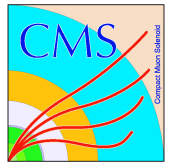

Relative alignment of tracker and muon system and track-based study of hardware results

Jim Pivarski

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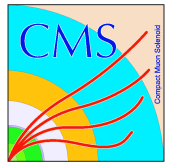
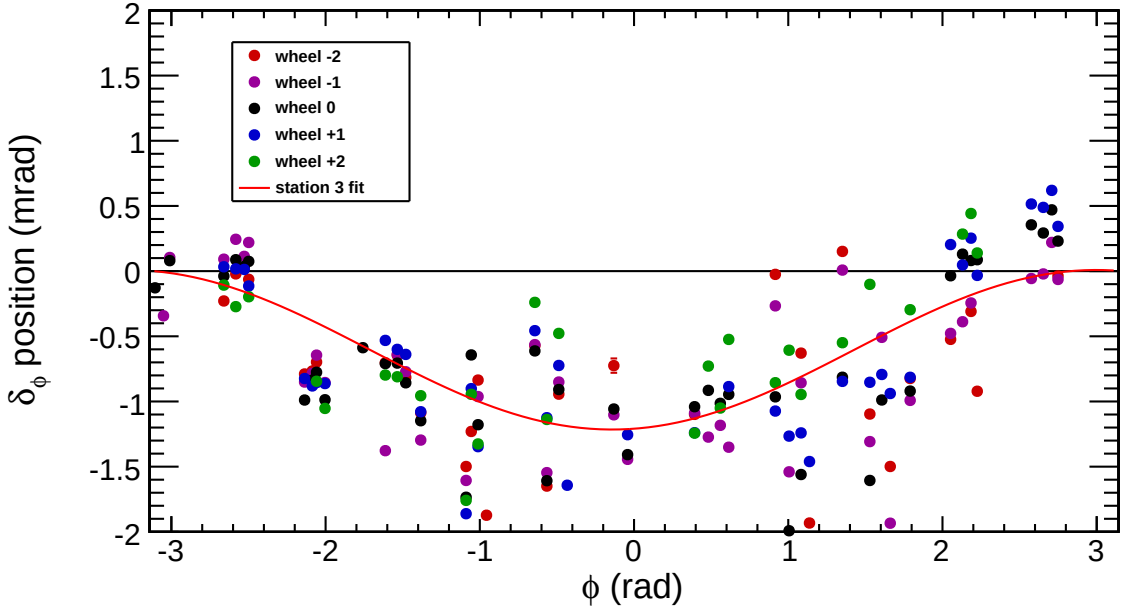
8 December, 2009

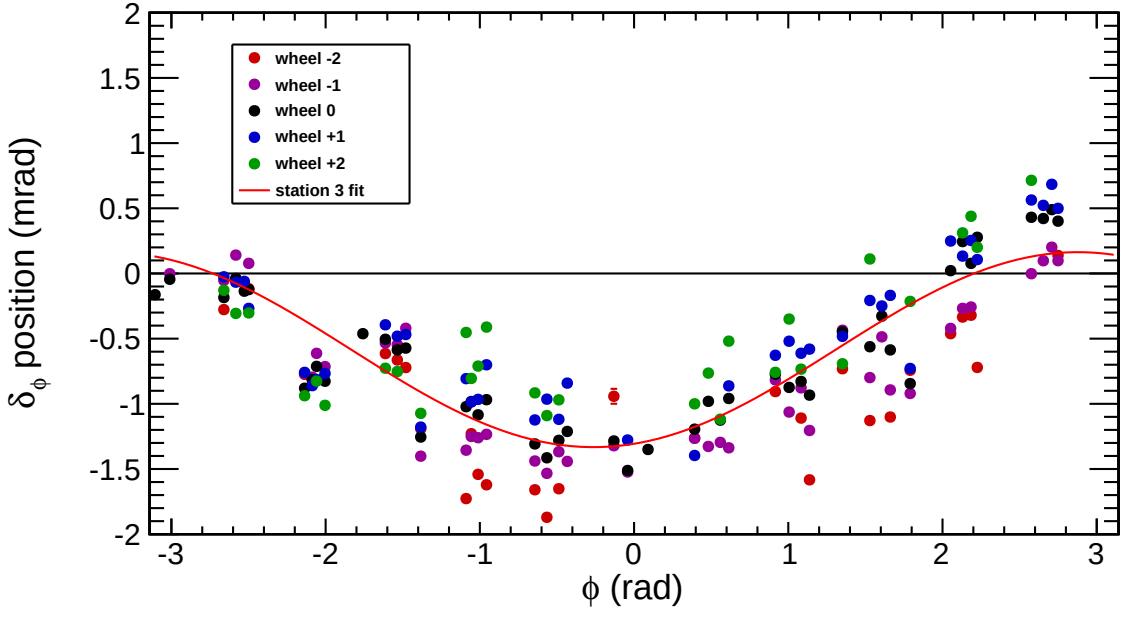
Outline



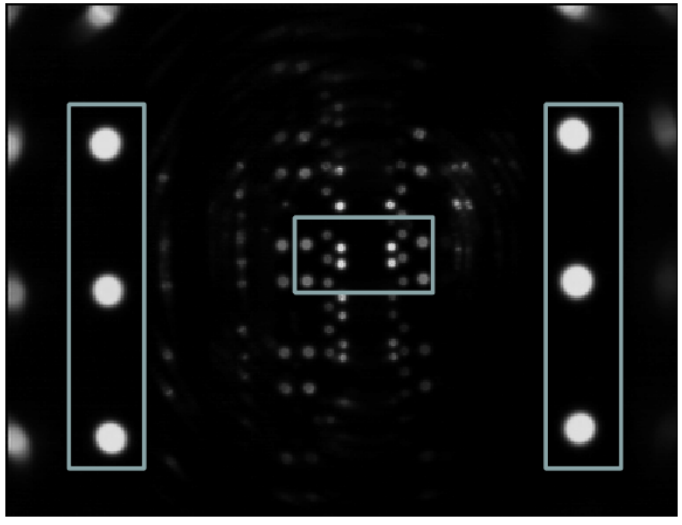
- Comparison of hardware geometry with track-based geometry
- Studies of tracker shape using muon residuals

