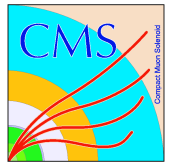

Shape of the DT Chambers from Track-based Studies

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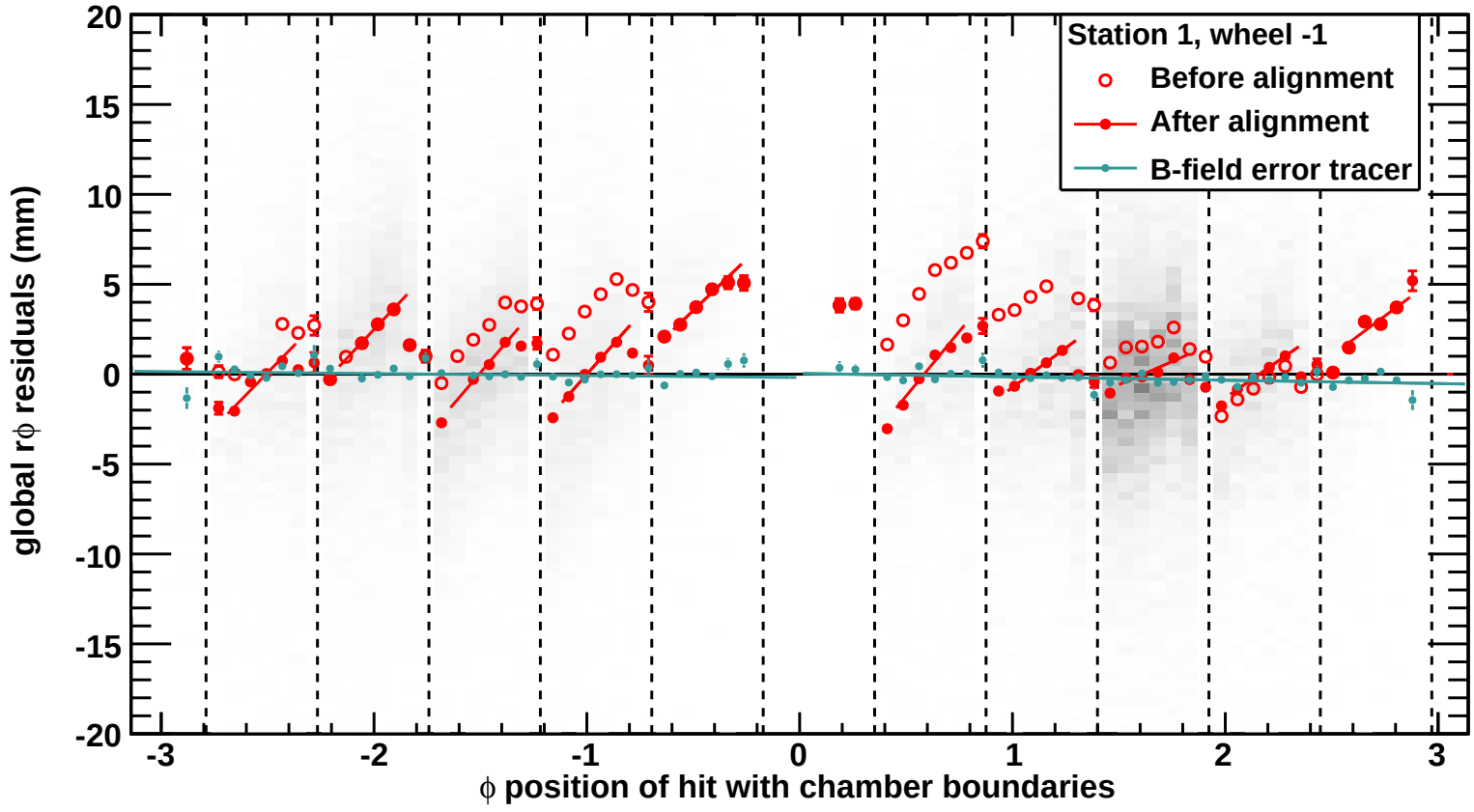
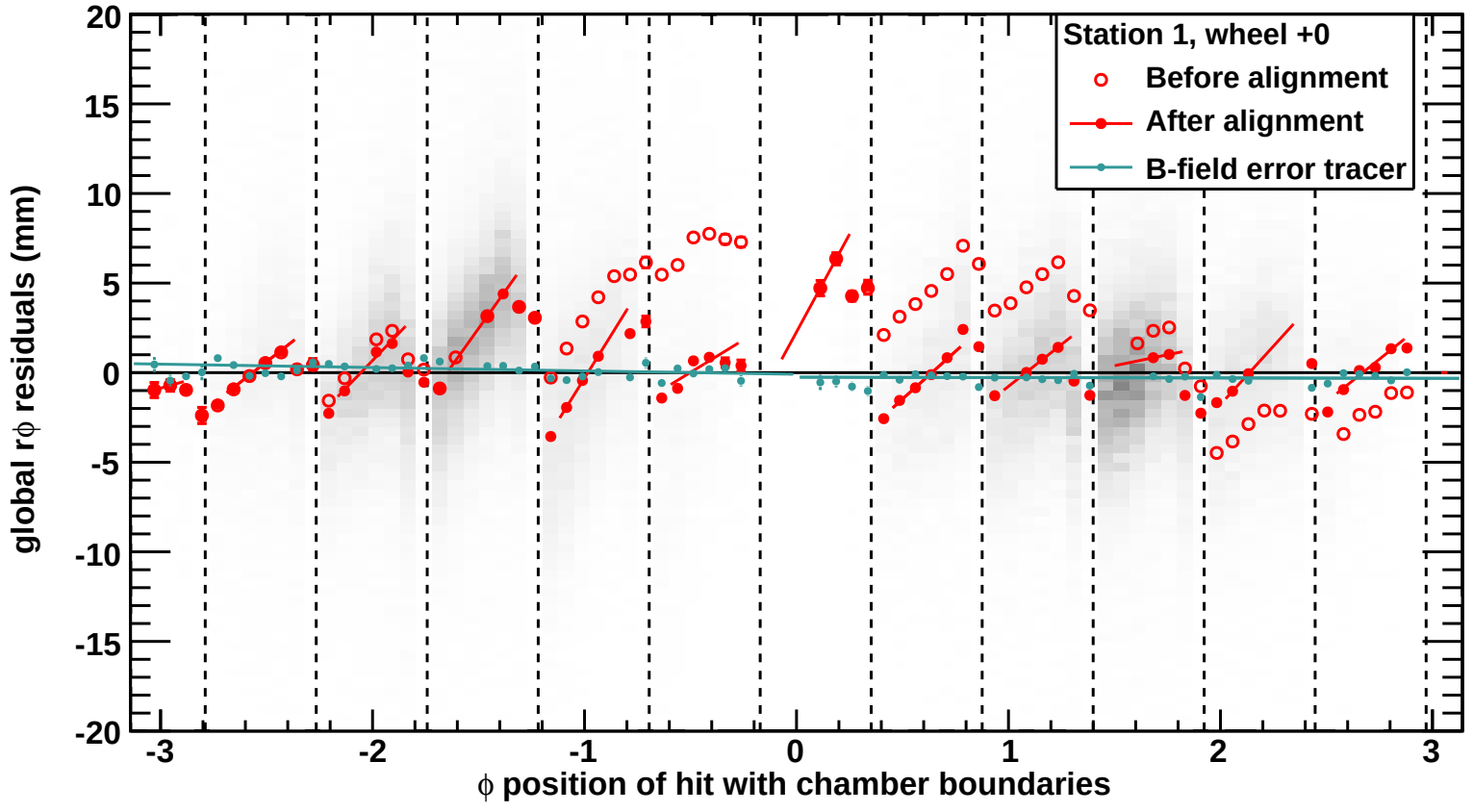
The clue (1/3)



