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GEM Profile Studies

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Abstract

Abstract Time Projection Chamber is a main tracking detector for International Linear Collider. Because direct detection of the charge is impossible, it is needed to use charge amplification device. For this purpose Gas Electron Multiplier(GEM) is used. In order to determine dE/dx properly and to get a better drift quality, Flatness of the GEMs are important. Because of that reason, GEM profiles are measured,Charge Transfer coefficients are fitted, for simulating the Effective gain.

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1 Theory

1.1 Time Projection Chamber

TPC is a gas filled cylinder and it is used for tracking detector. When a charged particle passes inside the chamber, it ionizes the gas inside the volume. Resulting electrons from ionization drifts towards the anode by the effect of strong electric field between anode and cathode. Electrons are amplified before reaching to anode in order to get proper signal. Anode has a segmented readout structure, by this segmented readout structure two dimentional projection of the track is measured and arrval time of the electrons at anode is measured. The z coordinate of the track is reconstructed by drift time and drift velocity. The z coordinate can be calculated by this formula;

$$z = v_d(t_2 - t_1) \tag{1}$$

where v_d is drift velocity of electrons in the electrons in the gas, t_2 is arival time at the anode and t_1 is the time of the passage. Time of particle passage is determined by an external timing trigger.

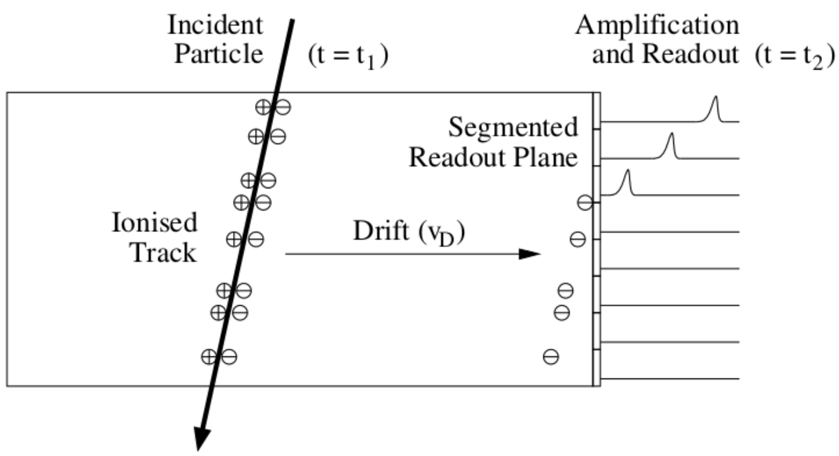

Figure 1: Time Projection Chamber

Another important characteristic of TPC is particle identification. This is done by applying the magnetic field parallel to electric field. Magnetic field bends the track of charged particles, by measuring the curvature, particle momenta is determined. Moreover magnetic field reduces the diffusion of electrons, and this provides a better single point resolution. Particle energy loss can be measured directly from the Readout plane. By using average specific energy loss and momentum of the particle identity can be determined.

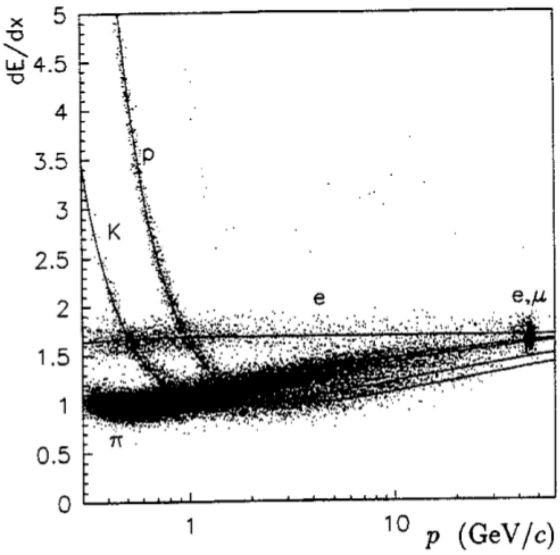

Figure 2: Specific energy loss over particle momentum measured in the ALEPH TPC

1.2 Gas Electron Multipliers

The Drifting primary electrons can not be read out directly, because of that reason they must be amplified before they reach the anode plane. Because of that reason GEMs are used for amplification.

