Technical Note 61
Helix Tracking Status

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Introduction

This technical note describes tests of the least squares helix tracking code which has been developed by the TWIST collaboration. Descriptions of the helix tracking algorithms and how to use this code can be found in forthcoming technical notes. The methods of testing the helix tracking code will be presented, and comparisons between two different pattern recognition codes will be made.

These tests were done to determine if the helix tracking code is at level where the Michel parameters and could be extracted from data at the 0.1% level. Naively we expect that the required tracking efficiency be at the 99.9% level, since the Michel parameters come into the decay spectrum linearly.

Methods of Testing the Helix Tracker

The helix tracking code was tested using TWIST GEANT version 2.0, with full digitization of TDC's. Two different GEANT conditions were tried to see how the fitting code would perform in different situations. Both GEANT runs had a polarized muon entering TWIST, and stopped in a mylar target. One of the GEANT runs was with energy loss, multiple scattering off, and no secondary processes turned on (clean GEANT data). The other GEANT run, in addition to energy loss and multiple scattering on, had all secondary processes turned on (dirty GEANT data).

Two methods of measuring the performance of the Helix tracking code are: to say that the tracking code successfully fit if its guess at total momentum (p) and cosine theta ($\cos\theta$) are close to the generated values (residuals method), or to say that the tracking code got a good fit if the tracking confidence level was above a certain level (confidence level method). The residuals method can only be done with GEANT data, and are a true measure of how well the code is performing. The confidence level method is what needs to be done with real data, and is all we will really know.

The following sections will describe: how well the confidence level is working, the tracking efficiency using confidence levels for clean and dirty GEANT data, the efficiency using residuals for clean and dirty GEANT, a comparison between the two working pattern recognitions using clean and dirty GEANT, methods used to locate events which are still failing to be fit, and further tests which can be tried.

How Well the Confidence Level is Working

The confidence level is a measure of how close the points used in the helix fitting code are to the track given by the parameters generated in the helix fit. Helix fitting was designed to fit helices with energy loss, and use only hits from the sparse Drift Chamber (DC) planes. Multiple scattering and delta rays can confuse the Helix fitting, and presumably could result in throwing away lots of hits from the fit, or could result in a low confidence level. Thus the confidence level need not be correlated with how close the helix parameters are to their true values.

The Chi−squared obtained by the helix fitting is used to calculate the confidence level, and is mostly independent of energy and angle. If we look at the chi−squared and confidence level for a clean GEANT run, there are some general trends in the confidence level, which can be attributed to physical processes. For example there appears to be slightly more large Chi−squared tracks which come from absolute value of cosine theta near 1.0, which might be attributed to a lower number of DC hits. Plots of confidence level versus chi−squared, chi−squared versus z vertex, chi−squared versus momentum, and chi−squared versus cosine theta are shown in Figure 1.

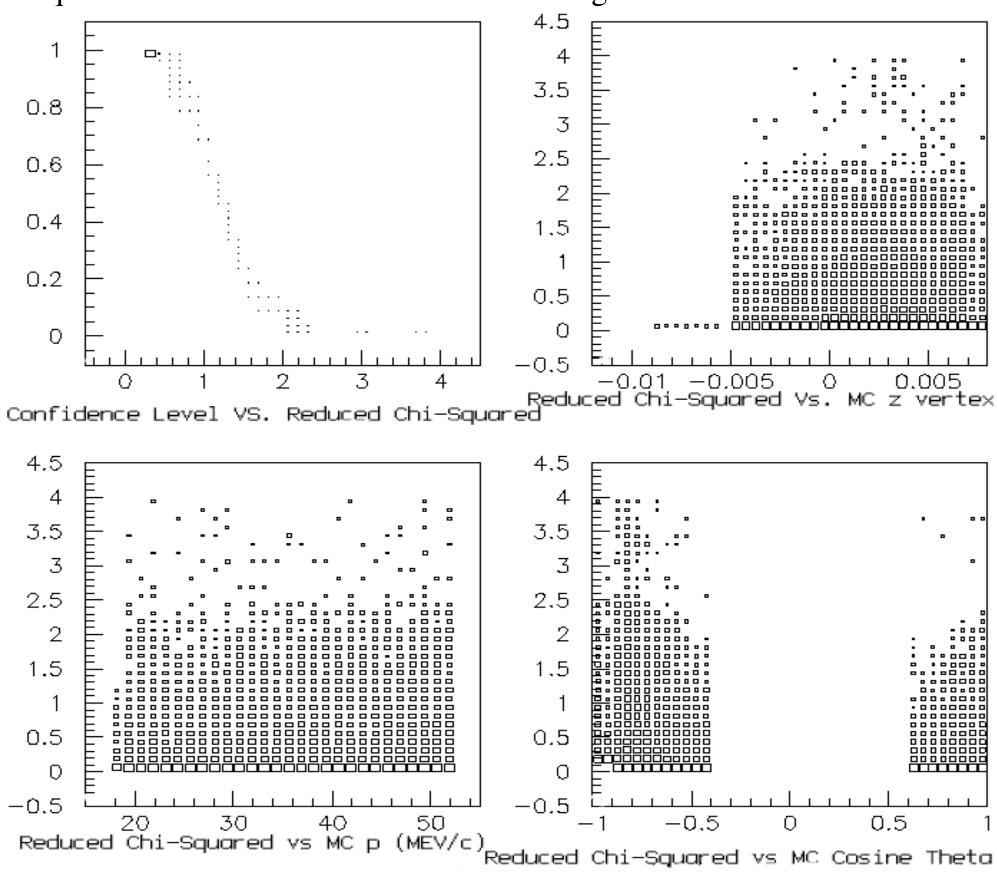

Figure 1 – Plots of confidence level versus chi−squared, chi−squared versus z vertex, chi−squared versus momentum, and chi−squared versus cosine theta. These plots are for clean GEANT data reconstructed with Konstantin's pattern recognition and helix fit.

