



GEM commissioning with PICO

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Outline

- ❑ GE1/1 studies: operation in magnetic field (paper in review)
- ❑ GE2/1 demonstrator: PICO commissioning
- ❑ Naples Lab activities
- ❑ Conclusions

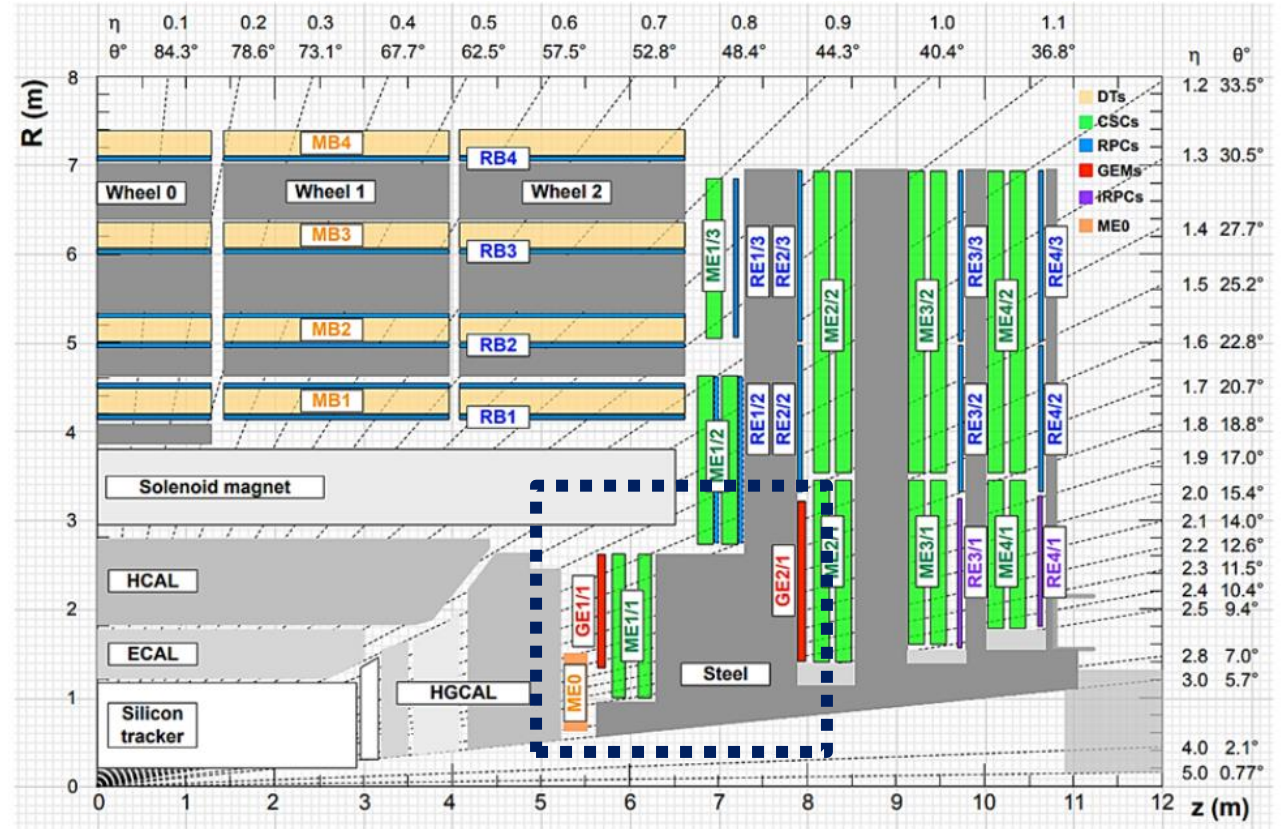
CMS Muon Upgrade

2026: HL-LHC

- ❑ Instantaneous Luminosity:
 $2 * 10^{34} cm^{-2} s^{-1} \rightarrow 5 * 10^{34} cm^{-2} s^{-1}$
- ❑ Pile-up events :
 $\sim 37 \rightarrow \sim 200$

GEM technology provides:

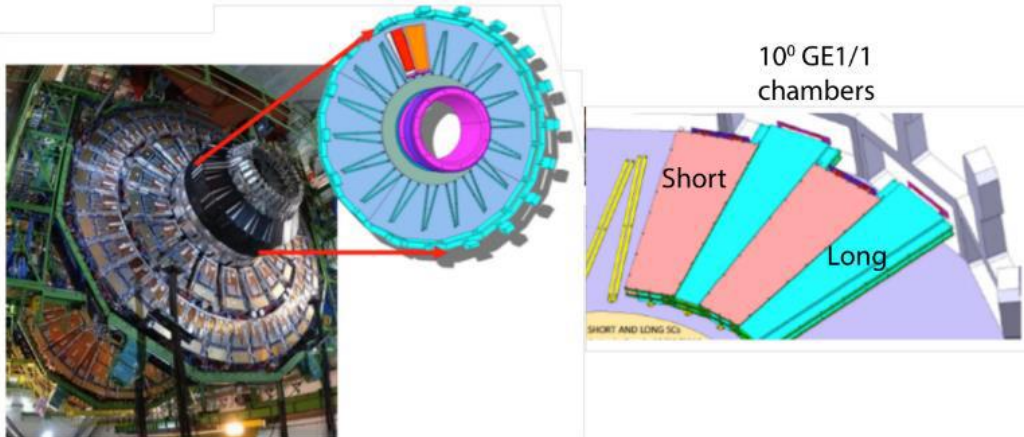
- ❑ Good time resolution
- ❑ High-rate capability



❑ **GE1/1 station** installed

❑ **GE2/1 station** slice test ongoing (expected in the next 2 years)

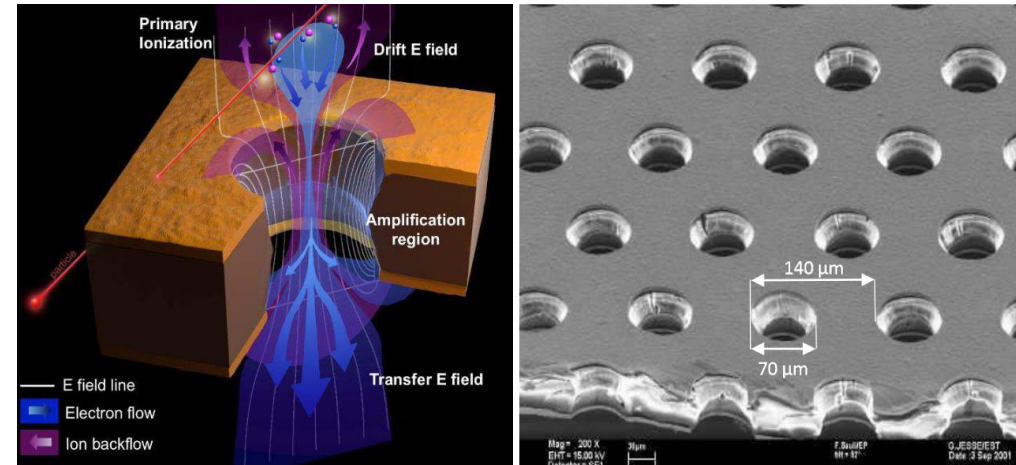
❑ **ME0 station** R&D almost finalized (expected LS3)



