A TPC test with varied gain

STAR Note #395

April 28, 1999

Howard Matis, David Hardtke and Howard Wieman
Lawrence Berkeley National Laboratory
Eric Hjort and Blair Stringfellow
Purdue University

The sensitivity of the STAR TPC has been measured as a function of voltage. Using a cosmic ray trigger, we have studied the behavior with The analysis of this data can be used to estimate how well the TPC can detect particles with unusual charges. A consistency test shows that the gain was set correctly.

During the October 1998 TPC cosmic ray running, several data sets were taken with adjusted anode wire voltages. These studies were taken in order to look at the efficiency and resolution as a function of the gas gain.

Experimental Setup

The gas gain can be related to the wire voltage by $Gain = G_0 e^{\alpha V}$, where V is the voltage, and G_0 and α are constants that depend on the geometry of the wire chamber and the gas properties. For the inner sector of the TPC, G_0 is 0.00137 and α is 0.01226. For the outer sector of the TPC, G_0 is 0.002820 and α is 0.00934. The nominal TPC anode wire voltages during this running period were 1150 V for the inner sector and 1400 V for the outer sector.

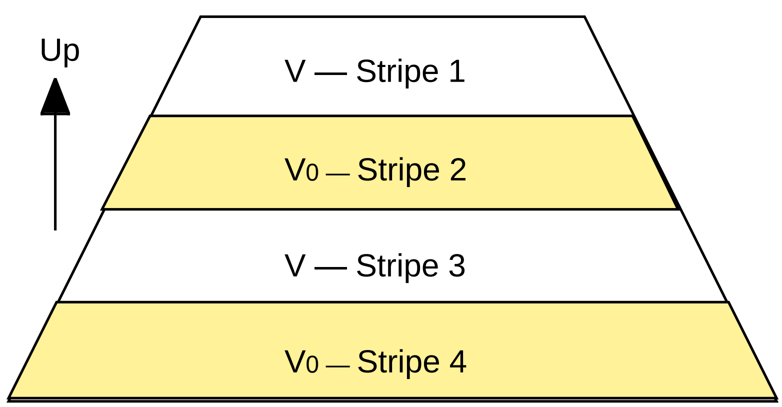

Figure 1 Arrangement of voltage stripes for the outer sector. The voltage of the shaded stripes V_0 was held constant while the other stripes were varied.

There were eight adjustable voltages for each super-sector. For the outer sector, each voltage controls 8 pad-rows (14-21,22-29,30-37,38-45). For the inner sector, the mapping between anode wires and pad-rows is not as clear. Therefore, this note will only contain analysis for the outer chamber. The arrangement of stripes for the outer sector is shown in Figure 1. The configuration of anode wire voltages used for the tests is shown in Table 1. This table shows the voltages used for the different runs.

Table 1 Voltage settings of the TPC to achieve different effective gains.

Gain of V (relative to V_0)	*Inner V_0 (Volts)*	*Inner V (Volts)*	*Outer V_0 (Volts)*	*Outer V (Volts)*
1/9	1150	977	1400	1165
4/9	1150	1086	1400	1314
2/3	1150	1118	1400	1357
4/3	1150	1172	1400	1431
16/9	1150	1194	1400	1462

The nominal voltage of the TPC was set to approximate the gain obtained from tracks with a magnetic field. As there was no magnetic field, the conclusions from this analysis are tentative.

