M.C. Studies of CDC Axial/ Stereo Layer Configuration

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How χ^2 is defined

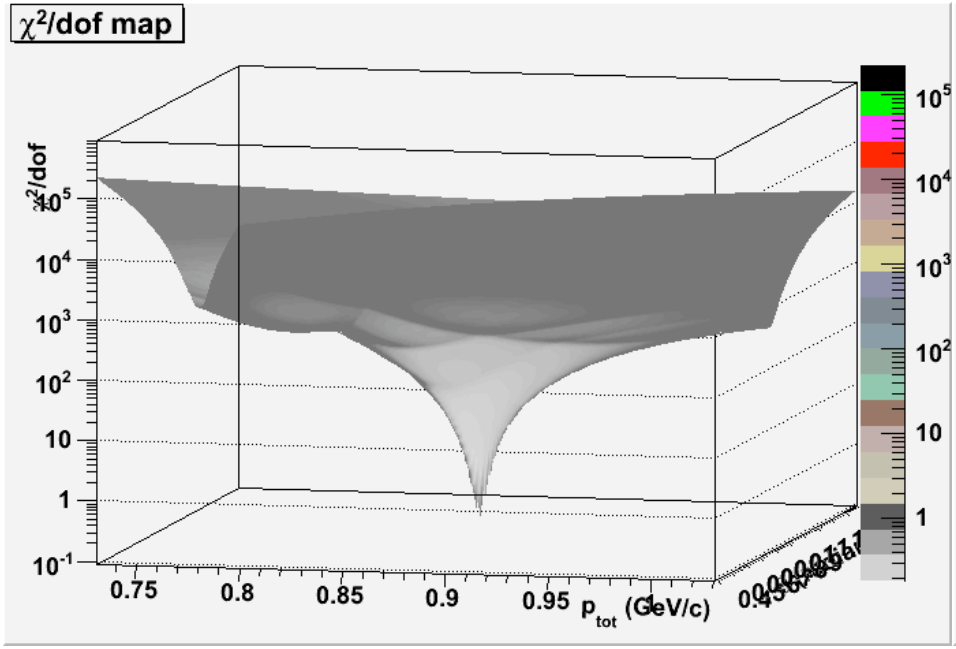
The χ^2 is formed using the residuals between the fit and thrown parameters:

$$\chi^2 = (\Delta p_t/p_t)^2 + (\Delta\theta)^2 + (\Delta\phi)^2$$

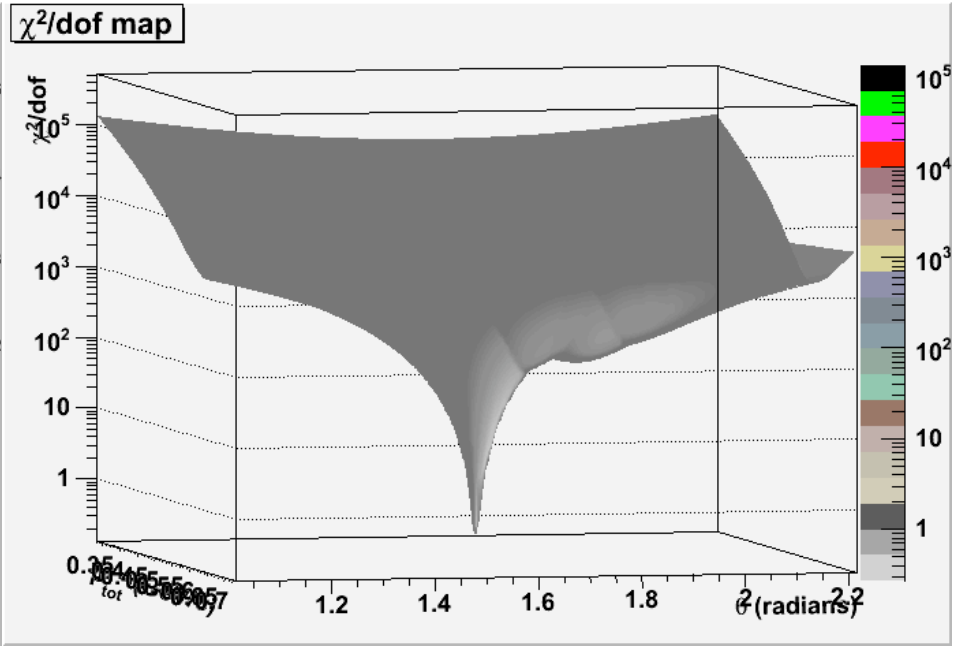
If the components are independent and drawn from a Gaussian parent distribution, this would follow a "chi-squared" distribution with a well-known probability distribution

