TN-97: Tests of the Energy Loss Correction in the Helix Fitter

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Abstract

The helix fitter includes code to correct the reconstruction to account for energy loss. I tested this code using Geant-generated monoenergetic positrons. I have found that the energy loss correction did not work correctly in its original state, but removing the momentum-dependent component and the fudge factor yields something very close to predictions. Several tests show that this change is reasonable; "harder" Bremsstrahlung is effectively unseen by our detector. Therefore, it is recommended that the energy loss correction be turned on by default in the helix fitter, as a momentum-independent correction as predicted by just the "ionization" energy loss calculations.

1 Introduction

The helix fitter currently assumes that the positron loses no energy during the track. Considering how thin the detector is, this is not a bad assumption, but correcting for the energy loss should result in better fits and more accurate momentum reconstruction.

The energy loss correction will be important for Geant validation studies, in particular, especially if any tuning of Geant is necessary. It will also be important for production analysis, so that we're measuring what we think we're measuring. It may also increase the tracking efficiency, as correcting for energy loss (and scattering) should allow Mofia to fit tracks which vary significantly from an ideal helix shape. (Early results, not shown here, suggest that the tracking efficiency is indeed improved, at the level of a few parts in 10^3; this will be studied in more detail.) It interacts with the end-point energy calibration, as well.

2 Description of Energy Loss Correction

Konstantin implemented the energy loss correction in the Mofia helix fitter by using formulas from the Particle Data Book to determine how much energy a particle should lose when it passes through a given amount of material. (So it is not a fit parameter.) The general formula for minimum-ionizing positrons is

$$\Delta E(p) = \frac{1}{\cos\theta} \sum l \left(\Delta E_{ion} + \Delta E_{brem}(p)\right) \tag{1}$$

where ΔE is the energy lost by the positron by passing through material of thickness l (measured along the Z axis), p is the positron momentum, θ is the angle the positron's momentum makes with the Z axis, ΔE_{ion} is the energy lost per unit thickness due to ionization in the material, and $\Delta E_{brem}(p)$ is the energy lost per unit thickness due to bremsstrahlung: $\Delta E_{brem}(p) = kp$, where k is a constant which depends on the material (radiation length, etc). The two energy loss rates depend on the material, of course, and for a series of materials the energy losses are simply added. Carl prepared a spreadsheet using these formulas (available from the TWIST Software Page under the "Material Interactions Spreadsheet" link, and herein referred to as the "PDG Spreadsheet"); the numbers Konstantin uses in Mofia are the same as the numbers returned by this Spreadsheet. (Of course, this formula only describes the *mean* energy loss, and does not account for energy straggling etc. But it is a good approximation.)

However, Konstantin has found it necessary to "tune" the energy loss correction by multiplying the above formula by a "fudge factor" of 0.5 in order to match the measured energy loss at the endpoint. This, however, was a very poor match for the energy loss at lower momenta. An alternative method of tuning was to remove the "fudge factor" and instead assume that $\Delta E_{brem}(p) = 0$ for all materials. This has shown to be a much better match to predictions at all momenta.

2.1 Implementing the Energy Loss Correction in Mofia

Energy loss is handled in the Mofia helix fitter mainly in the routines `helixfit_mod::HelixFit1` (which drives the fitting, from what I understand), and `helixfit_track_mod::setPositions` (which calculates the track positions at various points in the cell, for calculating distance of closest approach and hence predicting hit positions for the calculation of residuals).

`HelixFitRadLenHe`	radiation length per cm of He gas, 1/cm	2.57E-6
`HelixFitRadLenFoil`	radiation length per foil, 1/1	2.07E-5
`HelixFitRadLenDC`	radiation length per cm of DC gas, 1/cm	4.81E-5
`HelixFitMinIonHe`	min. ionizing per cm of He gas, MeV/c/cm	3.68E-4
`HelixFitMinIonFoil`	min. ionizing per foil, MeV/c/1	1.52E-3
`HelixFitMinIonDC`	min. ionizing per cm of DC gas, MeV/c/cm	3.86E-3

Table 1: Default values of the HelixFit namelist variables containing energy loss constants.

2.1.1 `helixfit_mod::HelixFit1`

This routine is where the energy losses for various materials (helium, DME, foils) are calculated, including momentum dependence and fudge factor, from the values for ionization and radiative energy loss supplied in namelist variables. The namelist variables (from the `HelixFit` namelist) are shown in table 1, and were set according to calculations by Konstantin.

