DT and CSC Alignments for 2nd CRAFT-09 Reprocessing

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Outline

- DT Alignment
  - parameters
  - global adjustment
  - differences with respect to hardware + link
  - segment difference plots
  - distribution of medians
  - map plots
  - fit plots
- CSC Alignment
  - parameters
  - ring adjustments
  - table of ring corrections
- Location of files

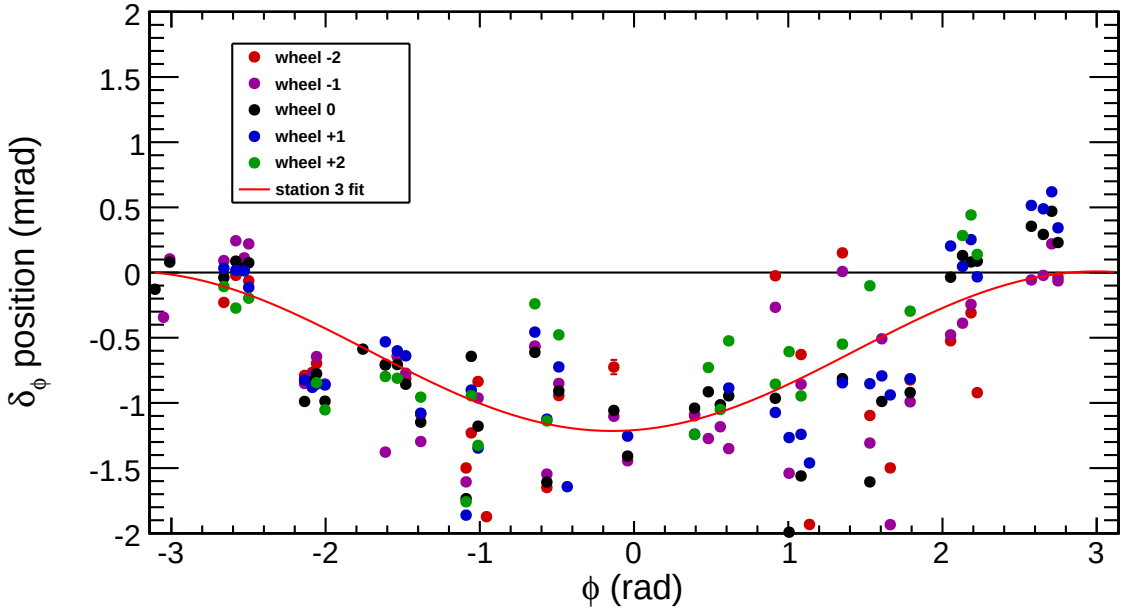
DT alignment parameters

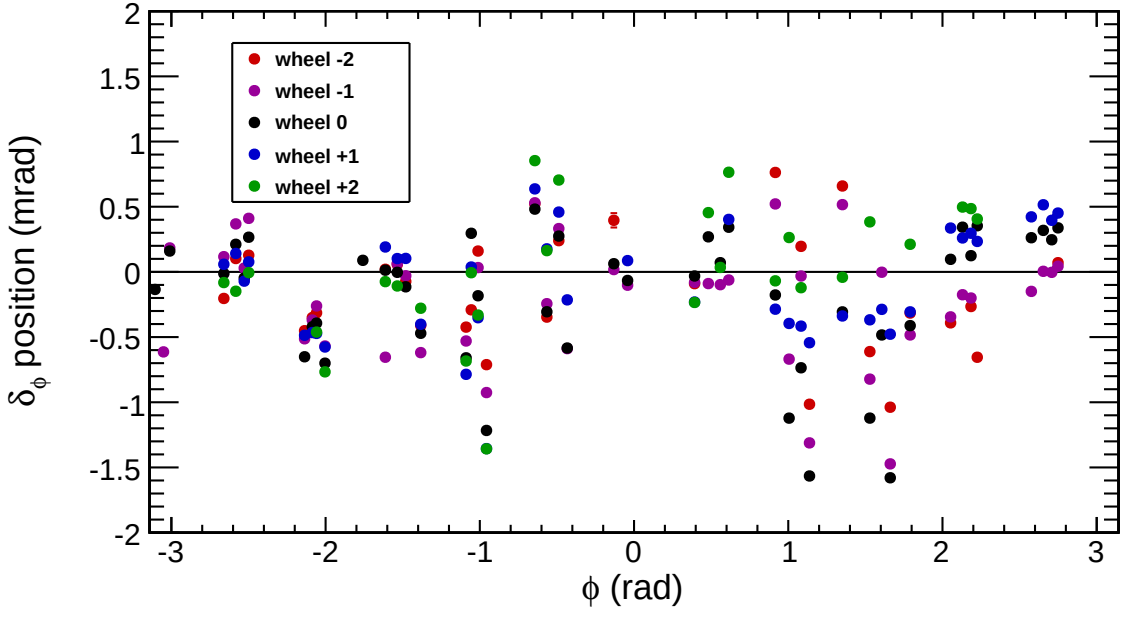
- Sequence:
  1. Barrel_Opt210-56.db: Hardware + Link-to-AR + internal layer alignment
  2. adjust whole barrel global δ_x, δ_y, δ_{ϕ_z} by hand
  3. track-based chamber alignment (keeping δ_{ϕ_x} fixed)

- Where each final aligned position/orientation comes from:
  - all layers/superlayers relative to chamber center: (1) survey + tracks
  - chambers poorly illuminated by cosmic rays, all parameters: (1) Hardware with (2) global adjustment
  - all chambers local δ_{ϕ_x}, station 4 δ_y, δ_z, δ_{ϕ_y}: (1) and (2)
  - well-illuminated chambers, other params: (3) track-based chamber alignment

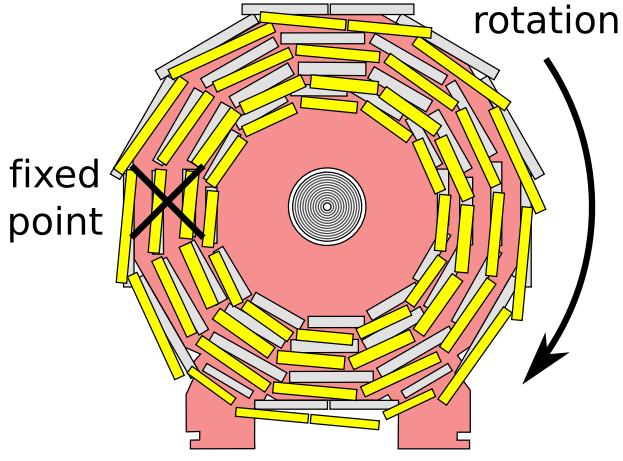
- Track-based chamber alignment parameters
  - Dataset: `/Cosmics/CRAFT09-StreamMuAlGlobalCosmics-CRAFT09_R_V4_CosmicsSeq_v1/ALCARECO`
  - Run range: 109011–109624 (tracker "peak mode")
  - Release: CMSSW_3_2_7
  - GlobalTag: CRAFT09_R_V4::All
  - Aligned parameters: stations 1–3 δ_x, δ_y, δ_z, δ_{ϕ_y}, δ_{ϕ_z}
    station 4 δ_x, δ_{ϕ_y}, δ_{ϕ_z}
  - Tracks: $100 < p_T < 200$ GeV, #tracker hits ≥ 15, tracker $\chi^2/\text{ndf} < 10$, no rejection of TID/TEC
  - No special correction for $\vec{B}(\vec{x})$, dE/dx
  - Criterion for alignment: at least 30 hits and no Minuit fit failure
  - 5 iterations (2 are necessary for most chambers)

Global adjustment

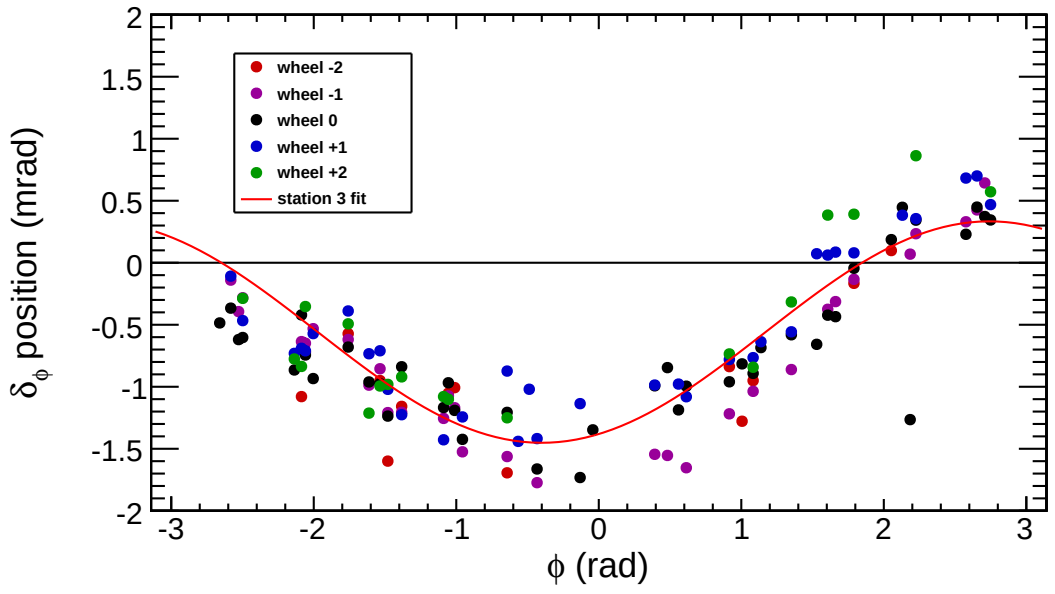


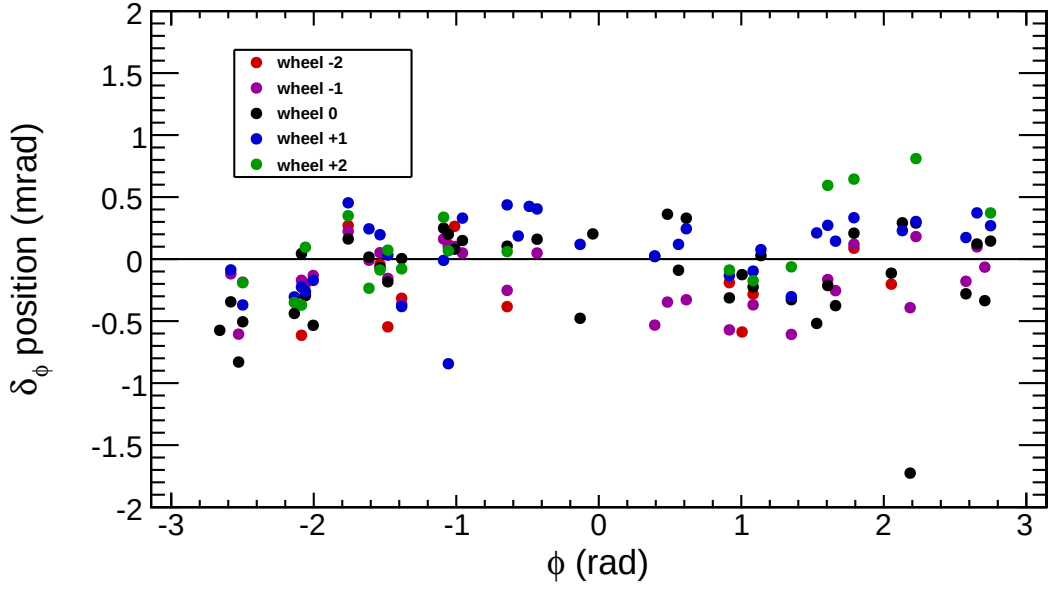


- Plotting differences between hardware + link geometry and track-based geometry
- Global adjustment:
  $\delta_x = 0.6$ mm,
  $\delta_y = 3.8$ mm,
  $\delta_{\phi_z} = 0.6$ mrad
- Almost perfect in δ_x
- δ_y and δ_{ϕ_z} are:



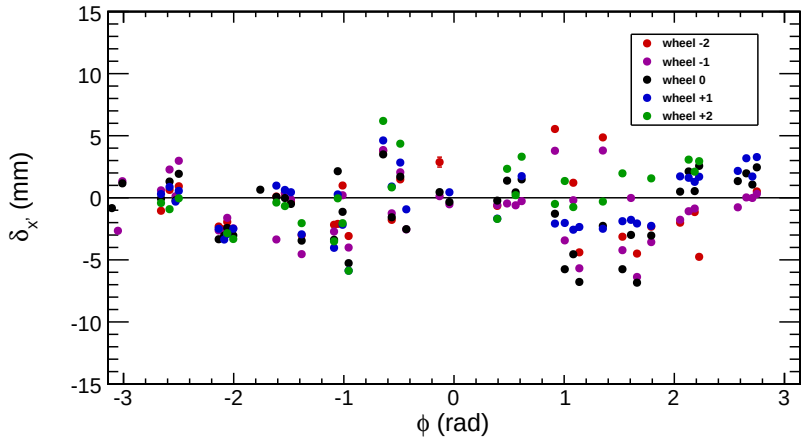
Compared to photogrammetry...

