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TOF Alignment Studies (Note 7693 draft)

- Motivation
- COT tracking resolution
- Hit bar model
- Alignment fits
- Consistency checks
- Time dependence
- Impact on reconstruction
- Minimal path length analysis
- Conclusions

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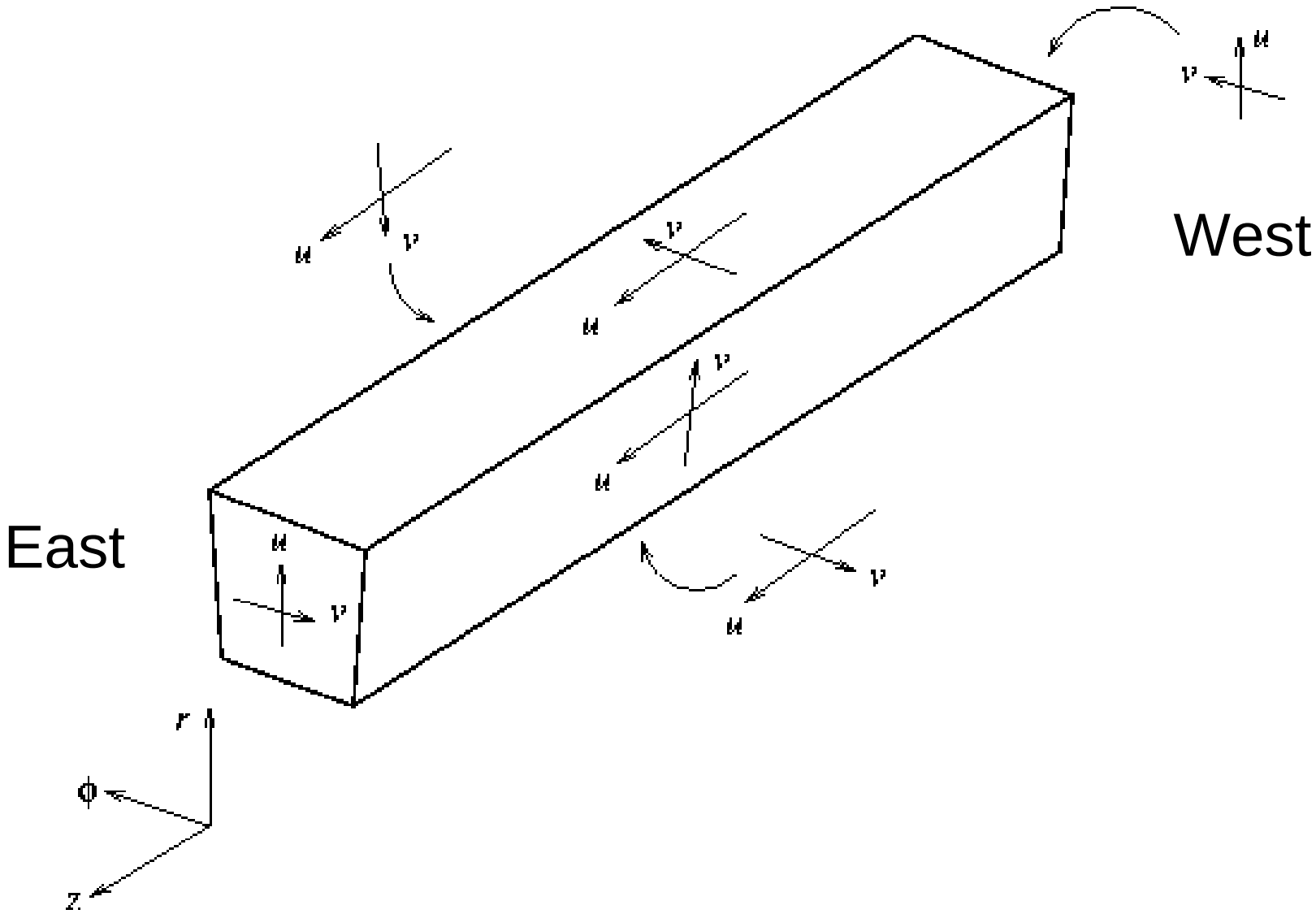
Motivation

- Suspect that an excellent alignment is needed to implement next phase of calibration models:
  - Local variation in light collection efficiency.
  - Need to know entrance and exit points with a precision of order a few millimeters.
- Another possible source of bias, particularly for low momentum protons.
- Although the alignment seemed okay, we never quantified its precision.

COT Tracking Resolution

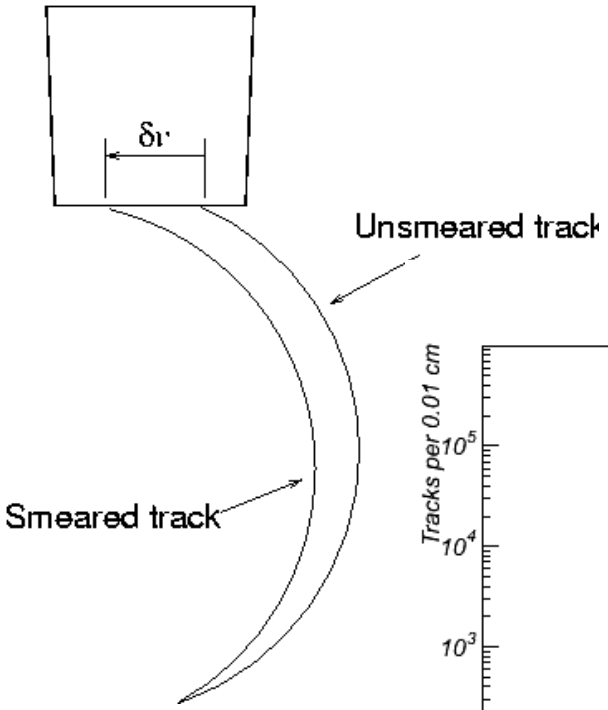
- How accurately can the COT point a track into the TOF system?
  - χ^2/dof for COT tracks is not unreasonable
  - Covariance matrix probably reliable
  - Multiple scattering in outer can of COT
- How resolutions are estimated:
  - Extrapolate original COT track to TOF
  - Smear track parameters and extrapolate
  - Compare smeared/unsmeared quantities