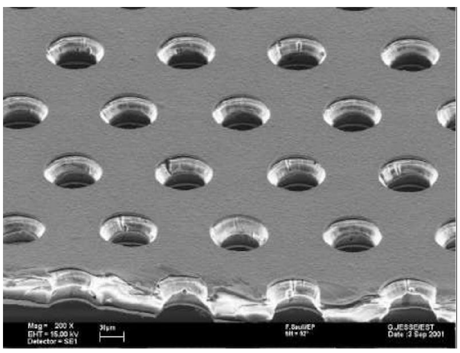

Figure 3: Microscopic view of GEM

GEM consists a copper plated polyimide substrane and its total thickness is about $60\mu_m$. As it is seen in the figure (3) , double conical holes are etched into the foil. Voltage difference between two copper surface is about 250V. Inside the holes electric field is the strongest, because of that reason gas amplification mostly occurs inside the holes. Gain is about 100.

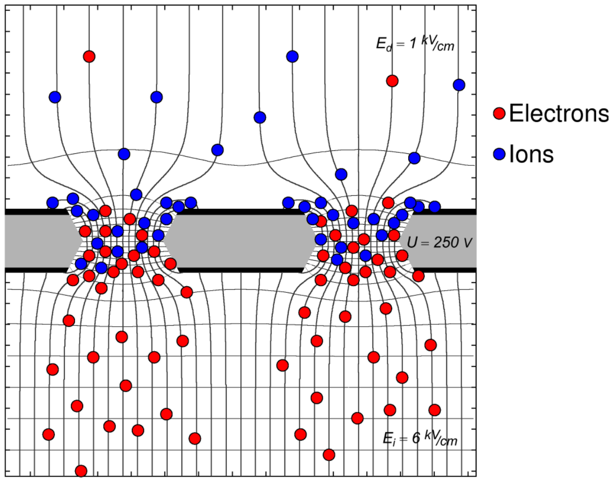

Figure 4: Electric field around GEM

Generally, two or three GEMs are installed on top each other with small gaps of a few milimeters. Our GEM module is composed of 3 GEMs and readout plane. Distance between GEMs is 2mms and distance between bottom gem and Readout plane is 3 mms. Most important advantage of triple GEM configuration with respect to single GEM is high gain with low discharge probability . In order to reach desired effective gain, you should apply very high voltage to single GEM. However in this configuration, by applying less voltage to the GEMs, desired effective gain can be reached. Low voltage causes low discharge probability.

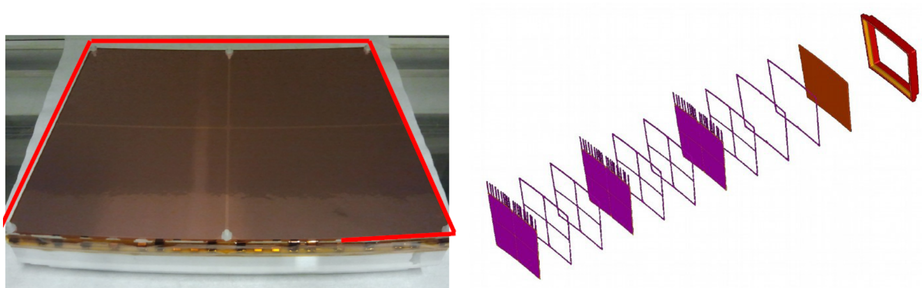

Figure 5: GEM Module

There are thin ceramic mounting grids between GEMs and between bottom GEM and Readout plane. Using this type of grids is good for the flatness. Because There is no electric field outside of the module, a field shaping wire encircles the module to get more stable electric field.

1.3 Charge Transfer and Amplification

Charge collection efficiency(C), gain(G) and charge extraction efficiency(X) are called as a charge transfer coefficients. Effective gain of a GEM is written as the product of these charge transfer coefficients. Geff=C.G.X As illustrated in figure (6), charge collection efficiency is described as the ratio of electrons collected into the hole.

$$C = N_{collected}/N_{start} \tag{2}$$

where Ncollected is number of electrons collected into hole and Nstart is electrons at the beginning. Gain is the electron amplification in the hole. Charge extraction efficiency is percentage of electrons that are able to leave the hole without being collected onto lower surface of the GEM. It can be described as follows