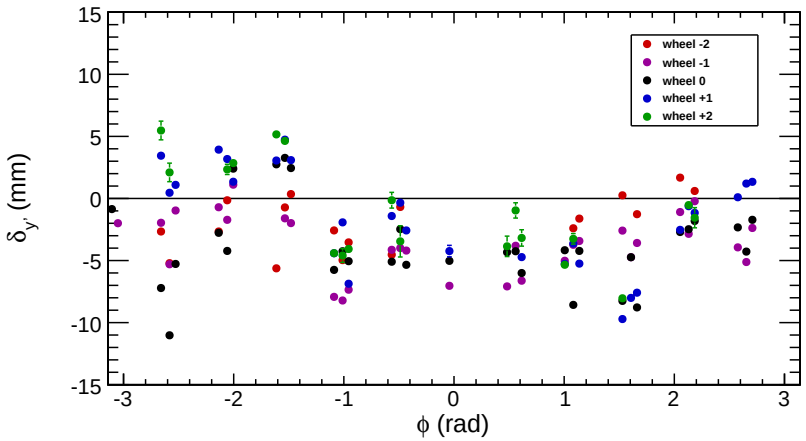


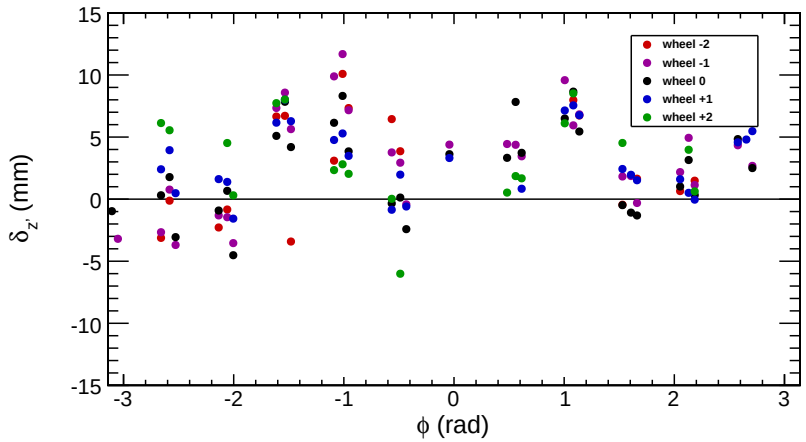


- Plotting differences between PG + cavern survey and track-based geometry
- Global adjustment:
  $\delta_x = 2.2$ mm,
  $\delta_y = 5.1$ mm,
  $\delta_{\phi_z} = 0.6$ mrad
- Not apples-to-apples:
  - cavern global coords, not tracker coords
  - different internal geometry? (Luca?)
  - $\frac{1}{10}$ track sample
- But PG vs. tracks is narrower than HW vs. tracks

Hardware vs. track-based



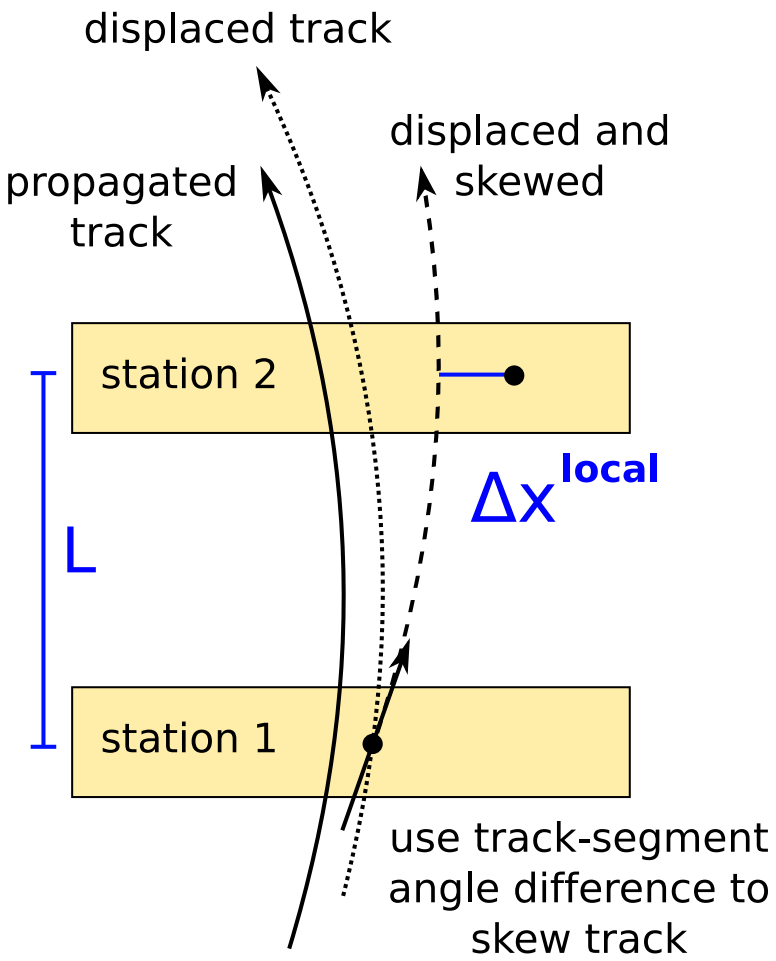




- Plotting differences between globally-adjusted hardware and track-based geometry
- Local x', y', and z' vs. ϕ (prime indicates consistent sign)
  - x': anti-clockwise $r\phi$
  - y': parallel to beamline, pointing west
  - z': radial, pointing inward
- Semi-regular patterns emerge from the differences: could indicate discrepancies in chamber center assumptions
  - especially sectors 8, 9, 10 ($-2.8 < \phi < -1.4$)

Segment differences (1)

- Standard segment-extrapolation test was unavailable this week, so I implemented a version with more realistic track-propagation



- Local angle difference is difference of residuals with respect to the propagated tracker track

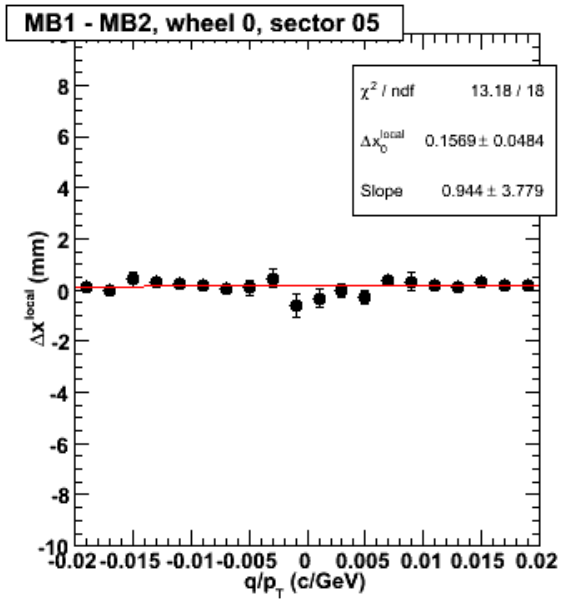
$$\Delta \frac{dx}{dz}^{\text{local}} = \Delta \frac{dx}{dz}_{\text{st.2}} - \Delta \frac{dx}{dz}_{\text{st.1}}$$

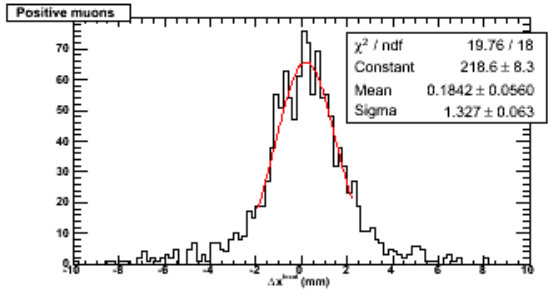
- Local position difference also needs to correct for segment direction by a linear transformation (see left)

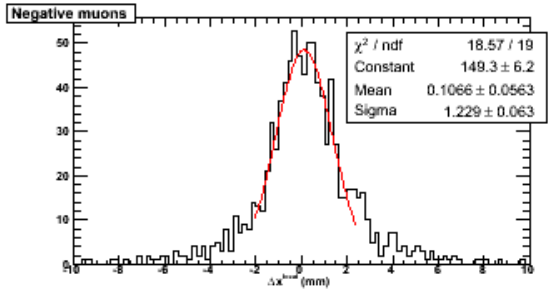
$$\Delta x^{\text{local}} = \Delta x_{\text{st.2}} - \Delta x_{\text{st.1}} - L \cdot \Delta \frac{dx}{dz}_{\text{st.1}}$$

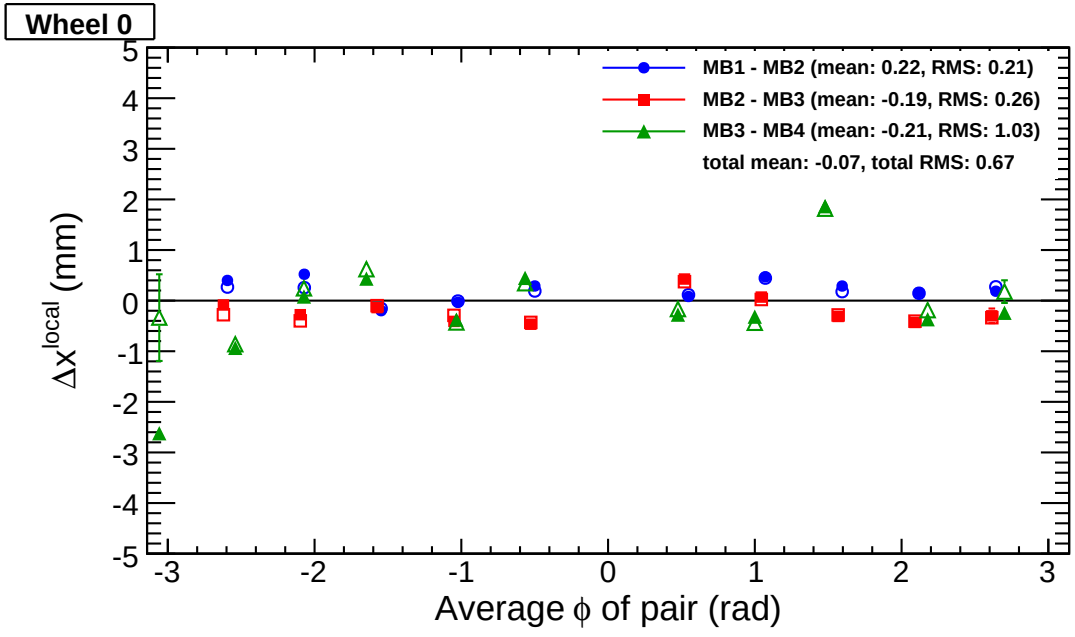
- In the limit of linear track propagation, this is exactly a linear segment extrapolation
- This is how Millepede applies track corrections to realistically-modelled tracks (small linear transforms)

Segment differences (2)







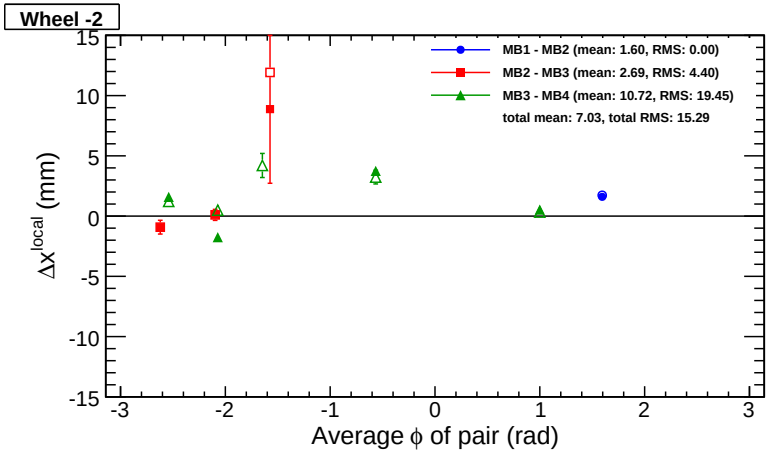


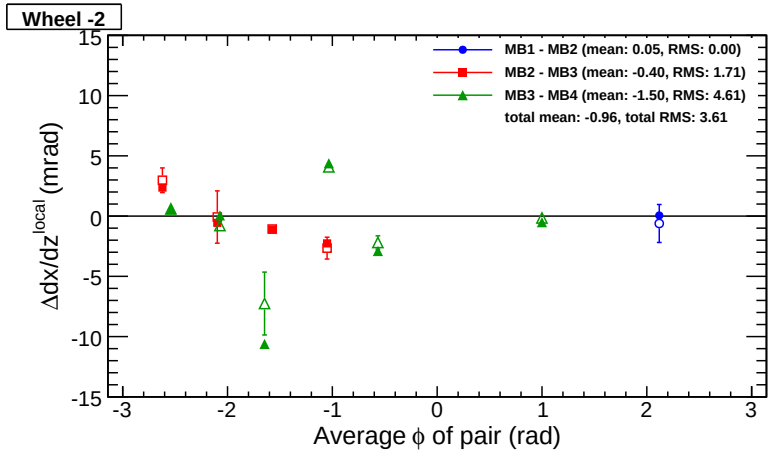
- Two fits: linear $q/p_T \to 0$ and Gaussian of positive and negative separately
  - linear $q/p_T \to 0$ results are *filled* circles, squares, and triangles
  - average of Gaussian fits are *hollow*
- 1.7–2.5× higher resolution in raw distributions and final results: RMS of stations 1–3 is 0.3 mm rather than 0.7 mm
- Reveals non-zero biases in alignment: $\mathcal{O}(0.2$ mm)

Segment differences: wheel −2

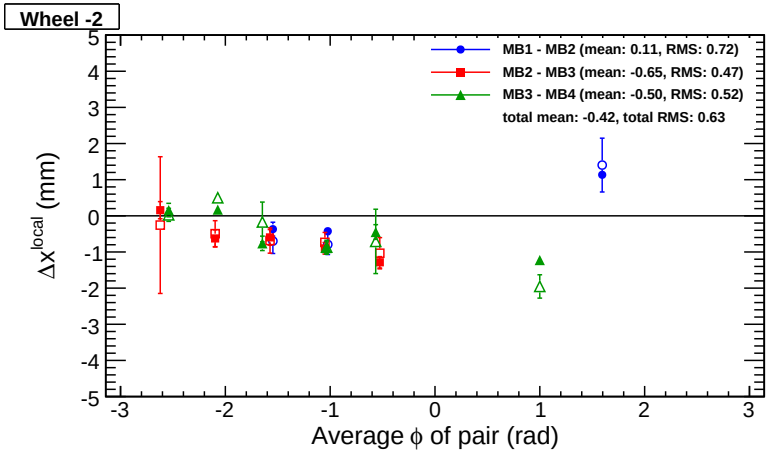
- A complete set of linear and Gaussian fits is in SegmentDifferences.pdf
- Careful of difference in vertical scales

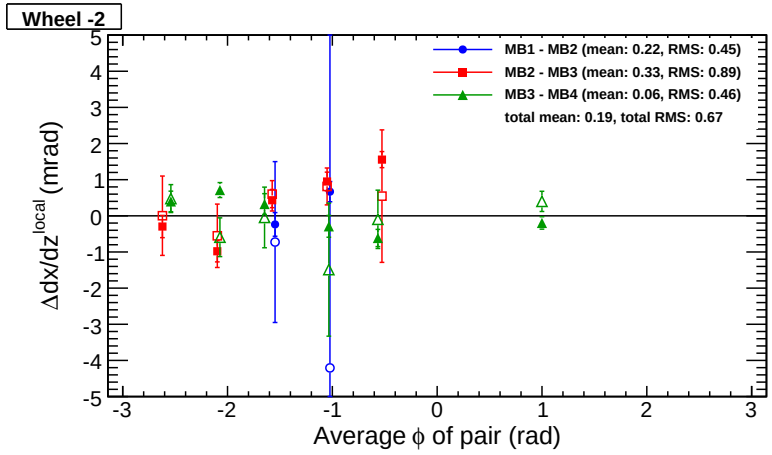
Globally-adjusted hardware geometry





Track-based geometry

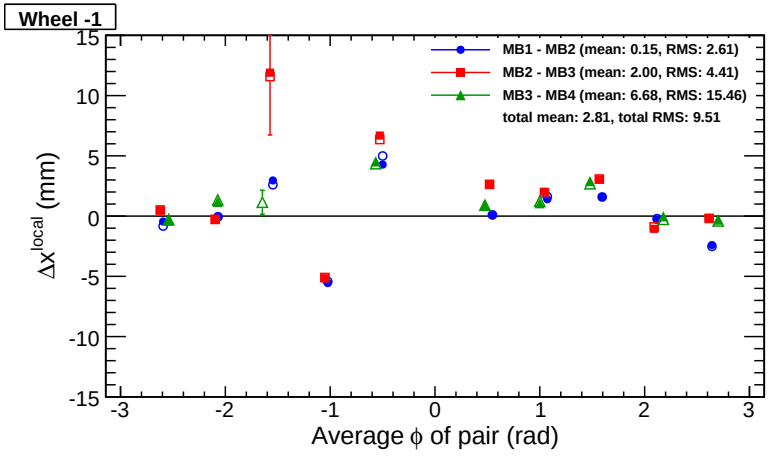


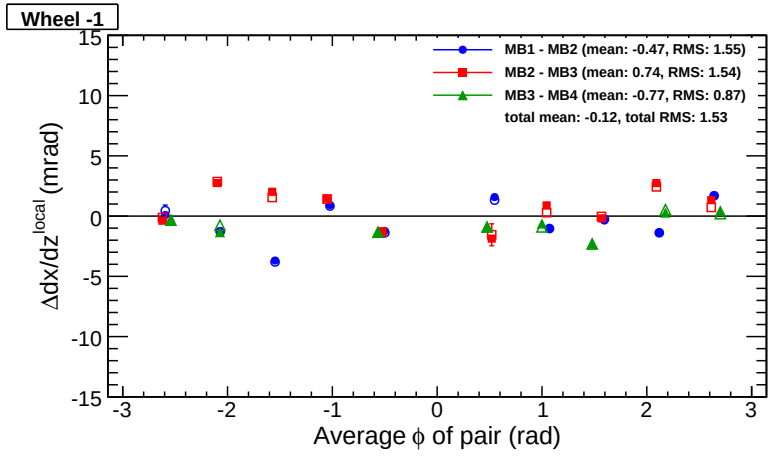


Segment differences: wheel −1

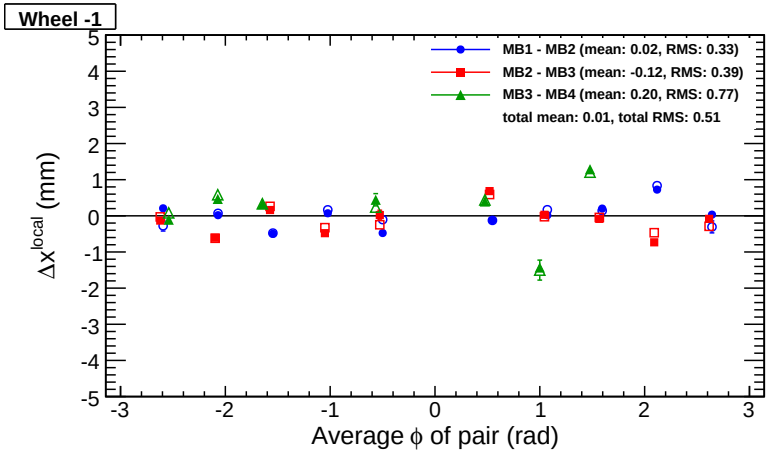
- A complete set of linear and Gaussian fits is in SegmentDifferences.pdf
- Careful of difference in vertical scales

