Analysis of discharge events in the CMS GE1/1 GEM detectors in presence of LHC beam

Simone Calzaferri[1]

on behalf of the CMS Muon Group

[1]*INFN sezione di Pavia*

simone.calzaferri@cern.ch

Istituto Nazionale di Fisica Nucleare

1. The CMS GE1/1 station

- **Purpose:** increase the muon spectrometer redundancy, to sustain the high radiation and to keep under control the trigger rate in the endcap region.
- **144 detectors installed, paired in Super-Chambers**
  - Layer 1 = closer to beams interaction point
  - Layer 2 = farther from beams interaction point
- **Two sizes of detectors:**
  - **Short chambers:** $1.61 < |\eta| < 2.18$
  - **Long chambers:** $1.55 < |\eta| < 2.18$

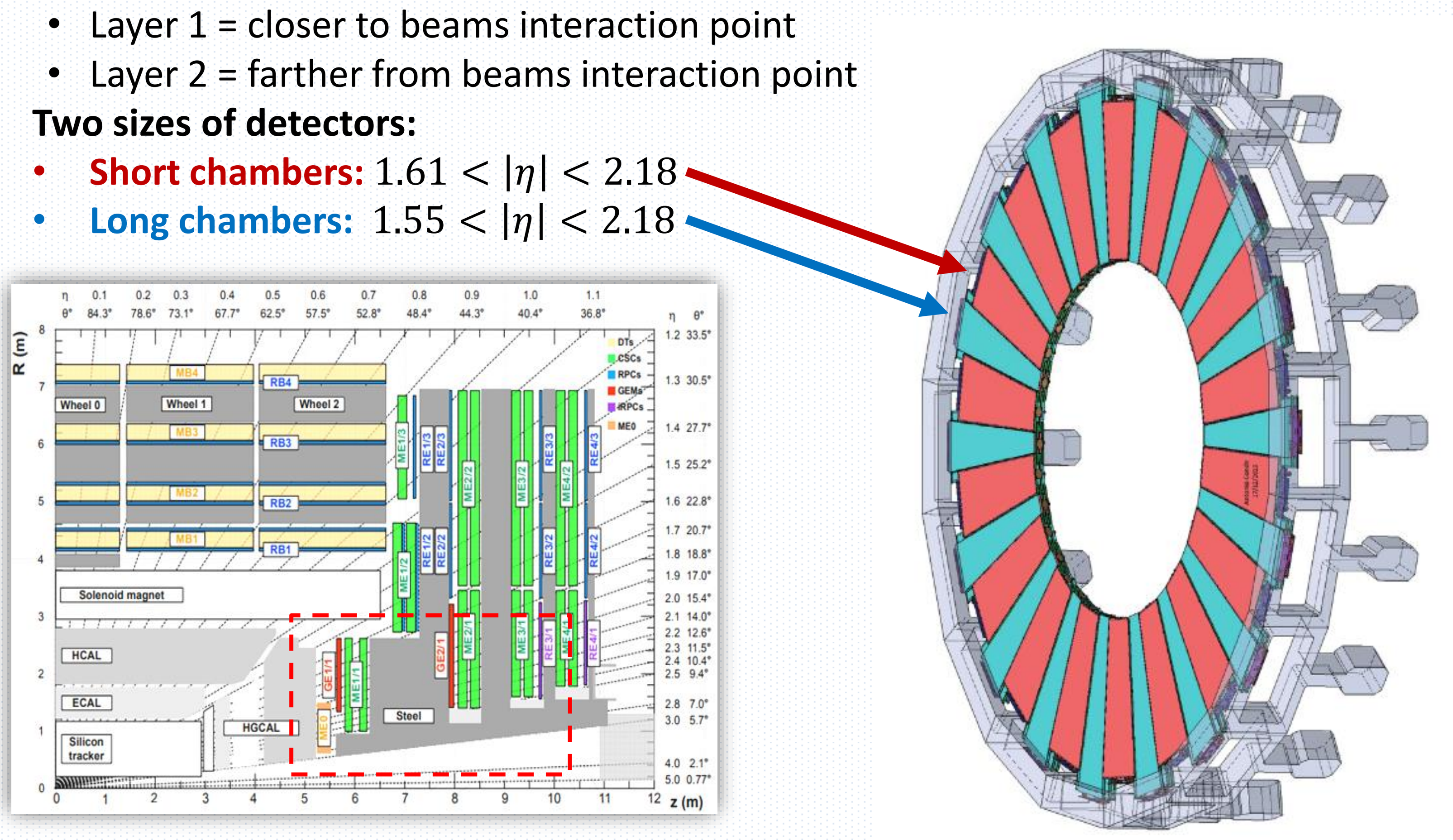


Figure 1. An $R - z$ cross section of a quadrant of the CMS detector, including the Phase-2 upgrades ($RE3/1, RE4/1, GE1/1, GE2/1, ME0$) [1][2]

2. High Voltage distribution for GE1/1 detectors

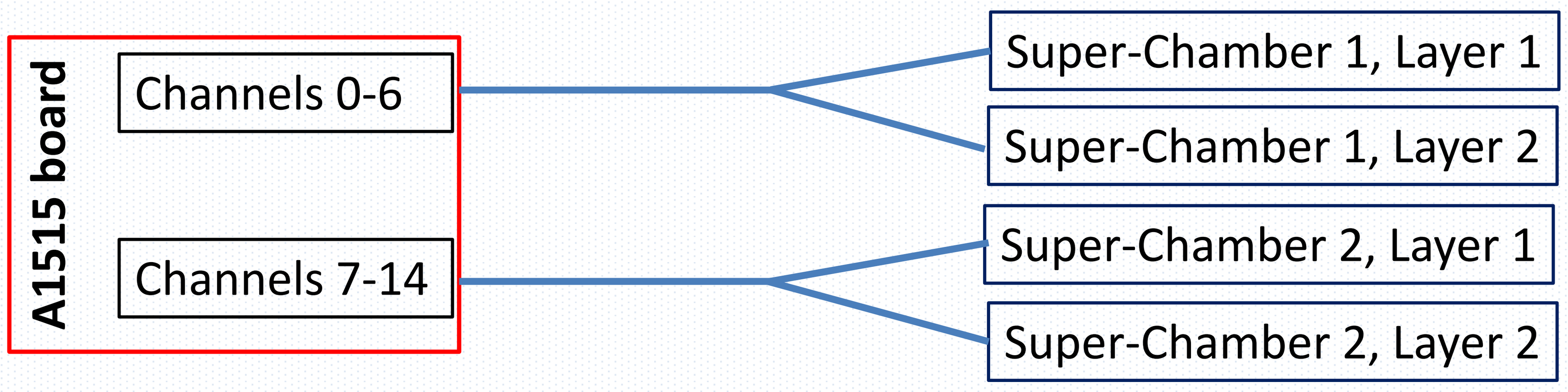


Figure 2. Original HV scheme: power one Super-Chamber (2 detectors) with a group of 7 channels of CAEN A1515 boards with the same cable

