Upgrade of the CMS Forward Muon System with triple-GEM Detectors

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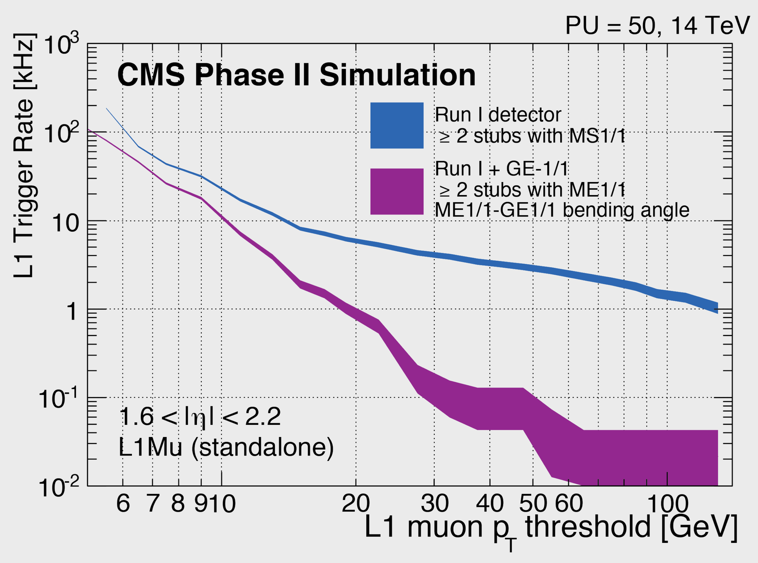
Introduction & Motivation

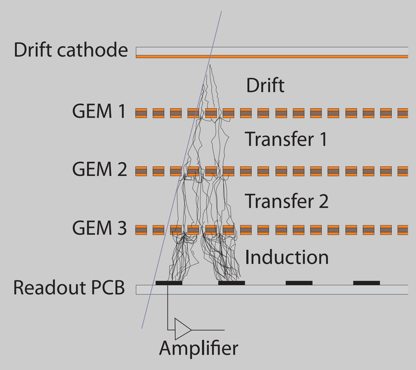
In order to cope with the harsh environment expected from the high luminosity LHC, the CMS forward muon system requires an upgrade. The two main challenges expected in this environment are an increase in the trigger rate, and increased background radiation leading to a potential degradation of the particle ID performance. Additionally, upgrades to the rest of CMS allow for extended coverage for particle tracking.

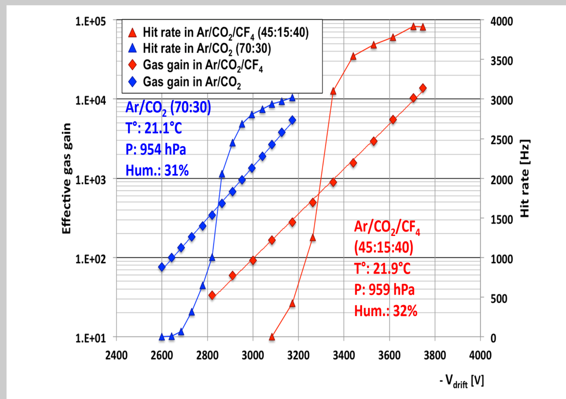
Following an extensive R&D program, CMS has identified triple-foil gas electron multiplier (GEM) detectors as a solution for the region $1.6 < |\eta| < 2.4$ (GE1/1), while continuing R&D is ongoing for additional regions (GE2/1 and ME0).

