Investigation of the stability in the performance of triple GEM detectors for High Energy Physics experiments

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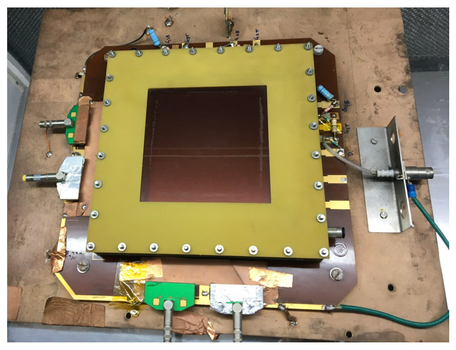
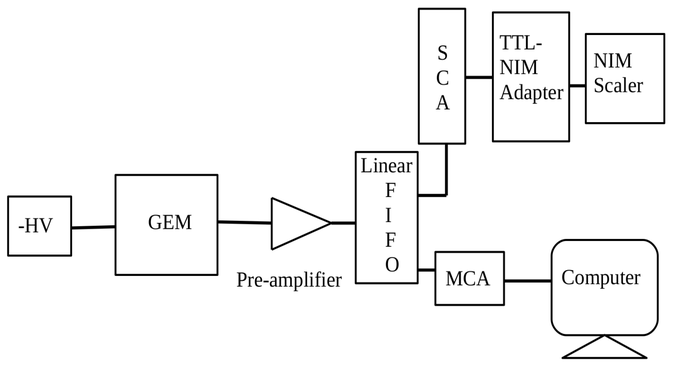
Introduction & Motivation

- **The Gas Electron Multiplier (GEM) is one of the most commonly used tracking detectors in High Energy Physics (HEP) experiments such as COMPASS, TOTEM, and ALICE at CERN and is also proposed for future high-rate experiments such as CBM at FAIR in Darmstadt, Germany, NA60+ at CERN etc.**
  - → Good position resolution (~ 100 μm) and High-rate handling capability (~ 1 MHz/mm^2)
- **Long-term stability is one of the important criteria for any detectors in HEP experiments**
  - → Long-term stability study is performed with a Single Mask (SM) triple GEM chamber
  - → Drift gap, transfer gaps and induction gap are kept at 3 mm, 2 mm and 2 mm respectively
  - → Operated with Ar/CO_2 gas mixture in 70/30 volume ratio
  - → Irradiated with ^{55}Fe X-ray source (~ 20 mCi) of characteristic energy 5.9 keV
  - → The same source is used to irradiate the chamber as well as to record the X-ray spectra
  - → ^{55}Fe energy spectrum fitted with a Gaussian distribution to obtain the gain of the chamber
- **The gain of any gaseous detector increases with increasing temperature and with decreasing pressure → correlated with T/p variation**
  - → Normalised gain = Measured gain/Aexp(BT/p), where A and B are the parameters obtained from the correlation plot
  - → Temperature and pressure are monitored using a data logger built in house
- **Energy resolution is anti-correlated with T/p variation**

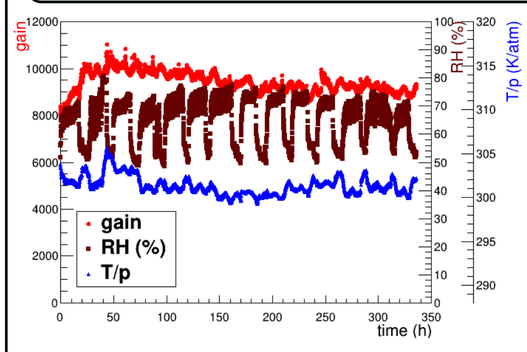


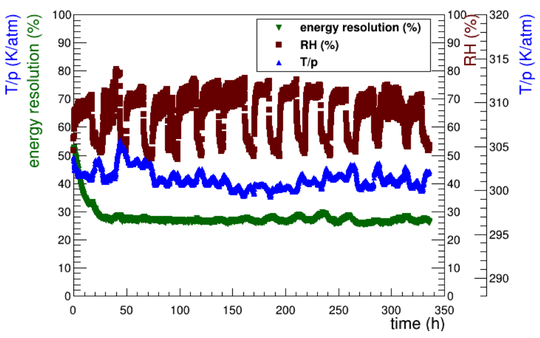
SM triple GEM chamber under testing at HEP detector lab of Bose Institute