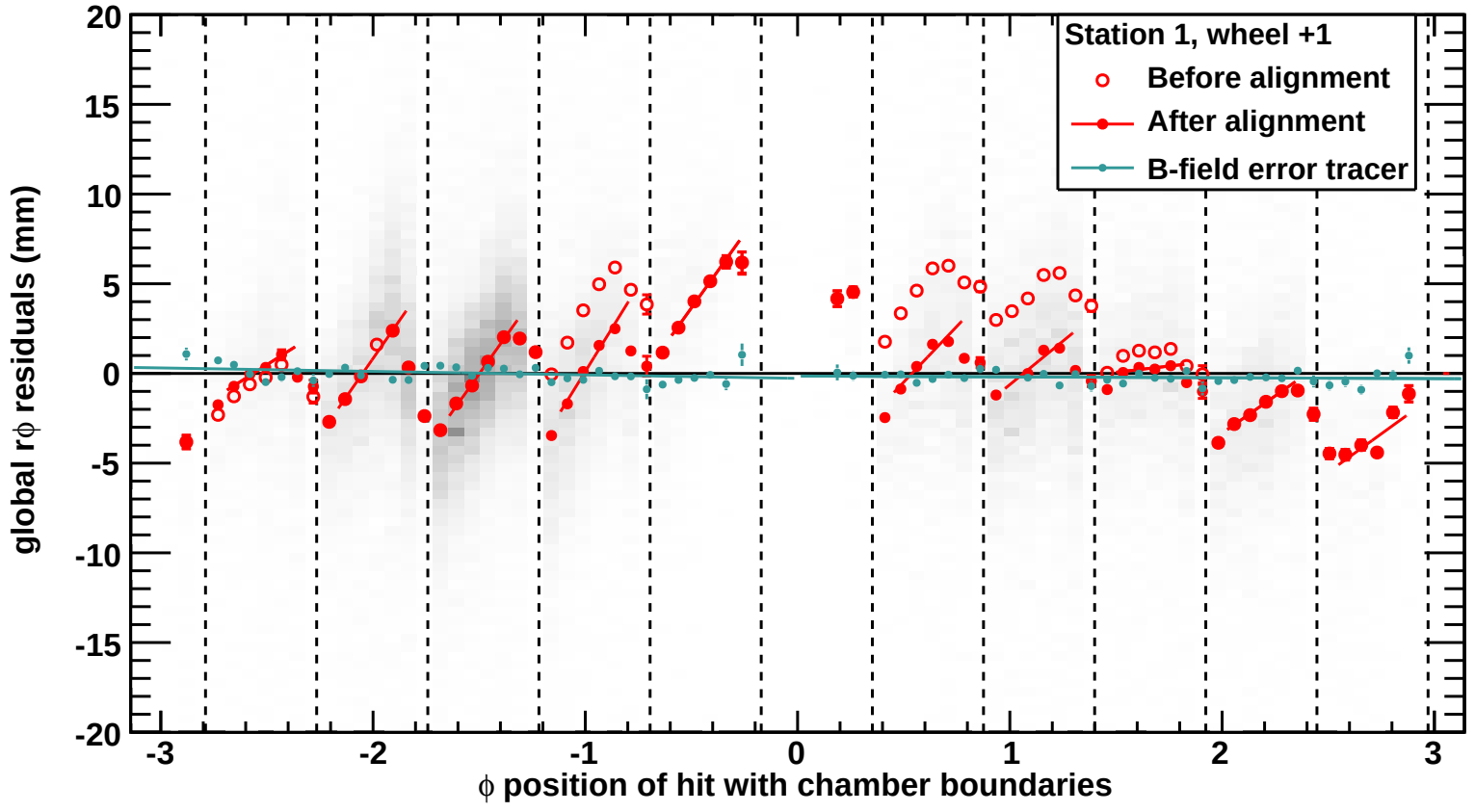
- Linear trends in unbiased $r\phi$ residual vs. ϕ inside each chamber
- Unaffected by local x alignment (as expected)
- Curious thing: they all seem to have the same slope

