STAR Note 412

# A Second TPC Test with Varied Anode Gain

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**Abstract**

The anode voltage across 8 outer sector pad-rows is varied during cosmic running with half field (B=0.25 Tesla). We study the efficiency, measured gain, and resolution as a function of anode wire voltage. The anode voltage is found to have been below the optimum level for the 1999 engineering run.

## 1 Introduction

Recently we published an analysis of the hit reconstruction efficiency in the STAR TPC versus anode wire voltage [1]. That study was undertaken to test the sensitivity of the STAR TPC to tracks with $Z < 1$. It was found that the nominal STAR anode voltages give good sensitivity to tracks with $Z = 2/3$ (gain = 4/9 * nominal), while the efficiency for tracks with $Z = 1/3$ (gain = 1/9 * nominal) was very low.

A shortcoming of the previous study was a lack of a magnetic field in the TPC. A magnetic field parallel to the drift electric field reduces the transverse diffusion in the TPC volume. This leads to narrower clusters. One would expect the reduced diffusion to increase the hit finding efficiency for tracks with low primary ionization as the ionization is concentrated on fewer pads and has a better chance of exceeding the electronics threshold. The present study was undertaken to test this hypothesis.

The magnetic field also allows for a measurement of the momentum of the cosmic ray track. For an efficiency study, one wishes to select minimum ionizing particles. In practice, the trigger and intervening material select out mostly minimum ionizing tracks.

In addition to the magnetic field, the present study differs from Star Note 395 in having much noisier electronics. With the transition from mini-daq/prototype read-out boards to real daq/final read-out boards there was an intermediate period where the electronics showed high levels of noise. The minidaq era data had mean R.M.S. noise of roughly 1.1 ADC counts,

[1] H. Matis, D. Hardtke, H. Wieman, B. Stringfellow, and E. Hjort, Star Note #395.

| | $G_0$ | $\alpha$ (Volts$^{-1}$) |
|---|---|---|
| inner | 0.00137 | 0.01267 |
| outer | 0.002820 | 0.00934 |

Table 1: The calculated gain parameters for the STAR TPC wire chambers.

| Outer Sector Anode Voltage (Volts) | Relative Gain |
|---|---|
| 1165 | 1/9 |
| 1282 | 1/3 |
| 1314 | 4/3 |
| 1357 | 2/3 |
| 1400 | 1 |
| 1431 | 4/3 |
| 1462 | 16/9 |

Table 2: Outer Sector Anode Voltages and calculated relative gains for this test.

while the engineering run data had mean R.M.S. noise greater than two counts. In addition there were many FEE chips that showed high levels of correlated noise, and many channels had large levels of digital corruption. The noise has since been reduced to the expected levels, so the conclusions of the present study will be superseded once low noise/magnetic field TPC data becomes available.

## 2 Experimental Set-up

The anode wire gain $G$ can be related to the anode wire voltage $V$,

$$G = G_0 e^{\alpha V}, \tag{1}$$

where $G_0$ and $\alpha$ are constants that depend primarily on the wire plane geometry. The calculated values for the STAR TPC wire chambers are listed in Table 1.

In this test, we left the inner sub-sector TPC anode wires at the nominal voltage (1150 V) for all cases. The outer sub-sector has four independent voltage controls which control 32 anode wires covering 8 pad-rows. We adjusted only one voltage controller, corresponding to pad-rows 30-37. The voltages used in the study and the corresponding gain (relative to the nominal 1400 V) are listed in Table 2.

The data was taken with only sector 12 enabled using the cosmic-ray trigger. 1000 triggered events were taken in each setting. Because of the noise problems with the electronics, the data were taken with a rather high threshold imposed by DAQ. A valid sequence on a pad was require to have at least 1 pixel about 12 ADC counts and at least 3 pixels above 3 ADC counts. The data was processed using the standard offline software (version sl99f). Gain corrections were applied to the data. In this analysis, we include all pad-rows in the definition of the track. This fact introduces some biases in the analysis. For instance, the hit is included in the track fit so that the residual is slightly reduced. Similarly, when a track is fit, the varied pad-row is included in the analysis. This procedure inflates the efficiency.

# 3 Results

In the analysis, we look at hits that come from tracks with more than 5 valid hits. Figure 1 shows the mean charge deposited divided by path length ($\langle dq/dx \rangle$) as a function of row number for the various gain settings. In general, $\langle dq/dx \rangle$ is larger for the inner sub-sector. We also see that $\langle dq/dx \rangle$ changes in the rows where the anode voltage is adjusted. Rows 29 and 37 seem to be an intermediate value between the nominal and adjusted gain settings.

