GEANT 3 Step Settings
I. TmaxFD
TWIST Techincal Note 83

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Abstract

Effects of the size of the parameter $TmaxFD$, the maximum allowed turning angle in one step due to the magnetic field, were investigated. The position of a pencil positron beam generated near the target was found to differ by as much as $150\mu m$ near the end of the half stack depending on the the value of $TmaxFD$. Furthermore, the effect of this parameter is systematic, with the maximum difference in beam position occurring at large angle helix tracks.

1 Introduction

For materials in the TWIST detector the step size is limited by physics processes, resulting in a step size that is sufficiently small, with the helium region being the only exception. In this region $TmaxFD$ is often the step size limiting factor for large angle helix tracks. While setting $TmaxFD$ to a small value is desirable, it has the disadvantage of increasing the CPU time, as well as the possibility of increasing rounding errors as a result of single precision in GEANT 3. It is therefore necessary to quantify changes in the helix track as $TmaxFD$ is changed and choose a setting that is a compromise between these competing factors.

To investigate this effect a pencil positron beam was tracked using the Runge-Kuta method starting at a position of $(0, 0, 2)cm$ (just outside the target) and various distributions were plotted at $(0, 0, 44.39)cm$. These distributions include the x and y position of the beam as well as the crossing angles in two perpendicular planes, xz and yz.

2 Effects of TmaxFD with no ELOSS or MS

The beam was first given an initial kinetic energy of $40MeV$ with $\theta = 30°$ and $\phi = 0°$ and with all physics processes turned off. A simulation with $TmaxFD = 2°$ gave the same result as that with $TmaxFD = 20°$, resulting in $x = 2.782cm$ and $y = -1.468cm$ for both cases. The simulation was then repeated for $\theta = 70°$, resulting once again in identical results, with $x = -2.529cm$ and $y = -0.5295cm$.

3 Effects of TmaxFD with ELOSS and MS

Energy loss (including delta ray production and bremsstrahlung) and multiple scattering were then turned on and a million positron tracks were simulated at $\theta = 70°$ and KE=40MeV with $TmaxFD$ set to the values 2°, 5°, 10°, 15° and the default value of 20°. The table below shows the means for various distributions after the beam traversed a distance of 42.39cm in z. Figure 1b shows the change in beam position as $TmaxFD$ is reduced from its default value of 20°, while figure 1c shows the change in beam angle. Figure 1d shows the percentage increase in CPU time as $TmaxFD$ is reduced. The position of the positron helix at $z = 44.39cm$ differs by as much as 150μm and the crossing angles by as much as 4$mrad$. The trend reversal observed around 5° is likely due to single precision rounding errors. Figures 2-6 show various distributions at $TmaxFD = 2°$. The same simulations were then

	$\langle x \rangle (cm)$	$\langle y \rangle (cm)$	$\langle \theta_x \rangle$(mrad)	$\langle \theta_y \rangle$(mrad)	CPU(msec)	% CPU increase
2°	-1.691	-1.183	1037	485.9	24.1	15%
5°	-1.686	-1.184	1036	484.5	23.9	13%
10°	-1.697	-1.176	1038	487.8	23.0	9%
15°	-1.696	-1.176	1039	487.4	22.0	5%
20°	-1.697	-1.168	1040	488.7	21.2	0%

Table 1: x, y, θ_x, θ_y of the positron beam at $z = 44.39cm$. The last two columns are the CPU time per event and the relative increase in CPU time as $TmaxFD$ is made smaller. The positron beam was simulated with a kinetic energy of 40MeV and a θ angle of 70°.

repeated for a positron beam with $\theta = 20°$ and KE=40MeV to investigate a likely systematic bias. For small angle helix tracks the limit on step size set by $TmaxFD$ is not typically encountered if $TmaxFD$ is set too high (20° for example) since the track does not curve by much within the space of the helium regions. Table 2 and figure 1a confirm these expectations showing that the difference in beam position is consistent with zero in this case.

