

# Tracking Studies and the CDC

Jan 30, 2009

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# Nostalgia from Sept. 2008 ...

## How $\chi^2$ is defined

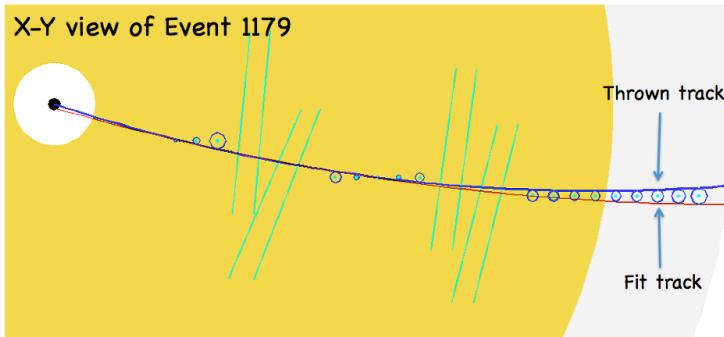
The  $\chi^2$  is formed using the residuals between the fit and thrown parameters:

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

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

- MC Studies of the CDC layer configuration had begun starting with option-1 (2 stereo s.l.) and option-2 (3 stereo s.l.) from the V4 geometry
- The studies used a *parameter*  $\chi^2$  as the figure of merit leading to  $\chi^2/\text{Ndof}$  of  $>1000$
- Straw alignments had been discovered in the CDC baseline design that lead to a  $\phi$  dependence in the tracking efficiency.

## Event 1179 has a large $\chi^2/\text{dof}$

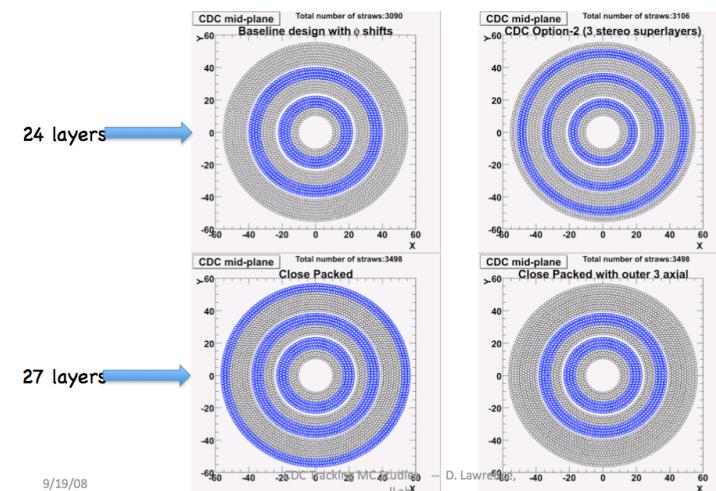


Event 1179				
	<i>p</i> <sub>tot</sub>	<i>theta</i> (rad)	<i>phi</i> (rad)	<i>chisq/dof</i>
Thrown	0.837	1.507	5.966	
Reconstructed	1.400	1.386	6.025	
resolution	0.013	7.212	2.976	
residual/err	51.399	-16.777	19.824	
$(\text{residual}/\text{err})^2$	2641.886	281.471	392.988	1105.448

9/19/08

## 5 CDC configurations studied

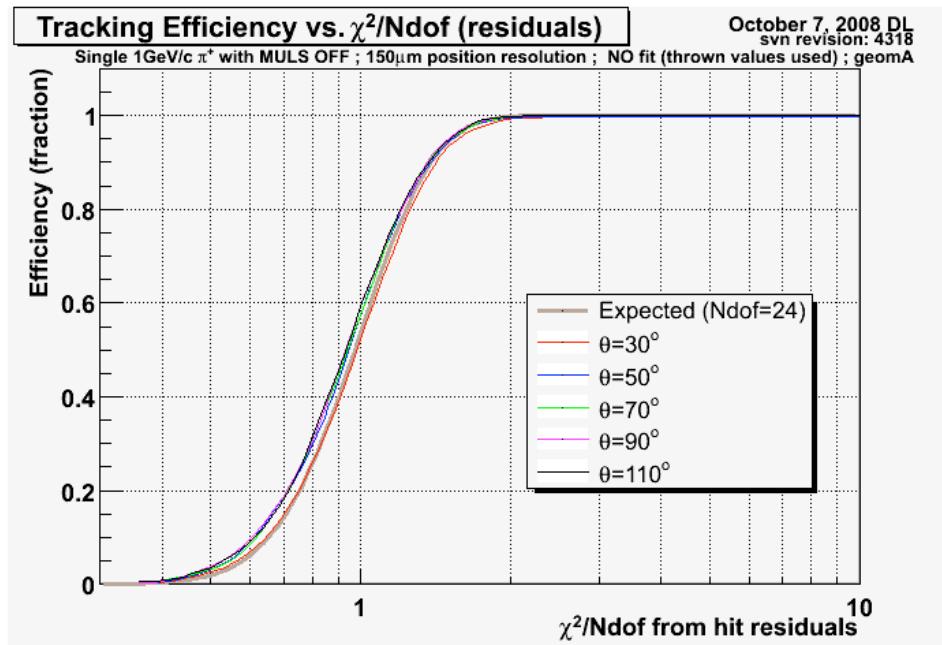
(yes, only 4 are shown)



Take a few steps back in order to move forward...

- The CDC endplate design was needed by January so we needed to quickly get a handle on the tracking efficiency and the  $\chi^2 > 1000$  problem
- On Sept. 26, 2008, we had a phone conference with 2 tracking experts from Hermes. They suggested looking at the *residual*  $\chi^2$  rather than the *parameter*  $\chi^2$
- In addition, we decided to proceed with both multiple scattering and energy loss turned off in the simulation in order to have complete control over the residuals

# Consistency Checking



4k single  $\pi^+$  1GeV/c events were thrown at 5 discrete angles ranging from  $30^\circ$  to  $110^\circ$ . Multiple scattering etc. was turned OFF

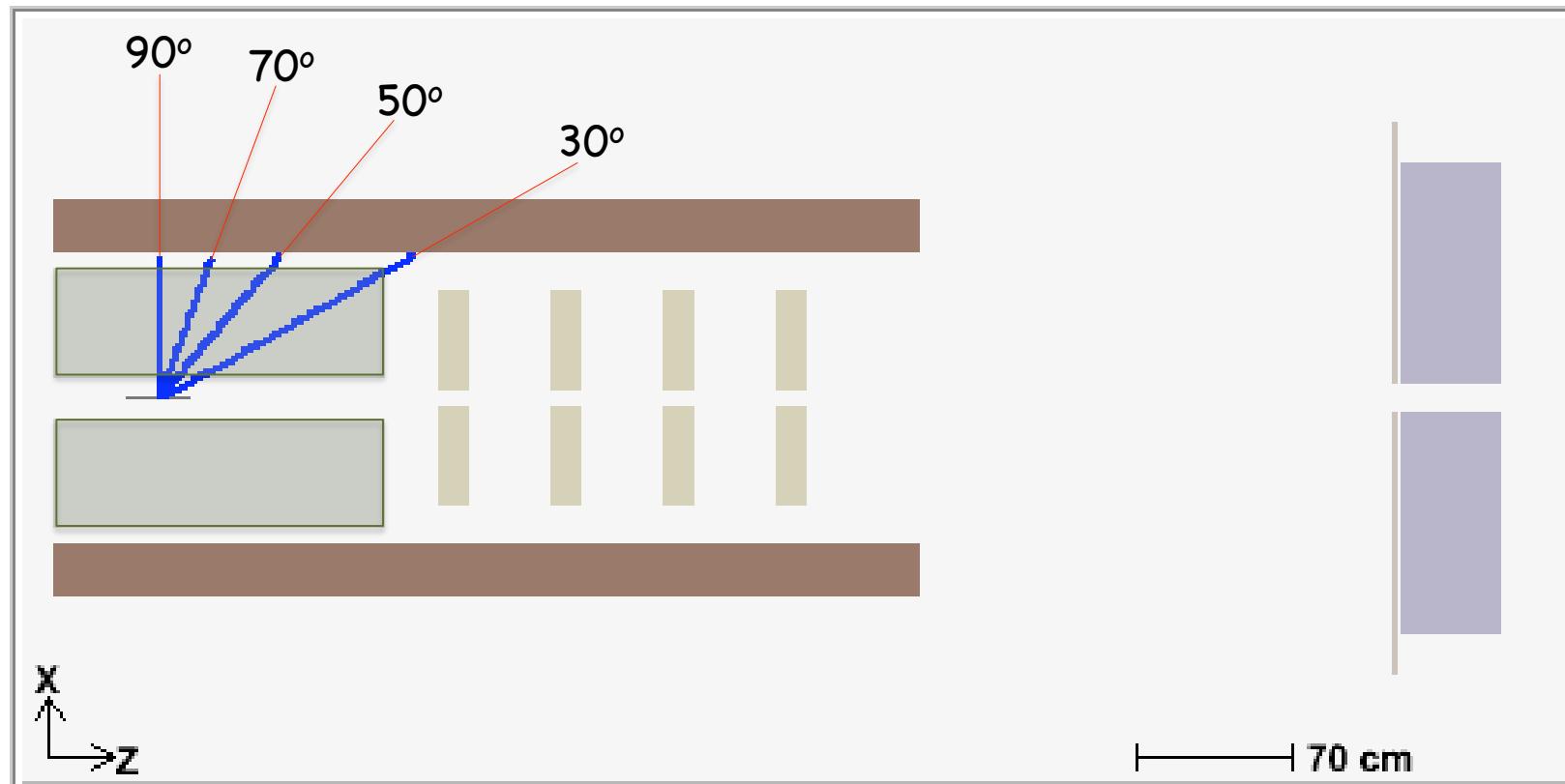
Drift times were smeared via Gaussian to give them a position resolution of 150  $\mu\text{m}$

A tracking  $\chi^2/\text{N}_{\text{dof}}$  was formed from the hit residuals using the known 150  $\mu\text{m}$  resolution

The  $\chi^2/\text{N}_{\text{dof}}$  distribution was integrated and compared to the known cumulative  $\chi^2$  function

