Single ionization of helium by high-energy protons using the parabolic quasi-Sturmian approach

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We investigate theoretically ion-atom ionizing collisions. For this purpose, we have developed a parabolic quasi-Sturmian approach [1] and applied it to the single ionization of helium by intermediate and high energy protons. The aim is to further understand this fundamental process by looking at fully differential cross sections (FDCS) for which measurements are available (on a relative scale for 1 MeV protons, and on an absolute scale for 75 keV protons).

In the framework of our approach [1], the proton-electron interaction is treated as a perturbation, and the transition amplitude is extracted directly from the asymptotic behavior of the solution of an inhomogeneous Schrödinger equation for the Coulomb three-body system $(e^-, \mathrm{He}^+, p^+)$. The driven equation is solved numerically by expanding in convolutions of the parabolic quasi-Sturmians [1] for the two-body (p^+, He^+) and (e^-, He^+) systems. We call these basis functions *convoluted* quasi-Sturmians (CQS).

Our calculated FDCSs converge pretty fast as the number of terms in the expansions is increased, and are in overall reasonable agreement with other theoretical results. At the same time, there are significant discrepancies between theoretical predictions for FDCSs and experimental data. For example, for 1 MeV protons, even well-established theories fail to give a proper account of the experimentally observed binary peak position. The situation gets worse for lower proton energies (see, e.g., [2]). Our CQS results for the 75-keV protons FDCSs (without the use of the pe-interaction cutoff proposed in [3]) are presented in Fig. 1. For comparison, we show the results of calculations [3] within the 3C model, which correctly takes into account the Coulomb wave function asymptotic behavior.

Thus, for 1 MeV incident protons, the CQS approach yields angular distributions in agreement with other theoretical calculations and in satisfactory agreement with relative scale experimental data. At lower incident energies, our FDCS results are reasonable as far as the absolute scale is concerned, but important shape discrepancies are present indicating that our description is incomplete. We are considering improving our model by including the electron-capture channel.

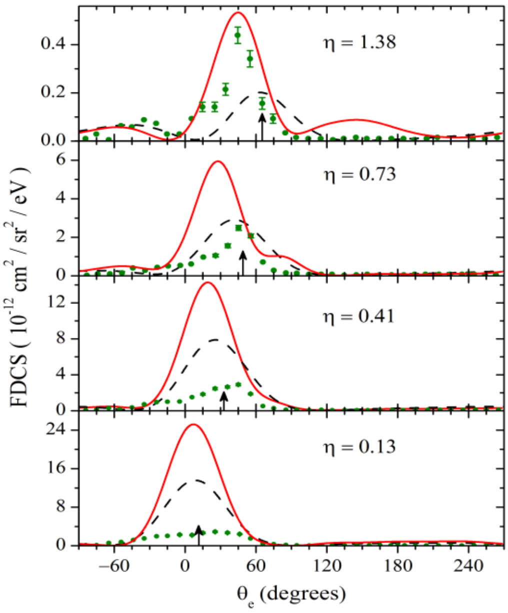

Figure 1. Our calculated FDCSs (solid line) are compared to experimental data [2] for single ionization of helium by 75 keV protons in the collision plane, for different transverse momenta η. The ejected electron energy is $E_e = 5.4$ eV. Dashed lines represent 3C calculations [3].

References

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