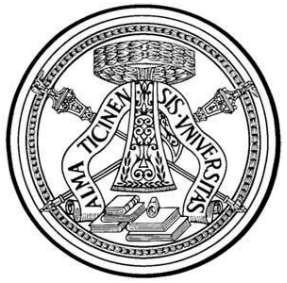
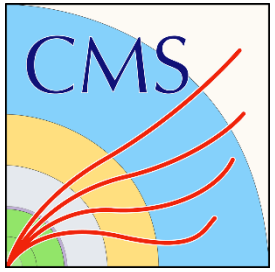




Production and installation of first GEM station in CMS

INSTR'20
24-28 February 2020
Novosibirsk, Russian Federation

Simone Calzaferri
On behalf of the CMS Muon Group

Outline

- The GEM project upgrade
- What is a GEM detector
- How GEMs are produced
- Installation of GE1/1 detectors in CMS
- GEM HV and LV monitor

The GEM project

Muons tracking and triggering done with 3 different technologies @ RUN 2

- Drift Tubes (DTs)
- Resistive Plate Chambers (RPCs)
- Cathode Strip Chambers (CSCs)

Run 3 and beyond

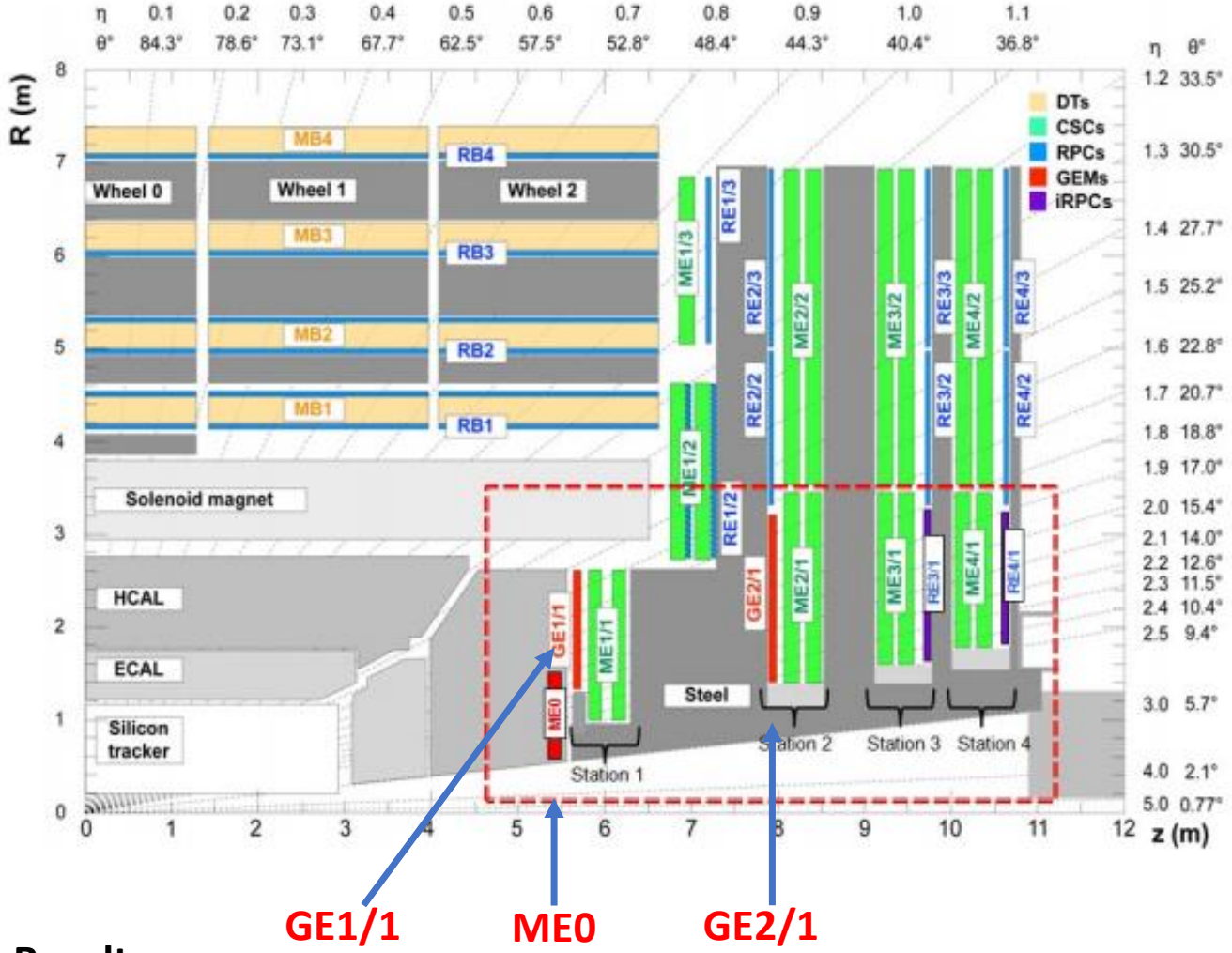
- Gas Electron Multiplier (GEMs)
  Ten GEM chambers were installed and operated in RUN2 to gain an operational experience and measure the muon detection efficiencies and environmental BKG rates **(GEM Slice test)**

Where GEMs will be installed?
In endcaps to cover $1.6 < |\eta| < 2.8$

Why GEMs?