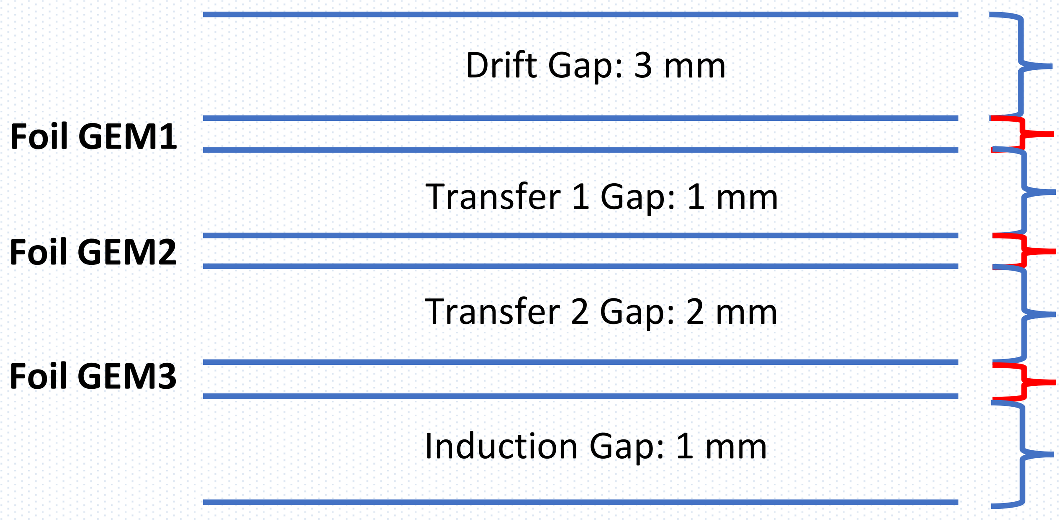


Figure 3. GE1/1 detector: three GEM foils stacked

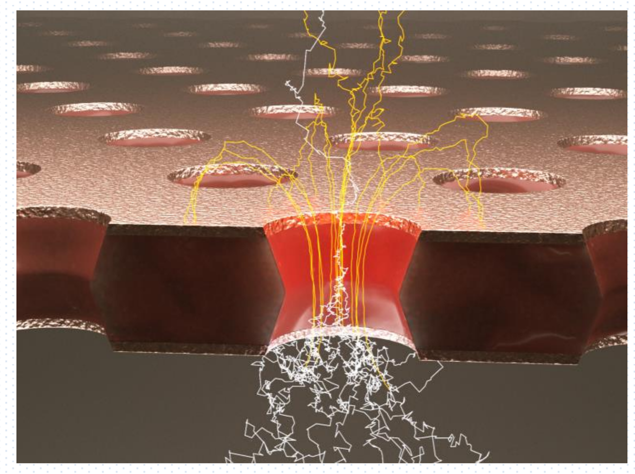


Figure 4. GEM foil:
- Polyimide foil: 50 µm
- Copper cladding on both sides: 5 µm

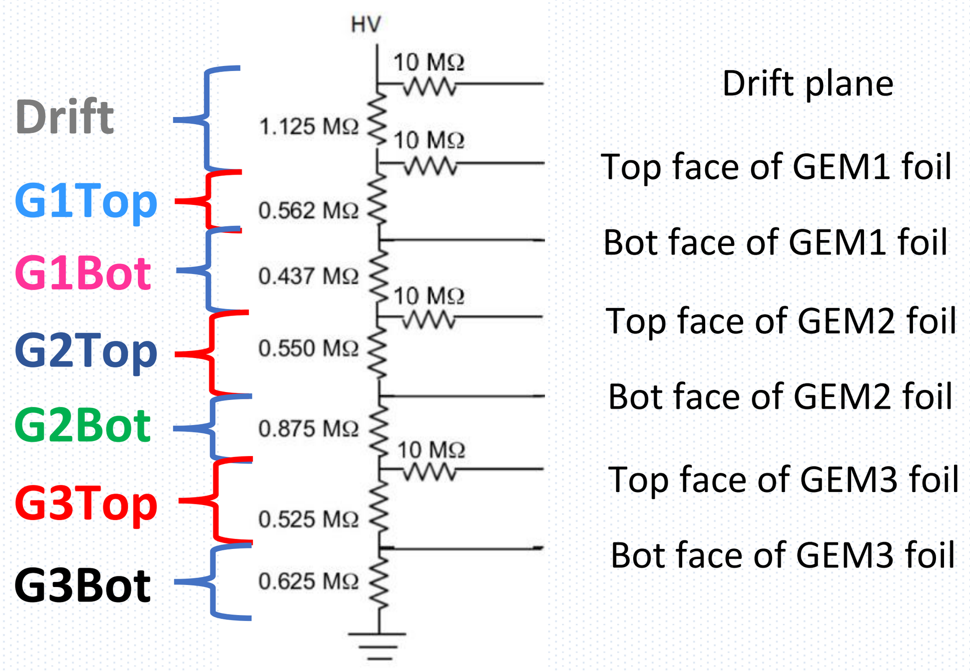


Figure 5. Voltages of operation of the 7 electrodes: set by proportions given by reference resistor divider and identified by equivalent current flowing in divider I_{eq}