Method of Analysis

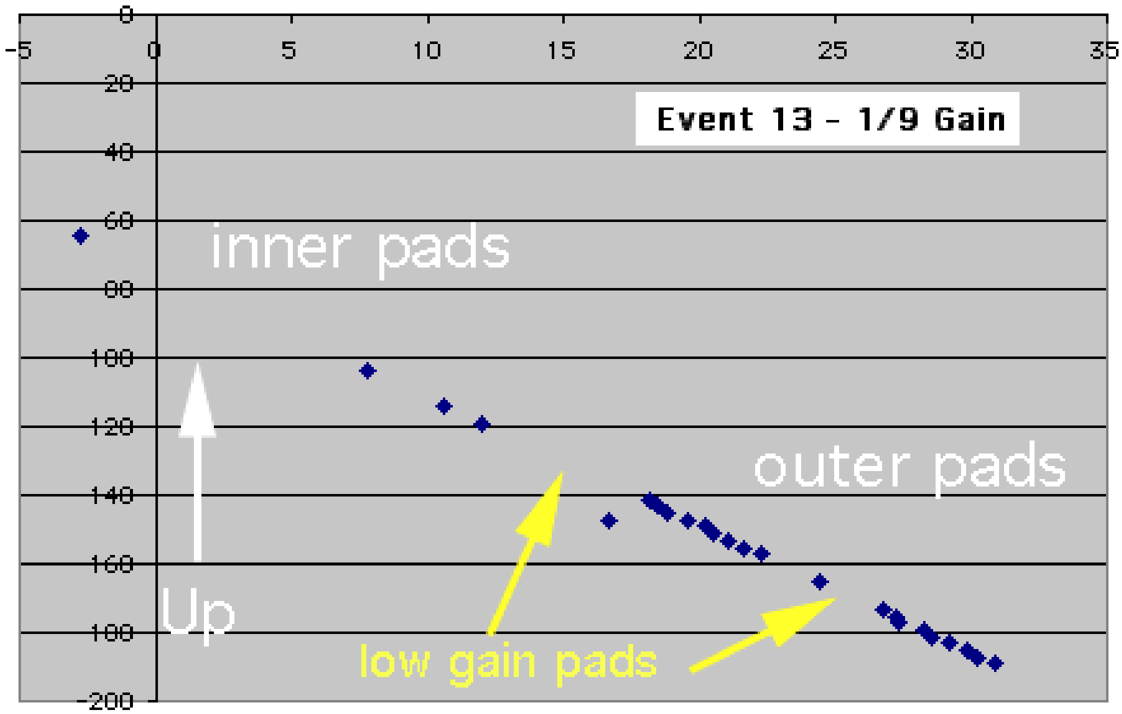

Figure 2 Plot of the x-y projection of a cosmic ray trigger. This event had a gain of 1/9. The units of this plot are in cm.

First, data taken from each gain setting were run through the STAR analysis package. Space points and their energy were first found. Then the STAR package made a straight line fit to these points and wrote the results to a separate file. This analysis was repeated with two different versions of the STAR analysis package. The second version had many significant improvements. Because of bugs in this package, not all of the data sets were analyzed for each analysis pass.

To further process the data, a TPC specific analysis program then read the file. This package used the algorithms described in the later sections. The package processed both passes of the STAR software in an identical manner.

Description of the Events

Figure 2 shows a plot of one of the events with 1/9 gain. In the second analysis pass, the tracks were checked to see if they bounded the variable gain sector strip. We demanded that a track has at least 5 hits from Stripe 2 (rows 22-28) and 5 hits from Stripe 4 (rows 39 to 45). Pad rows 29 and 38 were not included because there was a distortion on them produced by the adjacent pad, which had different voltage. If any track met these criteria for both Stripes 2 and 4, then we declared the track good. We only used tracking in the x and y direction as the constants for the z direction was not well defined.

