Undergraduate Research:
Analysis of the FNAL Beam Test Results

Author: Shreeya Khanal
Florida Institute of Technology
Melbourne, FL, United States

In order to understand something as big as the universe, it is crucial to master the smallest particles first. Particle physics has been one of the most popular fields of research in the past 50 years. In such research process, particle detectors have played major role in fulfilling Physicists wish to study more about the smallest bits of matter. Among many, one of the detectors is the Gaseous Electron Multiplier (GEM) detector. Total 9 runs of experiment was run with a 10 x 10 cm GEM detector and the data was recorded. After data recording and processing, the results were obtained in the form of TTrees, the output files in the ROOT software system. The analysis of those output TTrees was achieved by comparing the values of different variables such as the number of hits, the total cluster charge and the Barycentric position. They were compared by applying the cut function in ROOT. Among various detectors, the main focus was on the one with 10 x 10 ZZ detector tilted 30^0 from the beam. The results obtained after applying the cuts, were easier to analyze.

1. Introduction

The bottom line of performing the experiment with this detector was to check if it works well and see the hit distribution, the charge distribution, and the positions of the. It is important to achieve knowledge of a small 10 x 10 cm if it detector works successfully, then similar design and methods of this smaller detector could be used to make bigger detectors. Hence, development of small detectors is very important so that progress could be made towards the bigger ones.

After the experimenting and data processing for this detector, the results were stored in the cluster in the form of TTrees. The focus of my analysis was mainly the 10 x 10 cm ZZ detector tilted in 30^0 with the beam. It was tested with total 9 runs; each run was conducted in 50 Volts more than the previous one. Within the 9 runs, the main focus went on the analysis of three sub-detectors within it—ETA05, ZZ.A (zigzag A) and ZZ.B (zigzag B). Inside these three were the basic data or the output which are the leaves of TTrees, which included the number of hits, the total cluster charge and the Barycentric position. The reason for these three sectors of output being the main focus is because they are the major part of the data, and it is their behavior that is being studied. Hence, questions such as what is the behavior of the charge and position of the particles in a 10 x 10 cm ZZ detector which is inclined by 30^0 from the beam and do the results match the hypothesis?

2. Materials and Methods

In order to achieve answers to the questions mentioned above, the main method of analysis that was used was the cut function in the ROOT software. This function helped in analysis by letting to choose the range in which the data values were most interesting for one variable and then, to compare that specific range of data of that one variable to the other variable.

Following is the list of Tree, its branches and the leaves that were primary focus of the analysis:

2.1 The Main Detector

- 10 X 10 ZZ detector angled 30^0 with the beam.

2.2 Number of runs (TTree contents):

- TTree_run001_HVScan_UVa3800_25GeV_20131014_344am.root

- TTree_run002_HVScan_UVa3850_25GeV_20131014_413am.root
- TTree_run003_HVScan_UVa3900_25GeV_20131014_0442am.root
- TTree_run004_HVScan_UVa3950_25GeV_20131014_0504am.root
- TTree_run005_HVScan_UVa4000_25GeV_20131014_0530am.root
- TTree_run006_HVScan_UVa4050_25GeV_20131014_0552am.root
- TTree_run007_HVScan_UVa4100_25GeV_20131014_0617am.root
- TTree_run008_HVScan_UVa4150_25GeV_20131014_0639am.root
- TTree_run009_HVScan_UVa4200_25GeV_20131014_0701am.root

2.3 Among these 9 runs, three of these sub-detectors were studied.

- SRSCluster.CMSZZ.ETA05;1
- SRSCluster.ZZ30A.ZZ01M;1
- SRSCluster.ZZ30B.ZZ02S;1

In between these branches, there were total of 12 leaves among which the part of focus were only on the number of hits (fNbHits), the total charge of the cluster (fTotalClusterCharge) and the Barycentric Position (fBarycentricPos).

The representation of each of the leaves is described below:

- fNbHits: number of strips

- fTotalClusterCharge (formerly called "fcharges"): This is the charge spectrum from ever strip in every cluster. Again, this is different from the normal histo output because it has no cuts
- fBarycentricPos (formerly called "fcharges"): This is the barycentric position of each cluster -- with no cuts applied

2.4 The script used to achieve this is mentioned below.

Step 1: root [0] TFile* f=new TFile (“TreeName”) *{this will open that Tree file}*
Step 2: root [1] f - > ls( ) *{this will list all the branches inside the Tree}*
Step 3: root [2] TTree* user-defined-name = (TTree*) f - > Get (“pick one branch that is to be analyzed”) *{this will get the branch file that is wished to be analyzed}*
Step 4: root [3] user-defined-name - > Draw (“variable1”, “variable2 >= (limit number) && variable2 <= (limit number)” *{this will limit or cut the variable value to the one that is chosen for analysis purposes}*

