CMS GE1/1: Commissioning and early performance studies

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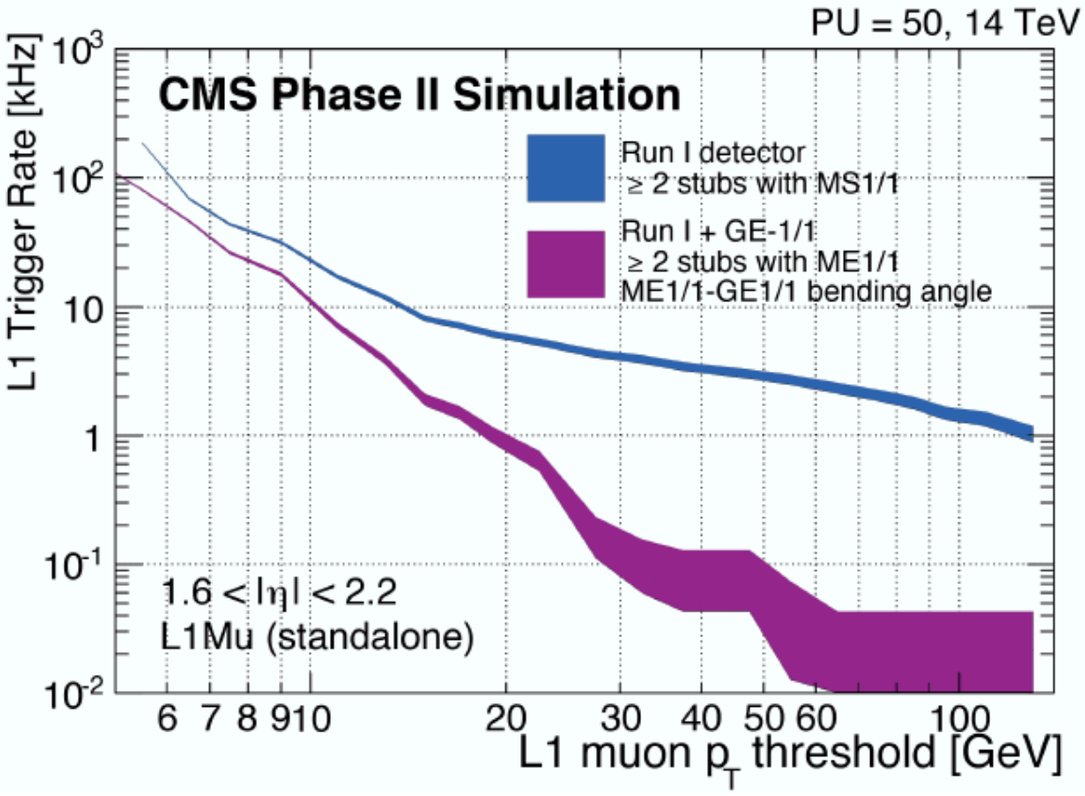
On behalf of CMS Collaboration

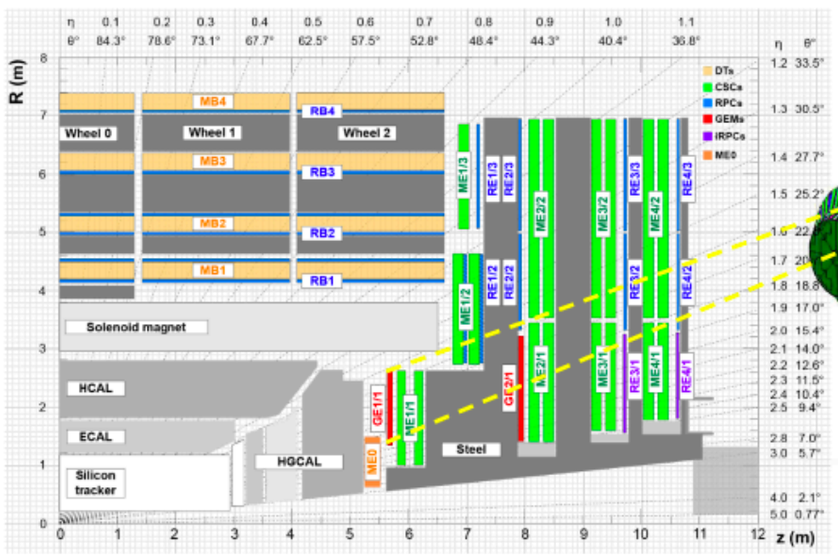
GEM: Gas Electron Multiplier

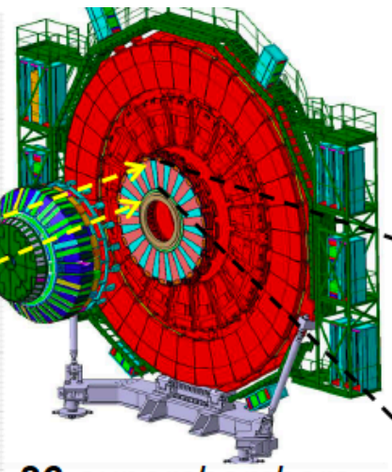
- During the Long Shutdown 2 CMS experiment is upgraded to cope with
  - high inst luminosity ~$5x10^{34}cm^{2}s^{-1}$ Run3 of LHC
  - high background rates expected and the muon trigger rate should be acceptable
- Addition of GEM hits to CSC hits will precisely measures the bending angle at trigger level, thus strongly reduce the rate of mis-measurement



