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Nuclear Instruments and Methods in Physics Research B 251 (2006) 520–523
NIM B Beam Interactions with Materials & Atoms
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Comment

Reply to A. Zecca's Comment on 'Positron scattering in helium: Virtual-positronium resonances' by G.P. Karwasz, D. Pliszka, A. Zecca, R.S. Brusa [Nucl. Instr. and Meth. B 240 (2005) 666]

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Received 12 April 2006; received in revised form 19 May 2006
Available online 1 September 2006

Abstract

Zecca [this issue] makes a-posteriori operations on experimental data for positron–helium scattering [G.P. Karwasz, D. Pliszka, A. Zecca, R.S. Brusa, Nucl. Instr. and Meth. B 240 (2005) 666], instead of performing independent checks and tests on He and other light gases. We find his judgments on a hypothetical background due to the ion-feedback and on the energy resolution not fully documented. Awaiting independent experimental verification, we stress again the as-far-as-possible accuracy and completeness of apparatus settings, pre-and post-experiment checks and measurement procedures in the Ar and He experiment by Karwasz, Pliszka and Brusa.

1. Introduction

Zecca in [1] puts into discussion measurements of total cross sections for positron scattering performed in Trento in 2004 [2–4] and in particular the discovery of resonant structures in helium [4]. Unfortunately, his statements contradict our previous papers, written in common [5–7]. Note that Zecca recently operated the Trento positron machine [8] but he did not participate directly in the machine tests and settings, done on simple gases and described in our paper [3]. He did not participate directly in He total cross section measurements [4] either.

First we answer the main scientific points on the basis of experimental procedures adopted in the Trento apparatus till February 2005 [3] and later respond to some minor points of Zecca. Shortly, the misunderstanding with Zecca comes from his qualitative, rather than quantitative discussion of the energy resolution, and from an arbitrary ("appropriate"), non-specified and a-posteriori correction of the original experimental data [4], producing stochastic noise instead of reliable cross-sections (see his Figs. 2 and 3 in [1]).

2. Energy resolution and energy scale

Any definite statement on the energy resolution and the energy scale can be done only (a) by measuring narrow structures, like the shape $^2\Pi_g$ resonance in N_2 molecule visible in electron scattering around 2.1 eV, see for example [9], (b) using a retarding field analyzer after the scattering cell. However, (a) recent careful searches performed in San Diego lab on H_2 and N_2 [10] did not show any *sharp* resonances for positron scattering and (b) a retarding field analyzer could not be applied in Trento apparatus due to construction reasons. Therefore one has to use indirect checks. The first test is an experimental check of dispersive properties of energy-defining elements; we did it both with

DOI of original article: 10.1016/j.nimb.2006.07.015
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doi:10.1016/j.nimb.2006.07.014

electrons and positrons [6,7]. The second check are cross section measurements with electrons [6]; the third – measurements of positron cross sections at the threshold for positronium formation [2,3]; the fourth – a pseudo-retarding field check.

The Trento machine, as discussed also in paper [3] contains three energy-defining elements in series. The rough selection, with $\Delta E/E = 1/100$ is done by the electrostatic 90° bend. The bend is operated at 160 eV positron energy; we checked effectively that the FWHM of transmitted positrons was 1.6 eV. The second dispersive element is the combination of narrow slits in the scattering cell with the longitudinal magnetic field. This element allows transmission only at selected combinations of the magnetic field and energy; experimental checks with electrons and positrons are shown in Figs. 2 and 3 of our common paper [6]. Finally, the optics of the first accelerator is of electrostatic type, and not using magnetic fields selects a narrow angular range, ±15° of positron emitted from the moderator, reducing the transversal energy spread.

We showed experiments done with electrons on the N_2 resonant structure in our common papers [6,7]. In conclusion of those checks, it was stated in paper [6]: "The energy resolution of our apparatus as deduced from these measurements is about 130 meV, see Fig. 4."

