DRAFT VERSION — DRAFT VERSION A comparison of TPC and STRAW TUBE Chamber performance in the HALL D Detector at Jefferson Lab

Curtis A. Meyer

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1 Introduction

Currently, we are considering two possible central tracking detectors for the HALL D detector at Jefferson Lab. A roughly 2 m long STRAW TUBE chamber, and a similar length TPC. In this study, we have used the MCFAST Monte Carlo program to make several comparisons between these two chambers.

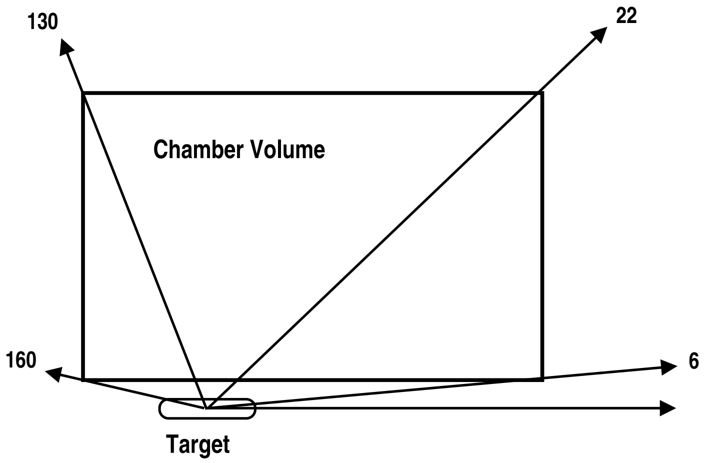

Figure 1: A figure showing angles in degrees from the center of the target when various reference points are hit. Tracks more forward than 6° miss the central tracker all together. Those between 6° and 22° pass through some number of layers. Tracks between 130° and 160° only see a fraction of the chamber in the backwards direction, and those tracks more backwards than 160° miss the central chamber all together.

1.1 The TPC

The TPC has been kludged in MCFAST using zero–mass silicon detectors. The simulation fills the tracking volume with 45 layers of strips with $r\phi$ sensitivity and 45 layers with z sensitivity. The radial layers are 1 cm thick, and fill the volume from $r = 15.0$ to $r = 60.0$ cm and extend from 50 cm upstream of the target center to 150 cm down stream of the target center. The z layers are centered at the same point as the r–layers, and the length is divided into 1000 individual detectors.

The material in the TPC is a shell around the gas volume, and chamber gas in the volume. The inner shell is a 2 mm thick Carbon fiber tube, while the outer shell is a 4 mm thick Carbon fiber tube. The upstream end plate is simulated with 2 cm of Aluminum, while the down stream plate is of variable thickness of Aluminum as shown in Table 1. The momentum resolution as a function of angle is shown in Figures 2 and 3 for the various material configurations. Figure 3 is a zoomed view of those tracks that match up with tracks in the forward packages.

Figure 4 shows probably the ultimate that could be achieved using a TPC. This has $200\,\mu$m resolution in $r\phi$ and 2 mm resolution is z. This is clearly better than all other plots, particularly in the central region where the resolution never gets worse than about 1%. There are two reasons for this. First, the TPC is implemented with 45 effective layers versus 22 straws for the STRAW TUBE chamber and the resolution goes like $\frac{1}{\sqrt{N}}$. Second, there is a lot less material in the TPC, so the multiple scattering is reduced.

Code	Material				Resolutions	
	r_{in}	r_{out}	z_{up}	z_{down}	$\sigma_{r\phi}$	σ_z
A	$2\,mm$	$4\,mm$	$20\,mm$	$5\,mm$	$300\,\mu m$	$4\,mm$
B	$2\,mm$	$4\,mm$	$20\,mm$	$10\,mm$	$300\,\mu m$	$4\,mm$
C	$2\,mm$	$4\,mm$	$20\,mm$	$20\,mm$	$300\,\mu m$	$4\,mm$
D	$1\,mm$	$4\,mm$	$20\,mm$	$10\,mm$	$300\,\mu m$	$4\,mm$
U	$2\,mm$	$4\,mm$	$20\,mm$	$10\,mm$	$200\,\mu m$	$2\,mm$

Table 1: Material parameters used in looking at the TPC resolutions. The most likely value of the downstream end plate is on the order of 1 cm thick. The $300\,\mu$m $r\phi$ resolution is fairly typical of TPC's especially in non–uniform magnetic fields. The 4 mm z resolution is the resolution at the downstream end. It will actually get better as the drift path of the electrons gets shorter.

