Study of GEM currents anomalies@GOLIATH magnet (CERN)

A.Boiano, A.Cagnotta, F.Cassese, A.De Iorio, F.Fabozzi, O.Iorio, A.Pandalone, P.Paolucci, G.Passeggio, B.Rossi, A.Vanzanella

21/12/2021

Outline

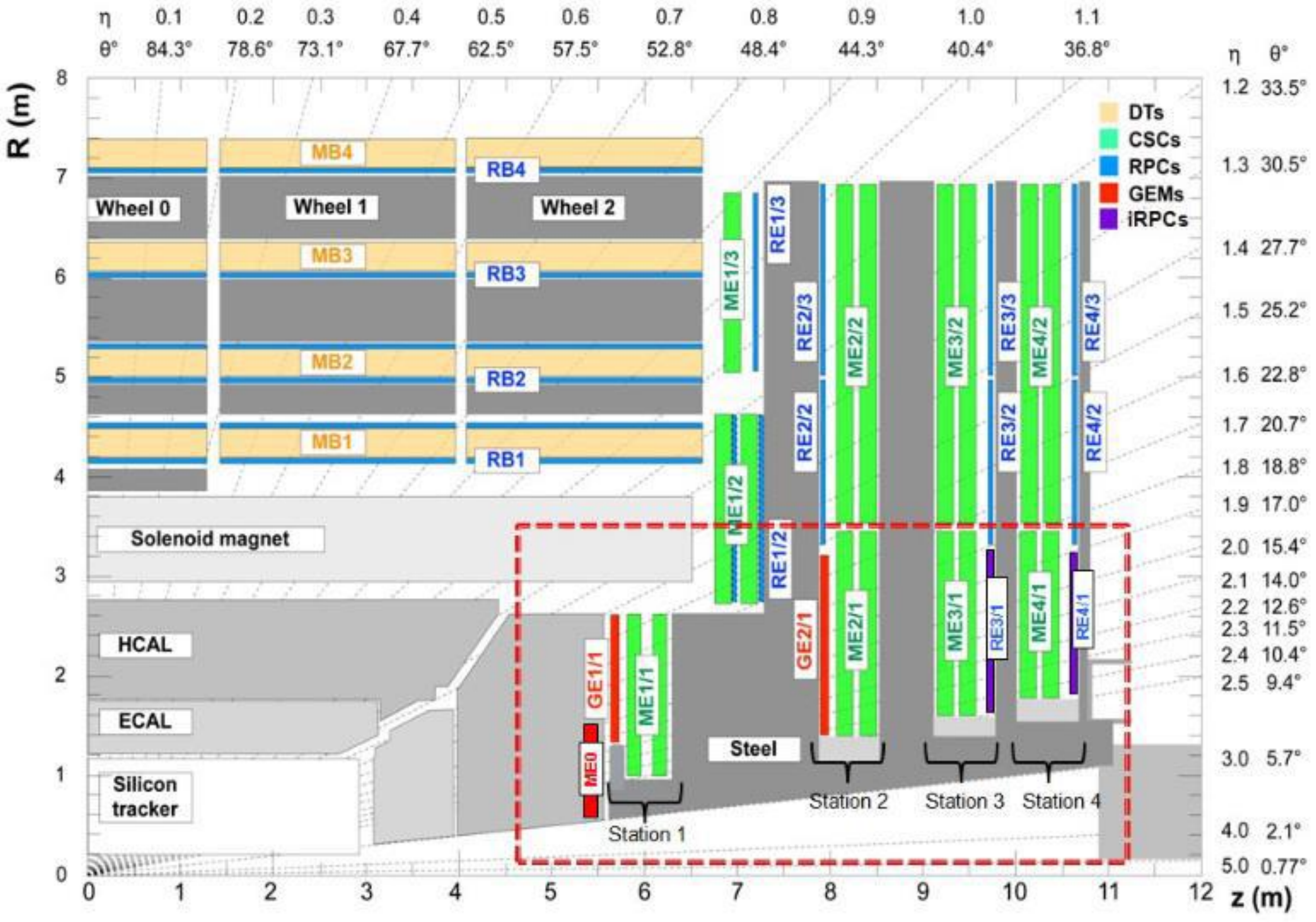
- ❖CMS Upgrade
- ❖Triple-GEM
- ❖INFN Napoli Pico-ammeter (PICO)
- ❖PICO @ Goliath test

Upgrade of the Muon Detectors

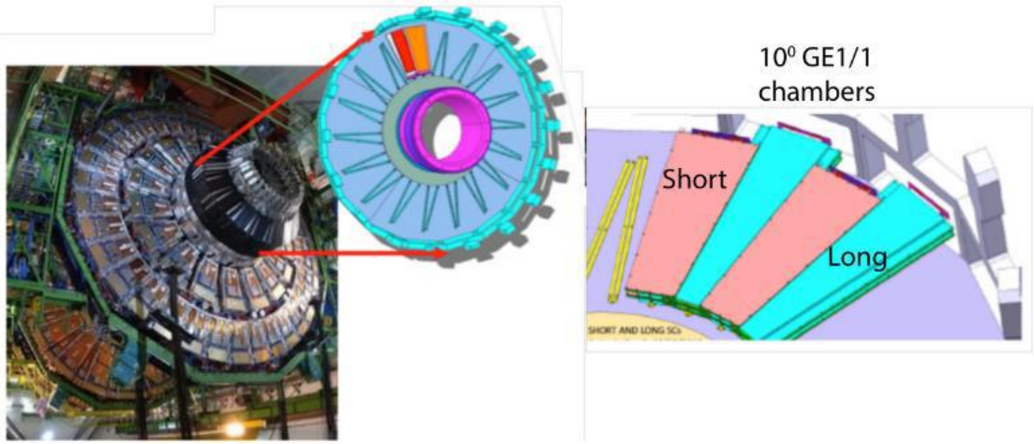
- 2026: HL-LHC
  - Instantaneus Luminosity:
    $2 * 10^{34} cm^{-2}s^{-1} \rightarrow 5 * 10^{34} cm^{-2}s^{-1}$
  - Pile-up events :
    $\sim 37 \rightarrow \ \sim 200$

- Add redundancy to the muon system in the endcap regions ($|\eta| > 1,6$)