The variables `elossHe`, `elossDC`, and `elossFoil` are where Mofia stores the energy losses for each material for the current track. If the `HelixFit` namelist variable `HelixFitDoLoss` is set to False, all energy loss values are set to zero. Otherwise, they're calculated according to

$$\Delta E_i = F(I_i + R_i p) \tag{2}$$

where i stands for the material (helium, DC gas, or foil), F is the fudge factor, and I_i and R_i are the ionization and radiation constants from table 1.

For the "modified" energy loss correction test, I simply replaced equation 2 with

$$\Delta E_i = I_i \tag{3}$$

and I plan to commit the more general

$$\Delta E_i = F_1 I_i + F_2 R_i p \tag{4}$$

where F_1 and F_2 are two separate fudge factors; default values will be $F_1 = 1$ and $F_2 = 0$.

2.1.2 `helixfit_track_mod::setPositions`

This routine tracks the particle through a cell (through the helium gap, through the first foil, through the gas, and out the other foil), using calls to the `trackswim_mod::TrackToZK` routine, passing the appropriate material's energy loss (from `helixfit_mod::HelixFit1`) as one of the routine's parameters. It calculates the trajectory positions at the entrance, centre, and exit of the cell, so that the distance of closest approach can be calculated. That distance is the "predicted" drift distance of the hit in that cell, and is compared against the actual hit to calculate the residual.

(Kink angles are calculated in the `setPositions` routine as well, with a call to `doKink`. Incidentally, kinks are controlled by the namelist variables `HelixFitDoKinksWC`, `HelixFitDoKinksDT`, and `HelixFitDoKinksTarget`, which enable kinks for wire-centre fits, drift fits, and at the target.)

The tracking proceeds as follows:

- Start the track just outside the first foil of the plane.
- Decrease the magnitude of the positron's momentum according to the energy it should lose passing through the foil, adjusted appropriately for the track angle θ where it intersects the foil.
- Use `TrackToZK` to swim the track through the gas volume in the cell, following a "helix with energy loss" trajectory, to the foil at the other side.
- Decrease the positron's momentum again for passing through the second foil.
- Swim through the second plane in the pair.
- Decrease the positron's momentum again for the final foil in the module.
- Swim the positron through the helium gap, again using `TrackToZK`.

This procedure is repeated for each module (modified appropriately for tracking through the dense stack, of course). In all cases, the pre-calculated "mean" energy loss is used; energy loss is not a fit parameter.

3 Monte Carlo Generation and Analysis

Mono-energetic positrons were generated at the centre of the detector, with a uniform distribution in $\cos\theta$; no muons were generated. At the time I generated this, I wasn't quite sure where exactly the aluminum stopping target was locates in Z; to eliminate any asymmetry that might result from this, I created a custom geometry file setting the material of the stopping target to "vacuum". The usual magnetic field map was used, and the field was set to 2.0 T at the origin.

Data were generated at 20, 30, 40, and 50 MeV/c.

Analysis was done using standard Mofia, with classification turned off. (The namelist variable `HelixFitAll` (from namelist `helixfit`) then had to be used to make the helix fitter fit tracks in spite of their classification.) The data files were analyzed twice, once with the standard Mofia settings, and once with the energy loss corrections enabled with

```
name helixfit HelixFitDoLoss = T
```

Helix fit parameters are calculated at a point 8 mm before the first DC used in the fit; a cut was applied during tree summing to require that tracks start at the DCs closest to the target.

4 Study Results

The energy loss correction was studied in two ways. First, the reconstructed momentum (p_{rec}) was compared to the momentum of the positron at generation (variously referred to as p_{thrown}, p_{true}, or $p_{MC}(tgt)$). Previous reports were made using this comparison; section 4.1 contains a summary of these reports, for original and "modified" energy loss corrections vs no correction.

A better method of studying the energy loss correction is to compare p_{rec} to the actual energy of the positron just outside the first DC ($p_{MC}(DC)$), where the helix fitter is actually calculating the helix parameters; these results are reported in section 4.2.

4.1 Comparison to p_{thrown}

(The results in this section were previously reported, and are included here for convenience. Section 4.2 is the recommended reading.)

The original energy loss correction in Mofia accounts for all materials through which the track actually passes (including the foil at the entry to the first DC of the track), so the difference between the reconstructed energy and the "thrown" energy at the positron's origin should be due to energy lost in the target PCs and the helium gas. This energy loss can be expressed as $p_{rec} - p_{true}$, where p_{rec} is the reconstructed momentum, and p_{true} is the momentum that the positron had when it was generated.

