Detailed Characteristics of triple GEM detector for future experiments

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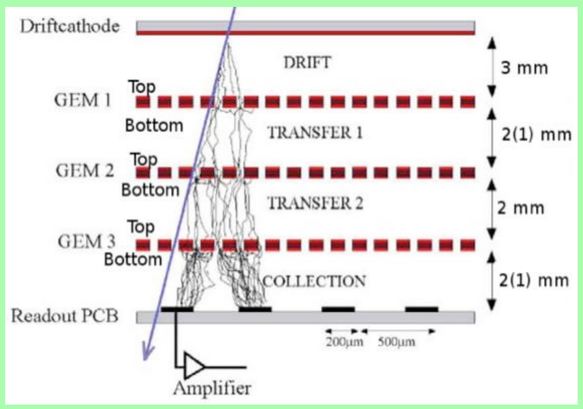
Introduction

Gas Electron Multiplier (GEM) detector [1] is a new generation micro-pattern gas detector (MPGD). It is used in a wide range of applications, from fast tracking in particle physics to detectors for astrophysics and medical imaging. The operational principle of the detector, consisting of multiple layers of GEM foils is shown pictorially in the figure.

The advantages like high rate handling capability, good energy resolution, ion suppression, low discharge probability, good position resolution (~100 μm) and good time resolution (~10 ns) make GEM detectors as a suitable candidate for long duration operations in many present and future high energy physics experiments, like in ALICE, CMS, CBM.

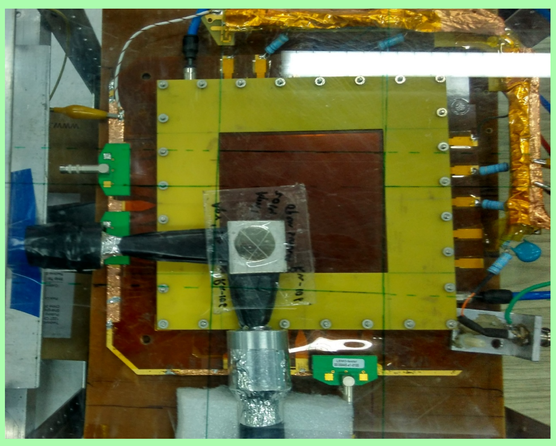


Operating principle of GEM detector

Main goal of the study

- Characteristics study of the detector: gain, energy resolution, efficiency and time resolution.
- Uniformity of gain and efficiency over the active area of the detector.