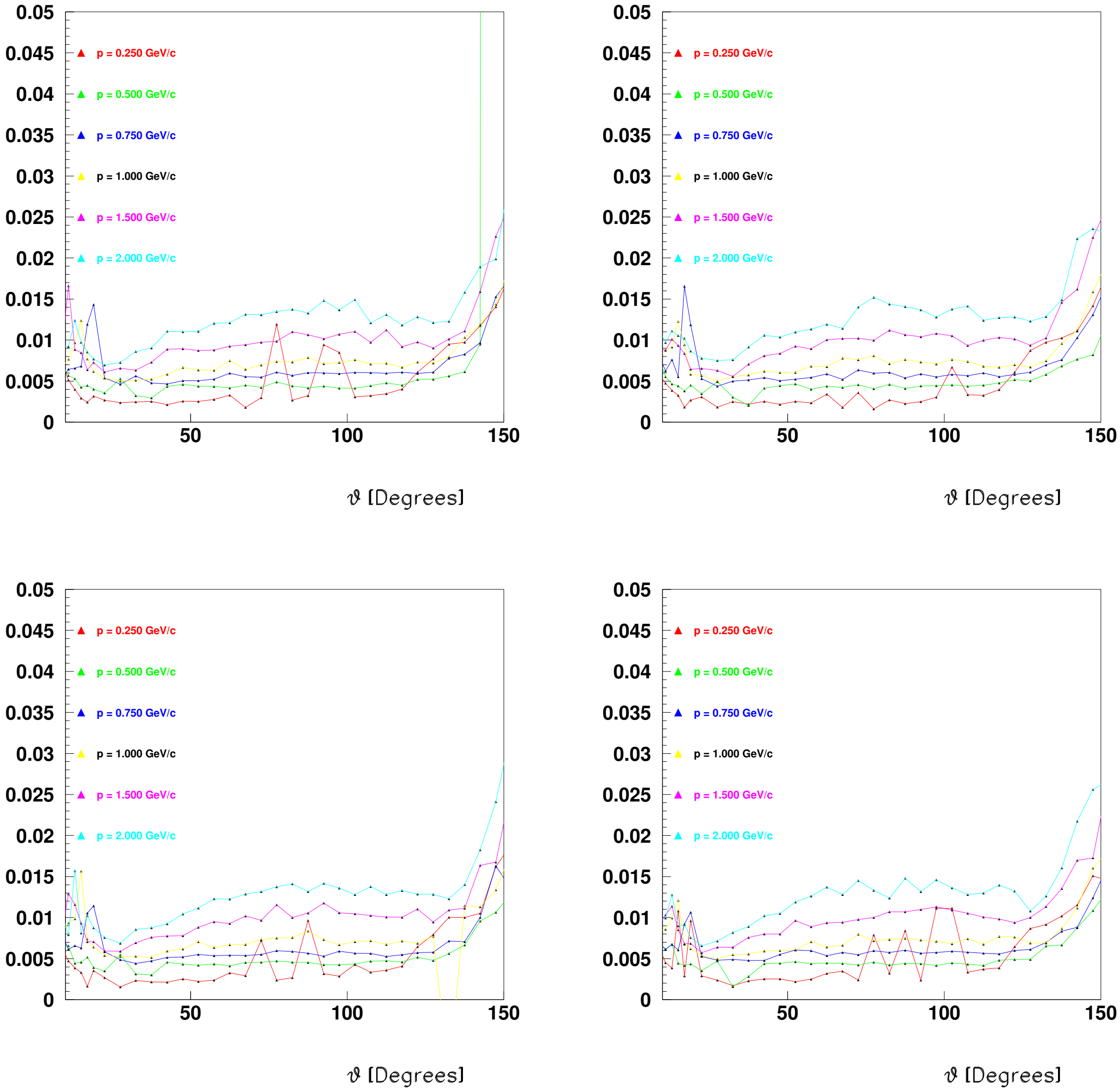

Figure 2: Momentum resolution as a function of angle in the TPC. The upper left figure corresponds to **A** in table 1. The upper right corresponds to **B**, the lower left to **C** and the lower right to **D**.

