Towards a unifying method for characterizing perturbative calculations including coherence effects

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Synopsis The ratio between the charge and velocity of the projectile in a collision experiment, the so called Sommerfeld parameter, is used as a reference for analyzing the suitability to adopt a perturbative description of the calculated cross sections, being more adequate for smaller values. Nevertheless, in a recent work [4], it has been uncovered that even in the most advantageous situation for this criterion to be used, it is not useful as a reference if the proper inclusion of coherence effects is not taken into account. In this work, we compare cross sections calculated both coherently and incoherently for two experiments with C^{6+} at different energy ranges, which helps to confirm that the discrepancies between theory and experiment reported in the past, can be attributed to coherence effects.

We study the single ionization of He by C^{6+} projectiles at 2 and 100 MeV/amu [1, 2]. The main contribution to the fully differential cross section (FDCS) in this process comes from the projectile-target electron interaction. In general, there is a remarkably good agreement between the predictions made even by first order theories, such as the first Born approximation (FBA), which neglects the projectile-target nucleus interaction. This agreement should be enhanced when decreasing the Sommerfeld parameter Z_P/v, being v and Z_P the initial velocity and charge of the projectile, respectively. However, not only higher order, but also relativistic approaches [3] have failed to explain this experiment which has been coined as the $C^{6+}-$ puzzle [2], because of the elusiveness for theoretical models to achieve good agreement with the experimental data which, contrary to the Sommerfeld parameter criterion, is worst at higher initial energies of the projectile.

Initial efforts to explain this problem have concentrated to correct possible flaws of the perturbative calculation methods. On the contrary, we propose that this collision experiment in particular is ideal to get more insight on the effect of the degree of coherence of the projectile, which is inherent to every scattering event, and therefore can and should be incorporated in the calculations [4]. On one hand, for the two experiments under analysis [1, 2], the momentum of the projectile is large enough to observe a significant effect of the incoherence of the projectile beam. On the other hand, there is an almost one order of magnitude difference in the velocity and momentum of the projectile between the two experiments, which is crucial to our study because this means that for the more energetic beam we have a smaller Sommerfeld parameter but smaller coherence length [5], i.e. a less coherent beam, which allows us to compare the competition between both effects. By performing a Born initial state and continuum distorted wave final state (CDW-1B) model calculation method, we observed that perturbative methods describe well both experiments whenever the coherence effects are included, but a coherent calculation alone, does not.

References

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