

Commissioning and operation in magnetic field of CMS

GE1/1 station

Simone Calzaferri¹

on behalf of the CMS Muon Group

¹INFN sezione di Pavia

simone.calzaferri@cern.ch



1. The muon system upgrade

In the context of the High Luminosity Large Hadron Collider (HL-LHC) program, in 2018 the CMS experiment started an upgrade campaign of its muon spectrometer. In particular, from July 2019 to September 2020, the installation of the GE1/1 station, based on the Gas Electron Multiplier (GEM) technology took place [1][2]. This station is installed in the experiment endcaps and covers the $1.55 < |\eta| < 2.18$ pseudorapidity region. The purposes of this station are to increase the muon spectrometer redundancy, to sustain the high radiation and to keep under control the trigger rate in the endcap region.

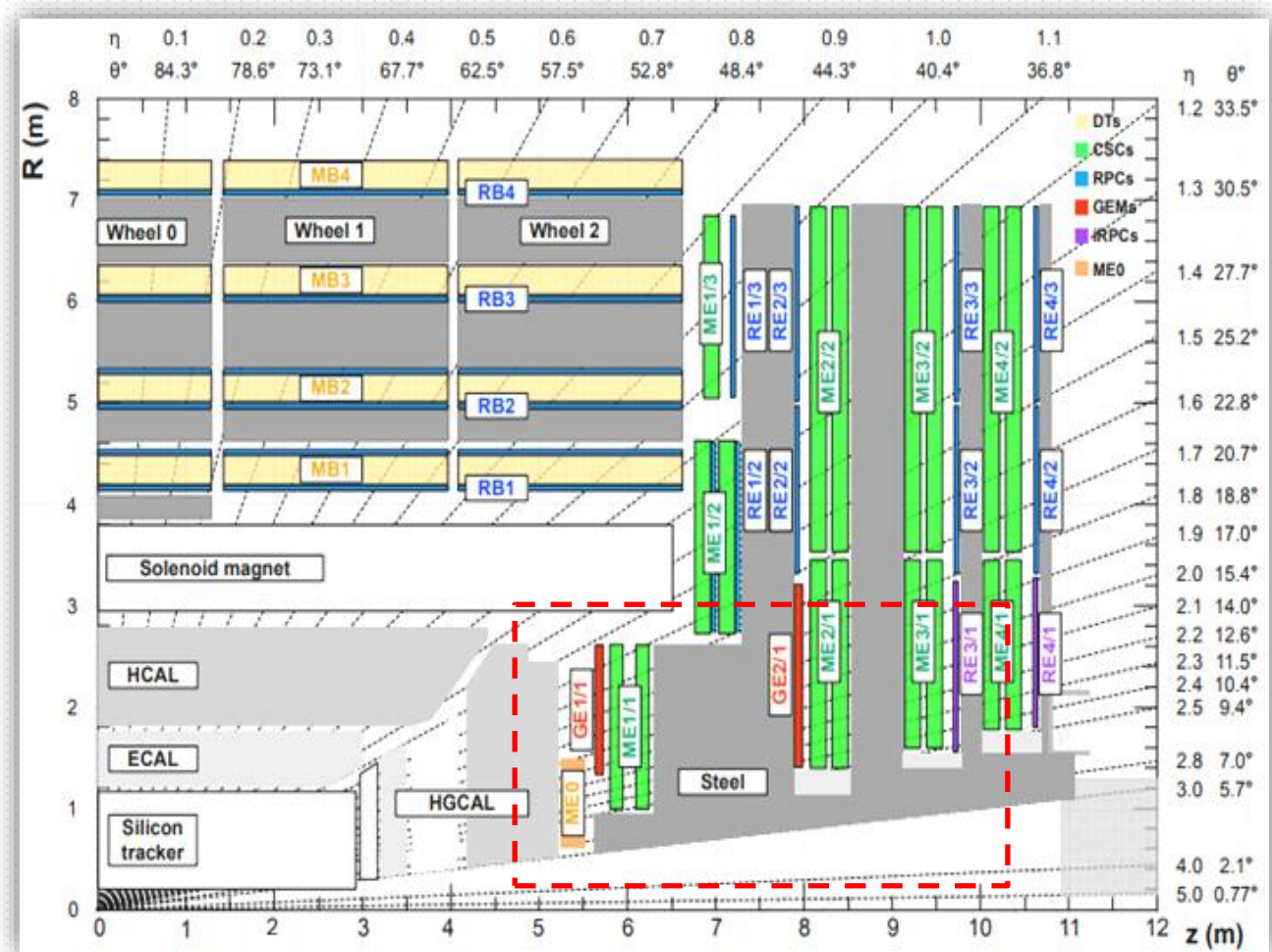


Figure 1. An R-z cross section of a quadrant of the CMS detector, including the Phase-2 upgrades (RE3/1, RE4/1, GE1/1, GE2/1, ME0).

2. Test of GE1/1 chambers at Goliath magnet at CERN North Area

During the first operations of CMS magnet, GE1/1 experienced the occurrence of many discharges, which triggered trips on high voltage (HV) channels. A test aimed at reproducing the unstable behaviour was set up with the Goliath magnet in the CERN North Area [3]. The final goal was to define a safe and smooth operational procedure for the detectors installed in the experiment. During the test 4 GE1/1 spare chambers were installed inside the Goliath magnet and the HV was provided with 4 independent cables from 2 A1515 boards.



