Performance of Gas Electron Multiplier (GEM) detectors

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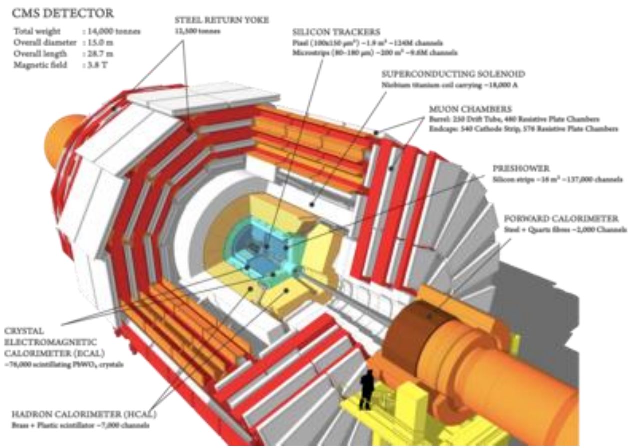
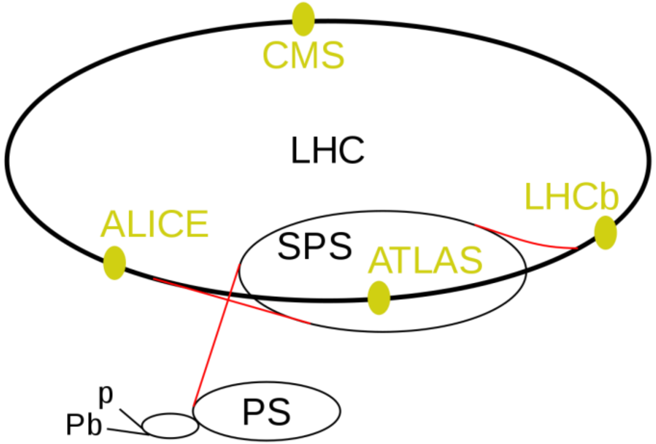
Abstract

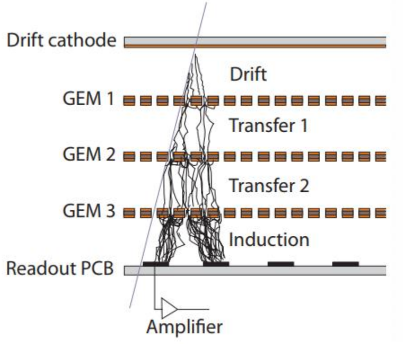
- ➢ The CERN Large Hadron Collider (LHC) is being upgraded in order to implement proton-proton collisions at a center of mass energy of 14 TeV and an instantaneous luminosity exceeding 7.5 times the original design value.
- ➢ The LHC has 4 experiments at interaction points and has 2 general purpose detectors (CMS, ATLAS)