To check consistency between the simulation and reconstruction geometries as well as transport through the magnetic field etc. , thrown values were used

# 1 GeV/c track locations in CDC



# 9 Geometries Were Studied

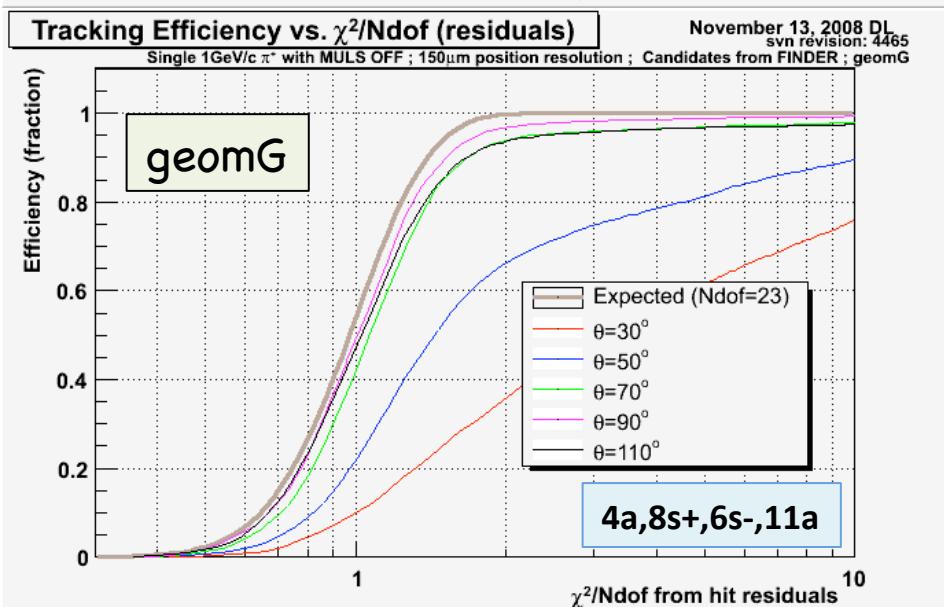
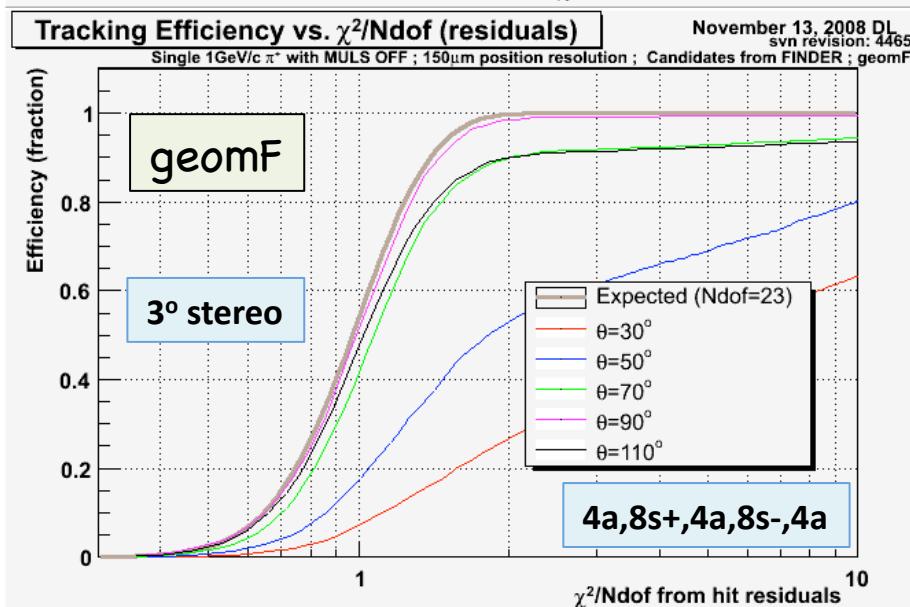
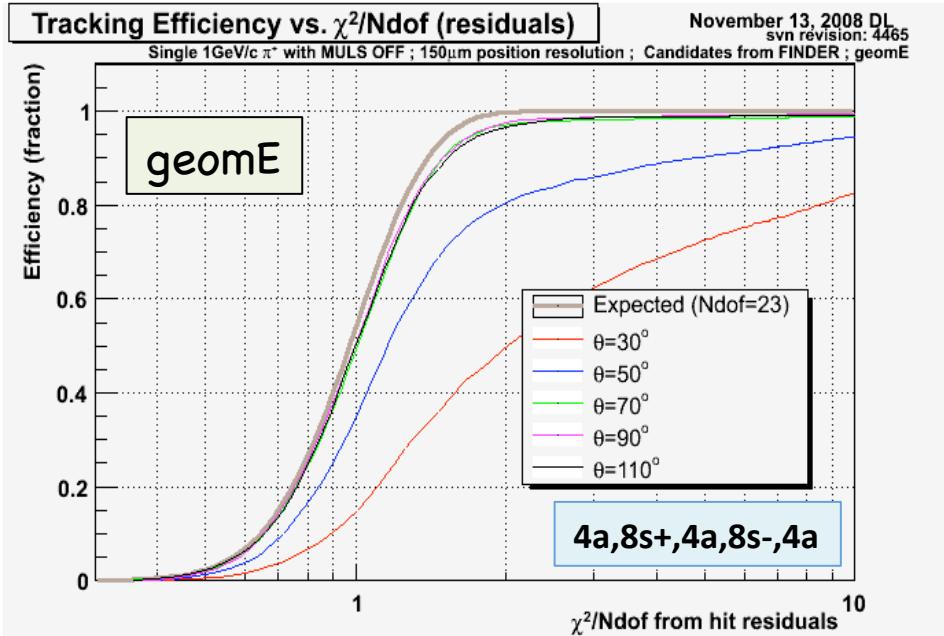
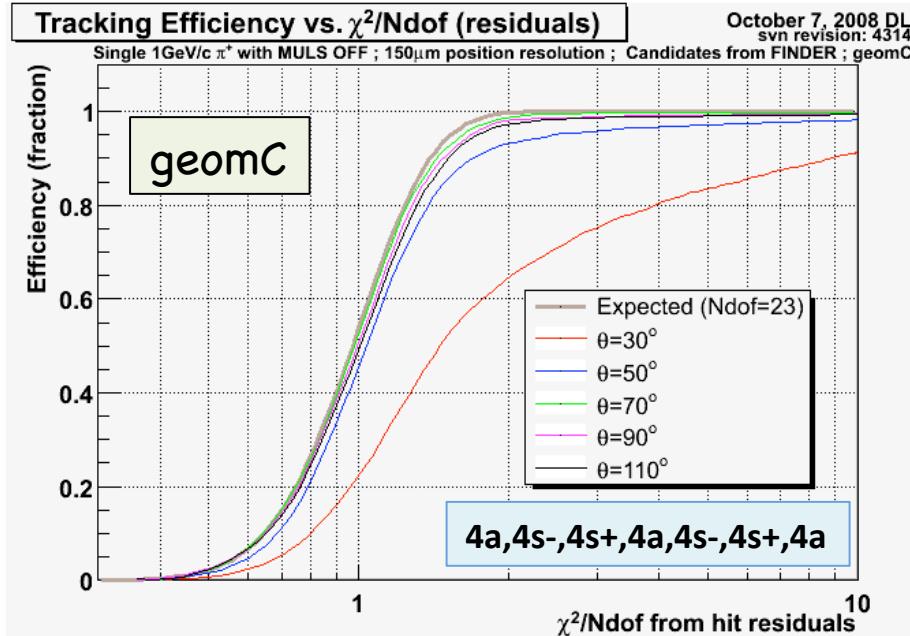
Geometry A	Geometry B	Geometry C	Geometry D
8 axial	8 axial	4 axial	3 stereo -6°
2 stereo +6°	4 stereo +6°	4 stereo +6°	8 axial
2 stereo -6°	5 axial	4 stereo -6°	4 stereo +6°
5 axial	4 stereo -6°	4 axial	4 axial
2 stereo +6°	3 axial	4 stereo +6°	4 stereo -6°
2 stereo -6°		4 stereo -6°	4 axial
3 axial		4 axial	

- Various configurations of the axial and stereo layers were studied
- Once the layer configuration was finalized, different stereo angles were looked at
- All of these designs (except the baseline “A”) used  $\phi$ -shifting and many used close-packing