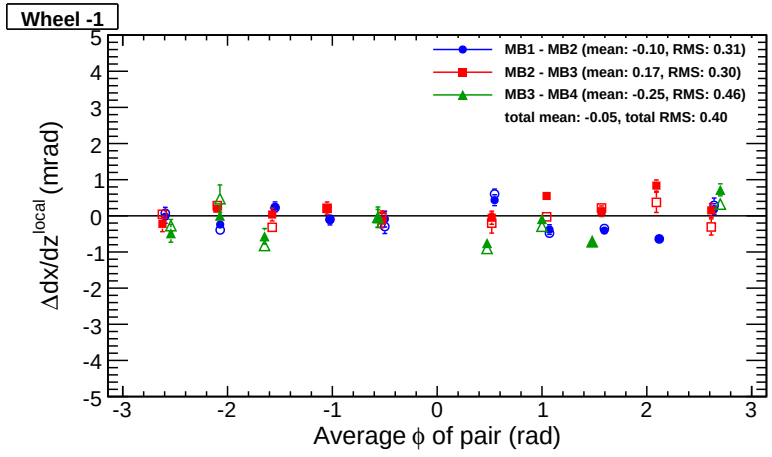
Globally-adjusted hardware geometry





Track-based geometry

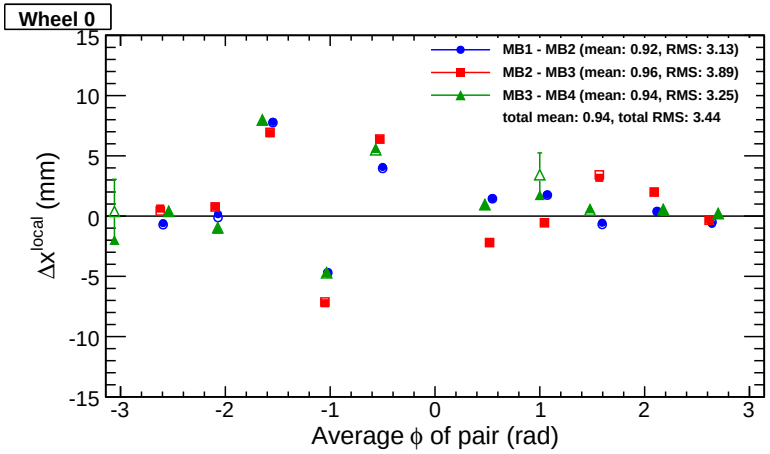


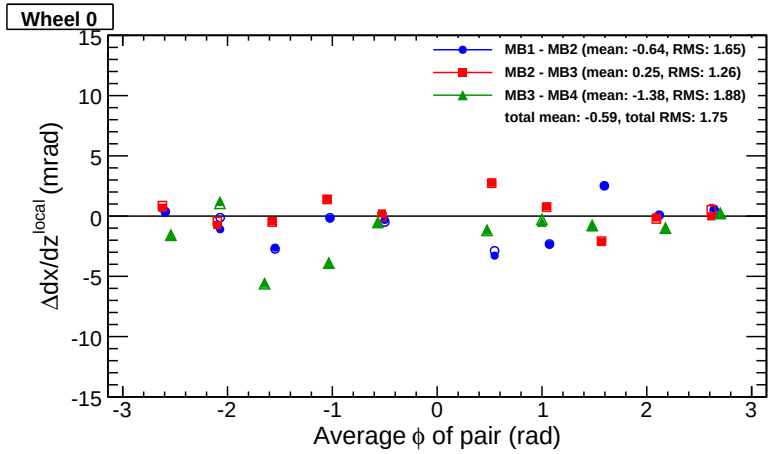


Segment differences: wheel 0

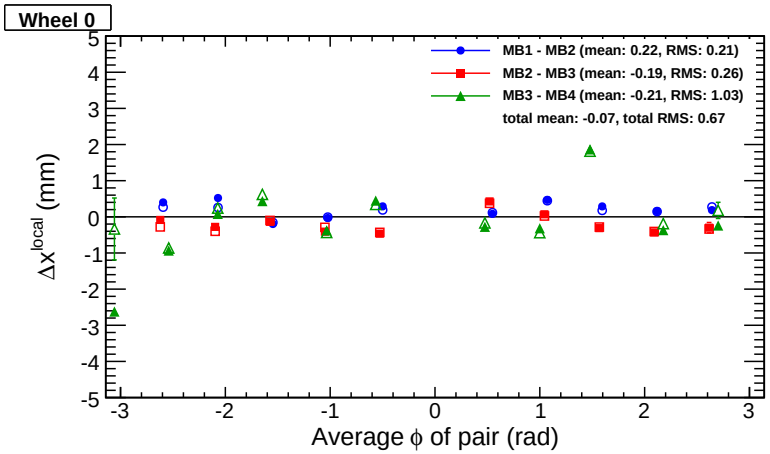
- A complete set of linear and Gaussian fits is in SegmentDifferences.pdf
- Careful of difference in vertical scales

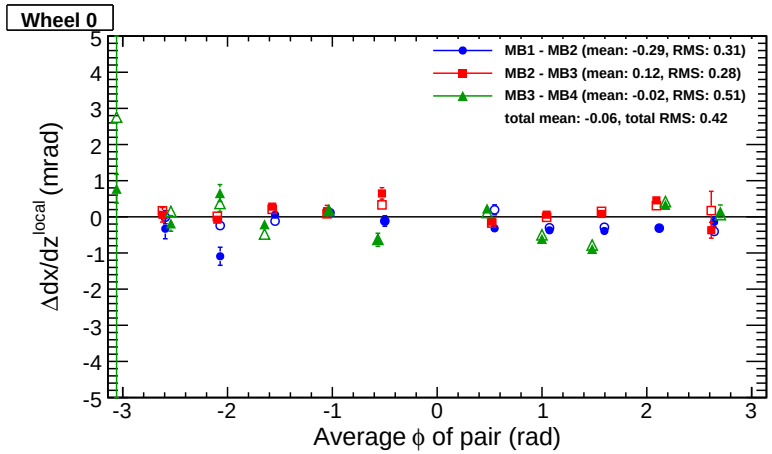
Globally-adjusted hardware geometry





Track-based geometry

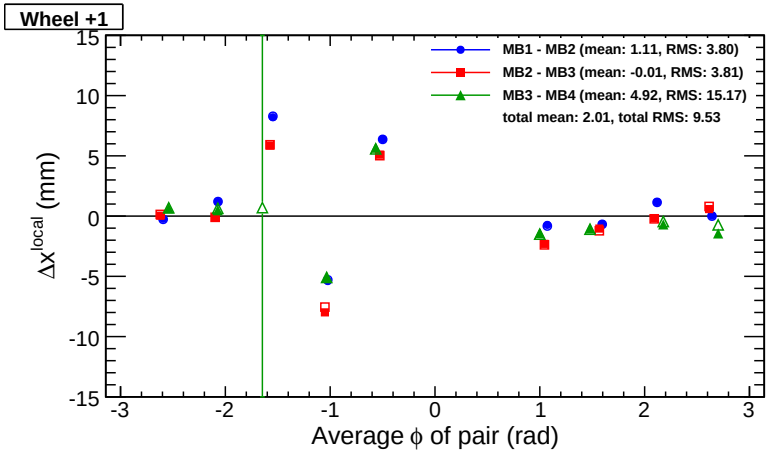


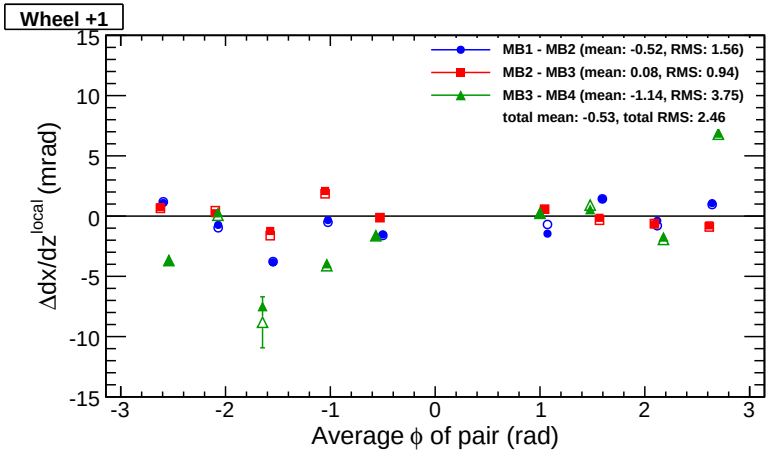


Segment differences: wheel +1

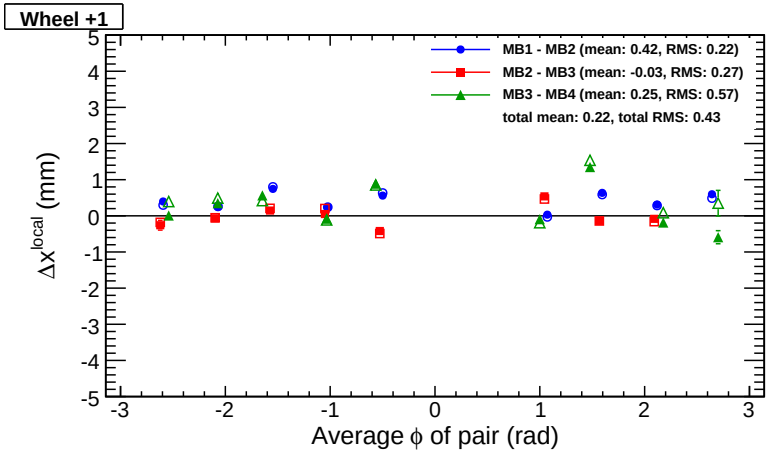
- A complete set of linear and Gaussian fits is in SegmentDifferences.pdf
- Careful of difference in vertical scales

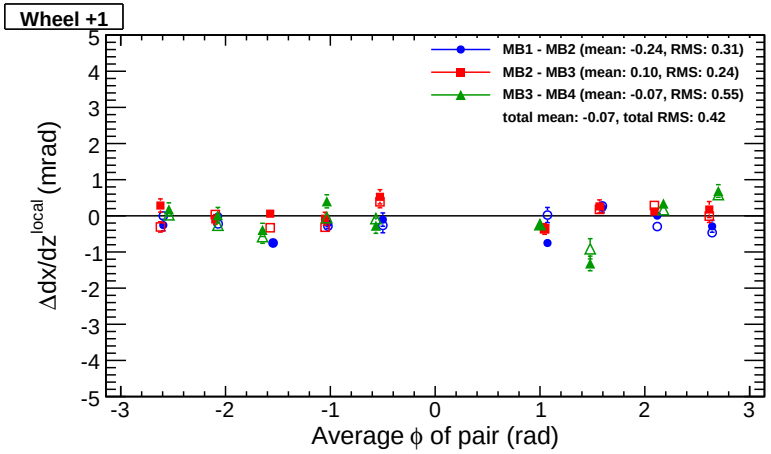
Globally-adjusted hardware geometry





Track-based geometry

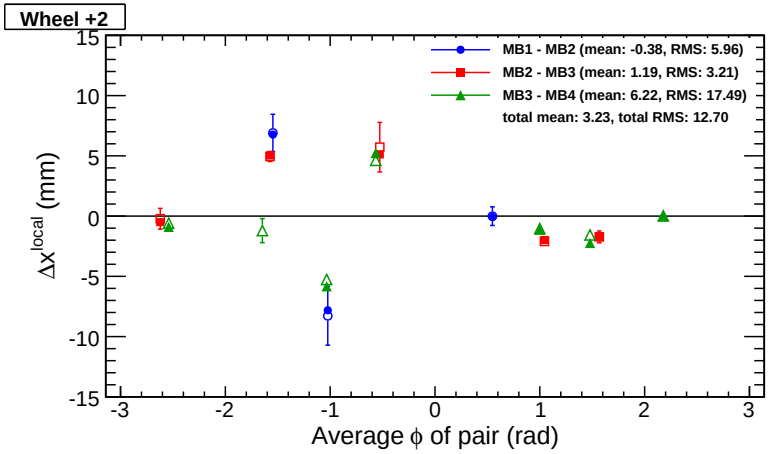


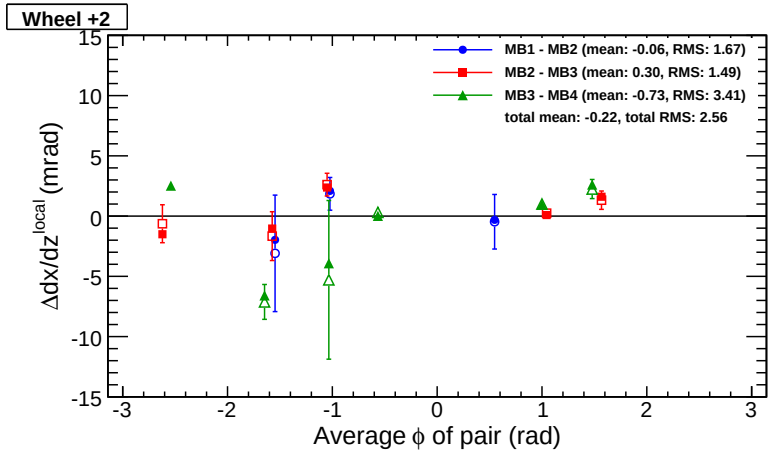


Segment differences: wheel +2

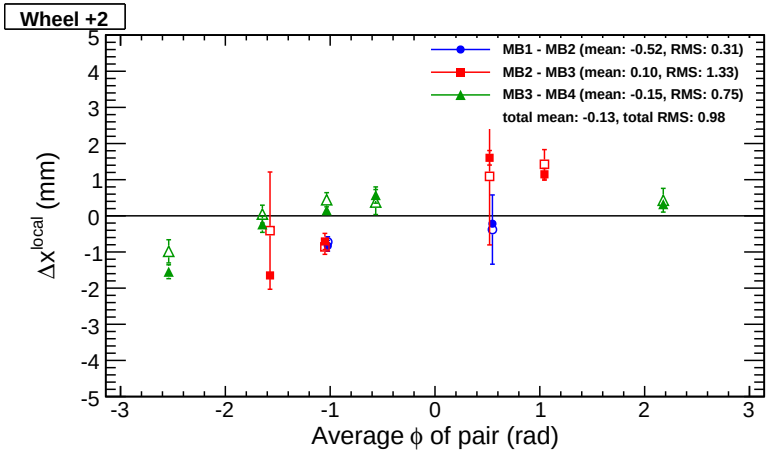
- A complete set of linear and Gaussian fits is in SegmentDifferences.pdf
- Careful of difference in vertical scales

