4 - 8 Proposal for Measuring Line Profiles and Angular Distributions of the Radiative-electron-capture Transition in Low-energy Ion-atom Collisions: Beyond the Impulse Approximation*

Li Tian and Yu Deyang

Radiative electron capture (REC) is an interatomic transition which features by momentum balancing between a photon and two nuclei. Up to now, all related experiments were performed with high-energy projectile ions and the results agree well with the impulse approximation with the independent electron model[1,2]. Due to recent advances in low-energy, strong-beam accelerators of highly charged ions, experimental studies of the REC by low-energy bare heavy ions becomes available. Owing to long ion-atom interacting duration, independent description of the target electrons, ignorance of the target polarization, dipole approximation of the electromagnetic transition, and assumption of nuclei non-energy sharing may become inaccurate. First, the REC line profile may show an observable asymmetry, although it has not been observed in high-energy collisions yet. Second, the peak energy of the REC photons may present an extra shift to the low-energy end of the photon-energy spectrum. Third, the polarization effect of the target atom may appear. The wave functions of target atoms can be distorted by the electric field of the highly charged projectile ion, and thus, the relative electron momentum distribution and therefore the REC line profile will be modified. Fourth, the REC and the NRC mechanisms may hybridize. In principle, REC is a four-body (*i.e.*, the electron, the two nuclei, and the emitted photon) process. Fifth, the REC line profile and the final target state may entangle.

We propose to measure line profiles and angular distributions of the radiative-electron-capture transition in collisions of sub-MeV/u Ar^{18+} with helium[3]. We showed that the asymmetry of the K-REC line profile and the deviation of the angular distribution from the $\sin^2\theta_t$ law are magnified in sub-MeV/u collisions, where θ_t is the angle between the directions of the REC photon and the projectile ion in the target frame. New treatment of the REC process in the low-energy region is eagerly expected. Accurate measurement of the REC line profile and angular distribution at low energies can serve as a sensitive probe to test future REC theories, especially when the impulse approximation does not hold well. Key requirements for the proposed experiment, such as the energy resolution of the photon detectors and the energy monochromaticity of ion beams, have been estimated. With the use of a usual bent-crystal spectrometer and a group of commercial silicon-drift X-ray detectors, one will be able to obtain a sufficiently precise line profile and angular distribution, which can be employed to distinguish different REC theories beyond the impulse approximation that has so far been employed. Moreover, accurate REC experiments in the sub-MeV/u energy region may provide insights into inter-atomic electromagnetic transitions.

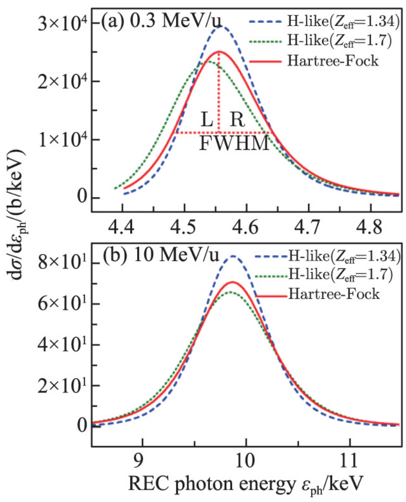

Fig. 1 (color online) Line profile of the K-REC transition in collisions of Ar^{18+} with helium at two projectile energies: (a) 0.3 and (b) 10 MeV/u, respectively. The target atom is modeled by hydrogen-like (with $Z_{\rm eff}$=1.34 and 1.7, which correspond to the first and the average ionization energies of helium) and Hartree-Fock wave functions, respectively. The line profile exhibits significant asymmetry at sub-MeV/u projectile energies.

