Present and future GEM activities in Aachen

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Technology of Gas Electron Multiplier

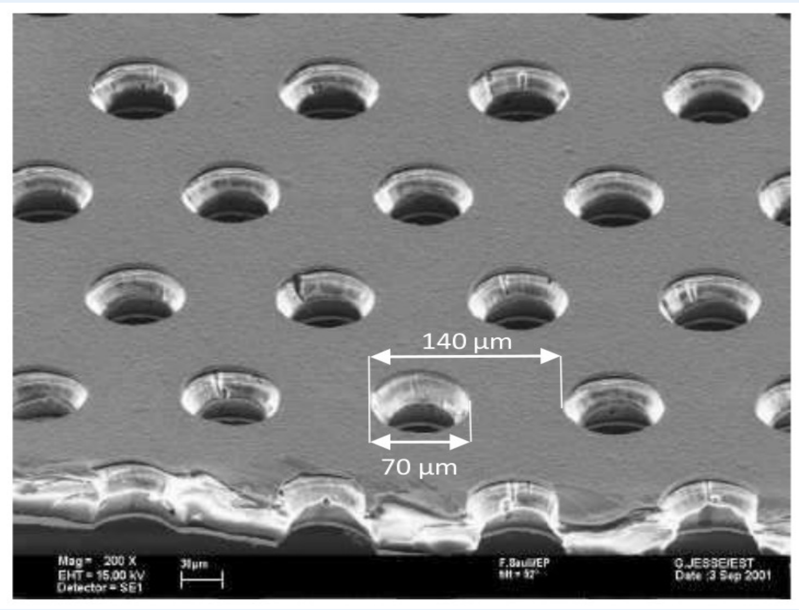

Figure 1: Scanning Electron Microscopic (SEM) picture of a GEM foil. [1]

Gas Electron Multipliers (GEMs) belong to the most modern and advanced gaseous detectors in the world. The GEM foils, being the core of the detector, consist of a thin (50 µm) kapton foil with copper (5 µm) cladded on both sides. The bi-conical holes of the foil are organized in a hexagonal pattern with a pitch of 140 µm and have an outer diameter of 70 µm and the inner diameter is 50 µm. In a triple-GEM detector, as it is used in the CMS detector, a stack of three GEM foils is inserted.

Detection principle and simulation

The GEM detection principle relies on the electron amplification inside microscopic regions. Electrons from primary ionization drift in the gap towards the GEM foil. Applied voltages on top and bottom copper layer of the GEM foils result in electric fields of around 50 kV/cm inside the holes. This is where the electron multiplication takes place. With simulation, the gas gain behavior of a GEM detector can be analyzed for different configurations using the Garfield toolkit [2].

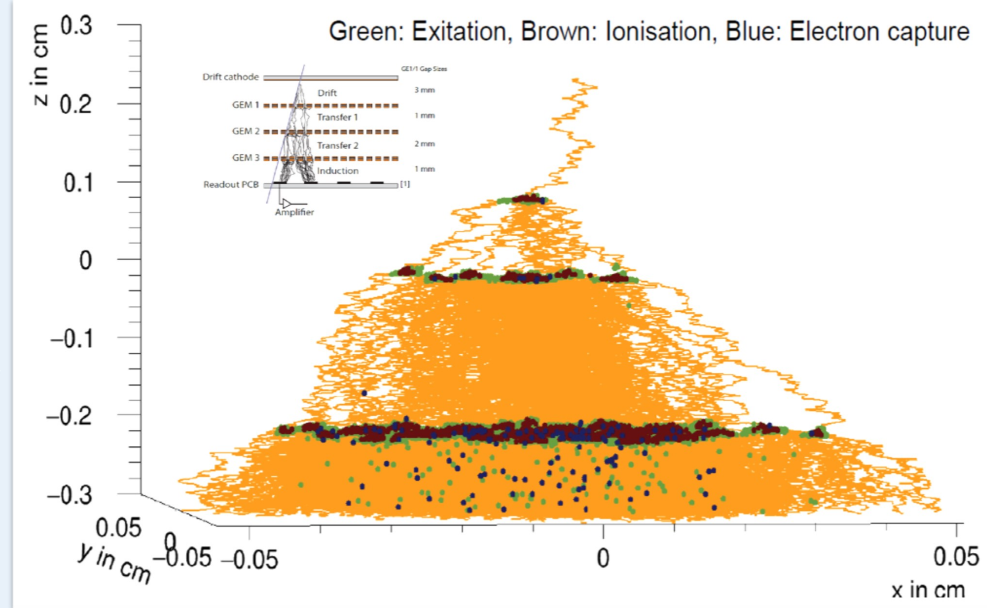

Figure 2: Microscopic simulation of electron avalanche in a triple-GEM detector.