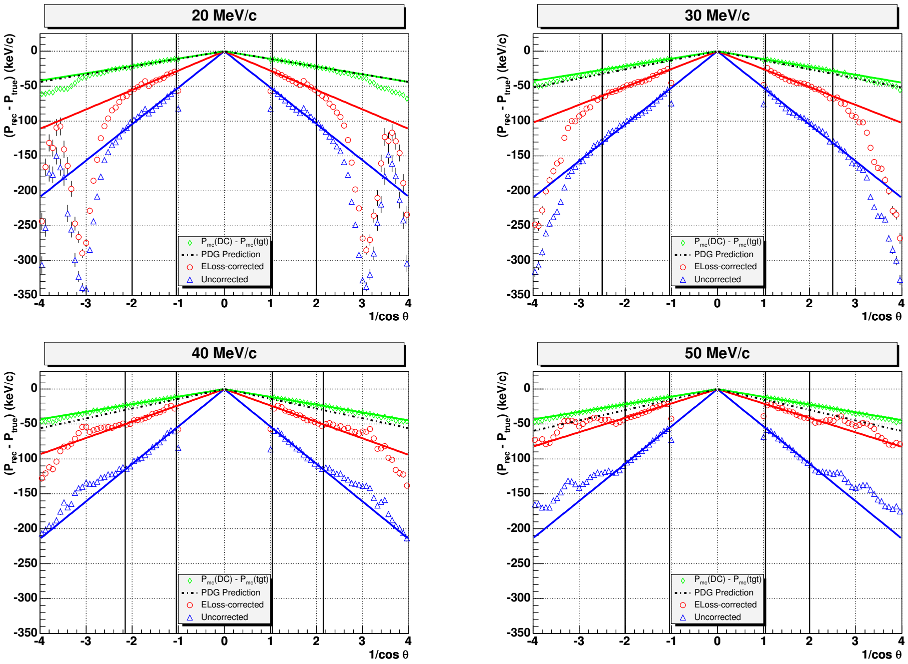
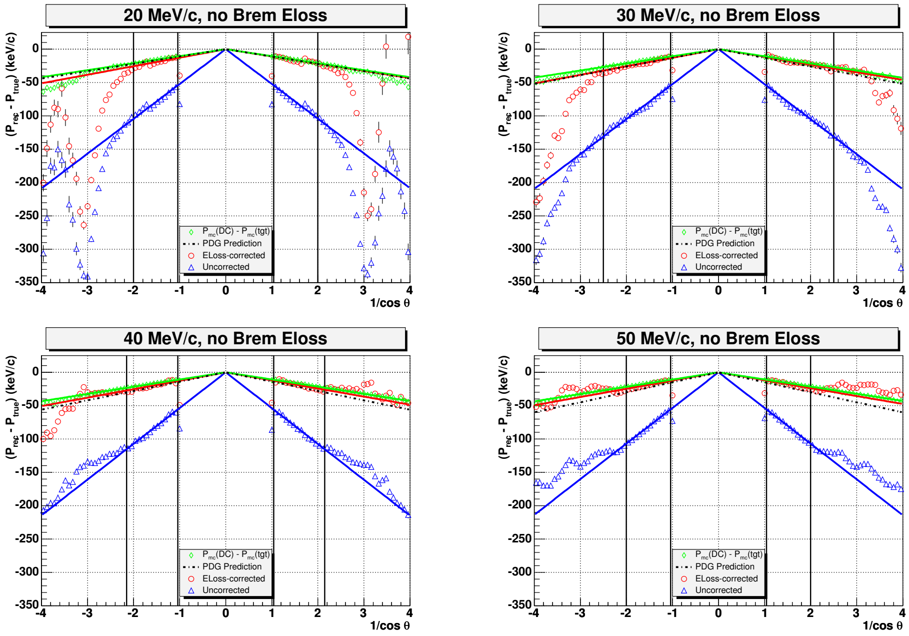


Figure 1: Momentum residuals $(p_{rec} - p_{true})$ vs $1/\cos\theta$. The vertical lines show the fit regions (chosen by eye) for the straight-line fits. The line labeled "ELoss-corrected" should roughly match the line labeled "PDG Prediction". See text for more details.

As Carl's PDG Spreadsheet includes the thicknesses and energy loss rates for all appropriate materials, it can be used to predict the slope of $p_{rec} - p_{true}$ vs $1/\cos\theta$. Figure 1 shows profile histograms of $p_{rec} - p_{true}$ vs $1/\cos\theta$ (error bars are uncertainties on the means in each bin), for uncorrected (standard Mofia) and energy-loss-corrected results. Also shown are the Spreadsheet-predicted lines, and what the Monte Carlo Truth Banks say the energy loss was between the origin and the first DC: $P_{mc}(DC) - P_{mc}(tgt)$. (The MC Truth Bank results are shown just as a 'sanity check'; because of straggling and other approximations it shouldn't necessarily match the PDG prediction exactly, but it should be "close" (and clearly is).) Since the Mofia correction uses the same formulas as the Spreadsheet, the energy-loss-corrected results should (roughly) match the Spreadsheet-predicted lines; the match shouldn't necessarily match exactly due to energy straggling etc, but it should be "close;" there is a clear discrepancy, especially at low momentum.