- GEM technology provides:
  - Good time resolution
  - High rate capability



GE1/1 Upgrade

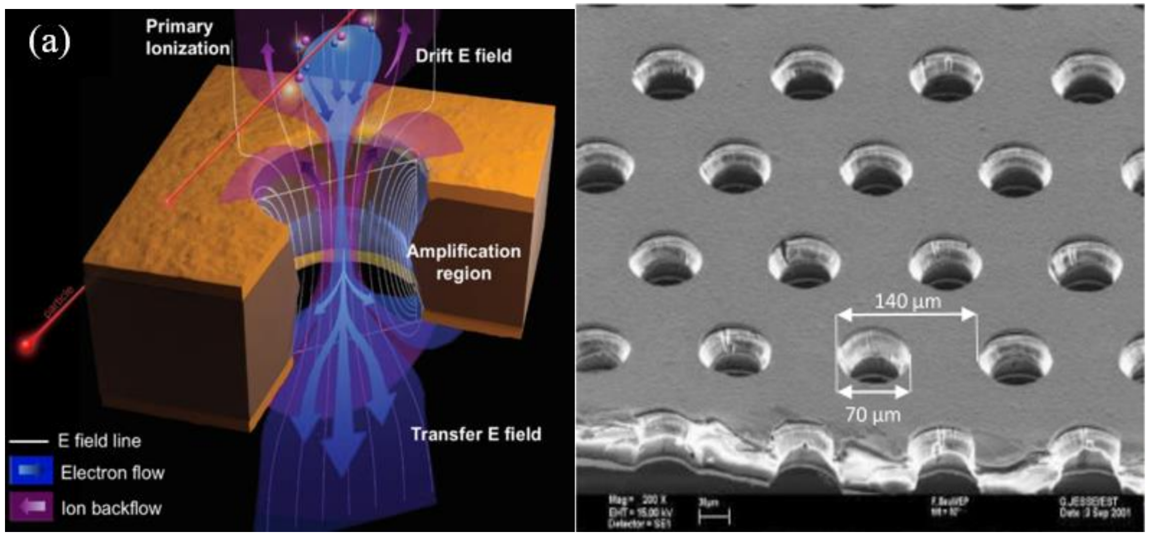


Performances

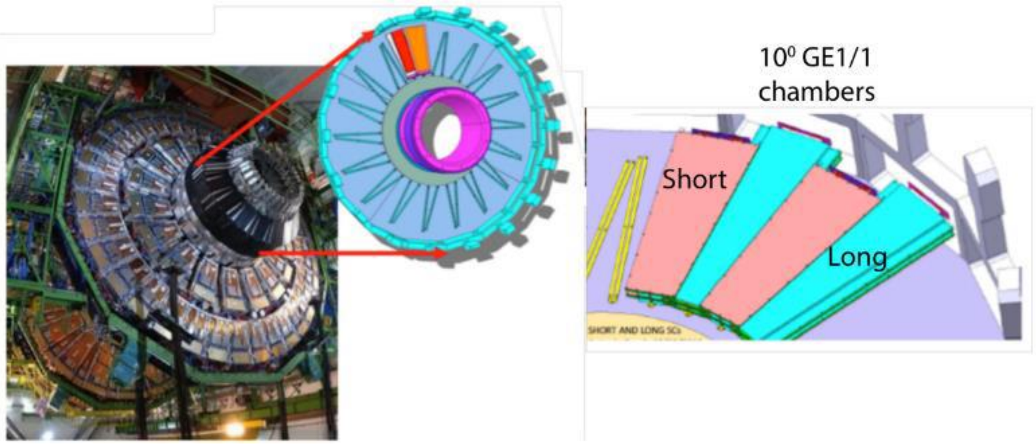
- Space Resolution <100µm
- Time Resolution *O*(10ns)

GEM technology

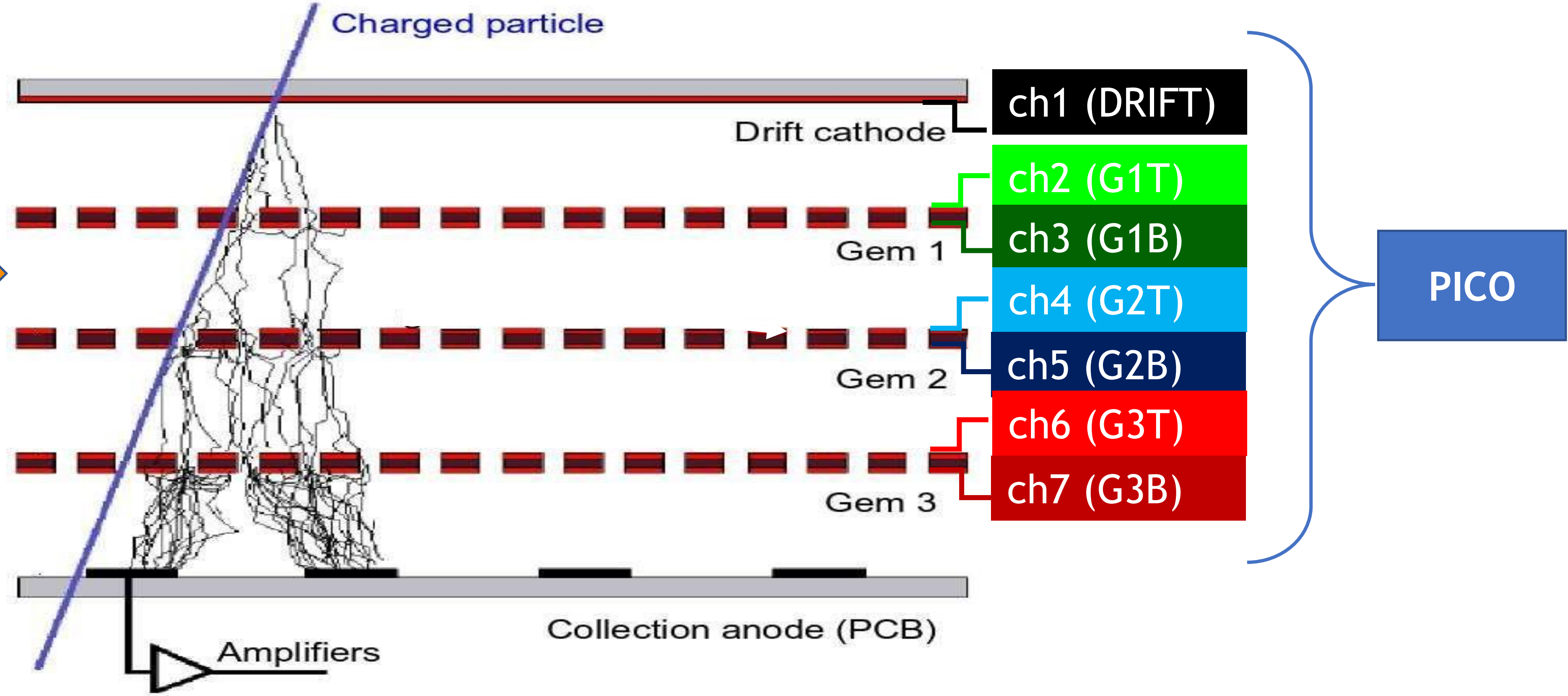
- Copper 5µm
- Kapton 50µm
- Holes density 50-100/mm^2



GE1/1 Upgrade

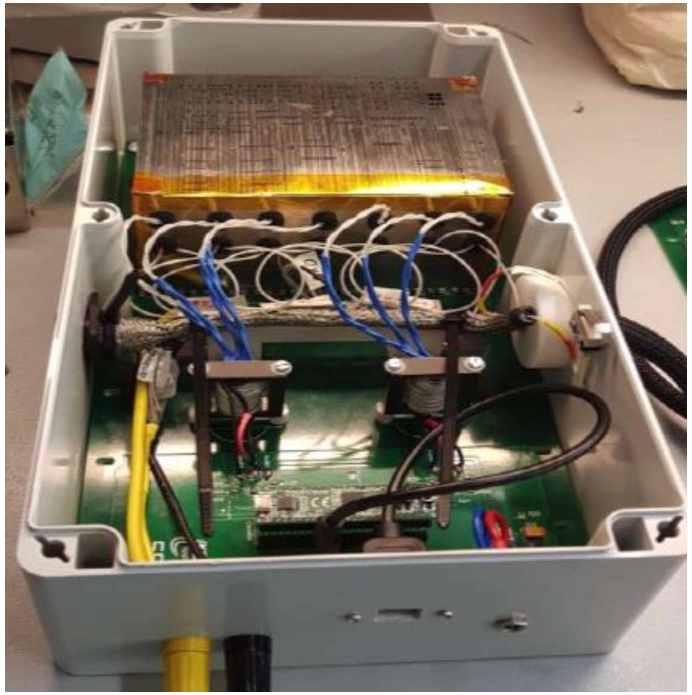


Triple-GEM



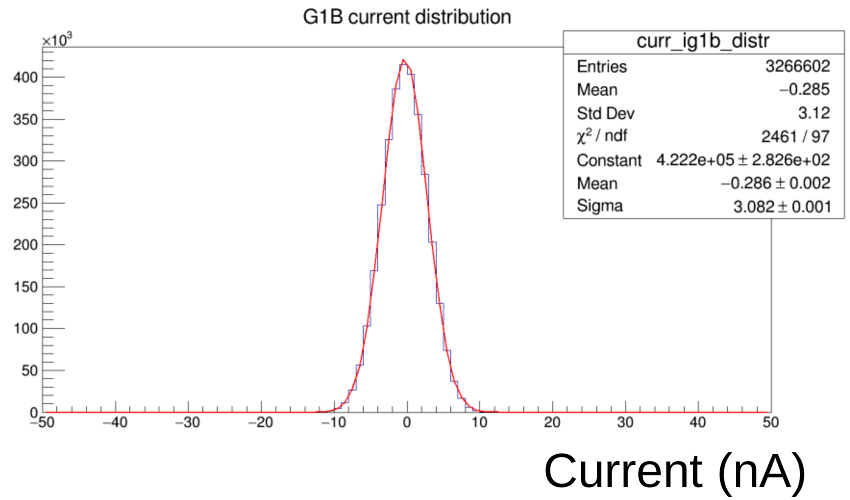
PICO:

pico-ammeter custom made @ INFN Napoli for Triple-GEM characterization



PICO

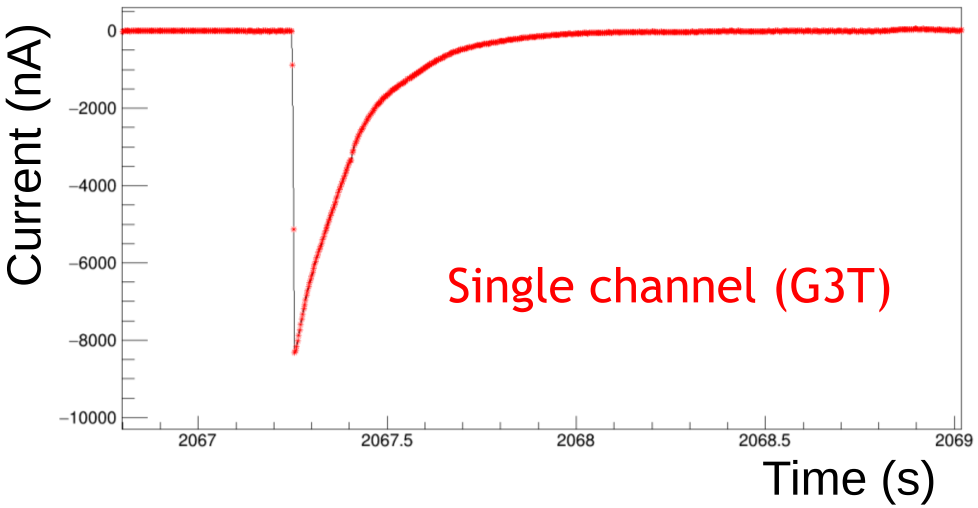
- PICO allows a simultaneous monitoring of **7 GEM electrodes**, both current and voltage

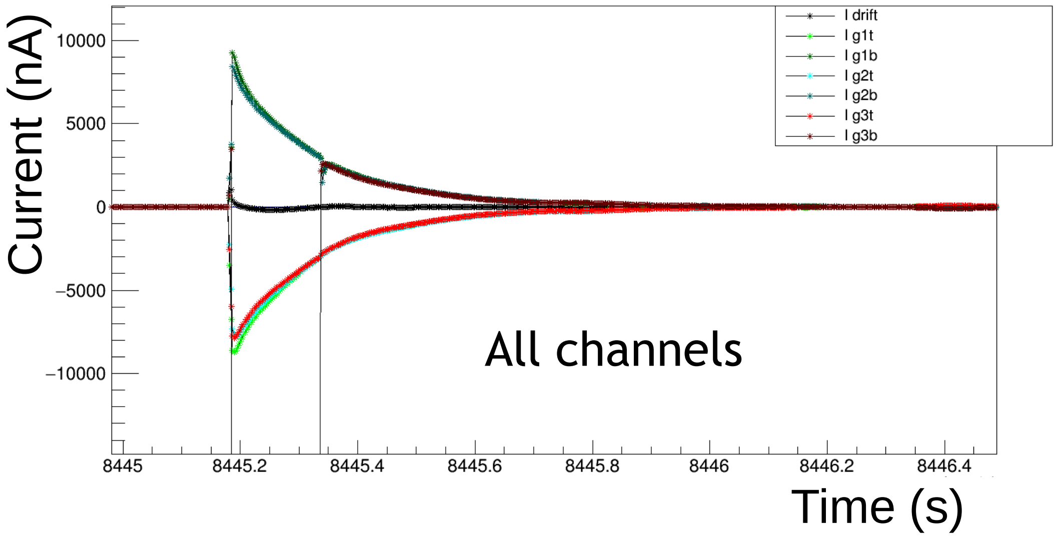


- **Sampling 380Hz**; Typical sampling of CAEN boards O(Hz)

- **Resolution ≤30pA** (much smaller than noise)

- **PICO fully tracks sparks** that CAEN board (A1515) is not able to detect



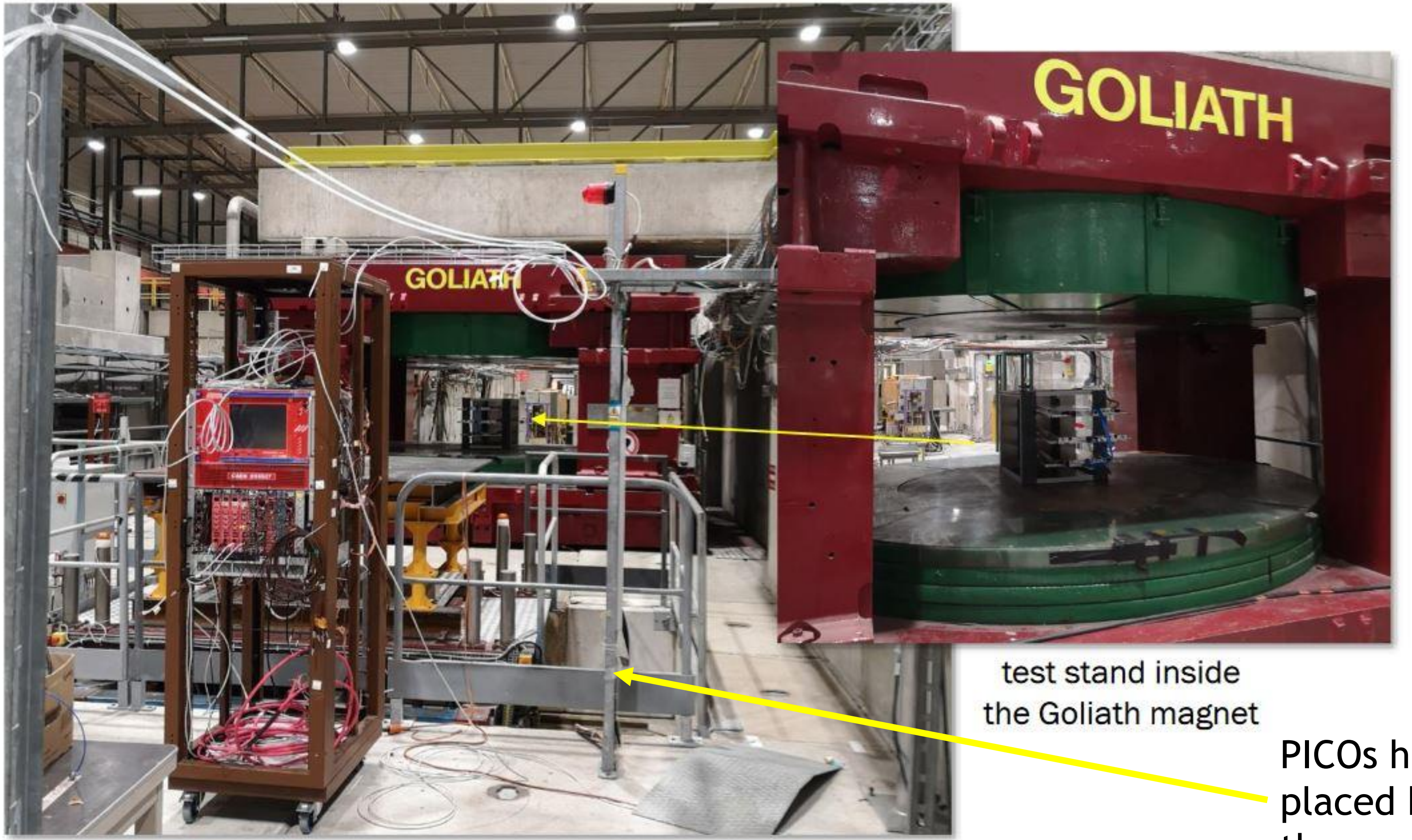


PICO@Goliath

Study of GEM behaviour with magnetic field up to 1.4T at the CERN magnet named Goliath

