HV and LV monitoring system for CMS GE1/1 detectors in the cosmic stand and in CMS experiment

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on behalf of the CMS Muon Group

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1. THE MUON SYSTEM UPGRADE

In December 2018 the Large Hadron Collider (LHC) entered the LS2 phase (Long Shutdown 2), which will last until beginning of 2021: in this period a maintenance program of LHC and of its injection chain is scheduled. In 2017 and during the whole 2018 LHC has reached the record beam luminosity of $2 \cdot 10^{34}\ cm^{-2}s^{-1}$, around a factor 2 beyond the LHC design. To cope with this and also looking at the following LHC phases, in which the luminosity will be further increased up to a factor 5, the same LHC experiments must be upgraded. In this context and concerning the muon subsystem, the CMS experiment began installing the first GEM based detectors station (GE1/1 station) in July 2019 almost 5 meters from the point of interaction and covering the pseudorapidity region $1.55 < |\eta| < 2.18$. The GE1/1 station will consist of 144 Triple Gas Electron Multiplier detectors (triple-GEM): this station is designed to work together with the Cathode Strip Chamber station (ME1/1 station), improving tracking and triggering of muons produced in the pseudorapidity region covered by these stations.

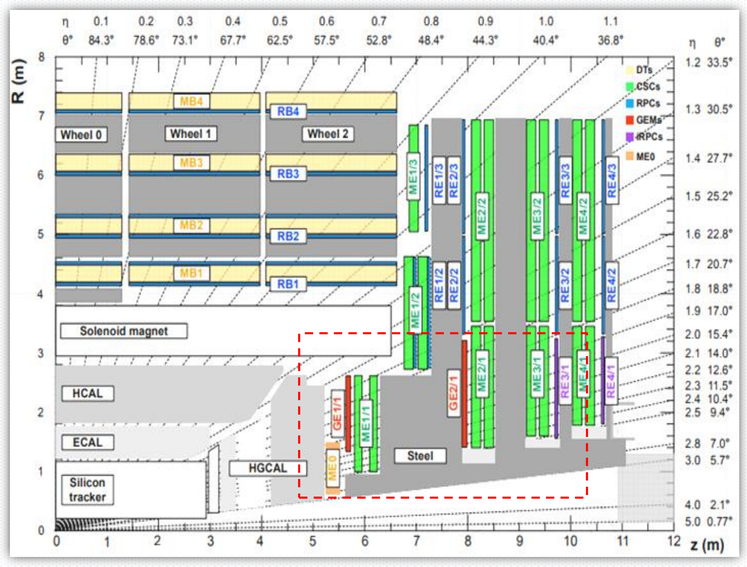


Figure 1. *An $R-z$ cross section of a quadrant of the CMS detector, including the Phase-2 upgrades $(RE3/1, RE4/1, GE1/1, GE2/1, ME0)$.*

2. GE1/1 SUPERCHAMBER PRODUCTION AND VALIDATION STEPS

While the single GE1/1 chambers are built all over the world, the final steps of the production, which consist of coupling two detectors to form a Super-Chamber with two detection layers, and the last quality controls to validate the chambers will essentially take place at CERN in the central production site. For the last Quality Control (QC8) the response of the detectors to cosmic muons is checked. To perform this last step, the Super-Chambers are connected to high voltage (HV) and low voltage systems and controlled by the Detector Control System (DCS) of the cosmic stand, whose data are stored in a database. The High voltage is provided by A1515 CAEN boards, while Low Voltage is provided by A3016 CAEN boards.