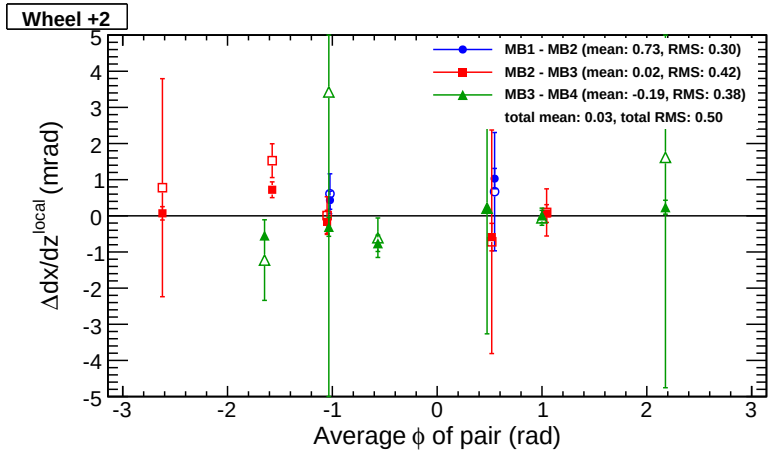
Globally-adjusted hardware geometry





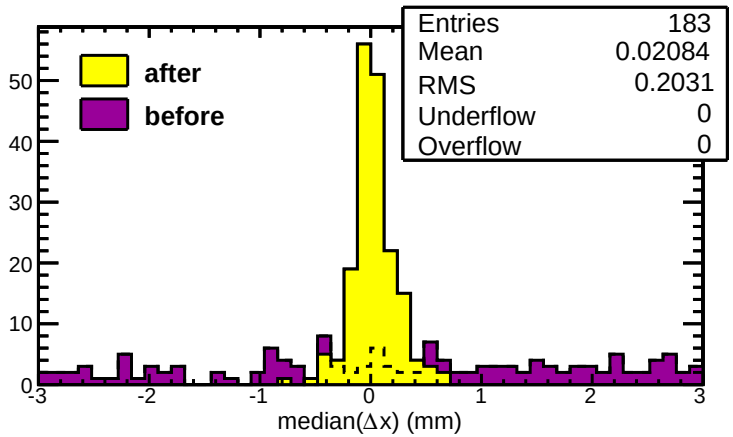
Track-based geometry

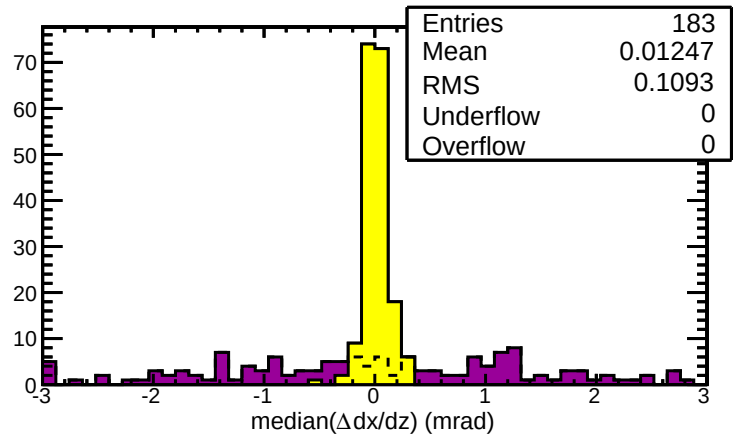


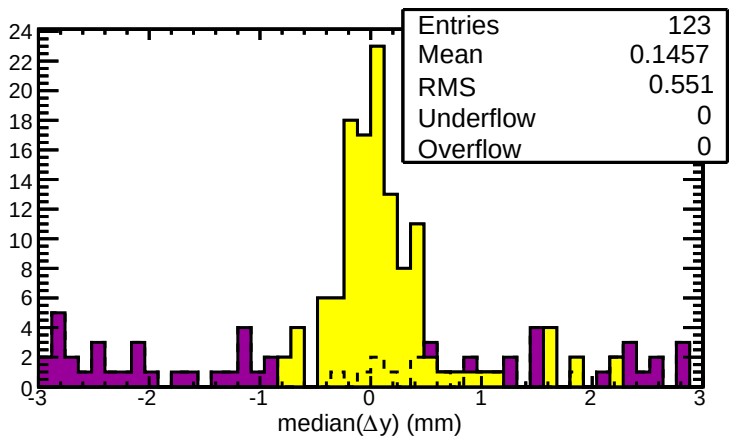


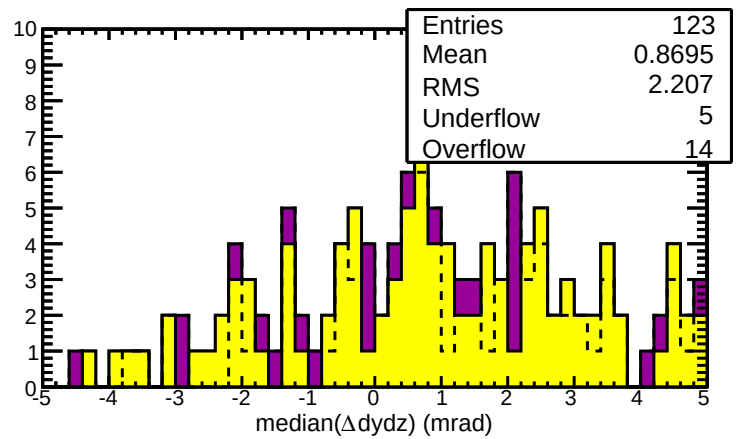
Distribution of medians (1)

- Each histogram entry is one chamber's median of residuals
  - tests self-consistency; median is a different way to be insensitive to residuals tails than the fitting method
- CRAFT-08 RMS Δx: 0.190 mm $\Delta\frac{dx}{dz}$: 0.085 mrad Δy: 0.166 mm $\Delta\frac{dy}{dz}$: 0.885 mrad; now we don't align $\Delta\frac{dy}{dz}$, which feeds into Δy



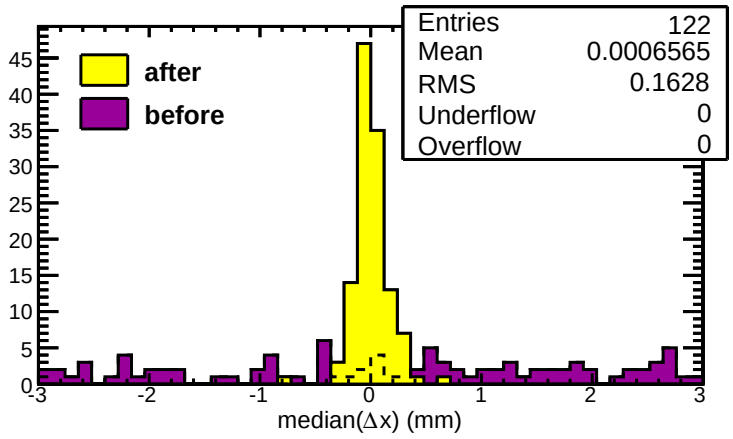


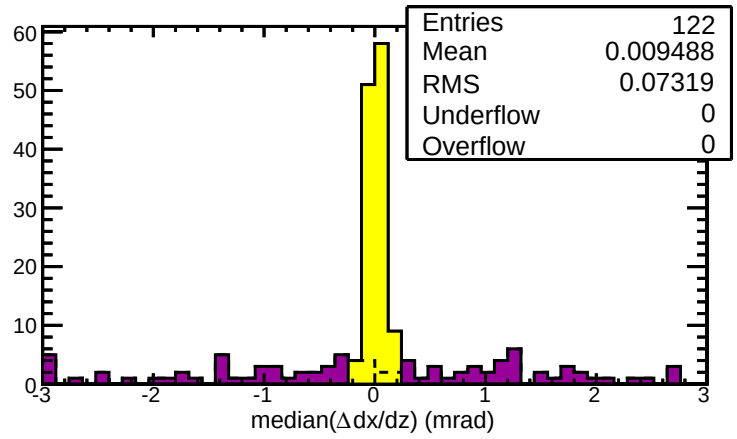


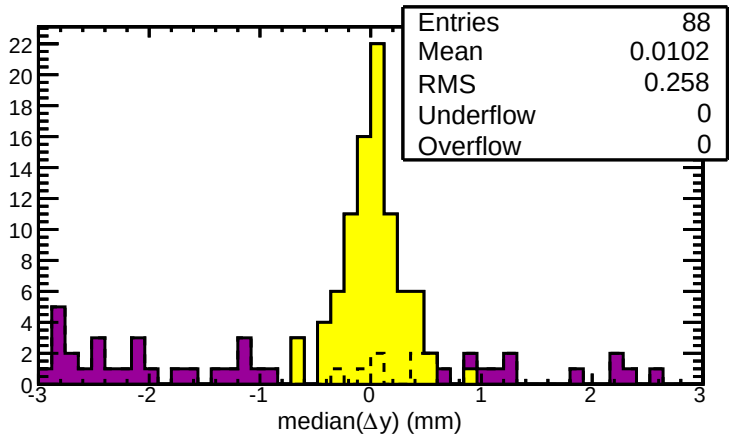


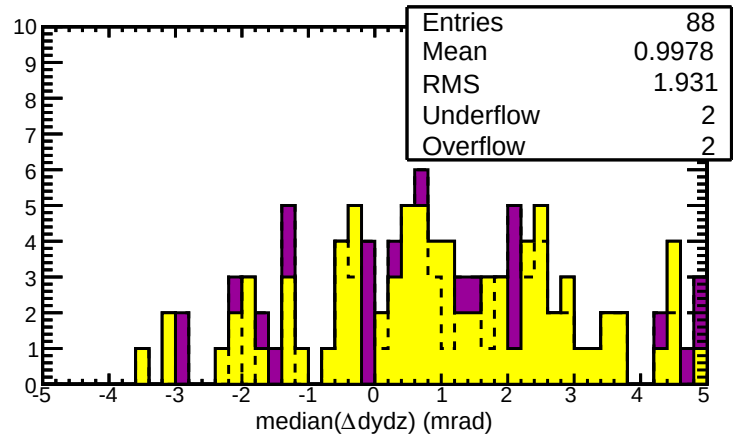
Distribution of medians (2)

- CRAFT-08 RMS Δx: 0.190 mm $\Delta\frac{dx}{dz}$: 0.085 mrad Δy: 0.166 mm $\Delta\frac{dy}{dz}$: 0.885 mrad; now we don't align $\Delta\frac{dy}{dz}$, which feeds into Δy
- Now also restricting to the set of CRAFT-08 chambers (wheel -1, 0, $+1$, all sectors except 1 and 7)