Map of χ^2/dof as a function of 2 of the 5 fit parameters

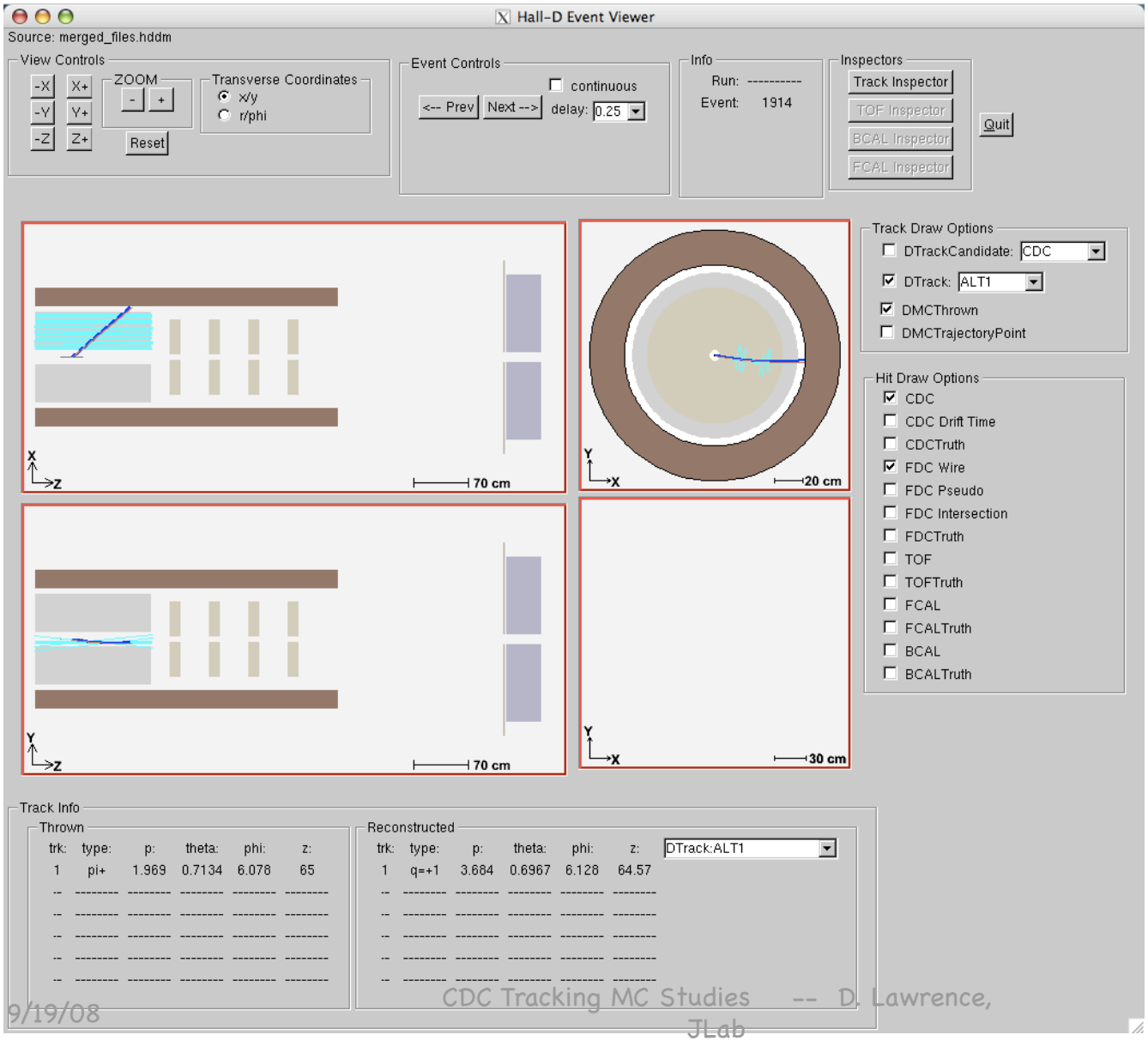
Event A



Event B



Event 1914 has a large χ^2/dof

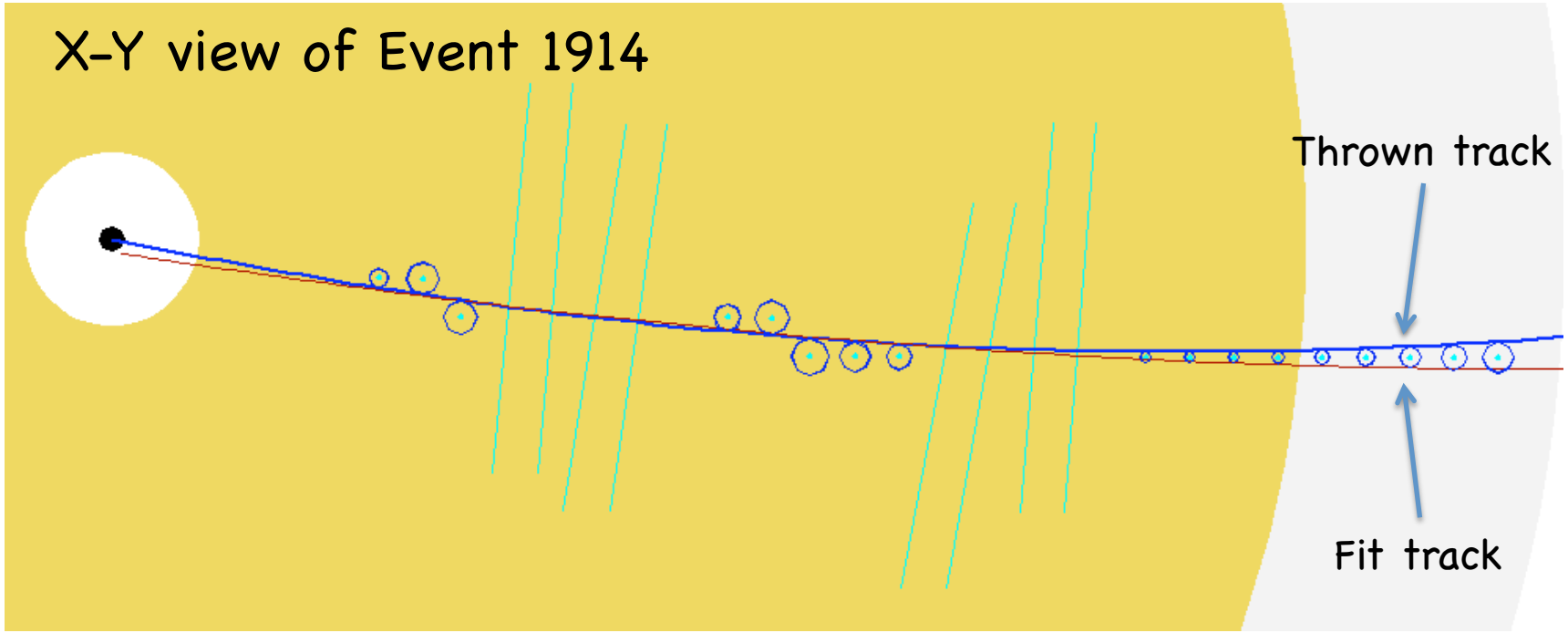


A bird's eye view of the event looks like everything is OK

Blue (thick) is the thrown track

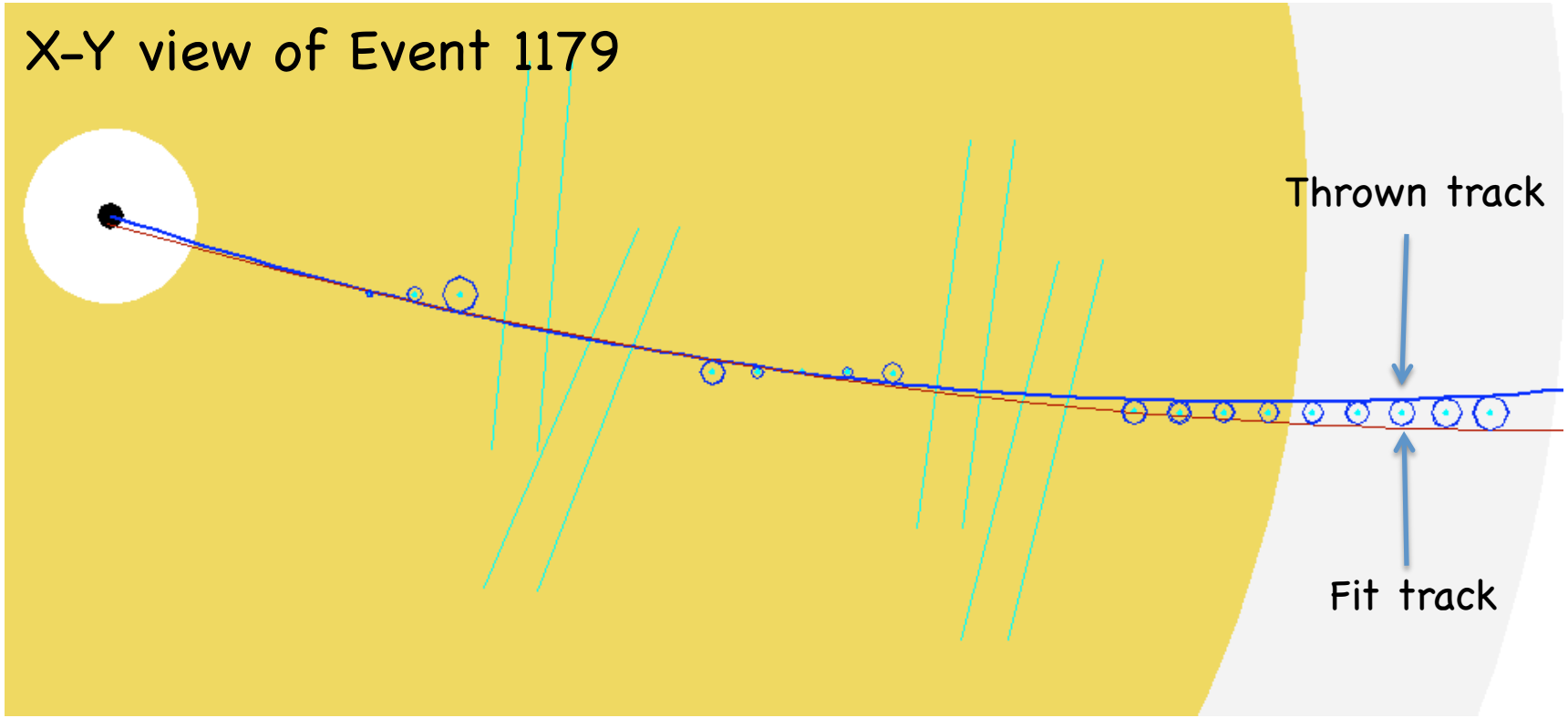
Orange (thin) is the fit track

Event 1914 has a large χ^2/dof



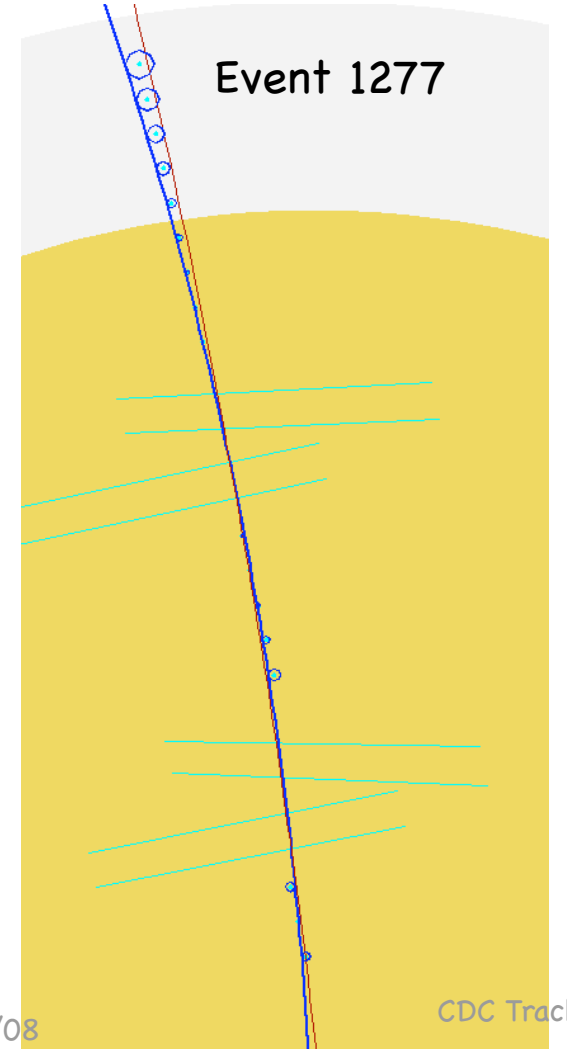
Event 1914				
	ptot	theta(rad)	phi(rad)	chisq/dof
Thrown	1.969	0.713	6.078	
Reconstructed	3.684	0.697	6.128	
resolution	0.014	3.086	2.485	
residual/err	58.133	-5.411	20.117	
(residual/err)^2	3379.488	29.284	404.710	1271.161

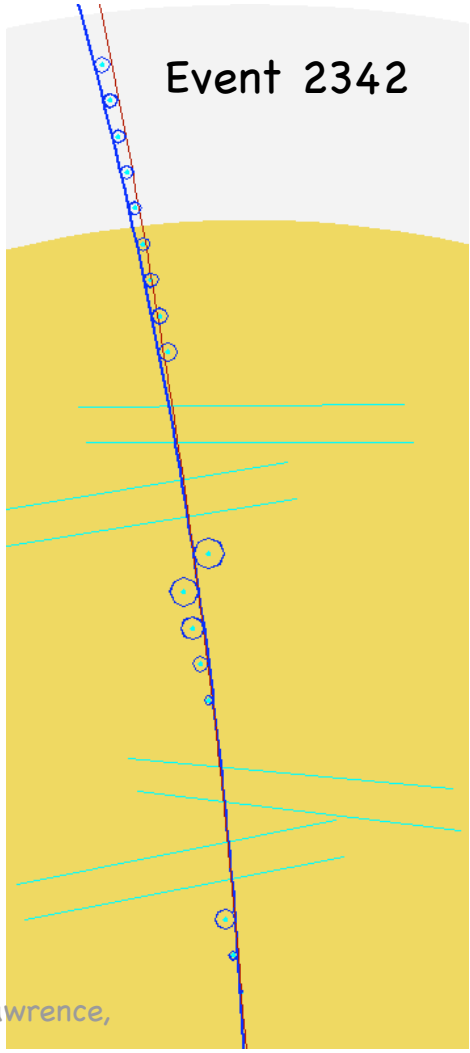
Event 1179 has a large χ^2/dof



Event 1179				
	ptot	theta(rad)	phi(rad)	chisq/dof
Thrown	0.837	1.507	5.966	
Reconstructed	1.400	1.386	6.025	
resolution	0.013	7.212	2.976	
residual/err	51.399	-16.777	19.824	
(residual/err)^2	2641.886	281.471	392.988	1105.448

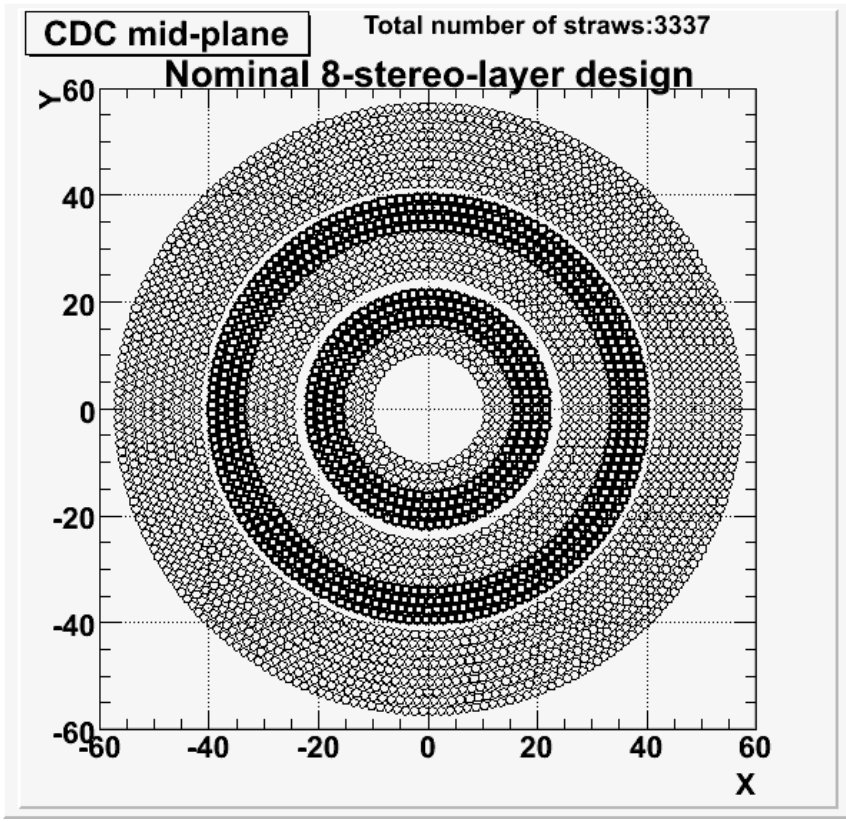
Other events with poor χ^2/dof with p_t as dominant term





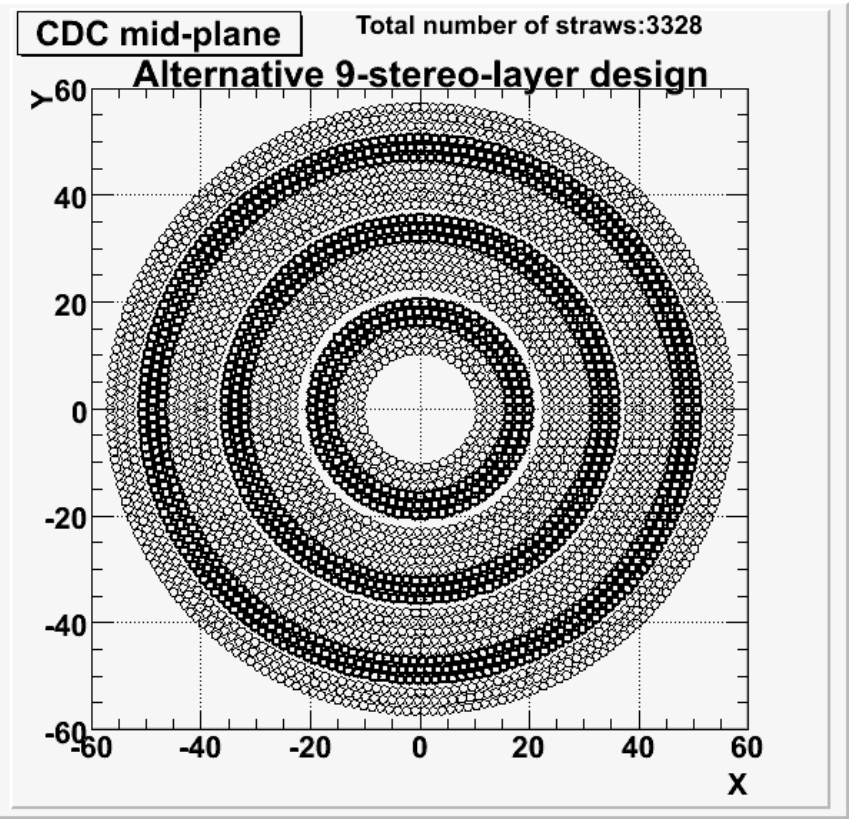
Two options for CDC stereo configuration

