Layout and performance of GE1/1 chambers for the CMS muon spectrometer upgrade

By

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On behalf of the CMS Muon Group

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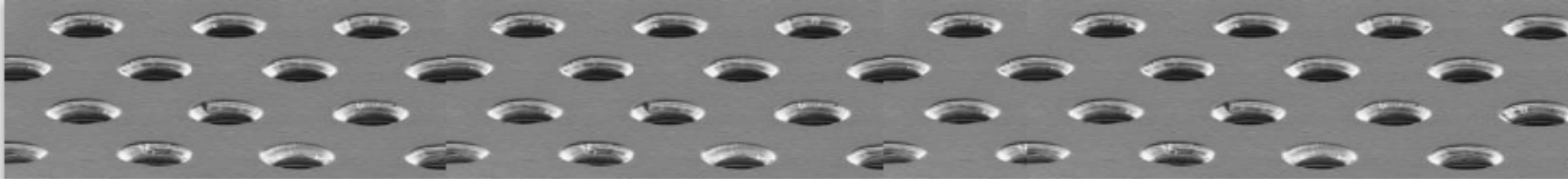


Introduction

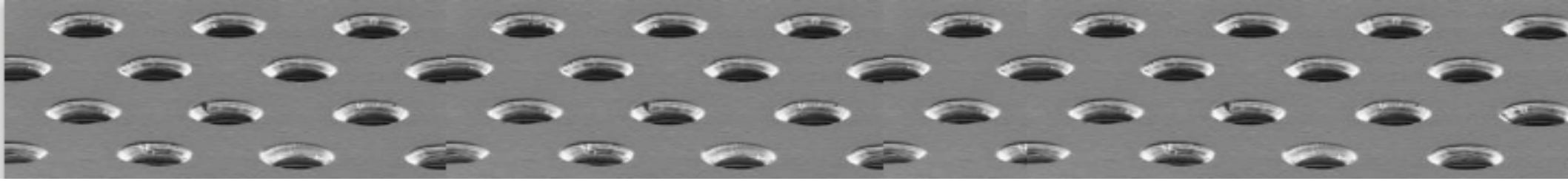
- Experiments to face high rate after the LHC upgrade

- Problems CMS muon system could face due to increase in background rate
  - Increase in the level-1 muon trigger rates in the forward region $|\eta| > 1.6$
  - May accelerate the aging of the current CSC system and could lead the loss of performance

- Phase II of CMS experiment requires the upgrade of forward muon endcap to maintain high level of performance

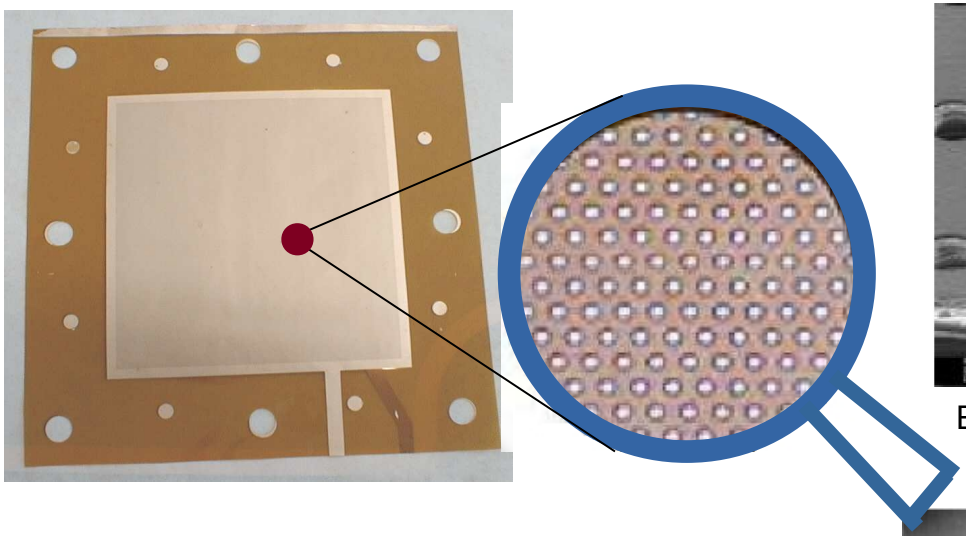
- Muon detector requirements
  - Detector should be able to cope up with high rate (~100 kHz/cm^2)
  - Good position (~100 μm or better) and temporal resolution (~20 ns or even better)
  - Should be radiation resistant