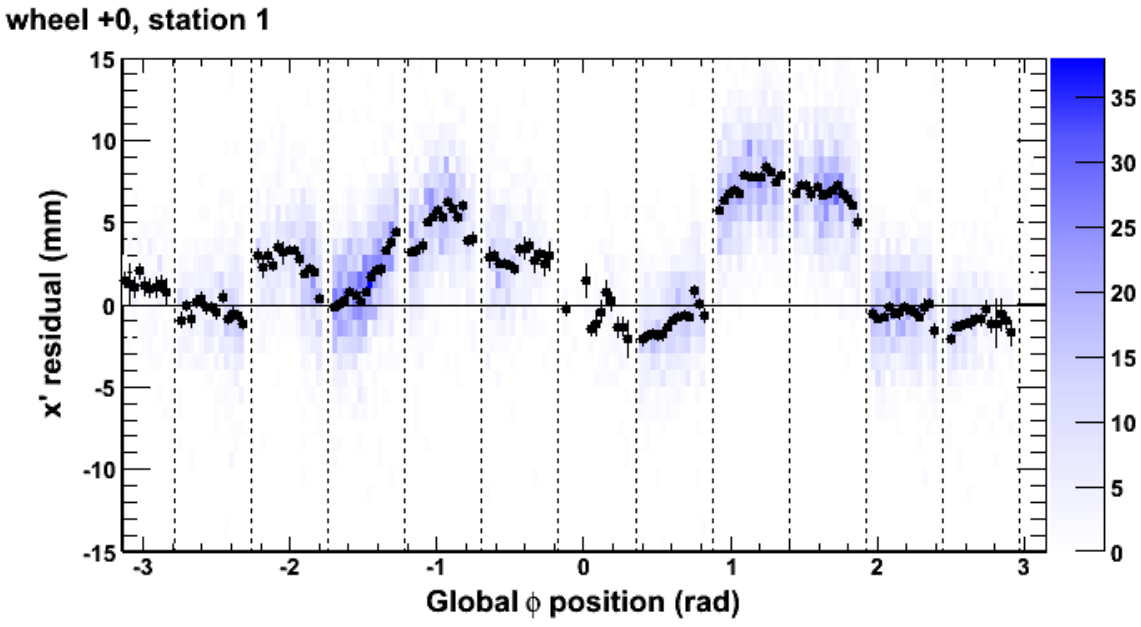


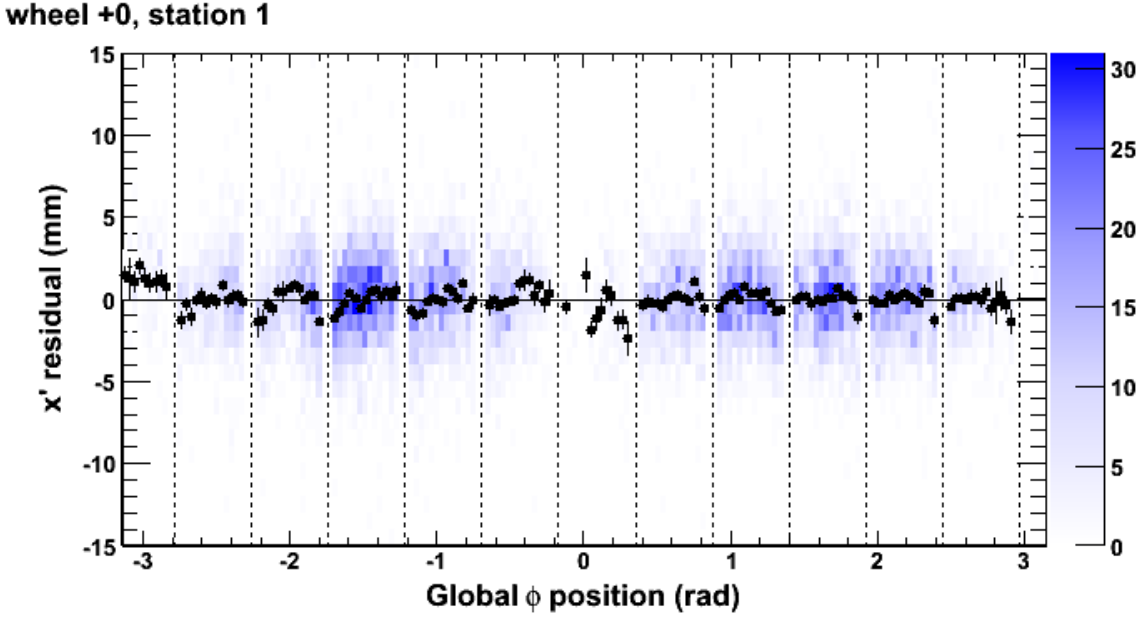






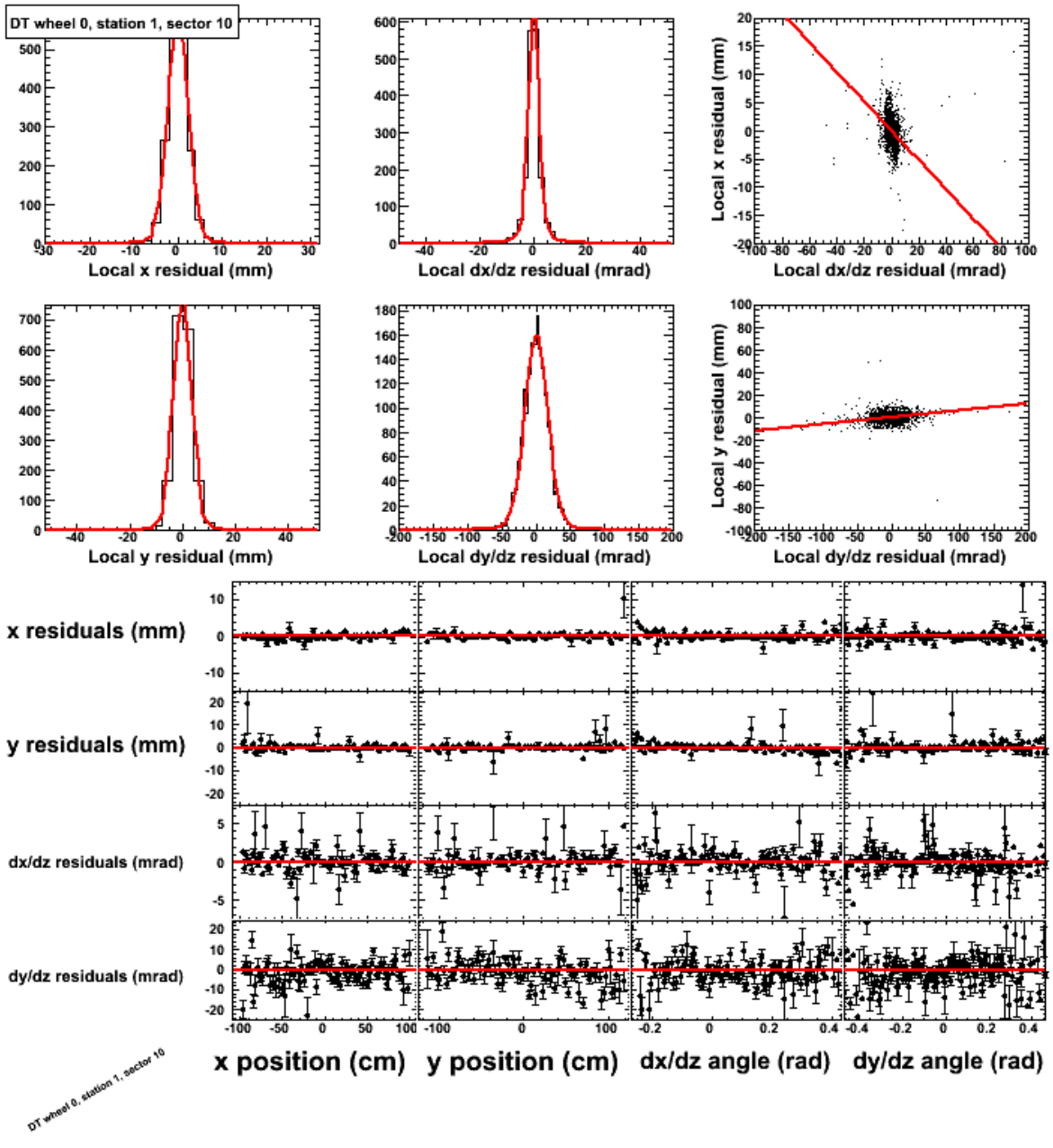
Map plots





- Residuals as a function of ϕ, z with chamber boundaries as dashed lines, color scale is 2-D plot, points are profile
- Top: globally-adjusted hardware geometry, bottom: track-based
- If the discrepancy were due to distortions in the track source or propagation, it wouldn't change abruptly at chamber boundaries
- Complete set in MapPlots.pdf

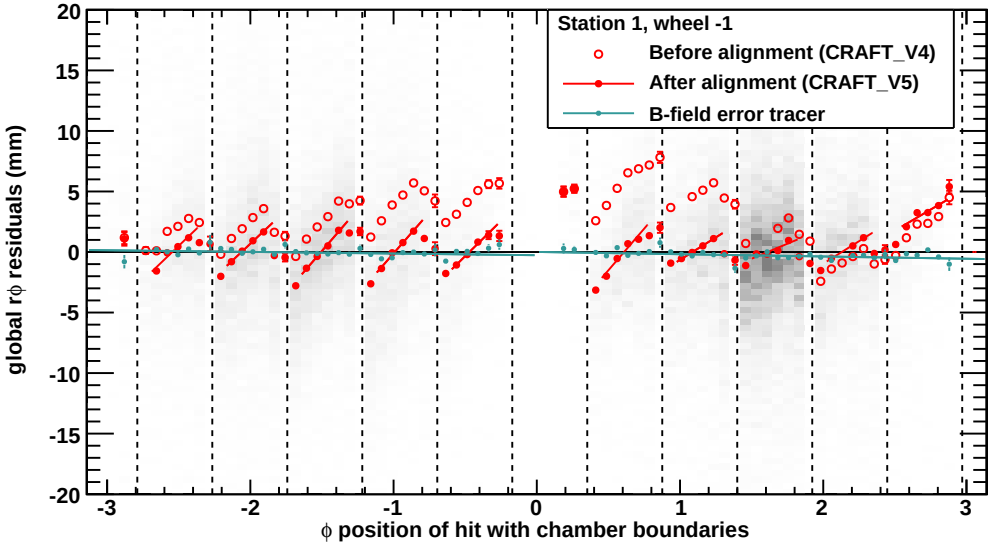
Fit plots

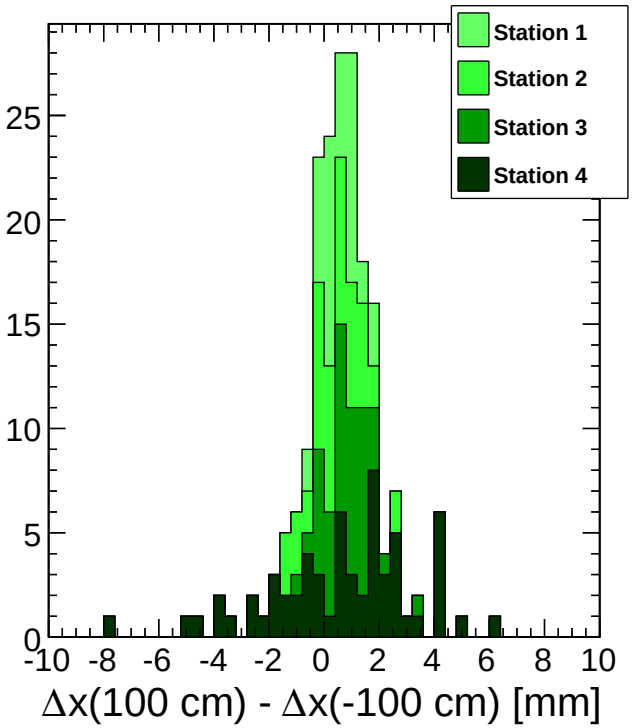


- Overlay of fit function on residuals projections (after alignment)
- Bell-curves are Gaussians + tails, should be centered (except unaligned $\Delta\frac{dy}{dz}$)
- Scatter plots are position-angle correlations, should *not* be flat (propagation)
- Points with error bars are residuals versus everything, should be flat (geometric)
- Complete set in FitFunctions.pdf

Sawtooth effect?

- Sawtooth effect is not very evident, scanning through map and fit plots
- Below is an old example plot showing the sawtooth:





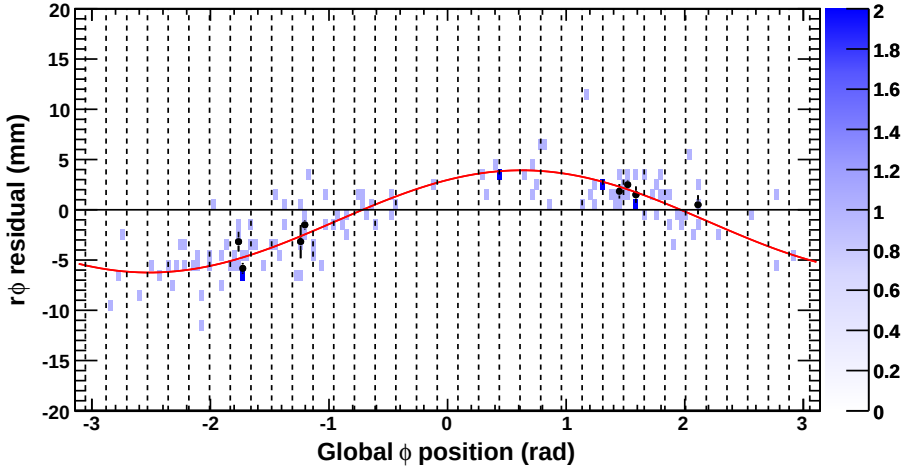
- ∼5 mm difference in Δx residuals from $x = -100$ to $+100$ cm
- How much is it now?
  Fit all Δx vs. x distributions,
  evaluate at ± 100 cm (new histogram on right)
- Less than half as large, and not all in the same direction
- Maybe due to calibration, and that was improved? (a guess)

CSC alignment parameters

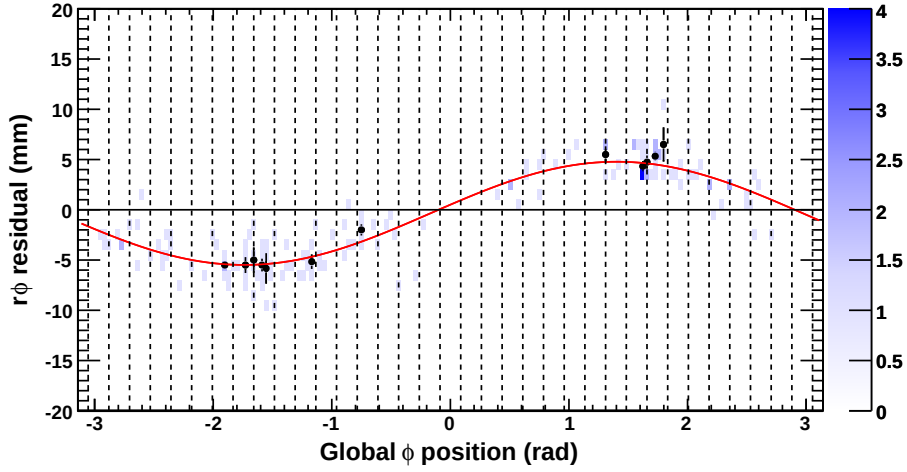
- Sequence:
  1. 2009 hardware alignment (δ_z and δ_{ϕ_x})
  2. adjust each ring's global δ_x, δ_y, δ_{ϕ_z} by hand
- Where each final aligned position/orientation comes from:
  - all internal layers relative to chamber center: ideal
  - all chambers δ_{ϕ_x} and δ_z: (1) hardware
  - all chambers δ_x, δ_y, δ_{ϕ_z}: (2) ring adjustment
- Track-based alignment parameters
  - Dataset: `/Cosmics/CRAFT09-CSCSkim_BFieldStudies-CRAFT09_R_V4_CosmicsSeq_v1/RAW-RECO`
  - Run range: 109011–109624 (tracker "peak mode")
  - Release: CMSSW_3_2_7
  - GlobalTag: CRAFT09_R_V4::All
  - Tracks: $100 < p_T < 200$ GeV, #tracker hits ≥ 15, tracker $\chi^2/\text{ndf} < 10$, no rejection of TID/TEC
  - No special correction for $\vec{B}(\vec{x})$, dE/dx
  - Alignment performed by fitting map plots
- Note: statistical errors in individual-chamber alignments are unacceptably high: 1 mrad in ϕ_y; that's why they were only collectively aligned
- This procedure compliments the beam-halo procedure well (which aligns individual chambers, but not the rings relative to the tracker)

Ring fits (1/8)