GE1/1 : GEM Endcap Ring1 Station1

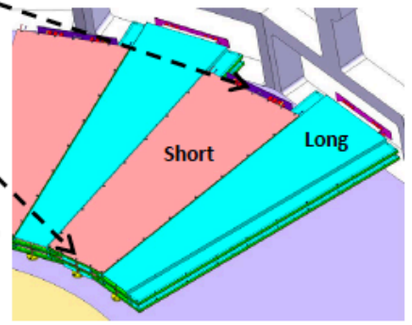
- 1.55< |η| < 2.18
- 36 Super chambers per endcap covering 10° in φ
- arranged in short and long chambers due to mechanical envelope of the existing endcap, in order to maximize the η coverage.
- gas mixture 70/30 : Ar/CO_2



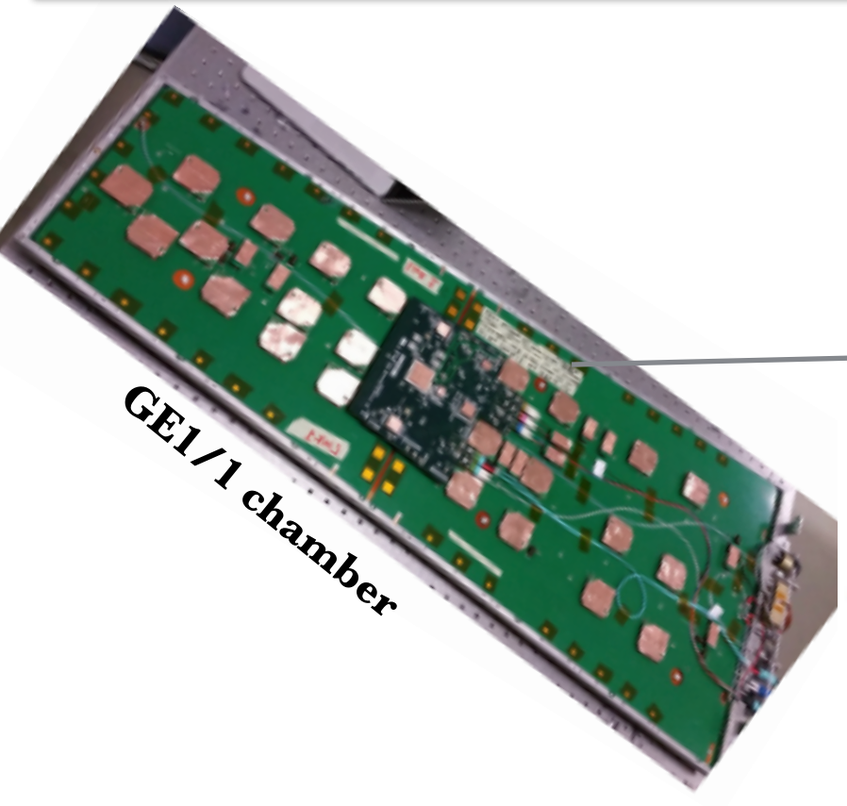


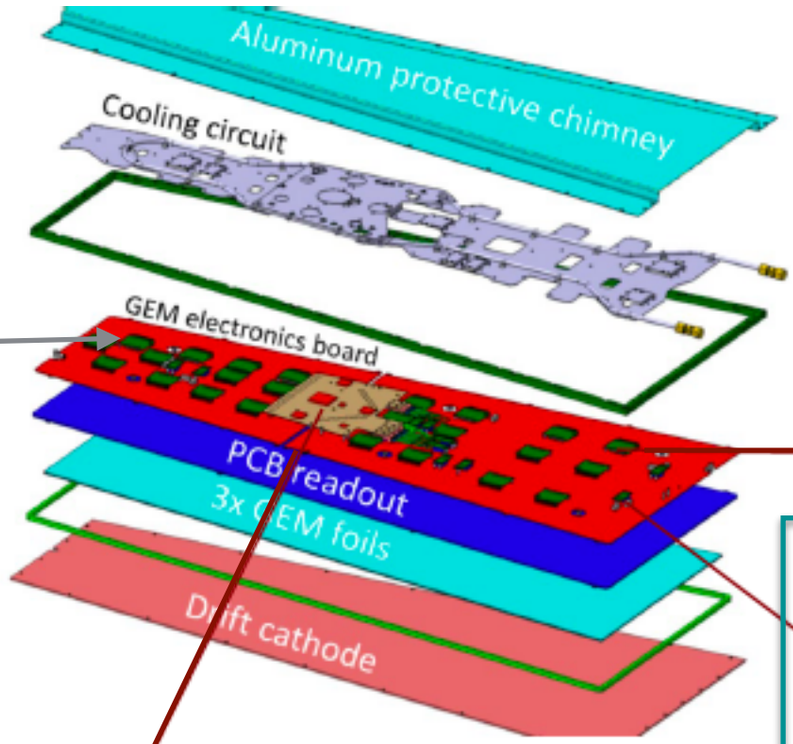
36 *superchambers* (SC) per endcap

short and long SCs
to maximise coverage
1.55 < |η| < 2.18

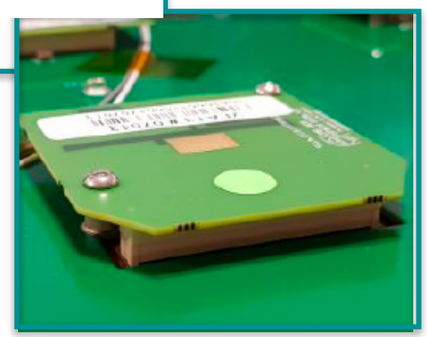


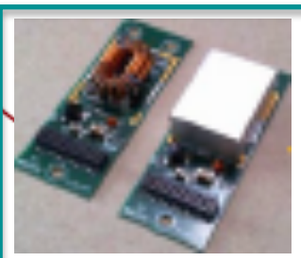
GE1/1 Readout electronics





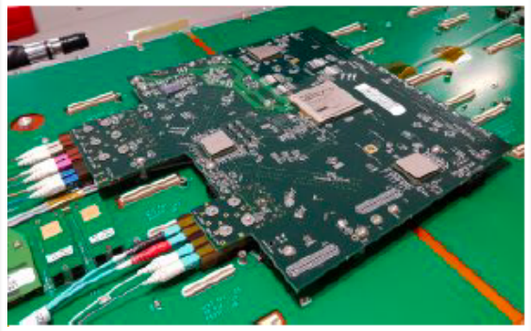
VFAT frontend chip
- Can deliver a calibration pulse
- Send trigger lines called SBITs
- 128 VAFTs , 8 SBITs