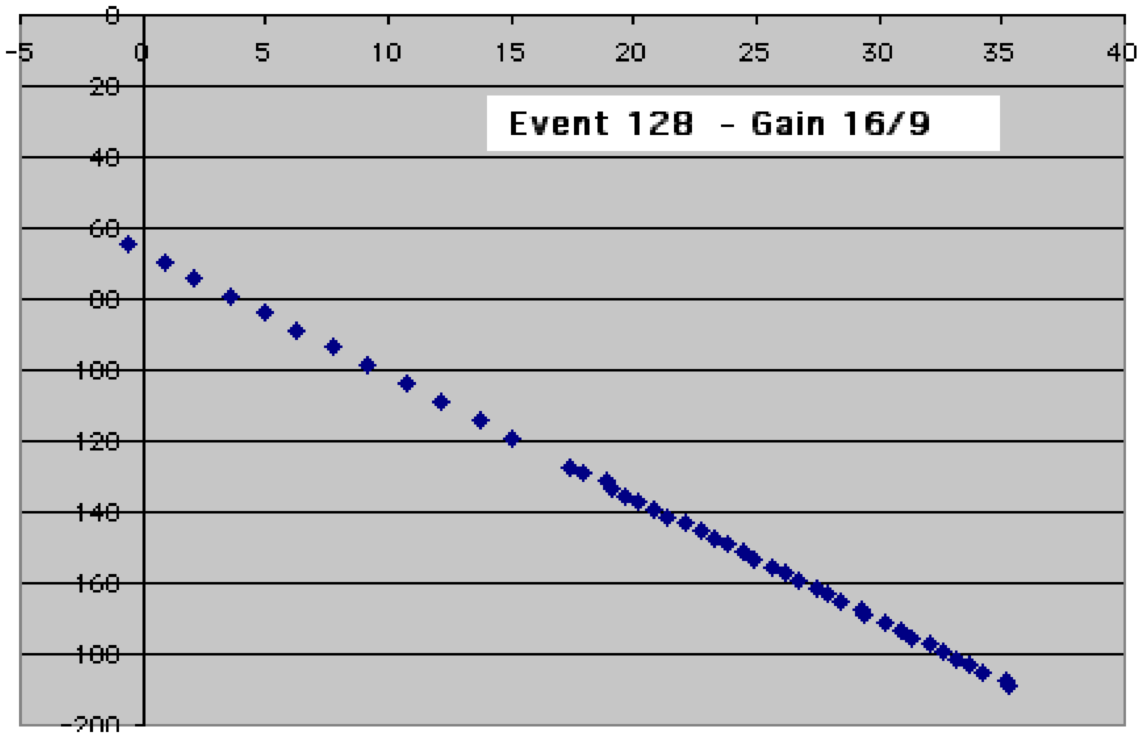

Figure 3 Event from a high gain run.

Once we had a good track, we selected rows 31 to 36. (These were the pads whose gain was varied.) Note that the row adjacent to the edge was not used because there were some edge effects with these rows. Stripe 1 was not tested because it of the poor performance of the inner pads with low variable gain. It was not possible to get a well-defined track that hit both the inner and outer pad rows and Stripe 1.

The inner pads were not very efficient. This is probably caused by the fact that the mapping of anode wires is not evenly distributed along pads. The two low gain regions of the 1/9 stripes are clearly shown. In this event, there is only one hit that shows up in the low gain region.

Contrasting Figure 2 is Figure 3, which shows an event with gain of 16/9. Every row is hit on this track except for row 1. This track is highly efficient. When the gain of the inner tracker was set higher, the inner pad rows were efficient.

Efficiency

To calculate the efficiency, we use the definition of a good track as defined in the previous section. For each event, there could be more than one good track. To increase the statistics, we added the results for each row, as there was very little row to row variation. The efficiency is simply a sum of the number of times a row was hit divided by the number of good tracks.

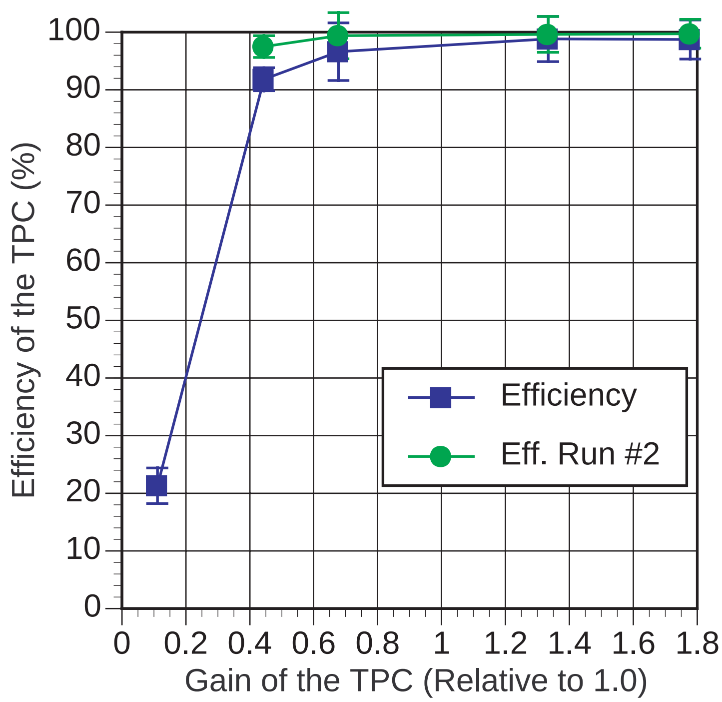

Figure 4 Measurement of the efficiency of the TPC. Run #2 refers to a reanalysis that was done about a month later.

Figure 4 displays the results of the efficiency plot. While the efficiency is not 100% at the higher gains, the deficiency is probably due to trackfinding problems. Run #2 refers to an improved hitfinder that was included in the second version of the STAR analysis package. These points have a higher efficiency than the first run. The errors are calculated as if they were gaussian. This approximation explains why the error bars exceed 100%.

