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NON-STANDARD GEM FOILS FOR GASEOUS DETECTORS*

Magdalena Kuich

for the eTPC Collaboration

University of Warsaw, Faculty of Physics, Pasteura 5, 02-093 Warsaw, Poland

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Gas Electron Multiplier (GEM) technology is widely used in many applications in nuclear and particle physics. It offers the potential to develop new gaseous detectors with unprecedented spatial resolution, high rate capability, sizeable sensitive area, operational stability, and radiation hardness. In this contribution, a brief overview of gaseous detector development at the University of Warsaw will be presented, as well as basic concepts, operational mechanisms, and performance of the gas amplifier structures based on standard and non-standard GEM foils will be discussed.

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1. Introduction

Introduced by Sauli in 1997 Gas Electron Multiplier (GEM) [1] constitutes a powerful addition to the family of fast radiation detectors. Originally, GEM foils were developed for particle physics experiments, nevertheless thanks to the excellent amplification potential, unprecedented spatial resolution, high rate capability, sizeable sensitive area, operational stability, and radiation hardness they found applications in various types of gaseous detectors in a broadly understood nuclear physics [2].

2. Gas Electron Multiplier

2.1. Basic concept

The standard CERN GEMs consist of an insulator made of a Kapton foil of the thickness of the order of 50 μm coated on both sides with thin,

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5 μm copper layers. This structure is perforated with high density and tiny holes. Between the two copper coatings, a voltage of a few hundred volts is applied, which results in a high gradient electric field inside each tiny hole. The electric field strength can reach several dozens of kV/cm, which is high enough for gas amplification. The principle of operation is presented in Fig. 1. It is possible to achieve a charge amplification up to ten thousand with a single GEM foil, but usually, an amplification setup consists of two or three successive GEM foils, as presented in the right panel of Fig. 1. The performance of GEM foil was widely studied over the years; more details can be found in Ref. [3].

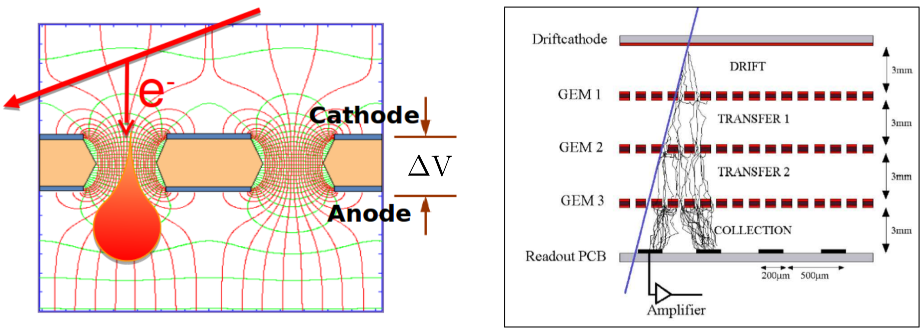

Fig. 1. Simulation of electric field lines inside GEM foil and illustration of charge amplification (left). Scheme of a typical gas amplification section based on GEM foils (right). Figures taken from Ref. [3].

2.2. GEM applications at Faculty of Physics, University of Warsaw

At the Faculty of Physics, University of Warsaw, GEM technology has been employed in several developments of Time Projection Chamber (TPC) like detectors, dedicated to studies of two proton radioactivity, β-delayed multi-particle emissions studies [4, 5], as well as studies of nuclear reactions at astrophysical energies [6, 7].

3. Non-standard GEM development

3.1. Motivation

In order to understand the carbon-to-oxygen ratio in the Universe, the reaction of burning helium C(α, γ)^{16}O is studied with currently growing astrophysical interest. The direct study of this reaction is unattainable in the laboratory, hence the approach of the reverse reaction, the oxygen photodisintegration reaction, was proposed. For this purpose, the low-pressure active-target drift detector (AGT-TPC), allowing for measuring the kinematics of low-energy charged particles, was designed [6, 7].

The AGT-TPC aims at working with a gas mixture based on CO_2 at an absolute pressure of the order of 50–200 mbar, which is going to serve as the reaction target and allow for measuring products of a reaction with $E_{\rm cm} \sim 1$ MeV. On the other hand, working in such extreme conditions means struggling with rising discharge probability, ion feedback effects, and reaching the operation limits of GEM technology. In order to minimise these effects whilst meeting the requirement of the high gas amplification capabilities, one may increase the distance between GEM foil electrodes and employ the non-standard GEM foils in the low-pressure TPC.