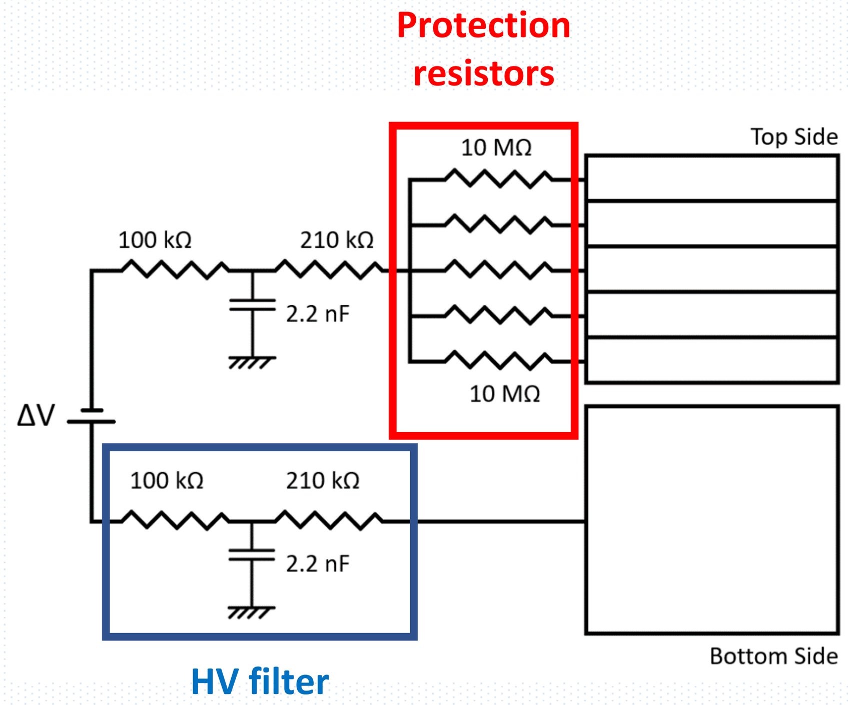


Figure 6. Segmentation of GEM foils and distribution of HV to the single GEM foil: done to power the foil also in presence of short circuits

3. Discharges in presence of LHC beam collisions

- Dicharge in one GEM foil leads to transfer of charge
- The voltage applied to the foil is altered
- The power supply reacts to restore the desired voltage, producing a spike in current

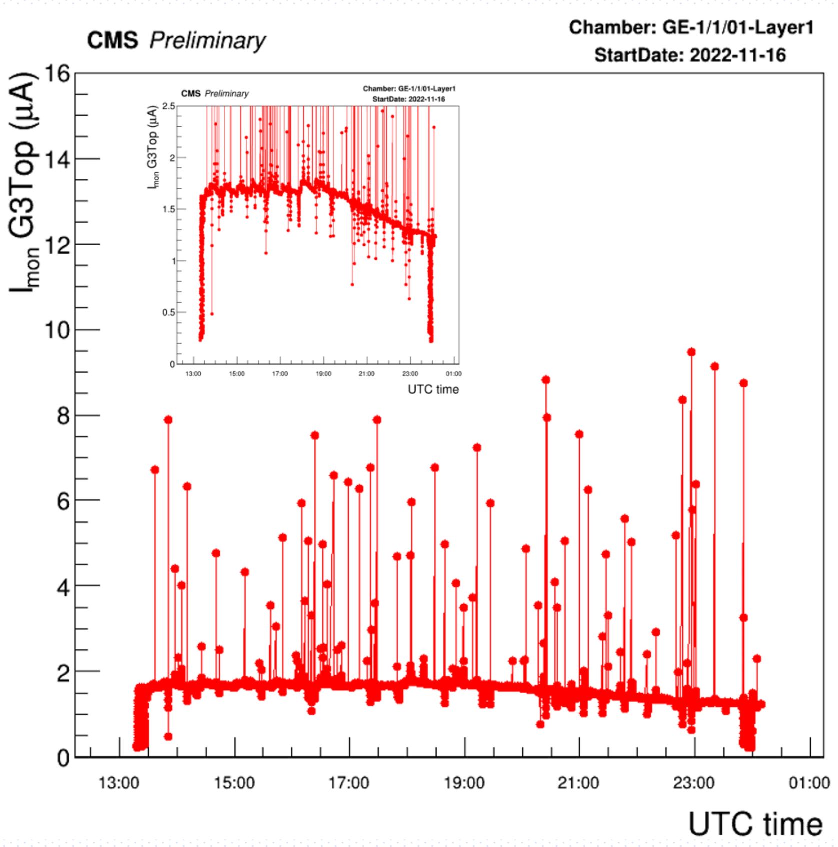


Figure 8. Example current observed on one power supply channel (G3Top) of one detector (GE-1/1/01-Layer 1) during LHC beam collisions

Discharge rate and baseline currents evolve in time with the luminosity of colliding beams!