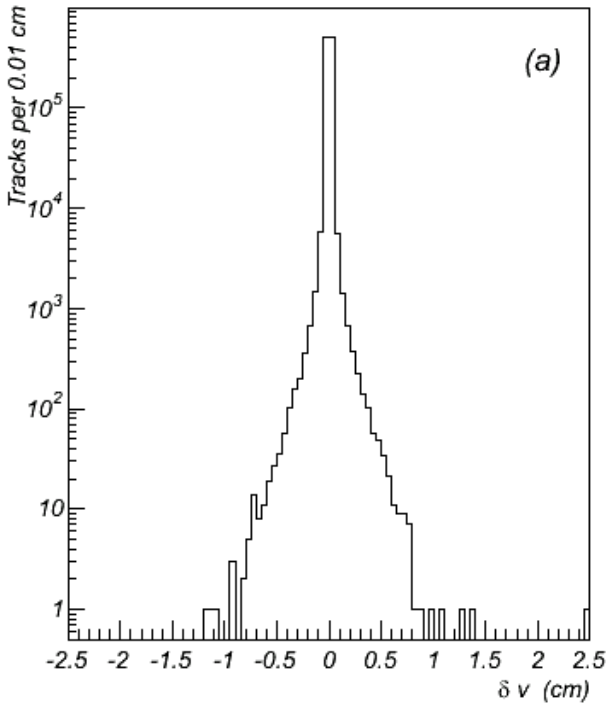
Local TOF Coordinate System

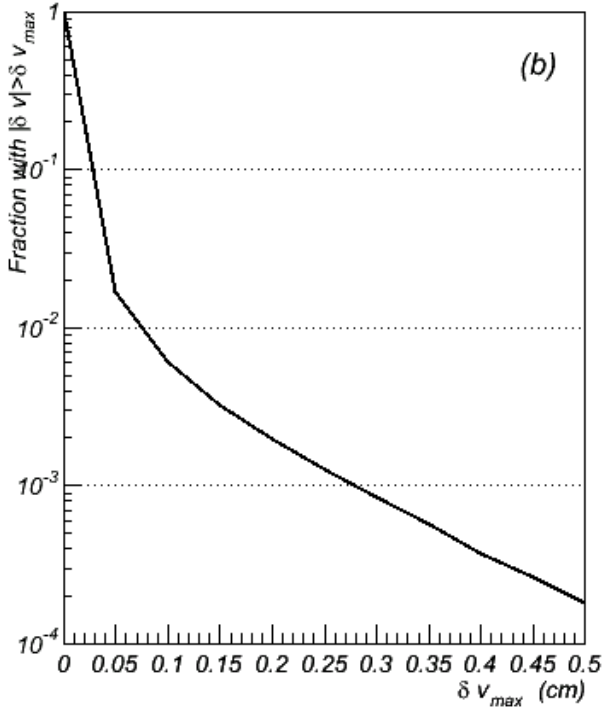


Resolution in transverse plane

RMS = 0.02 cm (all tracks)