Barrel hardware — track-based

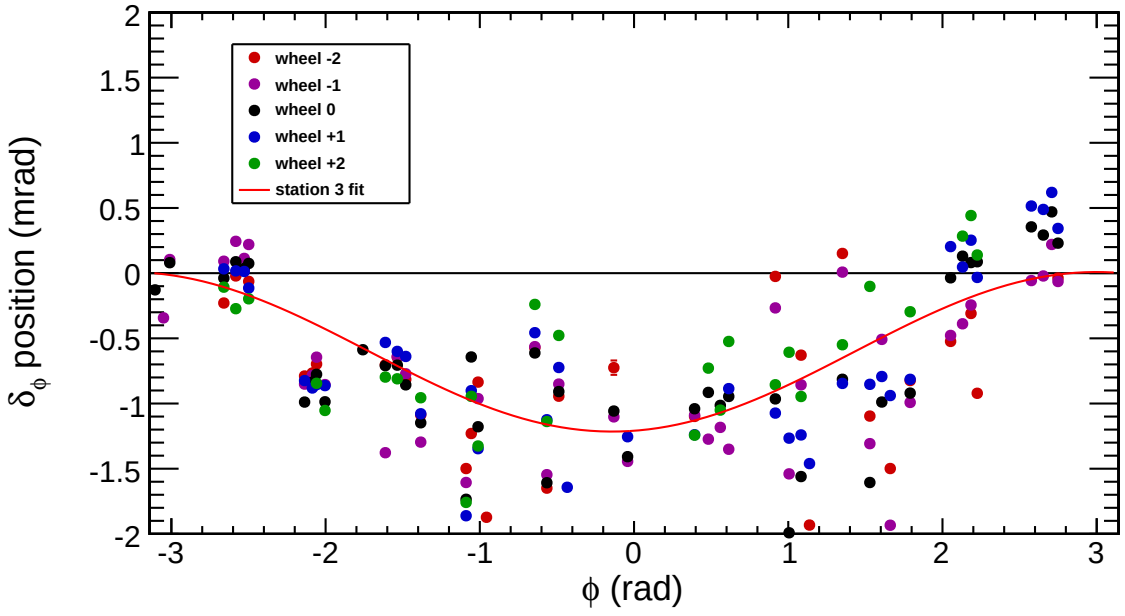


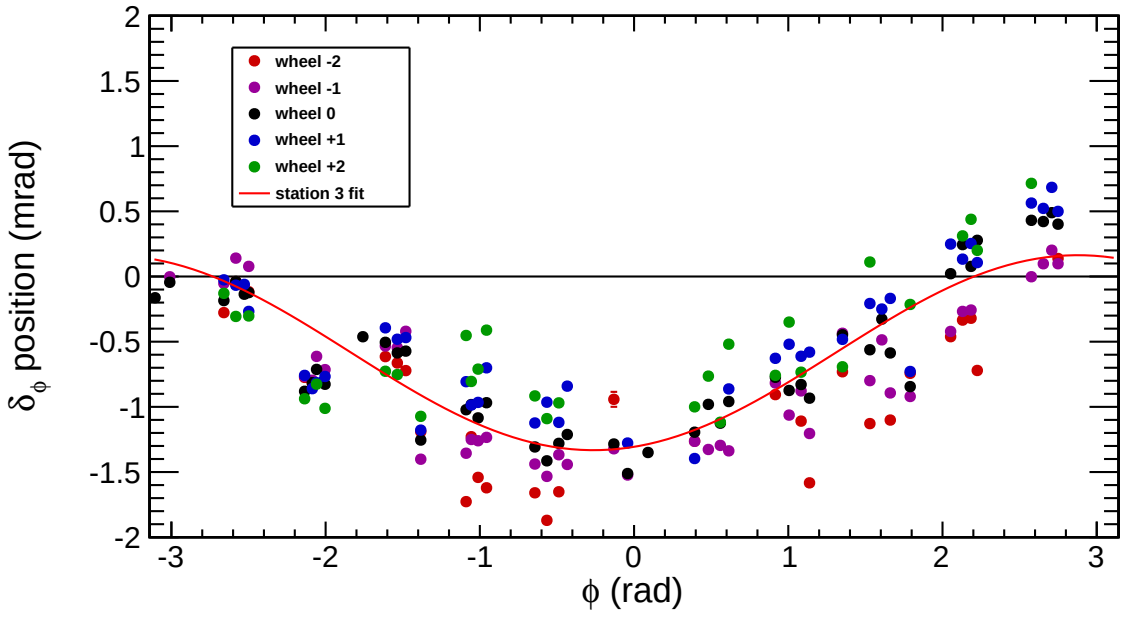


- Differences in chamber positions between hardware and track-based geometries
- Top-left: reconstruction was following some LED reflections
- Bottom-left: corrected

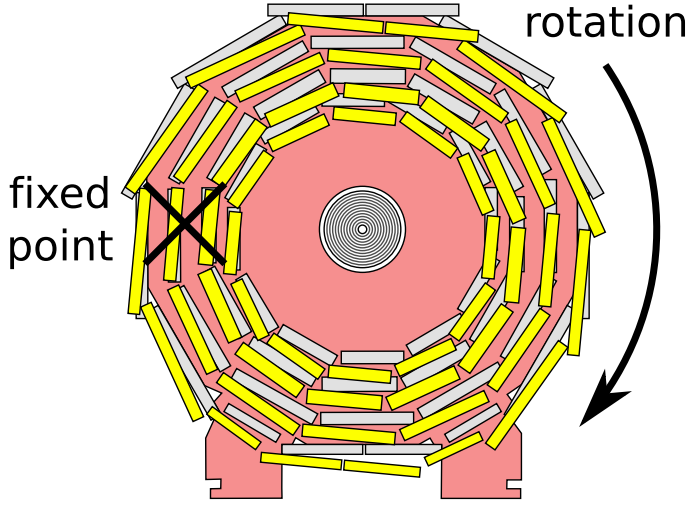


Barrel hardware — track-based

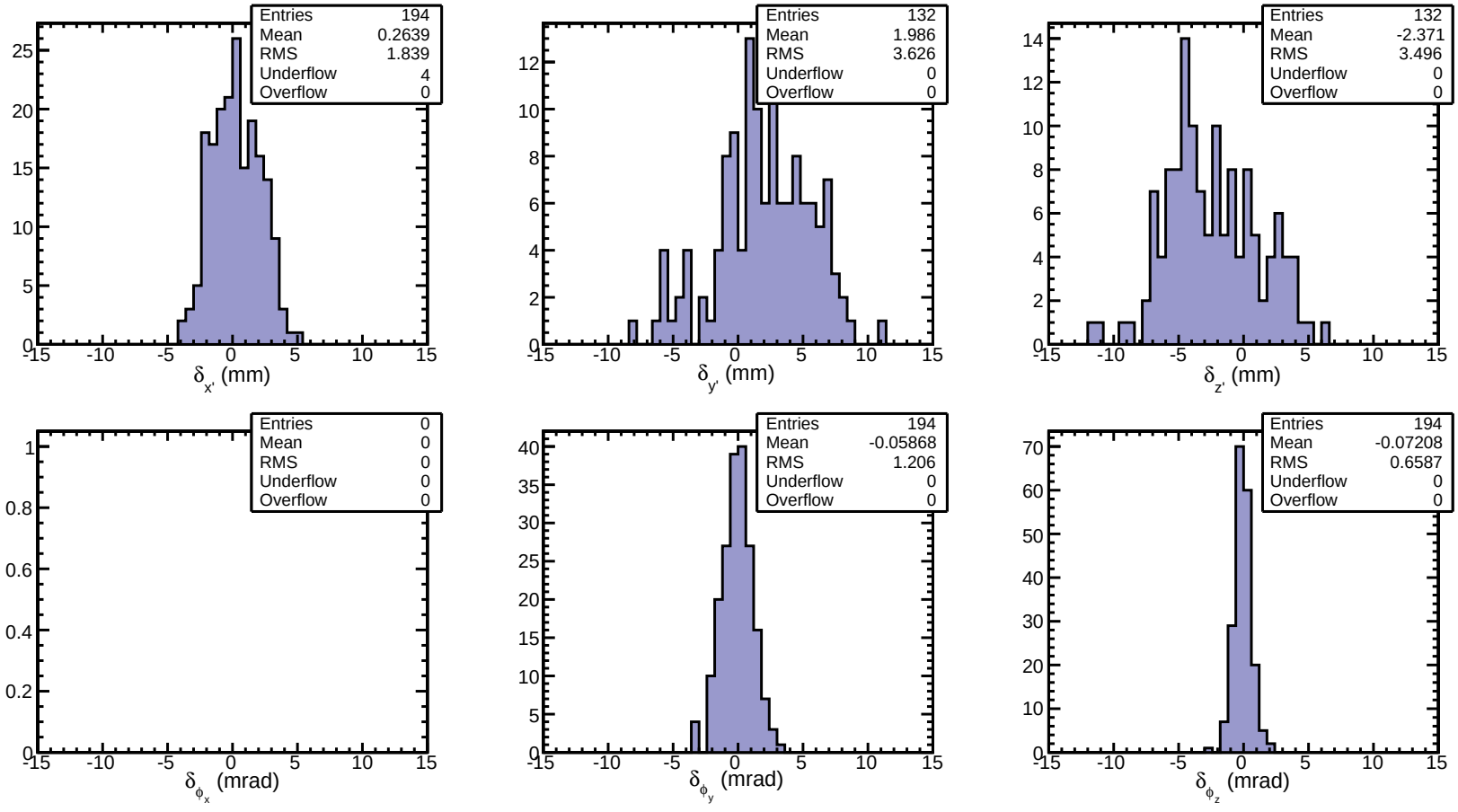




- Differences in chamber positions between hardware and track-based geometries
- Sine curve: global position with respect to tracker
  - $x \longrightarrow 1.2$ mm
  - $y \longrightarrow 4.5$ mm
  - $\phi_z \longrightarrow 0.58$ mrad

