# Production and quality control of GEM detectors for the Phase 1 upgrade of CMS experiment


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**On behalf of the CMS Muon Group**



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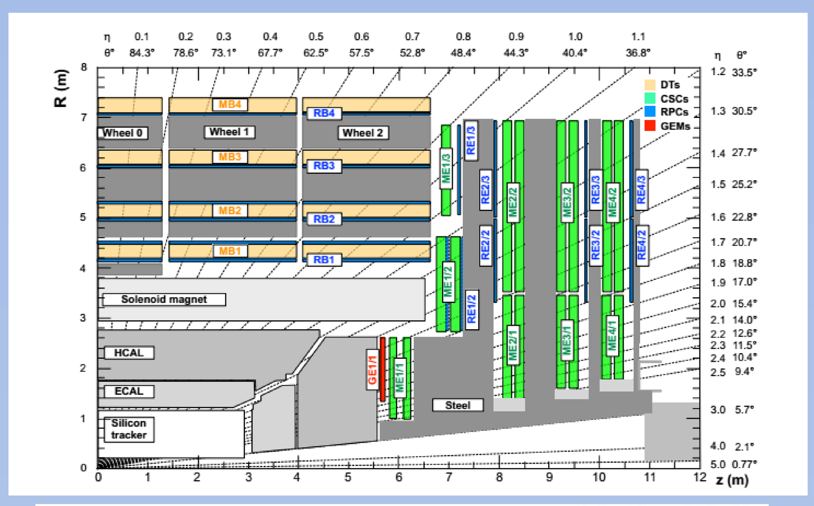
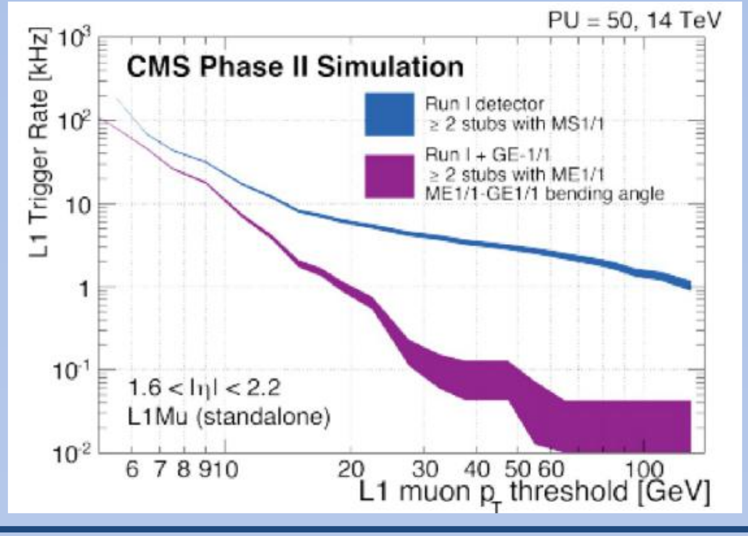
## Motivations for the GE1/1 muon detector upgrade



(a)




(b)