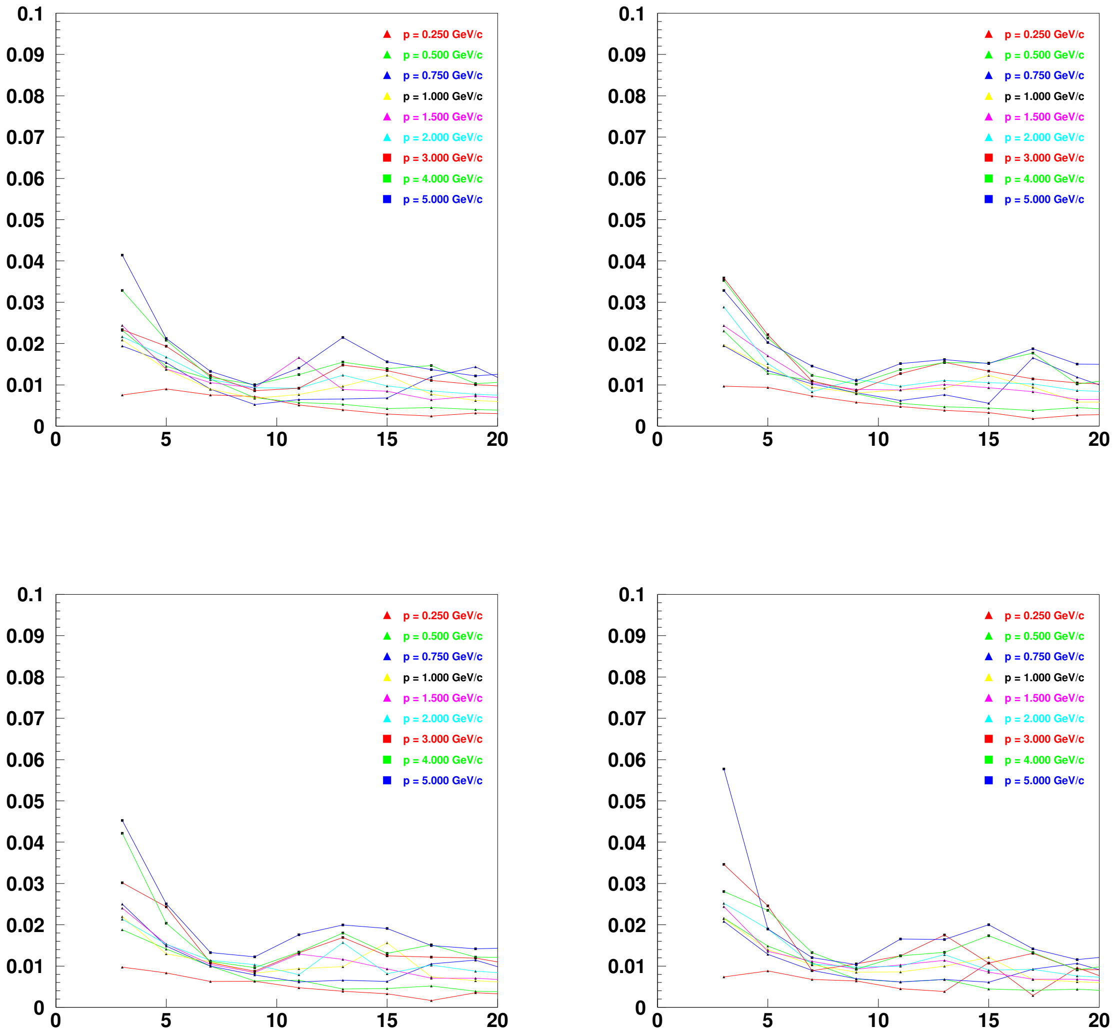

Figure 3: Momentum resolution as a function of angle in the TPC. The angular region corresponds to those tracks that make it into the forward tracking package. The upper left figure corresponds to **A** in Table 1. The upper right corresponds to **B**, the lower left to **C** and the lower right to **D**.

