Behaviour of a single-mask triple GEM Detector after long-term radiation

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Introduction

The Gas Electron Multiplier (GEM), introduced by Prof. F. Sauli in 1997, is a widely used detector technology within the family of micro-pattern gas detectors (MPGD) [1]. The GEM technology has become increasingly popular in High-Energy Physics (HEP) experiments because of its exceptional position resolution ($\sim$ 100 μm), and impressive rate capability ($\sim$ 1 MHz/mm^2). Long-term stability test of GEM detectors are being carried out with Argon and CO_2 gas mixtures in different ratios, keeping in mind to use it in future experiment such as CBM at FAIR [2, 3]. The effect of irradiation rate, temperature, pressure, and relative humidity on the performance of the detectors is also studied under prolonged irradiation. In the previous studies the detector did not show any sign of classical ageing due to polymerisation after long-term irradiation. However, it seems to experience some high voltage (HV) instabilities [2]. The behavioural changes in the performance of the chamber under irradiation is observed over the surface of a Single-Mask (SM) triple GEM detector. The findings are presented in this article.

Experimental Setup

A 10 $\times$ 10 cm^2 SM triple GEM prototype detector with 3-2-2-2 configuration (drift gap - transfer gap 1 - transfer gap 2 - induction gap) is characterised using 5.9 keV ^{55}Fe X-ray source. It operates with a Ar/CO_2 mixture in 70/30 volume ratio at 4 l/h flow rate.

NIM-based electronics is used to process the signal. A HV of - 4470 V, producing a ΔV of 398 V across each of the GEM foils, is applied. The signals are read out from an XY printed board with 256 X-tracks and 256 Y-tracks, each connected to two 128-pin sum-up boards provided by CERN. Total 4 sum-up boards are used 2 for X-side and 2 for Y side. The signal from the output of a sum-up board is then passed through a VV50-2 preamplifier (gain: 2 mV/fC gain, shaping time: 300 ns) and split by an analogue FIFO module to record the spectra with a multi-channel analyser (MCA) and to count the X-ray rate by a combination of single channel analyser (SCA) and Scaler module [2].

Each spectrum is recorded for one minute. The temperature and pressure are also monitored by a data logger.

Results and Discussion

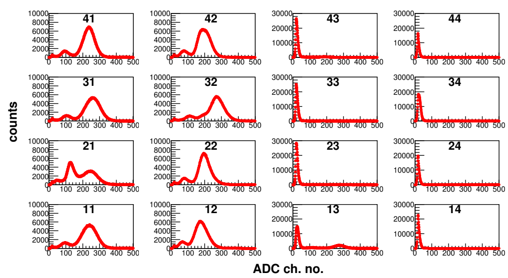

FIG. 1: ^{55}Fe spectra at an applied ΔV = 398 V from 16 different places over the detector.

The GEM detector surface is divided into a 4×4 imaginary grid, with positions labeled 11, 12, 13, 14; 21, 22, 23, 24; 31, 32, 33, 34 and 41, 42, 43, 44. It is to be mentioned here that 21 and 12 are two positions which are exposed to long-term irradiation for the stability study over 95 days and 20 days respectively, at an average rate of 200 kHz continuously. In this particular study the data was taken only from one sum-up board and the spectra were stored keeping the ^{55}Fe source on the 16 segments.

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Sixteen ^{55}Fe X-ray spectra are shown in FIG 1. As expected, it is clear from the FIG 1 that good ^{55}Fe spectra were observed only for 8 segments. In all these spectra the 5.9 keV full energy peak and Argon escape peak are clearly visible.

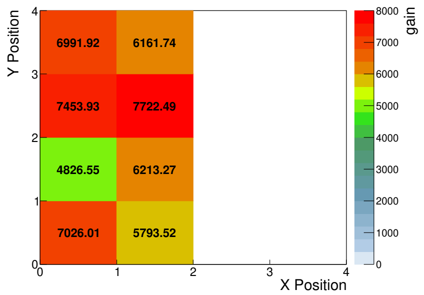

FIG. 2: Gain at 8 different places on the active region of the detector.

The gain and energy resolution of the chamber is determined by fitting the full energy peak with a Gaussian function, as described in Ref [2]. The rate of X-ray are also measured for those positions. The gain, energy resolution and the count rate over these 8 positions are shown in FIG 2, 3 and 4 respectively.

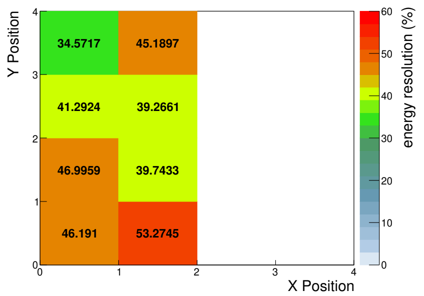

FIG. 3: Energy resolution at 8 different places on the active region of the detector.

It is observed from FIG 1 that the spectrum from position 21 of the GEM detector exhibits an abnormal spectrum, indicating a behaviour different from the other positions or an anomaly at this specific location. This peculiar feature in contrast to the other positions, suggesting a local change in the chamber because of continuous high radiation. FIG 2 and 3 indicate that the gain at position 21 and 12 are $\sim$ 4800 and $\sim$ 5800 respectively, which is comparatively lower than that of the other locations, whereas the energy resolutions are measured to be $\sim$ 47% and $\sim$ 53% respectively, which are higher than the other positions. The best energy resolution of 34.6% is obtained at 41 position. The energy resolution at irradiated positions 21 and 12 are respectively $\sim$ 36% and $\sim$ 53% higher than that of the best position. Additionally, FIG 4 shows that the count rate at 21 and 12 positions ($\sim$ 173 kHz and 162 kHz respectively) are lower indicating lower efficiency in those positions. These observations collectively suggest that the performances of the chamber at positions 21 and 12 changed because of continuous irradiation.

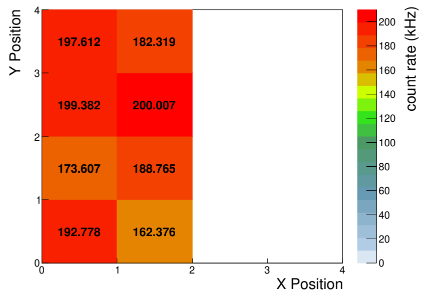

FIG. 4: Count rate (kHz) at 8 different places on the active region of the detector.

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