Figure 2. GE1/1 chambers inside Goliath magnet

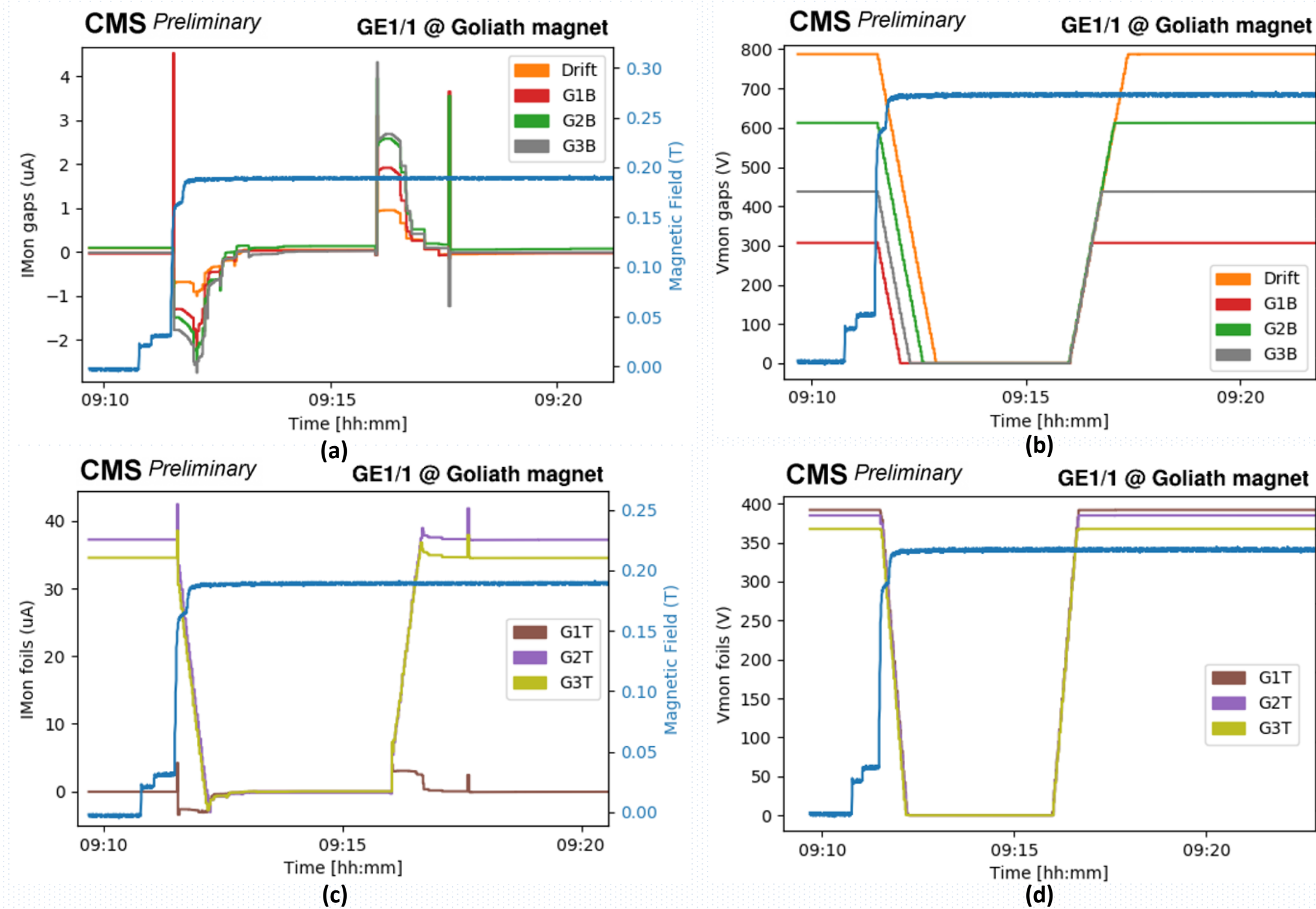


Figure 3. Current and voltage data read from A1515 board channels

3. Current and voltage data from A1515 board

During the test many magnetic field variations were performed, adopting at the same time different chambers' parameters. The current and voltage observed on the A1515 board for the 7 HV electrodes powering the chambers have been monitored. The scheme of HV electrodes for a GE1/1 detector is reported in Fig. 4.

From plots in Figure 3a and 3c, the occurrence of discharges can be identified as a current spike. HV ramp up and ramp down are instead visible in Figure 3b and 3d; they are also characterized respectively by positive and negative currents shown in Fig. 3a and 3b at the same time. A ramp down can be triggered by the occurrence of a discharge overcoming a protection threshold called I_0 in the A1515 board settings, in an event called trip, such as for the discharge illustrated in Fig. 3 at time 9:12. In addition, this chamber presents a short circuit in the second and third GEM foil, resulting in a high baseline current for G2T and G3T HV channels when HV is applied (Figure 3c).

