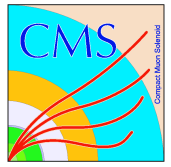

Summary of Current Knowledge of Global Track-based Alignment

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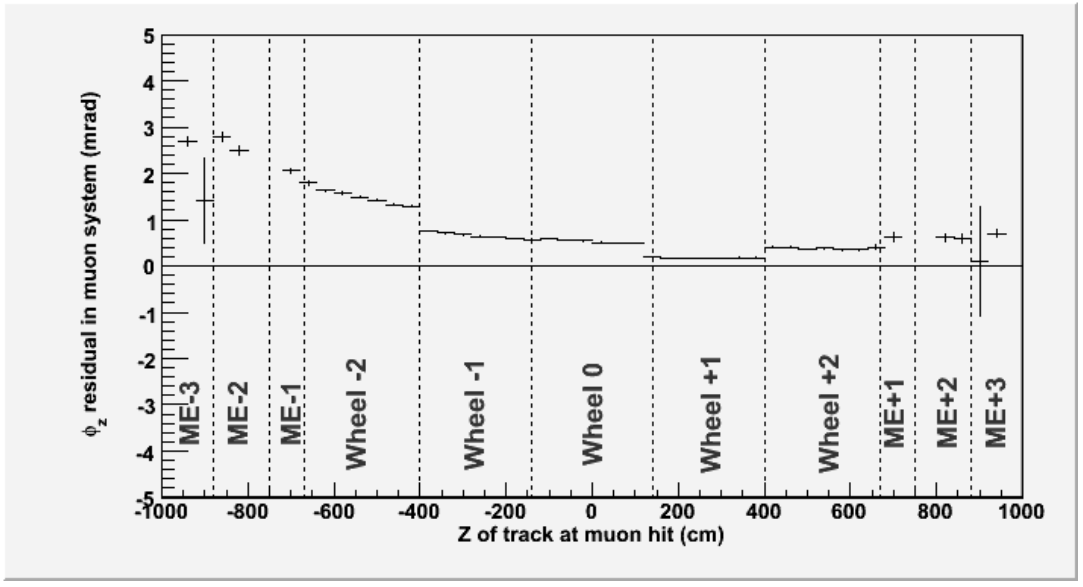
Understanding old plots

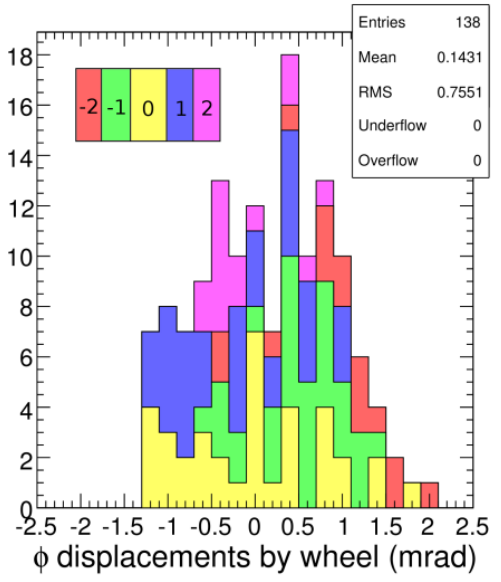
- A lot has been learned since the first CRAFT globalMuons
- Now would be a good time to summarize the results, as they're currently understood
  - No rotation/twist with respect to the tracker
  - Magnetic field errors $\lesssim$ statistical with two-bin approach
  - Progress in understanding the "sawtooth effect" (new)
  - "Deterioration" of globalMuons in cosmic splitting resolved (new)
  - Residuals distributions of hits that pull the fit
  - Incompleteness of the current alignment
  - Access to all 6 parameters with non-Gaussian fits (new)
  - Alignment software updates (new)
  - A comment about HIP and MillePede approaches

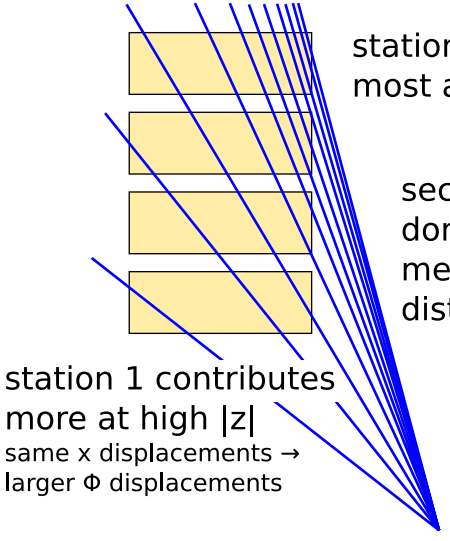
No significant rotation or twist

Residuals merged across stations and sectors (Nov '08)



chamber alignments (Feb '09)