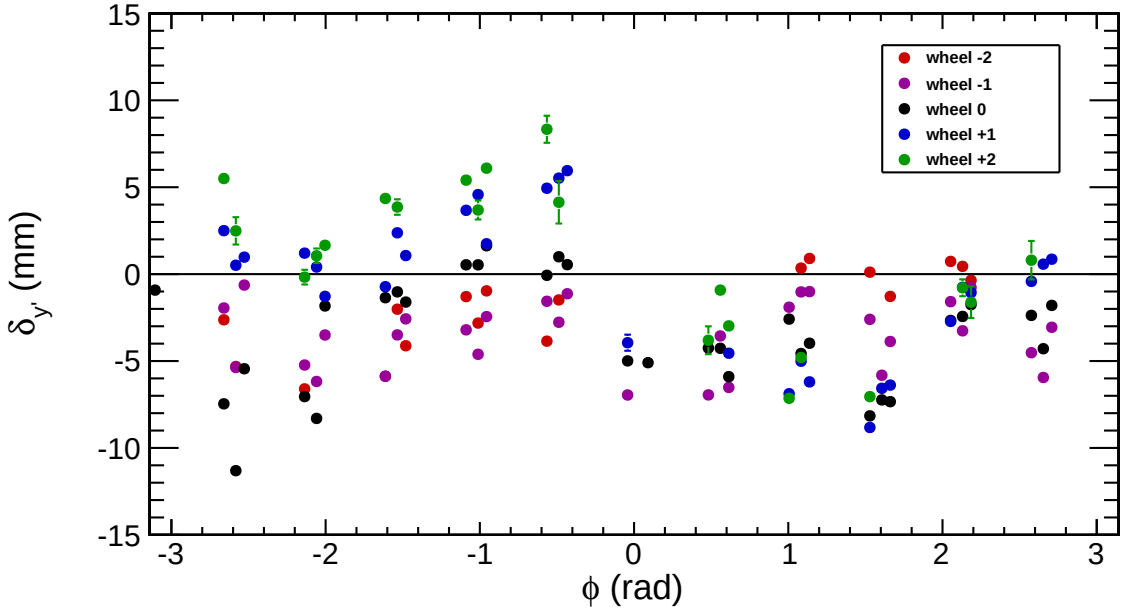


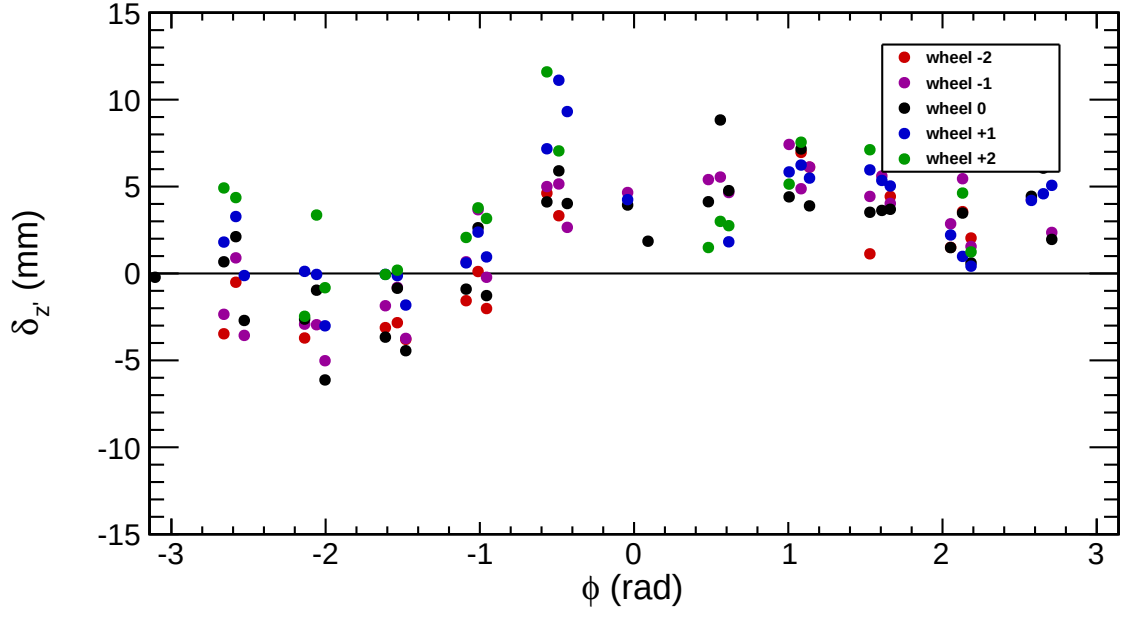
After global translation/rotation



- RMS of x' deviations (top-left) is only 1.8 mm after removing global offset in transverse plane
- Similar to photogrammetry, which had an RMS of 1.6 mm

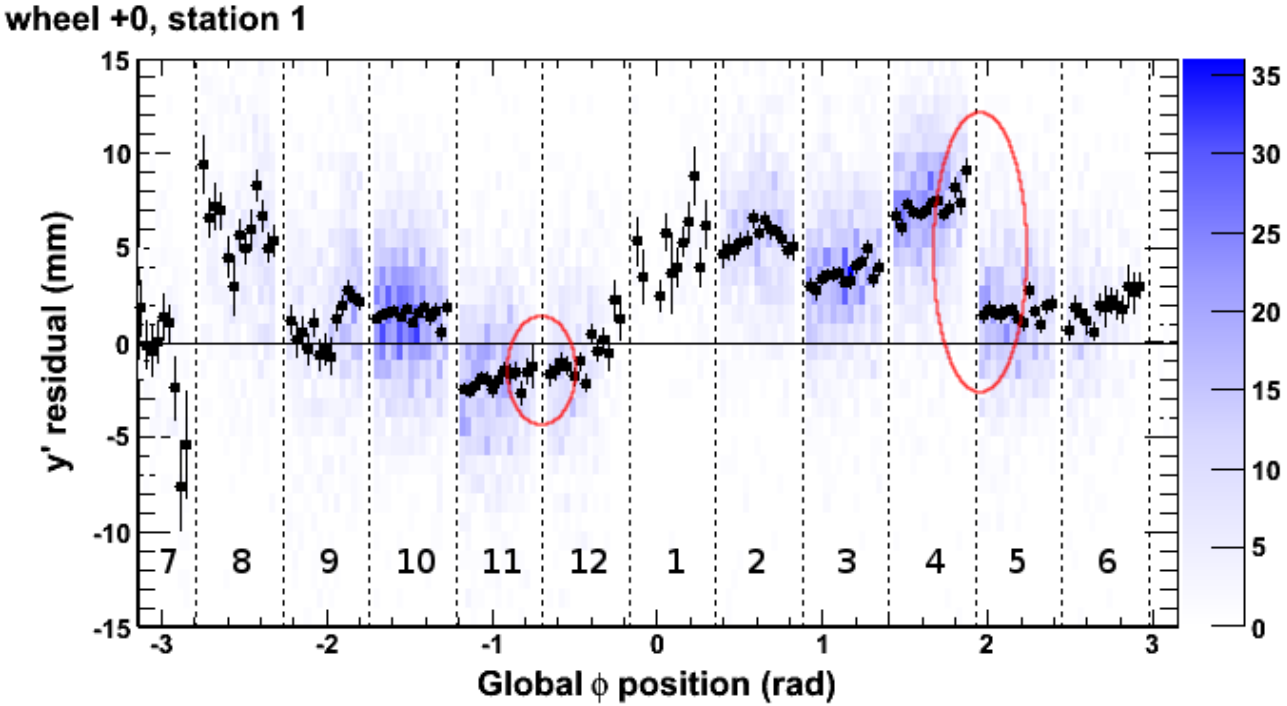
Other translational d.o.f.