2 stereo superlayers



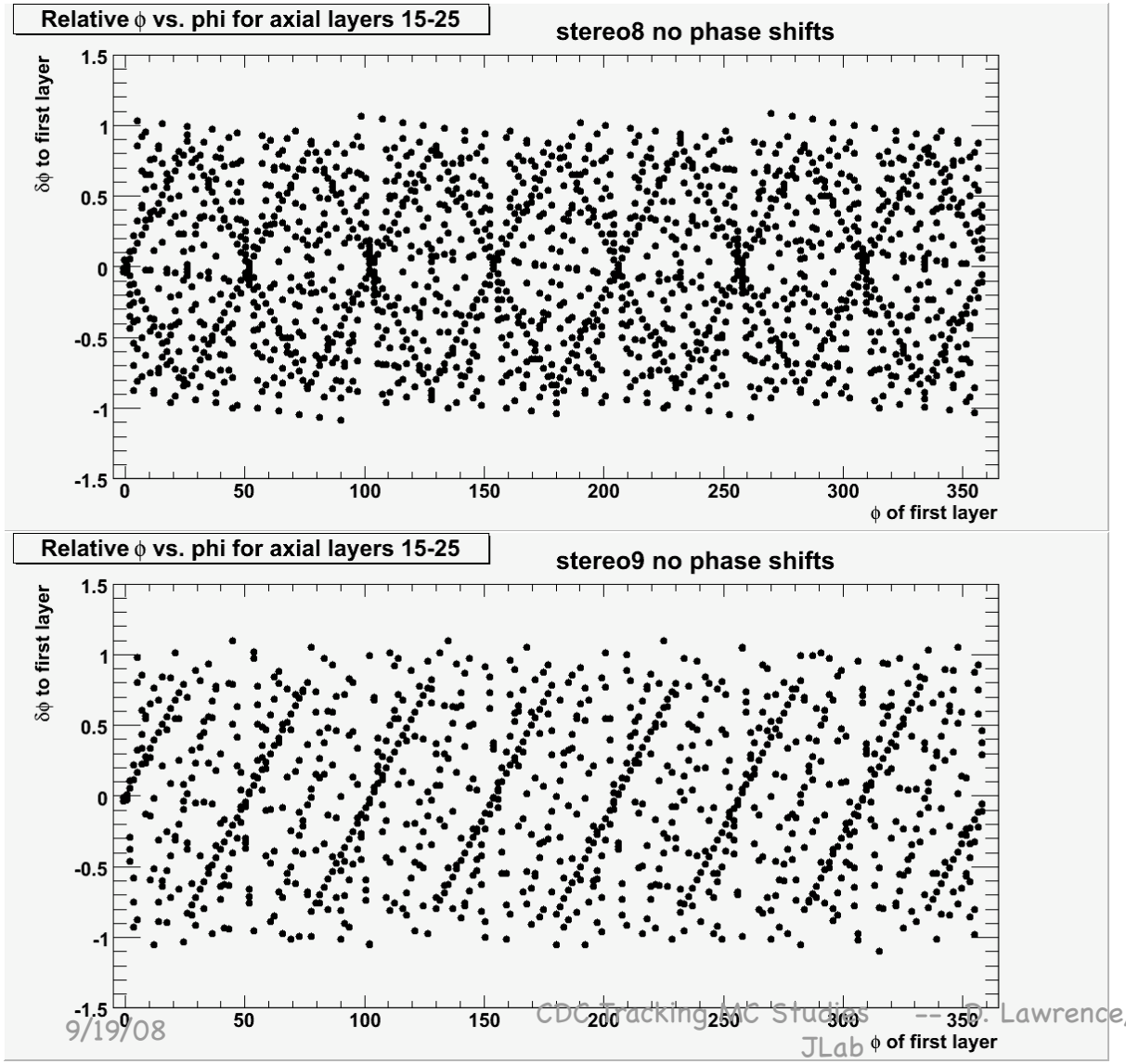
stereo8

3 stereo superlayers



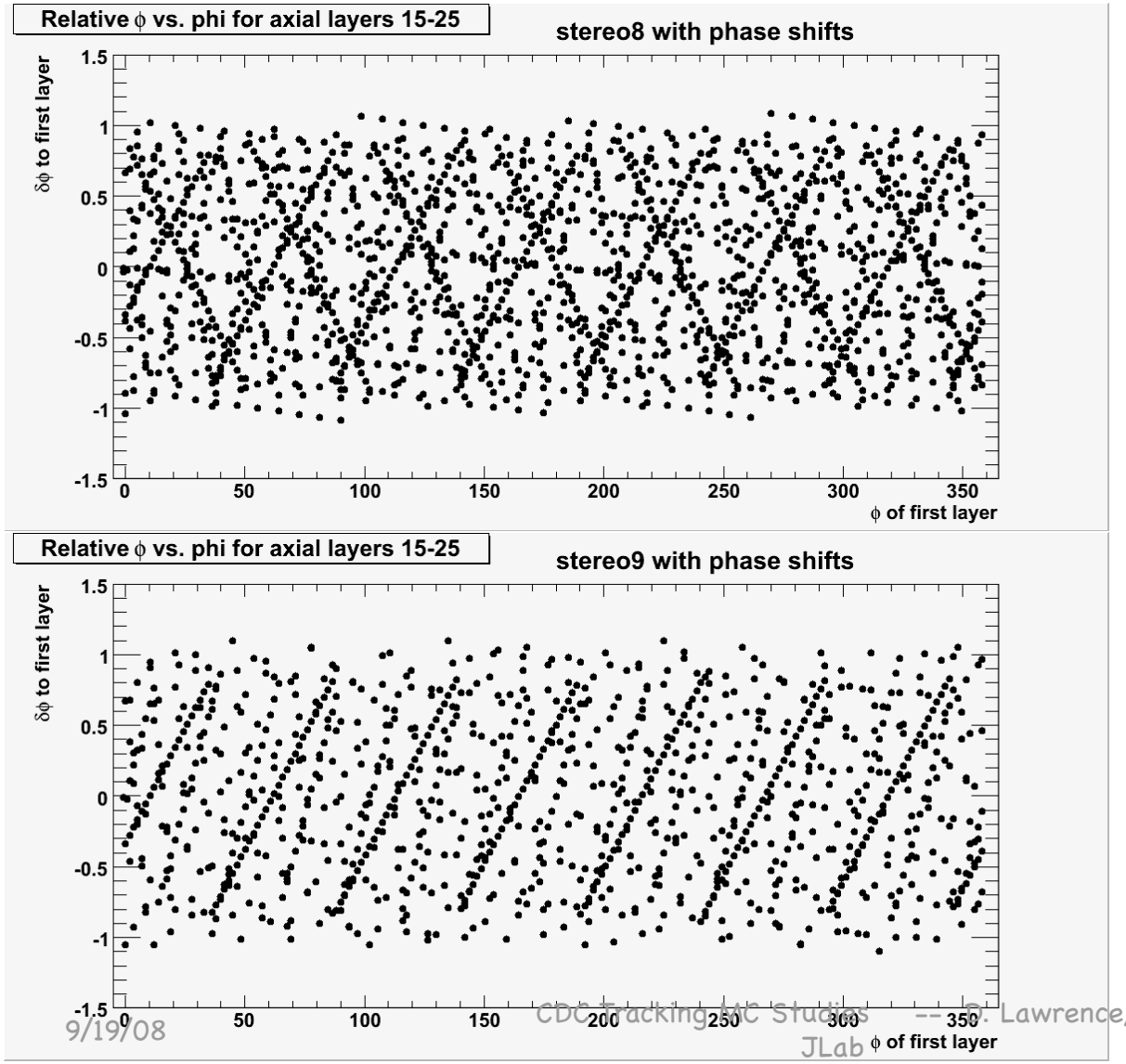
stereo9

Alignment of CDC straws



- $\delta\phi$ relative to the ϕ of the wire in layer 23 as a function of ϕ.
- Pattern comes from neighboring layers having only slightly more (or less) straws than layer 23.
- ϕ values with high density of points indicate areas where there is a high degree of alignment.

Alignment of CDC straws w/ phase shifts



- To disrupt the alignment of the wires, phase shifts in ϕ were introduced for each layer.

- Every 4th layer was rotated by:

  0

  $+\Delta\phi_i/2$

  $-\Delta\phi_i/3$

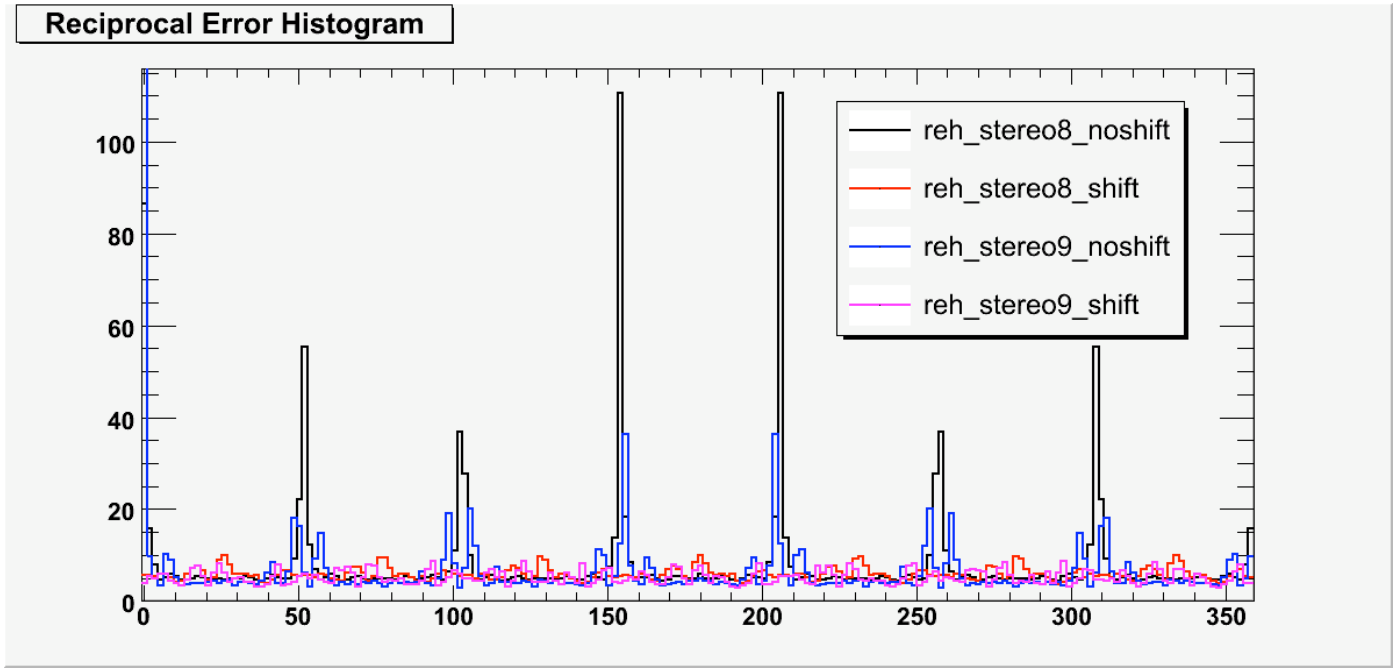
  $+\Delta\phi_i/5$

where $\Delta\phi_i$ is the angle between adjacent wires in the layer

Reciprocal of phase difference density

In this plot, larger values indicate greater alignment of the straws in the outer layers (15-25).

The stereo9 configuration is slightly better than stereo8, but both are improved significantly by adding relative phase shifts between layers.

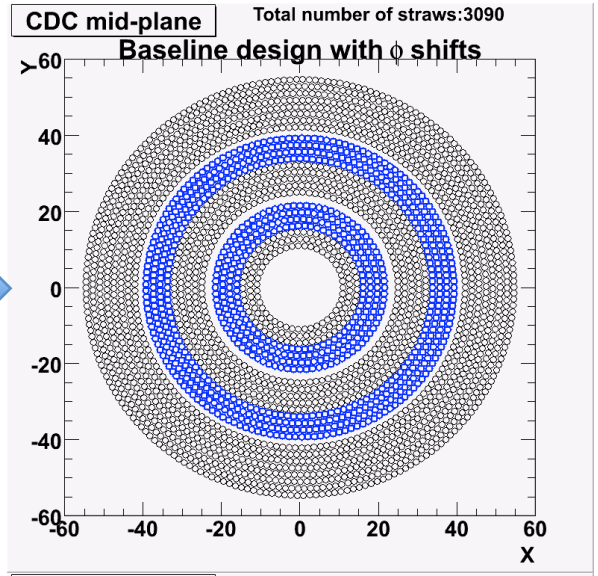


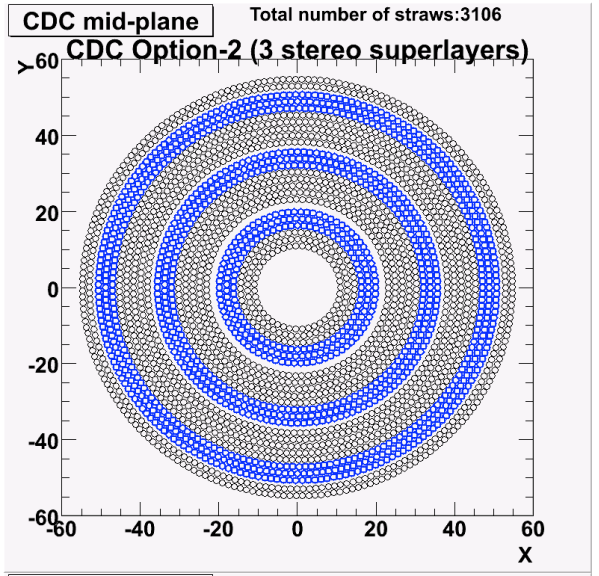
5 CDC configurations studied

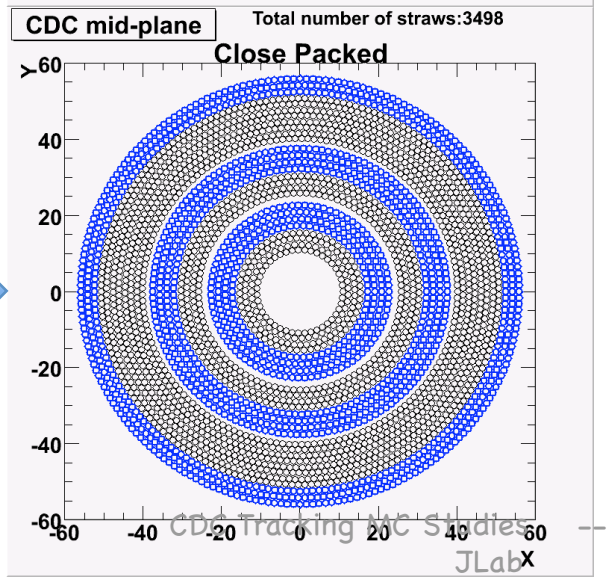
(yes, only 4 are shown)

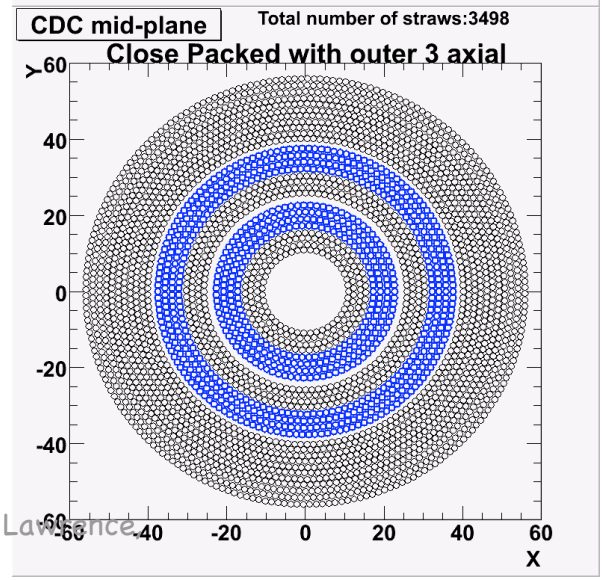
24 layers

27 layers









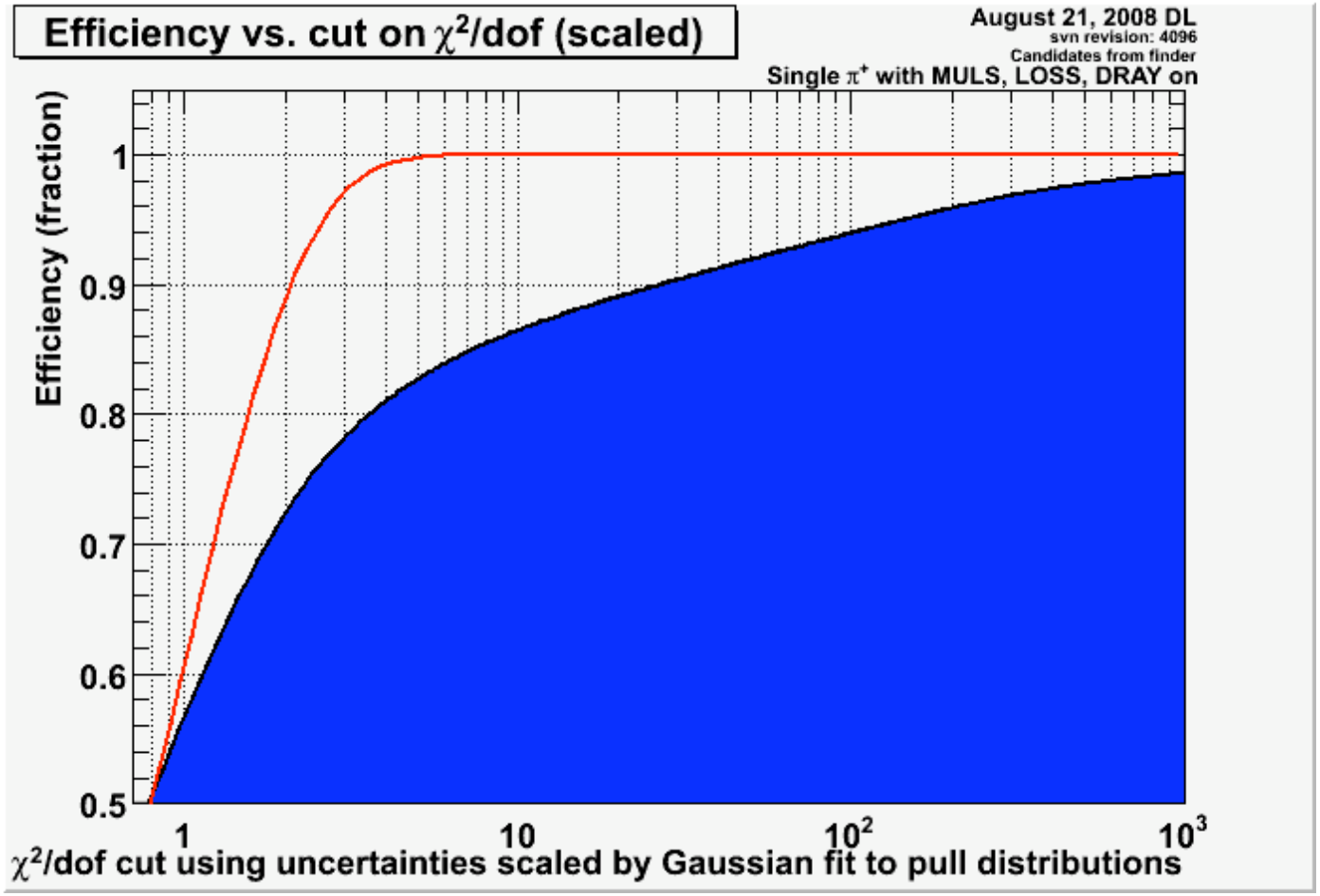
What was simulated

- 1 million single π^+ events for each configuration. MS, E-loss on, but ***no*** position smearing