The positron-scattering total cross section shows a sharp rise at the positronium formation threshold. We used such a determination for N_2 data in our preliminary communication [2] – the energy shift established was about +2.3 eV, see Fig. 1 in [2]. A more precise determination was done by detailed measurements around the positronium thresholds in Ar, and these data are reported in Fig. 1 of [4]. The energy scale determined both from N_2 and Ar was +2.4 eV with ±0.1 eV uncertainty, in perfect agreement with the determination of Amerenda et al. [11] for a similar tungsten moderator.

Because the impossibility to introduce a retarding field analyzer, in November 2005, one of the present authors (D.P.) on Zecca's proposal made measurements in pseudo-retarding field configuration (probably these data are quoted by Zecca as "independent checks"). They consisted in lowering the beam energy to zero, i.e. in rising the retarding bias applied to the moderator compared to the rest of the apparatus. Positrons were detected just outside the scattering cell. We show these data in Fig. 1, together with a Gaussian fit of the current derivate. As it can be seen from these fits, immediately after the moderator treatment the beam energy profile can be described by a single Gaussian curve, with 130 meV FWHM, worsening after a few days, but still remaining at about 150 meV.

Now we come to the question of moderators. The existing measurements of reemitted slow positrons from the tungsten moderator leave place for possible controversial interpretations but are enlightening. For thick W-wanes [12] the positron energy distribution is broad, usually stated as about 2 eV. For thin W monocrystals, like that in Trento, measurements available to our knowledge showed:

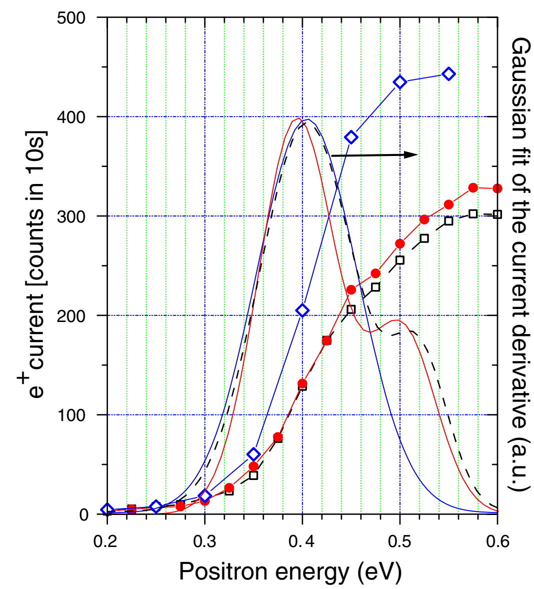

Fig. 1. Pseudo-retarding field-analyzer checks of the energy resolution of the Trento positron apparatus (performed by D.P. under A. Zecca supervision): the positron signal reaching the detector while lowering the absolute value of retarding field bias applied to moderator. The "zero" energy corresponds to the negative −2.4 V bias applied to the moderator. The counting rate lowers in few days after moderator annealing but the energy distribution FWHM remains almost the same (about 150 meV). Smooth curves are analytic fits (by single or double Gaussian) to the derivative of the positron current (normalized to "400" for easier evaluation).

(1) a 250 meV FWHM energy spectrum from W monocrystal thin films as primary moderator in transmission geometry [11], (2) a 230–420 meV FWHM energy spectrum from a thin monocrystal W-foil [13] provided by Chevalier, Århus University, i.e. the same type as used in Trento, (3) a 40–50 meV FWHM for positrons remoderated after injection with 2–5 keV energy [14].

In conclusions all these indirect checks seem to confirm a possible resolution of 130–150 meV of the apparatus, in the configuration used for measurements in [3] and [4].