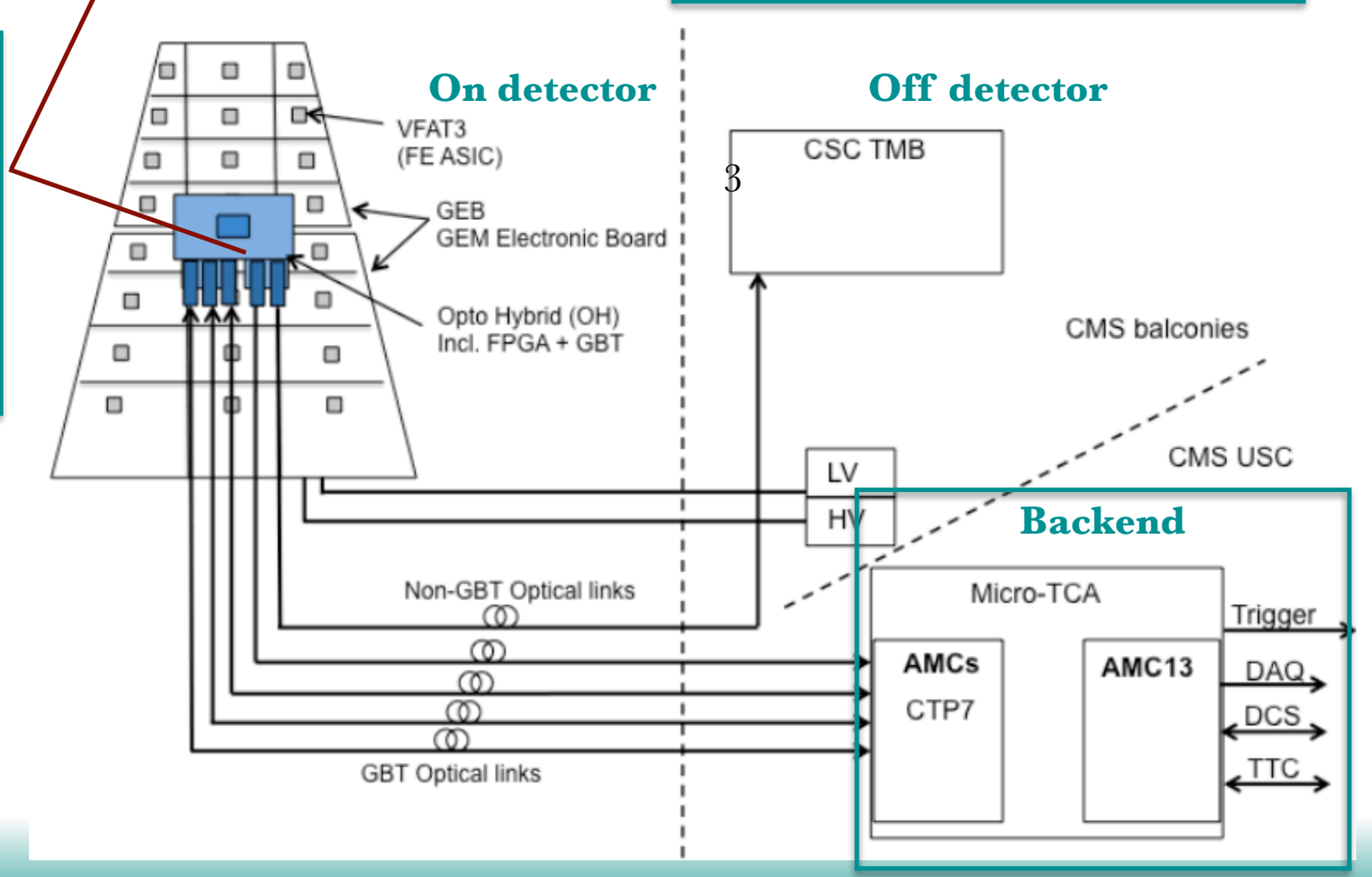




Feast
- DC converter
- LV, VFAT3 &OH

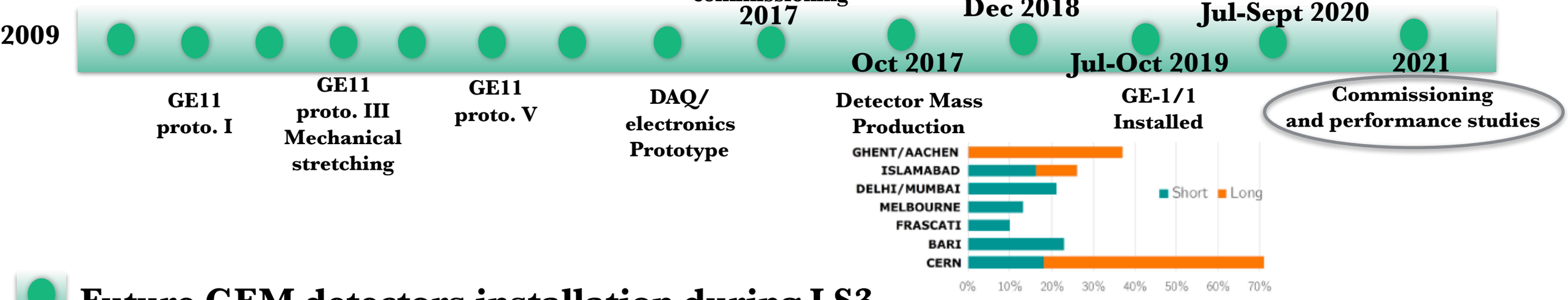
Optohybrid
- Communicate between the VFAT and the backend electronics via GigaBits transceivers(GBTs)
- Send slow control commands to the frontend electronics
- tracking and transfer trigger data to CSCs and backend elctronics



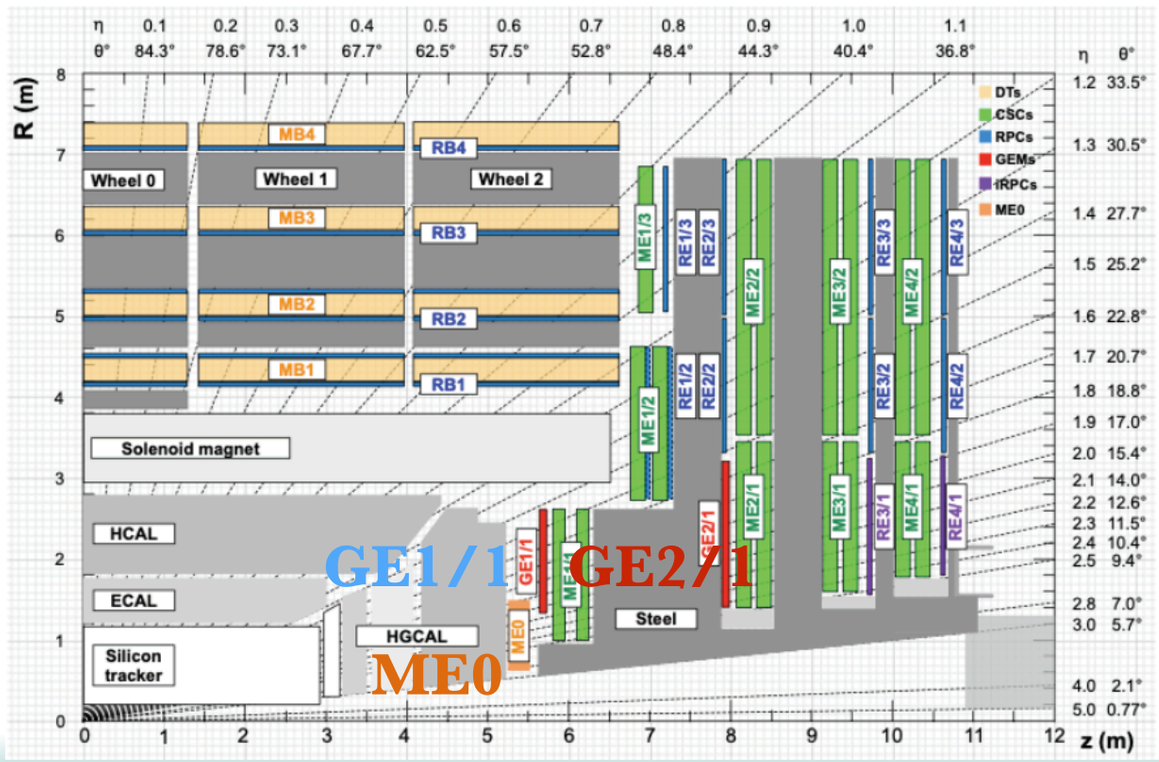


GEM Project

NIMA 972 (2020) 164104



Future GEM detectors installation during LS3



GE2/1 demonstrator installed

ME0:(installation during LS3)

- 18 stacks per endcap
- 6 layers of triple GEM detector per stack
- 20° in ϕ
- 2.0< |η| < 2.8

GE2/1: (installation during LS3)

- 18 Superchambers per endcap
- 2 triple GEM detector per SC
- 20° in ϕ
- 1.6< |η| < 2.4

