Potential impact of a new GEM-based Muon Detector on CMS Triggering

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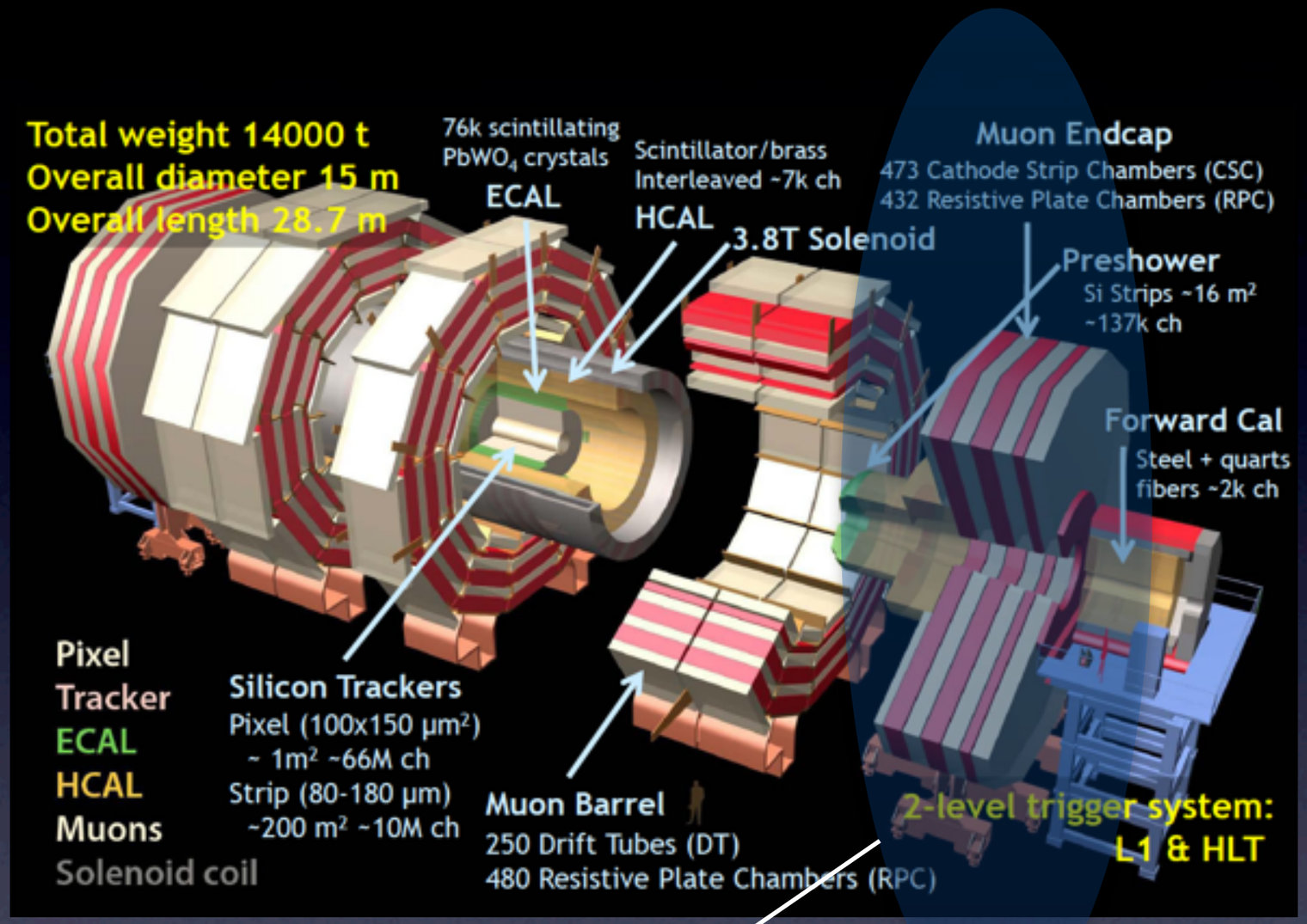
Outline

- Motivation
- CSC Muon System
- GEM Project
- Triggering with GEMs
- GEM Prototypes
- Test Beam Analysis
- Summary and Plans

CMS detector overview



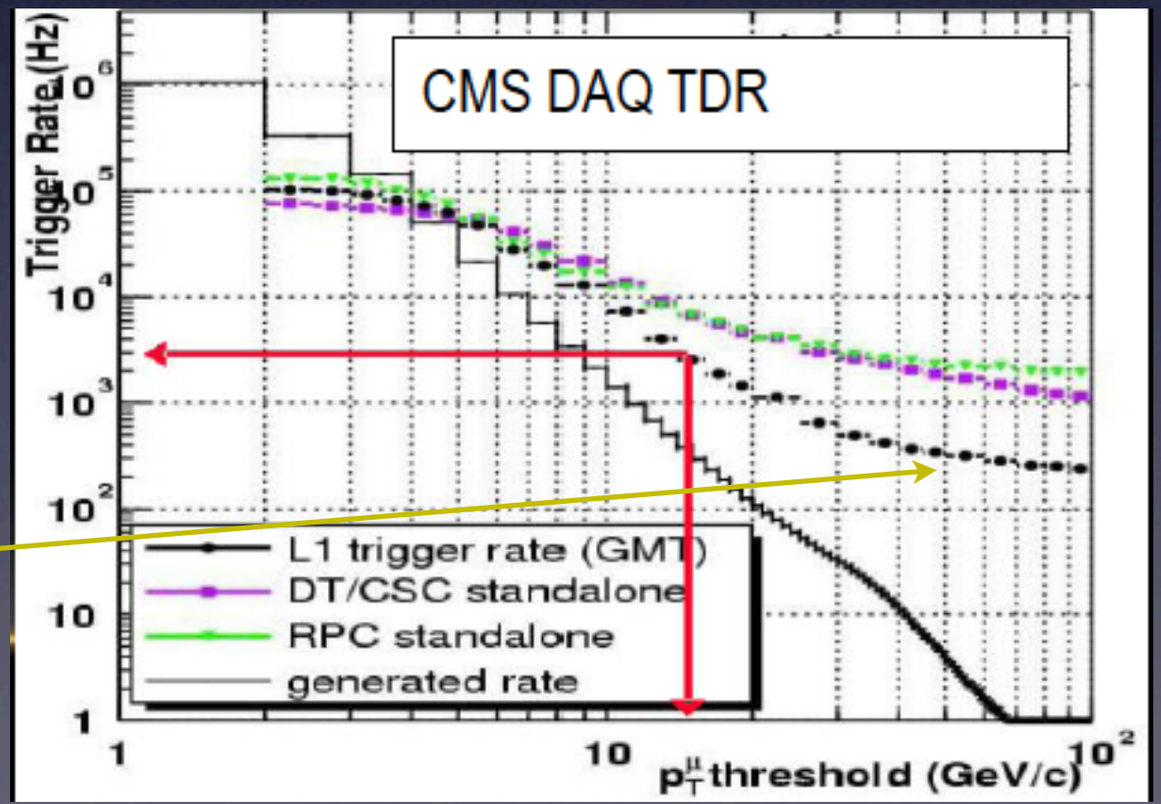
- State of the art detector
- Ideal for direct particle detection of electrons, muons,jets, etc...
- Indirect identification of neutrinos
- During the long shutdown many of these sub-detectors are under maintenance and upgrading

Today I will talk about a project to include a second muon detector (in addition to the CSC) system in the forward region

