Performance of a single GEM detector using Ar/CH_4 gas mixture

C. Yadav, R. G. Thomas*, S. T. Sehgal, V. K. S. Kashyap,
L. M. Pant and A. K. Mohanty
Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA
** email: rgthomas@barc.gov.in*

Introduction

Gas Electron Multipliers (GEM) are gaseous charge amplification structures invented by Fabio Sauli in 1997 [1,2] at CERN. The remarkable features of GEMs such as good position and timing resolution, high rate handling capability and high amplification factor with low discharge probability, make them very attractive in particle and nuclear physics research as well as in applications such medical imaging, neutron radiography and muon tomography etc [3].

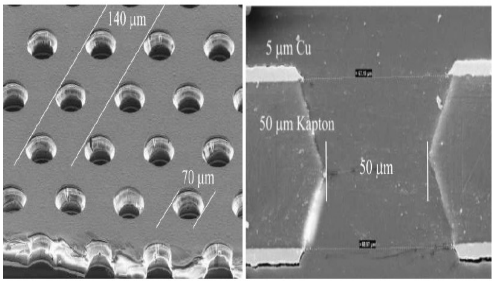

Fig.1 GEM foil structure.

GEM is a thin polymer foil (kapton), metal-coated (Cu) on both sides, chemically etched with a high density of holes (~ 50 micron diameter), typically 50 to 100 per square millimeter (Fig. 1). On application of a voltage between the two conducting sides, a high dipole electric field (~ 30 kV/cm) is created in the holes. Electrons released by ionization on one side of the foil drift into the GEM holes and multiply in avalanche before emerging on the other side. Typical gains ~ 10^3 can be achieved with the use of one foil with voltages ~ 300-400 Volts applied across the foil. Cascading several such foils can provide very high gains without reaching the Raether limit of breakdown.

Single GEM Detector

A standard GEM detector is a parallel plate gas detector, which contain one or more GEM foils inserted between a drift cathode and an anode (i.e., the readout board). We report here the performance of a single GEM detector operating in P-10 gas (90% Ar +10% methane). The GEM foil used in this work, with standard dimensions (10cm x 10cm), were manufactured at CERN. The schematic of single GEM detector is shown in Fig.2. It consists of a drift cathode, a GEM foil and a readout anode. The separation between drift cathode and top of GEM foil is 3mm (i.e., Drift Field) and that between the bottom of GEM foil and readout anode is 2mm (i.e., Induction Field). While the drift plane is made of Cu clad Kapton, the induction plane is realized on a PCB. The entire assembly is enclosed in a chamber with an entrance window made of Kapton. The chamber is equipped with gas inlet/outlets and high voltage and read out pads. Mounting of the GEM foil into the detector chamber has been done in a clean room and in dry and clean conditions. Fig. 3 shows the photograph of detector setup. Before applying the high voltage, P-10 gas is flushed for several hours (usually 6-7 hours) at a rate of 5 lts/hr to guarantee that the entire volume of the detector is displaced several times with the gas.

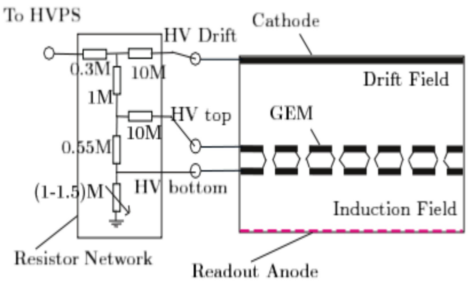

Fig.2 Schematic of single GEM detector with resistor network.

To power the drift cathode and the GEM a simple resistor network (Fig. 2) is used along with a high voltage power supply (CAEN N470) . The values of the resistances used in the network were chosen to obtain the appropriate voltages across the various regions. Two current limiting resistances were also provided to protect the the GEM foil in case of discharges. The maximum current through the network was limited to 860 micro ampere.

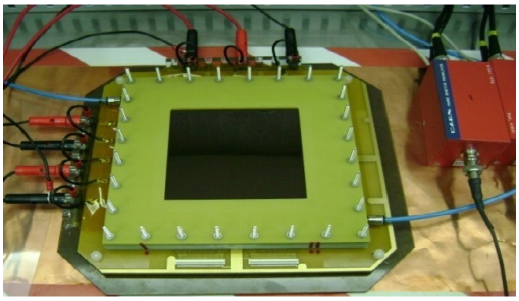

Fig.3 Photograph of assembled GEM detector.

Preliminary results

Measurements were made by exposing the detector to 5.9 keV ^{55}Fe X-ray source (un-collimated). As the X-rays pass through the chamber, each photon generates ~ 200 primary electron-ion pairs in the drift region. These electrons move towards the GEM holes due to electric field between the drift plane and the top plane of the GEM. When the potential difference of 280V-400V (ΔV_{GEM}) is applied to the two conducting sides of GEM foil, a strong electric field is generated inside the holes. The electrons pass through the holes and amplified by avalanche. The amplified electrons arrive at the readout anode along the field lines. The induced signal on the anode is read out by a charge sensitive preamplifier connected across a 100 k-ohm resistance. Depending on the applied voltage difference, gains upto ~10^3 can be reached with a single GEM. Fig. 4 shows the pulse height spectrum of 5.9 keV X-ray obtained at ΔV_{GEM} = 283 V, Drift Field = 1.71 kV/cm and Induction Field = 2.57 kV/cm. Typical X-ray spectrum of ^{55}Fe shows 5.9 keV peak along with 3 keV Ar-escape peak. It can be seen in Fig. 4, that escape peak is not well resolved owing to a poor signal to noise ratio of the detector. A ^{90}Sr beta-ray source was also used to test the detector and the energy loss spectrum obtained is shown in Fig. 5.

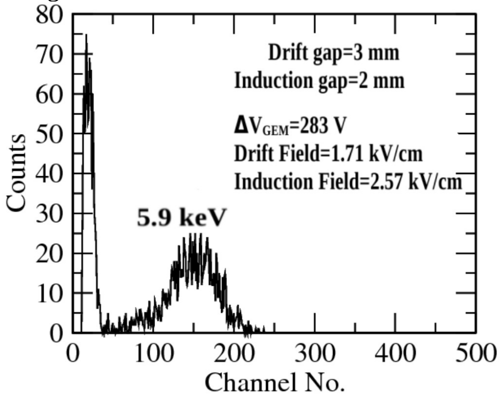

Fig.4 X-ray pulse height spectrum obtained with Single-GEM detector for P-10 gas.

Work is in progress to improve the S/N ratio of the detector and also on implementing the bi-dimensional position sensitive readout system. In future implementations we would like to study the triple stacked GEM detector with both P-10 gas and Ar(70%)+CO_2(30%) gas mixture.

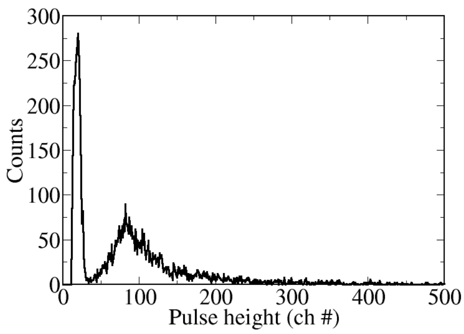

Fig.5 Beta energy loss spectrum from a ^{90}Sr source obtained with Single-GEM detector for P-10 gas.

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References

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