	$\langle x \rangle (cm)$	$\langle y \rangle (cm)$
2°	0.8831	-0.2484
5°	0.8829	-0.2486
10°	0.8824	-0.2477
15°	0.8832	-0.2494
20°	0.8832	-0.2483

Table 2: x and y position of the positron beam at $z = 44.39cm$. The positron beam was simulated with a kinetic energy of 40MeV and a θ angle of 20°.

4 Conclusions

A dependence on the $TmaxFD$ is observed for large angle positron tracks. For a positron beam simulated at $KE = 40MeV$ and $\theta = 70°$, a difference of up to $150\mu m$ in the mean beam position and up to $4mrad$ in the crossing angles is seen as $TmaxFD$ is reduced from the default of 20° to 2°. This effect is shown to be systematic resulting in a bias in beam position if $TmaxFD$ is set too large for large angle positron tracks, while the low angle tracks are largely unaffected. Rounding errors as a result of single precision in GEANT 3 appear to only be encountered at $TmaxFD < 5\circ$ as may be inferred from the kink at $TmaxFD = 5°$.

As a result of this systematic bias, it is recommended that $TmaxFD = 5°$ be used instead of the default. This would represent a small enough turning angle to avoid a large systematic bias while avoiding large single precision rounding errors as well as avoiding a big increase in CPU time.

