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 in this article.

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 Picoammeter 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.

Results

The output anode current due to the source is given by,

$$i_{source} = i_{with\ source} - i_{without\ source} \quad (1)$$

where i_{source} is the anode current due to source, $i_{with\ source}$ is the measured anode current when the detector is irradiated by the Fe^{55} source and $i_{without\ source}$ is the anode current without any source.

The absolute gain of the detector is calculated from the formula

$$gain = \frac{i_{source}}{r \times n \times e} \quad (2)$$

where, r is the rate of the X-ray (350 kHz), n is the number of primary electrons (212) and

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e is the electronic charge. It is well known that the gain of any gaseous detector depends significantly on T/p, where T (= t+273) is the absolute temperature in Kelvin and p (p in mbar/1013) is in atmospheric pressure. The dependence of the gain (G) of a GEM detector on absolute temperature and pressure is given by [6]

$$G(T/p) = Ae^{(B\frac{T}{p})} \tag{3}$$

where A and B are the parameters to be determined from the correlation plot. The correlation plot, i.e. the gain is plotted as a function of T/p and fitted with a function

$$gain(T/p) = Ae^{(B\frac{T}{p})} \tag{4}$$

and is shown in FIG. 1.

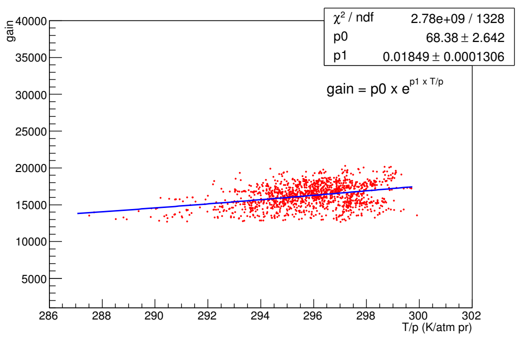

FIG. 1: Correlation plot: Variation of the gain as a function of T/p.

The values of the fit parameters A and B obtained, are 68.38 ± 2.642 and 0.0185 ± 0.0001 atm pr/K. Using the fit parameters, the gain is normalized by using the relation:

$$gain_{normalized} = \frac{gain_{measured}}{Ae^{(B\frac{T}{p})}} \tag{5}$$

To check the stability of the detector with continuous radiation, the normalized gain is plotted against the total charge accumulated per unit irradiated area of the detector (that is directly proportional to time). The normalized gain as a function of dQ/dA is shown in FIG. 2. Although there is a fluctuation about 1 in the normalized gain value in Figure 2, but there is no steady decrease in the normalized gain. The distribution of the normalized gain is fitted with a Gaussian function. The mean of the Gaussian distribution has been found to be around 1.001 with a sigma of 0.089. In this long-term test total accumulation of charge per unit area is $\sim$ 7.25 mC/mm^2.

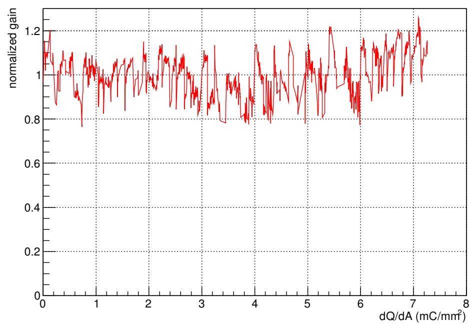

FIG. 2: Variation of normalized gain as a function of charge per unit area i.e. dQ/dA.

Conclusions

Triple GEM detector prototype is built and tested with a gas mixture of Ar/CO_2 of 70/30 volume ratio. The long-term stability test of this detector is performed using Fe^{55} X-ray source. The gain is measured and normalized for the T/p effect. Only a fluctuation about 1 in the normalized gain is observed after T/p correction. No ageing effect is observed even after operation of the GEM detector for about 450 hours or after an accumulation of charge per unit area of greater than 7 mC/mm^2.

References

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