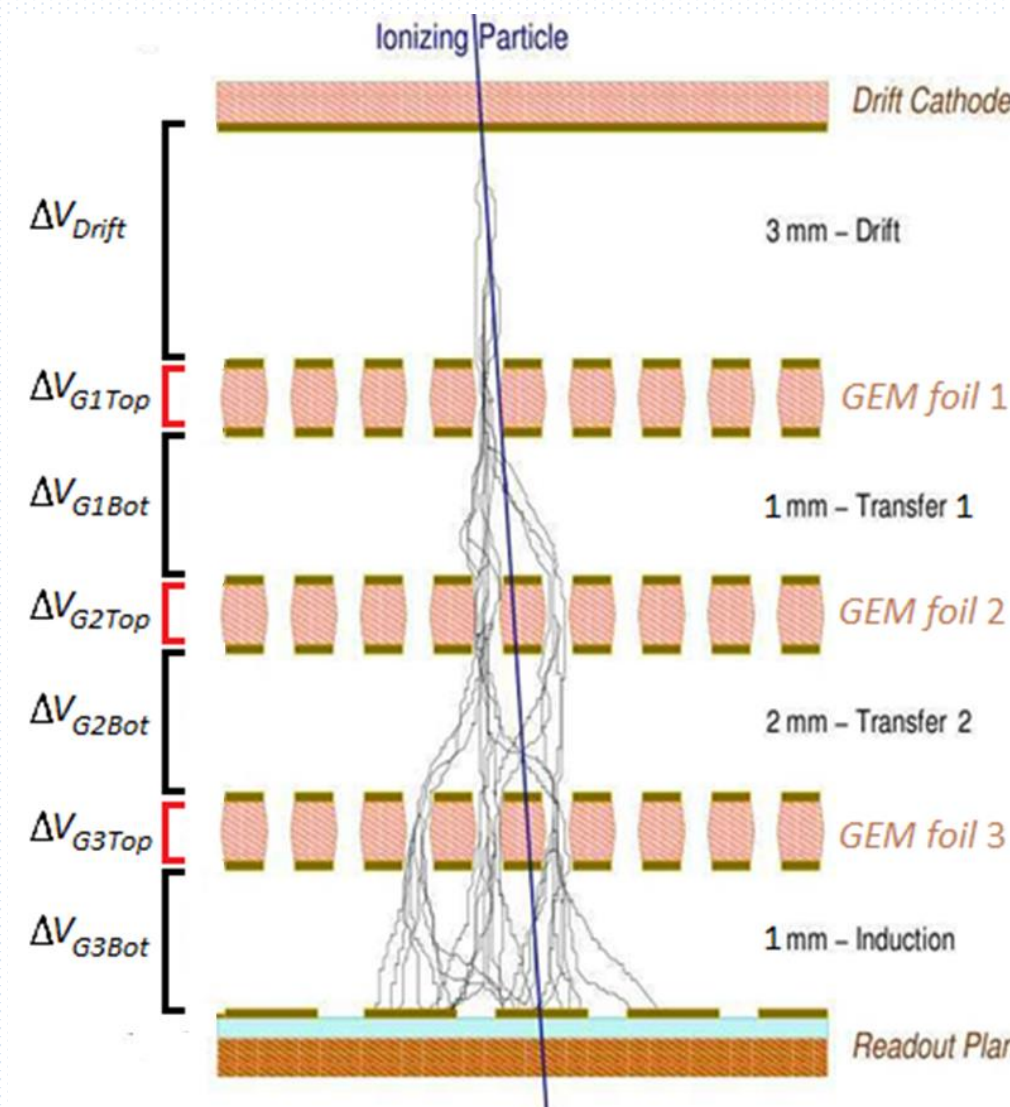


Figure 4. Scheme of HV electrodes in a GE1/1 detector

4. Discharges and cross talk ratio

In Figure 5, the distribution of currents observed at the occurrence of a discharge on each electrode and the maximum per each discharge event (AbsMax) is represented. Fig. 6 shows instead the fraction of discharge events overcoming a given threshold. These information are useful to tune the I_0 threshold to trigger a trip only when really needed.

When a discharge occurs in one chamber, a small induced current is observed on the other chamber powered with the same A1515 board. This phenomenon, known as cross talk was measured and the result is displayed in Fig. 7: it's clear that the electrodes more prone to cross talk are the closest to the ground. The collected data have shown as the cross talk phenomena will not represent anyway a problem for chambers operation, setting an adequate I_0 threshold ($> 2 \mu A$).

