Linearity of the Double Gas Electron Multiplier (DGEM) as an X-ray Fluorescence Detector

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Abstract- We have tested a 10 cm x 10 cm Double Gas Electron Multiplier (DGEM) fluorescence X-ray detector for linearity by making gradual decrease of the X-ray florescence entering the detectorobtained from a testsample. The X-ray fluorescence emitted by the sample and directed towards the detector is attenuated and transmitted byplacing multiple layers of identical Aluminum (Al) foil sheets on thedetector's entrance window. The transmitted portion of the fluorescence passing through the Al foil layers ionizes the detecting gasand the ionized electrons are amplified by the DGEM. We have repeated the same experiment with no Al foils, and by adding one extra layer of identical Al foil for each separate scan up to five (5) foils. The normalized scans for a diluted prepared "Fe" sample, using Athena software, indicate that all the scans have good identical similarities. This shows that the DGEM detector is a linear detector with respect to the X-ray quantity reaching the DGEM detector.

Keywords- *Detectors, Gas Electron Multiplier,*

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I. INTRODUCTION

We have built and tested a 10 cm x 10 cm Double Gas Electron Multiplier (DGEM) florescence detector [1-2] to detect dilute or low concentration elements in a test sample. The advantage of the Gas Electron Multiplier (GEM) has been demonstrated before [3]. The GEM provides an exponential amplification of the primary ionized electronic charge as the charge is drifted towardsthe electrodes of the GEM. The charge amplification is due to the impact ionization caused by the accelerated electronsaccelerated by the high electric filed within the GEM electrodes. As the accelerated electrons, repeatedly collide with the neutral gas atoms, they create an avalanche of electrons producing the amplification gain.

In this paper we used doubleGEMs that are placed in a consecutive order with a small transition region about 1/8 of an inch (3 mm) apart as shown in Figure 1. The intent of using the double GEM is to decrease the electric field across each GEM and therefore to avoid sparkdischarges caused by applying high electric fields. At the same time,the double GEM detector increases the amplification of the electronic charge since it passes through two regions of GEM amplification. In this paper, we have tested the DGEM detector to show if the detector is linear. This means thatas the amount of X ray fluorescence entering the detector is decreased,by transmitting the fluorescence through stacked Al foils,or otherwise for other experiments, then the DGEM will always provide identical normalized scans. We conducted the experiment using a prepared "Fe" sample diluted in a large quantity of Boron Carbide. The normalized scans made with no Al foils obstructing the fluorescence emitted by the sample entering the detector are compared with those scans obtained after one or multiple layers of Al foils were placed at the entrance of the detector's window as in figure 1. The experiment is repeated by adding one extra Al foilone at a time for each consecutive scans at the detector's entrance window.

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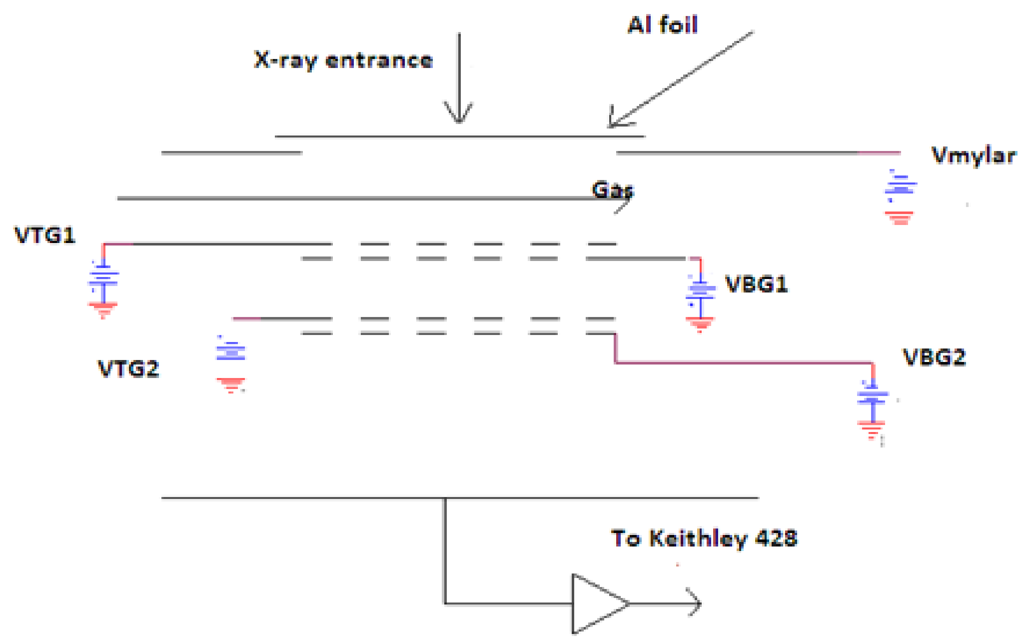

Figure 1: The Double GEM with Al foils at the X-ray entrance window to attenuate the X-ray to ionize the detecting gas and amplified by the GEM

Figure 2 displays the scans of a prepared diluted "Fe" sample in Boron Carbide using different layers of Al foils stacked one on top of the other at the X-ray entrance window.

The scans represent different runs with no Al foil obstructing the fluorescence emitted by the sample and consequent scans that were obtained by adding one layer of Al foil, at a time, for each consecutive scan up to five (5) Al foil layers. The normalized scans look remarkably identical with a good similarity as the X-ray fluorescence entering the detector is being repeatedly decreased. This supports the fact that such a detector can be used to detect dilute or low concentration samples that very low X-ray fluorescence. The scans were plotted using Athena software [4].