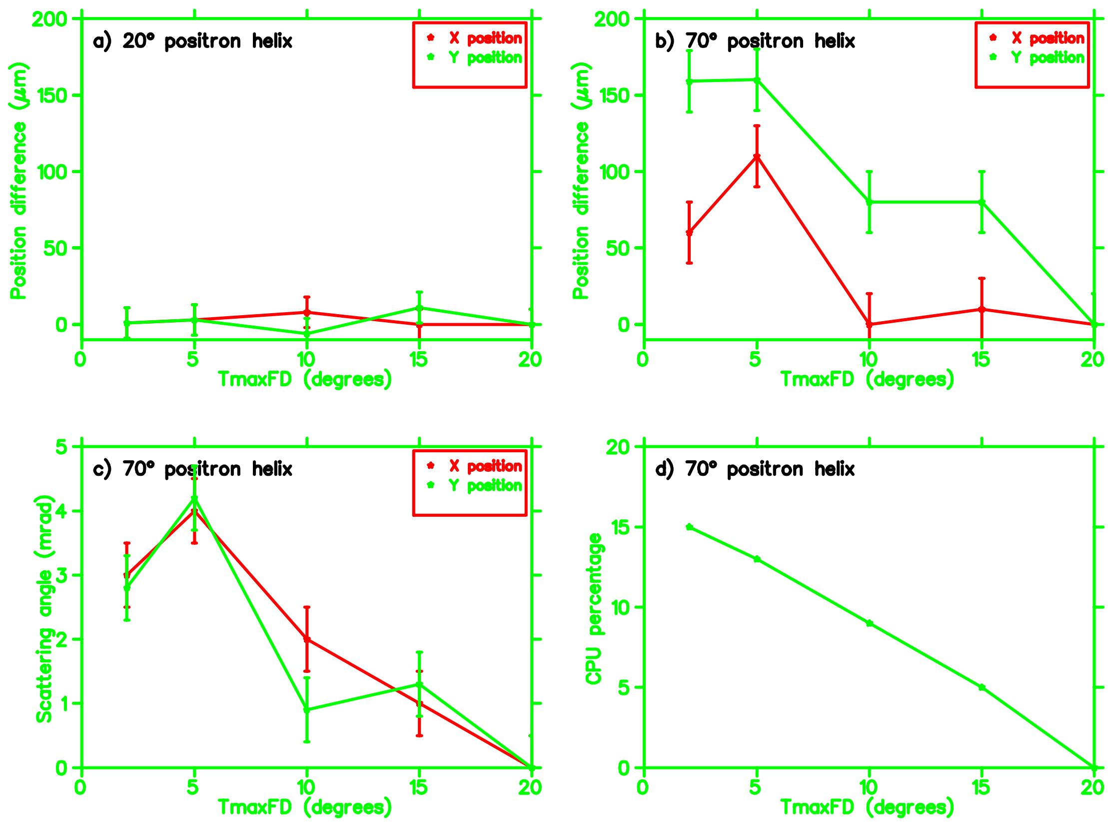

Figure 1: 1a) difference in the mean x (red) position and the default ($TmaxFD = 20°$) for various values of $TmaxFD$; the green curve is the same for y. The positron beam was generated with a kinetic energy of $40MeV$ and a θ angle of $20°$. 1b) same as 1a for a positron beam at $\theta = 70°$. 1c) difference in the mean crossing angles in the xz plane, θ_x, (red) and the yz plane, θ_y, (green) and the default. 1d) percentage CPU increase as $TmaxFD$ is lowered from the default.