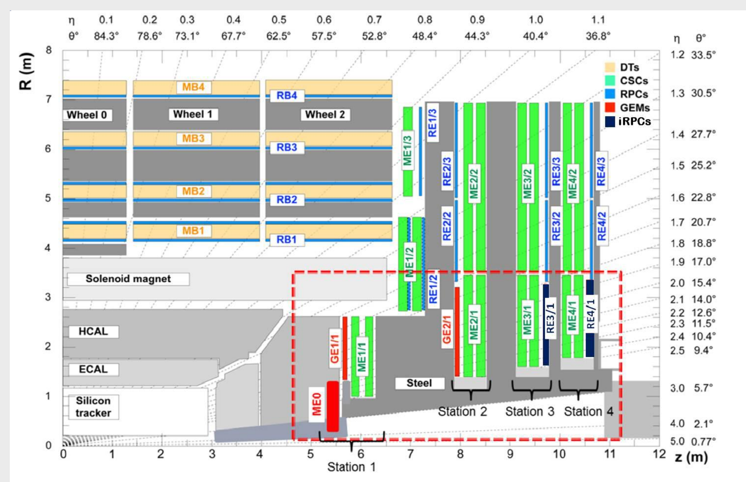


The key features of these detectors are:

- Large gain for moderate voltage
- High rate capability (10 kHz/cm^2)
- Single-chamber efficiency > 97% for mips
- Time resolution better than 10 ns
- Gain uniformity better than 15% across and between chambers
- No gain loss due to aging effects after 3000 fb^{-1}

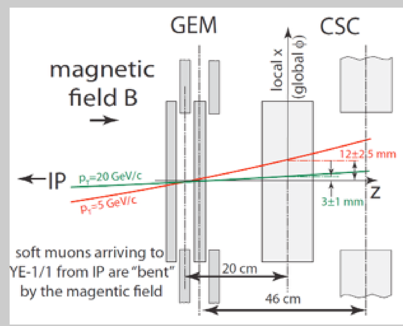






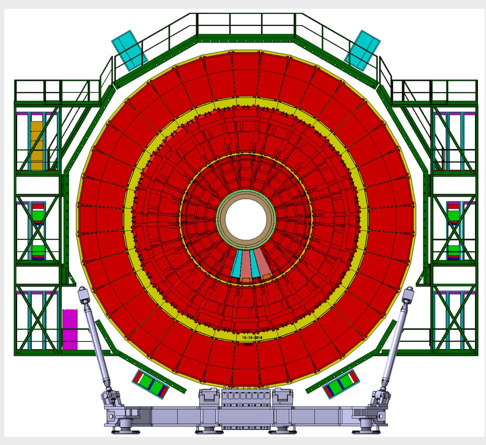
The benefits to the CMS experiment are:

- Maintain lower p_T muon trigger performance by exploiting the better measurement of the bending angle to discriminate between muons and low p_T background
- Recover redundancy in the forward muon system where there is currently only single chamber coverage



CMS GE1/1 System

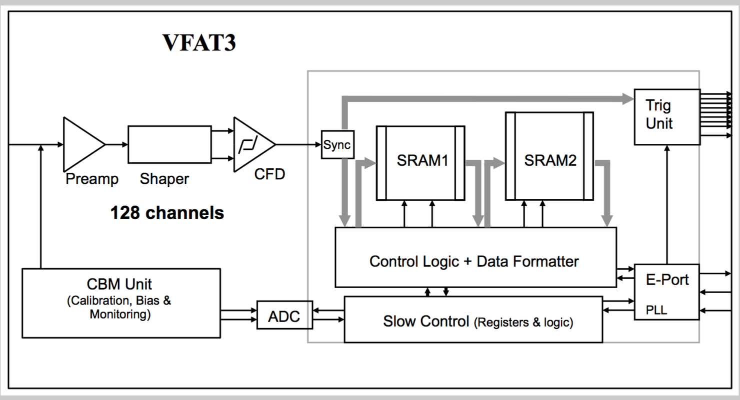
- The GE1/1 (GEM endcap first station) will be composed of alternating short $1.6 < |\eta| < 2.2$ and long $(1.5 < |\eta| < 2.2)$ pairs of GEM chambers assembled as a "superchamber"
- Each superchamber will cover 10 deg in φ, for a total of 72 per endcap
- The readout board of each chamber is divided into 3 columns (in φ) of 8 sectors (in η) each having 128 strips