- Top: y' differences (direction parallel to beamline)
- Bottom: z' differences (radial)
- These are more consistent within sector groups
- y' has a clear trend with respect to wheel

Map plots

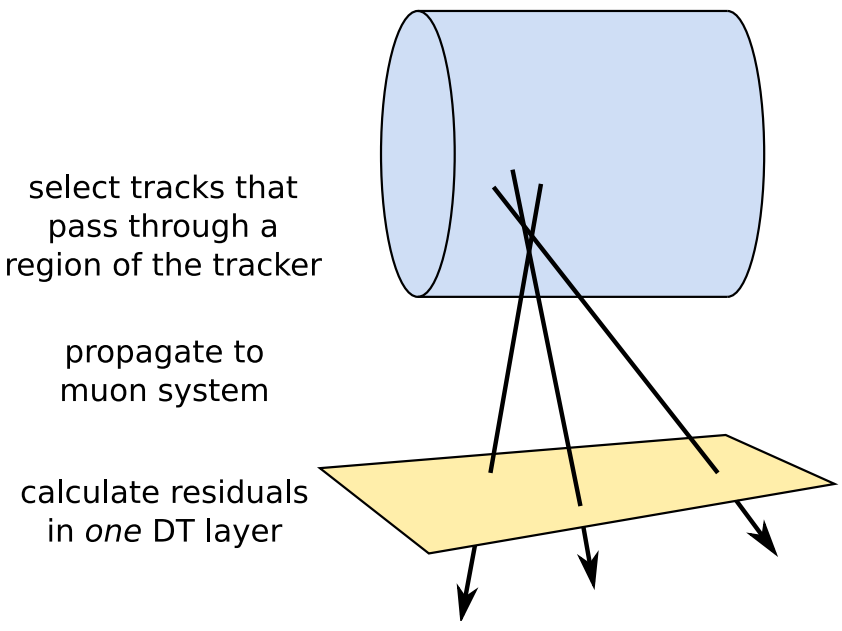


- Map plots show that the remaining differences are not due to tracker distortions
- For example, the statement "relative misalignment of sectors 4 and 5 is 6 mm" is tracker-independent and propagation-independent
- When the hardware geometry correctly describes the muon system as a rigid body, the differences with respect to track-based will be a *smooth* function in these plots (e.g. between sectors 11 and 12)

For all plots, see https://hypernews.cern.ch/HyperNews/CMS/get/muon-alignment/423/1.html

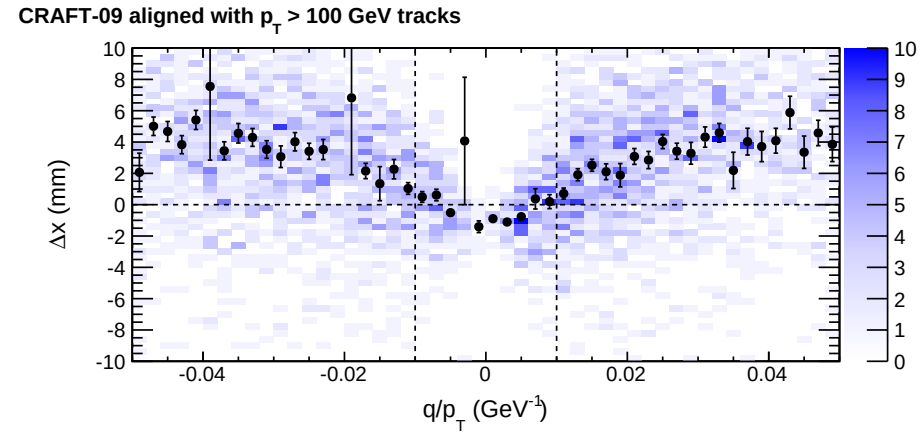
Resolving tracker distortions

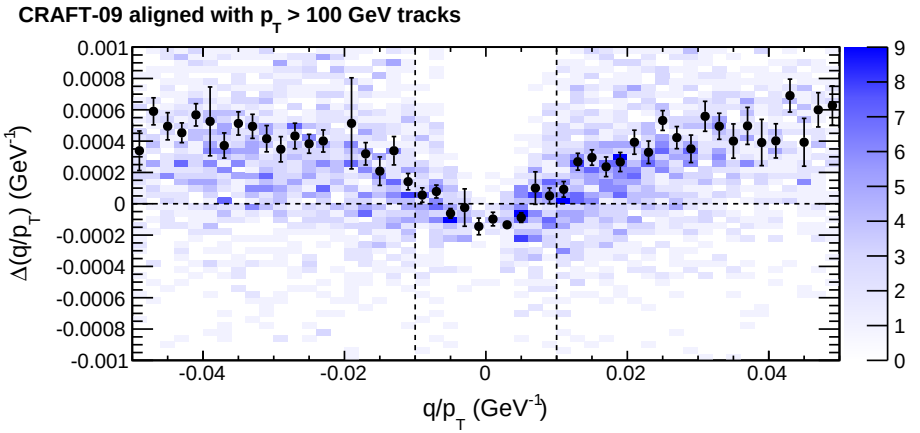
- We can identify tracker global distortions using muon chamber data
- Without introducing circularity when we later align the muon system with tracker tracks

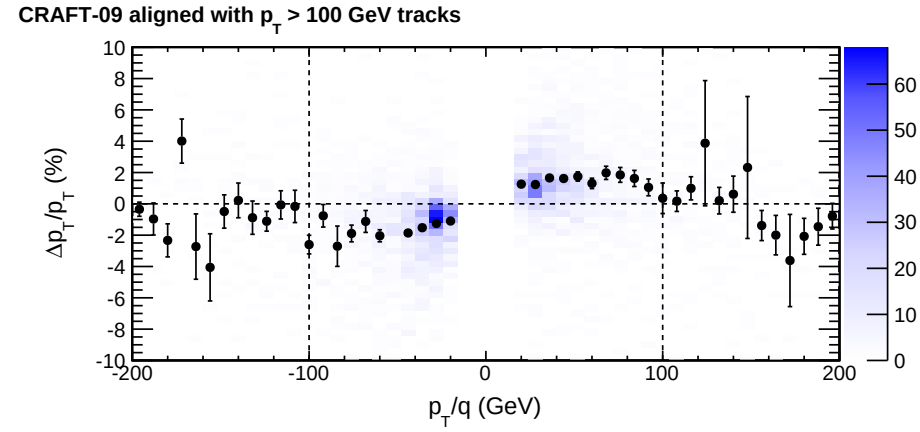


- Independence from muon alignment: plot residuals in *only one muon layer* (wh 0, st 1, sec 10, lay 2) and disregard global position of that layer
- Look at muon residuals as a function of p_T
- We only assume that the muon layer is in one location that can't be a function of the p_T of the tracks used to measure it