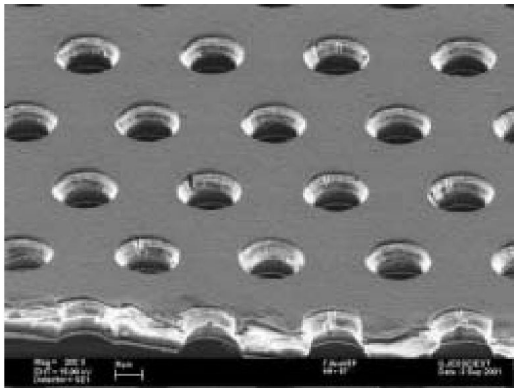
- Solution proposed by CMS collaboration
  - Technology going to be used “GEM”
  - Provide fast triggering and precise tracking
  - Improve muon trigger



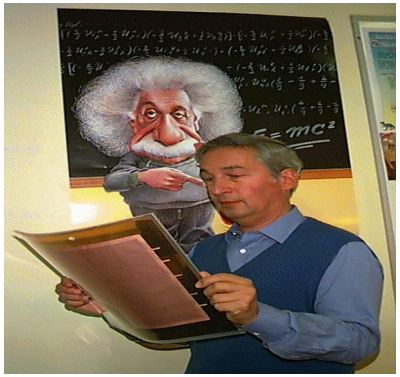
Gas Electron Multiplier (GEM)

- **Concept of GEM introduced by Fabio Sauli***

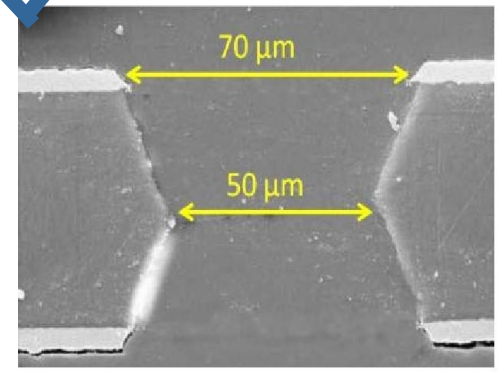




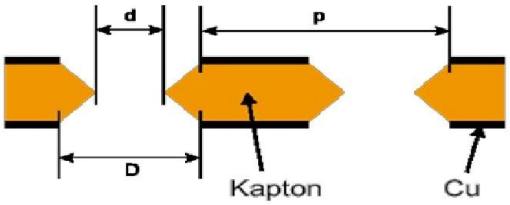
Electron Microscope view of a GEM



- **Thin double-sided metal-coated polymer foil chemically pierced by a high density of holes**



$$D = 70\ \mu m$$
$$d = 50\ \mu m$$
$$p = 140\ \mu m$$

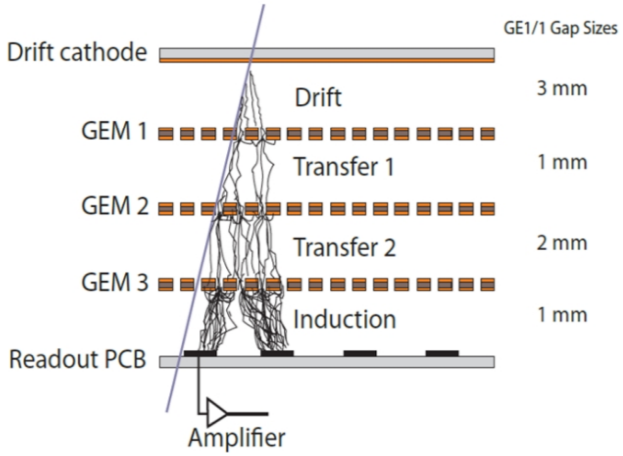


- **Typical parameters:**
  - **Kapton metal coated~ 50µm**
  - **Pitch~140µm**
  - **Cu thickness~5µm**
  - **Hole density ~50 to 100mm^{-2}**

