Principles and Applications of Thick Gaseous Electron Multipliers (THGEMs)

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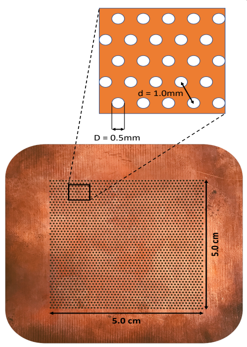
Introduction

Thick gaseous electron multipliers (THGEMs) are used to create significant gain and increase energy resolution in particle detectors. Gain is an important factor in detectors that amplifies a signal before the readout so that recorded events can be easily distinguished from the background. This is an essential principle when dealing with rare events such as detections of dark matter or neutrinos. The enhanced energy resolution resulting from THGEMs is another elemental quality that allows one to characterize values in an energy spectrum from the detector.

THGEM Geometry

The geometry of a THGEM is one of the most important factors that determines how much gain is achieved and by how much the energy resolution can improve. Currently, there are many different geometries being used for gaseous electron multipliers (GEMs) from flat plate GEMs to cylindrical GEMs. The model fabricated at the University of Houston is a flat plate THGEM made of 10 cm x 10 cm copper plates with a G10 insulator between them. The following is a list of some of the pros and cons of the THGEM fabricated at the University of Houston:



Pros
- Higher breakdown/discharge voltage due to thickness (~2400 V)
- G10 is a strong insulator that can undergo tests in liquid or gas
- Flat THGEMs allow for more arrangements in the experiment, especially cascading multiple THGEMs or altering distance of drift fields

Cons
- Large hole size – Gain increases as D decreases for D ≥ 70 μm [1]
- No etching of the hole edges – this can cause breakdown/discharge at lower voltages

Figure 1. Dimensions of THGEM's holes diameter (D), hole separation (d), and effective area.

Theory

In a gaseous or liquid medium, a high voltage is applied to the THGEM and drift plates. The HV across the drift plates directs a source of electrons towards the THGEM, and after passing through the THGEM to the wire readouts. The HV across the THGEM generates a strong electric field that accelerates the electrons in the gaseous/liquid medium. There occurs Bremsstrahlung interactions and electron avalanche from the bombarded particles. These electrons are then drifted towards the readout wires connected to multiple channels of an ADC (Analog to Digital Converter) for detection.

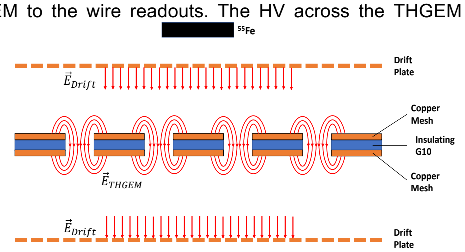


Figure 2. Diagram of electric fields generated by the HV across the drift plates and THGEM.

Analysis

Since the detected monoenergetic spectra resemble a Gaussian distribution, one can analyze the theoretical effects of a THGEM by examining the affected Gaussian parameters.

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

$f(x)$ is the Gaussian function where σ^2 is the variance and μ is the average energy value, or effectively the corresponding energy value with the maximum counts.

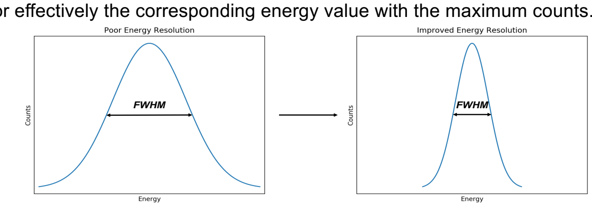


Figure 3. Theoretical Gaussian distributions of monoenergetic spectra with degraded and improved resolutions.

The energy resolution in terms of the full-width at half-maximum (FWHM) obeys the following equation, where μ is the peak/average energy value of the Gaussian:

$$R = \frac{FWHM}{\mu}$$

Amplification through a good THGEM will result in a narrower Gaussian, effectively improving the energy resolution. This allows one to better distinguish energy values in a spectrum. The other important factor previously mentioned is gain.

$$G = \frac{\mu * G_{elec}}{n_0 * e}$$

The gain, G, is a function of the peak/average energy, μ, the amplification gain from electronics, G_{elec}, the initial electrons produced by full energy deposition, n_0, and the and the charge of an electron, e [2].

Conclusion

THGEMs are, overall, an principal part of a detector that will increase gain and energy resolution. Alterations in THGEM's geometry and operation voltage are the most influential factors in how well the THGEM will affect the gain and resolution along with the medium in which it is placed.

The future direction for our experiment is to quantitatively simulate the electric fields throughout the detector. These simulations will allow us to acquire the optimum set-up that we can test by altering distances and voltages. Ultimately, we will then test the THGEM in argon mixed with different impurities to find the maximum possible gain.

Acknowledgements:
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Citations:

[1] Jacob Snäil, 'Tests and simulations of GEM foils for use in an active target gaseous detector' (2016) p.14, M. Sc. Thesis, Lund University

[2] Rajendra Nath Patraa, Rama N. Singarajua, Saikat Biswasb, Zubayer Ahammeda, Tapan K. Nayaka, Yogendra P. Viyogiaa, 'Nuclear Instruments and Methods in Physics Research A' 816 (2017) 25-30, https://doi.org/10.1016/j.nima.2017.05.011