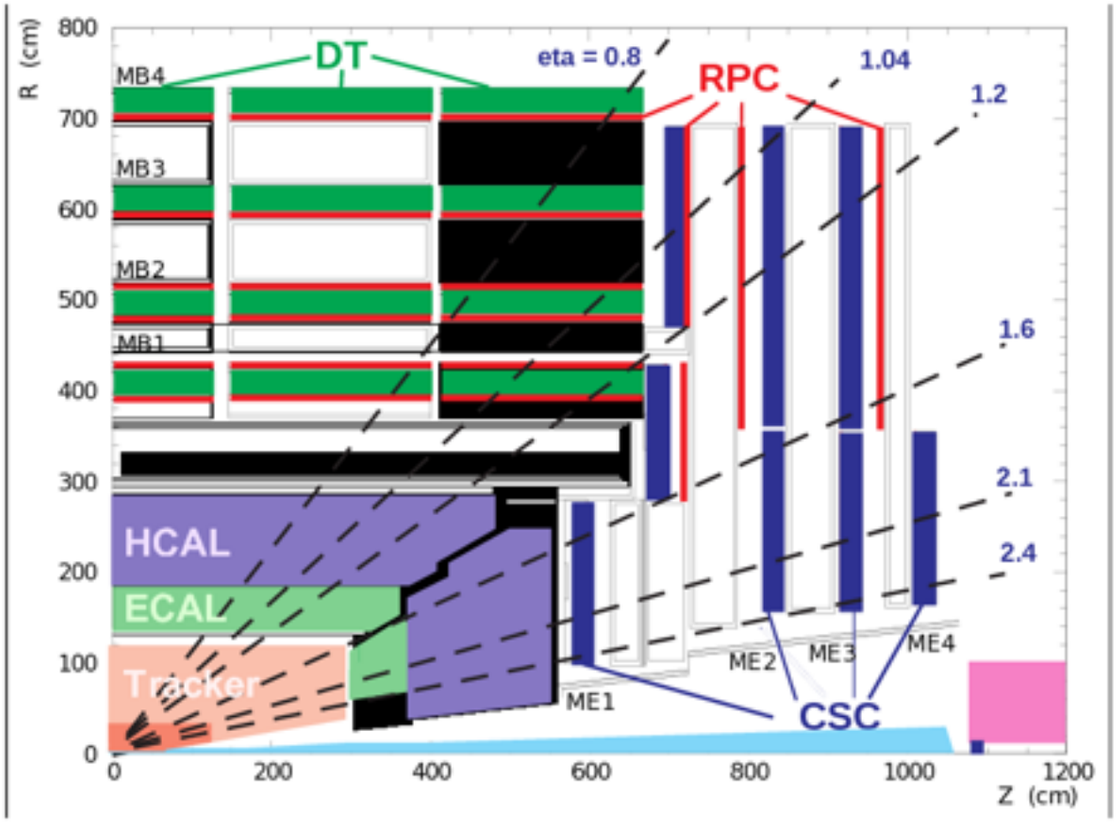
Motivation

- With the imminent LHC luminosity increase muon triggering becomes a real challenge
- In order to keep a constant bandwidth muon pT thresholds have to be raised
- Currently L1 Trigger rate inflated by momentum mis-measurements in the CSC system
- A second muon system in the forward region could help to reduce trigger rate and improve momentum measurement

Flattening on
L1 Trigger Rates

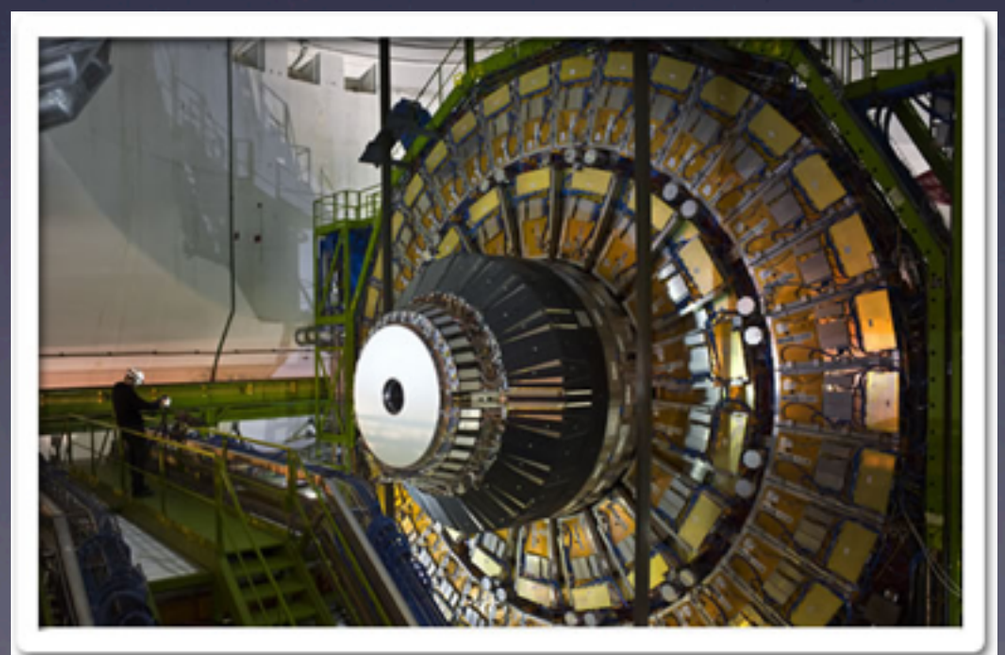


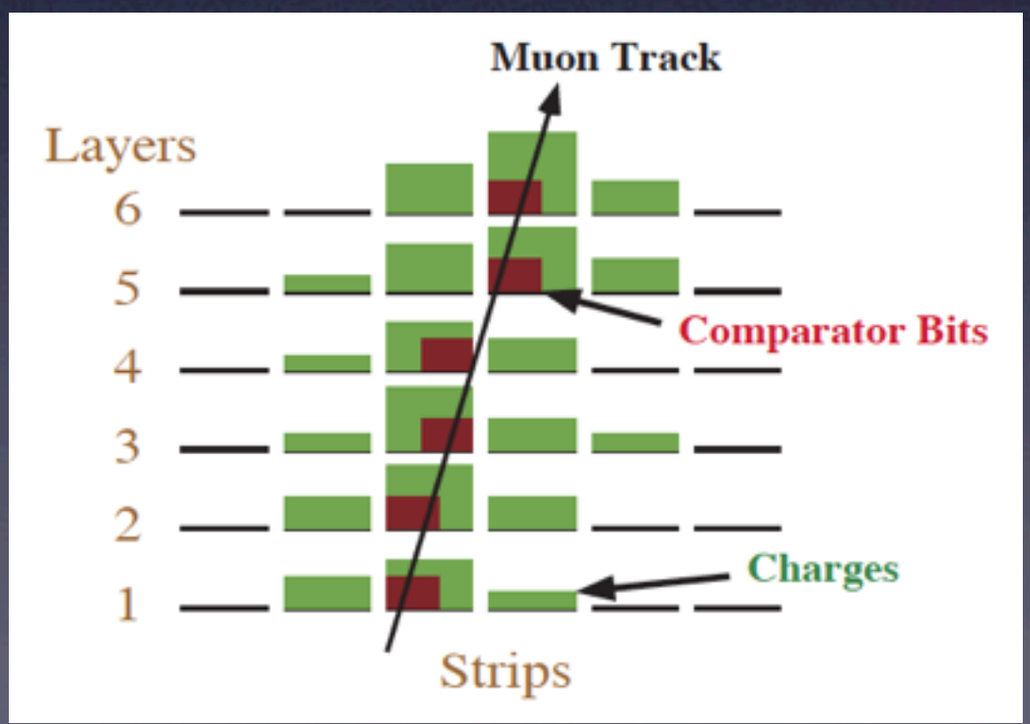
CSC Muon Detection System



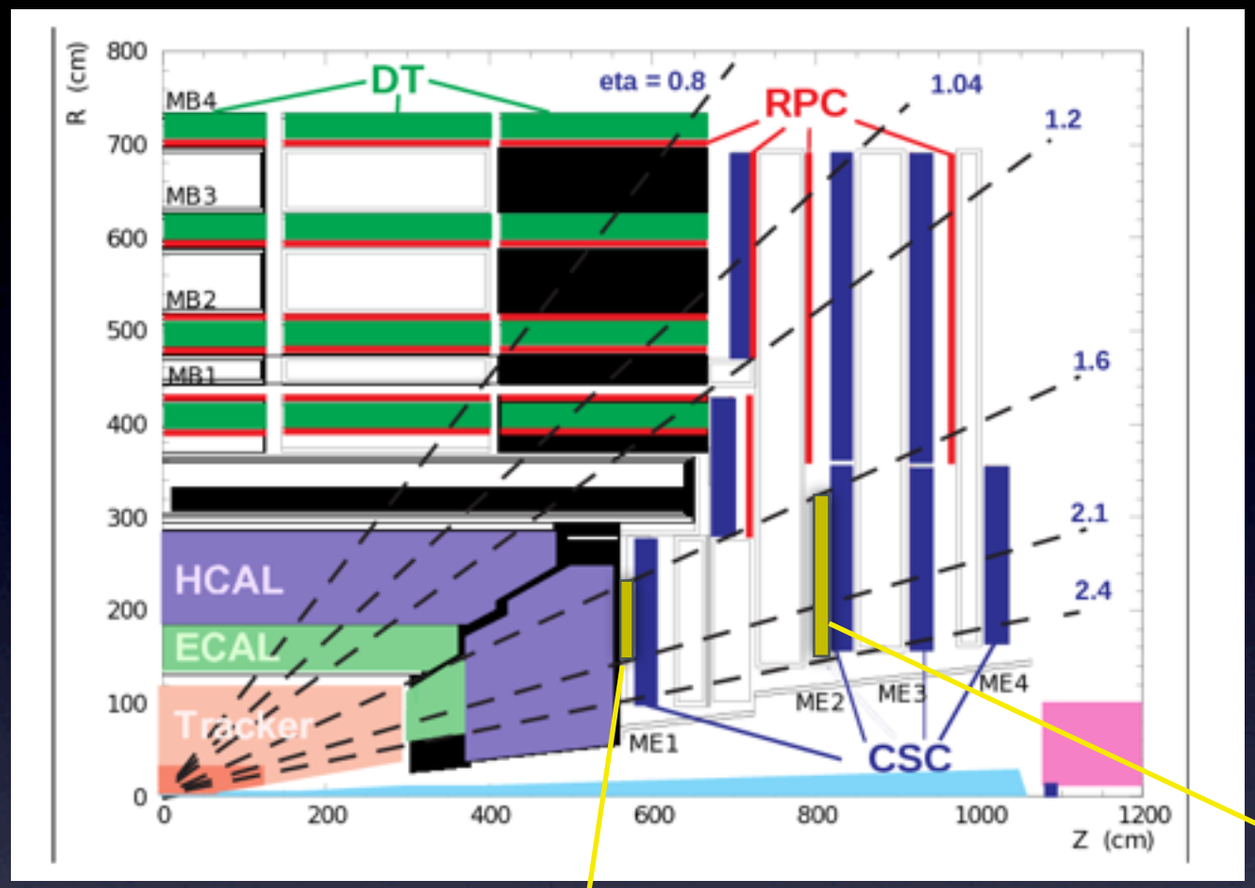
- CMS forward muon triggering ($1.6<|\eta|<2.4$) relies entirely on the Cathode Strip Chamber (CSC) system
- CSC chambers contain six layers of radial cathode strips
- The actual trigger configuration require to have tracks that leave a signal in at least 2 CSC stations

