Set-ups for gas properties characterization

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Introduction

Each detector type, with its particular **working principle**, is normally associated with a gas filling

Large experimental setups, however, have **requirements beyond those dictated by their working principles**

This led to the search for new additives to adjust the main gas properties to the particular needs of the experiment, without jeopardizing other **useful side features**

This search, and the long-lasting R&D work on gas detectors, motivated the development of a **diversity of devices that could characterize the several features of a filling gas** for a given purpose

Introduction (cont.)

Recently, the search for **eco-friendly alternatives to detector gas fillings** has become a major endeavor of the scientific community as a consequence of the alarm on growing **climate changes**

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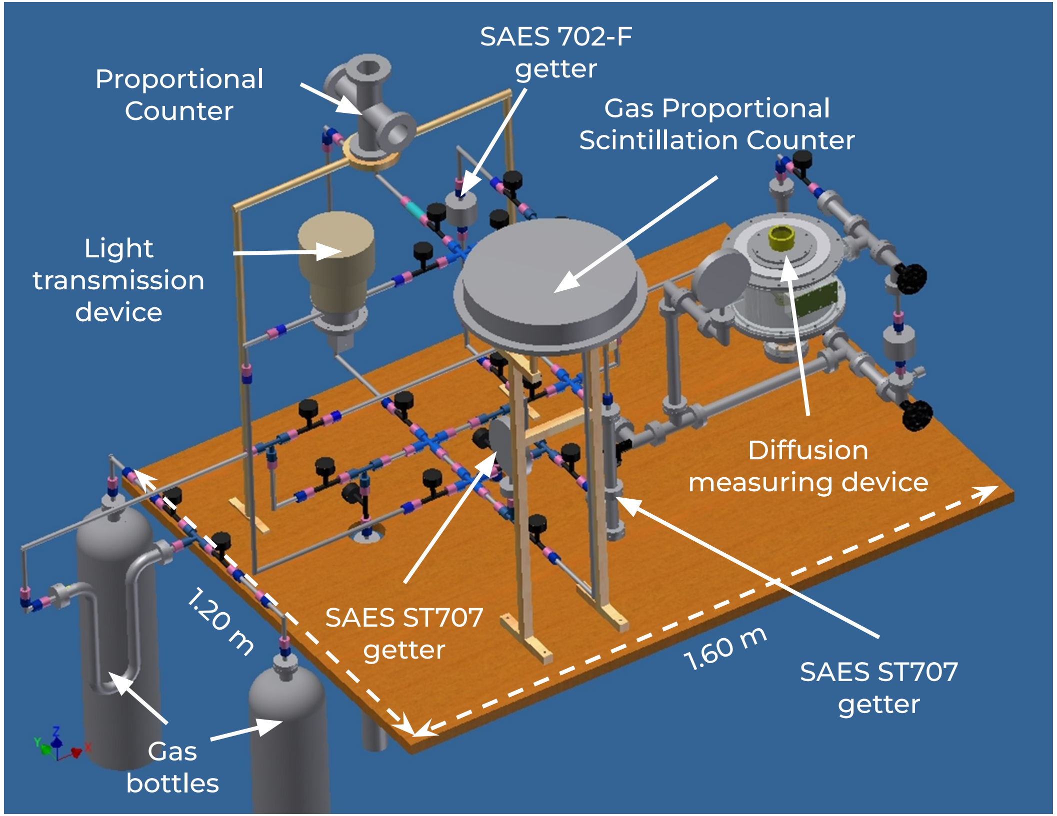
However, traditional gases have been crucial in the achievement of the best possible detector performance

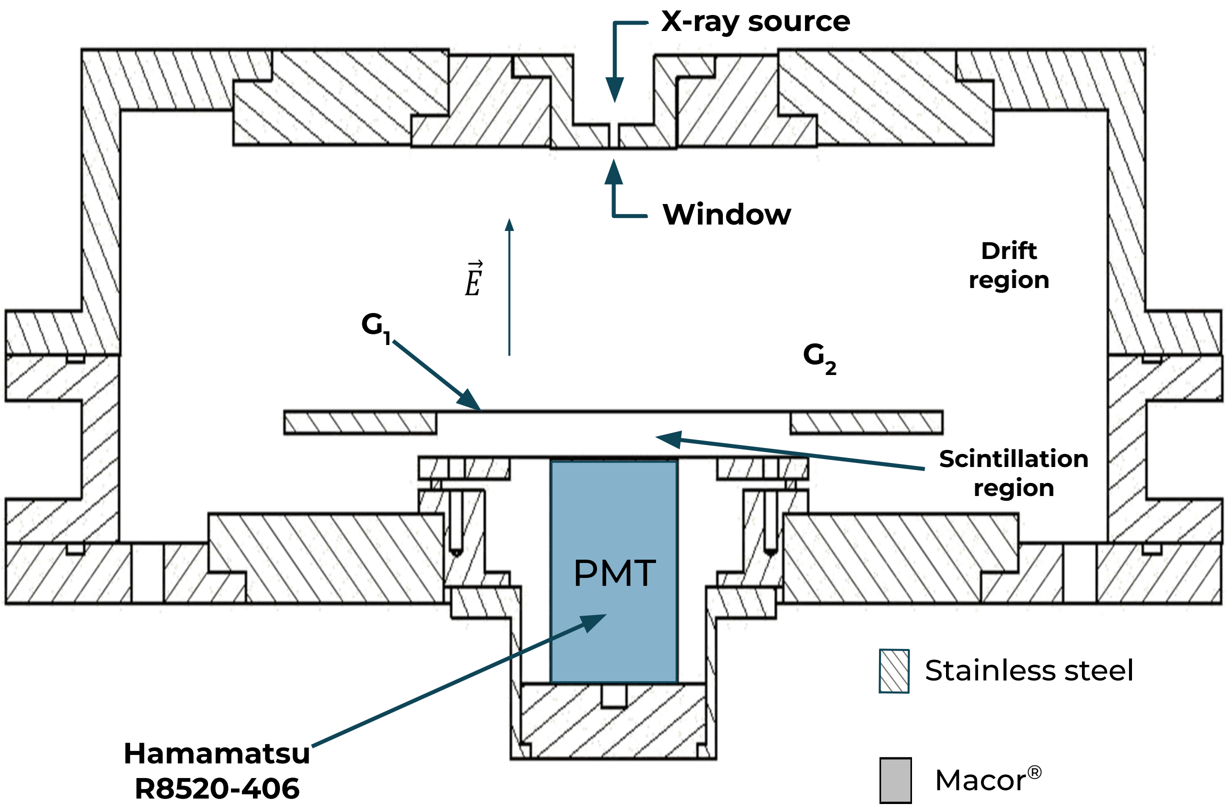
Our system, being a self-contained and **an independent assembly of different devices,** can be very useful in picking candidate eco-friendly gases for further testing