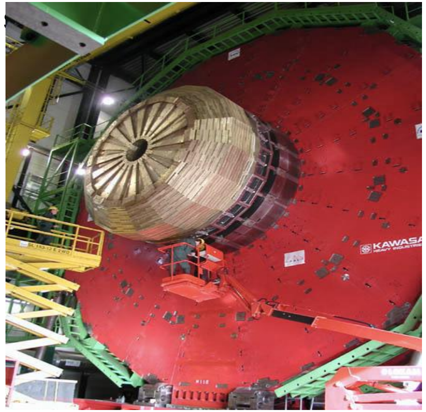




Introduction

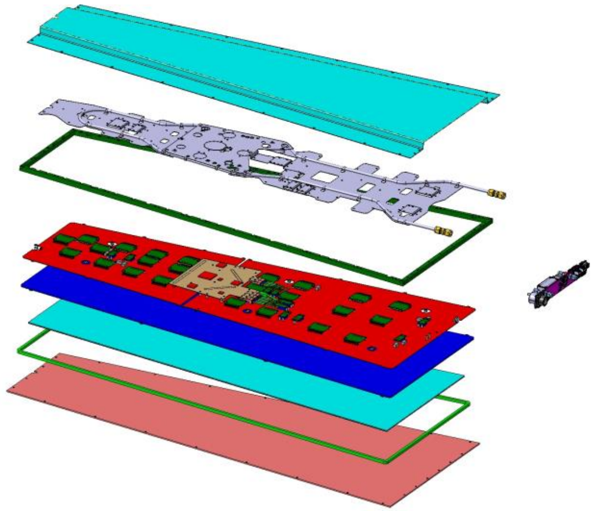
- ➢ GEM detectors will help enhance the performance of the CMS experiment. To ensure that the data stays in the storage system and expands coverage in the muon system, Triple-GEM chambers will be placed in three stations of the CMS end caps.
- ➢ This upgrade will increase the muon spectrometer redundancy and help the endcap region undergo high radiation.
- ➢ CMS GEM detector is composed of a drift board, a readout PCB, and triple-GEM (a stack of 3 GEM foils) .
- ➢ A GEM is a thin, metal-coated polymer foil with high density of holes with three main processes: Ionization (an atom needs a - or + charge by losing or getting electrons), amplification (increased

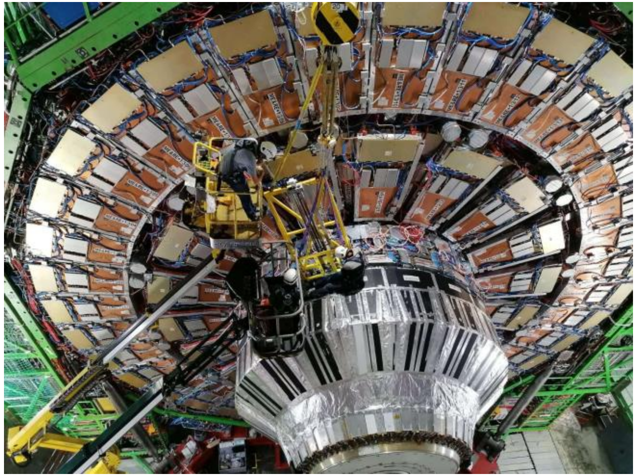




GEM Detectors

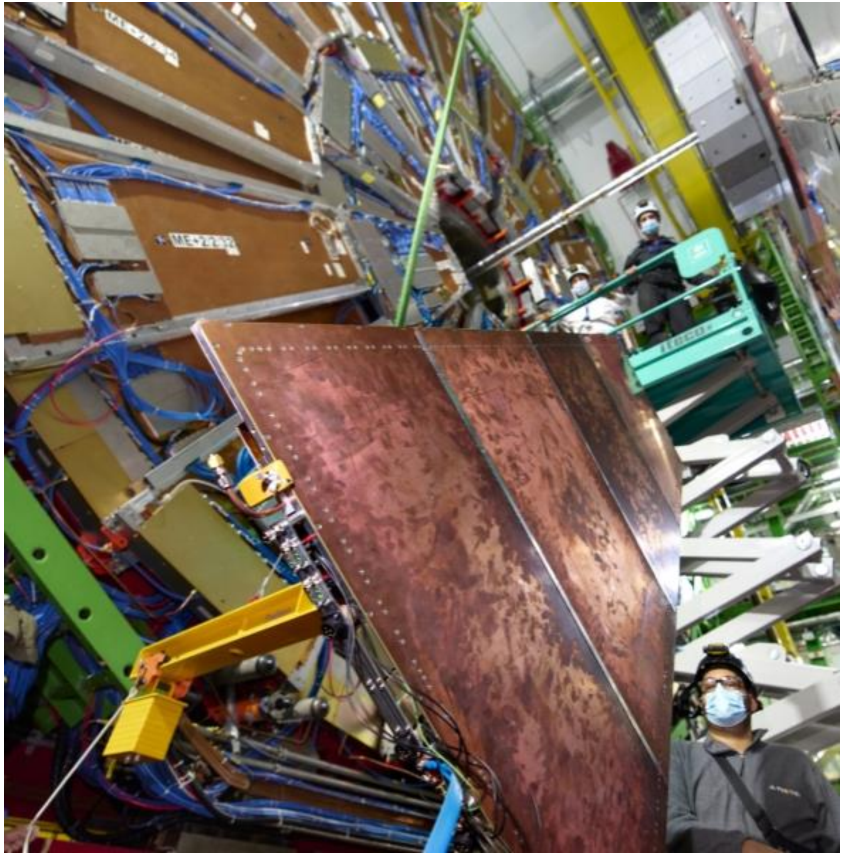
- GEMS are being installed in three rings of the first two stations.
- The first GEM station was successfully installed between Jul 2019- September 2020 to improve the muon track reconstruction and reduce the trigger rate.
- GE1/1 detector system has 72 super chambers, 3456 VFAT3 chips and 432 optical links.





