GEM Detector Simulation

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Introduction

Gas Electron Multiplier Detectors (GEM) are used for charged particle tracking in many high energy experiments. These detectors can work at high rates and provide high spatial distribution. The electron amplification inside the GEM holes depend upon the electric field distribution around these micro-holes. We have modelled a Gas Electron Multiplier (GEM) Detector using the Garfield++ Simulation toolkit. In our simulation, we studied the spot size and electron distribution for a triple GEM for a range of operating voltages.

Simulation Methodology

Simulation of the triple GEM was done by generating a single primary electron in the drift gap. Complete Garfield++ simulations of triple GEM would take hundreds of hours, so we put an appropriate size limit
Simulating the entire geometry of the GEM detector was not required. We modelled only a certain portion - *the unit cell*, and utilised its inherent X and Y periodicity to generate the infinite *sea of holes* structure of the detector.

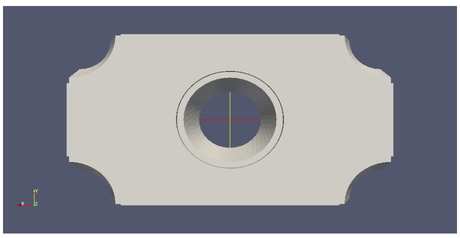

FIG. 1: Unit Cell of GEM detector

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Over a range of operating GEM voltages, we simulated multiple events for each voltage.

GEM Detector Parameters

1. Transfer/Induction Gaps $2mm$
2. Transfer/Induction Field: $2.5kV/cm$
3. Drift Gap - $3mm$, Drift Field: $1kV/cm$

Analysis

Using ROOT, we plotted the X and Y coordinates at which the electron impinged on the readout. From here, we calculate the standard deviation(σ), and attempt to fit a suitable function. To measure the spot size, we define a term ν as -

$$\nu = \sqrt{\sigma_x^2 + \sigma_y^2}$$

Plots

For $\Delta V_{GEM} = 500V$, Figures 2 and 3 show the spreads in X and Y coordinates.

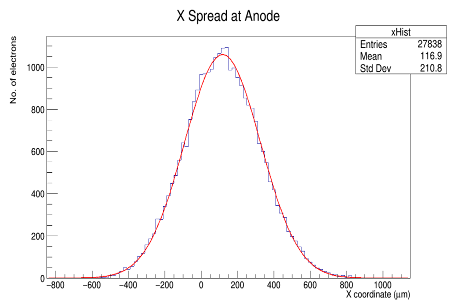


FIG. 2: X Spread

Fig. 4 shows the electric field in the holes, which is far higher than in the gaps.

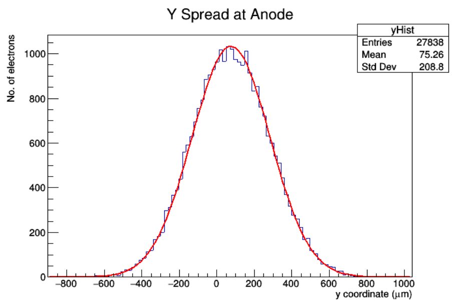


FIG. 3: Y Spread

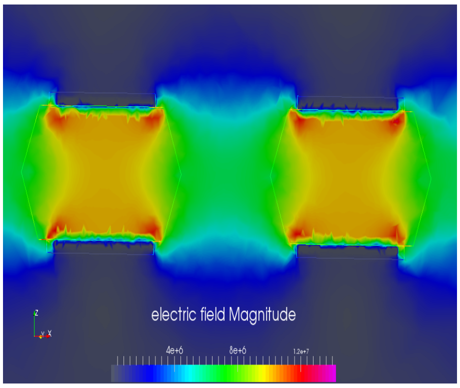
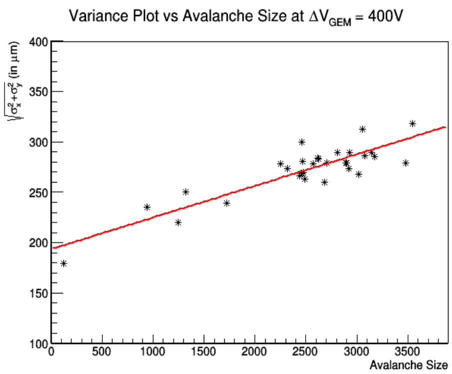


FIG. 4: $\Delta V = 500V$



Conclusion

The X and Y spreads of the electron shower are observed to be Gaussian in nature, and the mean of the distributions are close to the release point of the generated primary at

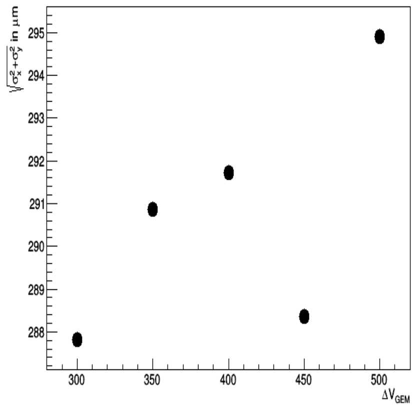


FIG. 5: ν vs ΔV_{GEM}

FIG. 6: Variance vs GEM Voltage

$(121\mu m, 70\mu m)$.

The value of $\nu = \sqrt{\sigma_x^2 + \sigma_y^2}$ has an apparently linear behaviour, an observation which will be discussed in detail. It merits more simulations over large number of events.

We note that the point at $450V$ seems to be an outlier, without which the fit would be linear in nature.

Acknowledgments

We are grateful to the author of Garfield simulation toolkit - Dr. Rob Veenhof, CERN for answering all our queries regarding the program.

References

[1] Garfield++ simulation toolkit `https://garfieldpp.web.cern.ch/garfieldpp/`