Stability study of gain and energy resolution for GEM detector

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PM2018 - 14th Pisa Meeting on Advanced Detectors, 27 May- 02 June 2018, La Biodola, Isola d'Elba, Italy

Introduction

A Large Ion Collider Experiment (ALICE) at the Large Hadron Collider (LHC) facility at CERN is upgrading the multi-wire proportional chamber based Time Projection Chamber (TPC) with quad GEM (Gas Electron Multiplier) units, to cope up with the high particle rate in Pb-Pb collisions after Long Shutdown 2 (LS2).

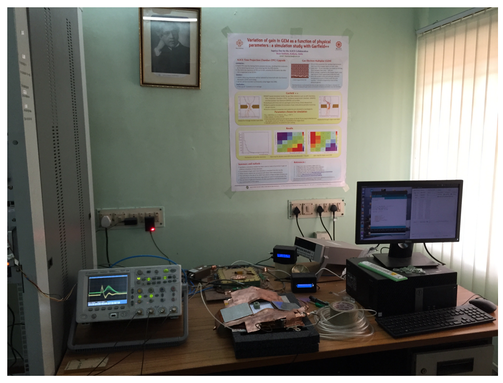
Triple GEM detectors will also be used to design the first two stations of the muon detection system MUCH (MUon CHamber) in the Compressed Baryonic Matter (CBM) experiment at the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany where high rate of particles flux is expected.

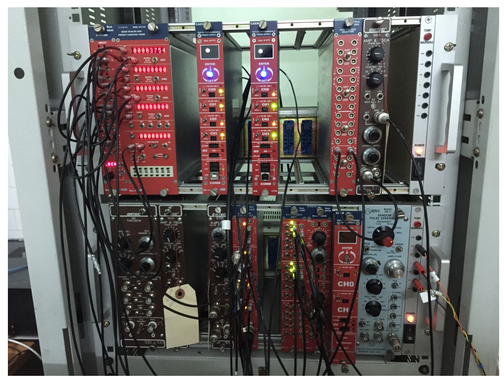
The stability test of GEM detector has been performed measuring the anode current continuously as reported earlier. Recently we have carried out the stability test of the triple GEM detector both for gain and energy resolution from the Fe^{55} X-ray spectrum with conventional Argon based gas mixtures. The motivation of this work is to study the performance of the GEM based detector operated at high X-ray rate. The details of the experimental set-up, measurement process and results are presented in this poster.

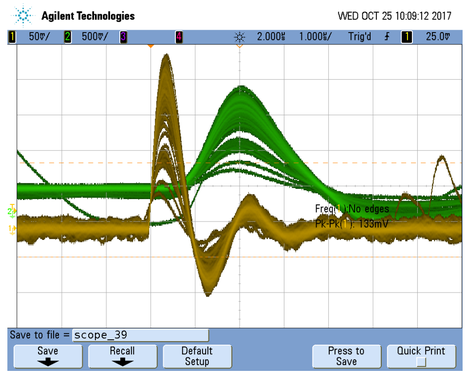
Experimental details

- Double mask GEM detector obtained from CERN is used
- Dimension: 10 cm × 10 cm
- Drift gap: 3 mm, Transfer gap1: 2 mm, Transfer gap2: 2 mm, Induction gap: 2 mm
- Gas mixture: Ar/CO_2 : 70/30, gas flow rate of 3 l/h
- One sum-up board is used for signal (9 pads each of area 9 mm × 9 mm)
- A low noise charge sensitive preamplifier (VV50-2) is used. Gain of the preamplifier is 2 mV/fC with a shaping time of 300 ns.
- A particular circular patch of area ~ 50 mm^2 of the detector is exposed with the X-ray from Fe^{55} source using a collimator of diameter 8 mm, corresponding to an on the detector.

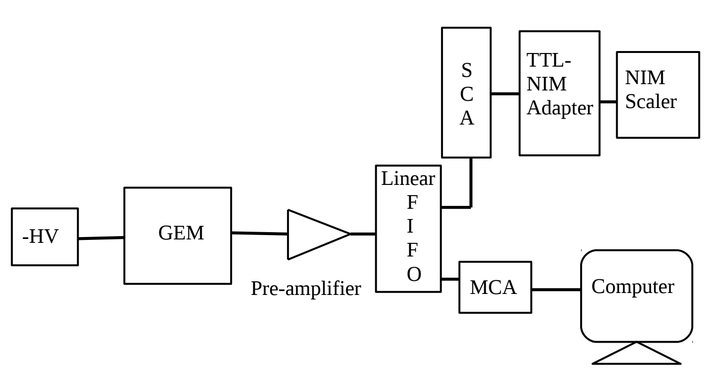
Experimental set-up and electronic modules