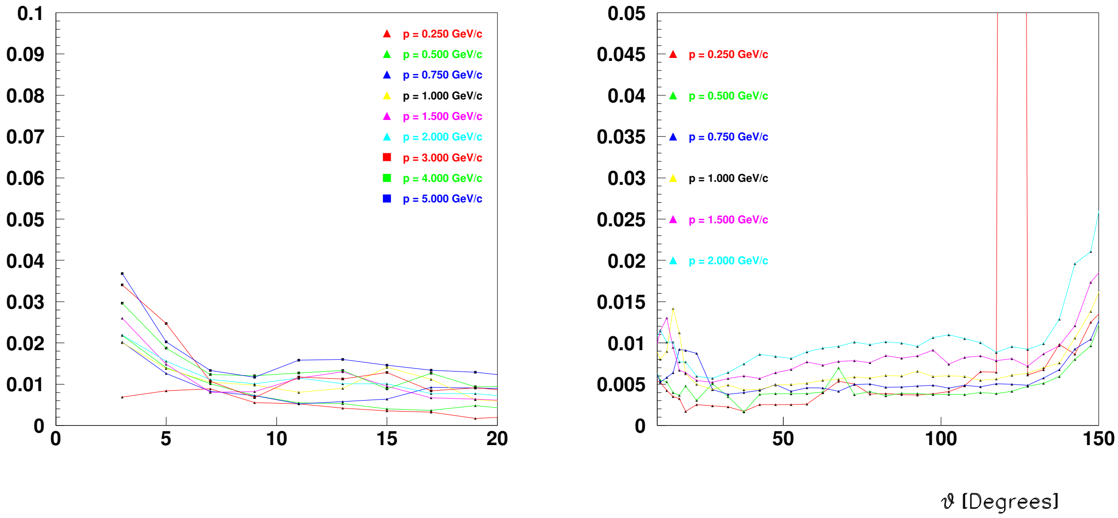

Figure 4: The momentum resolution as a function of angle for a TPC as given in **U** in Table 1. This has $\sigma_{r\phi} = 200\,\mu$m and $\sigma_z = 2\,$mm.

1.2 The STRAW TUBE Chamber

The material in the STRAW TUBE Chamber consists of a shell similar to the TPC, a gas volume, and twelve cylinders of $400\,\mu$m thick aluminum spread throughout the gas volume to simulate the straw material. The nominal values for the material is shown in Table 2. The resolutions corresponding to these material parameters are shown in Figure 5 and in 6. The latter figure corresponds to the angular region where the tracks make it into the forward package.

There is also discussion of a cathode readout on the inner shell of the STRAW TUBE chamber to provide an accurate z point as the track enters the chamber. If we add such a detector, with no thought given on how we are going to be able to read it out, then the resolutions are as shown in Figures 7 and 8.

Code	Material					Resolutions	
	r_{in}	r_{out}	z_{up}	z_{down}	Straws	$\sigma_{r\phi}$	Stereo
E	2 mm	4 mm	20 mm	20 mm	$2.4\,mm$	$200\,\mu m$	6°
F	2 mm	4 mm	20 mm	20 mm	$4.8\,mm$	$200\,\mu m$	6°
G	2 mm	4 mm	20 mm	20 mm	$7.2\,mm$	$200\,\mu m$	6°
H	2 mm	4 mm	9 mm	9 mm	$2.4\,mm$	$200\,\mu m$	6°

Table 2: Material parameters used in looking at the STRAW TUBE chamber resolutions. The most likely value of the downstream end plate is on the order of 2 cm thick. The $200\,\mu$m $r\phi$ resolution is fairly typical of such a drift chamber. The z resolution is obtained by having roughly one–half the wires at 6° stereo angles. The column labeled *Straws* corresponds to the total thickness of aluminum used too simulate the straw material.

