Dual-Polarity Ion Drift Chamber: Experimental results with Xe-SF_6 mixtures

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Introduction

- In gas detectors, the mobility of ions directly affects the **attainable rate capability**, **spatial resolution**, and **pulse shape formation** [1]
- The **positive ions** formed at the amplification stage may have a negative effect as their production rate creates space charge effects distorting the electric field
- **Electronegative molecules** are seen as an obstacle in gas detectors, capturing the drifting electrons leading to a reduction in the detector's signal amplitude
- Recently, **electronegative gases** (e.g. SF_6) have been used to improve the spatial resolution by exploiting the ions' reduced diffusion when compared with electrons

Negative Ion Drift and Ion Mobility

Diffusion coefficient (D), in m^2/s:

$$D = \frac{2}{3\sqrt{\pi}}\frac{1}{p\cdot\sigma_0}\sqrt{\frac{(kT)^3}{m}}$$

$\boldsymbol{k}$ - Boltzmann's constant
$\boldsymbol{T}$ - temperature
$\boldsymbol{p}$ - pressure
$\boldsymbol{m}$ - charge's mass
$\boldsymbol{\sigma_0}$ - total collision cross section of a charged particle with a molecule

Ions have a 10^2-10^3 times smaller diffusion comparing to electrons, which leads to better spatial resolution

Possible to determine the z-position of an ionisation event and reconstruct its 3-D track, improving the fiducialisation and background discrimination

The measured **z-coordinate** depends on the **value of the ions' mobilities**:

$$\left.\begin{array}{l} v_d = K\cdot E \\ K = K_0\cdot N/N_0 \end{array}\right\} \Rightarrow \frac{v_d}{E}\cdot\frac{N}{N_0}$$

$\boldsymbol{v_d}$ - average ion velocity
$\boldsymbol{K}$ - ion mobility
$\boldsymbol{K_0}$ - reduced ion mobility
$\boldsymbol{N}$ - gas number density
$\boldsymbol{N_0}$ - Loschmidt constant

Langevin's polarization limit [1]:

$$K_{pol} = 13.88/\sqrt{\alpha\mu}$$

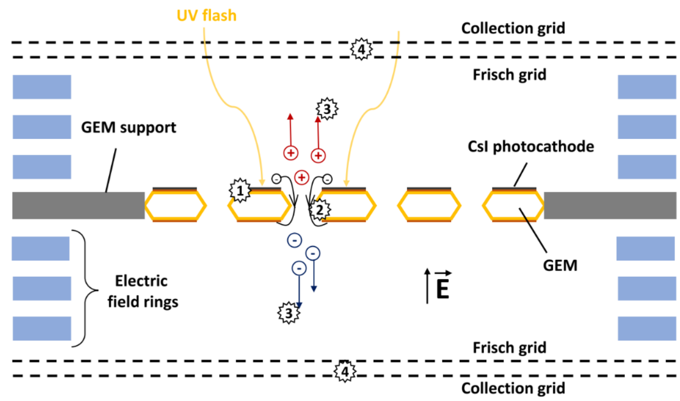
$\boldsymbol{\mu}$ - ion-neutral reduced mass
$\boldsymbol{\alpha}$ - neutral polarizability in $Å^3$ of the neutral atom/molecule

Blanc's empirical law [1]:

$$1/K = \sum_i^N f_i/K_i$$

$\boldsymbol{K_i}$ - mobility of an ion in the gas i
$\boldsymbol{f_i}$ - fraction of the gas i in the mixture with N components

Working Principle



① A xenon UV lamp emits photons that hit a CsI photocathode deposited on top of a GEM, **releasing photoelectrons**

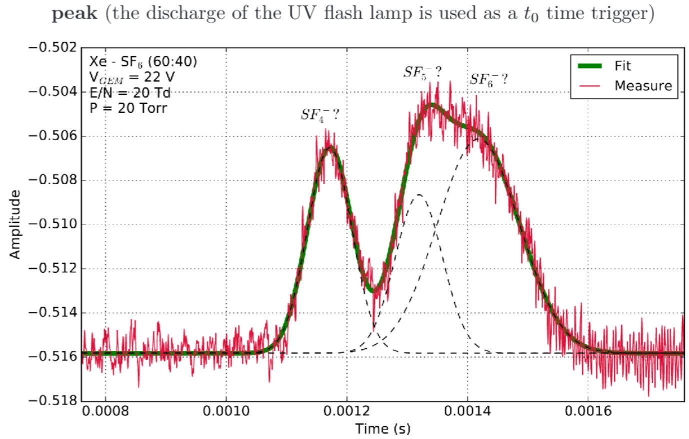
② The **electrons are guided to the GEM holes** due to an electric field where they are accelerated and generate: **Positive ions** (electron impact ionisation) or **Negative ions** in electronegative mixtures (immediate attachment or energy loss in inelastic scatterings and consequent attachment)

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

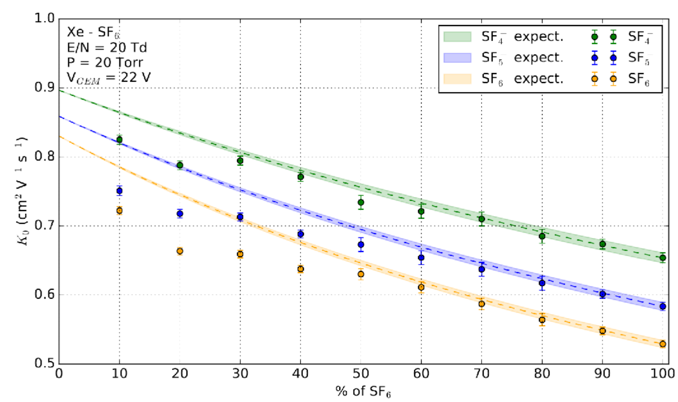
④ The ions induce a signal in the **Collection grid** after the **Frisch grid** which is converted to voltage and fed to a digital oscilloscope (128 pulses average)

Data Analysis

- The peaks in the ions' time-of-arrival are fitted to **Gaussian curves**
- The **ion's reduced mobility is calculated from the centroid of each peak** (the discharge of the UV flash lamp is used as a t_0 time trigger)



Results



Conclusions and Future Work

- This detector **determines the mobilities of negative ions in mixtures** for large volume detectors
- The results, for the mixture Xe-SF_6, are fairly **in accordance with the expected** using the Langevin's polarization limit and Blanc's empirical law
- Future studies will focus on different electronegative gases in mixtures at higher pressures

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References

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