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Radiation studies on resistive bulk-Micromegas chambers at the CERN Gamma Irradiation Facility

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B. Alvarez Gonzalez[*], **CERN, E-mail:** `balvarez@cern.ch`

J. Bortfeldt, CERN, E-mail: `jonathan.bortfeldt@cern.ch`

M. T. Camerlingo, Universita e INFN, Napoli, E-mail: `maria.teresa.camerlingo@cern.ch`

E. Farina, CERN and Universita e INFN, Pavia, E-mail: `edoardo.maria.farina@cern.ch`

P. Iengo, CERN, E-mail: `Paolo.Iengo@cern.ch`

L. Longo, Universita del Salento and INFN, Lecce, E-mail: `luigi.longo@cern.ch`

J. Samarati, CERN, E-mail: `Jerome.Samarati@cern.ch`

O. Sidiropoulou, CERN and Julius-Maximilians-Universität Würzburg, E-mail: `ourania.sidiropoulou@cern.ch`

J. Wotschack, CERN, E-mail: `Joerg.Wotschack@cern.ch`

With the growing diffusion of resistive Micromegas detectors in HEP experiments the study of long-term aging behaviour is becoming more and more relevant. Two resistive bulk-Micromegas detectors were installed in May 2015 at the CERN Gamma Irradiation Facility and exposed to an intense gamma irradiation with the aim to study the detector behavior under high irradiation and the long-term aging. The detectors have an active area of 10×10 cm^2, readout strip pitch of 400 μm, amplification gap of 128 μm and drift gap of 5 mm. The desired accumulated charge of more than 0.2 C/cm^2 has been reached for both chambers, equivalent to 10 years of HL-LHC operation. The efficiency, amplification, and resolution of the Micromegas after this long-term irradiation period is compared with the performance of a non irradiated detector. In addition, the latest results of the measured particle rate as a function of the amplification voltage is presented and compared with those obtained in 2015.

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[*] Speaker.

1. Introduction

The CERN Gamma Irradiation Facility (GIF++) [1, 2], operational since March 2015, is located in the North Area of the CERN Super Proton Synchrotron. It is a unique place where high energy charged particle beams (mainly muons) are combined with a flux of photons from a 13.9 TBq ^{137}Cs source. About 50% of the photon current comes from photons with energy 662 keV. The high source activity produces a gamma (γ) field intense enough to accumulate doses equivalent to the High-Luminosity Large Hadron Collider (HL-LHC) experimental conditions in a reasonable time[1]. Thus, GIF++ is motivated by strong needs from the LHC detectors and accelerator communities in order to perform long-term aging studies for future upgrade projects.

Two resistive bulk-Micromegas, Fig. 1, were installed at GIF++ in May 2015 and have been irradiated for about 2 years with the aim of studying their behaviour under high irradiation and carrying out a long-term aging study. Micromegas technology has been considered for future upgrade projects of large scale experiments like the ATLAS New Small Wheel (NSW) upgrade project of the Muon Spectrometer [3, 4]. These resistive bulk-Micromegas detectors are situated in the upstream area at 1 m from the source exposed to a γ flux up to 44 MHz/cm^2, corresponding to 10 times more than the highest expected counting rate at the HL-LHC in the NSW region.

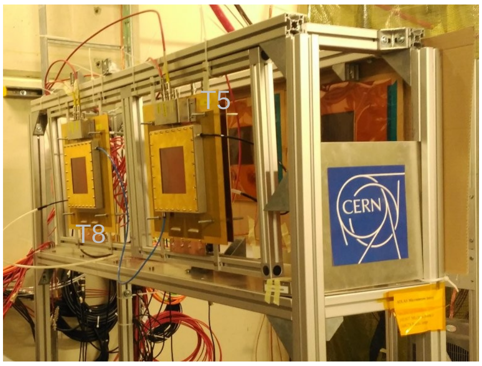

Figure 1: T5/T8 chambers in the GIF++ bunker.

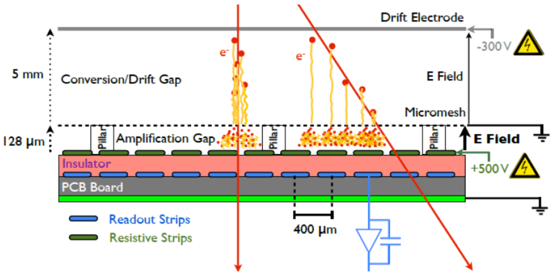

Figure 2: Micromegas detector schema.

