Study of discharges in the CMS GEM GE1/1 station with LHC beam

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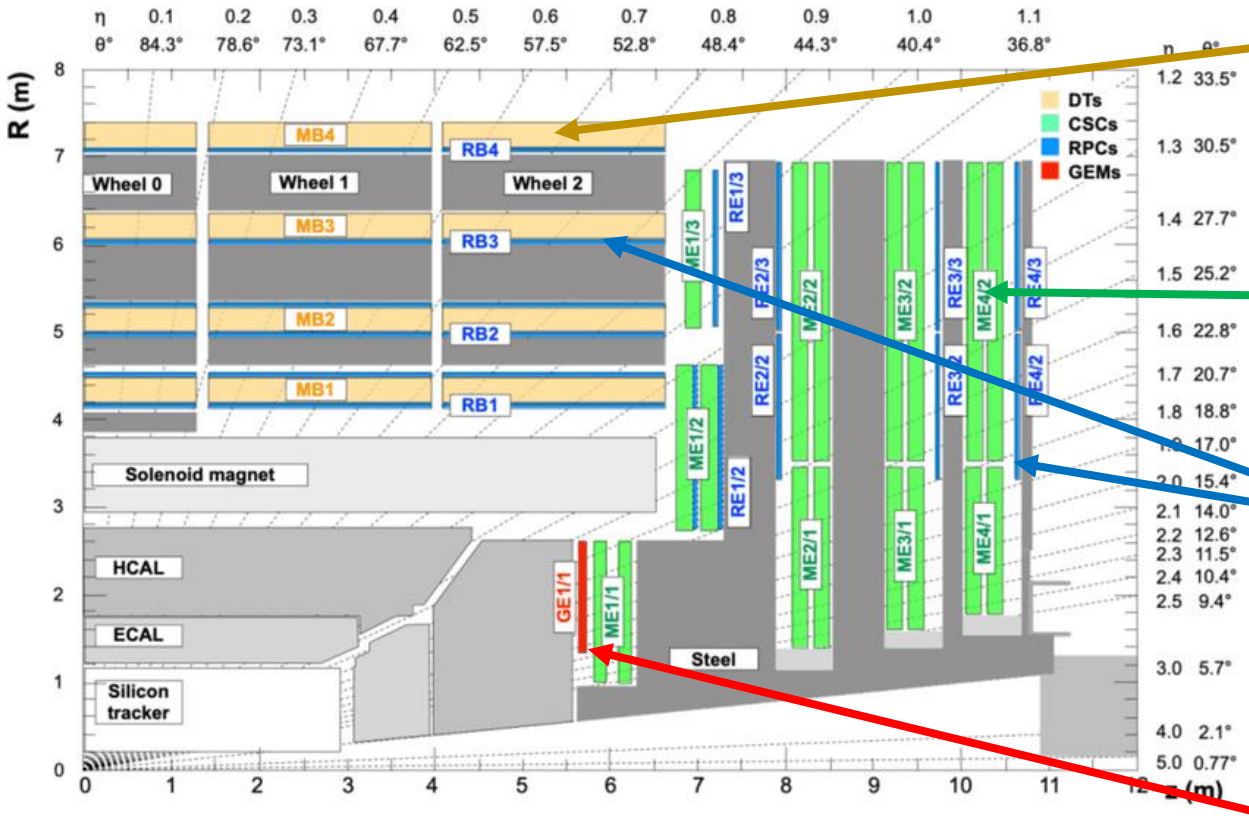
On behalf of the CMS Muon Group

The CMS muon system



DT: Drift Tubes

Coverage: |η|<1.2

CSC: Cathode Strip Chambers

Coverage: $0.9 < |\eta| < 2.4$

RPC: Resistive Plate Chambers

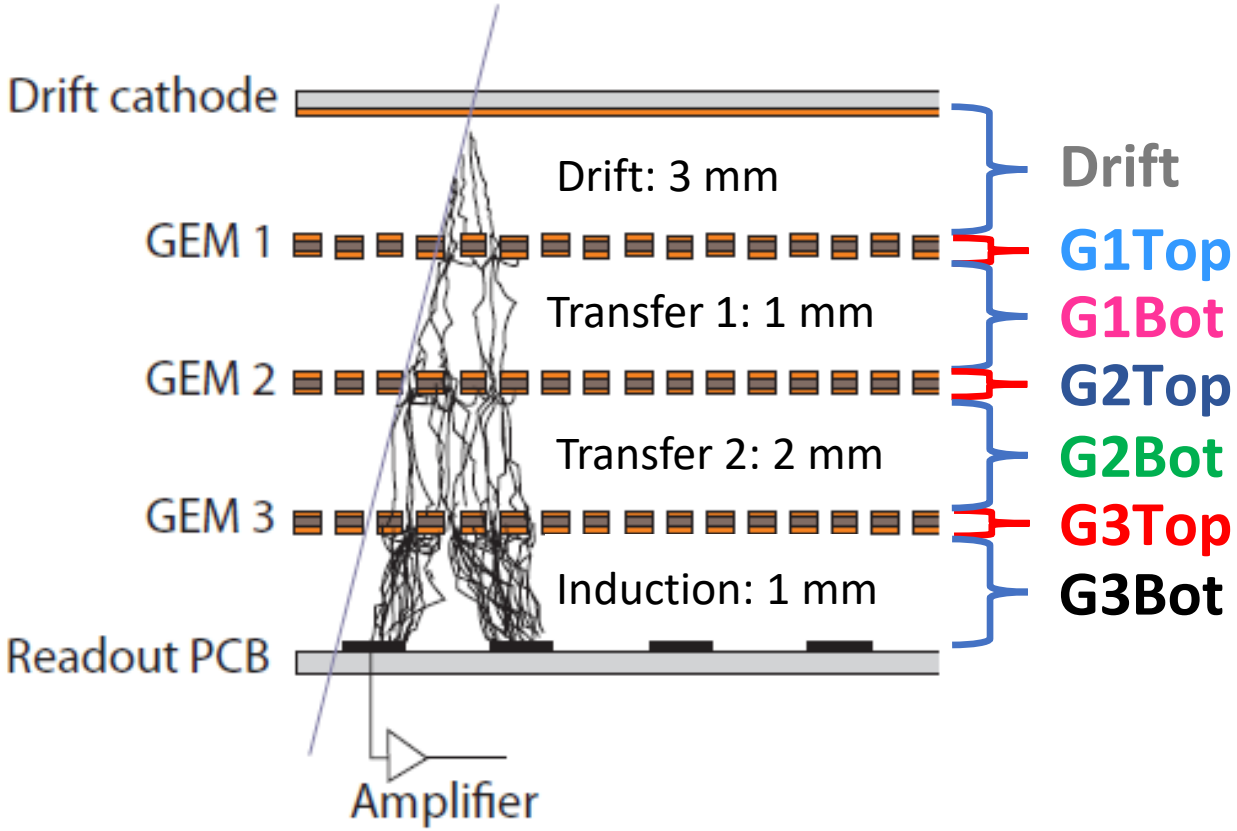
Coverage: |η|<1.9

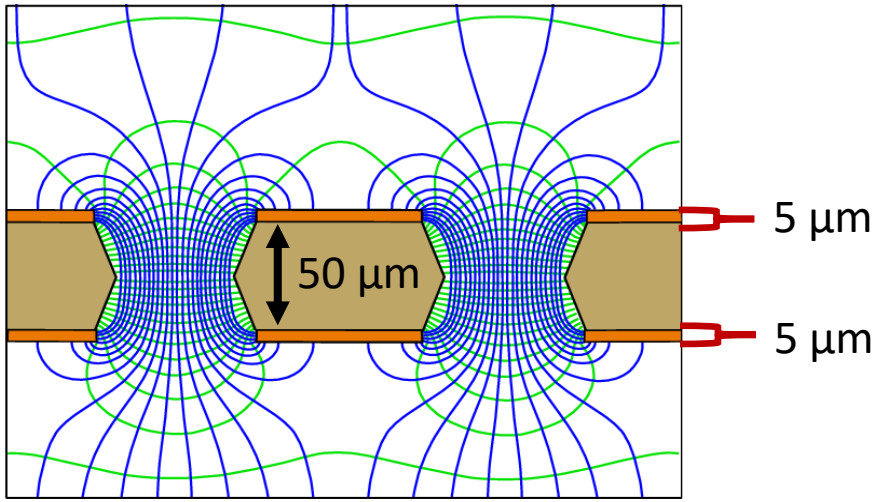
GEM: Gas Electron Multiplier

Coverage GE1/1: 1.55 < | η | < 2.18

The CMS GE1/1 station

- Triple GEM detectors
- HV provided with multichannel power supply CAEN A1515 boards

