Triple and quadruple GEM detectors for high energy physics experiments

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Introduction

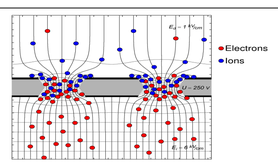
Gas Electron Multiplier (GEM) detector [1], one of the pioneer kind of Micro-Pattern Gas Detectors (MPGD), has been chosen for particle trigger and tracking in most of the recent high energy physics experiments (ALICE, CMS, CBM, STAR, sPHENIX). ALICE has decided to use quadruple GEM detector for its TPC upgrade in recent future to fulfill its purpose whereas other experiments are using triple GEM detector. The advantages of quadruple GEM detector are more stable operation against discharge and low ions back flow in comparison to triple GEM.

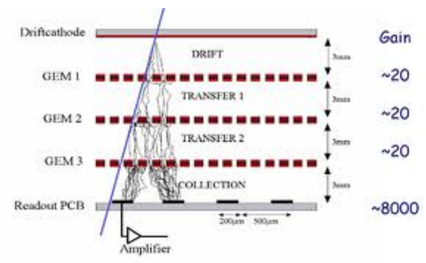
We have studied both triple GEM and quadruple GEM detectors. The advantages of one over another is reported here.

- Characteristics study of a quadruple GEM in terms of detector gain, energy and time resolution, efficiency measurement.
- Effect of drift field in electron transparency study.
- Comparison of the results with triple GEM.

Working principle of GEM

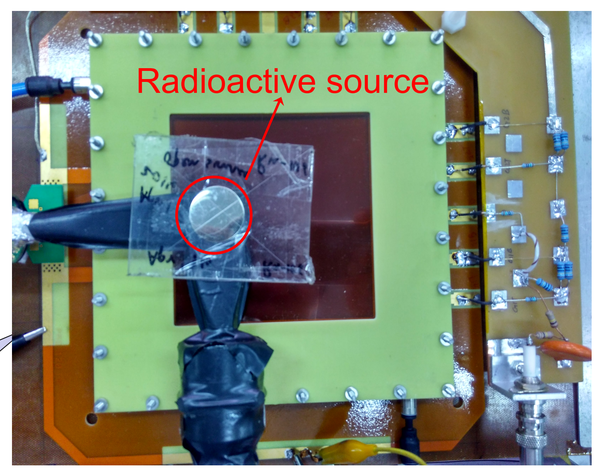
- A high electric field (~70 kV/cm) within the tiny hole (dia 50 um) produce cascade of electrons.
- Multi stage cascades are done before collecting the electrons in the readout.
- Electrons those are in the induction gap are collected in the readout (anode)





Experimental setup

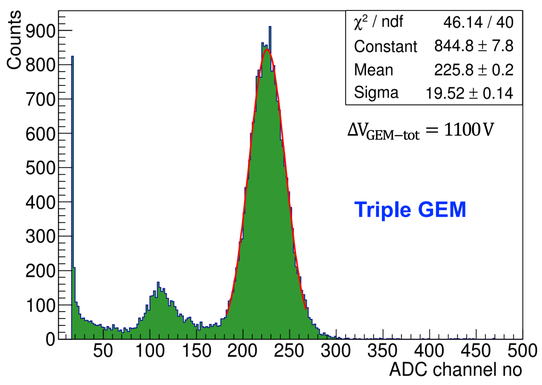
A quadruple GEM detector of size 10x10 cm^2 and a triple GEM detector of the same size have been assembled and operated using Ar and CO_2 gas mixtures in proportions of 70:30 and 90:10. Detailed performance studies of the detectors have been made by using ^{106}Ru-Rh β-source and X-ray spectrum of ^{55}Fe source.

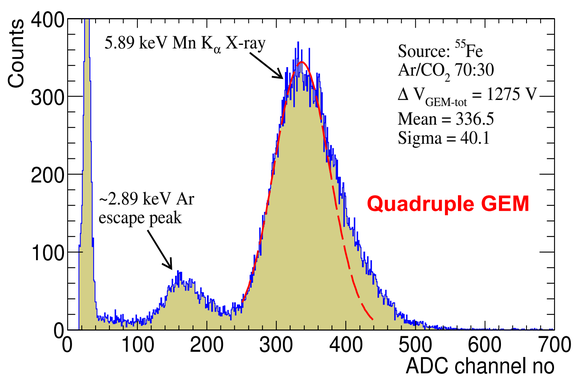


Laboratory set-up of the quadruple GEM detector at VECC, Kolkata

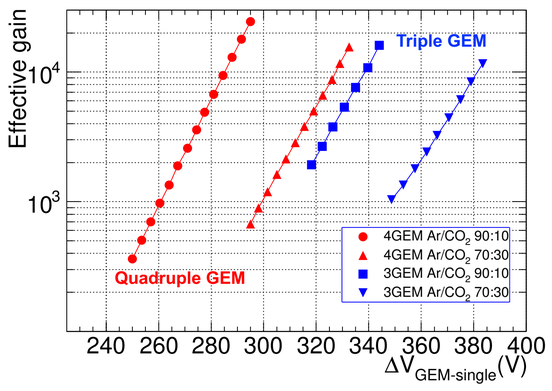
Test results:

