Comparative study of triple GEM and quadruple GEM detectors and effect of drift field on the electron transparency

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Introduction

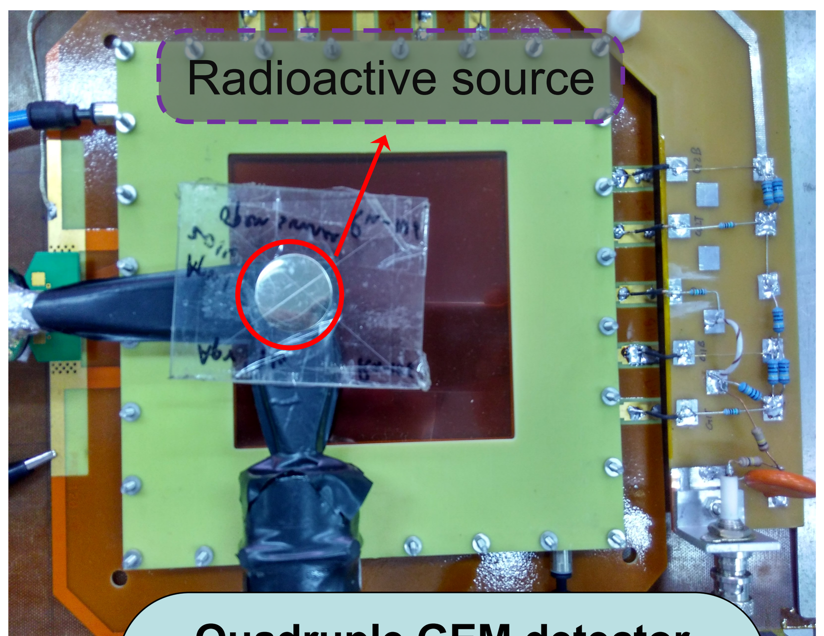
Gas Electron Multiplier (GEM) detector [1], one of the pioneer kind of Micro-Pattern Gas Detectors (MPGD), has been chosen for particle trigger and tracking in most of the recent high energy physics experiments (ALICE, CMS, CBM, STAR, sPHENIX). ALICE has decided to use quadruple GEM detector for its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

A quadruple GEM detector has been tested using standard resistor chain and ALICE-TPC like resistor chain which provides special voltage setting for low IBF. The test results are compared with our triple GEM results.

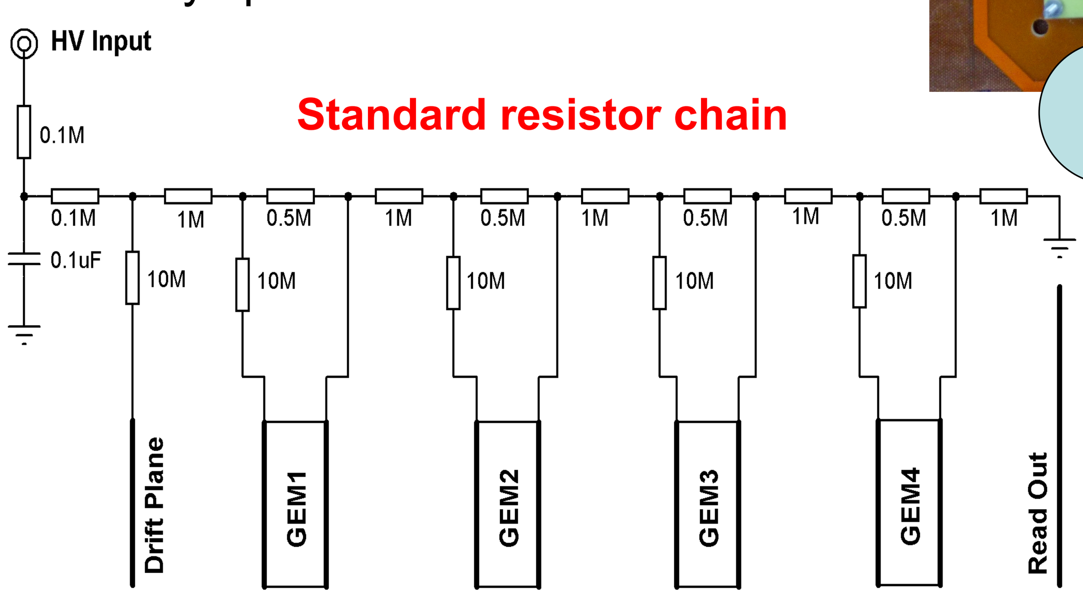
- Gain and energy resolution comparison between triple GEM and quadruple GEM detectors.
- Understanding of gain and resolution difference in standard and ALICE-TPC like resistor chain settings.
- Effect of drift field in time resolution and electron transparency study.