Triple-GEM technology

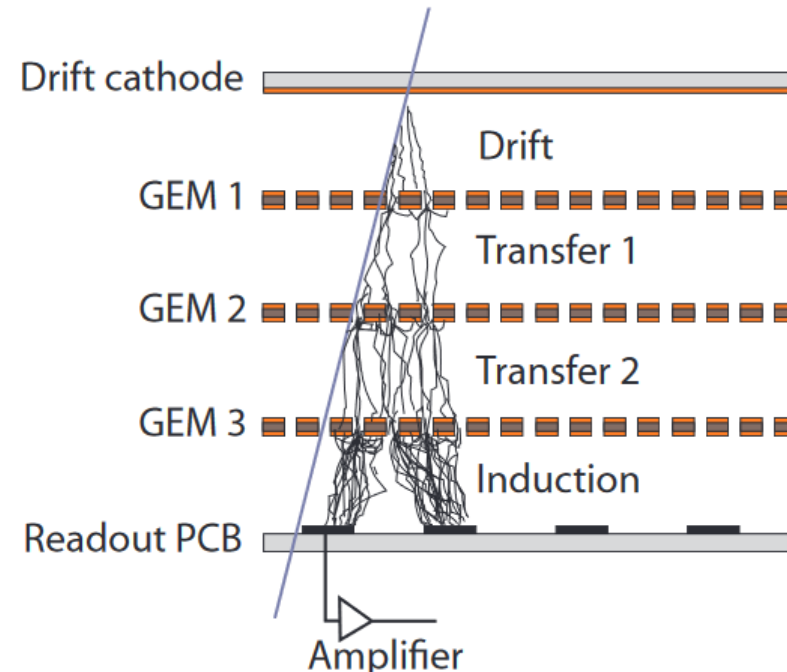
❑ GEM technology

- ❑ 2 conductive plates (Copper) spaced out by an insulation material (Kapton)
- ❑ bi-conical holes are performed in the foil
- ❑ Copper 5 μm , Kapton 50 μm
- ❑ Electron amplification in the holes



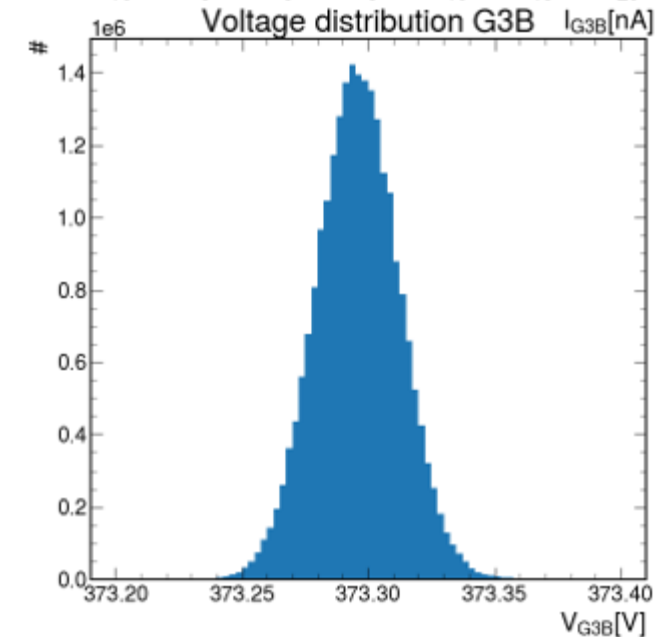
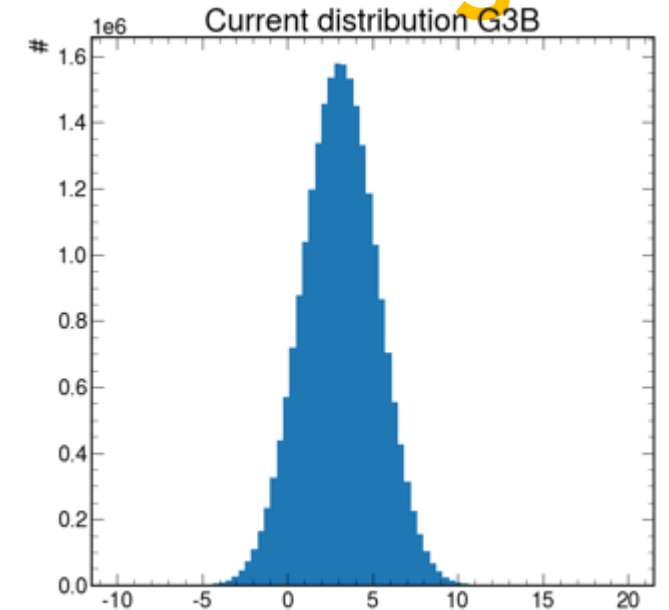
❑ Triple-GEM

- ❑ 3 cascade GEM foils
- ❑ Gas mixture Ar:CO₂ 70:30
- ❑ Amplification up to 10⁵ with a modest high voltage (~400V)



Pico-ammeter for triple-GEM monitoring

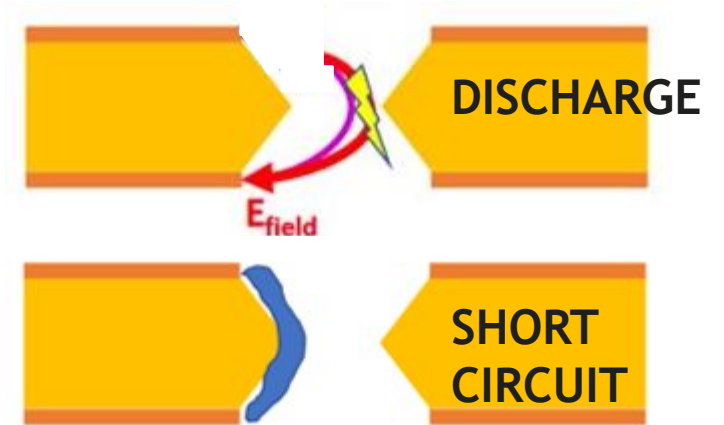
- ❑ High-granularity, high-resolution Pico-ammeter (PICO for friends) 100% made in Naples
- ❑ PICO allows a simultaneous monitoring of 7 GEM electrodes, both current and voltage
- ❑ Sampling 380Hz, typical sampling of CAEN boards O(Hz)
- ❑ Resolution $\leq 30\text{pA}$ (much smaller than noise)



Operation in Magnetic field (GE1/1)

Possible sources of damage for the detector:

- ❑ High # of electrons \rightarrow current between the two conductive plates \rightarrow **discharge event**
- ❑ An elevated number of discharges can damage and/or create a connection between the plates \rightarrow **short circuit**
- ❑ To prevent shorts a security system is implemented in the HV board \rightarrow **trip**



Test at high-intensity magnet «**GOLIATH**» @ **CERN**:

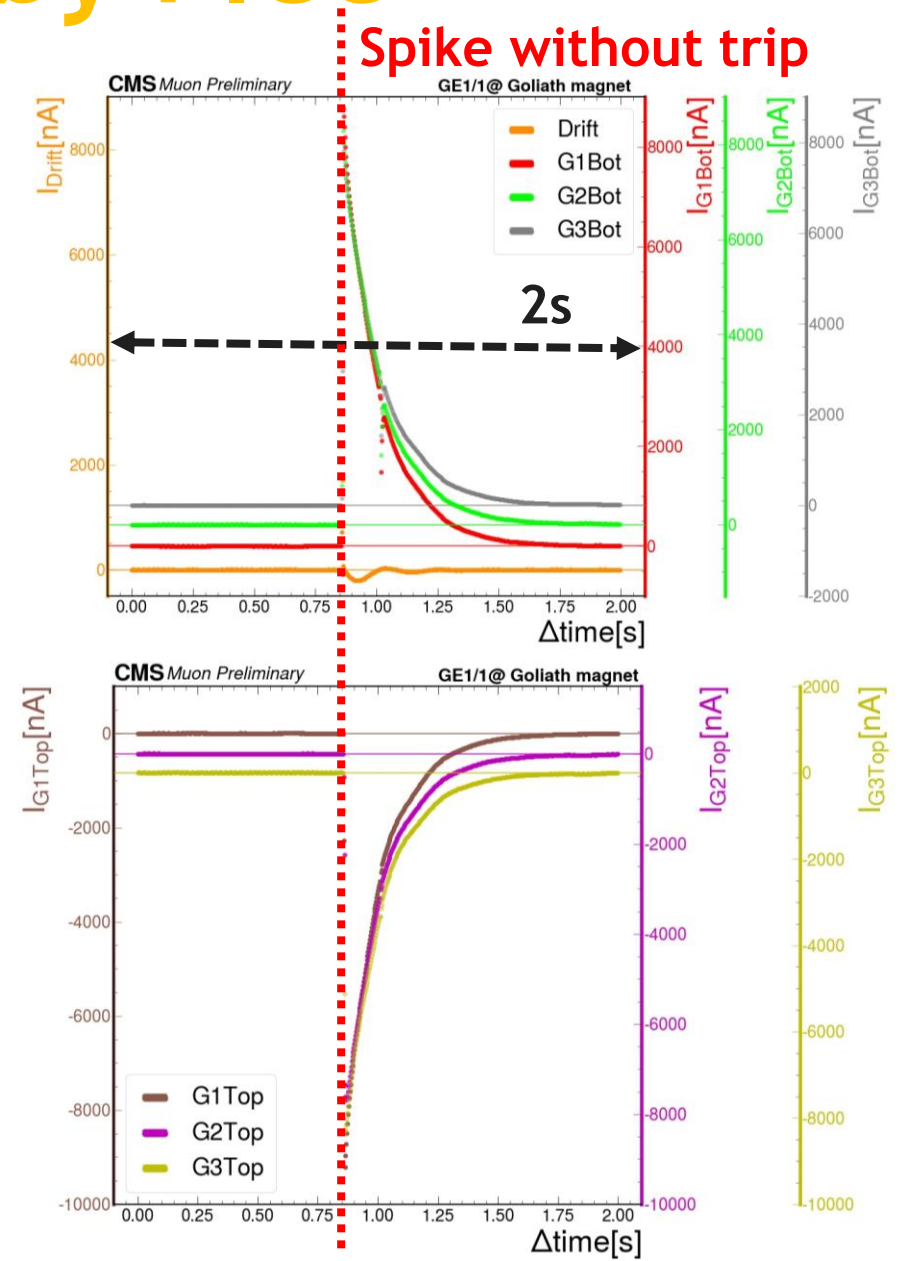
- ❑ Reproduce **discharges and trips** of chambers during CMS magnet ramps
- ❑ **Define a procedure** for safe operation
- ❑ Understand how to create and repair **short circuits**

- ❑ 4 chambers tested, 2 HV boards A1515
- ❑ Data collected with 2 independent tools:
 - ❑ Sampling from A1515 board @ 10Hz;
 - ❑ PICO



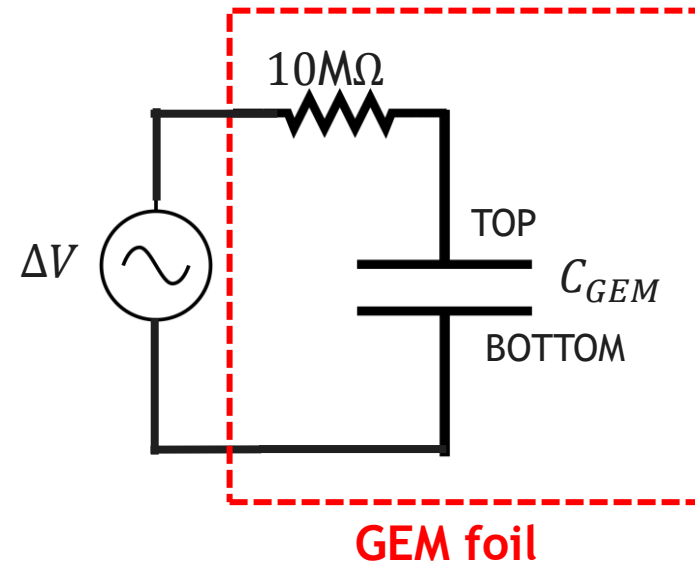
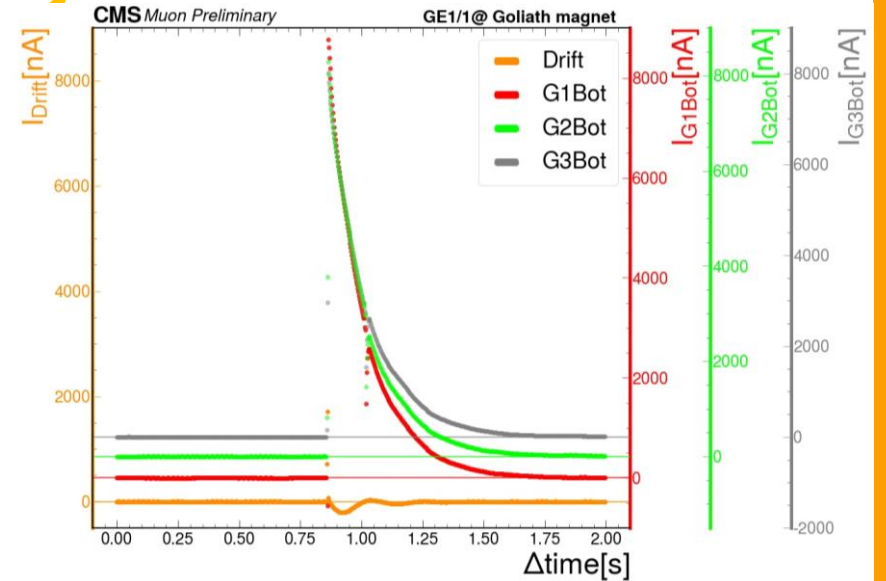
Discharge event recorded by PICO