*F. Sauli, Nucl.Instrum.Meth. A386 (1997) 531-534

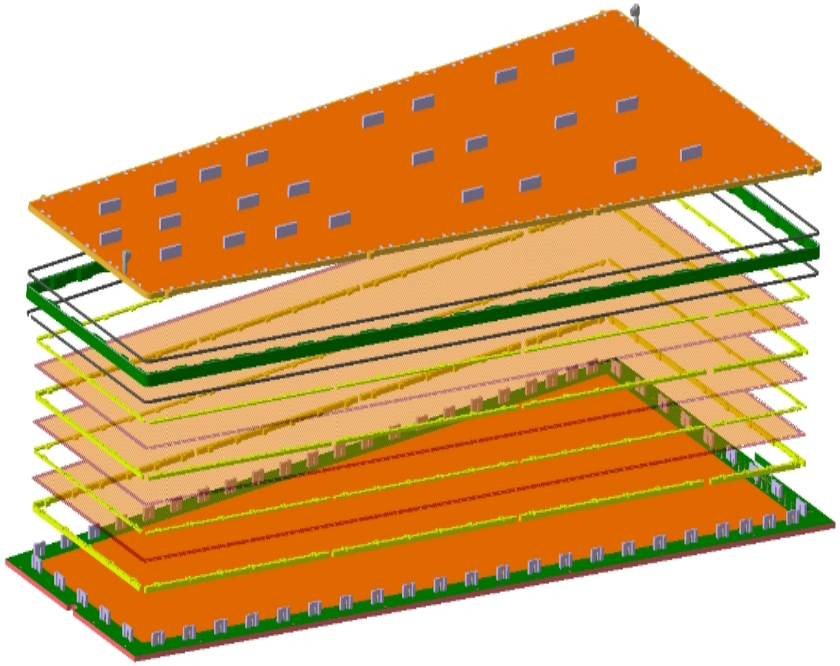
CMS GE1/1 Chamber design

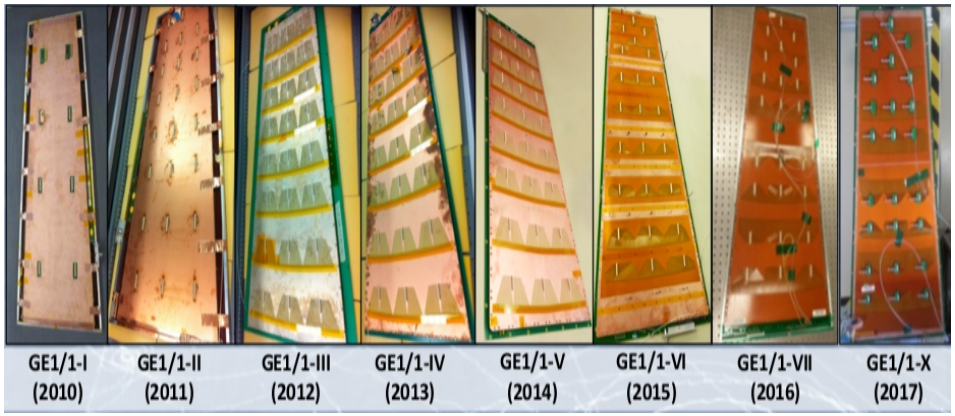
- **An arrangement of three cascaded GEM foils allows to attain gain ~10^5**



Fields

- Drift field ~2.5 kV/cm
- Induction field ~ 5kV/cm
- Transfer fields ~ 3kV/cm
- Arcoss hole ~80-100kV/cm





