Robert Johnson
November 13, 2017

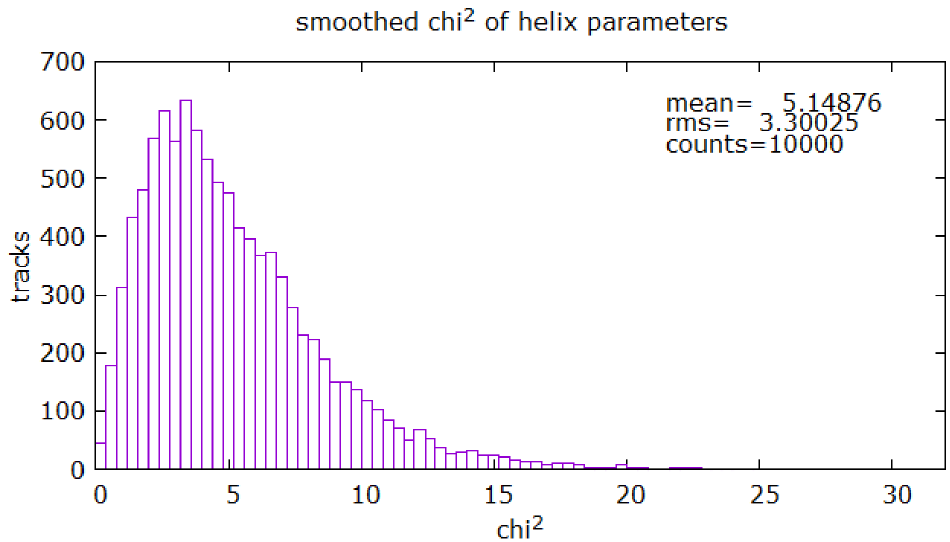
Status of the Kalman filter fitting with the HPS field map.

This is still a stand-alone test in which the HPS layer geometry is approximated and the simulated "data" are generated with perfectly Gaussian errors. The B field is read from the actual HPS field map and interpolated with a tri-linear interpolation.

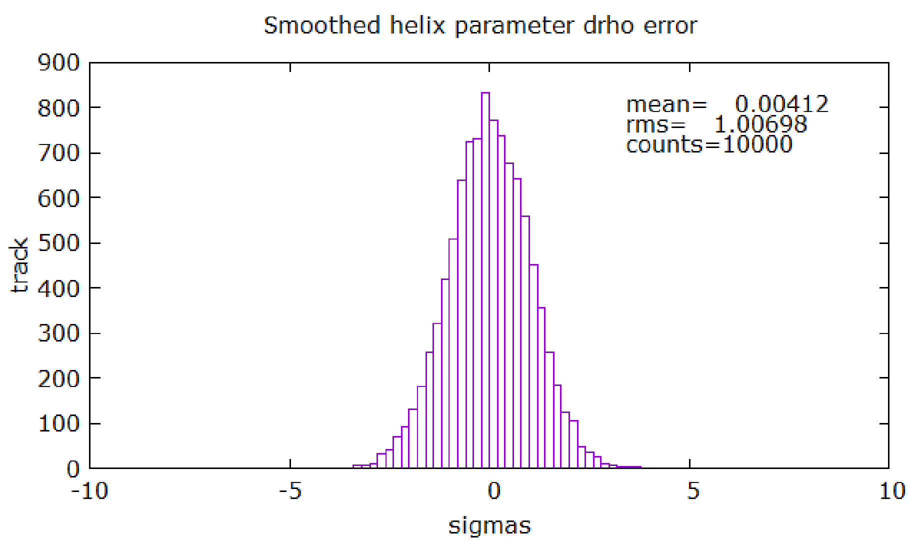
The starting "guess" for the Kalman fit is derived by randomly varying the MC true helix parameters and then blowing up the covariance matrix by a factor of 1000. Using a circle/line fit to the first few points does not give equally good results, with significant tails to the residual distributions, but the point here was just to test the mathematics of the Kalman fit with a non-uniform field.