Figure 2 shows the same plots as in figure 1, but for the "modified"



20 MeV/c, no Brem Eloss

30 MeV/c, no Brem Eloss

40 MeV/c, no Brem Eloss

50 MeV/c, no Brem Eloss

Figure 2: Momentum residuals $(p_{rec} - p_{true})$ vs $1/\cos\theta$, reconstructed without the fudge factor or the momentum-dependent component of the correction. The vertical lines show the fit regions (chosen by eye) for the straight-line fits. The line labeled "ELoss-corrected" should roughly match the line labeled "PDG Prediction". See text for more details.

energy loss correction (no fudge factor or momentum dependence). These come much closer to the PDG Spreadsheet predictions.

The points in figures 1 and 2 were fit to straight lines with intercepts fixed at 0. (Even using the correct magnetic field setting in reconstruction, the fitted intercepts are generally not exactly 0, probably due to a slight fitter bias; see section 4.3.) The slopes of the fit lines are listed in table 2 and plotted in figure 3. Notice that the slopes of the uncorrected results, and the predicted slopes, both increase with positron momentum, while the corrected results *decrease* with momentum. This is further evidence of something amiss. The slopes of the results with the "modified" correction come out very similar to the PDG Spreadsheet prediction, although obviously independent of energy and therefore not a perfect match at any momentum.

p (MeV/c)	Fit Range $\lvert 1/\cos\theta \rvert$		Slope (keV/c)	
			Upstream	Downstream
20	$[1.04, 2.00]$	Uncorrected	52.2 ± 0.1	-52.1 ± 0.1
		Corrected	27.8 ± 0.1	-27.8 ± 0.1
		Corrected, No Brem	12.8 ± 0.1	-10.8 ± 0.1
		$P_{mc}(DC) - P_{mc}(tgt)$	10.52 ± 0.05	-11.01 ± 0.05
		Predicted	11	-11
30	$[1.04, 2.50]$	Uncorrected	52.4 ± 0.1	-52.5 ± 0.1
		Corrected	25.6 ± 0.1	-25.7 ± 0.1
		Corrected, No Brem	12.8 ± 0.1	-11.5 ± 0.1
		$P_{mc}(DC) - P_{mc}(tgt)$	10.65 ± 0.04	-11.24 ± 0.05
		Predicted	13	-13
40	$[1.04, 2.15]$	Uncorrected	53.0 ± 0.1	-53.0 ± 0.1
		Corrected	23.2 ± 0.1	-23.2 ± 0.1
		Corrected, No Brem	12.7 ± 0.1	-12.1 ± 0.1
		$P_{mc}(DC) - P_{mc}(tgt)$	10.83 ± 0.05	-11.21 ± 0.05
		Predicted	14	-14
50	$[1.04, 2.00]$	Uncorrected	53.4 ± 0.1	-53.5 ± 0.1
		Corrected	20.6 ± 0.1	-20.7 ± 0.1
		Corrected, No Brem	12.4 ± 0.1	-11.9 ± 0.1
		$P_{mc}(DC) - P_{mc}(tgt)$	10.88 ± 0.03	-11.11 ± 0.04
		Predicted	15	-15

Table 2: Slopes of the fit lines from figures 1 and 2 (momentum residuals vs $1/\cos\theta$). "Corrected, No Brem" entries refer to the "modified" version of the correction (eqn. 3). $P_{mc}(DC) - P_{mc}(tgt)$ shows the actual energy lost between the origin and the first DC, according to the MC. Predictions are from Carl's PDG Spreadsheet. These slopes are plotted in figure 3.

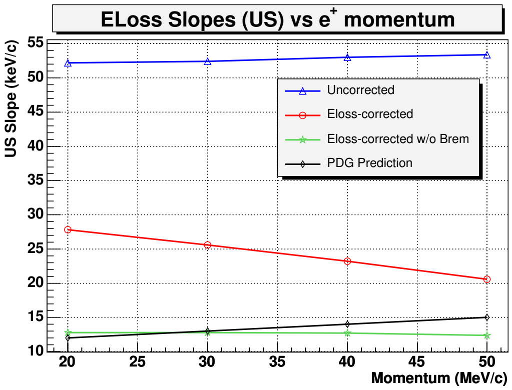


Figure 3: Slopes of the fit lines from figures 1 and 2 (momentum residuals vs $1/\cos\theta$) vs positron momentum. The values plotted are tabulated in table 2.