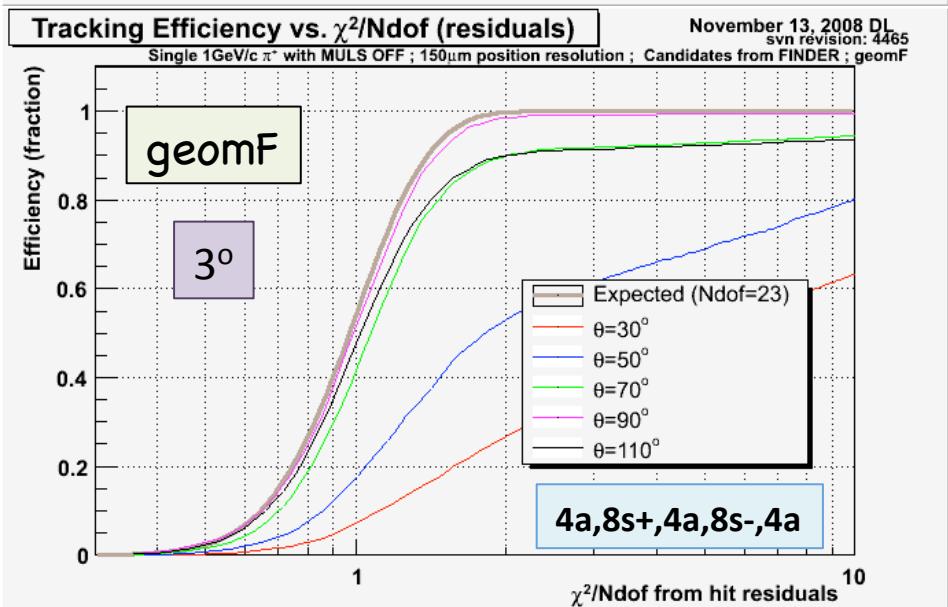
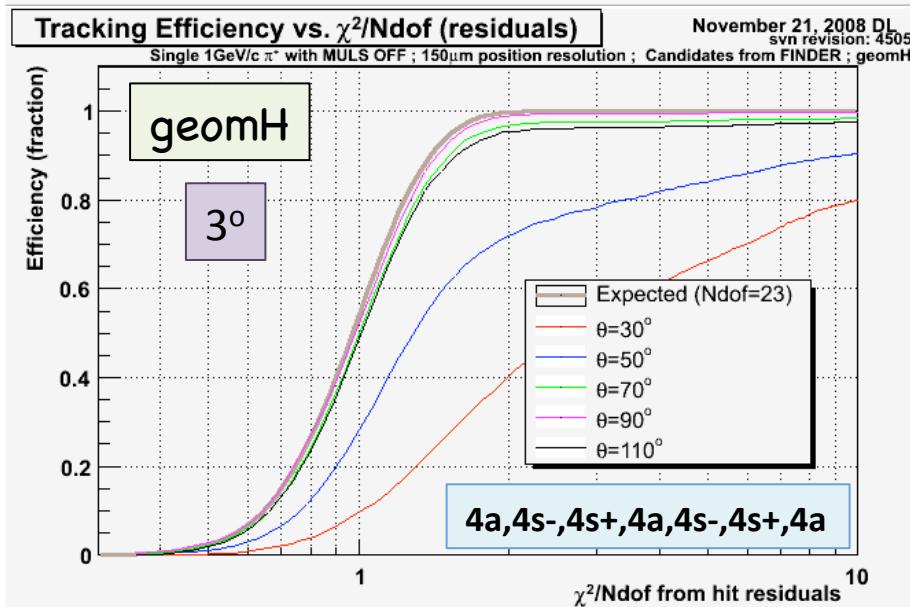
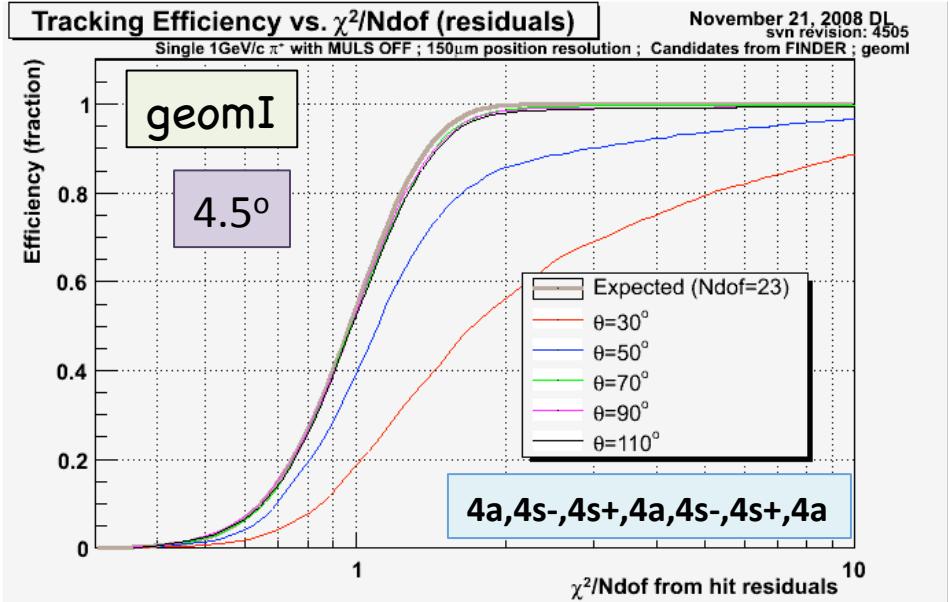
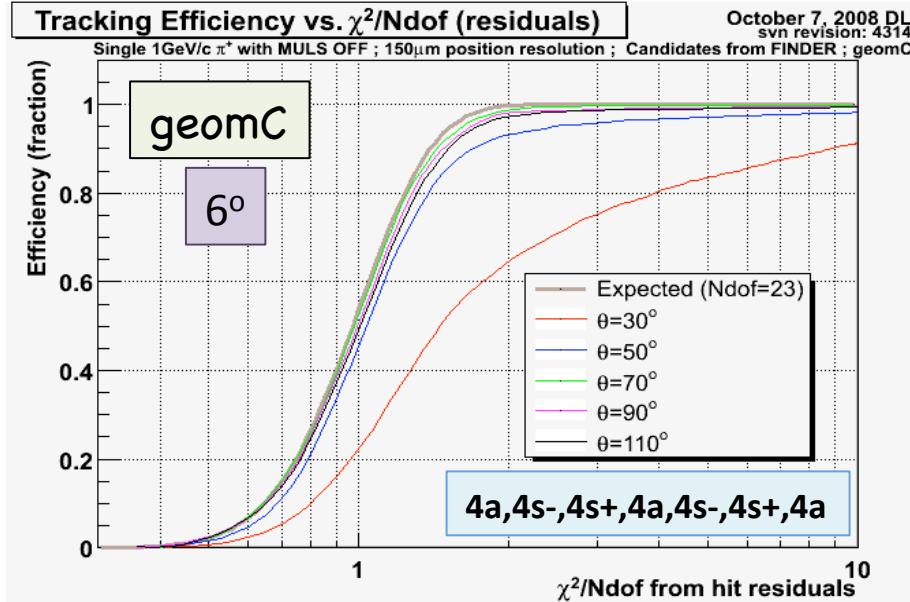
Geometry E	Geometry F	Geometry G	Geometry H	Geometry I
4 axial	4 axial	11 axial	4 axial	4 axial
8 stereo -6°	8 stereo -3°	6 stereo -6°	4 stereo +3°	4 stereo +4.5°
4 axial	4 axial	8 stereo +6°	4 stereo -3°	4 stereo -4.5°
8 stereo +6°	8 stereo +3°	4 axial	4 axial	4 axial
4 axial	4 axial		4 stereo +3°	4 stereo +4.5°
			4 stereo -3°	4 stereo -4.5°
			4 axial	4 axial

• *geomC* was ultimately shown to give the best tracking efficiency using the available tools

# Full Reconstruction – layer configs



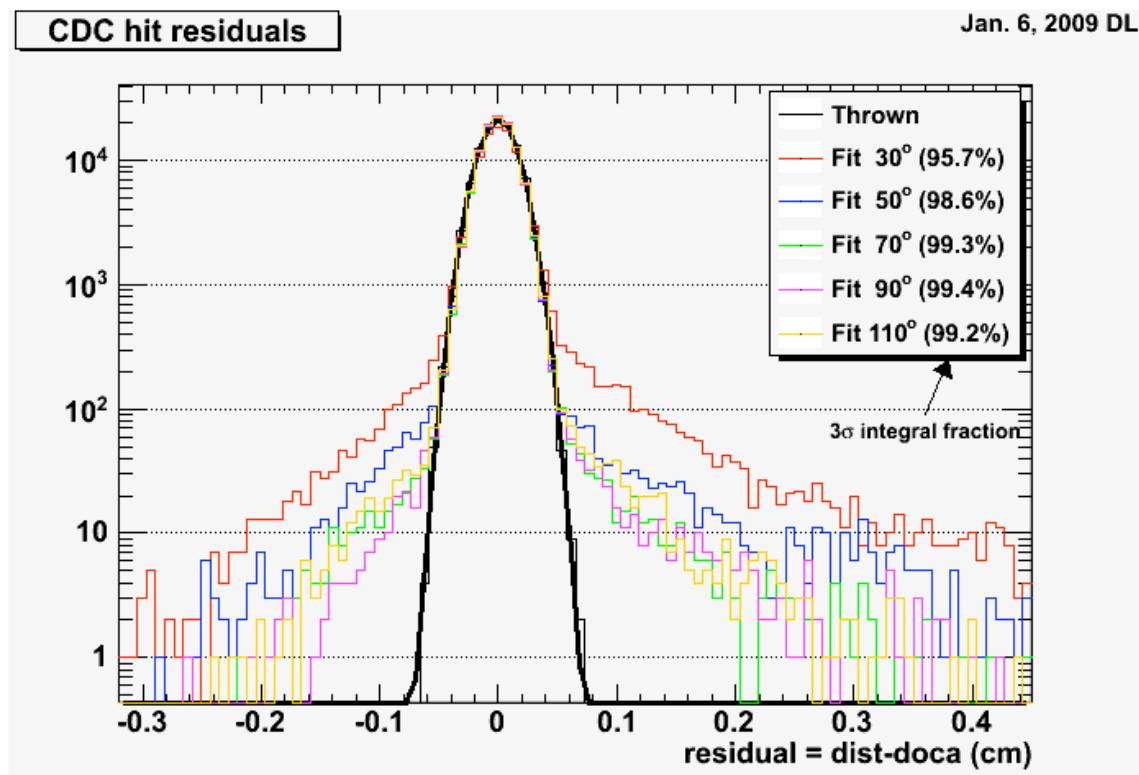
# Full Reconstruction – stereo angle



Tracking efficiency gets worse as the stereo angle decreases!