- ❑ In the upper plot are showed the currents flowing on GEM bottom + drift foils,
 - ❑ positive polarity
 - ❑ exponential shape
- ❑ In the lower plot are showed the currents flowing on GEM top foils,
 - ❑ negative polarity
 - ❑ exponential shape
- ❑ With PICO we have the possibility to check for consecutive events (more than 1 discharge in 1s) and also to follow eventually minor damages on the foils



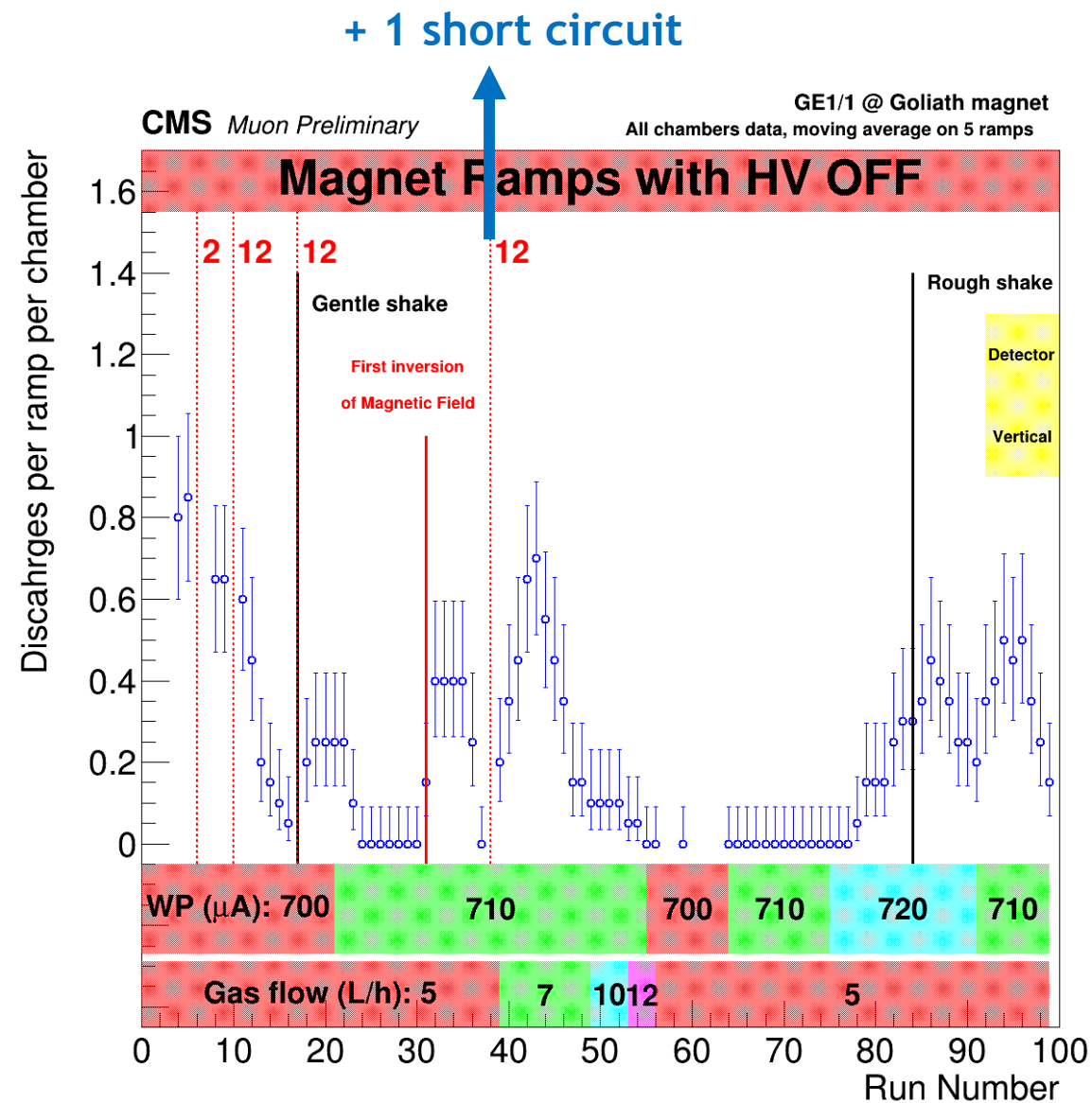
Discharge event recorded by PICO

- Examples of discharge recorded by PICO,
- In the upper plot are shown the currents flowing on GEM bottom + drift foils,
 - positive polarity
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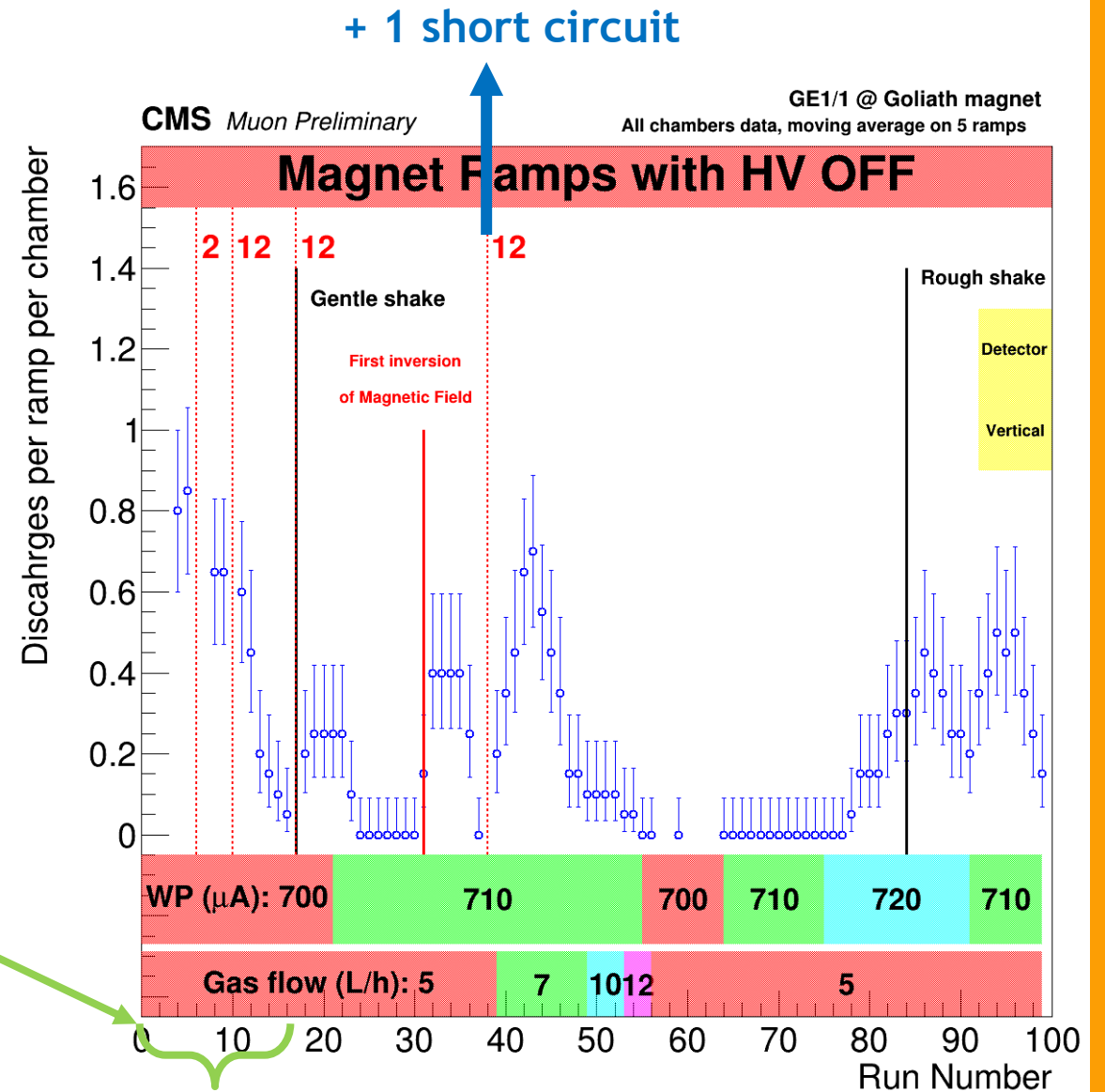
Number of discharges in different operating conditions

