A New Experimental System for Electron Transverse Diffusion Measurements

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On behalf of LIP Coimbra Gaseous Detectors R&D

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RD51 Collaboration Meeting

Outline

Motivation

- The knowledge of **electron diffusion coefficients in gases** has become very important with the growth of high dimension experiments for which event tracking is of special importance, while other research fields increasingly demand event tracking
- To measure the transverse diffusion of electrons in gases under an electric field, **a new experimental system was developed and tested with success** (at 800 Torr) for two gases with markedly different diffusion properties: a noble gas (Xe) and a molecular gas (CH_4)
- In this new experimental system, electrons are generated in a transmissive CsI photocathode by a Xe VUV pulsed lamp and drift a fixed distance that can be varied from 4 to 60 mm. The charge is multiplied in a GEM and collected at a multistrip target

Outline

Vertical cut of the experimental system

- Electrons are generated in a **transmissive CsI photocathode** by a **Xe VUV pulsed lamp**
- They drift under an external **low drift electric field a fixed distance** that can be varied from 4 to 60 mm by a **precision linear motion feedthrough**
- The charge is then **multiplied in a GEM** and **collected at a multistrip target**

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Customization is an important feature of the device

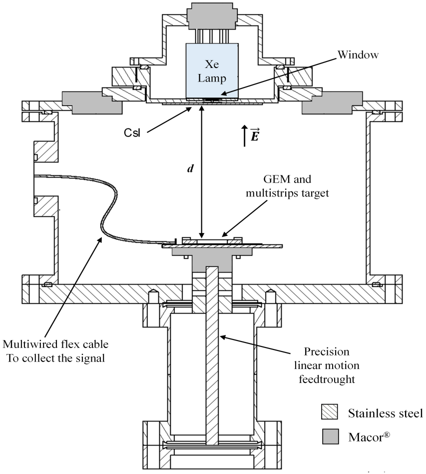


Figure 1: Vertical cut of the experimental system.

Charge measurement procedure

- Results were obtained by **measuring the charge in each strip** of the multistrip target **per time interval** using an **electrometer**. **When collecting the charge in a particular strip, all other strips are grounded**
- Measurements were performed several times and averages were taken. Also, **the sum of the charges obtained in each strip** were cross-checked with the charge collected with all the strips connected
- An assessment of the origin of all the charge arriving to the charge collecting device was made in order to define the charge that diffuses (actual signal) from which we should calculate diffusion parameters, and other contributions that might blur our final results
- **Three different contributions could be identified and were defined as background**

Photoelectron production

- The scheme represents the widening of the area of the CsI photocathode irradiated by VUV light, where photoelectrons are produced
- The widening comes from **reflections within inner device surfaces**:

$\Downarrow$

What would be an initial 270 μm diameter circle from the collimators, turns out to be 3700 μm diameter

- This increase will produce an **uniform charge distribution in all charge collecting strips**, and this contribution was designated by **background 1**, and is expected to decrease with drift distance

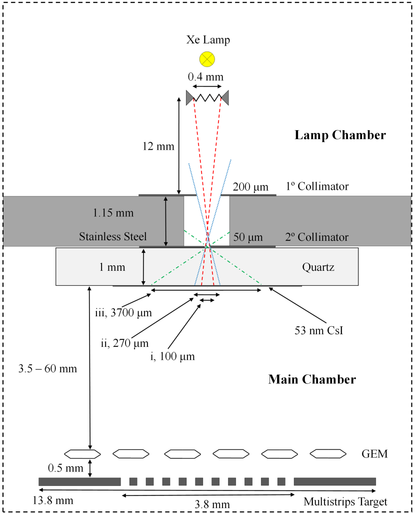


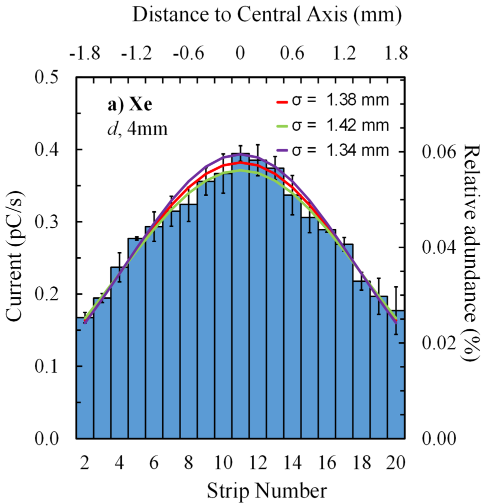
Figure 2: Detail of the lamp and main chamber.