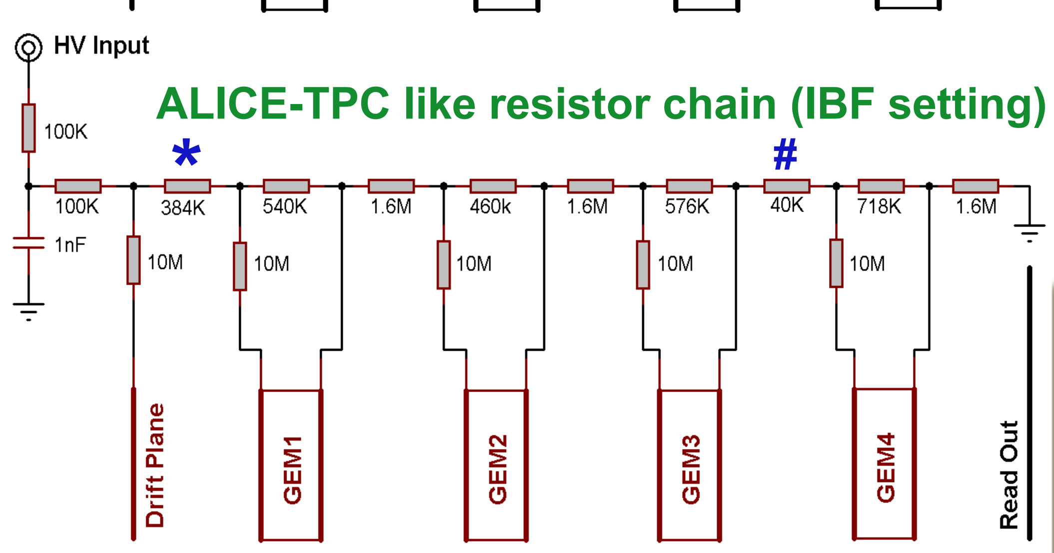
Experimental setup

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.