Schematic of the gas system



- Each device can be isolated by vacuum valves if not in use
- 2 independent high pressure gas containers + 2 gas purifiers (molecular and noble gases)
- Gas circulation by **hot getters** or **cold getters** (using heating sleeves)
- Vacuum level is monitored by a Pirani (Varian 0536) and Penning (Varian 525), achieving an ultimate pressure of **10^{-7} Torr**
- Gas pressure in the devices is monitored by a MKS Baratron 722A (5000 Torr, 0.5% precision) and a WIKA (15 bar, 0.05 bar precision) pressure gauge
- Residual gas analyser (Hiden HAL IV RC) accessible through a needle valve

Gas Proportional Scintillation Counter (GPSC)



- Same **working principle as the optical TPC**
- After the formation of excited noble gas atoms, a highly probable three body collision forms an excimer that emits a VUV photon (**wavelength dependent**)

Scintillation is a **very high efficiency** process, with **low fluctuations** and with **no space charge effects**

↓

Near intrinsic energy resolution

Purpose of the device

INITIAL MOTIVATION → **The GPSC device** allows to characterize the scintillation properties of gas fillings

Noble gases have high diffusion which is a severe drawback in large dimension setups where tracking is needed → This can be solved with the **addition of a molecular component at ppm level, yet with the loss of scintillation efficiency**

Scintillation is produced **always by the same mechanisms but** in two circumstances (**with different yields**)

When the incident particle is absorbed (**primary scintillation**)

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Very convenient **time trigger** (simultaneous to the incoming event), but with **low yield** and low tolerance for quenching or inhibition mechanisms

When an appropriate electric field is applied (**secondary or proportional scintillation)**

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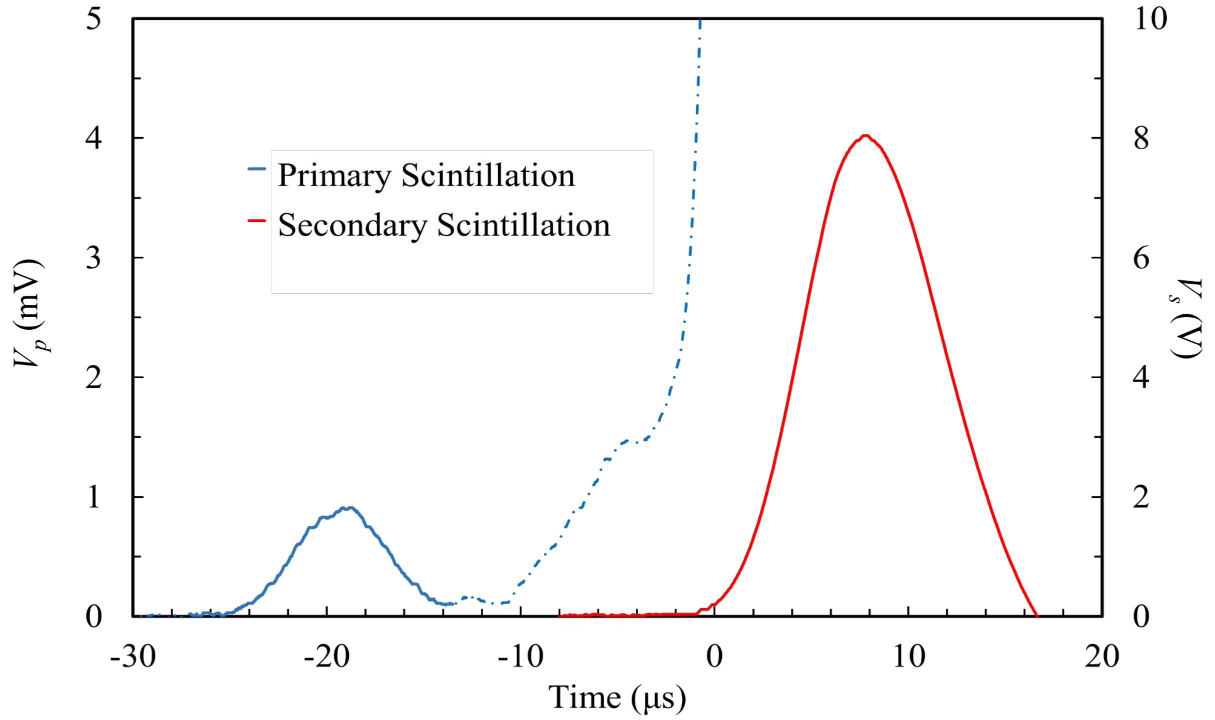
High yield process responsible for the **very good energy resolution** found in TPCs or GPSCs (with some margin for losses that need to be checked)