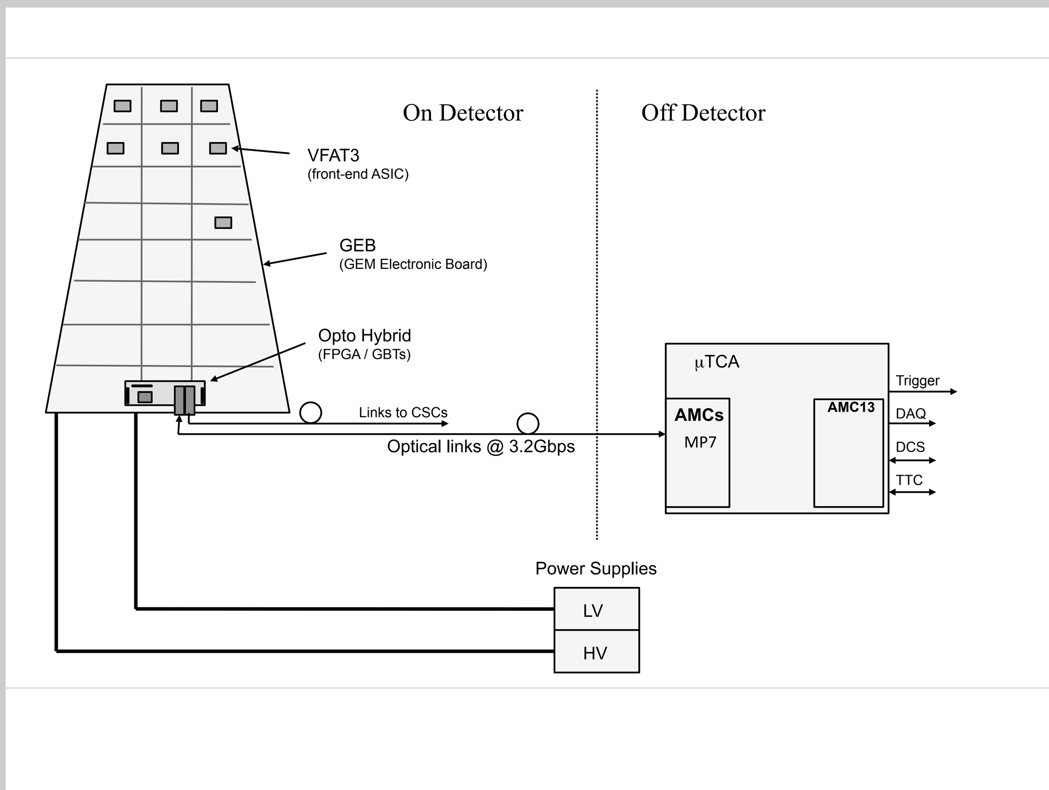
Slice test

- Installation of 4 superchambers during winter 2016-2017 prior to the end of Run 2 in preparation for the full installation of LS2
- Extend the commissioning period for a smoother full installation
- Test the integration of the electronics and DAQ with the CMS DAQ system
- Provide data based verification of the simulated performance gains.

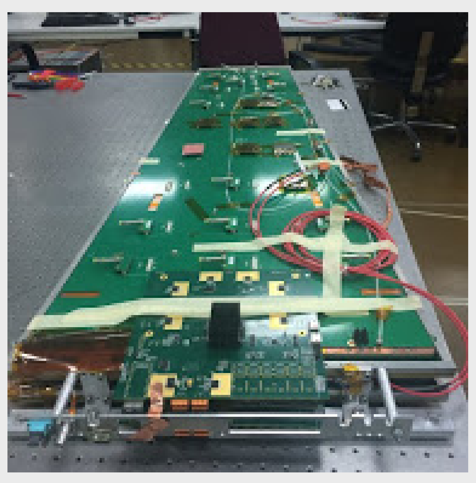
Readout system



- VFAT3 ASIC creates trigger/tracking data from hits
- GEM electronics board routes signals and power to VFAT3s
- OptoHybrid: concentrator and optical link to back end
- Back-end: μTCA system with Virtex7 based AMCs distribute triggers to front ends and build events to send to central DAQ system