CMS ENDCAP REGION

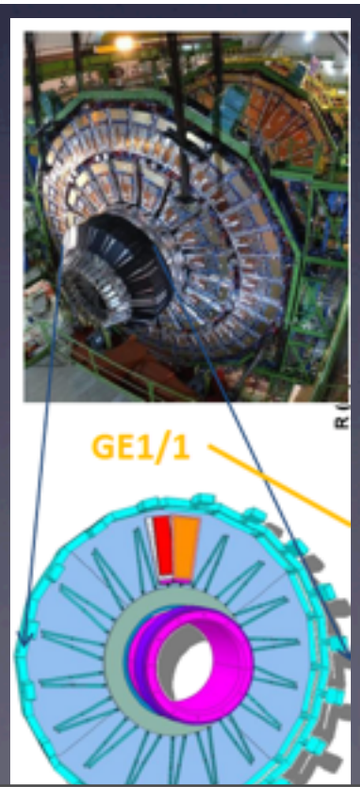




GEM Project



- Gas Electron Multiplier (GEM) is a ionization detector
- Installation of GEM detectors is proposed in the CMS high-eta region $1.6<|\eta|<2.1$-2.4
- GEMs would provide redundancy in the muon system for a robust tracking and triggering

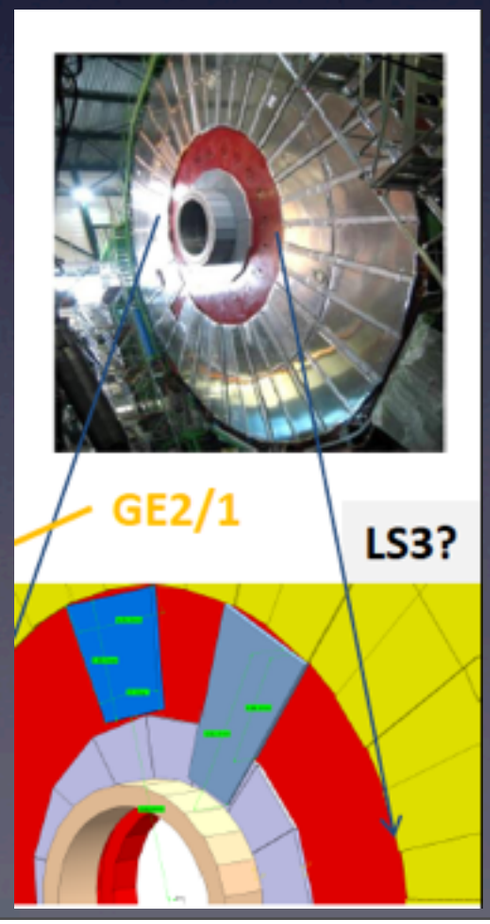


GE1/1

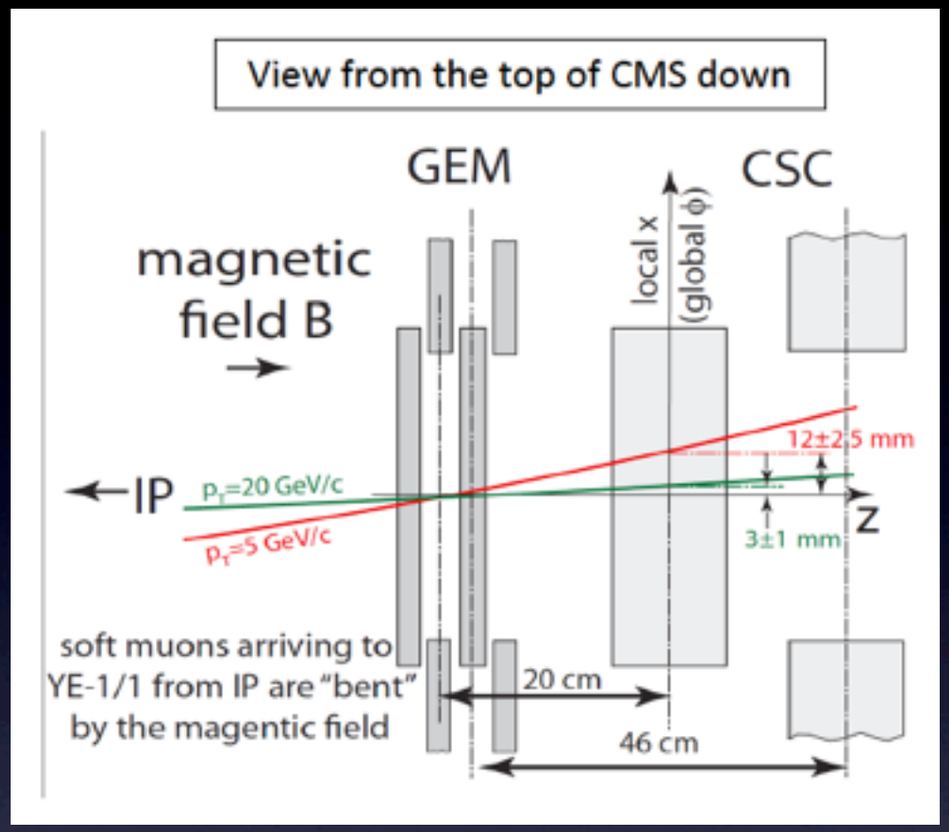
GEM GE1/1 detector installation proposed for the second long shutdown (2016-2017)

GE2/1

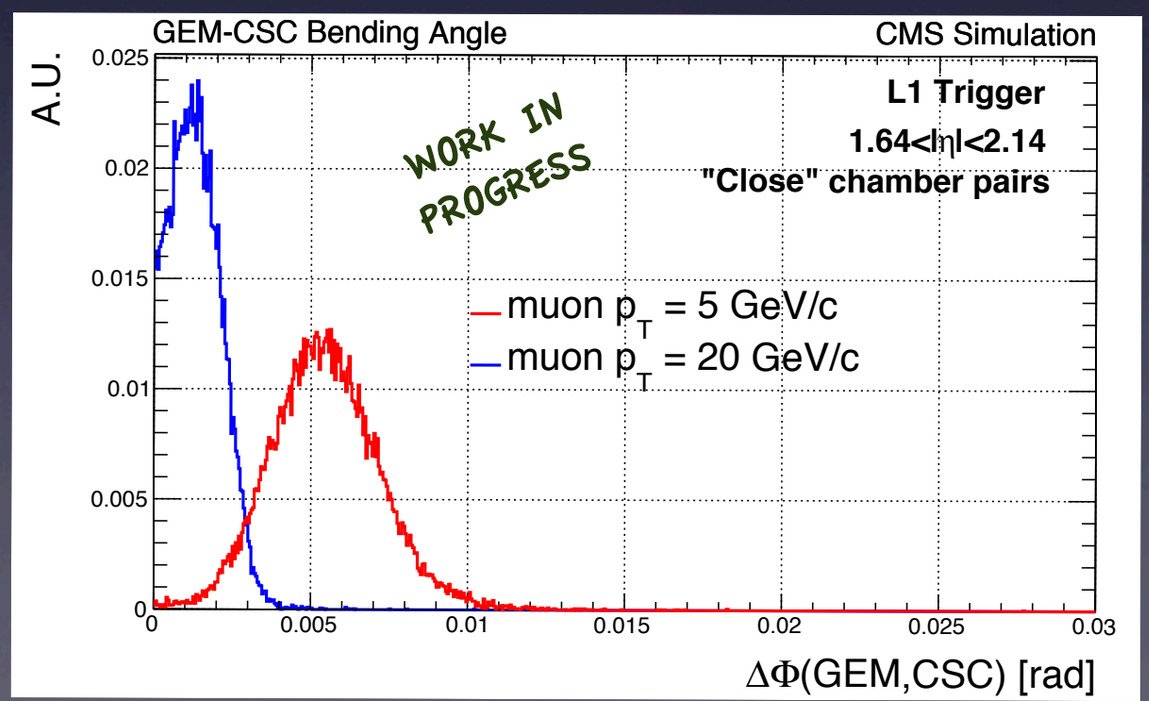
Possible installation of a second GEM station (GE2/1) for the third long shutdown (feasibility studies undergoing)