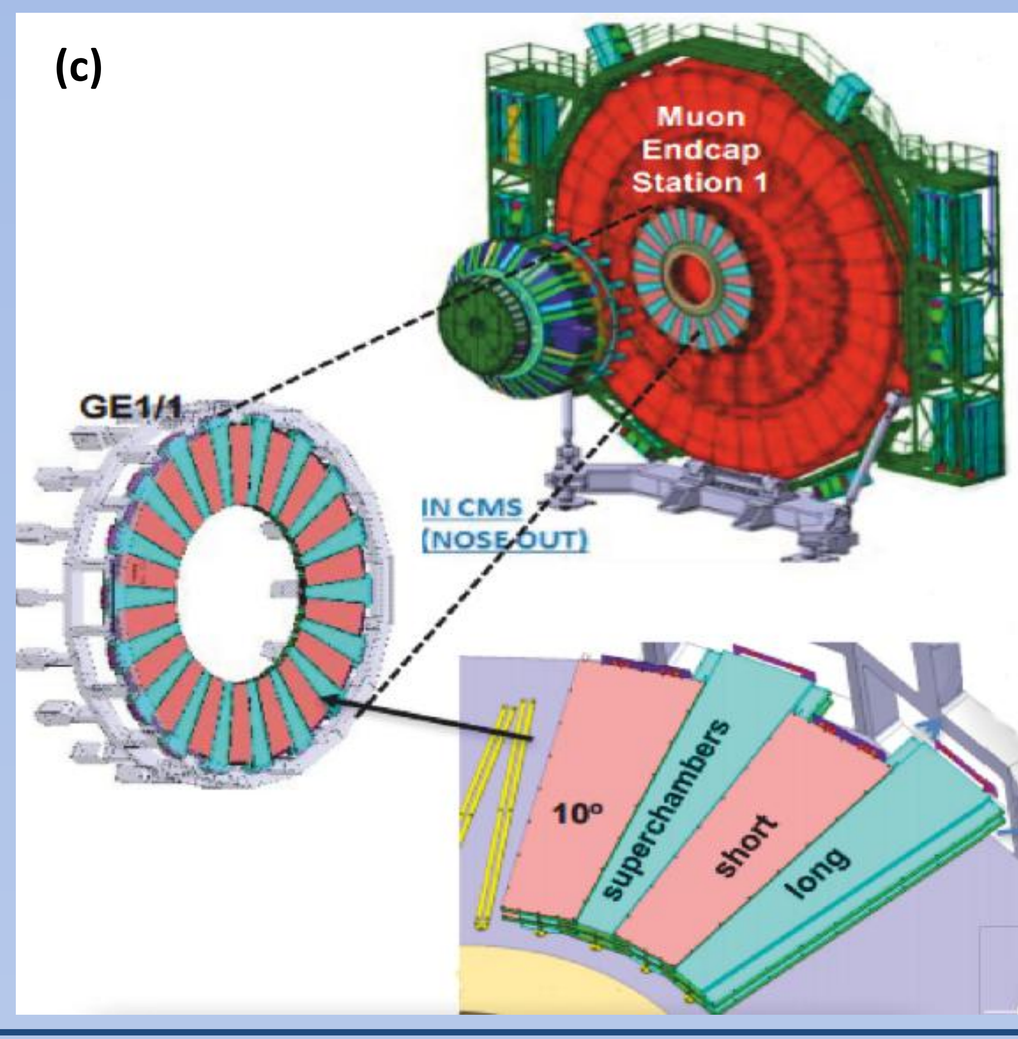
CMS collaboration have approved the installation of an additional set of muon detectors, based on triple-gem technology in the first endcap muon station: GE1/1 (a).

It will be place in 2019 during the second Long Shutdown (LS2) planned by LHC. The installation will improve the forward muon triggering (b) and reconstruction in the region with pseudorapidity 1.55<|η|<2.18, in particular (c), it will allow to:

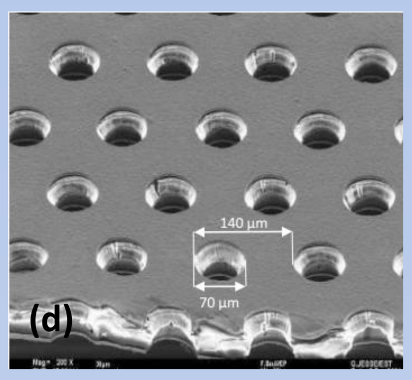
- Restore the redundancy in muon system for robust tracking and triggering;
- Improve the Level 1 (L1) and the High Level Triggering (HLT) muon momentum resolution to reduce or maintain global muon trigger rate
- Ensure about 100% trigger efficiency in high PU environment;

The full azimhutal coverage of the ring will be provided by 72 superchambers, each one will cover $10^0$ azimuthal angle, the long superchambers will cover the 1.55<η<2.18 region, they will alternate with the short superchambers that will cover the 1.61<η<2.18 region.

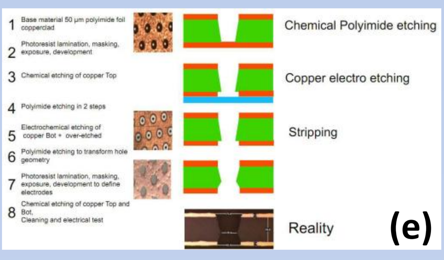
(c)



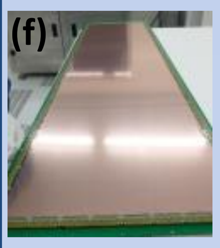

## Construction and performance of gas electron-multiplier detectors (GEM)



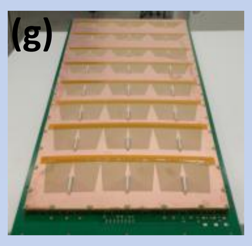
(d)