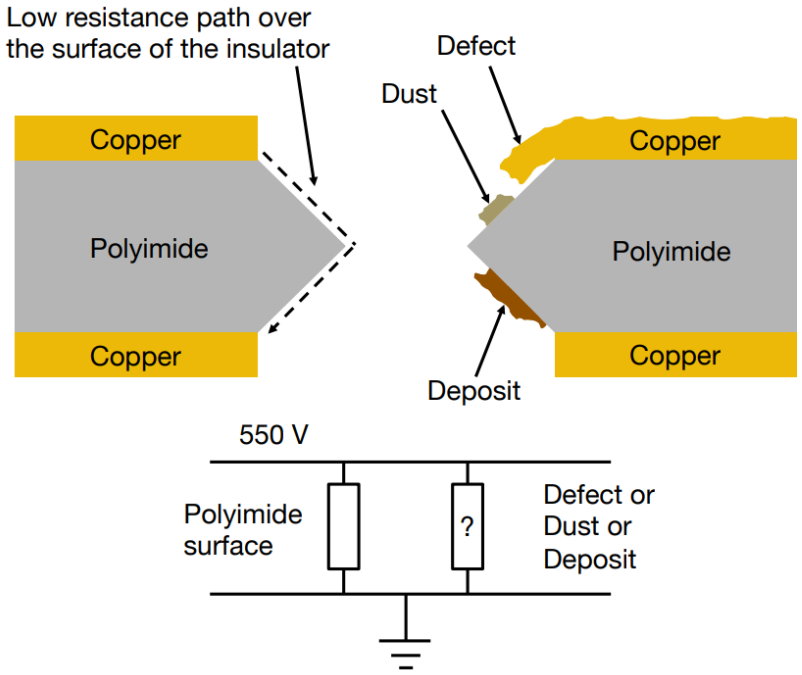




The GEM foil:

- Biconical holes
- Diameter: 70 µm
- Pitch: 140 µm
- Kapton thickness 50 µm
- Copper cladded on both sides (5 µm)

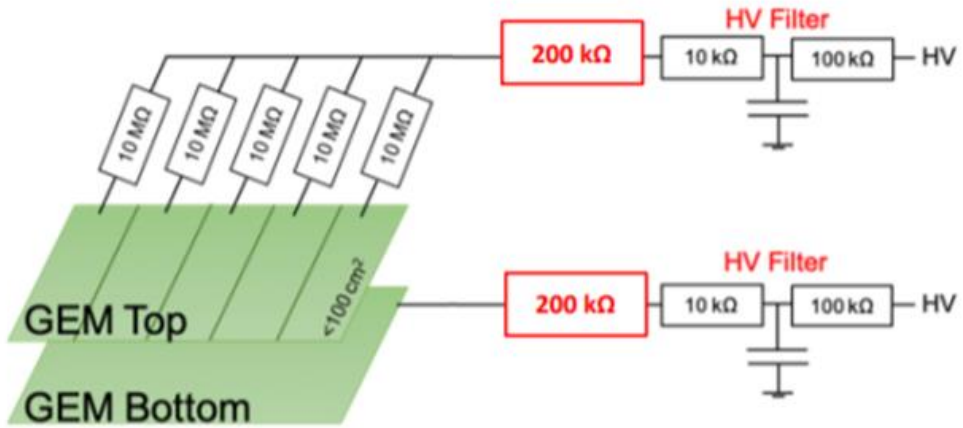
Design of HV distribution



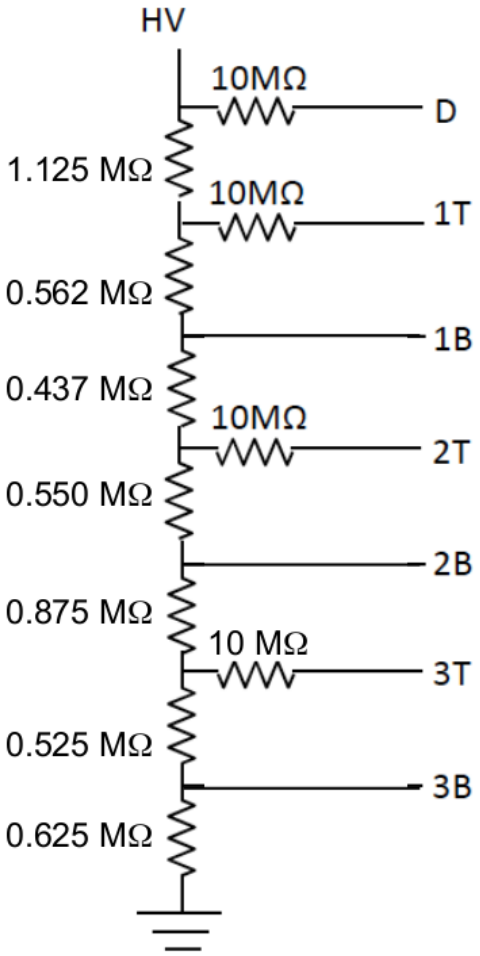
Quality Control of Mass-Produced GEM Detectors for the CMS GE1/1 Muon Upgrade
https://arxiv.org/pdf/2203.12037.pdf

Defects or depositions on GEM foil:

- Can create temporary or permanent short circuit between top and bottom face
- **Impact:** drop of the voltage applied → the foil stops amplifying the crossing electrons
- **Mitigation:** segmentation of the foil in sectors
  - if one sector deactivates the others keep operating
  - 40 (47) HV sectors in short (long) GE1/1 chambers
  - High current drained by the power supply if a short circuit is created



HV working point



- The gain of chambers is measured using a **resistive divider**
  - Fixes the ratios between voltages applied on the 7 electrodes
  - Reference for the setting of the chamber when powered with a **multichannel power supply**
    - Voltage global working point is identified by the current flowing in the reference resistive divider