- Finder and fitter used in conjunction (*previously, all fit results came from using the thrown values for the candidates*)

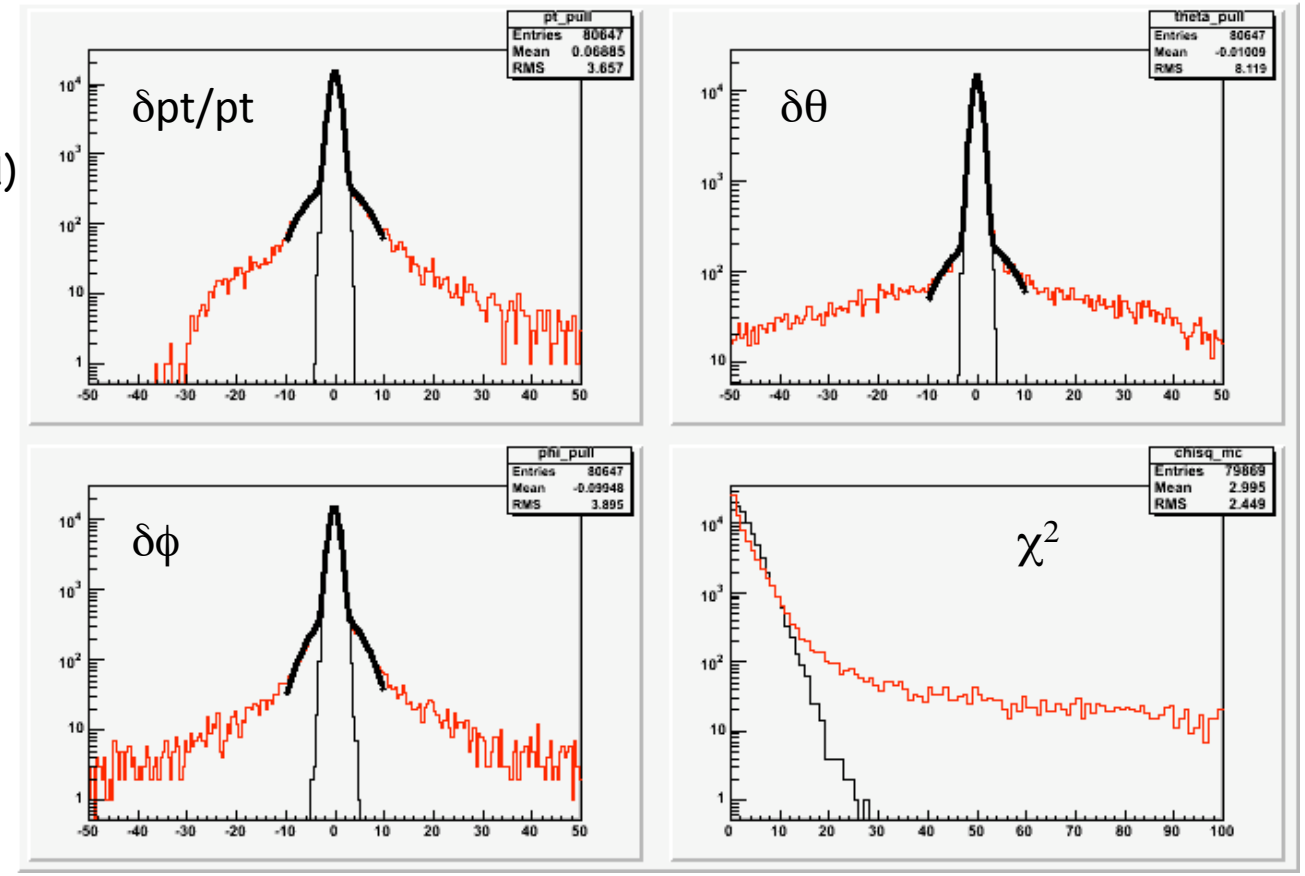
- Efficiency determined by cut on χ^2/dof derived from parameters (*not* hit residuals)

"Tracking Efficiency" compared to χ^2 cumulative distribution function



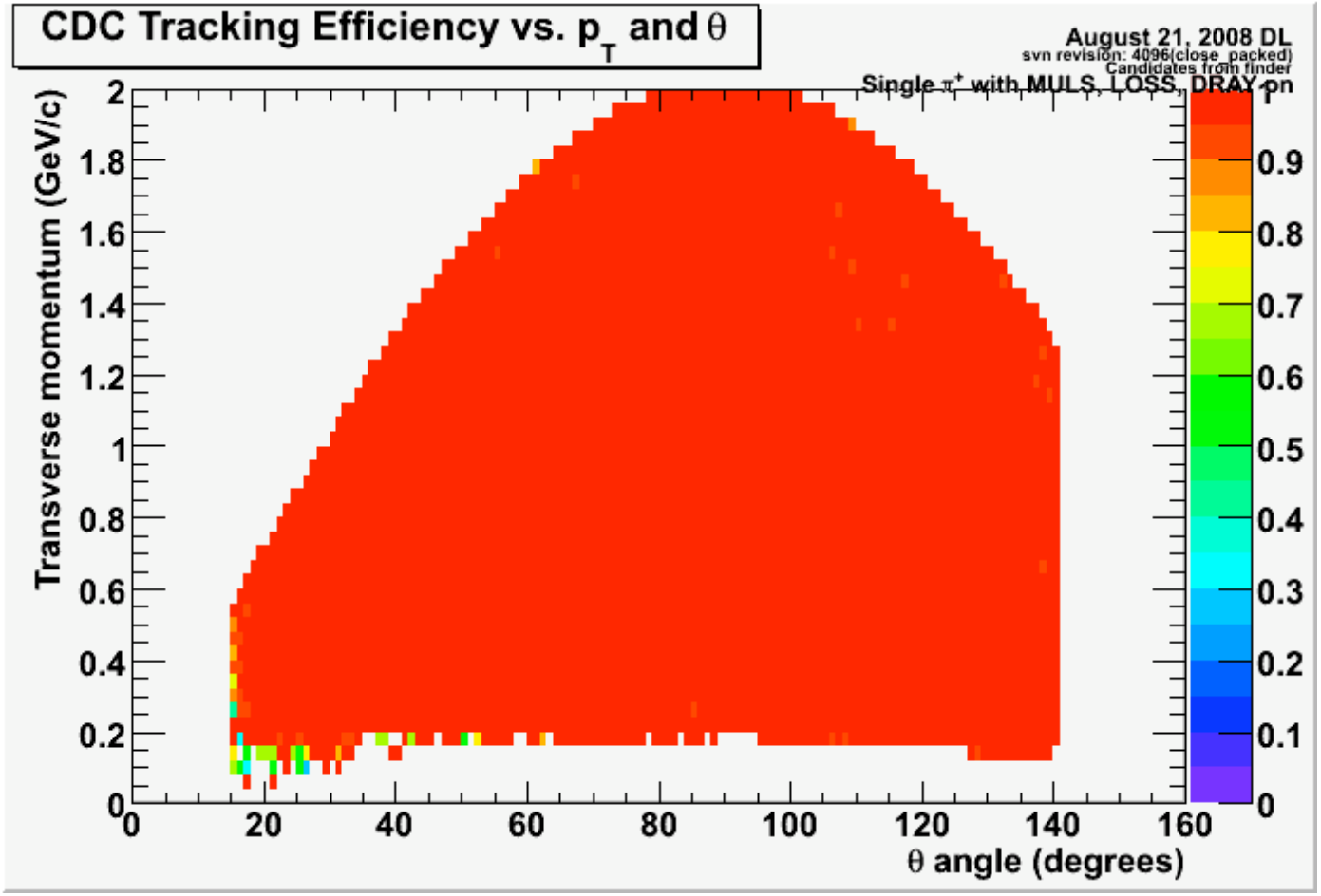
Pulls with double Gaussian fits

Red = Tracking Results
Thick black = double gaussian
Thin black = gaussian (sampled)



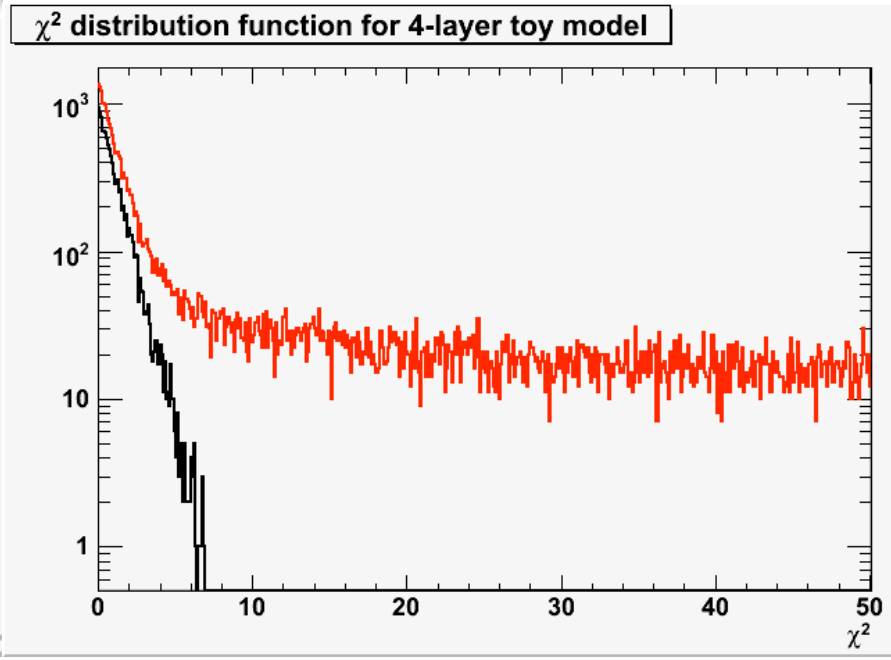
Efficiency as a function of phase space

0.2 GeV/c ≤ p ≤ 2.0 GeV/c 15° ≤ θ ≤ 140°

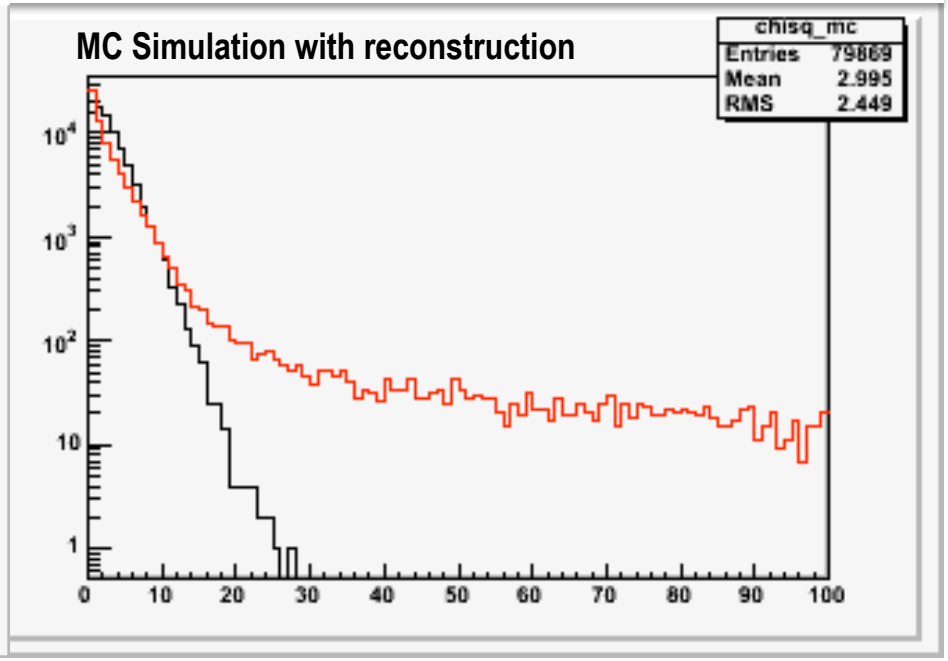


Toy model χ^2 shares features with MC Simulation study

Toy model plot (left) includes all L-R solutions (including 15 "wrong" ones)