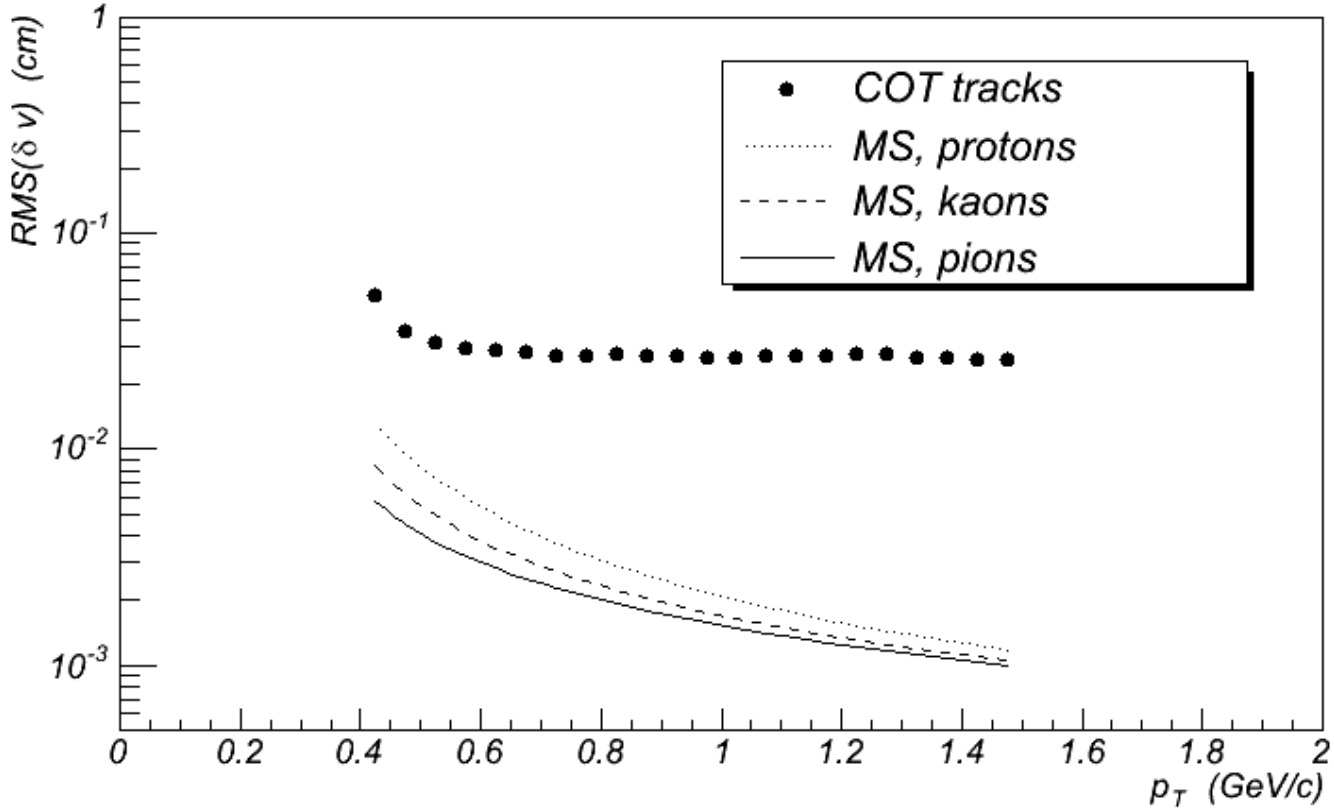






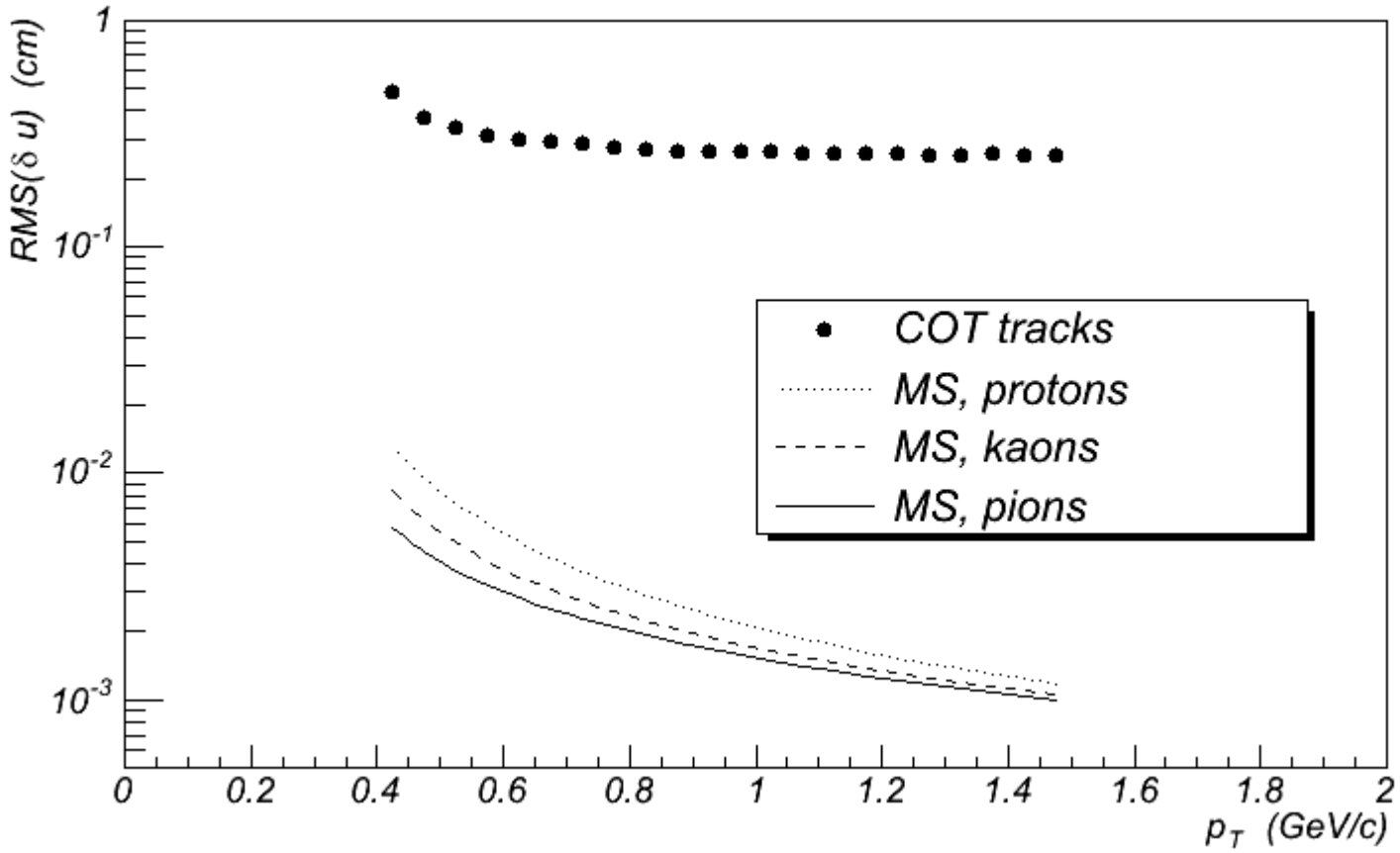
Resolution in Transverse Plane

- Resolution is somewhat dependent on p_T.
- Multiple scattering effects are small.