- High rate capability (up to $100\ MHz\ /\ cm^2$)
- High spatial resolution ($140\ \mu m$)
- Radiation hardness (up to $1.56\ C\ /\ cm^2$)

Three GEM stations to be installed: **GE1/1, GE2/1, ME0**

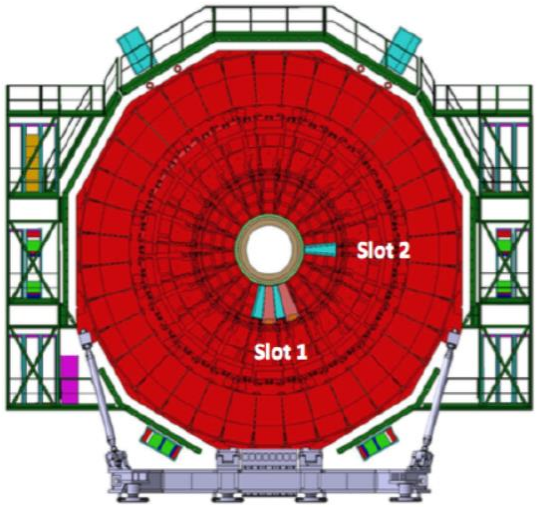


Result

- GEM detectors **increase the redundancy** --> Higher number of hits to reconstruct muons
- GE1/1 and GE2/1 allow to **keep under control the trigger rate**, without increasing the p_T threshold
- ME0 ($2.0 < |\eta| < 2.8$) **increases the CMS η coverage**