4.2 Comparison with $p_{MC}(DC)$

The study in section 4.1 is difficult to interpret, because it tests not the energy loss in the fit region but the energy loss in the target region—which the helix fitter obviously cannot account for. Presented here is a more direct study, which compares the positron momentum calculated by the helix fitter to the MC's report of the positron's actual momentum at the same point. If everything is working "perfectly" then these momenta should match within a few keV.

As stated above, $p_{MC}(DC)$ is the momentum the positron had just outside the first DC (closest to the target), according to the MC "truth" banks, and should correspond to what the helix fitter is measuring. Then the mean of $(p_{rec} - p_{MC}(DC))$ should be very close to zero at all angles and momenta if the energy loss correction is working properly.

Cuts were imposed on the data to make these results easier to interpret: tracks were required to start next to the target module, and to reach the appropriate dense stack (i.e. they weren't truncated by the fitter).

Results in this section don't really show anything that wasn't evident in section 4.1, but they remove the ambiguity of the energy loss in the target module and are therefore easier to understand.

Figure 4 shows plots of $(p_{rec} - p_{MC}(DC))$ vs $1/\cos\theta$ for the momenta studied. For a perfect energy loss correction, the lines labeled "Eloss-corrected" should be flat, but in reality they should probably be just "close", and they are. There are slight but troubling asymmetries in upstream vs downstream (on the order of a couple of keV in the fit regions, and worse outside); these asymmetries are present both before and after corrections, and so are not the result of the correction itself. (These asymmetries are evident in section 4.1 as well, though they're not as obvious.) The asymmetries are being investigated.

Slopes of the fitted lines are listed in table 3 and plotted in figure 5. The fact that the uncorrected slopes change very little with momentum is once again confirmation that there is little momentum dependence in the energy loss as seen by the helix fitter. The detailed fluctuations of the fitted slopes, for both uncorrected and corrected results, may be due more to the fits themselves; there is a lot of keV-scale structure to the plots (figure 4), which may limit the reliability of the straight-line fits at the keV level. Again notice that the asymmetry in the slopes does not change when the energy loss correction is applied.

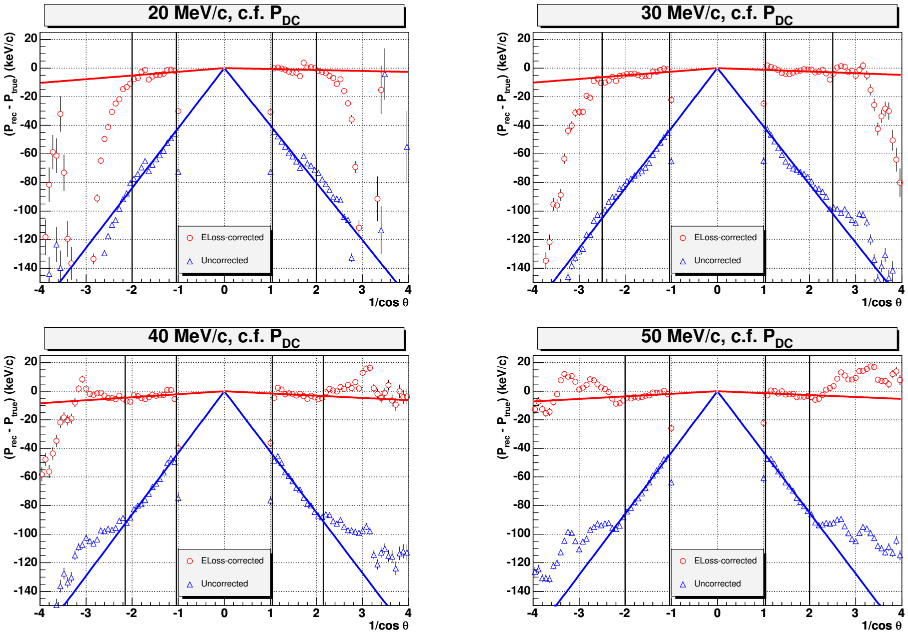


Figure 4: Momentum residuals ($p_{rec} - p_{MC}(DC)$) vs $1/\cos\theta$. The vertical lines show the fit regions (chosen by eye) for the straight-line fits. The correction made here includes only the "ionization" component of the energy loss, without the energy-dependent component, and without the fudge factor.

p (MeV/c)	Fit Range $\|1/\cos\theta\|$		Slope (keV/c)	
			Upstream	Downstream
20	[1.04, 2.00]	Uncorrected	41.9 ± 0.1	-40.2 ± 0.1
		Corrected	2.6 ± 0.1	-0.7 ± 0.1
30	[1.04, 2.50]	Uncorrected	42.0 ± 0.1	-40.7 ± 0.1
		Corrected	2.5 ± 0.1	-1.2 ± 0.1
40	[1.04, 2.15]	Uncorrected	43.1 ± 0.1	-42.5 ± 0.1
		Corrected	2.1 ± 0.1	-1.6 ± 0.1
50	[1.04, 2.00]	Uncorrected	42.9 ± 0.1	-42.5 ± 0.1
		Corrected	1.8 ± 0.1	-1.3 ± 0.1

Table 3: Slopes of the fit lines from figure 4. "Corrected" here uses the "modified" correction, with no momentum-dependent component and no fudge factor. Slopes are plotted in figure 5.

