Mechanical Properties of a GRID GEM System

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Abstract:

I worked in the FLC_TPC group and my supervisor was Klaus Dehmelt. In my group a new support structure for the GEMs has been developed: a ceramics structure. During the Summer Student Program my work consisted in investigate if in a GRID GEM system in an upright position there were significant bending and compare this preliminary result with the same measurements conducted on a GRP framed GEM. The idea was to investigate this surface with a laser displacement sensor. In order to do this, first I had to create the proper program that could control a moving table to which the measuring head of the laser was fixed. After that, I reconstructed these surface and, as a preliminary result, I can assert that the distribution profile of a GRID GEM is more uniform than the profile of a GRP framed GEM. It verify the efficiency of the ceramics structure.

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1. Introduction

§ 1.1 Time Projection Chamber

For the International Linear Collider (ILD) a Time Projection Chamber (TPC) will be used as main tracking detector. A TPC is a gas filled cylinder as illustrated in figure 1

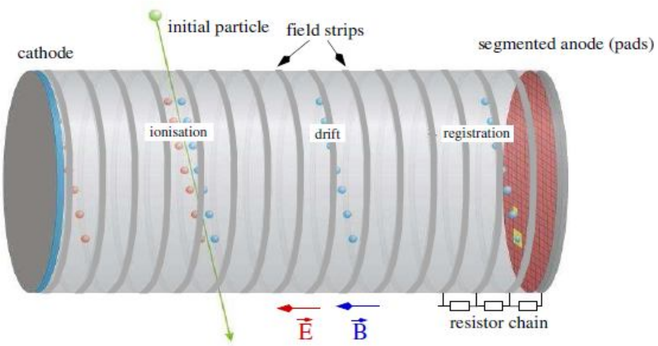


Figure 1: Time projection chamber principle. [L. Hallermann]

It is used for tracking of charged particle and is based on ionization principles. Both electric and magnetic fields have to be parallel in order to focus the electrons on the drift direction. In order to provide an electric field in the drift region, on the cathode a negative high voltage of the order of kV is applied. A charge particle passing the chamber ionizes the gas inside the volume and the resulting primary electrons drift in the electric field towards the anode. Since a direct detection of these electron clouds is not possible due to the small amount of charge, an amplification stage is installed in front of the anode. The anode is electrically equipped in such a way that returns a two dimensional projection of the track. Coordinate z is reconstructed by means of drift time measurements.

§ 1.2 Amplification

The drifting primary electrons have to be amplified before they can be readout at the anode plane. Conventionally charge amplification with Multi-Wire Proportional Chamber (MWPC) shows too bended electric field lines near the wire, as shown in figure 2 and because of that some electrons can be bent away due to the Lorentz force.

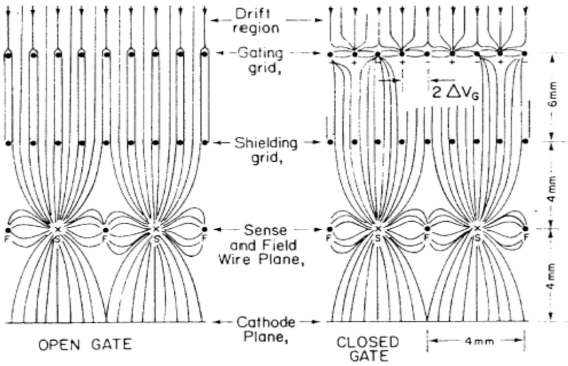


Figure 2 Conventionally charge amplification via MWPC

This problem can be solved minimizing the distance in between the two electric field sources.

§ 1.3 Gas Electron Multiplier

Using Micro Pattern Gas Detectors (MPGD) as amplification devices we reach micrometrical distances. A Gas Electron Multiplier (GEM) belong to this family of devices. The Gem consists usually of a copper plated polyimide substrate with double conical holes etched on the surface and in these holes amplification takes place. With these devices, the distance is reduced from 2mm to 50micron, so the field lines are negligibly bended, as shown in figure 3 and the Lorentz force cannot bend electrons away.