The clue (2/3)



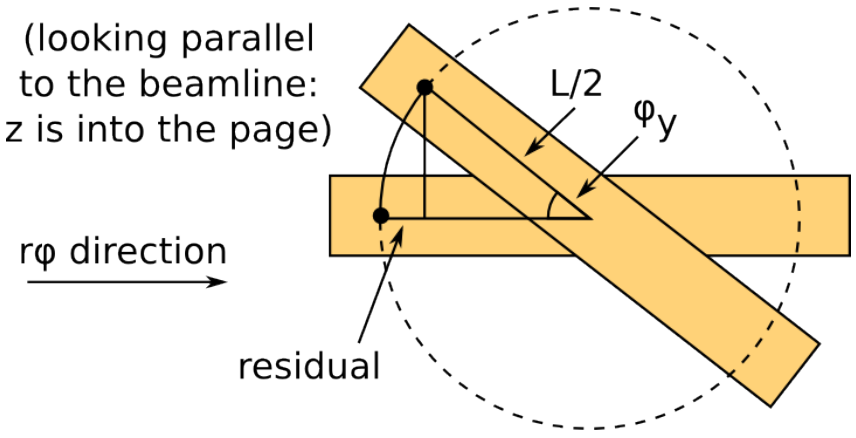
- What if it's a linear bias in the distribution from the track source, partly absorbed by the alignment?
  - impossible: ϕ must have periodic boundary conditions
  - if we realigned chambers to make a continuous line, it could not match at $\pm\pi$ (it would fail a "closure condition")

The clue (3/3)



- So it's a real effect related to the chambers, not the track source
  - not fixing it would smear chamber resolution by 5 mm!
- What rigid body misalignments can cause it?
  - ϕ_y (rotation around axis parallel to the beamline)
  - ΔR (radial displacements)

The ϕ_y possibility

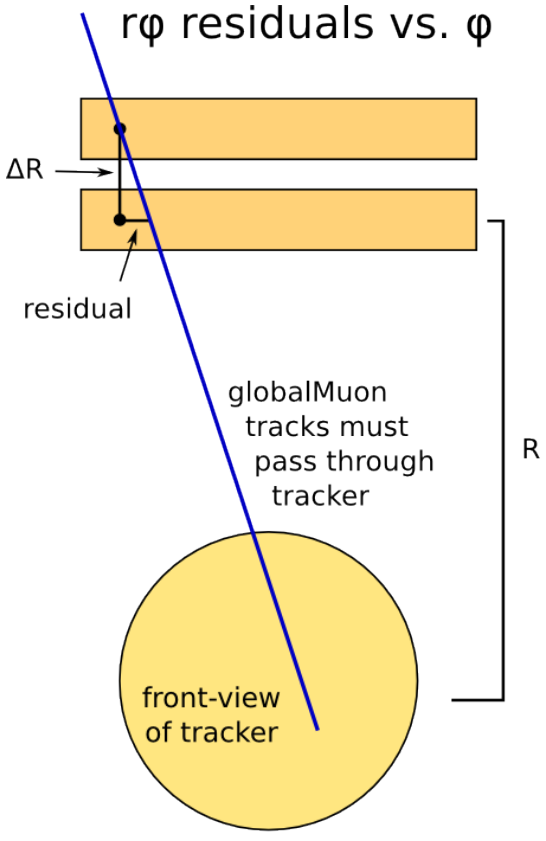


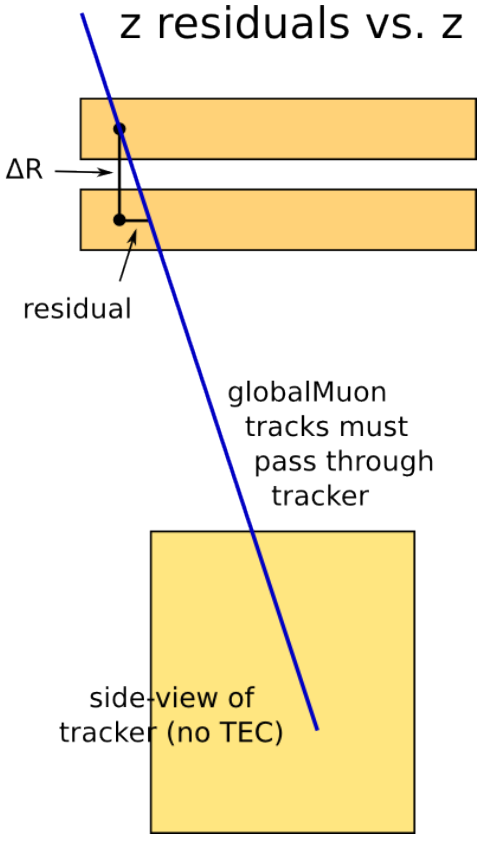
- ϕ_y rotation can make a chamber appear narrower
- but it's a second-order effect:

$$\begin{aligned} \text{residual} &= (L/2)\,(1 - \cos\phi_y) \\ \phi_y &\approx 70 \text{ mrad} \end{aligned}$$

- Could *all* the chambers be independently misaligned by about 70 mrad?
- Same effect observed in IDEAL and CRAFT_ALL_V4 constants: it would have to be a physical misalignment of real chambers
- I think we can safely say that this is not what's happening
  - the magnitude is too big, and
  - the pattern is too regular

The ΔR possibility





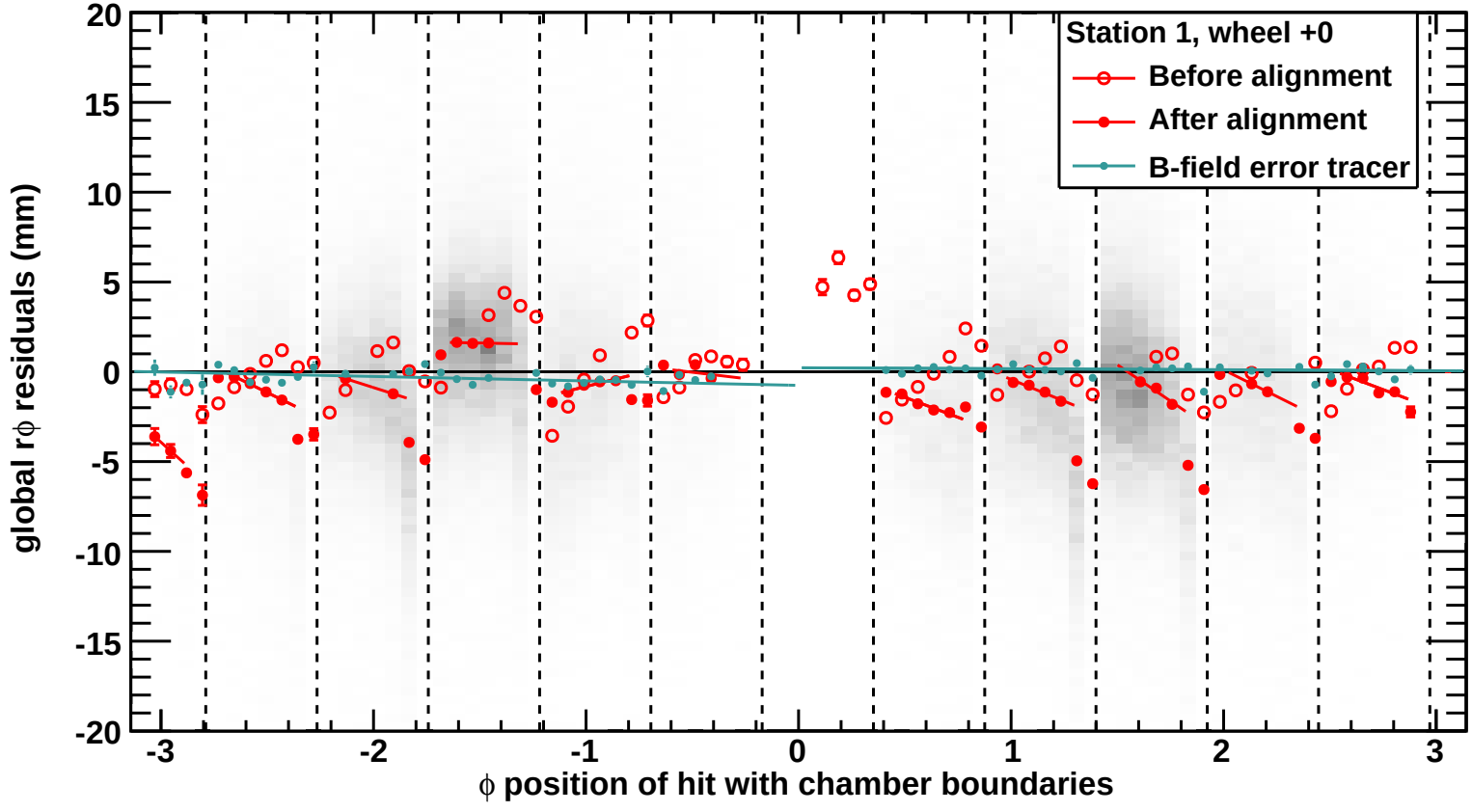
- A track sample constrained to pass through the tracker can introduce effects of this sort

