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UPDATE OF IONISATION CROSS SECTIONS FOR XENON

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Abstract The number of produced electron-ion pairs by a free electron per unit length in a detector volume, known as Townsend coefficients can be calculated at certain electric field strengths by using ionisation cross sections of gases. Possible errors on cross sections may lead big uncertainties on Townsend coefficients, thus affecting gas gain which is an essential characteristic property of detectors, considerably. In this work we have investigated Xenon ionisation cross sections in order to update Magboltz program commonly used in gas detector simulations. We have seen from pioneer calculations for Xenon-Methane gas mixture that results of such an update will be crucial on the simulation studies for Xenon-based gas mixtures. Further, correctness of Xenon update may have great importance for development of micro-pattern gas detectors recently produced in CERN RD51 project.

Introduction

In the course of Penning transfer study [1] we have seen some signs that Xenon ionization cross sections used in Magboltz simulation program [2] could probably be higher than as it is. In literature, numerous measurements [3, 4, 5, 6, 7, 8] and calculations e.g. [9] have been made of relative cross section measurements of Xe, using e.g. the data of D. Rapp and P. Englander- Golden(REG) [10] for normalisation. Such measurements or calculations are not relevant for our purposes since we should use absolute values of the cross sections in order to update Magboltz for Xe. To our knowledge, there is only a handful of three independent measurements for the absolute electron-impact ionisation cross section of Xe:

- The most referenced and reliable work by other studies is of REG [10] has 7 % error on ionisation gross cross sections.
- In the measurements of R.C. Wetzel [11] et al., errors up to the 12 % on the cross sections have been reported.
- R. Rejoub et al. [12] have measured the cross sections independently and seen that a well agreement with [10]. The errors remain on the order of % 5 for cross sections while 0.5 eV for all over the energy range.

The biggest gap among the three independent measurements rises in R.C. Wetzel et al. data in which low precision of overall energy region (Figure 1). However, considering the high error bars (12%) on the cross sections, this work still gives the similar values to that of [10]. Such big errors would lead big uncertainties on the calculations of Townsend coefficients which are calculated with ionization cross section for a given gas by Magboltz. So, this data too, is not suitable for the update of Magboltz.