As part of these tests:

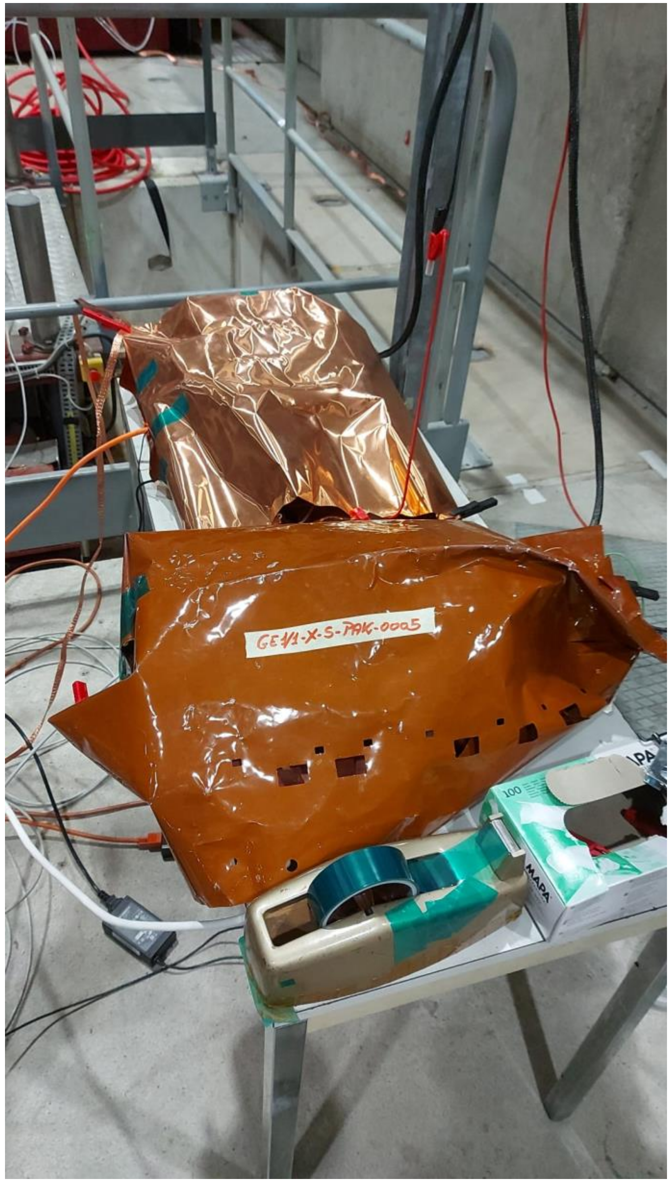
- Commissioning of 2 INFN Napoli PICOs
- Characterization of discharges (spikes) through its main properties (**amplitude**, **slope**) and simultaneus analysis of the 7 channels (Drift, G1T, G1B,..)
- Search for precursory phenomena of discharges (a particular current/voltage behavior, a sequence of small discharges,…)