# CDC residuals by angle

1 GeV/c  $\pi^+$  tracks

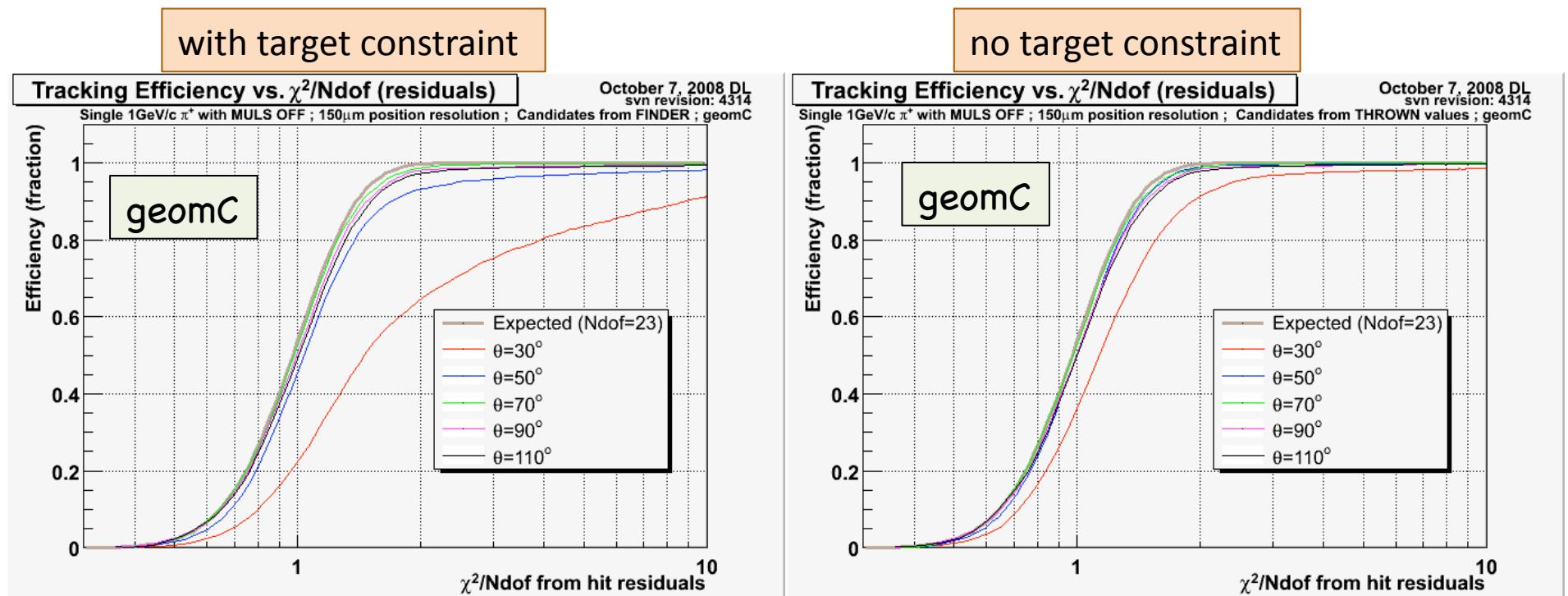


30° tracks have larger “wings” than other angles which pushes the tracking  $\chi^2$  further out in the tails of the  $\chi^2$  distribution.

# Night of the living target constraint

For a long time the ALT1 global track fitter has included a fuzzy target constraint.

This did very bad things when the candidate's vertex was inaccurate.



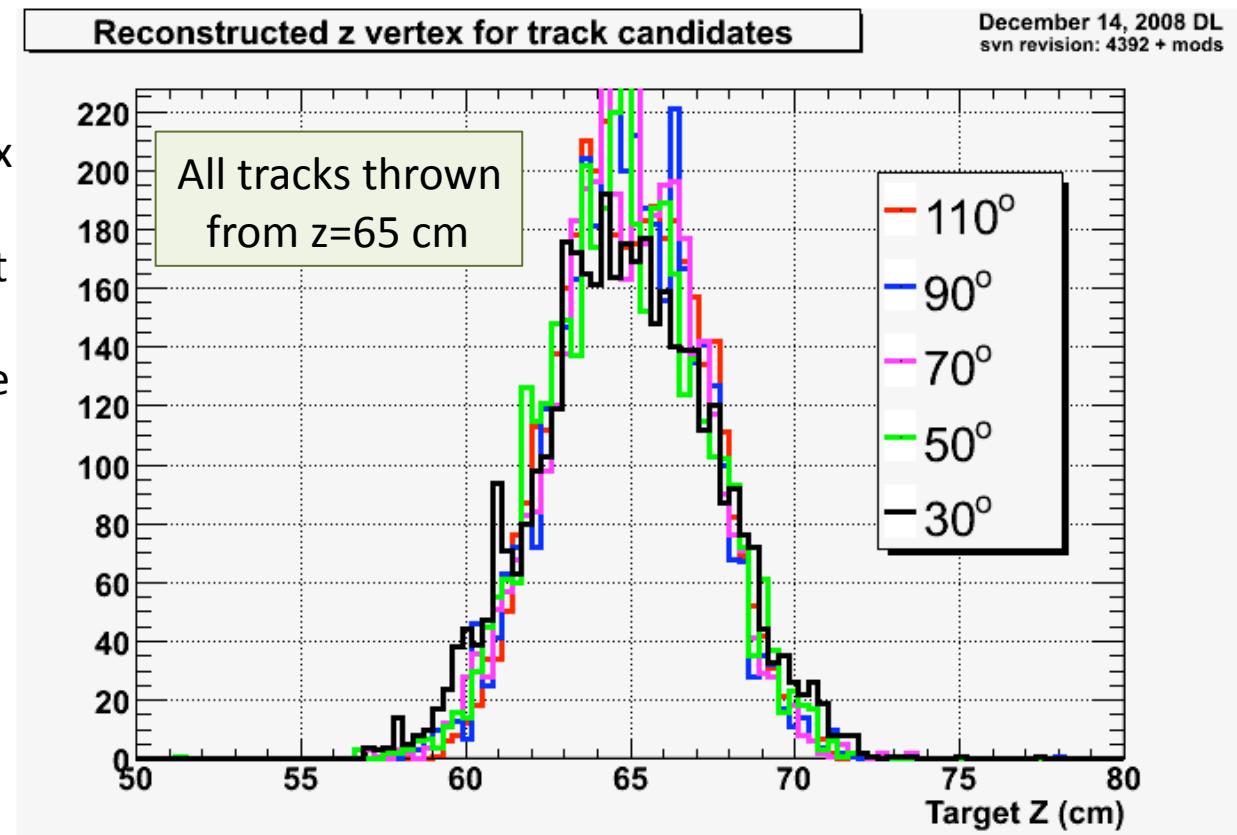
The target constraint has now been disabled.

# Vertex resolution for track candidates

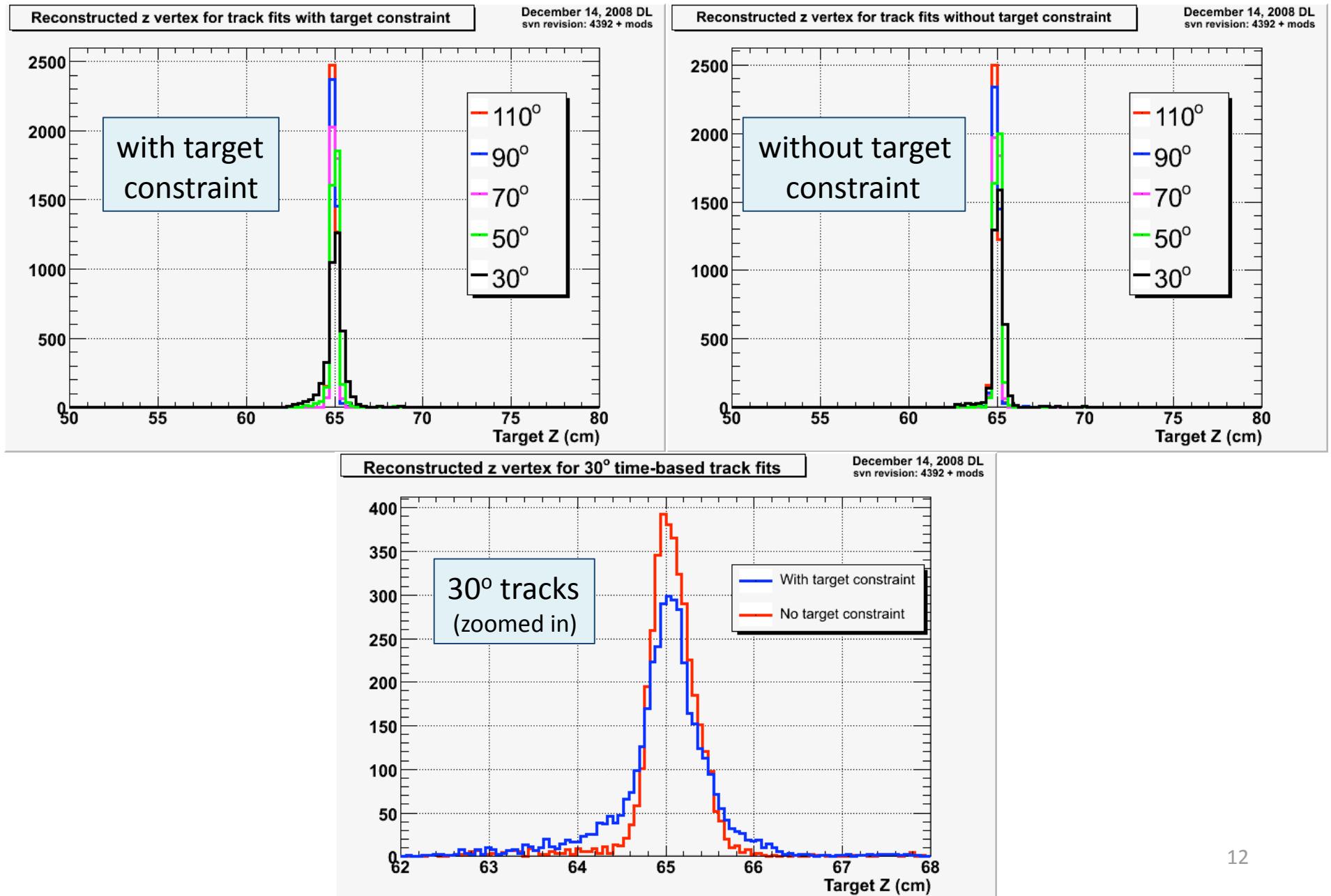
The “vertex constraint” used is based on a 3cm segment of the beamline centered on the z\_vertex reconstructed for the track candidate.