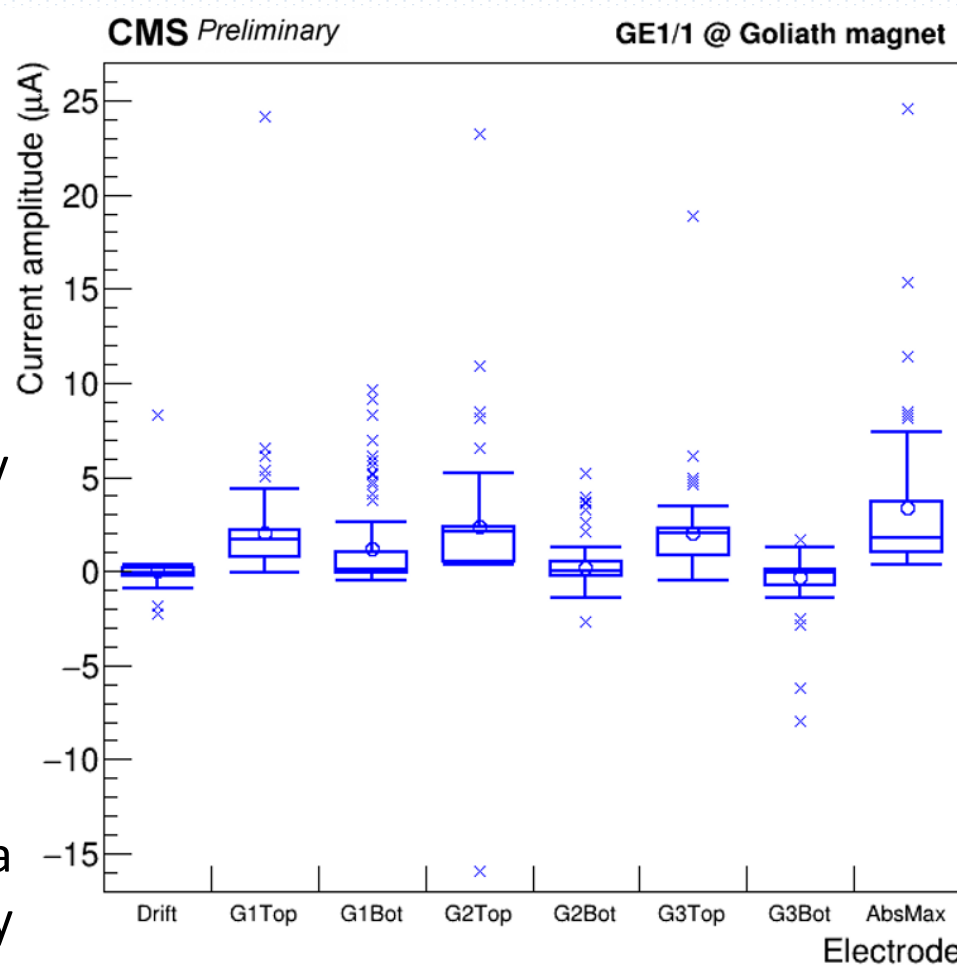


Figure 5. Current values observed at discharge instant, for each electrode and the maximum for discharge event (AbsMax)