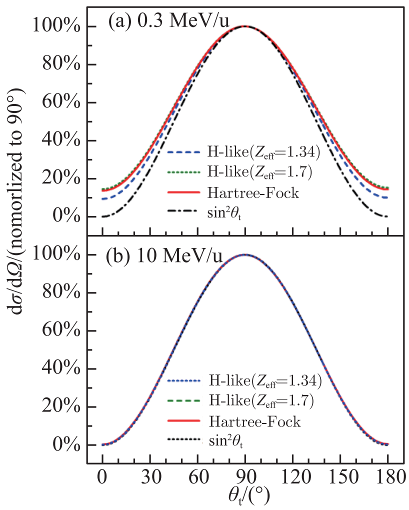

Fig. 2 (color online) Angular distribution of the K-REC photons in collisions of Ar^{18+} with helium for two projectile energies: (a) 0.3 and (b) 10 MeV/u, respectively. Descriptions of target atoms are the same as those in Fig. 1. At sub-MeV/u projectile energies the angular distribution deviates from the $\sin^2\theta_t$ law, while at 10 MeV/u this effect disappears.

References

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*National Key Research and Development Program of China (2017YFA0402300) and National Natural Science Foundation of China (11774356)

4 - 9 Momentum Computed Tomography of Low-energy Charged Particles Produced in Collisional Reactions

Zhang Yuezhao and Yu Deyang

We propose the MCT measuring method[1]. It promotes the image reconstruction methodology into the momentum space of the secondary particles produced in collision experiments. MCT pursues a projection-reconstruction solution to the measurement problem. Firstly, the three-dimensional particle momentum is projected into a lower-dimensional position space in a programed way. This produces a series of projections consisting of curve-integral measurements in the particle momentum space. Then, the momentum distributions of included particle species are reconstructed from these integral measurements. Taking a parameterized MCT spectrometer for instance, we firstly lay down the projection theory both in continuum and discretized forms. In the context of a Poisson statistical model, we further provide a reconstruction procedure under the MAP framework. The *a priori* knowledge of transform sparsity of the momentum distributions is assumed, the regularization term is constructed in the CS scenario as the TGV function, and the problem is solved by the PADMI algorithm. We illustrate the projection process and demonstrate the reconstruction algorithm performance with numerical experiments in the context of the sputtering phenomenon. Figure 1 shows the comparison between the original and the reconstructed momentum distributions.

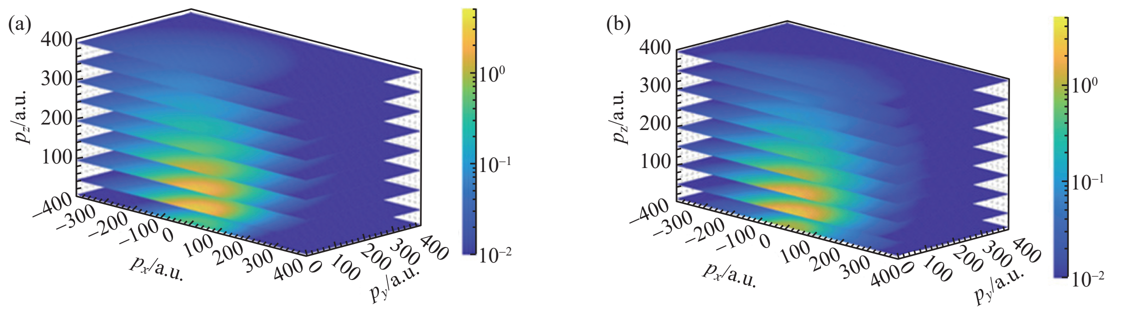

Fig. 1 (color online) The stack of the slices at different p_z viewed from the p_xOp_z plane of the original (a) and the reconstructed (b) momentum distributions.

We believe MCT creates a new paradigm of spectrometry in physical collision experiments. It is especially suitable for the measurement of intense particle showers, providing a new probe of high-energy-density matters. The mechanical and electrical design of MCT spectrometers can vary a lot depending on specific applications. The sampling fields don't necessarily need to be uniform or even static, for the deterministic classical trajectory equation always holds. On the other hand, the integral measurements of MCT are different from that in former tomography instruments in that they are along curves configured by the measurement scheme, rather than regularly-aligned straight rays or straight rays with small perturbations, and that the projections may cover multiple momentum sub-spaces. In this sense, it generalizes the image reconstruction and restoration area, opening another broad space for the tomography community.

Reference

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