Development of GEM based Muon Chamber detector for the Compressed Baryonic Matter experiment at FAIR

Rama Prasad Adak[1]*
Bose Institute, Centre for Astroparticle Physics and Space Sciences, Kolkata-91, INDIA.

The Compressed Baryonic Matter (CBM) experiment is a future experiment at FAIR, GSI, Germany. The experiment aims to study the properties of the rarely produced particles in order to investigate the behaviour of the matter at moderate net baryon density that prevails in the core of a neutron star. The rarely produced particles will be reconstructed via their decay into dileptons *i.e.* via decay into dimuons or electron-positron pair. The experiment will be performed in two different modes, namely- the electron mode to detect electron-positron pairs and the muon mode to detect dimuons. India has the full responsibility of constructing the Muon Chamber (MuCh) detector system. The experiment will start with a version of MuCh using 3 hadron absorbers with 3 detector stations placed behind each absorber. Each of the detector station consists of 3 layers of gaseous detectors [1]. This setup is suitable for the energy range corresponding to SIS100 accelerator. Later, there will be 6 absorber segments along with 6 detector stations. This setup corresponds to SIS300 accelerator where the maximum kinetic energy per nucleon for the proton and Au-ion will be 90 GeV and 45 AGeV respectively. The interaction rate of the ions in this fixed target experiment will reach up to ∼10 MHz. In order to identify the rare particles produced in this high interaction rate, the conventional detector and the data acquisition system are not sufficient. The data will be acquired in trigger-less mode since during selecting a trigger some valuable data might be missed. Out of the presently available detector technologies, Gas Electron Multiplier (GEM)

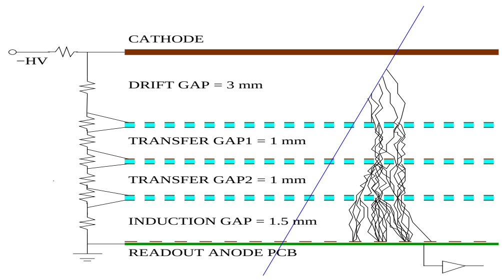

FIG. 1: A schematic of a triple GEM detector.

based detector [2] is found suitable to work efficiently at this extremely high rate and in a harsh radiation environment. The required efficiency of the GEM detector is >90% for the track reconstruction and most importantly they should be capable of handling high flux of particles.

In the direction of developing the MuCh detection system, several R&D on GEM based detector have been carried out. In this thesis, details of these studies using triple GEM detector prototypes starting from a small 10 cm× 10 cm chamber to a large real size detector have been described.

The key element of a GEM based detector is a 50 μm kapton foil sandwiched between two copper foils of 5 μm thickness. A high density of holes of diameter 70 μm, are etched over the foil surface with a hole pitch of 140 μm in a standard GEM foil. A triple GEM detector is fabricated using 3 GEM foils maintaining a transfer gap between two foils. A kapton plane with one side cladded with copper is used as a drift plane. The anode readout plane is segmented into small rectangular pads. The gap between the drift and the top of 1^{st} GEM foil is called drift gap. The gap between the bottom of the last GEM foil and the anode plane is called the induction gap. The R&D started

*Electronic address: rpadak@jcbose.ac.in

with a small 10 cm×10 cm prototype GEM detector with a drift, transfer and induction gaps of 3 mm, 1 mm, 1.5 mm respectively as shown in Fig. 1. The small prototype has been successfully tested in the laboratory using Fe^{55} X-rays and using pion beams with an efficiency >95% [3]. The tracking residue of the array of 3 GEM detector prototypes has been found to be 0.12 cm. After this, a medium size (31 cm×31 cm) trapezoidal shaped triple GEM detector has been tested using proton beam with efficiency >95% at COSY, Jülich, Germany.

The main challenge is to make the detector capable of handling high flux of particles. A large real size trapezoidal shaped prototype triple GEM detector has been successfully tested using intense proton beam of momentum 2.36 GeV/c at COSY, Jülich, Germany. The active area of the prototype detector is 708 mm along the radial side and the inner (outer) ring width is 100.2 mm (381 mm). The active area of the anode readout plane is divided into readout pads of increasing dimension along the radial direction. Each column in this segmentation scheme covers 1° of the azimuth. A premixed gas of Ar:CO_2 in 70:30 volume ratio has been used inside the GEM chamber. The efficiency of the detector reaches 96% at $\Delta V_{GEM} = 375.2$ V at a detector gain of 4000. This prototype has uniformity of efficiency and gain up to 2.8 MHz/cm^2 [4] as shown in Fig. 2. This rate is well above

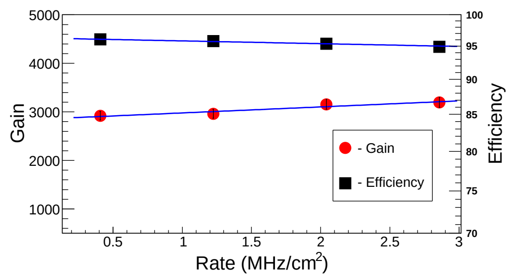

FIG. 2: Variation of the efficiency and gain of the detector with the rate of incoming particle.

the particle rate expected at the 1^{st} detector station of the MuCh system.

The detectors will have to be operated in an environment with a very high level of radiation, so the long-term stability test of the detector is very important. For this purpose, a small 10 cm×10 cm triple GEM detector prototype has been tested in the laboratory for its performance on a long-term basis. As the gain of a gas detector depends on the temperature (T) and pressure (p), the gain is normalised with respect to temperature and pressure. The normalised gain of the detector has been found to be stable at 1.003 with sigma of 0.086 up to a charge acquisition of 12 mC/mm^2 [5] as shown in Fig. 3.

In summary, a series of R&D with GEM based prototype detectors confirms that this technology is appropriate to design the MuCh detector system for the CBM experiment with high efficiency at high rate of particles and the detector is able to be operated for a long time without significant ageing.

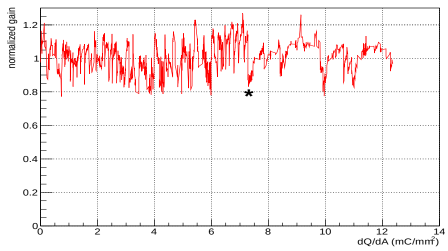

FIG. 3: The Variation of the normalised gain with accumulated charge.

References

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