Test beam and irradiation test results of Triple-GEM detector prototypes for the Upgrade of the Muon System of the CMS experiment

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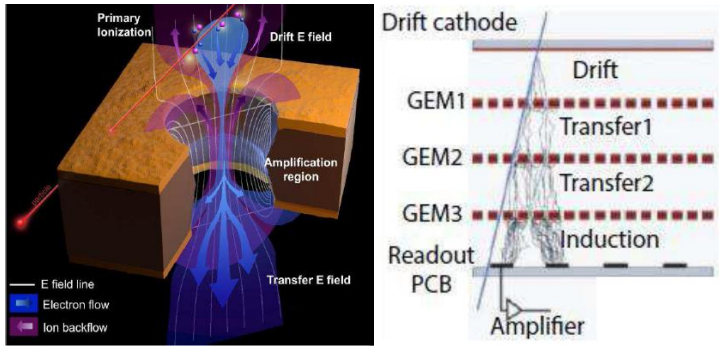
The CMS Collaboration is improving the Muon System to maintain the high level of performance achieved during Run 1 also in the harsh environment of High Luminosity LHC (HL-LHC). The **installation of additional detectors** in the endcap muon stations, in particular a **GEM station** in the forward region $1.6 < |\eta| < 2.2$ (GE1/1) is expected to fulfill the HL-LHC requirements.



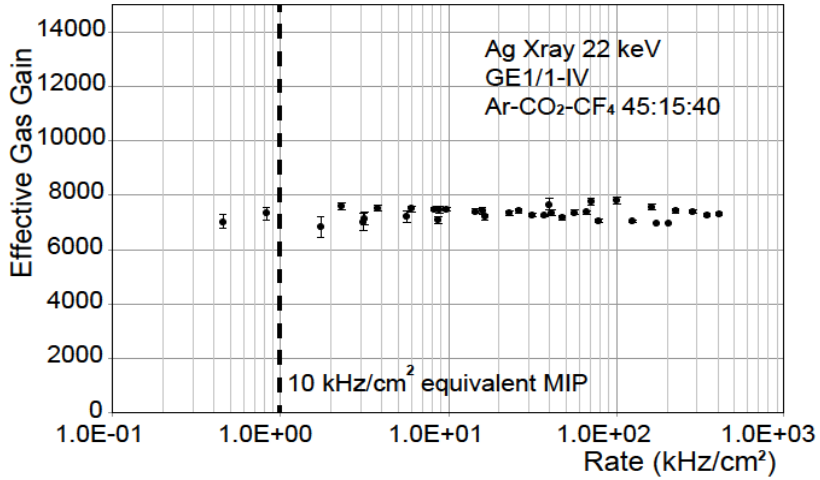
Left: Schematic view of the electric field lines (white), electron flow (blue) and ion flow (purple) in a GEM hole. Right: Principle of operation of a generic Triple-GEM chamber.

A **Gas Electron Multiplier** foil:

- a 50 μm-thick kapton foil cladded on both sides with a 5 μm-thick copper layer perforated by a high density of holes
- Voltage applied between the copper layers: electric field of ~60 kV/cm in the kapton and of few kV/cm in the gas gaps.

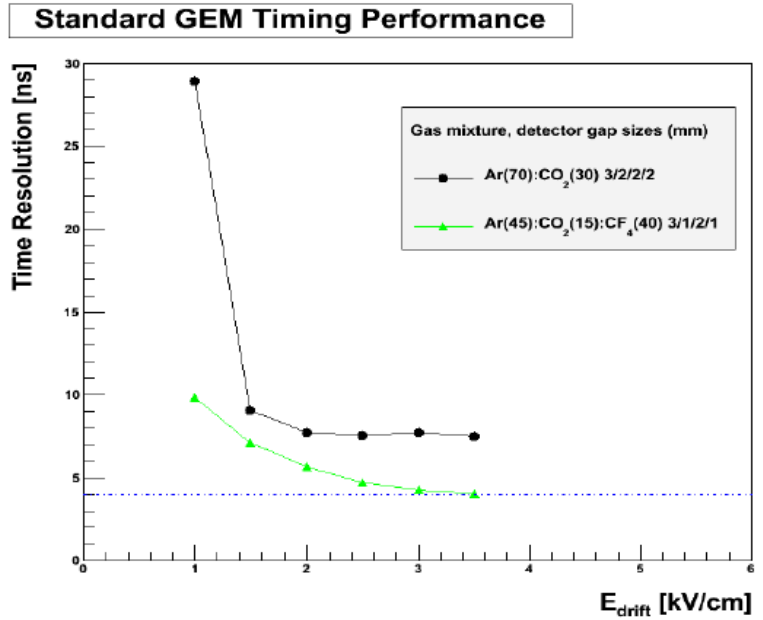
A charged particle passing through the detector ionizes the gas: the created electrons move along the field lines reaching the holes in the GEM foils, where they are accelerated by the intense field, thus inducing an avalanche. It is possible to reach gain up to ten thousand, but usually a detector consists of two or three successive GEM foils, that can be operated at lower voltages with higher stability. The electron signal is then measured directly on the readout plane, which leads to a faster signal and a better time resolution.