Resolution in *r-z* plane

- Typically of order 0.5 cm:



Hit Bar Model

- Things that can trigger the discriminator:
  - A track that goes through the bar and produces sufficient light
  - Another track that goes through the bar
- Things that do not trigger the discriminator:
  - A track that misses the bar
  - A track that does not produce enough light
  - A “fake” track

Hit Bar Model

- Probability that no hit is found:

$$\mathcal{P}_{\mathsf{hit}}(\vec{p},\vec{q}) = \mathcal{P}_{\mathsf{rnd}}\mathcal{P}_{\mathsf{fake}} + (1-\mathcal{P}_{\mathsf{fake}})(\mathcal{P}_{\mathsf{rnd}}+\mathcal{P}_{\mathsf{trk}}-\mathcal{P}_{\mathsf{rnd}}\mathcal{P}_{\mathsf{trk}})$$

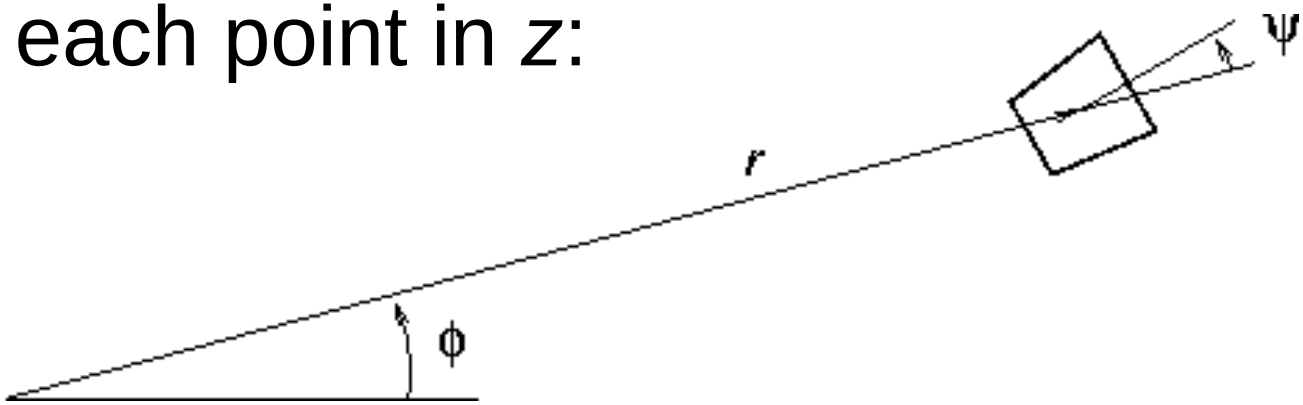
Track parameters

Alignment parameters

- Likelihood function constructed from these probabilities and the observed hits or absence thereof.

Alignment Parameters

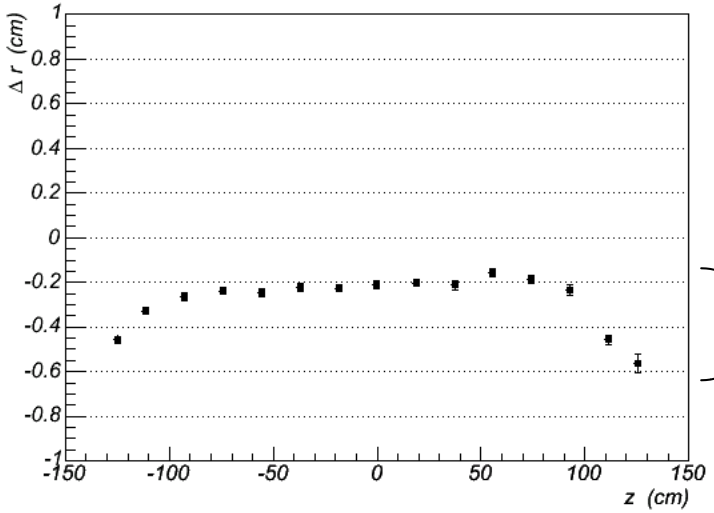
- Define position and orientation of bars at each point in *z*:



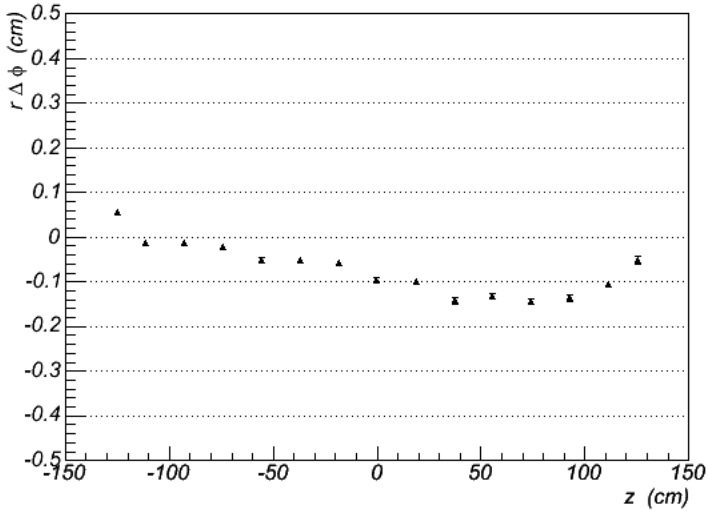
- Measure deviations from previously assumed positions ("ALIGNED" model):

$$
\begin{aligned}
r(z) &= r_0 + \Delta r(z) \\
\phi(z) &= \phi_0 + (r\Delta\phi)(z)/r_0 \\
\psi(z) &= \psi_0 + \Delta\psi(z)
\end{aligned}
$$

Typical Example (Bar 0)