station 4 contributes most at low |z|

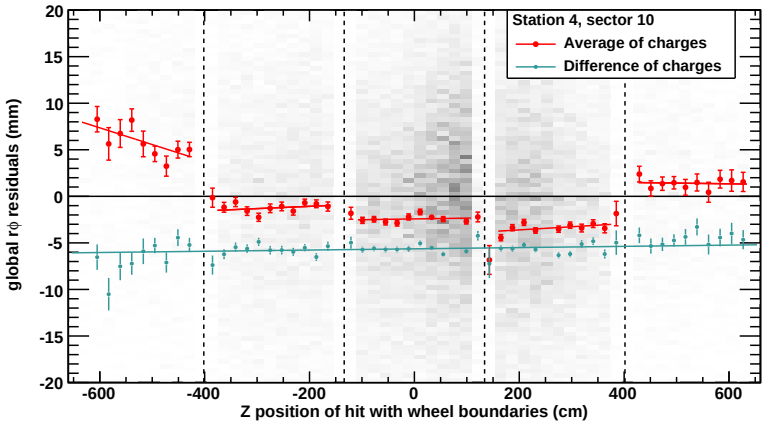
sectors 4 and 10 dominate the merged residual distribution

station 1 contributes more at high |z|
same x displacements → larger Φ displacements

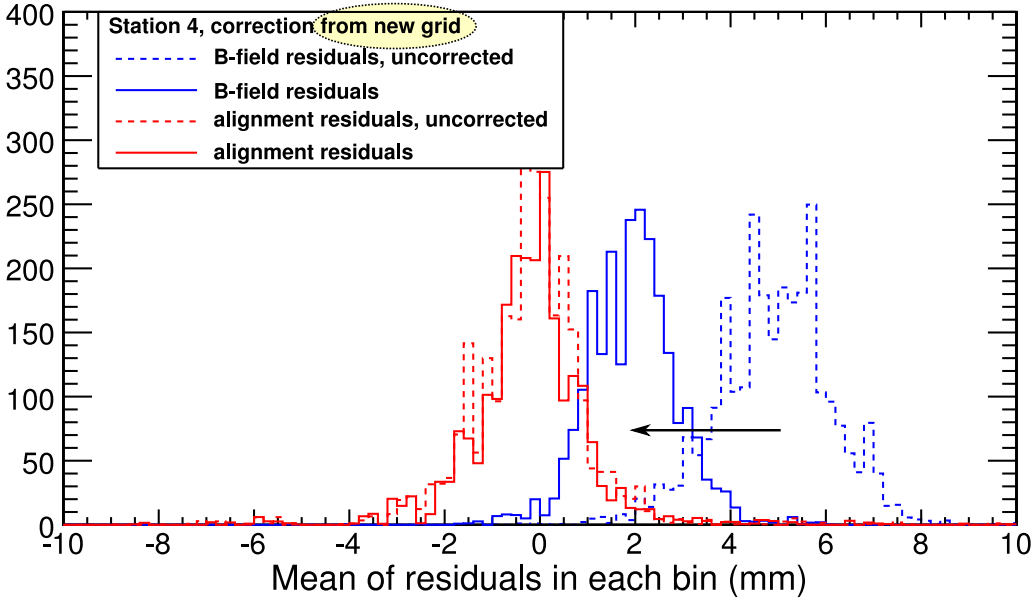
- Tracker alignment changed between Nov and Feb, but not enough to explain difference
- Failing to separate residuals by chamber allows a few chambers to dominate wheel-by-wheel averages because of steep ϕ, θ cosmic ray distributions
- 16/50 chambers in wheel -2 have an average ϕ displacement of 0.7 mrad, spread of 0.5
- Chamber-by-chamber alignment is important!

