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MPGD2015: Investigation of THGEM technologies for Nuclear Security Applications

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Abstract. The use of Thick-Gas Electron Multipliers (THGEMs) for nuclear security applications, including muon scattering tomography, is discussed and the initial characterisation of a THGEM prototype presented. Pulse shape and rate are examined as a function of THGEM voltage, drift field and gas flow. An operation range of 3800-4200 V is determined for the considered configuration and a maximum recorded efficiency of approximately 30 %. Agreement was shown between initial GARFIELD simulations and experimental results.

1 Introduction

Thick Gaseous Electron Multiplier (THGEM) technology, which utilises copper coated insulating plates with patterns of hexagonal drilled holes, has proved to be scale-able [1], robust [2] and relatively cheap and easy to manufacture [3], and is therefore suitable for large area scanning. The combination of these characteristics mean there are a number of applications suitable for nuclear security; such applications were previously discussed at the RD51 collaborators meeting in Paris, 2008.

This paper reports the initial progress in the characterisation of a THGEM detector for use in nuclear security applications within the National Nuclear Security programme at the Atomic Weapons Establishment. Within the National Nuclear Security programme a portal system based upon muon scattering tomography is under construction for the passive scanning of cargo containers for regions of abnormally high density, which are indicative of special nuclear material. One of the current muon tomography system, utilises a series of orthogonally positioned drift tubes which track the pre-scatter and post-scatter trajectory of cosmic-ray muons to infer the scattering angle and thus the density of a concealed object. THGEMs are proposed for inclusion in this type of system.

2 Double-THGEM

Our current prototype THGEM system consists of a double THGEM within an argon-methane (95:5) gas mixture at room temperature and atmospheric pressure. The THGEM boards have thickness, t of 0.8 mm, hole diameter, d, of 0.8 mm, pitch, a, of 1.5 mm and rim width, w, of 0.1 mm.

The THGEM boards were mounted 12 mm below a drift mesh and separated by a 9 mm transfer gap. The voltage was applied across the two boards using a voltage divider, shown in Figure 1. A photograph of the THGEM and enclosure is shown in Figure 2.

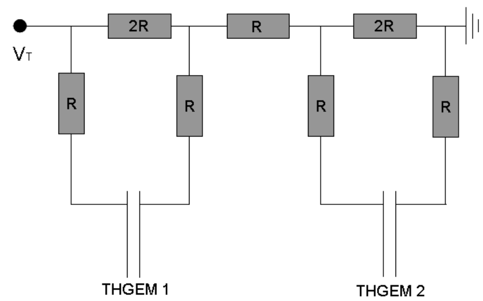

Figure 1. Illustration of the voltage divider used to apply the voltage across the THGEM boards.

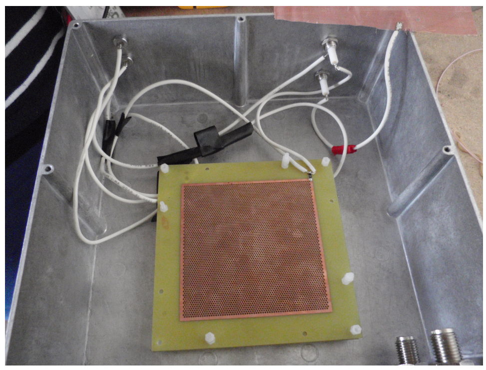

Figure 2. Photograph of the double THGEM boards, without the drift mesh, and the enclosure.

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The THGEM boards are secured within a 300×300 mm aluminium box and sealed using a rubber gasket and vacuum grease. The system is continuously flushed with an argon-methane (95:5) mixture at atmospheric pressure and room temperature. The output of the detector is taken from the lower side of the second board, this is read through a 49 pF capacitor via a DRS4 evaluation board.

3 Initial Characterisation

Initial characterisation of our double THGEM detector was conducted by investigating the effect of THGEM voltage (V_G), drift voltage (V_D) and gas flow. Figure 3 displays a selection of the typical pulses obtained from the double THGEM system, where (a) is noise and (b), (c) and (d) are suspected muon events with and without the presence of sparking.