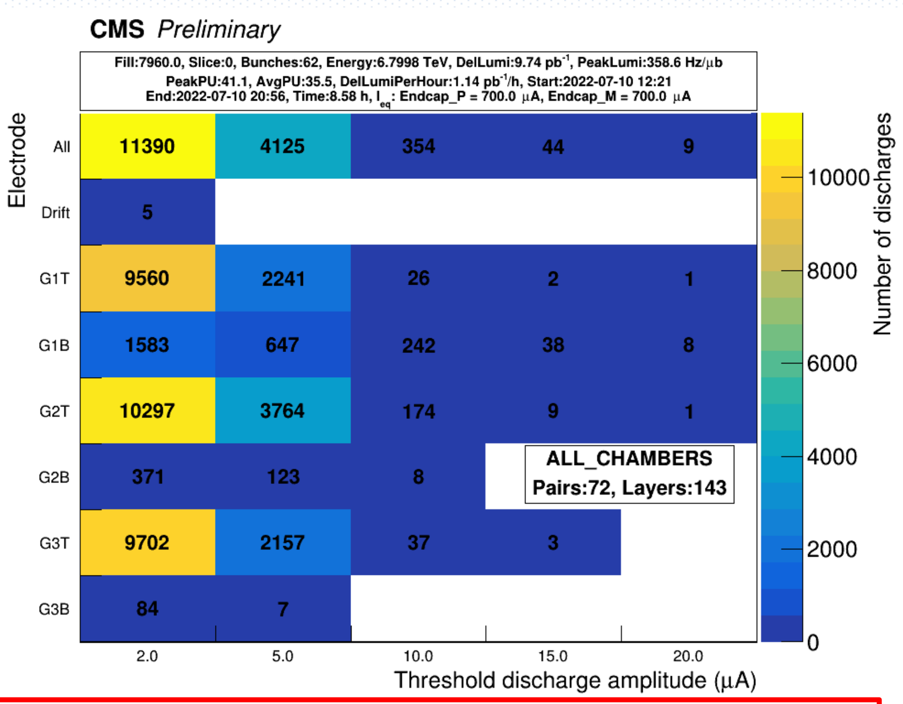


Figure 9. Number of discharges in all GE1/1 detectors per electrode in one example LHC fill (7960). Count discharges by their current amplitude over baseline currrent.