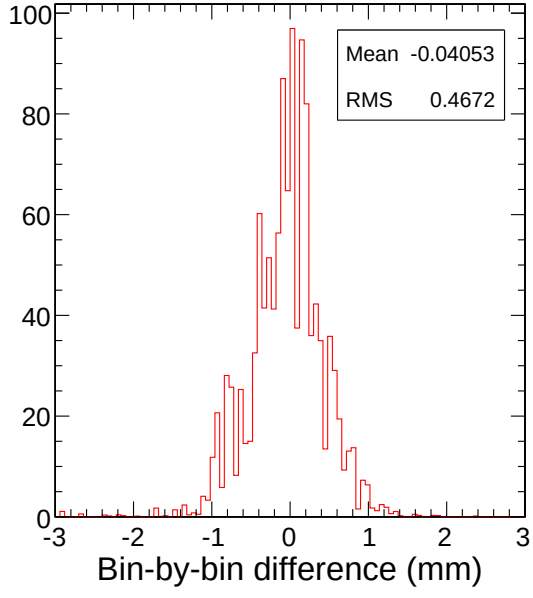
$\vec{B}(\vec{x})$ is well controlled

"Alignment map" with $\vec{B}$ error tracer in blue



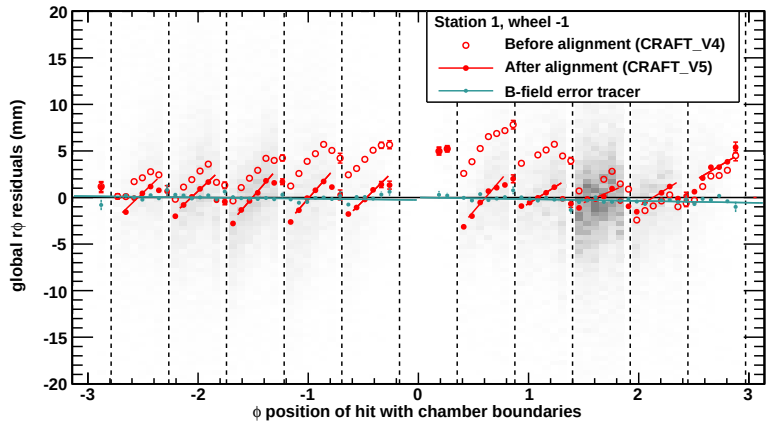
- Below: re-create the "alignment map" plots with new $\vec{B}(\vec{x})$ simulation
  - Red points show insensitivity of alignment to $\vec{B}(\vec{x})$
  - Blue test correctness of new $\vec{B}(\vec{x})$
  - $\vec{B}(\vec{x})$ differs by up to 30%
- Bottom-right: how each alignment bin changes (statistical errors are ∼0.5 mm)



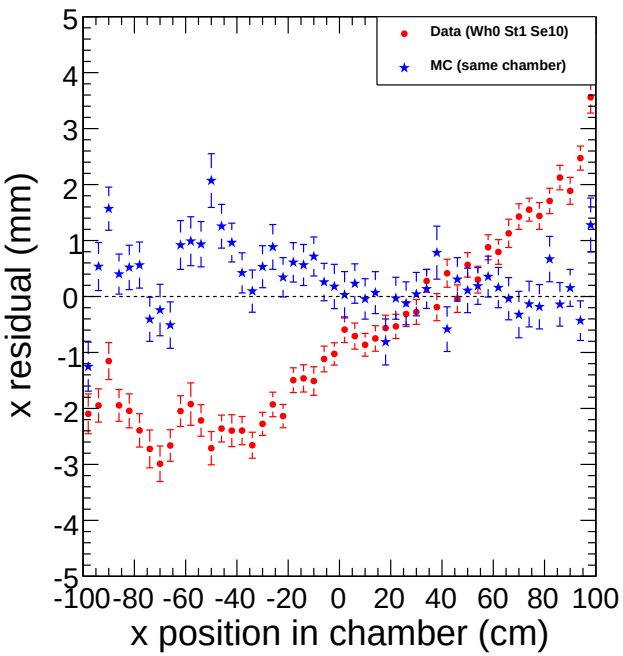


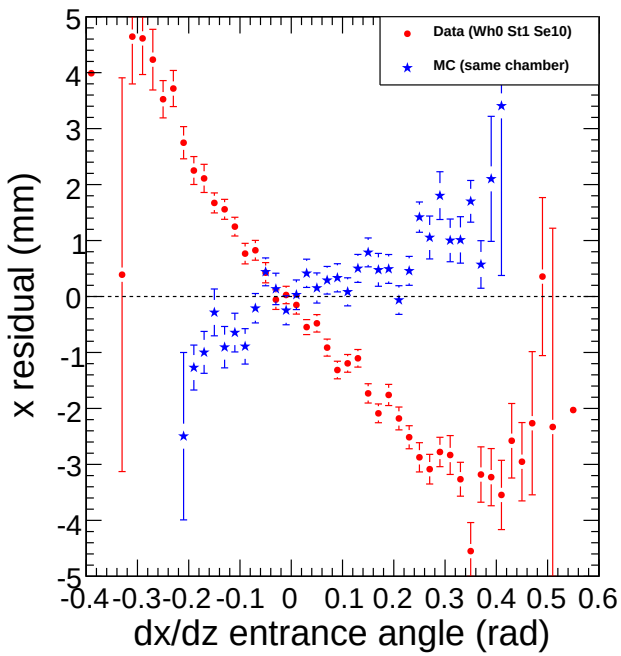
Sawtooth effect (1/2)

- Alignment plots revealed $r\phi$ residual vs. ϕ structure inside chambers (right)
- Entrance angle is correlated with ϕ_{global} (i.e. x) and more relevant for chambers; correlation in data is stronger (below)
- Collisions MC doesn't show the effect (shows a radial displacement instead: confirmed in orthogonal residuals, a separate problem involving the propagator?)