- In the plot are reported the moving average number of discharges per magnetic ramp, mediated on 5 ramps.
- the red dashed lines indicates when the magnetic ramps with detector HV OFF were performed
- the black lines indicates when chambers were mechanically stressed
- Main phase of the tests:
 - classic P5 operation
 - mechanical stress
 - inversion of the magnetic field



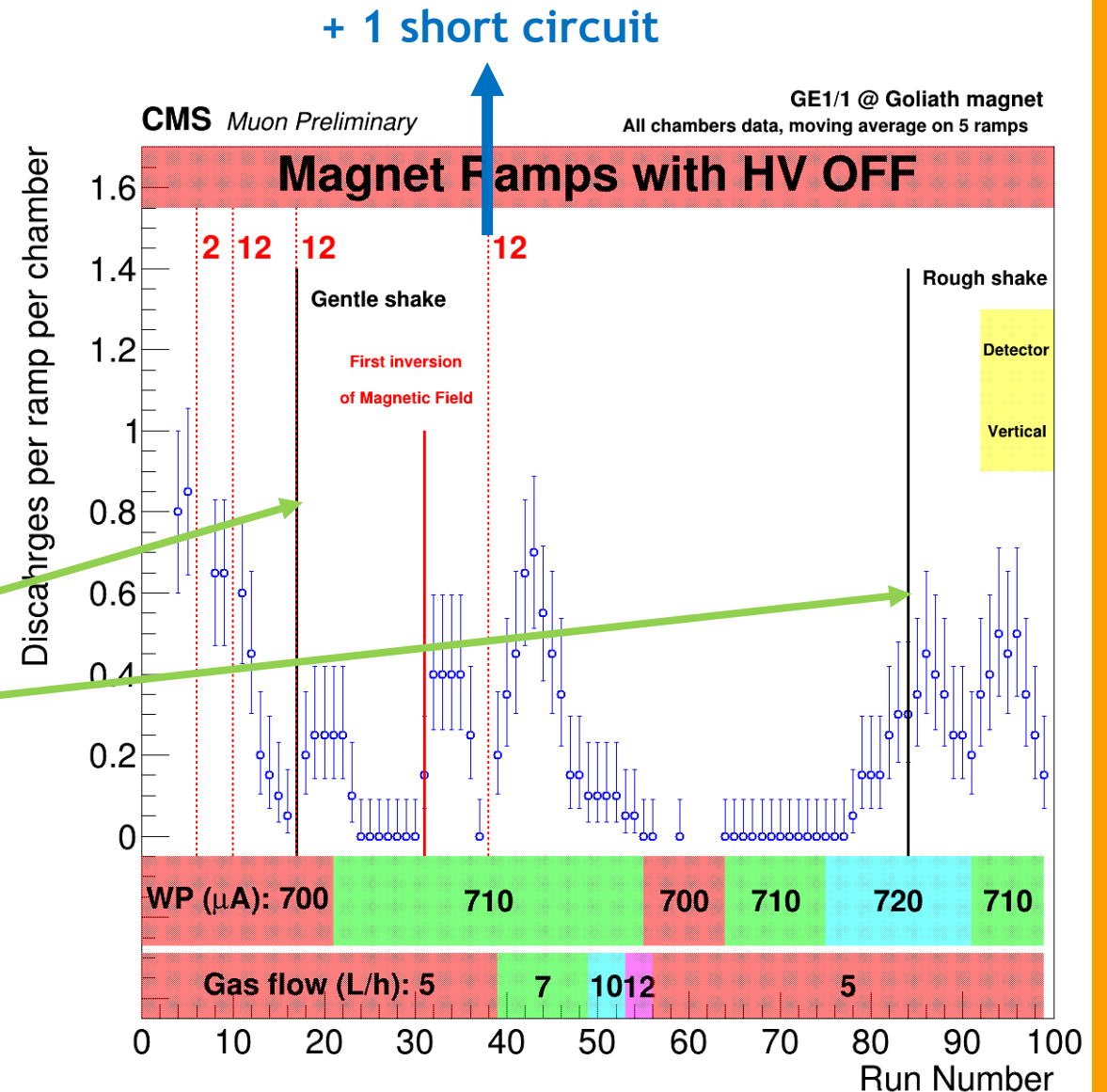
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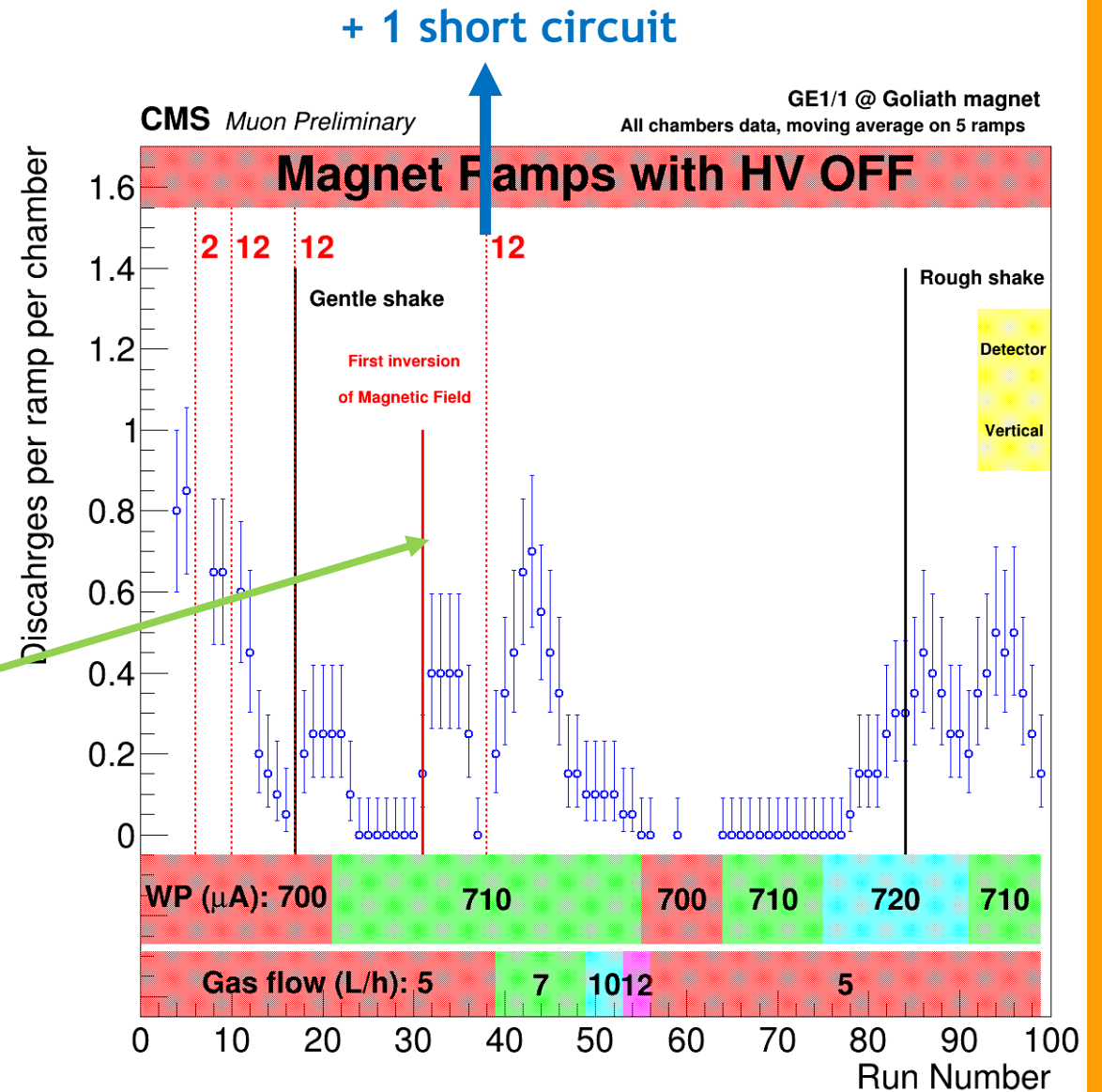
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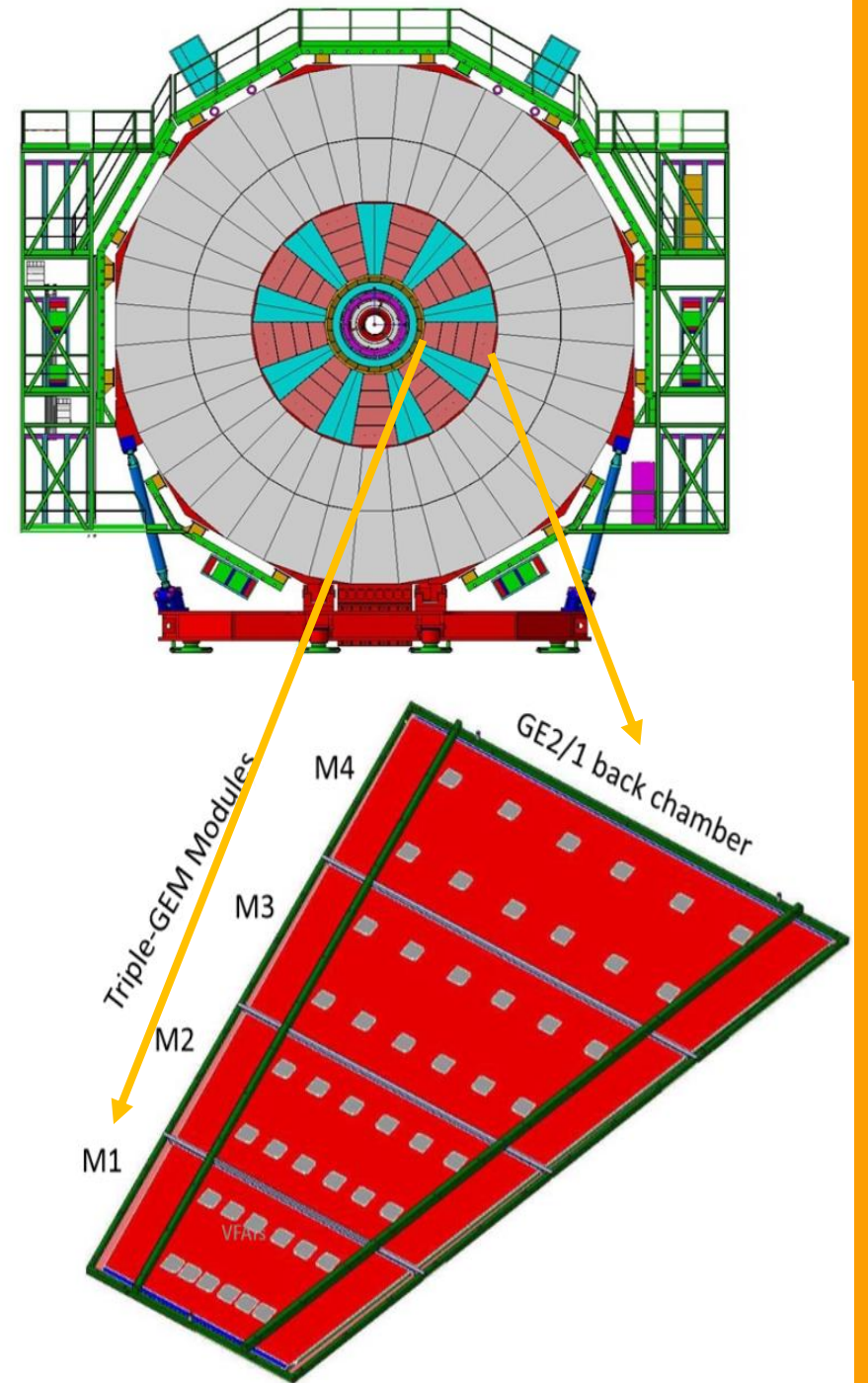
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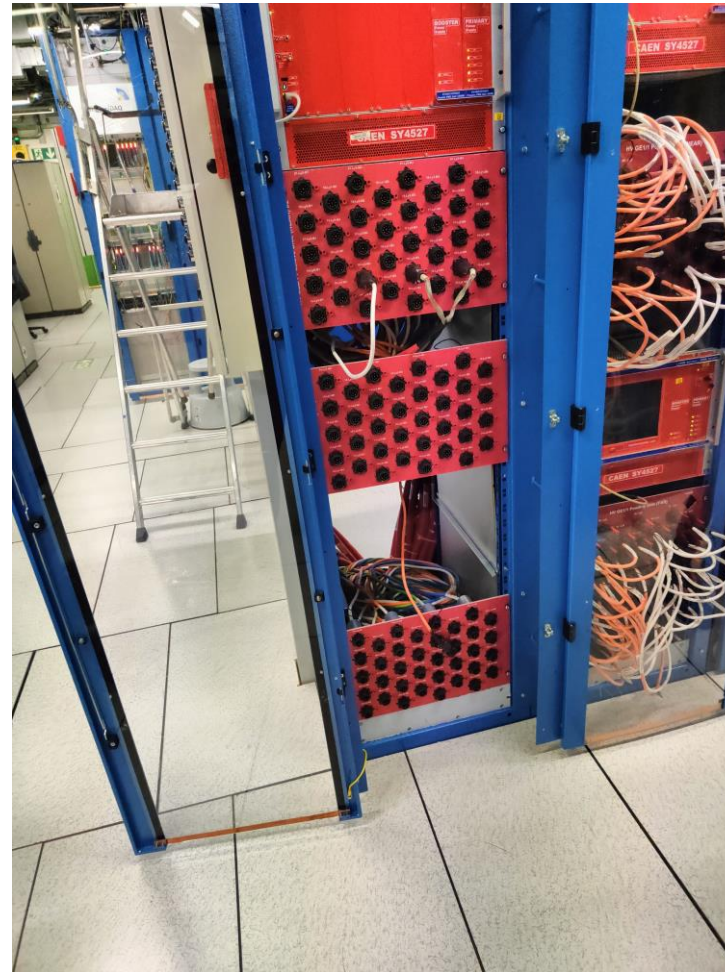
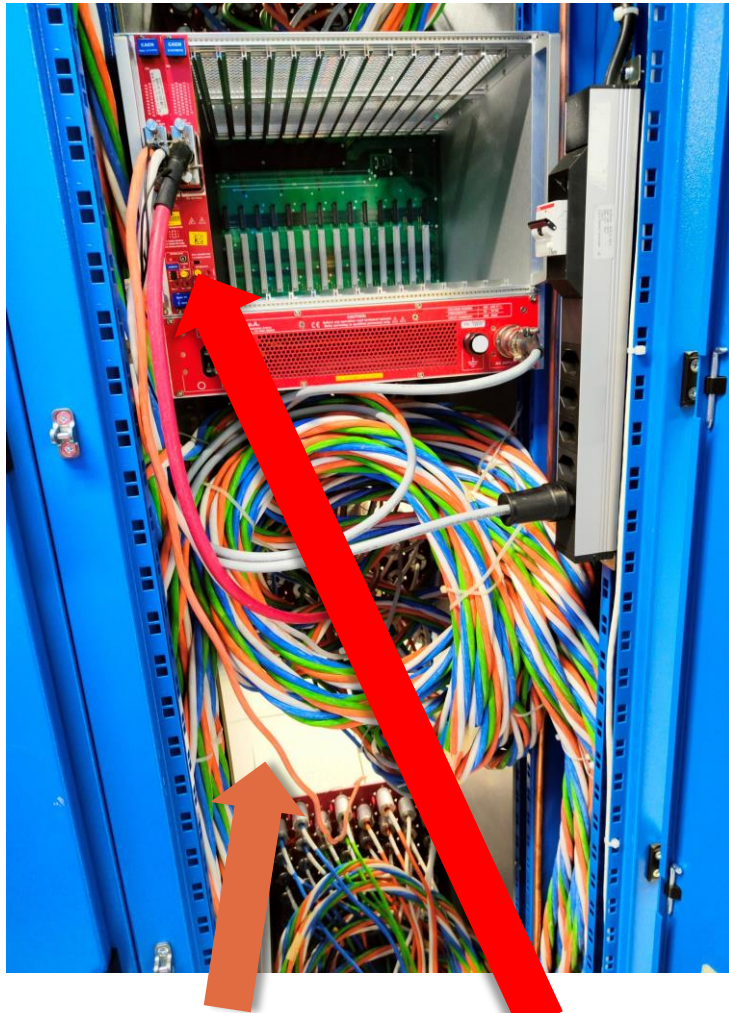


