

Upgrade of the CMS muon system with Triple-GEM detectors

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Summary. — The CMS collaboration considers upgrading the muon forward region which is particularly affected by the high-luminosity conditions at the LHC. The proposal involves Gas Electron Multiplier (GEM) chambers, which are able to handle the extreme particle rates expected in this region along with a high spatial resolution. This allows to combine tracking and triggering capabilities, which will improve the CMS muon High Level Trigger, the muon identification and the track reconstruction. Intense research and development has been done since 2009 and it has led to the development of several GEM prototypes and the associated detector electronics. All GEM prototypes have been put to extensive tests in the lab and in test beams at the CERN SPS. The contribution will review the status of the CMS upgrade project with the usage of GEM detector, discussing also the trigger performance.

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1. – The CMS muon system upgrade

The CMS muon system [1] is designed to provide robust, redundant and fast identification of the muons traversing the system, in addition to trigger capabilities and momentum measurement. One of the main goals during the upgrade phases will be to have a detector capable of fully exploiting the increased LHC performance [2], and sustaining reliable operation for at least ten years.

In order to cope with very high operation condition, high pile-up and background environment in particular in the forward region, the CMS Collaboration is planning to install a detector based on the GAS Electron Multiplier technology [3]. Two layers (super-chambers) of triple-GEM will be installed closed by Cathode Strip Chambers (CSC), already present in the CMS Endcap Muon System (fig. 1, CSC are in green). In particular the super-chambers will be placed in front of the first station of CSC (ME1/1) during the LHC Long Shutdown 2 (LS2) and in front of the second station of CSC (ME2/1) during the LHC Long Shutdown 3 (LS3). Furthermore 6 layers of triple-GEM (ME0) near-tagger will be placed behind the future shortened hadron calorimeter during LS3. In fig. 1 it is possible to see the GEM detectors position (red boxes) in the forward region of CMS.

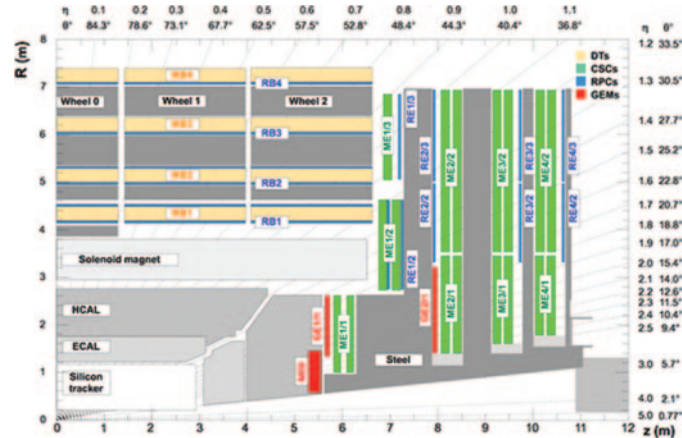


Fig. 1. – Transverse section of CMS showing the Muon system with DTs, CSCs and RPCs. The proposed GEM stations, GE1/1, GE2/1 and ME0 are given by the red boxes.

2. – The Triple-GEM Detectors

Three subsequent GEM foils allow for a reasonable amplification at every GEM foil and providing a high total amplification of about 15000. A pair of such triple-GEM chambers is combined to a so-called superchamber. To fulfill the CMS requests, several improvements have been achieved in the production and assembly fields. The development of a new production technique allows to produce GEM foils with an area of $\sim 0.5 \text{ m}^2$ and the “self-stretching assembly” technique introduces a new way to stretch the foils and assembly a chamber without spacer and glue.

Five different prototypes for the GE1/1 chamber have been developed since 2010, achieving a detector efficiency $> 98\%$, a time and spacial resolution of $\sim 4 \text{ ns}$ and $\sim 104 \mu\text{m}$ and a rate capability of $\sim 10^5 \text{ Hz/cm}^2$ (gas mixture: Ar(45%), CO₂(15%), CF₄(40%)).

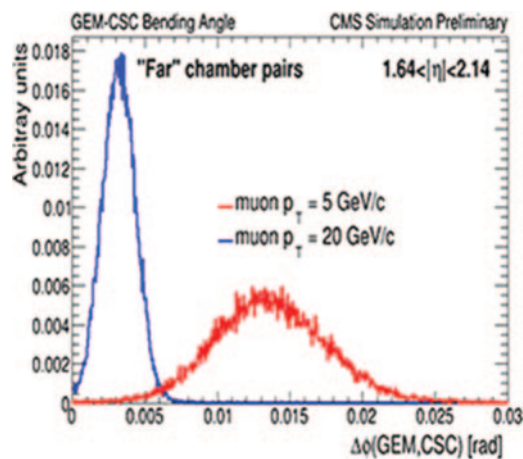


Fig. 2. – GEM-CSC bending angles for soft (5 GeV/c) and hard (20 GeV/c) muons for odd numbered GEM chambers.

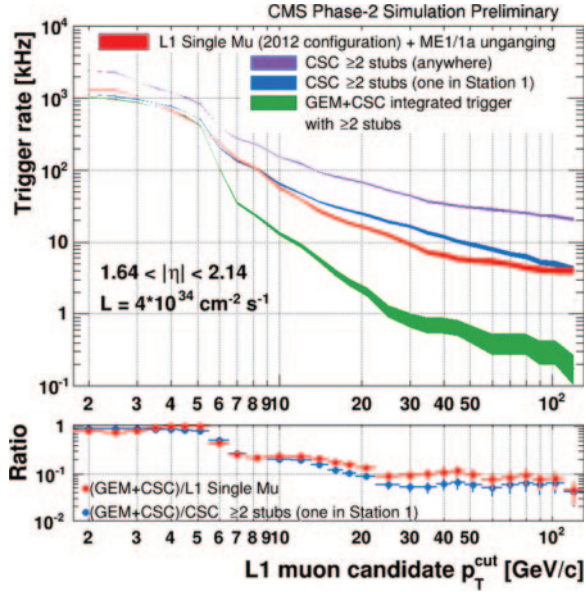


Fig. 3. – Comparison of the trigger rates for the Global Muon Trigger in the 2012 configuration with the CSC Track-Finder track rates for at least 3 stubs (loose), at least 3 stubs with at least one 1 stub from ME1/b (medium), and at least one 3 stubs with at least one 1 stub from ME1/b and a GEM pad (tight). The CSC TF used all patterns. The bottom plot shows the ratio of tight/GMT and tight/medium.

3. – Impact on trigger

The scattering of soft muons due to multiple-scattering in the iron yoke flattens the trigger rate curve. This behaviour produce a promotion of low- p_T muon to high- p_T . L1 muon momentum resolution can be improved with a second detector if we can measure the “bending angle”. GEM detector in front of CSC can measure muon bending angle in magnetic field (fig. 2). In this way we could increase the “level arm” and improve the limited p_T resolution. We can exploit the “bending angle” power of the new system GEM + CSC in the L1 trigger. Combining the CSC trigger with the information taken from the GEM, it is possible to obtain a better discrimination of high momentum and lower p_T threshold, lowering the trigger rate as is shown in fig. 3.

4. – Conclusions

Triple-GEM detectors installation in the CMS high eta region will allow to improve the muon momentum resolution measuring the bending angle and will help to reduce the trigger rate in high-luminosity scenarios. Over 5 years of R&D resulted in the validation of performance characteristics, assembly and quality control of triple-GEM detectors for the CMS Muon System upgrade.

REFERENCES

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