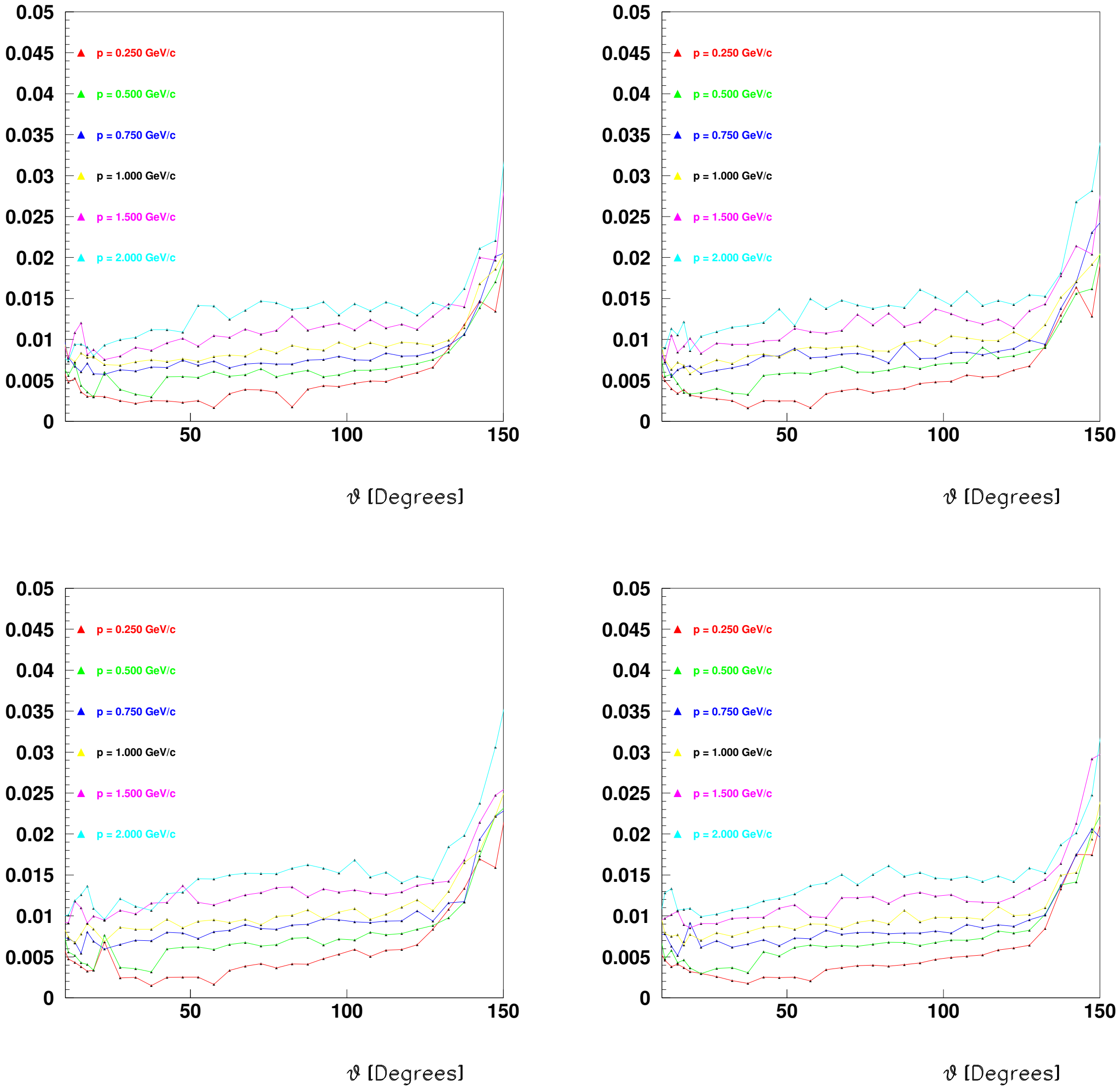

Figure 5: Momentum resolution as a function of angle in the STRAW TUBE chamber. The upper left figure corresponds to **E** in table 2. The upper right corresponds to **F**, the lower left to **G** and the lower right to **H**.