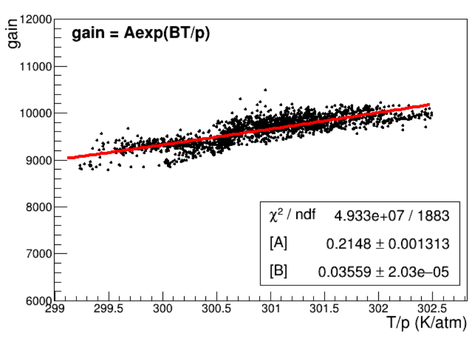


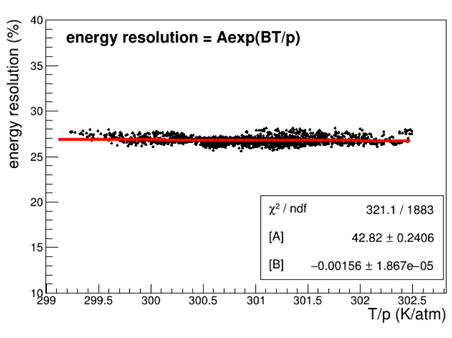
Schematic of the electronic circuit

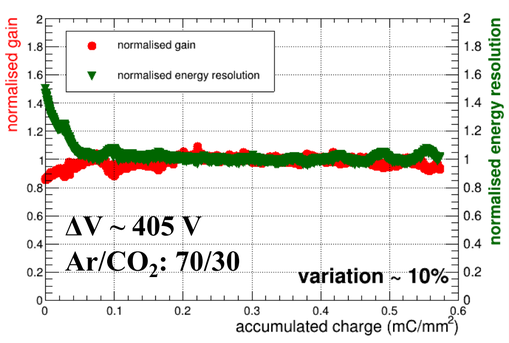
Variation of gain and energy resolution with time and their normalisation with T/p









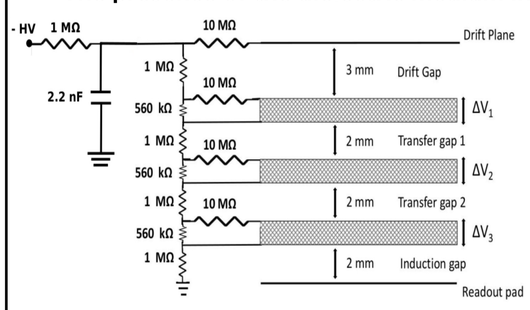


The ΔV across each of the SM GEM foils are kept at ~ 405 V and the chamber is irradiated continuously with 5.9 keV X-ray flux of ~ 2 kHz/mm^2

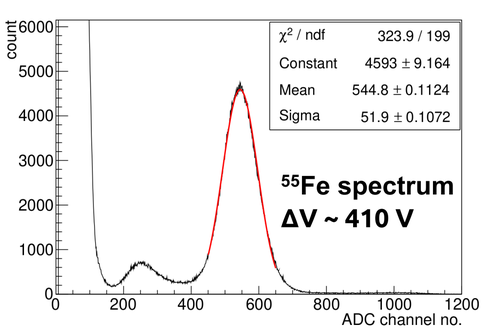
- **No significant degradation in performances is observed till an accumulation of charge per unit area ~ 0.6 mC/mm^2**
- **No significant degradation in performances is observed till an accumulation of charge per unit area > 12.0 mC/mm^2 in a separate long-term study with the same chamber measuring the anode current**
- **A double mask GEM prototype under a similar test did not show any significant degradation in performances till an accumulation of charge per unit area > 6.5 mC/mm^2**
- **In all the cases a fluctuation of ~10% in the normalized gain and energy resolution is observed**

Study of Charging up effect

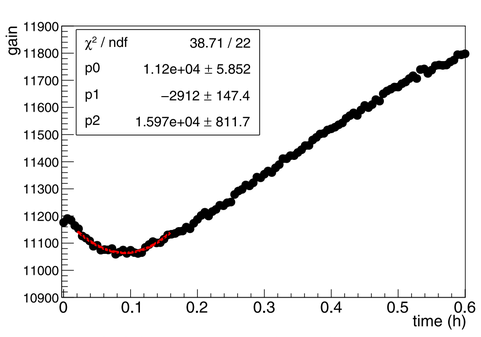
The presence of the dielectric medium inside the active volume of the GEM detector changes its behaviour when exposed to external radiation. This mechanism is commonly referred as the charging-up effect.