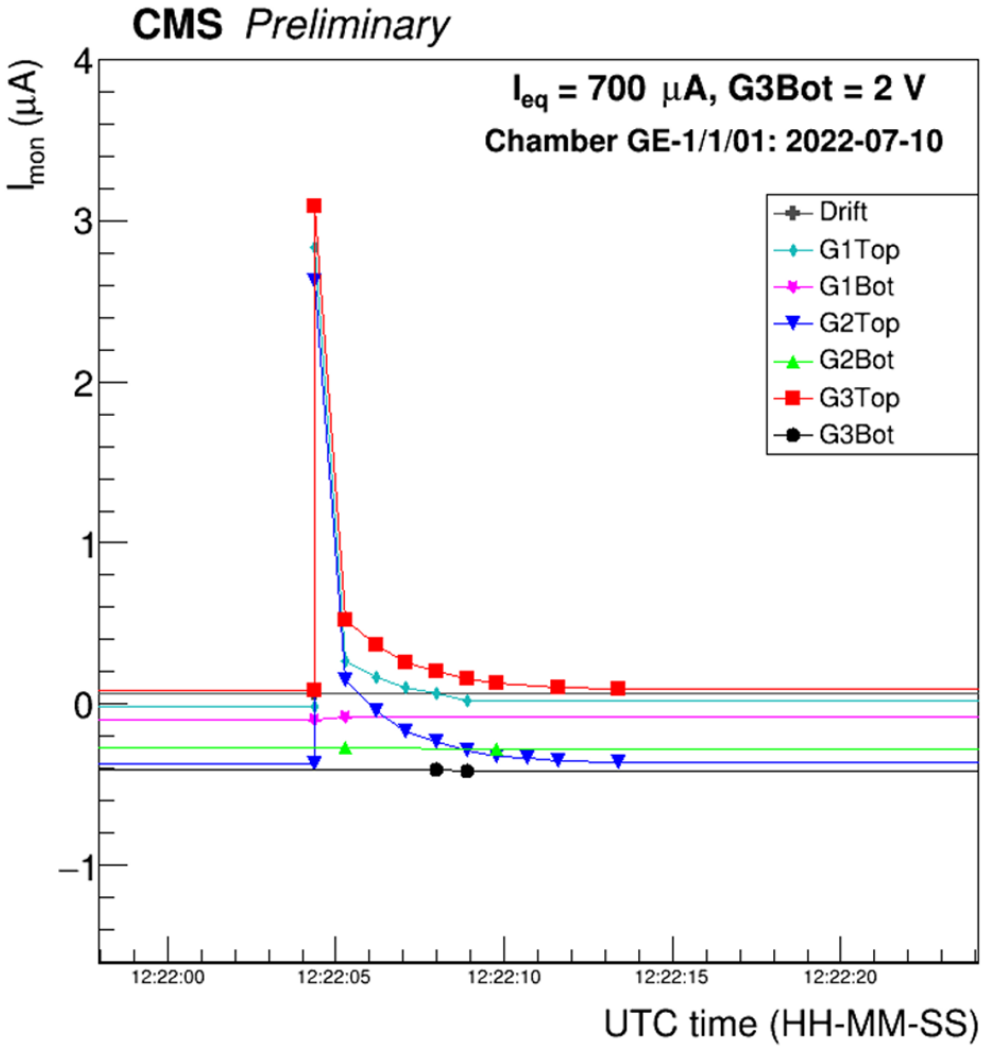
Configuration $I_{eq} = 690\ \mu A$			
Drift	776 V	**G1Top**	387 V
G1Bot	302 V	**G2Top**	379 V
G2Bot	604 V	**G3Top**	362 V
G3Bot	431 V		

Operation during first months of Run 3 (1)

5th July 2022 – First collisions in LHC

7th July 2022 – GE1/1 detectors chambers started to experience frequent HV trips (8 bunches colliding in LHC)

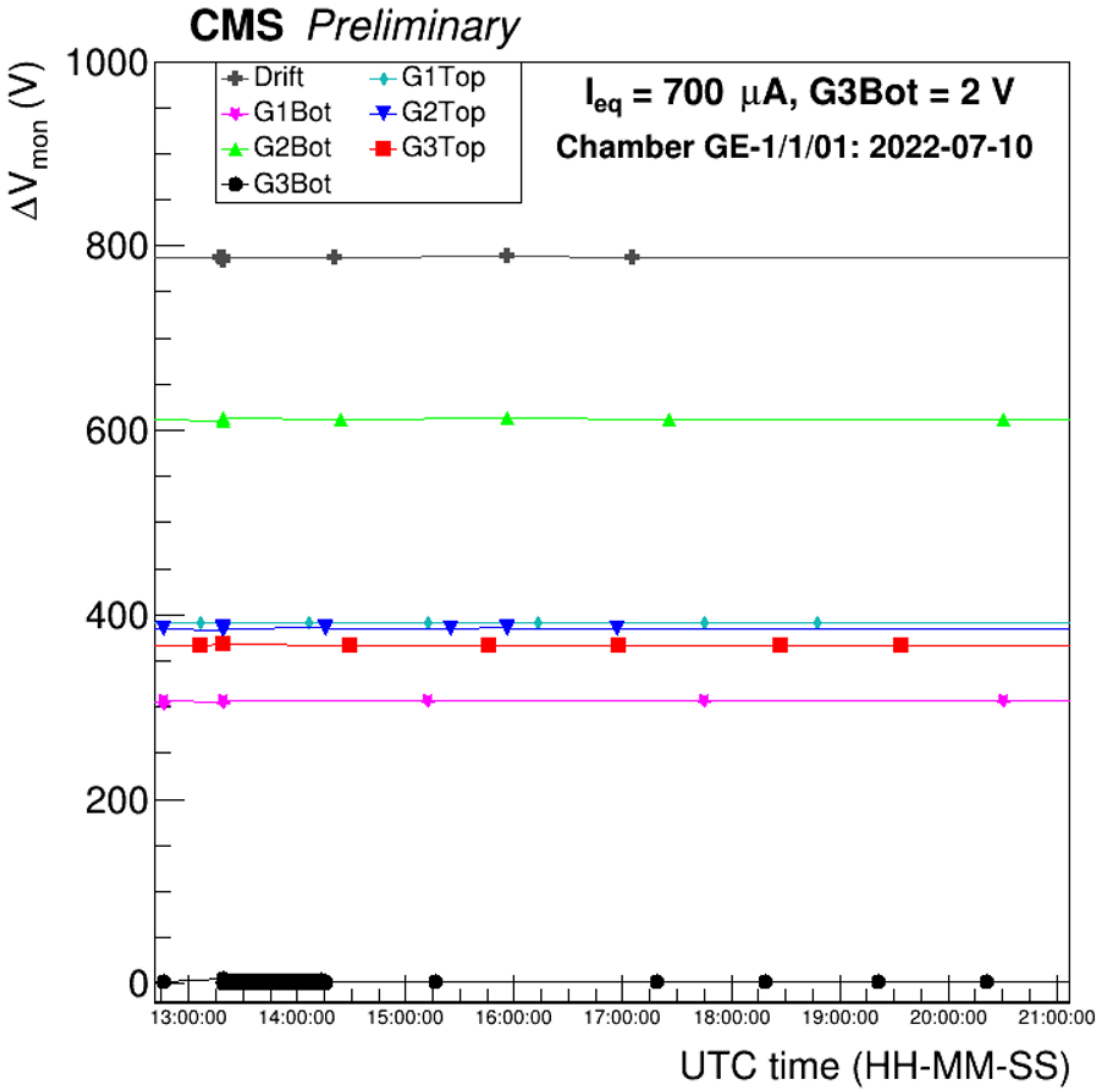
- **HV trip** = protection turn off of the HV when the current flowing in a power supply channel, feeding an electrode, overcomes a give threshold (I_0)
- **Cause:** frequent discharges overcoming the limit $I_0 = 2\ \mu A$
- **Strategy** = increase I_0 to $10\ \mu A$ during collisions
  - $I_0 = 2\ \mu A$ maintained for runs with cosmics



Operation during first months of Run 3 (2)