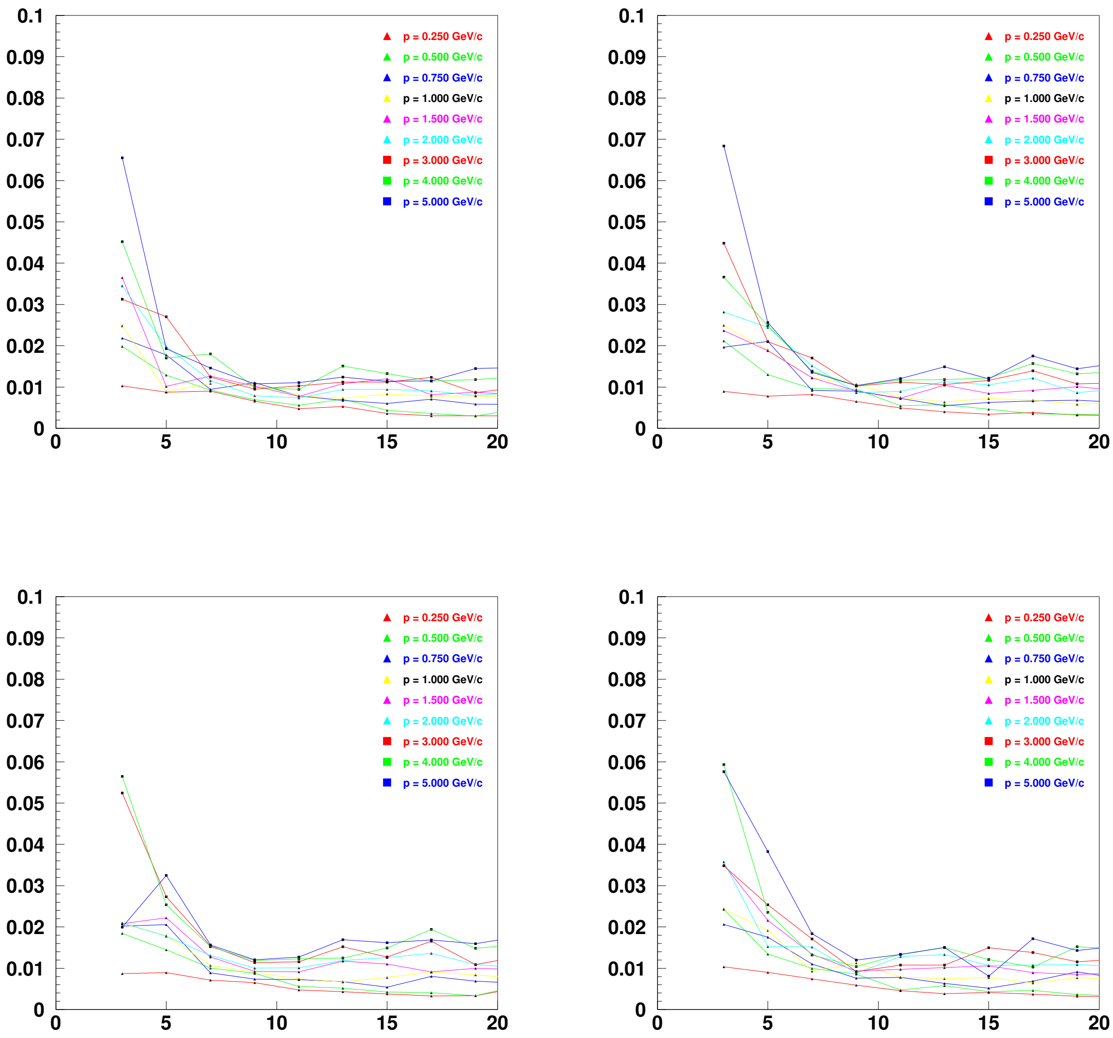

Figure 6: Momentum resolution as a function of angle in the STRAW TUBE chamber. The upper left figure corresponds to **E** in table 2. The upper right corresponds to **F**, the lower left to **G** and the lower right to **H**.