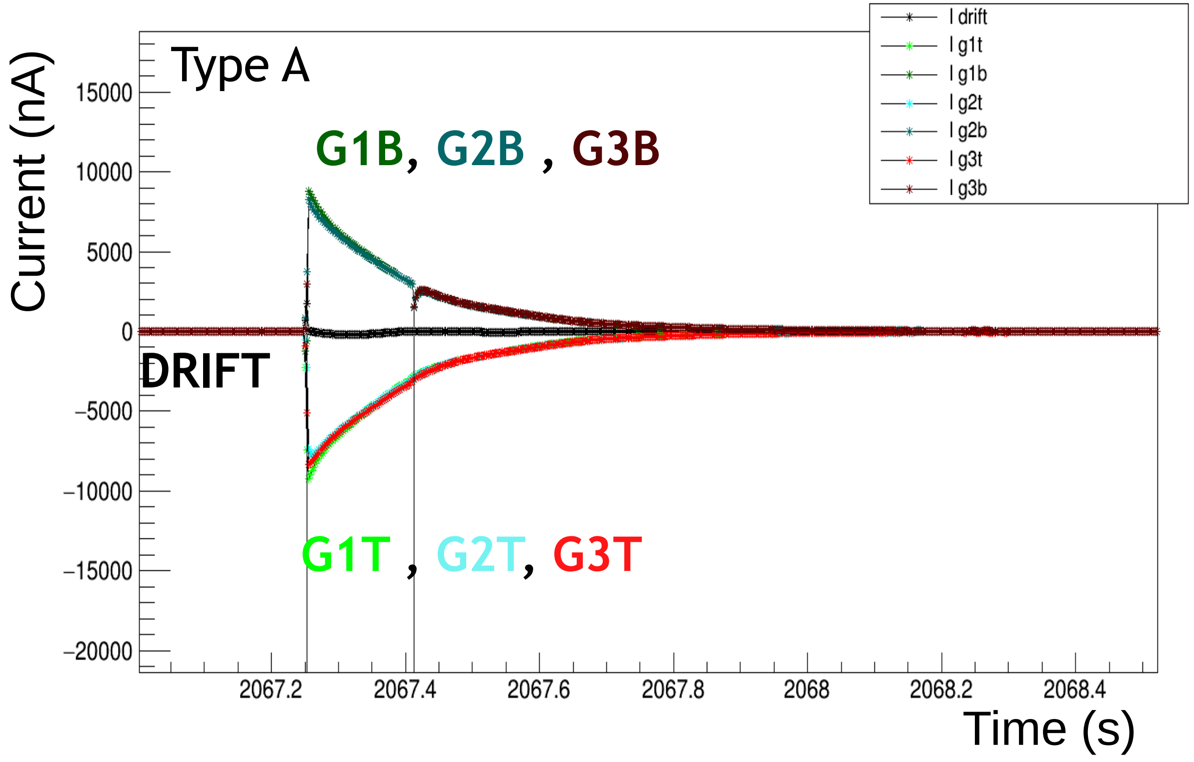
test stand inside the Goliath magnet

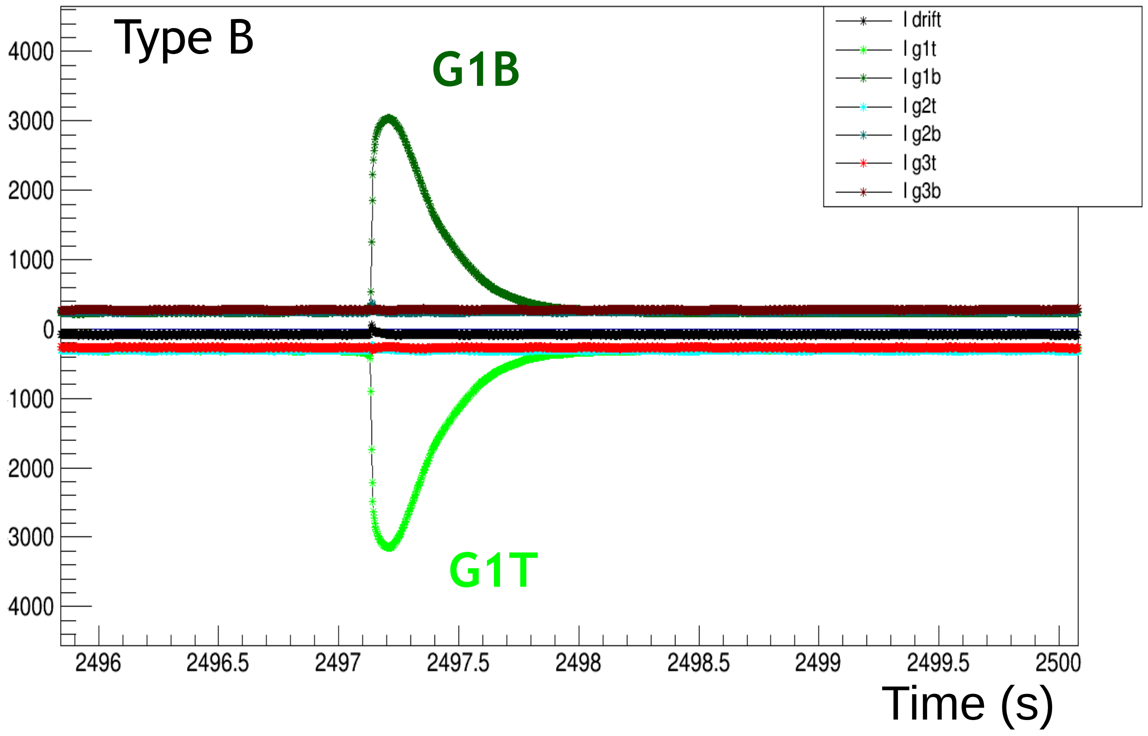
Installation in the experimental area

PICOs have been placed here (see the next slide)


GE1/1-X-S-PAK-0005

Preliminary studies on discharge signals





G3 discharge ←

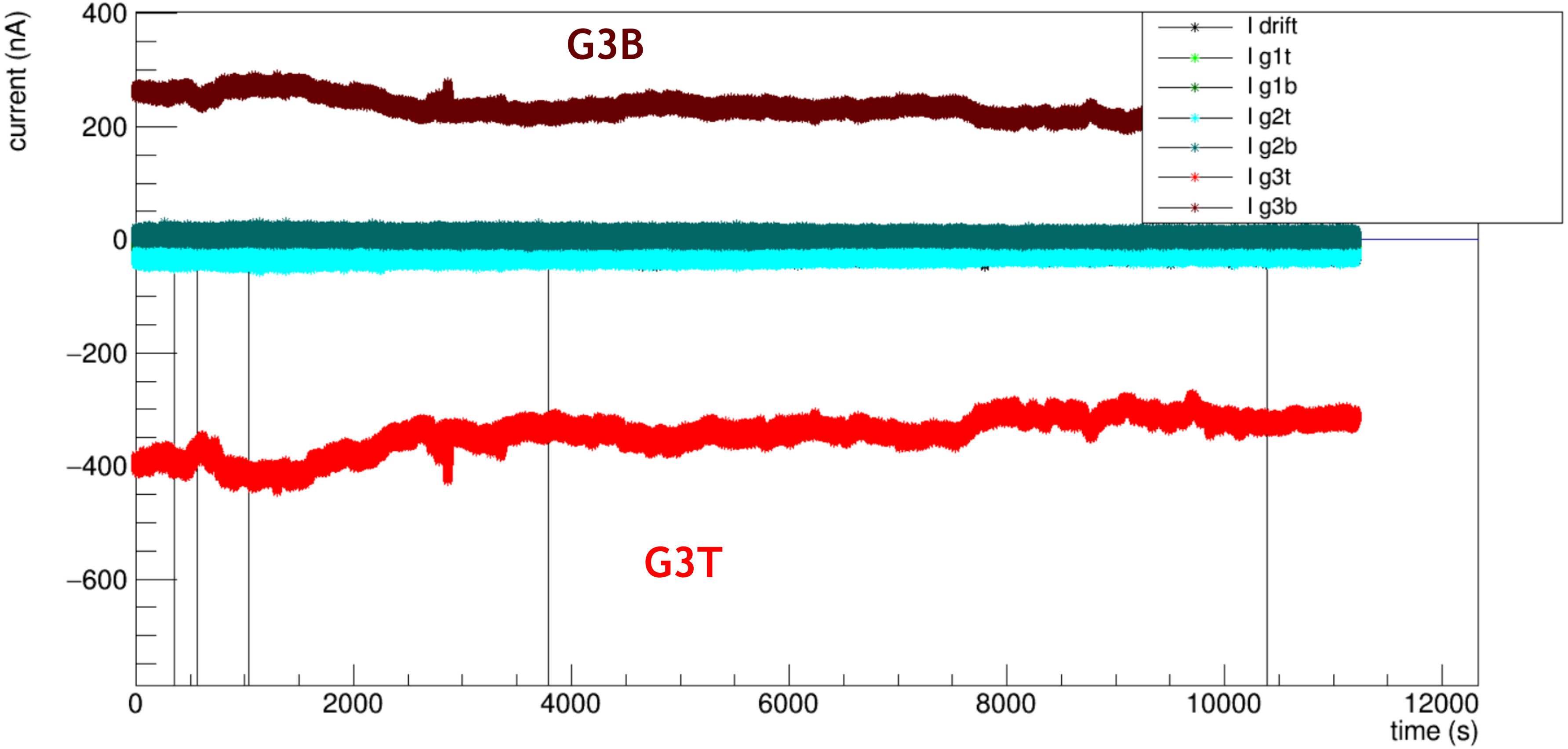
- GEM Top negative polarity
- GEM Bottom positive polarity
- Same amplitude

G1T and G1B currents: same amplitude, same shape, opposite polarity → **G1 discharge**

PICO as inspection tool for small currents

- Example of an abnormal current not seen by the CAEN board.

still under investigation!



Conclusions

- ❑ Commissioning of PICO fully successful for the entire week without any kind of malfunctioning
- ❑ PICO is the the perfect instrument to study GEM currents anomalies, it is designed ad hoc for that!
- ❑ It is well suited instrument to detect and characterize different types of discharges, in particular we could individuate the GEM foil in which the spike is located
- ❑ There will be chances for new tests before RunIII

BACKUP

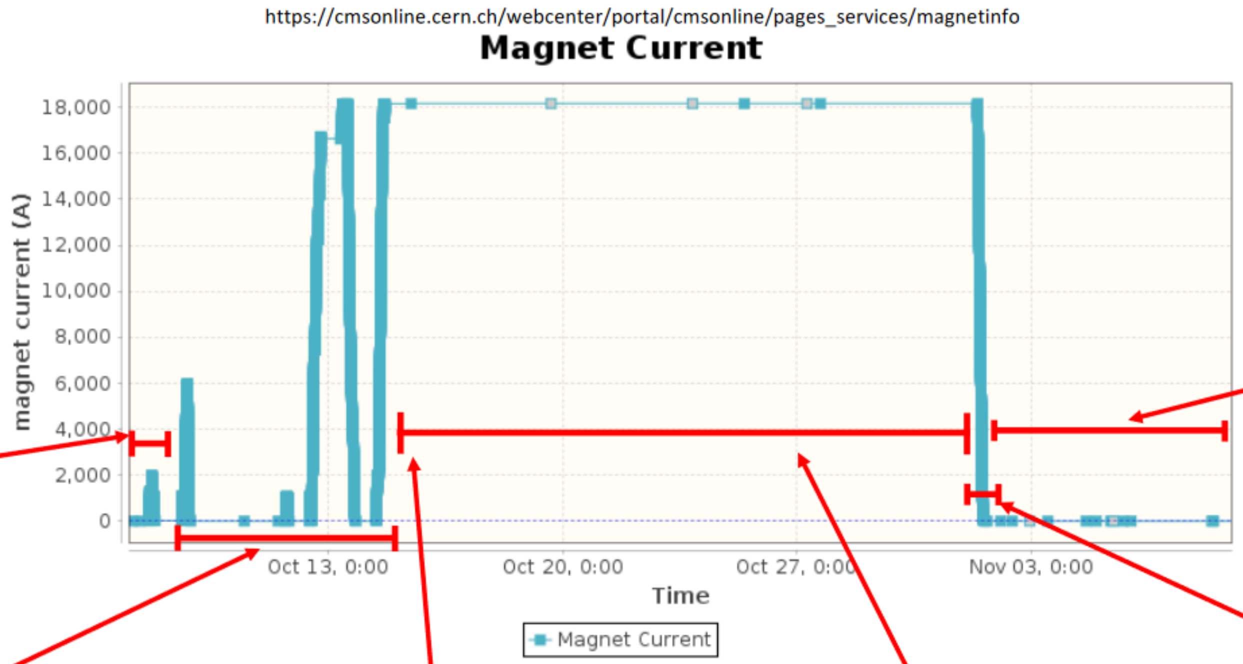
Goliath test goals

- ❑Reproduce anomalies (discharges and/or trips) as seen at P5 with GE1/1 detectors during magnet ramp