The way the candidate determines the z vertex is biased to finding it in the center of the target

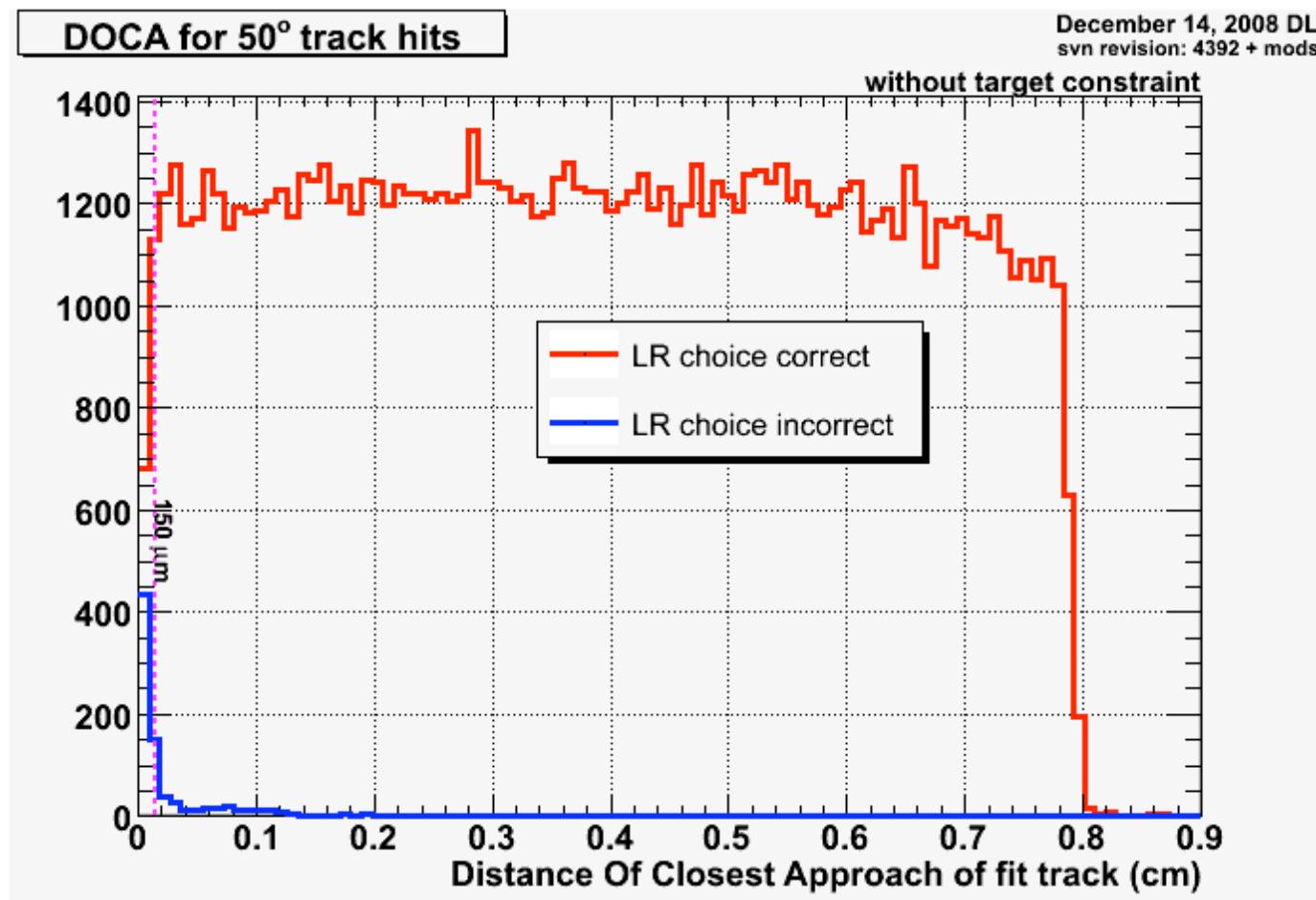
This actually gave some benefit early on when developing the fitting algorithm, but now turns out to be a bias that hurts more than helps