$$\Delta R = \frac{R}{(L/2)}\,(\text{residual})$$

- But it has to appear in both types of residuals

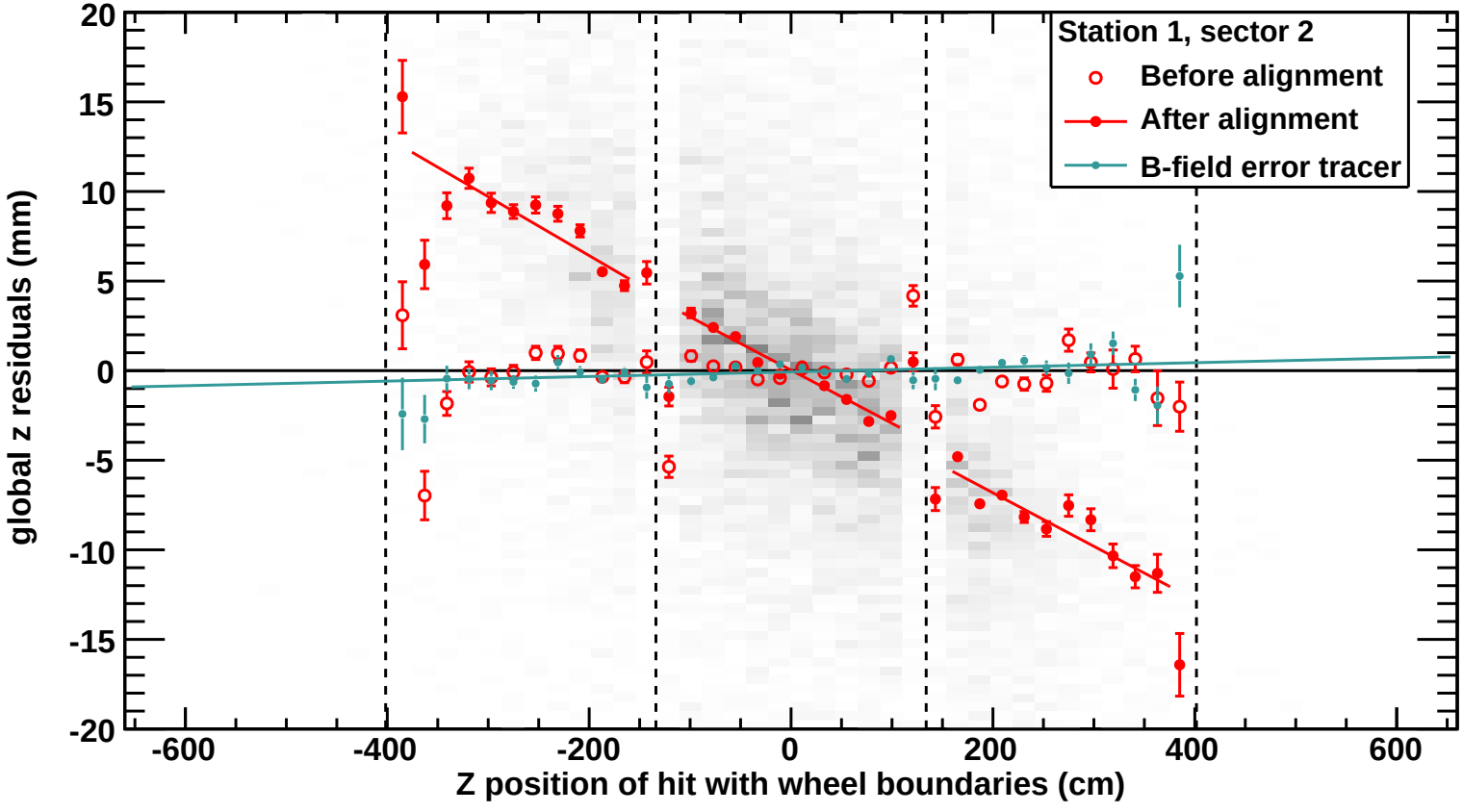
Trial ΔR alignment (1/2)