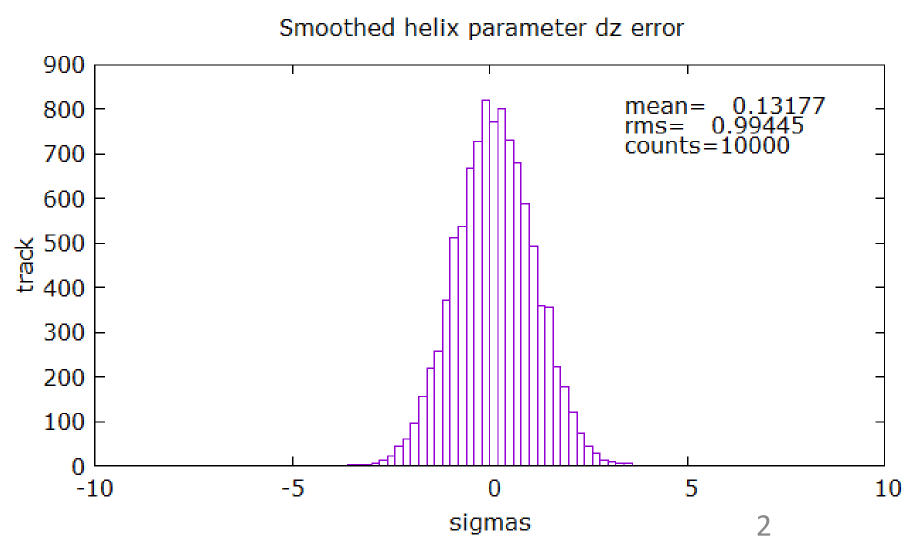
The fit is done using a piecewise helix. To extrapolate from one layer to the next the code rotates into the frame of the local B field, such that the field points along the z axis, and then extrapolates to the next layer using a perfect helix. Additional virtual dummy layers can be inserted in between silicon layers in order to take finer steps in the field if necessary.

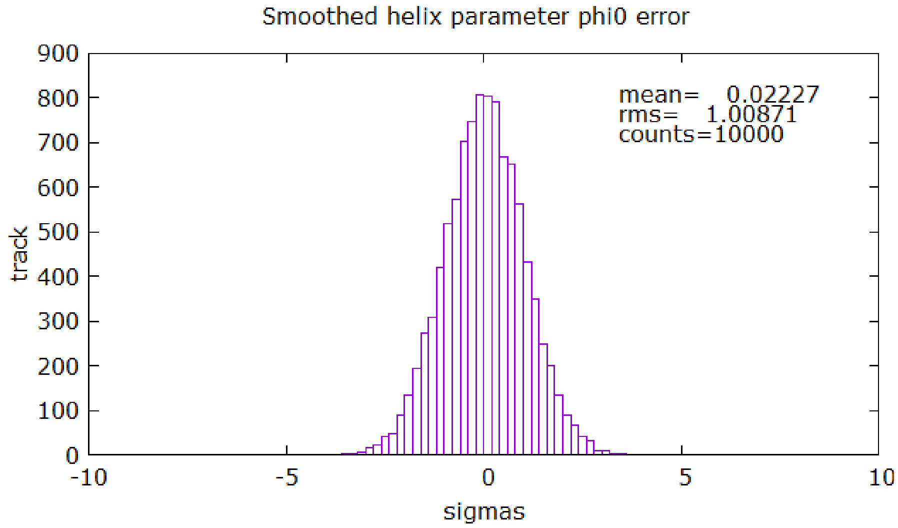
The fit performs essentially perfectly with the actual HPS field map (~0.24 T) in terms of predicting correctly the helix-parameter covariance matrix after the filter and smoothing steps. This was a 1-GeV particle propagated through the field by Runge-Kutta integration, with Gaussian multiple scattering simulated (0.3 mm Si) and a detector point resolution of 12 microns simulated.