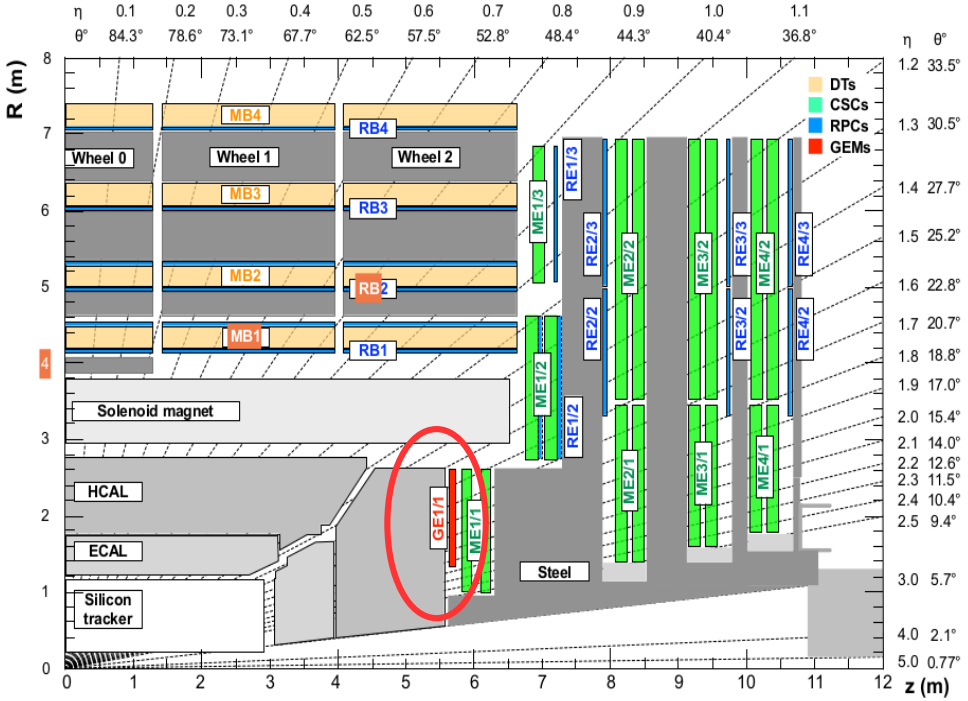
Evolution of GE1/1 detector's since 2010 from generation-I to X (2018)

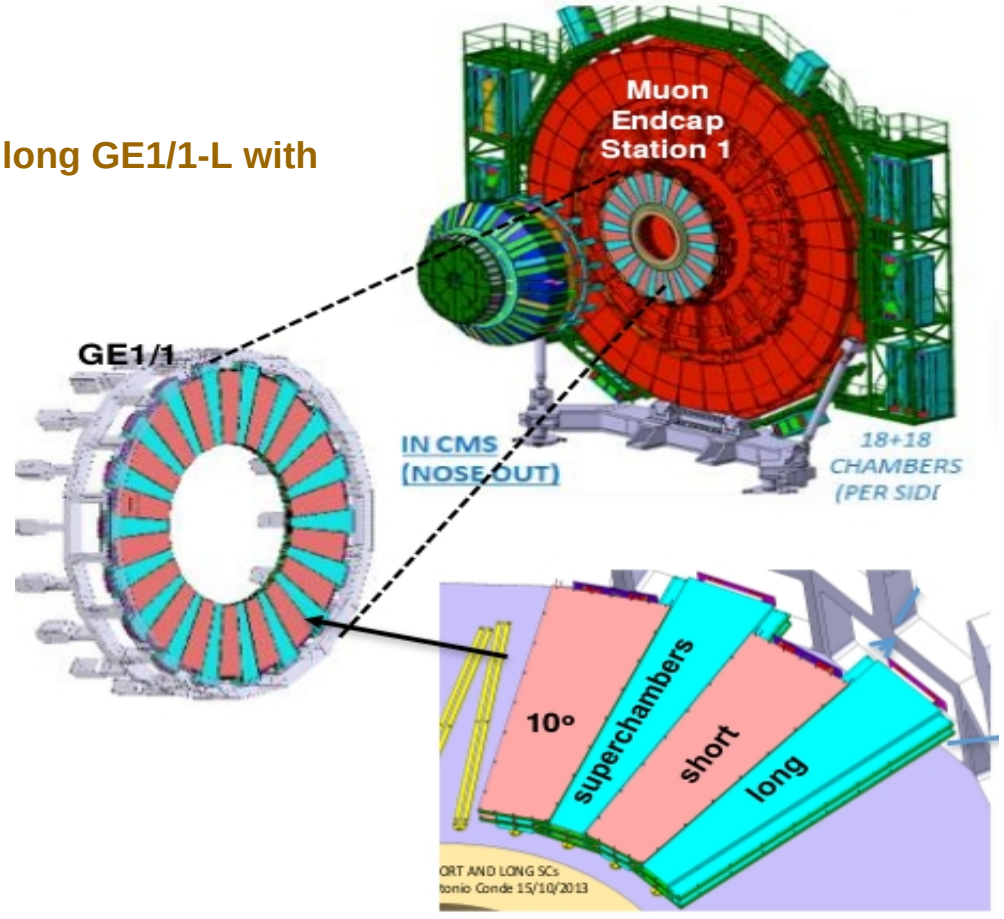
Details:

- ***Aashaq Shah et al.**, CMS DN-2015/020*
- ***CMS Muon Collaboration**, Nucl. Inst. Meth. A 918 (2019) 67*

GE1/1 project description

- **GE1/1 chambers to cover 1.6 < |η| < 2.4**
- **A total of 144 chambers needed**
- **Mechanical constraints, two versions of chambers, the long GE1/1-L with a length of 128.5 cm and the short GE1/1-S of 113.5 cm**

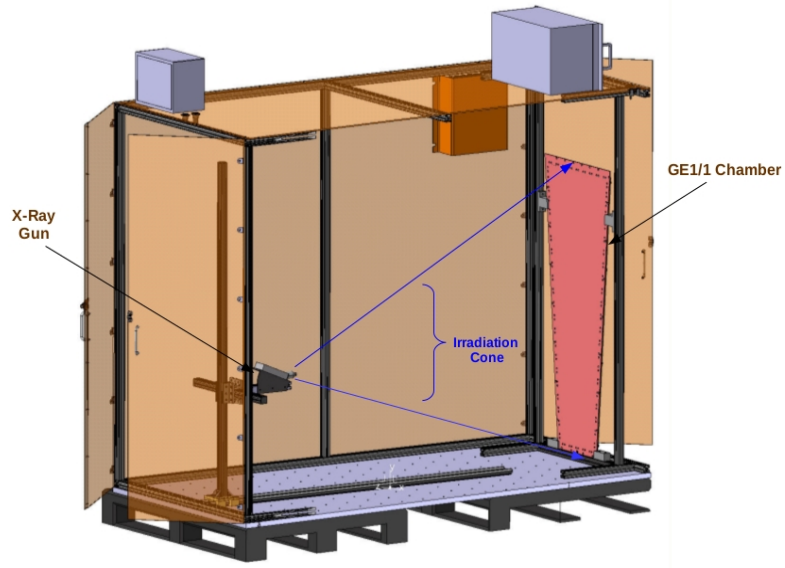




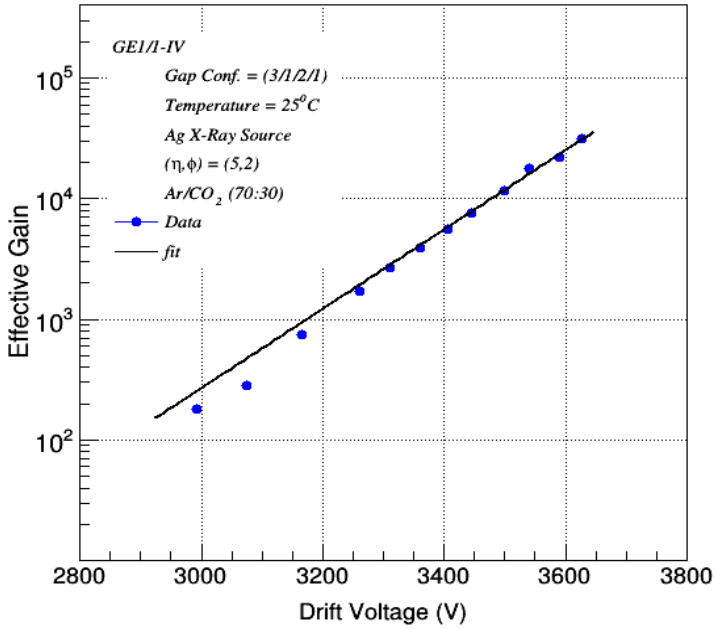
Installation in LS2

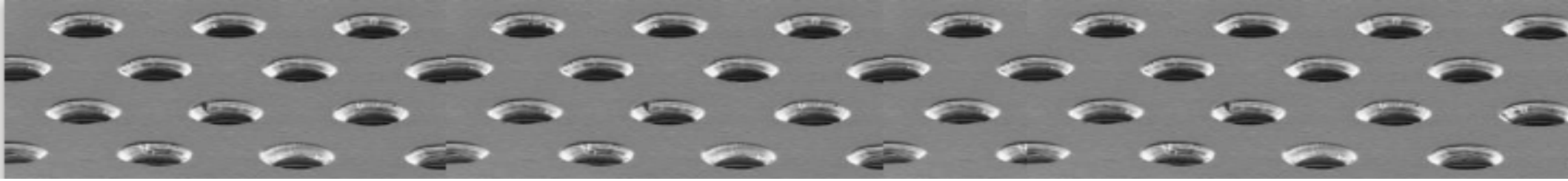
GE1/1 Performance: Gain Measurements

- The effective gas gain is measured by exposing the detector to an X-ray source
- CMS operating gas mixture Ar/CO_2 (70/30)
- Comparing primary current in the drift gap with the amplified output current induced on the readout board



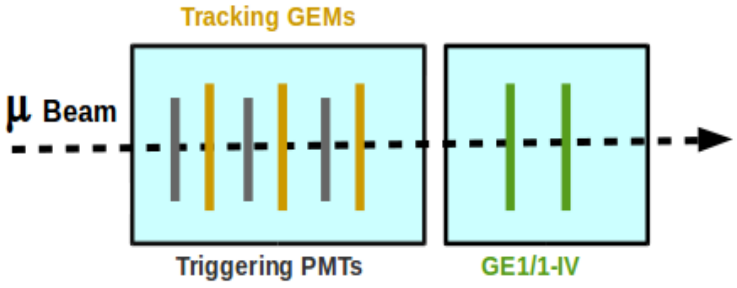
Design of the setup used for gain measurements with X-rays and the GE1/1 detector inside the copper chamber