Upgrade of the CMS Muon System with GEMs

In the upcoming years, the LHC will undergo a series of upgrades leading to an increased luminosity of up to 5×10^{34} $cm^{-2}s^{-1}$. In order to cope with the challenges in this extreme environment, the CMS detector needs to be upgraded. For the upgrade of the CMS Forward Muon System, GEM detectors have been selected in order to maintain or even improve the muon trigger and reconstruction capabilities. The rate capability of GEM detector exceeds 10 kHz/mm^2 which are typical for Multiwire Proportional Chambers.

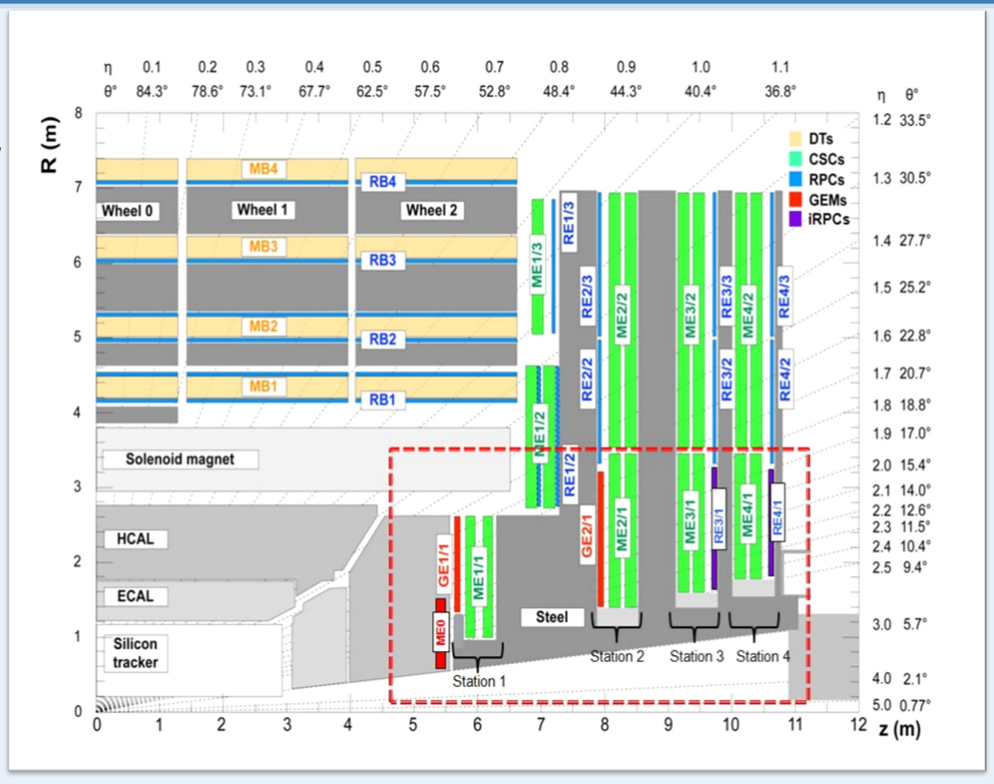

Figure 3: Quadrant of the CMS detector showing upgraded Muon forward stations with GEM detectors in red dashed box. [1]

The GE1/1 Project

For the installation of GE1/1 in CMS in 2019 and 2020, 144 GEM detectors have been assembled and tested. Production sites in 7 different countries have been set up and certified to take part in the mass production. After assembly, each chamber has to pass a predefined set of Quality Control (QC) tests. Two successfully tested chambers are matched according to their working point in terms of gain and paired to form a superchamber. Each of them covers 10.15° of the total GE1/1 disk in both endcaps. This is resulting in a small overlap of two neighboring chambers. The GE1/1 station consists of alternating long and short modules.