- To see if this is plausible, I expanded the radius of all DT stations by 15 mm in a private test
  - seems to cancel the $r\phi$ residual vs. ϕ trend in the $-\pi < \phi < 0$ range, but overshoot slightly in the $0 < \phi < +\pi$ range



Trial ΔR alignment (2/2)

- However, look what happens to the z residual vs. z: clearly both types of residuals can't be satisfied!
- The open circles are the case of no ΔR shift



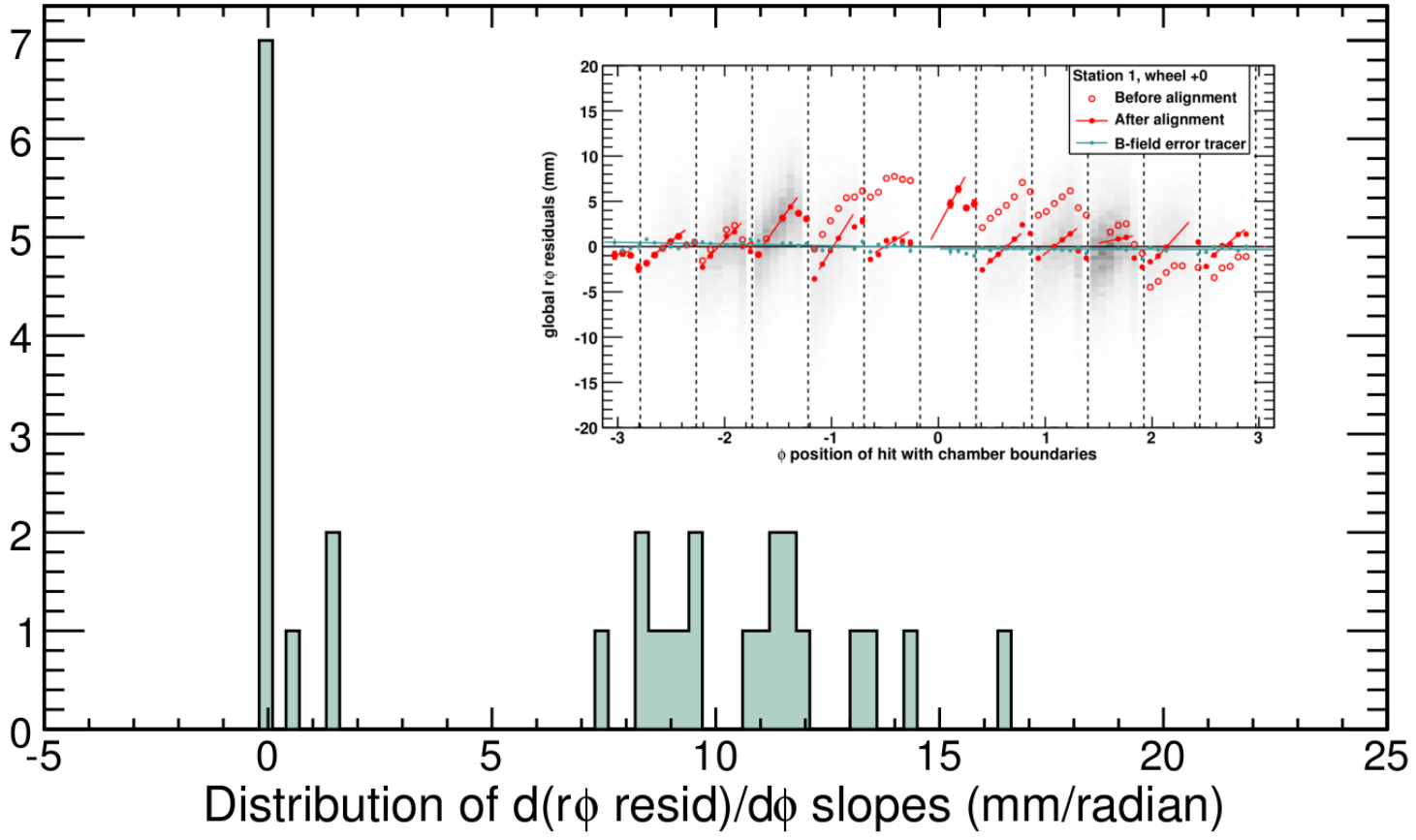
So, what could it be?

