Eur. Phys. J. D **37**, 153–154 (2006)
DOI: 10.1140/epjd/e2005-00320-5

THE EUROPEAN
PHYSICAL JOURNAL D

Reply to the comment

On positron scattering on He (and Ar) at low energies

G.P. Karwasz[a]

Instytut Fizyki, Pomorska Akademia Pedagogiczna, 76200 Słupsk, Poland

Eur. Phys. J. D **35**, 267–278 (2005)

Received 2 November 2005
Published online 6 December 2005 –

Professor A. Zecca, kindly rose some questions [1] on resonant structures observed in a recent positron–helium scattering experiment in Trento [2]. Obviously, any resonant features, in particular in helium [3] are always subject to confirmation or dismissal [4], so in first instance we are waiting for new experiments. Extensive details of Trento measurements in He are given in our common paper [5]; here I discuss two points:

(1) the energy resolution of the apparatus and
(2) the interpretation of these resonant structures.

1. A decisive way to determine the energy resolution are measurements on some resonant structures, like the $^2\Pi_u$ resonance in N_2 or the $(1s2s^2)$ 2S in He. In Trento apparatus careful checks using a thermoionic cathode placed in front of the scattering cell were done around 2 eV for electron scattering on N_2; the monochromating action is due to a weak guiding magnetic field. As stated by Zecca et al. [6] "the energy resolution of our apparatus as deduced from these measurements is about 130 meV". Two more elements contribute to tailoring the positron energy in Trento set-up. The moderator used and procedures of its thermal treatment were developed for our two previous experiments: on positron annihilation in solids [7] and on intermediate-energy gas scattering [8]. We agree [1,2] that the spectrum of re-emitted positrons from micron-thin monocrystal W films is much better than from thick, ribbon-like tungsten. Finally, the 90° bend cuts any tail of the energy distribution larger than 1.6 eV FWHM; this is valid also for electrons, contrary to the value 4–5 eV as stated in [9].

2. Discussing the shape and depth of $e^+ + \mathrm{He}$ structures, note first that in resonance on a hard sphere, as predicted by Fano [10], the elastic cross-sections changes, across the resonance, between zero and a maximum of $4\pi(2l+1)/k^2$. This, with $l = 0$ would give at 2 eV a maximum of as much as 24×10^{-20} m^2. But, the structures reported in [5] show an inverted shape, if compared to a "hard sphere" resonance, see for example Figure 4.9 in reference [11].

3. This latter observation is of basic importance, both for He and other targets. The measured structure in He clearly shows a $+\pi$ resonant phase shift, see the inset in Figure 14 in [2]. This must be an *attractive*, and not a repulsive hard-sphere like potential, to give the observed shape of the cross-section. What kind of attractive, short range potential do experience positrons at the distance of valence electrons from nucleus? In paper [2], the $e^+ + \mathrm{He}$ low-energy structures are interpreted as Feshbach resonances in the virtual positronium formation channel. The new ab-initio calculations by Gribakin [12] indicate that the virtual positronium formation contributes indeed to the elastic cross-section, also in other noble gases like Ar. So atoms show-up in the low positron scattering not as hard spheres, but rather like "sticky" balls: incoming positrons are captured (in a transient way) by valence electrons. This would explain the observed shape of low-energy resonances in He, but not only.

4. For Ar the absolute values from the experiment reported in [2,5] show a wonderful synergy with Gribakin's recent theory [12]. In his calculations this is the virtual positronium channel which "levels up" the elastic cross-section. A similarly good agreement with the experiment in He [2,5] show calculations of Gianturco [13], with correlation effects precisely included. In any case, the virtual positronium and/or electron-positronium correlation seem to be essential mechanisms in positron scattering at a few eV. These effects could explain "flat" cross-sections up to the free positronium formation threshold in H_2, N_2, Ar, Kr, CO_2, see [2].

[a] e-mail: `karwasz@chemie.fu-berlin.de`
or `karwasz@science.unitn.it`

5. Here, a more serious question arises. Remember that a constant cross-section is predicted by classical mechanics for a rigid sphere. In what way does the elastic channel sum up with the virtual positronium contribution to give a constant, hard-sphere (or sticky ball) cross-section? In other words: why does Quantum Mechanics yield exactly the classical result?

I stress again complementary contributions from the whole Trento group in experiments performed in 2004. In 2005, I enjoyed the hospitality of prof. E. Illenberger and his group. Written in Berlin, 01.10 and 22.10.2005

References

1. A. Zecca, Eur. Phys. J. D (2006, d05395)
2. G.P. Karwasz, Eur. Phys. J. D **35**, 267 (2005)
3. D.E. Golden, A. Zecca, Phys. Rev. A **1**, 241 (1970)
4. D.E. Golden, Adv. At. Mol. Phys. B **14**, 43 (1978)
5. G. Karwasz, D. Pliszka, A. Zecca, R.S. Brusa, Nucl. Instr. Meth. Phys. Res. B **240**, 666 (2005)
6. A. Zecca, R.S. Brusa, M. Bettonte, E. Rajch, S. Mariazzi, G.P. Karwasz, Rad. Phys. Chem. J. **68**, 319 (2003)
7. R.S. Brusa, G.P. Karwasz, M. Bettonte, A. Zecca, Appl. Surf. Sci. **116**, 59 (1997)
8. G.P. Karwasz, M. Barozzi, R.S. Brusa, A. Zecca, Nucl. Instr. Meth. Phys. Res. B **192**, 157 (2002)
9. A. Zecca, C. Perazzolli, M. Brunger, J. Phys. B **38**, 2079 (2005)
10. U. Fano, Phys. Rev. **124**, 1866 (1961)
11. C. Joachain, *Quantum Collision Theory* (North Holland, Amsterdam, 1975), p. 99
12. G. Gribakin, Int. Work. Low Energy Positron and Positronium Physics, Campinas, 27–30 July 2005, Book of Abstracts, edited by S. d'A. Sanchez, R.F. da Costa, M.A.P. Lima, p. 24; G. Gribakin, in *Photonic, Electronic and Atomic Collisions (XXII ICPEAC) Proceedings*, edited by J. Burgdorfer, J. Cohen, S. Datz, C. Vane, Rinton Press (2002); and private information
13. F.A. Gianturco, A. Jain, J.A. Rodriguez-Ruiz, Phys. Rev. A **48**, 4321 (1993)