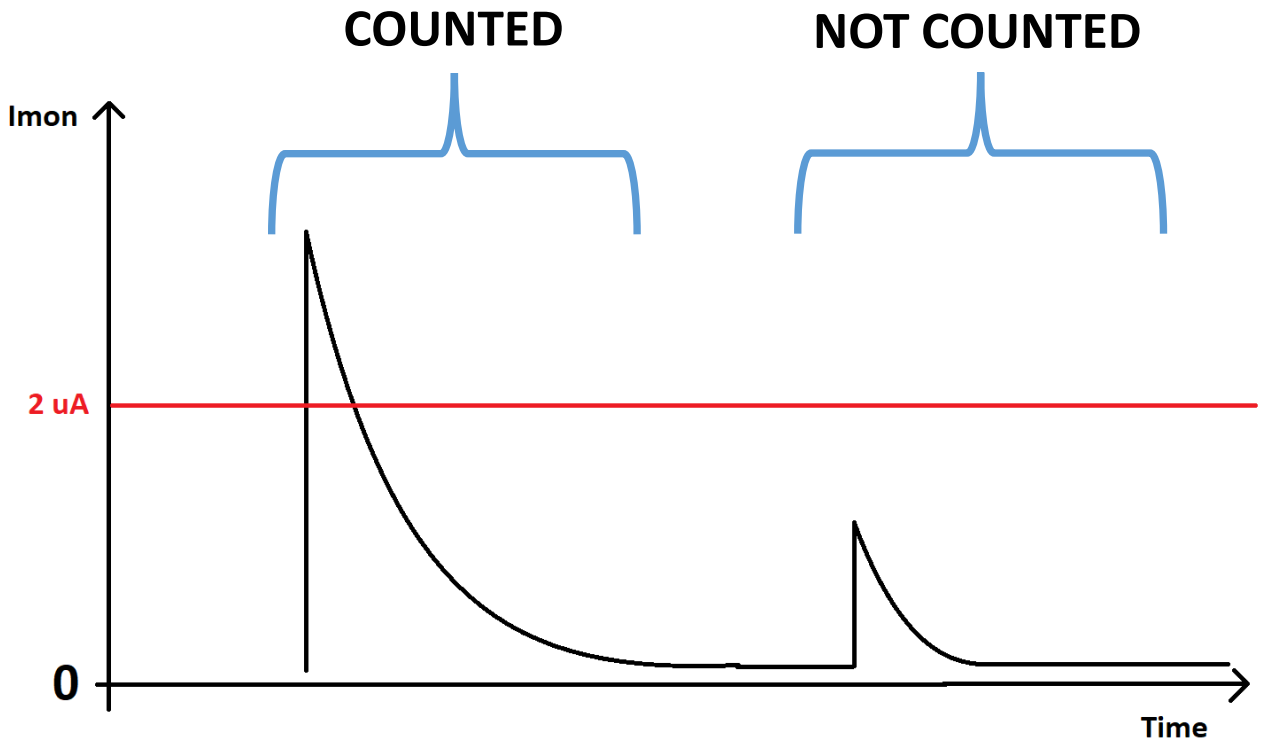
10th July 2022 – The induction gap (G3Bot) was turned off to protect the electronics from discharges propagating towards the readout

- Procedure to tune the HV working point started, monitoring the discharge rate in chambers
- **HV original working point:** 700 μA
- LHC continued its operations in the meantime, increasing gradually the number of colliding bunches