- Process of elimination for all rigid body degrees of freedom
  - ~~ϕ_y: implausible~~
  - ~~ΔR (a local z translation): can't reconcile both $r\phi$ and z residuals~~
  - local x, y translations: can't introduce any linear trends in residuals, only offsets
  - ϕ_z rotation: introduces a linear trend in $r\phi$ residuals vs. z and z residuals vs. ϕ, but not what we're looking for
  - ϕ_x rotation: also would have to be implausibly large, and only affects z residuals (the opposite of what we're looking for)

- Non-rigid degree of freedom

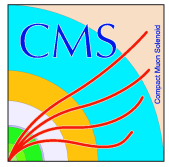
  - *some kind* of stretching would easily explain it
  - an error in the geometry description, duplicated by CMSSW, would account for its regularity (with outliers due to small individual ΔR misalignments)

Regularity of the effect



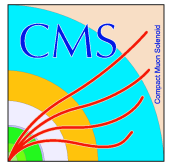
- Distribution of slopes in $r\phi$ residuals vs. ϕ (wheels -1, 0, $+1$) peaks at roughly 10 mm/radian
- 0 underflows, 1 overflow
- Small individual ΔR misalignments can smear this

Analogy with CSC case



- Last year, a similar track-based technique uncovered a 0.8 mm error in CSC widths
- For the same reasons, chamber stretching was degenerate with increasing the distance from the beamline
- Degeneracy was resolved with photogrammetry of alignment pins
  - track-based procedure reproduced $r\phi$ positions of alignment pins with 270 μm accuracy
  - R positions of pins were therefore directly comparable, and constrained distance from the beamline
- CSC geometry experts investigated and quickly found a 10 μm strip pitch angle error, which, compounded over 80 strips, changed the width by 0.8 mm, explaining the observation with tracks
- DTs have an advantage over CSCs in that they precisely measure z residuals in addition to $r\phi$ residuals, so we can already break degeneracy between ΔR and stretching
- In the CSC case, we predicted the magnitude but made a mistake in guessing the sign: we'd follow up on any effect of this magnitude

Conclusions: what to do?



- I would like to ask DT geometry experts to look for a chamber description error on the order of 5 mm across the local x dimension
- We have shown that it is a real chamber-level effect and ruled out the possibility of it being caused by any rigid chamber misalignment
- "Stretching/squashing" can be interpreted loosely
  - only distortions which affect active elements matter
  - a bulging layer can look narrow (though that's a second-order effect, like ϕ_y)
  - a $\phi_y \sim 70$ mrad rotation built into the chamber?
  - a ΔR misalignment for superlayers 1 and 3 and not superlayer 2 could explain the incompatibility of $r\phi$ and z residuals
  - it's hard to imagine timing effects playing a role, since left- and right-hand sides of each wire would be affected oppositely
  - ...
- Since it's causing ± 2.5 mm unbiased residuals errors at the ends of the chambers, it's as important for resolution as alignment