CSC-GEM bending angle

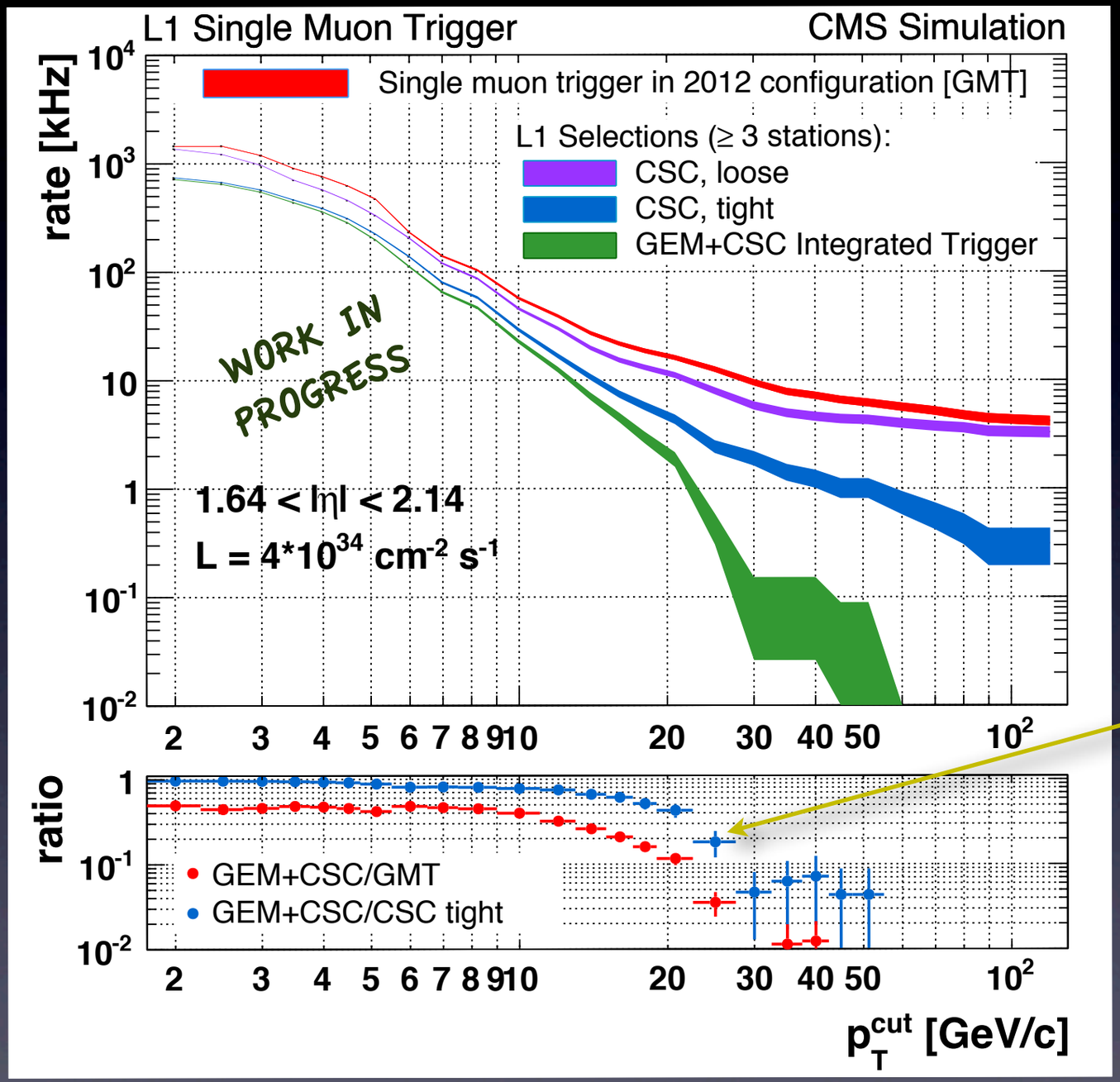


- L1 muon momentum resolution can be improved with a second detector
- A second muon system could improve resolution if one can measure the "bending angle"
- CSC are too thin (11cm) to see the bend



- GEM-CSC bending angle measured using full GEANT simulation
- Using muons with pT=5 and pT=20 GeV
- Good discrimination and a powerful tool to handle on pT resolution

Trigger rate reduction with GEMs



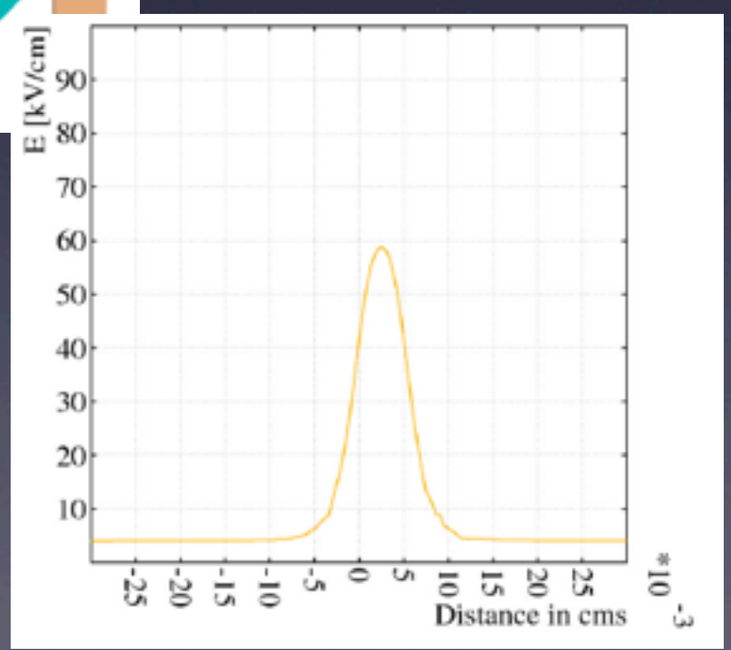
- GEMs allow a strong rate reduction and high reconstruction efficiency for lower thresholds
- From preliminary simulation studies we can get 5x rate reduction for muons with pT=25GeV compared with the tight CSC scenario (requiring a track with hits in at least 3 CSC stations)
- By reducing the rates we can lower the muon pT thresholds allowing to explore an extended range used for different analysis

Standalone GEM simulation

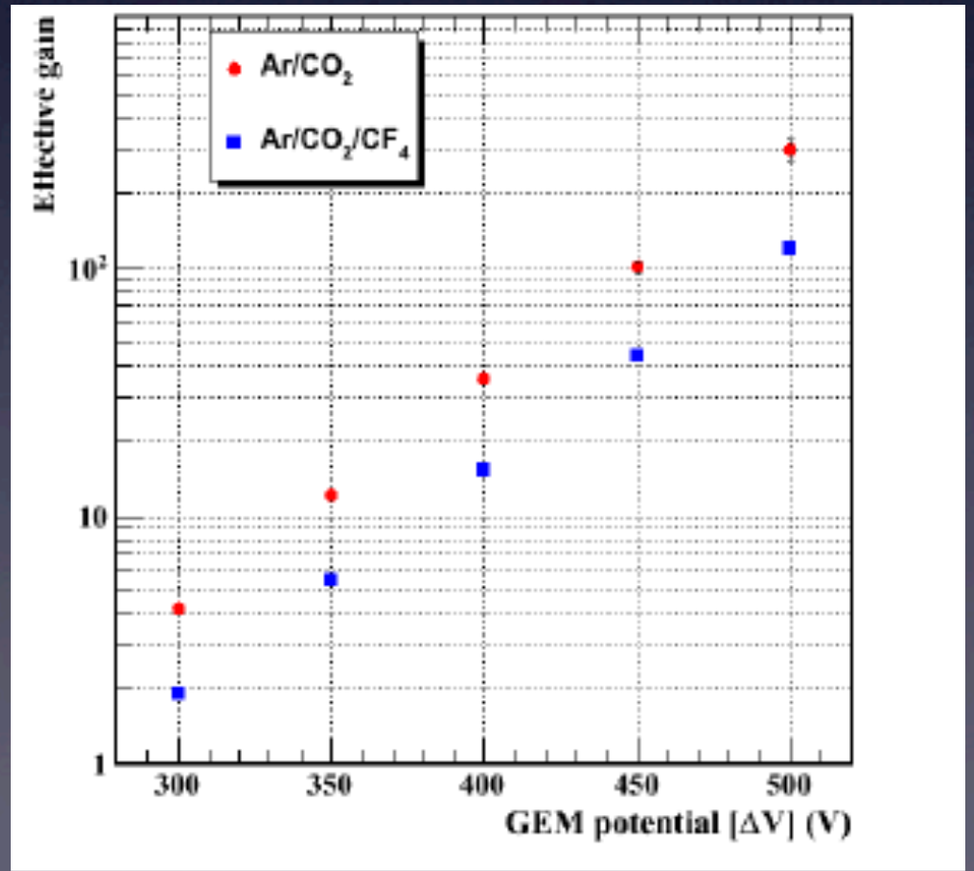
- Standalone simulation of GEM detector using ANSYS and GARFIELD
- High electric Field in the GEM Hole is simulated
- Gas under consideration is a mixture of $Ar/CO_2/CF_4$
- Several parameters can be studied as a function of the electric field, such as diffusion, gain, drift velocity, etc..