In order to measure the relative gain response of the chambers, we calculate the ratio,

$$\text{Measured Gain} = \frac{\langle \mathrm{dq/dx} \rangle (\text{rows } 30 - 35)}{\langle \mathrm{dq/dx} \rangle (\text{rows } 17 - 25)}. \tag{2}$$

The averages are calculated by fitting the data in Figure 1. In Figure 2 we compare the measured relative gain (Equation 2) with the calculated relative gain (Equation 1). This figure shows that above the nominal gain, the chamber follows the exponential relationship in Equation 1. Below the nominal gain, however, the measured gain is higher than expected. We will show later that this is probably due to a large inefficiency at low anode voltage which biases us towards highly ionizing hits.

In order to estimate the efficiency, we plot the number of hits used in a reconstructed track versus row number in Figure 3. We see that adjusting the gain does change the number of hits used in rows 30-37. In fact, for gain greater than 1, we see a higher efficiency in these rows. Figure 4 shows the relative efficiency as a function of gain. The relative efficiency is defined as the ratio,

$$\text{Efficiency} = \frac{\#\,\text{hits}(\text{rows } 30 - 35)}{\#\,\text{hits}(\text{rows } 30 - 35)\text{ in reference run}}. \tag{3}$$

We see that the efficiency is very low for gain=1/9, increases linearly between gain=1/3 and gain=1, and begins to saturate at gain=4/3. The fact that the relative efficiency saturates at roughly 120% of the nominal efficiency indicates that the nominal setting is only 80% efficient. Apparently, many hits are being lost due to the electronic noise and/or DAQ

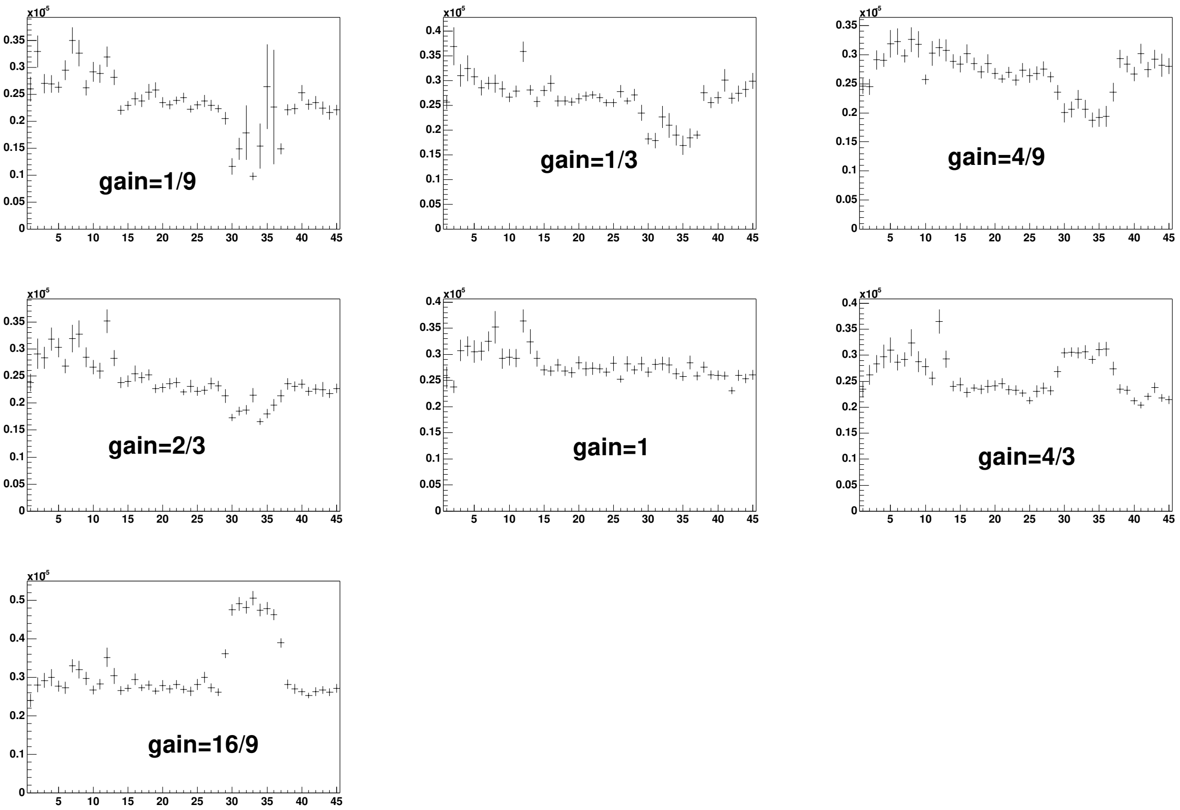


Figure 1: The mean charge divided by the path length as a function of row for the various anode voltage settings.