3. Pressure and "background" evaluation

The main point of Zecca manuscript is the discussion of the "background" that he subtracted from the original experimental data, in attempt to invalidate the presence of resonances. Here we answer shortly. (1) Any background, due to "ion feedback" should depend on the gas pressure, different at different energies and/or experimental runs. Zecca subtracts the same background from all cross sections. Such a procedure mixes up measurements of different runs and can lead only to a stochastic noise in the data, having little to do with the measured cross sections, as seen from Zecca's Figs. 2 and 3. (2) Subtracting *the same* background from counts with and without gas must overestimate cross sections. This punctually happens on Zecca's Figs. 2 and 3, in spite of his complaint that He cross sections from paper [4] were already too high. (3) An easy experimental check, if any 'ion feedback" exists, is to check

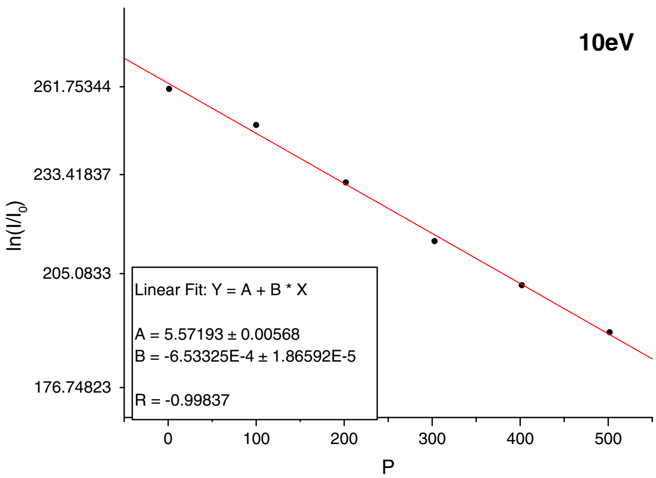

Fig. 2. A plot of the logarithm of the positron count rate versus helium pressure. Uncorrected data by Zecca (measurements performed under his supervision by D.P. in June 2004). We show the original numerical labeling, please compare with Fig. 1 from the comment of Zecca [1].

counts with gas and with a defocused beam – we did not observe any counts in the He experiment and wonder if Zecca made this check. (4) A real background, of 0.5 counts/s or less, due to dark current of the channeltron was checked in each run and subtracted. (5) Zecca, to our knowledge performed only *two* measurements of the attenuation linearity in He. This first measurement at 2.4 eV shows two highest-pressure points departing from linearity; the same-day measurement at 10 eV (see Fig. 2) does not show any departure. (6) The hypothetical non-linearity is based on two points, at pressures above 4 mbar. (Zecca does not give the absolute scale in his Fig. 1!) In the He measurements, pressures of 2–3 mbar were used. (7) We are not aware (neither it is stated in [1]) what is the "appropriate" background, to be subtracted. It can be either 100 or 150 counts/10 s (compared to about 250–350 real counts in 10 s!) as we deduce from his graphs shown here in Fig. 3 (this "evaluation" was done by D.P. on Zecca's request).

4. Minor points

Several minor points also show Zecca's misunderstanding of the machine performance and measurement procedures. On page 2 he states "We stress that the positron spectrometer was designed and planned for a research project on rather large molecules with cross sections in the range $10–100 \times 10^{-20}$ m^2." This is in clear contradiction with gas targets declared in the paper which we wrote at the stage of the machine designing [6]: "The last requirements (*re-moderation stage and reduction of scattering chamber apertures*) is important for measurements below 1 eV: here some gases, like Ne or O_2 are known to exhibit very low values of total cross sections for electron scattering. We guess that similar low values can be expected for positron cross sections. In such instances, high pressures in the scattering chamber will be needed." Zecca discusses also "presence of magnetic field as possible source of error', forgetting its intrinsic role in beam transmission. Further, he discussed the angular resolution error. "At odds with this knowledge, Karwasz and collaborators advance an

