Development of triple GEM detector for a heavy ion physics experiment

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Introduction

Building and testing of micro-pattern gas detector such as Gas Electron Multiplier (GEM) for several upcoming High-Energy Physics (HEP) experiment projects, is an advance area of research in the field of detector development [1, 2]. We have carried out the long-term stability test and the uniformity of the relative gain over a GEM detector. The method of long-term test and uniformity of the relative gain 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, obtained from CERN is assembled. 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 built by resistors and a single high voltage (HV) channel is used to power the GEM detector. 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 (provided by CERN) is used. The Lemo output of the sum-up board is directly connected by a short length Lemo cable to a 6485 Keithley Pico-ammeter to measure the anode current.

The long-term stability of the triple GEM detector is studied using Sr^{90} radioactive source and measuring the output anode current with and without source continuously [3]. 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, with a time stamp [4]. In this study Ar/CO_2 gas in 70/30 volume ratio is used.

The 10 cm×10 cm detector is assumed to be divide into four zones each of area 25 cm^2 and total anode current is measured to calculate the relative gain. Negative HV is varied from 3300 V to 3700 V to the GEM detector through a voltage divider. The anode current is also measured with and without Sr^{90} source in Argon/CO_2 in 80/20 volume ratio. This is done for each zone and the t, p and RH are recorded [4].

Results

The output anode current for the source (i_{source}) is measured. The anode current (due to source) is negative. The |anode current| is plotted as a function of T/p and fitted with a function |anode current|(T/p) = $Ae^{B(T/p)}$, where T (= t+273) is the absolute temperature in Kelvin and p is in atmospheric pressure.

The value of the parameters A and B obtained are 0.002 nA and 0.015 atm pr/K. Us-

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ing the fit parameters, the i_{source} was normalised by using the following relation:

$$i_{normalized} = \frac{i_{source}}{Ae^{B(T/p)}} \quad (1)$$

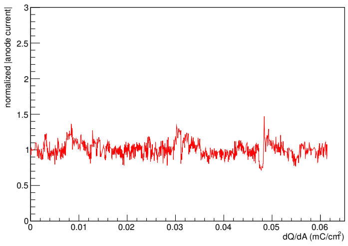

FIG. 1: Normalised |anode current| vs $\frac{dQ}{dA}$.

To check the stability of the detector with continuous radiation, the normalised |anode current| was plotted against the total charge accumulated per unit irradiated area of the detector. The normalised |anode current| vs $\frac{dQ}{dA}$ is shown in FIG 1. The distribution of the normalised |anode current| when fitted with a Gaussian function gives a mean ~ 1 and sigma of 0.086.

The absolute gain and the relative gain of the detector are defined as:

$$Absolute\ gain = \frac{i_a}{rate \times N_p \times e} \quad (2)$$

$$Relative\ gain = \frac{i_a}{rate \times e} \quad (3)$$

where i_a is the output anode current, *rate* is the maximum count rate at saturation region in the count rate vs. voltage curve, N_p is the primary no. of electrons per particle and e is the electronic charge. Since N_p is not known for Sr^{90}, relative gain is measured in place of absolute gain. For each zone the voltage is varied and the relative gain is measured. It is observed that for each zone the relative gain increases exponentially. The average temperature and pressure during the measurement is recorded to be 26 ^oC and 998 mbar. The value of the parameters A and B for Argon/CO_2 in 80/20 are 0.005 nA and 0.013 atm pr/K respectively. The T/p corrected relative gain at 26 ^oC and 998 mbar is calculated by the formula

$$\frac{T}{p}\ corrected\ relative\ gain = \frac{\frac{i_{a\ (measured)}}{Ae^{B(\frac{t_i+273}{p_i/1013})}} \times Ae^{B(\frac{26+273}{998/1013})}}{rate \times e} \quad (4)$$

where t_i and p_i are the temperature in ^oC and atmospheric pressure in mbar respectively measured during measurement for each voltage settings. The T/p corrected relative gain as a function of voltage is shown in Fig. 2.

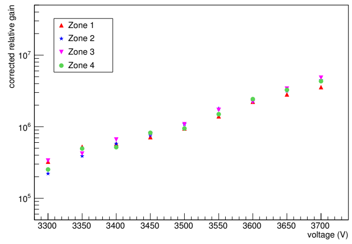

FIG. 2: T/p corrected relative gain Vs. voltage.

Conclusions and outlooks

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 0.06 mC/cm^2. T/p corrected relative gain vs the voltage plot for all 4 zones shows a variation of 41% and 29% for 3300V and 3700V respectively.

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