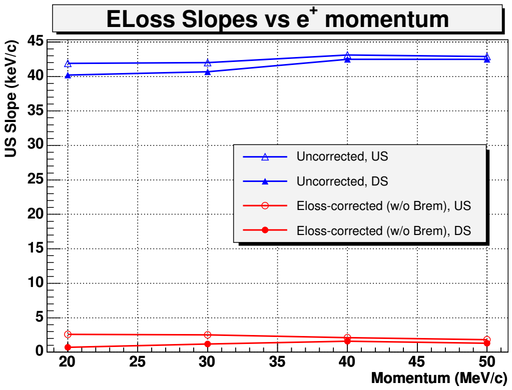


Figure 5: Slopes of the fit lines from figure 4 ($(p_{rec} - p_{MC}(DC))$ vs $1/\cos\theta$) vs positron momentum. The values plotted are tabulated in table 3. "US" refers to upstream measurements, and "DS" to downstream measurements. Slopes for downstream measurements are absolute values, for comparison purposes.

4.3 Test of Fitter Bias

Figure 6 shows $(p_{rec} - p_{true})$ vs $1/\cos\theta$ for a 50 MeV/c set with physics processes turned off, on the same vertical scale as that of the plots in figure 1. In principle this should be a flat line at 0, and the figure shows that it is nearly so within the fiducial, but closer examination reveals the points to be all slightly positive (mean is around +4 keV/c), with a slope of about 2.6 keV/c. This is small, but it is not zero. The MC Truth Banks (not plotted) show that the actual difference in energy between the origin and the first DC really is zero for all angles, so this is happening at the level of the fitter. I believe this is an indication of slight biases in the helix fitter; Konstantin confirms that this is likely.

4.4 Energy Loss Correction and χ^2/dof

I compared the Helix Fitter χ^2/dof distributions given by Mofia with and without the energy loss correction. If the energy loss correction is working right, in principle the χ^2 should get smaller, as the reconstructed track should better fit the data; in practice, the kinks may help to compensate for the way the energy loss changes the track shape (and thanks to the magnetic field, energy loss *does* change the track direction), so it's not obvious *a priori* that the energy loss correction should improve the χ^2 even if the

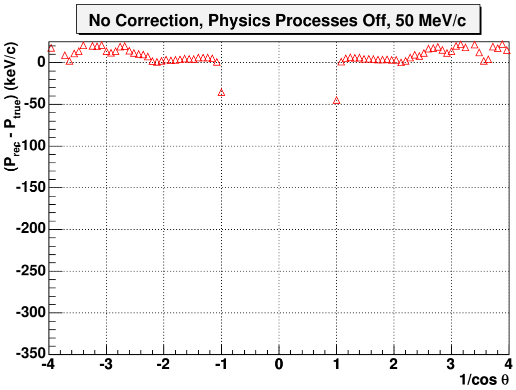


Figure 6: Momentum residuals $(p_{rec} - p_{true})$ vs $1/\cos\theta$, physics processes off.

correction is working properly. (It should probably be expected, though, as increasing kink angles also increases the χ^2, by design.) However, if the correction makes the χ^2 *worse*, this is a clear sign that something is wrong. As figure 7 shows, the energy loss correction is clearly improving the χ^2 significantly. (Actual χ^2/dof distributions look basically the same with and without the energy loss correction.) The modified energy loss correction gives the same or slightly better mean χ^2/dof compared to the original correction. Note that the calculation of the mean χ^2/dof will be heavily weighted to higher momenta due to the shape of the decay spectrum; since the energy loss seen by Mofia is effectively constant for all momenta, it represents a smaller relative effect on tracks with larger momenta, which may explain the deceptively small (though significant) change in χ^2/dof when energy loss corrections are applied. Further studies should examine how the χ^2/dof is affected as a function of p, p_z, p_t, $\cos\theta$, etc.

The energy loss correction has the same effect on the reconstruction of decay events for standard surface muon data and MC; see table 4.