Focus on just one chamber (wheel 0, station 1, sector 10), $p_T > 40$ GeV

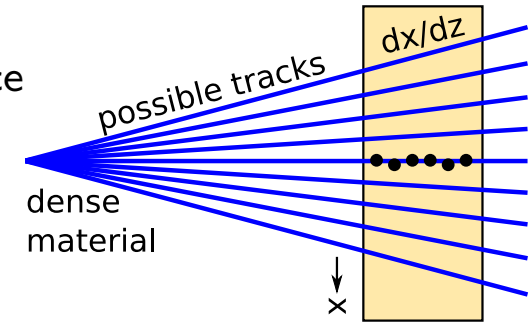




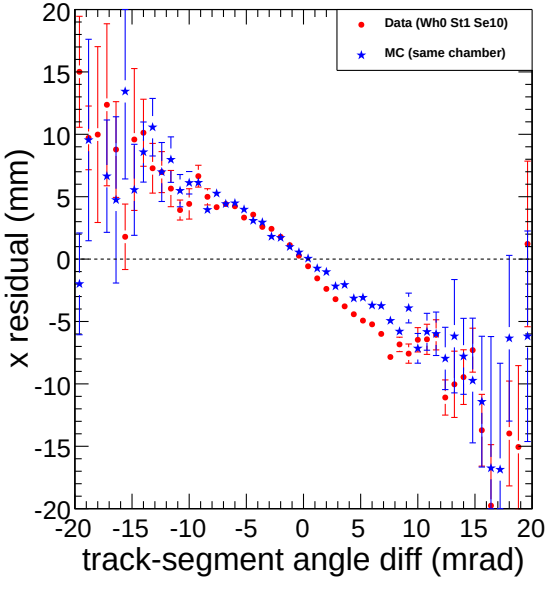
data include latest $\vec{B}(\vec{x})$ map and superlayer radial corrections

Sawtooth effect (2/2)

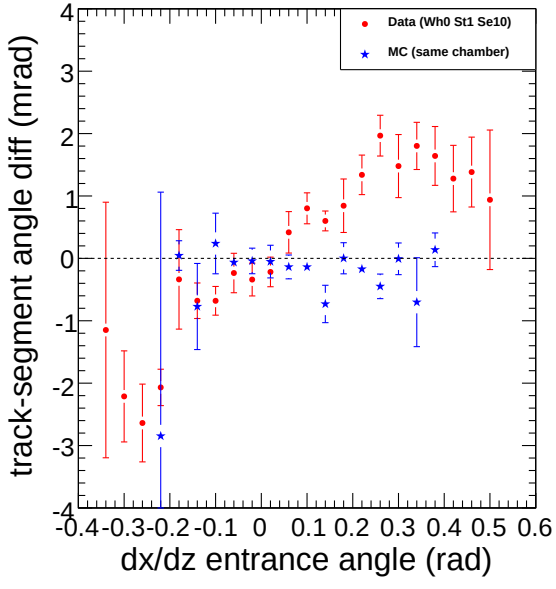
- Seems to derive from an understandable effect: x residuals *should* be correlated with track-segment angle difference
- But an unexplained correlation between the angle difference and the angle links x residuals to angle (sawtooth effect)
- Second correlation is not understood and not in MC, independent of q and p_T (unrelated to $\vec{B}$ and dE/dx)
- Also, same effect in y residuals vs. dx/dz angle!
- Ugo, Pablo, Alicia, and Paolo have started investigating with segments and tracks