The low efficiency at 1/9-gain shows that the TPC is not efficient for low-ionizing particles. Consequently, the TPC will have great trouble searching for |1/3| charged quarks which deposit energy as Z^2. If we would want to detect these particles, then the whole TPC would have to be run at higher gain.

Resolution

To determine the resolution, we took the track found by the STAR tracker and refitted it using only pads with the nominal voltage. Then, we calculated the difference between the position of the found track and the hit with variable voltage. Again, to increase the statistics, we summed the results from each pad row.

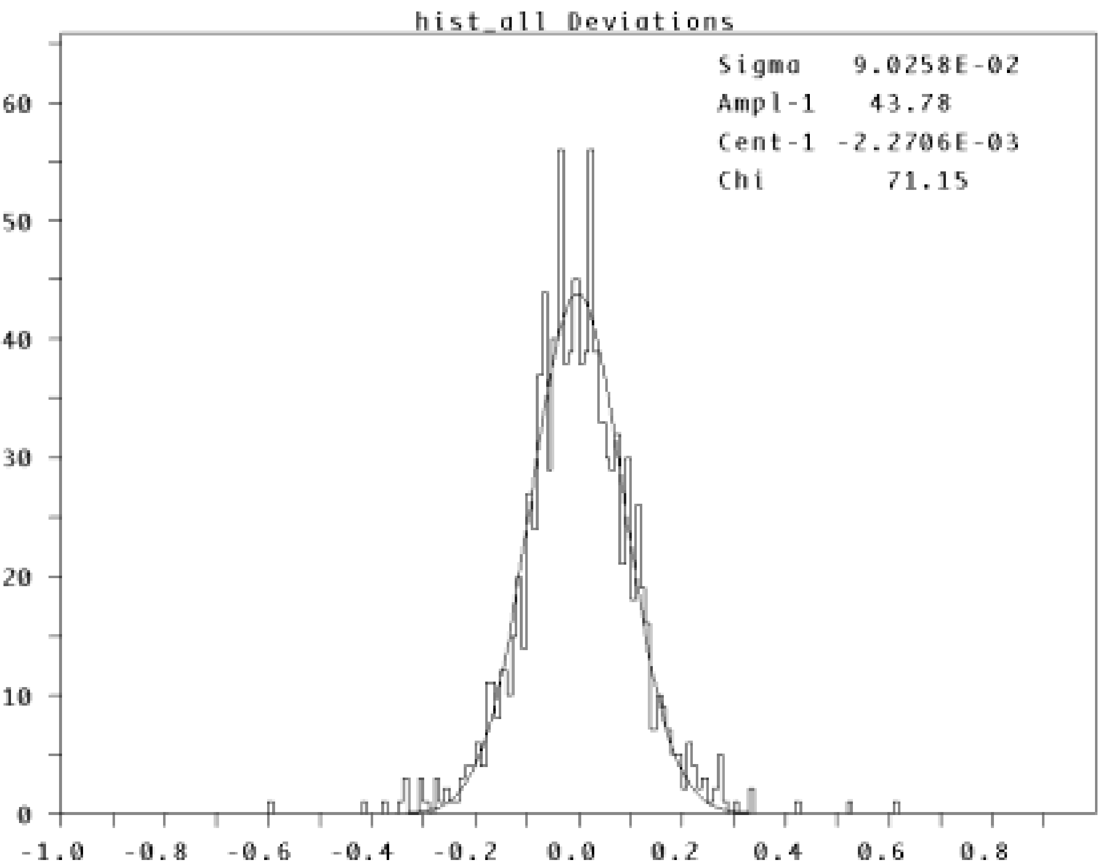

Figure 5 Difference between expected hit of pad and measured position of the pad. This distribution is for the 4/3 gain data. The units of this plot are in cm.

The distribution, which is shown in Figure 5, is well described by a gaussian. As there are very few outliers, the trackfinder found hits that are directly attributed to the track.

Using the same fitting technique as used in Figure 5, we can calculate the resolution as a function of gain. Figure 6 shows the results from this analysis. As can be seen in this graph, the resolution is slow function of the gain. There was a significant increase in the resolution in the second analysis run.