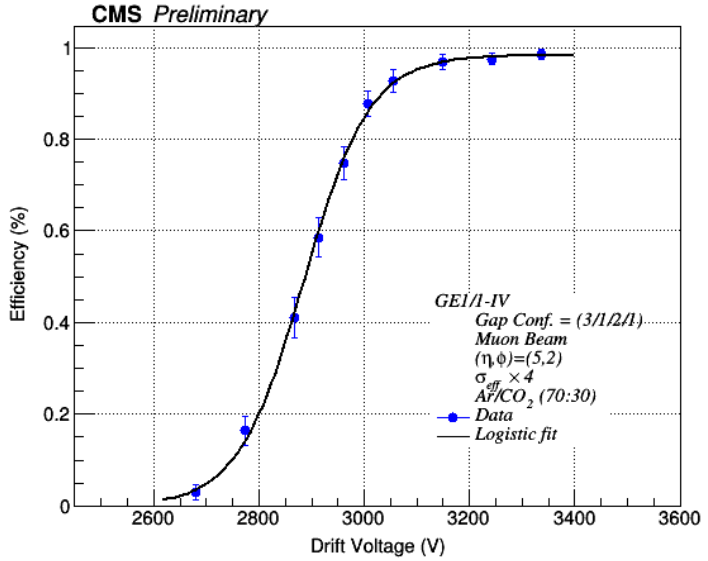


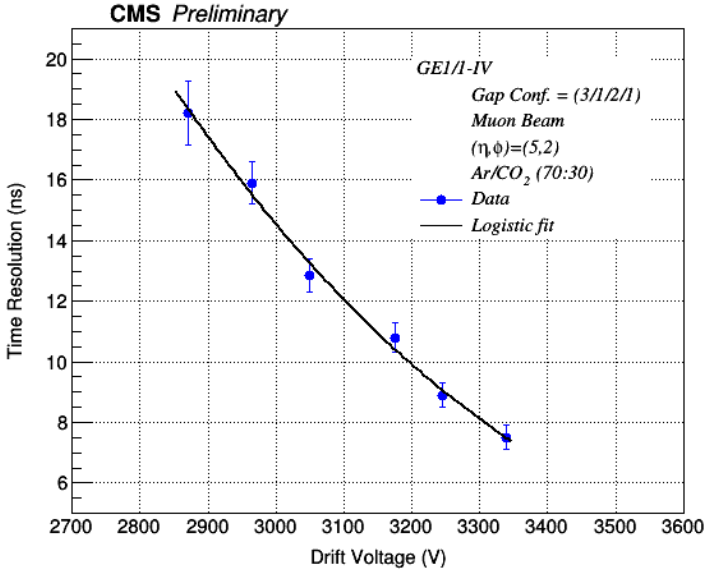


Beam tests: Efficiency and timing

- CERN's H4 and H6 beam facilities at Prevessin have been used
- RD51 Tracking Telescope consisting three scintillators S1, S2 and S3, three 10 cm × 10 cm GEM trackers
- Muon beams of 150 GeV energy
- 98% efficiency is estimated at a gain of 2 x 10^4
- Timing resolution upto ~ 7 ns

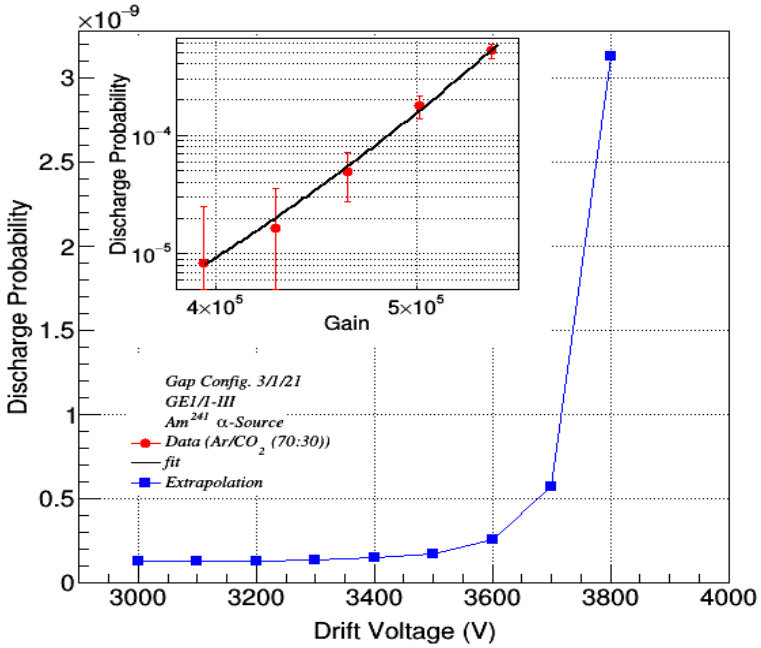




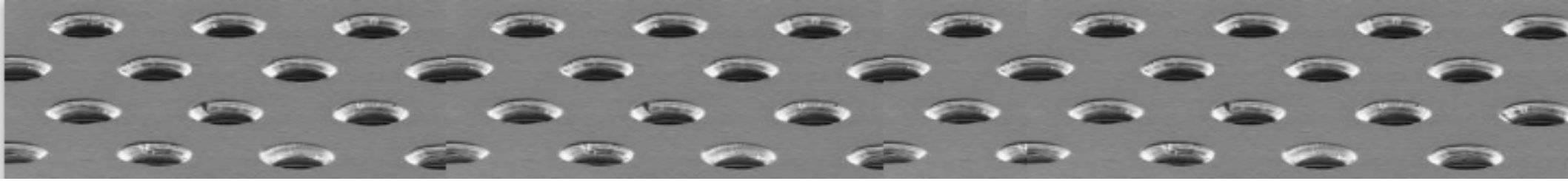


Discharge Probability

- Discharges initiate when the charge exceeds Raether limit and could damage the chamber
- Gain is set to extremely high value ranging from 4 to 6×10^5 and the detector is irradiated by densely ionizing α-particles from ^{241}Am source
- The actual discharge probability is calculated by extrapolation to CMS region
- Alpha particles from the ^{241}Am source, produces nearly hundred times more primaries than a MIP and hence, the discharge probability is divided by this factor and is observed to be less than 10^{-11} for standard CMS operating conditions