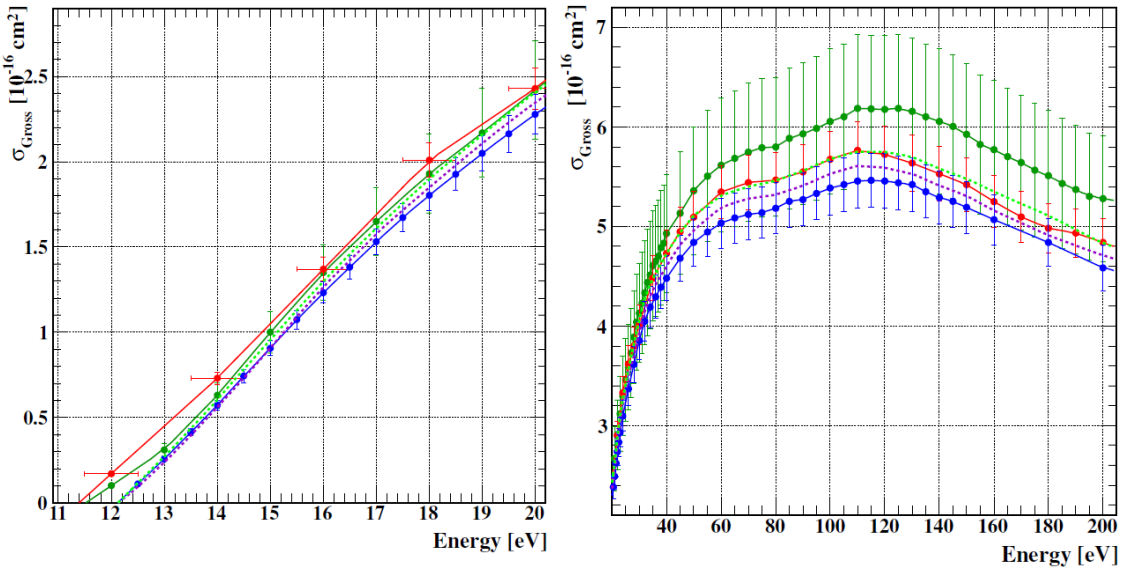


Figure 1: Absolute electron-impact ionisation cross sections of Xe. **a)** gross ionisation cross sections up to 20 eV.**b)** the same as left up to 200 eV. Dark-green lines R. C.Wetzel et al. [11], red lines R. Rejoub et al. [12], dashed green lines Magboltz 8.9.3, dashed purple lines Magboltz 8.9.1, blue lines REG [10].

Methodology

After all discussions given above, the superior choice seems to take into account measurements of R. Rejoub et al. in order to update gross ionisation cross sections of Magboltz since the precision of the data (5 %) is lower than given the other independent measurements. On the other hand, in data of R. Rejoub et al. the first value of cross sections is given at 12.0 eV. Extrapolating for this starting point gives the ionisation potential of 11.4 eV which does not correspond to well known threshold energy of Xe as 12.1 eV in literature e.g. [13]. This deviation comes from the less precision of energy resolution of R. Rejoub et al.'s measurements. We therefore can still use data of REG with a scaling factor to the data given by R. Rejoub et al. in the low energy region for the update.

As seen from Figure 1a, 7 points (up to 16 eV), the cross sections used in Magboltz 8.9.1 (the same in 8.9.2 version) are less than data of REG (see Figure 1a). Further, in the rest of the energy region, Magboltz 8.9.1 ionisation cross sections sit between data of REG and R. Rejoub at al. The main purpose, while preparing the cross sections of Magboltz 8.9.1, was to scale the data of REG by factor of 1.026 to match the peak height of the data measured by R. Rejoub et al. Although such kind of scaling factor was indeed used at high energy region, the first 7 data of REG were multiplied by 1/1.026 inadvertently [14]. Eventually, S.F. Biagi has decided to update the cross sections for the latest version of Magboltz (8.9.3) using a common scaling factor of 1.055 on given data by REG in all over the energy region in order to get better agreement with measurements of R. Rejoub et al. [12].

Considering updated cross sections, separations from Magboltz 8.9.1 (incorrectly scaled for the 7 points) get bigger towards to the ionisation threshold (e.g ≈ 5 % at 15 eV and ≈ 20 % at 12:7 eV); and after 15 eV the fractional differences oscillate around ≈ 2:5 % (Figure 2). In addition, the updated cross sections and measurements of R. Rejoub et al. are in well agreement since the fractional differences, except from low energy region where data of R. Rejoub et al. Poor in precision, are mostly fluctuate around zero.

Result and Discussions

In order to find out the effect of ionization cross sections on Townsend coefficients we have used three different kinds of data in Magboltz.

- At first, we calculated Townsend coefficients updating Magboltz with the cross sections given by R. Rejoub et al. [12].
- Next bearing in mind that data of R. Rejoub et al. are poor in precision at low energy, we used a partial scaling for cross sections of REG to the data of R. Rejoub et al. (up to 20 eV) and took the same data of R. Rejoub et al. for the rest of energy region.
- Finally, we used updated latest version of Magboltz (8.9.3).