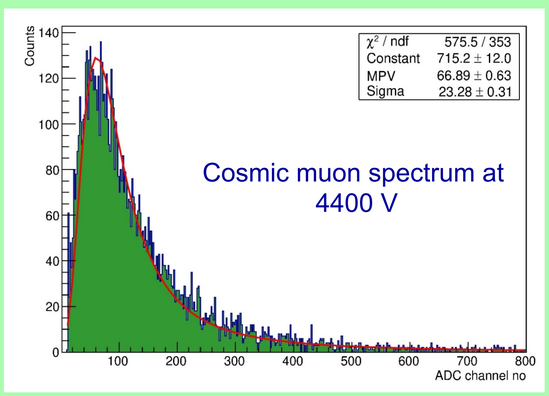
Characteristics study

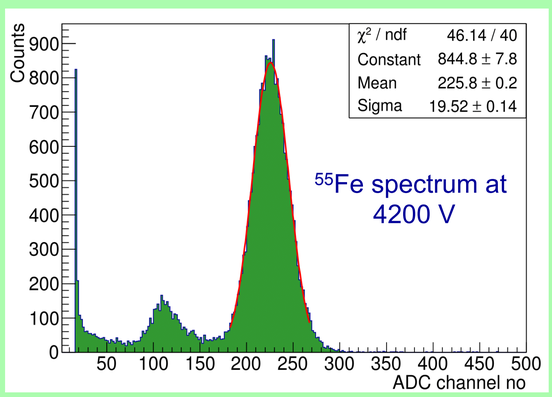


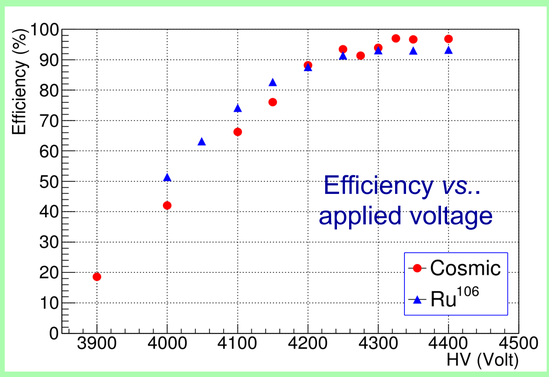
GEM detector test set-up

A 10X10 cm^2 triple GEM detector using Ar/CO_2 70:30 gas mixture, with 3-2-2-2 mm gap configuration, has been tested. The set-up picture of the detector is given in the left side

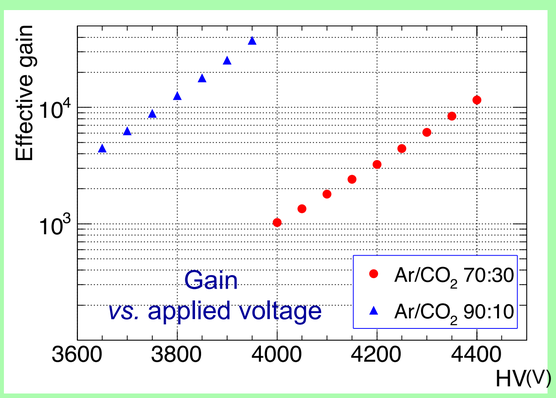
The charge spectrum for cosmic muons at 4400V and energy spectrum for ^{55}Fe at 4200V are shown below.

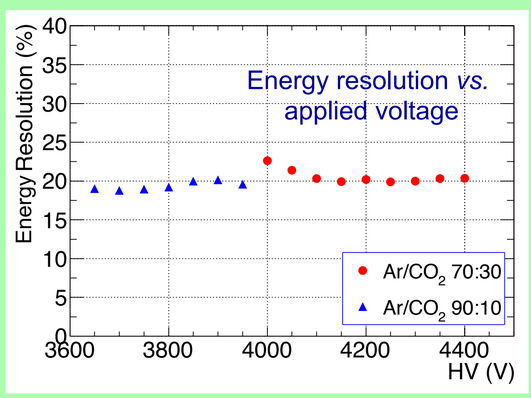






(a) *Efficiency* has been measured using (i) cosmic muons, (ii) ^{106}Ru-Rh β-source, as a function of applied voltage. The efficiencies are observed to be similar for the two cases at the plateau region.



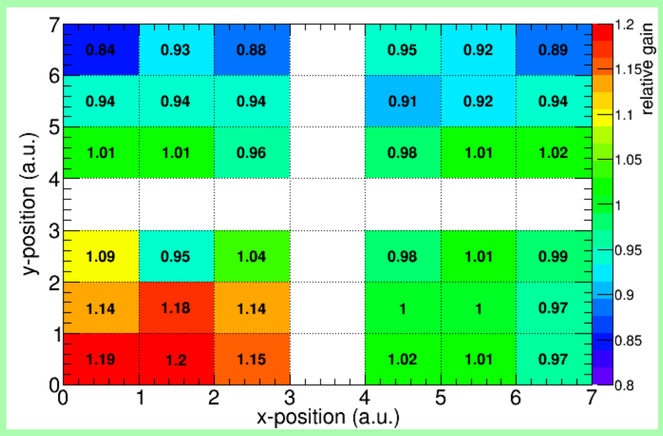


(b) *Gain and energy resolution* calculated using the main peak of ^{55}Fe 5.9 keV X-ray spectrum. The detector gain at 4400V is found ~10^4 and the energy resolution (in terms of FWHM) is ~20%.