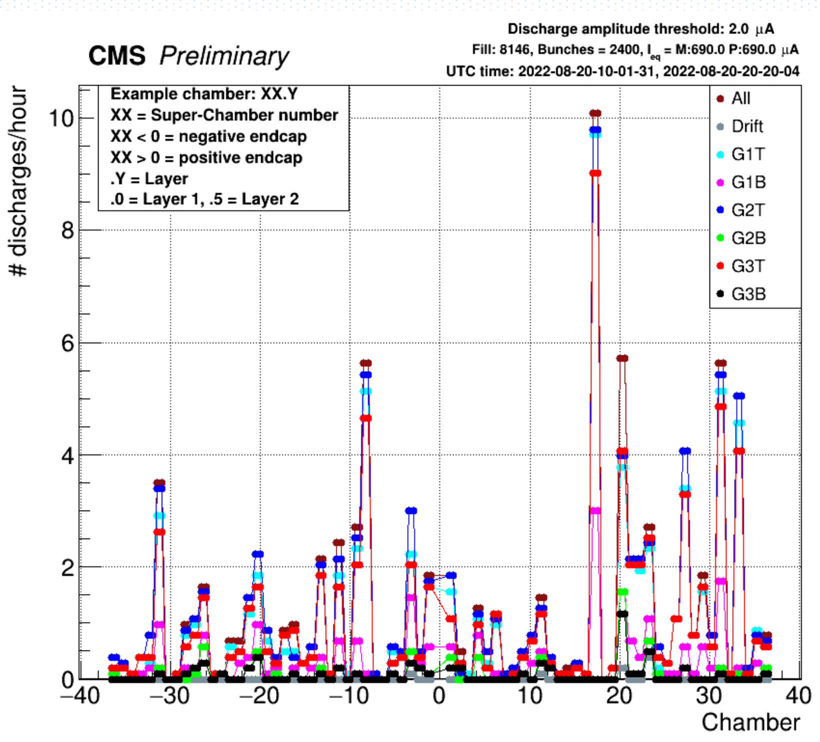


Figure 10. Discharge rate per chamber during one example LHC fill (8146). The discharge rate is different chamber per chamber and evolves in time.

GE1/1 operations in 2022:

- 5th July - Start of Run-3 collisions (HV working point $I_{eq} = 700\ \mu A$.
- 7th July - 8 colliding bunches, frequent protection turn off of HV (HV trip) due to discharges → Increased turn off protection parameter I_0 from $2\ \mu A$ to $10\ \mu A$.
- 10th July - Turn off of G3Bot to protect electronics from discharge propagation
  - Start of tuning of HV working point
- 4th August - $I_{eq} = 690\ \mu A$ with G3Bot off, discharge rate stabilized
- 11th August – Chamber fully on $I_{eq} = 690\ \mu A$
- 24th August stop of collisions due to LHC problems
- October and November: $I_{eq} = 690\ \mu A$
  - 7-16th October HV scan to assess chambers efficiency

4. Short circuits in GE1/1 detectors

- Contexts of generation of shorts: GEM foil HV training, CMS disk movement, ramp of CMS magnet, discharges in presence of LHC beam collisions
- HV remapping introduced on 26th October 2022 to handle short circuits