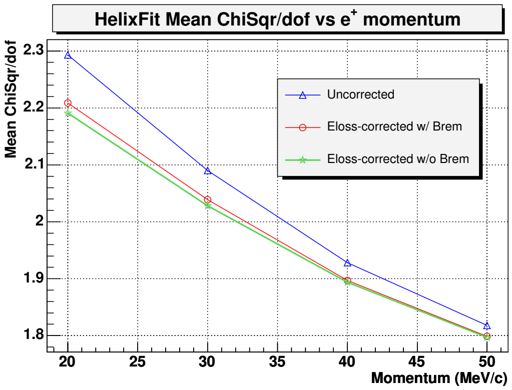


Figure 7: HelixFit χ^2/dof vs momentum, with and without energy loss correction, and with "modified" correction. Statistical error bars are shown, but are invisibly small (typically ±0.002).

		Mean χ^2/dof
Set 35	Uncorrected	2.673 ± 0.004
	Corrected	2.637 ± 0.004
Gen 148	Uncorrected	2.05 ± 0.01
	Corrected	2.01 ± 0.01

Table 4: Mean HelixFit χ^2/dof from Mofia, uncorrected and corrected for energy loss, for standard surface muon data (set 35, run 18899) and MC (gen 148, run 9999).

5 Bremsstrahlung vs. the Helix Fitter

Clearly there is strong evidence that the helix fitter sees little to no momentum dependence of the positron energy loss. The likely interpretation of this is that events which lose too much energy to Bremsstrahlung do not get reconstructed. This interpretation is supported by Peter Kitching's calculation of the Bremsstrahlung energy distribution:[1] the distribution drops very rapidly, with a very long tail, so that any truncation of the tail will significantly decrease the mean Brem energy. (Radiation length calculations to predict the mean energy loss due to Brem use the entire distribution, of course.)

A test of this interpretation is that the mean energy loss along tracks which were *not* reconstructed will be significantly larger than the events which *were* reconstructed. This is shown in figure 8, which shows $(p_{MC}(lastDC) - p_{MC}(firstDC))/2$ vs $1/\cos\theta$ for events which were not reconstructed. ($(p_{MC}(lastDC) - p_{MC}(firstDC))/2$ should correspond to $(p_{rec} - p_{MC}(DC))$ for the uncorrected helix fitter; it's half of the energy loss in the detector material.) Compare this to the "uncorrected" $(p_{rec} - p_{MC}(DC))$ for the reconstructed tracks (figure 4); the reconstructed tracks have energy losses of around 50–140 keV, whereas the unreconstructed tracks have energy losses around 250 keV.

5.1 MC with Bremsstrahlung Off

To see how much (or how little) an effect that Bremsstrahlung has on the helix fitter's results, MC was run with Bremsstrahlung processes turned off (ffcard `BREM 0`), at 20 and 50 MeV/c. If the theory that the significant Bremsstrahlung is basically invisible to the helix fitter is correct, then the momentum residuals $(p_{rec} - p_{MC}(DC))$ shown in figure 4 should change very little. On the other hand, PDG Spreadsheet calculations show that the mean Brem component of the energy loss, including the entire tail, should be about 50% of the ionization component, or a third of the total energy loss.

The momentum residuals for Brem-off MC are shown in figure 9, with slopes of the fitted lines tabulated in table 5. Apparently, turning off Brem in MC results in a reduction of energy loss by a couple of keV, with little to no dependence on momentum. This is consistent with conclusion that "hard Brem" events are not reconstructed.

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[1] See TWIST Forum posting titled "bremsstrahlung energy loss", Peter Kitching, 6 May 2005.