The design and manufacturing procedures of the non-standard GEM foils are the same as in the case of the standard GEM foils. Where they differ is primarily the thickness of the Kapton foil, 125 μm instead of 50 μm, and also perforation density.

3.2. Test-bench detector

The non-standard GEM development was tested, for the first time, at the Faculty of Physics, University of Warsaw, in a test-bench low-pressure small-volume TPC, as shown in Fig. 2. The active volume of the detector is filled with pure carbon dioxide or gas mixtures based on noble gases and carbon dioxide at an absolute pressure of the order of 50–1000 mbar. As the ionisation source, the X-ray lamp (Amptek Mini-X generator with XRF fluorescence filters) is used. The source generates a quasi-monochromatic X-ray spectrum with a maximum at the energy of 4.9 keV (peak FWHM%9).

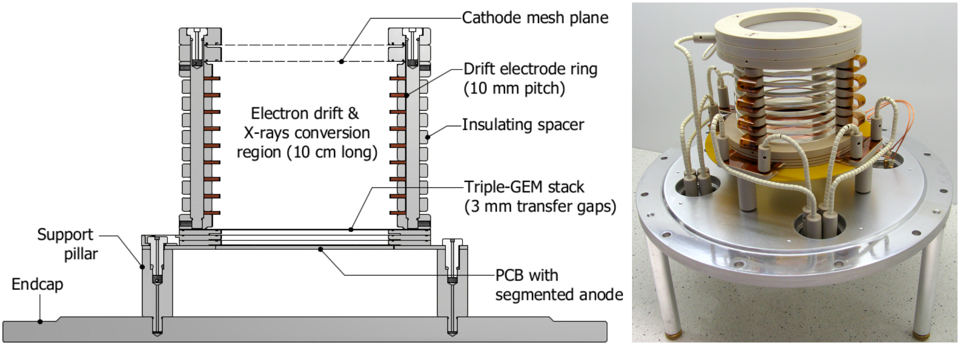

Fig. 2. The scheme (left) and the photo (right) of the test-bench detector.

3.3. Results

In such a set-up, the measurements of the effective gas gain capabilities with using the stack of 3 standard GEM foils, as well as stacks of 3 and 2 non-standard GEM foils as a charge amplification structure were performed.

The results are presented in Fig. 3. Application of non-standard GEM foils in the low-pressure TPC, in both cases: double and triple stack, allowed to obtain almost two orders of magnitude higher gas gain with respect to triple-stack of STD GEMs and operating without uncontrolled discharges.

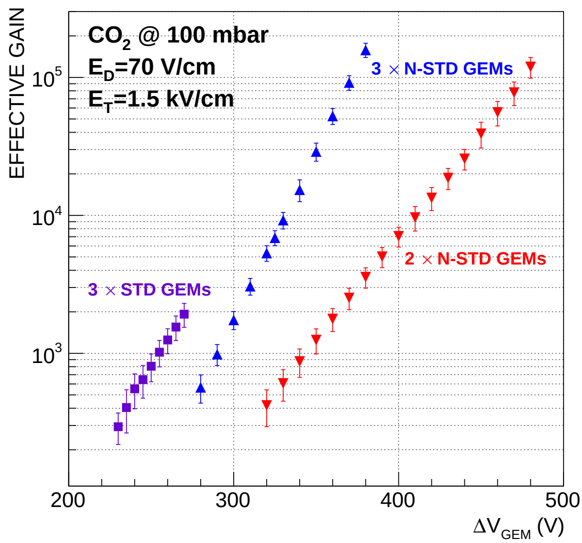

Fig. 3. Effective gas amplification gain of: triple standard GEM stack (squares), triple non-standard GEM stack (triangles pointing up), and double non-standard GEM stack (triangles pointing down).

4. Summary

The results on the gas gain capabilities of the non-standard GEM are promising, and the R&D of non-standard GEM foils application in nuclear reaction physics as well as particle physics, in the context of the future MPD sub-detectors, is ongoing.

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