3. Results

The results seemed to match the physical concepts when analyzed. The sector where cuts were applied was the number of hits, also known as the number of strips. The cuts were applied in specific regions where there was the highest number of entries. In such active region, where the number of entries was highest, it was predicted that the charge would also be the highest.
Now in context of position, wherever the charge deposits are found, that would be the position in the data. Hence, more the charge distribution is, narrower the position in that charge distribution area. The following TTree output with cuts were used to verify the hypothesis.

(NOTE: All the y-axes represent the number of entries. X-axis represents the total ADC Count for the charge graphs, and again, the x-axis represents the actual position for position graphs in mm)

3.1 Run 1, ETA05 (3800 Volts)

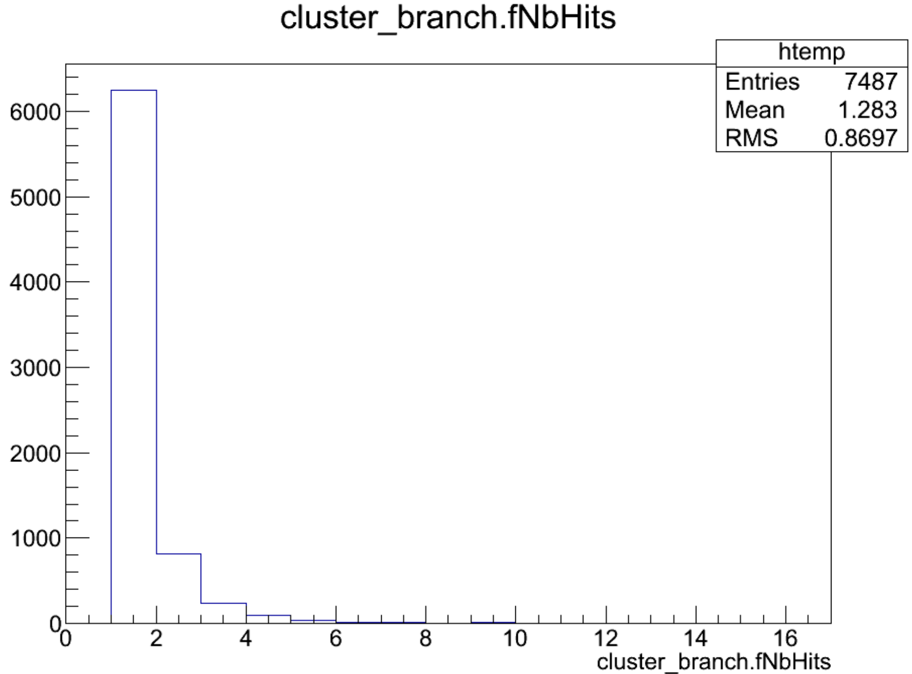

Figure 1) Total number of strips vs. entries for Run 1, ETA 05.

After applying cuts:

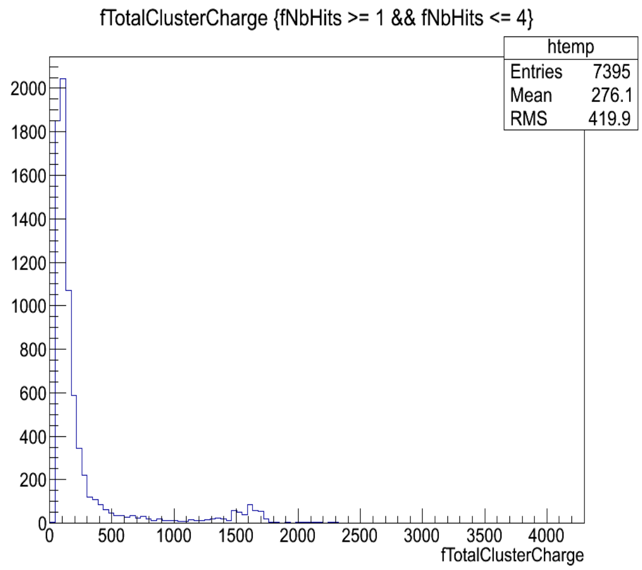

Figure 2) Figure showing the charge affected after applying cut of 1 to 4 in the number of strip.

