Nuclear Inst. and Methods in Physics Research, A 936 (2019) 427–429

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

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

F. Fallavollita *, on behalf of the CMS Muon Group

INFN Pavia, Pavia, Italy
University of Pavia, Pavia, Italy
CERN, Geneva, Switzerland

ARTICLE INFO

Keywords:
GEM
CMS
Long-term operation
Aging
High rate

ABSTRACT

We present the results of aging and discharge probability studies of CMS (Compact Muon Solenoid) triple-GEM detectors. These studies has been performed in the framework of an R&D activity on triple-GEM detectors for the innermost region of the muon spectrometer of the CMS experiment in order to confirm the robustness of the triple-GEM technology and evaluate the effect of the irradiation and neutron-induced discharges on the long-term detector operation.

Contents

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 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 detector, the triple-GEM technology might be subject to aging effect 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.

Detectors installed in HEP experiments are dip in a high flux neutron field. For example, the triple-GEM detectors will be installed in the vicinity to the beam pipe in the CMS muon system, where a high intensity (10^5–10^6 n cm^{-2} s^{-1}) neutron background is present. In order to assess the capability (particularly related to discharge probability) of working in intense neutrons environment, a 10×10 cm^2 triple-GEM detector has been tested using an harsh radiation fields available at the CHARM facility [2].

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

* Correspondence to: University of Pavia, Pavia, Italy.
E-mail address: francesco.fallavollita@cern.ch.

https://doi.org/10.1016/j.nima.2018.10.180
Received 30 June 2018; Received in revised form 19 October 2018; Accepted 24 October 2018
Available online 27 October 2018

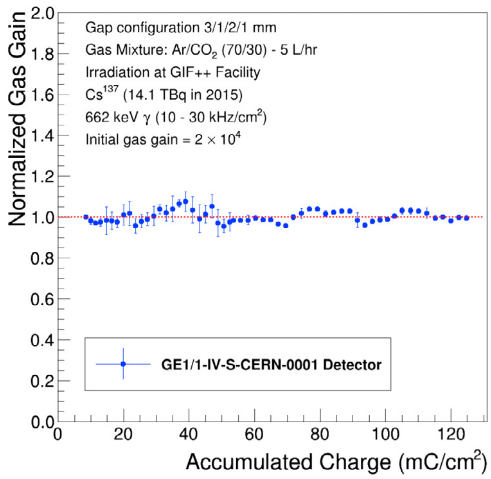

Fig. 1. Result of the GEM aging test at GIF++ showing the normalized and corrected effective gain as a function of the accumulated charge. The detector under test is a GE1/1 chamber operating in Ar/CO_2 (70/30) at an initial gas gain of 2×10^4.

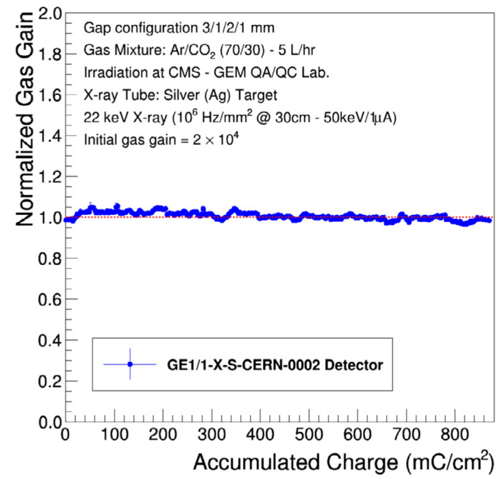

Fig. 2. Result of the GEM aging test with X-ray showing the normalized and corrected effective gain as a function of the accumulated charge. The detector under test is a GE1/1 chamber operating in Ar/CO_2 (70/30) at an initial gas gain of 2×10^4.

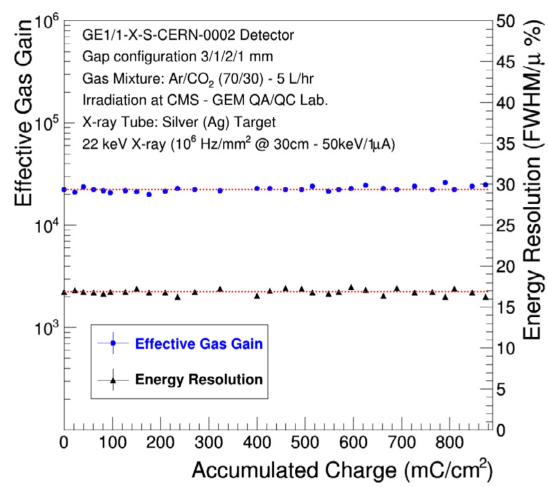

Fig. 3. Result of the GEM aging test with X-ray showing the normalized corrected gain and energy resolution as a function of the accumulated charge. The entire test represents 10 years of real ME0 operation in CMS with a safety factor 3.1.

