Studies of characteristics of triple GEM detector for the ALICE-TPC upgrade

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Introduction

Gas Electron Multiplier (GEM) is a novel gas detector in the field of radiation detection. GEM detectors have tremendous advantages over other types gas detectors like high rate handling capability with high efficiency and very low ion back flow (IBF). These detectors are most suitable for the use in the future experiments in high-energy proton-proton and heavy-ion collisions at the Large Hadron Collider (LHC) at CERN and Facility for Antiproton and Ion Research (FAIR) at GSI.

A Large Ion Collider Experiment (ALICE) at the LHC is a dedicated experiment for the study of Quark Gluon Plasma (QGP). In few years, the data taking rate for Pb-Pb collisions will increase by 100 times to 50 KHz. The ALICE Time Projection Chamber (TPC) [1] is the main tracking detector in ALICE. It is planned that by the year 2018, GEM detectors will replace the present readout planes of TPC. The goal of the present study is to characterize the GEM detector to achieve the performance goal of the TPC.

Details of Specification

The GEM foil [2] is a 50 μm thin kapton foil clad up with 5 μm thick copper on both sides having a bi-conical holes with inner diameter of 50 μm and outer diameter of 70 μm and 140 μm pitch. With applied voltage, 300-400 V across the GEM foil, the field produced within the hole is ~75 kV/cm. In this high electric field the electron multiplication takes place for the primary charges produced by the incident radiations. The 10x10 cm^2 prototype triple GEM detector has been built by placing three GEM foils one above another and one drift plate on the top most. The drift gap, two transfer gaps and the induction gap are kept as 3-2-2-2 mm respectively. This structure is kept within a gas chamber with Ar/CO_2 (70/30), used in flow mode [3]. For the signal extraction a two dimensional striped read-out board is used.

Tests and Results

The motivation of testing the GEM detector is to study the characteristic and to see the variations of gain, efficiency and cosmic ray responses with negative high voltage (HV). First measurement of the detector leakage current with applied voltage (HV) was made. Detailed studies are made using radioactive sources and cosmic rays.

The energy spectrum obtained with Fe^{55} X-ray source is shown Fig. 1, which shows the 5.9 keV main peak and 2.9 keV Argon escape peak at -4200 V. The detector is also tested with Sr^{90}, β^- source at - 4350 V.

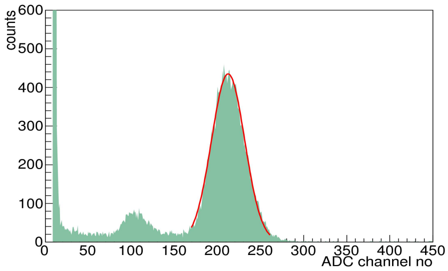

Fig.-1. The energy spectrum of Fe^{55} X-ray source.

Gain measurements

The effective gain, G_{eff}, is calculated for the 5.9 keV peak of Fe^{55} source by using the relation,

$$G_{eff}=Q/(N_p.q_{e-})$$

where, Q is charge collected at the read out, N_p is number of primary ionization, and q_{e-} is electron charge. Here, for this specific gas mixture the value Np=200 is used. Fig. 2 shows the variation of the effective gain with sum of the voltages across the three GEM foils, which is called global GEM voltage.

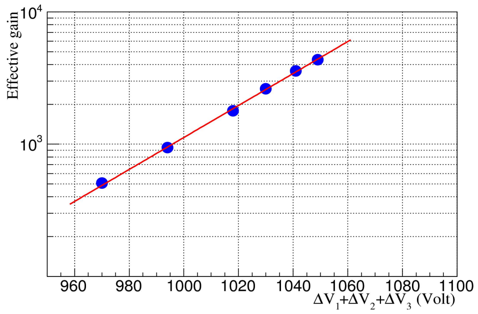

Fig.-2. Effective gain variation with the global GEM voltage.

Energy resolution measurements

The energy resolution is defined as ΔE/E. Where, E and ΔE are mean and FWHM of the Gaussian fit of the 5.9 keV peak of the Fe^{55} energy spectrum respectively.

Energy resolution is calculated for different HV and the optimized value is found to be 21.19% at - 4250 V. Fig.-3 shows the changes of ΔE/E with the global voltage.

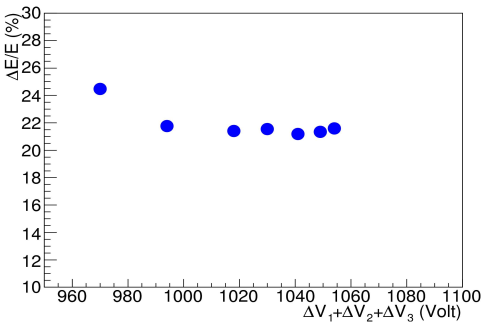

Fig.-3. Energy resolution as a function of global GEM voltage.

Cosmic ray setup and efficiency measurements

Characterization of the triple GEM detector is studied systematically by cosmic ray muons. In this study a 3 fold (3F) trigger is used with the help of the coincidence signals from three plastic scintillator detectors.

Minimum ionization particle (MIP) spectra is taken at different HV using the MCA with the three fold trigger. The MIP spectra showed well separation from the noise peak. The MPV shifted towards higher ADC channel for low to higher HV.

The efficiency measurement is done with the same cosmic ray setup. The 3F trigger signal is given to a counter and the GEM signal with this trigger gate is given into the MCA.

The efficiency, ε is defined as,

$$\varepsilon = N_{GEM}/N_{3F}$$

where, N_{GEM} - no of detected signals with trigger,

N_{3F} - no of 3F trigger signals,

Triggered GEM signal counts, $N_{GEM,}$ is obtained from the sum of the MIP spectra counts with a LLD cut to minimize the noise counts. Fig.-5 shows the variation of efficiency with the applied HV for GEM detector and the plateau reached at - 4325 V with efficiency ~ 95%.

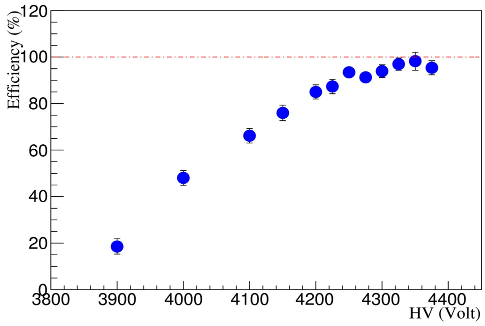

Fig.-5. Efficiency as a function of HV.

Summary

A novel triple GEM detector is assembled and tested with Fe^{55} and Sr^{90} sources. The gain measurement and the energy resolution is calculated for the detector. The detector is tested with cosmic ray muons to obtain efficiency, which is about 95% at the optimal voltage.

Acknowledgments

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Referances

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