Primary and secondary scintillation spectra in pure xenon



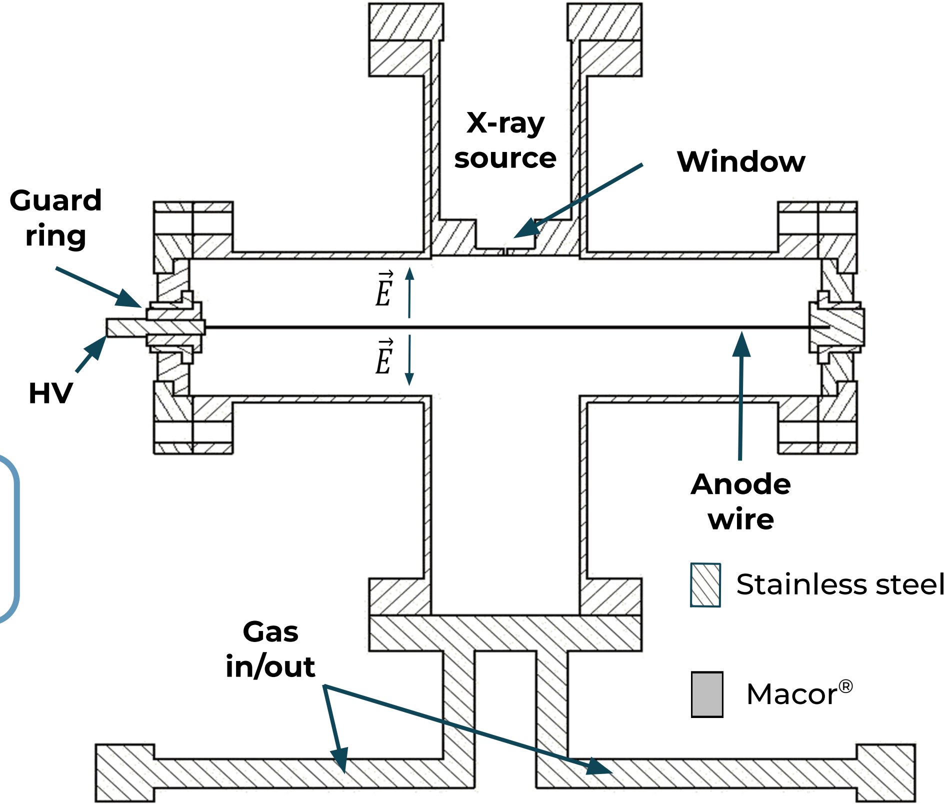
Please note the time shift between the two signals (the drift time of electrons travelling across the drift distance) and the different vertical scales of the two signals. The dotted line represents the secondary scintillation signal in the same vertical scale as the primary signal shifted in time.

Proportional Counter (PC)

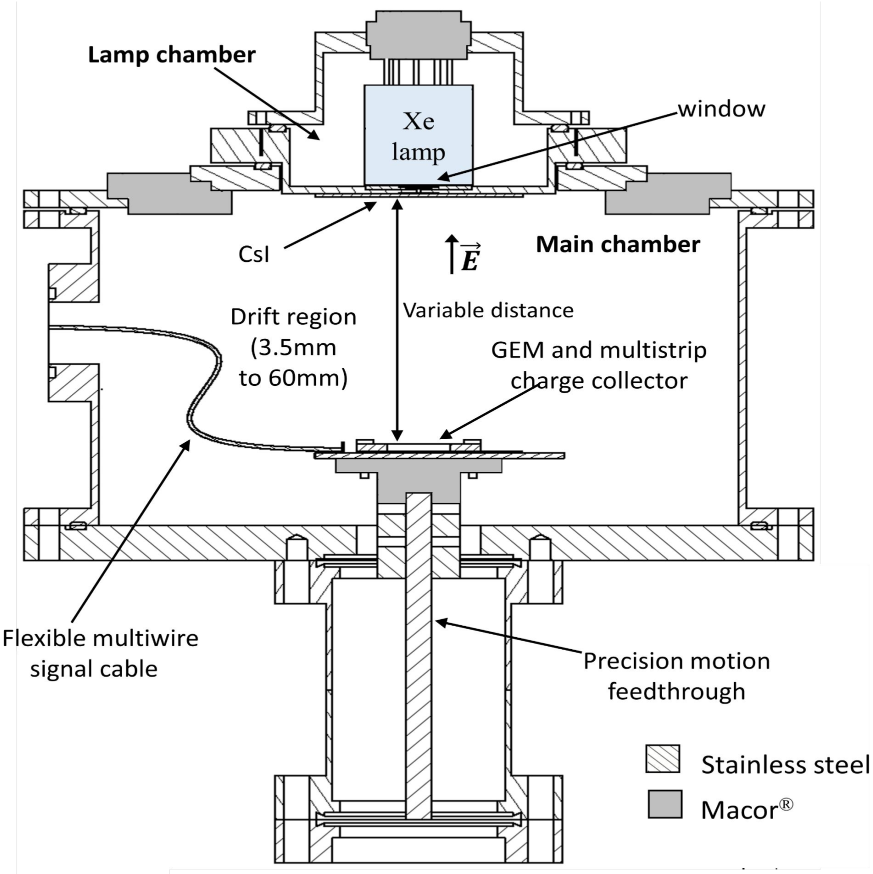
- Well known, low cost, widely used device, usually implemented in cylindrical geometry
- Allows to **study the performance of gases or gas mixtures regarding charge multiplication**, the capability to stand high voltage, the response to the applied voltage, etc
- It relies on **charge multiplication** (on the vicinity of the anode) as amplification process

Charge multiplication is a **high fluctuation** process affecting energy resolution. Further degradation can come from **space charge effects**

Energy resolution is thus worse than in GPSC (optical-TPC)



