Design of Read-Out Boards for ME0 Upgrade of the CMS Experiment at LHC facility

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Introduction

Gas Electron Multipliers (GEMs) are state of the art gaseous ionization detectors that are being designed and installed as an upgrade to the Compact Muon Solenoid (CMS) Muon System. The GEMs are highly pixilated detectors, providing both timing and tracking of muons in the forward regions. The ME0 consists of GEM detector assemblies located in the very forward region in a 30 cm space [1] between the first end cap and end cap calorimeters as shown in Fig.1. The ME0 detectors are expected to cover the pseudo rapidity region between 2 and 3. BARC, in collaboration with CMS project at CERN has successfully designed read-out boards (ROB) for ME0 modules.

Each ME0 detector will consist of 6 layers of ME0 detector assemblies, in which each detector assembly contains 8 identical detector chambers, each spanning 20 degrees in phi. The layout of the ME0 detector system is shown in Fig.2. The detector chambers will contain on-board 128 channels VFAT3 front-end ASICs for pulse processing and opto-hybrid (OH) boards for interface with back end electronics like Data Acquistion (DAQ) system and Trigger system.

Design of ME0 ROB:

The ROB is a two sided PCB that serves both as anode of the GEM chamber and the first stage of the signal readout chain [2]. The avalanche electrons produced by the interaction of the charged particles with the gas mixture, (Argon + CO2 : 70:30) inside the GEM chamber are collected by the ROB. Copper strips facing the GEM chamber behave like electrodes on which charge is induced due to the electrons produced. The charge induced is transmitted to the other side of the board through vias. Copper traces are present on this side, which route the signals produced to the VFAT3 front-end ASIC through a HRS connector present on the ROB.

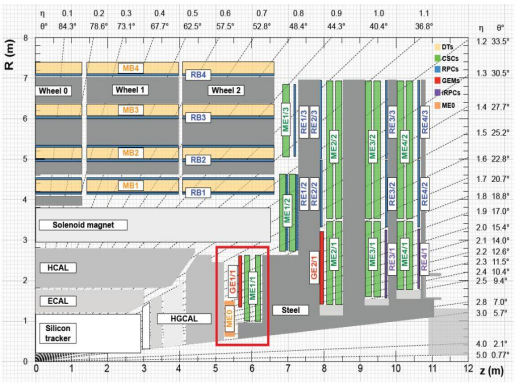

Fig. 1 Position of ME0 detector in the CMS Muon System [1]

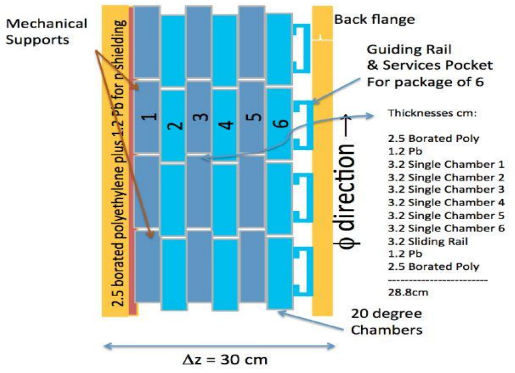

Fig. 2 Layout of ME0 detector system [1]

The design of the ME0 ROBs is based on experience in design and fabrication of GE11 and GE21 detectors. The active area of the ROB spans 20 degrees in phi and is split into 8 eta segments, where each segment contains 384 strips in phi. Hence a single ME0 chamber will contain 3072 strips. The gaps between the phi strips are constant and maintained at 0.2 mm as a

trade-off between achieving required spatial resolution in phi and optimizing SNR by reducing inter-strip capacitance. The separation between the individual eta segments have also been maintained at 0.2 mm.

The placement of the HRS connector on the ROB is influenced by the placement and mechanical clearance required for the components on the GEM Electronics Board (GEB) like VFAT, opto-hybrid, optic fiber cables and FEAST. The layout of the various electronic modules in a single ME0 chamber is shown in Fig.3. The overall space available for placement of components is constrained due to limited mechanical dimensions of the detector compared to the GE2/1 and GE 1/1 detector. The footprint of the opto-hybrid has been reduced significantly by transferring its FPGA to the back-end electronics, leaving behind only the LpGBT optical transceivers.

Placement of the vias and HRS connectors are done such that the length of the copper traces connecting the vias to the HRS connector is minimized. Care has also been taken during connector placement to ensure that the time difference between read-out signals associated to the given opto-hybrid is minimized. The input capacitance of the strips are expected to be significantly less than GE2/1 due to lower strip lengths as a result of smaller mechanical dimensions of the detector. Python based design scripts used for design of GE2/1 ROB were modified to generate layouts, via positions and connector placements on the ROB. Automated routing of traces to the HRS connector was avoided due to the non-uniform routing solutions for the different connectors, especially for the narrow eta segments. The overall layout of the ROB after connector placement, strip generation and routing is shown in Fig.4. The gaps between the strips are shown in blue and fabricating the 'negative' of this layer will produce the copper strips. The drawings generated (in DXF format) can be imported easily by most PCB design tools to produce the required Gerber files for fabrication.

Conclusion:

The ME0 design builds upon the design experience and software tools developed for GE1/1 and GE2/1 detectors. The software scripts used for the design of GE2/1 ROB were updated to comply with the requirements of the ME0 detector. The design of the ROB has been

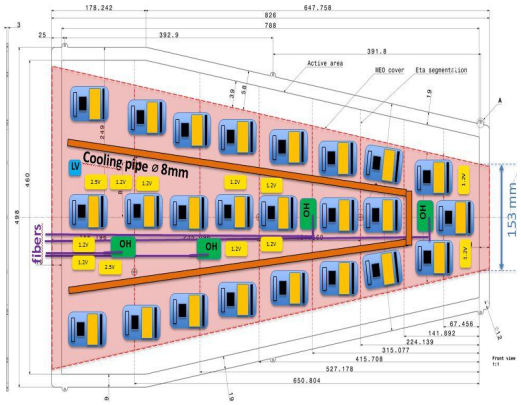

Fig. 3 Layout of electronics on ME0 module [3]

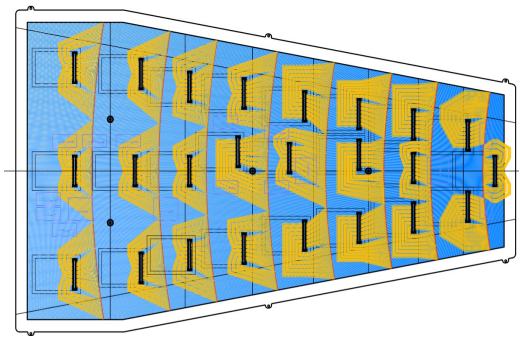

Fig.4 Layout of ME0 ROB

reviewed and accepted by CERN. ME0 chambers along with associated electronics are being fabricated and tested at CERN for performance evaluation.

References:

[1] Technical Proposal for the Phase-II Upgrade of the Compact Muon Solenoid, CERN-LHCC-2015-010/LHCC-P-008

[2] CMS GEM Collaboration, URL - https://twiki.cern.ch/twiki/bin/view/CMSPublic/GEMReadoutBoardSpecifications

[3] ME0 VFAT3 on Hybrid, GEM-Phase-2 Electronics Meeting, 28-03-2019