$$X = N_{extracted}/N_{produced} \tag{3}$$

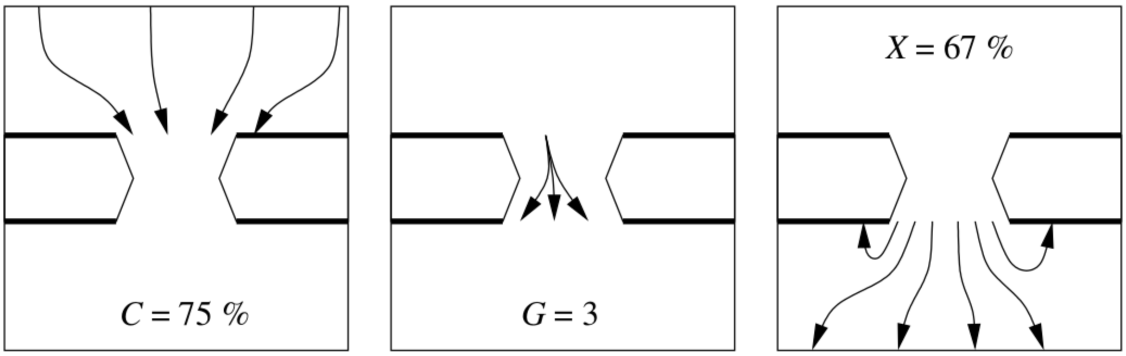

Figure 6: Charge Transfer Coefficients

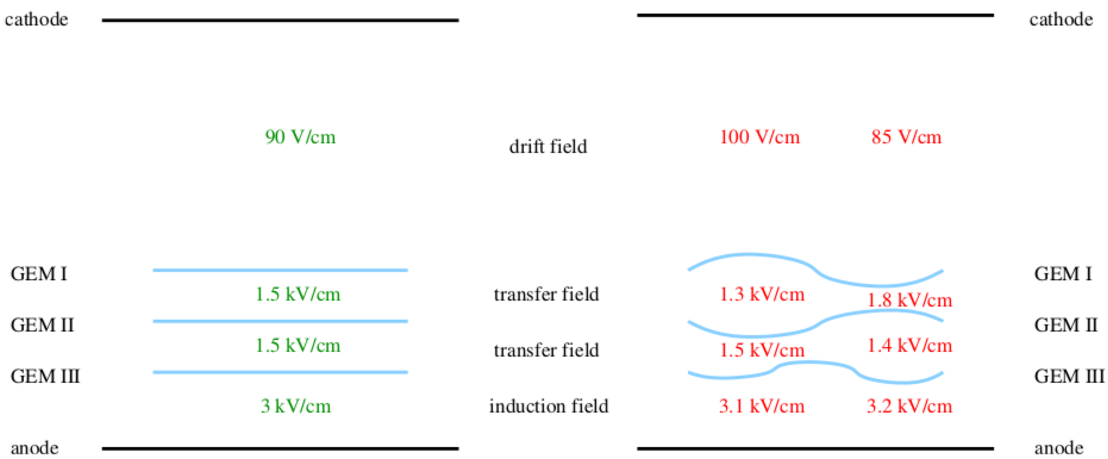

Figure 7: Effect of bending of GEMs on the local fields

Gain depends on the field inside the GEM holes. Field inside the GEM holes depends on GEM voltage, two geometry dependent parameters (a and b), field above and below the GEM. It can be calculated as follows;

$$E_{hole} = a.U_{GEM} + b.(E_{top} + E_{bottom}) \tag{4}$$

For the standart CERN GEMs $a = 142.9cm^{-1}$ and b=0.062. Main motivation of this project is the dependence of Gain on the fields above and below the GEMs.

2 Measurement

Measurement setup is composed of xy table for motion control and laser displacement sensor for profile measurement of GEMs. In order to get GEM profiles, it is needed to know bendings x-y-z coordinates (z for vertical measurements). Because of that reason, first laser and xy table must be Synchronized and for this purpose, a labview program is used. Labview program for motion control was ready and labview subprogram for the taking data from the laser is implemented to xy table labview program.