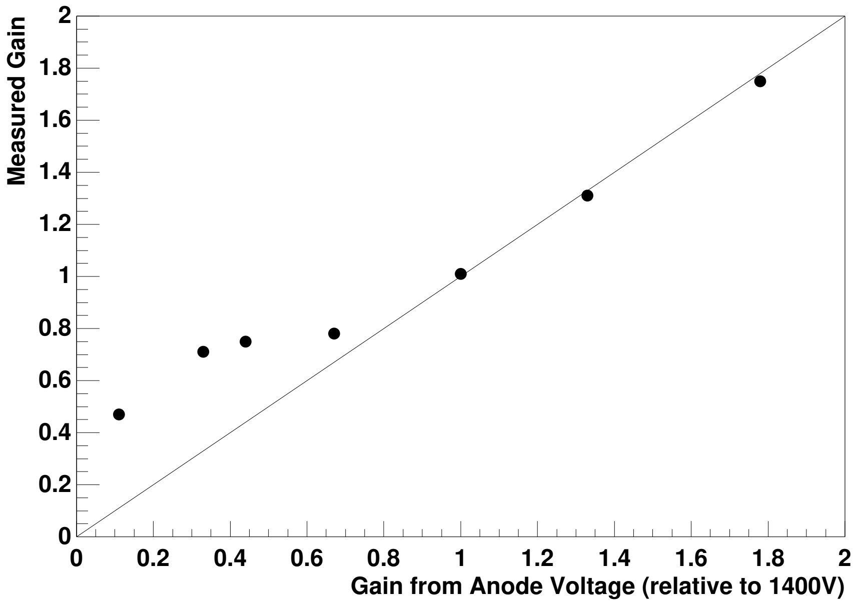


Figure 2: The measured gain vs. the nominal gain calculated from the anode wire voltage.

threshold. In the previous study without magnetic field and with low noise electronics (SN0395), the efficiency saturated around gain=1/2. The observed inefficiency also explains the non-exponential gain response seen above.