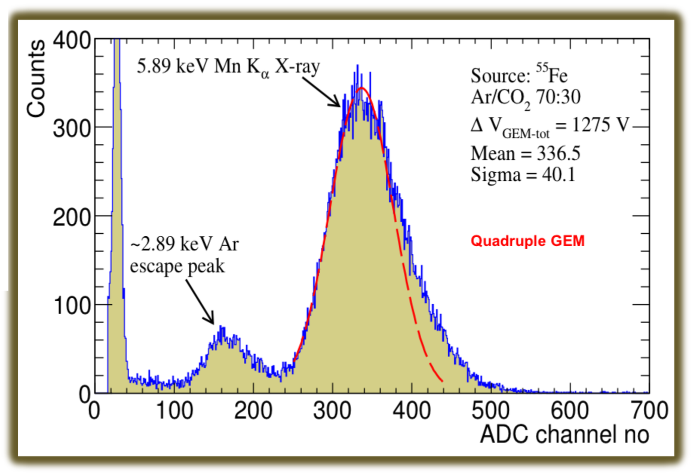


Quadruple GEM detector setup at VECC, Kolkata



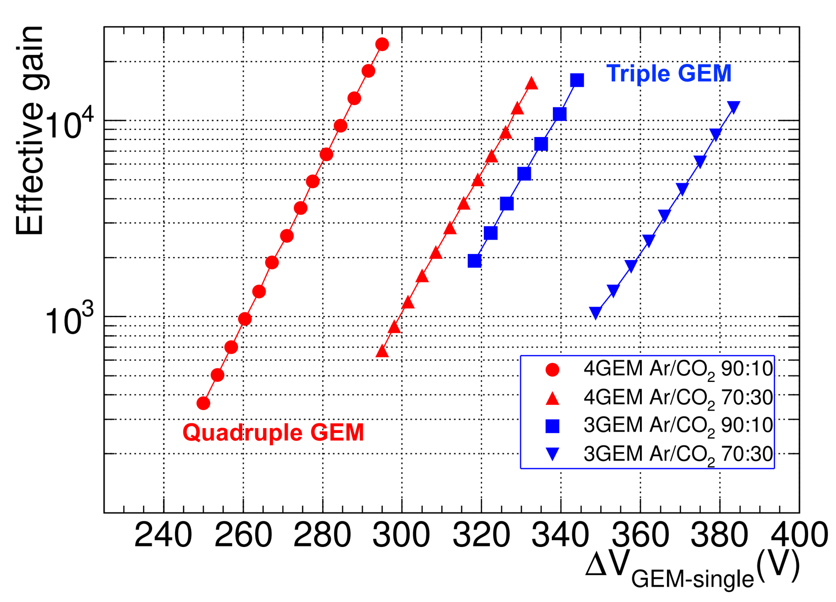


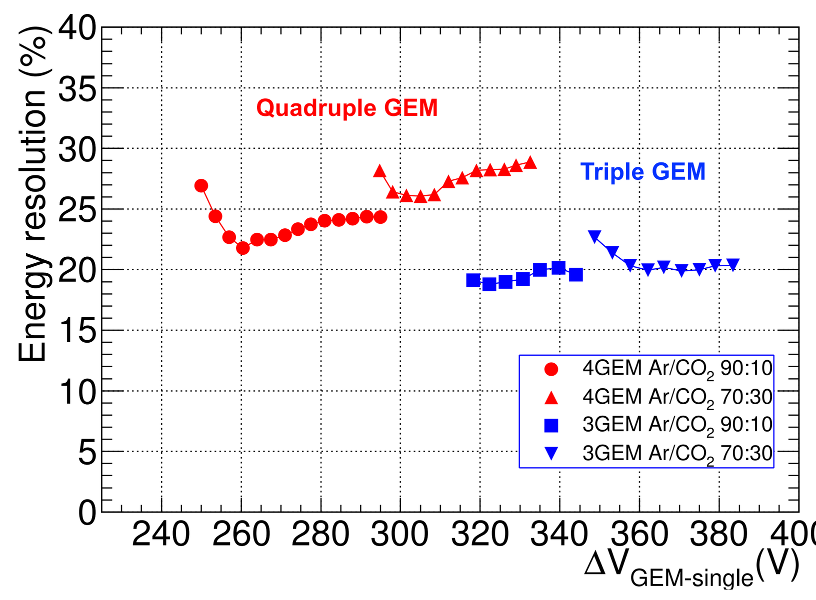
- All the tests of the quadruple GEM detector are done using standard resistor chain otherwise mentioned
- ALICE–TPC like resistor chain is modified with the resistors (*)1 MΩ and (#)0.34 MΩ in operation of Ar/CO_2 70:30 gas.