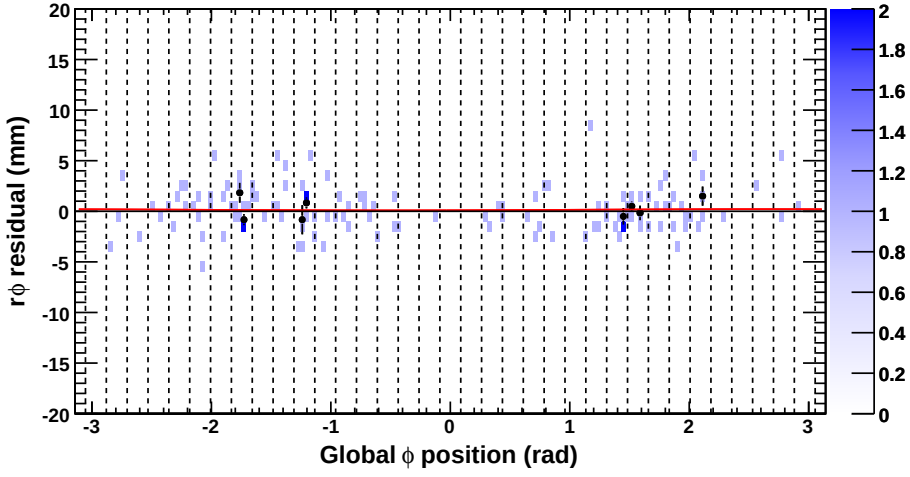
ME-1/1 before ring alignment



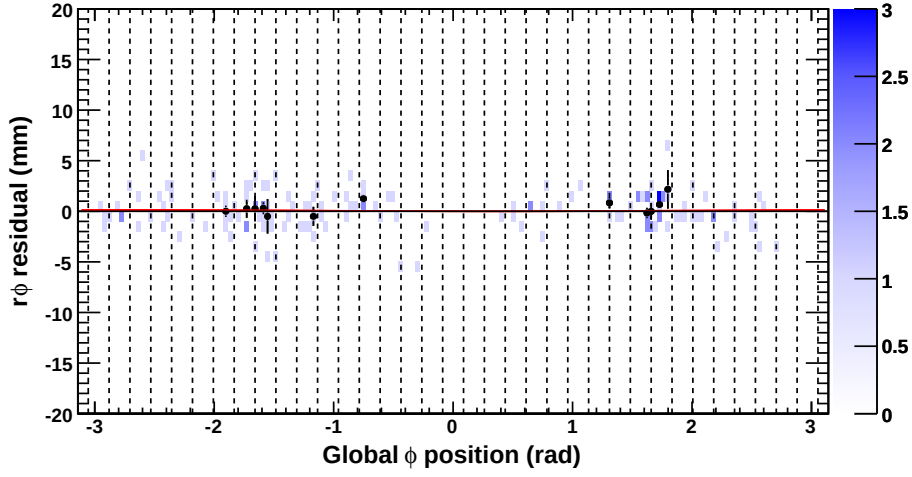
ME+1/1 before ring alignment



ME-1/1 after ring alignment

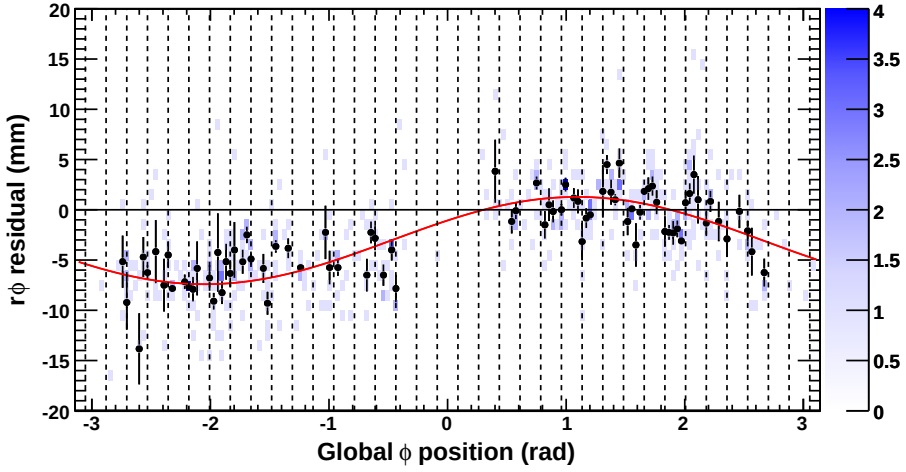


ME+1/1 after ring alignment

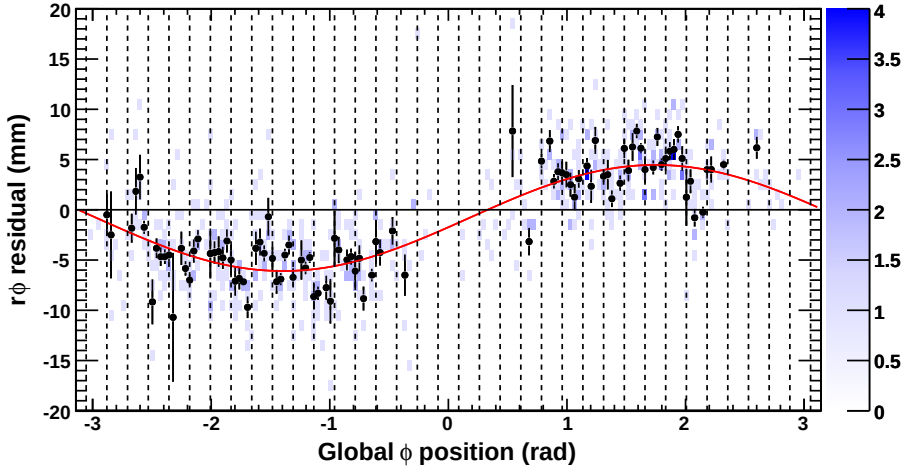


Ring fits (2/8)

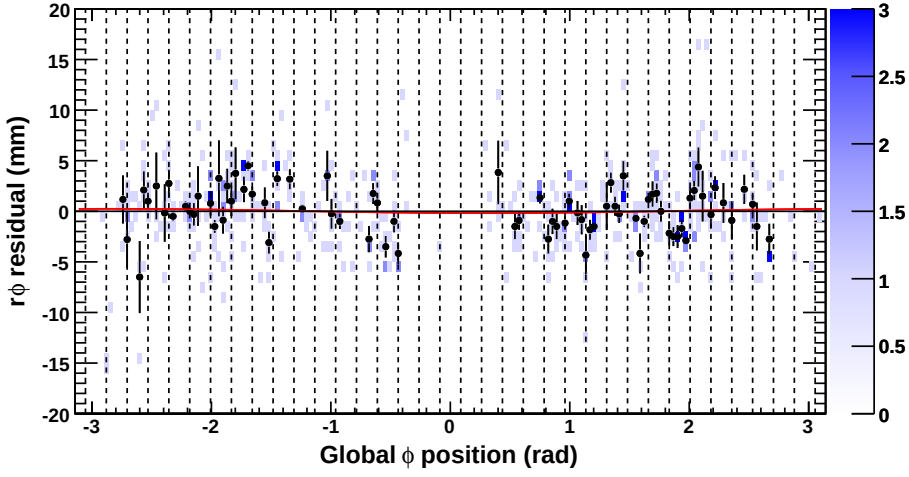
ME-1/2 before ring alignment



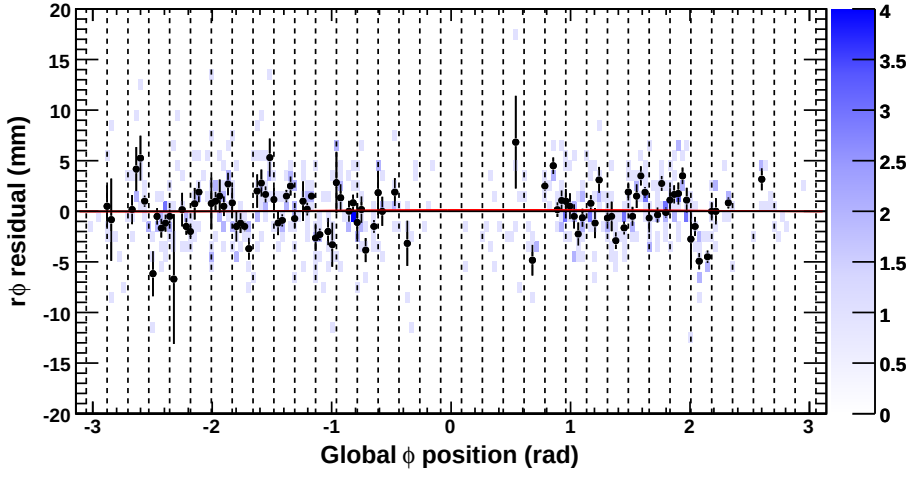
ME+1/2 before ring alignment



ME-1/2 after ring alignment

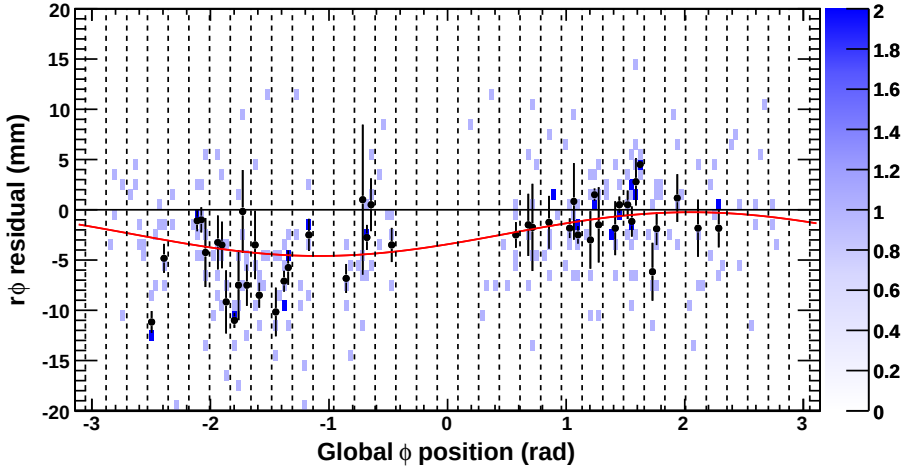


ME+1/2 after ring alignment

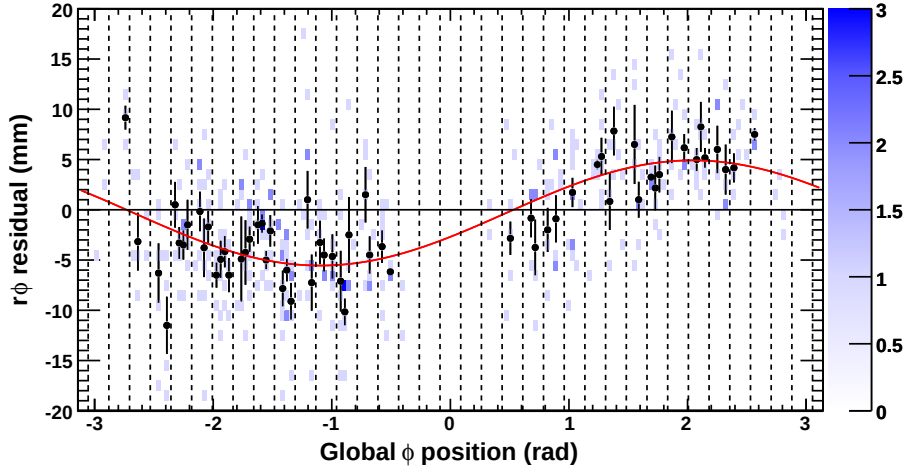


Ring fits (3/8)

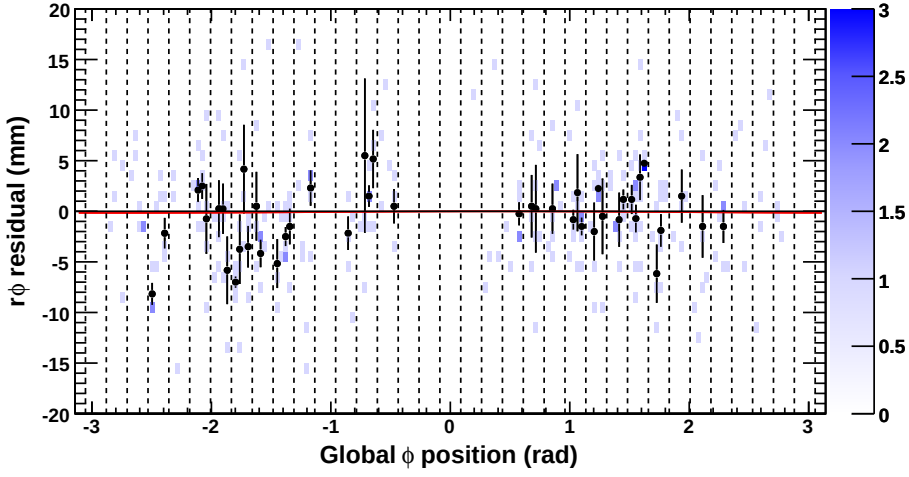
ME-1/3 before ring alignment



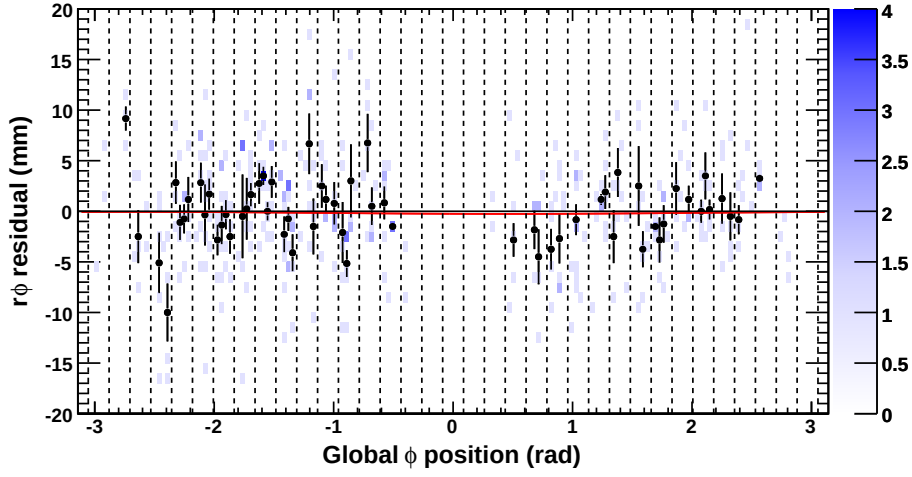
ME+1/3 before ring alignment



ME-1/3 after ring alignment

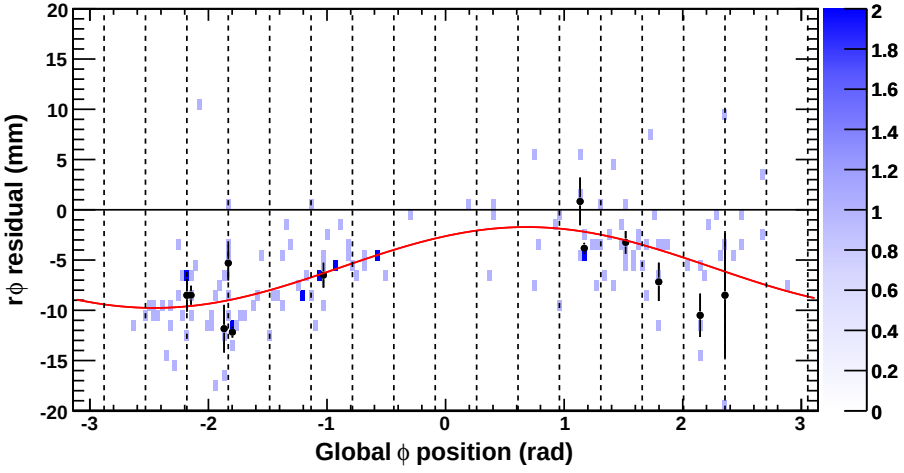


ME+1/3 after ring alignment

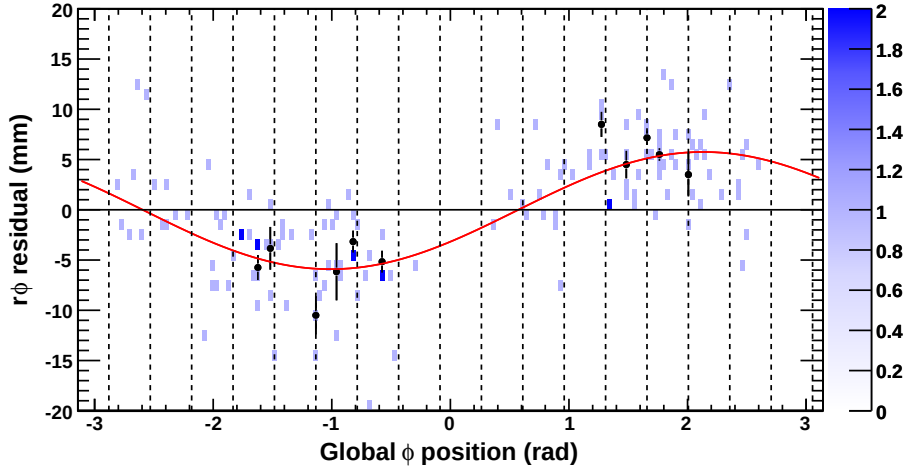


Ring fits (4/8)

