Stability test of the GEM detector

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Introduction

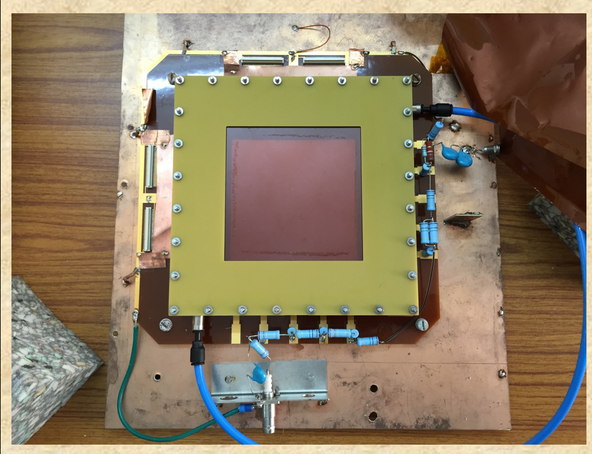
ALICE (A Large Ion Collider Experiment) will upgrade its MWPC (Multi Wire Proportional Chamber based Time Projection Chamber using GEM (Gas Electron Multiplier) chambers. CBM (Compressed Baryonic Matter) experiment at FAIR will also use GEM in its muon chamber [1–3]. In both the experiments the GEM detectors will be operated at high rate and for long period. So before installing the chambers in the experiments the long-term stability test is very essential. The long-term stability test is carried out for a triple GEM detector using a high rate Fe^{55} X-ray source. The method of long-term test and the results are presented.

Experimental details

A triple GEM detector prototype, consisting of 10 cm × 10 cm standard stretched single mask foils, has been assembled and initially tested at the RD51 laboratory at CERN. The drift gap, 2-transfer gaps and induction gap of the chamber are kept as 3,2,2,2 mm respectively. A voltage divider network is used to distribute the high voltages (HV) to different GEM foils and different gaps. The detector has XY printed board (256 X-tracks, 256 Y-tracks) in the base plate and that works as the readout plane. Each of 256 X-tracks and 256 Y-tracks are connected to two 128 pin connectors. In each 128 pin connector a sum-up board (procured from CERN) is used. There are four sum-up boards in total. The Lemo output from all the sum-up boards are again summed and is directly connected by a short length Lemo cable to a 6485 Keithley Pico-ammeter to measure the anode current. In this study Ar/CO_2 gas in 70/30 volume ratio is used in a flow rate of 3 l/hr.

The long-term stability of the triple GEM detector is studied using a 100 mCi Fe^{55} X-ray source and measuring the output anode current with and without source continuously [4]. At intervals of 10 minutes, the anode current with and without source are measured. Simultaneously the temperature (t in ^oC), pressure (p in mbar) and relative humidity (RH in %) are recorded from a data logger, built in-house [5], with a time stamp.

Complete GEM detector



Experimental set-up

Measurements and analysis

The output anode current due to the source:

$$i_{\text{source}} = i_{\text{with source}} - i_{\text{without source}}$$

The absolute gain of the detector is calculated from the formula:

$$\text{gain} = \frac{i_{\text{source}}}{r \times n \times e}$$

r is the rate of the X-ray, n is the number of primary electrons and e is the electronic charge.

The rate of the X-ray in the above equation is modified according to the following formula:

$$r = r_0 \exp\left(\frac{-0.693\, t'}{t_{1/2}}\right)$$

r_0 being 350 kHz, t′ is the period of operation and $t_{1/2}$ is the half life of the Fe^{55} source

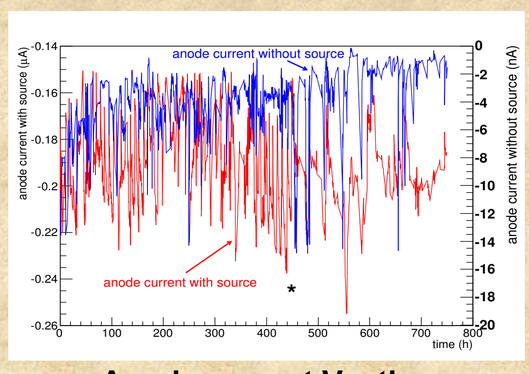
The dependence of the gain (G) of a GEM detector on absolute temperature and pressure is given by:

$$G(T/p) = Ae^{(B\frac{T}{p})}$$

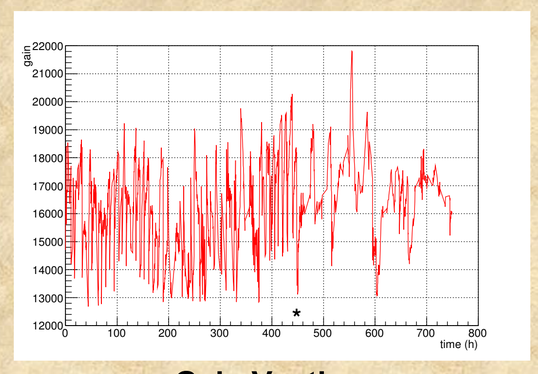
The gain is normalized by using the relation:

$$\text{gain}_{\text{normalized}} = \frac{\text{gain}_{\text{measured}}}{Ae^{(B\frac{T}{p})}}$$

