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Reduction of High Voltage Discharge in GEM Detectors for the ME0 Station of the CMS Forward Muon System

Salwa Mohamed[1,4], Tamer Elkafrawy[2], and Jeremie A. Merlin[3]

On behalf of CMS Muon Group

[1]Egyptian Network of High Energy Physics, ASRT, Cairo,
[2]Florida Institute of Technology, Melbourne, Florida, USA
[3]University of Seoul, Seoul, Korea
[4]Higher Technological Institute, 10th of Ramadan City, Egypt
Contact: Salwa.Mohamed@cern.ch

CMS GEM ME0 project

Phase 2 upgrade of the CMS muon spectrometer (Fig. 1.a): Three triple-GEM detectors were developed to improve the muon trigger and tracking performance [1].

GE1/1 $1.55 < |\eta| < 2.18$

GE2/1 $1.62 < |\eta| < 2.43$

ME0 $2.00 < |\eta| < 2.80$

- ME0 stack (Fig. 1.b) is composed of 6 layers of triple-GEM detectors.
- ME0 covers the high-flux environment (150 kHz/cm^2) which led to studies of:
  - Discharge propagation mitigation
  - Rate capability

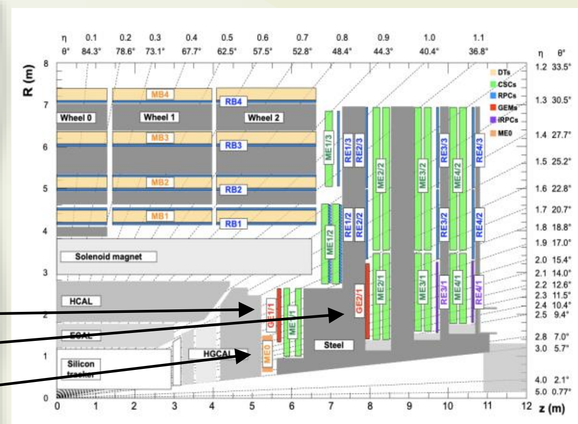

Fig. 1.a: A quadrant of the CMS Muon spectrometer

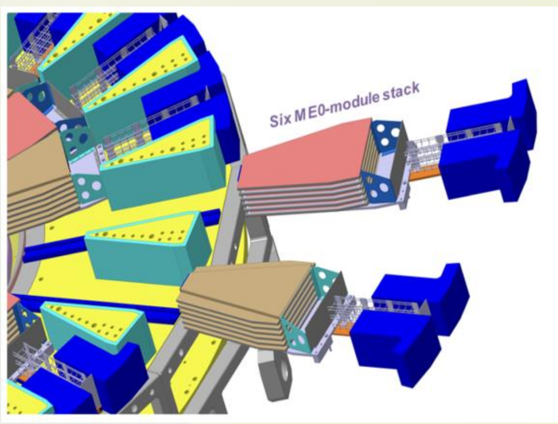

Fig. 1.b: Schematic view of the ME0 stack with six triple-GEM

Discharge and discharge propagation

- Discharge is the phenomenon of transferring stored charges on the GEM foil during the operation which could damage the structure of the holes [3].
- Discharge created inside the foils can propagate to another foil and then the readout electronics may get destroyed.

Fig. 2.a,b: Schematic of GEM foil (a) expressed as a capacitor (b)

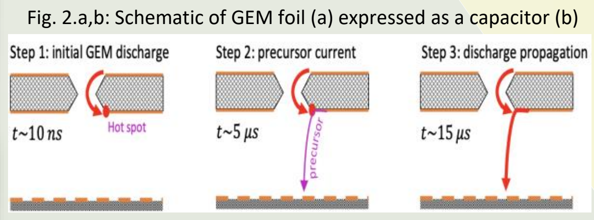

Fig. 2.c: Schematic view of the discharge propagation process

Discharge propagation mitigation

- Based on CMS GE2/1 reviews and approvals:
  - New GEM design with double segmentation (Fig. 3.a)
  - New HV filter with improved protection resistance
  - New readout protection with AC-coupling unit (Fig. 3.b) and drain resistors [3]
- Discharge propagation and electronics damage probabilities are reduced to 10^{-7} and 3%, respectively.