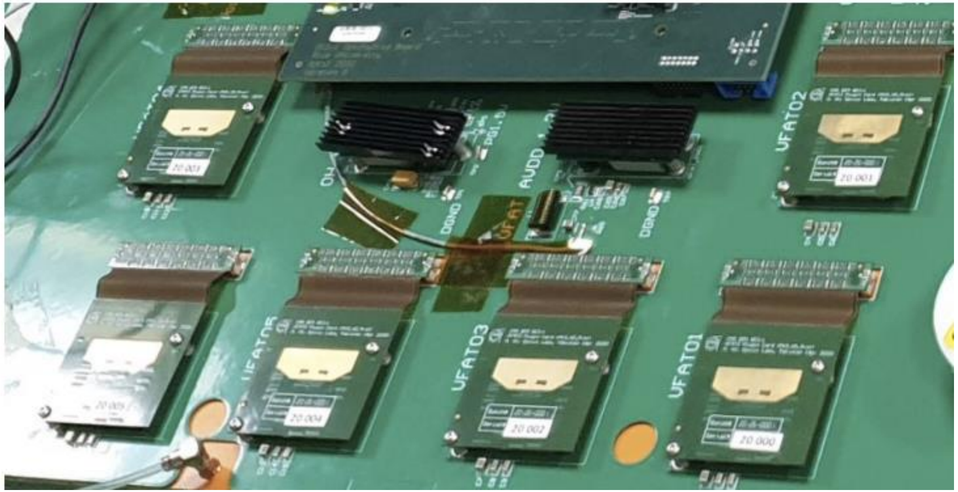
Future upgrades

- The second GEM station targets the high luminosity operating regime which helps avoids large increases in trigger rate and improves trigger efficiency.
- GE2/1 Detector System has 72 total chambers, 4 triple GEM modules per chamber, and 20-degree chambers, arranged in 2 layers per endcap.
- ME0 detector will extend the range of the CMS muon system but has to operate in very difficult conditions (high radiation environment)