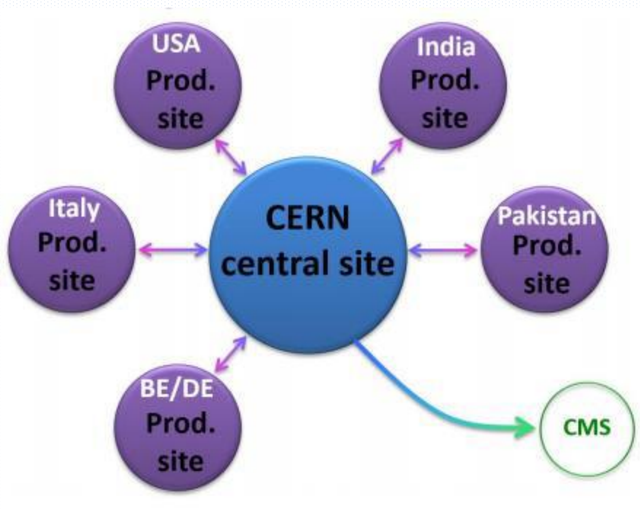


Figure 2. Organisation of production and validation sites of GEM detectors

3. WHAT CAN BE RETRIEVED FROM QC8 AND CMS DATABASES

In the QC8 database for each HV and LV electrode, the current flowing, the voltage and the status of the considered electrode, paired to the time stamp of the registered value are stored. In the CMS database, current, voltage and status are stored together with a boolean variable implemented to show if the chamber was powered or not (IsOn) and the temperature registered where the SuperChamber is installed. The status is saved as a decimal code.

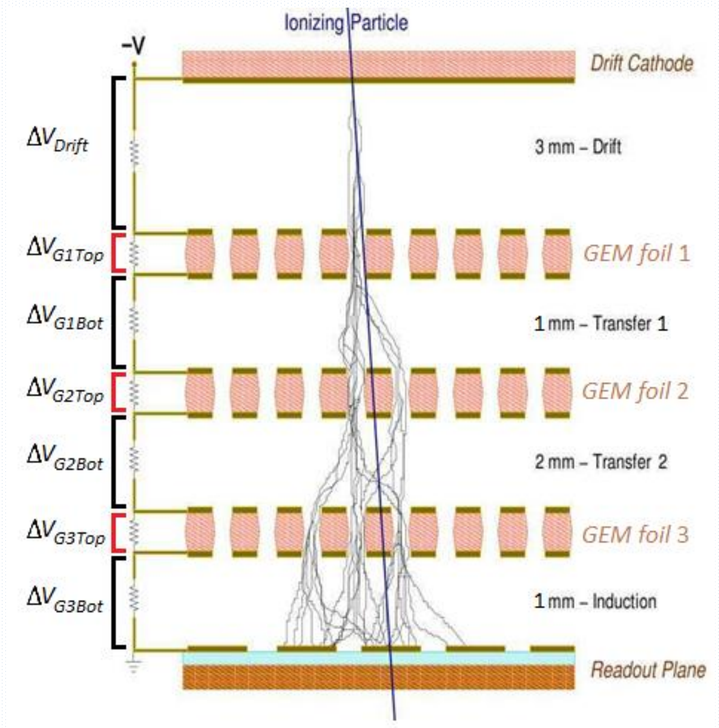


Figure 3. Scheme of a GEM detector with explaination of voltage differences saved in databases

4. A CLARIFICATION ON VOLTAGE DATA

In the database the voltage value saved is the **voltage difference** present between the electrodes, **not the voltage measured with respect to the ground.**

5. MAPPING OF HV AND LV IN QC8 STAND AND IN CMS

To be powered a GE1-1 SuperChamber needs two HV cables and 2 LV cables: in the QC8 cosmic stand all the 14 HV channels of one HV board are used to power one Superchamber and in the database 14 different alias need to be used to completely map a SuperChamber. In the CMS experiment, instead, only 7 channels of one HV board are needed to power both the two layers of the SuperChamber, resulting in 7 alias to completely map the SuperChamber.
For the LV system the situation is the same in the cosmic stand and in the CMS experiment: 2 channels of one A3016 board are used to power the 2 layers of the SuperChamber, resulting in 2 alias in the database to completely map the SuperChamber.