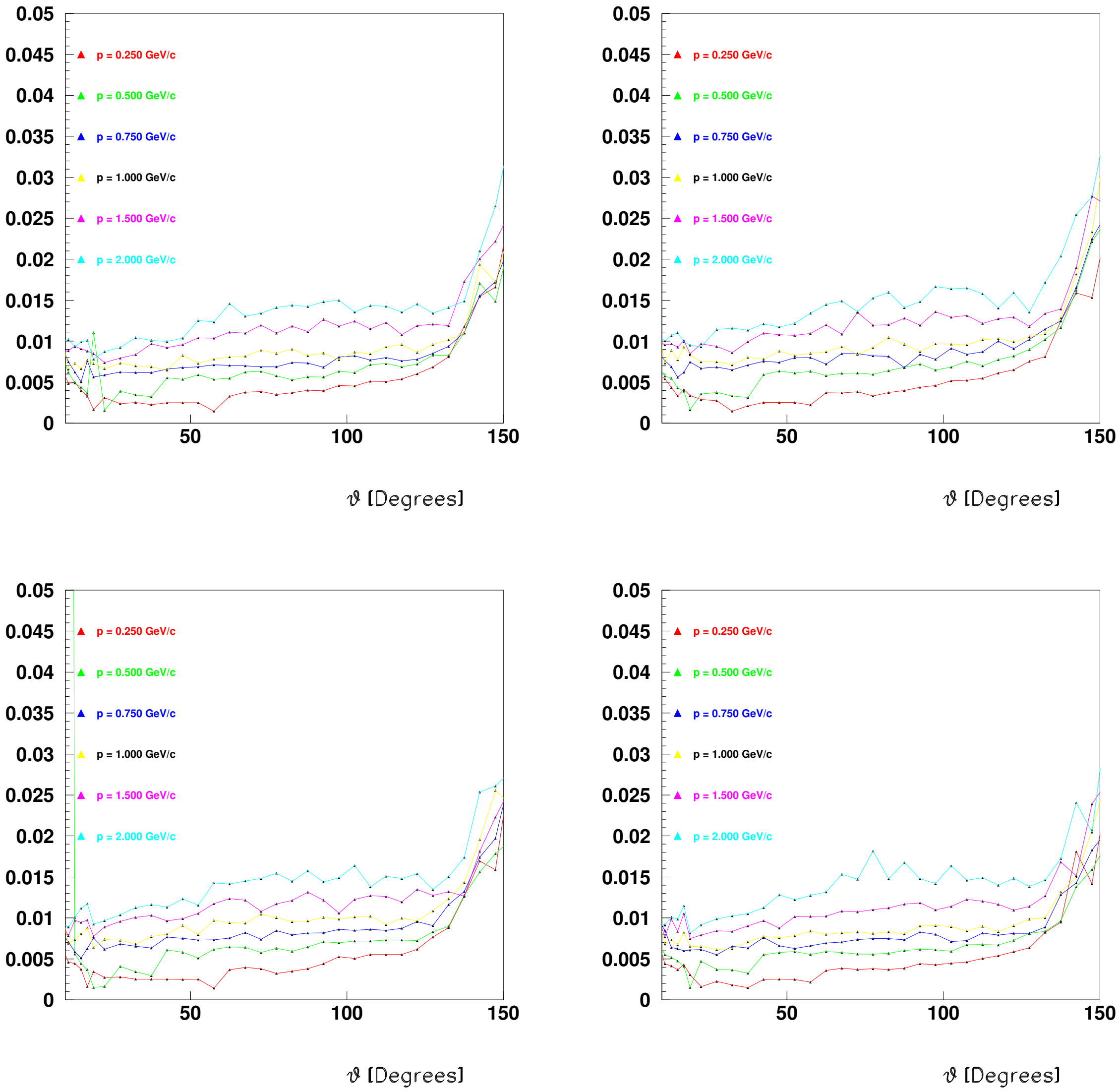

Figure 7: Momentum resolution as a function of angle in the STRAW TUBE chamber assuming that there are cathode pads with $\sigma_z = 0.5\,\mathrm{mm}$ on the inner shell of the STRAW TUBE chamber. The upper left figure corresponds to **E** in table 2. The upper right corresponds to **F**, the lower left to **G** and the lower right to **H**.

