Abstract

Exploring Size Variation of Ionic Clusters in Gas Detectors: A Comparative Analysis of Ar-CO_2 and Ne-CO_2 Gas Mixtures Across Varied Parameters

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Ionizing radiation or particles passing through gas-filled detectors induce ionization, resulting in the formation of positively charged ions. The presence of these ions introduces challenges to the detector's functionality within the detector volume. Ionic clusters create an electric field, causing distortions in subsequent ion and electron drift paths, thereby impacting the detector's spatial resolution. This phenomenon, known as the space charge effect, is a crucial aspect to consider. Cations and cluster ions migrate towards the cathode under the influence of the electric field, leading to unwanted signals or noise within the detector. This ion backflow effect adversely affects the detector's energy resolution and introduces additional uncertainties. Additionally, ions can recombine with electrons, neutralizing their charge and reducing the number of ion pairs available for collection. Recombination consequently affects the overall detector efficiency.

The mobility of ions or ionic clusters in the gas volume is primarily influenced by their size. Theoretical studies have investigated the formation of van der Waals-like bonds between ions and atoms, shedding light on the sizes of ionic clusters formed in gas detectors. However, experimental measurements of these cluster sizes in the drift region are scarce in the literature.

In this study, we present the results of an experiment conducted to measure the sizes of ionic clusters formed in the drift region of a Gas Electron Multiplier (GEM) detector under standard conditions. We employed the widely-used dimensional analysis method with Rayleigh scattering. The GEM detector, constructed using a standard GEM sheet, was placed within a vacuum and pressure-resistant chamber. A compact photomultiplier tube (PMT) and a fiber optic cable, along with a 532 nm green laser light source, were positioned perpendicular to each other within the drift region of the detector.

To trigger the detector, a Fe55 source was employed, and the light scattered by structures such as atoms, molecules, ions, and ionic clusters within the drift region was collected by the PMT. The resulting PMT signal was carefully analyzed, enabling us to perform size measurements in Ar-CO_2 and Ne-CO_2 gas mixtures at various mixing ratios, temperatures, and humidity levels. The experimental results were comprehensively interpreted.

Our findings provide valuable insights into the impact of space charge and ion backflow effects on the performance of gas-filled detectors. By accurately characterizing the sizes of ionic clusters, we contribute to the advancement of detector design and optimization, enhancing their spatial resolution, energy resolution, and overall efficiency.