Status Of The GE2/1 and ME0 Integration At CERN And FIT For The CMS Muon Upgrade

B. Alsufyani, T. Elkafrawy, M. Hohlmann and E. Yanes On behalf of the CMS Muon Group
Florida Institute of Technology

CMS Upgrade Days at CERN, February 6–8, 2023, CERN, Geneva, Switzerland

Introduction

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).

Figure 1: Test stands of GE2/1 at CERN (left), GE2/1 at FIT (center), and ME0 at FIT (right).

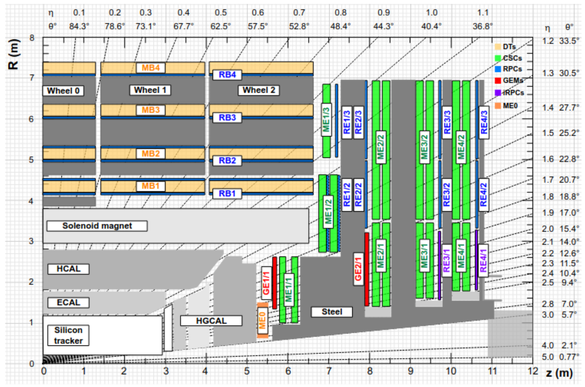

Figure 2: Quadrant of the CMS experiment. ME0 and GE2/1 can be seen in the lower center of the image [1].

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 trigger path, • S-curves: checking noise behavior and problematic channels, • Threshold scan: identifying disconnected channels.

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

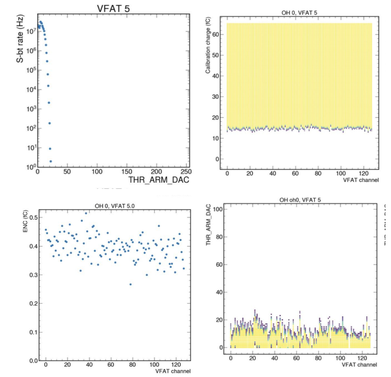

Figure 3: Top left: S-bit rate scan, top right: S-curves, bottom left: noise extracted by fitting s-curves, bottom right: Threshold scan.

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 exculded for showing re-ignition.
- The other three are good, and the 51-kΩ is the baseline filter.

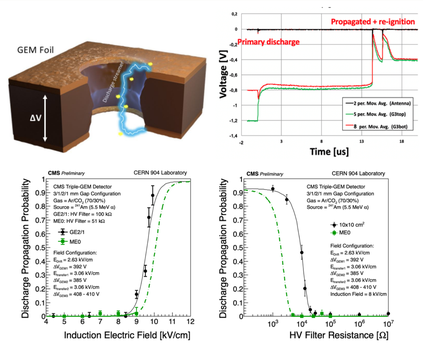

Figure 4: Schematic for discharge in GEM foil (top left), oscilloscope capture of discharge propagation in 10×10 cm^2 GEMs (top right), and measured discharge propagation probability against the induction electric field (bottom left) and the HV filter resistance for $E = 8$ kV/cm (bottom right).

HV Hardware and Software at FIT

Hardware:
- CAEN `A1515` power supply is housed in `SY5527` mainframe.
- HV board `A1515TG` is used for GE21.
- HV board `A1515BTGHP` is used for ME0.
- Each board has 14 channels, split into two groups of seven.
- A group of seven channels can control one TGEM (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. Ivone records channel parameters over time.
- A local Grafana instance plots channel's I and V over time.

Stress Test on ME0 and GE21:
- HV on a single GEM foil ramps up in steps of 10 V.
- Highest HV is determined by the recorded No. of discharges.
- 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.

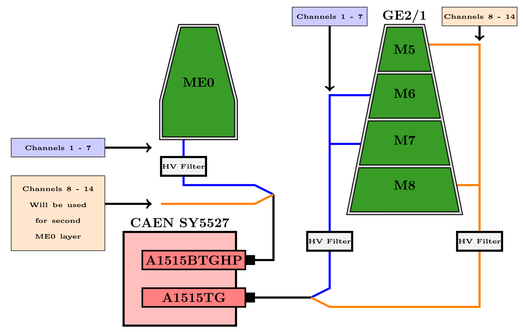

Figure 5: Block diagram of HV connection at FIT.

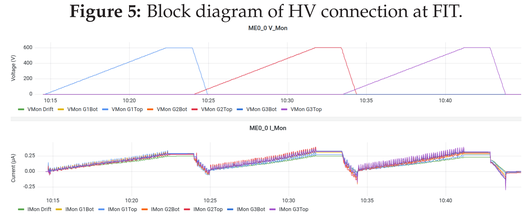

Figure 6: Current leaks in ME0 HV filter during Stress Test at FIT.

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.

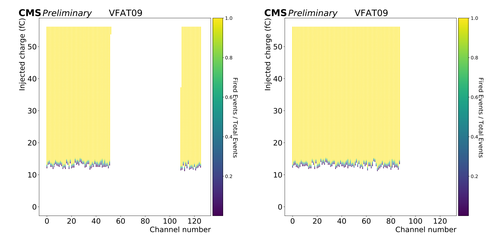

Figure 7: S-curves for two VFATs at the same geographical location of ME0.

Optical Power (μW)	Duration (h)	FECs	FECs per hour
850	1	39	39
800	1	17	17
700	24	106	4.4167
650	24	27	1.125
600	13	4	0.308
550	12	0	< 0.083

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

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-VFATs' channels has been resolved by using lower-power Vitex QSFPs.

Acknowledgements

We would like to thank the DOE's Office of Science (HEP) for their support of this work through the grant DE-SC0013794. We would also like to thank all members of the CMS GEM group including S. Butalla for their contributions and the fruitful discussion.

References

[1] CMS Collaboration, *The Phase-2 Upgrade of the CMS Muon Detectors: Technical Design Report*, CERN-LHCC-2017-012, CMS-TDR-016, (2017).

[2] S. Mohamed, T. Elkafrawy, and J. Merlin on behaalf of the CMS Muon Group, *Reduction of high voltage discharge in GEM detectors for the ME0 station of the CMS forward muon system*, *PoS LHCP2022*, **422**, 265 (2022).