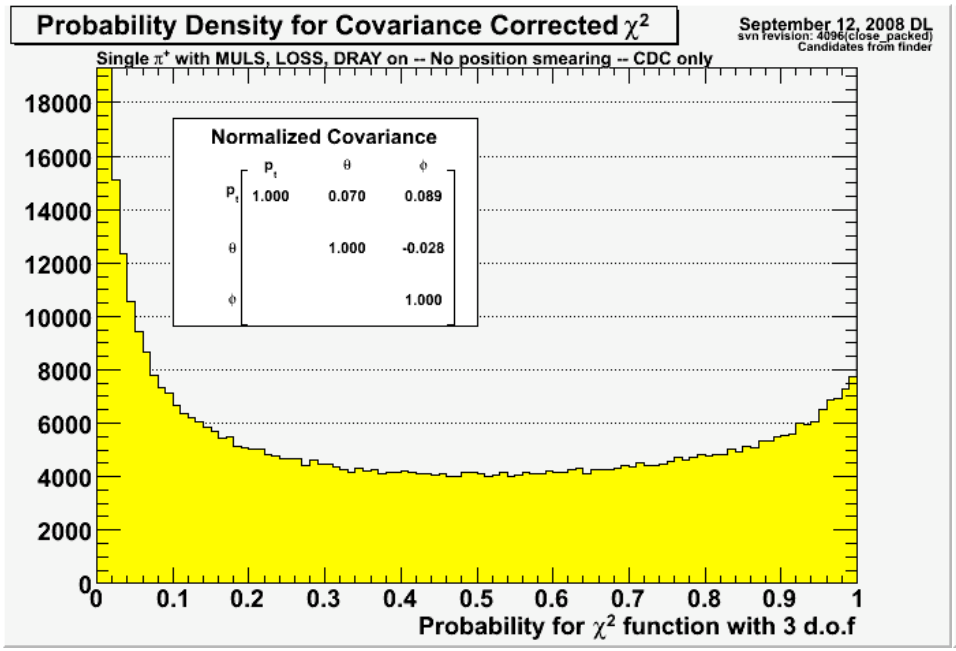


MC Simulation includes 1 guess for L-R solution

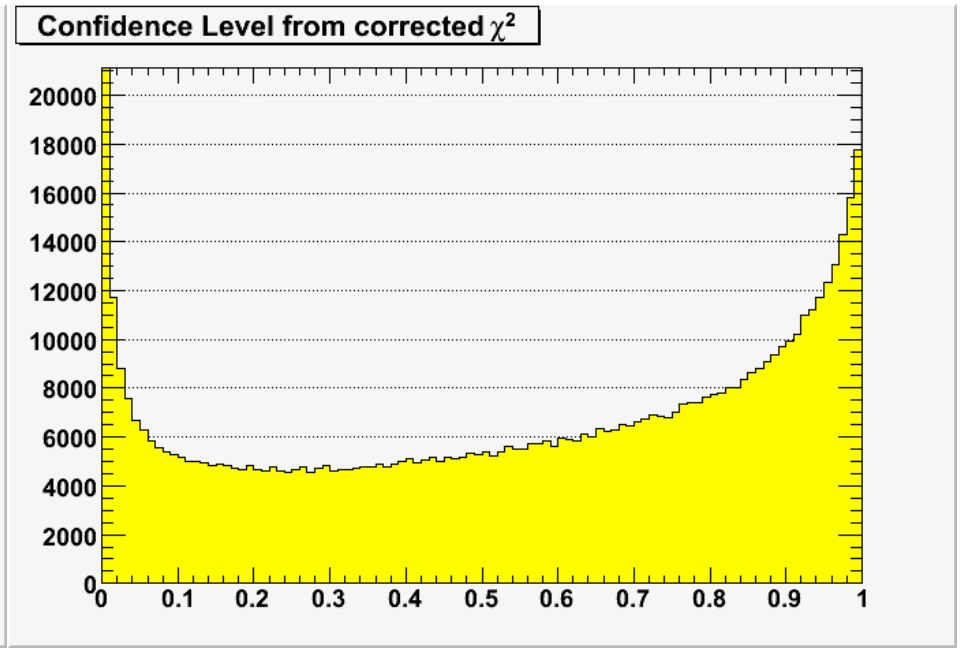


Probability Distributions for two ways of fitting pull distributions

Gaussians fit only to core of pull distributions

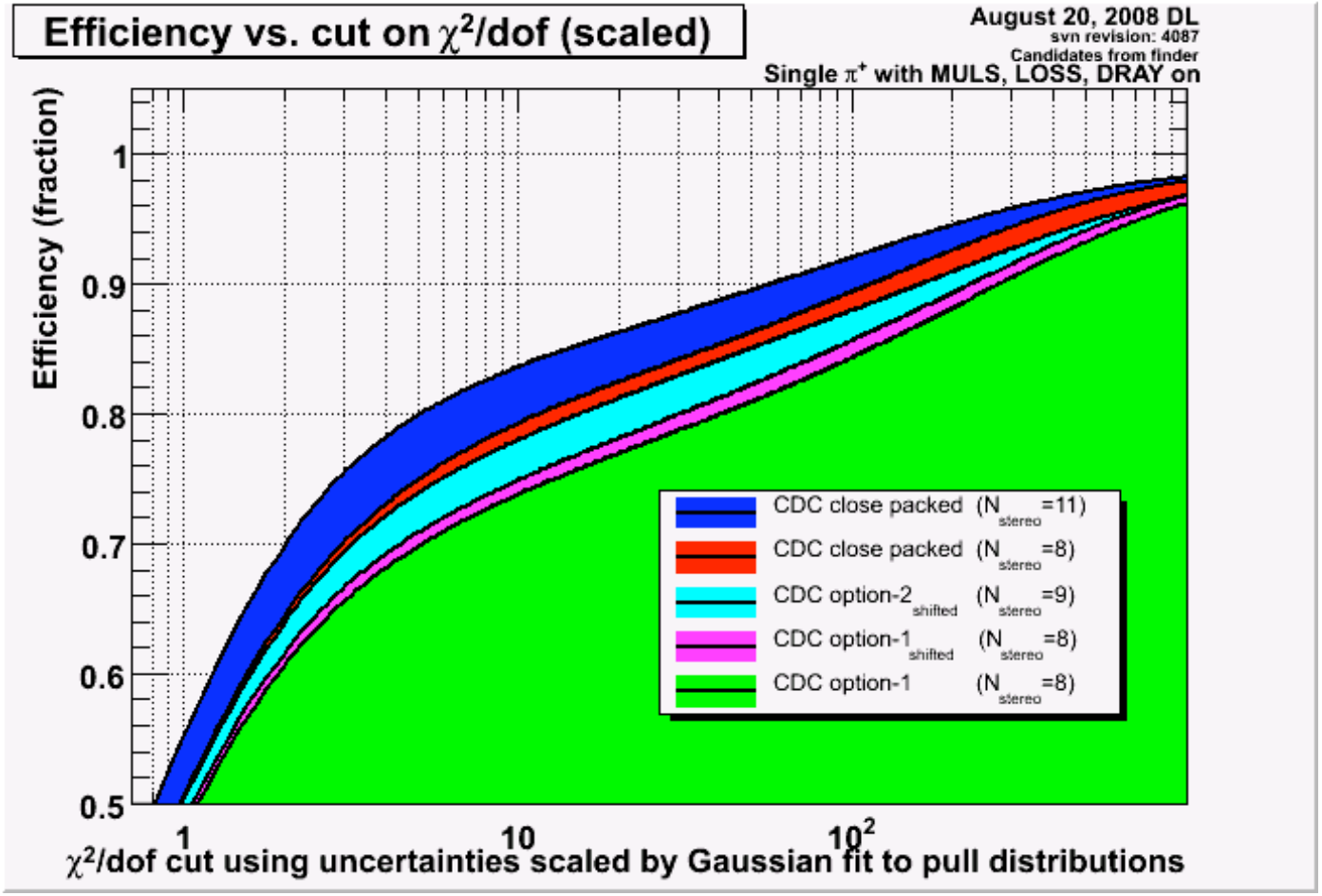


Gaussians fit to full pull distributions



Tracking Efficiency for Several CDC Configurations

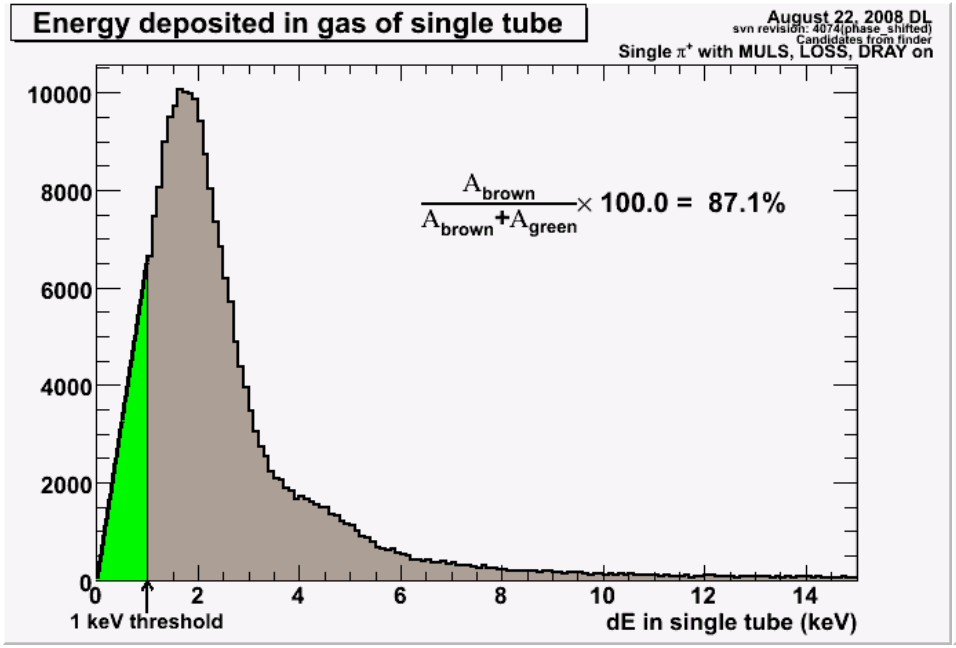
Phasespace: range



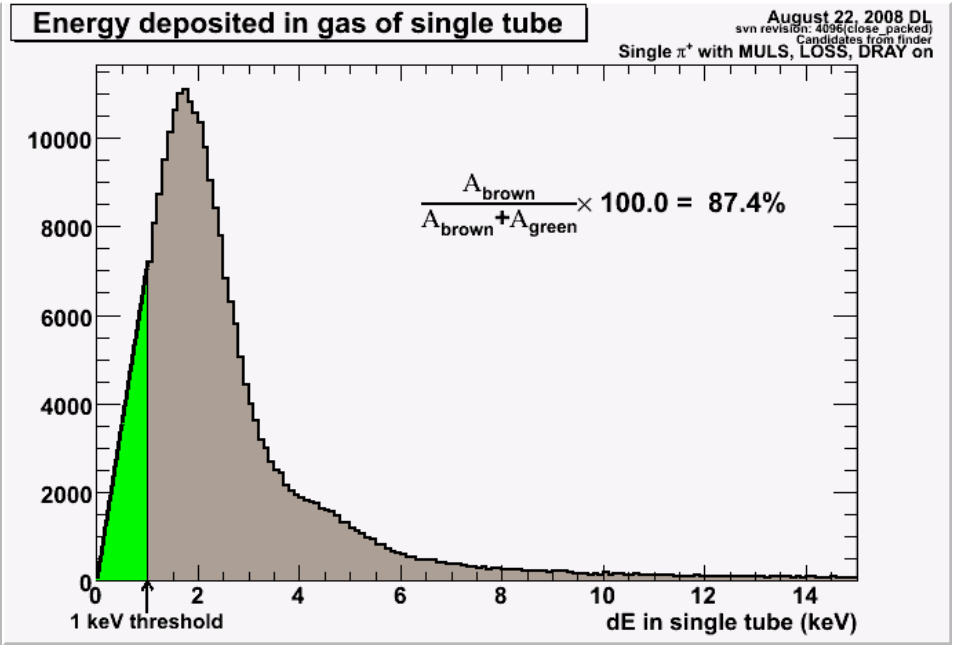
dE in single tube reported by *hdgeant*

Phasespace: 1 GeV/c ; 90°

Nominal Geometry



Close Packed



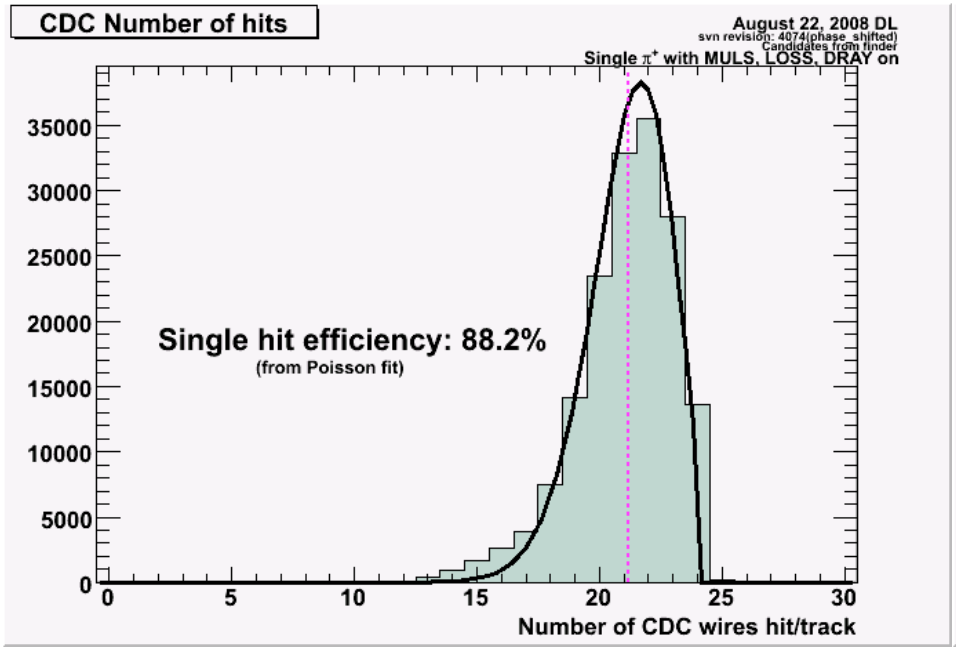
Green regions are estimates of hits discarded by dE threshold. Estimate is made by straight line from 0,0 to 1keV point. This likely overestimates the below-threshold contribution.

