Photon Detection With a Thick GEM
Work Report for Summer Student Program

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1 Brief introduction to GEM and THGEM

Accordingly to Sauli, who introduced them in 1997 [1], **Gas electron multipliers** (GEM) can be defined as: "A composite grid consisting of two metal layers separated by a thin insulator, etched with a regular matrix of open channels". On the other hand thick GEMs (THGEM) were described in 2004 [2] and are basically a scaled up version of GEM [3].

Below at figure 1 we present a scheme of the constituents of THGEMs. First, from top to down, we show the drift electrode, then the photocathode (here CsI) in contact with the metal upper surface electrode. Just in the middle we have the insulator (G10 in our case) followed by the bottom metal electrode and finally the induction electrode.

Electrostatical parameters are: The drift field E_{drift} which is defined as the electrical field in the volume between the upper metal electrode and the drift electrode. The difference of potential ΔV between both sides of the two electrodes attached to the insulator and finally the electrical field between the bottom metal electrode and the induction electrode called the induction field E_{ind}.

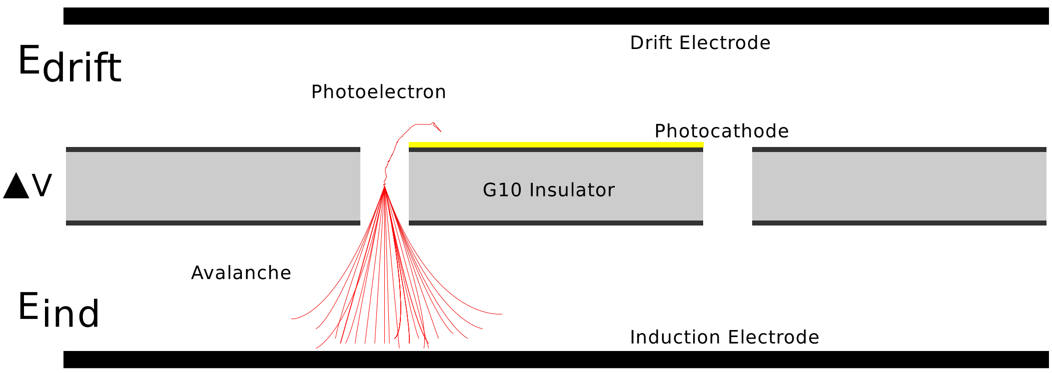

Figure 1: Schematic view of the THGEM. The trajectory of an electron that produced an avalanche is show in red.

The GEM and THGEM operational schemes are basically the same. A differential of potential is applied between the insulator and this creates a dipole field which is very strong. This allows to focus correctly the electrons into the holes and, since the electric field is very strong in the holes, avalanches are created over there amplifying thus the number of electrons collected. In THGEMs the electron collection is more efficient that in GEMs because the hole diameter is bigger than the electron transverse diffusion range when approaching the hole [4].

In figure 2 we show the hexagonal geometry of the GEM and THGEM periodic structure. Further explanations are given at the figure caption.

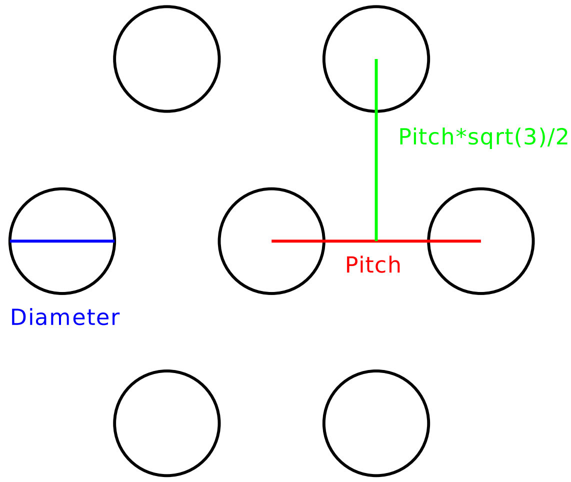

Figure 2: Geometrical arrangement of the THGEM. The geometry is characterized by two elements: the pitch and the diameter of the holes.

2 Electron Backscattering

Since 1955 in a work by L.B Loebe it was recognized that once escaped from a photocathode some electrons diffuse back, even in the presence of electric field, due to the elastic collisions with the gas molecules [5].

Accordingly to [6] one of the most important parameters contributing to photoelectron backscattering occurrence is the ratio of elastic collisions versus inelastic collisions. If elastic conditions are predominant then we will have a high probability of electrons suffering an elastic collision in the reverse direction with enough energy to made it back to CsI. On the other hand if we add inelastic collisions we can reduce the energy of the average particle by those collisions and thus avoid the scenario described above.

Taking in account that model adding gases like CH_4, CF_4 or $C0_2$, which posses reasonable inelastic cross sections, decrease backscattering effects [7].

3 Simulations of Effective Detection Area I

The first part of the project consisted on simulating the trajectories of the electrons without taking into account the backscattering effects or quantum efficiencies. First we created the geometry and calculated the electrical field on it by the **Finite Element Method (FEM)** with the help of **Ansys** software.

We simulated the gas with **Magboltz** package and handled the electrical field and the geometry to **Garfield** which calculated the trajectories using the **Runge-Kutta-Fehlberg** method.

A problem with THGEM is that some of the electrons produced by the photocathode don't make it to the holes, therefore they don't produce avalanches and are not detected. We call the area where those non detected electrons area created **Unusable area**. On the other hand the area of the holes where there can't be photocatode also is useless. Therefore we define **Effective area** as the total area of the surface minus the surface of the holes and the unusable area.