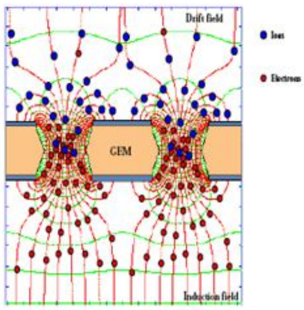


Figure 3 Simulation of electric field Lines in a MPGD

Moreover the density of the electric field lines inside the holes is high, hence we have a gain per GEM up to 10^3. As we can stack GEM, the total effective gain of the stack is definitely high. But the gain is proportional to the distance. So it is very important that the distance in between two GEMs remain constant, as shown in the ideal situation below

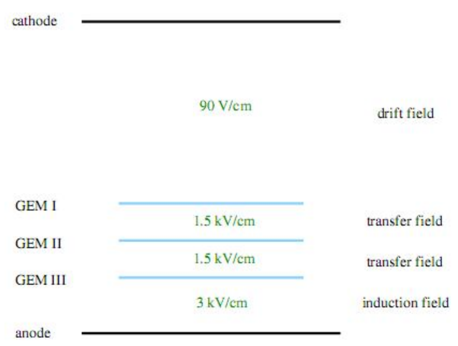


Figura 4 Constant distance determins constant local field

§ 1.4 Support Structure

Each GEM need a support structure in order to be mounted in the TPC in an upright position. My group noticed that with the traditional Glass fiber Reinforced Plastic (GRP) frame, the GEM sags in the middle, as shown in figure 4

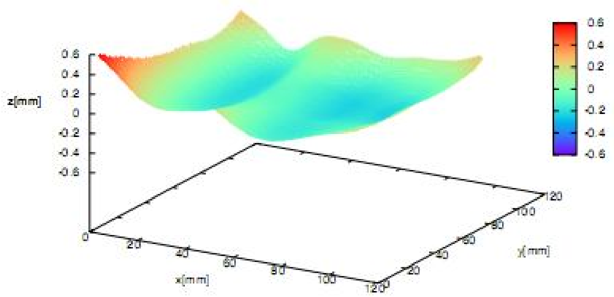


Figure 5 Measured GEM profile [L. Hallermann]

As a result, the electric field in between two GEM is not constant anymore, as shown in the simulation below

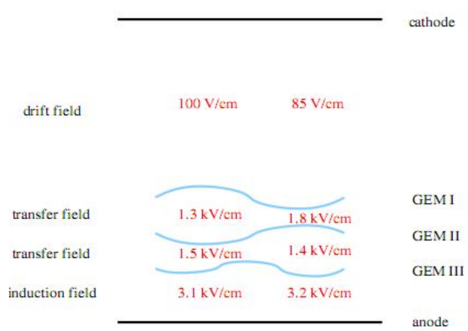


Figura 6 The distances between the bent GEMs determined the local fields. [L. Hallermann]

Thus, my group developed a new support structure.

§ 1.5 Ceramics Structure

This structure is shown in figure 6 and is a ceramics frame with a grid. As This structure is contemporaneously a support structure and a spacer in-between two GEMs in the stack, we are going to create a system where we mount a grid, than a GEM, than again a grid than a GEM and so on. This is the reason why we call it GRID GEM system. In the TPC of ILC it will be mounted in an upright position.

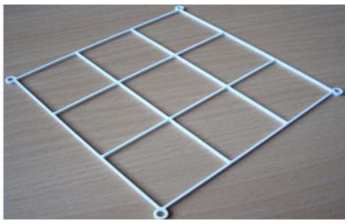


Figura 7 Ceramics grid for GEM mounting [L. Hallermann]

2. Aim

The aim was to prove if with ceramics grid the distance in between two GEMs of the stack remain constant and than compare these results to a GRP framed GEM in the same position (my group tested GRP framed GEMs in an horizontal position).

3. Methods

To invesitgate if really, with this new support structure, the distance remain constant, I had to put the grid gem system in an upright and investigate this surface by scanning it with a laser displacement sensor, whose misuring head is fixed while the movable table is moving on the yz and zy axes.

§3.1 Measuring Device: Laser Displacement Sensor

The laser has a resolution of 1 micron and a reference distance of 10mm, with a measurement range of ± 1mm. It gives in output the distance between its sensor and the surface thanks to the triangulation method. The laser beam is emitted on the top of the laser, as pointed in picture a) and is projected on the surface of interest. The nearer is the surface, the bigger is the entrance angle, as you can see in picture b). Via the position of the reflected laser light on the sensor, the entrance angle and the distance are determined.