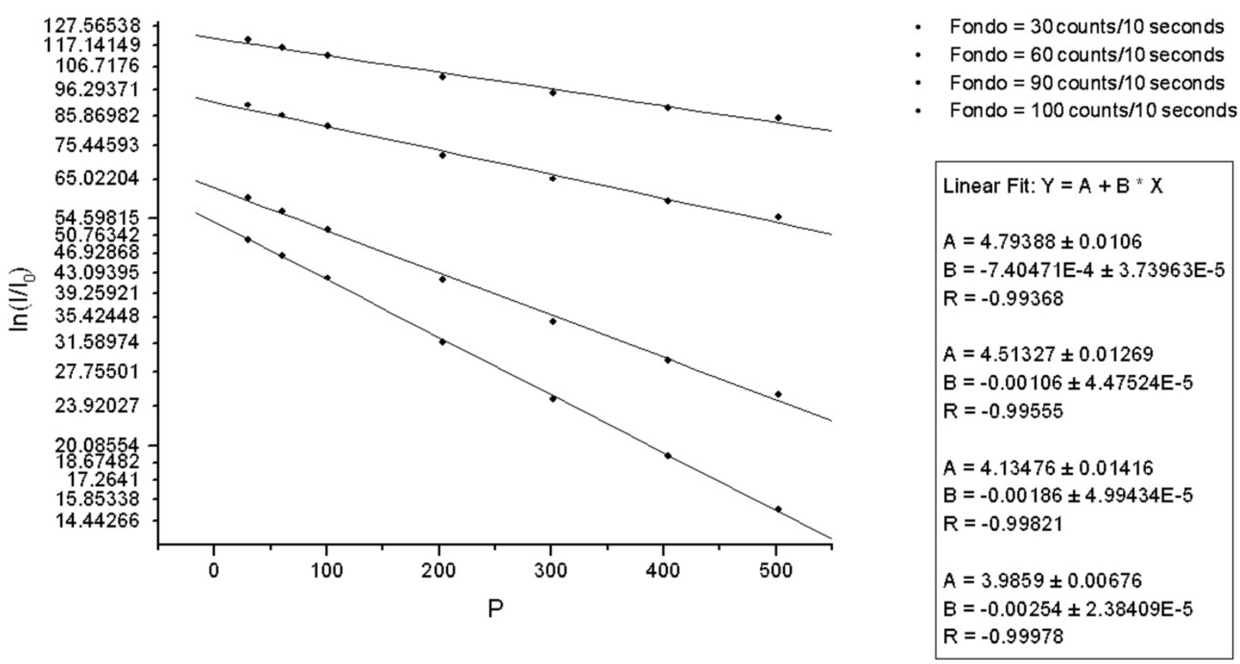

Fig. 3. Post-experiment elaboration of helium data (attenuation factor versus pressure) as originally done by D.P. for Zecca (Origin graph "ln(counts) versus P_2,4 bisbis.org"). Note that both absolute scales are given (pressure in 10^{-5} bar), differently from Zecca's Fig. 1. Note also from this figure that the subtraction of the exact background "fondo") is completely arbitrary. Probably, the lower curve in Fig. 1 from Zecca's manuscript corresponds to the lowest curve from this graph (i.e. the biggest "background" subtracted). In this way any dependence (and also absolute values of cross sections) can be changed arbitrarily. We leave the original spelling.

angular resolution error to explain their large cross section values!" This is just opposite. The Trento apparatus uses *narrower* apertures in the scattering cell (1–1.5 mm diameter) compared, for example to the Tokyo apparatus [12] (6 mm in diameter). With a similar magnetic field, it gives a better angular resolution, by a factor of about 20.

5. Final remarks

Zecca in attempt to discredit the discovery of positron resonances in helium makes his own estimate of the energy resolution but he does not show any quantitative tests to prove it. Further, he performs arbitrary corrections of KPB data [4], again not giving any numerical value used by him nor numerical scales on figures. From laboratory records on helium we deduce that his correction is probably based on a single measurement (two pressure points at a single energy) while another his measurement that day did not confirm it. On the bases of this single data he corrects all measured cross sections between 0.5 eV and 4 eV adopting an unphysical procedure. Only in one point we agree with Zecca: that he did not participate in measurements reported in [4].

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