# Fast Neutron Detector using the Gas Electron Multiplier with $^{4}$He gas mixtures

Sang Mook Kang [a], Cheol Ho Lee [a], Yun Ho Kim [a], Jang Ho Ha [b], Han Soo Kim [b], Yong Kyun Kim [a*]
[a] *Department of Nuclear Engineering, Hanyang University, 17 Haengdang, Seongdong, Seoul 133-791, Korea*
[b] *Korea Atomic Energy Research Institute, 150 Deokjin, Yuseong, Daejeon 305-353, Korea*
[*] *Corresponding author: ykkim4@hanyang.ac.kr*

## 1. Introduction

A study of neutron detection of a double GEM detector in Helium-4 gas mixtures is presented. The gas electron multiplier (GEM) was introduced in 1997 by Sauli and consists of a 50 μm insulator foil, 5 μm copper on both sides, perforated with a high density of small holes. Remarkable features of GEMs make them attractive for numerous applications in high-energy physics, nuclear physics, astrophysics, and the field of medical imaging, etc. We used GEMs with a 5×5 cm$^2$ active area and 140 μm hole pitch. The hole shape is double conical with an inner diameter of 50 μm and outer of 70 μm. Operating voltage test of Single GEM and avalanche current of GEMs was carried with a 5.9 keV $^{55}$Fe X-ray source in pure Ar. Also neutron measurement was used $^{252}$Cf source with 5 cm lead shielding absorb in $^{4}$He/$CO_2$ mixture gas.

## 2. Methods and Results

### *2.1 Gas Electron Multiplier*

Fig. 1 shows the diagrams of electric field and electron avalanche and pictures of GEM. The GEM was developed by F. Sauli [1,2] at CERN. It consists of a thin insulating foil, usually Kapton with a thickness of 50 μm, with a 5-17 μm layer of copper on both sides. Using a photolithographic process, it is perforated with a regular matrix of holes. The holes typically have a diameter of some 50-100 μm and have a pitch of 120-200 μm. [3]

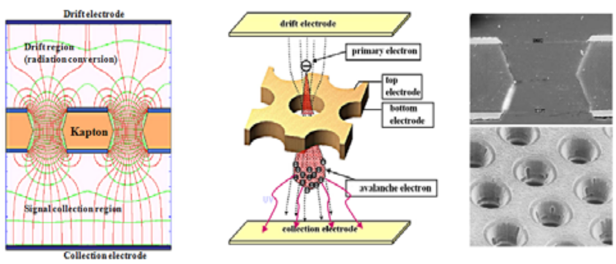


Fig. 1. Diagrams of electric field (left) and electron avalanche (middle) of GEM structure and pictures (right) of cross section of GEM hole and GEM surface.

When a voltage of typically 300-600 V is applied over the electrodes of the GEM, an electric dipole field develops that reaches values in the order of 100 kV/cm within the holes; high enough for electron multiplication. An electric drift field before the GEM brings electron clouds, deposited by interaction with radiation, into the holes, where they are multiplied. The electrons, produced in the avalanches, are partially collected on the lower electrode of the GEM (the anode or collection electrode). The rest is released in the drift field on the other side of the GEM, called induction field or collection field. This fraction, usually 20-80% depending mostly on the induction field strength, [4-6] can be transported to a pick-up electrode or another amplifying detector structure such as a wire or another GEM.

### *2.2 Single and Double GEM test*

The GEM size is 5x5 cm$^2$, one of the standard types produced at CERN; the hole shape is double conical with an inner diameter of about 50 μm and 70 μm at the metal surface. The hole pitch is 140 μm arranged in a hexagonal pattern; the overall thickness of the GEM foil is about 60 μm : 50 μm thick Kapton with 5 μm copper on each side. (Fig. 2.)

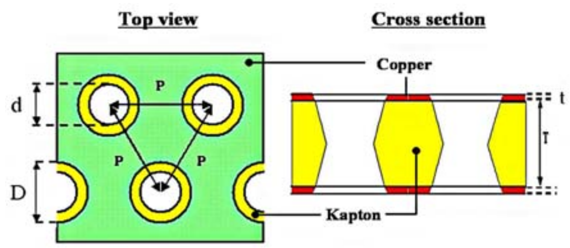


Fig. 2. Diagram of GEM hole structure. ( P : hole pitch, D : hole diameter on metal side, d : hole diameter on insulator, T : insulator(Kapton) thickness, t : metal thickness, hole shape: double conical, active area: 5x5 cm$^2$).

