The High Luminosity (HL) upgrade of the Large Hadron Collider (LHC) intends to increase the instantaneous luminosity by five-fold. With this increase, the CMS experiment is in the process of upgrading its muon spectrometer. ME0 and GE2/1 are two triple-Gas Electron Multipliers (triple-GEM) detector systems undergoing this upgrade [1]. This poster addresses the status of the GE2/1 and ME0 integration at CERN and Florida Institute of Technology (FIT).

GE2/1 ELECTRONICS TESTING AND CHAMBER ASSEMBLY PROGRESS AT CERN

Electronics test (QC7 test):
- Stage of calibration & integration of the front-end electronics.
- Performed for individual modules then for full chamber.
- Passing QC7 test:
  - Passing QC7 puts the detector in the final configuration.
  - Next (final) quality-control stage (QC8) is the cosmic-ray test.

Goals of QC7 test:
- To identify broken components, fix communication failures, ensure that No. of working channels per eta partition is ≤ 3.
- Validation of the front-end electronics nominal operation such as low noise and reliable response of the read-out.

QC7 test components:
- GBT phase scan,
- DAC scan,
- S-bit rate scan: checking triggering path,
- S-curves: checking noise behavior and problematic channels,
- Threshold scan: identifying disconnected channels.

Current status:
- Four GE2/1 chambers have been assembled.

INVESTIGATING THE DISCHARGE PROPAGATION IN GE2/1 AND ME0 DETECTORS AT CERN

Discharge:
- Transferring stored charges on GEM foil during operation.
- It could damage the structure of the GEM foil micro-holes.

Discharge propagation:
- Discharge created inside the foils can propagate to other foils.
- Discharge propagation may destroy the readout electronics.

Discharge mitigation:
- New GEM-foil design with double azimuthal segmentation.
- New HV filter with improved protection resistance.
- New readout protection w/ AC-coupling & drain resistors.

Result:
- Discharge propagation and electronics damage probabilities are now reduced to 10% and 3%, respectively.

Baseline HV filter:
- Five HV filters (5, 10, 25.5, 51, 100-kΩ) have been tested [2].
- The 5 and 10-kΩ ones are excised for showing re-ignition.
- The other three are good, and the 51-kΩ is the baseline filter.

HV HARDWARE AND SOFTWARE AT FIT

Hardware:
- CAEN A1515 power supply is housed in SY5527 mainframe.
- HV boards A1515TG is used for GE2.
- HV board A1515TGHP is used for ME0.
- Each board has 14 channels, split into two groups of seven.
- A group of seven channels can control one TEGM (Fig. 5).
- Power supply connects to detector by 52-pin Radiall cable.

Software:
- LabVIEW programs written by Universidad de Antioquia.
- Four programs control and detect sparks on each HV channel.
- Software from F. Ione records channel parameters over time.
- A local Grafana instance plots channel’s I and V over time.

Stress Test on ME0 and GE2:
- HV on a single GEM foil ramps up in steps of 10 V.
- Highest HV is determined by the recorded No. of discharged.
- Current leaks are also recorded in Grafana plots if measured.
- Current leak of 0.3 µA at 600 V was seen for ME0-HV filters (Fig. 6).
- Reason of this leak seems to be the lack of urethane, an insulating coating, which will be provided shortly.
- No current leak was measured for GE2/1-HV filters.

SOLVING A PROBLEM OF MISSING CHANNELS IN VFAT S-CURVES AT FIT

Missing VFAT channels:
- S-curves for ME0-VFATs showed random missing channels (Fig. 7).
- Missing channels increased with the increase of Forward Error Correction (FEC).
- The high light output of Quad Small Form-Factor Pluggable (QSFP) optics transceiver modules are believed to cause data loss on the way from the front-end to the back-end.

Attenuator:
- A QSFP’s attenuator was found to reduce the light output for one lpGBT at a time.
- FECs decreased as the optical power to lpGBT 2 is reduced (Table 1).

Resolving the issue of missing channels:
- Missing channels disappeared in the absence of FECs.
- This fact has been confirmed by taking 40 S-curves in a row.
- Using lower-power Vitex QSFPs (without attenuator) resolved the issue in full.

Table 1: Data for FEC’s rate change by varying the optical power of lpGBT 2.

<table>
<thead>
<tr>
<th>Optical Power (µW)</th>
<th>Duration (s)</th>
<th>FECs</th>
<th>FECs per laser</th>
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<td></td>
<td></td>
<td>0.000</td>
</tr>
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</tr>
<tr>
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<tr>
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SUMMARY

- GE2/1 QC7 stage at CERN is established and started where 17 modules have passed it.
- Four GE2/1 back chambers (M1–M4) have been assembled at CERN and are now ready for the cosmic-ray test (QC8).
- Discharge propagation in GE2/1 and ME0 at CERN has been mitigated to a very low (safe) level towards the final production.
- Software and hardware required for Stress Test for ME0 and GE2/1 at FIT is successfully functional.
- The problem of having missing ME0-VFAT’s channels has been resolved by using lower-power Vitex QSFPs.

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REFERENCES