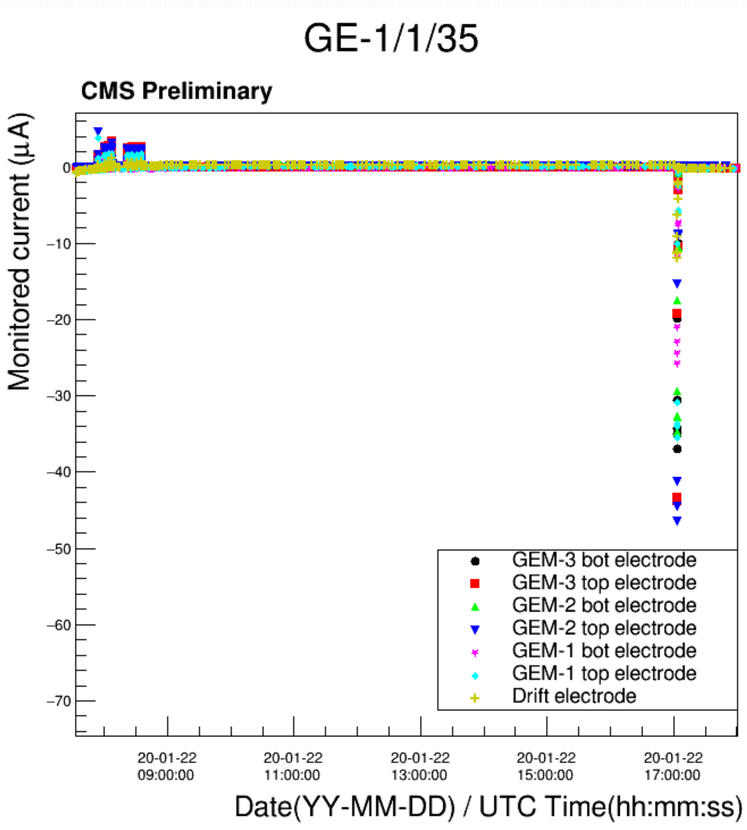
6. PRESENTATION FORMAT OF DATA FOR A CHOSEN CHAMBER

A tool that retrieves every data and saves them in a root file in different formats has been developed:

- Histograms showing how many times a certain current, voltage, status or temperature values has been registered
- Value vs Time plots, showing how the behavior of current, voltage, status or temperature evolved during the operation period observed.
- A table (a root tree) dedicated to the status codes, saved in decimal, binary or in human readable string format is also available

7. A POWERFUL WAY TO SPOT PROBLEMS

During the chamber validation in the GEM lab at CERN or during the commissioning in the CMS experiment problems can arise: for example one chamber can trip or one HV board is working in an unexpected way, affecting the correct operation of the detector. This tool can help retrieving all the history of the detector status and from the CMS DCS database, making faster to spot problems and plan a possible solution.



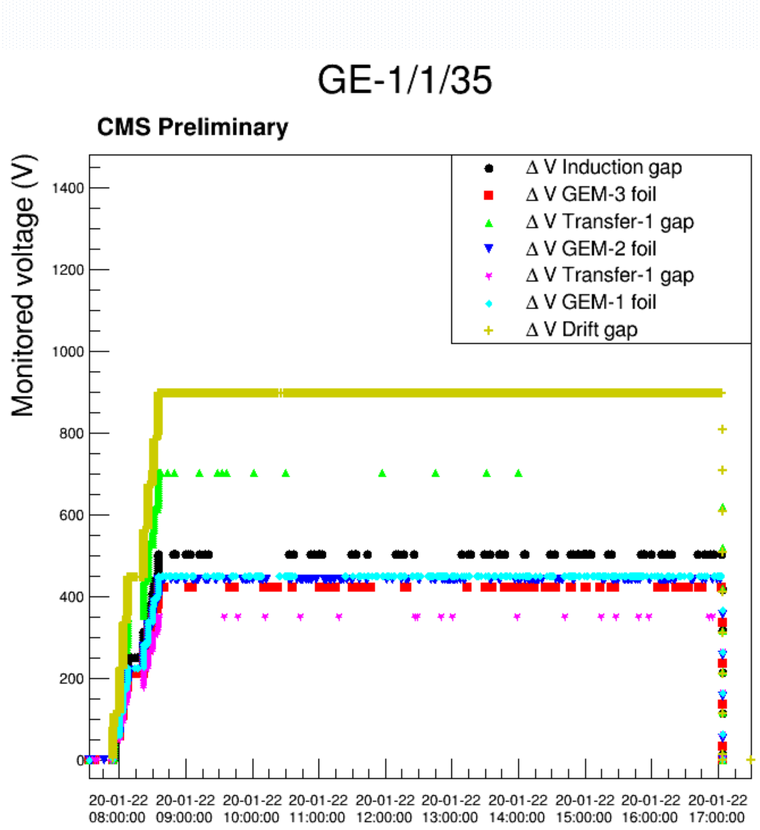


Figure 4. (left) and Figure 5 (right) show respectively current and voltage differences observed on the 7 HV electrodes of chamber GE11-35 installed in P5. Data are retrieved from the CMS database. Time is in UTC format (UTC = CET – 1). Variations in current can be observed in the first and last times displayed in the plot, due to the ramp up and ramp down in voltage, done respectively to turn on and off the SuperChamber.