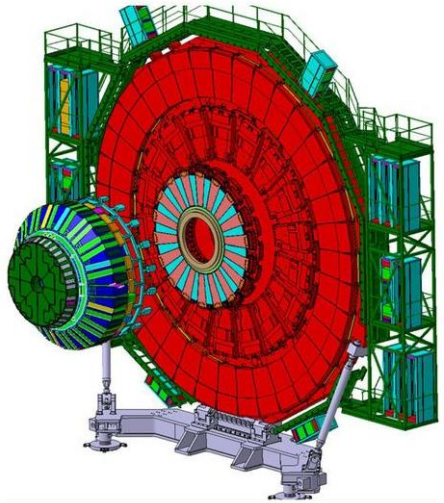
GEM upgrade timeline

RUN 2
2017-2018



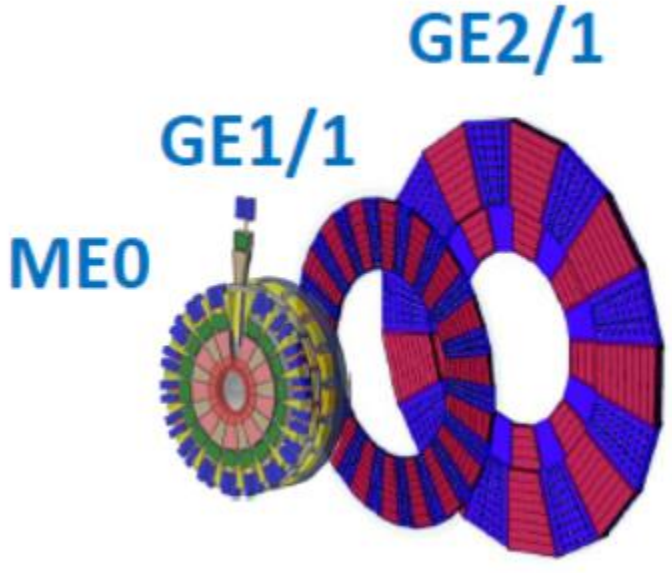
Slice test
Demostration of GEMs in CMS

Long Shutdown 2
NOW



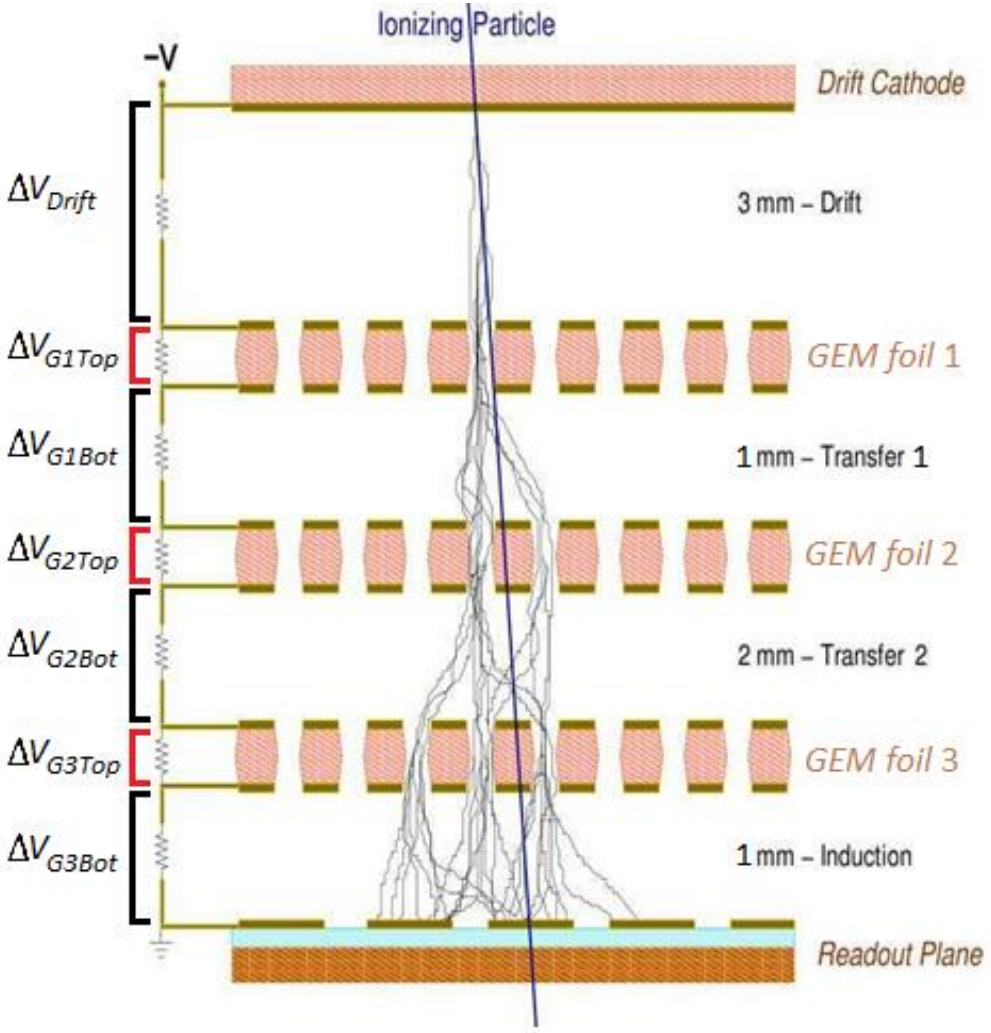
GE1/1 installation

Year End Technical Stops and Long Shutdown 3
2022-2026



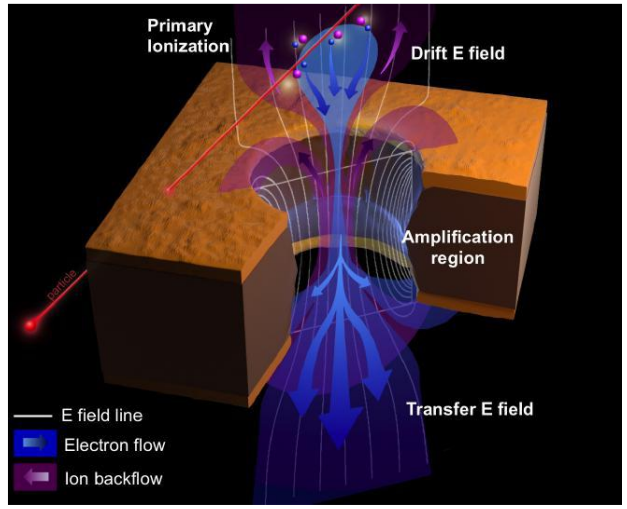
Installation of ME0 and GE2/1
GEMs stations by the end of LS3

How a GEM is made?



Structure

- **Three GEM foils** stacked one over the other
- A GEM foil is a $50\mu m$ thick polymer foil, with **copper on both sides**
- $70\ \mu m$ **biconical holes** etched on foils, interspaced by $140\ \mu m$

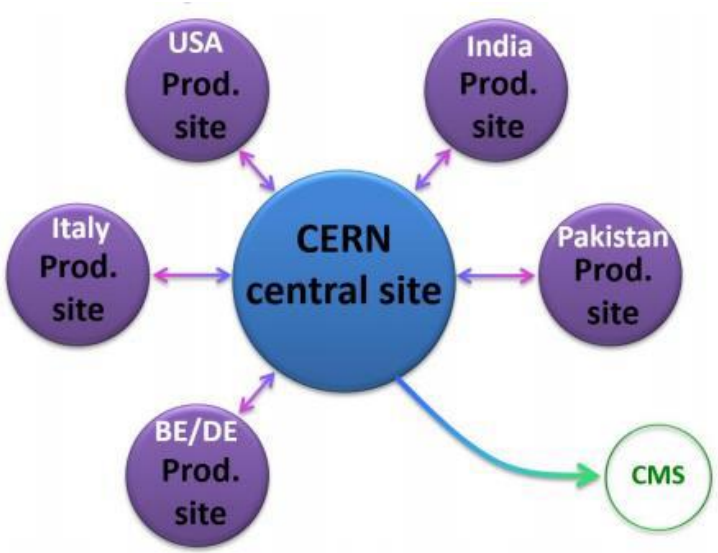


Operation

- A particle produces a **ionisation in the gas medium** (Ar/CO_2 70% / 30 %)
- The **electrons drift** by the electric field in the gaps
- **High electric field** in **holes** causes an **avalanche multiplication** of electrons
- The avalanche is collected by **copper strips** placed below the last GEM foil (GEM 3)
- **Signal** can be **read from strips** with a proper electronics

GE1/1 Assembly

GE1/1 is made of **144 GEM detectors: production effort is shared among different labs around the world**



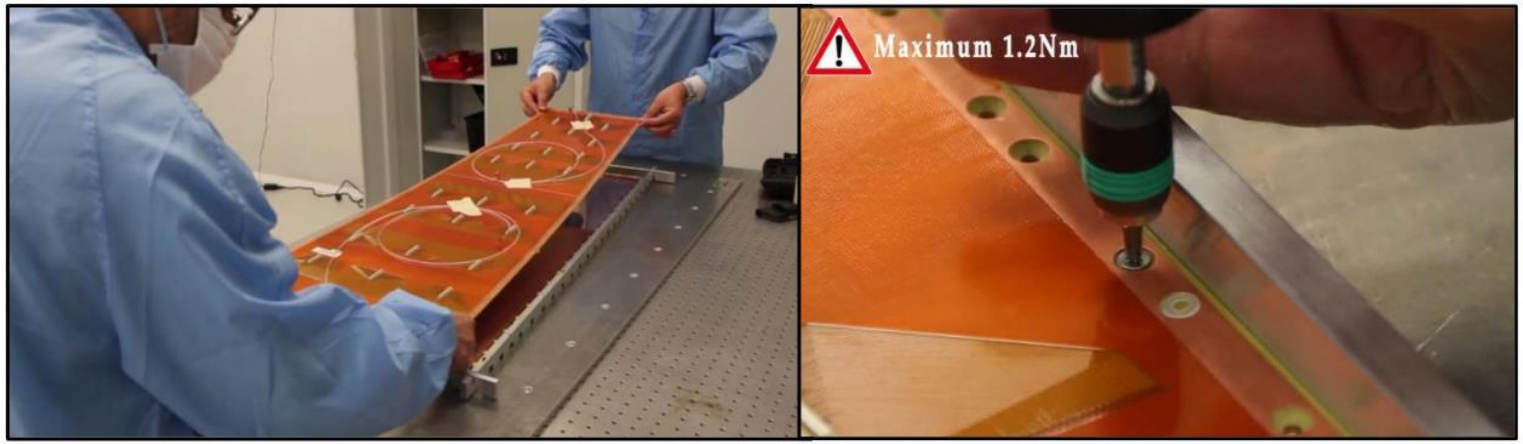
Step 1: preparation of material in the lab