- ❑Define an HV setting such as to be able to keep the GE1/1 detectors in a safe status during the CMS magnet ramp

- ❑Define a proper procedure to burn the short-circuits in the operating gas mixture Ar-CO_2 (70-30%)

P5 observation (october-november2021)



First ramp and Multiple trips → we decided to stay OFF during next ramps

Other ramps → GEM OFF

Magnet stable → GEM back on but 3 shorts detected

Operation in magnetic field → Nothing particular

Magnet down → GEM OFF

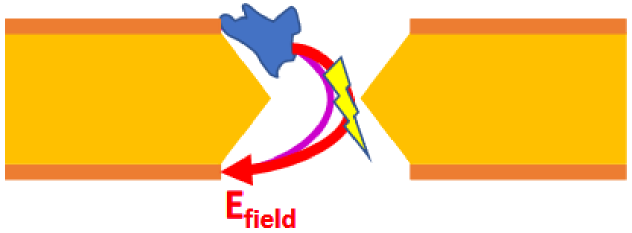
Magnet OFF → GEM back ON and additional 7 shorts detected

Hypotesis:

Microscopic dust that 'approach' the GEM electrodes

TRIPS during ramp

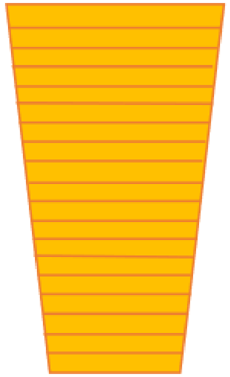
- Dimensions <10μm (detectors assembled in class 1000 clean room)
- Probably metalic but not ferromagnetic (such materials are not present)
- Light dust particles can detach from surfaces with the small force they receive from the magnetic field change (also if they are para/diamagnetic)



N.B.

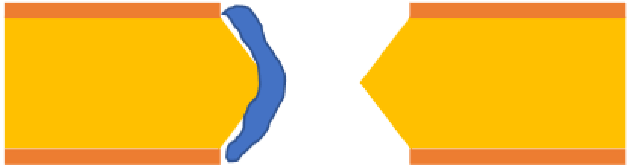
GEM foils are segmented (40 for short and 47 for long) and the segments are decoupled with resistors

One short means loosing ≈2.5% of the detector active area



SHORTS with detector OFF

- Same particles that deposit near hole but no electric field is present
- When slowly ramping the detector, the dust can melt and create a permanent conductive path



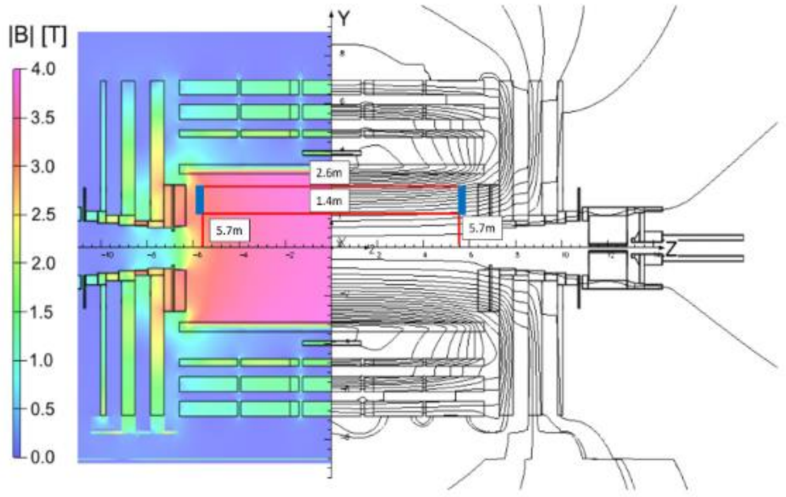
GEMHV_DFiorina_CMSWeek

Experimental setup

- Goliath magnet (up to 1.4T) present at the H4 beam line in North Area
- Four chambers were selected for the test:
  - GE1/1-L-X-CERN-0002;
  - GE1/1-L-X-CERN-0009;
  - GE1/1-S-X-PAK-0005;
  - GE1/1-S-VII-CERN-0006.

Observed with PICOs

Magnetic field in CMS and in Goliath



- **GE1/1 subsystem is inside the CMS solenoid**
- **The magnetic field lines are "almost" perpendicular to GE1/1 detector**
- **On the contrary, the gravity force is parallel to the detectors**
- **Nominal ramp rate of the CMS magnet of ≈1.5 A/s**

(https://cmsonline.cern.ch/webcenter/portal/cmsonline/pages_services/magnetinfo)

