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Performance of a large size triple GEM detector at high particle rate for the CBM Experiment at FAIR

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ABSTRACT

In CBM Experiment at FAIR, dimuons will be detected by a Muon Chamber (MUCH) consisting of segmented absorbers of varying widths and tracking chambers sandwiched between the absorber-pairs. In this fixed target heavy-ion collision experiment, operating at highest interaction rate of 10 MHz for Au+Au collision, the inner region of the 1st detector will face a particle rate of 1 MHz/cm^2. To operate at such a high particle density, GEM technology based detectors have been selected for the first two stations of MUCH. We have reported earlier the performance of several small-size GEM detector prototypes built at VECC for use in MUCH. In this work, we report on a large GEM prototype tested with proton beam of momentum 2.36 GeV/c at COSY-Jülich Germany. The detector was read out using nXYTER operated in self-triggering mode. An efficiency higher than 96% at ΔV_{GEM} = 375.2 V was achieved. The variation of efficiency with the rate of incoming protons has been found to vary within 2% when tested up to a maximum rate of 2.8 MHz/cm^2. The gain was found to be stable at high particle rate with a maximum variation of ~9%.

1. Introduction

The Compressed Baryonic Matter experiment at FAIR [1] will explore the region of the phase diagram of strongly interacting matter at high baryon density and moderate temperature. This fixed target experiment will use beams of protons and other species up to gold (Au). The maximum available beams energies will be up to E_{lab} of 90 AGeV and 35 AGeV beams of proton and Au respectively. The experiment aims to study the chiral symmetry restoration, search for the phase transition, locate the critical end point, study the equation of state at high baryon density among other topics. The observables of this experiment include low mass vector mesons (LMVMs) like ρ, ω, charmonia along with the collective flow of particles, their correlations and fluctuations. The main challenges include the measurement of low multiplicity, rare probes with high accuracy. In order to attain reasonable statistics for rare probes at a reasonable running period, the interaction rate of beam particles with target nuclei in this experiment will reach ~10 MHz. The main tracking device of the CBM experiment is a set of 8 layers of silicon tracking detector placed inside a superconducting dipole magnet. The system measures the momentum of charged tracks with a resolution ($\Delta p/p$ of 1%). The LMVM like ρ, ω, ϕ and charmonia will be reconstructed from their decay into dileptons. The CBM Muon Chamber (MUCH) consists of alternating layers of hadron absorbers and detector stations to track muons. These segmented absorbers allow to identify muons over a wide range of momentum depending on the number of segments that the particle passed through. A schematic layout of MUCH is shown in Fig. 1. The MUCH geometrical detector acceptance will cover scattering angles from ± 5.6° to ± 25°. The lower limit is given by the beam pipe, whereas the maximum is defined by the aperture of the CBM dipole magnet. MUCH will be operated in different setup configurations by varying the positions of the absorber-detector combinations. The combinations include 3, 4, 5 or 6 such pairs for use in SIS-100 and SIS-300 [2] energy regions of FAIR and two measurement options i.e., LMVM and charmonia. The 1^{st} detector station of MUCH will have to face a hit density of 0.1/cm^2/event for a given interaction rate of 10 MHz of the colliding ions as obtained from GEANT3 simulations [3] using particles from UrQMD event generator [4] for central Au+Au collisions at E_{lab} = 25 AGeV. The choice of the detector is motivated by the required high rate capability of the detector and by the cost of manufacture to cover the large area. Considering the detector technologies presently available or under intense research and developing phase, Gas Electron Multiplier (GEM) [5] technology is found to be a suitable candidate for building the chambers. GEM based detectors has been used in CMS,

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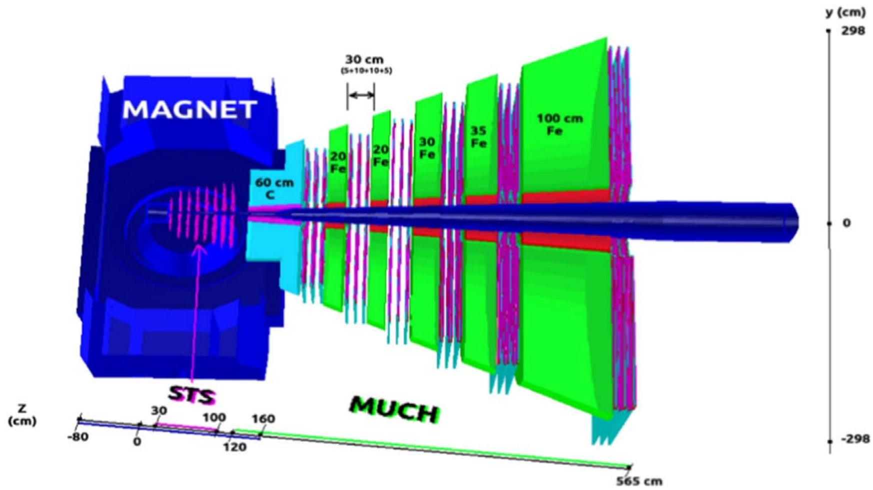

Fig. 1. A schematic view of the MUCH of CBM experiment with carbon as the first absorber and iron as the remaining absorbers.