Background contributions

- Another contribution to the total charge collected comes from **light coming either directly from the lamp or reflected that passes the photocathode and, after reflection on the Cu coating of the GEM impinges on CsI, producing more electrons**. This contribution was designated **background 2**, and again is expected to decrease with drift distance
- A third background contribution, **background 3**, has to be considered in xenon, coming from **scintillation emission (isotropic), some of which impinges on CsI**.
- All these contributions are intrinsic to the system and must be subtracted before treating the results

Outline

Typical histograms of the charge collected



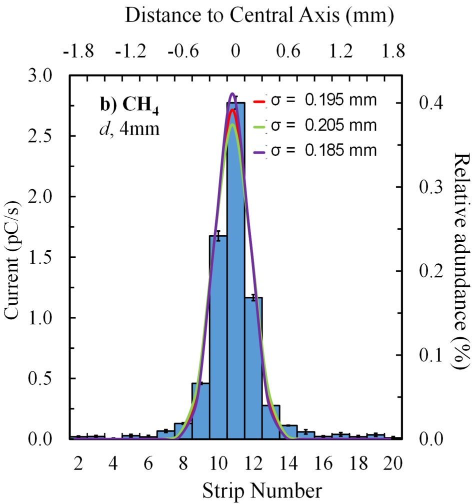


Figure 3: Typical histograms for the average charge fraction collected, for a fixed drift distance of 4 mm, after background removal, for a) Xenon and b) CH_4.

Analysis of the results

- For each **background-subtracted histogram**, a **gaussian fitting** procedure was performed to obtain the standard deviation (σ) and variance (σ^2) from the experimental distribution
- These distribution parameters are related to the **diffusion coefficients**:

$$\sigma^2 = 2 \cdot D \cdot t$$

  where D is the **diffusion coefficient**, and t the **drift time**
- In our system diffusion is only one component of the final dimension of the electron cloud because the initial cloud has a width. There are, thus, **two components to the final variance**, for a **drift distance** d:

$$\sigma^2 = \sigma_0{}^2 + \left(\sigma'_x\right)^2 \cdot d$$

  where $\sigma_0{}^2$ is the component related to the **initial electron distribution**, which is drift distance independent. Different measures of σ^2 at different drift distances allows the determination of the diffusion coefficients
- Representing σ^2 as a function of the drift distance, we can get the **slope of straight line fitting to the data** and relate it to the diffusion coefficient

Calculation of the diffusion coefficient

- Straight line fitting to σ^2:

$$\sigma^2 = b + m \cdot d \quad (1)$$

- From the slope of the straight line (m), the diffusion coefficient can be calculated

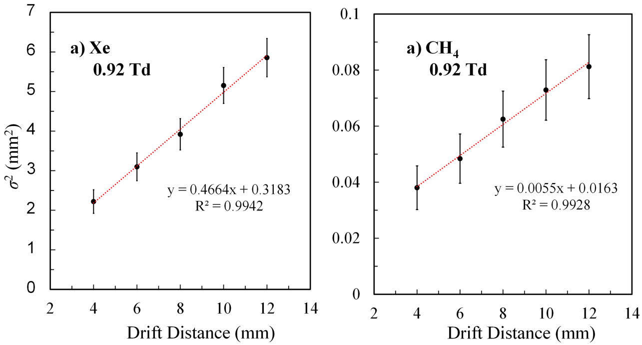


Figure 4: Variance of the transverse electron distributions, for $E/N = 0.92$ Td, for a) Xenon and b) CH_4.