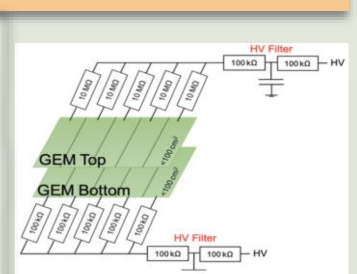

Fig. 3.a: Double segmentation schematic

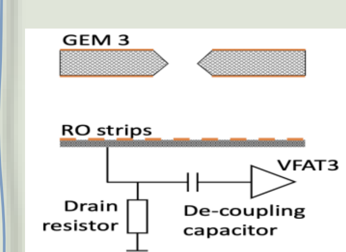

Fig. 3.b: AC-coupling used in GE2/1

The rate capability of ME0

- Transversal segmentation of ME0 (Fig. 4.a) foils experienced a high gain drop and more than 50% of gain dis-uniformity.
- A redesign of the ME0 (Fig. 4.b) foil segment orientation (Azimuthal) was a solution to allow an effective gain compensation and minimize the gain drop during the CMS beamtime [2].
- For any change in the design of foil or HV filter, we have to revalidate its impact on the discharge propagation probability.

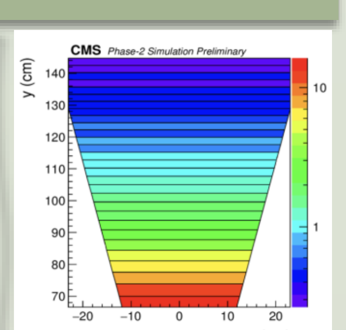

Fig. 4.a: ME0 1st generation

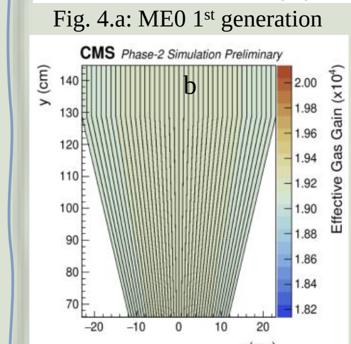

Fig. 4.b: ME0 2nd generation

References

(1) F. Fallavollita, Novel triple-GEM mechanical design for the CMS-ME0 detector and its preliminary performance, Inter. Conf. Instr. for Colliding Beam Physics Novosibirsk, Russia, 24–28 February 2020.

(2) A. Pellecchia, Rate capability of large-area triple-GEM detectors and new foil design for the innermost station, ME0, of the CMS endcap muon system, arxiv:2201.09021v1 physics. ins-det, 22 January 2022.

(3) J.A. Merlin, Discharge protection, cross-talk and rate capability, talk presented at RD51 Collaboration Meeting, 8 October 2020.

Experimental setup and procedure

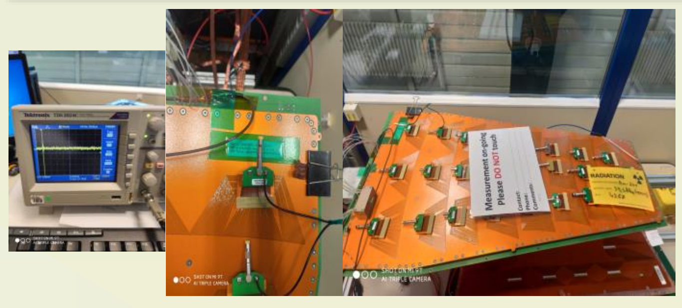

Fig. 5.a: Measurement setup at 904 lab.

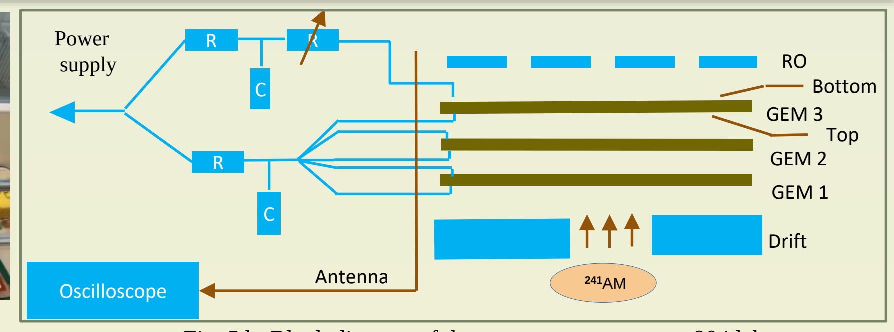

Fig. 5.b: Block diagram of the measurement setup at 904 lab.

- Measurements were performed in the 904 lab at CERN (Fig. 5.a,b) for the second generation of the ME0 GEM detector.
- Discharge counts were created by injecting alpha particles via a specific hole created during the assembly and applying a suitable field configuration on the foils. Using the antenna, discharges and discharge propagations at several induction fields have been counted using different values of HV filter resistance to investigate the effect of both segment orientation and HV filter resistance on the discharge propagation probability.

Results

Figure 6: Discharge propagation probability versus the induction electric field for the GE2/1 configuration (black), ME0 configuration (green) (Fig. 6.a) and 10x10 cm^2 (red) (Fig. 6.b) GEM muon detectors.