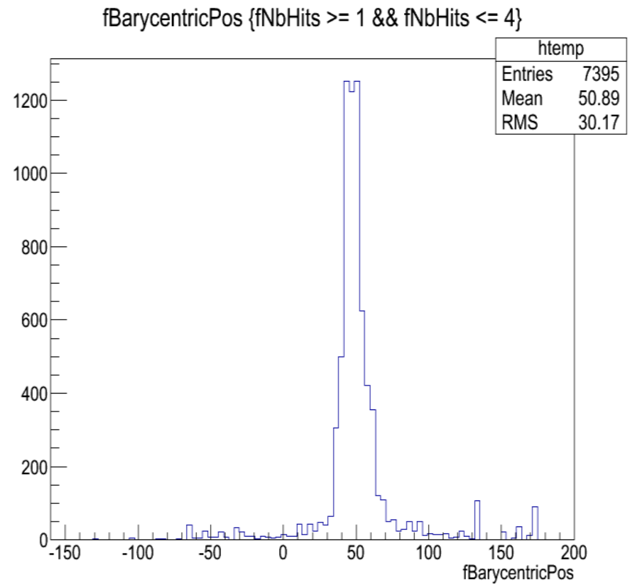

Figure 3) The position after applying cut of 1 to 4 in the number of strips.

As it can be seen from the graphs, the most probable values of both the graphs for charge and position are highest when the number of entries per strip is set to the highest, too. Hence, this does seem to qualify the hypotheses. Similarly, for all the other runs, the results were similar, except that they were conducted in a high voltage. The only significant difference that was observed was the increment in the number of entries as the voltage increased.

3.2 Run 1, ZZ. A

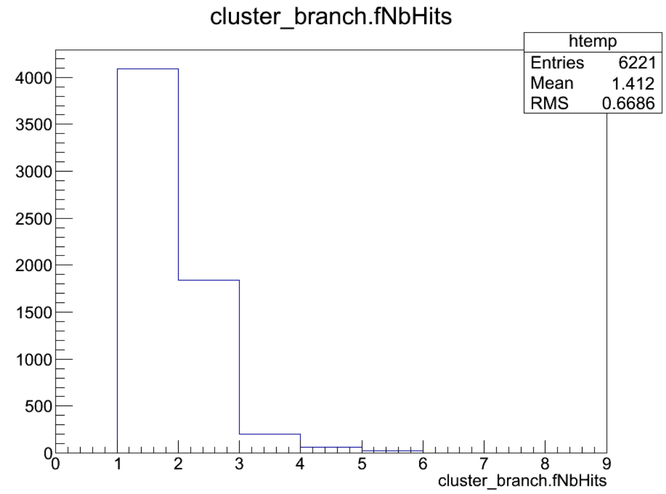

Figure 4) Number of strips for the ZZ.A

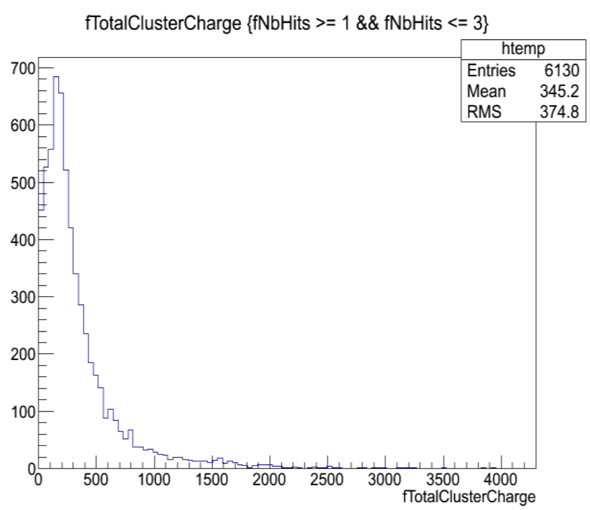

Figure 5) The total charge after cut in the number in strips.

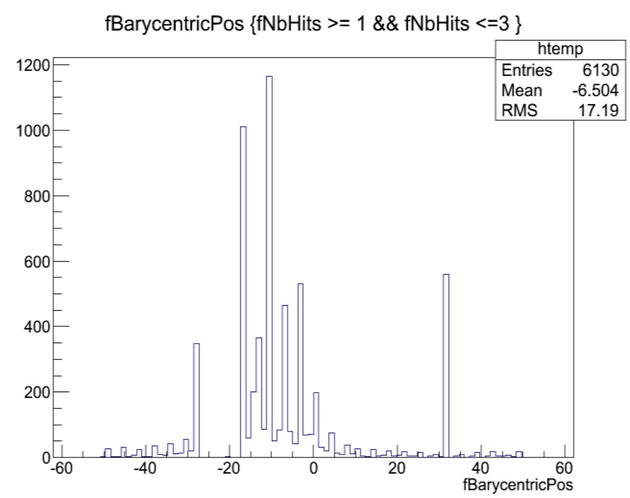

Figure 6) The position after cut in the number of Strips.