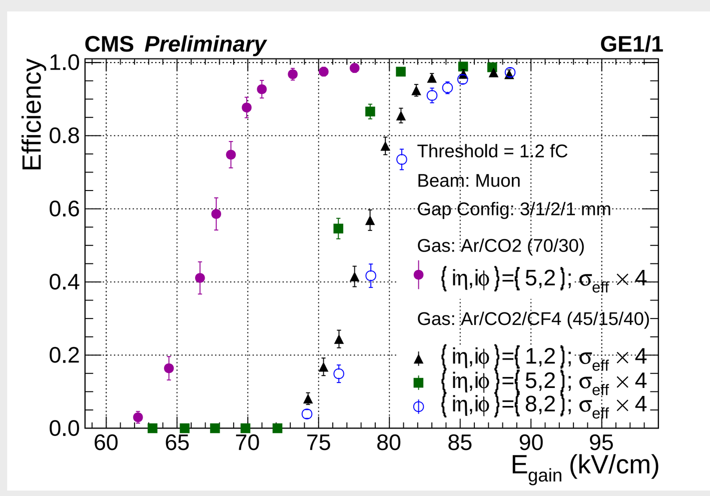


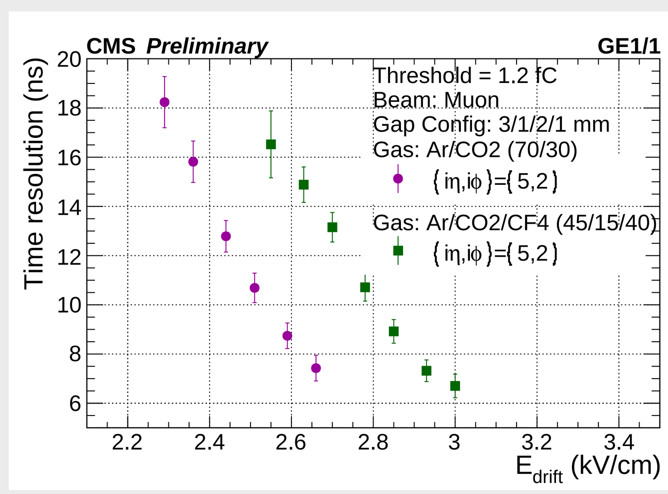
Recent testbeam results



The most recent testbeam campaigns (fall 2014 and 2015) undertaken at the CERN SPS North Area have focused on testing the detectors and electronics that will be installed in the slice test. Utilizing both μ and π beams, DAQ and detector properties have been studied

- Efficiency vs. detector gain (near)
- Time resolution vs. drift field (far)
  - N.B.: HV divider ensures all fields in the chamber are varied simultaneously