14 TBq (2015) ^{137}Cs source emitting 662 keV γ-rays, and at the CMS-GEM Production Lab. using as irradiation source a 22 keV X-rays tube. Both detectors are operated with 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 CMS-ME0 project which is expected to integrate an accumulated charge of 283 mC/cm^2 in 10 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 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 Fig. 1 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 3 years of exposure because of the duty factor of the GIF++ and its concurrent use by other experiments. An aging test was also set up in summer 2017 that exposes a GE1/1 chamber to 22 keV X-rays from an X-ray source with Ag(silver)-target at a higher rate.

2.2. X-ray exposure

After eight months of continuous irradiation with X-ray, the detector accumulated a total charge of 875 mC/cm^2, thus providing a safety factor of more than 3 with respect to 10 years of HL-LHC operations in the CMS-ME0 environment. The anode current remained stable, proving the detector gas gain was not affected on the whole irradiation period (Fig. 2).

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 mC/cm^2 of accumulated charge (Fig. 3).

3. Discharge probability studies with triple-GEM detector

Several measurements of the discharge probability have been performed to confirm the robustness of the CMS triple-GEM, estimate the total number of discharges seen by the detectors, and evaluate the effect of discharges on the long-term chamber operation. More recently, the GEM Pavia group has conducted a series of tests in the harsh radiation fields available at the CERN High-energy AcceleRator Mixed field (CHARM) [4] facility to measure the neutron sensitivity and the discharge probability for the triple-GEM in more realistic conditions. The CHARM facility provides a unique irradiation environment with a mixture of neutrons, photons, electrons/positrons, and charged hadrons. The energy spectrum of produced neutrons is similar to that of the neutron background in CMS with ranges from 0.1 eV up to 1 GeV [5]. A triple-GEM detector in CMS configuration was placed near the CHARM target and was irradiated to reach a neutron fluence close to $2.5 \times 10^8/cm^2$ and a dose of about 9.4 Gy. The detector was operated at a gas gain of 3.5 10^4 in Ar/CO_2 (70/30). High voltage is delivered to the chamber through a CAEN A1515—Floating High Voltage Power Supply, which allows to power independently the drift and the three GEM-foils. In order to measure the triple-GEM discharge probability under neutron irradiation, a current and voltage measurements have been performed. The anode current, read out from the anodic pads (connected all together) using a KEITHLEY 6487 pico-ammeter, has been combined with the current and voltage information provided by the CAEN 1515—Power Supply: if a discharge occurs in one of the three GEMs, the corresponding potential difference will drop to zero. As a consequence, the gain of one of the three GEMs is temporarily reduced and a lower anode current is measured on the anode. Additionally, measuring the current from the individual channels and observing an increase in the current value particularly from the top of the three GEMs is another way to determine the occurrence of a spark during a spill. Thus, the occurrence of a spark can alternatively be determined from such a sudden current increase on any one of the GEM-electrodes. The current threshold in our experiments was set to 2 μA to define a spark. Finally, the signals induced on the bottom electrode of GEM 3 were used to count the total number of particles crossing the detector and to identify the high-charge signals induced by HIPs. No trips of the power supply or disruptive events were recorded during the entire test. As a results, considering the average interaction rate at the CHARM facility, we find a preliminary upper limit for the discharge probability of $2.85 \times 10^{-9}/\mathrm{neutron}$ at 95% CL, which is fully compatible with the previous discharge probability studies performed with alphas source [2,6].

4. Conclusion

The ongoing aging studies at GIF++ facility and in parallel at CMS-GEM Production Lab. aim to identify the possible aging of triple-GEM detector 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. In addition, due to the complexity of the neutron interactions with the GEM detectors and the dearth of experimental studies on this topic, a dedicated test was done at the CHARM facility to confirm the robustness of the CMS Triple-GEM and evaluate the effect of discharges on the long-term detector operation. Gain calibrations were performed before and after the neutron test in order to identify a possible degradation of the GEM foils in the irradiated areas. The effective gas gain was not affected by the discharges, nor the energy response of the detector [2].

Acknowledgments

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

References

[1] M.R. Jäkel, et al., CERN GIF++: A new irradiation facility to test large-area particle detectors for the high-luminosity LHC program, in: Proceedings, 3rd International Conference on Technology and Instrumentation in Particle Physics (TIPP 2014). Amsterdam, Netherlands, June 2-6 (2014).

[2] A. Colaleo, et al., CERN-LHCC-2017-012, CMS-TDR-016, 2017.

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

[4] J. Mekki, et al., CHARM: a mixed field facility at cern for radiation tests in ground, atmospheric, space and accelerator representative environments, IEEE Trans. Nucl. Sci. 63 (4) (2016) 2106–2114.

[5] A. Infantino, FLUKA Monte Carlo Modelling of the CHARM Facility's Test Area: Update of the Radiation Field Assessment. CERN-ACC-NOTE-2017-0059, 38 pp, 2017.

[6] S. Bachmann, et al., Discharge studies and prevention in the gas electron multiplier (GEM), Nucl. Instrum. Methods A 479 (2000) 294.