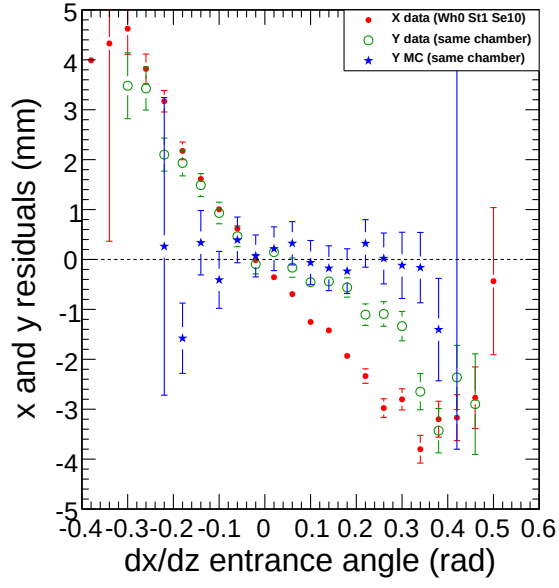
this makes sense



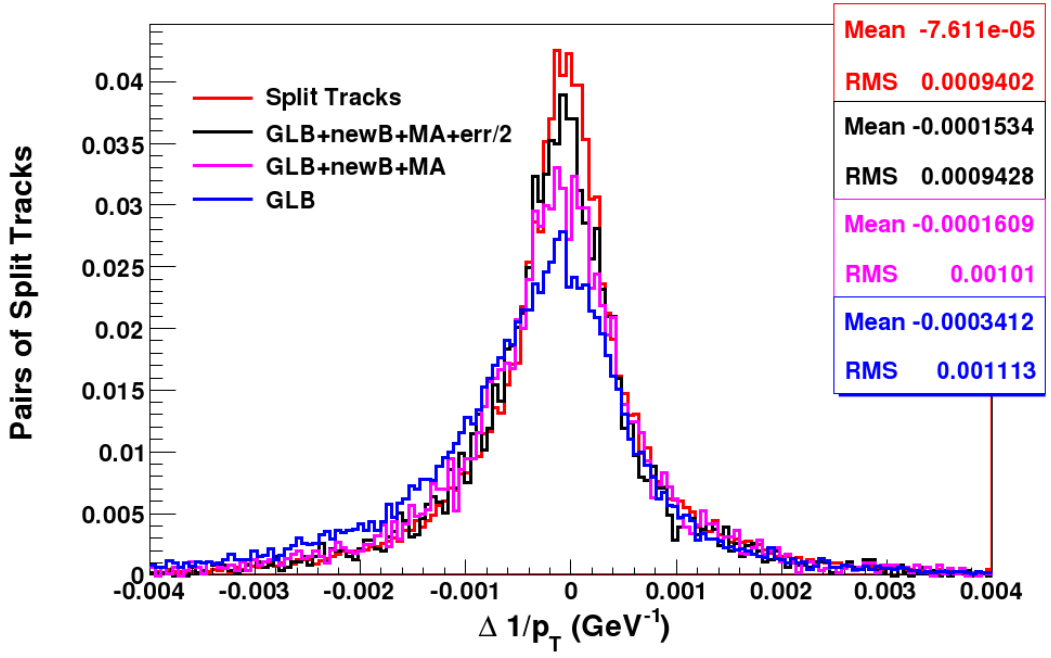
why is this correlated in data?

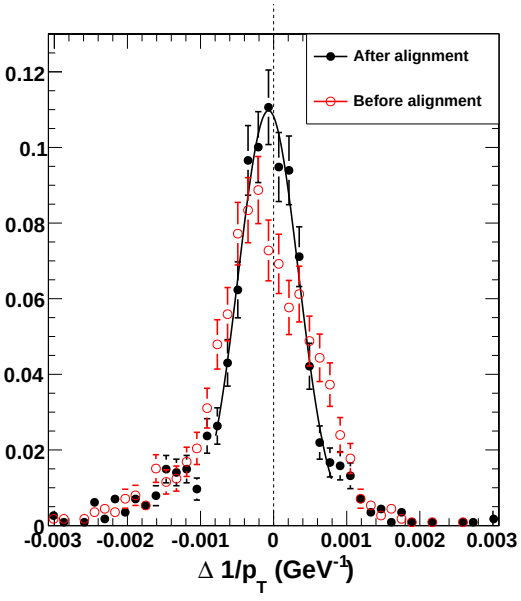


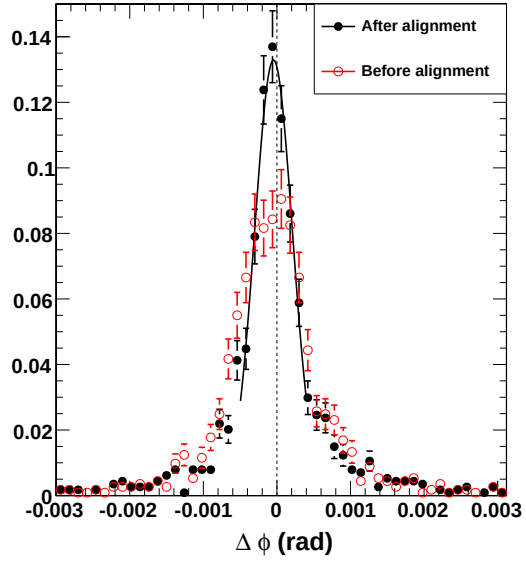
and why do we see same effect on other parameter?