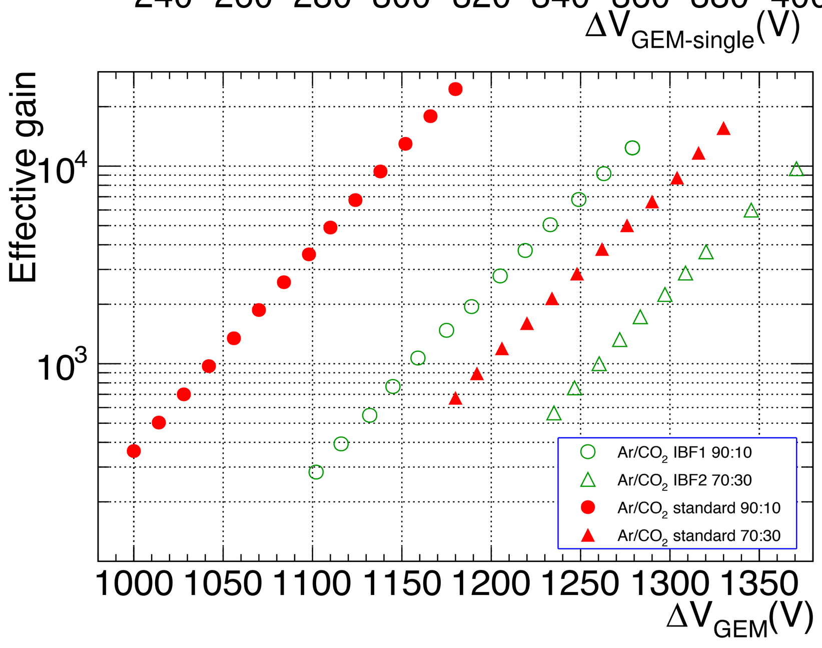


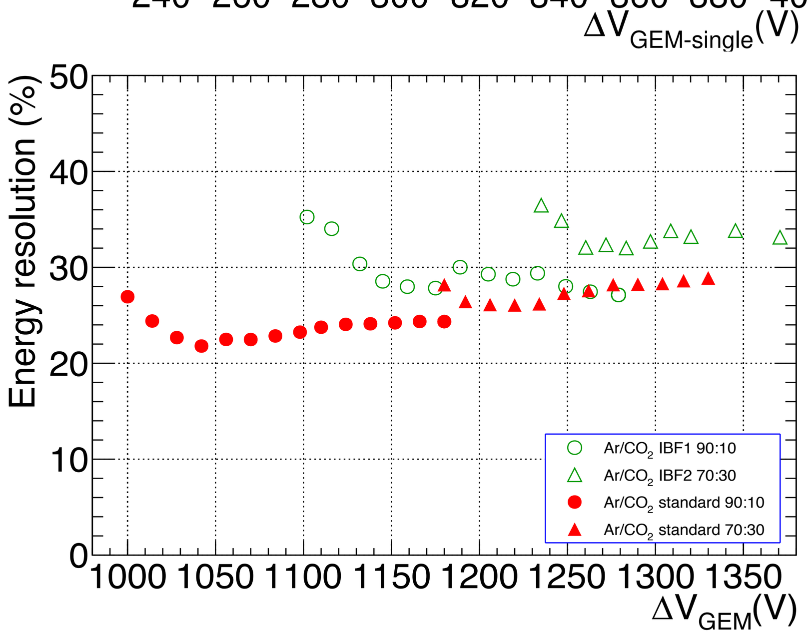
Test results:

Comparison of gain and energy resolutions





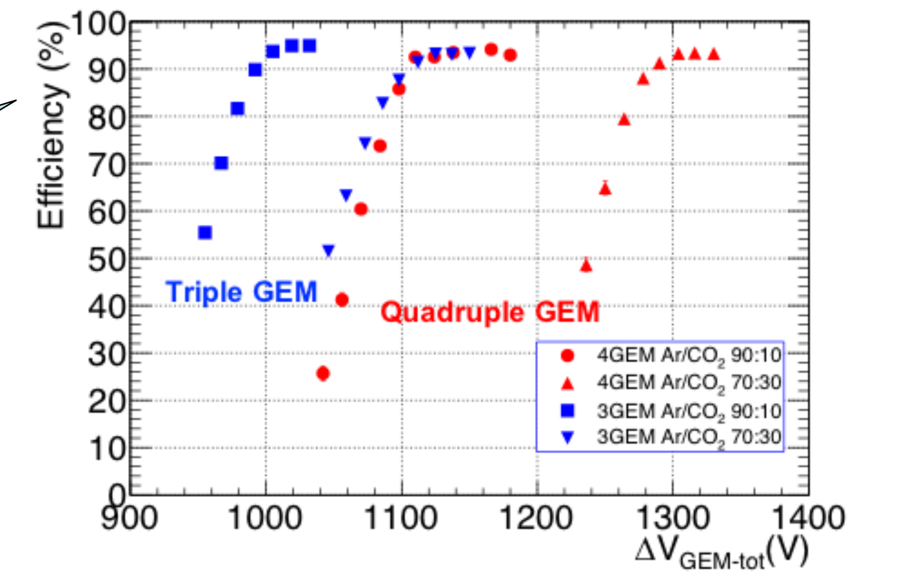




- The Operation Voltage ($\Delta V_{GEM-single}$) of Quadruple GEM detector is lower compared that of the triple GEM detector.
- Lower operating voltages are helpful for stable and long term use.
- Energy resolution become worse in quadruple GEM detector in comparison to triple GEM detector.
- Operating voltage of low IBF setting (ALICE-TPC like) is higher than the standard operational condition.
- The energy resolution of low IBF setting worse than standard voltage configuration of the quadruple GEM detector.

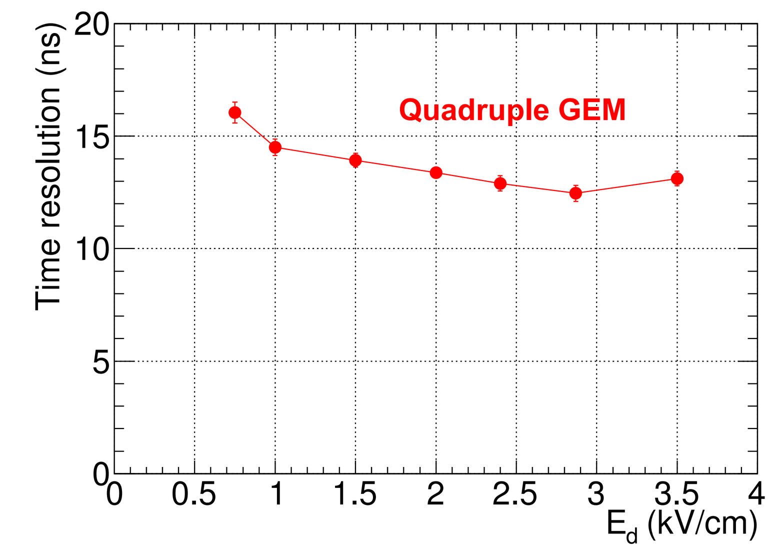
Efficiency vs. $\Delta V_{GEM-single}$

Efficiency measurement of the GEM detector using ^{106}Ru-Rh β-source, with 3-Fold trigger provided by the scintillator detectors.
Efficiency obtained ~95%



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.