2. Description of the Micromegas used in GIF++

Two resistive bulk-Micromegas [5] (T5 and T8 shown in Fig. 1) produced at the CERN PCB workshop are used in GIF++ for the studies described in this document. These chambers have an active area of 10×10 cm^2, a single readout plane with 400 μm strip pitch and 300 μm strip width. The readout strips are covered with a 50 μm thick insulator carrying high resistivity (∼100 kΩ/sq) carbon strips for spark protection. The gas volume is divided in two regions, Fig. 2, by a metallic micro-mesh. The mesh consists of 18 μm diameter wires with 64 μm pitch. The amplification gap is 128 μm, and the drift gap is fixed at 5 mm with a drift field of 600 V/cm.

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[1] A filter system permits attenuating the photon rate in several steps to reach attenuation factors of several orders of magnitude (∼10^4 - 10^5).

2.1 Data-taking and working conditions

APV-25 front-end ASICs [6] and the RD51 Scalable Readout System (SRS)[7] have been used for the data-taking. The measurements were performed varying the amplification voltage on the detectors and the attenuation filters of the source. The following attenuation factors [1, 1.5, 2.2, 4.6, 6.9, 10, 22, 33, 46, 69, 10^2] have been used. The used amplification voltages go from 420 to 530 V in 10 V steps, that corresponds to an amplification field of 33-42 kV/cm. The working conditions during the measurements were as follows: gas mixture: Ar/CO_2 93%/7%, gas flow 5 l/h, and operating gain of $\sim 2\text{x}10^4$ at 530 V.

3. Accumulated Charge

When the studies at GIF++ started the main goal was to accumulate the equivalent integrated charge expected after 10 years of HL-LHC operation to study the detector behavior under high irradiation and the long-term aging. After ~2 years, from May 2015 to June 2017, of exposure to an intense γ irradiation the desired accumulated charge of more than 0.2 C/cm^2 has been reached for both T5 and T8 chambers as shown in Fig. 3.

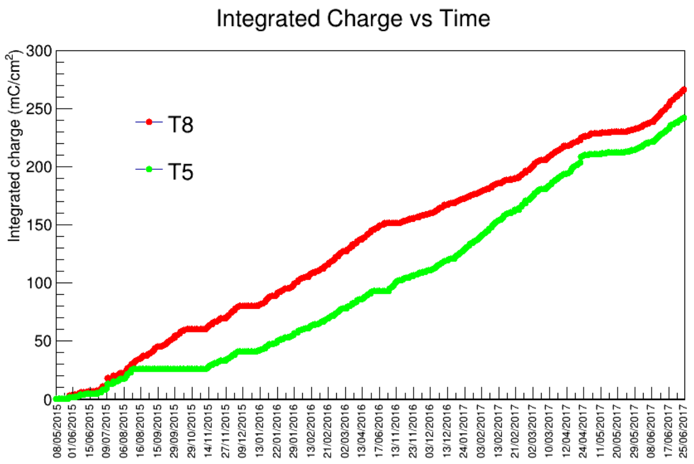

Figure 3: Integrated charge [mC/cm^2] as a function of time.

4. Detector Properties

The efficiency, gain, and tracking resolution of these Micromegas detectors after the long-term irradiation period are compared with the performance of the detectors before irradiation. The detection efficiency has been measured as a function of the amplification voltage with respect to some reference detectors using muon tracks. In May 2015, the measurement was performed using muons from cosmic rays at the CERN RD51 GDD lab, and in May 2017 the muons were coming from the muon beam inside the GIF++ bunker. The results of the efficiency measurements are shown in Fig. 4. Both datasets reach full efficiency around 500 V. The voltage was not corrected for temperature, pressure and humidity conditions. No degradation of the efficiency has been observed due to irradiation.