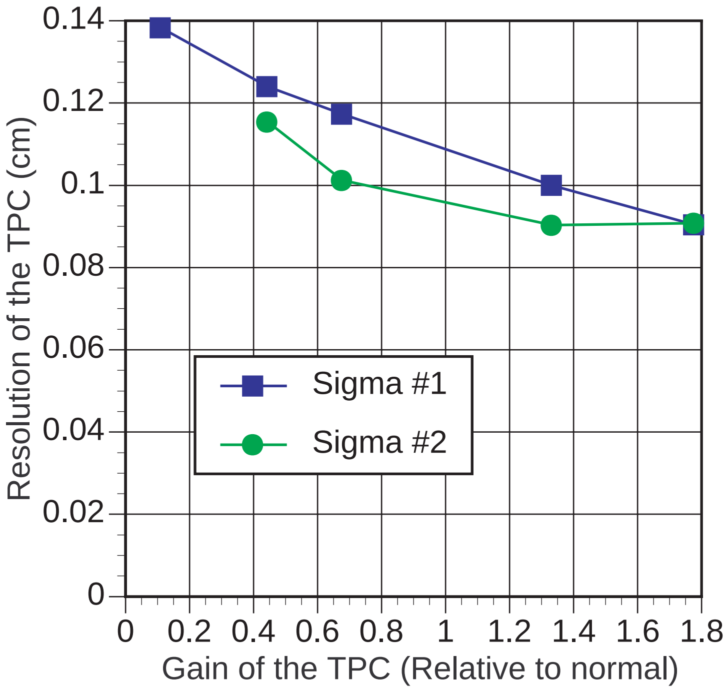

Figure 6 Measurement of the resolution of the TPC. The number for each data set refers to the analysis number.

The position resolution for charge |2/3| quarks is only slightly worse than that for muons. Clearly, the resolution for highly ionizing particles is much better. This feature will make it easier to measure di-quarks with charge higher than 1 and particles such as ^{3}He and ^{4}He. However, these particles' masses must be different from the conventional particles so that the energy bands are distinct.

We also looked at the displacement of the residuals. The displacement is calculated in the gaussian fit of the residuals. For instance, in Figure 5 the displacement of the center of the distribution was 23 μm. Typically, the displacement was of the order of 20 μm. Within the constraints of this analysis, this value is consistent with zero.

Consistency Check

To determine if the gain of the tracks was as expected, we can look at the energy loss for each run. There was no correction for pathlength along the pad-row. A dE/dx distribution can be seen in Figure 7. The shape is just like the expected distribution. There is the gaussian-like rise at low energy, while the Landau tail is clearly shown. The vertical axis is multiplied by 10^6 in this plot. The unit is the STAR standard energy number.

To estimate the gain of the TPC, we looked at the peak of this distribution for each gain run. If this peak is multiplied by the expected gain, then we should have a straight line. Because of the paucity of data it was very difficult to make a good fit of the data.

Therefore, to determine the gain of each run, we estimated the peak of the distribution. An error was assigned to the approximate range that the peak could be assigned.

Figure 8 shows the distribution of energy deposited on each pad. With the range of assigned errors, the gain looks very consistent. The data from Run #2 have a very low χ^2 so that the error bars are probably underestimated. Since a straight line with a slope of zero can describe the figure, we conclude that the gains were set correctly.

