Dual-Polarity Ion Drift Chamber: Experimental results with Xe-SF$_6$ mixtures

A.P. Marques$^2$, D.J.G. Marques$^{3,4}$, N.G.S. Duarte$^1$, J.P.M. Teles$^1$, A.F.V. Cortez$^2$, A.M.F. Trindade$^2$, J. Escada$^2$, F.P. Santos$^{1,2}$ and F.I.G.M. Borges$^{1,2,*}$

$^*$Corresponding author: f1lipa.borges@coaboa.11pt

1Department of Physics, Faculty of Sciences and Technology, University of Coimbra, Coimbra, Portugal; 2Laboratory of Instrumentation and Experimental Particle Physics - LIP, Rua Larga, 3004-516 Coimbra, Portugal; 3Gran Sasso Science Institute, viale Francesco Crispi, 7 - 67100 L’Aquila, Italy; 4Instituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Gran Sasso, Assergi, L’Aquila, 67100, Italy. 5Institute of Experimental and Applied Physics, Czech Technical University in Prague, Husova 240/5, 110 00 Prague 1, Czech Republic

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:**

$$D = \frac{2(\frac{kT}{m})^{1/2}}{3\sqrt{\pi}}$$ where:

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

The measured $z$-coordinate depends on the value of the ions’ mobility:

$$v_z = \frac{qI}{m}$$

where $v_z$ - average ion velocity

**K** - ion mobility

**K$_{reduced}$** - reduced ion mobility

**N** - gas number density

**N$_0$** - Loschmidt constant

**Langenstein’s polarization limit [1]:**

$$I_{polar} = \frac{13.88\sqrt{\mu_\alpha}}{d_\alpha}$$

where $\mu$ - ion-neutral reduced mass

$\alpha$ - neutral polarizability in Å$^3$

**Blanc’s empirical law [1]:**

$$1/K = \sum_{i} (1/k_i)$$

where $k_i$ - mobility of an ion in the gas $i$

$x_i$ - fraction of the gas $i$ in the mixture with $N$ components

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).

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 Langenstein’s polarization limit and Blanc’s empirical law.
- Future studies will focus on different electronegative gases in mixtures at higher pressures.

Working Principle

A xenon UV lamp emits photons that hit a CsI photodetector deposited on top of a GEM, releasing photoelectrons.

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).

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

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).

Results

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