Interference between direct ionisation and positronium formation in continuum in positron-hydrogen collisions

A. S. Kadyrov [1], I. Bray, A. T. Stelbovics

ARC Centre for Antimatter-Matter Studies, Curtin University, GPO Box U1987, Perth, WA 6845, Australia

Synopsis The fully differential cross section for positron-impact ionisation of hydrogen is calculated in a two-centre Born approximation. It is suggested that two-centre approaches to the problem should assume incoherent combination of contributions from direct ionisation of the atom and positronium formation in continuum.

We consider fully differential positron-impact ionisation of H. Depending on the kinematical situation this process can be regarded as direct ionisation (DI) or Ps formation in continuum (PFC). PFC was calculated using the Born [1] and 3C [2] approximations, where the total wave function was approximated by the initial-channel one. In the Born approximation the final state wave function was taken as a product of the Ps continuum wave and a plane wave for the motion of Ps relative to the proton. The 3C method used a three-body Coulomb-distorted wave for the final state. Both approaches gave a singular structure in the fully differential cross section (FDCS). The divergence in the FDCS occurred when the scattered projectile and ejected electron have small relative momentum corresponding to PFC. However, both being the first-order high-energy approximations, their validity at 50 and 100 eV, where there are experiments [3], is questionable. In addition, the Born approximation can not take into account DI.

So far the convergent close coupling has been the only approach capable of taking account of the two-centre nature of the problem in a non-perturbative way [4]. However, an artefact of this approach is that it treats DI and PFC separately. The question is then how to combine the contributions from DI and PFC, coherently or incoherently, to get the total? We investigate this point using a two-centre Born approximation.

Figure 1 shows the raw unconvoluted FDCS in the forward direction for DI and PFC at 50 eV incident energy. Figure 2 presents the raw coherently- and incoherently-combined total FDCS in the same direction at the same energy. An unphysical interference in the coherent FDCS suggests that the two-centre approach to positron-impact ionisation of H should assume incoherent combination of the contributions from DI and PFC. Details of the calculations as well as justification of the two-centre approach and how it follows from a surface-integral formulation of

scattering theory [5] will be given.
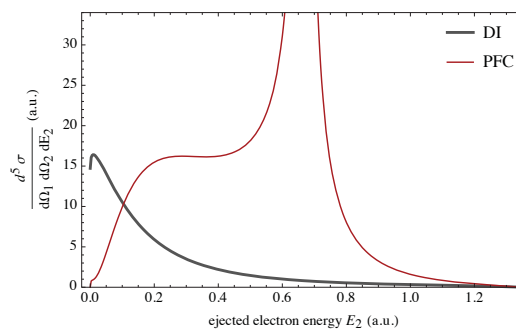
Figure 1. The FDCS in the forward direction for DI and PFC in e$^+$-H collisions at 50 eV.
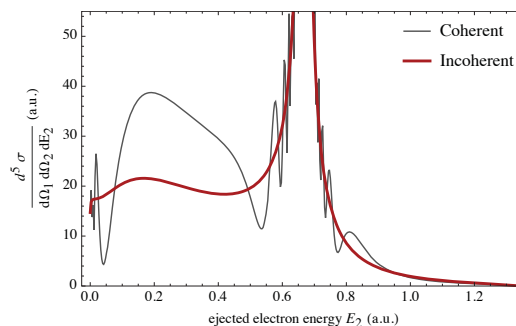
Figure 2. The coherently and incoherently combined total FDCS in the forward direction for ionisation in e$^+$-H collisions at 50 eV.

References

[1] M. Brauner and J.S. Briggs 1986 *J. Phys. B* **19** L325–L330

[2] M. Brauner M and J.S. Briggs 1991 *J. Phys. B* **24** 2227–2236

[3] C. Arcidiacono *et al.* 2005 *Phys. Rev. Lett.* **95** 223202

[4] A.S. Kadyrov and I. Bray 2002 *Phys. Rev. A* **66** 012710

[5] A.S. Kadyrov *et al.* 2009 *Ann. Phys.* **324** 1516

[1] E-mail: A.Kadyrov@curtin.edu.au