The task that that we set for our program for the first simulation was an easy one: A binary decision, if one electron starting at the mere surface of the THGEM (modelling an electron just produced in the photocathode) made it to the collection electrode (or close enough) we color that point green, otherwise we paint it red. With this idea we can have a visual representation of the Unusable area and the Effective area. In the figure 3 below we present an example of the kind of graphs that we have obtained in ours simulations.

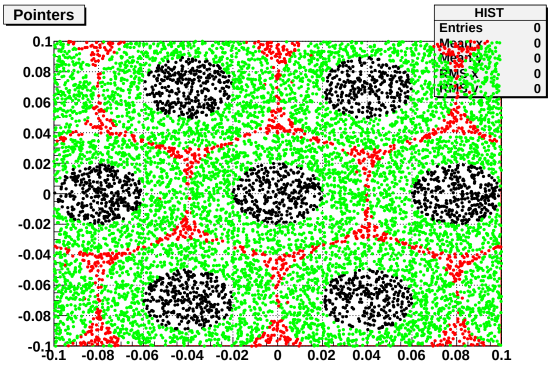

Figure 3: Result of a particular simulation of electrons generated randomly all over the surface. The red area corresponds to the unusable area and the green to the effective one. The geometry of this simulations is given by diameter=0.04 cm and pitch=0.08 cm. The electrostatic values are $\Delta V = 600\frac{V}{mm}$, $E_{drift} = 0$, $E_{ind} = 300\frac{V}{mm}$.

Taking a more systematic approach we can approximate the unusable area by calculating the proportion of all the produced electrons that do not make it to the collector space. Also we can approximate the effective area by calculating the proportion of the electrons that made it.

Varying the parameters systematically we can produce tables like the one below which represents the phase space for the diameter and the pitch variations. From the geometry the pitch is always bigger than the diameter. The value of the left represents the percentage of unusable area where the value of the right represents the respective percentage of effective area.

$\frac{Pitch(mm)}{Dia(mm)}$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.8	•	•	•	•	•	•	•	•	36/8
0.7	•	•	•	•	•	•	•	35/11	48/6
0.6	•	•	•	•	•	•	17/3	43/14	56/8
0.5	•	•	•	•	•	0/64	17/42	42/25	56/16
0.4	•	•	•	•	31/21	0/64	21/5	43/34	57/24
0.3	•	•	•	57/29	44/25	23/53	12/7	38/47	53/35
0.2	•	•	64/0	77/0	56/28	89/0	89/0	91/0	95/0
0.1	•	•	90/0	94/0	67/29	97/0	98/0	98/0	99/0

4 Simulations of Effective Detection Area II

For the second set of simulations we calculate the probability for a given electrical field to extract an electron from the photocathode with data from [8]. We use random number generation to simulate quantum efficiency and extraction efficiency. We define **effective gain** as the number of avalanche electrons produced by an electron staring at that particular point that make their way to the induction electrode o close enough.

In our simulations we calculate the effective gain as a function of position in a line that connects two hole's centres varying the value of drift fields E_{drift}. We show our results in the figure 4.

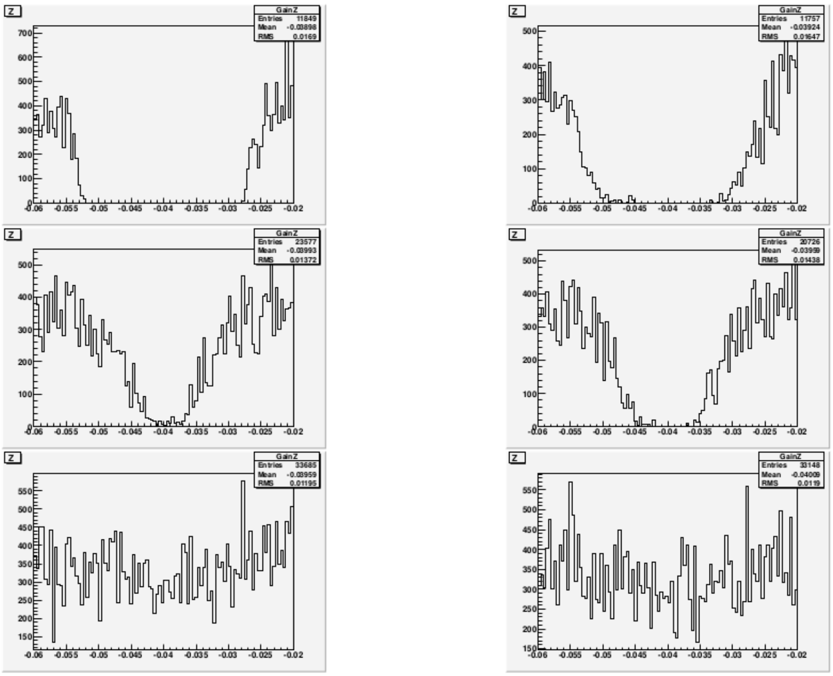

Figure 4: From the upper left corner and going counter-clockwise we have the simulation with the following drift field's values: $170\frac{V}{mm}$, $83\frac{V}{mm}$, $17\frac{V}{mm}$, $-17\frac{V}{mm}$,$-83\frac{V}{mm}$ and $-170\frac{V}{mm}$. In the x axis we graph position from the edge of one hole to the other at the right of it, on the y axis we have the gain. We can see that the gain increases at the center with decreasing E_{drift}

5 Final Comments

Further work is necessary in order to make a full gain map for all the surface. There is some recent experimental work in that direction [9] and the aim would be, if it is possible, to reproduce it.

A more detailed version of the work and the code involved in the simulation is documented at Garfield web-pages, access is possible by clicking here.

References

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