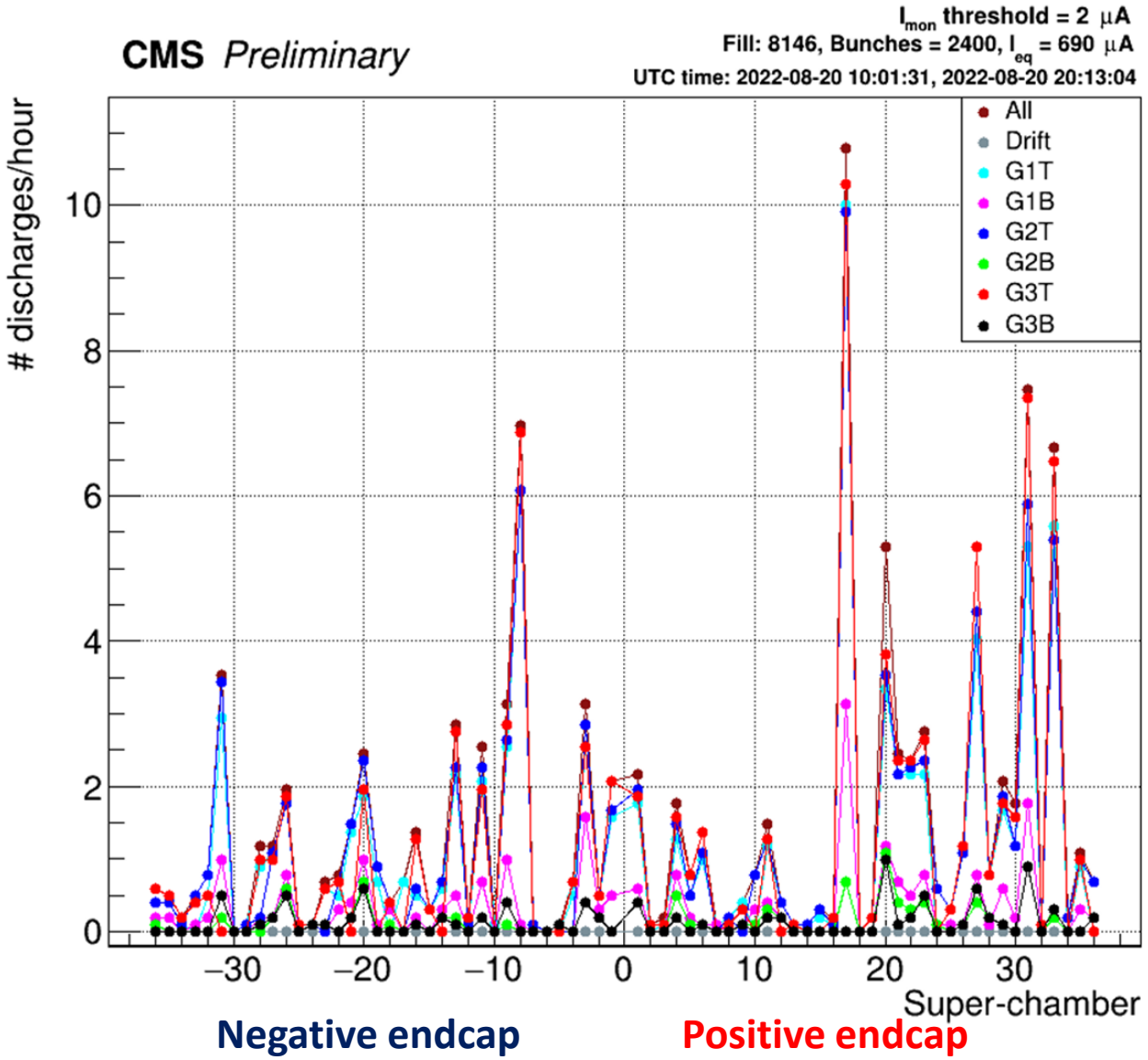


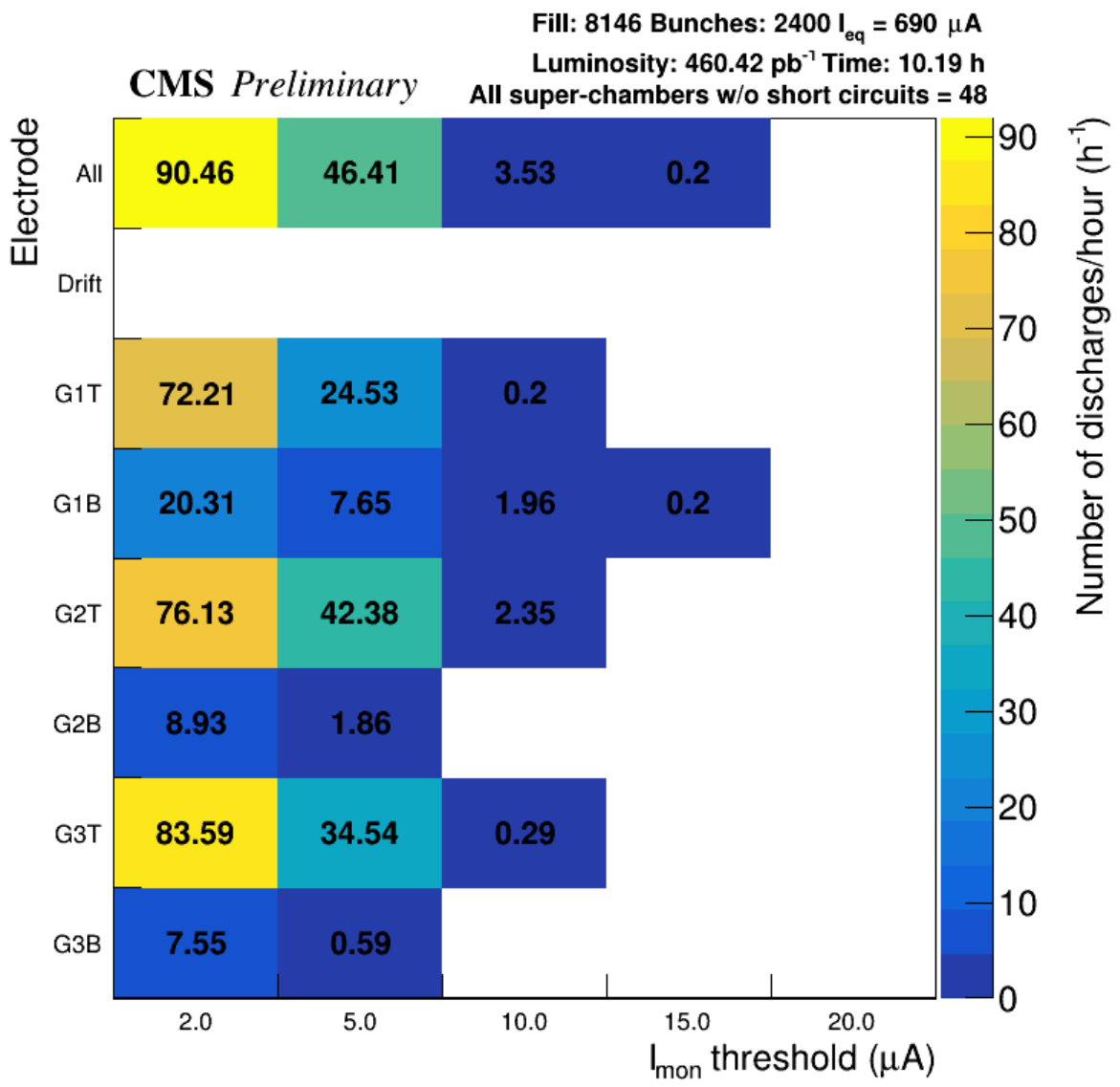
How discharges data are analyzed

- A **current threshold** value is set to count discharges
  - The available ones in the analysis are: 2, 5, 10, 15, 20 µA
- Every time a peak of current overcomes the desired threshold value a discharge event is counted