(e)



(f)

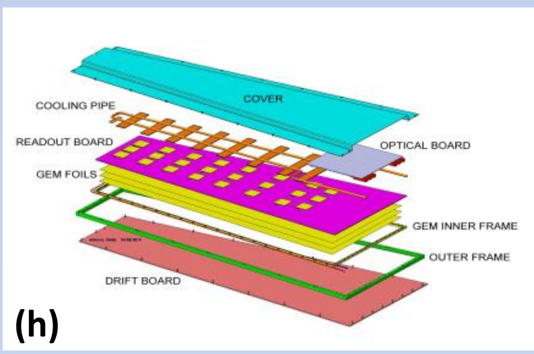


(g)

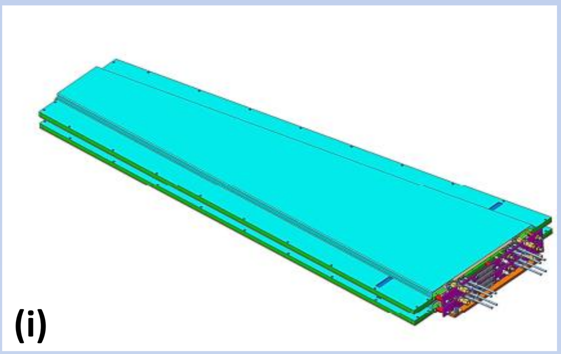
Large area Gem foils (d) for GE1/1 are now produced by using a single mask technique (e). In the single mask the hole pattern (f) is transferred to only one side of the substrate instead to need the alignment step as well as in previous double mask.

A GE1/1 chamber (h) consists of a trapezoidal gas volume (with active area of 990 × (220 − 445) mm²) containing a large triple-Gem structure between a drift electrode and a readout board (g) . The electrode gap configuration is 3/1/2/1 mm (drift/transfer 1/transfer 2/induction) .

24 readout sectors in 3X8 array cover the chamber in ϕ- η plane with 384 strips in ϕ coordinate. $ArCO_2$ (70/30) gas mixture is used . Two identical GE1/1 detectors are combined to form a Super Chamber (i) in order to obtain two detection planes and maximize the efficiency and redundancy of the GE1/1 layer.




(h)

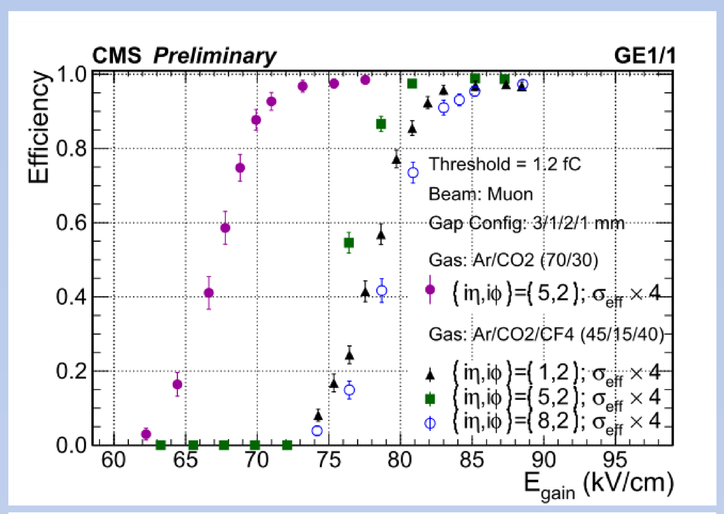


(i)

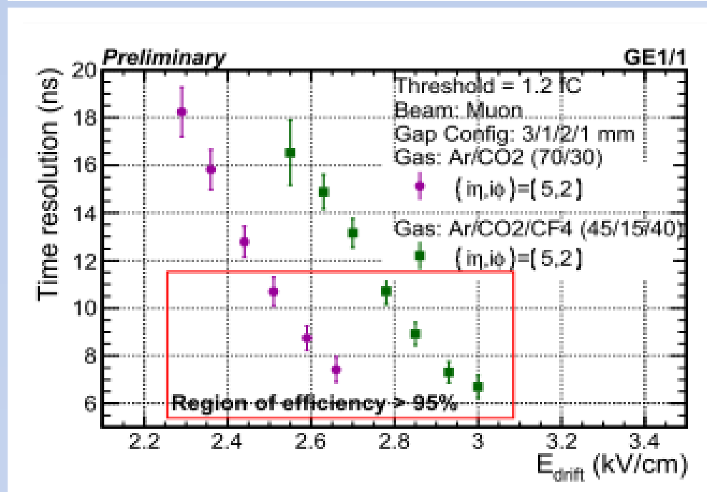
The performance of the GE1/1 muon detector have been tested in 2014 at the CERN North Area with high energy pions and muons beams.