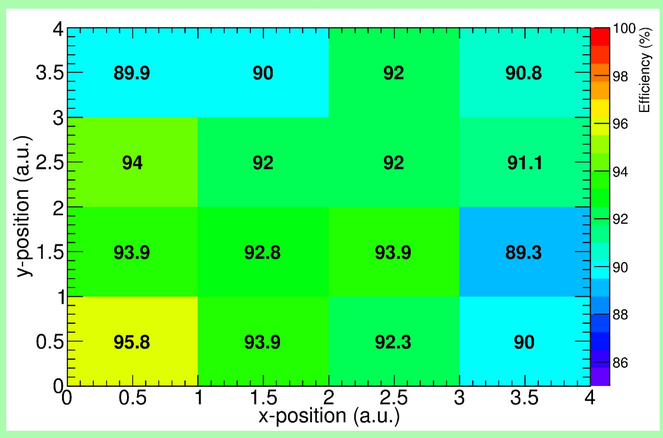
Uniformity study

For large area detectors used in the high energy physics experiments it is necessary to have uniform gain and efficiency over the entire area. The uniformity of the GEM detector depends on factors like hole diameter variations, variations in gas gap due to defective stretching and electron transparency. A procedure for uniformity measurements has been developed.

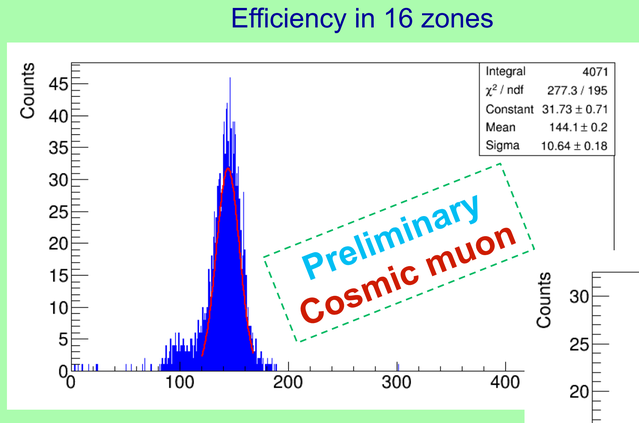
For gain uniformity study, the active area of the detector is divided into 36 zones of equal area (as shown in the picture). The gain variations are random over the area having the RMS variations only 8.8%.The value is comparable with others reported in the literature [3].

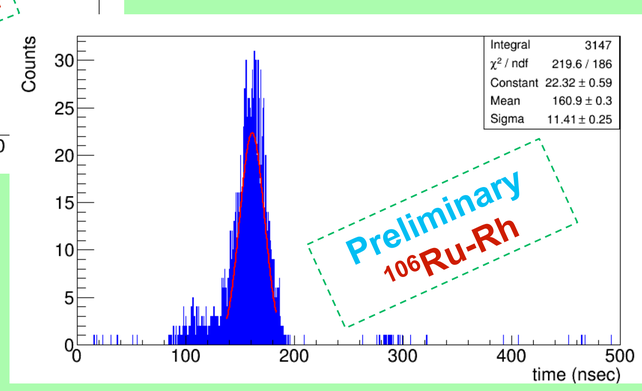


Relative gain in 36 zones



Efficiency in 16 zones





For the efficiency uniformity measurement the active area is divided into 16 zones of equal area. It is found that the efficiencies are uniform over the active area having RMS variation of 1.9% only. The variation is random, in contrast with the other report [4] which showed that the efficiency is low at the corners.

Time resolution

Time resolution of any detector is the determinations of how fast two events can be separated. We have measured time resolution for the triple GEM detector using cosmic muon and ^{106}Ru-Rh β-sources. In both cases results are similar. Time resolution of the detector is obtained ~10 ns at ~4500 V.

Summary

- A detailed characteristics study of a prototype 10×10 cm^2 triple GEM detector has been performed with Ar/CO_2 gas in 70:30 and 90:10 mixing ratio.
- Gain and energy resolution are 10^4 and ~20% respectively at the operating voltage of the detector.
- The gain and efficiency uniformity is measured over 16 zones, and the RMS variations are found to be 8.8% and 1.9% respectively.
- Time resolution of the detector is obtained ~10 ns ~4500 V.

References

[1] F. Sauli, Nucl. Instr. and Meth. A. 386 (1997) 531.

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[3] F. Simon et al., IEEE Trans. Nucl. Sci. 54 (2007) 2646-2652.

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