Charge diffusion measuring device



- Electrons are produced by a pulsed xenon lamp (Hamamatsu L2435) impinging on a **CsI transmissive photocathode** deposited in the main chamber side of the assembly, on a quartz window
- At the top of the **precision motion feedthrough** (which allows for the variation of depth of the drift region) the GEM and multistrip charge collecting device are mounted
- The charge collecting device has 21 strips, 15 mm long 100 μm wide and 100 μm apart
- The charge collected at each strip is read by a Keithley 602 electrometer through a multiwire flexible cable (which also carries the GEM polarization voltage) connected to the outside through the side of the device

Working principle

After drifting a pre established (variable) length under a uniform drift electric field, **electrons go through the GEM where a slight multiplication** (not affecting their position) turns them to a measurable charge and are collected at the grounded multistrip device

The **drift distance is then varied** while **keeping the electric field and pressure constant** for each set of measurements

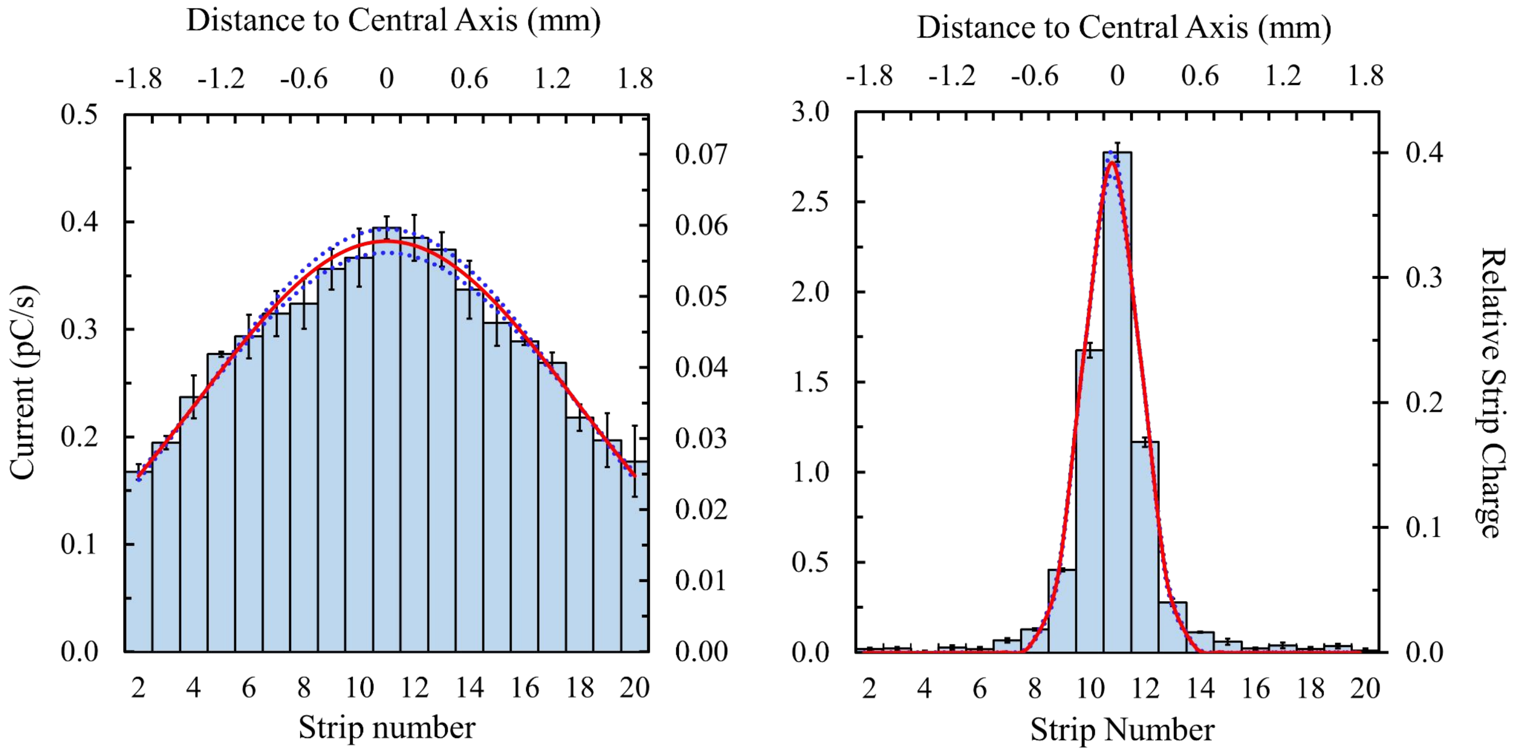
Data handling

The evolution of the charge profile of the 21 stripes with the distance is represented in an **histogram whose shape is fitted**

From the parameters of the fitting and from known relations the **transverse diffusion can be calculated**

All due corrections are made (geometrical, background, reflections, photocathode extraction efficiency, transparency at the different surfaces, etc.)