Understanding GEM electronics

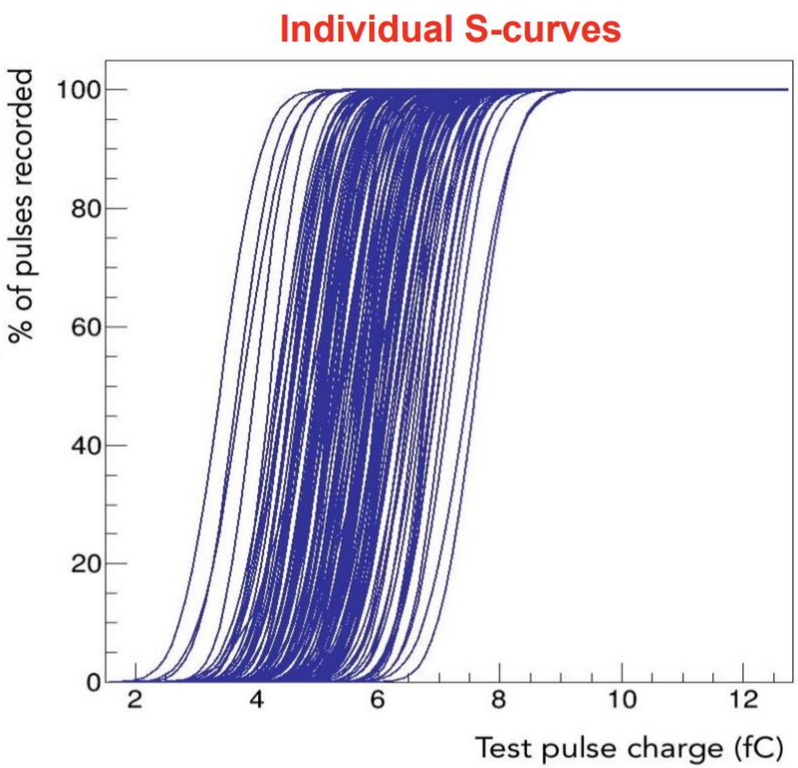
- ➢ VFAT front-end chip is used to read out the detector
  - binary chip meaning that a threshold has to be set to determine if there is a hit or not.
  - 128 readout channels
  - Between 12 and 24 VFATs on a GEM detector



Measuring thresholds and noise for the calibration

How to evaluate the response of the VFAT front-end chip:

- Use internal charge injection circuit on all 128 threshold.
- Use fixed threshold and inject more and more charge, and look how the binary chip registers the signal as a hit.
- This leads to a S-curve which we must fit in order fo the noise level and threshold of response to be extracted.

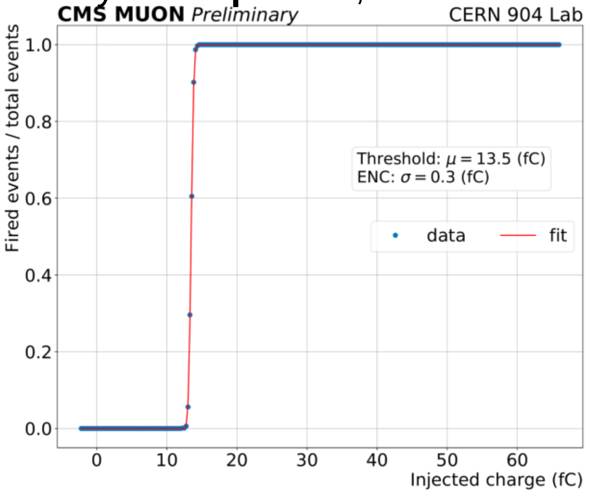


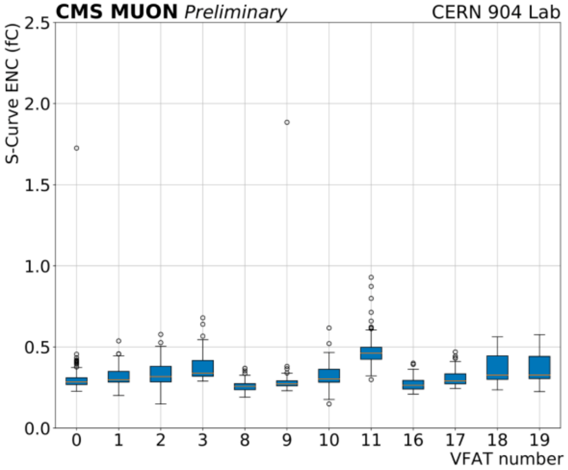
Measuring thresholds and noise for the calibration

Coding-wise:

- First, we use SciPy to perform a curve fit and extract parameters.
- Then we change to iminuit to do fitting.
- Finally, we implement likelihood with asymmetric uncertainties on the data point to minimize it and extract the parameters with their uncertainties.

We're currently on **step three**, where we must write down full likelihood and minimize it.





Conclusion

- We were able to extract a first estimate for the noise and threshold from this dedicated S-curve run.
- We would like to improve the fitting even further to tweak the performance of all GEM stations.
- This would allow us to lower the thresholds and increase the efficiency of the chambers.

References

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