Triple-GEM arrangement

Electric Field at the center of the GEM

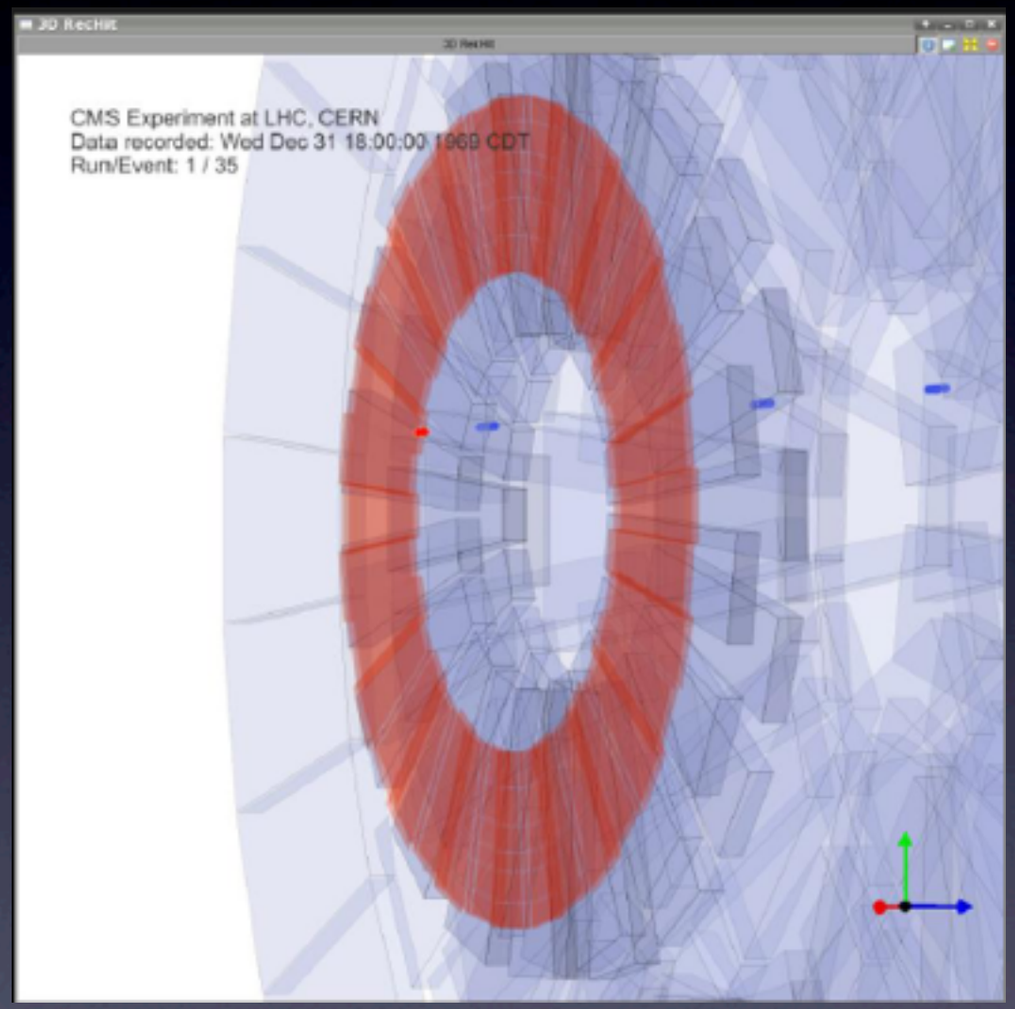


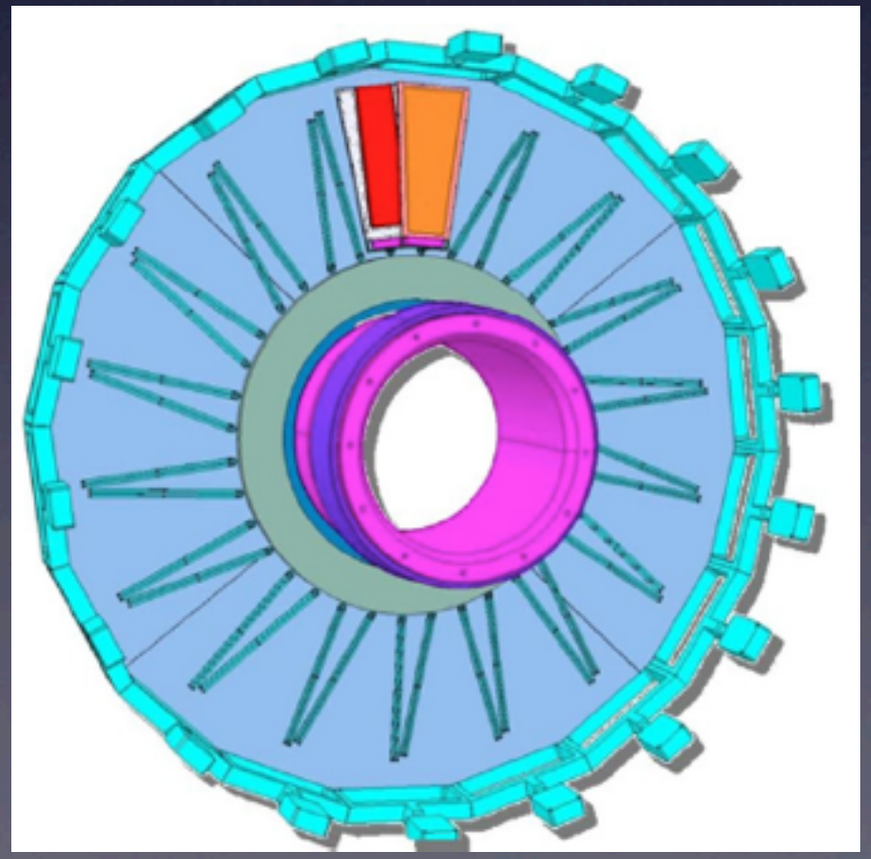
Effective gain comparison for two different gas mixtures



GEM Detector Simulation

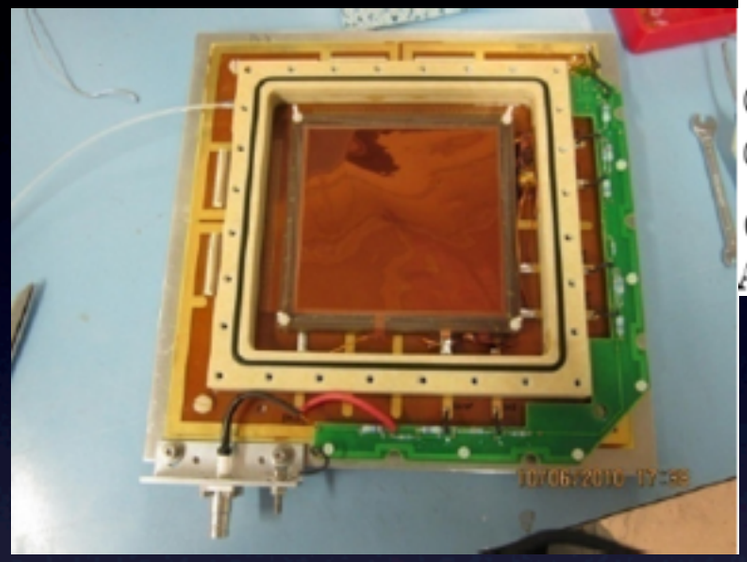
- Full simulation of the GEM detector
- GE1/1 geometry considered
- No modeling of cluster size
  - Preliminary test beam results for average cluster size of ~1.5 strips
- No extra random noise
  - Probability of a noise hit is 0.5% per BX per chamber and has negligible effect on quantities we are concerned about