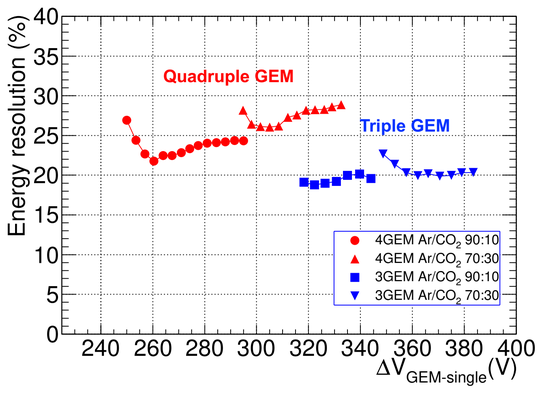
^{55}Fe spectrum in Ar/CO_2 70:30 gas





Comparison of gain and energy resolutions

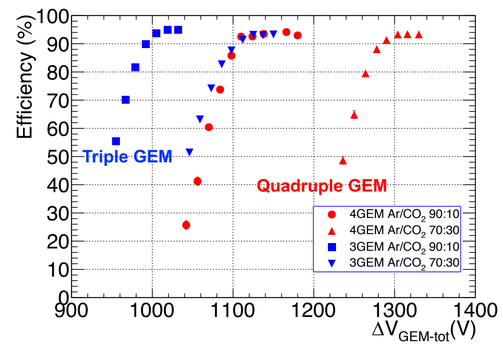




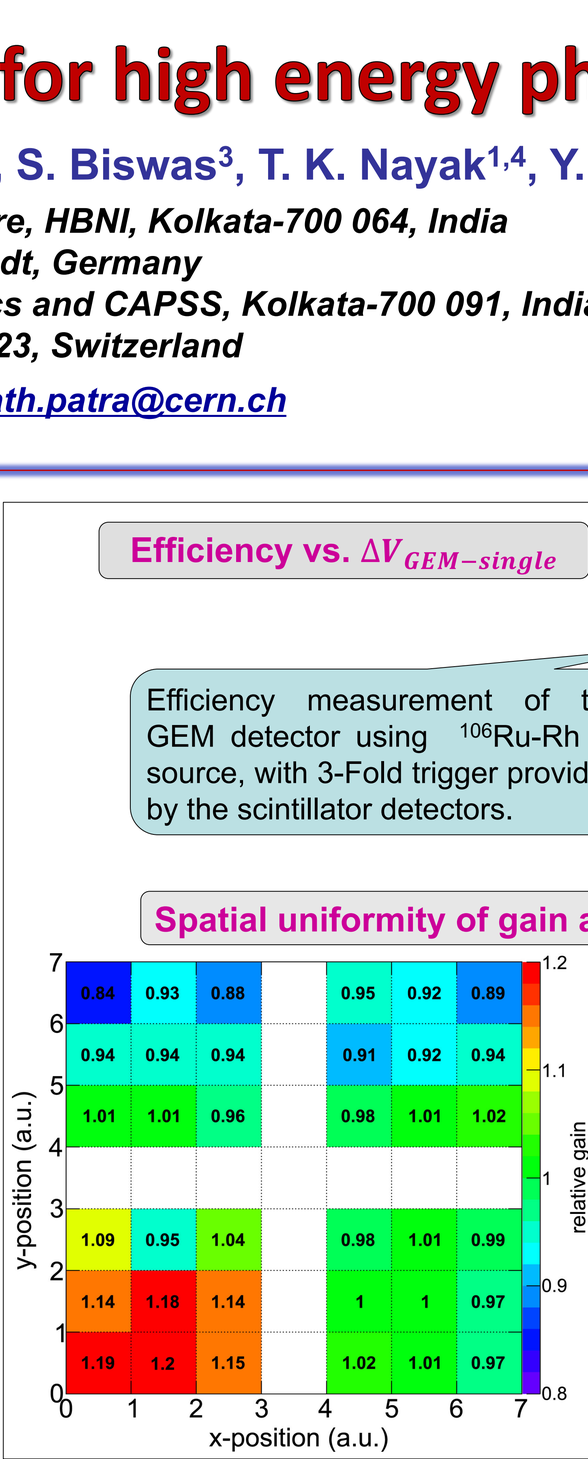
- ❖ The Operation Voltage ($\Delta V_{GEM-single}$) of Quadruple GEM detector is lower compared that of the triple GEM detector.
- ❖ Lower operating voltages are helpful for stable and long term use.
- ❖ Energy resolution become worse in quadruple GEM detector in comparison to triple GEM detector.

Efficiency vs. $\Delta V_{GEM-single}$

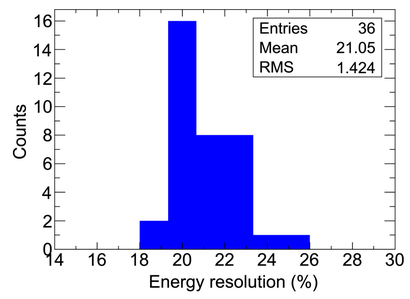
Efficiency measurement of the GEM detector using ^{106}Ru-Rh β-source, with 3-Fold trigger provided by the scintillator detectors.