p_T-dependent muon residuals



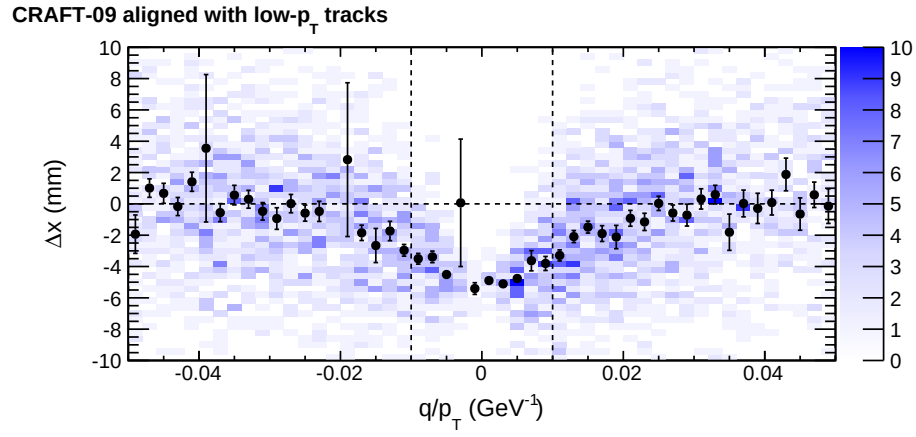


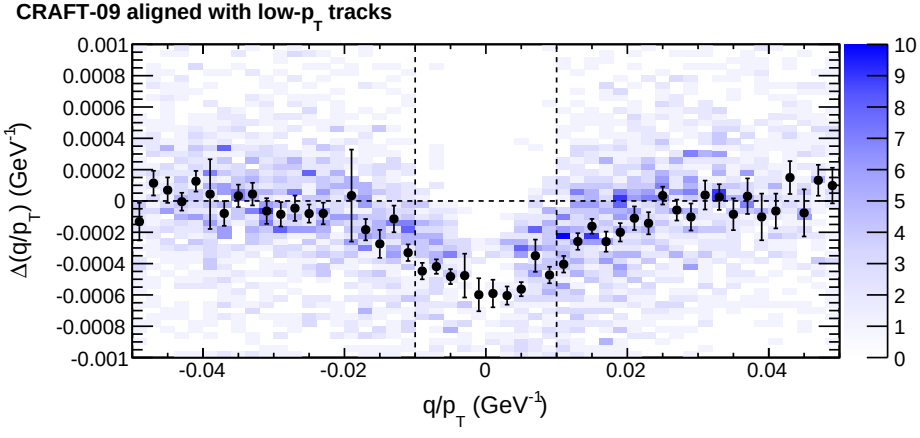


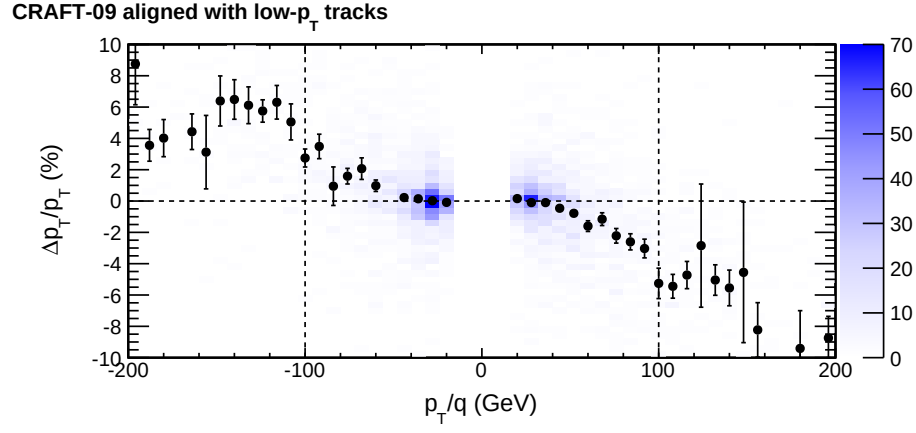
- Three ways of looking at it:
  - as a muon residual (Δx)
  - tracker curvature error ($\Delta\kappa = \Delta x \frac{d\kappa}{dx}$, $\kappa = q/p_T$)
  - tracker momentum error ($\Delta p_T = \Delta x \frac{dp_T}{dx}$)

  where $\frac{d\kappa}{dx}$ and $\frac{dp_T}{dx}$ come from track propagator, numerically
- $\frac{d\kappa}{dx}$ is nearly constant for a single DT layer (depends on distance from tracker)
- From muon hits, we learn something which is purely about the tracker's shape
- If errors were from $\vec{B}(\vec{x})$ or dE/dx, top plot would be antisymmetric, not symmetric

Ambiguity from muon alignment



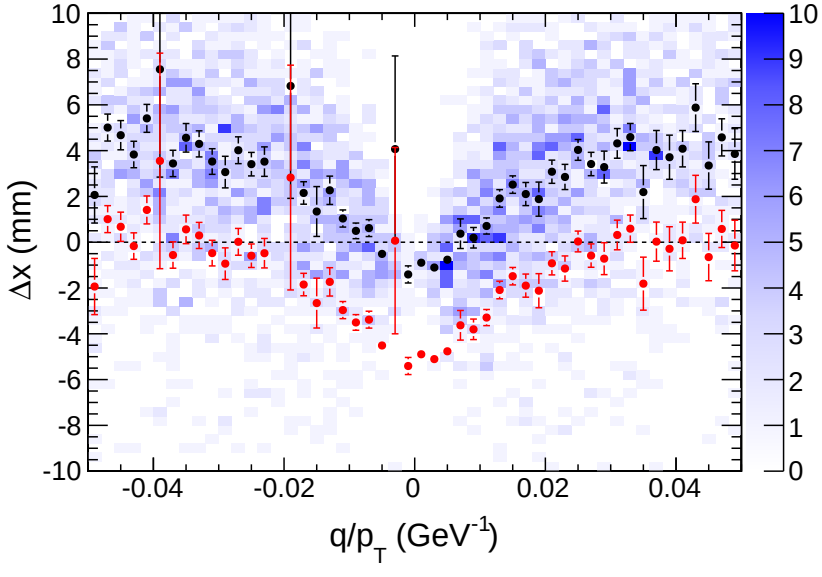


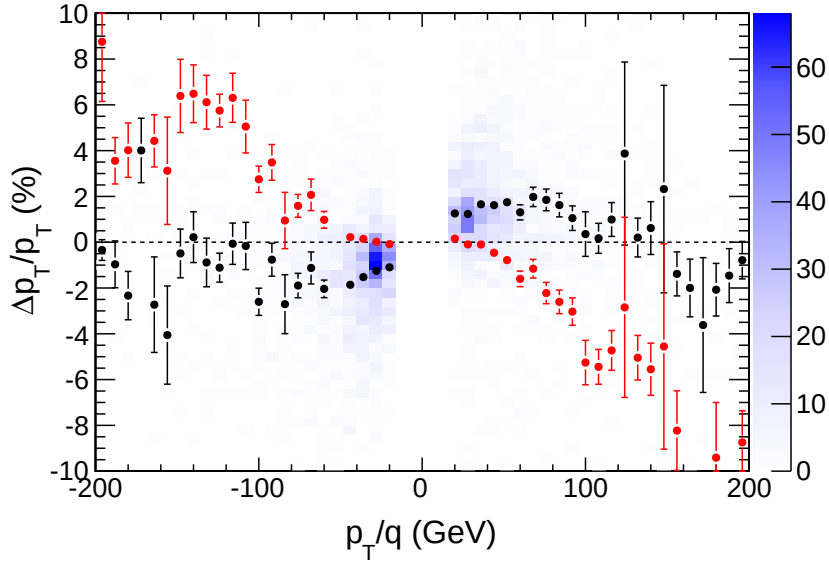


- To avoid a circular argument, we should keep the position of the muon chamber as a free parameter in this study
- Knowledge of tracker shape will later be used to determine positions of muon chambers (track-based alignment)
- Freedom to make low-p_T region "correct" and high-p_T region "wrong"
- Still, difference in curvature between low- and high-p_T regions is the same: this should constrain models of the tracker's shape