In Figure 3 we placed the same normalized scans obtained in figure 2 one on top of the other to show identical similarity although each scan was obtained using decreased transmitted fluorescence as it passes through multiple Al foils *obstructing the X-ray* detector's entrance

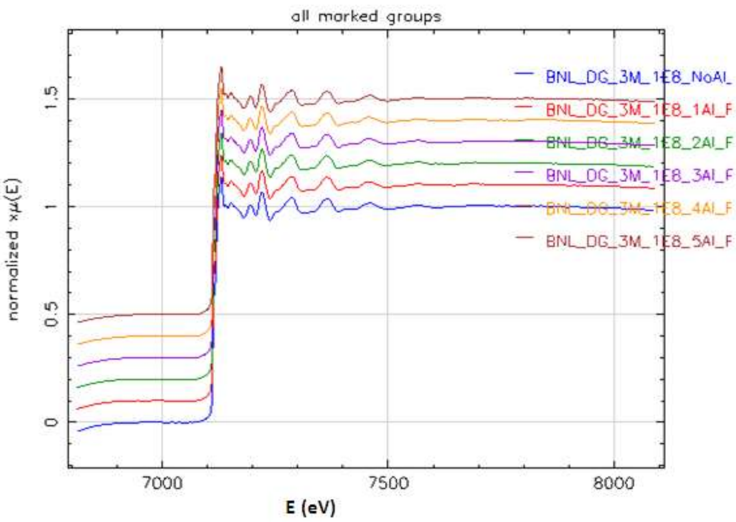

Figure 2: Fe samle scans with no Al foil, and with one, two .. up to five Al foils at the X-ray entrance. The scans are stacked for comparison with excellent similarity

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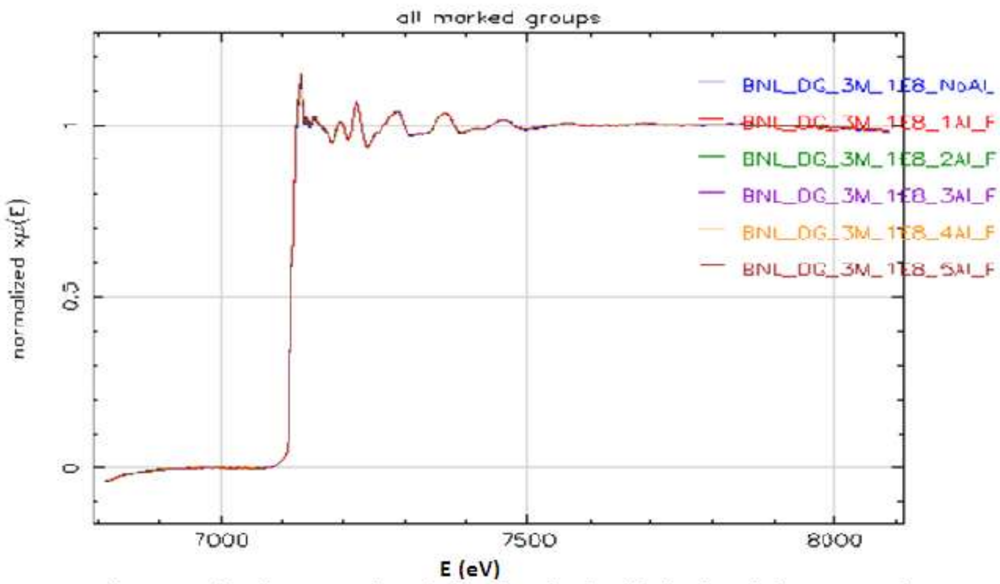

Figure 3: The normalized scans with no foil and multiple Al foils placed obstructing the X-ray entrance window with identical similarity

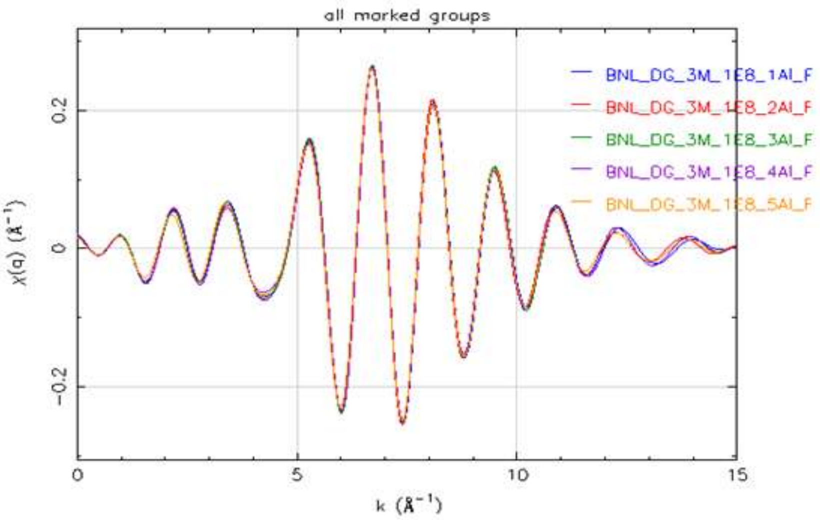

Figure 4: The same scans as above with multiple Al foils but using the "q" parameter in Sthena softwrae

Figure 4 shows the scans of the detector using the “q” parameter in Athena software 4]. The similarity of the scans with different Al foils is very good.

II. SUMMARY AND CONCLUSION

The DGEM detector, based on the above results, demonstrates that it has linear performance with respect to the attenuated amount of the fluorescence X-ray entering the detector. Decreasing the X-ray fluorescence entering the detector is achieved by placing multiple Al foils covering the window entrance of the DGM detector. This suggests that such a detector can be used for very dilute or low concentrations elements where the fluorescence from such element is usually very small.

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