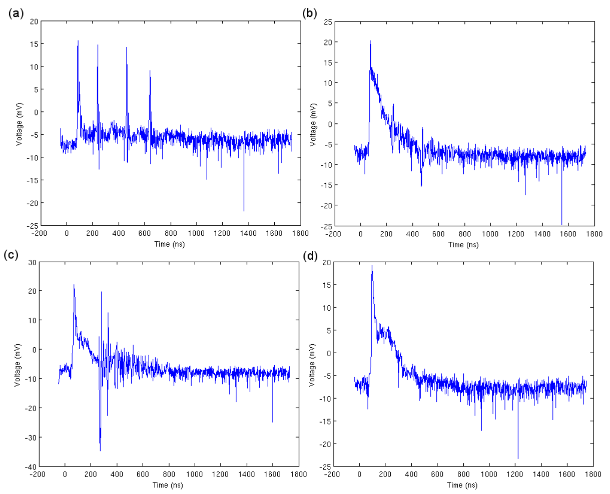

Figure 3. Pulses obtained using the double-THGEM system at THGEM voltage = 4000 V and 85k V/cm drift field.

Preliminary experiments involved examining the effect of the THGEM voltage on peak height and peak rate, these measurements were obtained at three different threshold levels in order to identify if the ratio of noise events to suspected muon events could be reduced. Figure 4 displays the average peak height as a function of voltage, this graph demonstrates that the height increases with voltage, however, the value plateaus at approximately 3800 V; the value of the trigger was observed to raise the average height, suggesting that a number of smaller peaks may be missed. The rate was also examined as a function of voltage, Figure 5 demonstrates that the rate increases with voltage to approximate 0.4 events per second. The estimated theoretical rate for a detector with an active area of 10 cm^2 is 1.7 Hz, this gives an estimated efficiency of 30 %. In addition to the rate and the height, the percentage of suspected muon events to the number of noise events was examined as a function of the voltage.

A histogram of the average peak heights is shown in Figure 6. This distribution resembles a Landau distribution which describes the energy loss of a particle through a specific material as a function of depth [4].

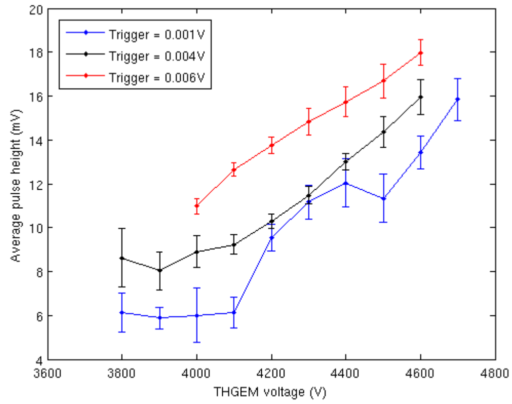

Figure 4. Average pulse height as a function of voltage for trigger levels 0.001, 0.004 and 0.006 V.

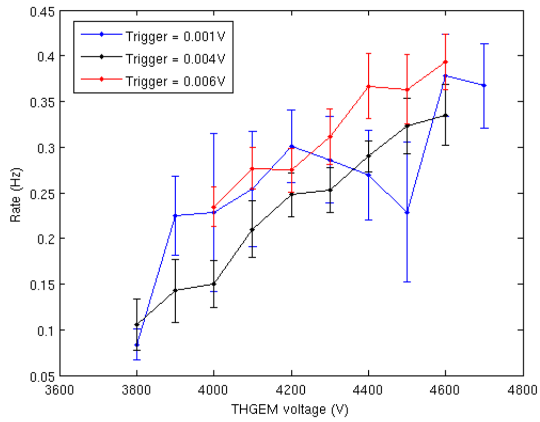

Figure 5. Rate as a function of voltage for trigger levels 0.001, 0.004 and 0.006 V.

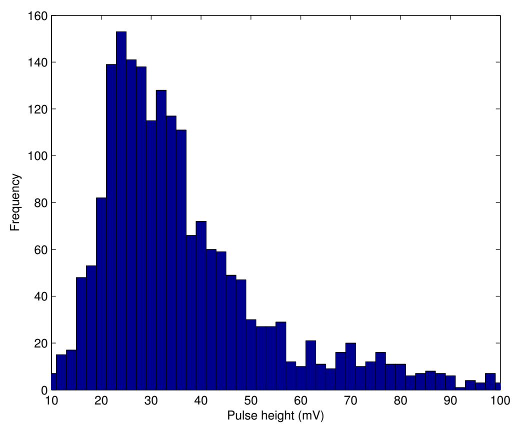

Figure 6. Histogram of peak heights for a trigger level of 0.004 V.