Here, as in the previous scenario, the cut has been set to the highest number of entries, and as predicted, the charge distribution is the highest for the highest number of entries. Also, the position has narrowed down than the original graph (not included); for that specific amount of peak charge, it occupied that amount narrow space. The position could also be related to the number of hits graph—whenever there has been the peak amount of entries, the position for that specific peak is always a small distribution. More the entries, broader the position distribution seems. As it can be seen in the figures above, for the cut of 1 through 4, the position distribution looks like that, but if the cut were, say, 1 to 6, the position distribution would be much broader.

3.3 Run 1, ZZ.B

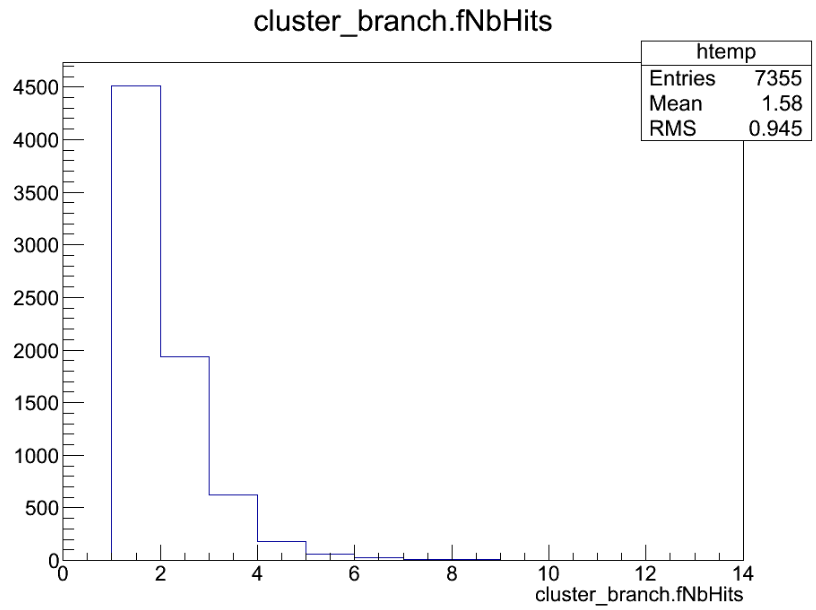

Figure 7) The number of strips for the sub-detector ZZ.B

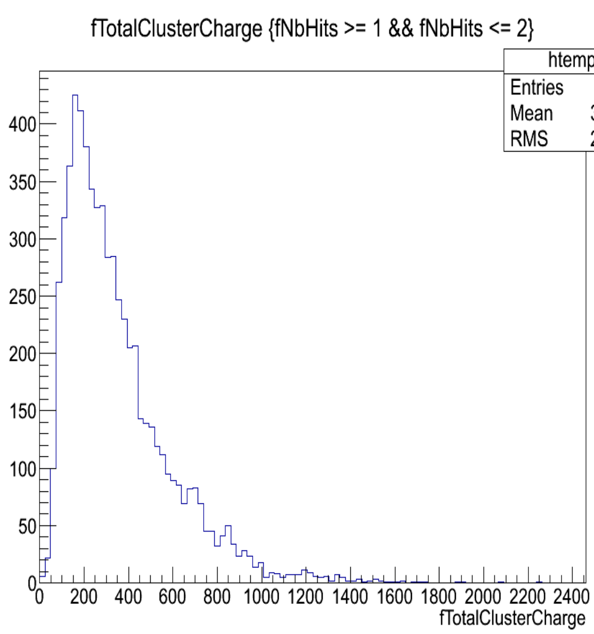

Figure 8) Total cluster charge distribution after cut.