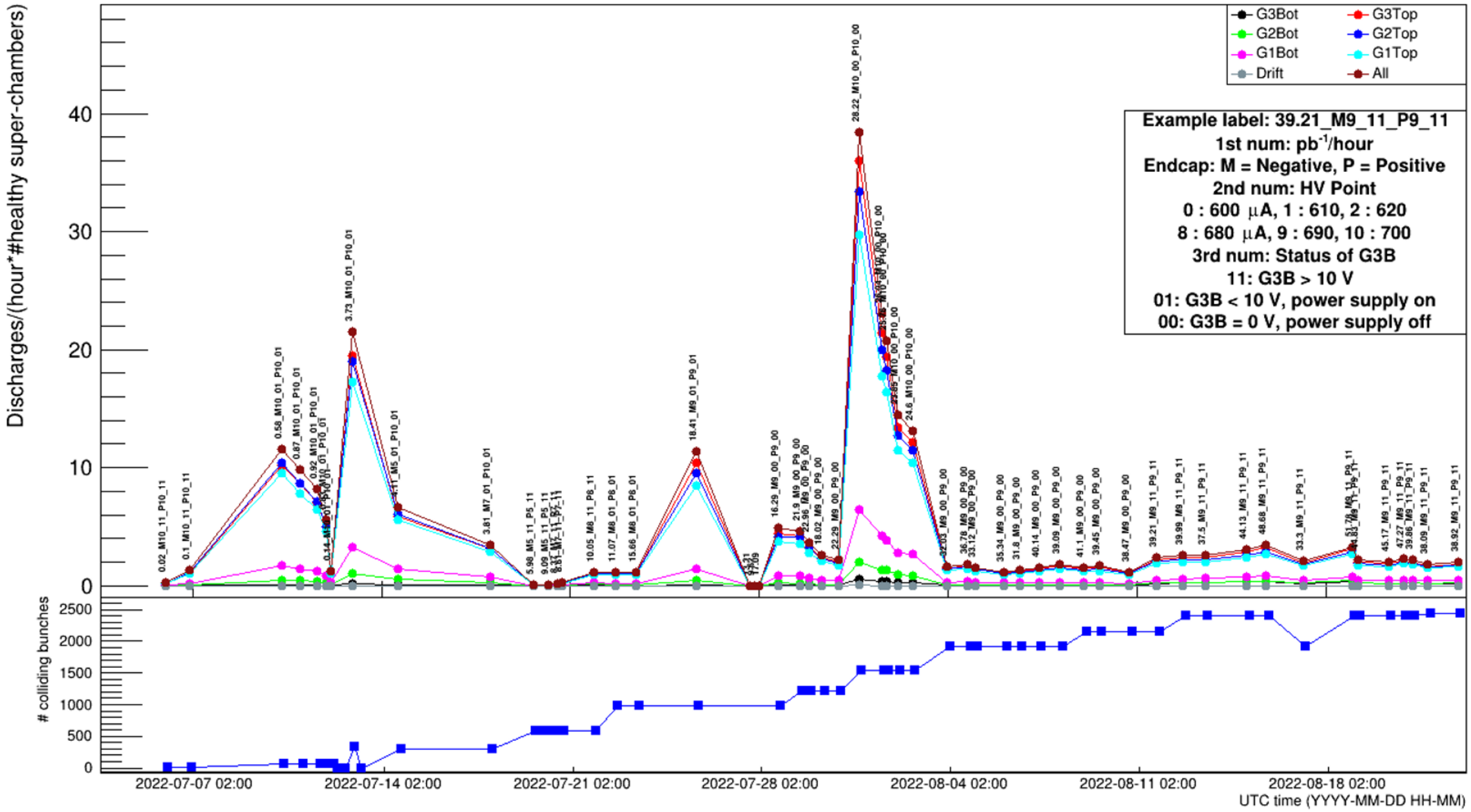


Observations per LHC fill





Evolution of the discharge rate



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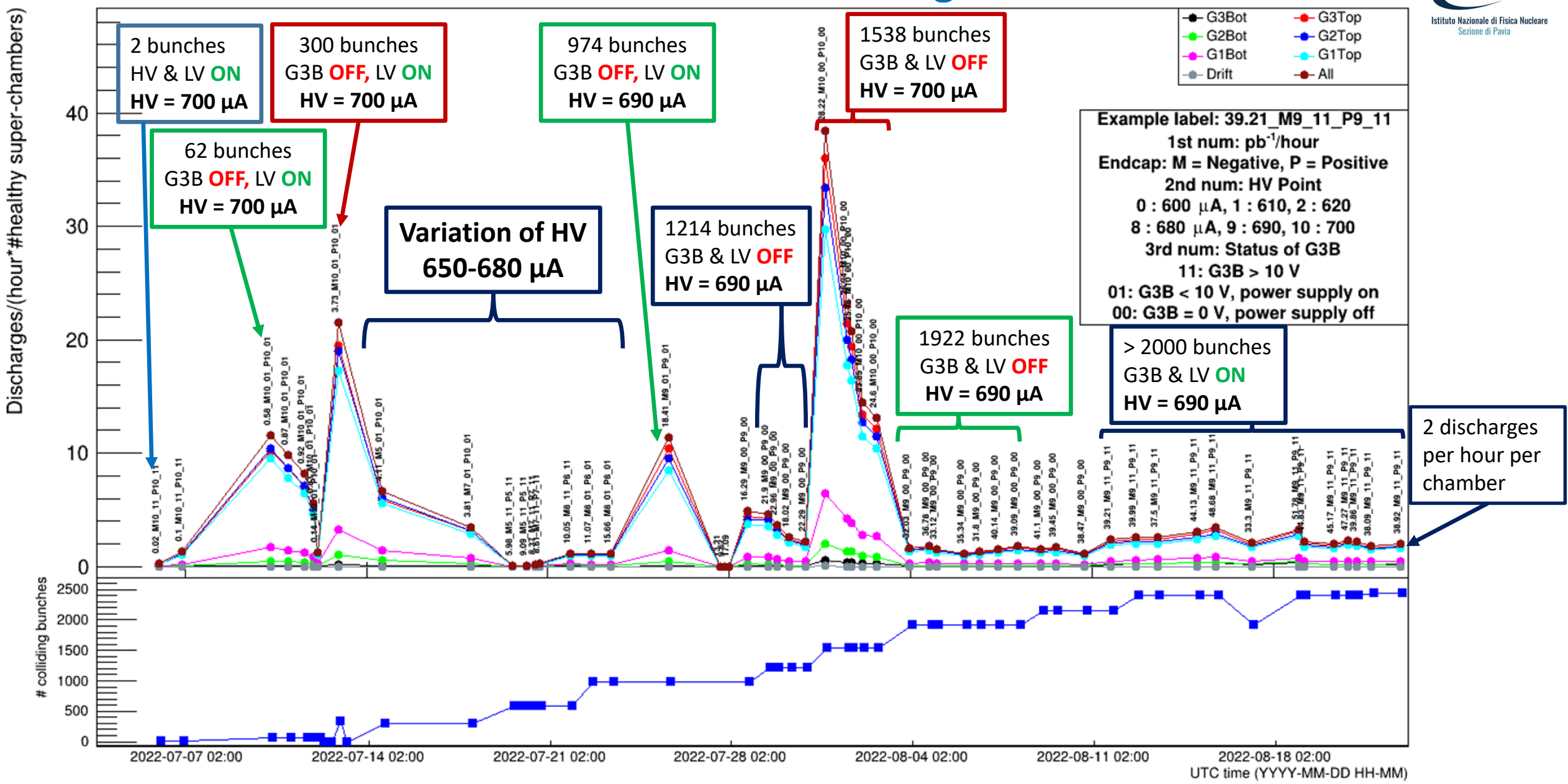
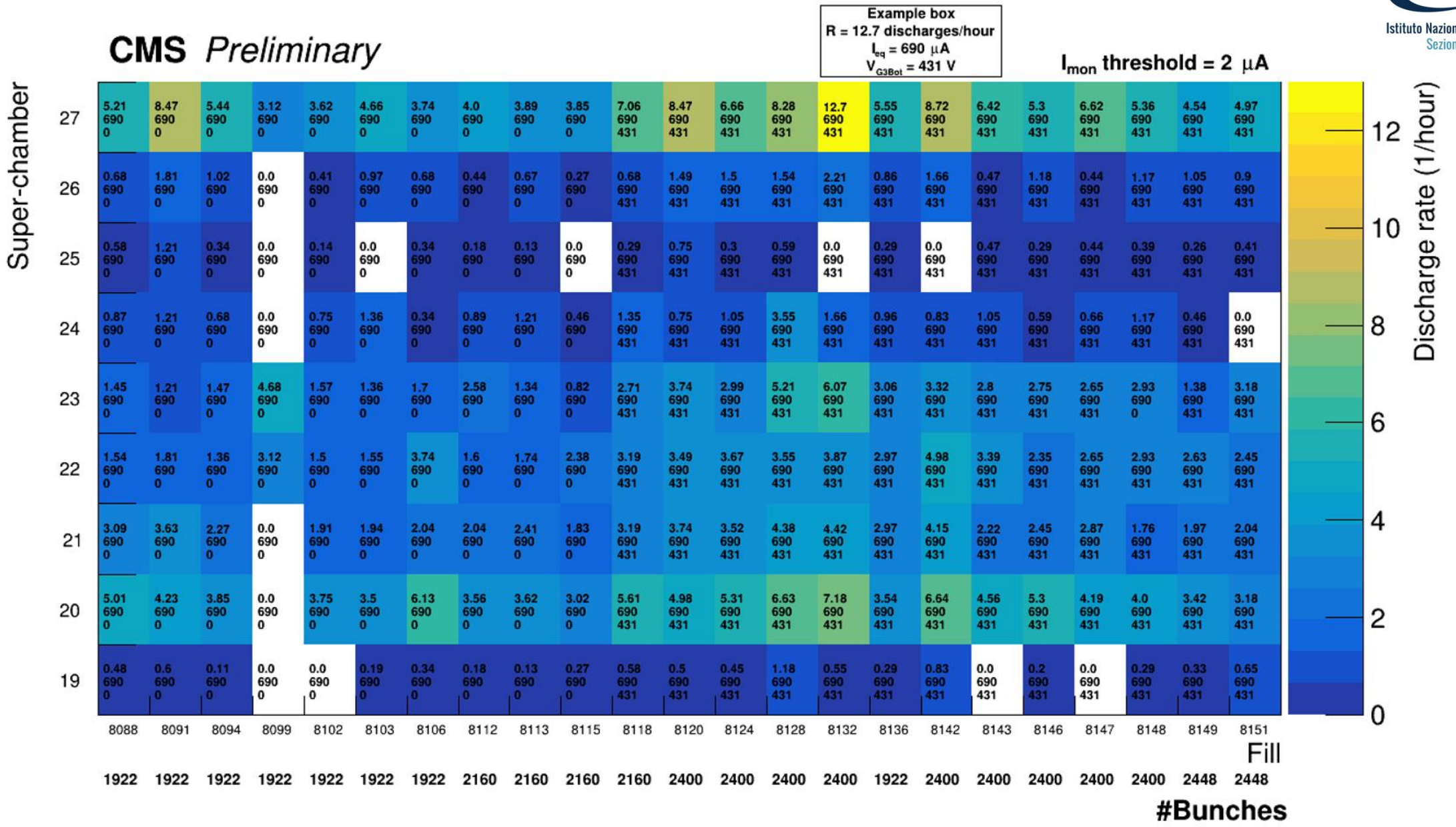