- A good efficiency is achieved of about 98%. While for gas mixture Ar/CO2 the threshold is shifted as compared to the Ar/CO2/CF4 because at fixed high voltage operating point, the effective gain with Ar/CO2 mixture is approximately one order of magnitude higher than Ar/CO2/CF4 mixture(j).
- Spatial resolution of about 290µm with VFAT2 (digital) and rate capability of about $10^5$ Hz/m² ;
- Time resolution of 6ns (k). The time resolution with Ar/CO2 (70/30) is higher for lower values of Edrift. However for any given point on the $Ar/CO_2$ curve has a gain approximately one order of magnitude higher than the corresponding gain with $Ar/CO_2/CF_4$ (45/15/40).

The excellent performance of triple gem detectors will allow to cope the challenging data-taking conditions of Run3.




(j)



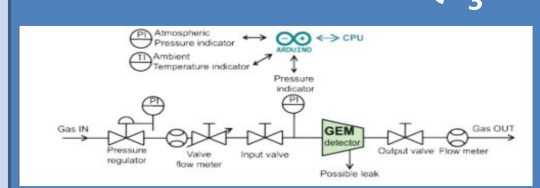

(k)

## Quality Control (QC) of CMS GEM detectors

### $QC_2$ Leakage Current Measurement

The $QC_2$ test determines the GEM foil quality by measuring the maximum leakage current flowing through the GEM holes. $QC_2$ test is mandatory before and after assembly.

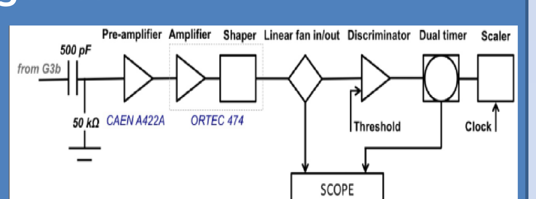
### $QC_3$ Gas Leakage test

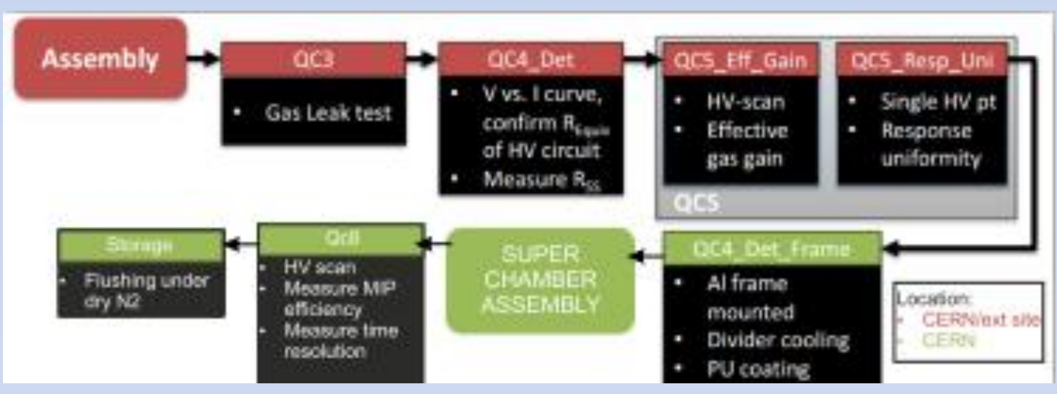


QC3 quality control is a gas leak measurement of the detector with $CO_2$. The set up is shown. The pressure drop should not exceed about few tenths of a millibar per hour.

### $QC_4$ High Voltage Test

$QC_4$ quality control identifies possible defects in the High Voltage circuit and check the linear behavior of the detector. The detector is flushed with pure $CO_2$ and powered up to 5kV.



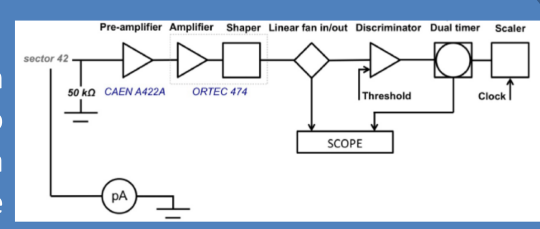

The CMS GEM collaboration has identified some sites that will be in charge of the production and test of the GEM chambers.