Charge histograms for Xe and CH_4

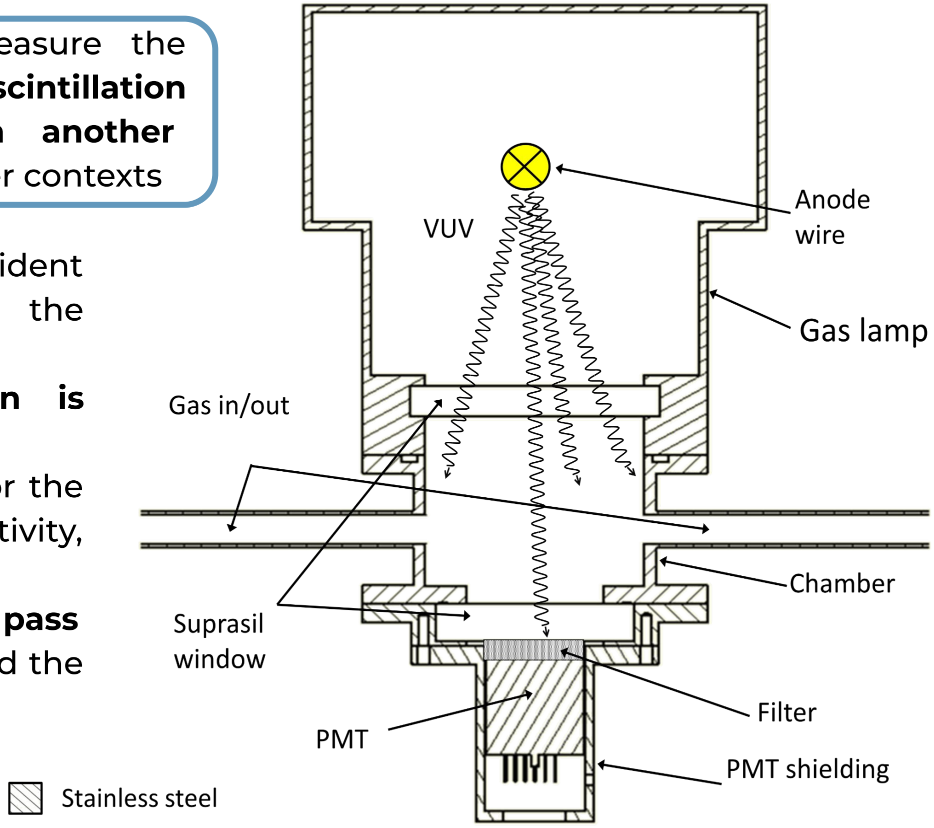


Results were obtained, and a good agreement was found with values from the literature

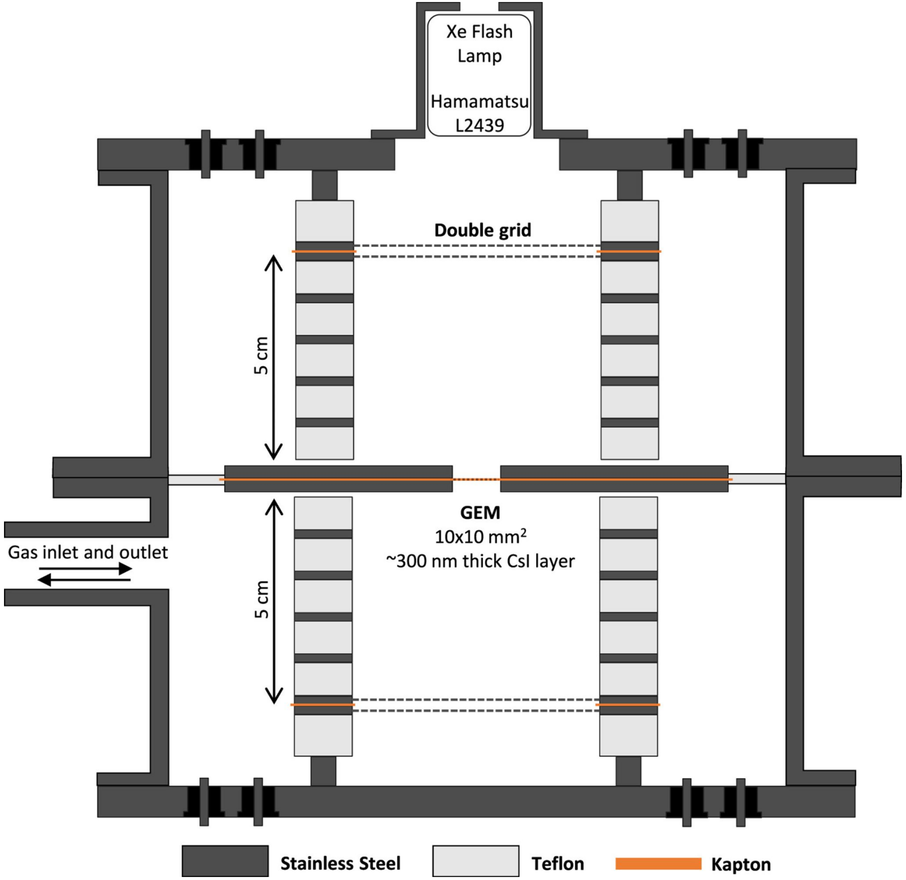
Light transparency device

This device was built specifically to measure the **absorption coefficient of TMA to xenon scintillation** (172 nm) and eventual **re-emission in another wavelength.** However, it can be used on other contexts

- The signals produced by the PMT for incident light through vacuum and through the gas/mixture being study are compared
- **After corrections, the light absorption is assessed**
- The sensitivity of the device is estimated for the working conditions and, within that sensitivity, results can be stated
- If assessing reemission, designated **band pass filters** can be used between the window and the PMT

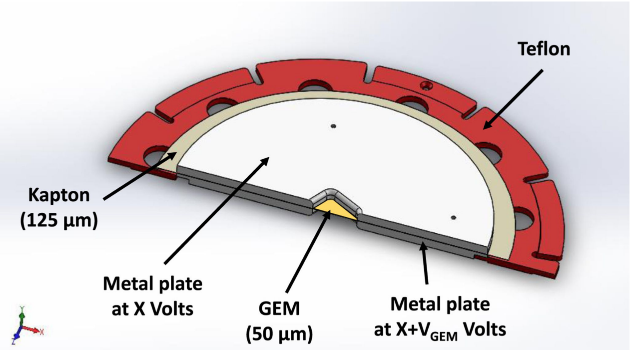


Dual-Polarity Ion Drift Chamber (DP-IDC)