For GE1/1 station, CMS has selected **Triple-GEM detectors**, made up of three GEM foils: the R&D performed lead to the production of a detector that can be assembled in few hours, with foils mechanically stretched and without gluing any component and capable of sustaining the harsh conditions of HL-LHC.



Effective gas gain as a function of the incident photon rate measured in a GEM1/1-III detector operated with Ar/CO2/CF4 45:15:40 and irradiated with a 22 keV Ag X-Ray source. The dashed line represent the expected rate in the CMS Muon System

The performance of all the CMS TripleGEM prototypes has been measured in **test beams** at CERN and at Fermilab, with two different gas mixtures and with two different readout systems.

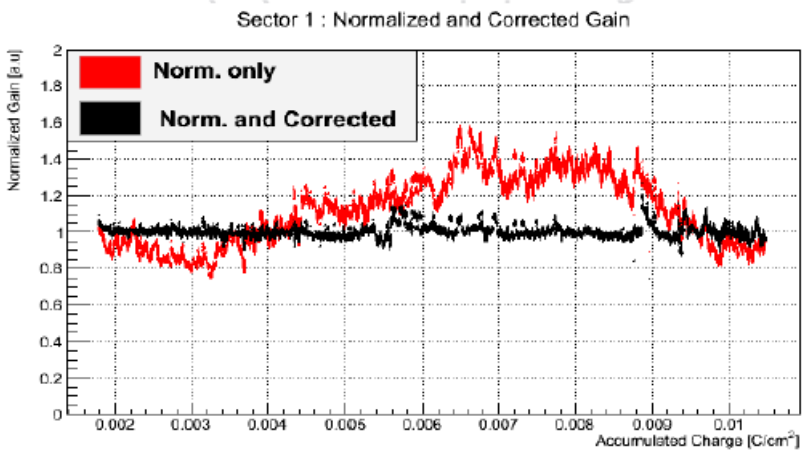


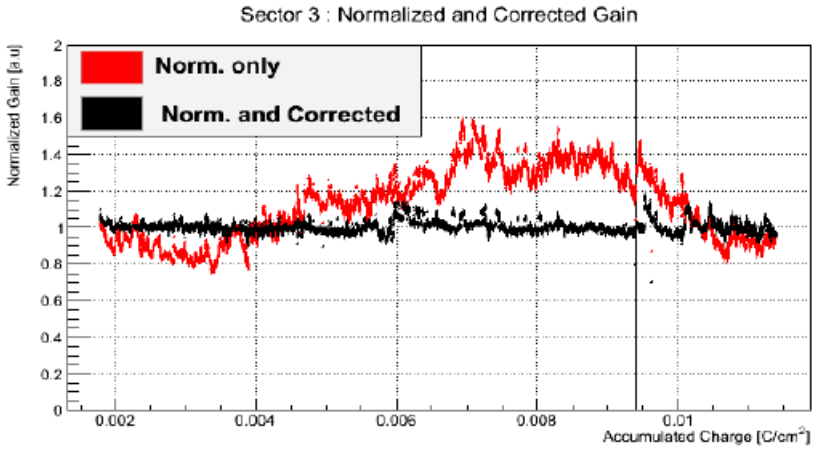
Timing resolution measured with a TDC for a small Triple-GEM detector as a function of drift field.

These results show that **the detector developed matches the requests** in:

- detection efficiency (97-98%)
- timing resolution (few ns)
- angular resolution (100-160 μrad)
- spatial resolution (2-300 μm)
- rate capability (100 MHz/cm^2).

The presence of a strong magnetic field (up to 1.5 T) does not deteriorate the performance of GE1/1 detector.





Corrected and normalized gain in irradiated GE1/1 sector 1 (left) and 3 (right) as a function of the total charge accumulated in the detector during the GIF aging test. No aging effects have been observed after a total accumulated charge of about 10 mC/cm^2.

Aging tests performed at the Gamma Irradiation Facility (GIF) at CERN, with a ^{137}Cs source of 566 GBq (Gamma rays 662 keV), show **no drop in the gain** of the irradiated sectors of the GE1/1-IV prototype after accumulating about 10 mC/cm^2 of charge, corresponding to about two years of GE1/1 operation at the HL-LHC.

Among the new technologies considered for the Upgrade of the CMS Muon System, Gas Electron Multipliers have been subjected to an intense R&D, leading to the development of a detector capable of sustaining the harsh conditions of HL-LHC.

In order to verify the integration of the GE1/1 chambers into trigger and to obtain operational experience with the new subsystem, a first **installation of a demonstrator** is foreseen for 2016-2017. After that, the installation of the full GE1/1 station is planned for 2018.

References

CMS GEM Collaboration, CMS-TDR-15-001-001; F. Sauli, *NIM A386 (1997)531-534;* R.Radogna on Behalf of the CMS GEM Collaboration, *Nuclear Physics B Proceedings Supplement 00(2014)1-3;* C. Calabria on Behalf of the CMS GEM Collaboration, *Nuclear Physics B Proceedings Supplement 00(2014)1-6*