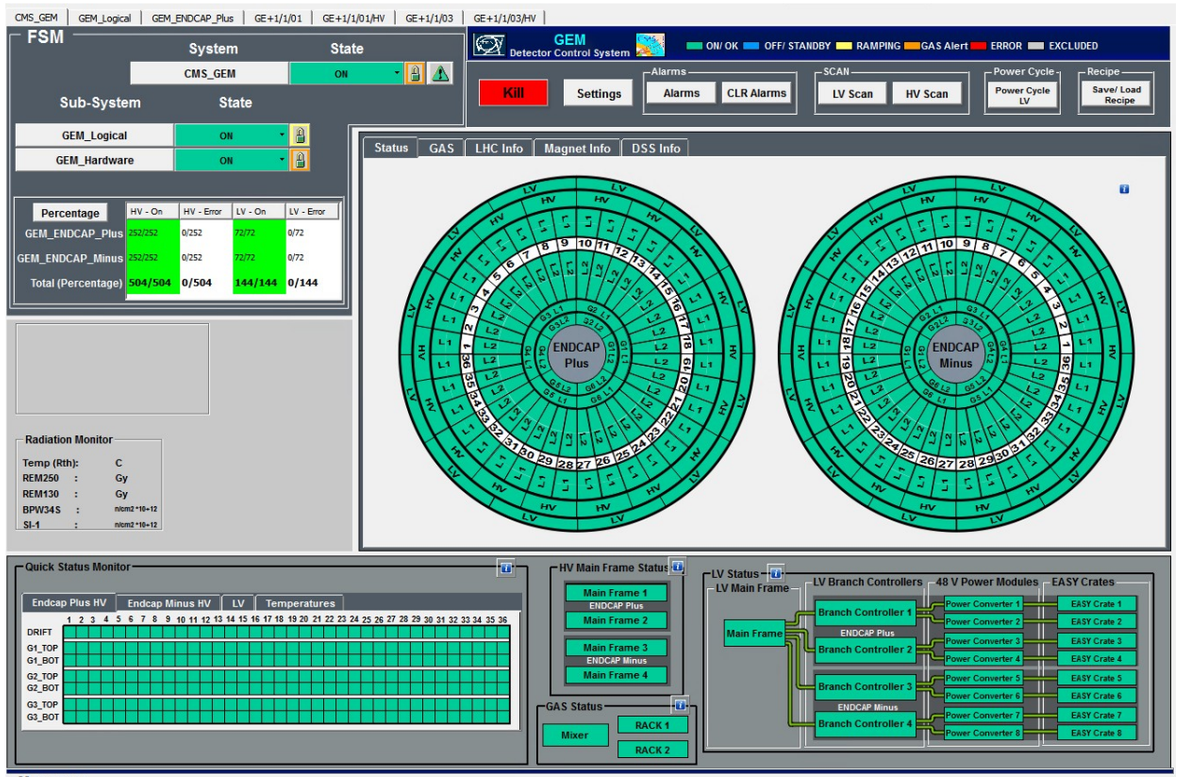
GE1/1 : Detector Commissioning : Initial Phase

- Every single GE1/1 detector and its front-end/back-end electronics were tested individually beforehand after the installation in the MuonSpectrometer of the CMS experiment through a series of rigorous tests
  - Any potential damage or performance losses that could have occurred during the detector transportation and installation can be immediately identified and repaired
  - **Hardware Commissioning** :
    - **Power and readout systems** :
      - High Voltage : multi-channel power supply. All GEM electrodes are powered independently. The status of voltage, current and channel are updated in the GEM database
      - Low Voltage: it provide supply to the frontend electronics
      - R/O fibres and link to CSC fibres : optical fibres for readout and trigger
      - Fibres for temperature sensors
      - RADMON sensors cables for radiation monitoring
    - **Gas system** (with dedicated gas monitoring system that keep track of inward and outward flow of gas)
    - **Water cooling pipes** for frontend chips and FPGA
- All electrical cables and readout fibers have been thoroughly tested and any potential detected failures understood and fixed
  - These control and cross-check procedures significantly reduced the potential mapping errors of such a complex system

GE1/1 : detector commissioning (Continue)

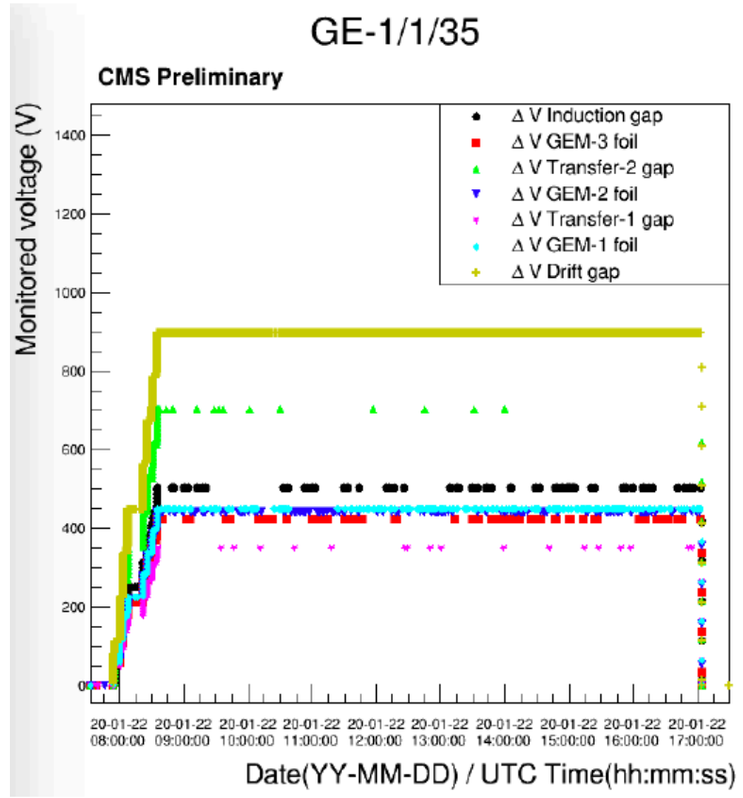
Software Commissioning:

- **Detector Control System (DCS)**
  - controls and monitor HV and LV , FPGA temperature, gas system, auto recovery
- **Data Acquisition System (DAQ)**
- **Data Quality Monitoring (DQM)**
  - accurately monitor the quality of data collected and the performance of the detectors
    - Online monitoring for DAQ errors, frontend status
    - Offline monitoring provides early performance information on promptly reconstructed data



HV training & maintenance

- Initially all chambers are HV trained in CO_2 and gradually trained in the final mixture of Ar/CO_2
- All Chambers are HV maintained (currently at 700uA) regularly to prevent from any trips from time to time and retrained if necessary
- After every shutdown or mechanical movement chambers are trained again in Ar/CO_2 mixture to ensure stable operations and are clean for any dust that may deposit on the GEM foils.