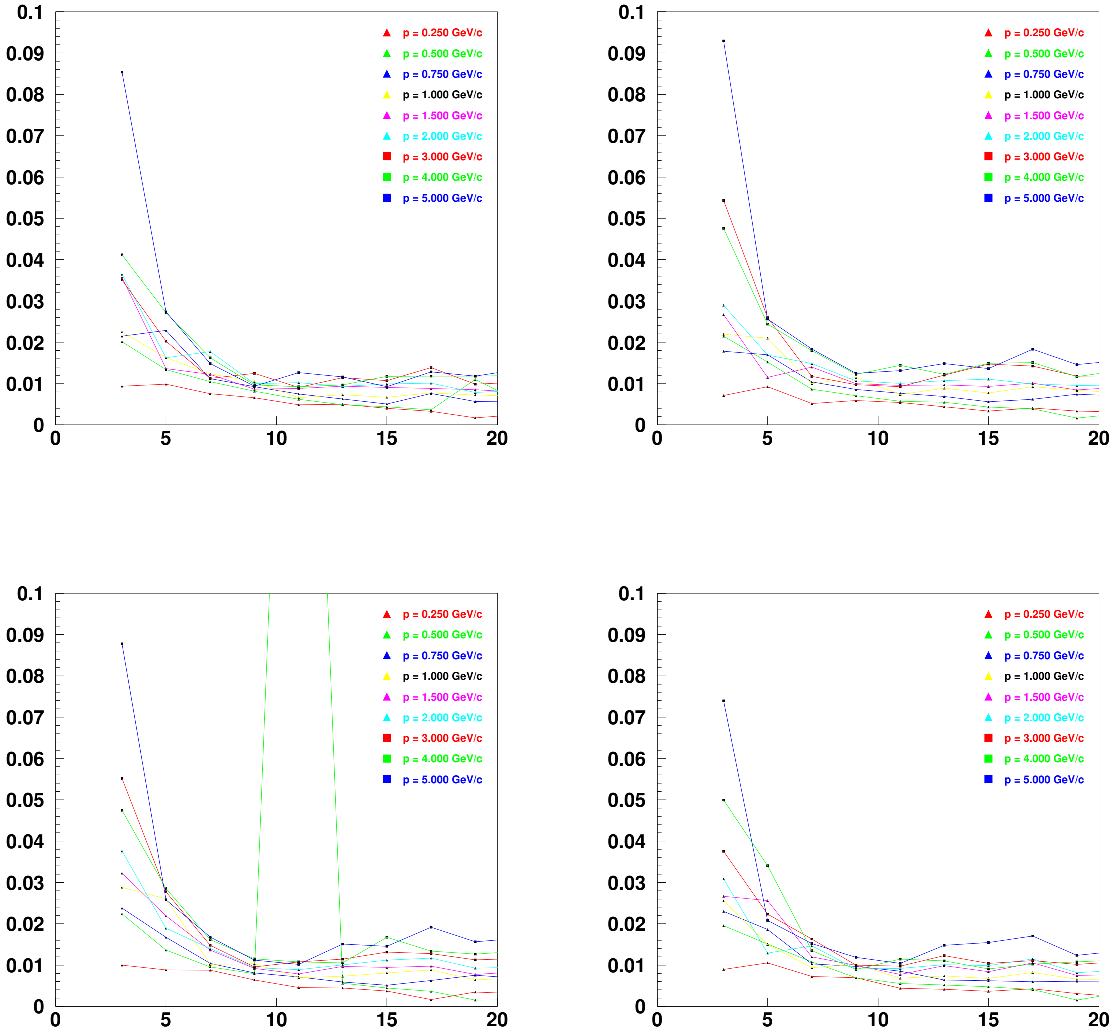

Figure 8: Momentum resolution as a function of angle in the STRAW TUBE chamber assuming that there are cathode pads with $\sigma_z = 0.5\,\mathrm{mm}$ on the inner shell of the STRAW TUBE chamber. The upper left figure corresponds to **E** in table 2. The upper right corresponds to **F**, the lower left to **G** and the lower right to **H**.

Comparisons

In comparing the two chamber types, the relevant figures correspond to models **B** for the TPC and **F** for the STRAW TUBE chamber. The most significant difference corresponds to very forward (under 5° tracks. The TPC reaches about 4% resolution for the highest momentum track, while the STRAW TUBE chamber reaches about 7% resolution. However, by about 10°, the two chambers are agreeing. In addition, for central angles, the TPC shows better resolution for low momentum tracks than the STRAW TUBE. However, as far as the resolutions go, the overall differences are subtle.

A second figure of merit that we have used in the past is the missing baryon resolution. We consider a reaction of the form:

$$\gamma p \rightarrow X^{+} n$$

where the X^+ decays into either 3 or 5 charged π's. We take those events where all the π's are observed, but treat the nucleon as missing and reconstruct the missing mass recoiling against X. These are shown in Figure 9 for several final states and both the TPC and STRAW TUBE chamber design. The main curves examine an $X^{+}(1600) \rightarrow \pi^{+}\pi^{+}\pi^{-}$ as a function of photon beam energy, E_γ. The open circles represent the STRAW TUBE chamber, (CDC) while the solid boxes represent the TPC. There are two full curves for the TPC. The upper has $\sigma_{r\phi} = 300\,\mu$m and $\sigma_z = 4\,$mm. The lower as $\sigma_{r\phi} = 200\,\mu$m and $\sigma_z = 2\,$mm. In fact, this quantity is dominated by the resolution of the forward chambers, which measure the highest momentum tracks. We also show single points for each chamber at $E_\gamma = 8.0\,$GeV for a 5π final state from an X^+ of mass $1.6\,$GeV/c^2 and $2.3\,$GeV/c^2. In all cases, there is little difference between the two chambers, but the TPC is slightly better.

In order to do a fairer comparison, it will be necessary to make an electronic layout that has similar numbers of channels for both the TPC and the STRAW TUBE chamber. This will imply certain limits on the number of samples that are collected, and will need to be fed back into the Monte Carlo. There is one place where the TPC will clearly win, and that is in the area of dE/dx.

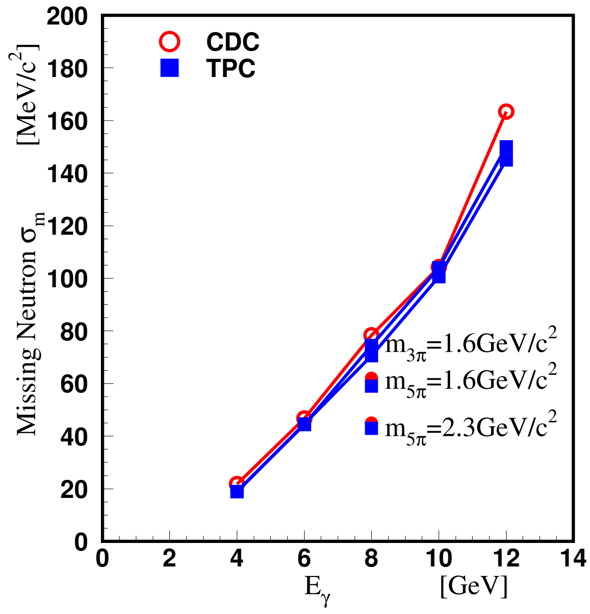

Figure 9: The reconstructed missing mass for an unobserved neutron in several photoproduction reactions. Comparisons are made between the TPC and STRAW TUBE chambers.