Muon Chamber Endcap Upgrade of the CMS Experiment with Gas Electron Multiplier (GEM) Detectors and their Performance

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Abstract

As the CERN LHC is heading towards a high luminosity phase a very high flux is expected in the endcaps of the CMS Detector. The presence of muons in collision events can be due to rare or new physics so it is important to maintain the high trigger efficiency of the CMS muon system. The CMS Collaboration has proposed to instrument the high-eta region (1.6 lt L_\eta lt 2.2) of the muon endcaps with Gas Electron Multiplier (GEM) detectors, referred to as GE1/1 chambers, during the LS2. This technology will help in maintaining optimum trigger performance with maximum selection efficiency of muons even in a high flux environment. We describe plans for a Slice Test to install a few GE1/1 chambers covering 50 degrees in azimuthal angle within the CMS detector in 2017, with subsequent operation during the current Run 2 of the LHC. We show the performance of the GE1/1 chambers to be installed during the slice test, specifically GEM foil leakage currents, chamber gas volume integrity, high voltage circuit performance, and effective gain. To check the detection performance over the entire surface of the detector response uniformity is also measured.

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Keywords: GEM Detector, Upgrade, Quality Control

1 Introduction

The Large Hadron Collider (LHC) is the most powerful particle accelerator till date, built by the European Organization for Nuclear Research (CERN). From time to time, LHC needs upgrade so that the discovery potential is increased. This involves the upgrade of the accelerator systems of LHC and its detectors. Compact Muon Solenoid (CMS) [1] is one of the multi-purpose detectors of LHC having onion-like structure which is capable of studying many aspects of proton collisions at TeV scale. Due to the LHC Upgrade, there will be increase in the centre of mass energy upto 14 TeV and luminosity to \(5 - 7 \times 10^{34}\) which will help to study the high energy range physics and rare decays that could be beyond the SM. By increasing the collision rate, the detection environment in CMS gets affected as the background rate of forward region of CMS muon end-caps increases abruptly. Therefore, CMS GEM Collaboration [2] decided to introduce additional gaseous detectors in the forward end-caps, which can operate at very high rates with good performance, which are known as Gas
Electron Multiplier (GEM). The upgrade project is named as GE1/1, where “G” stands for GEM, “E” for End-cap and “1/1” corresponds to first muon station and its first ring, respectively. The full $\phi$ coordinate and the pseudo-rapidity region $1.55 < \eta < 2.18$ will be covered by trapezoidal super-chambers (layer of 2 triple-GEM detectors).

Few detectors are going to be installed inside CMS cavern for testing and commissioning purpose called Slice Test [3] in which 10 detectors with 2 different geometries (Short and Long) are used. These Slice Test detectors should pass few Quality Controls which are described below.

2 Quality Controls

CMS GEM Collaboration has decided to perform following tests before installing the detectors for Slice Test and this paper consists of results with 4 long and 6 short GEM detector prototypes (generation VII).

2.1 QC2: Leakage Current Test

When a voltage is applied across the GEM Foil, a current flows from top to bottom due to the surface conductivity of the polyimide (Kapton) which is known as leakage current. Applying voltage across the foil also burns the dust inside the holes and blow it away. The results are shown in fig. 1 left.

![Leakage Current Test](image.png)

*Fig. 1. Left: showing the leakage current of 4 long and 6 short GEM detector prototypes. Right: showing the HV Test of 2 long and 2 short GEM detector prototypes.*

2.2 QC3: Gas Leak Test

To test the gas tightness after assembling a detector, it is first over-pressurized under the safe limit of 25 mbar. The input and output valves of the detector are bypassed to detect any gas leak. Ideally, the detector is said to be gas tight if the over-pressure in its volume remains constant with time. The results of this test are not yet approved.
2.3 QC4: High Voltage Test & Spurious Signal

This test is performed under the high voltage (HV) environment to check the behaviour of the HV distribution circuit of the detector. The result is shown in fig. 1 right. If the rate of particles is observed in cool gas at high voltage, such signals are known as Spurious Signals. We measure this rate from the bottom of the third GEM Foil as a function of the current across the HV divider. The result is shown in fig. 2 left.

![Fig. 2. Left: showing the spurious signal rate of 4 long and 5 short GEM detector prototypes. Right: showing the Gain of 4 long and 4 short GEM detector prototypes.](image)

2.4 QC5: Gain Test

Gain is defined as the ratio of the output current to the input current. The current & rate are measured across the \((i_\eta, i_\phi) = (4, 2)\) readout sector under the radiation of X-rays as shown in fig. 2 right.

3 Conclusions

Two prototypes of GEM detectors are used i.e. Short \((106.1 \times 23.1 \times 42.0)\) & Long \((120.6 \times 23.1 \times 44.6)\) in the upcoming slice test. We have shown the performance, specifically: GEM foil leakage currents, chamber gas volume integrity, high voltage circuit performance, and effective gain of the GE1/1 chambers which are going to be install during the slice test.

References

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