Spatial uniformity of gain and energy resolutions

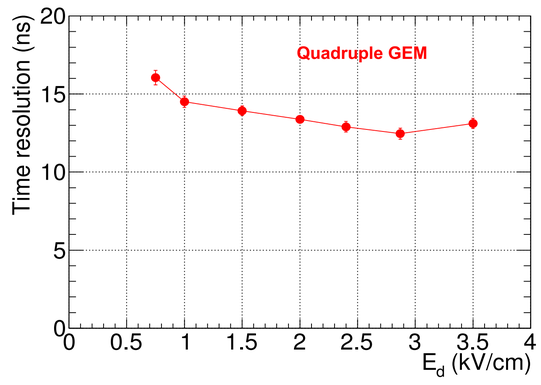


- Uniformity measurement are done using ^{55}Fe source in the triple GEM detector.
- We found that the uniformity of the gain and energy resolution of the detector are found 8.8% and 6.7%, respectively.



Time resolution

- Time resolution approaches to a plateau with increasing E_d.
- Measured time resolution for the triple GEM and quadruple GEM detectors are 11 ns [2] and ~ 13 ns, respectively.



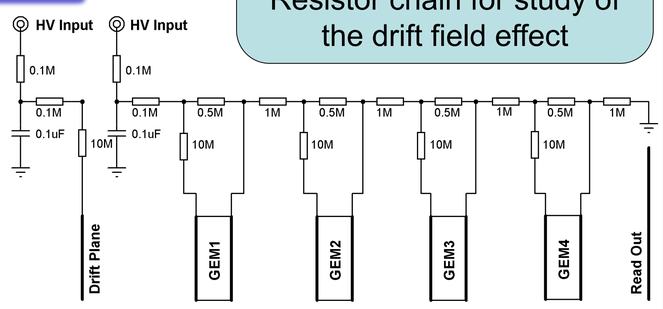
Effect of drift field on GEM

Electron transparency= fraction of electrons reach from the drift volume to1st GEM foil

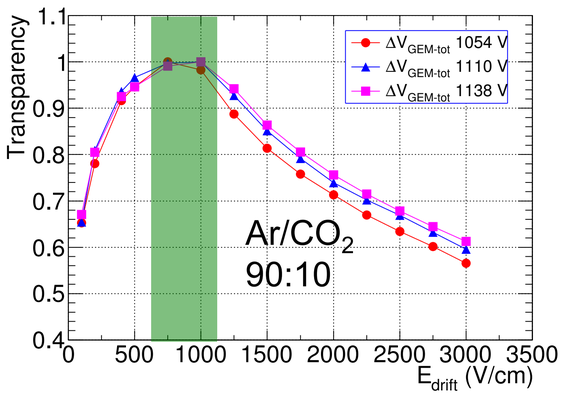
Electron transparency depends on:

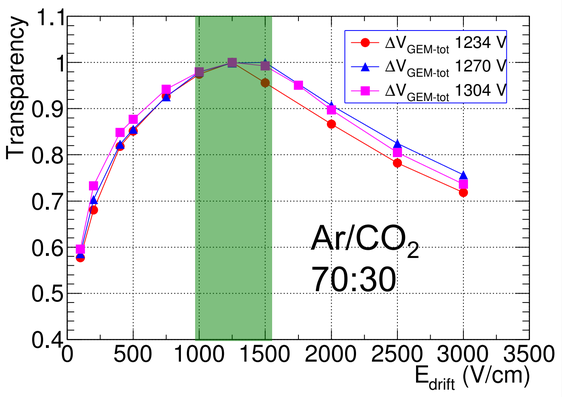
- Electric field of the drift and 1st GEM
- Gas property (e- drift and diffusion)

Resistor chain for study of the drift field effect



Drift field and electron transparency





- ➢ Drift field has a strong influence on electron transparency of the GEM.
- ➢ Drift field optimization is crucial for optimum GEM operation.
- ➢ Optimum operating region of E_d depends on the gas choice also.

Summary and Conclusion

- ✓ Characteristic study of a quadruple GEM detector using Ar/CO_2 90:10 and 70:30 gas mixtures has been performed and compared with results from triple GEM detector.
- ✓ The operational GEM voltage of quadrupole GEM detector can be lower in comparison to that of the triple GEM detector. Lower GEM voltage has the advantage as the detector can have long term operation without degradation.
- ✓ However, energy resolution of the quadruple GEM detector observed to be worse than triple GEM detector.
- ✓ Time resolution was found similar value for both the detectors.
- ✓ Drift field has an important role in electron transparency, so field optimization is required.

References:
[1] F. Sauli, Nucl. Instr. and Meth. A. 386 (1997) 531.
[2] R. N. Patra *et al.* Nucl Instr. And Meth. A. 862 (2017) 25.

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