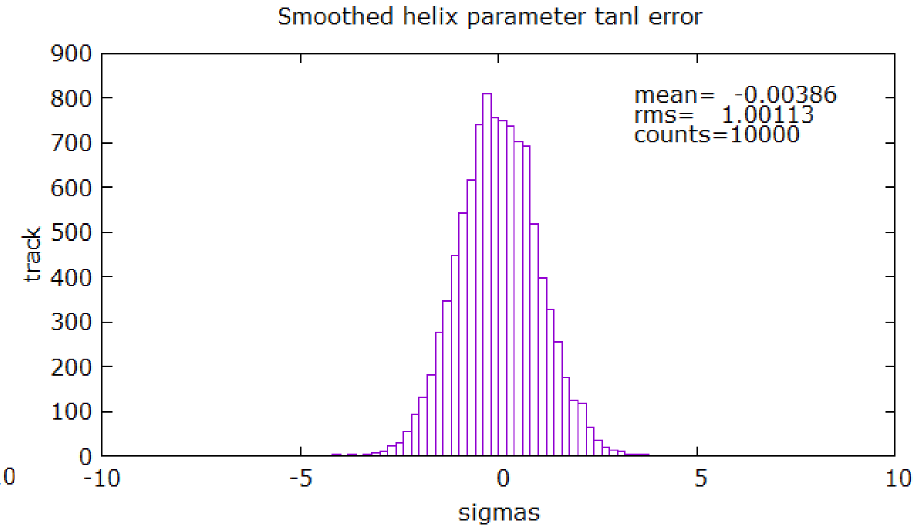


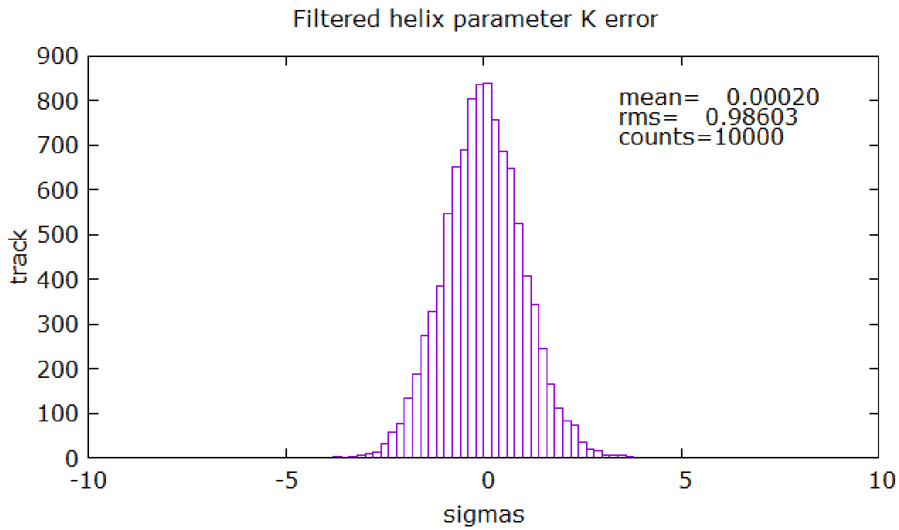
This calculation of the helix parameter chi**2 includes the full covariance matrix. Following are histograms of the errors in the individual parameters.