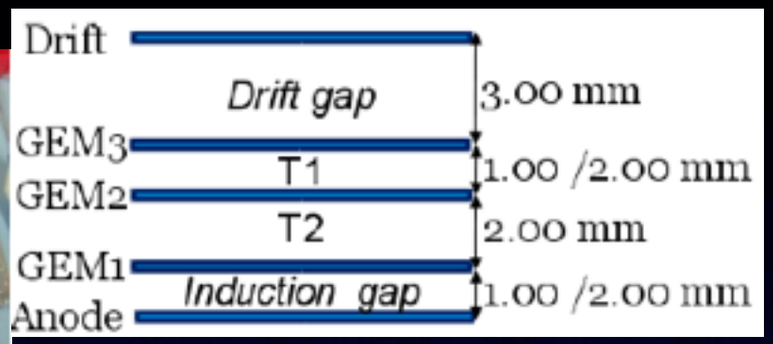




Triple-GEM prototypes

Small GEM prototype

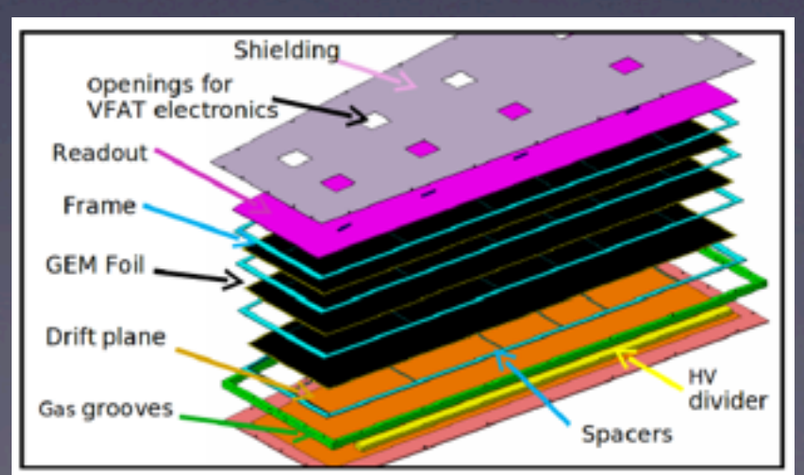




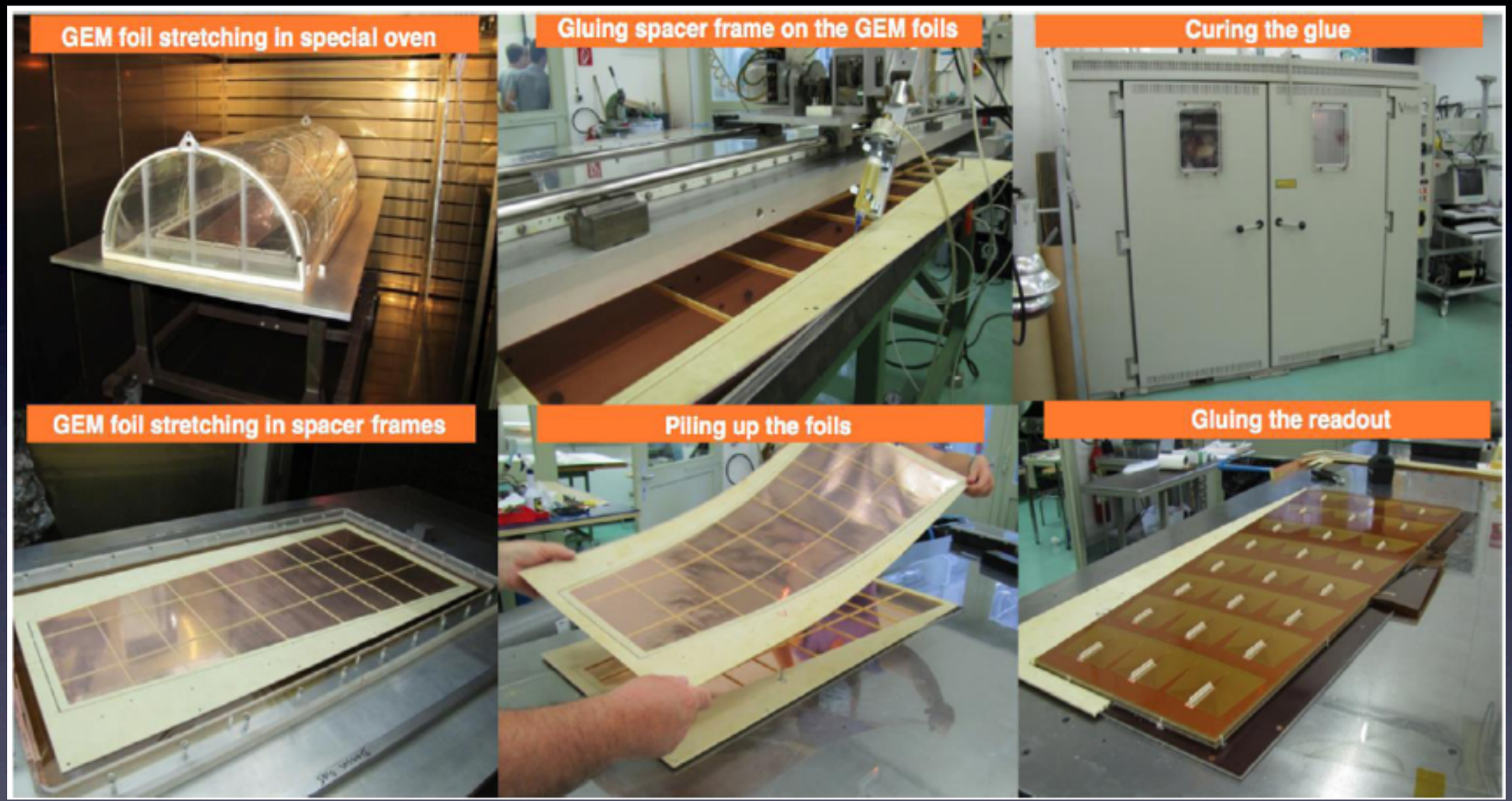
- Active area of 10x10cm
- tested in RD51 CERN lab
- Using standard Ar/CO_2 gas mixture
- Characterized by measuring gain and pulse height spectra with radioactive sources

Full-size Triple-GEM prototype

- Full size prototype for a CSC GE1/1 station with trapezoidal shape
- Active area of 990mm x (220-455)mm
- 1024 channels, 4 η partitions