Tracking Efficiency Using Confidence Levels

The definition of reconstruction efficiency using confidence levels is defined for a given bin in cosine theta or reduced energy. For each bin, the efficiency is the ratio of all the MC events which were tracked with a reasonable confidence level over all of the MC events generated in that bin of cosine theta or reduced energy. For clean GEANT and Konstantin's pattern recognition were done using a set of 9×10^6 total events, to which the following cuts were applied. A cut on the decay time between 1000 ns and 9000 ns to eliminate prompt decays which will have positron hits mixed with the muon hits. We required a decay in the target, and that the decay be in the fiducial volume of $0.4 < \cos(\theta) < 0.97$, and reduced energy $x>0.3$. The confidence level cut on the numerator was at a confidence level of 0.5%. The tracking residuals and efficiency by the confidence level method, and using Konstantin's simple pattern recognition on clean GEANT is shown in Figure 2.

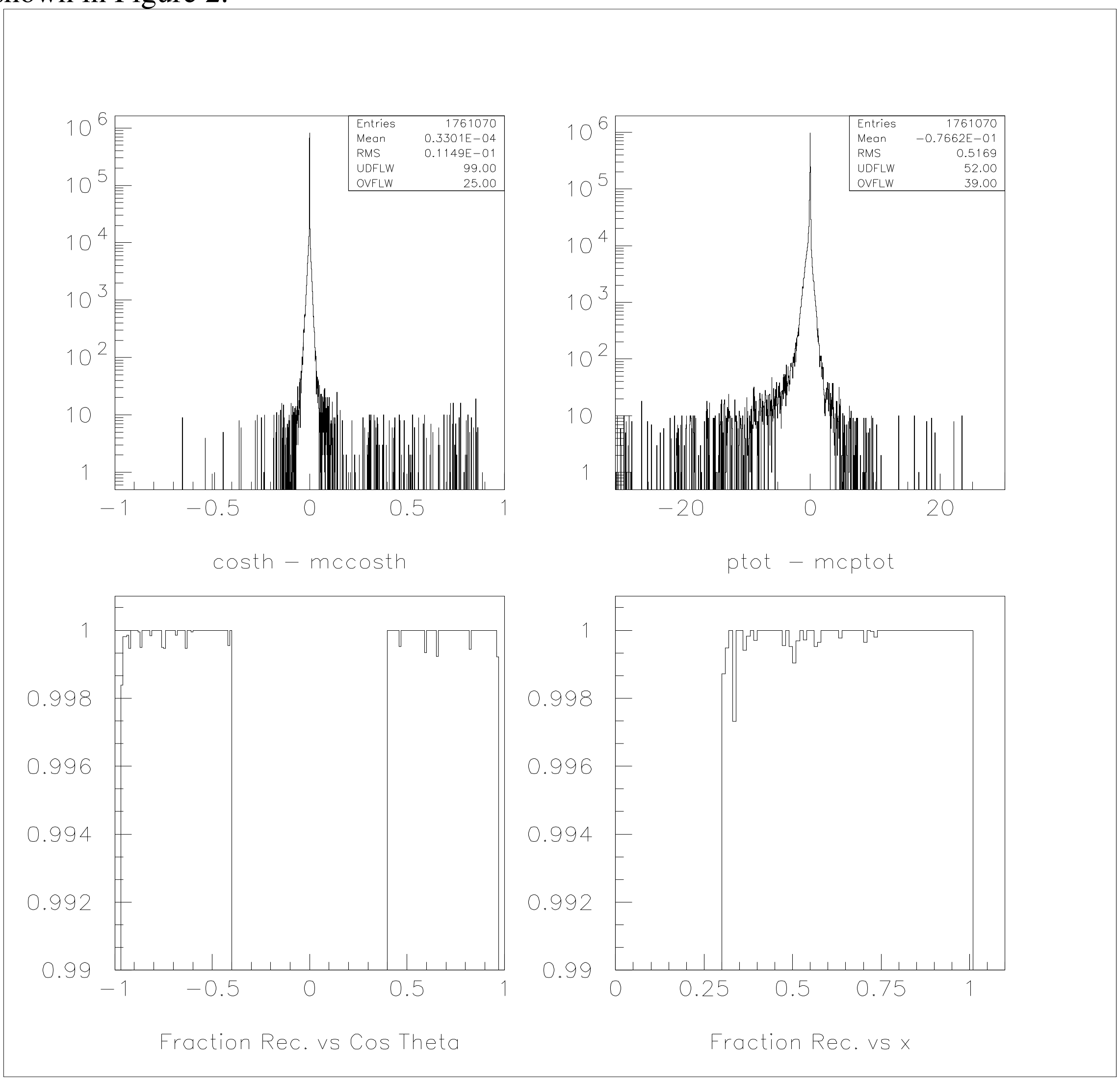

Figure 2 – Tracking residuals and efficiency in reduced energy and cosine theta for 9×10^6 clean GEANT events reconstructed with Konstantin's pattern recognition and least−squares helix fitter.