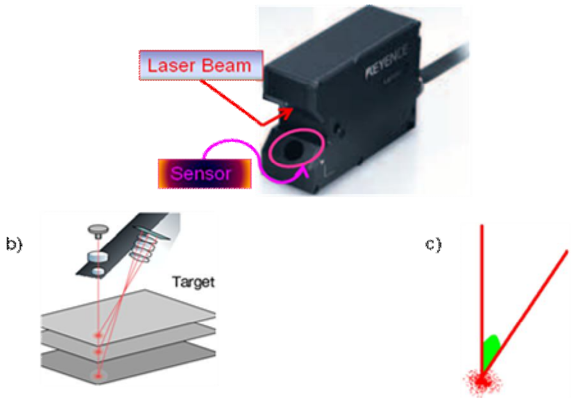


Figure 8 Sketch of the measurement principle of the displacement sensor

§ 3.2 My Workbench

My starting instrumentation consisted of a moving table and a laser. The table can move on 3 independent axes with a sub-micrometrical resolution. It can be moved either with a joystick or with a software. As we need very precise measurements we cannot use the joystick. So we needed a software. But the problem was that the included software allowed only meanders on a horizontal plane. So first I had to create the proper program to allow movements on a vertical plane (vertical meanders are sketch in figure 8 with dotted arrows). To do this, I used the software LabVIEW 2009, which is a graphical programming language.

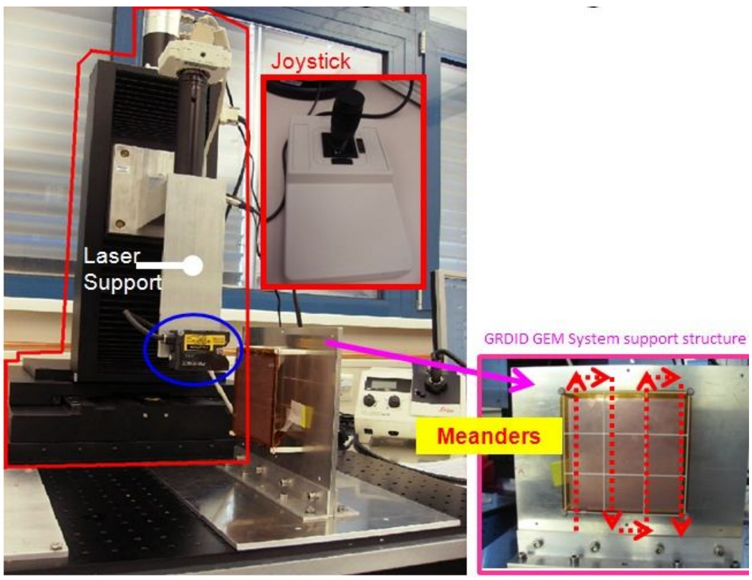


Figure 9 My whole instrumentation

I also designed the laser support and the GRID GEM system support structure.

§ 3.2 Developed Programs

This is Meander.Vi, the program I developed to do meanders in any of the independent measurements we can do. With this program I can set the movement parameters : choose one of the 3 coordinate planes, the speed of movement, the number of meanders and the distance in between.

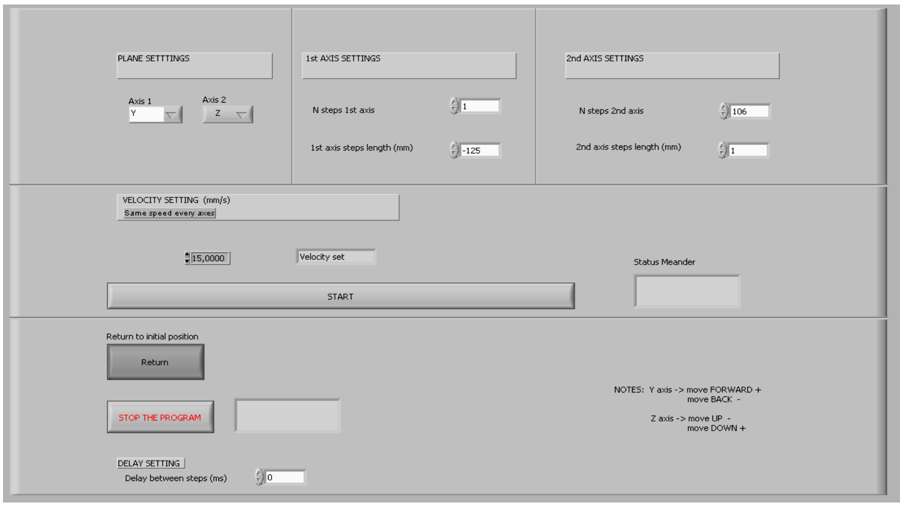


Figure 10 Front Panel of Meander.vi

As we need to connect to the table before to run meander.vi, I developed the next program called New_main panel.vi from where I can control my whole instrumentation.