- Cleaning of components
- Preparation of the HV circuit
- Mounting of the pull-outs
- Selection of the O-ring

Step 2: assembly in clean room

- Fast test of GEM foils
- Mounting of the stack
- Closing the chamber

Time to assemble one chamber: 1 day



GE1/1 Production and validation

CERN

- QC1 — Material inspection
- QC2 — GEM foils test

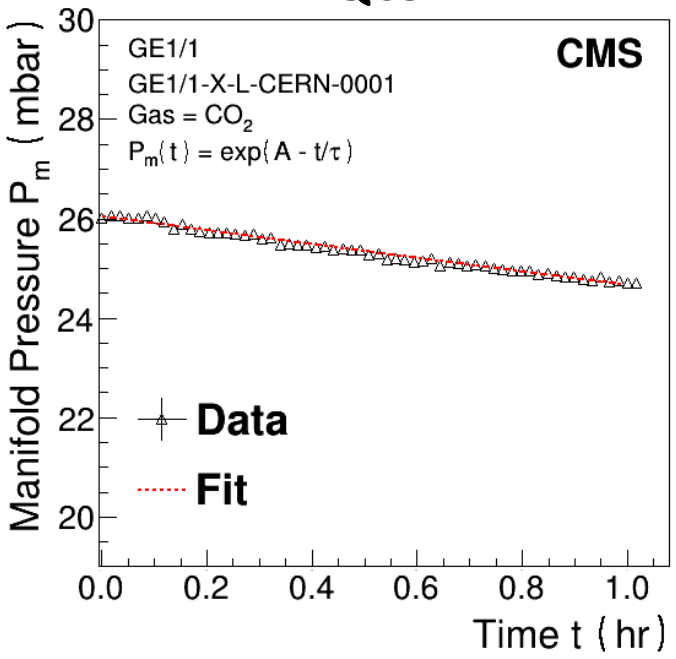
Production Sites

- Assembly
- QC2 — GEM foils test (fast)
- QC3 — Gas leak test
- QC4 — HV test
- QC5 — Gas gain calibration

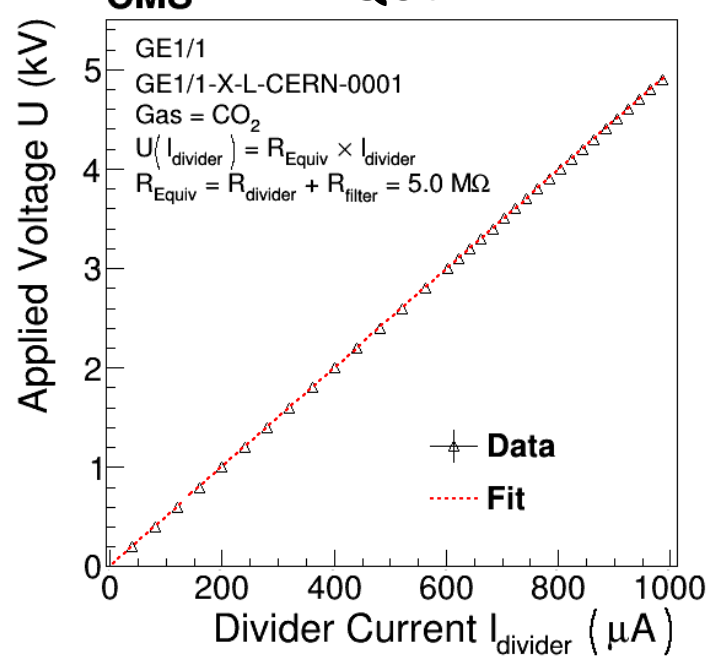
CERN

- QC6 — HV stability test
- QC7 — Electronics connectivity test
- Coupling — Two chambers are coupled: A SuperChamber is made
- QC8 — Cosmic muons test