NOTE: Max energy deposition at 90° : (1.6 cm)(2.6 keV/cm) = 4.16 keV

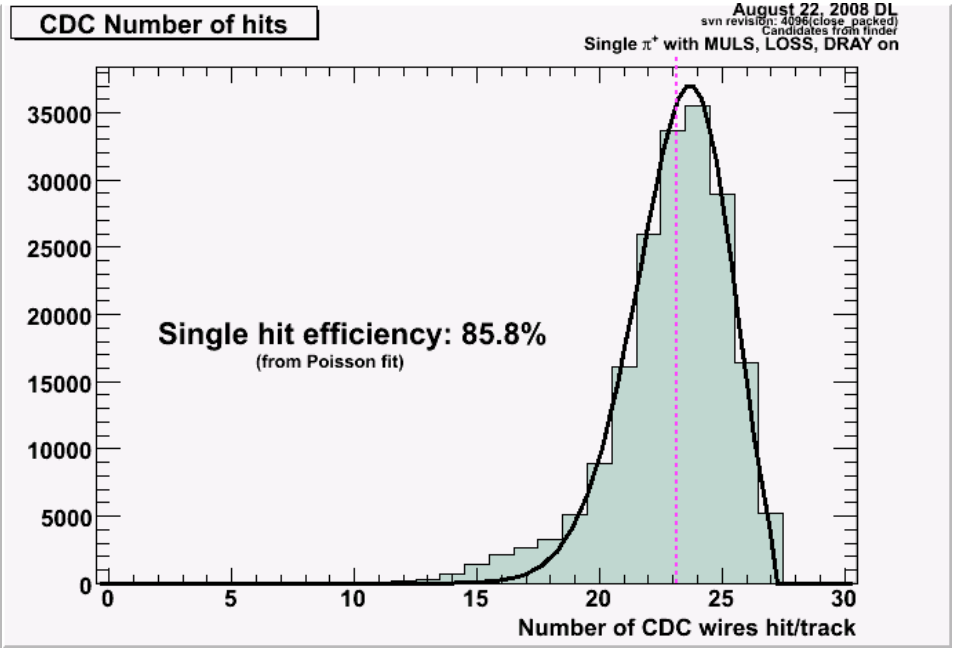
CDC hits per track

Phasespace: range

Nominal Geometry



Close Packed



The number of ***missing*** hits was fit to a Poisson and the mean taken as the average number of missed hits.

The *Nominal Geometry* is consistent with the single hit efficiency derived from the dE plots.

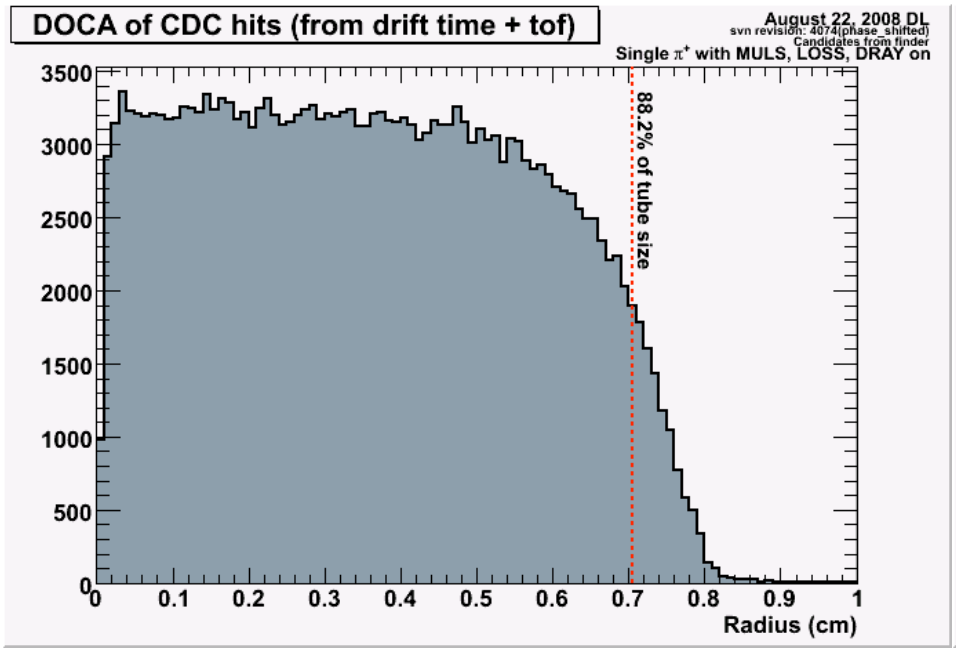
The *Close Packed* geometry is consistent with ~9% inefficiency on average due to gaps in the "close-packed" axial layers.

Distance of Closest Approach (DOCA)

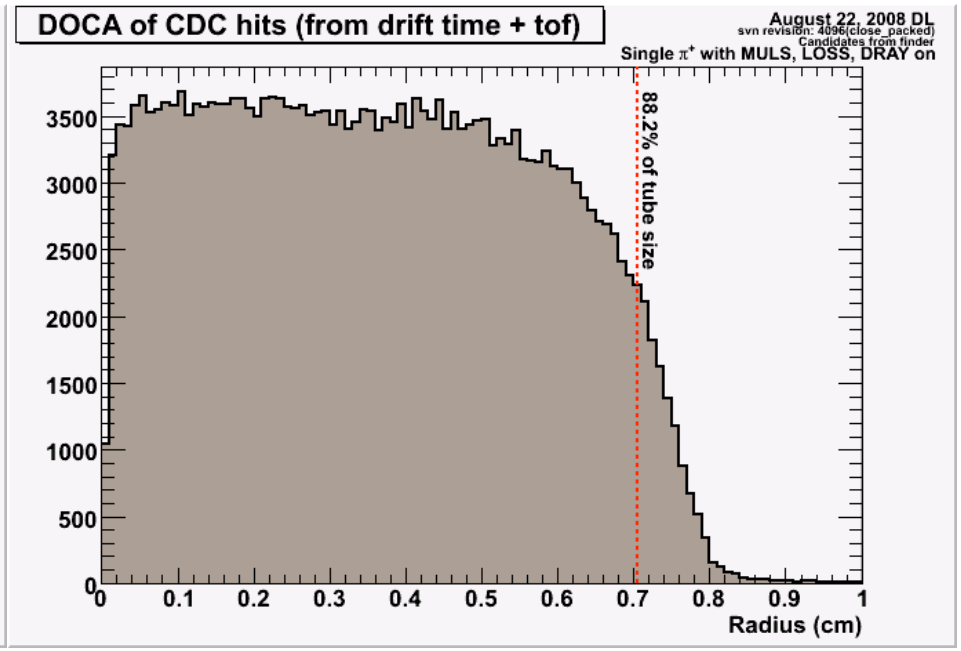
Phasespace: 1 GeV/c ; 90°

(calculated from t_{drift}-tof)

Nominal Geometry



Close Packed

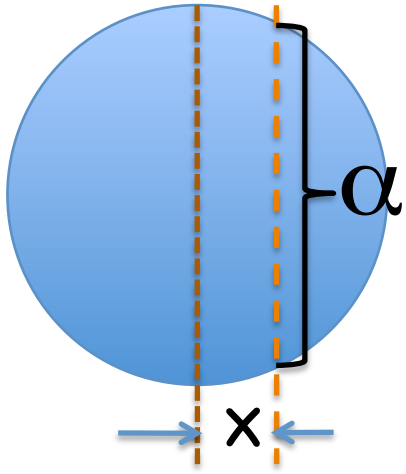


DOCA distributions seem consistent with the 88.2% single hit efficiency and cut on dE which corresponds to the outer part of the tube.

Expected energy loss in CDC gas

	dE/dx (MeV/g cm²)	ρ (g/ℓ)	dE/dx (keV/cm)
Ar (85%)	1.519	1.622	2.464
CO_2(15%)	1.819	1.842	3.351

- Total for CDC gas dE/dx = 2.597 keV/cm



$$\langle\alpha\rangle = \frac{1}{r_o}\int_0^{r_o} \alpha(x)\,dx$$

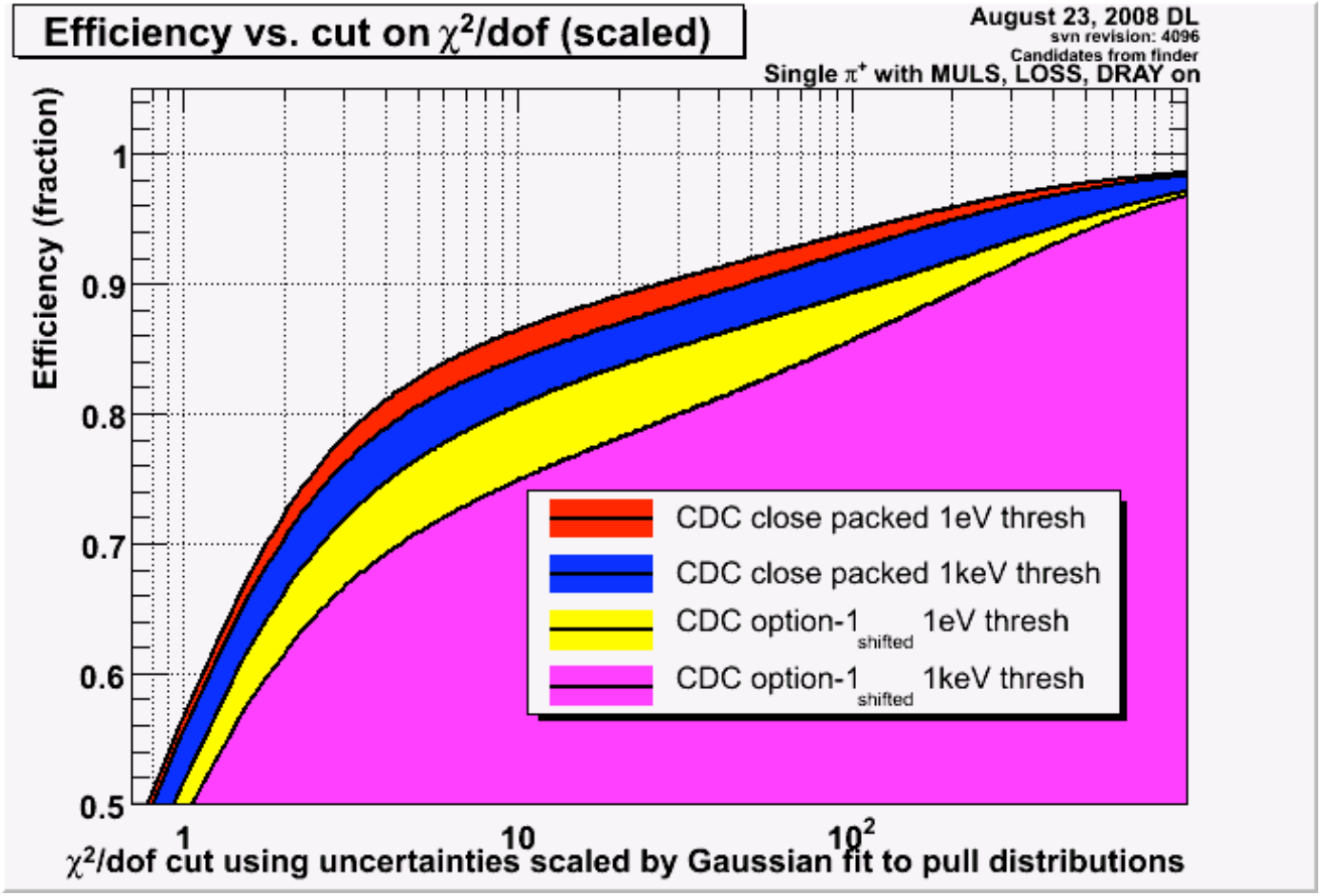
= 1.26cm

➡ ***3.27 keV***

Note: for a 1 keV energy loss, expect x=7.8mm or about 2.45% inefficiency

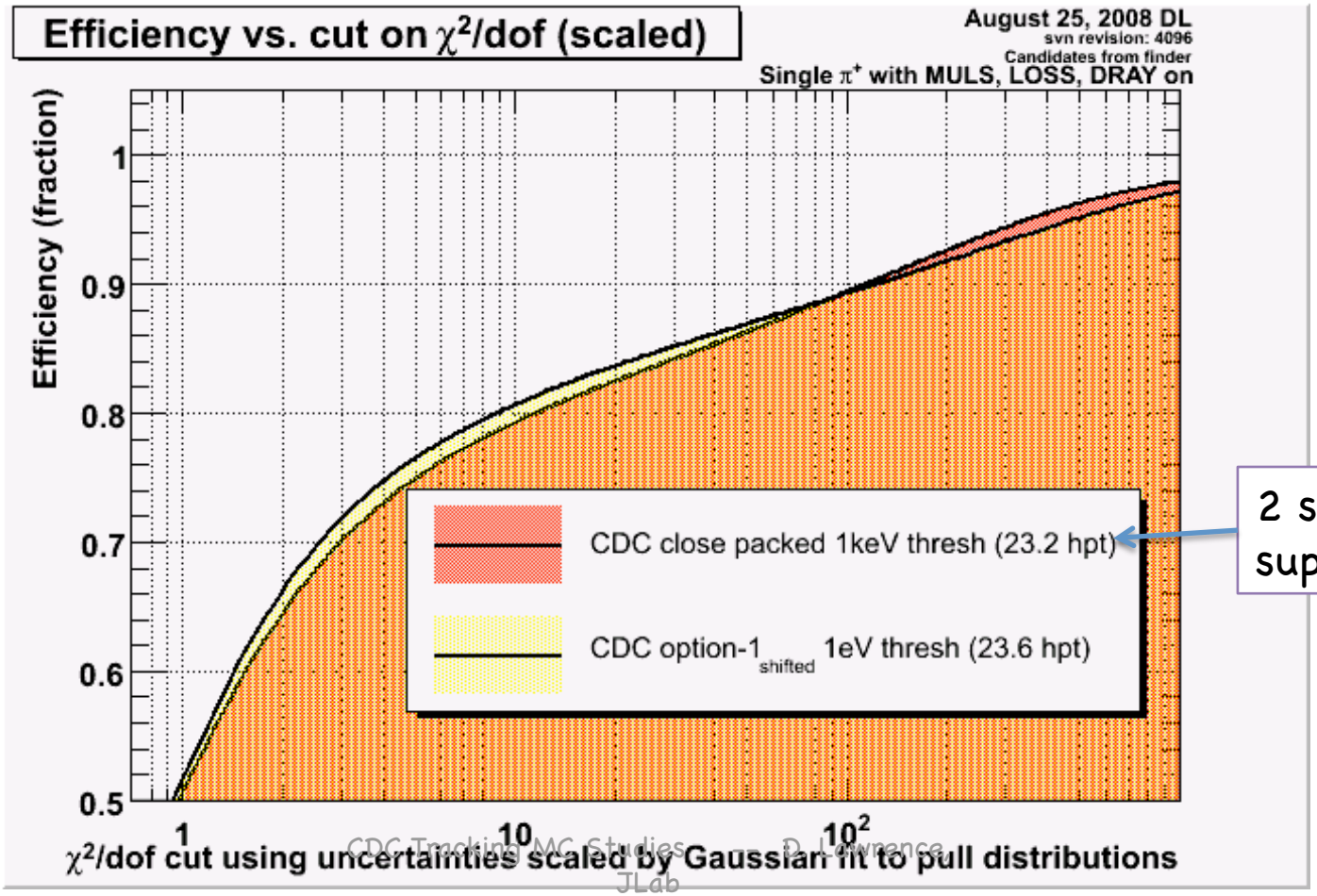
Tracking Efficiency with and without dE threshold

Phasespace: range



Close packing vs. extra layers

The low-threshold baseline design (shifted) has approximately the same number of hits per track as the close packed design with a high threshold. This gives a suggestion as to how much close packing buys vs. extra layers.