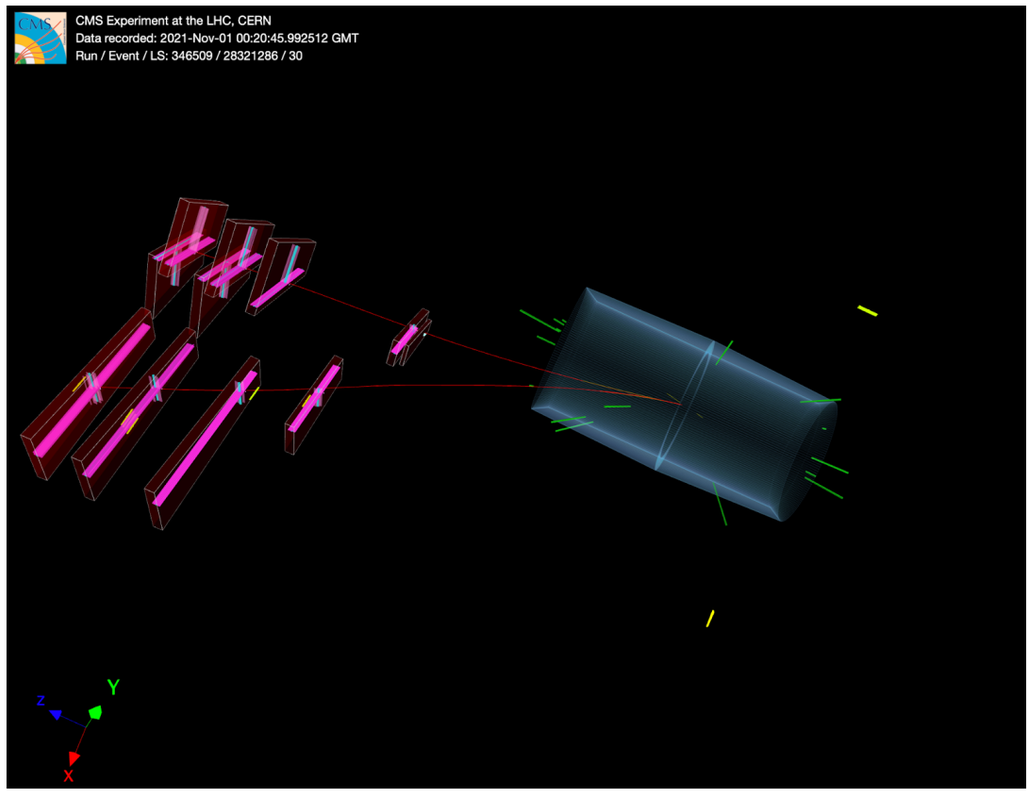


Issues and possible solution

- **Electronic noise due to LV system**
  - Intervention on the LV cables and installation of filters
    - it successfully lowered the noise level
- **Instabilities in the front-end electronics**
  - GBTx not locking
    - implemented automatic recovery at the configuration step
  - VTRx chip failures
    - CERN wide problem ; under investigation
- **High Voltage : discharge problem**
  - GEM technology suffers from discharges due to the pollution/dust, gain fluctuations
    - HV training procedure needs to be repeated after every movement

Global Commissioning & Data taking

- During LS, detector perform **global commissioning (cosmic runs)** for few days continuously (MWGR) where all sub-detector participate
  - this is done to test and commission whole sub-detector , trigger, DAQ software in view of pp collision 2022
  - GEM DAQ was included in September 2020 for the first time for data taking and after that GEM participated successfully in global commissioning during all the **MWGRs in 2021** and perform
    - Latency and HV scans performed
    - GEM-EMTF trigger link connectivity test
    - Cosmic data taking and Prompt feedback Analysis
    - Online/Offline data quality monitoring has been integrated
    - Data certification procedure is ready
  - **C**osmic **RU**n at **ZE**ro **T**esla (**CRUZET**) **2021** :
    - 6 weeks of continous data taking
  - **C**osmic **R**uns **A**t **F**our **T**esla (**CRAFT**) **2021** :
    - GEM participated in all overnight CRAFT runs



J/ψ event candidate at 900-GeV pp collision
Run :346509 Event :28321286: LS: 30)

- **Pilot beam and pp collisions @ 900 GeV**
  - GEM participated in collisions run with stable beam @900 GeV(~37 runs)

Performance Studies (1)

- Analysis of prompt data for feedback during operations

  - Will be very helpful to spot issues and report to DAQ/detector experts within few-days time scale

  - **Prompt data Analysis** :