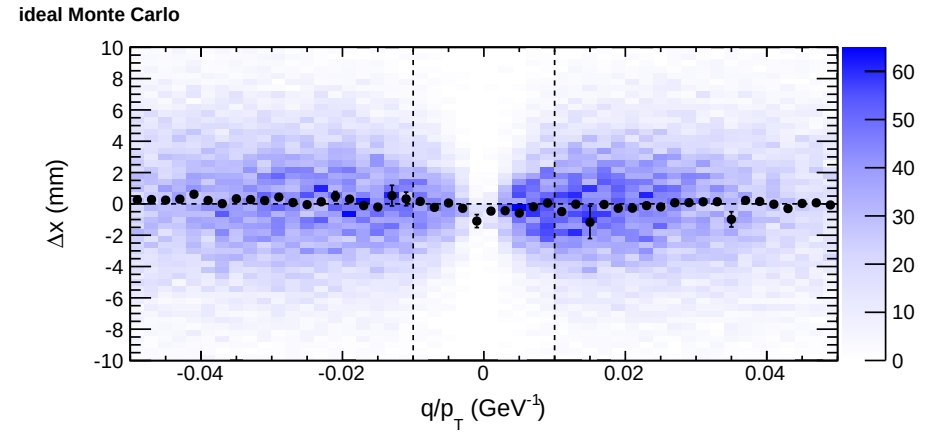
On one slide

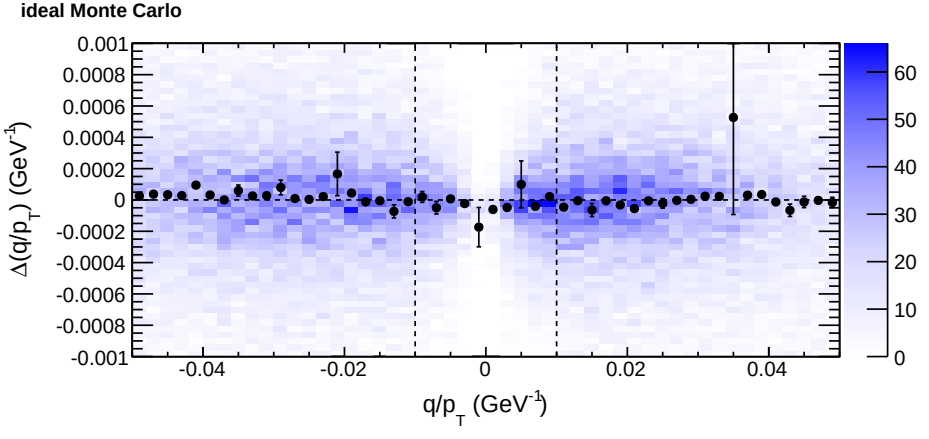
- Freedom in DT layer position yields different fractional p_T error profiles
- One thing which is not consistent with the data is: zero momentum bias across the whole p_T range
- Minbias alignment, with primary vertex constraint, information from resonance masses, etc. can further correct or constrain this

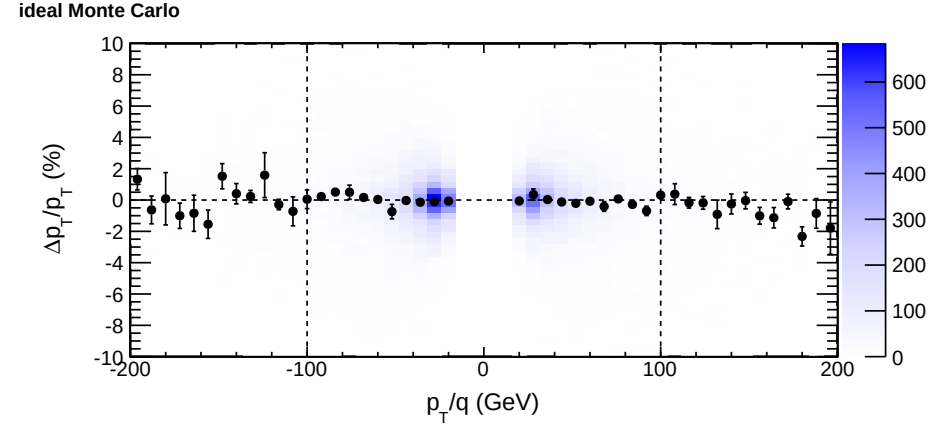




Does this analysis make sense?

