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

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

- 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
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 requires to have tracks that leave a signal in at least 2 CSC stations.
GEM Project

- Gas Electron Multiplier (GEM) is an 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 \( p_T = 5 \) and \( p_T = 20 \) GeV.
- Good discrimination and a powerful tool to handle on \( p_T \) resolution.

**WORK IN PROGRESS**

**CMS Simulation**

**L1 Trigger**

\[ 1.64 < |\eta| < 2.14 \]

"Close" chamber pairs

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- Using muons with \( p_T = 5 \) and \( p_T = 20 \) GeV.
- Good discrimination and a powerful tool to handle on \( p_T \) resolution.

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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**

**Effective gain comparison for two different gas mixtures**

- Electric Field at the center of the GEM
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 \(\times\) (220-455)mm
- 1024 channels, 4 \(\eta\) partitions
GEM foil stretching

GEM foil stretching in special oven

Gluing spacer frame on the GEM foils

Curing the glue

GEM foil stretching in spacer frames

Piling up the foils

Gluing the readout
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

WORK IN PROGRESS

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Test Beam Analysis

Test Beam Results

GE1/1 Spatial Resolution

- Entries: 13026
- \( \chi^2 / \text{ndf} \): 929.6 / 112
- Constant: 1387 \pm 17.1
- Mean: -0.02642 \pm 0.00263
- Sigma: 0.2761 \pm 0.0022

\[ \sigma = 2.76 \mu m \quad \sim \text{pitch/sqrt(12)} \]

GE1/1-IV
- Thr=12 vfat units
- Icomp=100
- Gas Mix: Ar/CO2/CF4
- 45/15/40

GE1/1 Cluster Size Distributions

GE1/1 Nov2012
- Thr=15 vux
- MSPL=1
- Icomp=100

Efficiency \( \sim 98\% \)

- GE1/1-IV
- Thr=12/15 vfat units
- Icomp=100
- MSPL=4
- Gas Mix: Ar/CO2/CF4
- 45/15/40

Work in progress
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:
  - $H \to WW$ and $ZZ$ are key to the precision on HVV couplings
  - $H \to \tau\tau$ 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

- $H \rightarrow \tau \tau \rightarrow \mu \tau_{\text{had}}$ 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