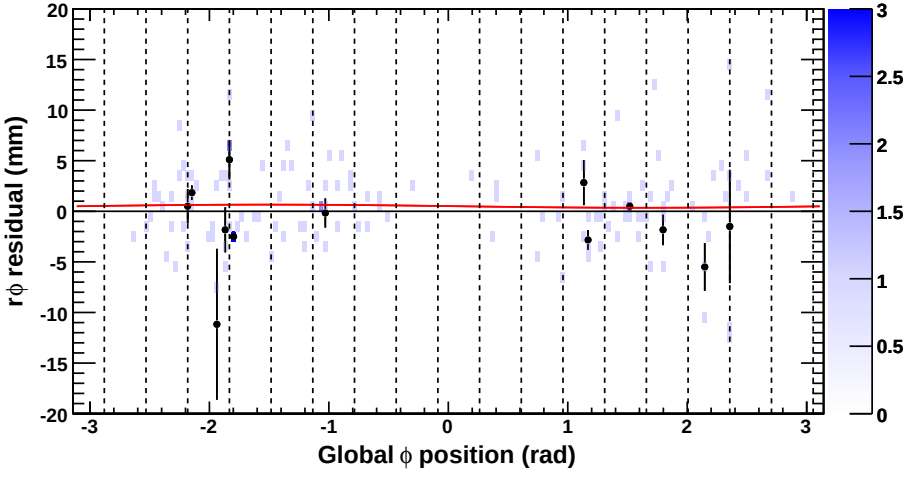
ME-2/1 before ring alignment



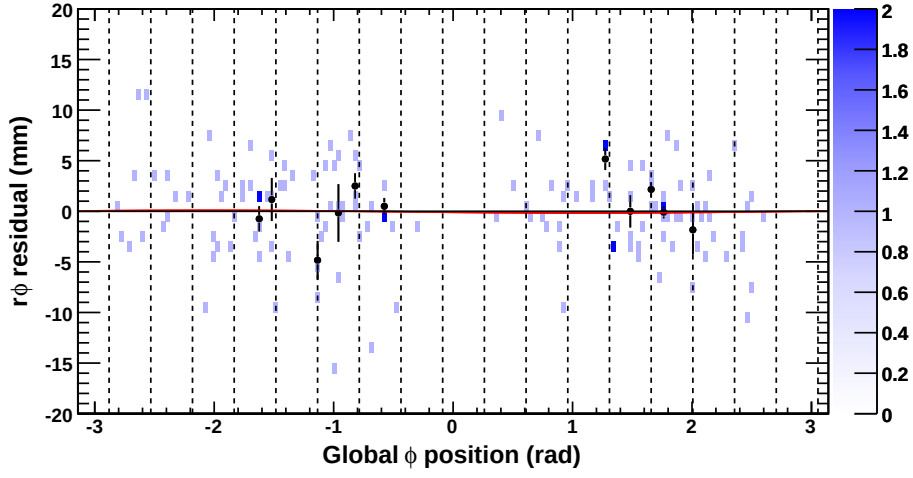
ME+2/1 before ring alignment



ME-2/1 after ring alignment

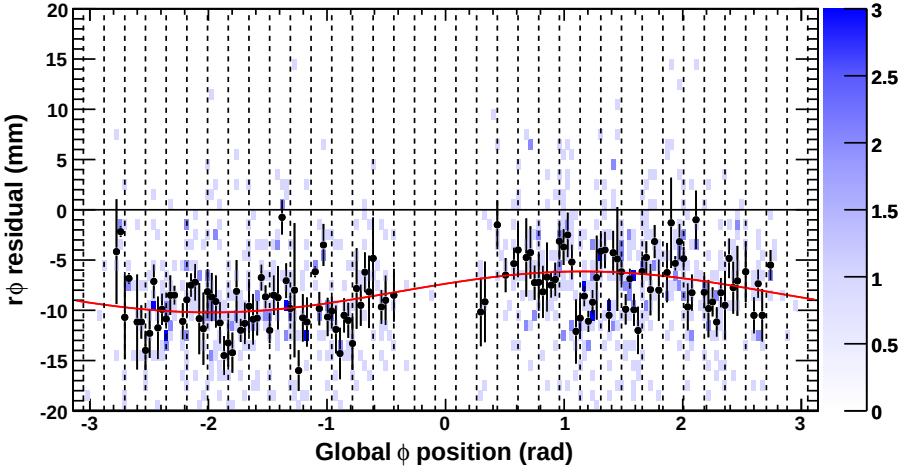


ME+2/1 after ring alignment

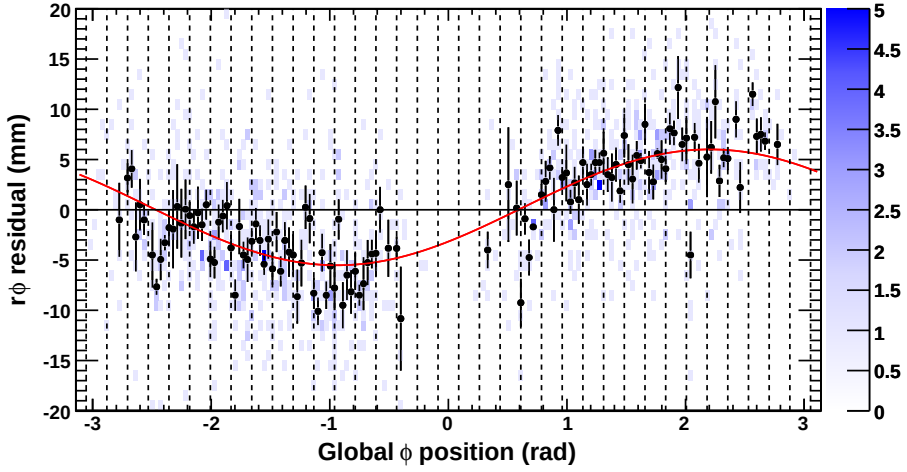


Ring fits (5/8)

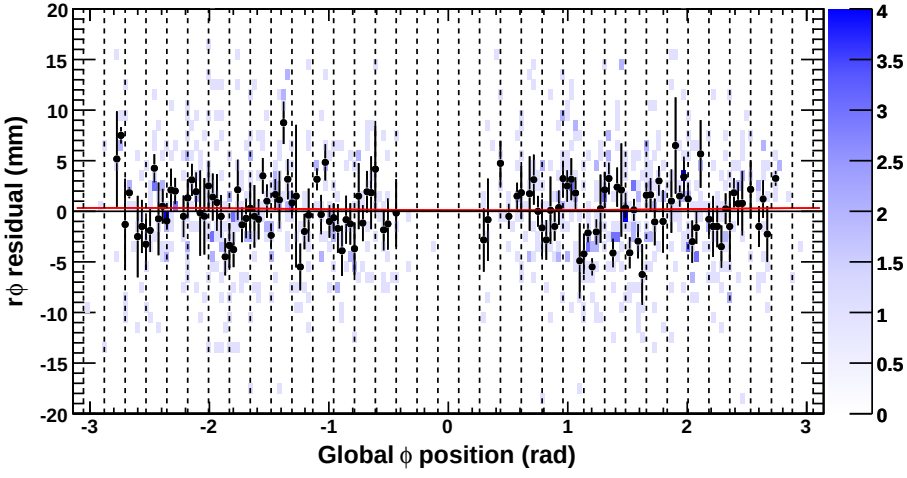
ME-2/2 before ring alignment



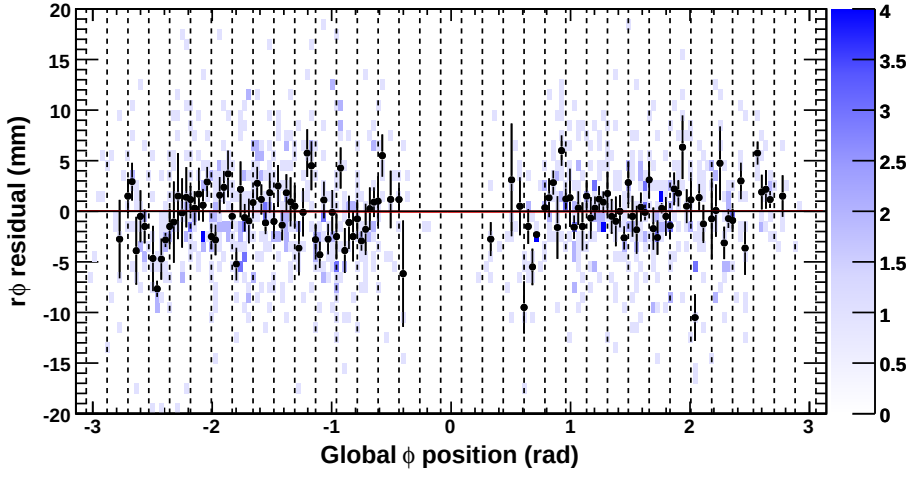
ME+2/2 before ring alignment



ME-2/2 after ring alignment

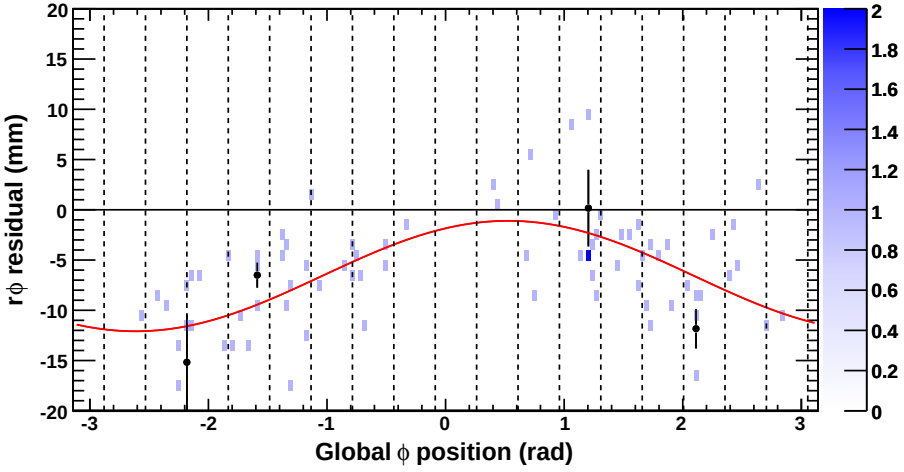


ME+2/2 after ring alignment

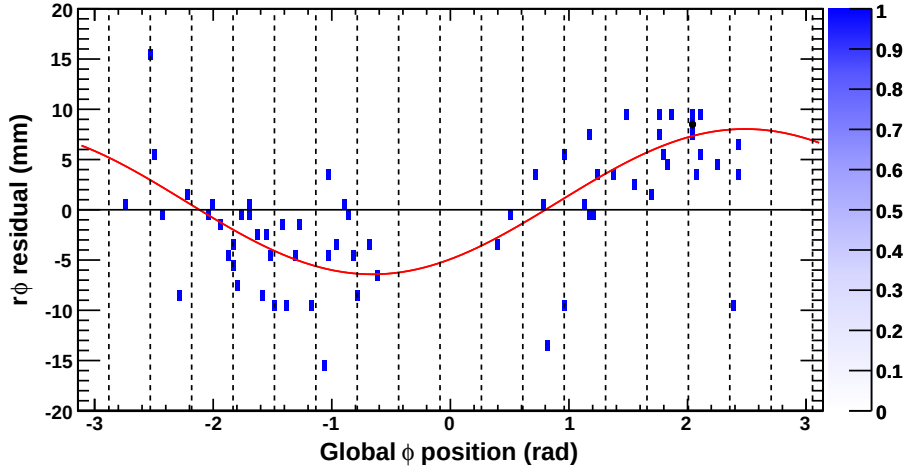


Ring fits (6/8)

