Measurement of energy resolution of a triple-GEM detector using ^{55}Fe source

Nirupama Sensharma[1]*, Anand K. Dubey[2]
[1]University of Delhi, Delhi - 110007, INDIA
[22]Experimental High Energy Physics & Applications Division, Variable Energy Cyclotron Centre, Kolkata - 700064, INDIA
* email: nirupama.sensharma@gmail.com

Introduction

The **Gas Electron Multiplier** (GEM) is a micro-pattern gas detector used in nuclear and particle physics for radiation detection [1]. It consists of a 50 μm thin polyimide foil metalized with 5 μm copper on both sides. Holes of 50 μm diameter are chemically etched at a pitch of 140 microns all throughout the surface of this foil. By applying voltages of 400–500V across the two surfaces of the GEM foil, an electric field as high as 100 V/cm is produced inside the holes, which act as multiplication channels for primary electrons produced in the gas by an ionizing particle or radiation. GEMs provide high gain, fast response time and high rate capability.

A GEM detector can be used to detect radiation at lower energies. Since they work in the proportional region, they can also be used to perform energy spectroscopy. GEMs are also a convenient choice as photo-detectors [2] and for X-ray radiography.

GEMs have a potential to be used in medical imaging area and also find their use as efficient neutron detectors in Reactor environments. While performing the task of measuring the energy of the incident radiation, the energy resolution of the detector determines the accuracy of the measurement for the corresponding energy. In this paper, we have studied the characteristics of a triple GEM detector in terms of its energy resolution using ^{55}Fe X-Ray source. The variation of the energy resolution of the detector is studied with different GEM voltages and an optimum GEM voltage is chosen for operation.

Experimental Setup

The picture of a triple GEM detector prototype is shown in the Fig.1. It consists of

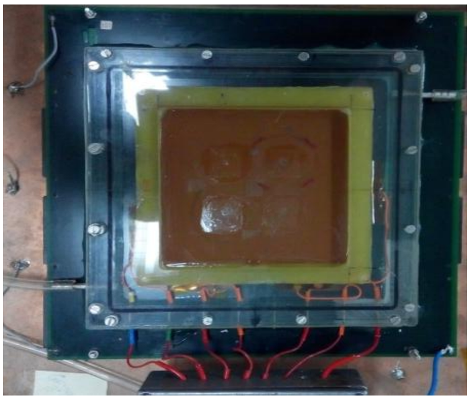

Fig.1. Picture of a 10 cm x 10 cm triple GEM detector prototype.

three layers of 10 cm x 10 cm single-mask GEM foils stacked in a configuration of 3/1/1/1.5 mm representing the drift gap also referred as conversion gap, the two transfer gaps and induction gap respectively. It was encapsulated in a gas-tight chamber filled with Ar-CO_2 (70:30) mixture as the fill gas. ^{55}Fe X-ray source having a characteristic energy of 5.9 keV was used as the radiation source. These X-rays undergo photoelectric absorption with Argon. However, there might be a few X-rays that do not get absorbed in the medium and escape out thereby resulting into the smaller escape peak. A resistive chain has been used to power the three GEMs and the drift electrode. The GEMs were powered in a symmetric configuration, which means all the three GEMs were at identical Vgem settings. The signal was readout from a finely segmented readout plane which was connected to standard NIM electronics and then fed to an MCA.

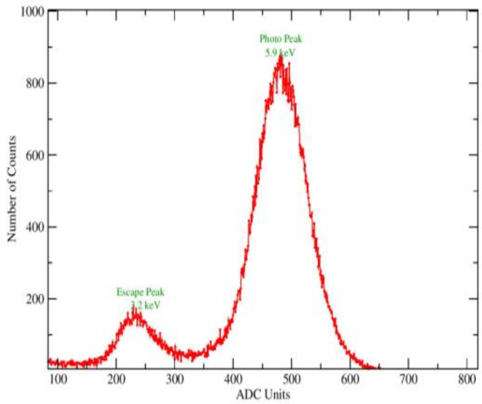

Fig. 2 ^{55}Fe spectra for Vgem = 376.7 V from the triple GEM detector

Test Results

Fig. 2 shows a typical pulse height spectra obtained from the detector when exposed to ^{55}Fe source and corresponding to a Vgem~376 V. The major peak corresponds to 5.9 keV X-rays while the lower peak is the escape peak. The spectrum is fitted with a Gaussian distribution to extract the peak and the sigma of the two peaks. As the bias voltage changes, the drift and the induction field also changes along with the GEM voltage as they are coupled to a resistive chain. Data were taken at several GEM voltage settings. The variation of peak pulse height with GEM voltage for both the major peak and escape peak is shown in Fig. 3. It shows an exponentially increasing trend with increasing gem voltage. The photo peak curve lies above the escape peak curve in the plot as the photo peak corresponds to a larger ADC value.

The resolution of the detector is calculated by determining the sigma of the Gaussian fit of the major peak, for every pulse height spectra and taking the ratio FWHM/peak, where FWHM=2.35 sigma. Shown in Fig. 4 is the variation of this resolution with varying GEM voltages. The curve initially shows a decreasing trend. It is inferred that as the gem voltage is increased, the electric field and hence the amplification is also increased. This in turn increases the statistics, the fluctuations decrease and hence the resolution also decreases. But beyond a certain value of the GEM voltage, the resolution starts worsening again. This can be attributed to the fact that increasing the voltage beyond a certain limit leads to more frequent UV emissions leading to an increase in fluctuations, thereby leading to worsening of the resolution. A minimum value of 22.8% has been obtained which is slightly larger than those available in literature for a gain of about 8 x 10^3 (for Vgem~370 V, for 250 ADC, as obtained from calibration). The reason of this difference could be due to different geometrical configuration of the triple GEM detector. Investigations are underway to understand the various contributing factors. All the results, schematic and analysis will be presented and discussed in detail.

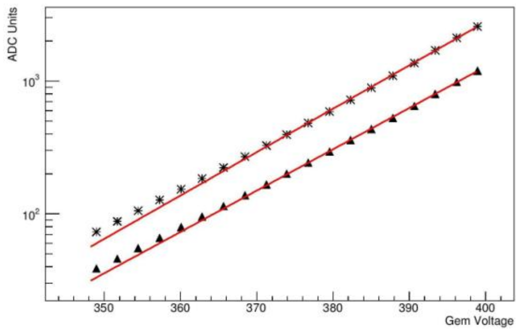

Fig. 3 Variation of the ADC units (photo peak and escape peak) with GEM voltage

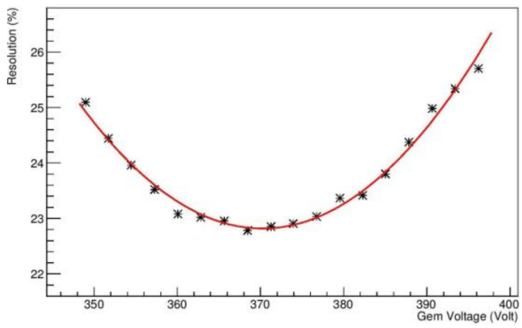

Fig. 4 Variation of Energy Resolution with GEM voltage

References

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