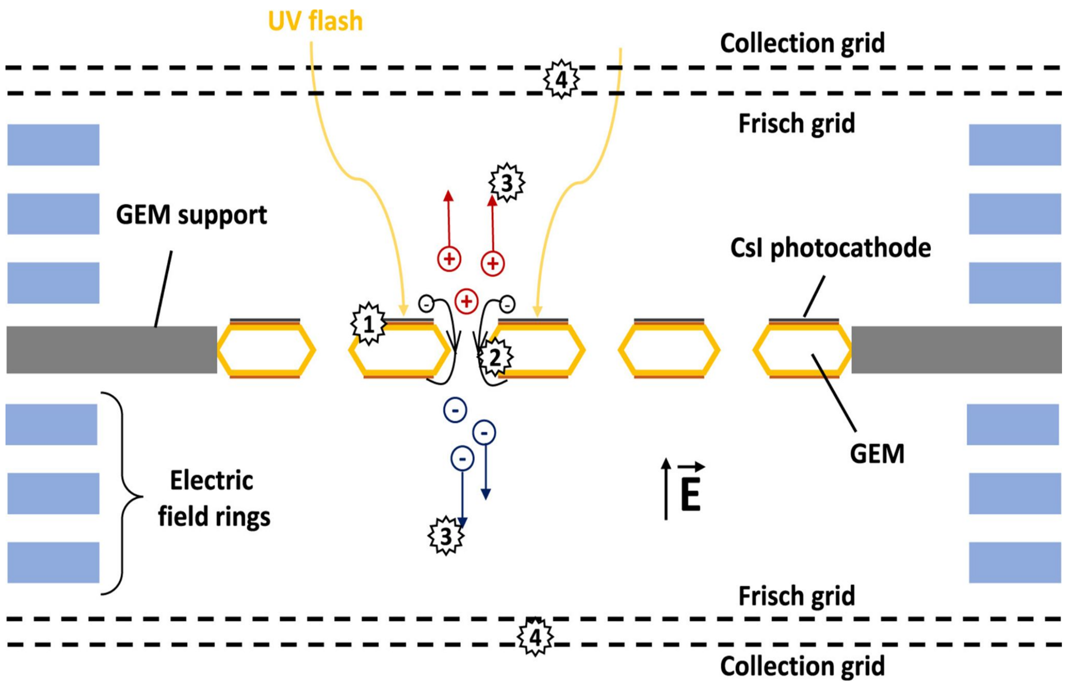
Device to measure the reduced ion mobilities of both positive and negative ions

- This is the only standalone system that has no purification
- It is directly connected to a dedicated vacuum system and results are taken within few minutes of a fresh filling with the gas under study.
- At the moment reliable results are available for pressures up to few tens of Torr



Working principle of the DP-IDC

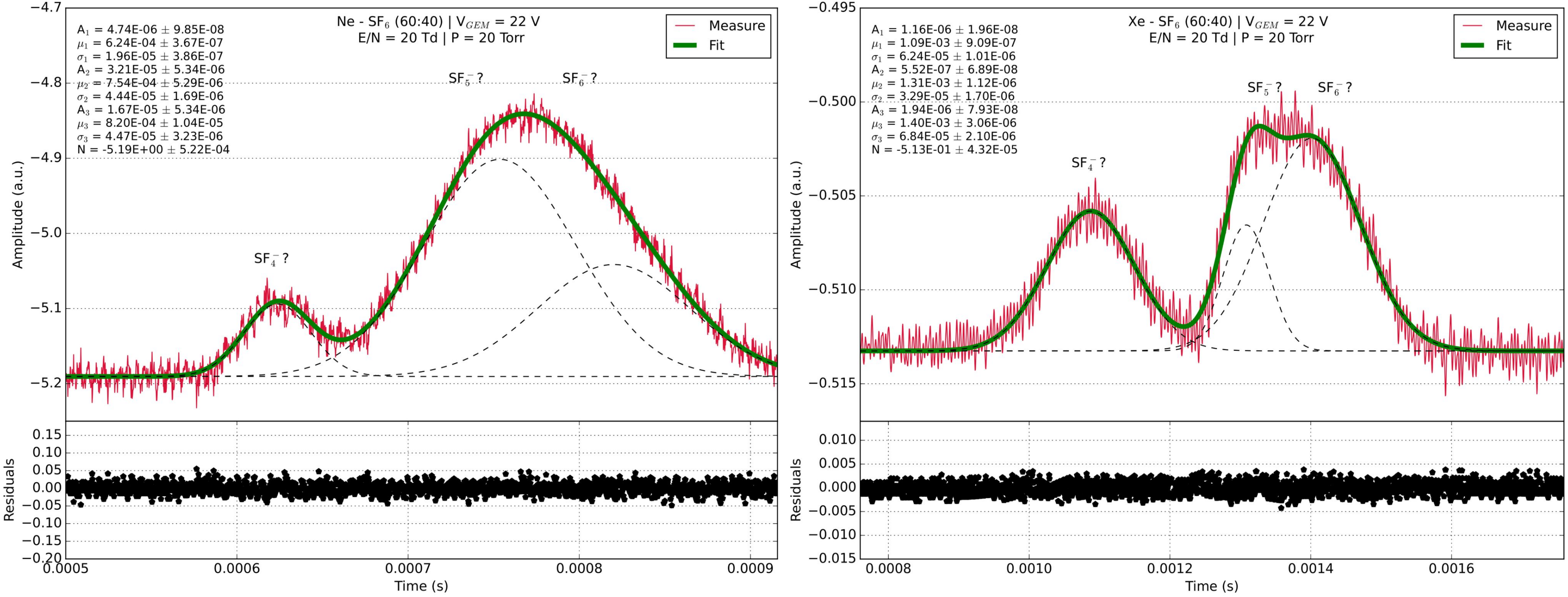
1) A xenon UV lamp emits photons that hit a **photocathode** deposited on top of a GEM, releasing **photoelectrons**
2) The electrons are guided to the GEM holes by an electric field and are accelerated inside the GEM generating **positive or negative ions**, depending on the gas
3) Ions drift towards the top/bottom double-grid depending on their polarity
4) Ions induce a signal in the Collection grid (after the Frisch grid) which is converted to voltage and fed to a digital oscilloscope