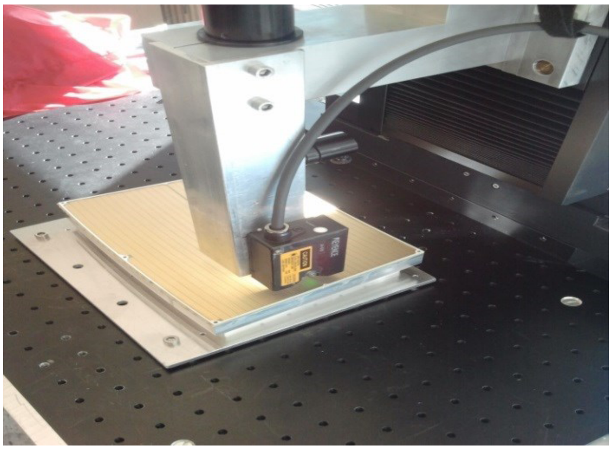

Figure 8: Measurement Setup

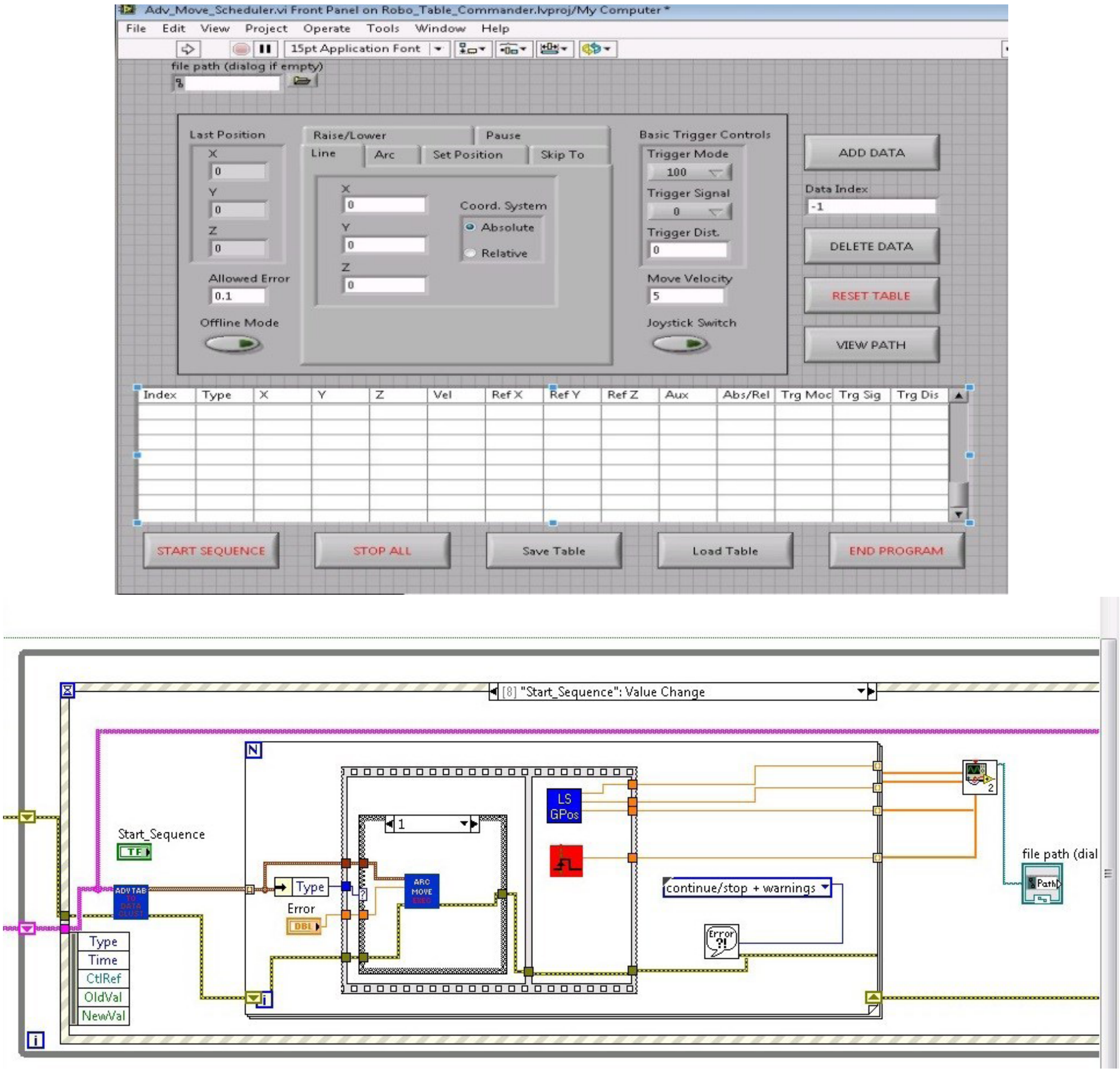

Figure 9: Labview Program for xy table

The labview program above, takes the scanning coordinates from xml file and automates the xy table. After implementation, program takes data from the laser, takes coordinates from the xy table then writes them to the txt file.