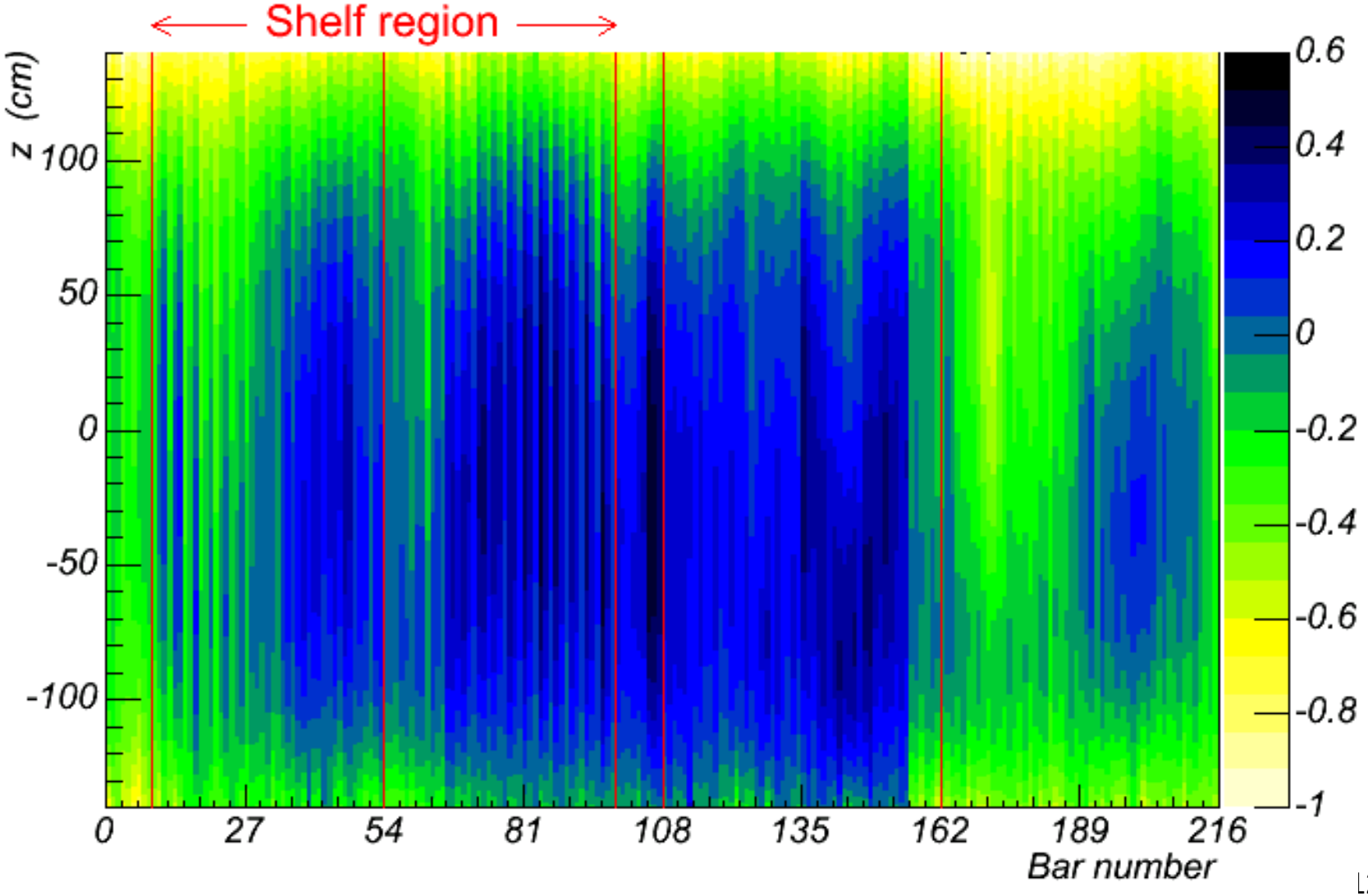


$\Delta r(z)$ varies by 4 mm

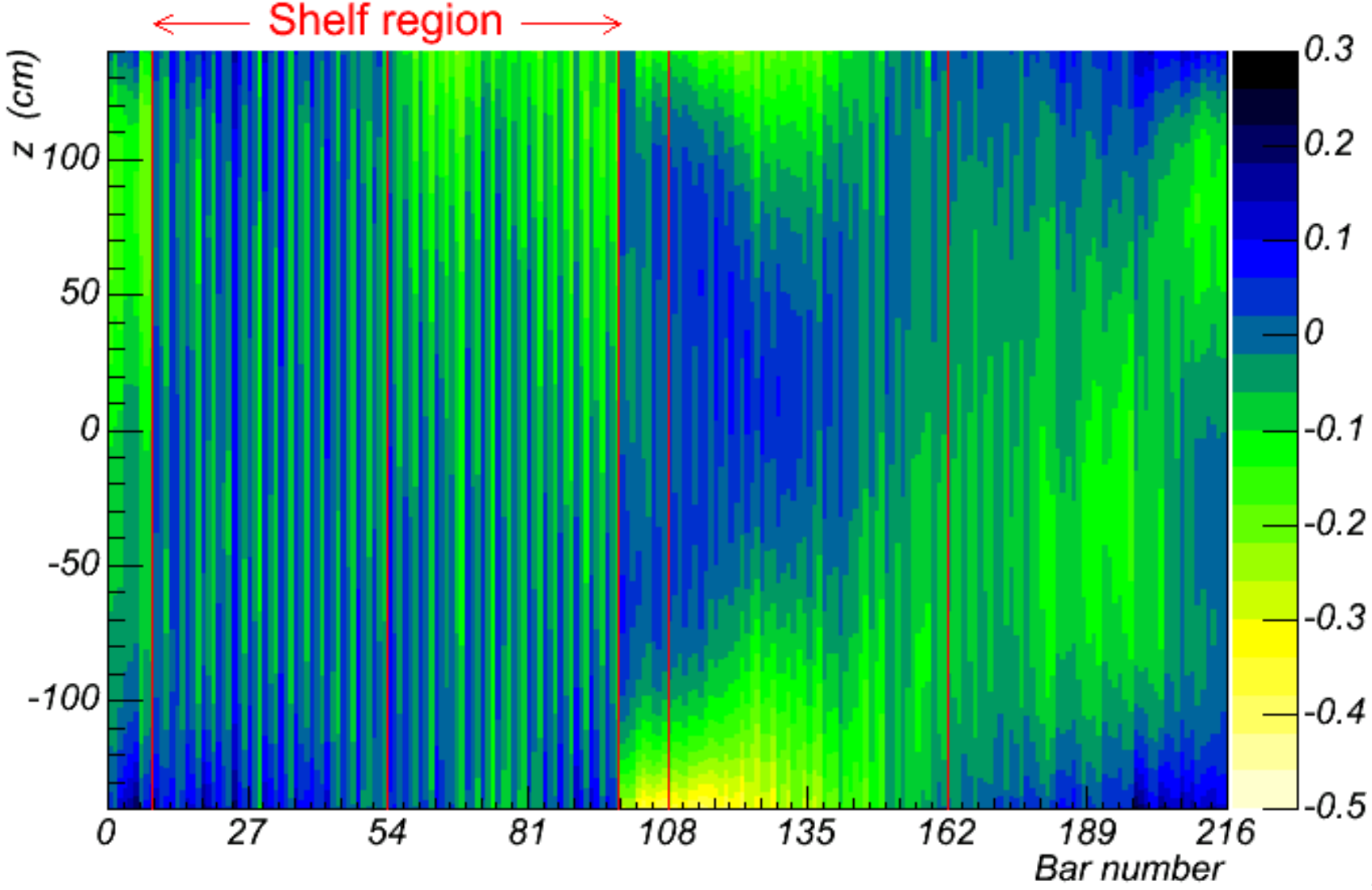


$(r\Delta\phi)(z)$ varies by 2 mm

Radial Misalignment



Azimuthal Misalignment

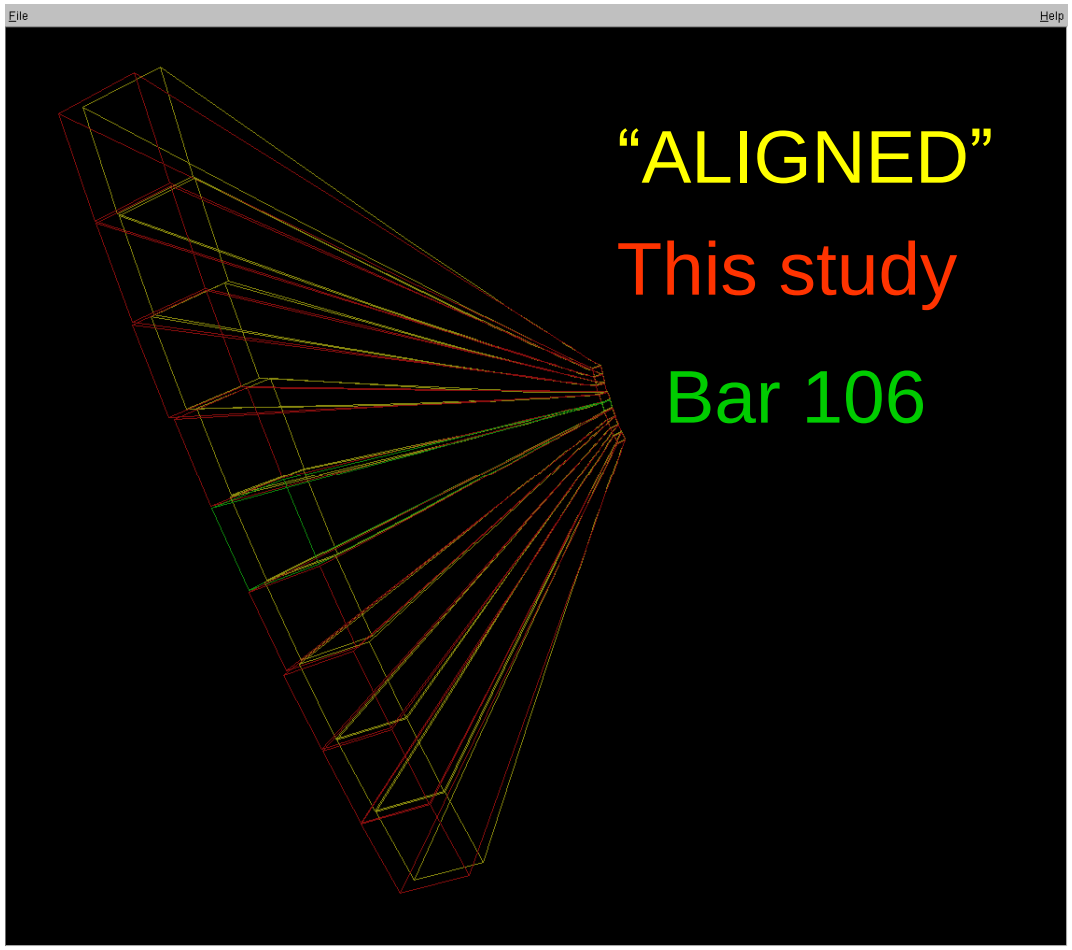


Consistency Checks

- Toy Monte Carlo gives sensible pull distributions for alignment parameters
- Deviations from assumed positions follow pattern expected from 3-packs
- Bars typically sag down but are supported in the middle
- More azimuthal uniformity in shelf region
- Forces needed to deform bars in this way are believable (of order a few pounds)