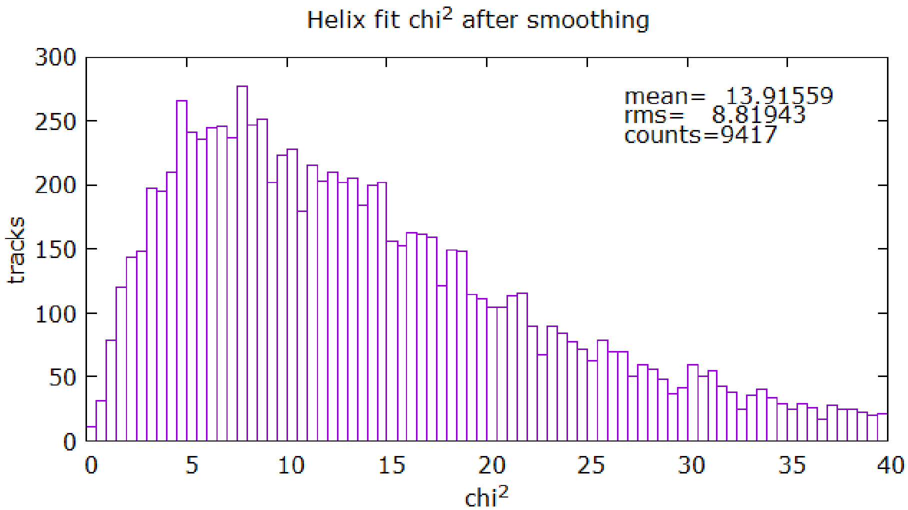






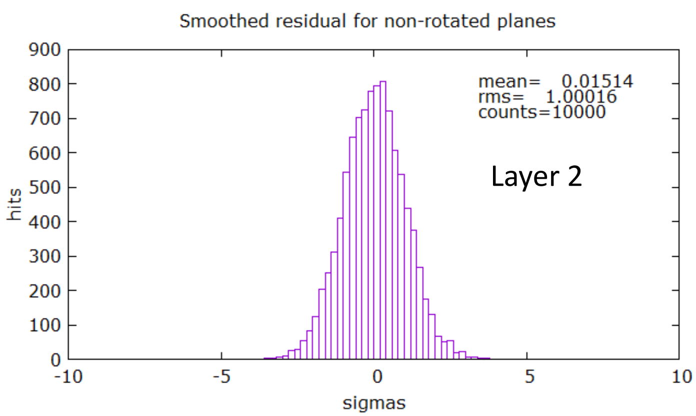


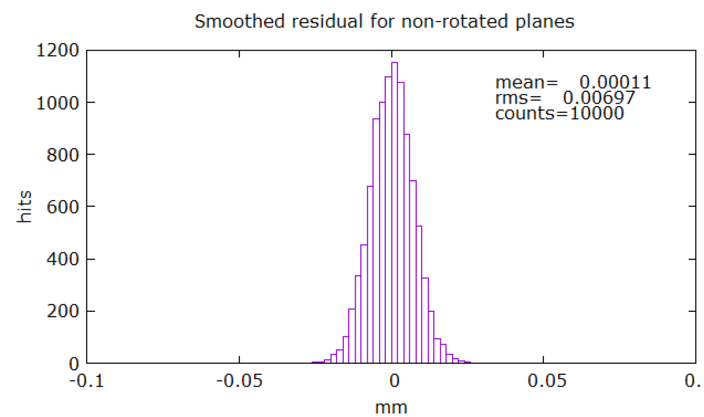
The fit chi**2, however, does not look so ideal, mainly due to bad residual distributions in the last two layers, especially layer 6.

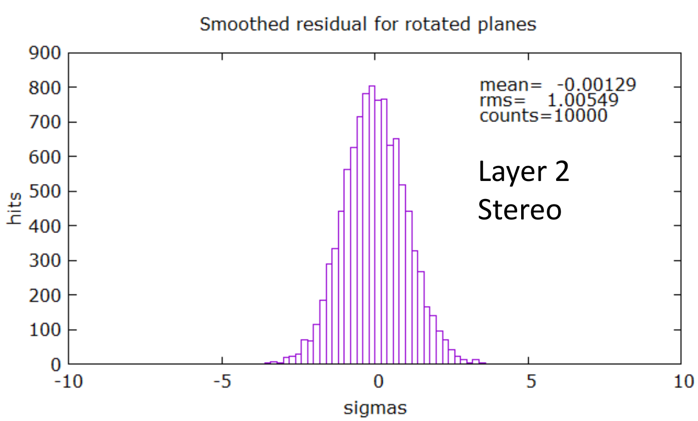


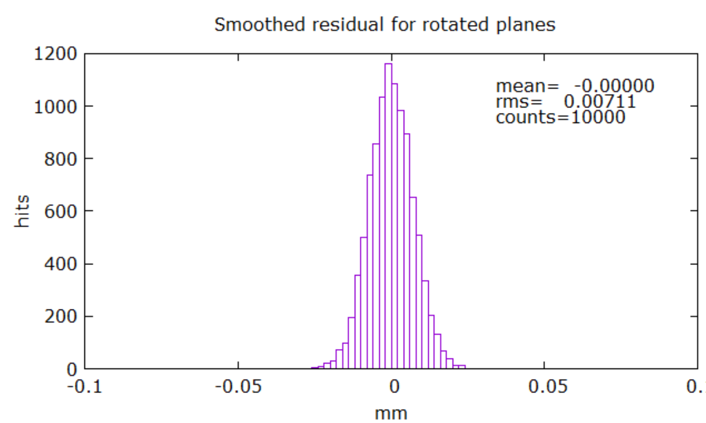
In principle this chi**2 distribution should have a mean of 12 and rms of 3.5.