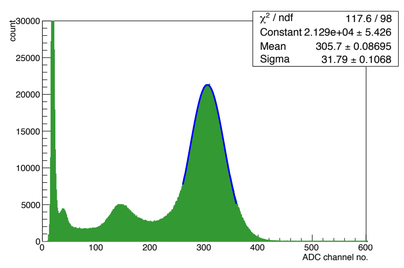


Fe^{55} Signals from GEM

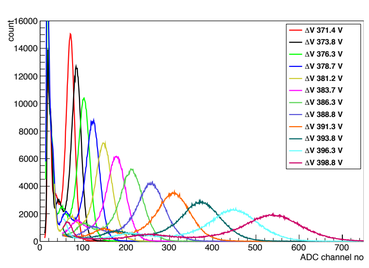


Schematic representation of the electronics setup

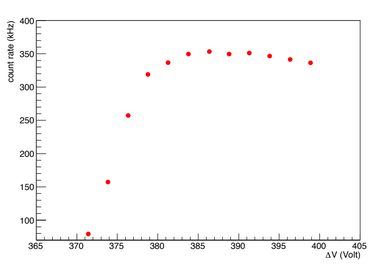
Preliminary test results



Energy Spectrum



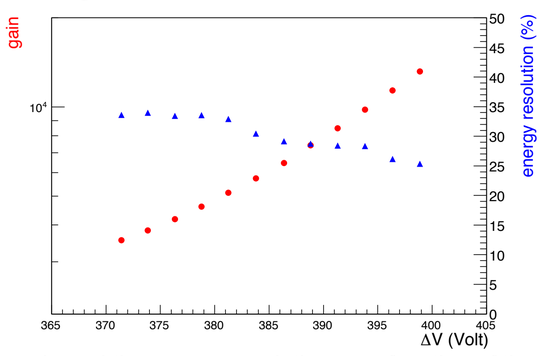
Energy spectra at different GEM voltage



Count rate as a function of the GEM voltage

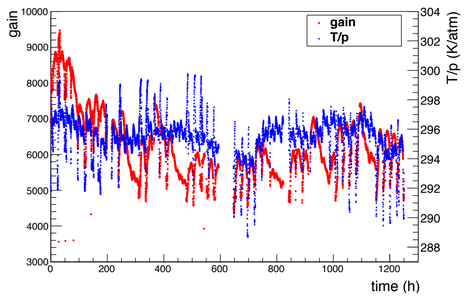
Details of stability test

- Same Fe^{55} source used for irradiation and monitoring spectrum
- Gas: Ar/CO_2 70/30
- Constant applied voltage to the divider: - 4100 V
- ΔV ~ 384 V
- Rate ~ 350 kHz in 50 mm^2 area
- Fe55 spectrum obtained in every 10 minutes
- Temperature, pressure are measured continuously

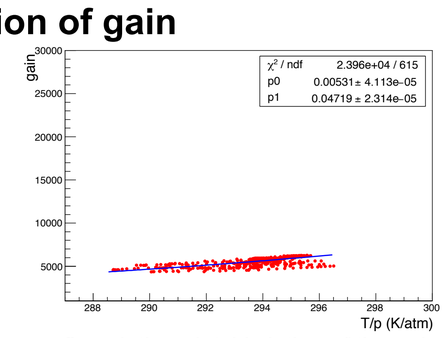


The gain and the energy resolution as a function of the GEM voltage. The error bars are smaller than the symbols.

Normalisation of gain



Variation of the measured gain and T/p as a function of the time.

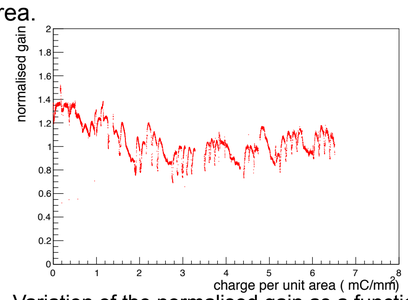


Correlation plot: Variation of the gain as a function of T/p.