✓ magnetic field lines

→ ***Goliath magnet:***

magnetic field lines ⊥ GEM-foils

→ ***P5 Solenoid:***

magnetic field lines ⊥ GEM-foils

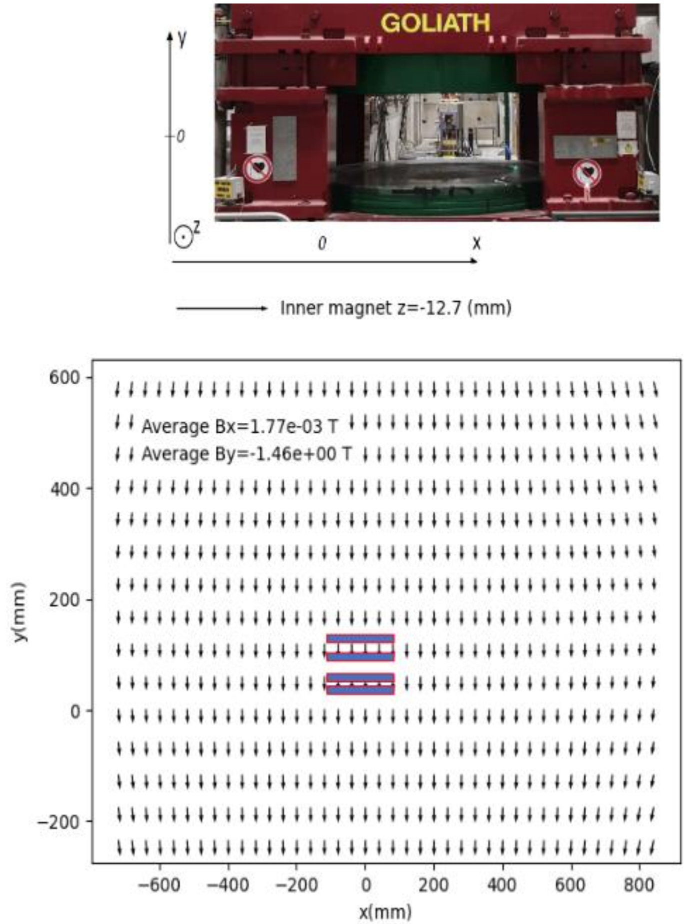
✓ gravity force

→ ***Goliath magnet:***

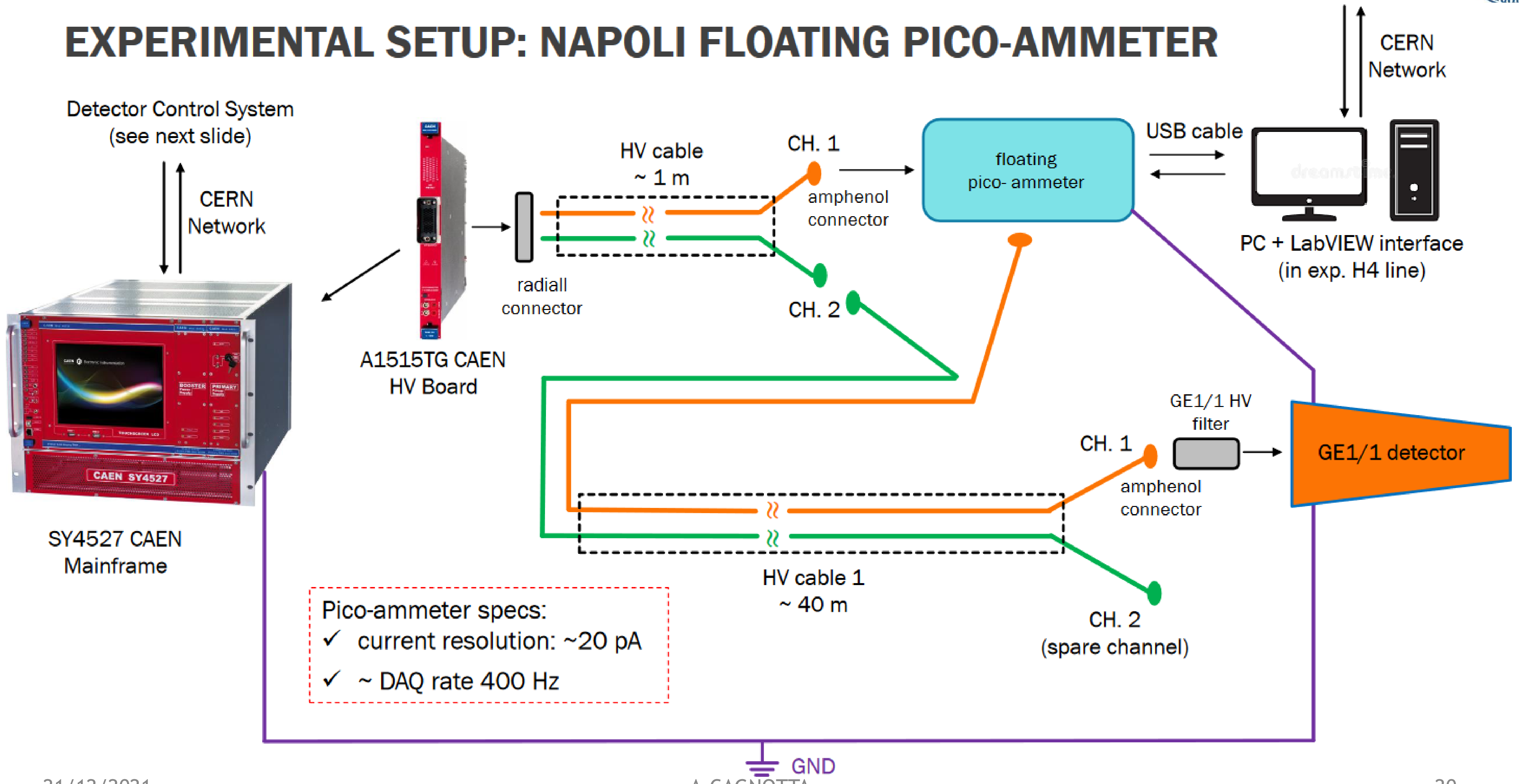
gravity force ⊥ GEM-foils

→ ***P5 Solenoid:***

gravity force ∥ GEM-foils

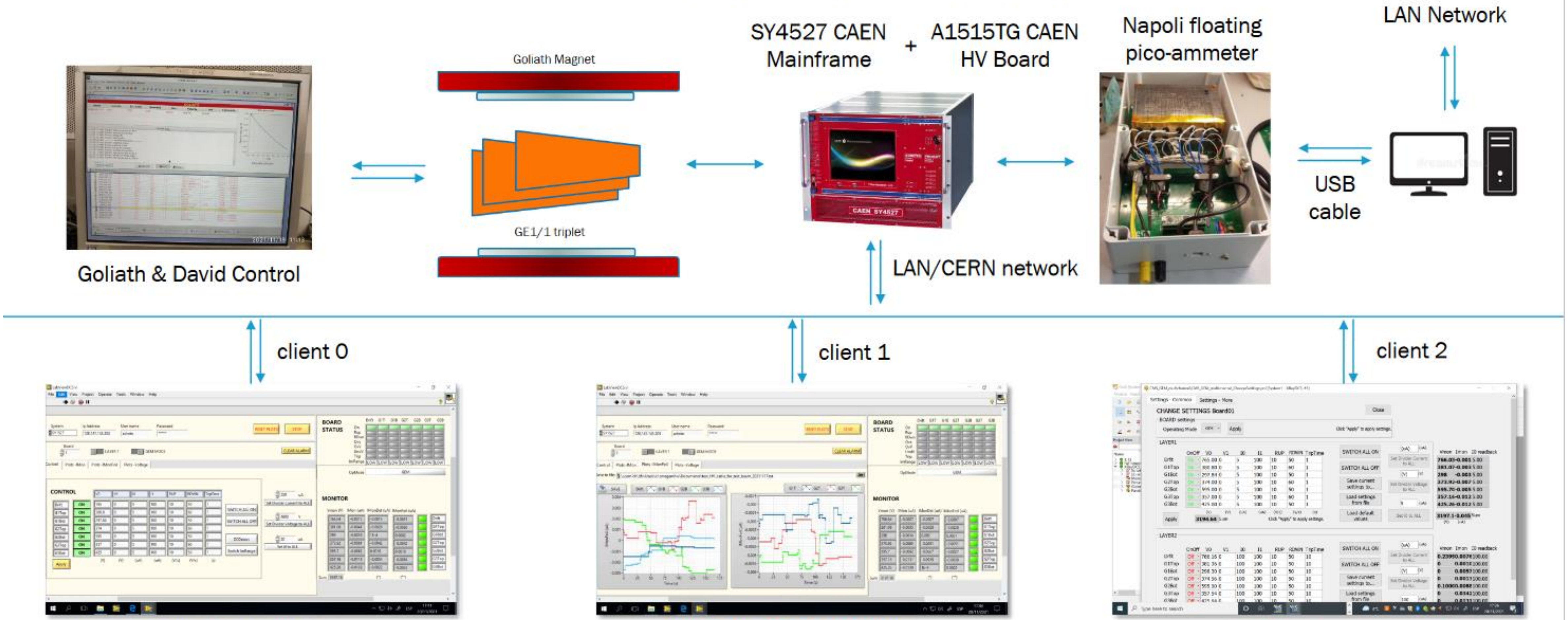


EXPERIMENTAL SETUP: NAPOLI FLOATING PICO-AMMETER



Pico-ammeter specs:
- ✓ current resolution: ~20 pA
- ✓ ~ DAQ rate 400 Hz

EXPERIMENTAL SETUP: DETECTOR CONTROL SYSTEM



1) DCS developed in LabVIEW
(database in 904 lab.)