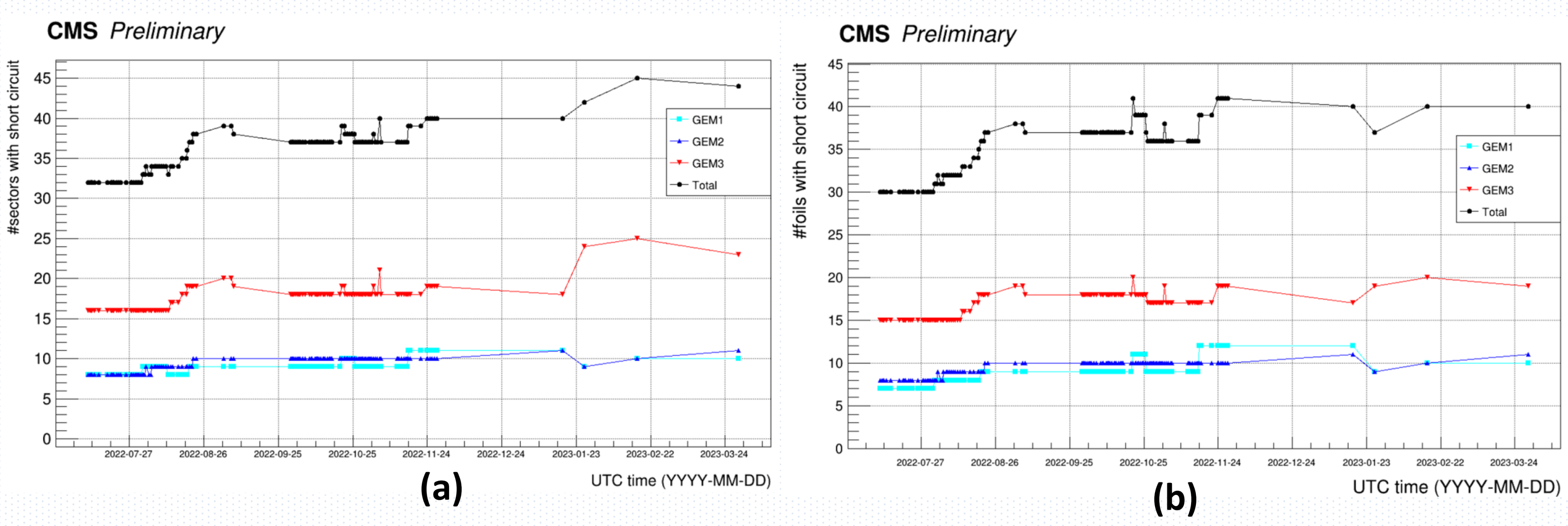
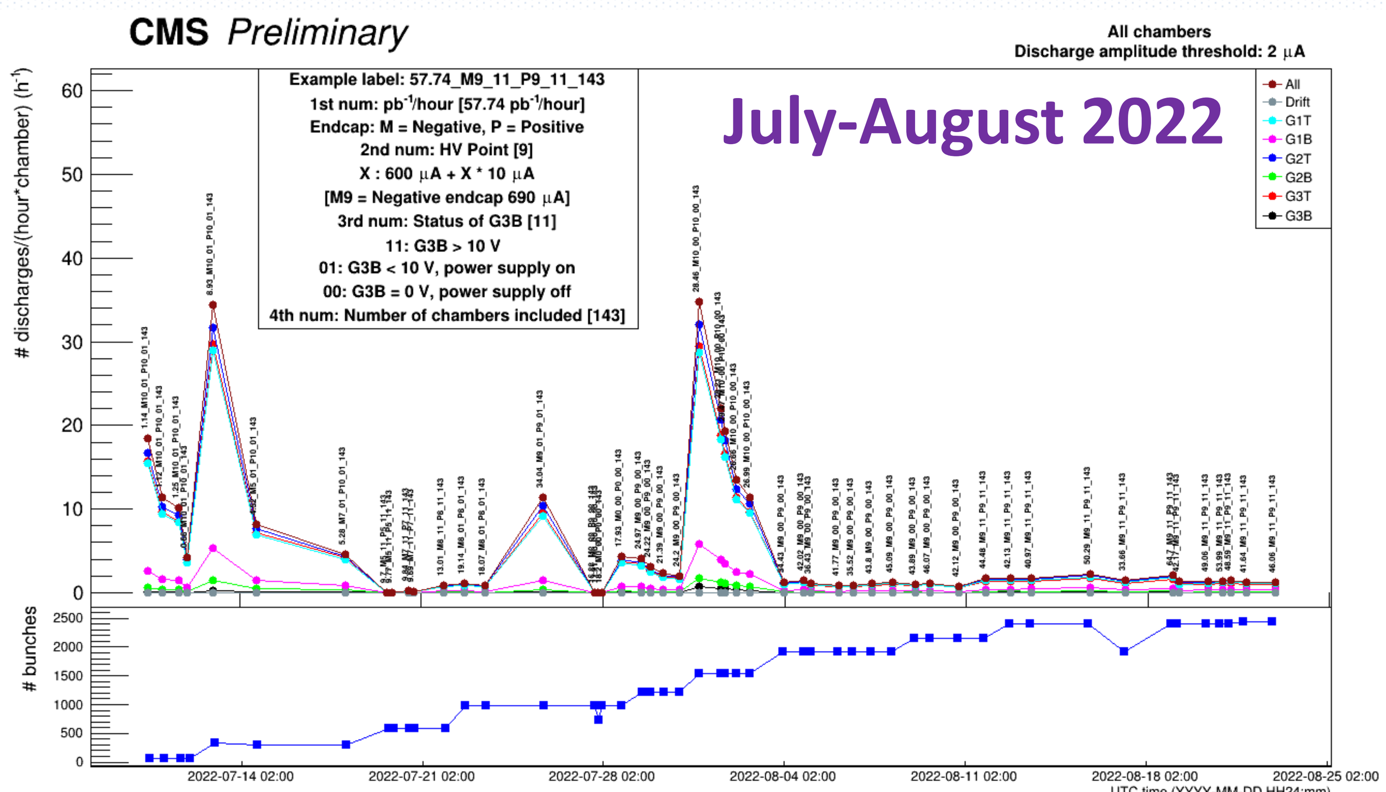
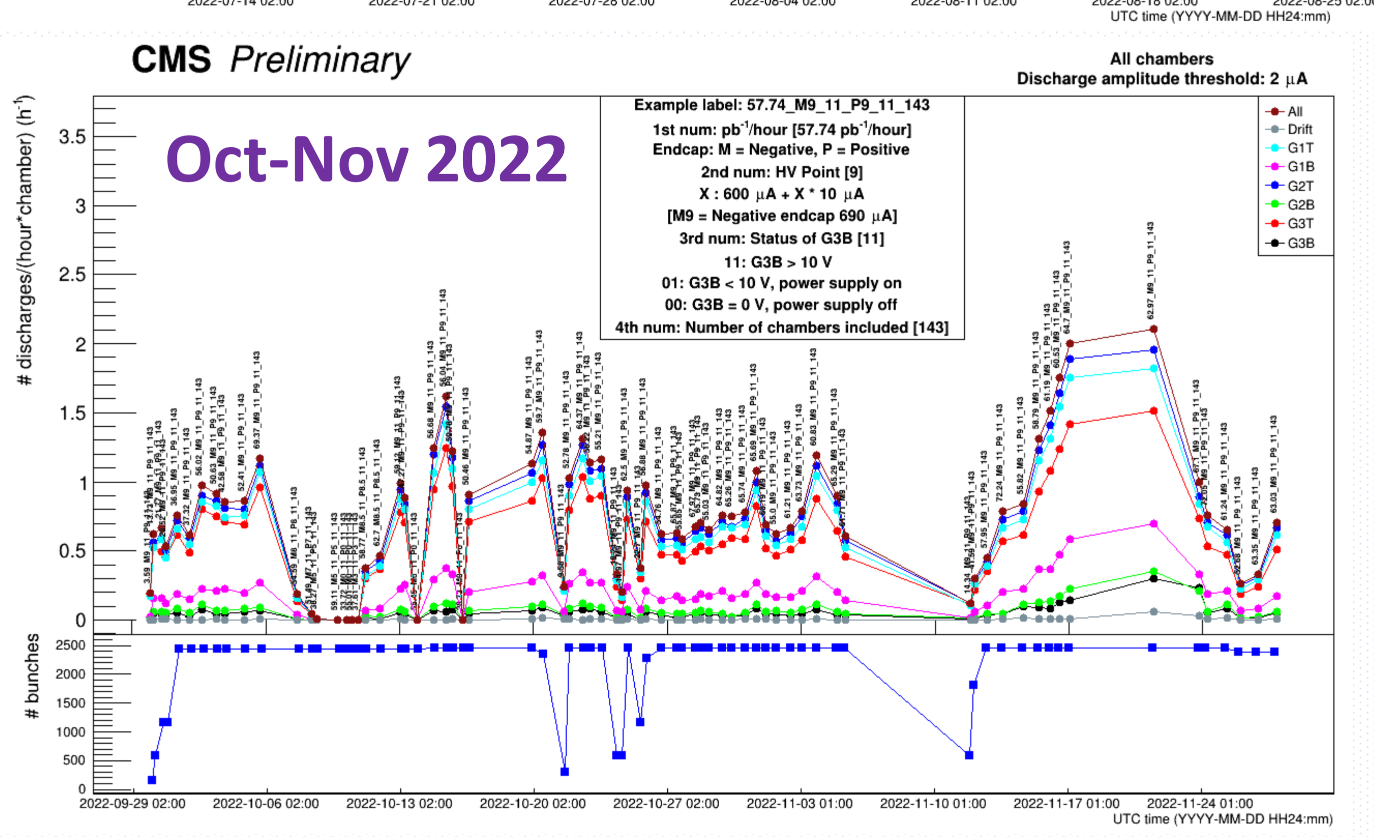


Figure 7. Evolution in number of short circuits from July 2022 to March 2023: (a) number of HV sectors affected by short circuit, (b) number of GEM foils affected by at least one short circuit

5. Evolution of discharge rate per hour per chamber during operations





6. Conclusion

- HV working point varied during 2022 operations
  - High discharge rate at $I_{eq} = 700\ \mu A$ (~ 30 discharges/(hour*chamber))
  - Stabilization of discharge rate at : $I_{eq} = 690\ \mu A$
  - Stable rate during October and November 2022 (< 2 discharges/(hour*chamber))
- Future step: implementation of compensation of gain losses due to short circuits
  - Possible thanks to remapping of HV system

[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.