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Single ionization of helium by fast proton impact: Searching for projectile coherence

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Synopsis The fully differential cross section (FDCS) for single ionization $p + \mathrm{He} \to p + e + \mathrm{He}^+$ at proton energy of 1 MeV is studied both experimentally and theoretically. The 3D angular electron distribution is presented. The role of electron-electron correlations both in a trial helium ground-state wave function and in the final helium state is inspected.

A 3D angular distribution of the electron ejected in the reaction $p + \mathrm{He} \to p + e + \mathrm{He}^+$ was measured at an incident proton energy of 1 MeV. The momentum transfer q was fixed to 0.75 a.u. and the electron energy to 6.5 eV. The distribution has a shape of a pear with a narrow node in the P-plane, which is perpendicular to the scattering plane (C-plane) and crosses the latter along the proton-velocity axis. The first Born approximation (FBA) describes satisfactory all angle domains except that in the P-plane.

Other well-established approaches employed in our analysis, in particular, such as EWBA, SBA and J-matrix, also fail to reproduce the experimental data in the P-plane. We normalized all theories and experiment to the binary peak in the C-plane, thus obtaining the normalization coefficients for the P-plane. SBA and EWBA give practically no contribution to the FBA calculations, but we find a noticeable difference in the backward peak for the ground correlated [1] (blue curve in Fig. 1) and non-correlated [2] (green curve) helium wave functions, as well as for calculations within the J-matrix approach [3] (red curve), where final correlations between the electron and the helium ion are included. The results in the P-plane are presented in Fig. 1.

Possible explanations of the observed discrepancies will be discussed, including coherence/incoherence of a projectile beam (see the most recent paper [4] and references therein). Nevertheless, theoretical problems occur when FBA is close to zero in the P-plane. In such a case, both dynamical mechanisms beyond FBA and experimental uncertainties can manifest themselves.

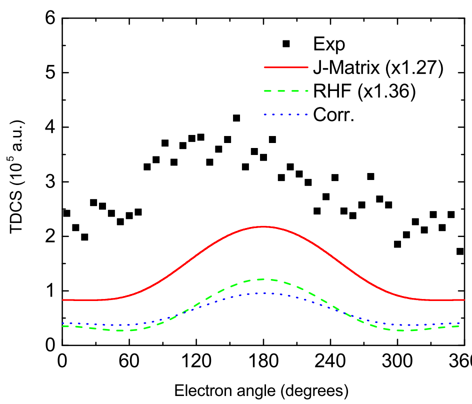

Figure 1. Experimental and theoretical electron angular distributions in the P-plane for singly ionizing 1-Mev $p + \mathrm{He}$ collisions. Blue curve represents FBA with a highly correlated helium wave function [1], green curve the same, but with a loosely correlated function [2], and red line the J-matrix calculations [3].

References

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