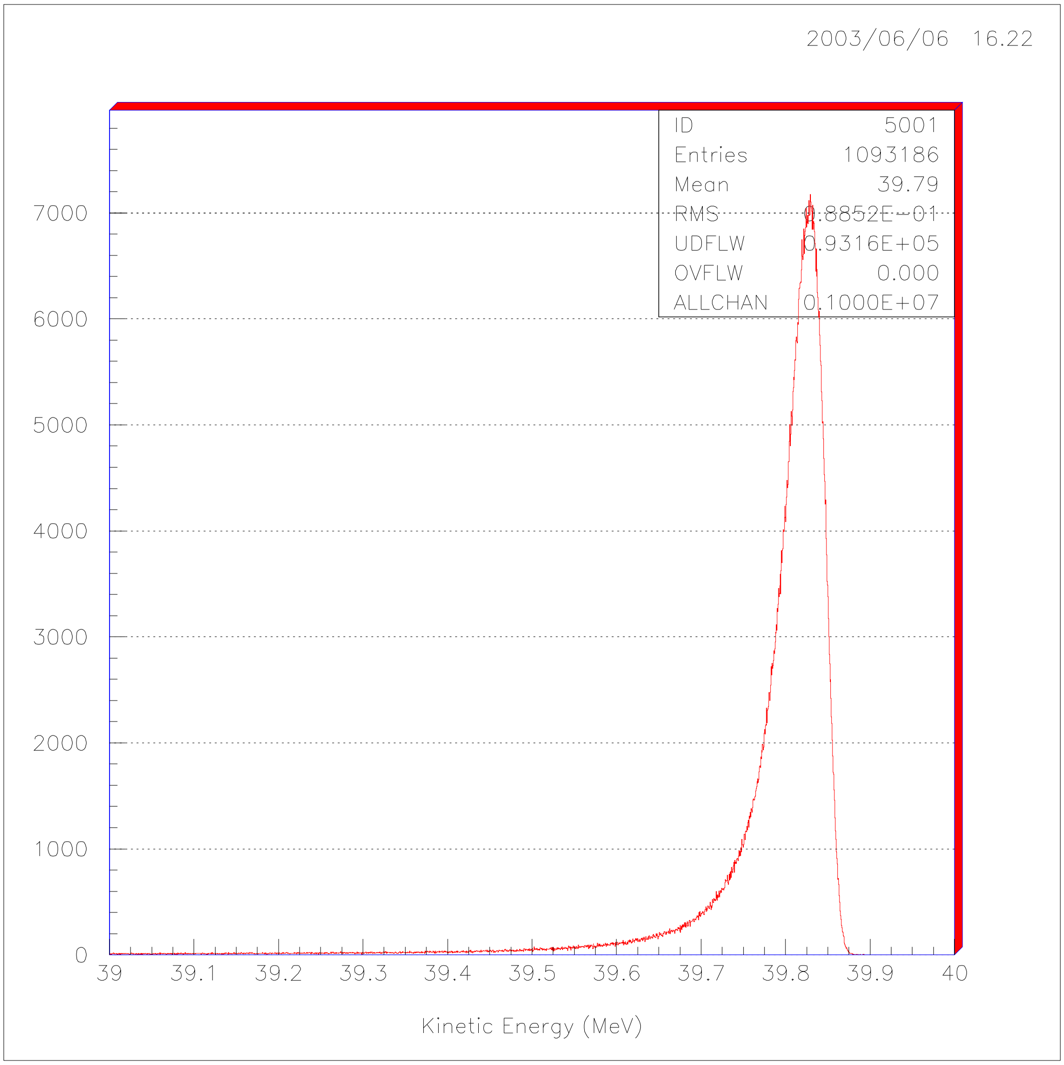

Figure 2: Kinetic energy of the positron beam at $z = 44.39cm$.

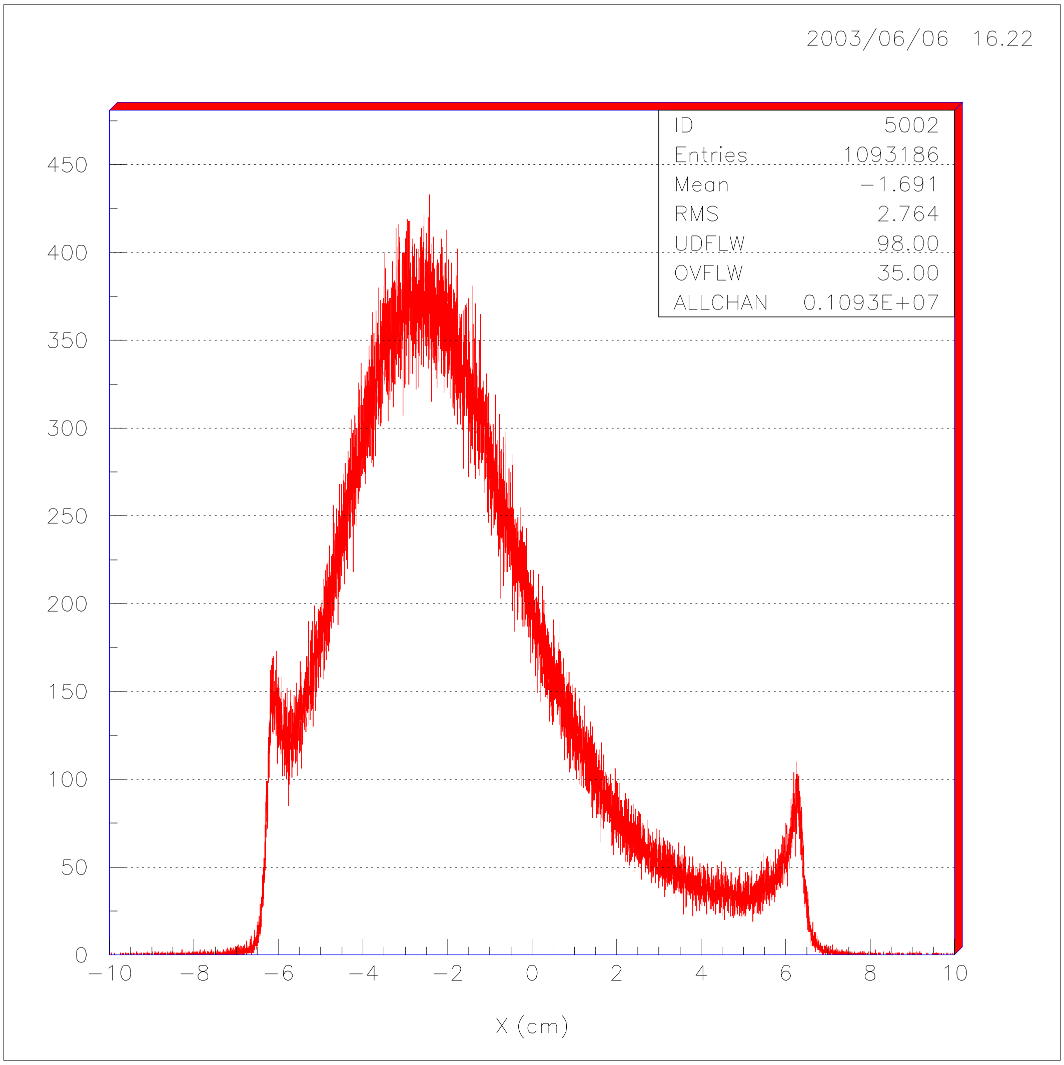

Figure 3: X position of the positron beam at $z = 44.39cm$.