COMPASS, PHENIX for their excellent rate handling capacity [6–8]. ALICE experiment will use GEM detectors for their TPC upgrade to handle high rate of particles. CBM will use GEM chambers as their tracking detectors in the first two stations of the muon detection system. Towards this goal, we at VECC-India have built several triple GEM chambers of dimensions 10×10 cm and 31×31 cm. These chambers have been tested with X-rays [9], proton [10] and pion beams [11] to achieve >95% efficiency. Even after the successful development of these chambers, testing of two main features of their use in CBM-MUCH remain unfulfilled i.e., large size and high rate capability.

In this work, we report the development of a sector-shaped triple-GEM chamber of 80 cm long and 40 cm wide. We also report the performance of the chamber using proton beams of momentum 2.36 GeV/c with a maximum rate of 2.8 MHz/cm^2. The present chamber is considered as a prototype for the 1st station downstream of the magnet that faces the highest particle density. The 1st station of CBM will have 3 layers with 16 sector-shaped chambers in each layer.

The paper is organized as follows, in Section 2 the layout of the GEM chambers for the CBM-MUCH is discussed. Section 3 contains the fabrication procedure of the GEM chamber including details of various components followed by the test setup, results and discussions in Sections 4 and 5 respectively.

2. Layout of chambers in CBM muon system

Fig. 2 shows the schematic diagram of a layer consisting of the sector-shaped chambers. Three such layers are to be mounted in a 30 cm gap between two successive absorbers. The number of sectors in each layer for the 1st and 2nd stations are 16 and 24 respectively. There will be a provision for a layer to be separated into two halves for services. For ease of production, all chambers in a particular station are identical. Two sector shaped chambers will be mounted back to back separated by an aluminium plate of 6 mm thickness. The active area of each sector will be larger than the area corresponding to 360° divided by the number of sectors. A single GEM chamber in the 1st station will cover 23° of azimuth including the overlap. This facilitates the overlap at the edges between two sectors. There are overlaps of 0.5° that corresponds to the mechanical support at the sides of the chambers.

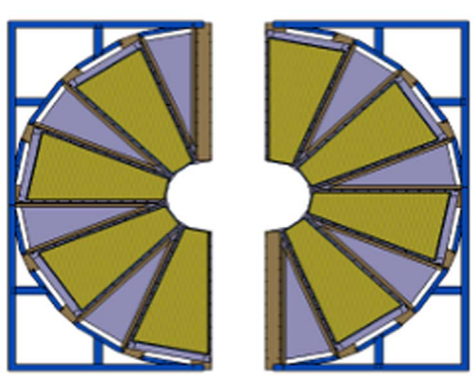

Fig. 2. Layout of sectors on a layer.

3. Fabrication of the GEM chamber

The chamber being discussed here is a real size prototype chamber for the 1st station of MUCH. The design and the fabrication of readout Printed Circuit Board (PCB) were carried out in India and the fabrication of other components and assembly were done at CERN.

3.1. GEM foils

This triple GEM chamber prototype is made of 3 standard single mask GEM foils. The drift gap, transfer gap and the induction gap of the chamber are 3 mm, 1 mm, 1.5 mm respectively. The GEM foils for the prototype have been fabricated at CERN. The GEM foils have been stretched by the NS-2 (no stretch, no spacer) technique [12,13] developed at CERN. The layout of the high voltage segmentation on the foil is shown in Fig. 3. The segmentation is made based on the occupancy of the chambers in Au+Au collisions at SIS-300 energy. Therefore, it is expected that the chamber will be able to handle a particle rate at lower energy collisions available at SIS-100, quite comfortably. Each GEM foil has been segmented into 24 sections on its upper surface. The size of the inner most 4 sections was 25 cm^2, the remaining sections are of 100 cm^2 area. Each of 24 sections was connected via a surface-mounted 1 MΩ protection resistor. Four zones,

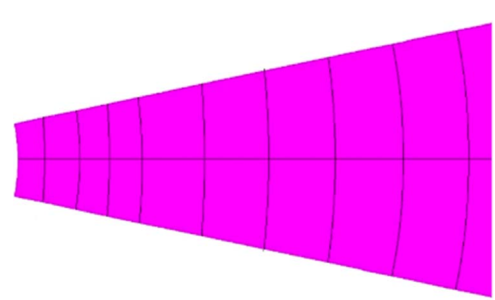

Fig. 3. Layout of the HV segmentation on the GEM foil, where only a part of the foil with only 20 segments has been shown.