For dirty GEANT, the efficiency calculations were done with a set of 10^6 total events. As expected, the efficiency obtained in reconstructing dirty GEANT was lower than for clean GEANT. Surprisingly the efficiency using Konstantin's simple pattern recognition is still above 99.5%, based on a confidence level cut of 0.5%. The tracking residuals and efficiency by the confidence level method, and using Konstantin's simple pattern recognition on dirty GEANT is shown in Figure 3.

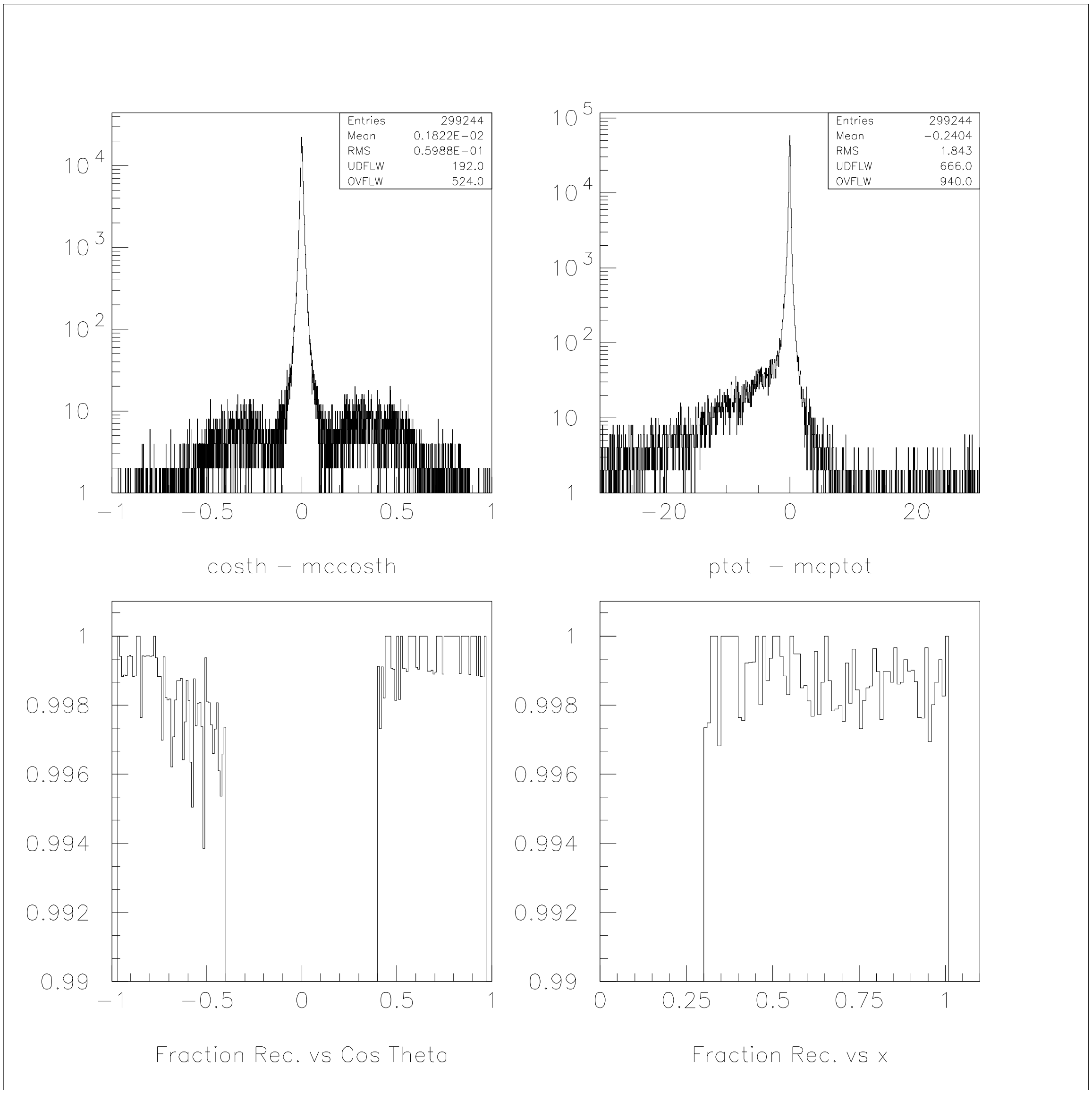

Figure 3 – Tracking residuals and efficiency in reduced energy and cosine theta for 10^6 dirty GEANT events reconstructed with Konstantin's pattern recognition and least–squares helix fitter.