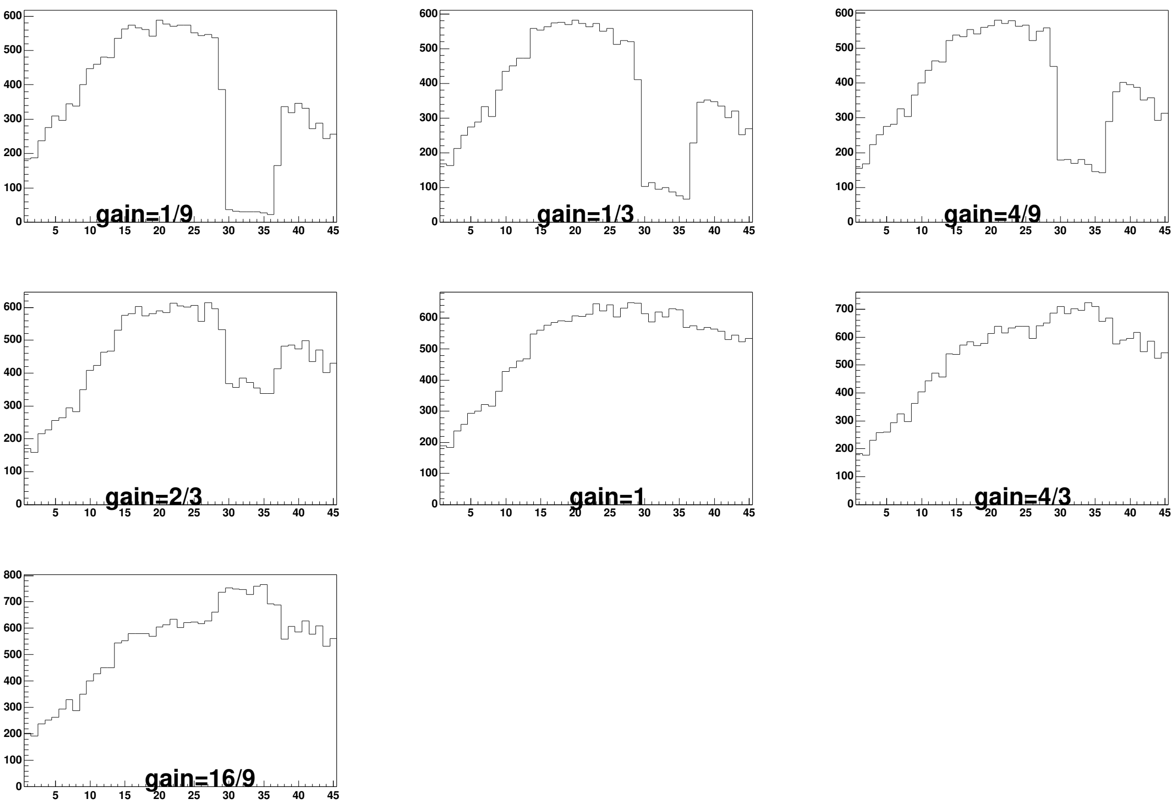


Figure 3: Number of used hits versus row for the various gain settings.

Another quantity expected to depend on the wire chamber gain is the position resolution of the hit. In the limit of low gain, the hit is recorded on a single pad as the signal on the neighboring pads is below threshold. As the gain is increased, the signal becomes distributed among several pads and the signal on each pad becomes much larger than the electronics noise. At some point, the resolution should saturate with increasing gain as intrinsic dE/dx fluctuations and crossing angle effects begin to dominate the resolution. In Figure 5 we plot the residual along the pad-row as a function of gain. In Figure 6 we make the same plot, but in the z-direction. In both cases we also plot a set of reference residuals (open squares) which are the residuals in rows 17-25. We see that these do not change, while the residuals in rows 30-35 decrease with increasing gain. Note that an auto-correlation exists in that the

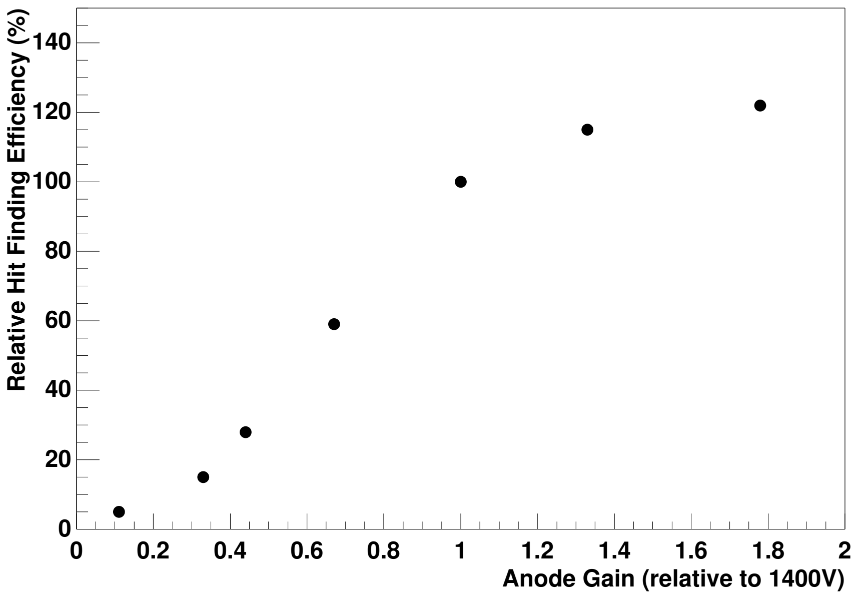


Figure 4: The relative efficiency as a function of gain.

point for which the residual is calculated is not removed from the track fit. We see that the resolution continues to decrease after the nominal gain, indicating that the resolution is not optimized given the electronics noise present in this data.