# Vertex Reconstruction

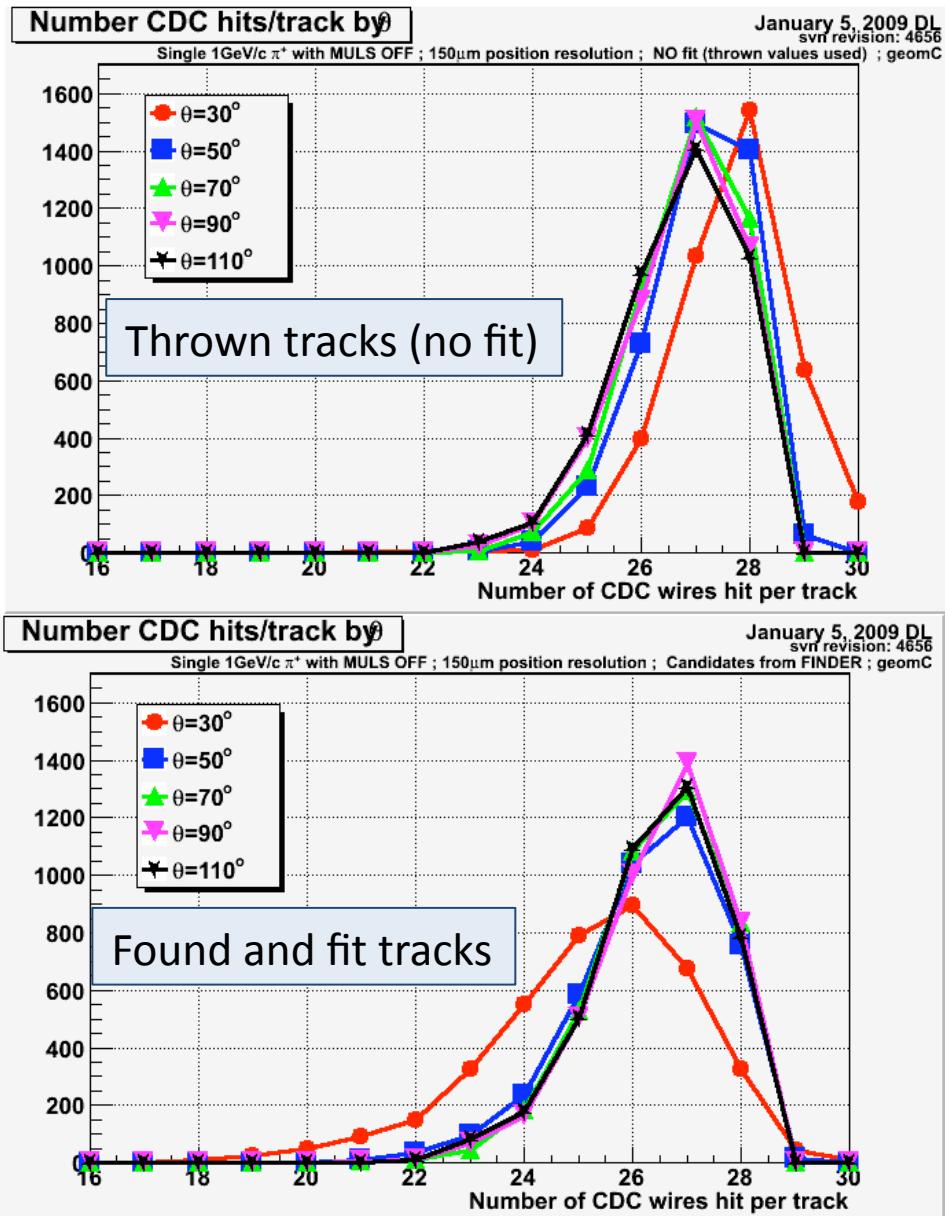


# DOCA values based on LR correctness



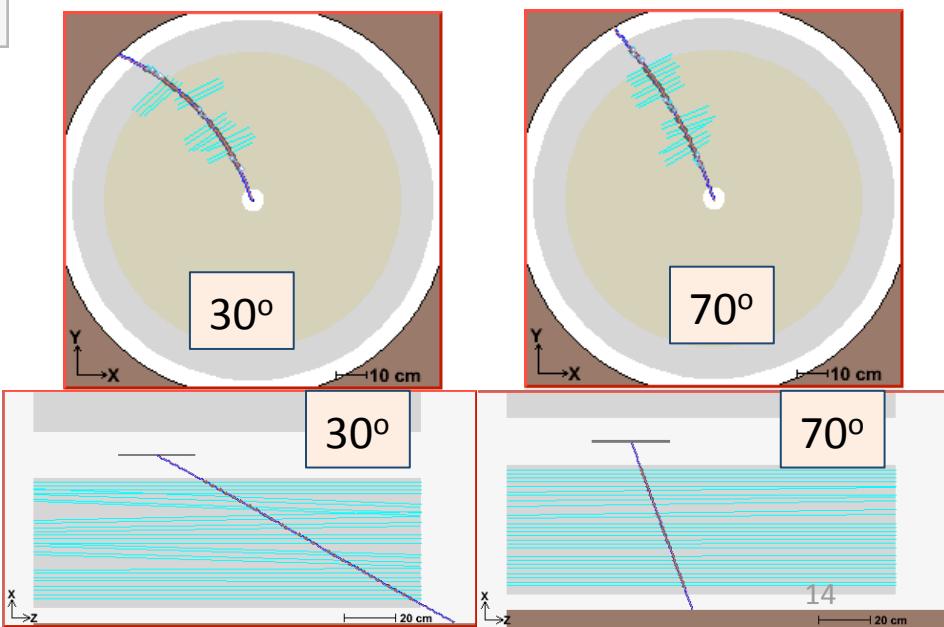
# Number of hits per track in CDC

## 1 GeV/c $\pi^+$ tracks

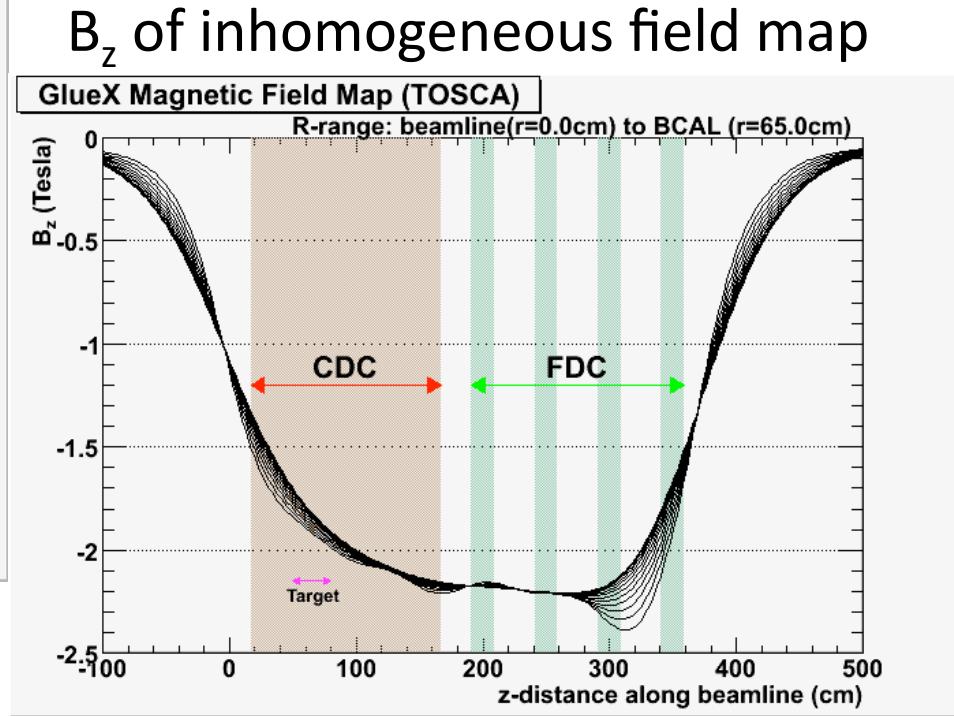
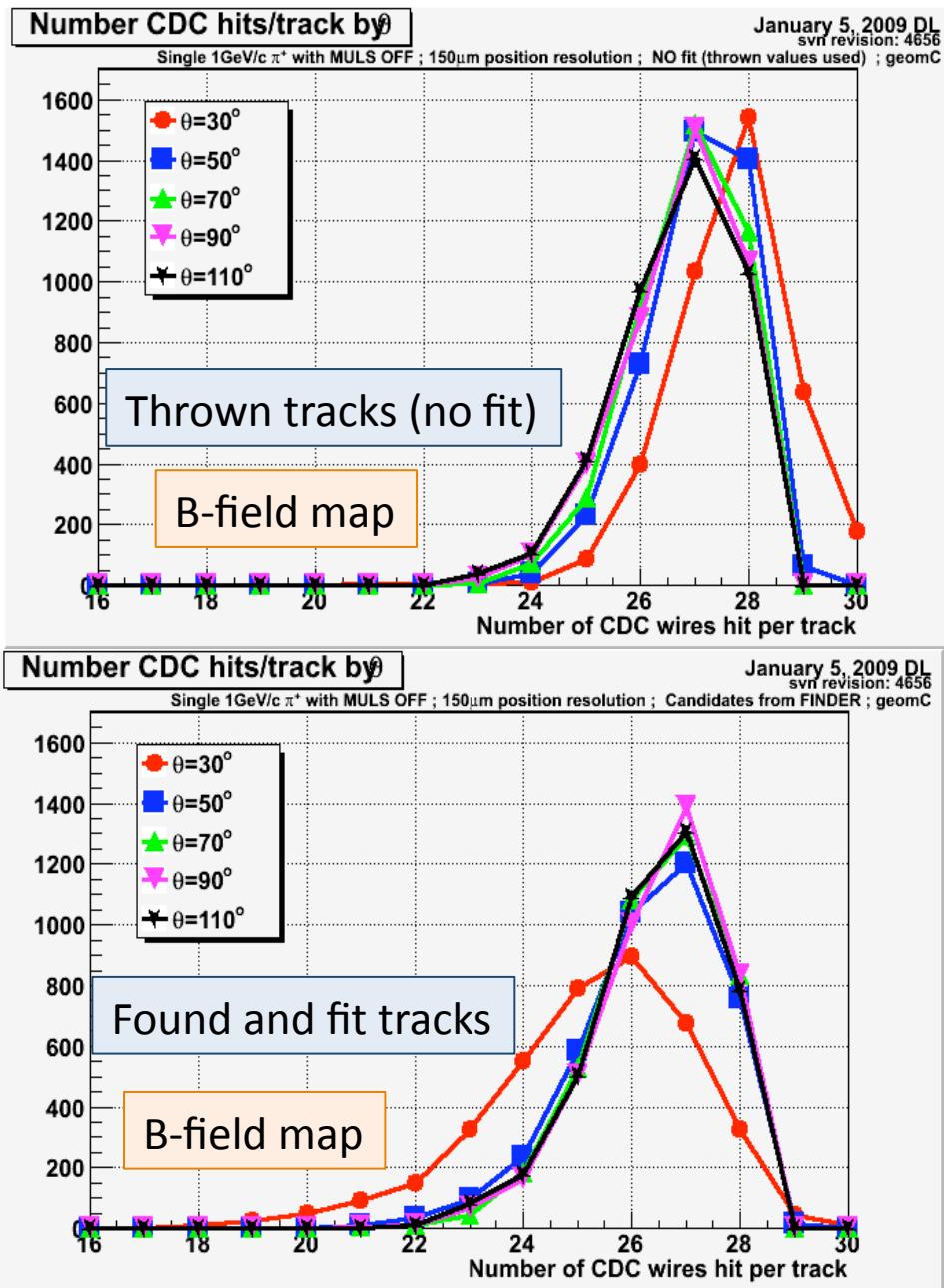


There is simultaneously a higher probability of getting multiple hits per layer in  $30^\circ$  tracks and a higher probability of rejecting hits that belong to a track.

Hit selection based on proximity to helical fit which will be worse in forward region where field becomes less uniform.