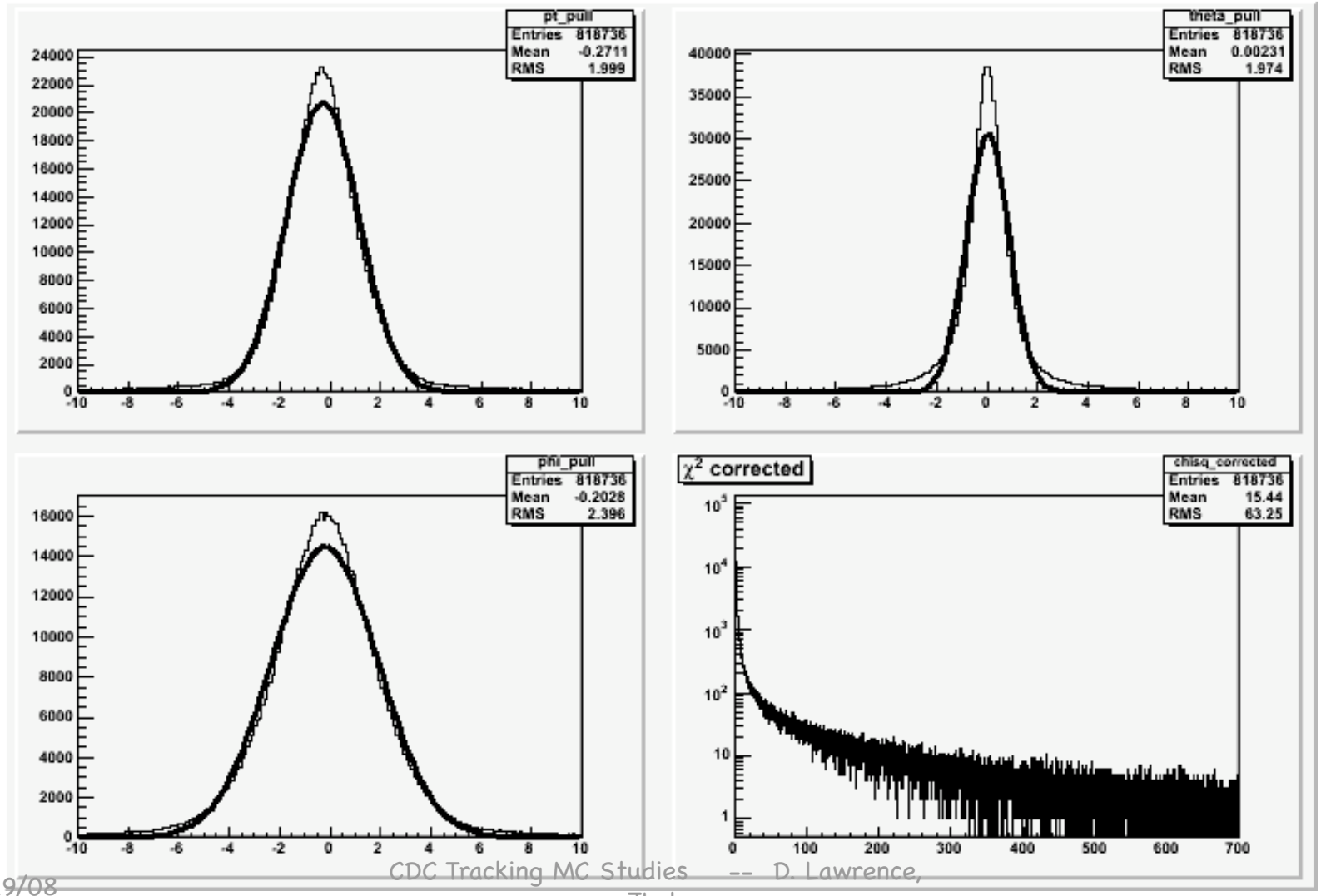
2 stereo superlayers

Conclusions

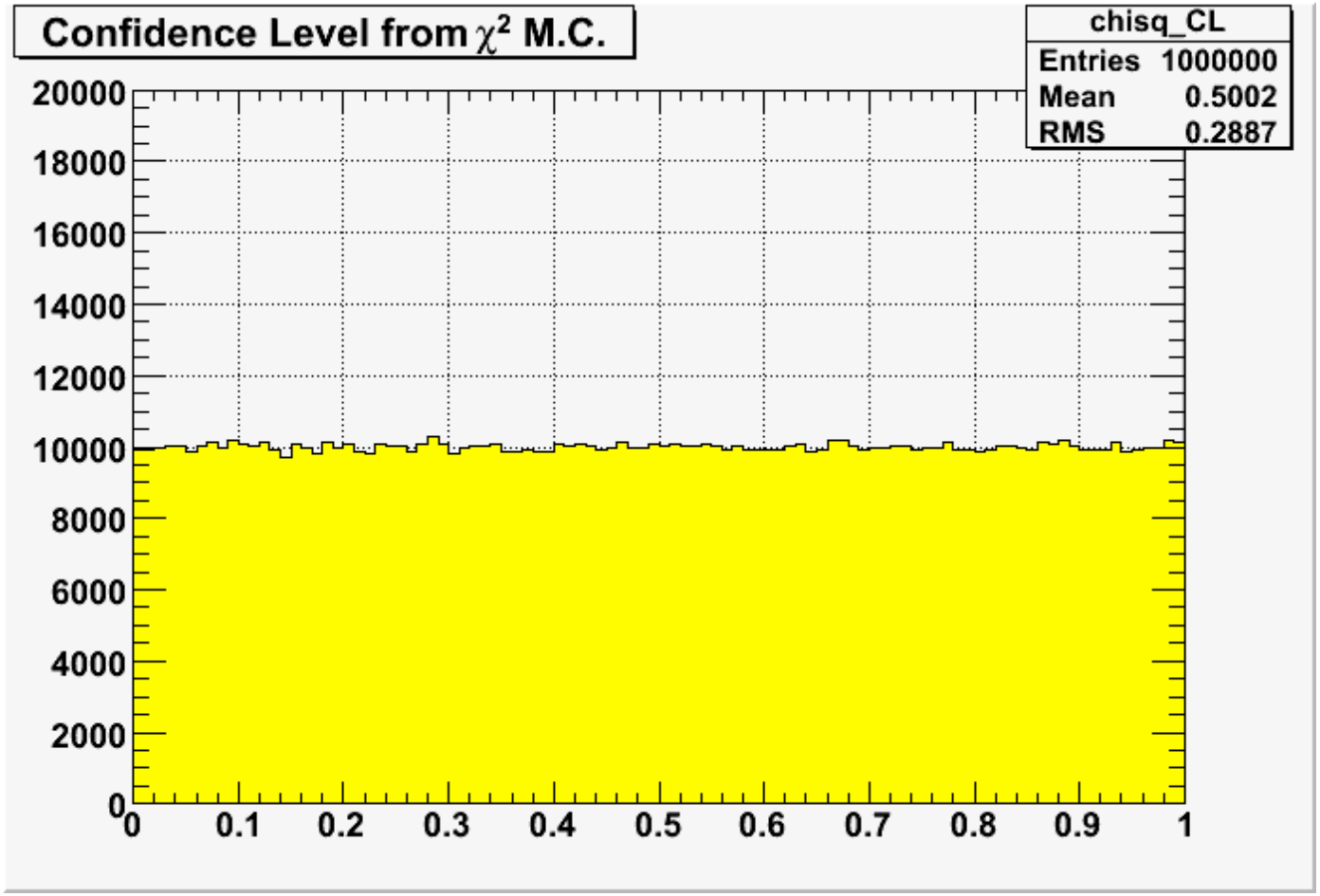
- 3 stereo superlayers improves tracking efficiency
- Additional layers improves tracking efficiency (we seem to be in a region of high sensitivity)
- Single hit efficiency due to 1keV threshold is ~88%. The energy distribution from *hdgeant* needs to be verified and then the threshold examined more closely
- χ^2 distribution is not yet fully understood, but tests are underway to see if it is linked to the Left-Right ambiguity issue

Backup Slides

Gaussian fits to full pull distributions (not just Gaussian cores)