Tracking Efficiency Using Residuals

The definition of reconstruction efficiency using residuals is defined for a given bin in cosine theta or reduced energy. For each bin, the efficiency is the ratio of all the MC events which were tracked with parameter values close to the generator values over all of the MC events generated in that bin of cosine theta or reduced energy. For clean GEANT and Konstantin's pattern recognition were done using a set of 9×10^6 total events, to which the following cuts were applied. A cut on the decay time between 1000 ns and 9000 ns to eliminate prompt decays which will have positron hits mixed with the muon hits. We required a decay in the target, and that the decay be in the fiducial volume of $0.4 < \cos(\theta) < 0.97$, and reduced energy $x > 0.3$. The residual cut was on the absolute value of the cosine theta residual less than 0.1, and reconstructed total momentum minus generated momentum between −3.0 MeV/c and 8.0 MeV/c. The tracking residuals and efficiency by the residuals method, and using Konstantin's simple pattern recognition on clean GEANT is shown in Figure 4.

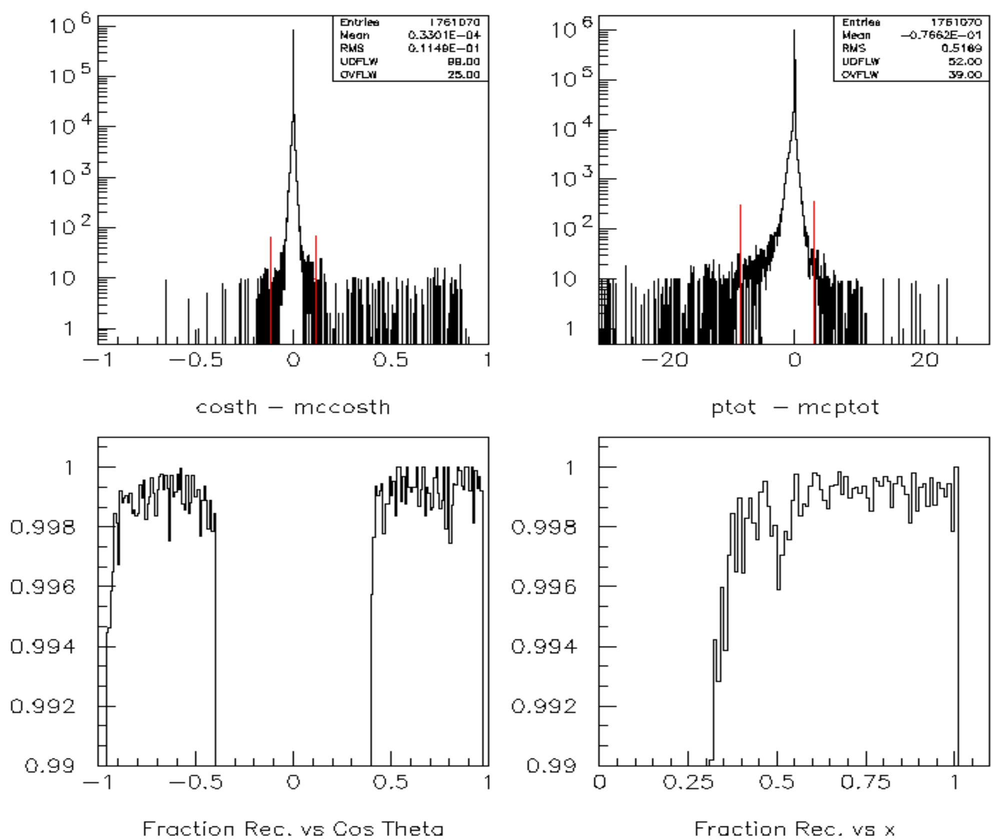

Figure 4 – Tracking residuals and efficiency in reduced energy and cosine theta for 9×10^6 clean GEANT events reconstructed with Konstantin's pattern recognition and least−squares helix fitter. The cuts on the reduced energy and cosine theta residuals are shown by the red lines.

Looking at the efficiencies in Figure 4, one notices that there is a slight drop off in efficiency for lower total momentum, and for cosine theta in the upstream direction. To see how much of a dependence on angle and momentum the fits have, we can look at residuals cut on different ranges of reduced energy, and on positive and negative decay angle. Histograms of the total momentum and cosine theta residuals cut on small reduced energy, medium reduced energy, large reduced energy, positive decay angles, and negative decay angles are shown in Figure 5.

