Theoretical study on projectile coherence effects in fully differential ionization cross sections

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Synopsis In order to clarify the origin of the projectile coherence effects we present a theoretical, ionization amplitude based study of ionization of helium by 100 MeV/u C^{6+}, 1 Mev proton, and 75 keV proton projectiles.

After performing fully differential cross section (FDCS) measurements for the ionization of helium [1] significant difference between experimental data and theoretical continuum distorted wave (CDW) results have been observed. These, and other similar theoretical calculations were not able to reproduce the experimentally observed structures in the perpendicular plane. However, our semiclassical calculations [2] and the convolution of the first Born approximation with elastic scattering [3] described fairly well these structures. The discrepancy between these calculations and the relationship with the experimental data has been explained, by the importance of the projectile coherence effects [4]. Significant differences have been observed in the FDCSs for projectiles causing the same perturbation, but having different transversal coherence lengths. If the coherence length was larger than the atomic dimensions, the results were closer to the CDW calculations, which assumes a plane wave for the projectile, while for smaller coherence widths the results were closer to the convoluted [3] and our semiclassical results.

Recently, we have shown in two extreme cases the FDCS dependence on the projectile coherence [6] by assuming classical particle and plane wave description of the projectile. Later, a more realistic, finite wave packet description has been proposed [7]. In the meantime, another fully differential study yielded good agreement between experiment and theory but no conclusive evidence regarding the projectile coherence effect was reported [5]. Accordingly, the topic is not closed yet, and surely it is intensively studied by the scientific community.

In order to clarify the effects which lead to the FDCS differences for coherent and incoherent projectiles, we present a theoretical, ionization amplitude based study for ionization of helium by 100 MeV/u C^{6+}, 1 Mev proton, and 75 keV proton projectiles. These studies are focusing on the averaged ionization amplitudes over the impact parameter's azimuthal angle, and the shape of the projectile wavepacket. These quantities are shown in Fig. 1 for the ionization of helium by 75 keV proton projectile, in a region where significant differences in FDCS have been detected for coherent and incoherent projectile beams [7]. In case of coherent projectile beam the whole impact parameter regime contributes to the FDCS, while in case of projectiles having shorter coherence length the FDCS is calculated by integrating ionization amplitudes over a shorter impact parameter region where only a single change of the signs of real and imaginary parts of the ionization amplitude is present.

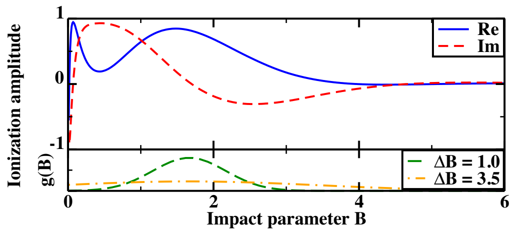

Figure 1. Top panel shows real and imaginary parts of the averaged ionization amplitude for ionization of helium by 75 keV proton projectile. The fixed x-component of the recoil-ion momentum $p_{rec} = 0.7$ au., the electron ejection angles are $\theta_{el} = 30°$, and $\phi_{el} = 90°$. The bottom panel shows the Gaussian functions which describes the shape of the coherent ($\Delta B = 1.0$) and incoherent ($\Delta B = 3.5$) projectile wavepackets.

The above described amplitude analysis is performed for many kinematical parameters and for different projectiles, too.

References

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