Helium double ionization by neutronic impact

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Synopsis The Generalized Sturmian Functions method is used to calculate fully differential cross sections of the helium double ionization by neutron impact. We compare the effect of applying the collective and one-body boost operators.

Currently, there are several facilities that carry out research on neutron scattering [1]. Considering the impressive progress that has been made in recent years in multi-particle coincidence techniques it may be expected that in the near future neutron scattering experiments will be accomplished [2]. From a theoretical point of view, neutron-impact ionization is an ideal process to study the interelectronic correlation in many-body electron systems, since it allows for transitions that are strictly prohibited or strongly reduced in the case of either charged-particles or photons impact [3, 4, 5]. Also, due to the very short ranged interaction between the neutron and the helium nucleus, the projectile-target collision can be treated as a First Born order to an exact degree.

The aim of this contribution is to study the dynamics of the electrons ejected to the continuum due to neutron scattering from a helium core. Within a first Born frame, and for a momentum **q** transferred by the projectile to the target, the three-body scattering solution $\Phi^{+}_{sc}(\mathbf{q},\mathbf{r}_2,\mathbf{r}_3)$ of equation

$$[E_a - h_{He}]\,\Phi^{+}_{sc}(\mathbf{q},\mathbf{r}_2,\mathbf{r}_3) = \frac{g}{(2\pi)^3} W\,\Phi_i(\mathbf{r}_2,\mathbf{r}_3)\,, \quad (1)$$

dictates the dynamics of the electrons ejected with energy $E_2 + E_3 = E_a$; $\Phi_i(\mathbf{r}_2,\mathbf{r}_3)$ is the $1s^2$ state of the helium target with Hamiltonian h_{He}, and W is the perturbation that contains the neutron-nucleus interaction. Using the Fermi pseudo-potential with coupling constant g, the perturbation is the collective boost operator, $W \approx B_c = e^{-i\mathbf{q}_M\cdot[\mathbf{r}_2+\mathbf{r}_3]}$, where $q_M = q/M_\alpha$ is the speed at which the nucleus takes off and M_α is the mass of the helium core. For low nucleus velocities the collective boost operator can be approximated by the one-body boost operator, $B_c \approx B_{1B} = e^{-i\mathbf{q}_M\cdot\mathbf{r}_2} + e^{-i\mathbf{q}_M\cdot\mathbf{r}_3}$, which is similar to the operator that governs Compton scattering or charged-particle impact on an N-electron atom [4].

We use the Generalized Sturmian Functions (GSF) method [6] to solve Eq. (1); both operators, B_c and B_{1B} are considered, and results compared. The transition amplitude is extracted directly from the asymptotic wavefunction, without requiring any further projection.

Figure 1 shows, as a function of the ejected angles θ_2 and θ_3, an example of fully differential cross section (FDCS) for helium double ionization by neutronic impact. We observe a very dipole-like emission pattern, with little or no back-to-back emission. The peaks' centers imply that the electrons emerge with mutual angles close to 90, which is expected for fast electrons, since their mutual repulsion has little time to push them apart at larger angles. Note also the smallness of the FDCS magnitude.

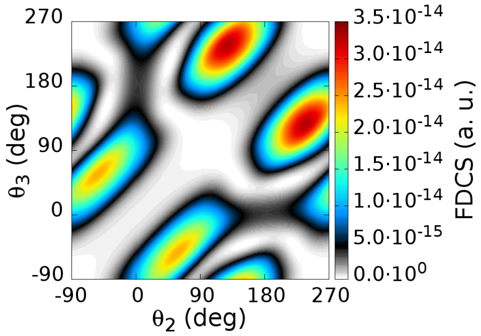

Figure 1. FDCS for the Helium double ionization by neutronic impact. The neutrons carry an incident energy of 10 keV and get deflected at 175°. The momentum transfer is 2312 a.u. Both electrons have the same energy of 50 eV.

References

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