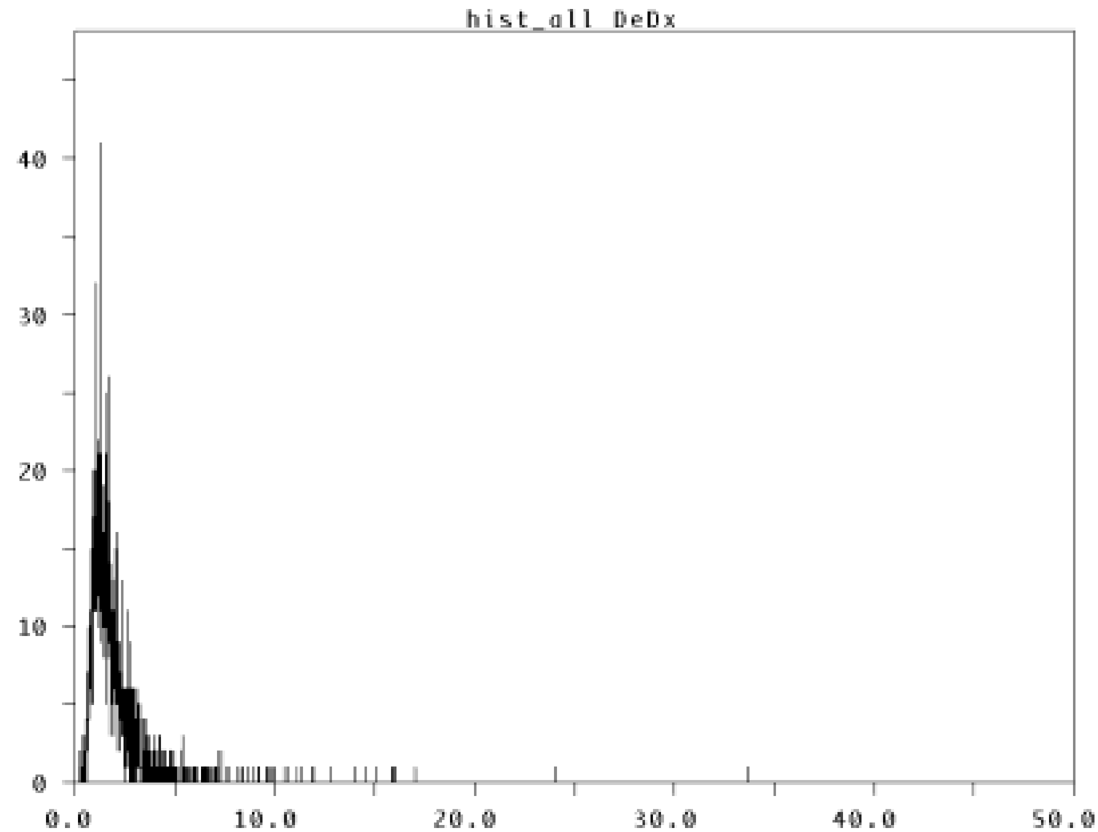

Figure 7 dEdx distribution for the 4/9 gain run. The sum of all of the energy for each pad is plotted.

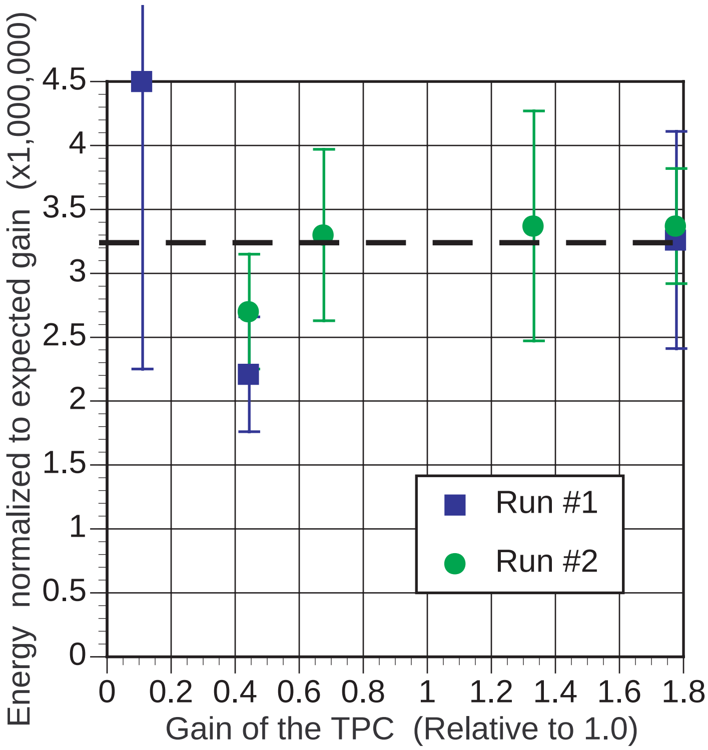

Figure 8 This plot shows the normalized gain for each of the different runs. The runs refer to the two different passes in the STAR analysis. The dotted line at 3.1 is only to guide the eye.

Conclusion

This is the first attempt to explore how well the STAR TPC can detect particles with unusual ionization. It is clear from this analysis that the TPC is working well. Because of the very low efficiency for the 1/9 gain run, it appears that it will be necessary to raise the voltage of the TPC to be efficient for charge |1/3| quarks. Due to the fact that there was no magnetic field, this analysis should be repeated. It would be important to do this test for distances in *z* so that any problems with the long drift of the TPC could be identified.