Figure 7: Discharge propagation probability versus the induction electric field for the GE2/1 configuration (black) with HV filter resistance of 100 kΩ and ME0 configuration (green) for different HV filter resistances (51, 25.5, 10, 5 kΩ).

In Figs. 6.a and 7.a,b,c,d, the green curve is produced by fitting the data using the error function up to an induction electric field of 9 kV/cm and by extrapolation beyond 9 kV/cm.

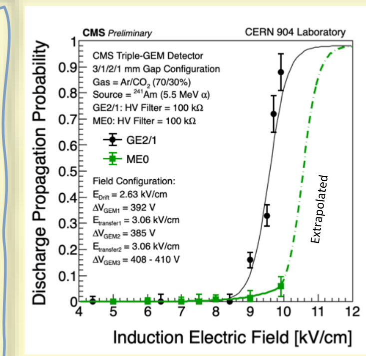

Fig. 6.a

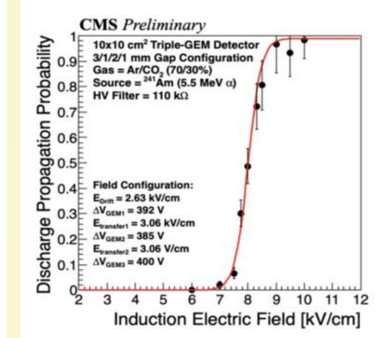

Fig. 6.b

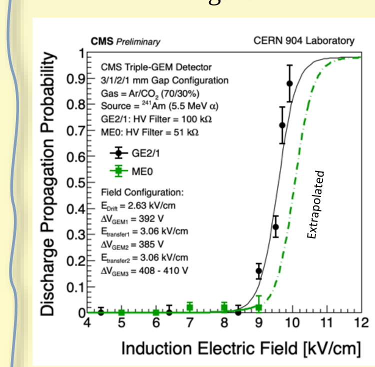

Fig. 7.a

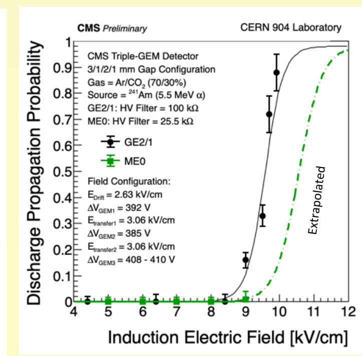

Fig. 7.b

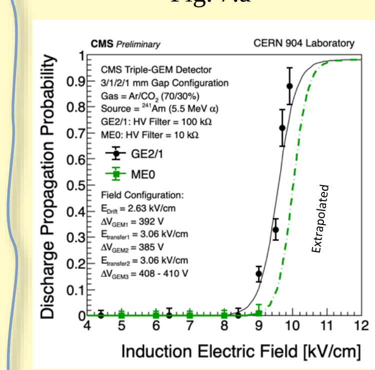

Fig. 7.c

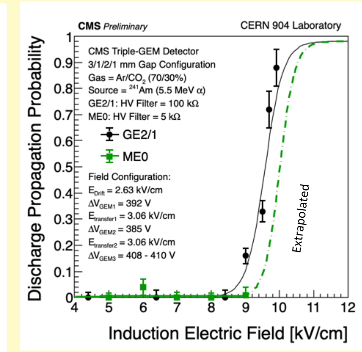

Fig. 7.d

Figure 8: Discharge propagation probability versus the HV filter resistance for applied induction electric fields of 8 kV/cm on ME0 (green) and 10x10 cm^2 (black) triple GEM muon detector. The green curve is produced by fitting the data using the error function down to 5 kΩ and by extrapolation over the region lower than 5 kΩ.

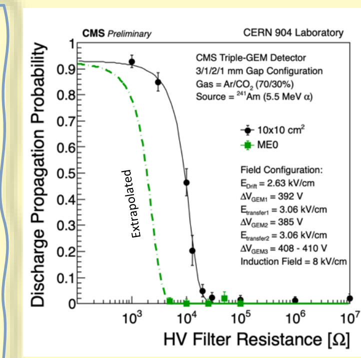

Fig. 8

Conclusion

In the scope of ME0 rate capability studies, we have measured the impact of the new design of the second generation on the discharge propagation probability behavior. Based on our recent measurements using ME0 without electronics installed, we have confirmed that the azimuthal segmentation and lowering the filter resistance from 100 to 5 kΩ do not have any significant impact on the discharge propagation. In addition, the size of HV segments in ME0 is smaller than that of GE2/1, which makes the ME0 chamber more resistant to discharge propagation. The next step will be to perform the same discharge propagation measurements with electronics installed and to confirm that dissipated discharge energy due to the new design/configuration will not cause any damage to the electronics.