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CMS CR -2018/258

The Compact Muon Solenoid Experiment

Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

10 October 2018 (v4, 06 November 2018)

Aging studies of the triple-GEM detectors for future upgrades of the CMS muon high rate region at the HL-LHC

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Abstract

The high-luminosity LHC (HL-LHC) upgrade is setting a new challenge for particle detection technologies. In the CMS muon system based on gas detectors, the increased luminosity will yield a ten times higher particle background compared to the present LHC conditions. To cope with the high-rate environment and to maintain the actual performance, new Gas Electron Multiplier (GEM) detectors will be installed in the innermost region of the forward CMS muon spectrometer, $2 < \eta < 2.8$ (ME0 project). The detailed knowledge of the detector performance in the presence of such a high background is crucial for an optimized design and efficient operation at the HL-LHC. A precise understanding of possible aging effects of detector materials and gases is of extreme importance. For this reason, aging tests of full sized triple-GEM detector operated with an $\mathrm{Ar/CO_2}$ $(70/30)$ gas mixture at an effective gas gain of 2×10^4, are in course at GIF++, the CERN Gamma Irradiation Facility. One detector is irradiated with $662\ \mathrm{keV}$ gamma-rays from a $14\ \mathrm{TBq}$ $^{137}\mathrm{Cs}$ source and, in parallel, a second similar detector with $22\ \mathrm{keV}$ X-rays at the quality control lab. This contribution describes the performance of triple-GEM detectors during the irradiation test and reports on their state-of-the art.

Presented at *ICHEP2018 39th International Conference on High Energy Physics*

PROCEEDINGS OF SCIENCE

Aging studies of the triple-GEM detectors for future upgrades of the CMS muon high rate region at the HL-LHC

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The high-luminosity LHC (HL-LHC) upgrade is setting a new challenge for particle detection technologies. In the CMS muon system based on gas detectors, the increased luminosity will yield a ten times higher particle background compared to the present LHC conditions. To cope with the high-rate environment and to maintain the actual performance, new Gas Electron Multiplier (GEM) detectors will be installed in the innermost region of the forward CMS muon spectrometer, $2 < \eta < 2.8$ (ME0 project). The detailed knowledge of the detector performance in the presence of such a high background is crucial for an optimized design and efficient operation at the HL-LHC. A precise understanding of possible aging effects of detector materials and gases is of extreme importance. For this reason, aging tests of full sized triple-GEM detector operated with an Ar/CO_2 (70/30) gas mixture at an effective gas gain of 2×10^4, are in course at GIF++, the CERN Gamma Irradiation Facility. One detector is irradiated with 662 keV gamma - rays from a 14 TBq ^{137}Cs source and, in parallel, a second similar detector with 22 keV X-rays at the quality control lab. This contribution describes the performance of triple-GEM detectors during the irradiation test and reports on their state-of-the art.

EPS-HEP 2017, European Physical Society conference on High Energy Physics
5-12 July 2017
Venice, Italy

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1. Introduction

In preparation of the High-Luminosity LHC (Large Hadron Collider) program, new triple-Gas-Electron-Multiplier (GEM) detectors will be installed in the innermost region of the CMS forward muon spectrometer in order to cope with the high-rate environment and maintain its present performance. The increase in luminosity will produce a particle background in the gas-based muon detectors that is ten times higher than under current conditions at the LHC. The detailed knowledge of the detector performance in the presence of such a high background is crucial for an optimized design and efficient operation after the HL-LHC upgrade. Similarly to other gaseous detectors, the triple-GEM technology might be subject to aging effects when operating in a high-rate environment. The goal of the CMS GEM aging test campaign at the CERN Gamma Irradiation Facility (GIF++) [1] and in the CMS-GEM Production Lab. [2] is to reproduce ten years of operation at HL-LHC, with a minimum safety factor of three.