Split globalMuon cosmics

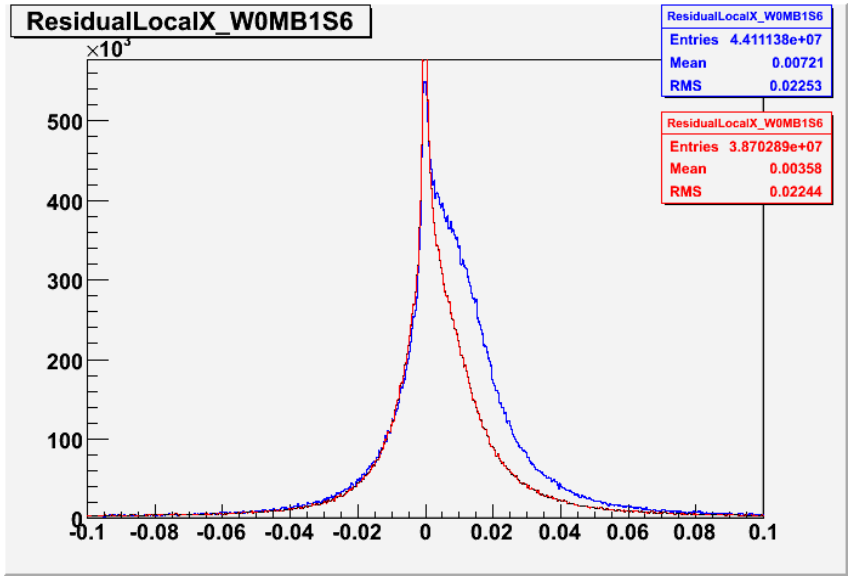


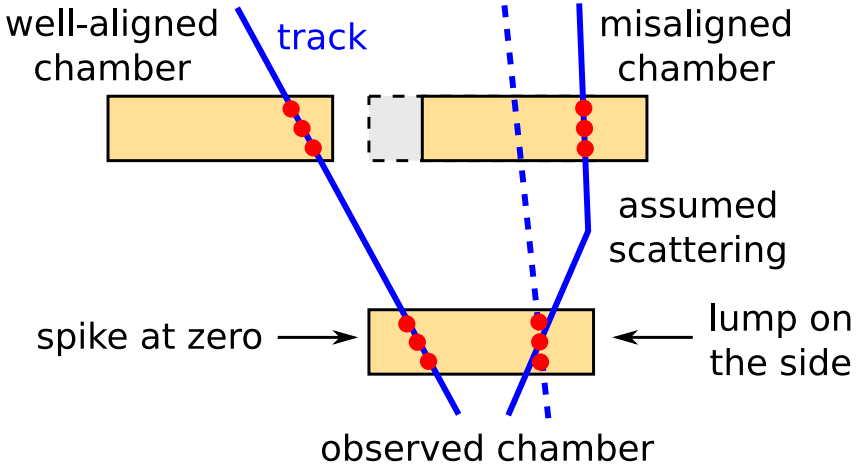




- Deterioration of globalMuons (GLB) relative to tracker only (Split Tracks) due to three factors:
  - muon alignment
  - wrong $\vec{B}(\vec{x})$
  - overestimated tracker alignment errors
- New globalMuons (black) almost reproduces tracker, as it's supposed to (MC is at this level of agreement)
- Bottom two plots highlight the muon alignment part
  - $p_T > 100$ GeV
  - stations 1&2 only
  - muon alignment is the only change shown

Residuals from hits in the fit

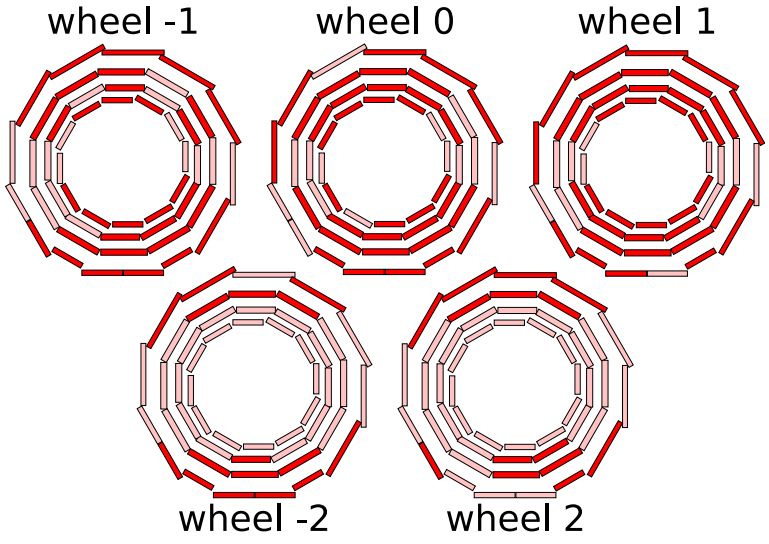




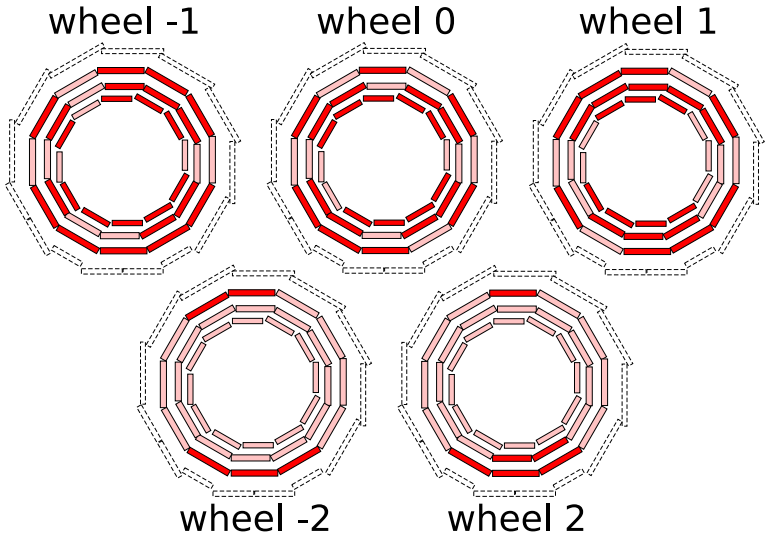
- Muon residuals for hits included in the track-fit are complicated:
  - non-Gaussian spike at zero from tracks biased toward hits
  - lump on the side from nearby misaligned chambers: segment is inconsistent with assumed scattering direction
  - long tails due to real scattering
- Mean and RMS do not characterize misalignment of observed chamber
  - side-lumps related to other misalignments in neighborhood
  - definition of "neighborhood" depends strongly on distribution of tracks (e.g. cosmics vs. LHC)
  - long tails hide lumps from RMS: 0.0224 vs. 0.0225 above
  - mean can be obscured by two lumps on either side