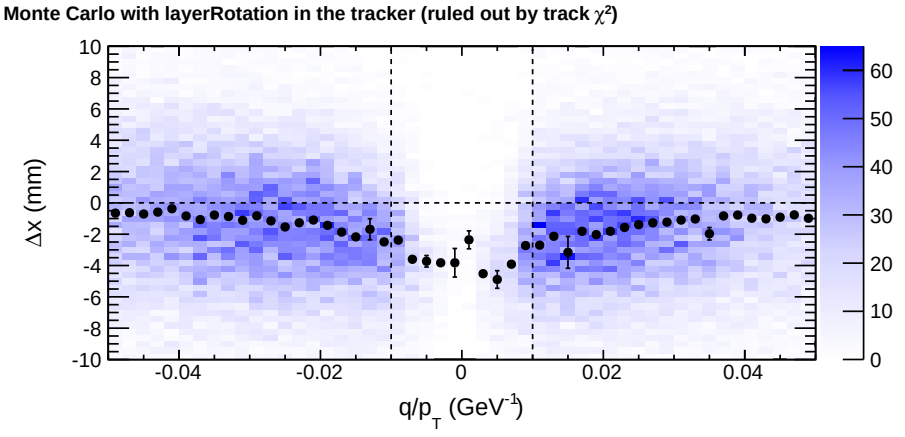


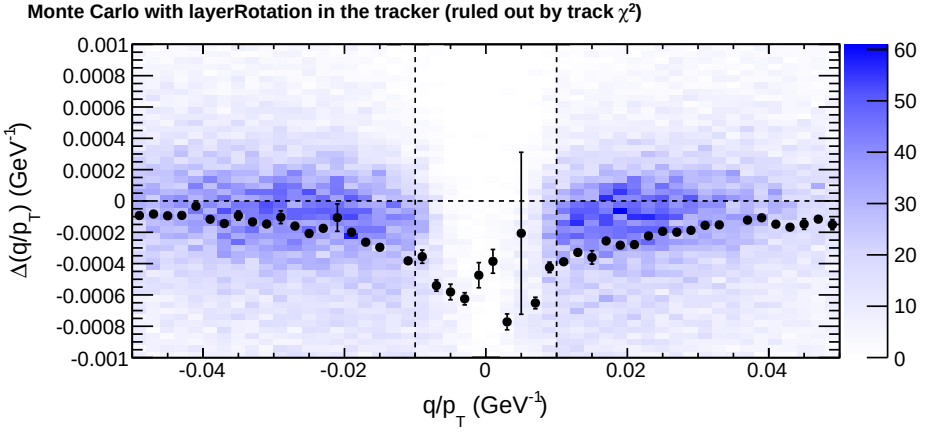


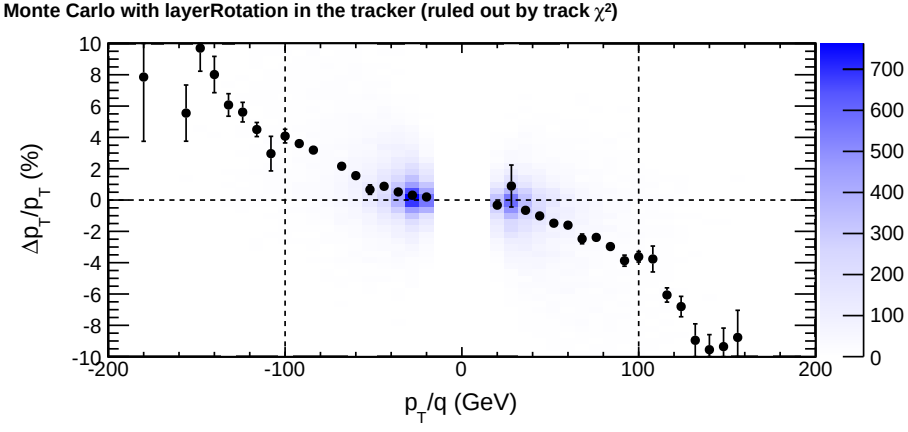


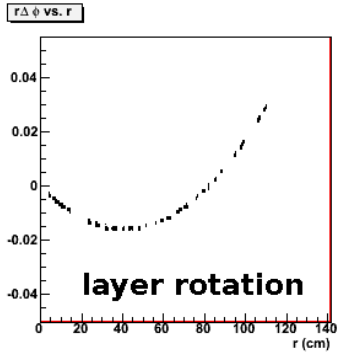
- When applied to ideal MC, everything is perfect
- That's good (not a software problem or anything)

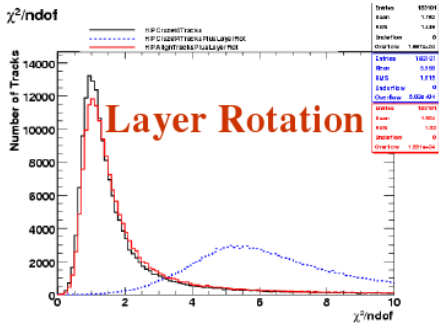
Straw-man global distortions (1)





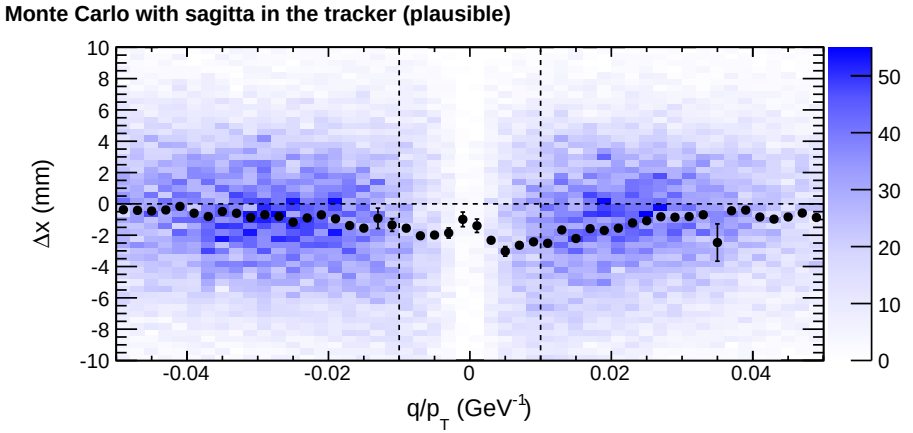


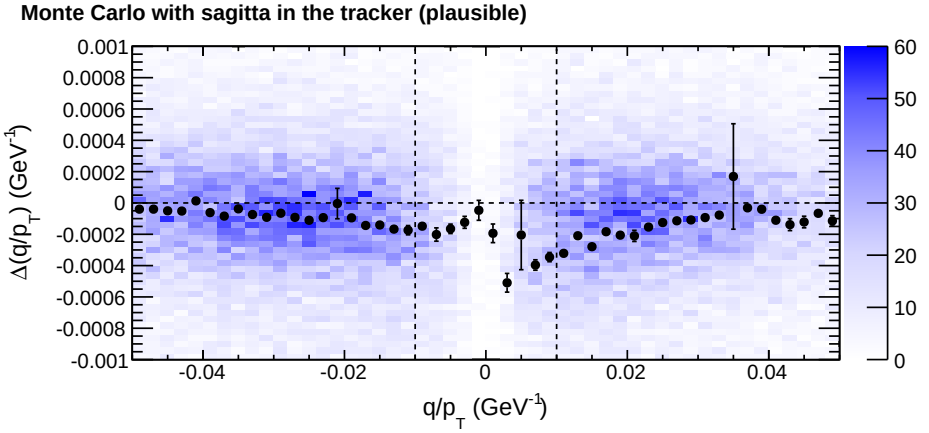


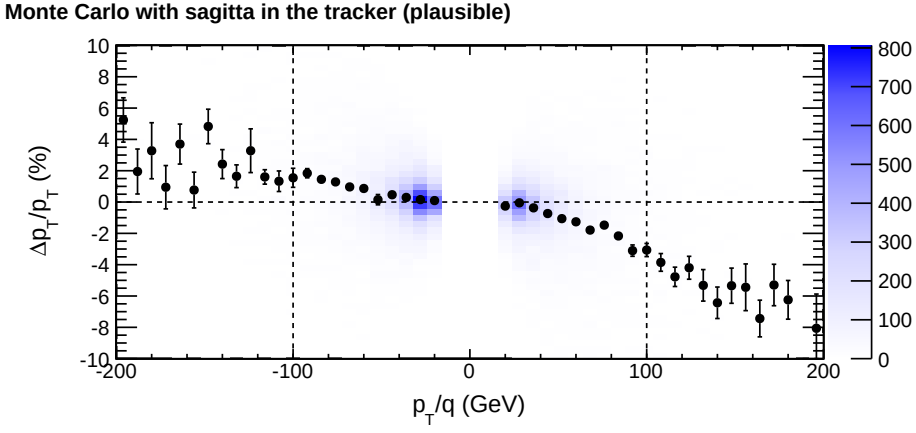


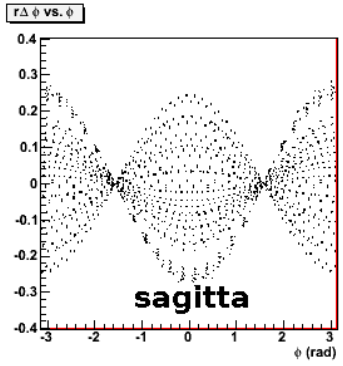
- $r\phi$ rotation of tracker layers as a function of r
- Tracker track χ^2 is highly sensitive to this, so it has been ruled out
- Nevertheless, it would produce a similar effect

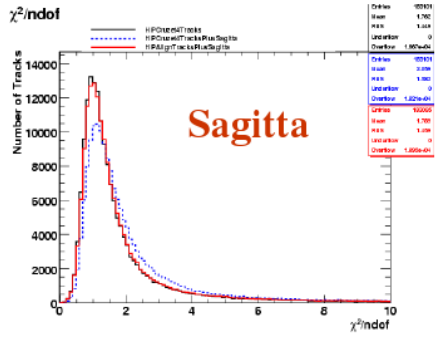
Straw-man global distortions (2)