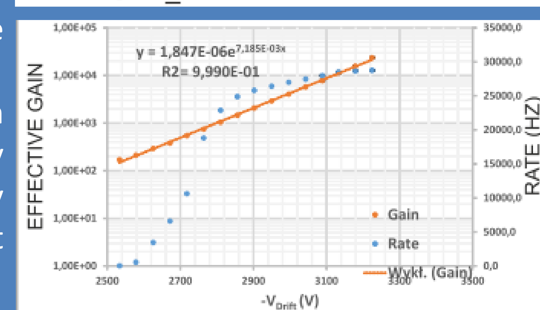
- Bhabha Atomic Research Center(BARC)-India
- INFN Sezione di Bari-Italy
- Ghent University (UGent)-Belgium
- National Center for Physics (NCP) Pakistan
- Aachen University
- CERN-Switzerland
- Florida Institute of Technology (FIT)-USA
- INFN Laboratori Nazionali di Frascati (LNF)-Italy
- Panjab University, Chandigarh
- DuSite, University of Delhi

### $QC_5$ Effective Gain Measurements

Quality control is a gain calibration measurement. It consists of two measurements: the effective gain as a function of the voltage applied and the response uniformity of the detector. The set up is shown.

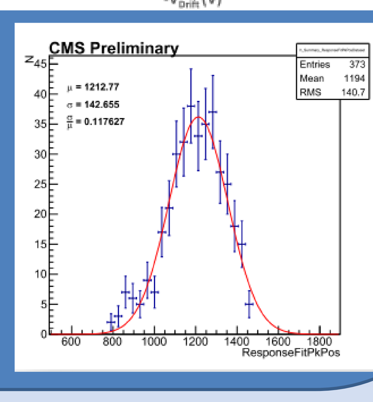
The measurement of the effective gain consists of comparing the primary current (NeR) induced in the drift gap by the X-ray source with the output current (I) after amplification: $G = \frac{I}{NeR}$





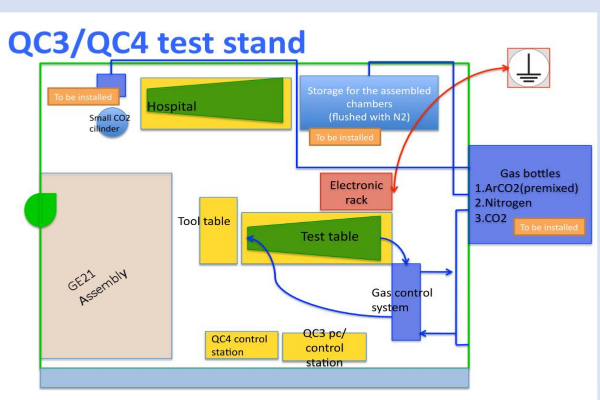

### $QC_5$ Response Uniformity

The pulse hight distribution is measured on the entire active surface of GE1/1 detector through APV connections. The response of each sector of the chamber is required to be uniform in the 15% .

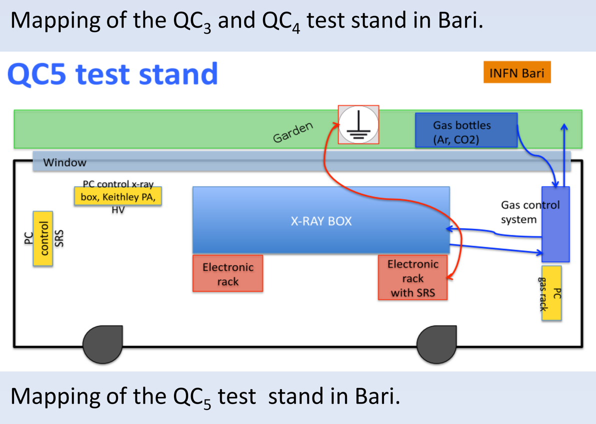



## Bari INFN Actions: chamber assembly and QC2, QC3, QC4, QC5 test

The Infn-Bari is preparing all the setup and requirements to be ready for chamber production: assembly and testing areas, a certified cleanroom, an X-ray setup.