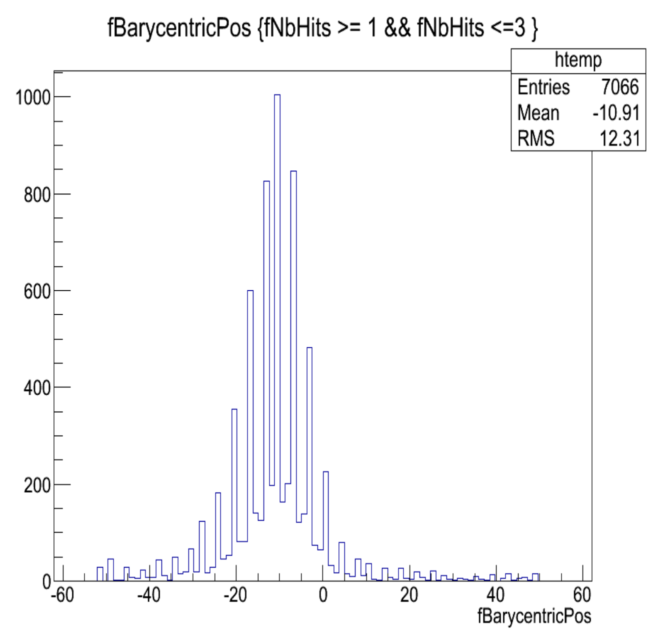

Figure 9) Position Distribution after applying cut.

The hypothesis stands correct for here as well, which says that the value of charge is higher when the number of entries is set to highest, and the position gets narrower. If the number of entries were to be set to, say, 4 to 10, then the charge distribution would have been too narrow, and the position would be broad.

Just like this one experiment analysis was for the three sub-detectors in run 1, cut function was carried out for the nine trials. Almost all of the results seemed consistent, except that the number of entries seemed increasing with increasing voltage. For example, in the following figure for run 5 which was carried out in the 4000 Volts, the number of entries has increased significantly than run 1. Almost all other aspects are similar to the hypothesis for run 1 in context of the charge distribution and position distribution.

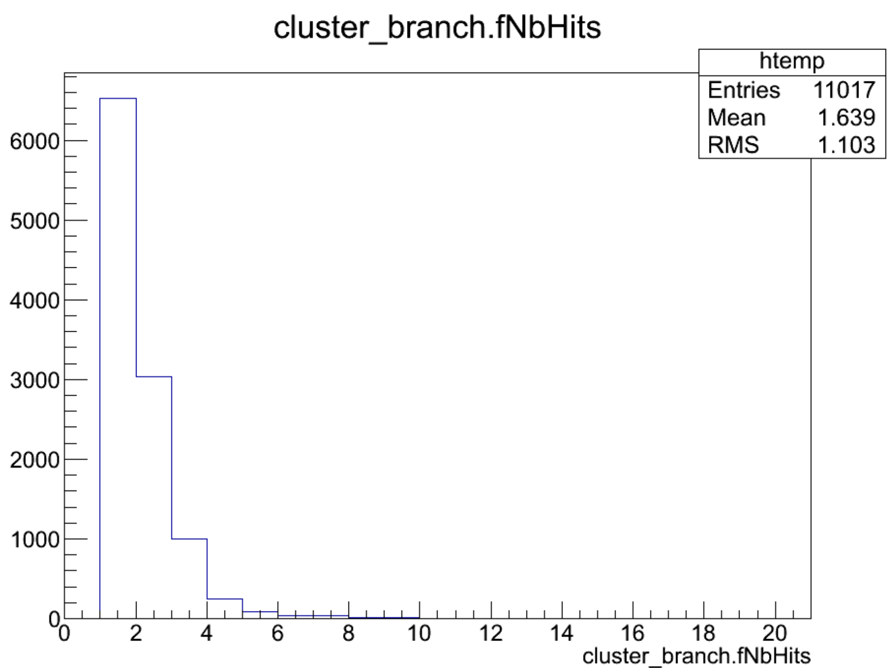

Figure 10) Figure showing the number of strips per entrees in run 5, ETA05.

For all other runs, the number of entries kept on increasing as the voltage increased.

4. Conclusion

After analyzing the outputs, the results were consistent with what was expected. Hence, it is concluded that applying cuts to the output TTrees helps in analyzing the data with the allowance to change the variables. The relationship between the number or entries per strip and position and charge is discussed and has been concluded that they are closely related. More the voltage, more the number of entries, and when a region has most number of entries, it normally has the most charge. However, most number entries occurs in a narrow region leaving the charge in the narrow place as well even if the voltage is high. The intensity of the charge might be high but the area covered by that charge is normally small. This causes the position graph to shrink even when the value of charge is high. On the other hand, when the entries are low, the charge intensity is low causing it to occupy more area, hence the position distribution seems bigger.

Even if the detailed analysis isn't presented in the paper, the basics of detectors outputs and their character has been discussed. Next semester, I plan to understand analysis better, and produce better plots with appropriate cuts.