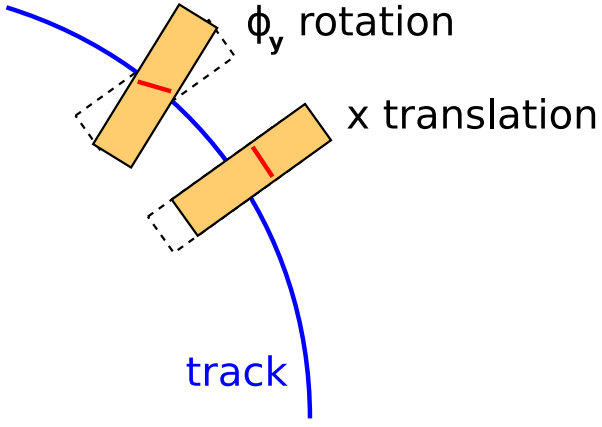
Current alignment incompleteness

Chambers aligned in x and ϕ_z



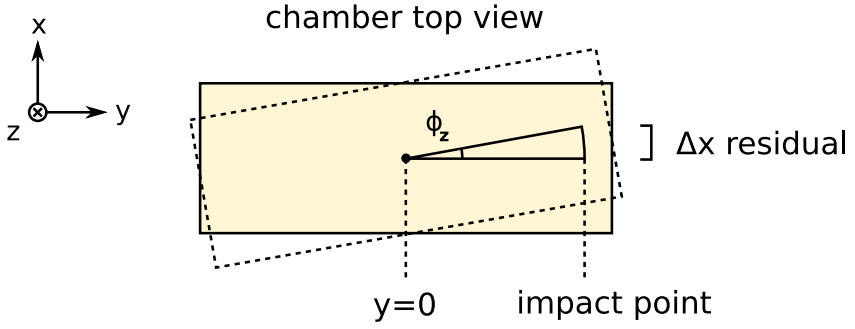
Chambers aligned in y (along beamline)

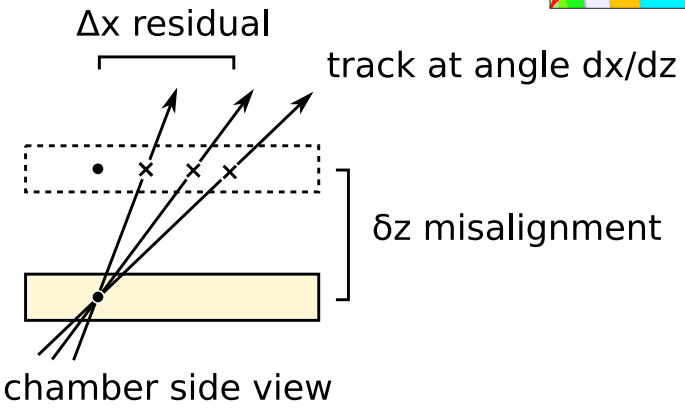




- Only chambers accessible to globalMuons aligned
  - many or most standAloneMuons cross both aligned and unaligned chambers
  - *shouldn't expect* improvement in standAloneMuons without controlling set of tracks and direction of fitting
- Only three parameters: x, ϕ_z, y
  - ϕ_y angle is also important for measuring curvature (charge ratio analysis)

All 6 parameters from fits



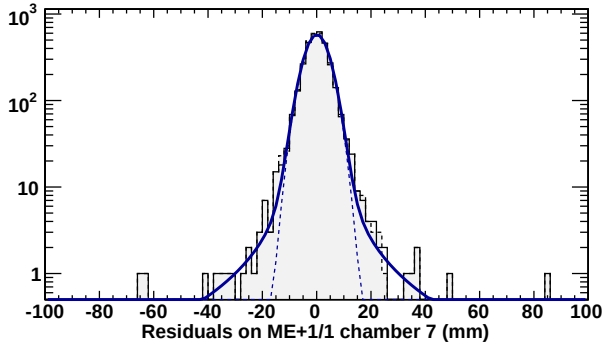


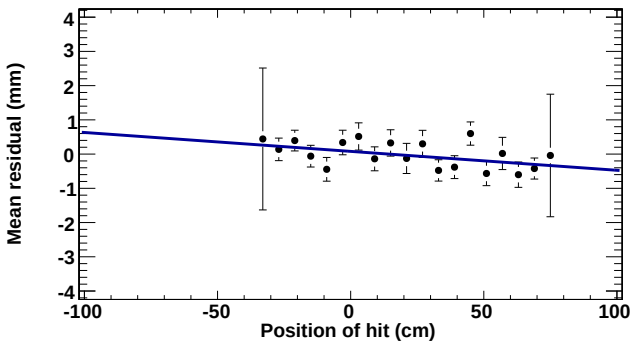
Four fits per chamber ($\times 2$ for two-bin $\vec{B}(\vec{x})$ and dE/dx control)

