Gaseous Detectors R&D Group (GASDET)

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July 8, 2022

Jornadas do LIP

Outline

The people

Filipa Borges (PhD)

José Escada (PhD)

Alexandre Trindade (PhD student)

Afonso Marques (PhD student)

David Marques (collaborator at GSSI)

Nicole Duarte (collaborator at UC)

João Teles (collaborator at UC)

The group

- **Design and planning of gas detectors**
- **Study of gas mixtures** to minimize electron diffusion, energy resolution (without compromising other relevant properties of the mixtures)
- **Study of electron drift of electrons and ions in gases**
- **Monte Carlo simulation** to complement experimental results

Active funding

- PTDC/FIS-NUC/3933/2021/NEXT
- CERN/FIS-INS/0026/2019
- CERN/FIS-INS/0013/2021
- 2021.05576.BD (FCT PhD scholarship)

Collaborations

- NEXT Experiment
- RD51/CERN

Publications of group members (2021 and 2022)

- 7 papers published (+1 almost submitted and +1 under editorial review)
- 2 NIM A Proceedings under editorial review
- 2 conference posters
- 2 conference communications

Outline

Using negative ions as charge carriers

- Recently, **electronegative gases** have been used to improve the spatial resolution by exploiting the **ions' reduced diffusion when compared with electrons** [1, 2]
  - → The **INITIUM** project is adding SF_6 to He-CF_4 mixture (NITPC to detect low-mass WIMPs)
  - → The **DRIFT** collaboration is considering CS_2 and O_2 (low-pressure NITPC designed to detect WIMPs)

- Negative ions may bring a new feature of great interest for rare-event searches:
  - → By measuring the **drift time difference** of the different anions, it is possible to determine the position of the original event (relevant for applications where t_0 is unknown)

$$\Downarrow$$

Dual-Polarity Ion Drift Chamber (DP-IDC), a detector that measures
a both positive and negative ion mobilities in different mixtures and at different conditions

Publications:

- **NIM A 1029 (2022) 166416**
- **Poster at 15th Pisa Meeting on Advanced Detectors**
- **Presentation at XeSAT 2022**
- **NIM A Proceedings** (under review)

Working principle of the DP-IDC

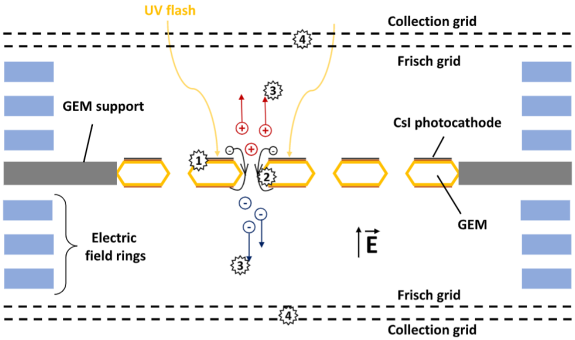

Figure 1: Working principle of the DP-IDC [3].

① Photons from a Xe UV lamp hit a CsI photocathode on top of a GEM, **releasing photoelectrons**

② The **electrons are guided to the GEM holes** due to an $\vec{E}$ where they are accelerated and generate **positive ions** by electron impact ionisation or **negative ions** by “immediate” attachment

③ The ions drift towards the **top/bottom double-grid depending on their polarity**

④ The ions induce a signal in the **Collection grid** after the **Frisch grid** which is converted to voltage and fed to a digital oscilloscope (128 pulses average)

Ion mobilities in Xe - SF_6 mixtures

- As expected, K_0 is independent of the E/N (other fields were used: 10, 15 and 25 Td)
- **In accordance with the expected values** for a fraction of $SF_6 > 50\%$, but **starts deviating after that**
- For fractions of $SF_6 < 10\%$, **it had Penning mixture-like behaviour**, as it started sparking

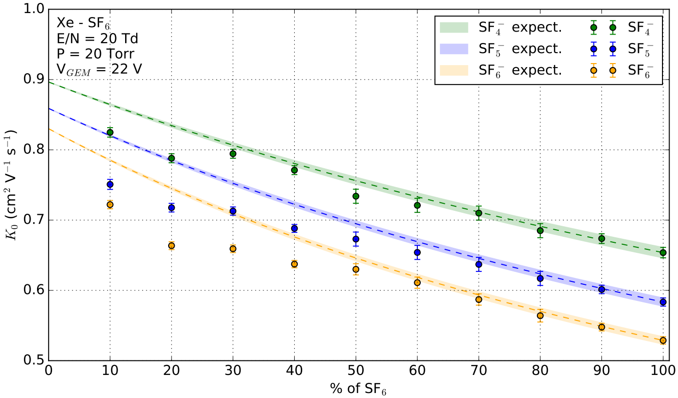

Figure 2: Reduced mobility values for a mixture of Xe-SF_6, with $E/N = 20$ Td, $P = 20$ Torr, and $V_{GEM} = 22$ V.