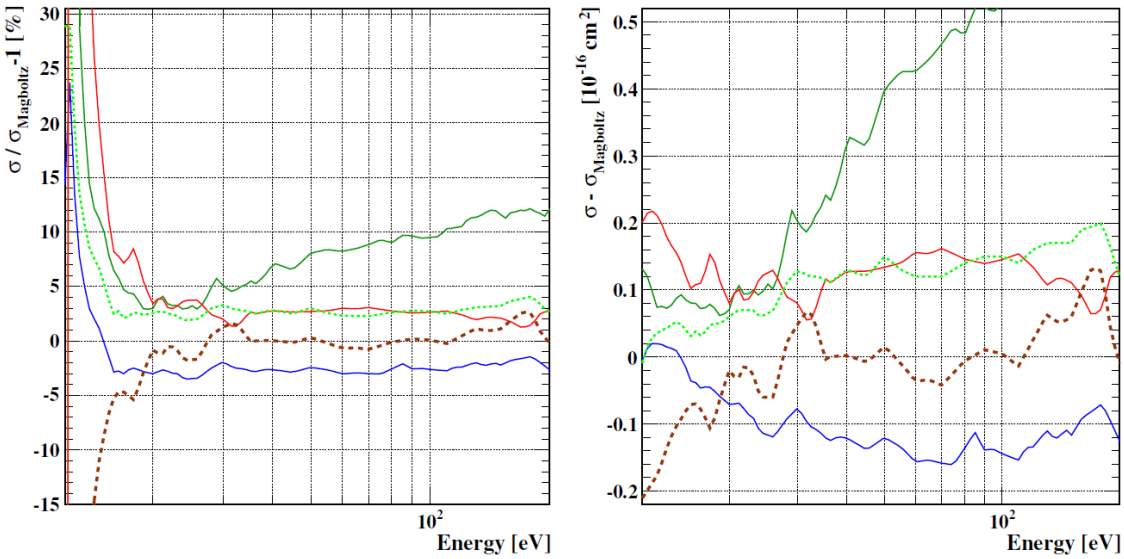


Figure 2. Comparisons of Magboltz Xe gross ionisation cross sections for three independent measurements. **a)** Fractional differences of the cross sections from Magboltz 8.9.1. **b)** Absolute differences of the cross sections from Magboltz 8.9.1. Red lines R. Rejoub et al., dark-green lines R. C. Wetzel et al, dashed green lines Magboltz 8.9.3, blue lines REG, Not: Dashed brown lines show differences for data of R. Rejoub et al. from Magboltz 8.9.3.

A comparison of Townsend coefficients with the use of above three different Magboltz versions is shown on Figure 3. Calculations are performed for a Xe 98 % CH_4 2 % gas mixture at p_{gas} = 1 atm and T_{gas} = 300 K temperature. The largest differences on the cross sections near the ionisation threshold (Figure 1 and 2) become particularly important at low electric fields where Townsend coefficients reach considerable magnitudes that multiplications start. Let's take a gain of G = 1000 and a fractional difference of 20 % (at E = 15kV/cm) on Townsend coefficient; then this discrepancy would lead a gain of G = 3981. Further, discrepancies on gas gain could be much higher for larger gains because of the exponential nature of the multiplication.