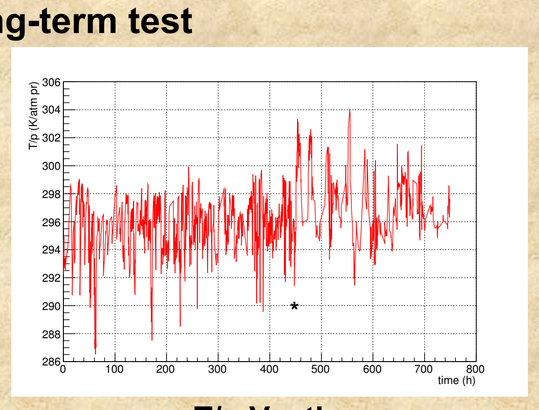
Results of long-term test



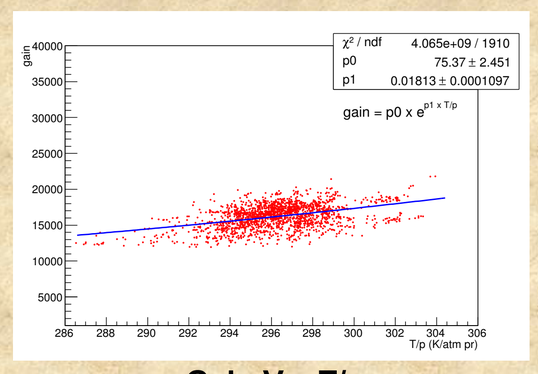
Anode current Vs. time



Gain Vs. time

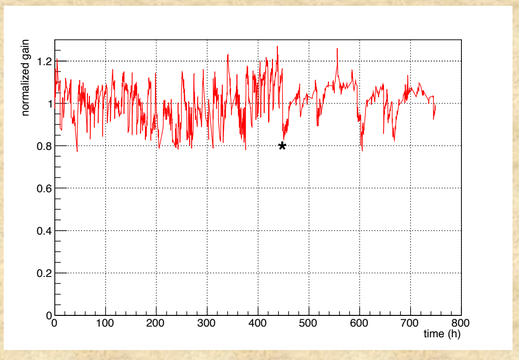


T/p Vs. time

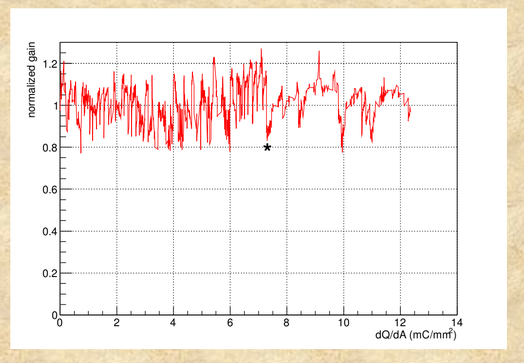


Gain Vs. T/p

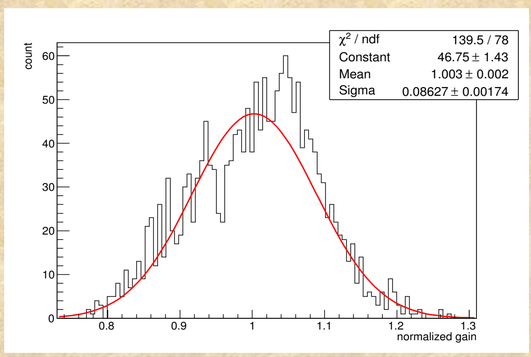
Normalized gain



Normalized gain Vs. time



Normalized gain Vs. $\frac{dQ}{dA}$



Distribution of normalized gain

Summary

- The long-term stability test of GEM detector is performed using Fe^{55} source
- The gain is measured and normalized for the T/p effect
- In the analysis the rate of the X-ray from the source is modified according to the radioactive decay law
- Only a fluctuation about the mean value of 1.003 in the normalized gain is observed after T/p correction
- **No ageing is observed till an accumulation of charge per unit area > 12.0 mC/mm² in about 750 hours of operation**

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