Outline

Electron transverse diffusion

- Electron diffusion has become a prominent property to consider in a detection medium as high dimension experiments requiring event tracking become increasingly popular. Also, other research fields demand progressively more tracking information.
- Measuring diffusion coefficients in gas media is thus of **paramount importance**
- **A new experimental system was developed and tested with success** (at 800 Torr) to assess the diffusion coefficients of two gases with markedly different diffusion properties: a noble gas (Xe) and a molecular gas (CH_4)

Publications:

- **Poster at 15th Pisa Meeting on Advanced Detectors**
- **Presentation at RD51 Collaboration Meeting** (invited by the organization after presentations at Pisa Meeting)
- **NIM A Proceedings** (under review)
- **Paper almost submitted to NIM A/JINST**

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**
- Results were obtained by **measuring the charge in each strip** (with the other strips grounded) per time interval using an **electrometer**
- Measurements are performed several times and averaged (cross-checked with the charge collected with all the strips connected)

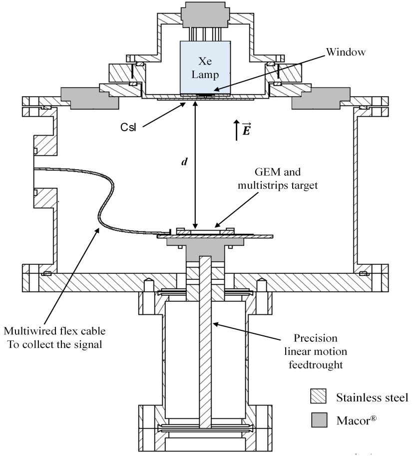

Figure 3: Vertical cut of the experimental system.

Typical histograms of the charge collected

- For each **background-subtracted histogram**, a **gaussian fitting** procedure was performed to obtain the standard transverse deviation (σ') of the experimental distribution

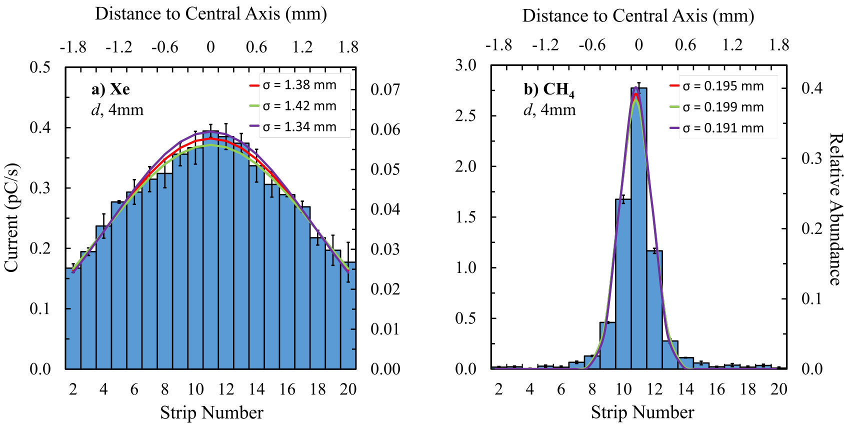

Figure 4: Typical histograms for the average charge fraction collected, for a fixed drift distance of 4 mm, after background removal, for a) Xenon and b) CH_4.

Results for Xe and CH_4

- The characteristic energy values associated with the transverse diffusion (ε_{kT}) were obtained for Xe and CH_4 at two different E/N values, at 800 Torr
- 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

Table 1: Characteristic energy associated with the transverse diffusion obtained in this work, for Xe and CH_4, at 800 Torr, for a drift distance between 4 and 12 mm. Simulations from [4–6] and other works from [7–9]. In *, the data is extrapolated from the available results.