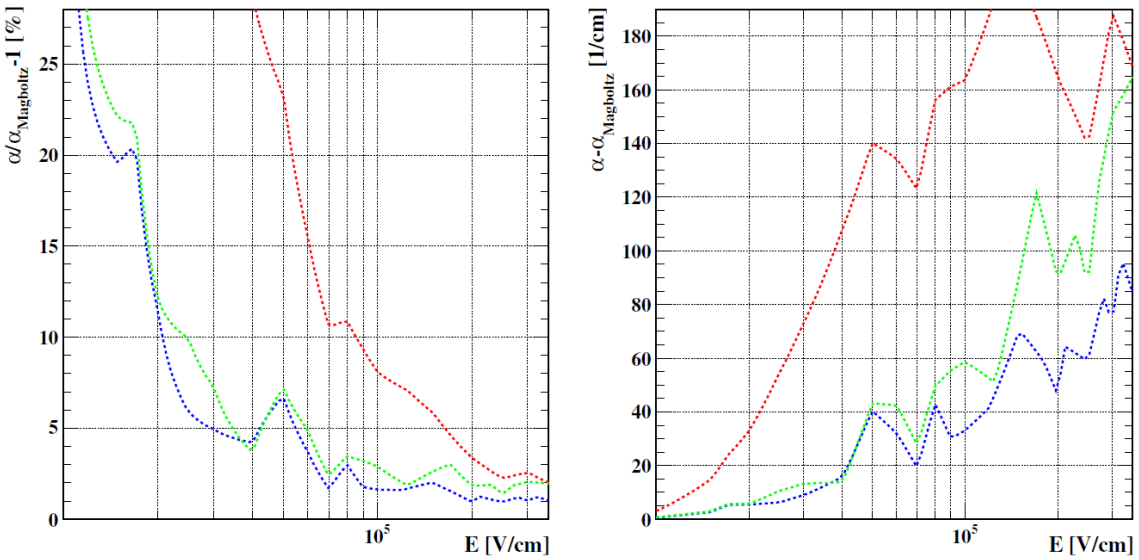


Figure 3 Differences of Townsend coefficients using three different cross section data to update Magboltz. **a)** Fractional differences of Townsend coefficients from Magboltz 8.9.1. **b)** Absolute differences of Townsend coefficients from Magboltz 8.9.1. Blue lines for Magboltz 8.9.3, green lines REG and of R. Rejoub et al. together, red lines for pure R. Rejoub et al.

Next, we will use the updated version of Magboltz in order to fit experimental gain data for Xenon-based gas mixtures. Thus, we will have an opportunity to investigate formation of Penning energy transfer processes in these mixtures, too, as we have already studied in our earlier work [1] by using Argon-based gas gain data.

Acknowledgment

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References

[1] Ö. Şahin, İ. Tapan, E.N. Özmutlu and R. Veenhof, *Penning transfer in argon-based gas mixtures, JINST* P05002 1, 2010.

[2] S.F. Biagi, *Monte Carlo simulation of electron drift and diffusion in counting gases under the influence of electric and magnetis fields,* Nucl. Instrum.Meth. A 421, 234 1999.

[3] F. J. de Heer, R. H. J. Jansen and W. van der Kaay, *Total cross sections for electron scattering by Ne, Ar, Kr and Xe*, J. Phys. B At. Mol. Opt. Phys. 12, 979 1979.

[4] A. Kobayashi, G. Fujiki, A. Okaji, and Toshio Masuoka, *Ionization cross section ratios of rare-gas atoms (Ne, Ar, Kr and Xe) by electron impact from threshold to 1 keV,* J. Phys. B At. Mol. Opt. Phys. 35, 2103 2002.

[5] D. Mathur and C. Badrinathan, *Ionization of xenon by electrons: Partial cross sections for single, double, and triple ionization*, Phys. Rev. A 35, 1033 1987.

[6] A. A. Sorokin, L. A. Shmaenok and S. V. Bobashev, *Measurements of electron-impact ionization cross sections of argon, krypton, and xenon by comparison with photoionization*, Phys. Rev. A 61, 022723 2000.

[7] K. Stephan and T. D. Mark, *Absolute partial electron impact ionization cross sections of Xe from threshold up to 180 eV, J. Chem. Phys* 81, 3117.1987.

[8] J. A. Syage, *Electron-impact cross sections for multiple ionization of Kr and Xe, Phys. Rev. A* 46 5679. Jack A. Syage, *Electron-impact cross sections for multiple ionization of Kr and Xe, Phys. Rev. A* 46,5679.

[9] M. Vinodkumar, C. Limbachiya, B. Antony and K. N. Joshipura, *Calculations of elastic, ionisation and total cross sections for inert gases upon electron impact: threshold to 2 keV,* J. Phys. B: At. Mol. Opt. Phys. 40, 3259 2007.

[10] D. Rapp and P. Englander-Golden, *Total Cross Sections for Ionisation and Attachment in Gases by Electron Impact. I Positive Ionisation.* J. Chem. Phys. 43, 1464 1965.

[11] R. C. Wetzel, F. A. Baiocchi, T. R. Hayes, and R. S. Freund, *Absolute cross sections for electron-impact ionization of the rare-gas atoms by the fast-neutral-beam method,* Phys. Rev. A 35, 559 1987.

[12] R. Rejoub, B.G. Lindsay, and R. F. Stebbings, *Determination of the absolute partial and total cross sections for electron-impact ionization of the rare gases,* Phys. Rev. A 65, 042713 2002.

[13] E.B. Saloman, *Energy Levels and Observed Spectra of Xenon,* Xe I *through* Xe LIV*, J. Phys. Chem. Ref. Data* 33, 765 2004.

[14] S.F. Biagi. Private communication, Nov 15th 2011.