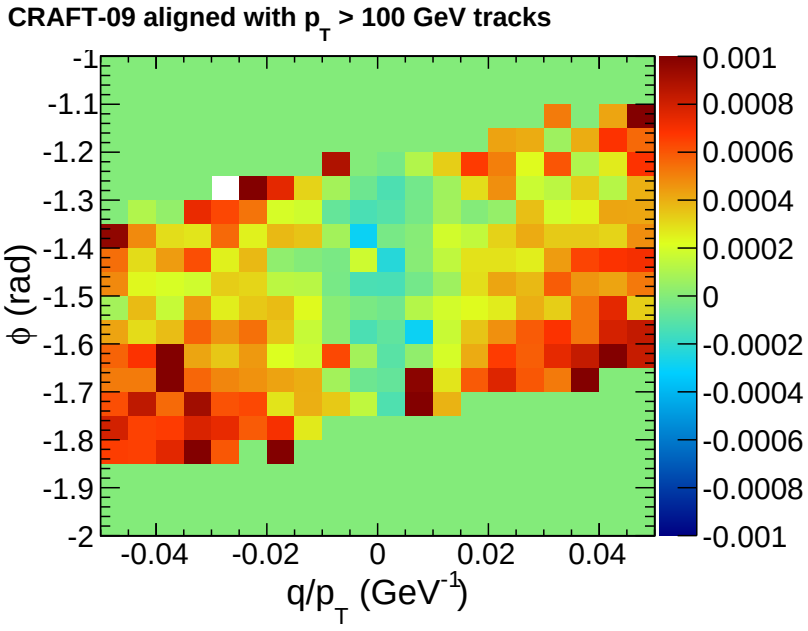


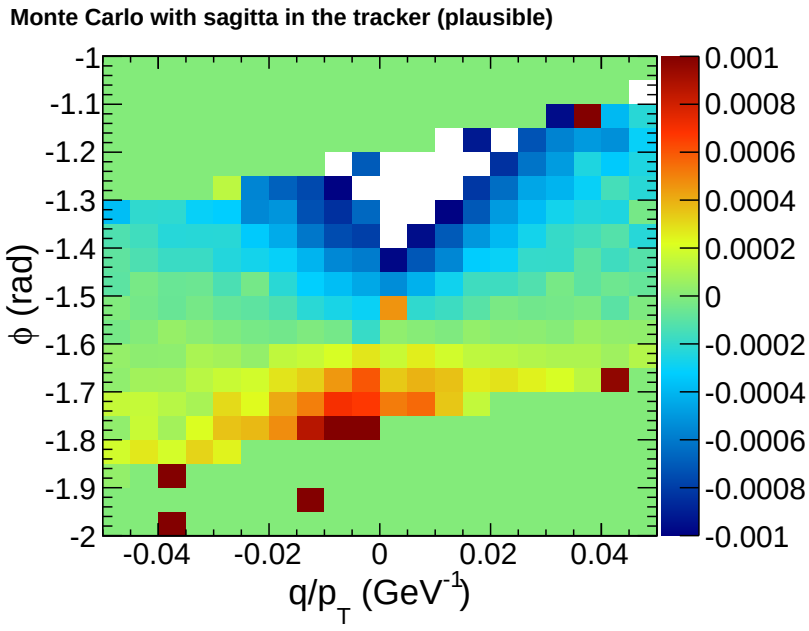


- $r\phi$ rotation of tracker layers as a function of ϕ
- Cosmic ray tracker tracks are not very sensitive to this
- It also produces a similar effect
- That doesn't mean that it's the only explanation

Why it's not sagitta

- Plot tracker curvature error $\Delta(q/p_T)$ on the color scale (GeV^{-1})
- Horizontal axes as indicated

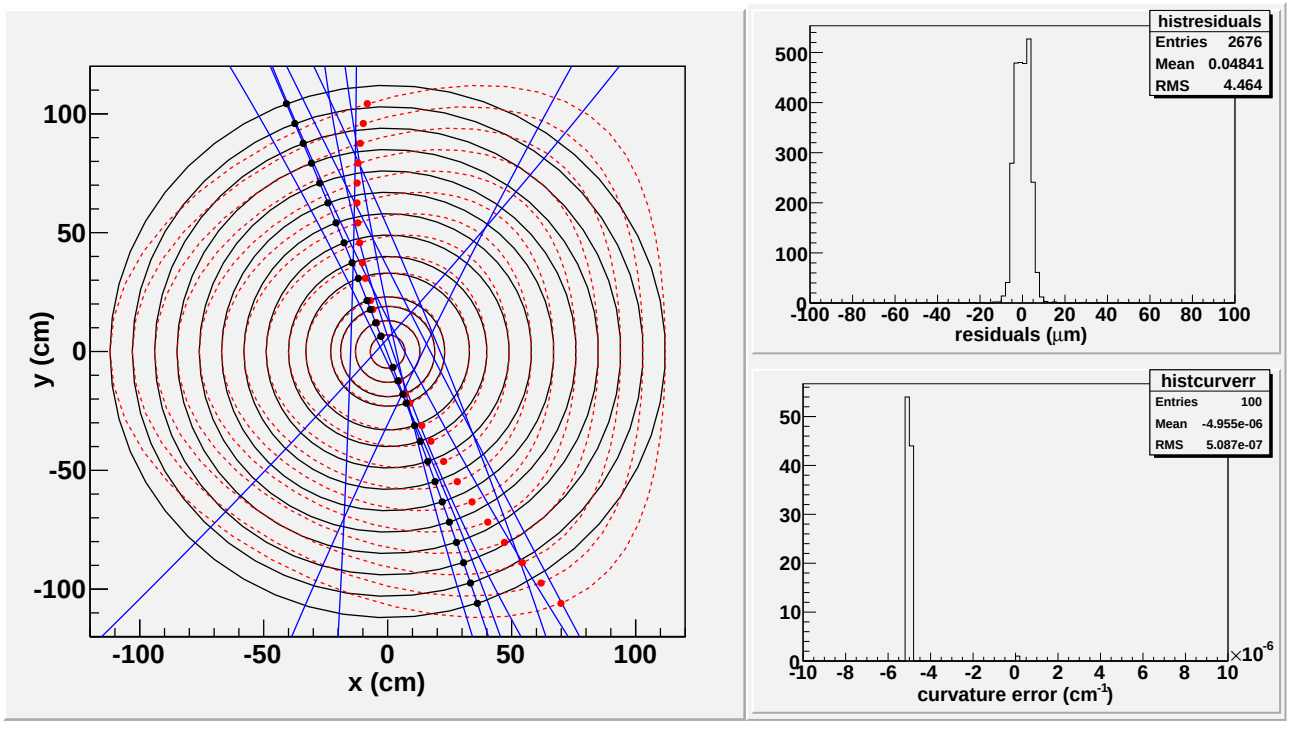




- Real distortion is more a function of q/p_T than ϕ
- Sagitta error is more a function of ϕ than q/p_T

Trying other distortions

- Following an idea by Markus, trying $f(x, y) = (x + 5 \times 10^{-6} y^2, y)$
- Quick toy MC: causes 5×10^{-6} cm^{-1} $= 0.0005$ GeV^{-1} distortions
  - without large residuals
  - without affecting cosmic ray splitting
  - unfortunately, also no dependence on p_T (this isn't the one)
  - collisions and resonances may be sensitive to it
- Should try this and variants on it with the real tracker alignment tools



Conclusions

- Barrel hardware alignment produced, actively being compared with track-based data
- Muon residuals provide some constraints on the global tracker shape
  - including estimates of momentum bias
  - should be part of a larger program of integrating knowledge from cosmics, minbias, resonances, etc.
  - large project: looking for people interested in working on it
  - tentative interest: Markus Stoye, Roberto Castello