    - Muon detection efficiency

    - Detector spatial resolution

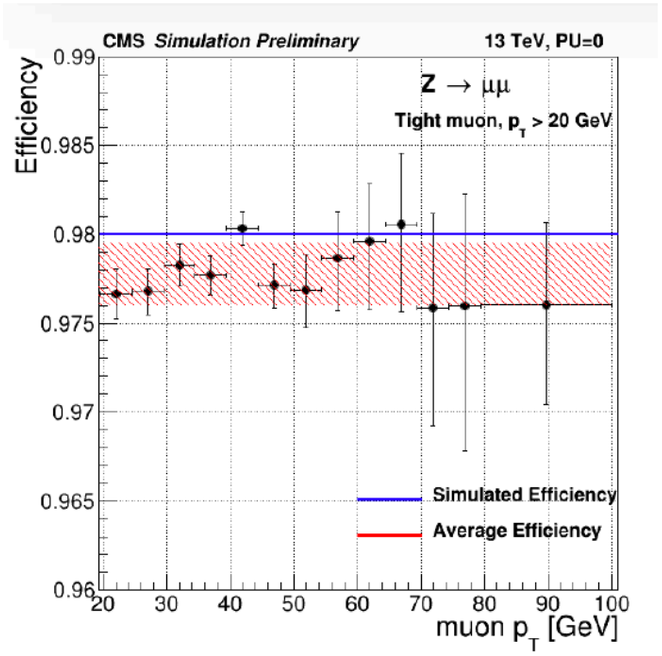
    - Inactive channels

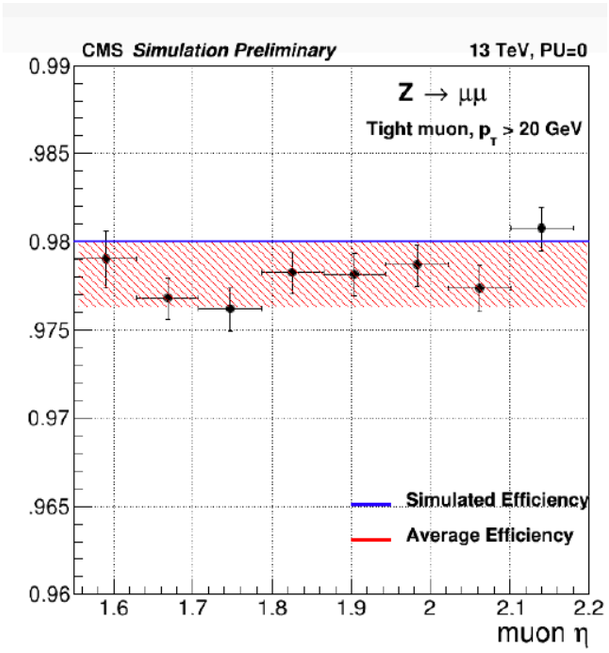
    - **Efficiency measurement validated on Z→μμ simulated sample**

      - ☆ Propagate muon track to GE1/1surface

      - ☆ match propagated position with GEM hit in the vicinities (RΔφ< 1cm)

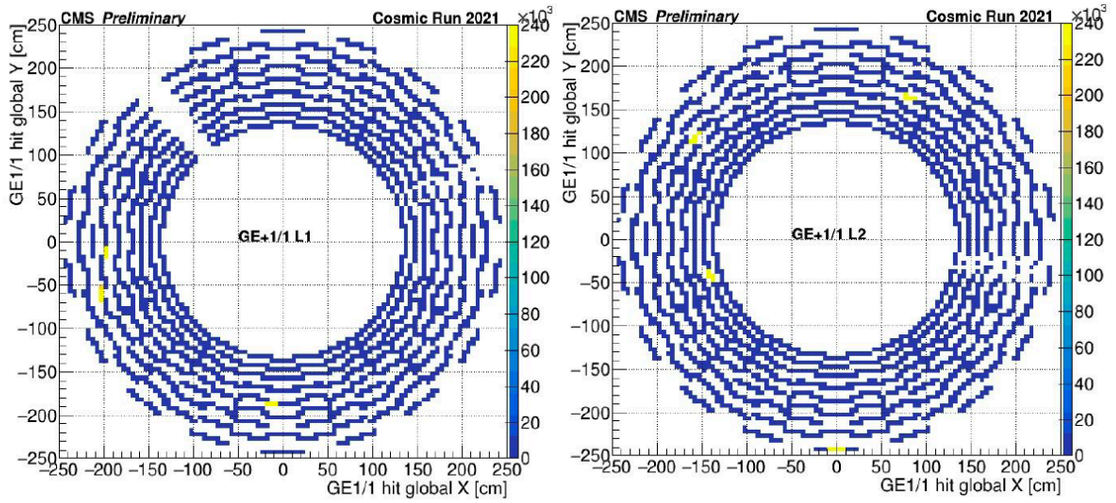
      - ☆ Efficiency = fraction of propagated muon hit matching with GEM hit





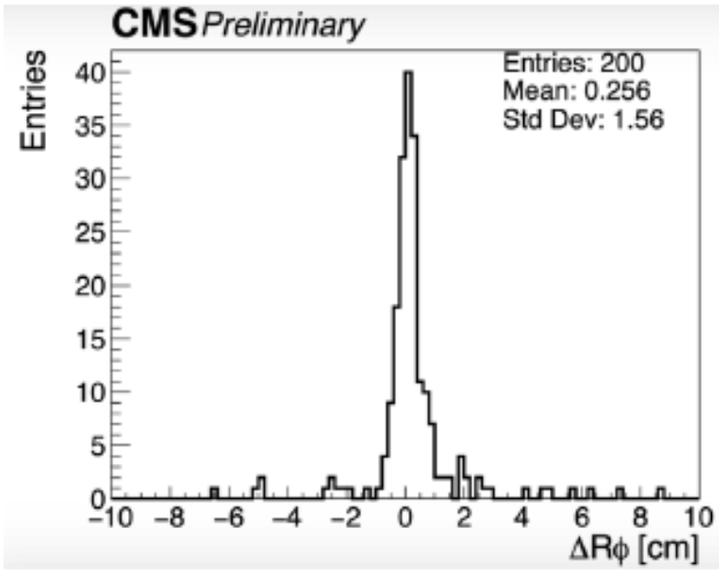
Performance Studies (2)

