# Optimizing Gas Detectors with Gas Mixture of Isobutane and $CO_2$: A Combined Experimental and Simulation Study

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## Introduction

The gas detectors are widely used device for detecting and measuring ionizing radiation. Its functionality relies heavily on the properties of the gas mixture used within the detector, which ionizes in response to incoming radiation, leading to the generation of an electrical pulse. Traditionally, argon-based gas mixtures have been employed; however, the search for alternative mixtures that can provide better efficiency, stability, and signal strength has become an area of active research.

In this paper, we explore the use of an alternative gas mixture comprising 90% Isobutane ($C_4H_{10}$) and 10% Carbon Dioxide ($CO_2$). Isobutane, a hydrocarbon, has a relatively high electron affinity and can enhance the detection efficiency of the GM counter. Carbon dioxide, on the other hand, acts as a quenching agent, preventing continuous discharge and ensuring the counter operates in the Geiger-Müller region.

The study is conducted using both experimental setups and simulations performed with Garfield++[1], a toolkit for simulating the behavior of gaseous detectors. The focus is on two main aspects: (1) the electric field distribution within the counter when a biasing voltage of 400 V is applied, (2) the signal produced by the detector in response to ionizing radiation when using the $C_4H_{10} - CO_2$ gas mixture.

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## Simulation

The simulated Geiger-Müller (GM) counter consists of a 15.1 mm stainless steel outer tube enclosing a 9.1 mm gas chamber filled with 90% isobutane and 10% $CO_2$. A 0.1 mm radius tungsten anode wire is positioned at the center, and a 9.1 mm mica end window allows particle entry. The 49.2 mm long assembly operates at 0.1 atm and 293 K, with the stainless steel cathode grounded at 0 V and the anode biased at 400 V.

The electric field within the GM counter is a critical factor that influences the motion of ionizing particles and the subsequent signal generation. In this study, the electric field was simulated using the ComponentAnalyticField method in Garfield++, with a potential of 400 V applied across the detector. FIG. 1 shows that the electric field is strongest near the anode wire, as expected, and decreases with distance from the wire.

After simulating the electric field, Magboltz[1] was used to generate the gas file containing the calculated drift parameters, including the Townsend coefficient, attachment coefficient, and drift velocity. Primary electrons were calculated using HEED[1]. These parameters are crucial for determining the secondary, tertiary, and subsequent electrons produced in the gas mixture from the primary electrons—a process known as gas multiplication. As these electrons drift, the multiplication leads to an avalanche, ultimately resulting in signal generation. Figure 2 illustrates the drift lines, representing the paths taken by

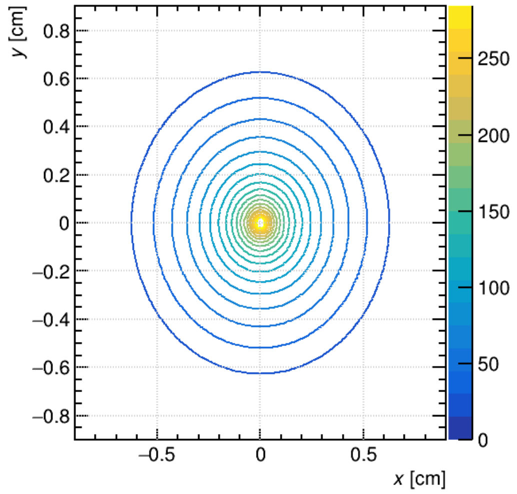


FIG. 1: The electric field distribution (Ex and Ey) within the GM counter at a bias voltage of 400 V.

ionized electrons within the detector under the influence of the electric field. These drift lines were produced by the interaction of a 59 keV gamma ray from an Am-241 source in a gas mixture of 90% isobutane and 10% $CO_2$, at a chamber pressure of 0.1 atm and a temperature of 293 K.

## Results and Discussion

The signal generated by the detector is the result of avalanche of electrons reaching the anode wire. In Figure 3, both the experimental and simulated signals are presented. The figure shows that the peak charge of the simulated signal is 0.19 femtocoulombs, whereas the experimental signal is around 0.15 femtocoulombs, with the rise time of the simulated signal being slightly lower at 80 ns. Despite these differences, the pulse shapes of both signals are remarkably similar, indicating that the simulation accurately replicates the detector's behavior. The signal amplitude and shape are indicative of the charge collected at the anode, and these characteristics provide valuable insights into the detector's response to ionizing radiation. Both experimental and simulation results suggest that a gas mixture of 90% isobutane and 10% $CO_2$ is an effective choice for this application.

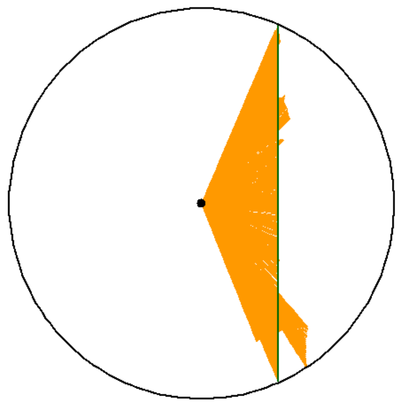

FIG. 2: Drift lines of ionized electrons in the gas volume for a gamma of 59.54 keV . The lines indicate the trajectories of the electrons as they move towards the anode wire.

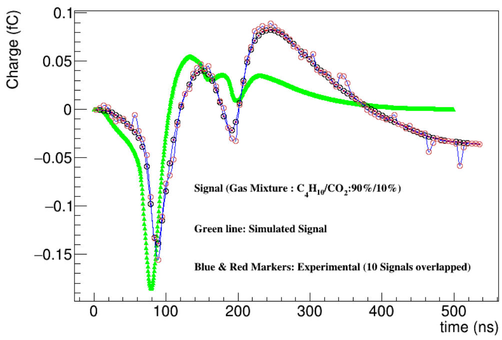


FIG. 3: The signal produced by the GM counter, Green line represents simulated signal and the Blue line represents the experimental signals.

## References


[1] H. Schindler, R. Veenhof, Garfield++ "simulation of ionization based tracking detectors", 2018