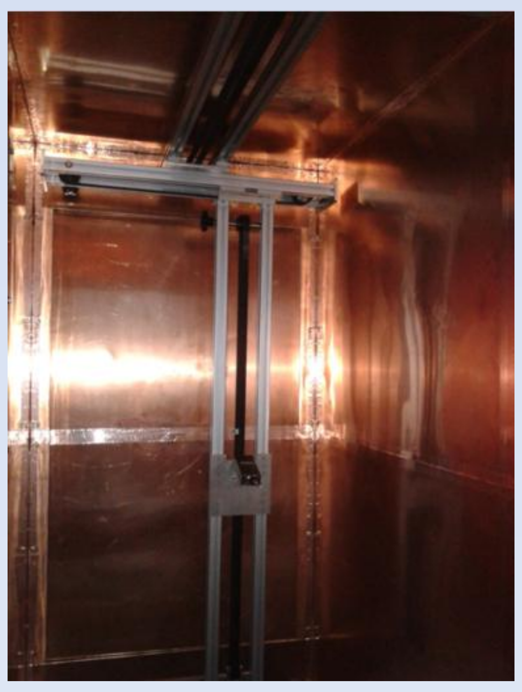



Mapping of the $QC_3$ and $QC_4$ test stand in Bari.

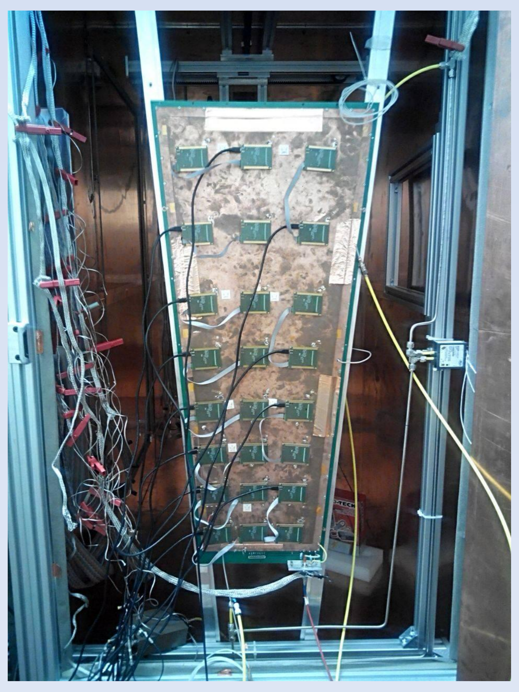



Mapping of the $QC_5$ test stand in Bari.

Certified cleanroom rated at class 1000 in Bari site.



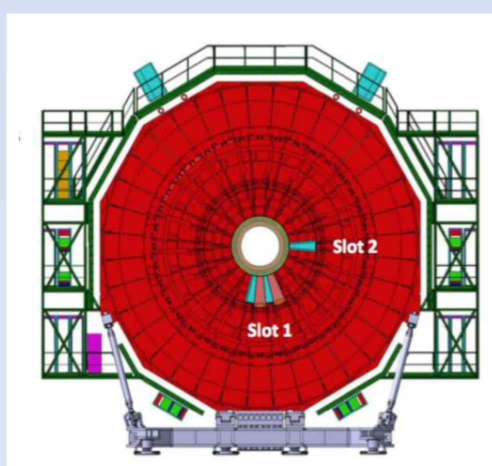
X-ray source set up in Bari site.



GE1/1 chamber inside X-box with FE electronics and grounding connections in Bari site.

## Following up

- The construction of GE1/1 detectors is aimed for completion in time for installation during LS2 in 2019.
- At the end of 2016 is started the ***GE1/1 Slice Test*** : 4 GE1/1 superchamber in slot 1 and 1 superchamber in slot 2 have been installed in order to gain first operational experience and demonstrate the integration of the GE1/1 chambers into the trigger.





[1] CMS-TDR-013, *CMS Technical Design report for the muon endcap GEM Upgrade*, ISBN 978-92-9083-396-3;

[2] Ram Krishna Sharma,*Testbeam results for full-size triple GEM detector*, CMS CR-2015/335;

[3] J.A. Merlin, *Study of long-term sustained operation of gaseous detectors for the high rate environment in CMS*, CERN-THESIS-2016-041;

[4] M. M. Gruchala, *New gas electron-multiplier detectors for the endcap muon system of the CMS experiment at the high-luminosity LHC design and prototype performance*, CMS-CR-2016-400