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

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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*

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

**Typical parameters:**
- Kapton metal coated ~ 50μm
- Pitch ~ 140μm
- Cu thickness ~ 5μm
- Hole density ~ 50 to 100 mm^-2
CMS GE1/1 Chamber design

- An arrangement of three cascaded GEM foils allows to attain gain $\sim 10^5$

Fields
- Drift field $\sim 2.5$ kV/cm
- Induction field $\sim 5$ kV/cm
- Transfer fields $\sim 3$ kV/cm
- Arcoss hole $\sim 80-100$ kV/cm

Details:
- Aashaq Shah et al., CMS DN-2015/020
GE1/1 project description

- GE1/1 chambers to cover $1.6 < |\eta| < 2.4$

- 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
The effective gas gain is measured by exposing the detector to an X-ray source.

CMS operating gas mixture Ar/CO₂ (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 $2 \times 10^4$

- Timing resolution up to ~ 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 $6 \times 10^5$ and the detector is irradiated by densely ionizing $\alpha$-particles from $^{241}$Am source.

- The actual discharge probability is calculated by extrapolation to CMS region.

- Alpha particles from the $^{241}$Am source, produce 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/CO₂.
- The shaded region is the recommended operational region of the chambers during their use in CMS.
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 experience

- 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 Preveslin building 904.
Integration of GE1/1 chambers with the CMS is ongoing

Project on schedule

Thank You!