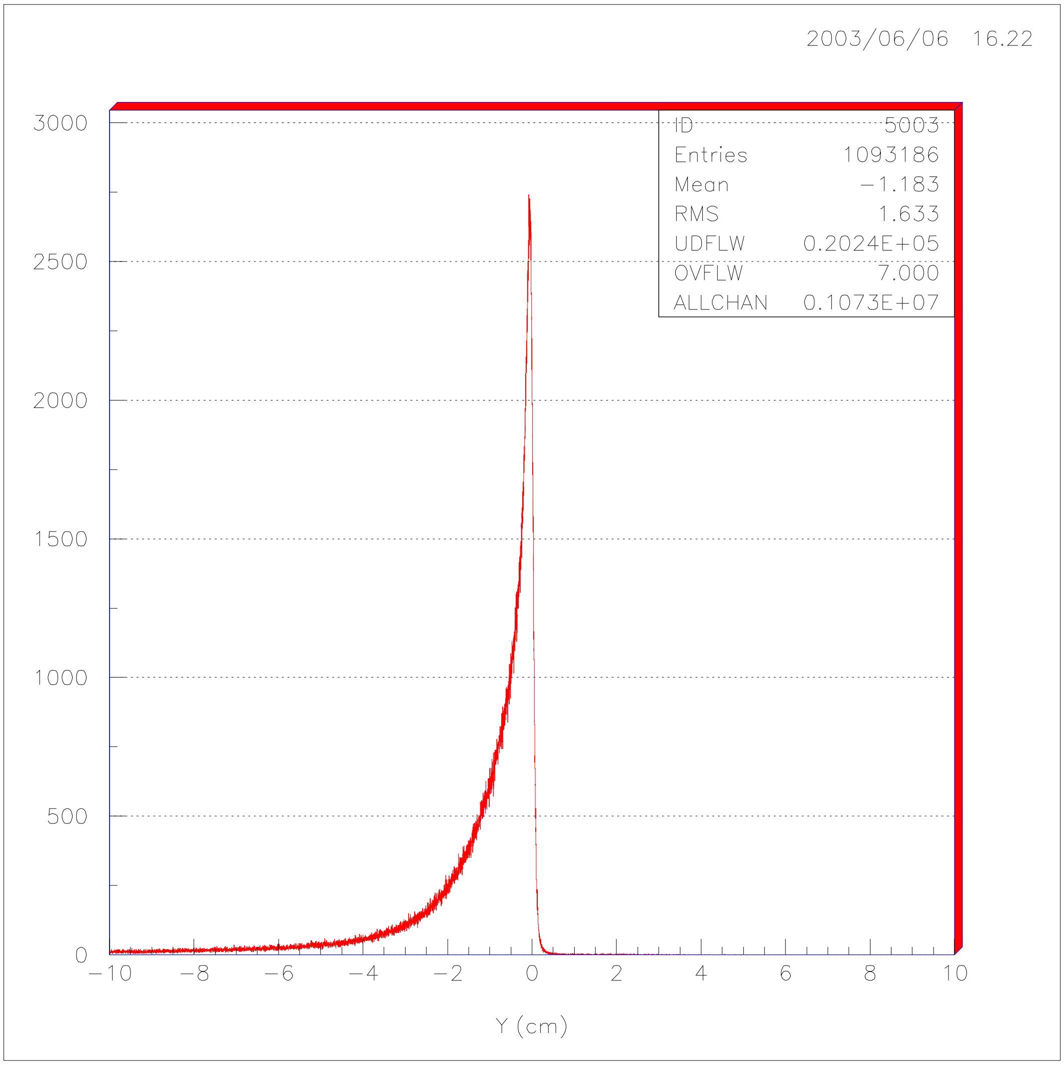

Figure 4: Y position of the positron beam at $z = 44.39cm$.