Gas	E/N (Td)	ε_{kT} (eV) This work	ε_{kT} (eV) Simulation	ε_{kT} (eV) Other works*
Xe	0.92	5.75 $\pm$ 0.45	6.06	[6.04 – 6.70]
	1.53	7.15 $\pm$ 0.63	7.02	[7.04 – 7.74]
CH_4	0.92	0.065 $\pm$ 0.005	0.058	$\sim$ 0.067
	1.53	0.097 $\pm$ 0.008	0.085	$\sim$ 0.102

Outline

Absolute Primary Scintillation Yield in Xe and Xe-TMA

- The S1 in noble gas detectors can be used to obtain the initial interaction time of a detected event, but existing results on this feature in gaseous Xe are scarce and their agreement is not satisfactory
- A standard GPSC was used to measure the w_p-value of S1 in gaseous Xe at 800 Torr for 5.9 keV X-rays, using the ratio between the S1 and S2 signals, while their detection efficiencies of both signals were determined by Monte Carlo simulation
- The S1 signal was also studied in Xe-TMA mixtures (with TMA fraction between 0.1% and 1.0%) and only observable up to 0.1% TMA concentration
- **Paper submitted to JINST**

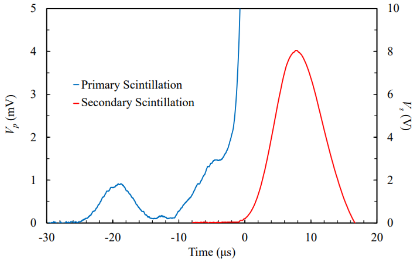

Figure 5: Average of 128 pulses observed in the oscilloscope for pure Xe at 800 Torr, with $(E/P)_{drift} = 0.2$ V/cm/Torr and $(E/P)_{scint} = 3.5$ V/cm/Torr.

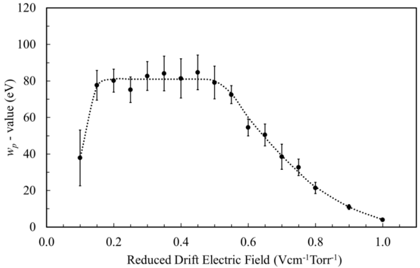

Figure 6: Results of w_p-value as a function of $(E/P)_{drift}$ for Xe at 800 Torr, for $(E/P)_{scint}$ of 3.0, 3.5 and 4.0 V/cm/Torr.

Outline

SWOT analysis

Strengths

- Students doing thesis, curricular internships and summer internships. In the past 3 to 4 years:
  - → 4 students in summer internships and 2 students in curricular internships
  - → 2 Msc thesis concluded
  - → 1 MSc student and 2 PhD students
- 7 summer internships this year
- Experience/know-how
- Great involvement with young researchers

Weaknesses

- Lack of/very limited and non-stable internal and external funding leading to less projects, grant holders, laboratory material and, ultimately, results
- Reduced number of early career researchers

Opportunities

- Possible partnership with CYGNO Collaboration
- New collaboration with Czech Technical University
- Successful student internships leading to MSc and PhD projects
- Negative ions as charge carriers may provide necessary knowledge on rare-event experiments
- Electron transverse diffusion studies **caught the eye of CERN** in PISA meeting and motivated RD51 talk

Threats

- **Possible loss of a key member of the team (Alexandre Trindade) after his PhD by lack of funding**
- Irregularity in funding projects (FCT, mainly)

Thank you for your attention!

References

[1] T. Ikeda et al., *Development of a negative ion micro TPC detector with SF6 gas for the directional dark matter search*, *Journal of Instrumentation* **15** (2020) P07015.

[2] E. Baracchini et al., *Negative ion time projection chamber operation with SF6 at nearly atmospheric pressure*, *Journal of Instrumentation* **13** (2018) P04022.

[3] D. Marques et al., *Dual-Polarity Ion Drift Chamber: A new system to measure the mobility of positive and negative ions*, *NIM A* **1029** (2022) 166416.

[4] J. Escada et al., *A Monte Carlo study of photoelectron extraction efficiency from CsI photocathodes into Xe-CH4 and Ne-CH4 mixtures*, *Journal of Physics D: Applied Physics* **43** (2010) 065502.

[5] J. Escada, *Detetores gasosos de radiação: efeitos da retrodifusão na emissão de fotoeletrões por fotocátodos de CsI em meio gasoso e eletroluminescência em Xe dopado com CH4 e CF4*, dissertation, University of Coimbra, 2012.

[6] J. Escada et al., *A monte carlo study of backscattering effects in the photoelectron emission from CsI into CH4 and ar-CH4 mixtures*, *Journal of Instrumentation* **2** (2007) P08001.

[7] S. Kobayashi et al., *Ratio of Transverse Diffusion Coefficient to Mobility of Electrons in High-Pressure Xenon*, *Japanese Journal of Applied Physics* **43** (2004) 5568.

[8] B. Schmidt and M. Roncossei, *Drift Velocity, Longitudinal and Transverse Diffusion in Hydrocarbons derived from Distributions of Single Electrons*, *Australian Journal of Physics* **45** (1992) 351.

[9] N. Hasebe et al., "Electron Transport Parameters Measurements in High-Density Gaseous Xenon." 2017.