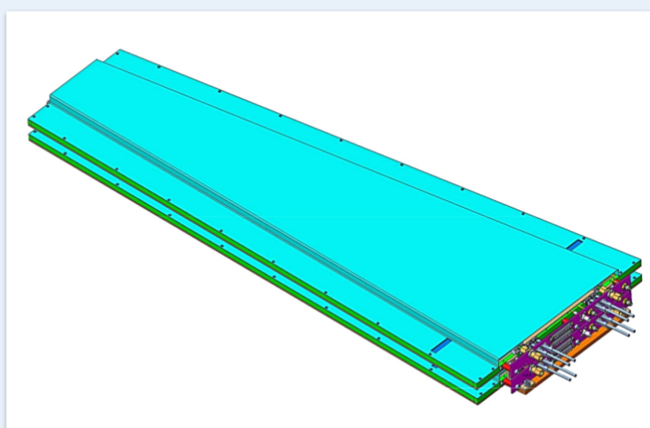

Figure 4: Superchamber shown as mounted inside CMS. [1]

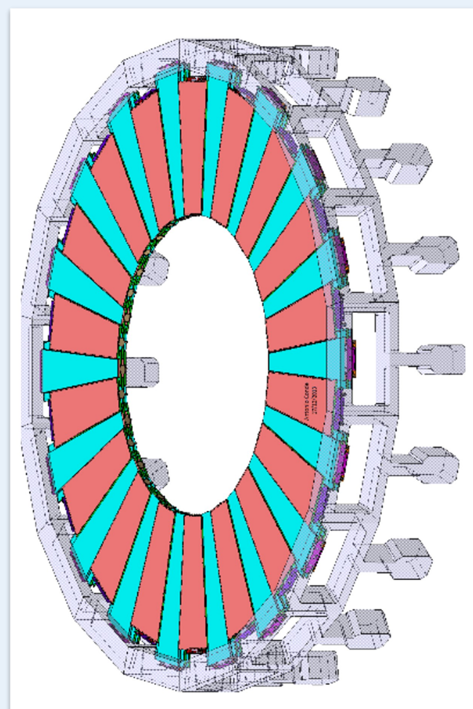

Figure 5: The GE1/1 station consisting of long (pink) and short (cyan) modules. [1]

Quality Control tests in Aachen

Figure 6: GEM Aachen team with

Aachen has been selected and approved to be one of the testing sites for GE1/1 mass production. After assembly and checks of individual components such as the GEM foils, the GEM chambers were sent to Aachen. In total, 21 long GE1/1 detectors have been tested in Aachen. Checks of the gas tightness (Fig. 7) and the HV integrity, as well as measurements on the gas gain uniformity by illuminating the whole detector surface area with an X-ray gun have been performed (Fig. 8 and 9). Testing the response uniformity is of utmost importance considering the large area covered by one detector.

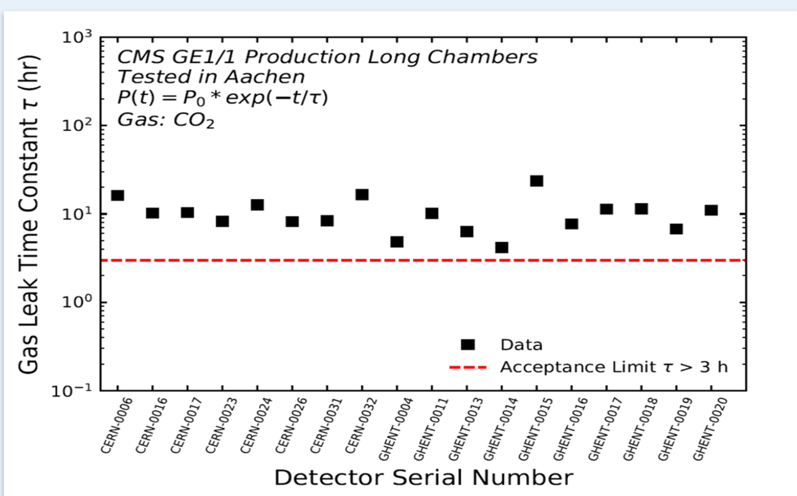

Figure 7: Leakage test results of GE1/1 detectors tested in Aachen.