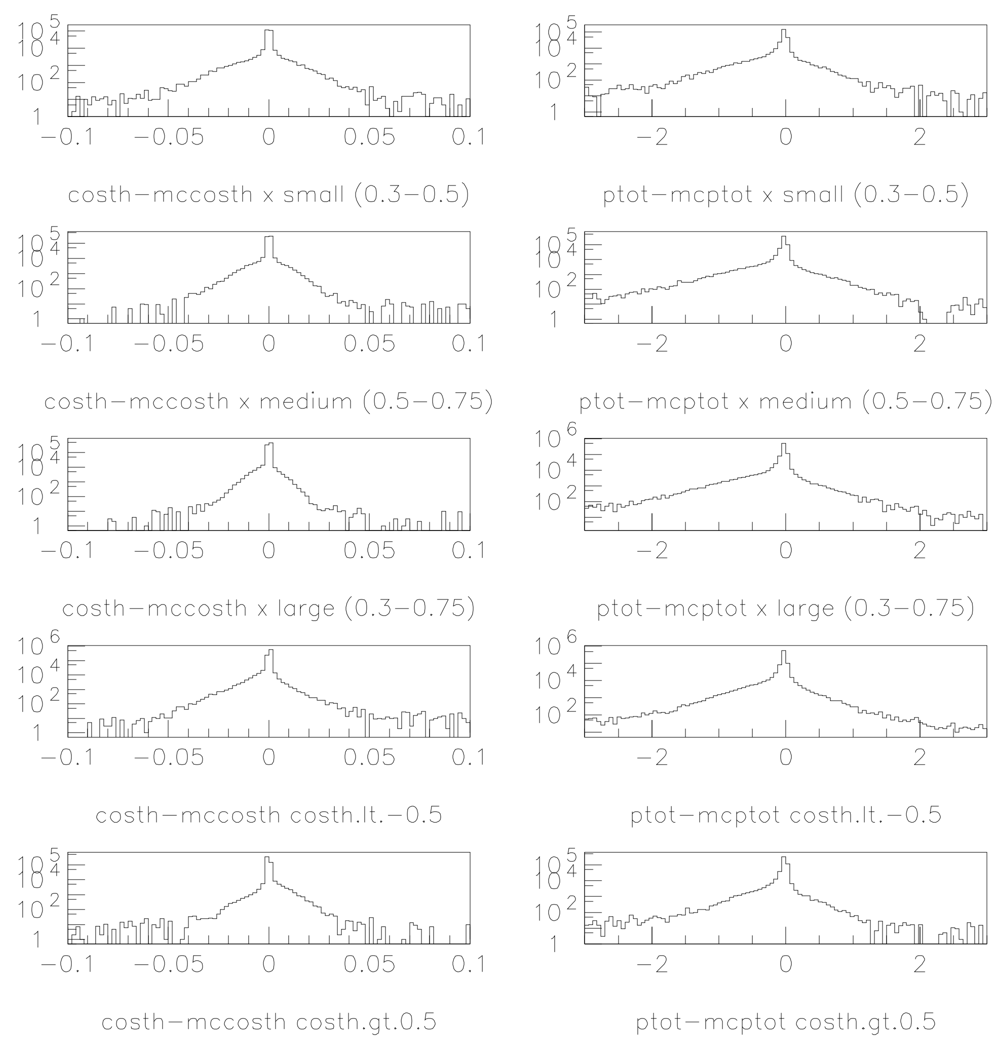

Figure 5 – Histograms of the total momentum and cosine theta residuals cut on small reduced energy, medium reduced energy, large reduced energy, positive decay angles, and negative decay angles.

For dirty GEANT, the efficiency calculations using the residuals method were done with a set of 10^6 total events. As expected, the efficiency obtained in reconstructing dirty GEANT was lower than for clean GEANT. This time however we see that for dirty events we have a harder time deciding if an event had a fit that matched the true momentum and cosine theta. Multiple scattering and secondary physics process resulted in extra hits which we were still able to fit with reasonable confidence level, but were far from the true generated values of momentum and cosine theta. The tracking residuals and efficiency by the residuals method, and using Konstantin's simple pattern recognition on dirty GEANT is shown in Figure 6.