2. Aging studies of CMS triple-GEM detectors

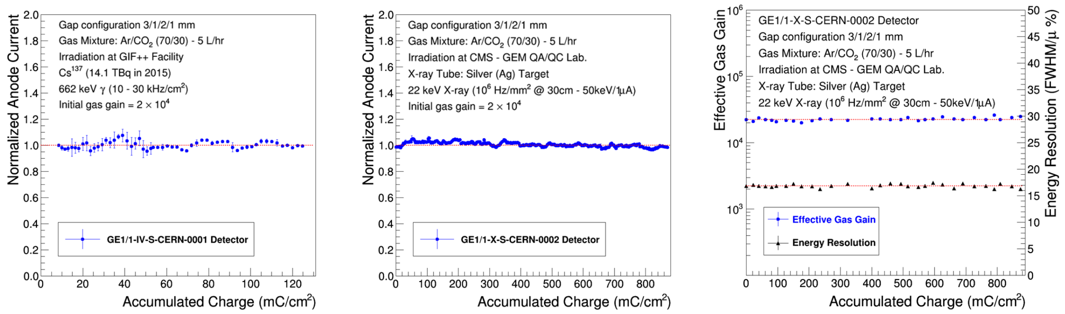
Aging tests of full size CMS-GE1/1 triple-GEM detectors are carried out in parallel at GIF++, using for the irradiation an intense 14 TBq (2015) ^{137}Cs source emitting 662 keV $\gamma-$rays, and at the CMS-GEM Production Lab using as irradiation source a 22 keV $\mathrm{X}-$ray tube. Both detectors are operated with an $\mathrm{Ar/CO_2}$ (70/30) gas mixture at an effective gas gain of 2×10^4. The aim of these aging tests is to validate the triple-GEM technology developed for the GE1/1 project also for the CMS-ME0 project which is expected to integrate an accumulated charge of 283 $\mathrm{mC/cm^2}$ in ten years of HL-LHC [2]. The results of these aging tests will be described in the following sections.

2.1 Gamma exposure

After twelve months of continuous operation at GIF++, the detector accumulated a total charge of 125 $\mathrm{mC/cm^2}$, which represents ten years of GE1/1 operation at the HL-LHC with a safety factor 21, ten years of GE2/1 operation with a safety factor 42, and 44% of the total ME0 operation. The result for the effective gain (corrected for pressure and temperature variations) shown in Figure 1(a) indicates that the CMS triple-GEM detector does not suffer from any kind of aging effects or long-term degradation [3]. This test will continue at the GIF++ under the same conditions until the detector accumulates a total charge equivalent to ten HL-LHC years in the ME0 environment. This will take about three years of exposure because of the duty factor of the GIF++ and its concurrent use by other experiments.

2.2 X-ray exposure

An aging test was also set up in summer 2017 that exposes a GE1/1 chamber to 22 keV $\mathrm{X}-$rays from an $\mathrm{X}-$ray source with Ag(silver) $-$ target at a higher rate. After eight months of continuous irradiation with $\mathrm{X}-$rays, the detector accumulated a total charge of 875 $\mathrm{mC/cm^2}$, thus providing a safety factor of more than 3 with respect to ten years of HL-LHC operations in the CMS-ME0 environment. The anode current remained stable, proving the detector gas gain was not affected over the whole irradiation period (Figure 1(b)). In addition to monitoring the anode current during the irradiation test, the effective gas gain and the energy resolution were continuously measured every week, i.e. every about 30 $\mathrm{mC/cm^2}$ of accumulated charge (Figure 1(c)).



(a) (b) (c)

Figure 1: Figure 1(a): Result of the GEM aging test at GIF++ showing the normalized and corrected anode current as a function of the accumulated charge. Figure 1(b): Result of the GEM aging test with X − ray showing the normalized and corrected anode current as a function of the accumulated charge. The detectors under test are a GE1/1 chamber operating in Ar/CO_2 $(70/30)$. Figure 1(c): Result of the GEM aging test with X − ray showing the normalized corrected gain and energy resolution as a function of the accumulated charge. The entire test represents ten years of real ME0 operation in CMS with a safety factor 3.1.

3. Conclusion

The ongoing aging studies at the GIF++ facility and in parallel at the CMS-GEM Production Lab aim to identify the possible aging of triple-GEM detectors for CMS experiment and understand the long-term operation in HL-LHC with its future upgrades. The preliminary results presented in this paper indicate that the CMS triple-GEM detector can sustain the continuous operation in the CMS endcap environment for over 10 years at HL-LHC without suffering from any performance degradation.[2].

Acknowledgments

We are especially grateful to Michele Bianco (CERN) and Jeremie A. Merlin (CERN) for many helpful suggestions, stimulating discussions and careful reading of this manuscript. I would like to thanks to Alessandro Braghieri (INFN Pavia and University of Pavia), Marcus Hohlmann (Florida Institute of Technology), Archana Sharma (CERN), Paolo Vitulo (INFN Pavia and University of Pavia) and Intae Yu (Sungkyunkwan University) for their valuable discussions and suggestions during course of the work.

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