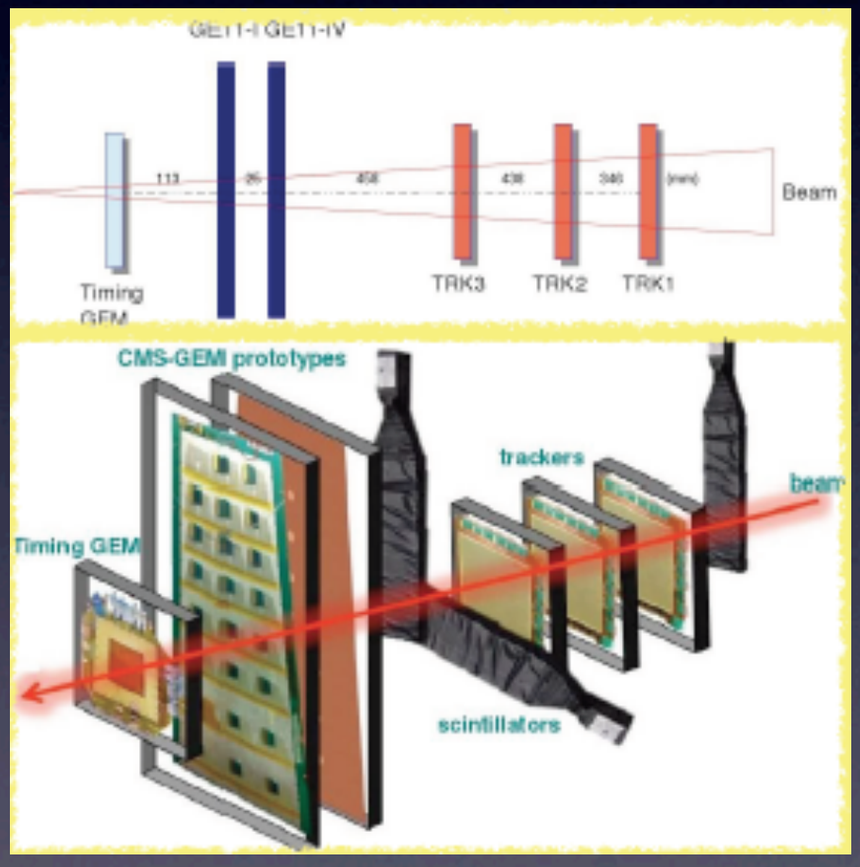
GEM foil stretching



Test Beam Analysis

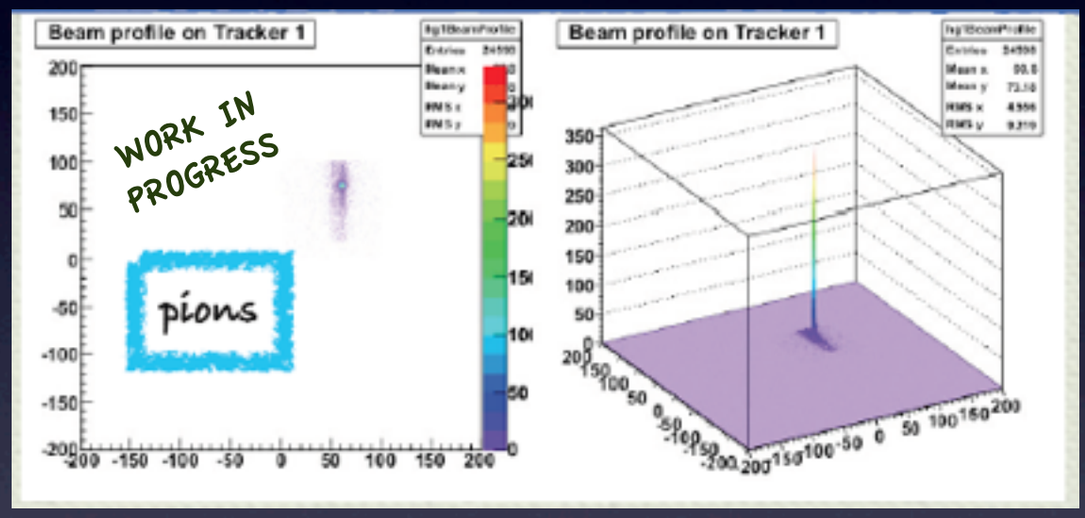
- Test beam analysis using muon and pion beams
- Using data from the 2012 data campaign
- Very preliminary results (still working on alignment issues)