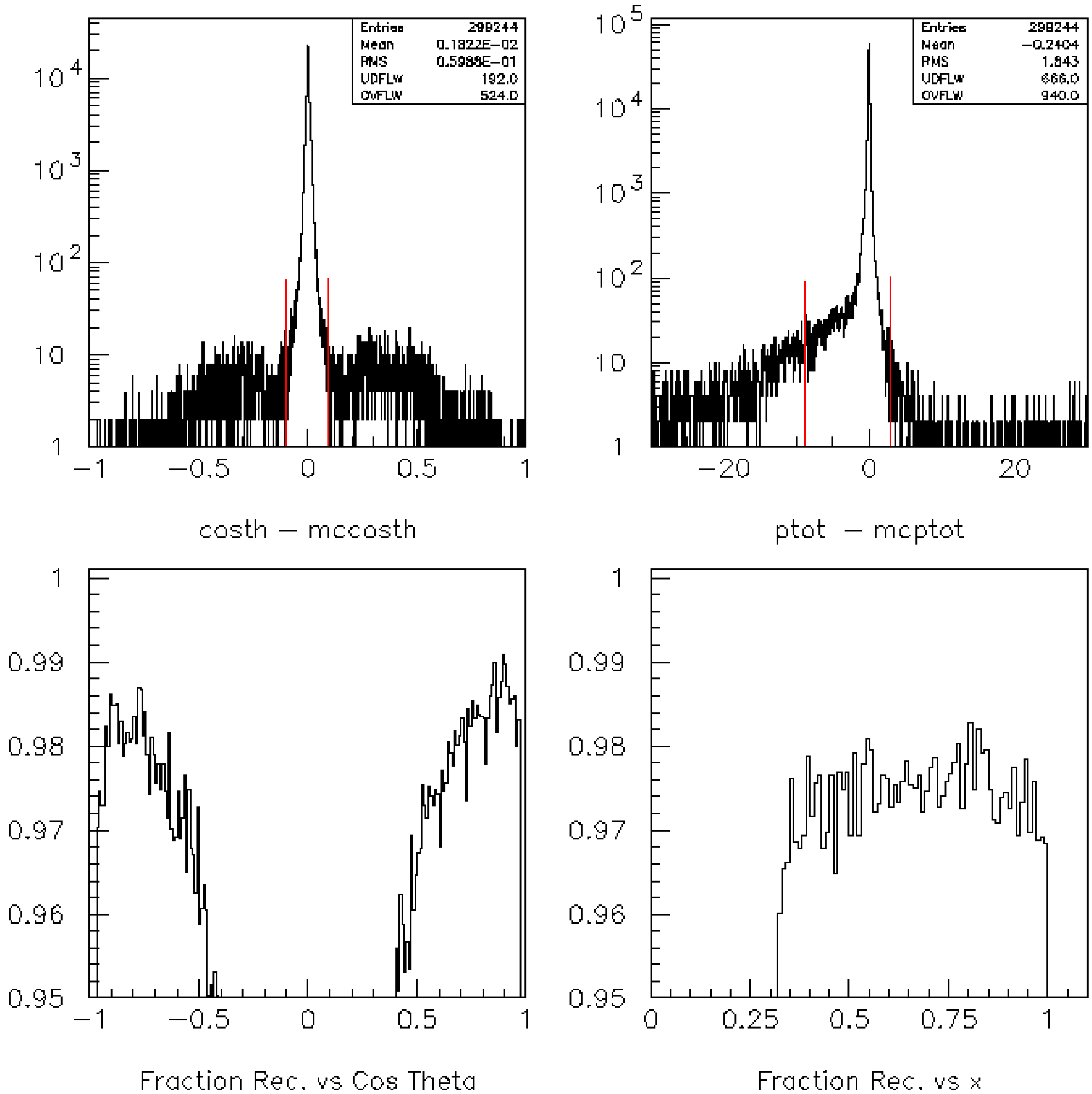

Figure 6 – Tracking residuals and efficiency in reduced energy and cosine theta for 10^6 dirty GEANT events reconstructed with Konstantin's pattern recognition and least–squares helix fitter. The cuts on the reduced energy and cosine theta residuals are shown by the red lines.

Comparison of Pattern Recognition Codes

All of the tests done in the previous sections were done using Konstantin's simple pattern recognition to obtain starting parameters for the least squares helix fit. We did not expect the simple pattern recognition to do well on dirty events, since no separation of particles in a single window was done. In this section efficiencies of the helix fitter using Jim's pattern recognition to obtain starting parameters for the least squares fit will be examined.

The results of analyses done using Jim' pattern recognition for initial parameter values to the least squares helix fit have not been very encouraging. Both clean and dirty GEANT runs were tried, and both gave unexpectedly poor efficiencies. One could argue that the more complex code may do worse than a simple code for clean GEANT data, but it seems the more complex code is even worse with dirty GEANT data. There is still the possibility that the pattern recognition parameters and wire hits being passed from Jim to Konstantin's code are not being chosen correctly. Another hint that this is the case is that if you look at the most common reason for a failed fit, the helix fitting code says that it did not get a fit from the pattern recognition. Figure 7 shows the tracking efficiency using the confidence level method with Jim's pattern recognition for obtaining starting parameters to the helix fit to clean GEANT data. Figure 8 shows the tracking efficiency using the residuals method with Jim's pattern recognition starting the helix fit to dirty GEANT data.