GE2/1 station

- GE2/1 station consists of “superchamber” : a pair of triple-GEM layers of trapezoidal shape
- In total $2 \times 18 = 36$ superchambers are needed.
- Coverage extends from $|\eta| = 1.6$ to $|\eta| = 2.4$
- Each GE2/1 chamber consists of four modules M1-M4, each being a single CMS triple-GEM detector



Pico commissioning@GE2/1 demonstrator

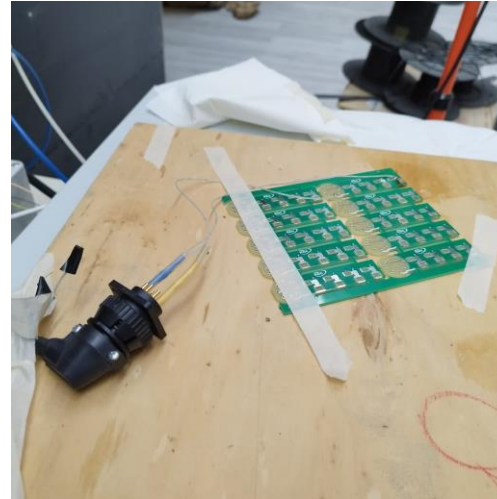


- Monitoring ongoing during 2022
- Results still under study (not public yet!)