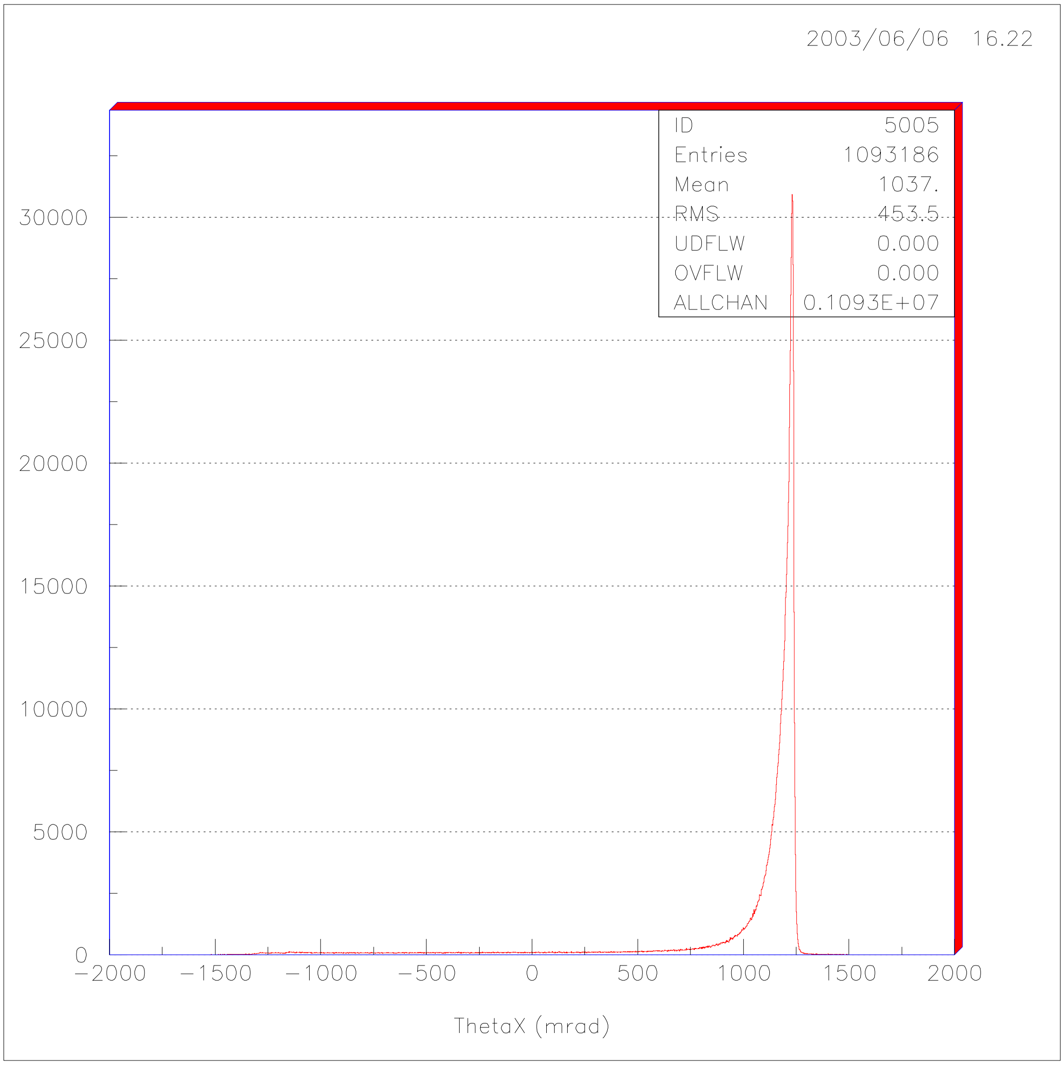

Figure 5: Positron beam angle in the xz plane at $z = 44.39cm$.