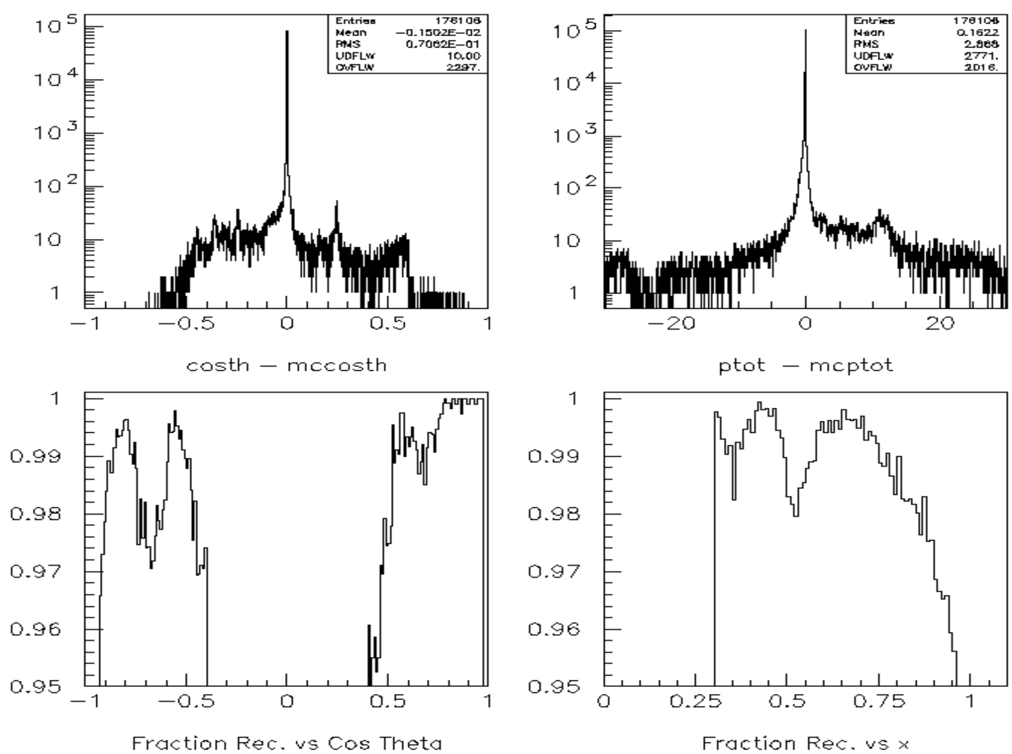

Figure 7 – Tracking residuals and efficiency using the confidence level method with Jim's pattern recognition for obtaining starting parameters to the helix fit to clean GEANT data.

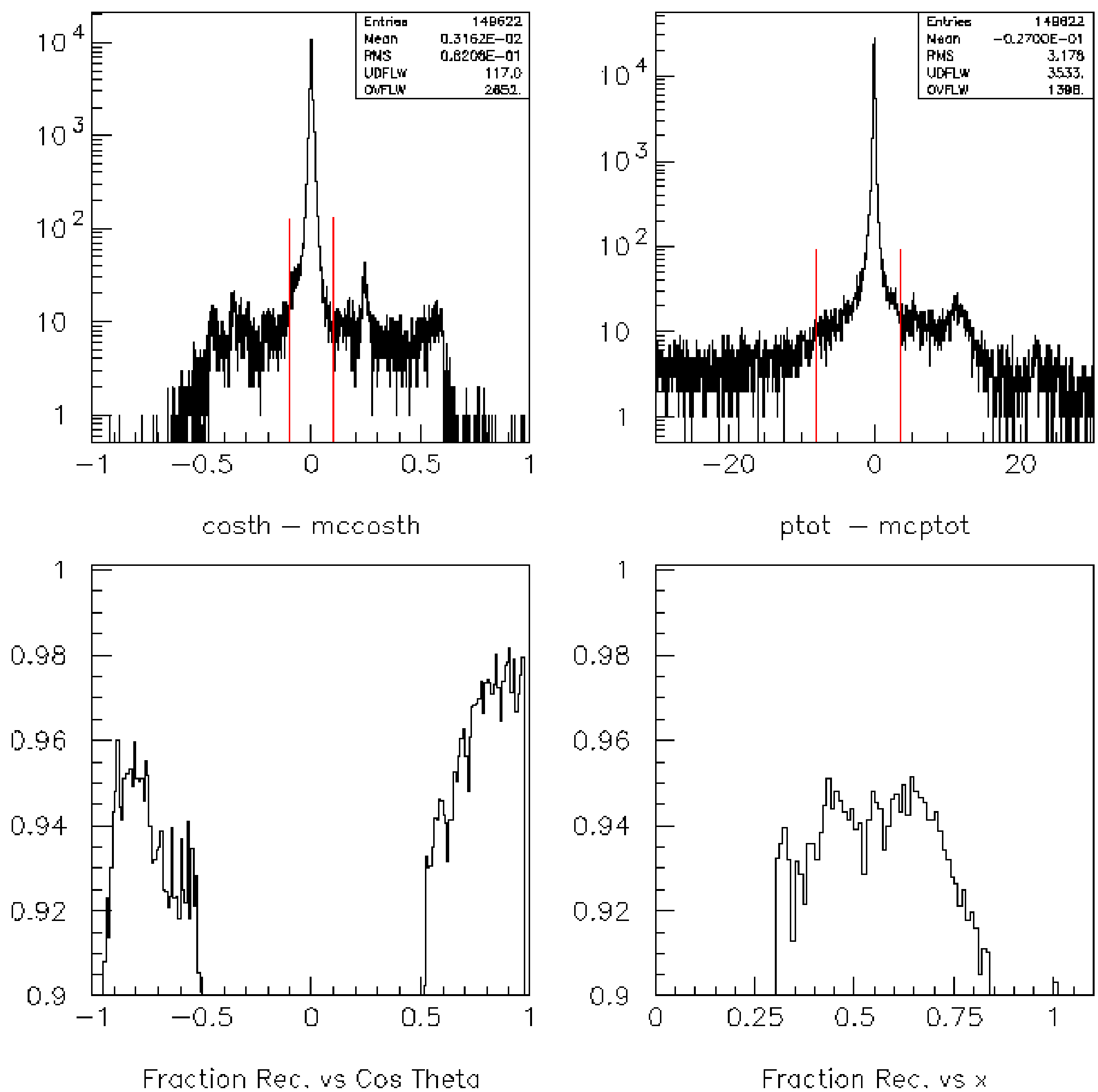

Figure 8 – Tracking residuals and efficiency using the residuals method with Jim's pattern recognition for obtaining starting parameters to the helix fit to dirty GEANT data.