# CDC Number of hits per track

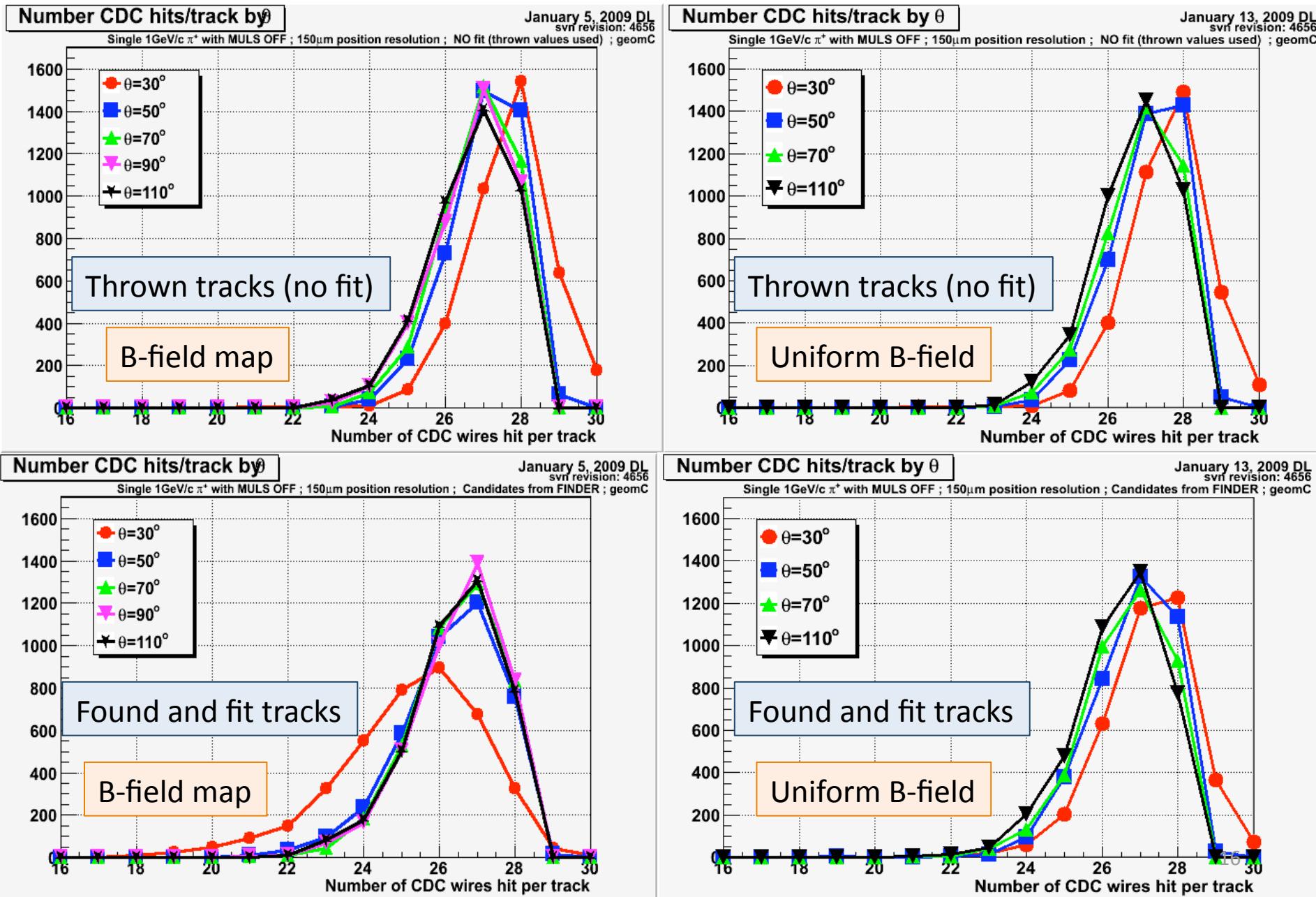


Target Center:  $B_z \approx 1.8\text{T}$

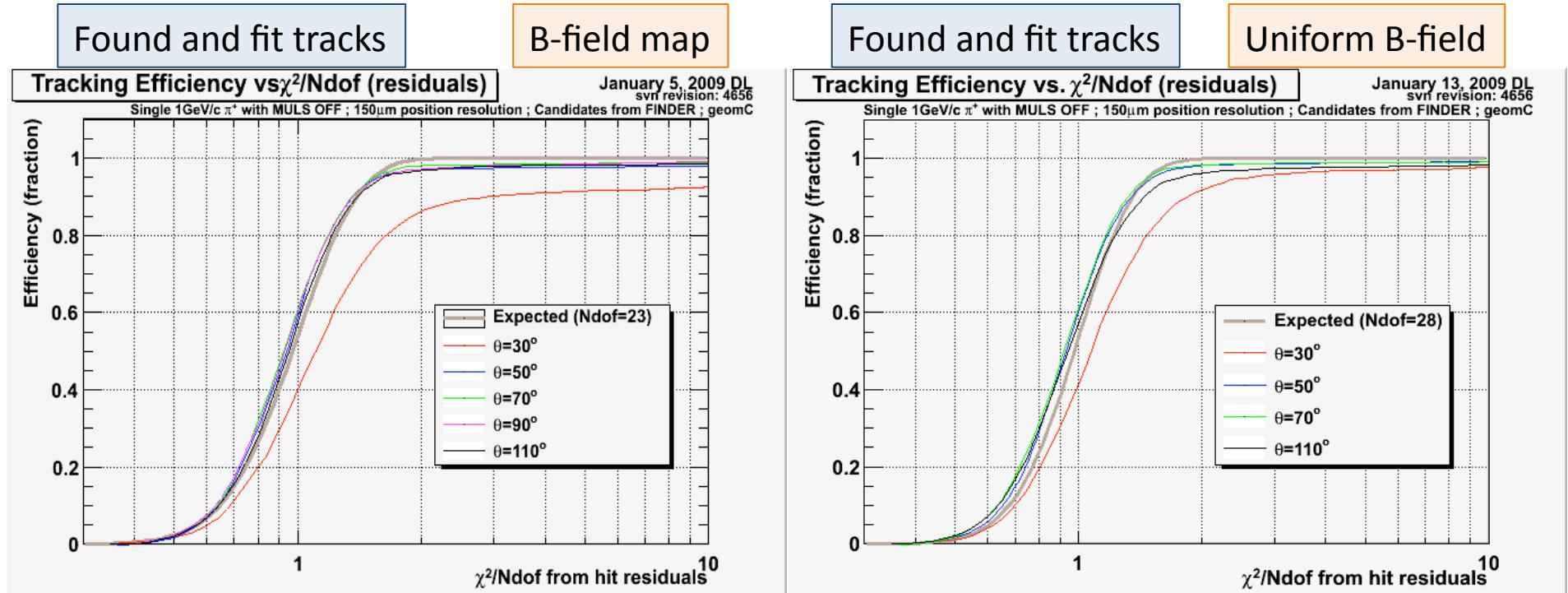
CDC downstream end:  $B_z \approx 2.2\text{T}$

field changes by more than 20% for tracks going forward through the CDC

# CDC Number of hits per track



# Cumulative $\chi^2$ distributions with uniform and non-uniform Magnetic fields



30° tracks still stand out a little with the uniform field but the difference is greatly reduced from the non-uniform case.

## ...clutch-in, shift, clutch-out ...

- At this point, we felt that we understood the efficiency plots and the cumulative  $\chi^2$  distributions were a good figure of merit for optimizing the design.
- We had some confidence that the *geomC* layer configuration for the CDC with a 6° stereo angle was close to the optimal design and decided to fix that as the new baseline.
- The hole pattern of CDC end plate still depended on the overall length of the CDC so more studies with more geometries were needed.

# Additional Geometries

Name	CDC length
geomL	175 cm
geomC*	150 cm
geomJ	125 cm
geomK	100 cm

\*geomC is the baseline geometry

Upstream end of CDC and position of last FDC package held fixed. Upstream FDC package positions adjusted to maintain equal spacing and spacing from CDC downstream end.

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The following values must be changed in the XML in order to change the length of the CDC to Lcdc.
Note that this will keep the upstream end of the CDC fixed at L=17cm in the lab system. Also, it
is assumed that the FDC package spacing will be adjusted so that the downstream end stays fixed
at z=190.0+83.5+76+4.5+3 = 357cm in the lab frame.

The width spanned by the FDC packages will then be Lfdc = 357 - (Lcdc+40.0)

fdc1 = (Lfdc -2*(4.5+3))/2
fdc2 = fdc1/3

This does not change the cable positions or cooling meshes.