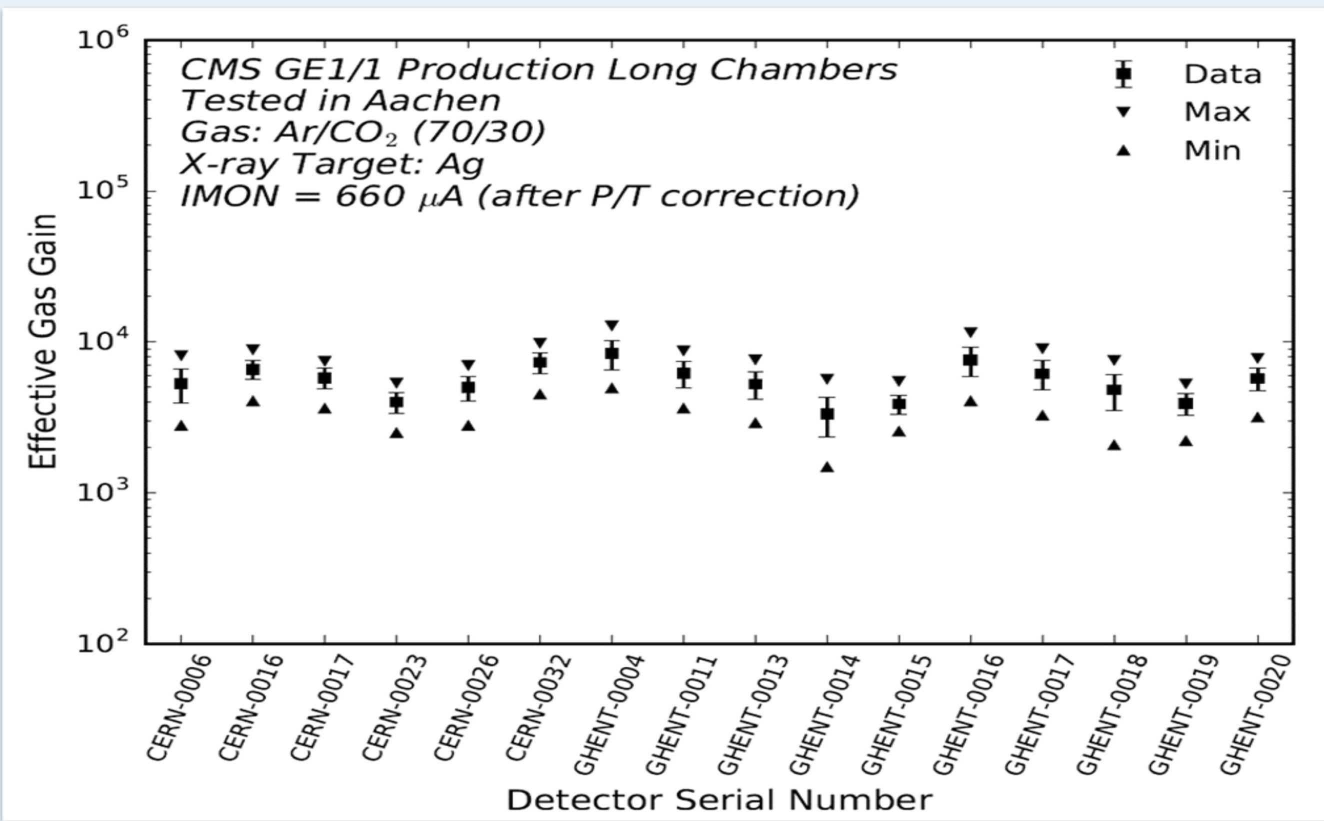

Figure 8: Effective Gas Gain of tested GE1/1 chambers. To measure the gas gain the standard QC5 methodology for GE1/1 production is used. The error bars represent the standard deviation of the gain distribution of the entire chamber, while the triangles show the extrema of that distribution.

