Design of the Read Out Boards for the GE21 upgrade of the CMS experiment at the LHC facility

A. Mohammad[1] S. Khole[1], M. Y. Dixit[1] and L. M. Pant[2,*]
[1]*Accelerator Control Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[2]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
* email : lmpant@barc.gov.in

Introduction

Gas Electron Multipliers (GEMs) are state of the art detectors, being installed for the GE11 upgrade (GEM chambers in the first ring of the first end cap) for the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider facility at CERN, Geneva. The GEMs are highly pixilated detectors, providing both the timing and tracking for muons in the forward regions. BARC, along with other assembly centres has contributed in building of GE11 chambers. GE21 deals with the GEMs in the first ring of the second end caps of the CMS experiment.

The GE21 detectors are approximately 2.5 times in area compared to GE11 detectors. As the maximum size of GEM foils is limited, the GE21 detectors are split into smaller sizes, which is integrated into a single detector (Fig. 1). A GE2/1 chamber is split into 4 modules, each containing its own set of on-detector electronics like front end ASICS (VFATs), Read-out Board (ROB), GEM Electronics Board (GEB) and Opto-hybrid (OH). Two chambers are sandwiched together to form a GE2/1 super-chamber. The dimensions of the modules of the two chambers differ slightly to minimize the dead area of the detector. Since the design of the individual modules, namely M1 to M4 for the front chamber and M5 to M8 for the rear chamber are unique, each module must be designed separately. BARC is involved in the design of the ROBs (M5 to M8) as shown in Fig. 2.

Design of GE21 ROBs (M5 to M8):

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 [1]. The avalanche electrons produced by the interaction of the charged particles with the gas mixture, (Argon + CO_2 :: 70:30) inside the GEM chamber are collected by the ROB.

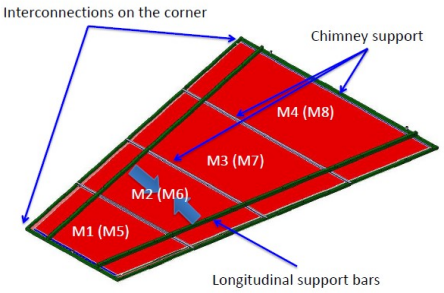

Fig. 1 Schematic of GE21-ROBs [M1 (M5) to M4 (M8)]

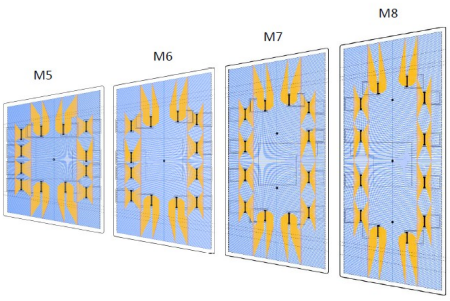

Fig. 2 Design of GE21-ROBs (M5 to M8) generated by automated scripts

The ROB as a part of the triple GEM foil stack is shown in Fig 3. 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. The VFAT3 is also connected to the GEM electronics board (GEB), which is responsible for routing of power, control data and read-out data to the on-detector electronic modules.

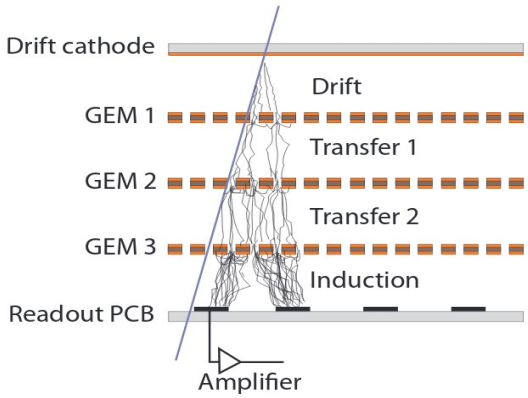

Fig. 3 Triple GEM foil stack [2]

GE21 ROBs have been designed based on the experience gained by the fabrication and testing of GE11 detectors. The active area of the detector spans 20 degrees in phi. The read-out board is split into 4 eta segments, where each segment contains 384 strips in phi. The gaps between the phi strips are constant and maintained at 0.2 mm as a trade-off between achieving required resolution in phi and minimizing inter-strip capacitance. The separation between the individual eta segments have also been maintained at 0.2 mm.

The placement of HRS connectors that interface with the VFAT depends on mechanical design constraints of the detector assembly like the placement of longitudinal support bars (shown in Fig.1). Since the VFAT hybrid is connected with both the ROB and GEB, the placement of the HRS connector also depends upon the clearances of the VFAT hybrid from components and cables on the GEB. The placement of vias on the ROB has been selected to minimize the length of the copper traces connecting the strip vias with the connector to minimize the time delay for transmission of pulse signals and the capacitive coupling between the individual read-out channels due to long lengths of parallel copper traces. A copper ground plane surrounding the copper traces has been avoided since noise measurement studies seem to indicate a higher noise level due to the ground plane especially at the strip edges. It has also been observed that the HRS connectors do not add any extra capacitance compared to the Panasonic connectors which have been used for the GE 1/1 boards [3].

Automated Python based design scripts have been deployed to generate the ROB strip layouts, via positions, connector placements and routing of copper traces between the ROB connectors and the strip vias. Fig. 2, shows the GE21-ROB design for M5 generated using the scripts. The script marks the gaps between the strips (shown in blue) and fabricating the 'negative' of this layer will produce the ROB strips. The copper traces connecting the strip via to the connector are marked in yellow. The outline of the space occupied by the VFAT hybrid has also been generated to validate the mechanical clearances required. The generated drawings (in DXF format) can be imported easily by most PCB design tools to produce the required Gerber files for fabrication.

Conclusion:

BARC, in collaboration with CMS project at CERN has designed the ROB layout for GE 21 M5 to M8 modules. Additional changes to the ROB design involving the placement of alignment studs and flanges are being conducted by the design team at CERN. After vetting the designs at CERN, it is proposed to have the prototypes fabricated and validated at Indian industries before being integrated with the GE21 GEM chambers at CERN for evaluating their extended performance.

References:

[1] CMS GEM Collaboration, URL - https://twiki.cern.ch/twiki/bin/view/CMSPublic/GEMReadoutBoardSpecifications
[2] CMS Technical Design Report for the Muon Endcap GEM Upgrade
[3] CMS GEM Collaboration URL: https://indico.cern.ch/event/715060/contributions/2939143/attachments/1620165/2577271/GE21_capacitance_and_noise_measurement.pdf