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Physics Modelling of Gas Electron Multiplier

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Abstract

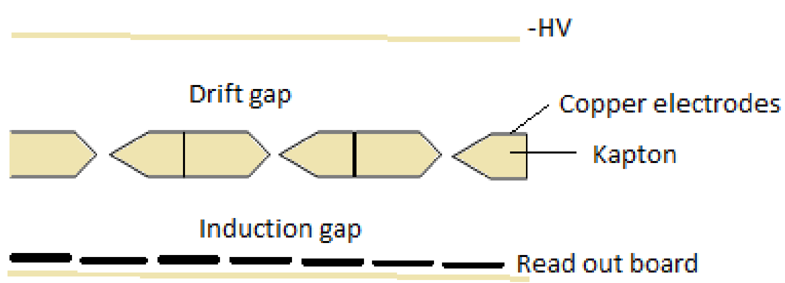
Gas Electron Multiplier (GEM) comes under the category of micro pattern gaseous particle detectors. GEM detectors were successfully used in many high energy a physics experiments. In this work we will calculate the electric field map of GEM detectors using Finite Element Method and characteristics gain of GEM detectors using Monte Carlo methods.

Key words: Gas Electron Multipliers (GEM), Finite Element Method (FEM) , Monte Carlo

1. Introduction

The fabrication of GEM detectors is mainly done by using a Kapton foil of thickness 50 µm and two 5 µm thick copper electrodes. Kapton foil is sandwiched between two copper electrodes. In this way, the structure forms a thin metal-polymer assembly. Then photolithographic technique is used to make high density holes on this structure. The diameter of one hole will be 70 µm and pitch is maintained at 140 µm. These holes are diconical shaped [Figure. 1] .The complete assembly is kept inside a chamber filled with gas mixture in the proportion Ar/CO_2 : 70% / 30%. We apply a few 100 voltages across the electrodes that will create a huge Electric Field in the holes. A particle which is traversing through the detector may ionize the gas mixture and primary electrons are produced. The electrons which are trapped in these holes are accelerated under the electric field. These electrons collide with gas mixture and produce secondary ionization. The secondary electrons produced again collide with nearby gas molecules and produce tertiary electrons and so on. This process is called gas multiplication. Large number of electrons are created and form an avalanche due to gas multiplication.

Figure 1: Schematic diagram of GEM detector



2. Simulation

Atmospheric muons of specified energy were selected as primary particles. The primary particle passing through the GEM detector creates primary clusters in the direction of traversing particle. The primary particle interaction and the resulting average number of electrons and cluster density are calculated using HEED [1]. The primary electron clusters are accelerated in the huge electric field. The electric field modeling is done by using COMSOL Multiphysics[2], a commercial finite element package. The electron transport parameters were calculated using MAGBOLTZ [3]. The production of avalanche of electrons and drift are simulated using Garfield++ [4].

3. Gain Calculation

The GEM electron transparency (T) can be studied [5] in terms of collection efficiency (ε_{coll}) and the extraction efficiency (ε_{extr}). T= $\varepsilon_{coll} \times \varepsilon_{ext,}$ where collection efficiency is the ratio of number of electron entering to number of electron generated and extraction efficiency is the ratio of number of electron extracted to number of electron in to the channel. The gain of GEM can be calculated in terms of intrinsic gain (G_{int}) or effective gain (G_{eff}). Intrinsic gain is the representation for average number secondary electrons produced. And effective gain will indicate the average number of secondary electron extracted. $G_{eff} = G_{int} * T$

Figure 2 : Map of GEM detectors with electron

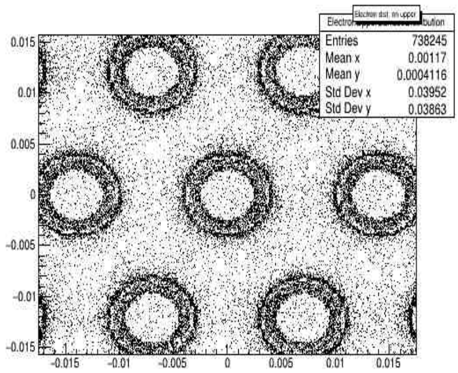


Figure 3: Electric Field Map in 2D for GEM

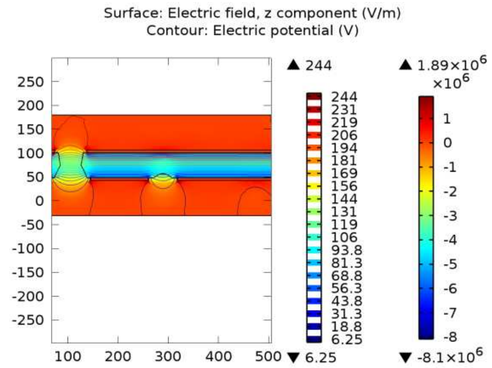


Figure 4: Electric Field Map in 3D for GEM

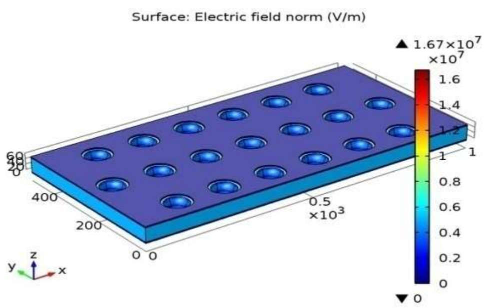
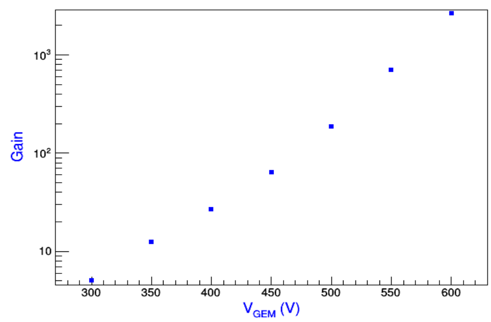


Figure 5: Gain for varying GEM voltages detector



4. Results and Conclusion

We have simulated the structure of a single GEM. Figure .2 shows the map of electrons distribution which appears at the upper surface of GEM detector. The electric field variation in the geometry is simulated. Figure.3 and Figure.4 shows the electric field map of the GEM detector in two dimensional and three dimensional respectively. With these simulated inputs we drifted the electrons through the GEM detector. We have used the microscopic avalanche class of Garfield++ and studied the effective gain for various GEM operating voltages. Figure .5 shows the effective gain for different gain voltages. It is clear from the nature of the curve that effective gain varies linearly with GEM voltages.

Acknowledgement

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