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Coulomb three-body effects in the single ionization of helium by 16MeV O^{7+} impact

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Abstract. Three-Coulomb-wave (3C) model is applied to study the single ionization of helium by 16MeV O^{7+} impact in the scattering plane. Fully differential cross sections (FDCS) is presented for the different momentum transfers. Our theoretical results are compared with the recent experimental data and the results of continuum distorted-wave eikonal-initial-state (CDW-EIS). It is shown that the 3C calculations qualitatively reproduce the experimental peak structure, especially at smaller momentum transfers.

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Key words: Three-Coulomb-wave,single ionization,fully differential cross section

1 Introduction

Single ionization by highly charged particle impact is a particularly suitable reaction for studying ion-atom collisions problem. With the development of the experimental technique known as COLTRIMS (cold target recoil ion momentum spectroscopy) [1], the fully differential cross-sections (FDCS) for single ionization by ion impact became available and providing a very stringent test of the theory. In particular, the heavy charged particle impact single ionization of helium has attracted much attention. Schulz *et al.* [2] and Madison D H *et al.* [3] measured the FDCS for single ionization of helium by 100MeV amu^{-1} C^{6+} . Fischer *et al.* [4] reported absolute experimental measurements for 2MeV amu^{-1} C^{6+} and 3.6MeV amu^{-1} Au^{Q+} (Q = 24, 53) single ionization of helium. Recently, Schulz *et al.* [5] measured the FDCS for target ionization in16MeV O^{7+} + He collisions.

On the theoretical side, a lot of calculations have been carried out for this particular process. For example, the first Born approximation (FBA) [6], the three-body distorted-wave (3DW) [7], the continuum distorted-wave eikonal-initial-state (CDW-EIS) approxi-

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mation [8] and the coupled-pseudostate (CP) approach [9] . Although their results qualitatively reproduced many of the features of the cross section and are in agreement with the experimental results , significant discrepancies can still be noticed.

The three-Coulomb-wave (3C) [10] is well known and have been shown to be capable of predicting the shapes of cross sections for various types of (e, 2e) and positron-impact ionization processes at intermediate and high energies [10-12]. The description was extended to high energy C^{6+} $-$ helium ionization and showed quite good agreement with experimental values at small momentum transfer in the scattering plane [13].

Following the idea of [13], we study the triple differential cross section for single ionization of helium by 16MeV O^{7+} impact in the scattering plane. It is worth noting that this model includes the passive electron in the channel wave function and in the perturbation. It is observed that 3C calculations qualitatively reproduce the experimental peak structure, especially at smaller momentum transfers.

2 Theoretical treatment

Considering single ionization of helium by the impact of O^{7+} with incident momentum $\mathbf{K}_i$ relative to the atomic center of mass. The $\mathbf{K}_P$ and $\mathbf{k}_T$ are the momenta of scattered projectile and ejected electron, respectively. The FDCS in the CM system is given by [11,12]

$$\frac{d^3\sigma}{d\Omega_P d\Omega_e dE_e} = N_e (2\pi)^4 \mu_{Te} \nu_P^2 \frac{K_P k_T}{K_i} |T_{fi}|^2, \tag{1}$$

where N_e is the number of electrons in the atomic shell. $d\Omega_P$ and $d\Omega_e$ denote the differential solid angles with respect to $\mathbf{K}_i$ for the scattered projectile and the ionized electron, respectively. And dE_e represents the energy interval of the ionized electron. μ_{Te} is the reduced mass of the ionized electron-He^+ subsystem and ν_P is the reduced mass of projectile-atom system. The T-matrix is defined as

$$T_{fi} = \langle \Psi_f^- (\mathbf{r}_1, \mathbf{r}_T, \mathbf{R}_P) | V_i | \Phi_i (\mathbf{r}_1, \mathbf{r}_T, \mathbf{R}_P) \rangle, \tag{2}$$

here $\mathbf{r}_T$ represents the coordinate of the ionized electron with respect to the target core. $\mathbf{R}_P$ is the position of the projectile relative to the atomic center of mass, and $\mathbf{r}_1$ is the coordinate of the remaining passive electron relative to the target nucleus. $\mathbf{R}$ is also needed, representing the position of the projectile with respect to the target nucleus.

The initial state wave function Φ_i will be written as the product of a plane wave with momentum $\mathbf{K}_i$ for the projectile and a wave function of helium atom in the ground state

$$\Phi_i = (2\pi)^{-3/2} \exp(i\mathbf{K}_i \cdot \mathbf{R}_P) \phi_i(r_1, r_T). \tag{3}$$

In the present calculation, we have chosen the analytical fit to the Hartree-Fock wave function given by Byron and Joachain [14] to describe $\phi_i(r_1, r_T)$,

$$\phi_i(r_1, r_T) = U(r_1) U(r_T), \quad U(r) = (4\pi)^{-1/2} (A\exp(-\alpha r) + B\exp(-\beta r)) \tag{4}$$