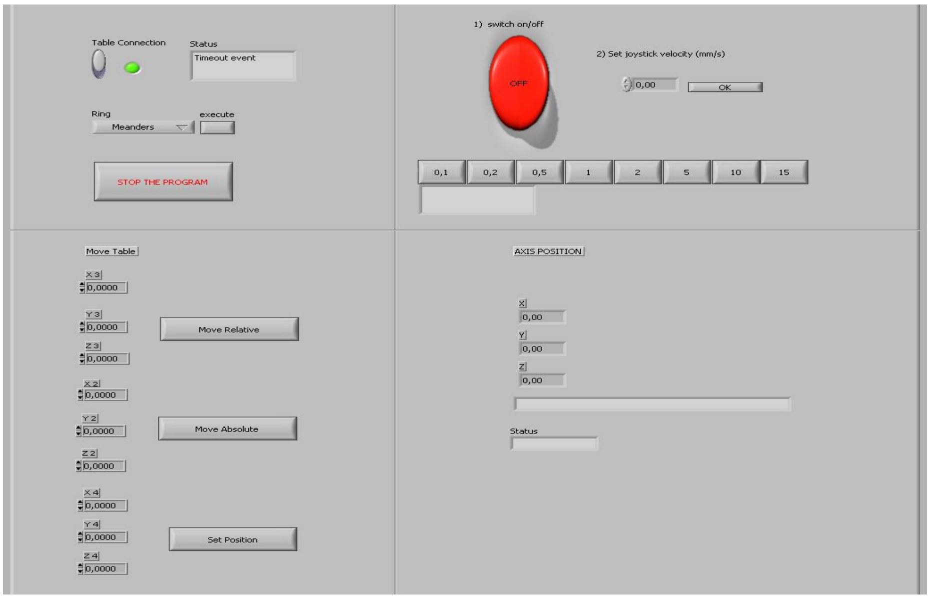


Figure 11 Front Panel of New_main panel.vi

As mentioned short before, it connects and disconnect to the table, switch the joystick on and off, set the speed of movement, and moreover, hence it can be further extended. With the botton „table connection“ we can connect or disconnect to the table, with the red botton we can switch on and switch off the joystick. Moreover we can set the moving speed with either preset speeds or with the control ring. The program return also the axes position. It gives also the possibility to set a position, move relative or move absolute. Moreover it allow me to call other programs using the menu ring. In figure 10, for example, I can call the meander.vi we have seen previously and run it pushing the execute botton.

What is very important with this program is that I created it in such a way that can be further extended with any program that will be needed because, in the menu ring, we can add whatever program and run it by pushing the execute botton.

§ 3.3 Profile Acquisition

I set the frequency of the laser at 20 Hz and I moved the table at a speed of 15 mm/s doing 1 step on the first axis and steps of 1mm on the second axis. The lenght of the former and the number of the latter must be choosen in such a way that the laser can identify a row, as explain further. I set a measuring average of 256.

I acquire profiles doing meanders on the yz axis and than on the zy axis. They can be also overlapped, as I fixed a coincidence point on the copper plate of coordinate (0,0,0). By moving absolute from this position I set an offset on y (0,Y,0) to do yz meander and that an offset on z (0,0,Z) to do zy meander. We had to set an offset because to reconstruct the surface profile, we collect rows of data taken by the laser and than we put them all together, and row by row we trace the whole surface. To identify the beginning and the end of the row we make use of the fact that the laser displays a –ffff value when is out of range. I scanned the surface behind a grid GEM system and than I turn the system 180 degrees to scan the surface behind. I also analyzed a GRP framed GEM in an upright position. The scatter plot below represents data taken behind a stack, where we have the ceramics support.

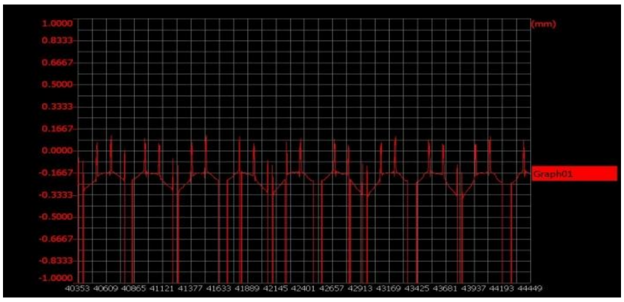


Figure 12 Scatter plot LK-Navigator

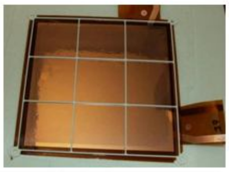
Each peak represents a data row whereas the sharper peaks represent the data taken on the ceramic structure.