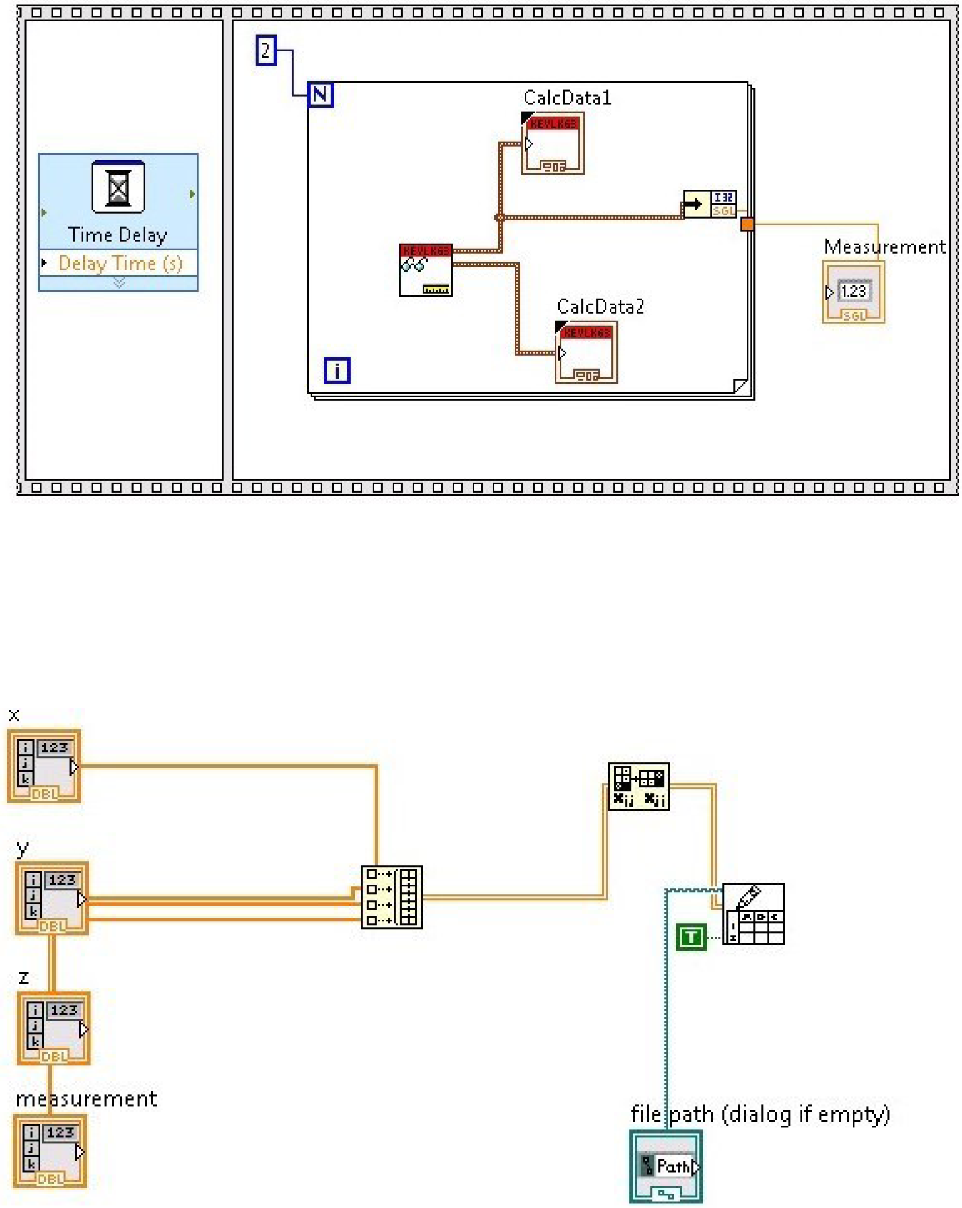

Figure 10: Labview sub-programs for laser driver

In the labarotory ,every 5 mm both in x and y coordinate of 3 GEMs and readout plane was scanned,The triple GEM stack fixed to air pressure table by screws.We measured first GEM and removed the GEM from the module and measured the next. By this method we measured 3 GEMs and readout plane.