Outline

Conclusions

- The diffusion coefficients were obtained for Xe and CH_4 at two different E/N values, at 800 Torr
- The **transverse diffusion** can be expressed as a function of the characteristic energy associated with the transverse diffusion (ε_{kT}), the electron's charge (e), and the electric field (E):

$$\varepsilon_{kT} = \left(\sigma'_x\right)^2 / 2 \cdot e \cdot E$$

- The values are in **good agreement** with results from the literature, and **the experimental system was validated** to obtain experimental values for electron transverse diffusion in gases

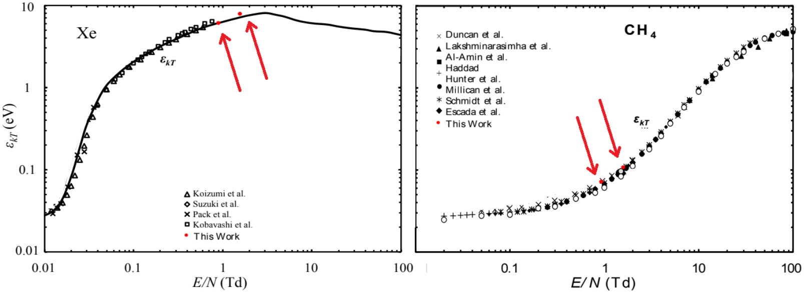


Figure 5: Comparison of the characteristic energy associated with the transverse diffusion obtained in this work with the values of the literature for Xe and CH_4.

Future work

- Assess the diffusion coefficient of other gas mixtures, at different pressures
- Automate the (tedious) data acquisition procedure
- Eventually increase the charge collecting device active area to widen the range of pressures, and to allow for more accurate results for higher diffusion media

Thank you for your attention!

Backup

Diffusion coefficients formulae

For an arbitrary direction i (x or y), the standard deviation σ_i associated to the diffusion coefficient D_i is given by:

$$\sigma_i = \sqrt{\frac{2 \cdot D_i \cdot d}{v_d}} = \sqrt{\frac{2 \cdot \varepsilon_{ki} \cdot d}{e \cdot E}} \tag{2}$$

where d is the drift distance, v_d is the drift velocity, ε_{ki} is the characteristic energy associated with the diffusion in the i direction, e is the electron's charge and E is the electric field. We can define $\sigma_i^{'}$ as:

$$\sigma_i^{'} = \frac{\sigma_i}{\sqrt{d}} = \sqrt{\frac{2 \cdot D_i}{v_d}} = \sqrt{\frac{2 \cdot \varepsilon_{ki}}{e \cdot E}} \tag{3}$$

The transverse standard deviation (σ_T) is given by:

$$\sigma_T = \sqrt{{\sigma_x}^2 + {\sigma_y}^2} \underbrace{\Rightarrow}_{D_x = D_y = D_T} \sigma_T = \sqrt{2} \cdot \sigma_x \quad \text{(at two dimensions)} \tag{4}$$

Finally:

$$\sigma^2 = {\sigma_0}^2 + {\sigma_T}^2 = {\sigma_0}^2 + \left(\sigma_x'\right)^2 \cdot d \tag{5}$$

Comparison of the results with the literature

Table 1: Characteristic energy associated with the transverse diffusion obtained in this work, for Xe and CH_4 at $P = 800$ Torr, $E/N = 0.92$ Td and $E/N = 1.53$ Td

Gas	P (Torr)	E/N (Td)	ε_{kT} (eV)
Xe	800	0.92	5.66 $\pm$ 0.73
		1.53	7.33 $\pm$ 1.12
CH_4		0.92	0.065 $\pm$ 0.005
		1.53	0.097 $\pm$ 0.008

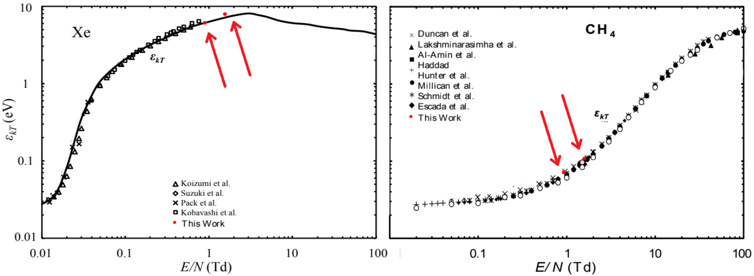


Figure 6: Comparison of the characteristic energy associated with the transverse diffusion obtained in this work with the values of the literature for Xe and CH_4.