the time-reversal of RR), can be treated within the same theoretical framework [1]. While total cross sections can be obtained by an approximate formula with reasonable accuracy, the estimation of angular distributions and polarization properties of the emitted radiation requires a fully relativistic treatment that is numerical expensive. Therefore we recently started the development of a fast calculator (called RECAL) for all relevant characteristics of RR and REC photons. The program is based on a grid of rigorously calculated data points for RR into bare ions, between which interpolation is performed to obtain radiation characteristics for specific collision systems.

For the grid points, differential cross sections and linear polarization values of the RR photons were calculated using parts of the DIRAC toolkit, see [2]. The accuracy of the RR calculation is mainly determined by the accuracy of the continuum wavefunction representing the initial state of the incident electron, which is described by a series expansion in terms of partial waves. A careful choice of the number of partial waves, defined by $\nu = 2\kappa_{max}$, with κ_{max} being the maximum number for the Dirac angular momentum to be taken into account, is of particular importance. More precisely, a too small choice of κ_{max} may lead to truncation errors, while, on the other hand, a too large value increases significantly computation time (approximately scaling with κ^3_{max}) and eventually leads to an explosion of numerical errors due to the rapid oscillations of the radial part of the continuum wavefunction.

For first test calculations, we generated a RR data base of capture into bare projectiles for atomic numbers Z between 1 and 92 and more than 100 kinetic energies between 2 MeV/u and 1 GeV/u. A comparison of angular differential RR cross sections obtained from the RECAL interpolation algorithm to fully relativistic calculations from [3] is shown in Fig. 1. Here the radiation stemming from the capture of free electrons into the ground state of bare lead ions was studied for several collision energies. An increasing deviation at high collision energies is seen, most probably due to an improper choice of κ_{max} for the underlying RR data base of the RECAL program. Currently, we are working on an optimized data base to provide reliable RR/REC cross section and linear polarization values for arbitrary collisions systems at ion beam energies between 1 MeV/u and 5 GeV/u.

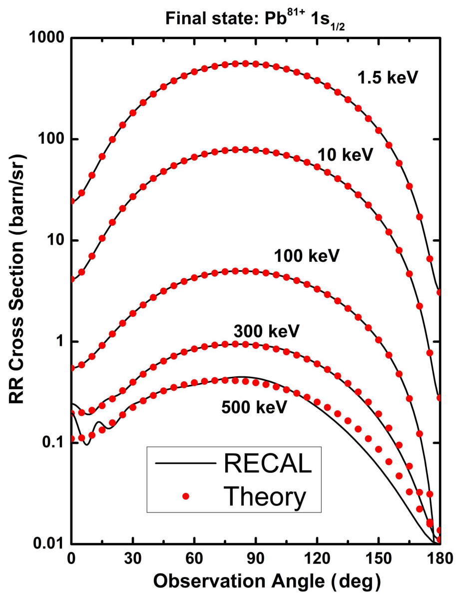

Figure 1: Angular differential RR cross sections for electron capture into the ground state of bare lead ions. Fully relativistic calculations from [3] are compared to RECAL predictions. An increasing deviation at high collision energies is seen due to an improper choice of κ_{max} for the underlying data base of the RECAL calculator.

References

[1] J. Eichler and Th. Stöhlker, Phys. Rep. **439** (2007) 1

[2] A. Surzhykov et al., Comput Phys Commun **165** (2005) 139

[3] A. Ichihara and J. Eichler, At. Data Nucl. Data Table **79** (2001) 187

* g.weber@gsi.de

 DOI:10.15120/GR-2015-1-APPA-MML-AP-08