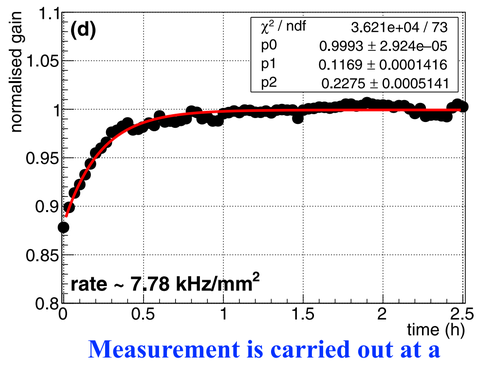
Schematic of the HV distribution through the resistive chain



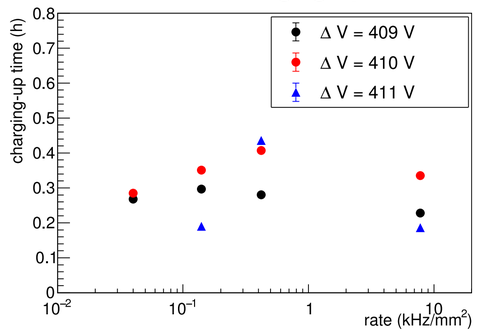
^{55}Fe spectrum at ΔV = 410 V



The initial decrease in gain due to the polarization effect



Measurement is carried out at a ΔV = 409 V



Charging-up time as a function of rate for different voltage settings

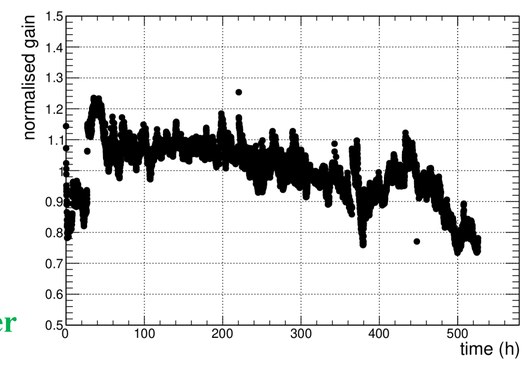
- **The time for initial polarisation of the dielectric decreases with increasing *ΔV* across the GEM foils**
- **At a given *Δ*V, with increasing particle flux, the time required to reach the minimum gain (because of for initial polarisation of the dielectric) value reduces**
- **For the SM triple GEM chamber, the charging-up time is found to be ~ 0.2–0.4 h at a gain of ~ 10000**
- **In comparison, for the double mask triple GEM chamber, the charging-up time is found to be ~ 1.3–2.3 h at a gain of ~ 5000.**

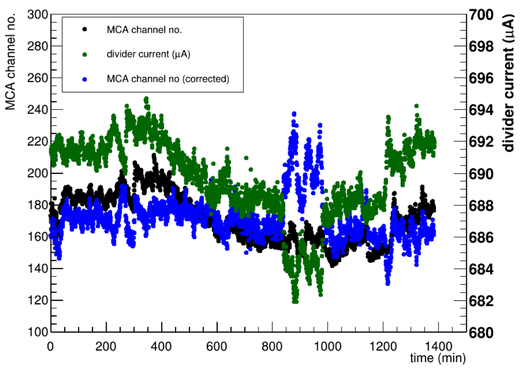
Investigation on the detector current variation

It is observed in the later part of the long-term test that the normalised gain decreases with time:
→ Variation in divider current with time

● Divider current is monitored continuously ● Variation of MCA channel no. from the 5.9 keV peak of ^{55}Fe X-ray is investigated as a function of time

→ Divider current is monitored continuously using the GECO software
→ Normalised gain is studied as a function of time
→ Normalised gain is found to be decreased with time
→ The MCA channel number variation is investigated with divider current
→ A correction is performed to eliminate the effect of divider current variation on the gain of the chamber





Probable reason behind the divider current variation could be due to the change in value of the resistors in the divider chain. The detail investigations are ongoing.

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