Evolution of discharge rate per chamber



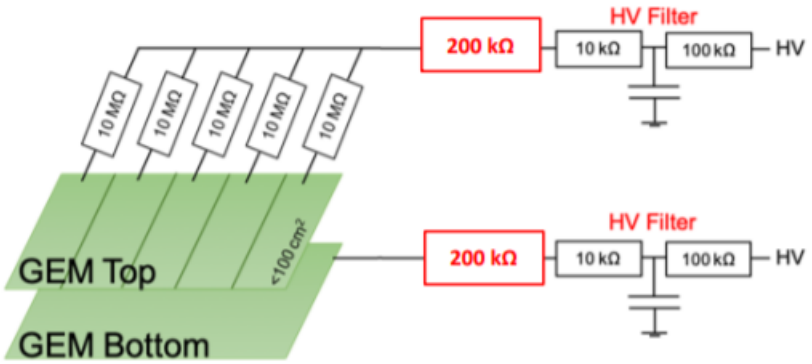
Conclusion

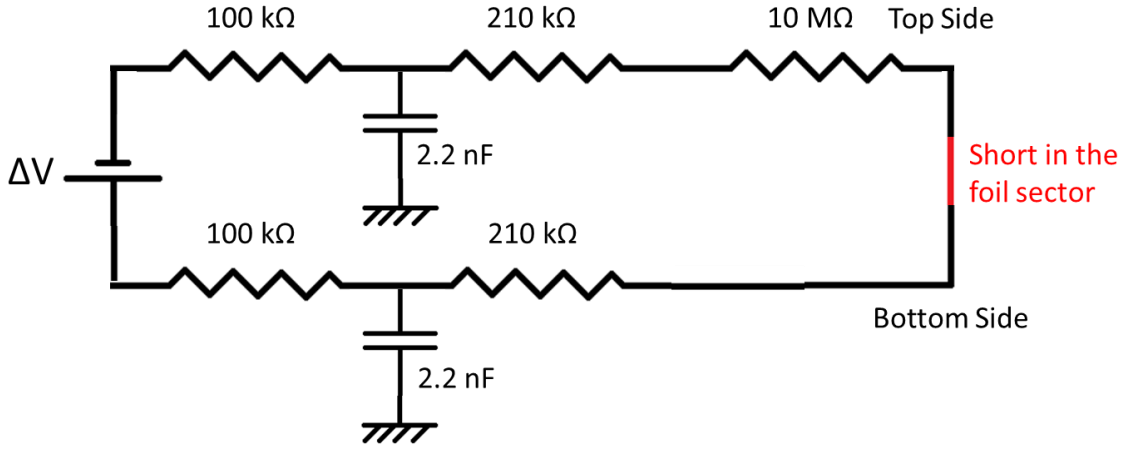
- Challenging operations for GE1/1 station in July and August 2022
  - Successfully found a stable configuration for HV working point
- Short circuits
  - Number of foils draining anomalous baseline current (> 10 µA) increased
  - 27 @ 6th July → 36 @ 22nd August
- Status of the analysis: **updating**
  - to include the chambers with short circuits and better calculate the discharge rate, globally and per chamber
  - Include discharge data from other GEM stations in CMS (GE2/1 demonstrator)

BACKUP

What is a short circuit in a GE1/1 detector

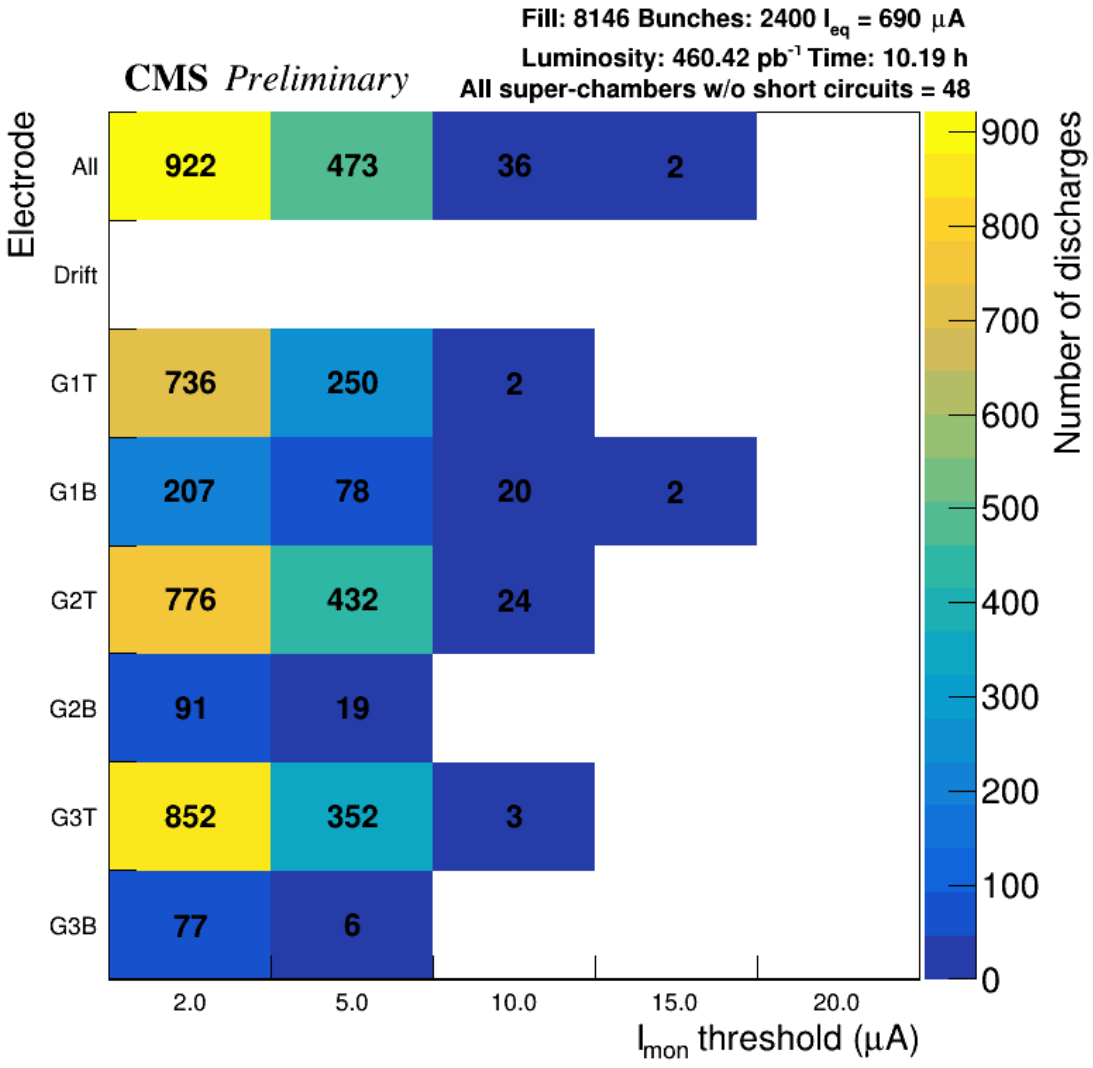
- **Short circuit:** connection between top and bottom face of a GEM foil
  - **Manifest as:** high current flowing in the channel powering the interested foil
  - Equivalent resistance of perfect conductive short: the resistance of resistances seen on the path of the short circuit (10.62 MΩ)