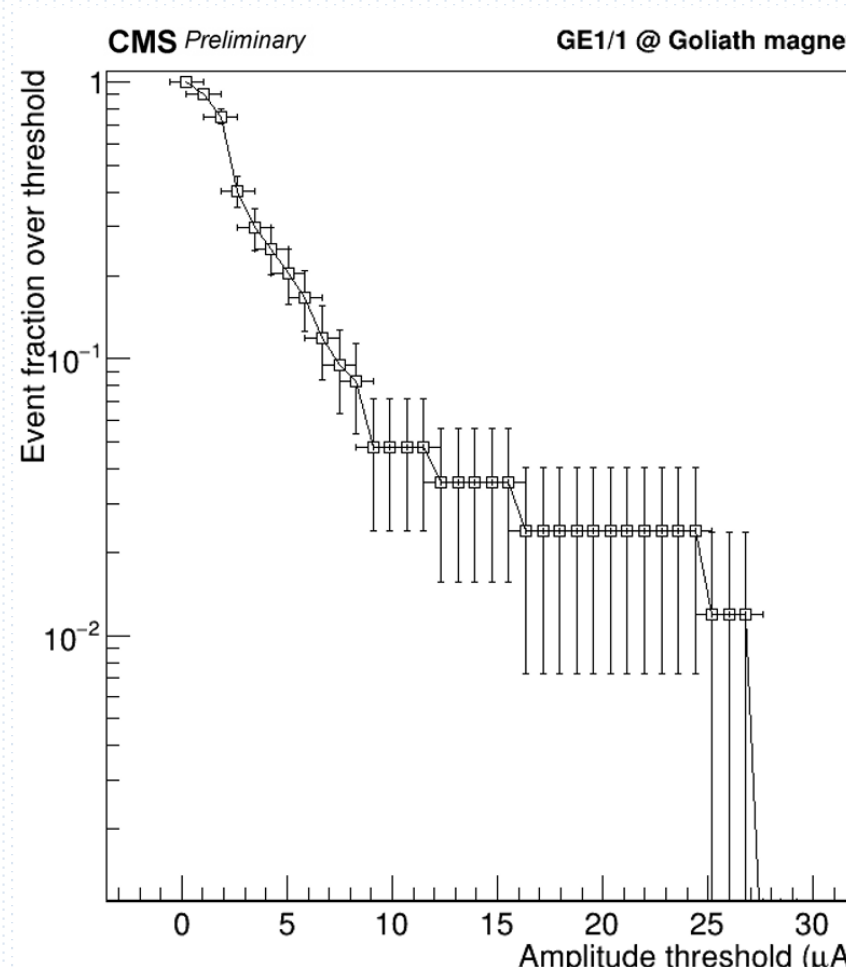


Figure 6. Fraction of discharges overcoming a given current threshold

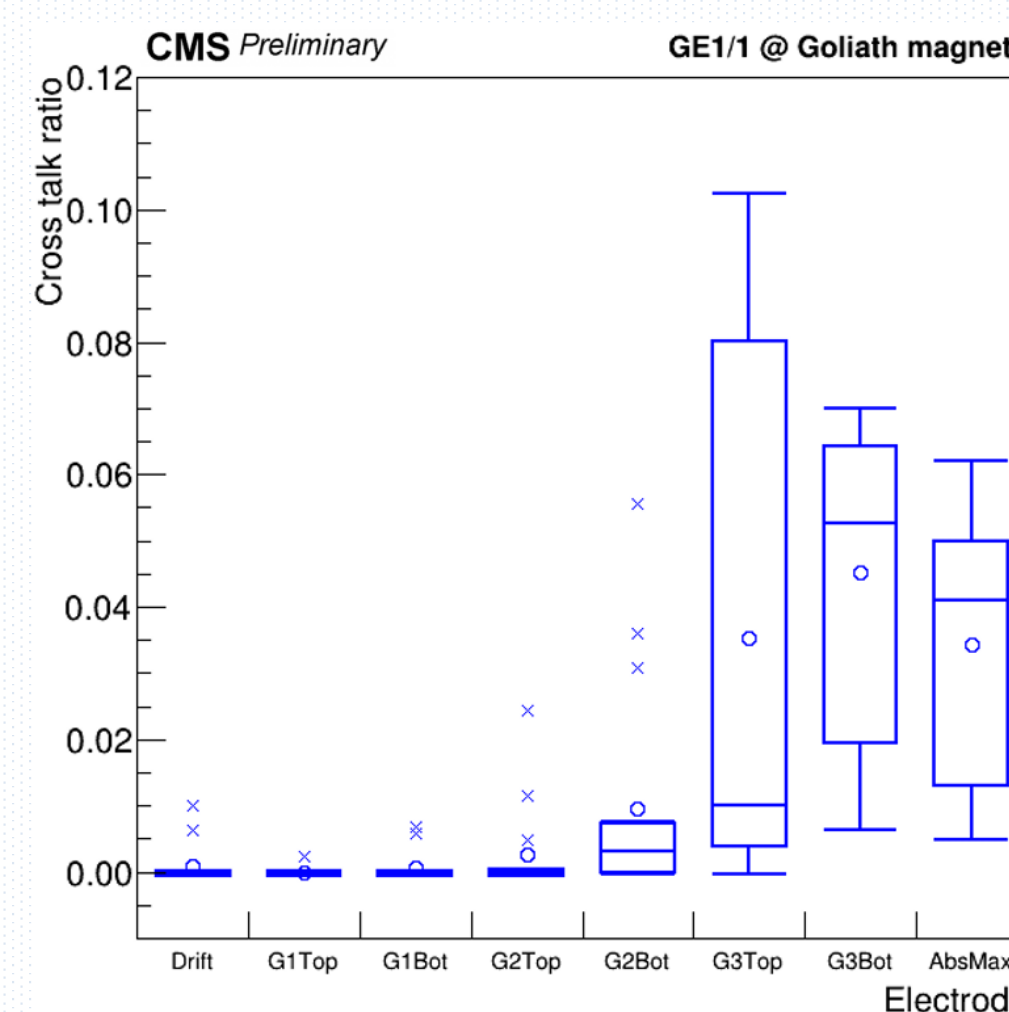


Figure 7. Cross talk ratio among chambers powered by the same A1515 board

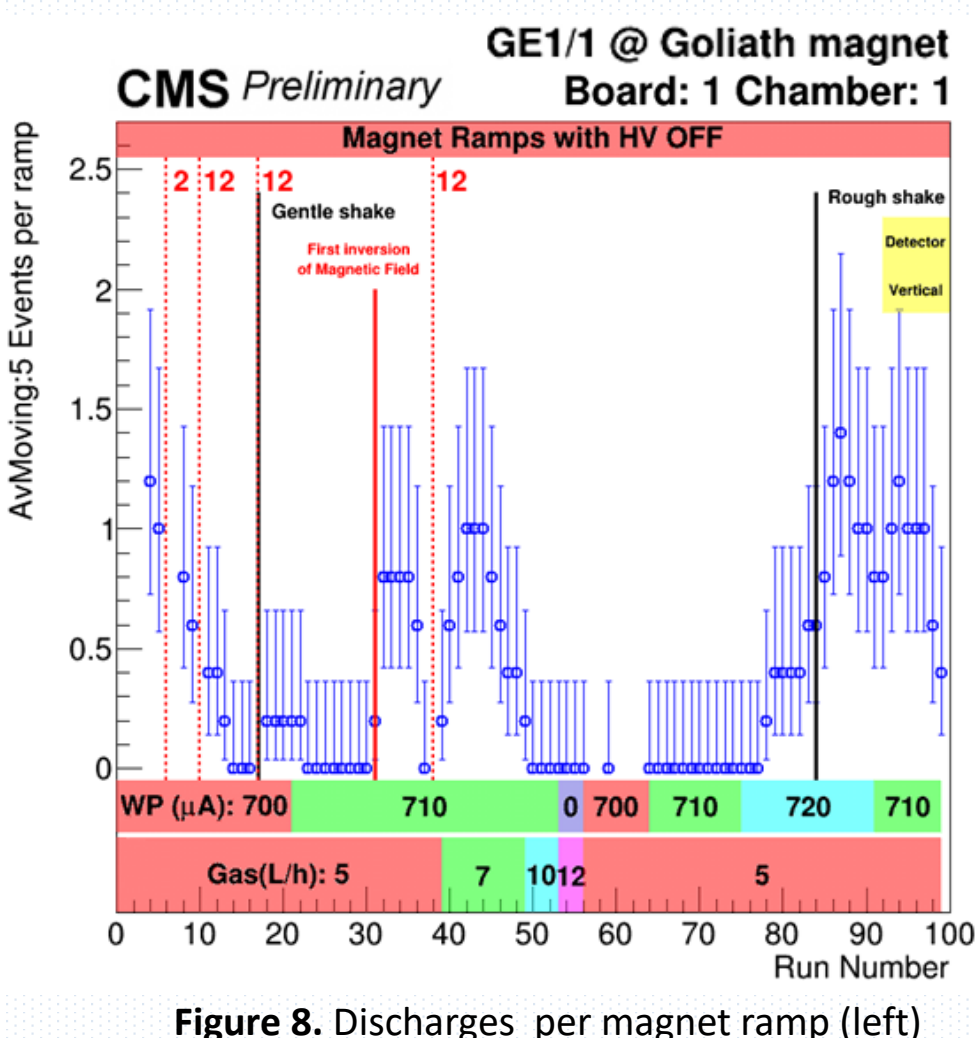


Figure 8. Discharges per magnet ramp (left)

5. Discharge rate evolution during the test

Figure 8 shows the evolution of the discharge rate during the test, using a moving average of 5 magnet ramps. The rate of discharge decreases with the increase of the number of magnet ramps performed, while it increases when a mechanical stress is applied (as in CMS during disk movements) or when magnetic field sign is inverted for the first time in the test. These observations are compatible with the