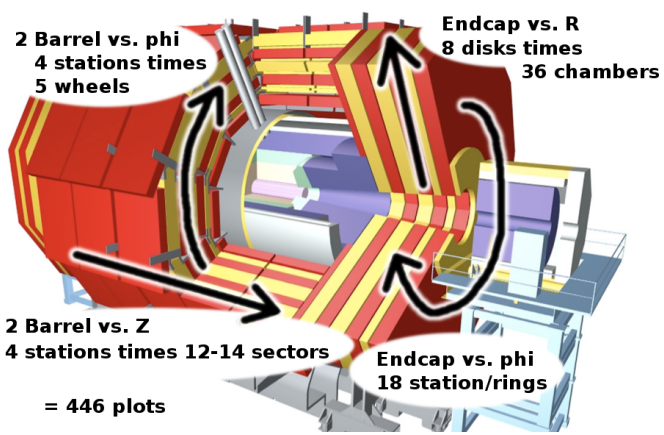
Superlayer 1&3 position residual		Superlayer 1&3 angular residual	
x	central value		
ϕ_z	slope w.r.t. y position	ϕ_y	central value
z	slope w.r.t. $\frac{dx}{dz}$ angle		
sawtooth	slope w.r.t. angular residual		

Superlayer 2 position residual		Superlayer 2 angular residual	
y	central value		
ϕ_z	slope w.r.t. x position	ϕ_x	central value
	(cross-check superlayer 1&3 ϕ_z)		

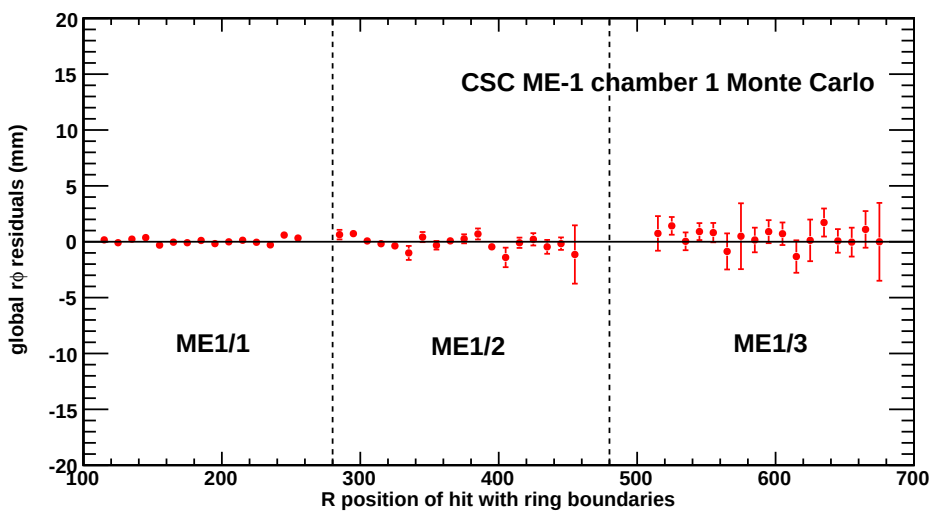
Alignment software updates







- MuonAlignmentFromReference now includes
  - multiparameter fits (example on left)
  - endcap chambers
- AlignmentMonitorMuonSystemMap
  - DT residuals vs. ϕ and z
  - CSC residuals vs. ϕ and R (below)
- Tests in high-statistics MC reveal some biases between propagator and GEANT
  - several mm in local z (related to sawtooth?)
  - several hundred μm in x in station 1 wheel ± 2 (where B_r is non-negligible)
  - related to J/ψ, K_s mass biases?



HIP and MillePede

- The difference between Standard HIP and Standard MillePede algorithms is how they handle the feedback between track-fitting and alignment adjustments

Standard HIP	Standard MillePede
alternate between track-fitting and alignment	solve combined problem as a large matrix

- There's no such distinction for procedures which align to an external reference
  - updating muon geometry doesn't affect tracker-only track fits
  - globalMuon-HIP and globalMuon-MillePede are the same algorithm
- Two implementations of the same algorithm isn't an independent cross-check
  - for the same reason that "residuals $\longrightarrow$ 0" isn't an independent cross-check
  - only verifies that two people didn't make different mistakes
  - presentation of intermediate plots and constructive criticism can catch mistakes with only one implementation
- Very local information (no propagation through iron) is independent of globalMuons
  - e.g. CSC Overlaps will severely check globalMuons approach in endcap
  - is something like a DT Overlaps possible? (constrain neighboring *sectors* in the same station?)