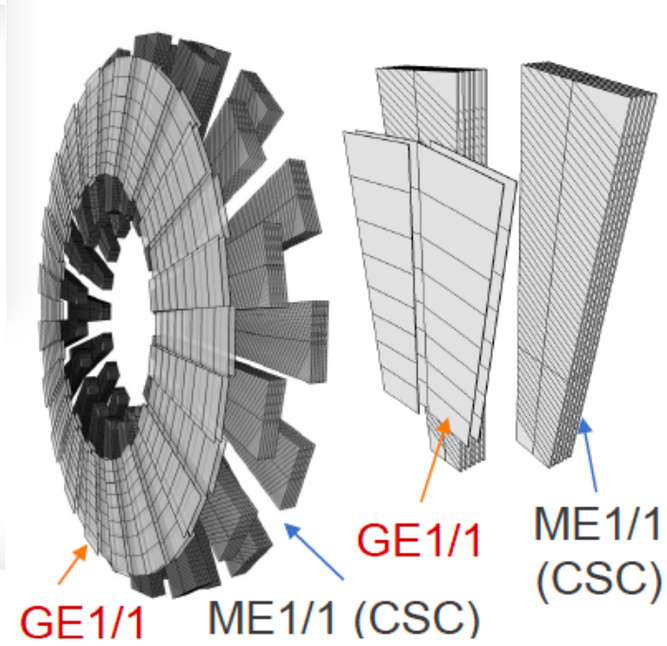
- Offline Monitoring
  - Provides early performance information on promptly reconstructed data
  - Tested during commissioning runs with cosmic muons



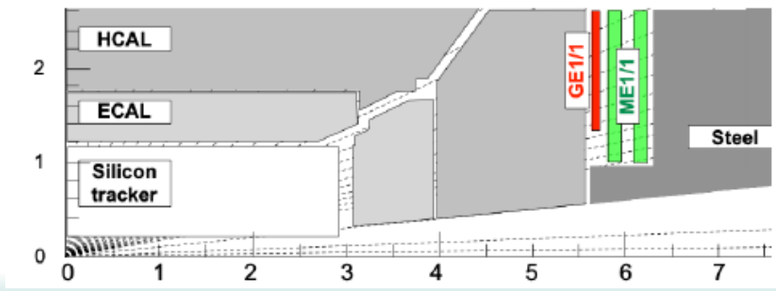
Reconstructed hits of two layers of GE1/1during one of the cosmic runs

- **Detector alignment Correction**
  - For Run3 : trigger based on information from GE1/1 and CSC
  - Important to correct offline for any GEM-CSC misalignment
  - Preliminary studies on simulated samples
  - Compared with cosmic data during the commissioning runs





- Propagate the muon tracks detected by CSC to GEM surface
- look at residuals (distance between propagated hits and GEM muon hits)



Summary

- Successfully installed 144 GE1/1 chambers in the CMS detector, the first completely new technology for a sub-detector introduced into CMS
  - Being in commissioning phase
    - check the behaviour of the system- FE connectivity, calibration scans, noise, HV stability.
    - some issues spotted and tackled with possible solutions
    - the DAQ and DCS system are being finalised
    - finalising the operating detector configuration : threshold, HV setting
  - Joined cosmic runs as well as data taking together with other detectors. The first data is very precious as it help us moving close to successful operation during Run3
    - In pipeline overall detailed detector performance using these runs
  - Early 2022: Full HV training, full recommissioning with calibration scans, finally timing + efficiency + alignment measurements

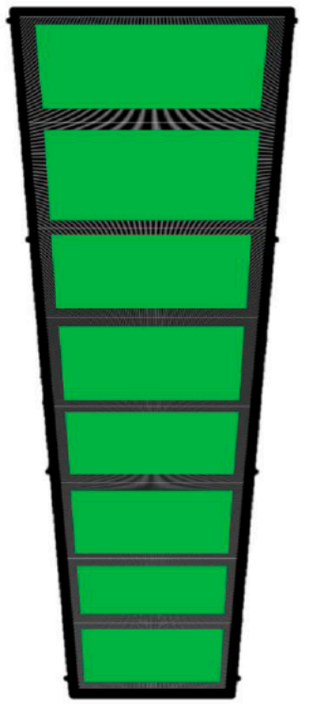
Back up Slides

Efficiency Calculation

GE11 Efficiency: Analysis workflow

1. Collections to be matched (when in the same Region,Layer,Chamb,EtaP)
   - ❖ **PropHit** == muon Stand Alone (*STA*) tracks through ME11, whose propagation ends on GE11. GEM hits are not yet used for STA!
   - ❖ **GEMRecHit**
2. Fiducial cuts:
   - ❖ Consider only **PropHits** within «Acceptance Region» *(1 cm , 5 mrad)*
   - ❖ Consider only **PropHits** with (err_R, err_Phi) < (1 cm, 10 mrad)
3. Matching:
   - ❖ DISTANCE* (***PropHit*** , ***GEMRecHit***) < 4 cm
4. Evaluate the efficiency

$$Eff = \frac{\#Matched\_GEMRecHit}{\#PropHit}$$



*Intended as RΔϕ