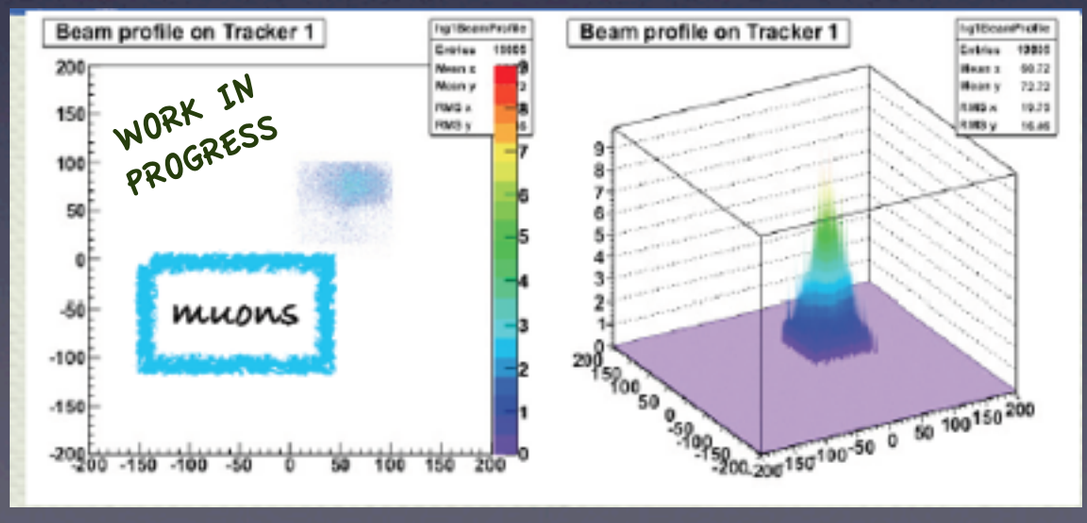
Test beam setup



- 3 scintillators for triggering
- 3 trackers: 10x10 triple GEMs
- 1 timing GEM

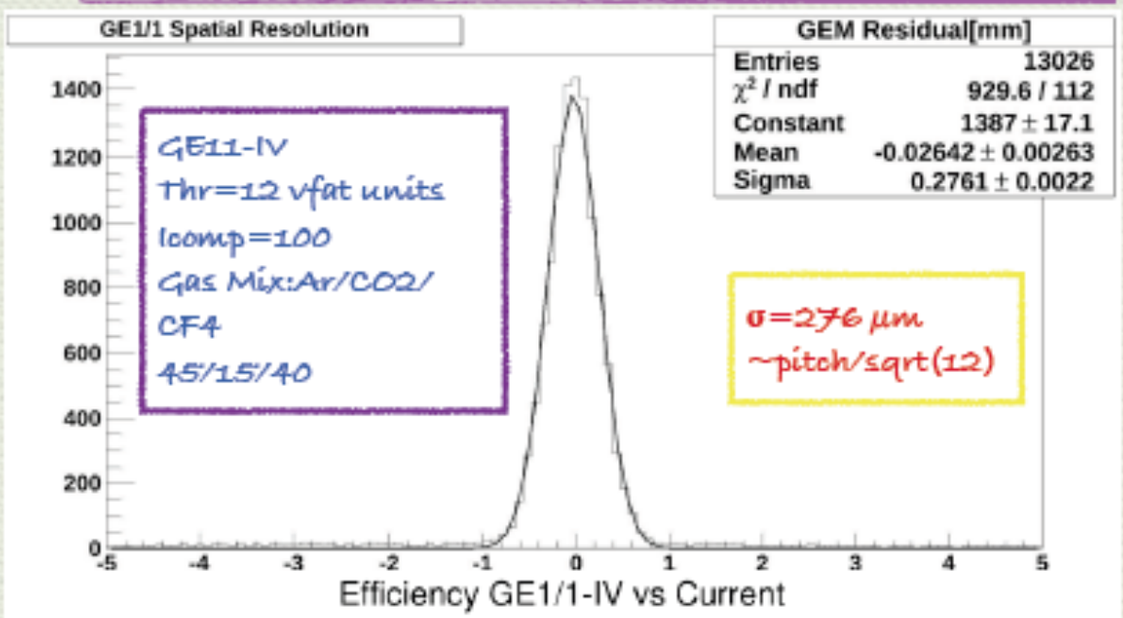
Beam profiles

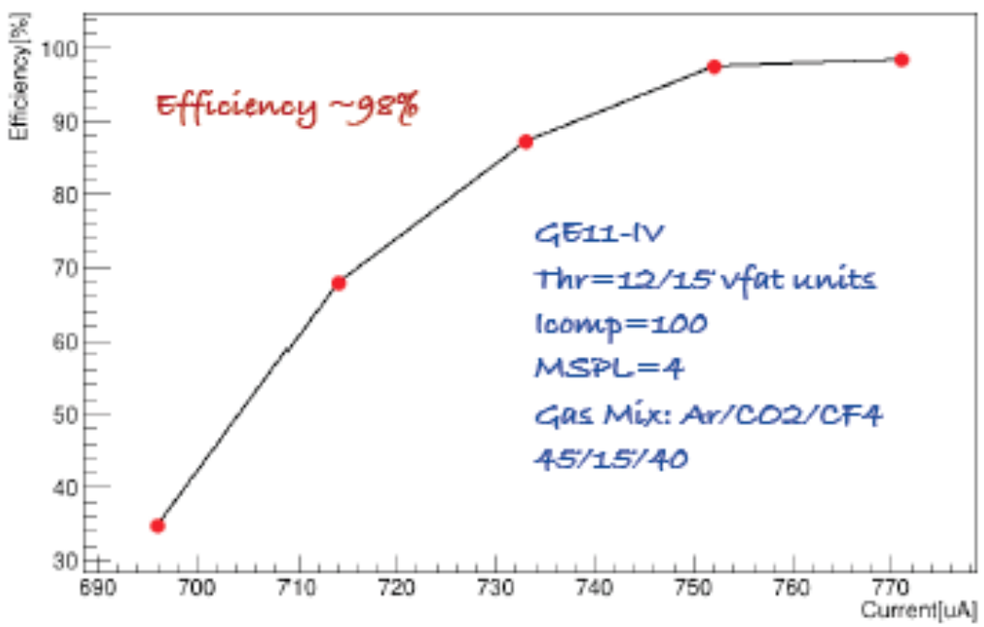


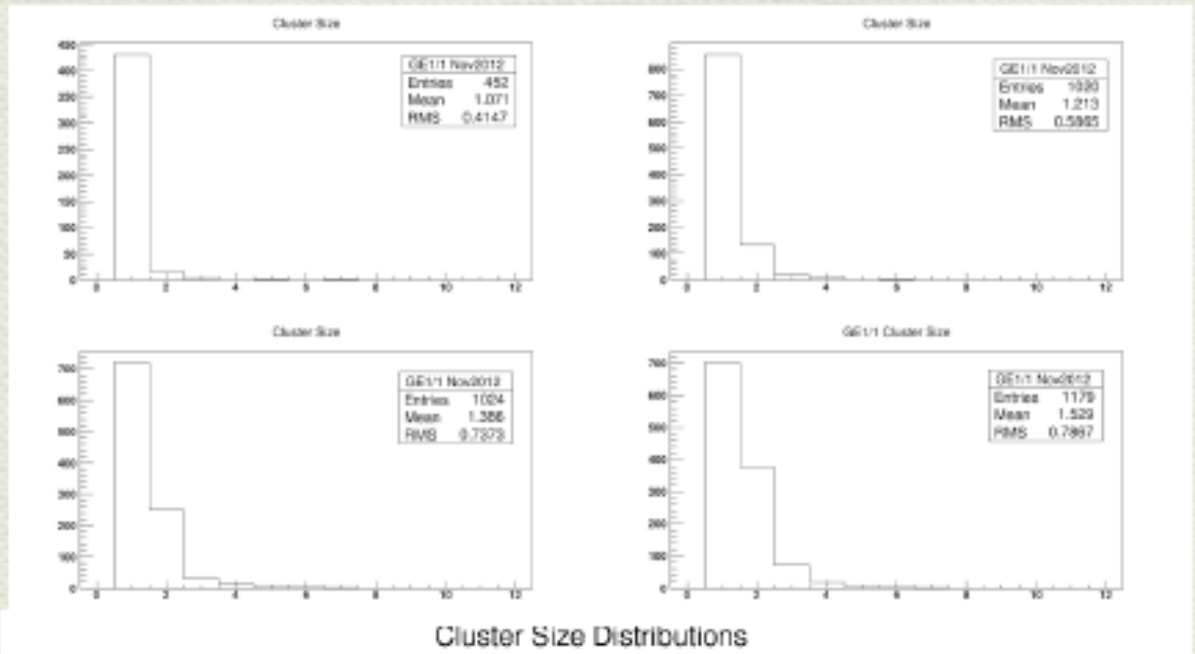


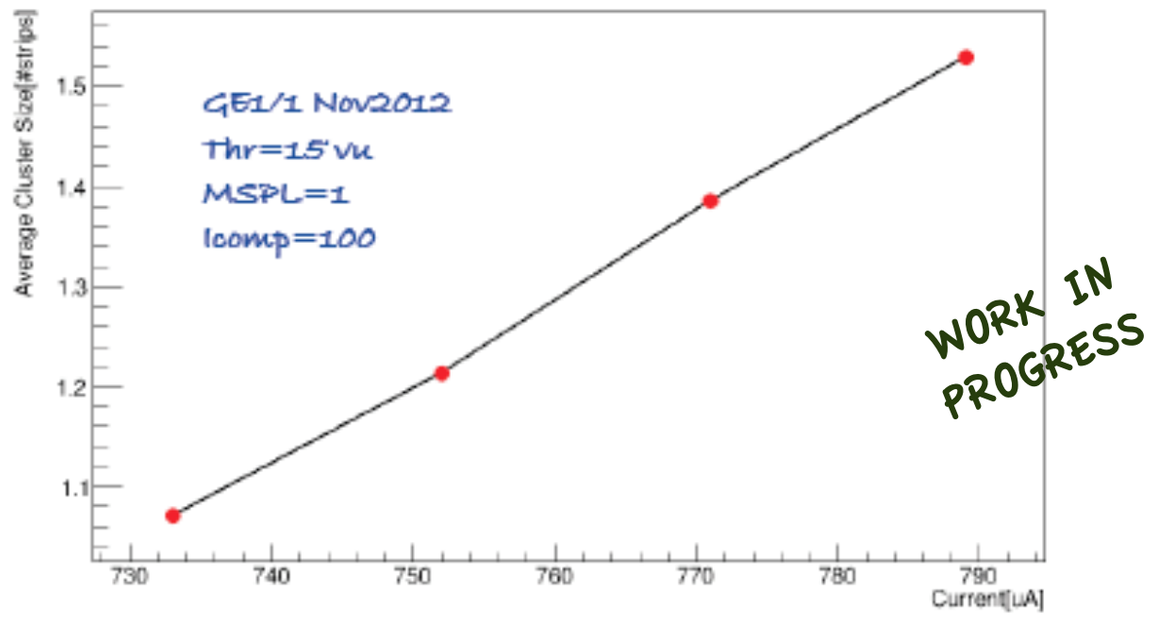
Test Beam Analysis

Test Beam Results









Summary and plans

- The installation of triple-GEM detectors in the high-eta region (1.6<|eta|<2.4) would help to reduce the trigger rate in high luminosity LHC scenarios and at the same time keep high muon reconstruction efficiency with lower thresholds

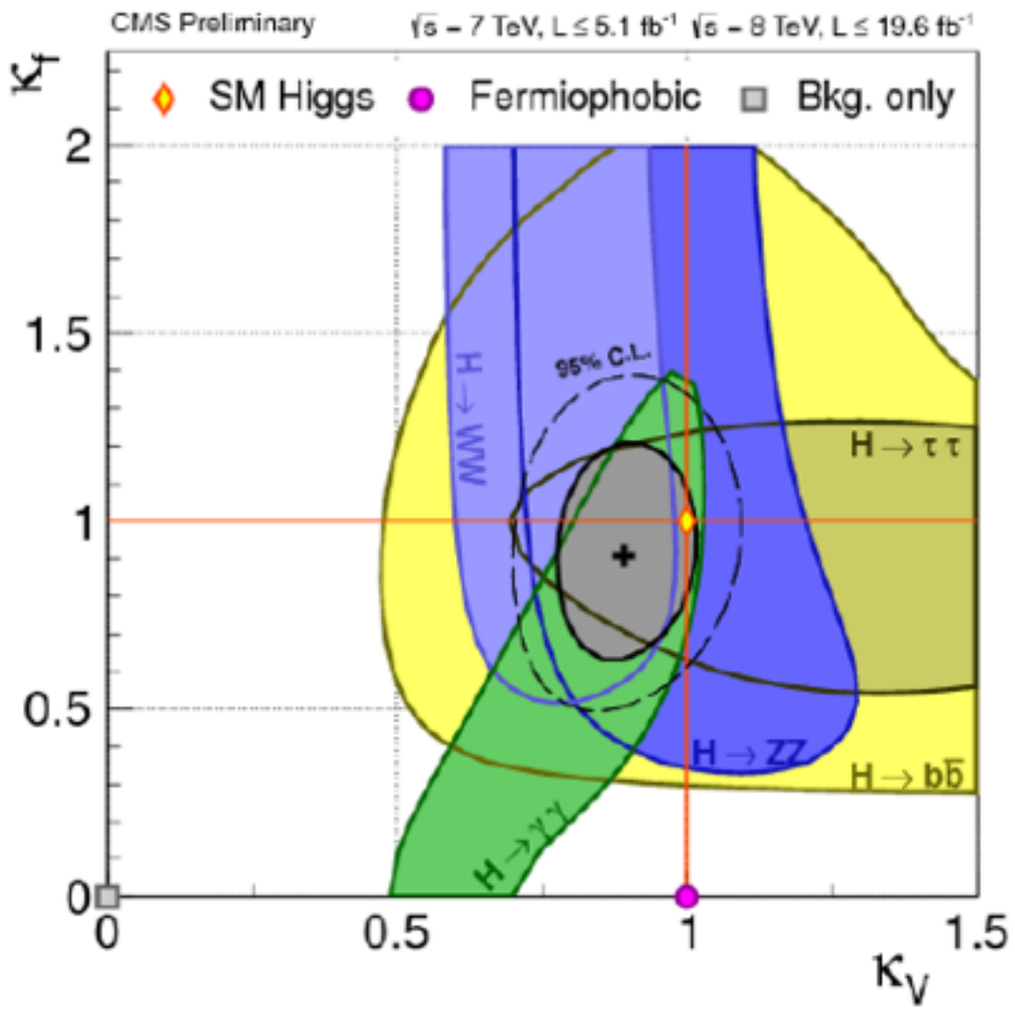
- The GEM project has moved forward, CMS collaboration has given green light for the preparation of a Technical Design Report (TDR) (expected to be ready by October 2014)

- The installation of the GEM (GE1/1) chamber is planned for the second long shutdown (2016-2017)

BACKUP

Muon System and Physics Reach

- Conservative scenario: focus on precision measurement of Higgs couplings
- Muon system is critical for both bosonic and fermionic couplings:
  - H→WW and ZZ are key to the precision on HVV couplings
  - H→ττ is key for measuring fermion couplings Hff
    - Muon + hadronic tau is the most sensitive channel; fully relies on muon trigger
- Requires an efficient muon trigger and offline
  - Maximizing the coverage is important



Impact of Trigger Thresholds

- $H \rightarrow \tau\tau \rightarrow \mu\tau_{had}$ signal: fast falling muon momentum spectrum
  - Need low p_T thresholds
  - Lose half (!) of the acceptance every time you increase p_T threshold by 10 GeV
- Better background rejection in the trigger is required
- If achievable, makes a large impact on the CMS physics reach