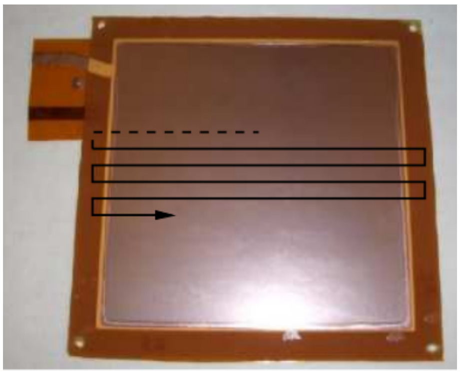

Figure 11: Illustration of the laser on the GEM surface

2.1 GEM Profiles

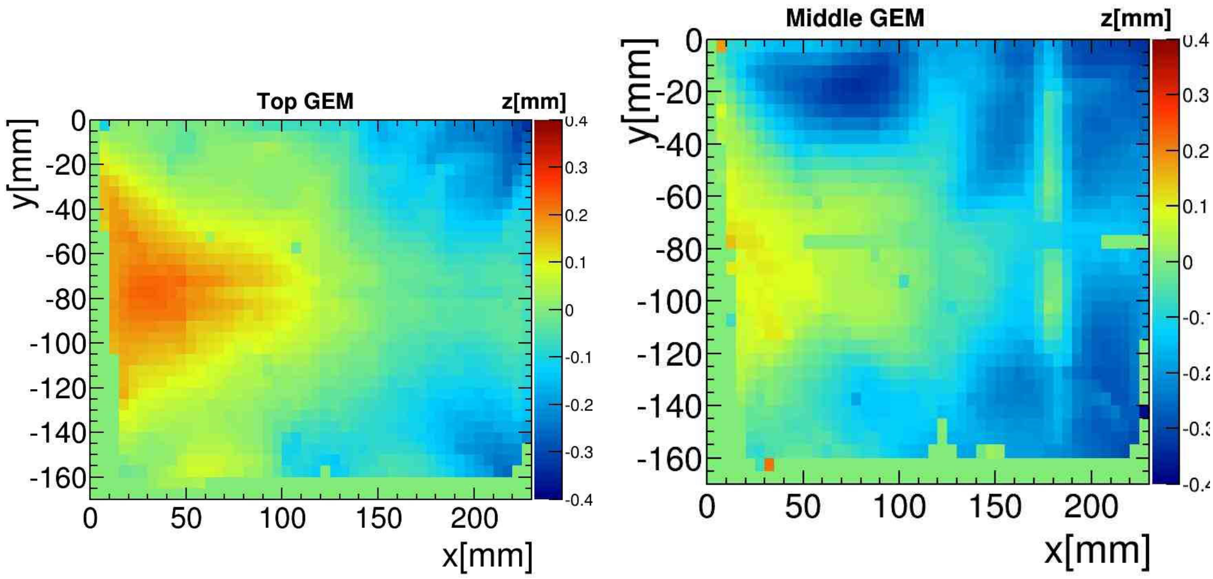

Figure 12: Top and middle GEM Profiles

Top GEM and middle GEM profiles are shown in figure (12). These histograms are acquired from txt files that is written by Labview program by Root framework. As you see from the figures, colors shift to blue from left to right. Because of that reason, reference plane must be used and readout plane used for this purpose.

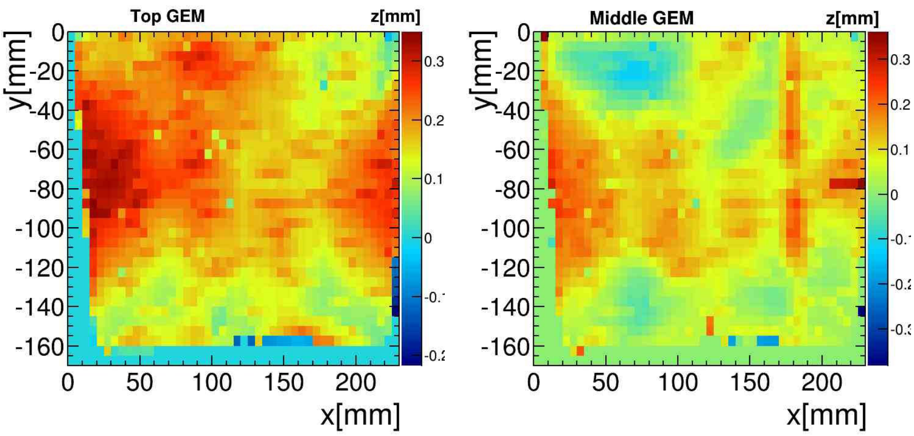

Figure 13: Top and middle GEM Profiles with respect to readout plane

When reference plane is used figure (13), more stable picture is gotten. Maximum bendings of the GEMs are about 0.3mms. As a result, GEMs are quite flat. Parametrisation of Charge Transfer Beyond the GEM profiles, charge transfer coefficients must be parametrized. In this study parameters of collection efficiency, single GEM gain, extraction efficieny and parallel plate amplification are found.

