



Motivation of the CMS Muon System Upgrade with Triple-GEM detectors



Raffaella Radogna (University & INFN Bari)

On behalf of the CMS GEM Collaboration

ICHEP, 2-9 July 2014, Valencia (Spain)



The CMS collaboration considers upgrading the muon detector in the forward region using a technology of 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 improve tracking and triggering capabilities, resulting in a lower trigger threshold along with redundant muon identification. In the last year the GEM project took a major leap forward by integrating triple-GEM chambers in the official CMS software, allowing physics studies to be carried out. The contribution will review the status of the GEM project at CMS.

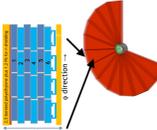
CMS Muon System Upgrade

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.

BENEFITS TO PHYSICS

- High p_T muon from boosted object where improved resolution would increase sensitivity;
- Softer muons are tracker-dominated but muon system is needed for ID;
- Multi-muon final states where η coverage is important;
- All channels with single, double muon trigger affected by higher threshold and η coverage (existing analysis with present geometry looking at possible issues and improvements at 14 TeV and high PU).

ME0



- $2.0 < |\eta| < 3$;
- 6-layers of triple-GEM detectors;
- 20° super chambers.

GE1/1



- $1.55 < |\eta| < 2.18$;
- 36 staggered chambers, each chamber spans 10° ;
- short and long super chambers for maximum coverage in pseudo-rapidity;
- To be installed during LS2.

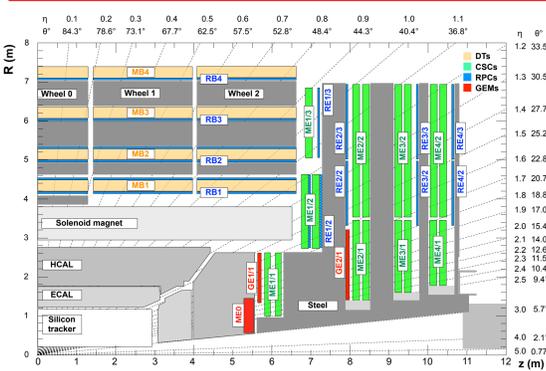
GE2/1



- $1.55 < |\eta| < 2.45$;
- Chambers spanning 20° ;
- 2 rings of double-layered triple GEMs (1 ring with short, 1 ring with long super chambers).

The high η region (innermost rings of all endcap stations), which is a third of the total CMS Muon acceptance, is only equipped with CSC chambers. This presents an opportunity for instrumentation with a detector technology that could sustain the radiation environment long-term and be suitable for operation at the LHC [2] and its future upgrades into Phase II.

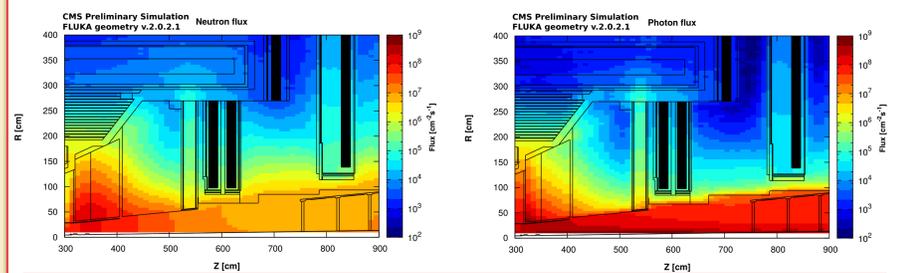
We propose to install two layers of triple-GEM [3] chambers in front of ME1/1 and ME2/1 and 6 layers of triple-GEM chambers behind future hadron calorimeter [4].



Background

The increased luminosity will create an unprecedented radiation environment the estimation of which is fundamental for detector design and the expected performance.

- Hadronic interactions lead to activation of materials and give rise to neutron backgrounds;
- long living neutrons can interact with nuclei and produce photons which Compton scatter or convert to $e^+ e^-$ pairs with some possibility to generate fake signals in the muon detectors ($n \rightarrow \gamma \rightarrow e^\pm$).

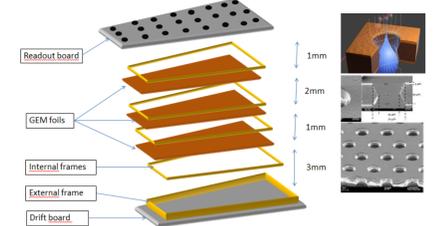


FLUKA [5] is a general purpose tool for calculation of particle transport and interaction with matter. CMS Phase-II geometry for FLUKA has been built. Color bands represent the particle fluxes from Neutrons (left) and Photons (right) for an instantaneous luminosity of $5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$.