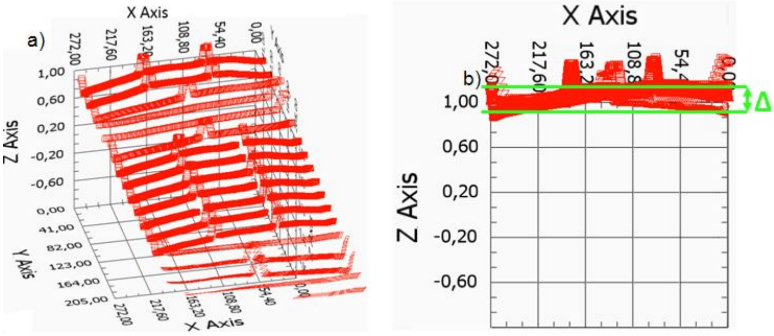
4. Preliminary results

§ 4.1 First Elaboration Profiles

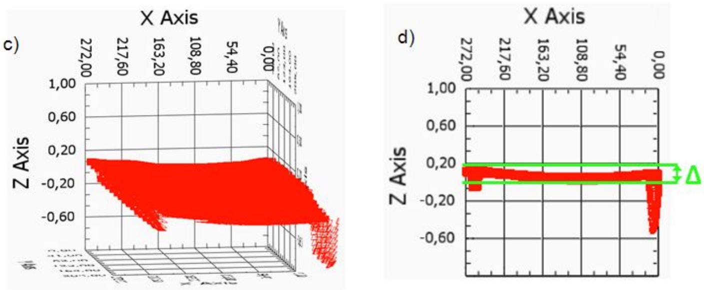
I processed these data with another labVIEW program that does a first elaboration of the surface in order to have a distribution profile. Some of them are shown below:

Elaboration 1: BEHIND the GRID GEM system

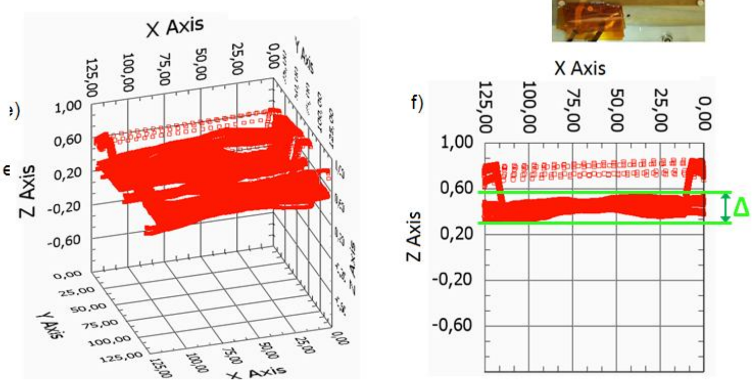




Elaboration 2: IN FRONT of the GRID GEM system



Elaboration 3: GRP framed GEM



§ 4.2 Considerations

i) Elaboration number 1 reports data taken behind the grid GEM system where we have the ceramic structure whereas the second elaboration reports data taken on the side without this structure.

In number 1 ceramics structure can be clearly seen. Concerning number 2 we can see that is rahter flat, as the peak to peak distance (Δ) is about 100 micron.

ii) The peak to peak distance (Δ) with the GRP GEM is bigger compared to the pk-pk distance in elaboration 1 and 2. Infact here is about 300 micron.

iii) Note that elaboration 2 and 1 are symmetric over the x axis, that is just what we expected as we have turned the system 180 degrees.

iv) In the xz projection of elaboration 2 we can clearly see a bending. This is due tot he fact that the only the ceramics frame is glued on the top oft he GEM, whereas the grid is not glued and so cannot keep up the GEM surface.

During further analysis I will neglect as all those points that correspond to the ceramics structure as other spikes that does not represent the surface of interest. For example, the two spikes in elaboration 2 are in the border of the back GEM.

§ 4.3 Conclusion

The maximum variation in GRID GEM is 100 micron, whereas with the GRP framed GEM is 300 micron. Hence, as a preliminary resutl, I can assert that ceramics grid profile has a more uniform distribution than GRP profile.

5. Outlook

Hereinafter I want to measure the influence of an applied high voltage and perform more detailed analysis of the surface structure and its influence on gain.

6. Reference

"Analysis of GEM Properties and Development of a GEM Support Structure for the ILD Time Projection Chamber", L. Hallermann

7. Acknowledgments

Thanks to Klaus Dehmelt, Stefano Caiazza, Lea Hallermann , Christoph Rosemann, Oliver Shäfer , Robert Volkenborn and Franziska Hegner.