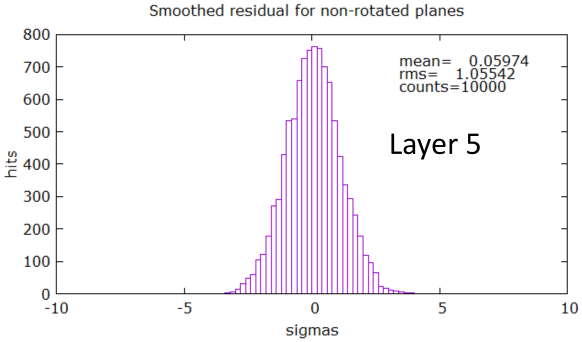
The individual residuals look good for all layers except where the field variation becomes large. These all represent fit value minus MC true value.

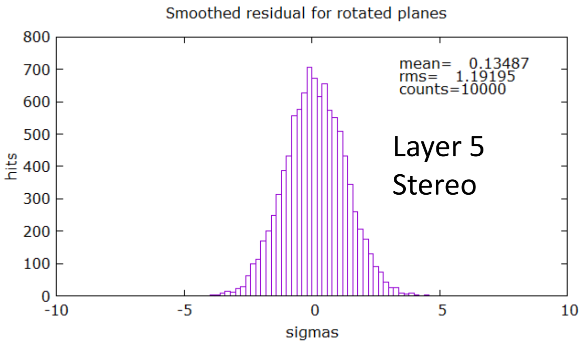


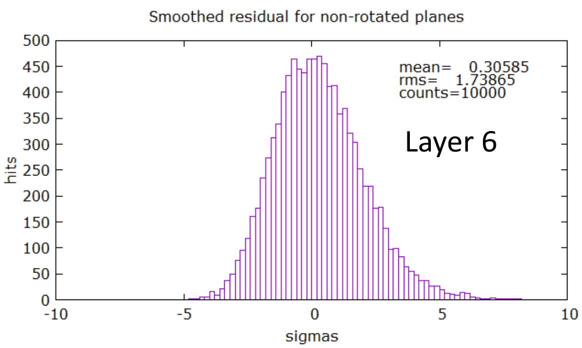


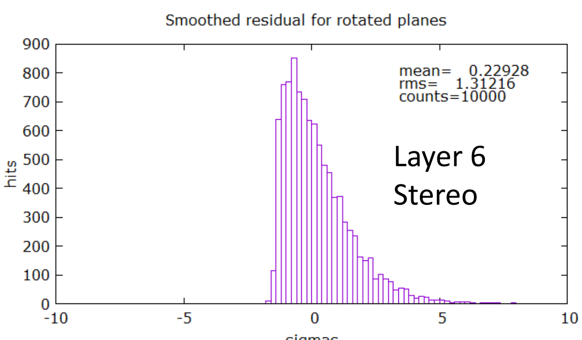


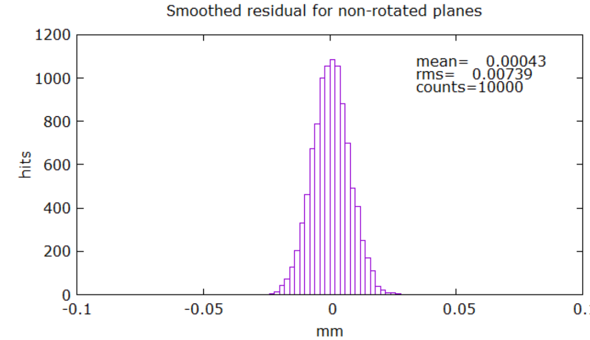


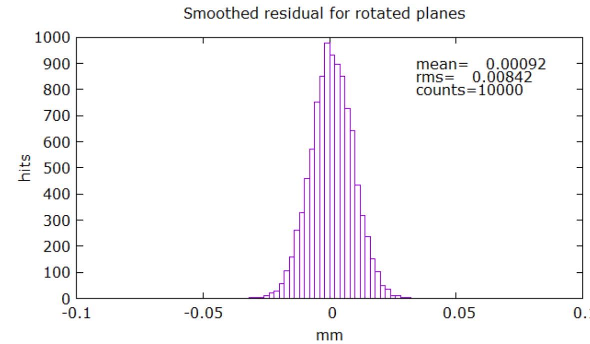


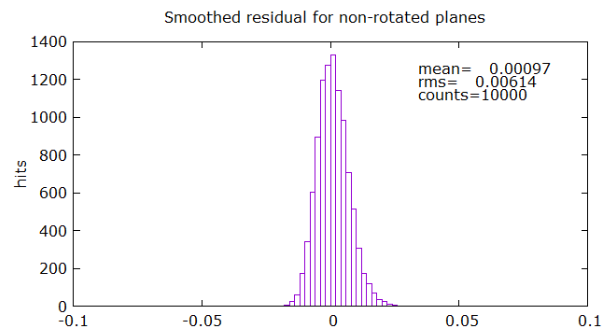


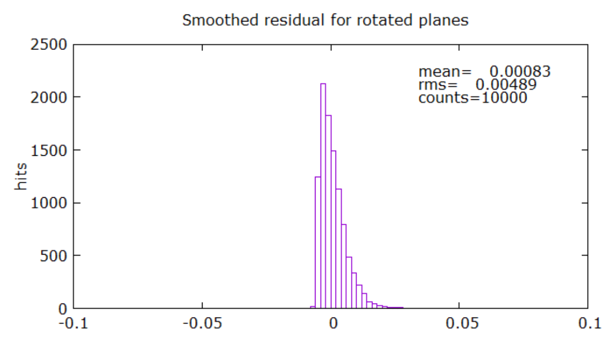




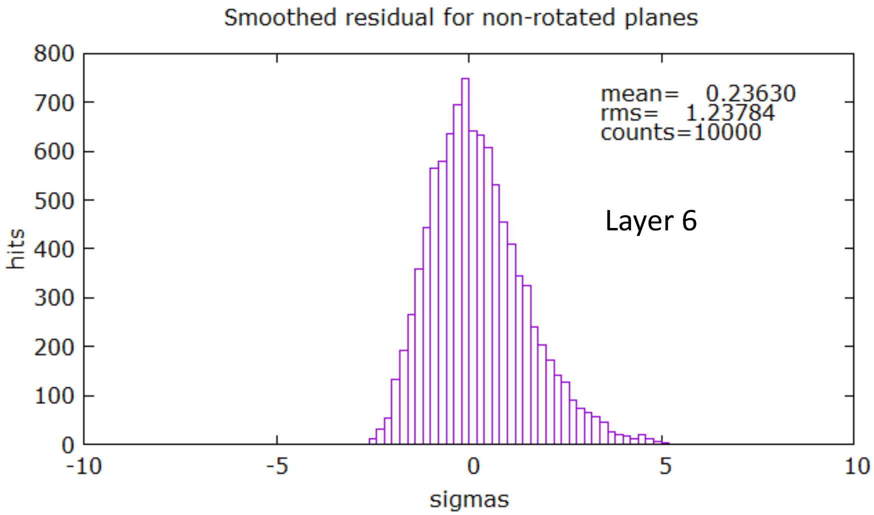


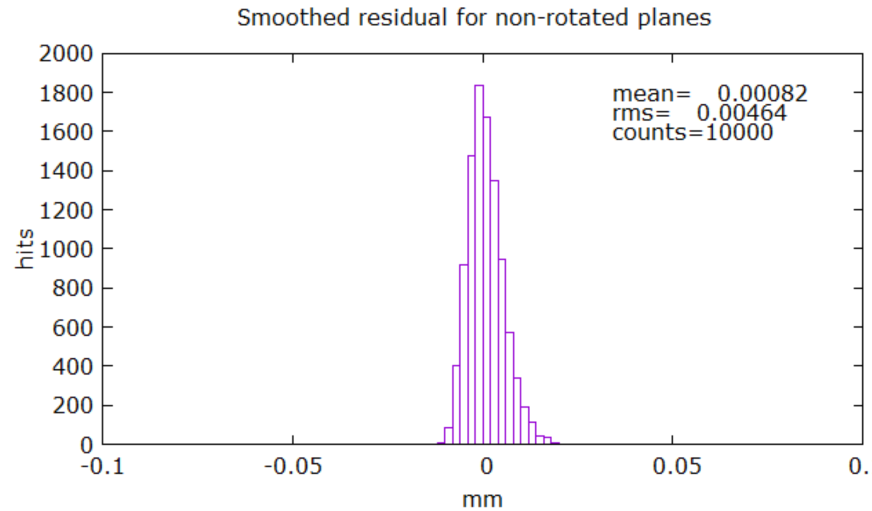


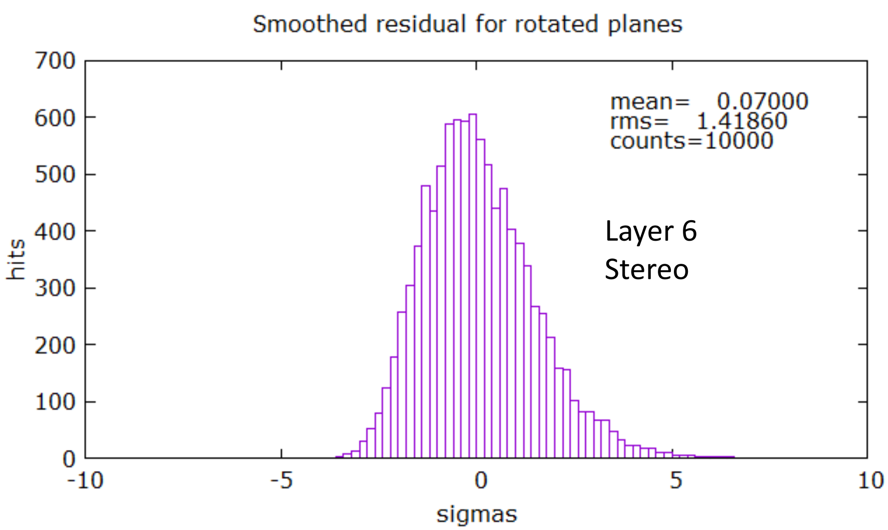


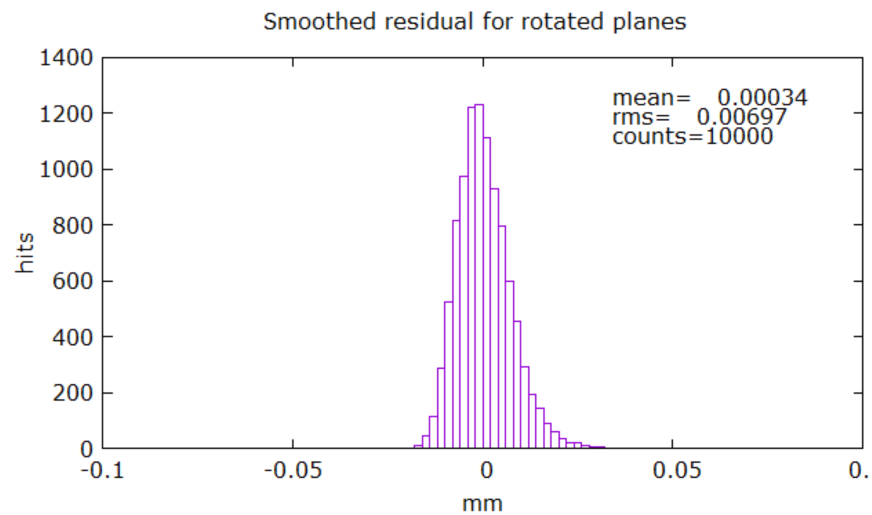


The residuals in layer 6 are especially odd, being asymmetric. They look the same for positive charge as for negative, and for lower momentum (0.5 GeV) or higher (2.0 GeV) the situation is essentially the same.









When the multiple scattering is reduced, as here, with 0.03 mm thick silicon, the asymmetry and the badness of the sigma are reduced.

The weird residuals in layer 6 only occur with the non-uniform field. I verified that the result is nearly the same if the MC truth is generated by a stepwise helix instead of Runge-Kutta integration. I verified that the helix extrapolation used in the fitter gives exactly the same result as in the simulation (i.e. the residuals become zero if the multiple scattering and detector resolution are turned down to zero).

Also, putting extra helix steps in the fitter between layers 5 and 6 does not help.

I thought that field variations might alter the extrapolation depending on where the fit was at layer 5, but the lateral variations are too small. Varying the starting point in a Gaussian distribution at layer 5 results in the same distribution for the extrapolated position at layer 6.

I haven't been able to find a mathematical error in the helix projection or covariance calculation. I've checked all the derivative calculations numerically. It is significant that at the end of the smoothing operation the errors in the helix parameters come out perfect, but there is something I don't understand about how the fitting works.