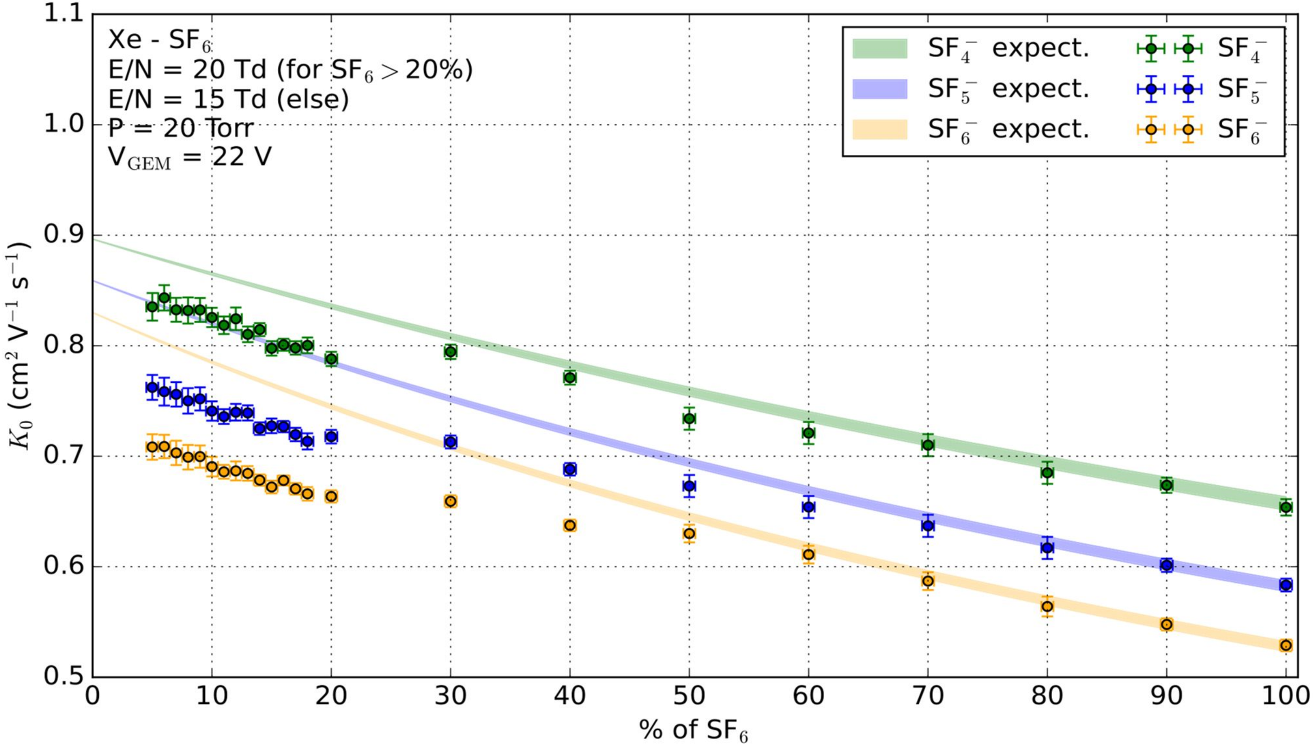
** The system does not provide direct identification of the ions produced

Ion Time of Arrival Spectrum

With tentative identification of the ions present for Ne-SF_6 (60:40) (left) and Xe-SF_6 (60:40)



Reduced mobility for Xe-SF_6 as a function of SF_6



Results for the reduced ion mobility as a function of the SF_6 content in a Xe-SF_6 mixtures.
Lines represent Langevin theory. Please note that the vertical scale is very extended.

Monte Carlo Simulation

Custom Monte Carlo simulation has been a standalone investigation tool for a diversity of fields in our group, acting as an alternative to experimental work

A model is developed, required data gathered and preliminary tests carried out → The range of energies to be covered is defined and results are obtained for the desired parameters

Lately MC simulation has also been used as a complement to experimental work to **estimate errors**, the **detection efficiency** of a system or the **sensitivity** of the setup