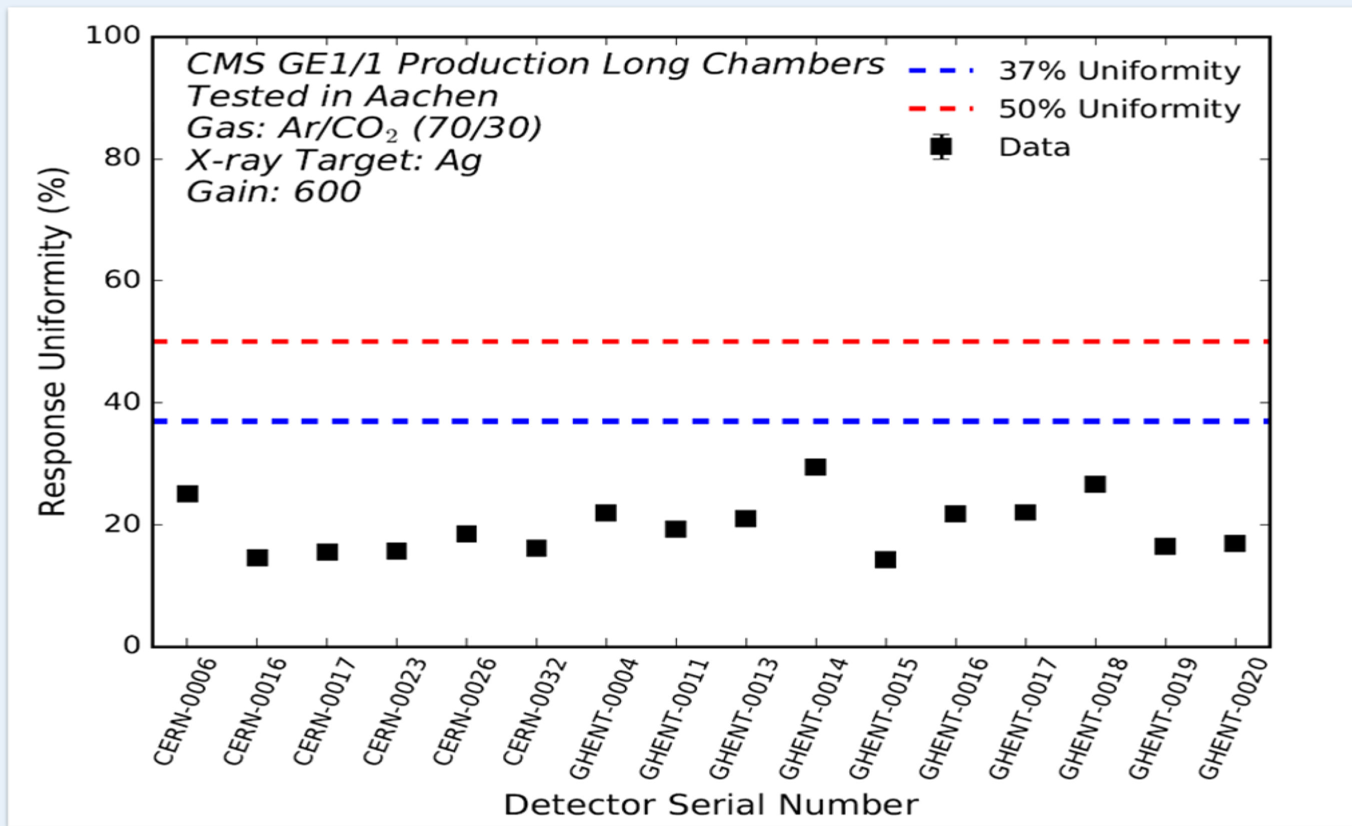

Figure 9: Response Uniformity of GE1/1 chambers tested in Aachen. To measure the gas gain the standard QC5 methodology for GE1/1 production is used. The standard deviation of the gain distribution is used as a measure for the response uniformity.

Upgrades and Cosmic test stand

An upgrade of the laboratory in Aachen is ongoing targeting performance studies by varying gas mixtures as well as applying different HV configurations.

In addition, the infrastructure in Aachen allows to integrate GEM detectors in a versatile cosmic test stand, which combines different types of muon detectors. Currently, the commissioning of the cosmic test stand is in progress. Operating the stand offers the possibility of precision measurements on tracking capabilites of GEM detectors, complementary to the tests with the X-ray gun.

Figure 10: Aachen Cosmic stand.

References

[1] A. Colaleo, A. Safanov, A.Sharma, and M Tytgat. CMS Technical Design Report for the Muon Endcap GEM Upgrade. Technical Report CERN-LHCC-2015-012. CMS-TDR-013, Jun 2015

[2] Rob Veenhof et al., Garfield++ Toolkit, http://garfieldpp.web.cern.ch/ garfieldpp/

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