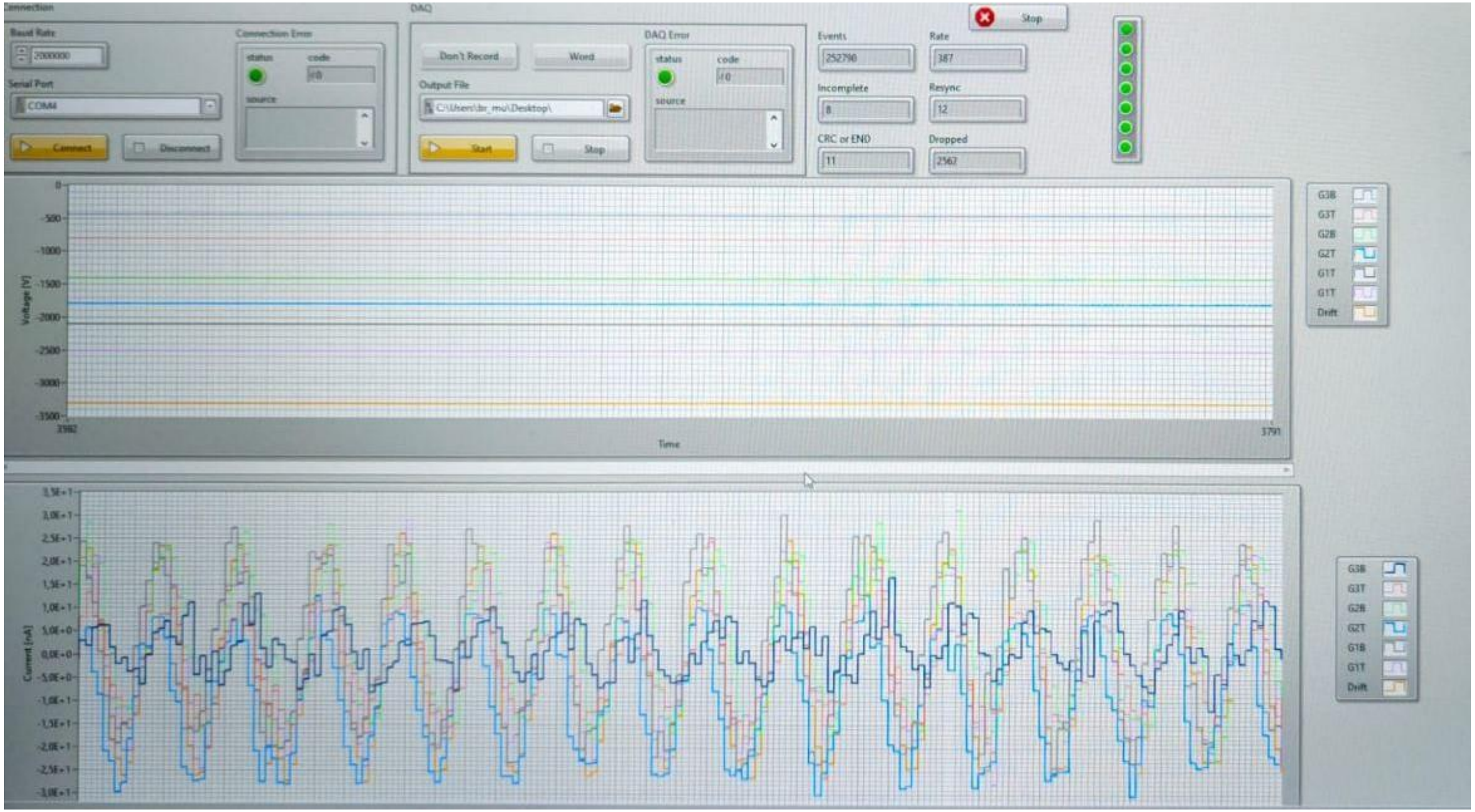
2) DCS developed in LabVIEW
(real-time monitoring in CR)

3) DCS developed in winCC-OA
(setting parameters in CR)

PICO LabView software

Voltage (V)

Current (nA)



Goliath info

- The software used for tune the magnetic field allows as to insert an input current corresponding to a magnetic field in the cavity.
- The magnet reaches the input current level in two step:
  - Goliath step (fast ramp)
  - David step (slow ramp)

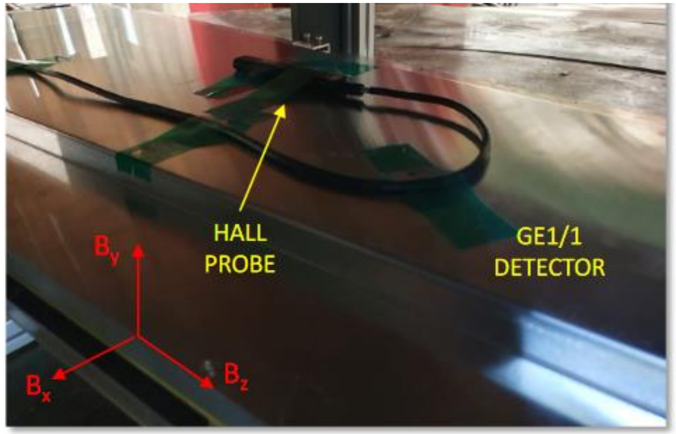
- Different current values are used during the test:

Current	Magnetic filed (T)
400 A	0.2
800 A	0.4
1.2kA	0.6
1.6kA	0.8
2.0kA	0.9
2.4kA	1.0
2.8kA	1.2
3.6kA	1.4
MAX	1.5

- The current can be set with a different sign, in that case we have the same magnitude of the field but in the opposite direction

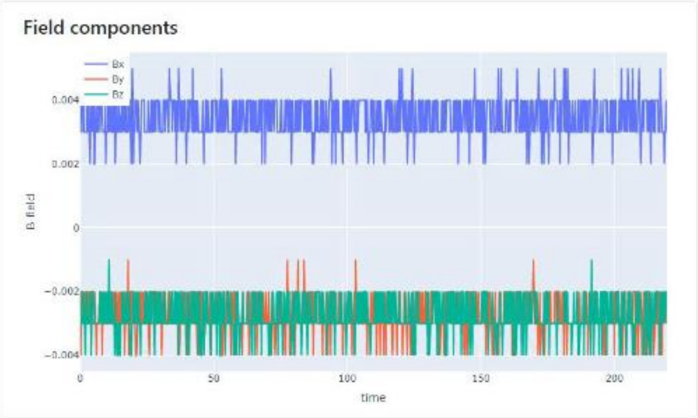
Magnetic field sensor

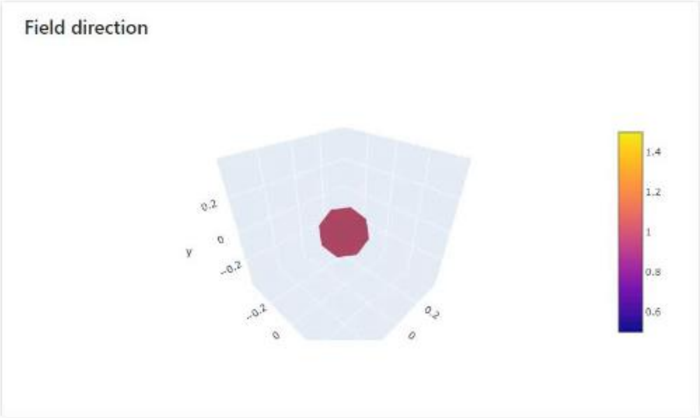
- Hall probe installed inside the experimental stand
  - → THM1176 3-axis Hall Magnetometer
  - → 3-axis Hall sensor enabling 3-axis field measurements
  - → monitor the magnet field around the GE1/1 chambers (monitor the ramp-up/down rate of Goliath magnet)
  - → dedicated software for real-time monitoring and data saving



Magnetic field monitor

- ✓ the code is written in Python code (by Antonello)
- ✓ the magnet field is recorded and saved with frequency ~ 5Hz
- ✓ the magnet field can be monitored with a refresh rate of 1Hz





Preliminary observation

- Magnet ramps easly trigger trips (i.e. sparks) in the detectors (HV ON)
  - This do not depends on the reached field (the detachement of the dust from the walls requires just a little force)
  - Such sparks do not produce shorts (the dust is burned instantaneosly in the foils)
- Magnet ramps can cause shorts if the detectors are OFF
  - Only one short produced in such a way (low chance)
  - Short successfully ‘burned’ with a Megger hit (in P5 configuration: 40m of HV cable and Ar/CO2)
- After multiple ramps and sparks the number of trips start to reduce
  - Chamber dust is burned during the multiple sparks
  - No trips detected during passage from standby-physics with field stable ON Field was half of P5 one