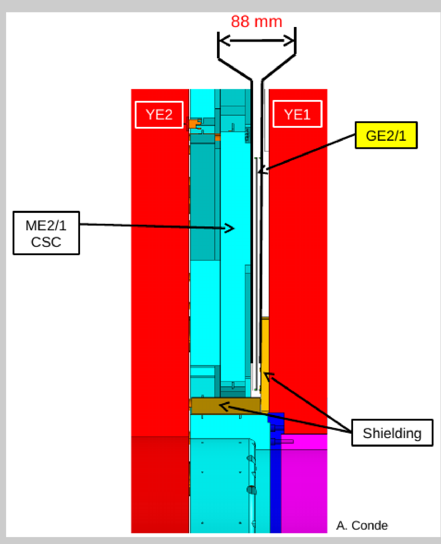


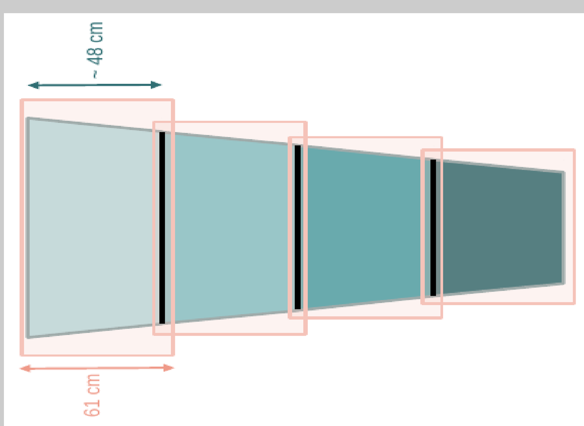


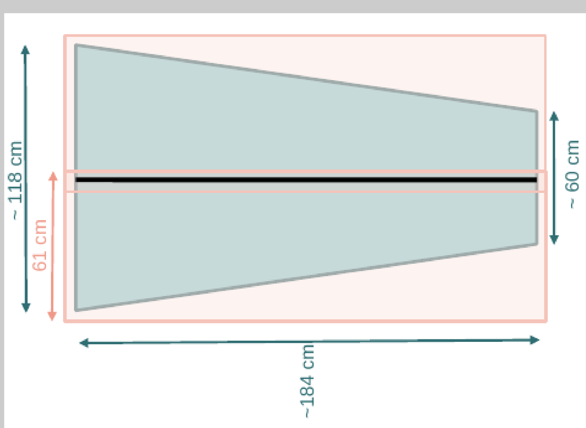
GE2/1

Extending triple GEM detectors to the second muon station $(1.6 < |\eta| < 2.4)$ brings several new challenges

- Size: Even larger than GE1/1:
  - Flatness of chambers to ensure uniformity of performance
  - 10 deg or 20 deg detectors, larger require splicing the foils when using triple GEMs
- Space constraints: must fit within the current detector configuration
- Considering μ-RWELL technology as a possible alternative

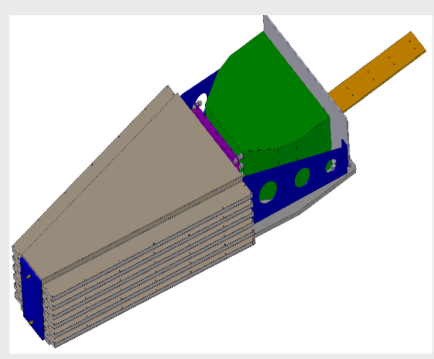


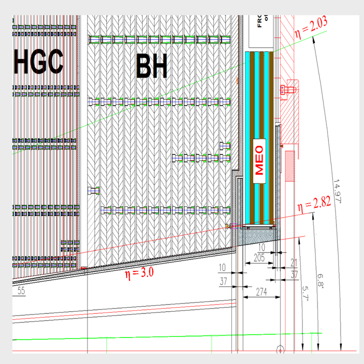




ME0

- Very forward region $(2 < |\eta| < 2.8)$
- Take advantage of extensions of the rest of CMS (tracker and calorimeter) for improved particle ID
- Multi-layer GEM detectors
- FTM (see talk by I. Vai)





References

[1] A Colaleo et al. *CMS TECHNICAL DESIGN REPORT FOR THE MUON ENDCAP GEM UPGRADE*. Tech. rep. CERN-LHCC-2015-012. CMS-TDR-013. Geneva: CERN, 2015. URL: `https://cds.cern.ch/record/2021453`.

[2] J Butler et al. *Technical Proposal for the Phase-II Upgrade of the CMS Detector*. Tech. rep. CERN-LHCC-2015-010. LHCC-P-008. Geneva. Geneva: CERN, 2015. URL: `http://cds.cern.ch/record/2020886`.