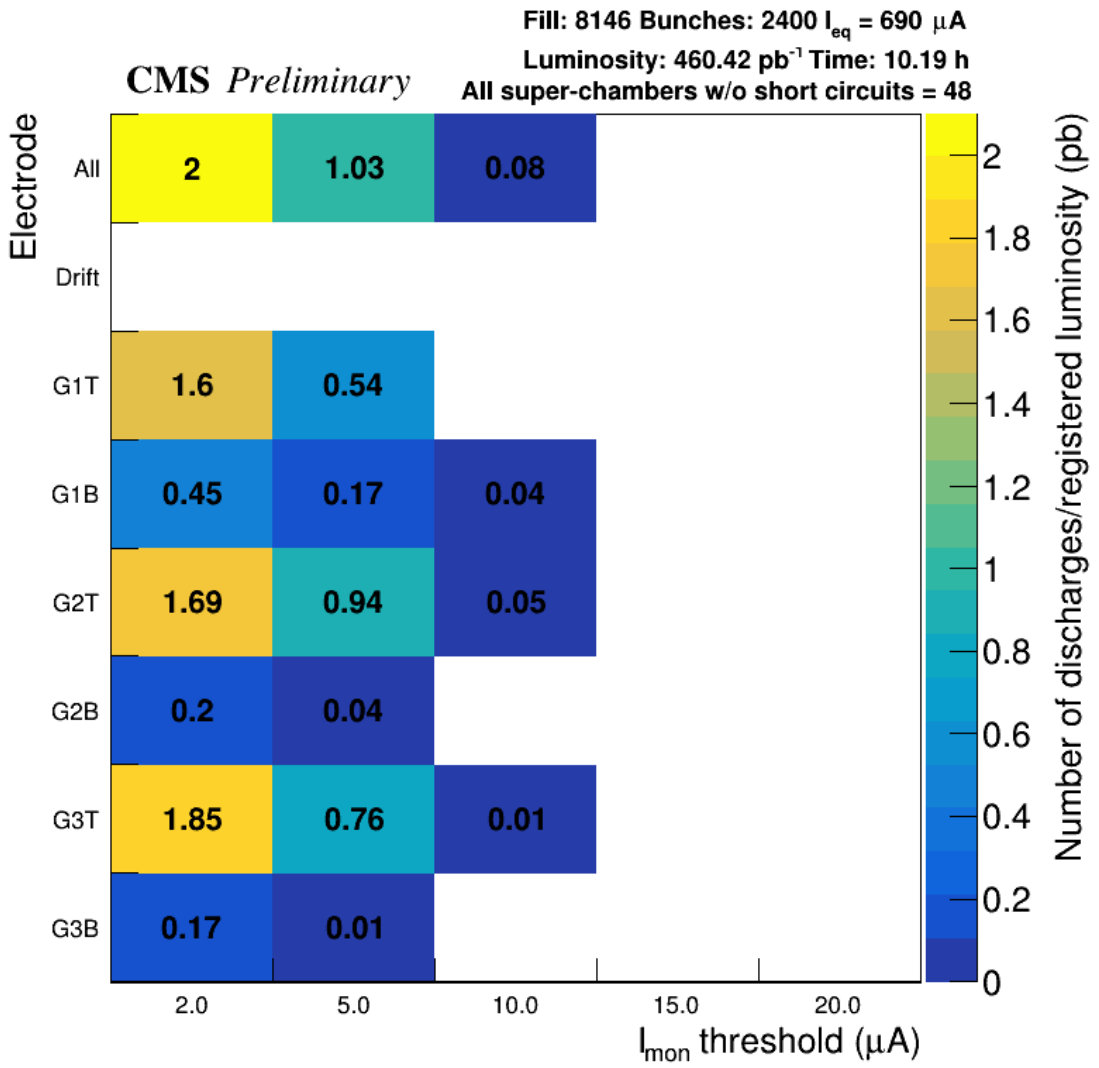




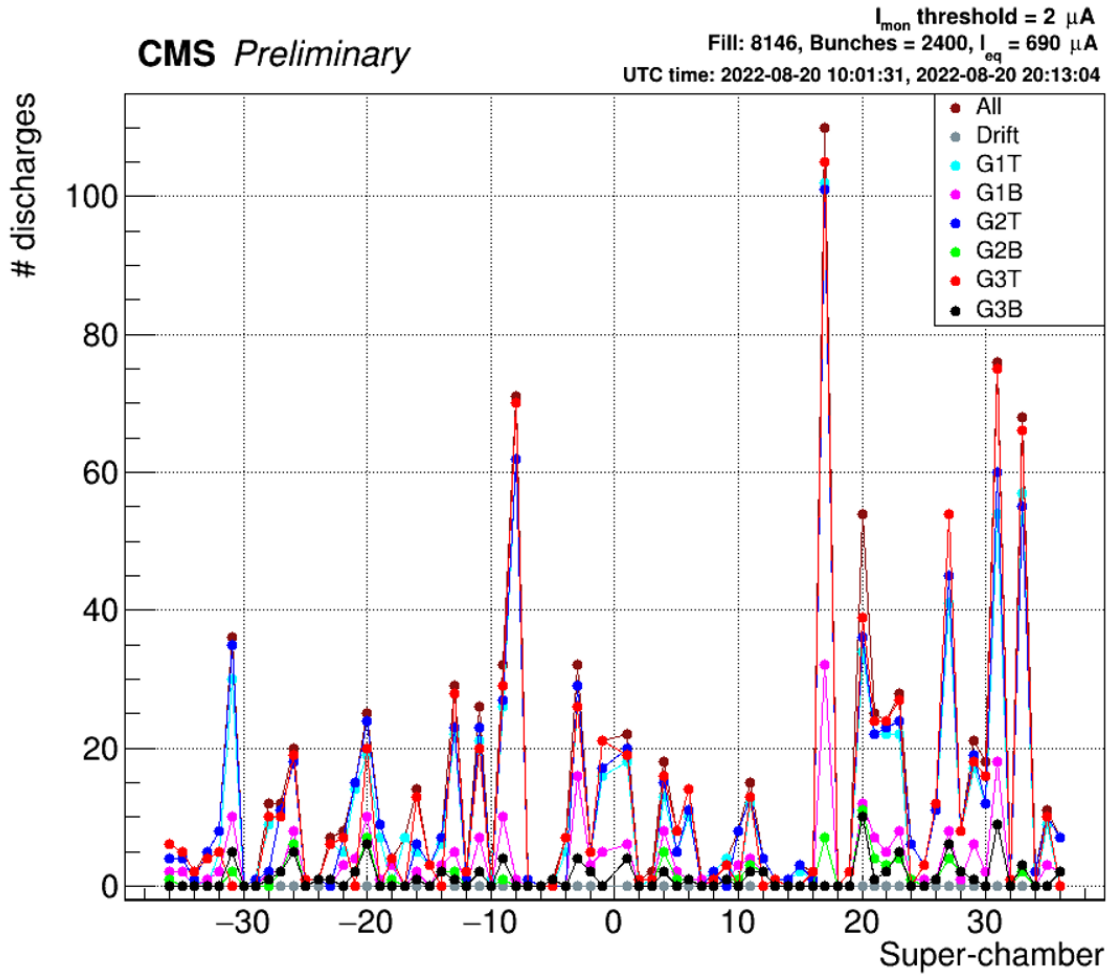
  - **Impact:** current flowing in resistors means voltage also falling on them
    - Voltage applied to the foil is lower than that set on the power supply channel

Raw counts and normalization on registered luminosity





Raw number of discharges



CMS *Preliminary*

I_{mon} threshold = 2 μA
Data: all super-chambers w/o shorts

Istituto Nazionale di Fisica Nucleare
Sezione di Pavia

Evolution of discharge rate
Number of discharges per picobarn of registered luminosity