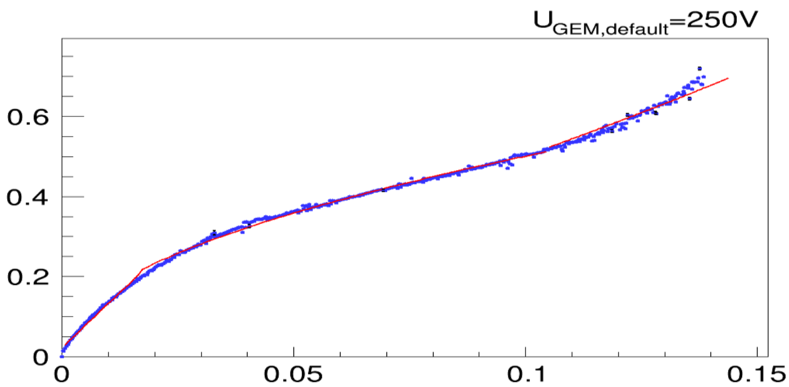

Figure 14: Electron extraction efficiency

The measurement of the electron extraction efficiency is fitted to function. The exponential increase after 0.105 field ratio is caused by the parallel multipication in the space between the third GEM and anode. r,s,g,y,e and z are free parameters. For the parametrisation,the extraction efficiency function is multiplied with the term for the parallel plate gain, and it fitted to the measured data.

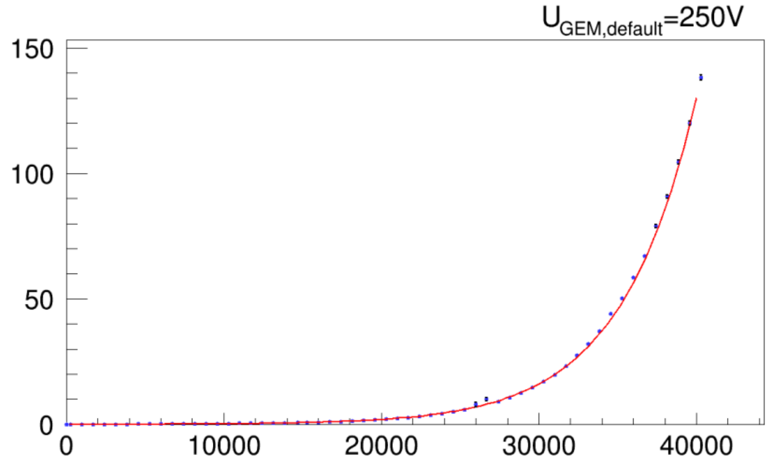

Figure 15: Single GEM Gain

Function of a single GEM gain depend on U_{GEM}, α and β is known as;

$G(U_{GEM}) = \beta.\exp(\alpha \mathrm{U}_{GEM})$.

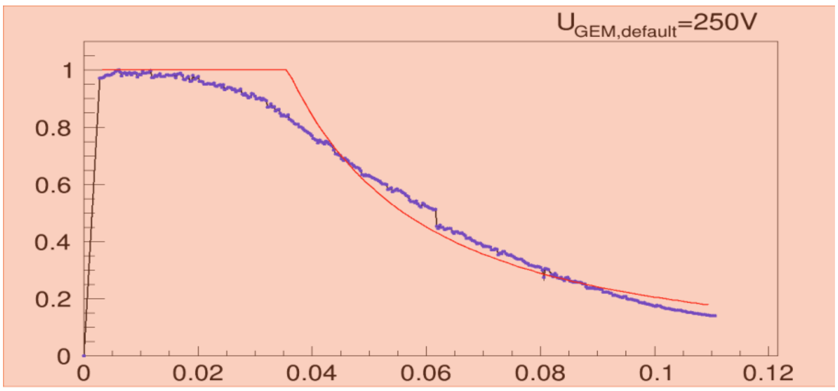

Figure 16: Electron Collection Efficiency

Function electron collection efficiency can be described as follows ;

$$C = \begin{cases} 1 & \text{for } \dfrac{E_{ext}}{E_{hole}} \leq r^{1/s} \\ \mathrm{r} \cdot (E_{ext}/E_{hole})^{-s} & \text{for } \dfrac{E_{ext}}{E_{hole}} > r^{1/s} \end{cases}$$

where r and s are free parameters. As it is seen from the figure (16) the fit is not very well. However it is good enough to get rough estimation for the effective gain of a triple GEM stack.