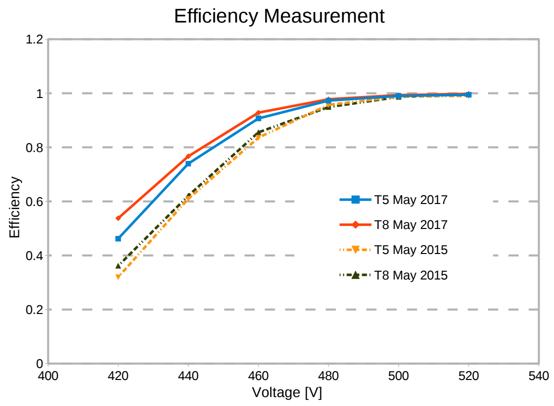

Figure 4: Efficiency vs amplification voltage.

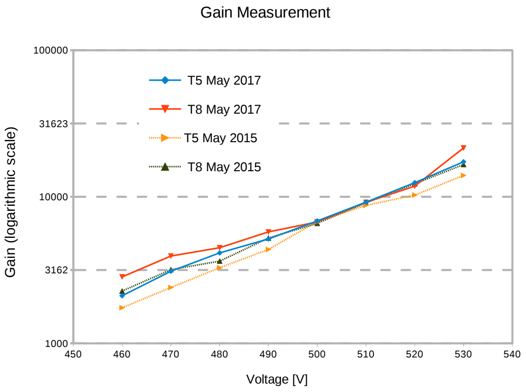

Figure 5: Gain vs amplification voltage.

Gain measurements were conducted on the chambers using an ^{55}Fe source in May 2015 and 2017, see Fig. 5. No significant changes on the gain are observed concluding as well that no degradation of the gain is observed due to irradiation.

Studies on the tracking resolution were also performed in November 2015; these studies will be repeated with the full accumulated charge. The resolution and the most probable value of the cluster charge are flat and stable up to 68 kHz/cm^2 [8] corresponding to more than 4 times the expected rate during the HL-LHC in the NSW region. The detectors operate without any performance degradation or gain reduction and the tracking algorithm works successfully and provides the same resolution under these high radiation conditions.

5. Particle Rate and Detector Sensitivity

The particle rate is defined as the average number of converted photons counted in a time window of 625 ns divided by the time window length and the active area. The particle rate as a function of the amplification voltage per attenuation factor was measured in November 2015 and 2016 for both chambers. Fig. 6 presents the data collected in November 2016 and shows very similar results for T5 and T8. Fig. 7 compares the data collected from November 2015 and 2016 for T8 only. The results are identical showing no irradiation effects.

From the measured rates in the plateau region (at 520 V) and the simulated flux [9] the detector sensitivity to γ's is extracted to be approximately 3.8×10^{-3}. This agrees with the Geant4 simulations which include the resistive bulk-Micromegas chambers.

6. Conclusions

The efficiency, gain, tracking resolution and particle rate measurements for two bulk-Micromegas chambers have been presented. After ∼2 years of irradiation at GIF++ with an accumulated charge of more than 0.2 C/cm^2 no aging effects have been observed in either of the two chambers.

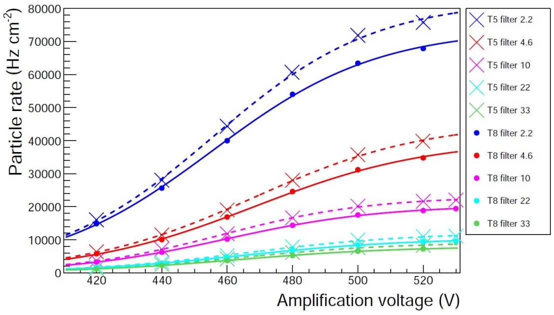

Figure 6: Nov 2016 data-taking, T5 and T8.

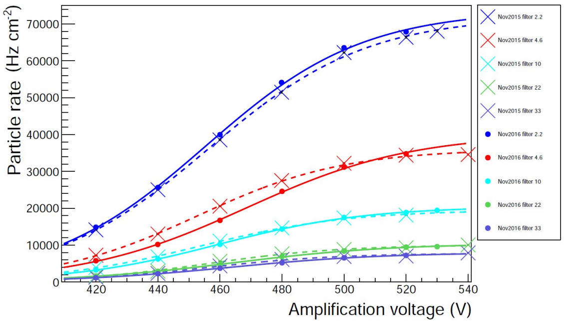

Figure 7: Nov 2015 and 2016 data-takings, T8.

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