Visualization

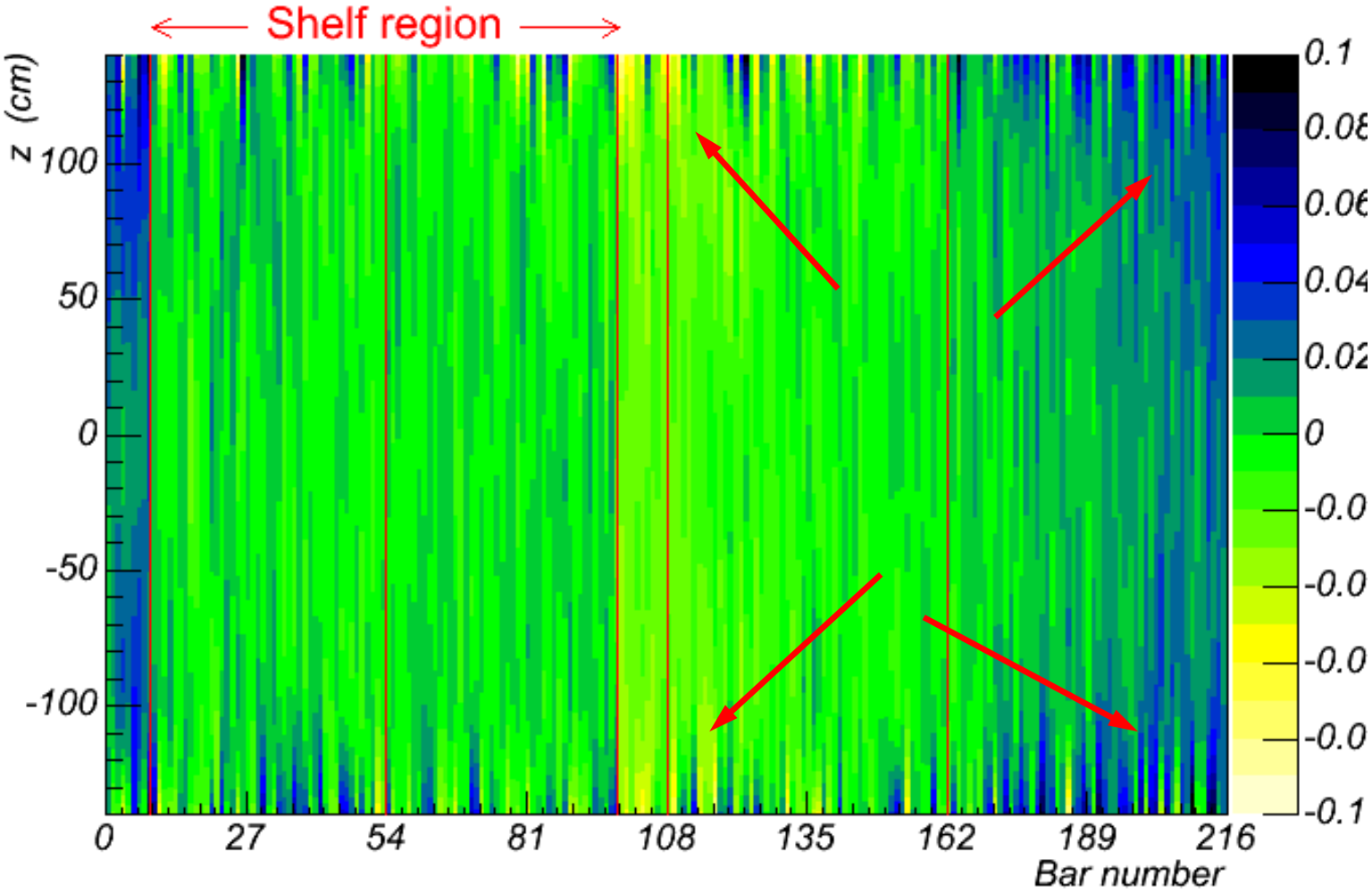
- Typical view of east end:



Visualization

Time Dependence

- Evidence of about 1 mm of sag in 2002:



Impact on Reconstruction

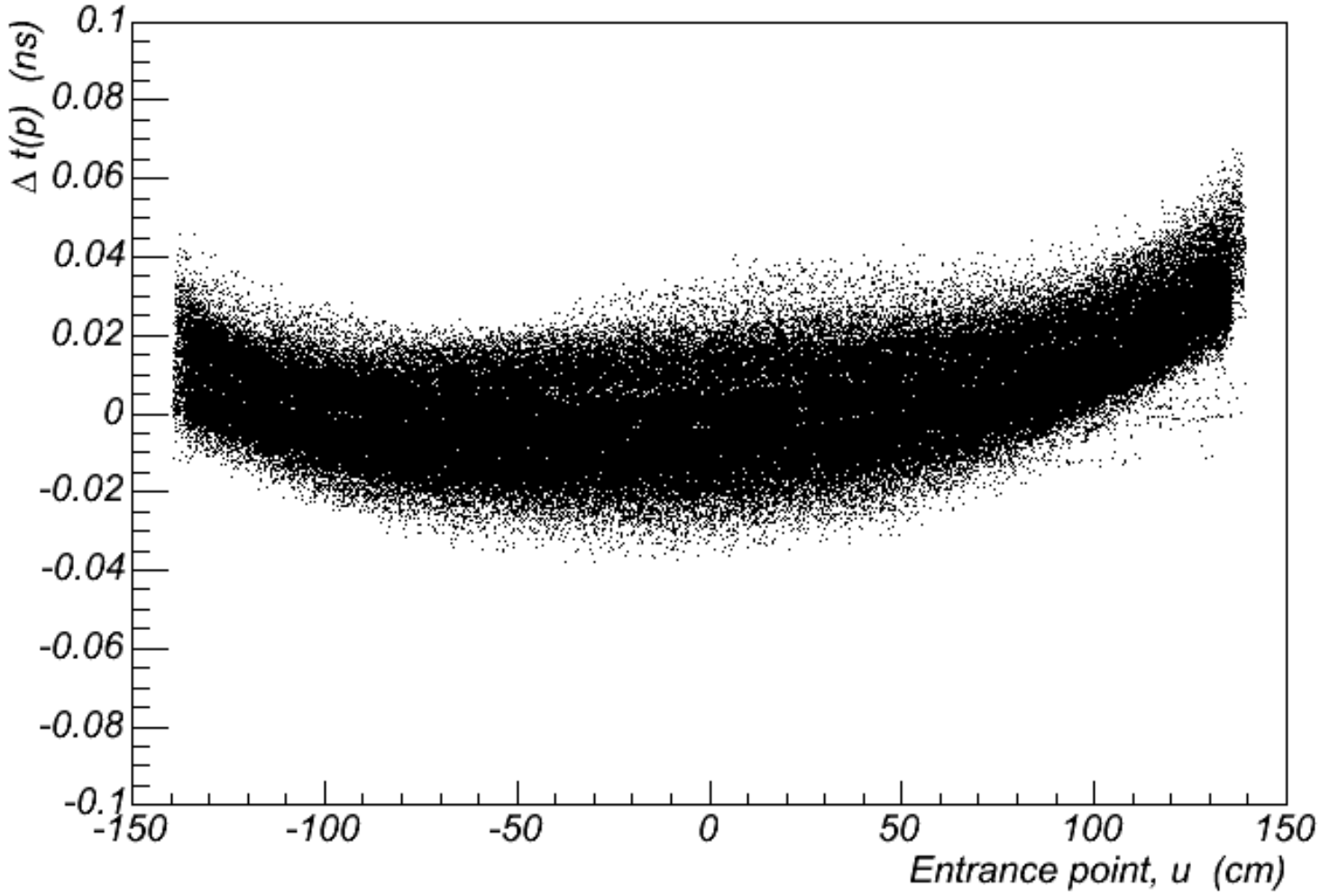
- Extrapolation efficiency improved by few %
- *Assume* that the calibrations absorb all radial misalignment for pions:
  - Requires at least 4th order *z*-dependence
  - Different from bar to bar
- Biases only remain for other particles:

$$\Delta t(m) = \frac{\hat{s} - s}{c}\left(\sqrt{1+\cot^2\theta + m^2/p_T^2} - \sqrt{1+\cot^2\theta + m_\pi^2/p_T^2}\right)$$

- Maybe 50 ps effect for slow protons

Impact on Reconstruction

- Protons with $0.4 < p_T < 0.5$ GeV/c:

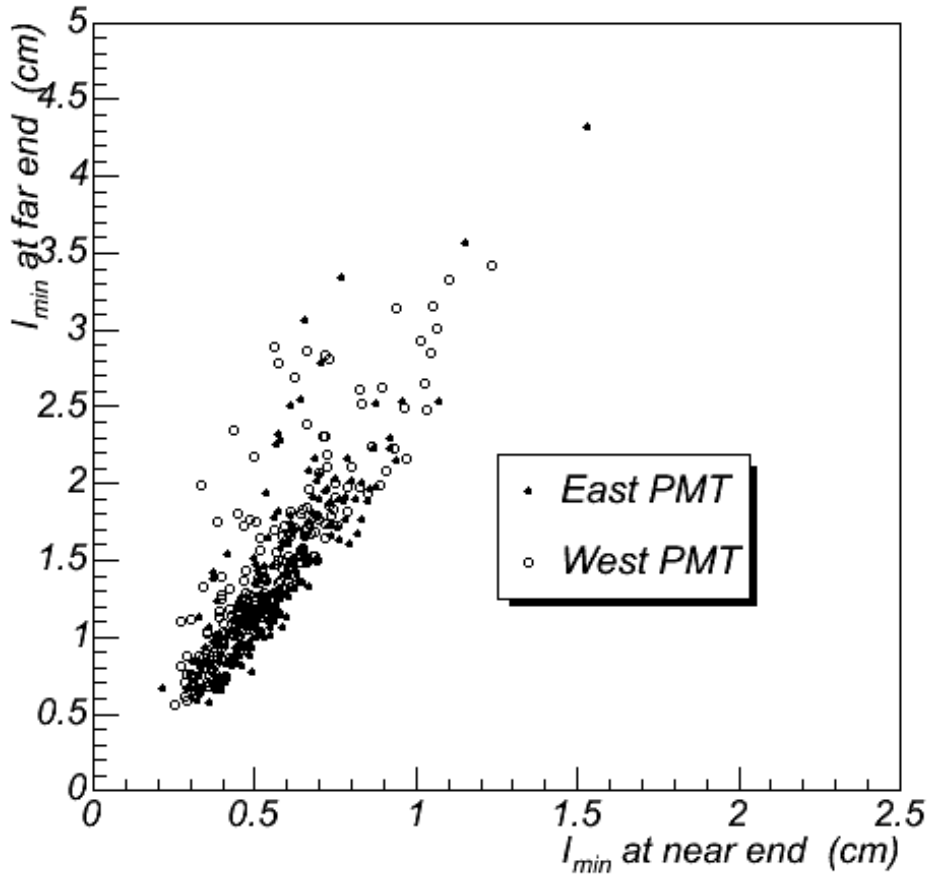


Minimal Path Length

- The fit determines the minimal path length in the scintillator required to trigger the discriminator:

- Could be used to improve matching performance.

- Could provide a more realistic treatment in the Monte Carlo.



Conclusions

- Better understanding of the precision of the alignment
- Probably good enough for calibration models that account for track propagation through scintillator
- Significant deviations in radial positions compared with “ALIGNED” geometry
- Biggest impact on slow protons