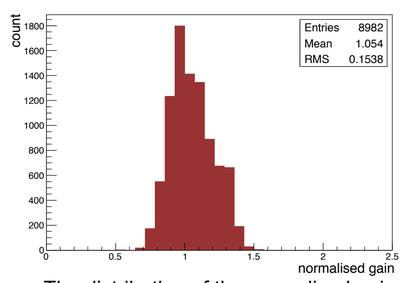
The gain is fitted with the formula: $G(T/p) = Ae^{(B\frac{T}{p})}$ A : 0.005 ± 4.11 × 10^{-5}, B: 0.047 ± 2.31 × 10^{-5} atm/K

The charge accumulated at a particular time is calculated by : $\frac{dq}{dA} = \frac{r \times n \times e \times G \times dt}{dA}$

where, r is the measured rate in Hz incident on a particular area of the detector, dt is the time in second, n is the number of primary electrons for a single X-ray photon, e is the electronic charge, G is the gain and dA is the irradiated area.

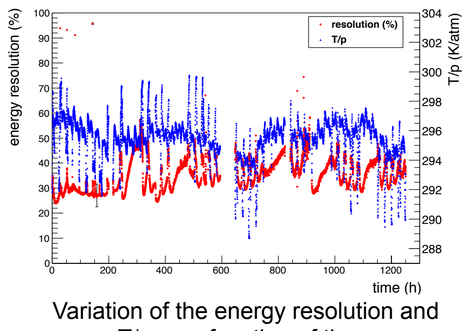


Variation of the normalised gain as a function of the charge per unit area i.e. dq/dA

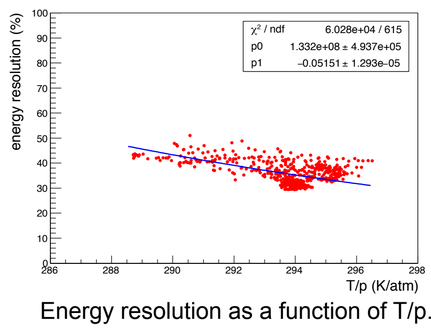


The distribution of the normalised gain.

Normalisation of energy resolution



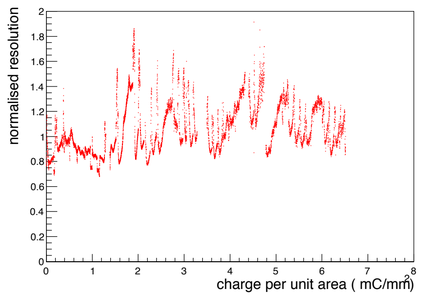
Variation of the energy resolution and T/p as a function of time.



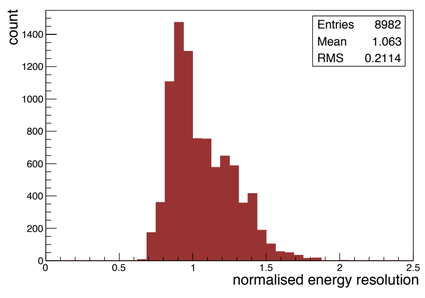
Energy resolution as a function of T/p.

The correlation curve is fitted with an exponential function: $energy\ resolution = A'e^{(B'\frac{T}{p})}$

A' : 1.33 × 10^8 ± 4.93 × 10^5, B': -0.05 ± 1.29 × 10^{-5} atm/K



Normalised energy resolution as a function of the charge per unit area



The distribution of the normalised energy resolution.

Summary

- A systematic study on stability of the gain and energy resolution of a triple GEM detector in long term operation under high rate of X-ray irradiation is performed with Ar/CO_2 gas mixture in 70/30 ratio, using the conventional NIM electronics.
- In this study the same Fe^{55} source is used to irradiate the chamber as well as to measure the gain and energy resolution at an interval of 10 minutes.
- Using a collimator the rate of the incident X-ray has been fixed to ~ 350 kHz on an area of ~ 50 mm^2 of the GEM detector equivalent to a rate of 0.7 MHz/cm^2.
- For the first time the detector has been continuously exposed to a high but realistic rate of X-ray (350 kHz in 50 mm^2 area) radiation for >1200 hours.
- In a continuous operation of > 1200 hours or an equivalent accumulated charge per unit area of ~ 6.5 mC/mm^2 the mean normalised gain and the mean normalised energy resolution have been found to be 1.054 with a rms of 0.15 and 1.063 with a rms of 0.21 respectively.

Acknowledgements

This work is partially supported by the research grant SR/MF/PS-01/2014-BI from Department of Science and Technology, Govt. of India and the research grant of CBM-MUCH project from BI-IFCC, Department of Science and Technology, Govt. of India. S. Biswas acknowledges the support of DST-SERB Ramanujan Fellowship (D.O. No. SR/S2/RJN-02/2012). R. P. Adak acknowledges the support UGC order no - 20-12/2009 (ii) EU-IV.

References

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