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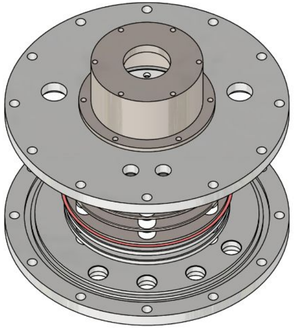
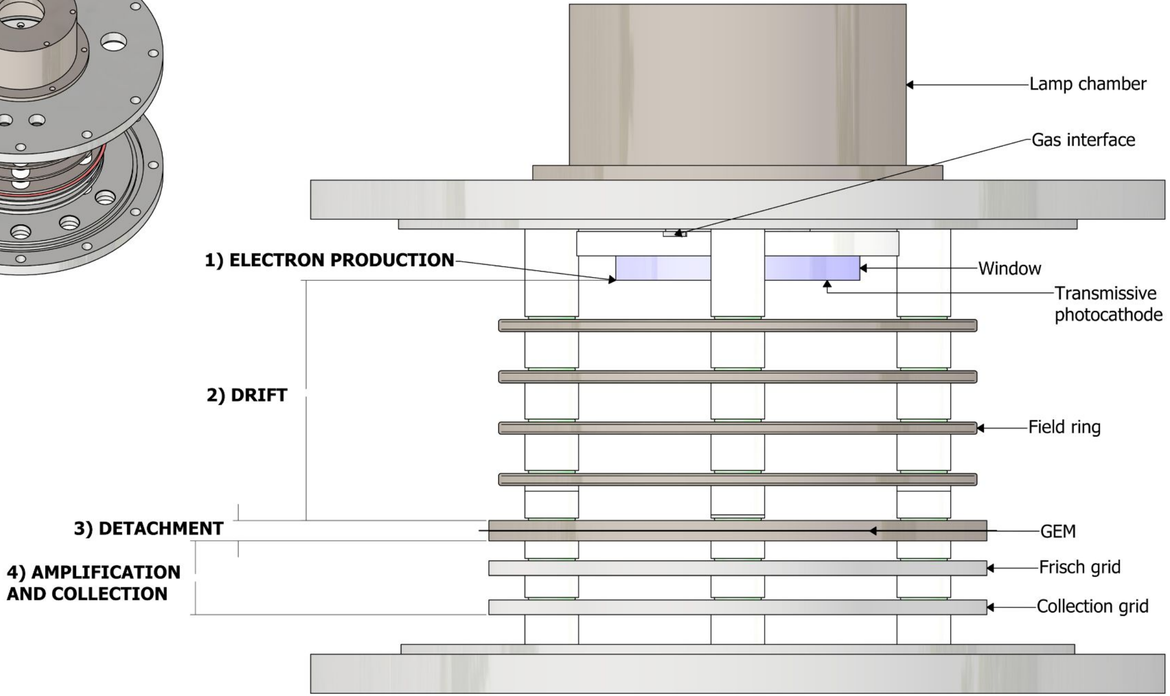
In fact, when **event characteristics change** (e.g. wavelength of a radiation) the **detection efficiency will generally change**. The variations depend on various factors and can be challenging to quantify or even estimate. **Detailed modeling of the events within the detector is required and needed data gathered**

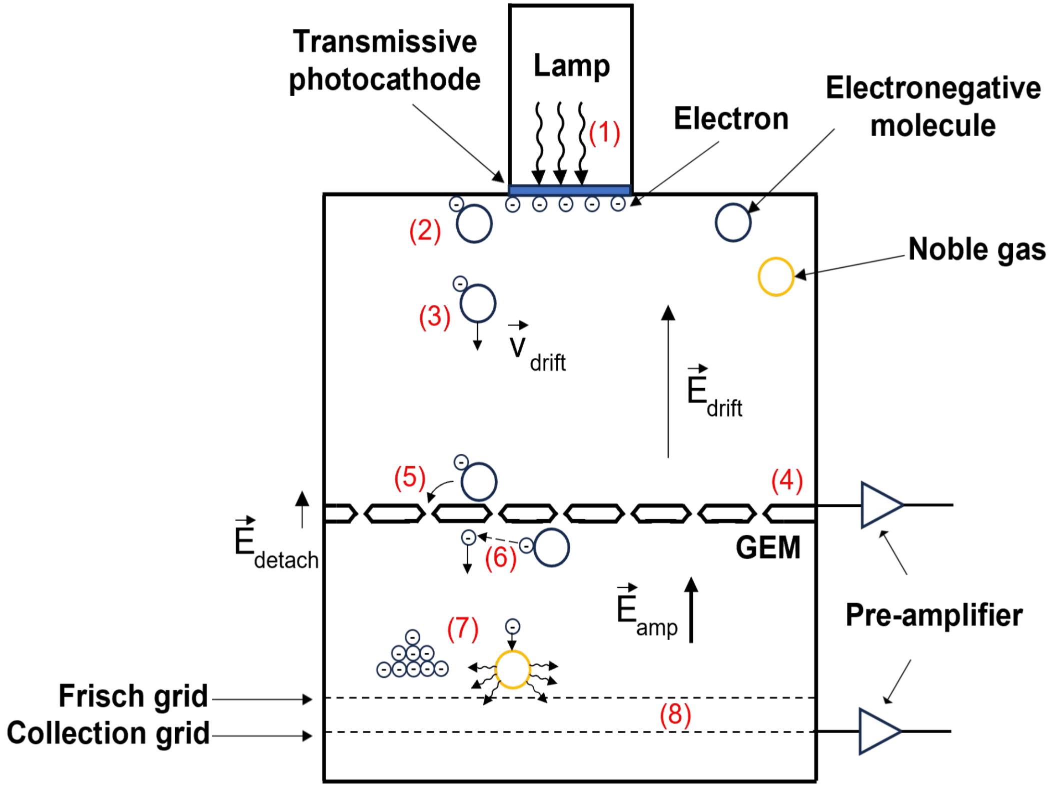
Study of negative ions as charge carriers

Drift region of the detector





Working principle



(1) Photons hit a transmissive photocathode, **releasing electrons**

(2) **Electron attachment** to the additive will occur very close to photocathode

(3) Negative ions drift towards a GEM under an appropriate electric field

(4) If no electric field is applied, the charge is collected on the top electrode of the GEM (for monitoring purposes)

(5) Applying an electric field across the GEM, guides ions to GEM holes and **induce electron detachment**

(6) An electric field on the subsequent region (drift) can produce signal **amplification**

(7) A system of two grids is placed after the amplification region (Frisch + collecting grids)

High pressure chamber

- Another device has also been developed to **study the capacity of a high pressure gas to stand high electric fields**, <u>but it has not been fully explored</u>
- Large dimension gas-detectors based experiments often use high pressure gas to increase detection efficiency. It has been noticed that, **at high pressure, the capacity of a gas to stand electric fields decreases**
- This effect is especially important in **optical devices** where moderate electric fields are required to achieve high electroluminescence yields

The device is a chamber **standing pressures up to 5 bar,** filled with the target gas, with **two non-connected parallel plates inside** between which an electric field is established

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The goal is to see if the lowering of the threshold for discharges is **intrinsic** or if it is somehow related to the **complexity of the high pressure experimental setups** where it is known to occur, and to investigate **a possible dependance on the gas used**

Thank you!

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LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Initial positive ion mobility device