QC3

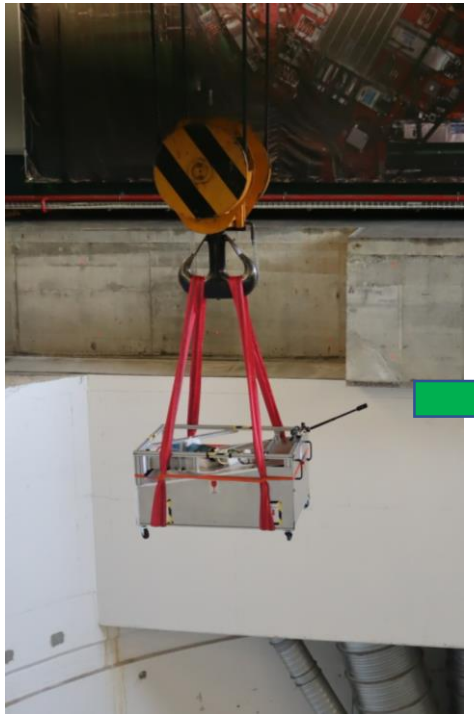


CMS QC4



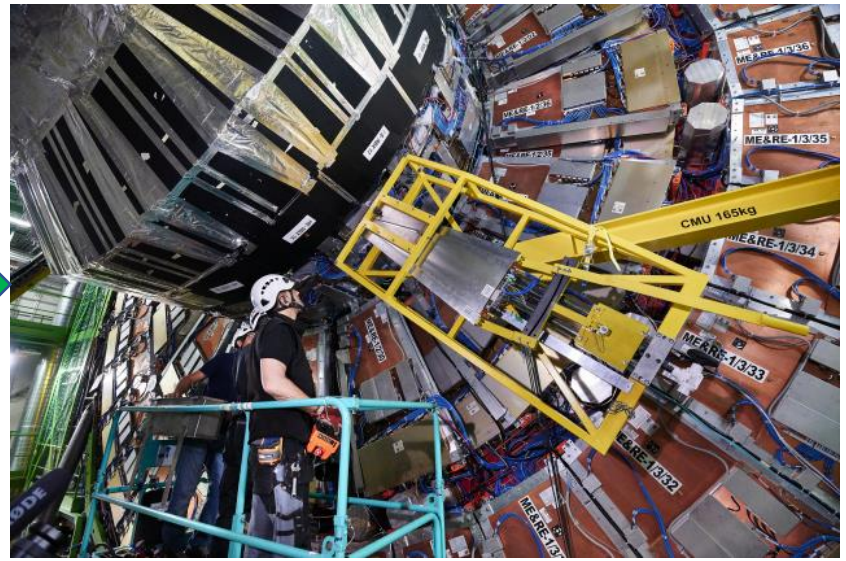
Between QC7 and QC8 GEM **chambers are coupled** to form one **Super Chamber**
144 GEM chambers --> 72 Super Chambers
36 Super Chambers per Endcap

Installation of GEM detectors in CMS



Validated Super Chambers **lowered to CMS experimetal cavern**

GEM Super Chamber mounted in the **installation jig**



GEM Super Chamber **installed** on the nose of CMS experiment

Installation in P5: status

Negative endcap

All 36 GE1/1 Super Chambers installed in the negative endcap

- All **services** installed on the disk
- **Gas and cooling** system operative for all chambers
- **HV and LV sysyem** is installed and fully operative
- **DCS** is under local test
- **Readout Back-End** Hardware installed