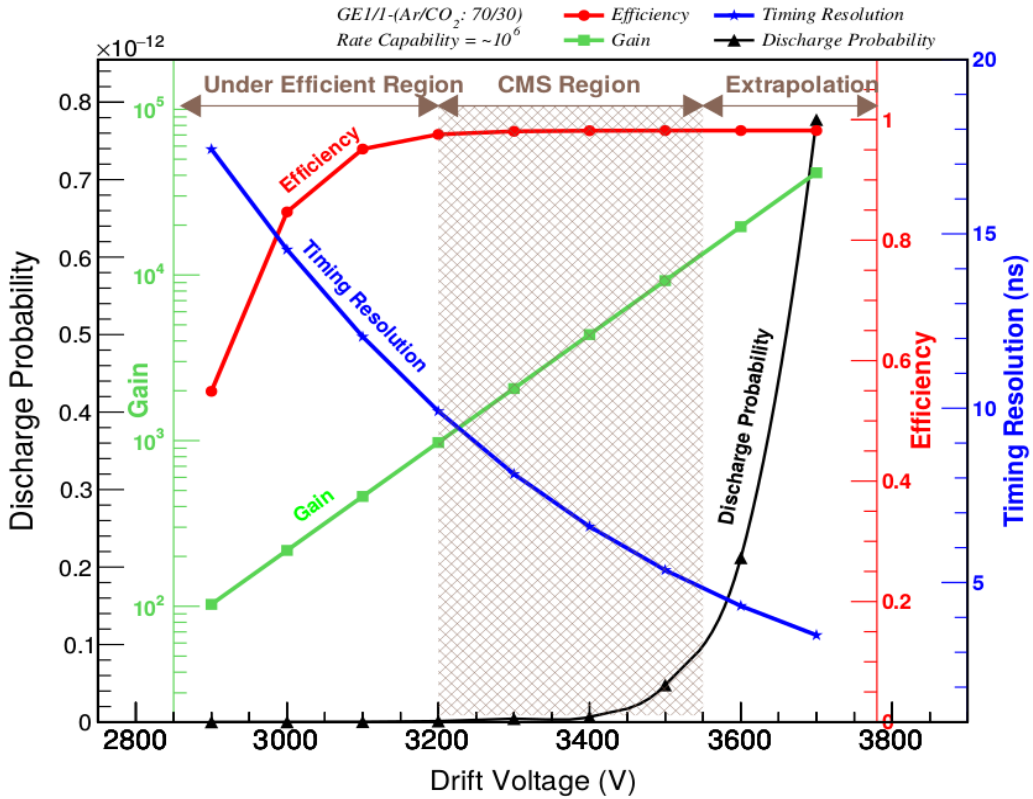
***Note:* Discharges were only induced and No discharges are expected in CMS**



Performance Summary

- The new data points have been calculated using the technique of interpolation
- Master plot of GE1/1 detectors showing the gain, discharge probability, efficiency and timing resolution for Ar/CO_2
- The shaded region is the recommended operational region of the chambers during their use in CMS

All-in-one plot



Current status of GE1/1 project

- The CMS Collaboration proposed the use of GEM in the muon endcap in 2009
- After, several years of R&D, various generations of GE1/1 chambers were produced with generation-X in 2017 as the latest and final
- Ten such chambers have been installed inside the CMS experiment during 2017 EYETS and are providing full operational experiance
- All the 144 GE1/1 chambers have been produced and validated (Dec. 2018) and will be installed in CMS experiment during LS2 (2019-2020)

A photograph taken in December 2018 showing some of the large size GE1/1 chambers that have been constructed and stored in racks at CERN Prevessin building 904.

Integration of GE1/1 chambers with the CMS is ongoing

Project on schedule

Thank You!