The schematic setup of the single or double GEM detector is shown in Fig. 3. We carried out operating voltage test of single GEM. The drift field (between the drift electrode and the top electrode of GEM) was fixed at 3 kV/cm and the collection field (between the bottom electrode of GEM and collection electrode) was set to 4 kV/cm. The chamber was irradiated with $^{55}$Fe, $^{241}$Am isotope sources in pure Ar gas. Avalanche current of single GEM increased exponentially with respect to biased voltage and the operating voltage range of GEM#1 and GEM#2 is 450 to 550 V, 450 to 630 V, respectively. Also, we compared current with respect to GEM position for double GEM structure. The case 1 used GEM#2 for primary electron avalanche and the case 2 used GEM#1. The collection current of case 2 was larger than case 1.

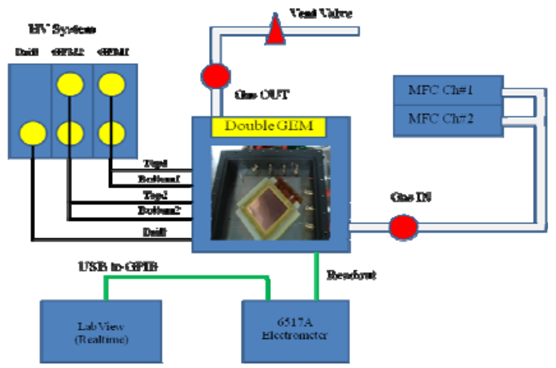


Fig. 3. Schematic of experimental setup. (HV system : N471A @ CAEN Inc., Electrometer : 6517A@ Keithley Inc.)

### *2.3 Neutron Response of Double GEM with $^4$He Gas Mixtures*

Fig. 4 shows the neutron response of double GEM detector. The test conditions of double GEM was similar the single GEM test and added transfer field condition (between bottom electrode of GEM#1 and top electrode of GEM#2). The transfer field was set to 3 kV/cm. The chamber was irradiated with $^{252}$Cf neutron sources on 5cm lead block in $^4$He/$CO_2$ (80/20) mixture gas. The lead block absorbed about 90% gamma ray irradiated by neutron source. [7] The current was measured real time method with GPIB cable and LabVIEW program in 0.5, 1.0, 2.0 bar, respectively. The level of neutron response signal is much higher than background noise and level of signal was about -5.0 ~ -2.0 pA.

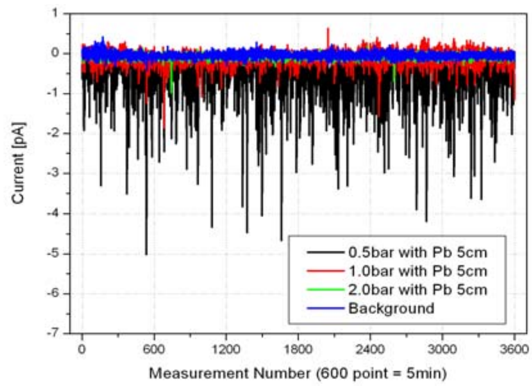


Fig. 4. Neutron response of double GEM structure with $^4$He gas mixture (1 point measurement time: 0.5 sec, total collection time: 30 min, total point: 3600 point)

## 3. Conclusions

We carried out operating voltage test of single GEM and compared current with respect to GEMs position for double GEM structure with $^{55}$Fe and $^{241}$Am isotope source in pure Ar. Also neutron response was used $^{252}$Cf source with 5 cm lead shielding absorb in $^4$He/$CO_2$ mixture gas at double GEM structure. Avalanche current of single GEM increased exponentially with respect to biased voltage and the GEMs worked in operating voltage range of 450 to 550 V, 450 to 630 V, respectively. Case 2 used GEM#2 for the primary electron avalanche was effective more than Case 1 for double GEM structure test. Neutron response was measured by real time method with GPIB cable and LabVIEW program to minimize current induced by gamma ray and the low pressure condition was effective for neutron detection. In further study, neutron spectrum experiment for precision analysis of the neutron response excepted gamma effect will be performed after preliminary test with commercial $^4$He detector.

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