LaTeX Charge Transport Simulation in Triple GEM Detectors

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Introduction

GEM Detectors are used in many particle physics experiments, for tracking charged particles, due to their high rate and spatial resolution capabilities. We simulate the operation of a GEM detector using the Garfield++ toolkit. The detector structure was designed in GMSH and the field maps were obtained using the Finite Element Solver ElmerFEM. An appropriate unit cell with X and Y periodicity was chosen.

Simulation Setup

We use the 3-2-2-2 gap configuration. The fields and voltages are shown in Figure 1. A single electron was released $70\mu m$ above the top GEM. Gas mixture was chosen to be Ar-CO_2 in 70-30 proportion. Temperature and pressure were 293 K and 740 torr respectively. Microscopic integration was chosen to compute electron drift lines.

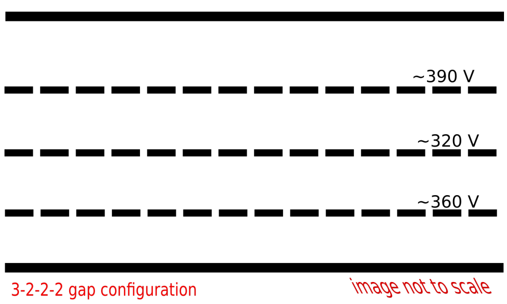

FIG. 1: GEM Detector Schematic

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A separate ion transport simulation was setup by generating an ion at the location of each electron avalanche, and allowing it to drift. For the case of ions, we used macroscopic tracking due to the large time interval involved for ion drift.

Analysis

The avalanche in the first GEM is constrained within a single hole, referred to as the central hole in subsequent layers. In each subsequent layer, the charge spreads outwards primarily due to diffusion, each hole acting independently as an amplifier below the Raether Limit. As a result, GEM Detectors are able to operate under high gain conditions without undergoing discharges. The outward spread of charge at each layer is quantified by the standard deviation σ.

We define a quantity:

$$\text{CR} = \frac{\text{Charge in central hole}}{\text{Charge in entire layer}} \quad (1)$$

Results and Discussion

The avalanche charge distribution is shown for the bottom GEM in Figure 2 and the charge deposition at the anode in Figure 3.

The charge ratio C.R was calculated for each layer individually. However, this is the average over all avalanches - to examine better the instantaneous value we implemented an algorithm to dynamically analyse the avalanche progression in time slices of 0.5 ns, and observed peaks in mid and bottom GEM that were far higher than the averaged value, as shown in Figure 4.

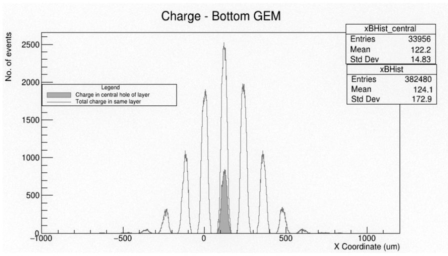

FIG. 2: Bottom GEM

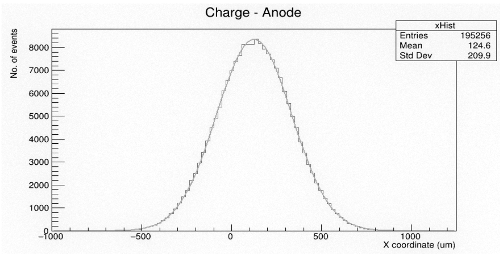

FIG. 3: Anode

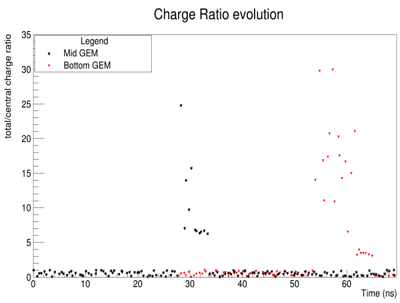

FIG. 4: Evolution of Charge Ratio

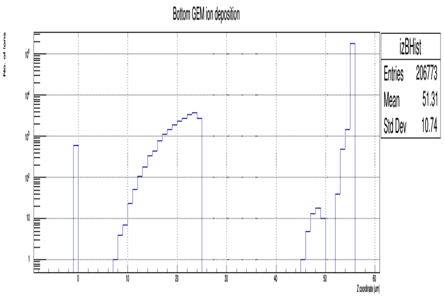

FIG. 5: Deposition of ions from bottom GEM

The standard deviations were seen to increase in line with theoretical predictions, in consecutive layers, with a value of $236.3\mu m$ at the anode.

For the ion simulation, we analysed the backflow from the lower layers [shown for bottom GEM in Figure 5]. The fractions of produced ions that were deposited on the dielectric foil and the copper electrodes have been calculated for each layer, both for backflow ions, and ions generated in same layer.

Similar analyses was carried out by varying the ratios of Argon and Carbon Dioxide in the mixture, and the gas pressure.

Acknowledgments

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References

[1] Garfield++, a Gas Detector Simulation Toolkit.