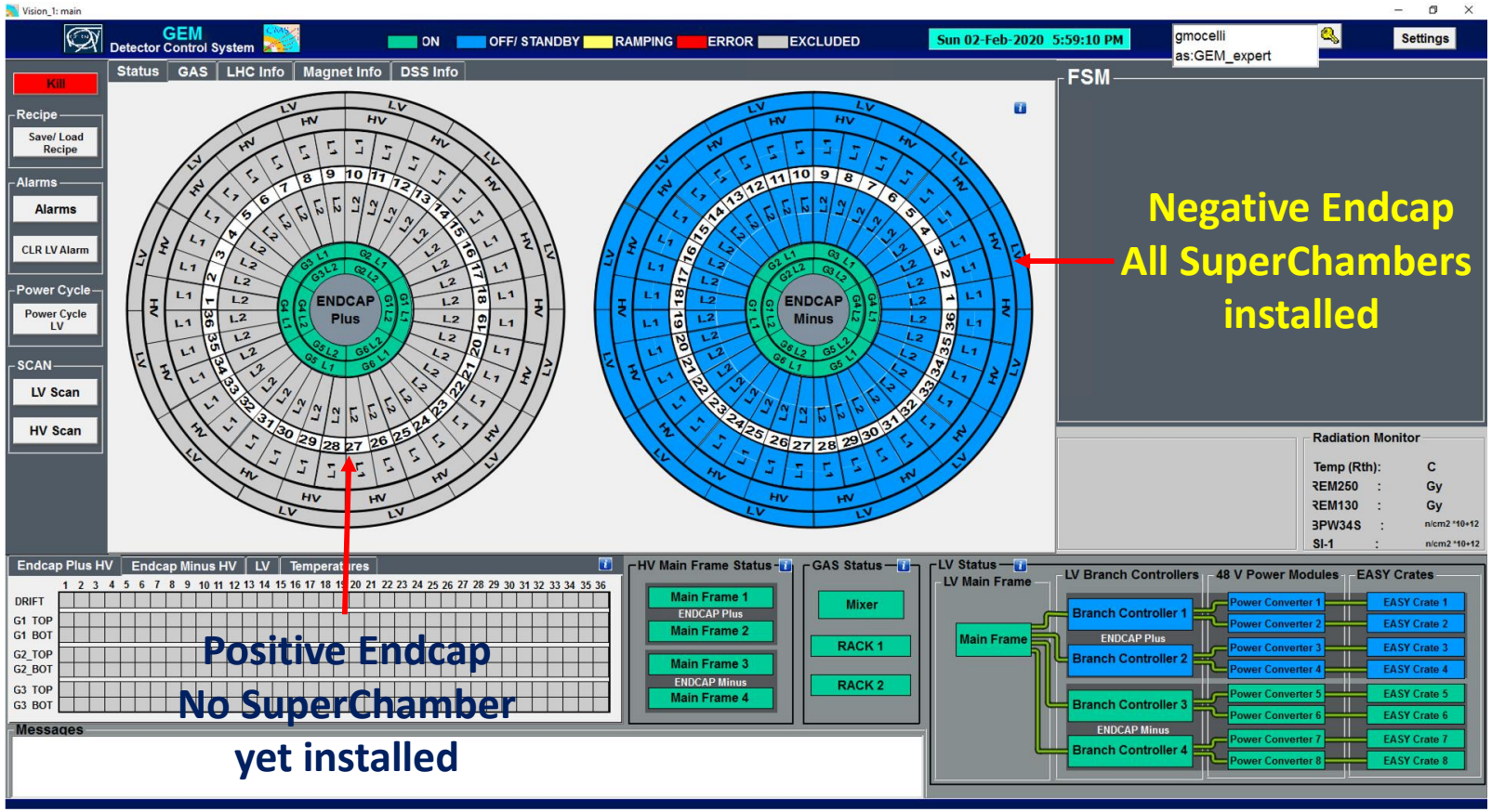
Positive endcap

No GE1/1 Super Chamber yet installed in the positive endcap (**installation window: May-June**)

- **Gas system**: under completion
- **Cooling system**: under completion
- **LV boards**: all installed
  HV boards: under delivery by the end of February
  Cables to be routed from periphery to disk in March
- **DAQ**: electronics and fibers under installation

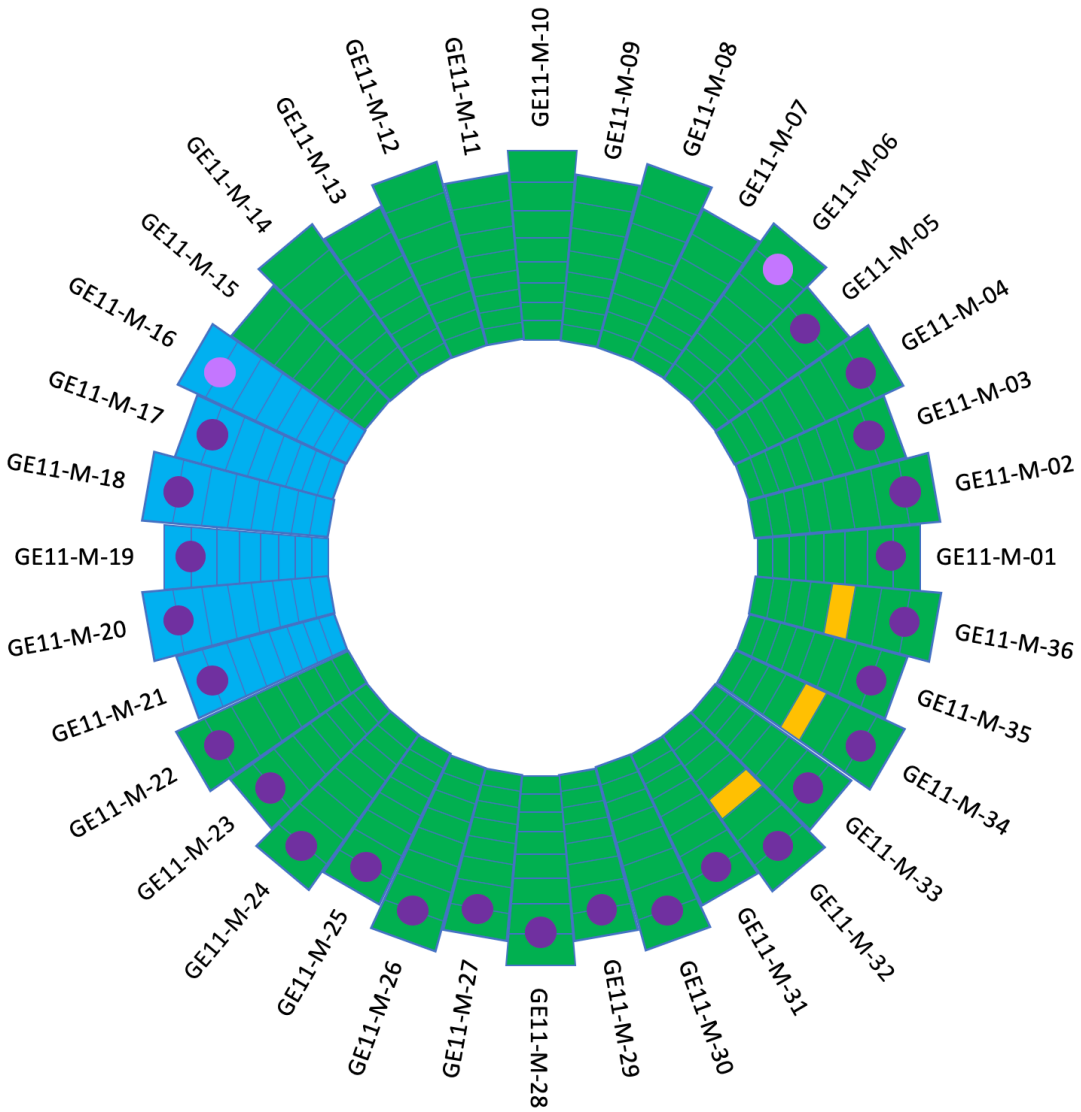
GE1/1 negative endcap: stability tests

- **36/36** Super Chambers installed in **negative endcap**
- After a chamber is installed in CMS, the GEM foils and FE electronics of each chamber must be tested
  HV --> test the stability of GEM foils
  LV --> test the communication with chamber FrontEnd electronics



GEM Detector Control System (DCS)