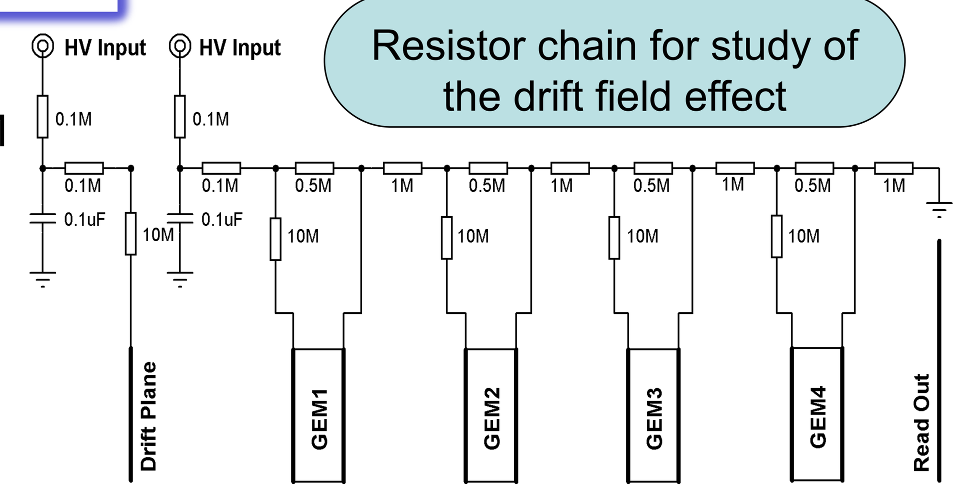


Effect of drift field on GEM

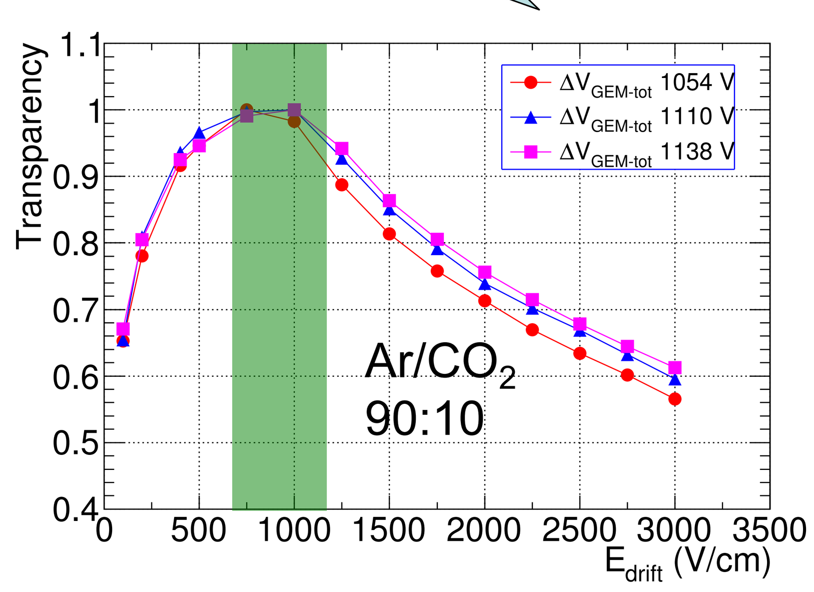
Electron transparency= fraction of electrons reach from the drift volume to1st GEM foil

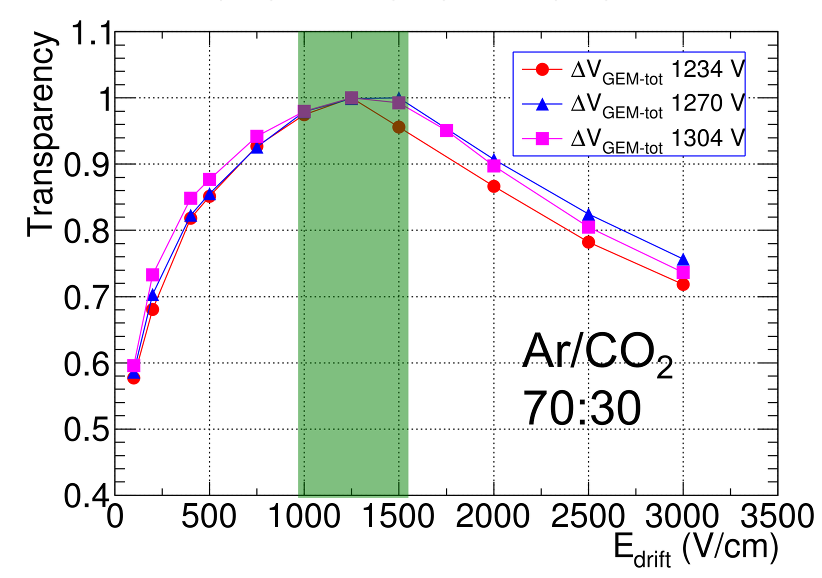
Electron transparency depends on:
- Electric field of the drift and 1st GEM
- Gas property (e$^-$ drift and diffusion)

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.
- ✓ IBF voltage setting has worse resolution compared to standard voltage setting in quadruple GEM detector. Triple GEM has better resolution than quadruple GEM.
- ✓ 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.