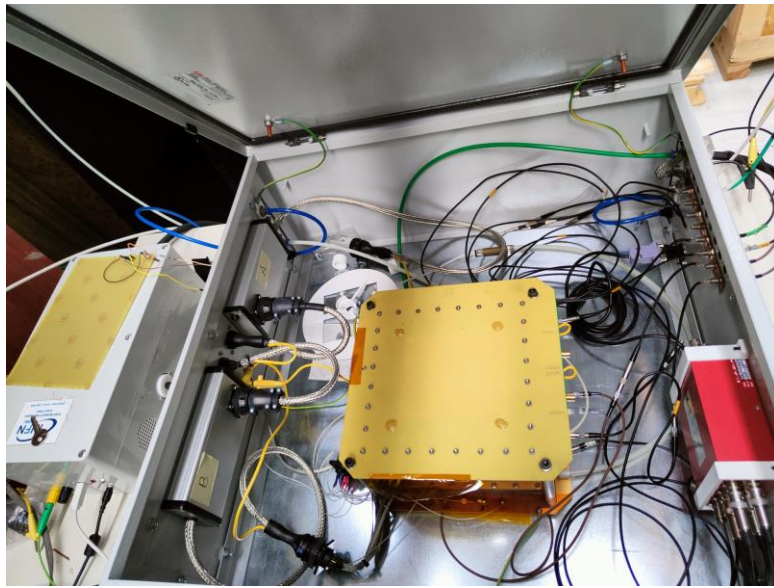
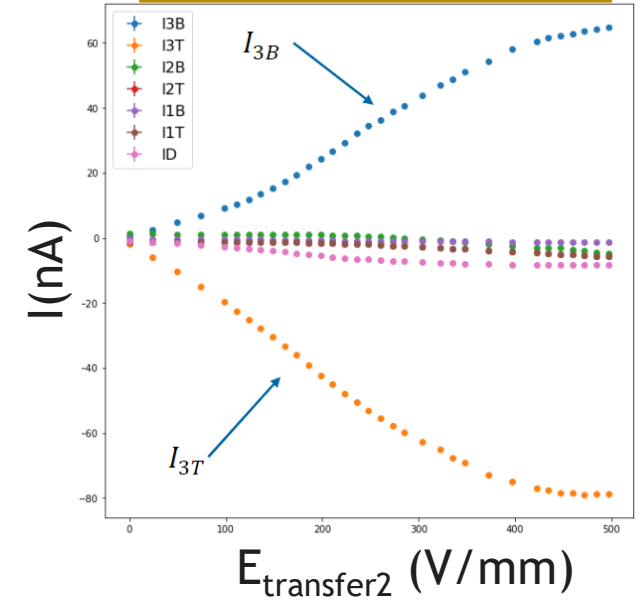
Orange cable from CAEN board to pico and then PICO to the chamber

Activities in Naples Lab

- HV filter tests for GE2/1
- Electric field characterization through PICO
- Future plans:
 - Dedicated study for discharge behaviour with different WP (PICO+Oscilloscope)



Thanks to Andrea Puglia for the plot



Results & Conclusions

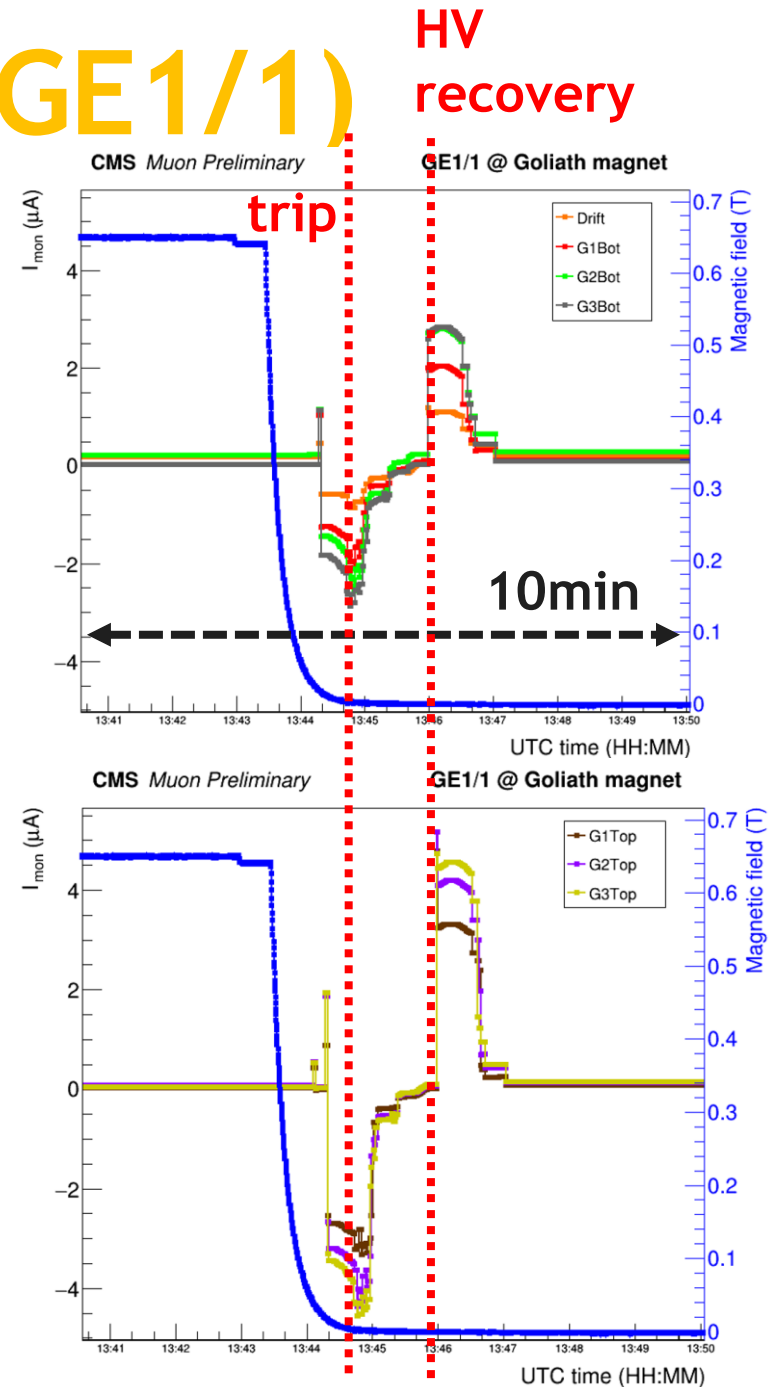
- ❑ 2022 has been an intense year for the whole CMS GEM group, with the starting of **GE1/1 operation** and the commissioning of **GE2/1 demonstrator**
- ❑ Results from **Goliath magnet** test,
 - ❑ One short circuit observed during a magnet ramp with detector HV OFF
 - ❑ Validated the procedure to handle the short circuit with a tester → 500V applied for less than 1s in Ar/CO2 mixture
 - ❑ Observations compatible with presence of dust in the chamber
- ❑ We are fully involved in the **GE2/1 monitoring**, PICO has been connected to M4 module from March to the end of 2022 LHC operation
- ❑ At the moment Pico is here (in Naples) for an upgrade and we are planning to reinstall it in USC before the start of LHC operation



backup

Operation in Magnetic field (GE1/1)

- Examples of discharge recorded by A1515 board during a magnetic field ramp, the discharge induced a trip (negative currents) followed by the HV recovery (positive currents)
- In the upper plot are showed the currents flowing on gaps
- In the lower plot are showed the currents flowing on GEM foils



Operation in Magnetic field (GE1/1)

Chambers' settings varied during the test:

- Gas flux
- WP
- Chamber orientation wrt magnetic field
- Order of powering HV electrodes
- Ramp up values for the single electrodes
- Mechanical stress

Currents monitoring description