GE1/1 negative endcap: status



Super Chamber and services installed

Connectivity tested

Front End fully tested

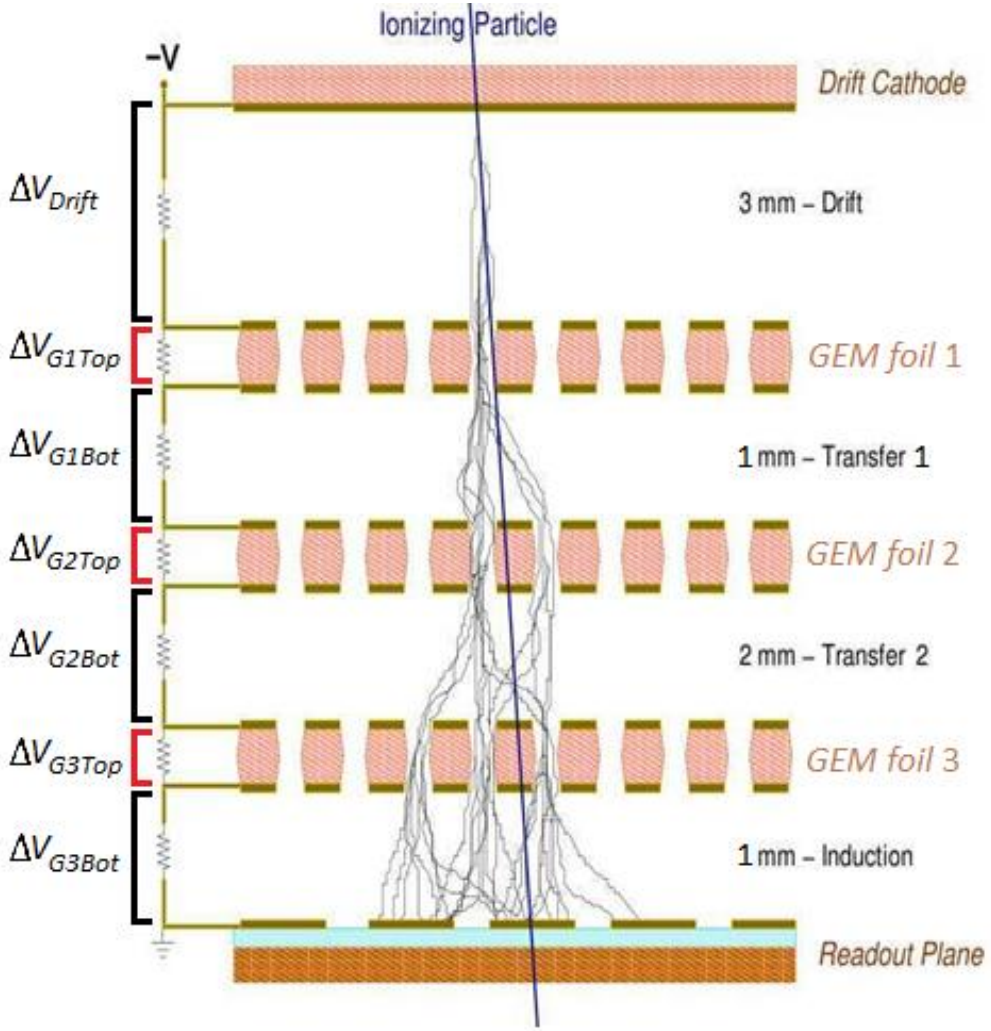
One VFAT not completely OK

HV GEM foils training completed

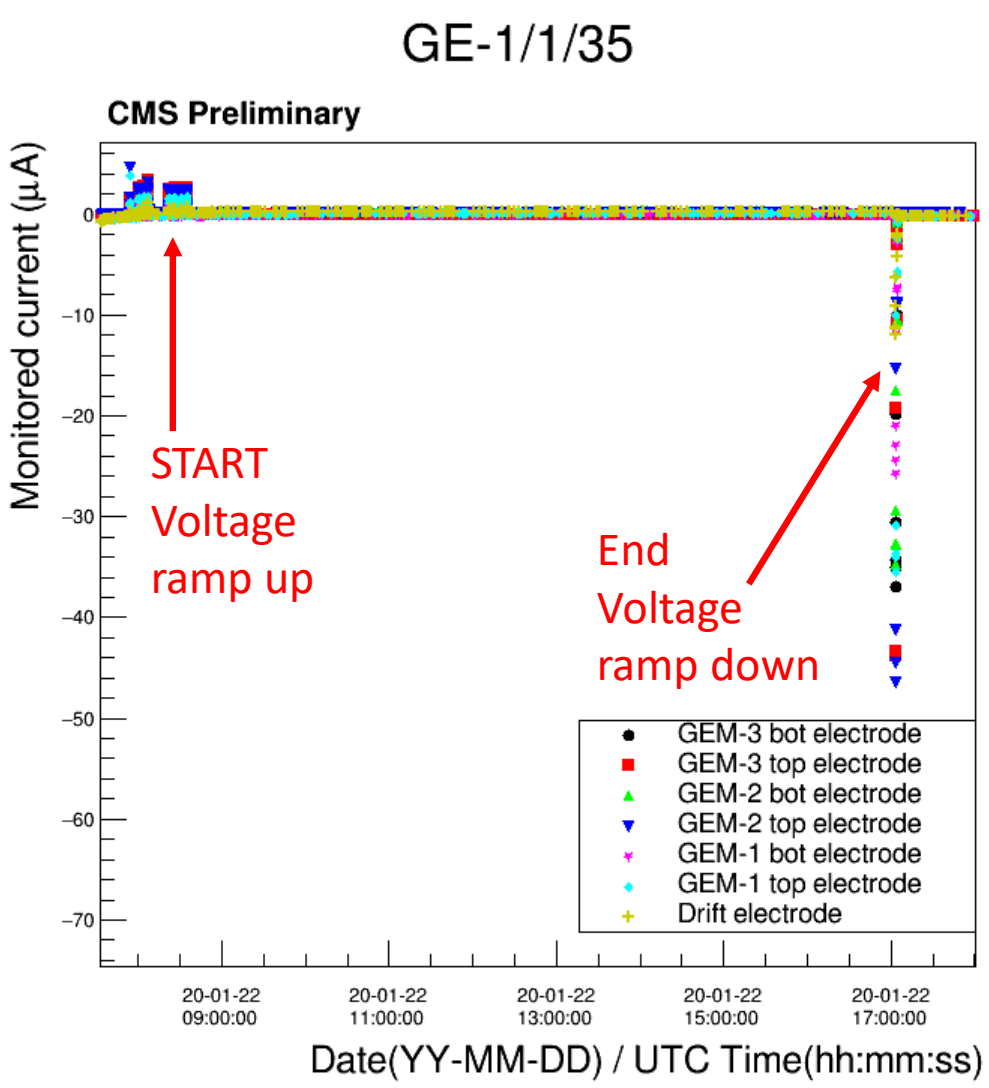
Partial HV GEM foils training

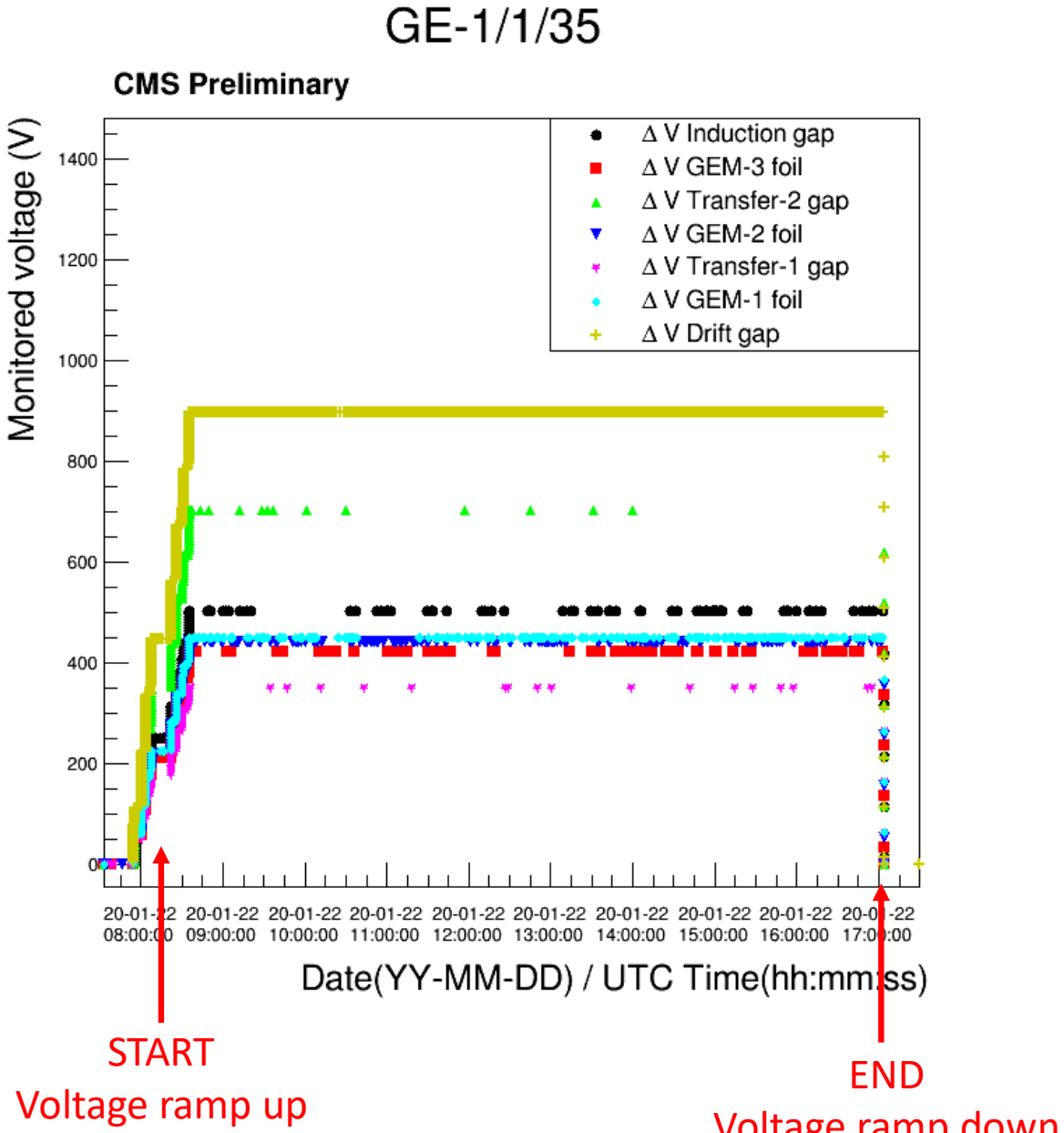
HV and LV monitor

- DCS powers chambers and stores **current, voltage differences** and **status** of the HV or LV board in a database
- **Problems that can arise during the commisioning**:
  - an HV or LV board can operate incorrectly
  - a chamber can trip and the history of the trip has to be retrieved, to **spot problems** and **solve them if possible**



An example: GEM foil training @ GE-1/1/35





Conclusion

- **All** Super Chambers **installed** in the **negative endcap**
- **HV training of GEM foils** is ongoing for the last chambers of the negative endcap
- **DCS operational** and ready to be integrated in Central DCS by the end of February
- **Positive Endcap**
  - services under installation
  - Installation of Super Chambers in **next months (May-June)**