	250V	260V	270V	280V	Mean	Standard Deviation
Beta	0.0312247	0.0310943	0.0259376	0.021386	0.02741	0.004711070
Alpha	0.000208387	0.000208025	0.000211867	0.000215629	0.00021	0.000003552
r_ext	0.139449	0.144809	0.150007	0.163887	0.14954	0.010492301
s_ext	0.48412	0.40850	0.42449	0.431632	0.43718	0.032749985
y	0.000994528	0.00359905	0.0011231	0.00224	0.00199	0.001209895
g	0.0337799	0.0634269	0.0258437	0.0373367	0.04010	0.016278470
T	0.0905747	0.0772543	0.0757770	0.0813036	0.08123	0.006655078
e	3.10411	4.94477	5.08957	5.10000	4.55961	0.972917850
z	3750.34	3653.42	3331.01	3071.71	3451.62	310.287639994
r_ecol	0.00591861	0.00448232	0.00215495	0.00178115	0.00358	0.001962128
s_ecol	1.54011	1.66225	1.93316	1.95000	1.77138	0.202873559

Figure 17: List of Free Parameters

Parameters for 250V, 260V,270V and 280V is shown above. Parameters are voltage independent and there are small deviations.

2.2 Effective Gain

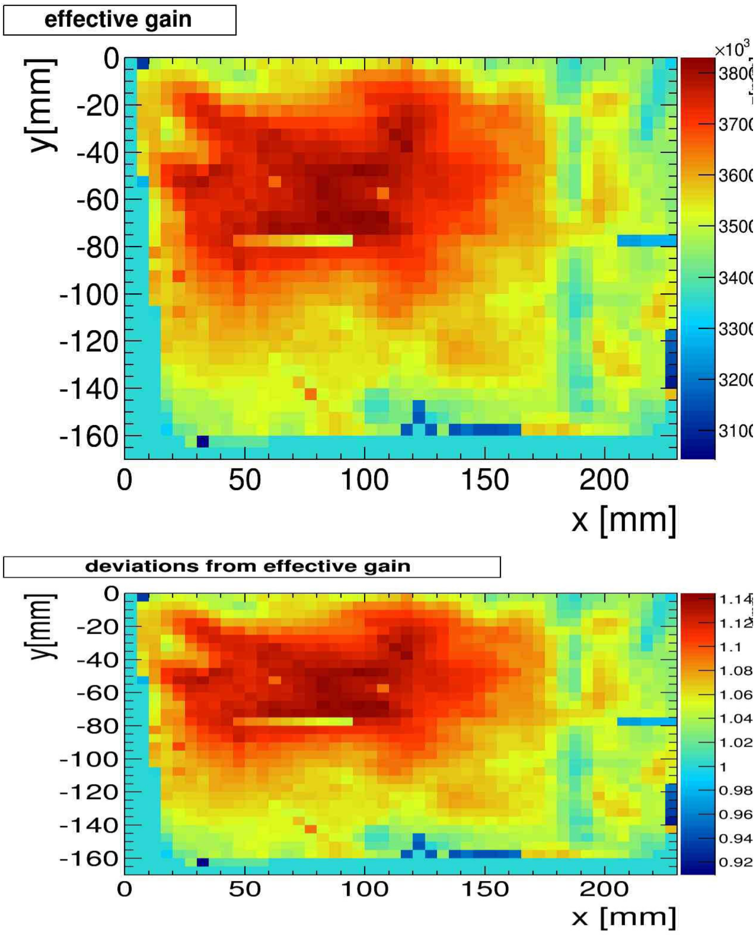

Figure 18: Effective Gain

By using GEM profiles and free parameters, Effective Gain map of the GEM module is acquired. As it is seen from the figure(18), effective gain is almost homogenoous. Homogenety of the GEM module is important for the measuring energy lost of the particle.When we are scanning the GEMs at some point we took data from grid,

3 Conclusion

In these summer project, Laser Measurement device and xy table are synchronized by Labview programing language. Surface profiles of GEMs and readout plane are measured. Parameters for gain calculation for the used gas are found. With the parameterization and the profile measurmentseffective gain of triple GEM module is simulated .

4 Bibliography

References

[1] L. Hallermann, Analysis of GEM Proporties and Development of a GEM Support Structure for the ILD Time Projection Chamber, DESY-Thesis-2010-015, April 2010