Locating Events Which are Failing

Events which the helix fitter fails to fit has been done in two ways. The first way is by brute force skimming the data on the criteria that the the residuals in momentum and cosine theta are large, and that generator momentum, decay angle and decay time are in the fiducial volume. A second quicker method is to scan the helix ntuples which can be created by the analysis code. Doing a scan of event numbers with a cut on the fiducial volume, and large residuals gives a list of events which can be examined.

Events which are failing to be fit have only been looked at for the case of using Konstantin's pattern recognition with the helix fitter. For this set of code, the events which fail to be fit in the clean GEANT, are true fit failures which would require further refinements of the fitting code. For events which fail to be fit for dirty GEANT, many of the failures are due to the failure to get the right winding number for larger angle events. Other failures are due to multiple scattering and delta rays which confuse the simple pattern recognition. An example of a true failure to fit a clean GEANT event is shown in Figure 9. For this event it looks like the positron must have gone through a wire to have changed its momentum so much.

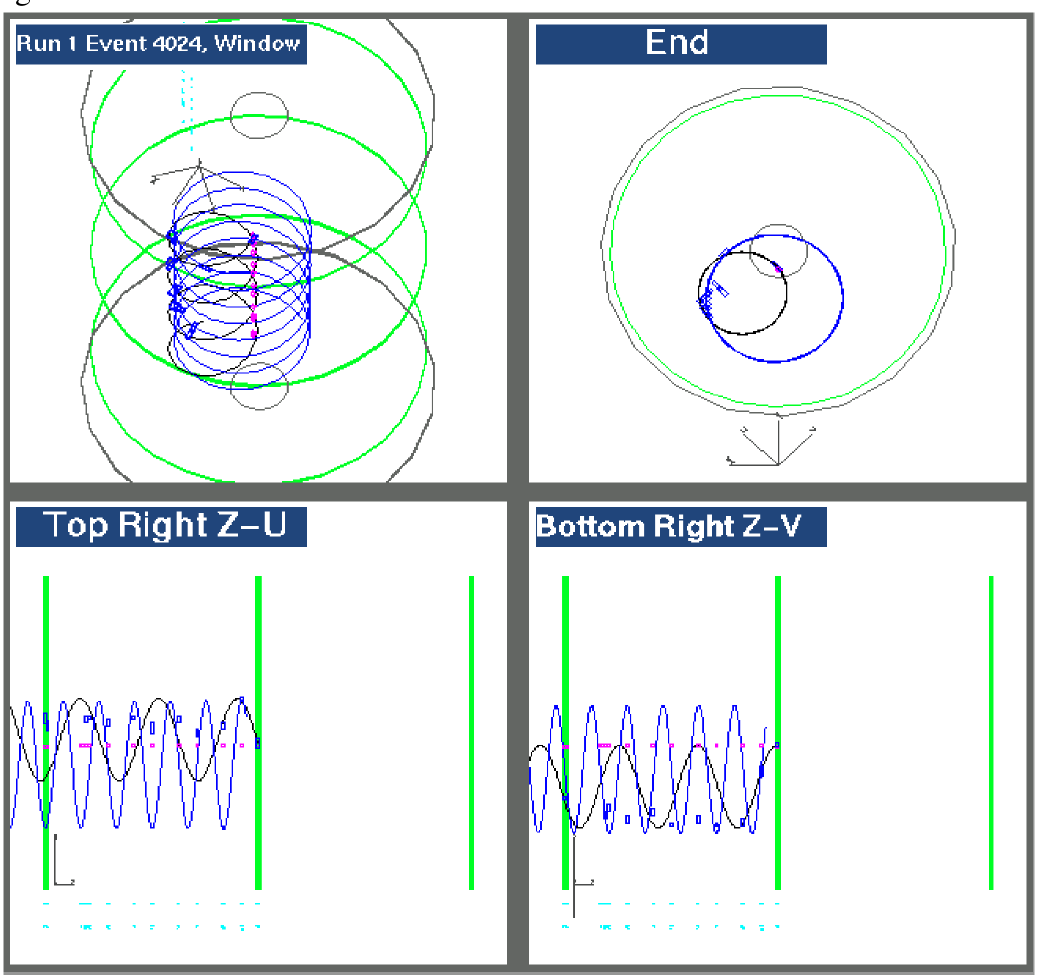

Figure 9 – An example of a true failure to fit a clean GEANT event.

Further Tests to Try

The tests which used Jim's pattern recognition need to be repeated if we can find if or why the pattern recognition results are being passed in the wrong way by the fitting code. Another test that needs to be done is to look at skimming simple events from dirty GEANT runs to see if what effect this has the decay spectrum. If we can remove the dirty events without effecting the spectrum, then the simple pattern recognition may be all we need.

Conclusion

Tests were done to determine if the helix tracking code is at level where the Michel parameters and could be extracted from data at the 0.1% level. Naively we expect that the required tracking efficiency be at the 99.9% level, since the Michel parameters come into the decay spectrum linearly. It was found that for clean GEANT data, the combination of Konstantin's simple pattern recognition and helix fit gave a tracking efficiency of better than 99.8% for most of the fiducial volume, and dropped to 99.5% for lower momentum positrons.