Fabrication and testing of the upgraded GEM module for the station-1 of MuCh system of CBM experiment at FAIR, Germany

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Introduction

The CBM experiment is designed to investigate the properties of dense nuclear matter in nucleus-nucleus collision at an unprecedented interaction rate up to 10 MHz. CBM will consist of 4 stations of Muon- Chambers (MuCh) sandwiched between absorber layers and each station will consist of 3 layers of gaseous detectors. The maximum hit density at 25 AGeV for the innermost part of the detector at the first station reaches upto 400 KHz/cm^2 [1]. Two real size GEM detector prototypes of the first station have been built at VECC and installed in the mini CBM experiment at SIS18 facility of GSI, Germany. The two modules have been participating in the data taking since last 4 years and have undergone some hardware modifications as we approach towards the final version [2]. In the earlier version of the drift PCB, some surface discharges were observed in the HV layout section, which resulted into link instability of the MuCh-XYTER readout electronics. In this report, we present the design modification of the drift PCB, fabrication of the detector and lab test results of the same.

Design and Fabrication

. An 8-layer readout PCB for the module has been designed at VECC using PROTEUS package. The readout plane consists of 97 rows and 23 columns of readout pads, i.e a total pad of 2231 according to progressive geometry. This PCB has been manufactured indigenously. A total of 18 FEBs, each FEB reading 128 readout pads, are employed to read one complete GEM module.

FIG. 1: 1st station module under test at VECC

We assembled the detector at VECC clean room using 3 GEM foils, drift PCB, readout PCB and other necessary components. QA procedures such as satisfatory leakage current tests, etc. were followed. Fig.1 shows the lab setup of the fabricated module for further tests.

Modification of the drift PCB

In April 2020 during the operation at the miniCBM beamtime, at module voltages higher than 4800V, some spikes were observed from the detector modules which resulted in link instability of readout electronics and asynchronized DAQ at the start of a new run. Timing offsets in MuCh data were observed during the run. Detailed investigation was carried out at VECC. Tests were conducted on a bare drift PCB.

It was observed that several spikes were getting generated in the optocoupler (OC) based HV distribution circuit introduced for GEM segment isolation. This was more dominant at higher voltages. An isolated single OC was mounted on a specialized PCB and tested.

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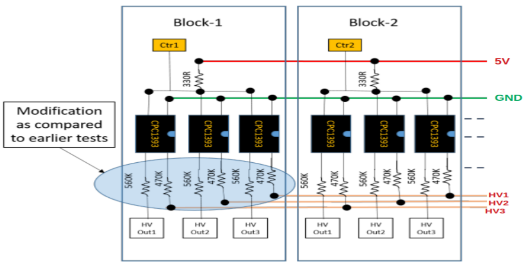

FIG. 2: Modified HV layout on new Drift PCB

This showed stable results. Problem happened whenever multiple OCs were connected to the same HV input line. The LV line then was found to get disturbed. The amplitude of the spike was also observed to increase with the number of optocouplers connected. To resolve this issue, an appropriate resistance was inserted at the input legs of each optocouplers, as shown in the Fig.2. In the modified layout the total resistance is now split into two. This approach thus isolates each optocoupler from one another [3].

Measurement of Detector Characteristics

After this modification, the triple GEM detector was tested in lab and it showed stable response. It was also tested later in a high rate environment at GIF++ experiment at CERN and was found to be stable during the entire operation, without any communication loss. The module with modified drift PCB has been tested at VECC lab with high voltage and the e-link was observed to be stable for a continuous operation of more than 48 hours. Fig.3 shows a Fe^{55} spectra from the module at summed GEM voltage of 1078 Volts with a gain of 2029. We prepared a cosmic muon coincidence setup and measured the efficiency of 96% corresponding to summed voltage of 1125 Volts (Fig.4). After a satisfactory lab test this module was installed in the mCBM cave. During March and June, 2022, it was tested at the runs with high intensity Uranium ($_{238}U^{73+}$) beam of 1.0A GeV and Gold (Au^{69+}) beam of 1.23 AGeV respectively. The preliminary high rate results show the stable behaviour of detector and electronics. Further data analysis is in process.

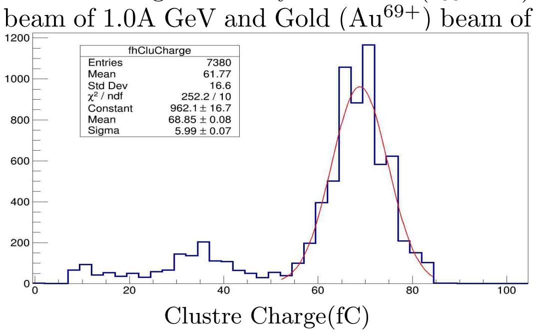

FIG. 3: Fe^{55} pulse height spectra

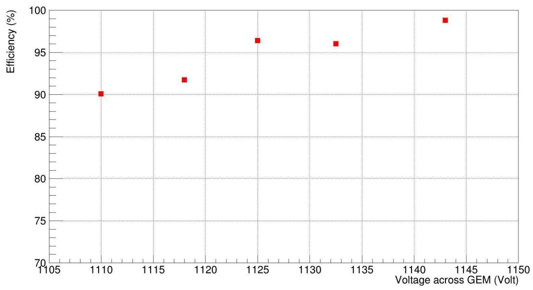

FIG. 4: Cosmic muon detection efficiency

References

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[3] Drift PCB modification of station-1 MuCh module for readout electronics link stability, CBM Progress report, p110.