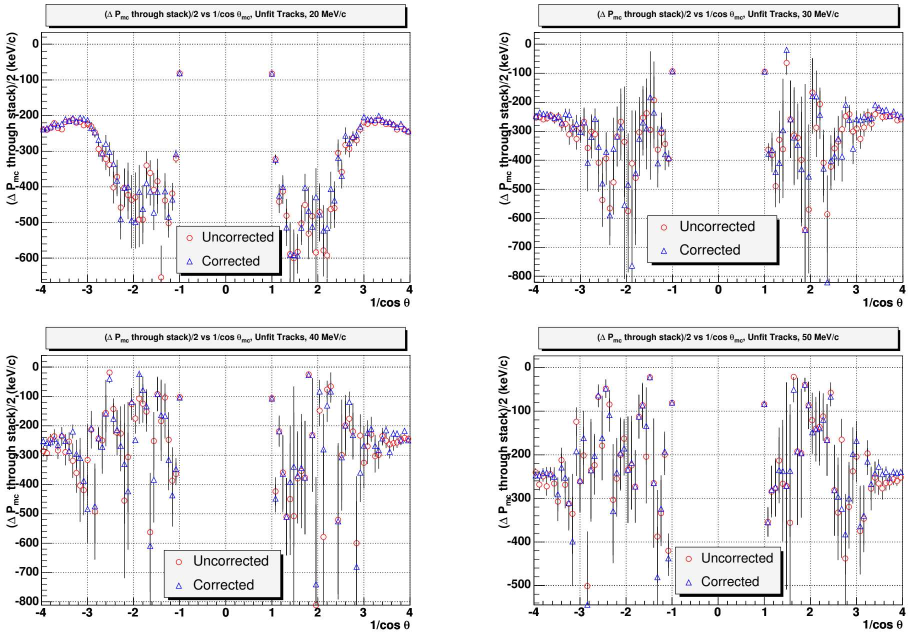

Figure 8: Energy loss through half a track $((p_{MC}(lastDC) - p_{MC}(firstDC))/2)$ vs $1/\cos\theta$ for events which were not reconstructed. $((p_{MC}(lastDC) - p_{MC}(firstDC))/2$ should be equivalent to $(p_{rec} - p_{MC}(DC))$ for the uncorrected helix fitter; it's half of the energy loss in the detector material. Energy loss along tracks which were not reconstructed is clearly much larger than that along tracks which were fit successfully.

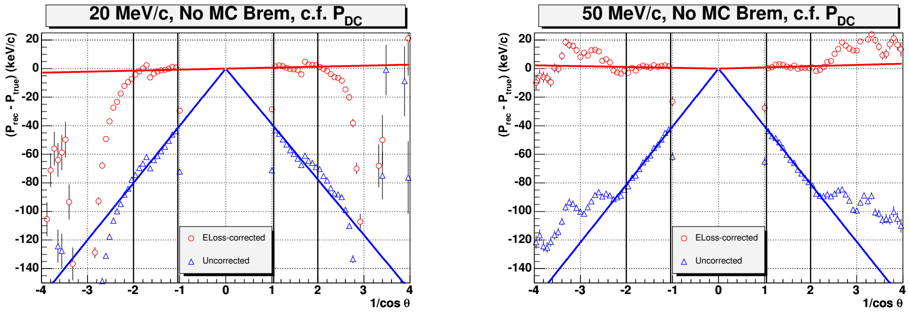

Figure 9: Momentum residuals $((p_{rec} - p_{MC}(DC)))$ vs $1/\cos\theta$ for Brem-off MC. Compare to figure 4.

p (MeV/c)	Fit Range $\|1/\cos\theta\|$		Slope (keV/c) Upstream	Downstream
20	$[1.04, 2.00]$	Uncorrected	40.0 ± 0.1	-38.8 ± 0.1
		Corrected	0.7 ± 0.1	0.7 ± 0.1
50	$[1.04, 2.00]$	Uncorrected	40.6 ± 0.1	-40.4 ± 0.1
		Corrected	-0.6 ± 0.1	0.9 ± 0.1

Table 5: Slopes of the fit lines from figure 9. "Corrected" here uses the "modified" correction, with no momentum-dependent component and no fudge factor. Compare to table 3; turning off Brem processes in MC resulted in a change of energy loss by a couple of keV/c.

6 On Tuning the Energy Loss Correction

The energy loss correction works well at the level of the smoothness of the momentum residuals (figure 4); it clearly comes very close to reproducing the "true" track energy at the track start. Note that any small errors in the track momentum due to an incorrect energy loss correction will show up in both MC and data, and so should (mostly?) cancel out. At this point all evidence suggests that the energy loss correction is sufficiently accurate.

If it is later shown that the actual track energies need to be reconstructed to better than a couple of keV, the energy loss correction may need to be tuned. To do this, first the definition of the "correct" answer would need to be determined; this would likely involve careful event selection so that we know what we're tuning to. Also, analysis and/or simulation parameters would need to be adjusted to try to smooth out the momentum residuals curves (e.g. figure 4) so that a straight-line fit becomes meaningful at the level of a keV or less.

Studies are planned for measuring the systematic sensitivity to the energy loss correction; the expectation is that the largest sensitivity will be to the momentum-dependent component (if any) of the correction, as that is not being measured by the energy calibration procedure.

7 Conclusions

The energy loss correction in the helix fitter has been shown to work correctly without a fudge factor, using only the energy-independent component of the energy loss estimates. The result reproduces the "true" momentum of the track at the track start, at least to within a couple of keV, at all tested momenta. Furthermore, the correction results in lower HelixFit χ^2/dof, which (probably) indicates better fits when the correction is applied. The energy loss correction is therefore recommended for use, using a fudge factor of 1.0 with a momentum-dependent component of 0.0.

Forthcoming studies will show the systematic sensitivity of Michel parameters to the details of the energy loss correction, especially the momentum-dependent component.