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Vortex rings in the ionization of atoms by positron impact

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Synopsis We uncovered the morphology of quantum vortex structures in positron-atom ionization collisions. By performing an exhaustive calculation of the position of vortices in the final momentum space of the problem with only one kinematic restriction, we could elucidate that quantum vortices form a closed structure, which is one of the two possible scenarios for their emergence in three dimensions. This is the first time that these structures are fully calculated for positron-atom collisions.

Quantum vortices have been subject of both theoretical and experimental interest in the last decade for the ionization of atomic and molecular targets by the impact with proton, electron and positron projectiles [1, 2, 3]. They are submanifolds of co-dimension 2 on the phase space of the T-matrix element of the collision. This means that they appear as points in two dimensions, and as lines in three dimensions. The *velocity field* associated with T [4] exhibits a solenoidal shape similar to that of irrotational vortices in *Fluid Dynamics*.

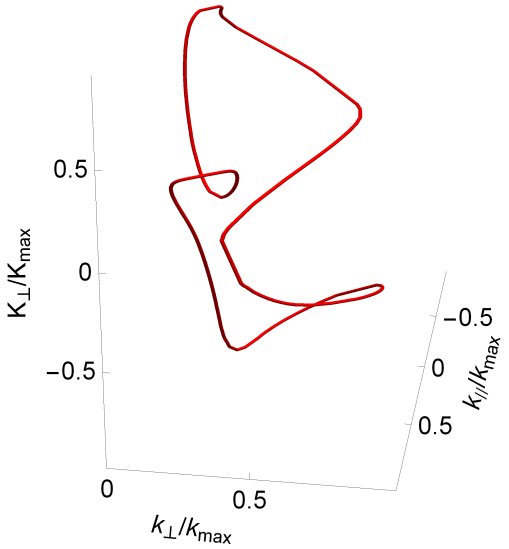


Figure 1. Vortex ring on the T-matrix element for the ionization of hydrogen by positron impact at an energy of 275 eV in coplanar geometry. It is represented in the phase space of the final momenta of the electron $k_{//}$ and $k_\perp$, and the positron $K_\perp$ (see the text), normalized by the maximum momenta that the particles can acquire due to energy-momentum conservation.

A previous systematic study [3] of the ionization of atoms for different positron impact energies, contributed to the understanding of how these structures emerge in a *collinear geometry* as pairs of isolated points with a velocity field of opposite circulation to each other. In a subsequent work [5] we analysed the same problem for a fixed collision energy in a *coplanar geometry* which proved that many structures that seemed isolated when studied in two dimensions where in fact part of a single *vortex line*.

In the current study, we deepen the analysis of the aforementioned vortex line for the whole coplanar phase space. We were able to fully trace the vortex structure on the phase space of the final components of the electron momentum $k_{//}$ and $k_\perp$, parallel and perpendicular (with respect to the initial direction of the projectile) and the perpendicular component of the final positron momentum $K_\perp$. As it can be seen in the figure, which corresponds to a positron impact energy of 275 eV, it forms a closed structure, named *vortex ring*, which is one of the possible scenarios for their emergence [6].

References

[1] J. H. Macek *et al.* 2010 *Phys. Rev. Lett.* **104** 033201

[2] Schmidt *et al.* 2010 *Phys. Rev. Lett.* **112** 083201

[3] F. Navarrete, R.O. Barrachina 2015 *J. Phys. B: At. Mol. Phys.* **48** 055201

[4] F. Navarrete, R. Della Picca, J. Fiol and R. O. Barrachina 2013 *J. Phys. B: At. Mol. Phys.* **46** 115203

[5] F. Navarrete, R.O. Barrachina 2016 *Nucl. Instrum. Methods. B* **369** 72

[6] I. Bialynicki-Birula *et al. Phys. Rev. A.* **61** 032110

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