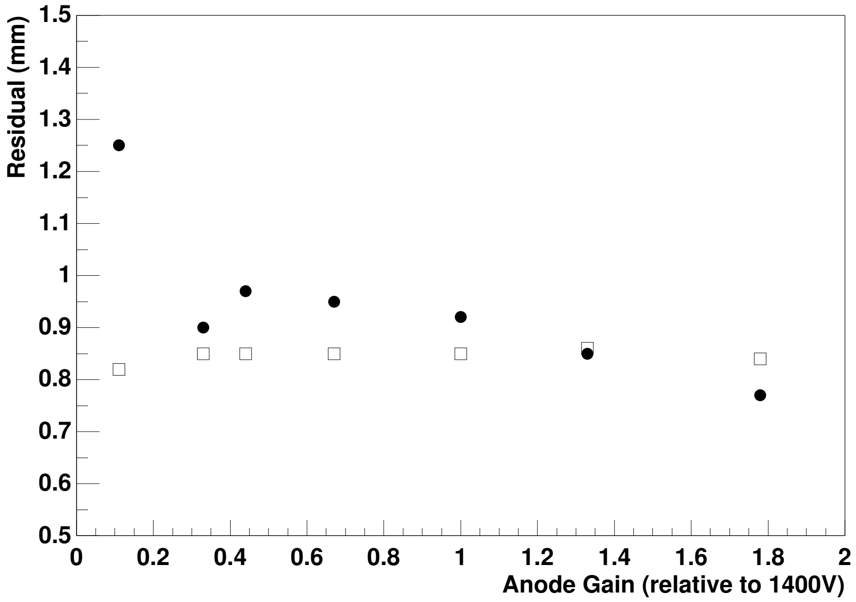


Figure 5: The residual along the pad-row as a function of gain. The black points are the residuals in the region of adjusted wire voltage, while the open squares are in a region of nominal anode wire voltage.

# 4 Discussion and Conclusions

Because of the level of electronics noise in this data and high threshold used by DAQ, many of the conclusions will no longer be valid in the future. Nonetheless, the outer sector anode wire voltage was below the optimum level for the summer 1999 engineering run. The hit reconstruction efficiency was not 100% and the resolution was not optimized.

It is difficult to disentangle the effects of the noise and the DAQ threshold. Of course, the electronics noise requires a high DAQ threshold in order to reduce data volume. Due to the high DAQ threshold, many of the hits were one- or two-pad hits, which have significantly worse resolution.

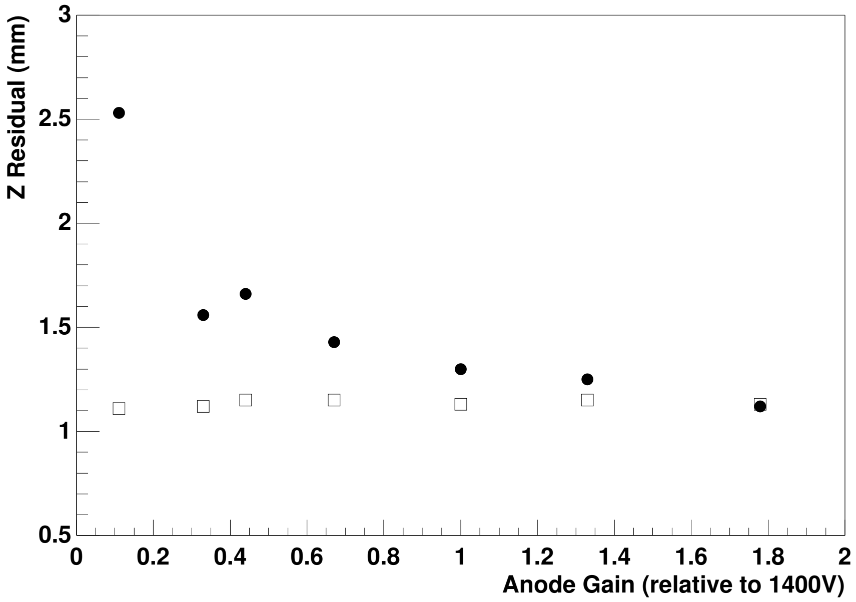


Figure 6: The residual in the z-direction as a function of gain. The black points are the residuals in the region of adjusted wire voltage, while the open squares are in a region of nominal anode wire voltage.

The original aim of this study was to estimate the efficiency of the STAR TPC for sub-MIP particles with Z=1/3e or Z=2/3e. This study would suggest that it is impossible to see these particles using the nominal anode wire voltages, but we cannot make such a conclusion until the study is repeated with reduced electronics noise and reduced DAQ thresholds.

This study should be repeated very early in the 1999-2000 physics run in order to optimize the wire chamber voltages. It should also include a similar analysis for the inner sub-sector. The primary goal should be to adjust the anode voltages to have nearly 100% hit reconstruction efficiency and optimum position resolution, while optimizing the dynamic range and minimizing wire chamber aging effects.