The second parameter examined was the voltage applied across the drift gap. Figure 7 demonstrates that the average peak height is increased initially by a higher drift field, however, this reaches a value of approximately 30 mV before appearing to saturate for drift fields of 83.3 V/cm and 166.7 V/cm. At higher drift fields, such as 416.7 V/cm a slight reduction in the average height is observed. These observations agree with initial GARFIELD simulations of the drift velocity, in which the peak velocity corresponds with fields of approximately 100 V/cm, and the velocity is significantly reduced around 400 V/cm, see Figure 8. The rate of the detector is shown in Figure 9, this graph does not demonstrate an increase in rate due to the drift field and displays a lower rate than previously observed.

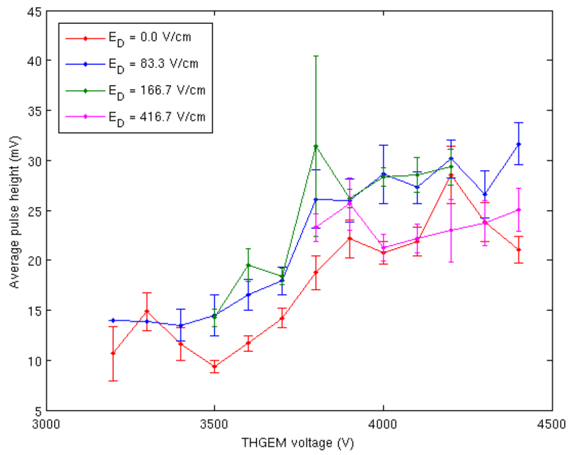

Figure 7. Average pulse height as a function of voltage for different drift fields.

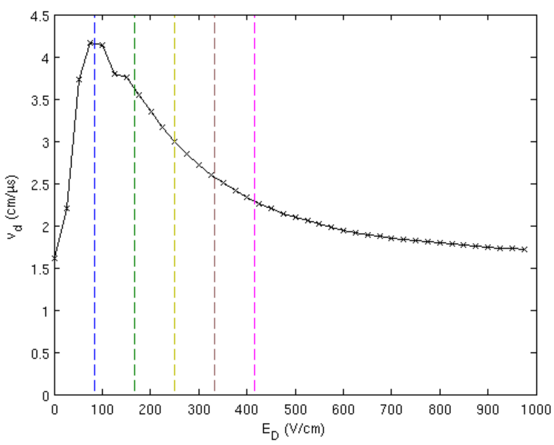

Figure 8. Drift velocity as a function of drift field calculated from GARFIELD simulations. Values which are experimentally tested are shown by the dashed lines.

4 Conclusions and Future Work

Preliminary investigations were conducted using a double-THGEM detector for the observation of cosmic-ray muons. Initial characterisation was carried out on the system by investigating the effect of voltage on the pulse height and rate. As expected, an increase in voltage produced a larger peak height and a greater rate. This investigation indicated an operating voltage range of 3800-4200 V and a trigger level of 0.004 V. Also investigated was the effect of drift field on the pulse height and rate. The pulse height was found to increase before reaching a plateau at higher field values. The optimal values were found to lie between 83.3 V/cm - 166.7 V/cm, this corresponded with the peak drift velocity values, calculated as part of preliminary GARFIELD modelling. As expected the rate of the peaks were not significantly effected by the change in drift field.

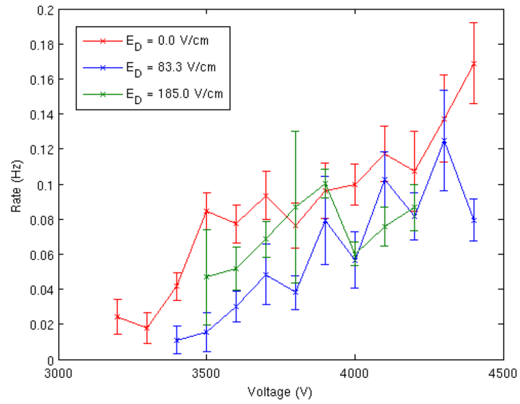

Figure 9. Rate as a function of voltage for different drift field.

In the short term, the forward strategy of the project will investigate the effects of different gas mixtures and different gas flow rates in an effort to purge oxygen within the system. This includes examination of THGEM boards with different geometric parameters, with supporting modelling conducted in GARFIELD. A long term goals include the examination of different read-out structures and the scaling of the system to large areas which would be more suited to the muon scattering tomography applications.

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