hypothesis of dust hidden inside the detectors and moved by the magnetic field variation. When the dust reaches a GEM hole, it can trigger a discharge and it is consequently burned. In addition, discharge occurrence seems to be not affected by gas flux or HV working point.

Magnetic field ramps were also performed while the HV was off and are indicated by the red vertical dashed lines: this operation induced a short circuit in one sector of one GEM foil in one of the chambers. We calculate then a short production probability of $p_{\text{short}} = 2.6^{+6.0}_{-2.2}\%$ (CL = 68%). This short circuit was then burned applying 1000 V with a MEGGER.

[1] Colaleo, A et al., CMS Technical Design Report for the Muon Endcap GEM Upgrade, CERN-LHCC-2015-012

[2] F. Sauli, The gas electron multiplier(GEM): operating principles and applications, Nuclear Instruments and Methods in Physics Research A805 (2016) 2-24.

[3] Rosenthal, Marcel et al., Magnetic Field Measurements of the GOLIATH Magnet in EHN1, CERN-ACC-NOTE-2018-0028

6. Conclusions

Observations performed during the Goliath test suggest that a short is created when the dust and other residuals are not immediately burned. For this reason, the suggested actions are the following:

- keep the HV on the foils ON during the magnet ramps, in order to burn the dust as soon as it starts moving
- increase the I_0 threshold in such a way that the HV trip is triggered only when there is a huge and dangerous discharge, allowing instead the smaller ones useful to burn residuals.