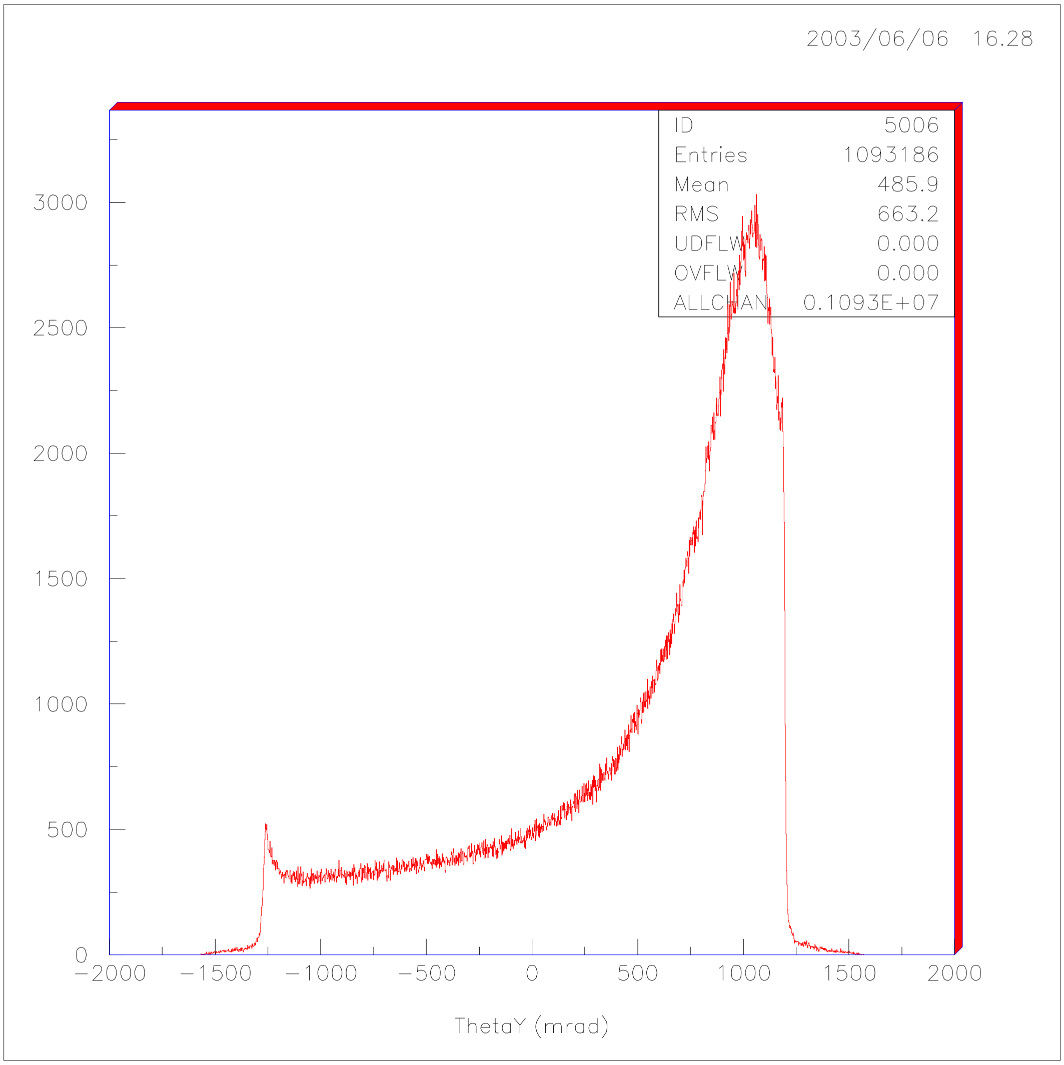

Figure 6: Positron beam angle in the yz plane at $z = 44.39cm$.