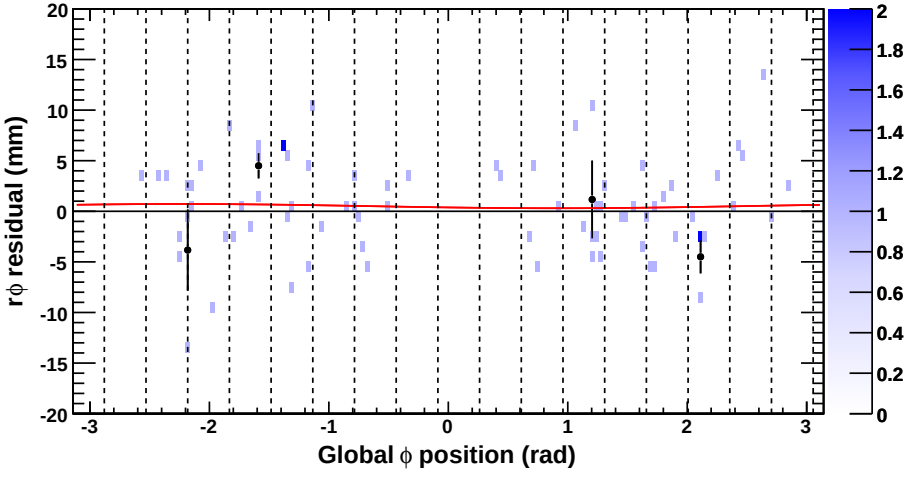
ME-3/1 before ring alignment



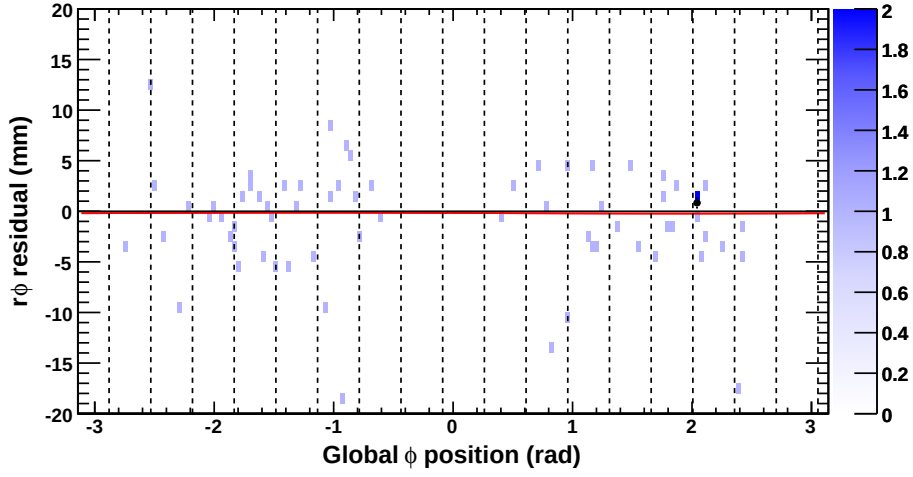
ME+3/1 before ring alignment



ME-3/1 after ring alignment

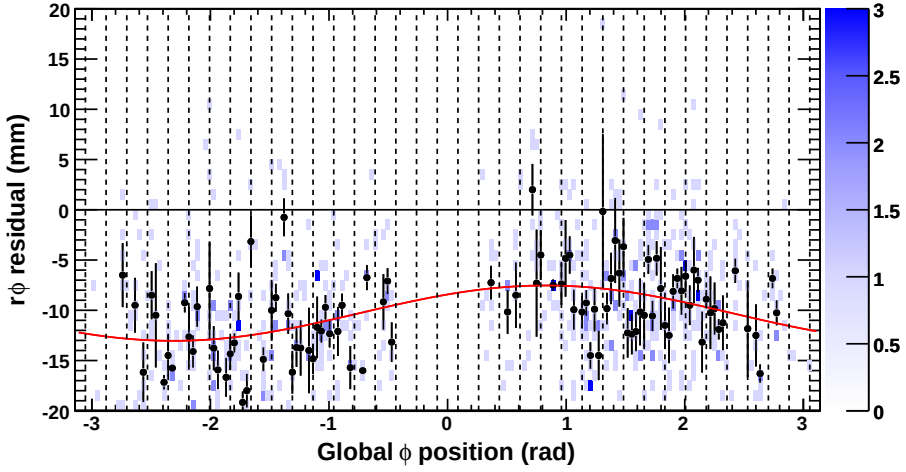


ME+3/1 after ring alignment

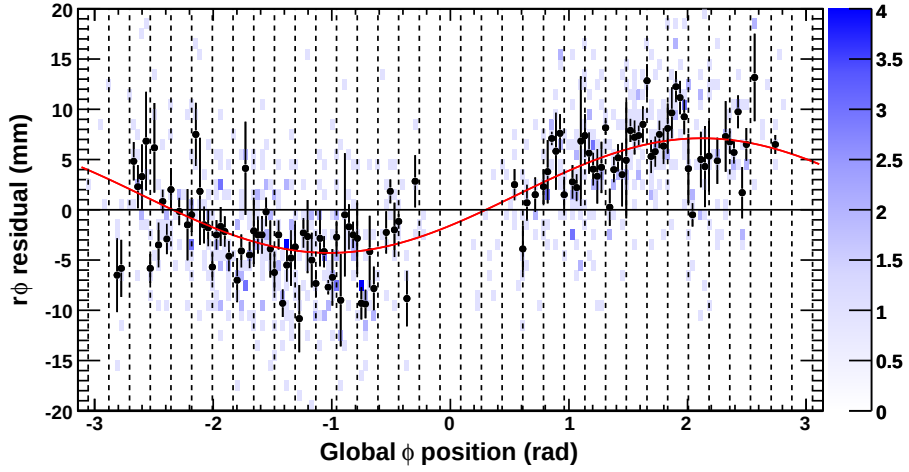


Ring fits (7/8)

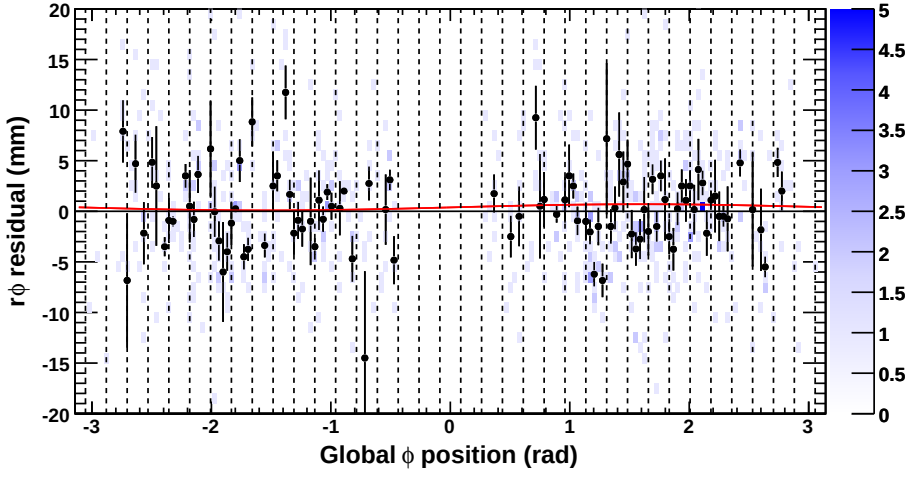
ME-3/2 before ring alignment



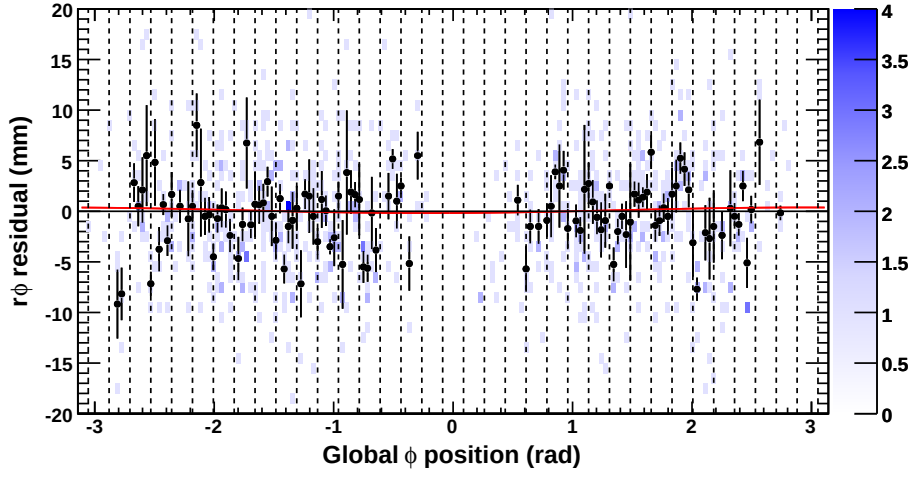
ME+3/2 before ring alignment



ME-3/2 after ring alignment

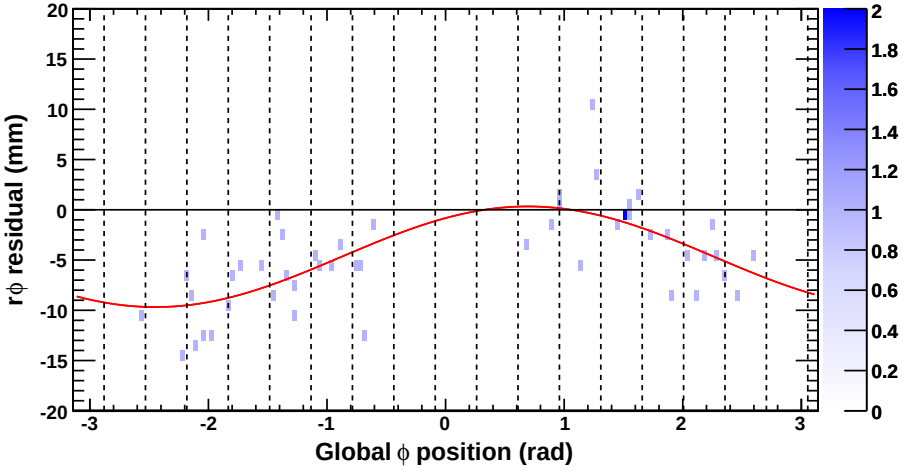


ME+3/2 after ring alignment

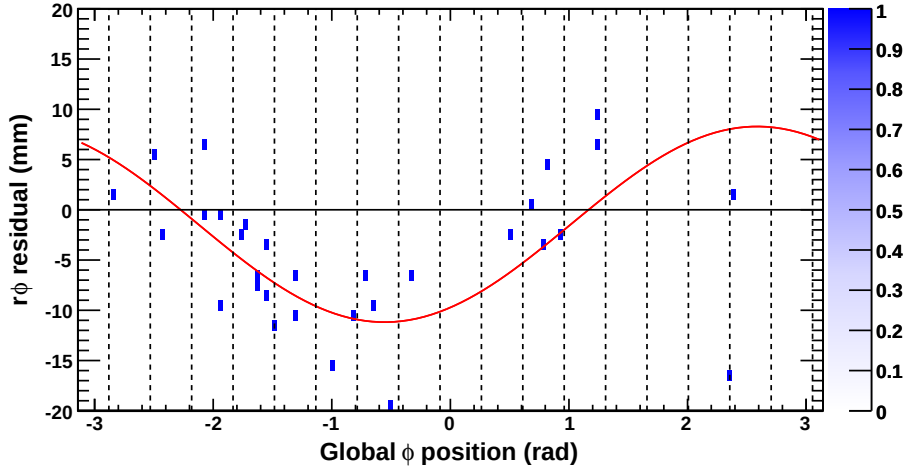


Ring fits (8/8)

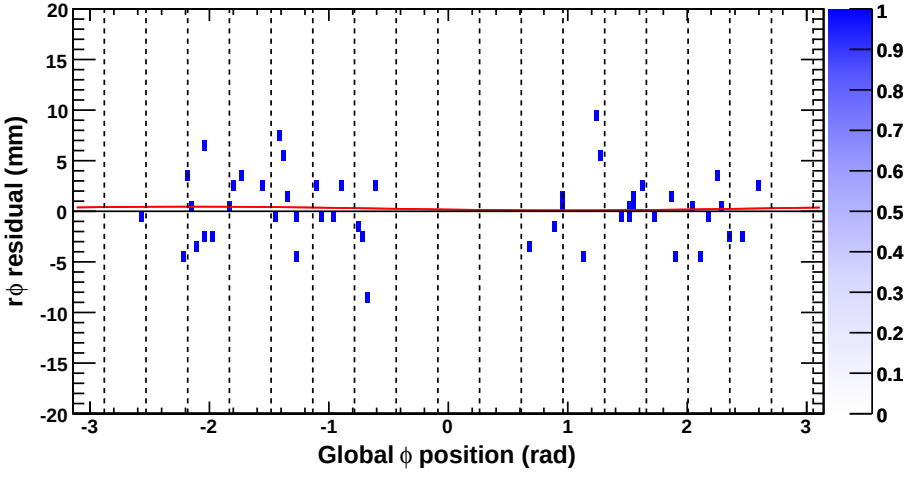
ME-4/1 before ring alignment



ME+4/1 before ring alignment



ME-4/1 after ring alignment



ME+4/1 after ring alignment

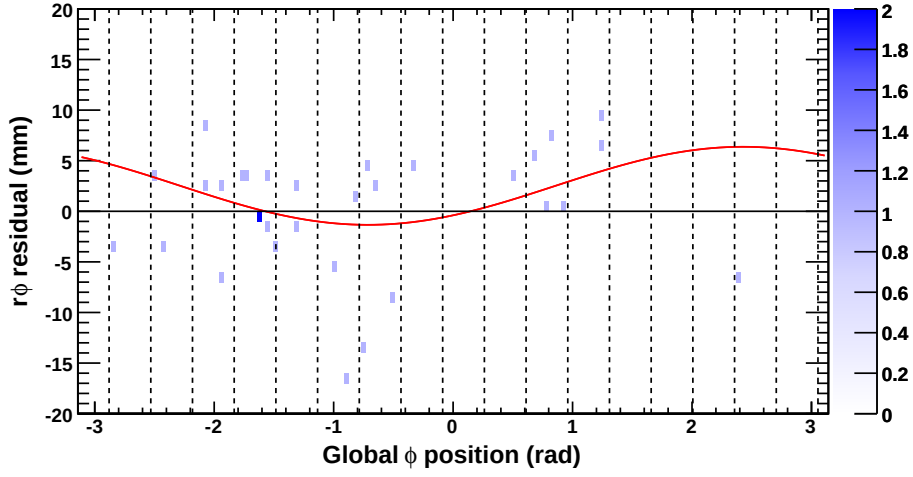
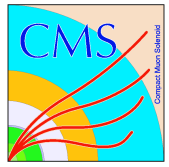


Table of ring corrections



- Grouped items are physically connected to the same disk; values are correlated but not exactly equal within fitting errors
- Large χ^2/ndf expected from incomplete chamber alignment

ring	δ_x (mm)	δ_y (mm)	δ_{ϕ_z} (mrad)	χ^2/ndf
ME−4/1	3.20 ± 0.17	−3.85 ± 0.29	1.78 ± 0.05	12.7426
ME−3/2	2.03 ± 0.05	−1.86 ± 0.08	1.95 ± 0.01	52.4465
ME−3/1	2.77 ± 0.13	−4.75 ± 0.21	2.61 ± 0.04	24.2564
ME−2/2	1.87 ± 0.05	−0.82 ± 0.07	1.55 ± 0.01	41.8597
ME−2/1	2.54 ± 0.10	−3.12 ± 0.17	2.37 ± 0.04	27.4691
ME−1/3	1.93 ± 0.08	1.01 ± 0.12	0.41 ± 0.01	45.7221
ME−1/2	3.86 ± 0.06	−2.00 ± 0.09	0.83 ± 0.01	17.4924
ME−1/1	2.97 ± 0.11	−4.13 ± 0.17	0.64 ± 0.05	9.08853
ME+1/1	5.06 ± 0.11	−0.86 ± 0.16	0.19 ± 0.05	3.48464
ME+1/2	5.20 ± 0.06	0.92 ± 0.09	0.22 ± 0.01	17.3722
ME+1/3	4.66 ± 0.07	2.37 ± 0.11	0.05 ± 0.01	32.8144
ME+2/1	4.94 ± 0.10	3.10 ± 0.16	0.03 ± 0.04	20.9203
ME+2/2	4.65 ± 0.04	3.41 ± 0.07	−0.05 ± 0.01	43.0836
ME+3/1	4.42 ± 0.14	5.72 ± 0.24	−0.32 ± 0.05	55.0455
ME+3/2	4.86 ± 0.05	2.98 ± 0.08	−0.27 ± 0.01	46.2096
ME+4/1	∼ 5.13 ± 0.25	∼ 8.27 ± 0.30	∼ 0.55 ± 0.08	78.0725

Conclusions

- DT alignment constructed from hardware, link, and tracks:

`/afs/cern.ch/user/p/pivarski/public/DTAlignmentRcd_CRAFT09_segments-hardware-globalMuons_3XY_v8_offline.db`

`.../DTAlignmentRcd_CRAFT09_segments-hardware-globalMuons_3XY_v8_offline_RELTOIDEAL.xml`

`.../DTAlignmentRcd_CRAFT09_segments-hardware-globalMuons_3XY_v8_offline_RELTONONE.xml`

  - tags: DTAlignmentRcd and DTAlignmentErrorRcd (infinite for unaligned chambers)

- CSC alignment constructed from hardware and tracks:

`/afs/cern.ch/user/p/pivarski/public/CSCAlignmentRcd_CRAFT09_hardware-globalMuons_3XY_v4_offline.db`

`.../CSCAlignmentRcd_CRAFT09_hardware-globalMuons_3XY_v4_offline_RELTOIDEAL.xml`

`.../CSCAlignmentRcd_CRAFT09_hardware-globalMuons_3XY_v4_offline_RELTONONE.xml`

  - tags: only CSCAlignmentRcd

- Corresponding tracker geometry: `MergedCenteredObject.db`
- If tracker alignment group choses their other geometry, we have an alignment for that too: it differs from the one presented here by 0.25 mm, 0.05 mrad (similarly for CSCs)