Triple-GEM Detectors

Gas Electron Multiplier: a micro-pattern gaseous detector

- 3 layers form triple-GEM;
- spatial and time resolution: $100\mu\text{m} / \sim 4\text{-}5\text{ns}$;
- efficiency: $>98\%$
- rate capability: 10^5Hz/mm^2
- radiation hard;
- gas mixture: Ar-CO₂-CF₄ 45:15:40 (non flammable)



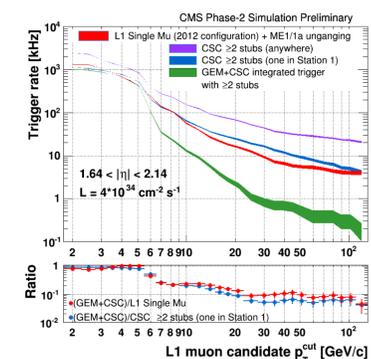
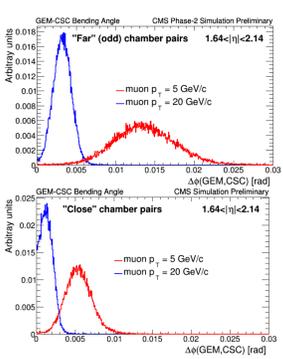
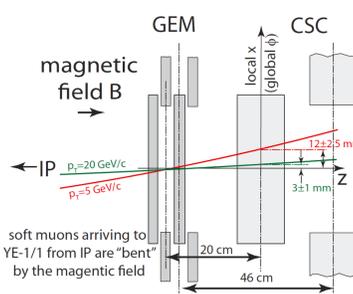
Over 5 years of R&D initiated in 2009 has resulted in the validation of performance characteristics, assembly and quality control of these detectors.

Trigger Motivation

As the LHC will be running at higher energy (13-14 TeV) and higher luminosity ($\sim 10^{34} \text{Hz/cm}^2$), there is a strong need for an improved L1 and HLT momentum resolution to reduce trigger rate, and ensure $\sim 100\%$ trigger efficiency in a high PU environment.

Scattering of soft muons due to multiple-scattering in the iron yoke flattens the trigger rate curve: promotion of low- p_T muon to high- p_T L1 muon momentum resolution can be improved with a second detector allowing to measure the "bending angle".

- CSCs are too thin (11 cm) to see the bend with sufficient resolution (around 0,5 mrad) to discriminate 5 GeV from 20 GeV muons.
- GEM detector in front of CSC can measure muon bending angle in magnetic field with:
 - increased "lever arm";
 - high point resolution improvement over the limited p_T resolution.

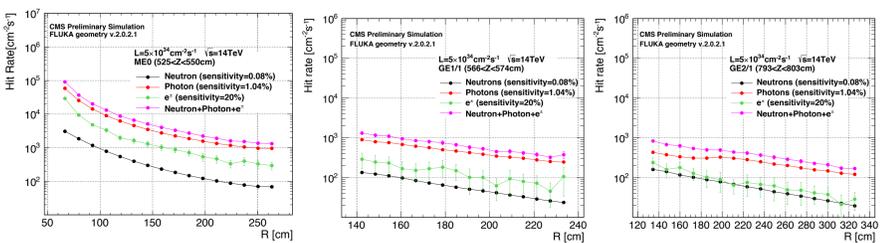


GEM+CSC combined trigger:

- better discrimination of high momentum using the bending angle measured;
- can lower p_T threshold increasing efficiency in GE1/1 region.
- Fully efficient trigger stub reconstruction with trigger rate reduction;

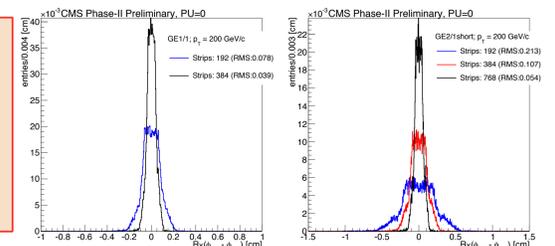
Not all particles will have an effect on the detector performance: GEM detectors have some sensitivity for every kind of particle.

Combining particle fluxes and detector sensitivities (GEANT4 simulation) gives a total "Hit rate" which can be used to estimate the impact on triggering and reconstruction.



GEM detectors rate capability is sufficient to handle the expected particle fluxes in the LHC environment. With the enhanced (η, ϕ) readout granularity and rate capability it is possible to improve the Level-1 muon trigger efficiency and even offer both triggering and tracking functions at the same time.

Muon hit residual distributions for different number of readout channels to optimize the ($\eta - \phi$) readout granularity. For each number of strips corresponds a strip width and consequently a given spatial resolution.



Best granularity (used in our simulations): 384 strips in GE1/1 and 768 strips in GE2/1 ($\Delta\phi/\text{strip} = 0.45 \text{mrad}$).

Conclusions

CMS GEM Project started in 2009. The Triple-GEM provide a suitable solution for the CMS muon trigger and tracking needs in the LHC Phase-II era:

- improve the muon momentum resolution measuring the bending angle;
- reduce the trigger rate in high luminosity scenarios thanks to the enhanced readout granularity and rate capability.

References: [1] The CMS Collaboration et al., (2008) JINST 3 S08004. [2] Lyndon Evans and Philip Bryant, (2008) JINST 3 S08001. [3] F. Sauli, Nucl. Instrum. Meth. A 386, 531, 1997. [4] D. Abbaneo et al., (2012) JINST 7 C05008. [5] <http://www.fluka.org/fluka.php?id=about>.