main_HDDS.xml:
-----
line 68: ForwardDC should have z value of 17+Lcdc+23

CentralDC_HDDS.xml:
-----
line 46: centralDC_option-1 should be Lcdc/2
line 48: CDBD should be Lcdc+1.5
line 49: CDGD should be Lcdc+10.5
line 67: CDPU should be -(Lcdc/2+0.45)
line 68: CDPD should be +(Lcdc/2+0.20)
line 82: CDPU should be -(Lcdc/2+0.45)
line 83: CDPD should be +(Lcdc/2+0.20)
line 95: CDPU should be -(Lcdc/2+0.45)
line 96: CDPD should be +(Lcdc/2+0.20)
line 143: CDPU should be -(Lcdc/2+0.45)
line 144: CDPD should be +(Lcdc/2+0.20)
line 156: CDPU should be -(Lcdc/2+0.45)
line 157: CDPD should be +(Lcdc/2+0.20)
line 169: CDPU should be -(Lcdc/2+0.45)
line 170: CDPD should be +(Lcdc/2+0.20)
line 221: CDPU should be -(Lcdc/2+0.45)
line 222: CDPD should be +(Lcdc/2+0.20)
line 236: CDPU should be -(Lcdc/2+0.45)

```

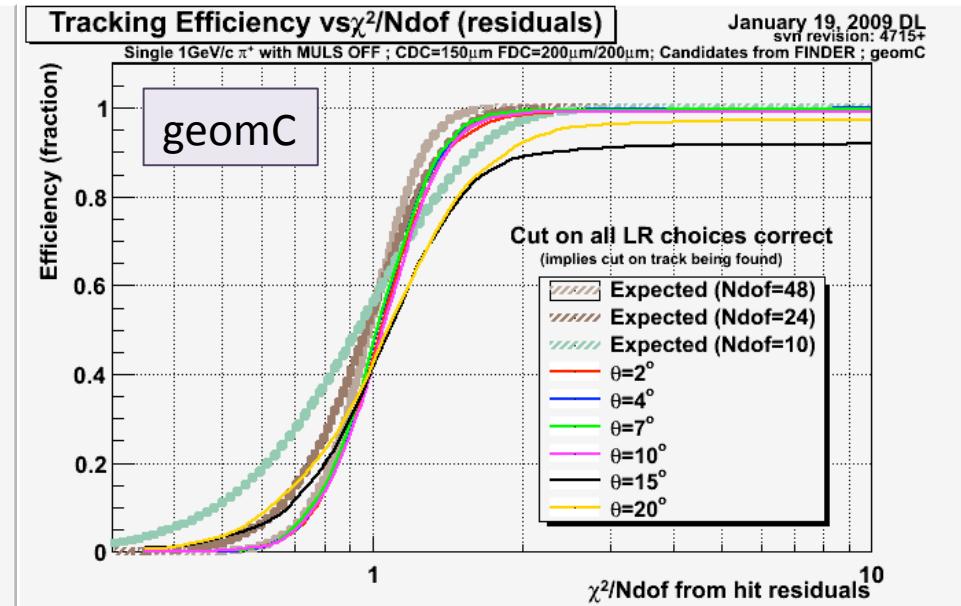
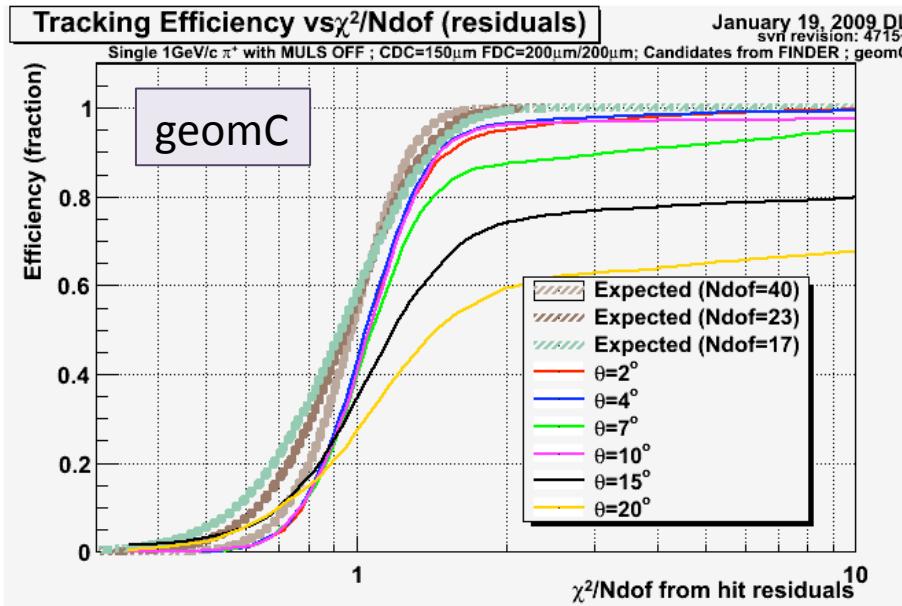
71 changes required in 3 XML files to modify CDC length!

(XML -> perl script -> XML-> C program -> Fortran code ->gfortran)

# Locking in the LR choice

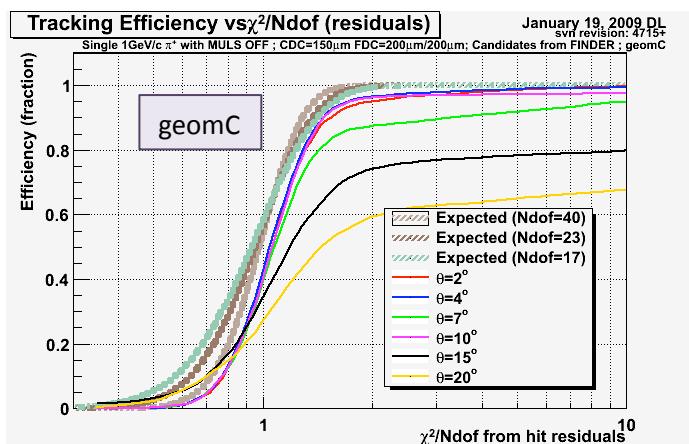
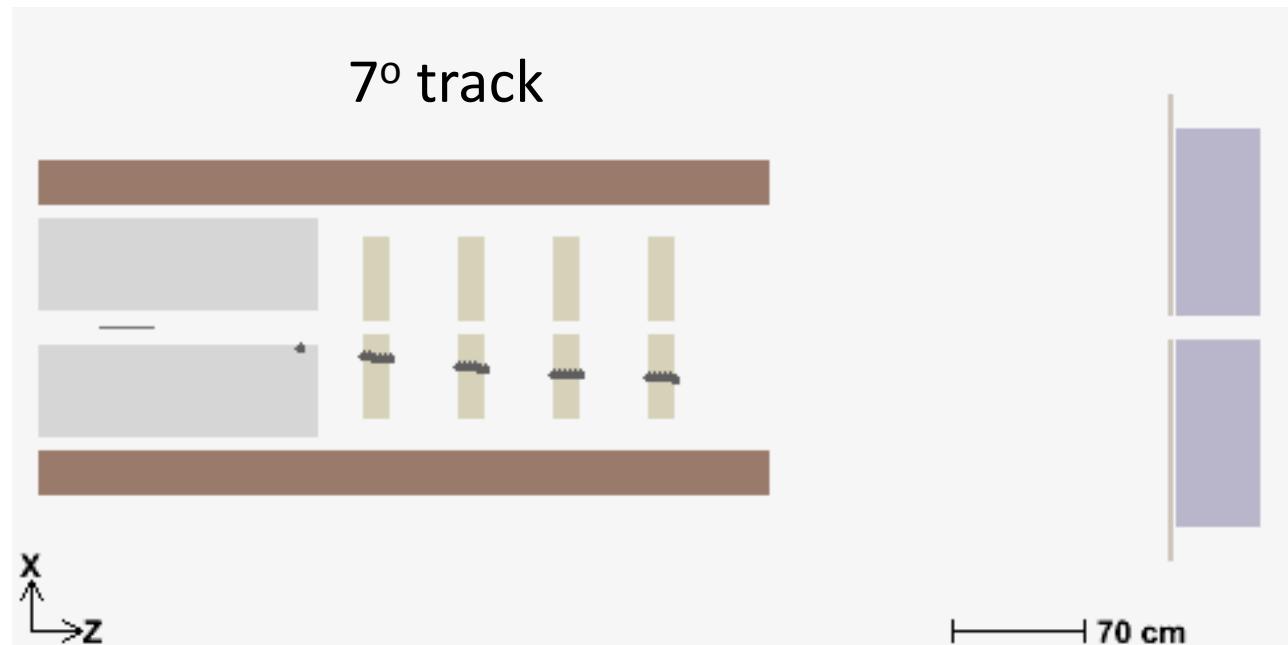
The ALT1 fitter locks in the left-right choice based on the results of fitting to the wire positions. Looking only at tracks that were found *and* had the correct L-R choice made for all hits gives a limit on what might be achieved with a better algorithm.

Notice on the left plot below that the  $7^\circ$  curve is out of order.



# Single hit in CDC can cause big problems when LR choice is locked

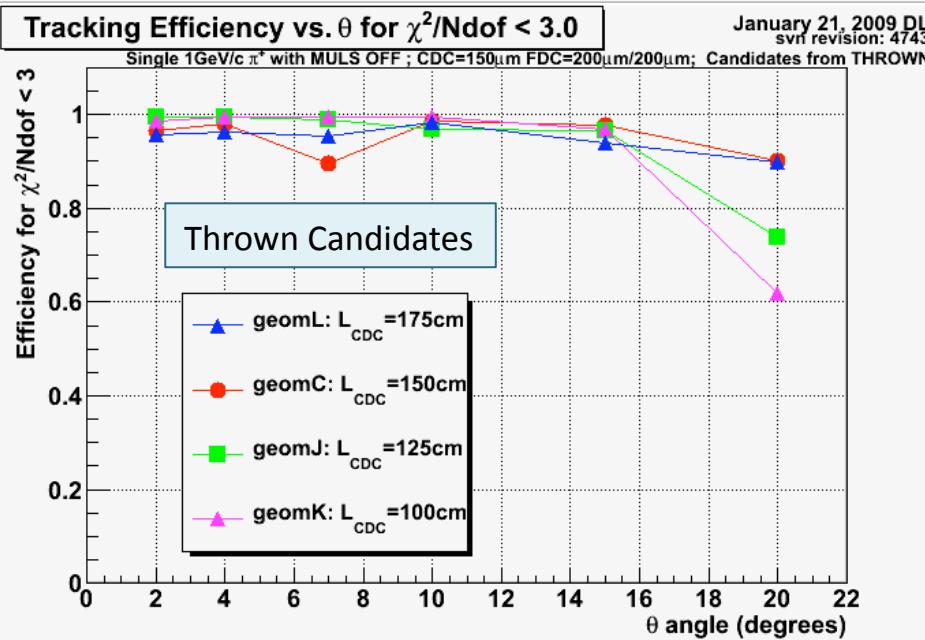
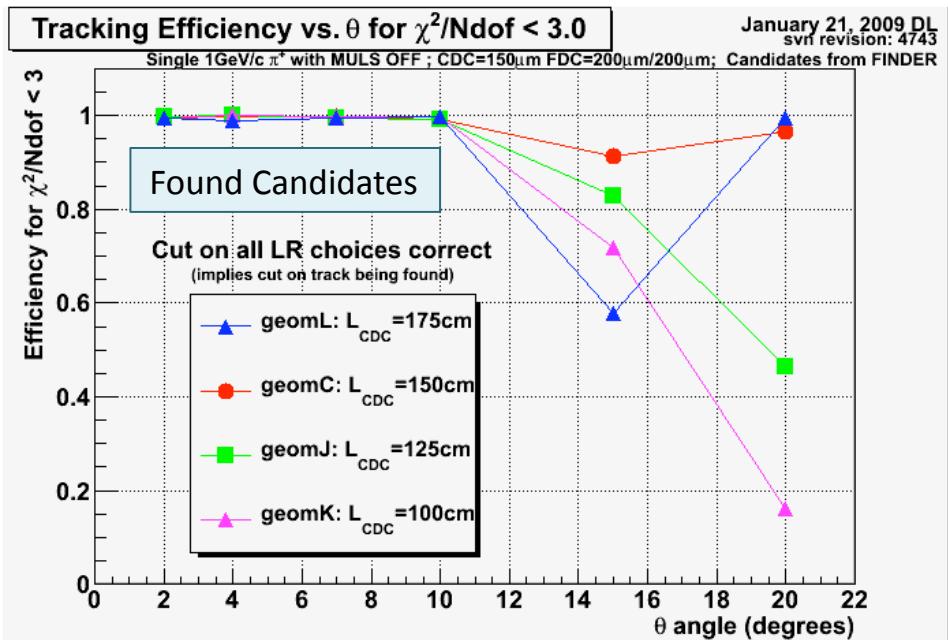
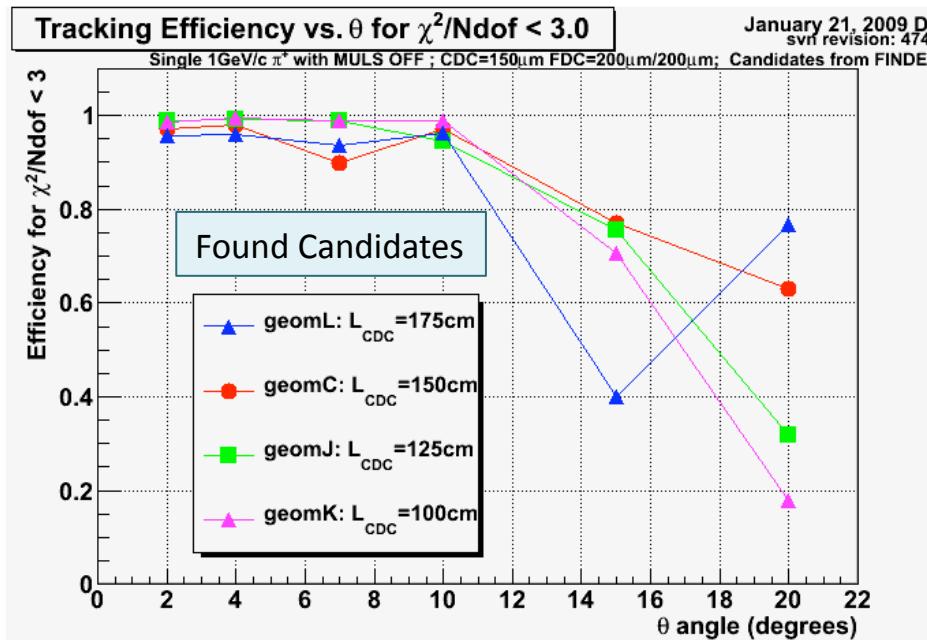
A single wire hit has only a little influence on the fit which leads to a higher rate of incorrect LR choices from the wire-based fit.



This problem showed up at  $7^\circ$  for the baseline geometry with 150 cm long CDC straws.

A similar problem shows up at  $15^\circ$  for a geometry with 175 cm long straws where there is a single hit in the 2<sup>nd</sup> FDC package.

# Efficiency vs. angle



Some of the inefficiencies are due to poorly defined track candidates which don't capture all of the hits from the true track.

Some are due to locking in a poor LR choice after wire-based fitting.

Inefficiency at higher angles and shorter CDC length attributed to CDC-FDC gap.

# Summary

- Monte Carlo simulations resulted in a decision to fix the CDC design at:
  - 28 layers,  $\phi$ -shifted where possible
  - Configuration: 4ax,4st-,4st+,4ax,4st-,4st+,4ax
  - Close-packed stereo and axial layers
  - $6^\circ$  stereo angle
  - 150 cm straw length
- Some problems were (re)identified in the ALT1 tracker:
  - No mechanism to try alternate L-R solutions
  - Target constraint sometimes constrained to places true track did not cross (*disabled now*).