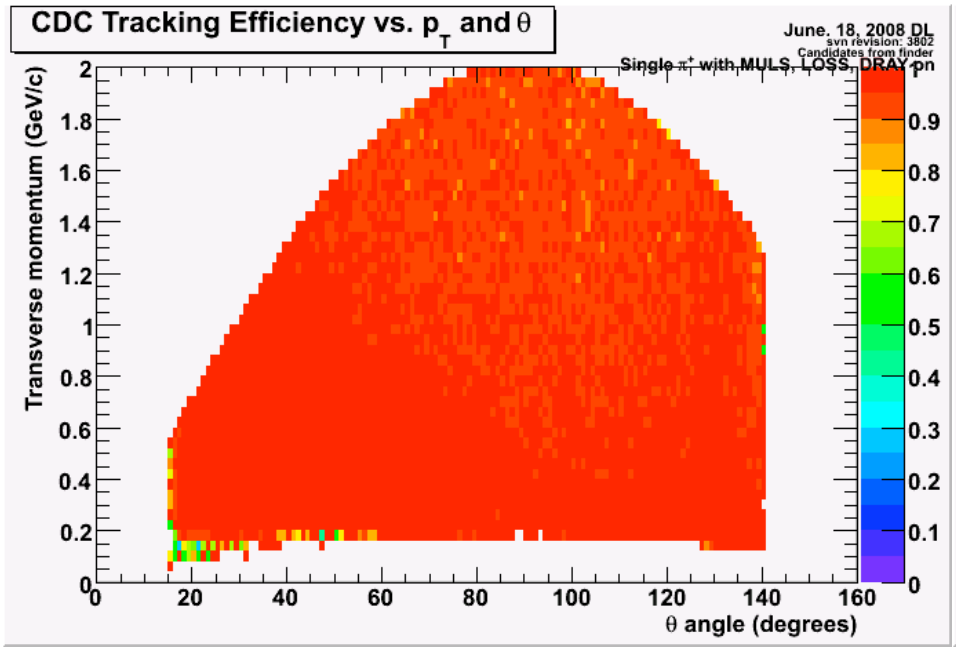


Expected Probability Density as a Function of the Integral Fraction

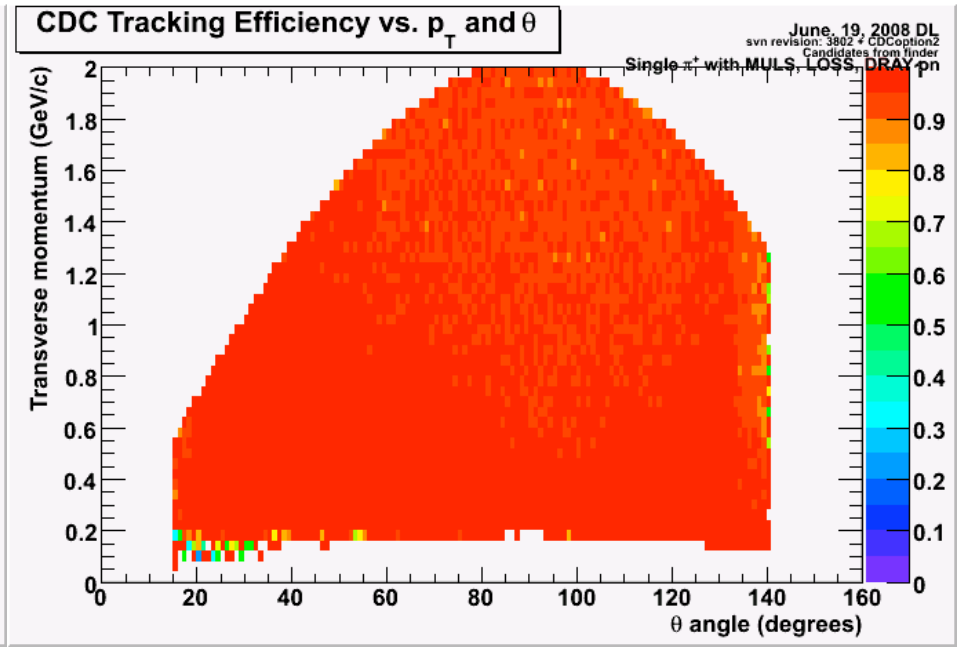


Efficiency as a function of transverse momentum and polar angle

stereo8



stereo9



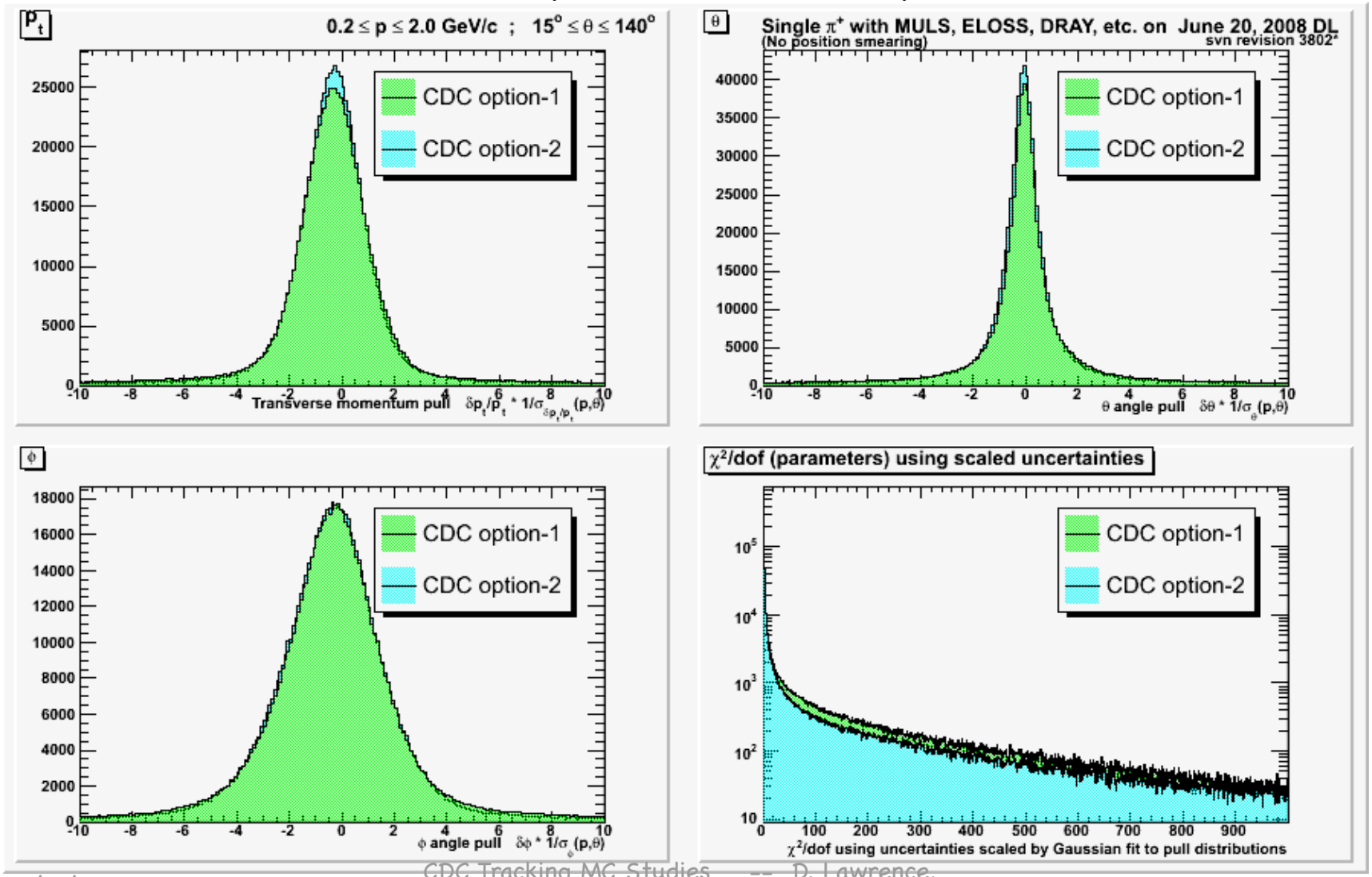
Total momentum range: 150MeV/c - 2GeV/c

Total angular range: 15° – 140°

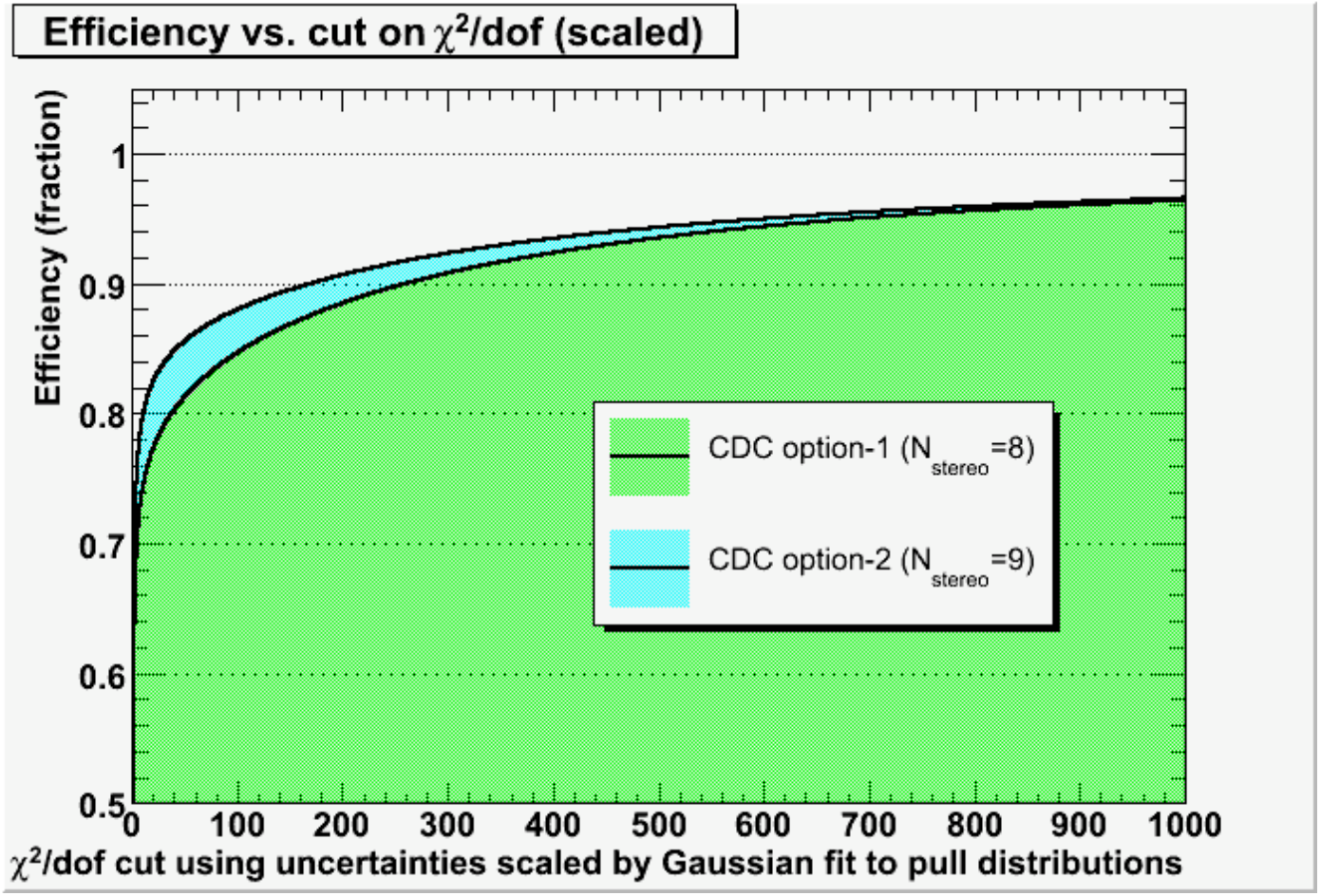
Differences not really noticeable here!

Pulls of momentum parameters

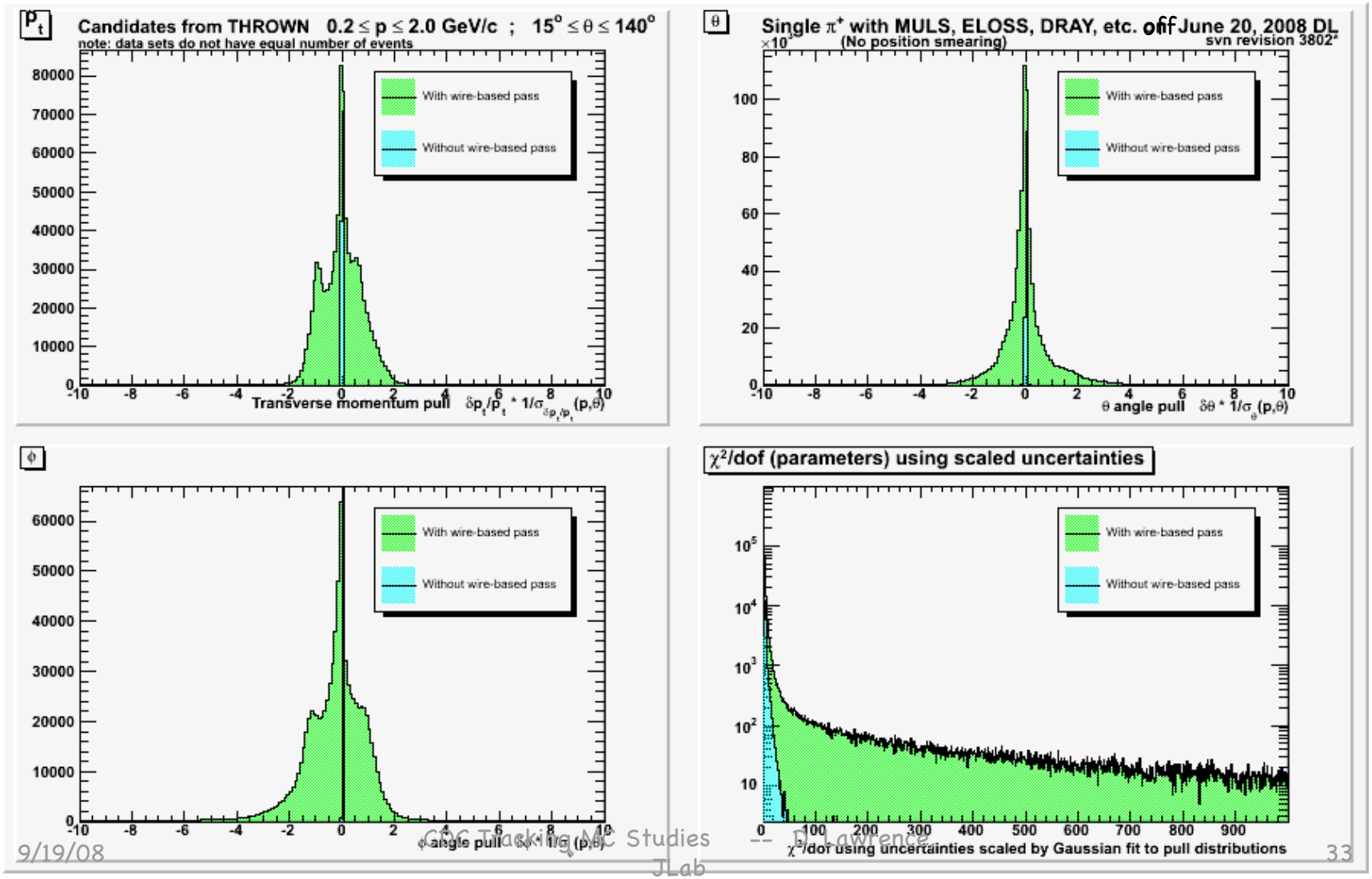
for CDC option-1 and option-2



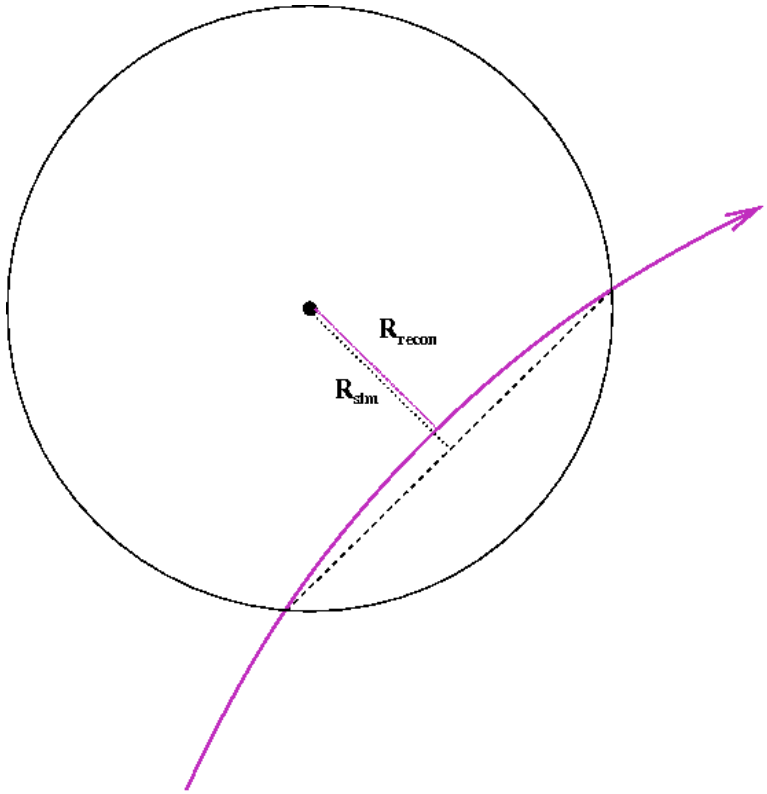
Efficiency vs. accuracy of fit parameters



Pulls from fits with perfect conditions for *stereo8*



Why "perfect" isn't perfect



- *hdgeant* estimates the point of closest approach (POCA) to be the midpoint of the entrance and exit points of the tube.

This is true to about 10 μm (systematic)

- Tracking reconstruction approximates trajectory as parabola near wire and calculates POCA from that

Efficiency for "perfect" conditions