Muon Alignment Constants Proposed for Sign-off (for CRAFT and Cosmic Ray Monte Carlo)

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for the Muon Alignment Community

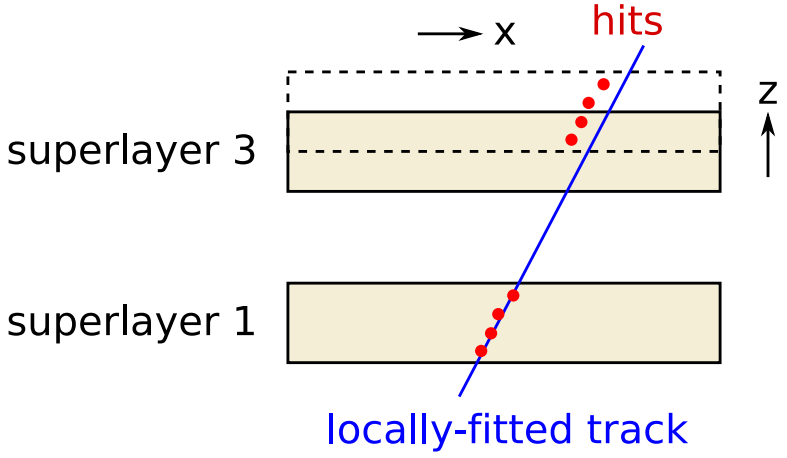
3 June, 2009

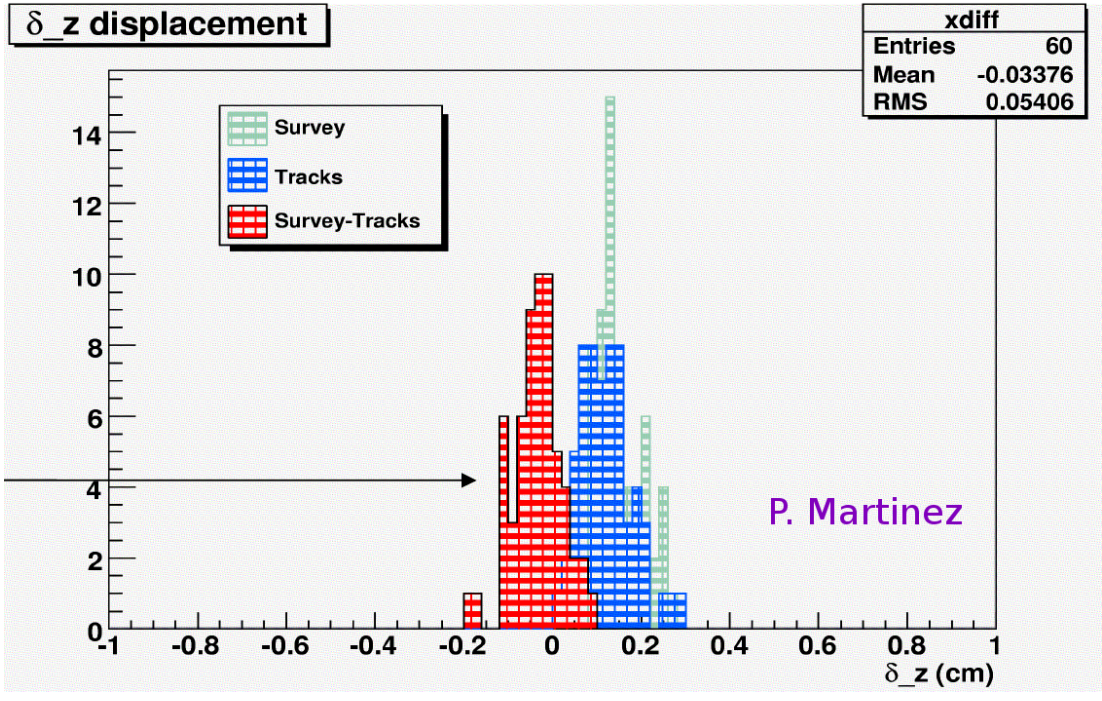
New sets of constants

- DTAlignmentRcd for CRAFT
  - internal DT alignment from tracks, independently confirmed by survey
  - global DT positions and angles from tracks, tested with relative differences and high-p_T momentum reconstruction
- CSCAlignmentRcd for CRAFT
  - individual chambers relative to disks from photogrammetry
  - disk-bending due to $\vec{B}$ from laser measurements
  - whole-disk positions relative to tracker from tracks
- Updated STARTUP Scenario for Monte Carlo
  - includes the above improvements
  - only appropriate for pre-collisions MC

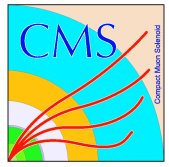
Internal DT alignment

- Physically-motivated corrections to internal chamber geometry (superlayers): layer of glue, about 1 mm thick in z
- Track-based measurement (x residuals versus entrance angle) and survey agree in z
- 540 μm verification in station 1 (plot)
- Track-based x corrections also improve whole-chamber segment angles





Global DT alignment



- Align individual muon chambers relative to tracker with tracker-only refits of globalMuons (unbiased residuals)
- Fully 6-DOF procedure, fitting for all alignment corrections and major instrumental/propagation effects together, once per chamber
  - four residuals: x, y position and $\frac{dx}{dz}$, $\frac{dy}{dz}$ entrance angle
  - correlation between position and angle residuals included
  - single-scattering (power-law) convoluted with Gaussian errors
- $100 < p_T < 200$ GeV, because low-p_T tracks are biased by an effect *other than* magnetic field map or material budget errors
- Consistent with tracker geometry in Tracker_Geometry_v5_offline
- Region aligned: wheels -1, 0, $+1$, all sectors except 1 and 7
- Realistic cosmic ray Monte Carlo study (except tracker misalignment); achieved the following systematics-dominated accuracy:

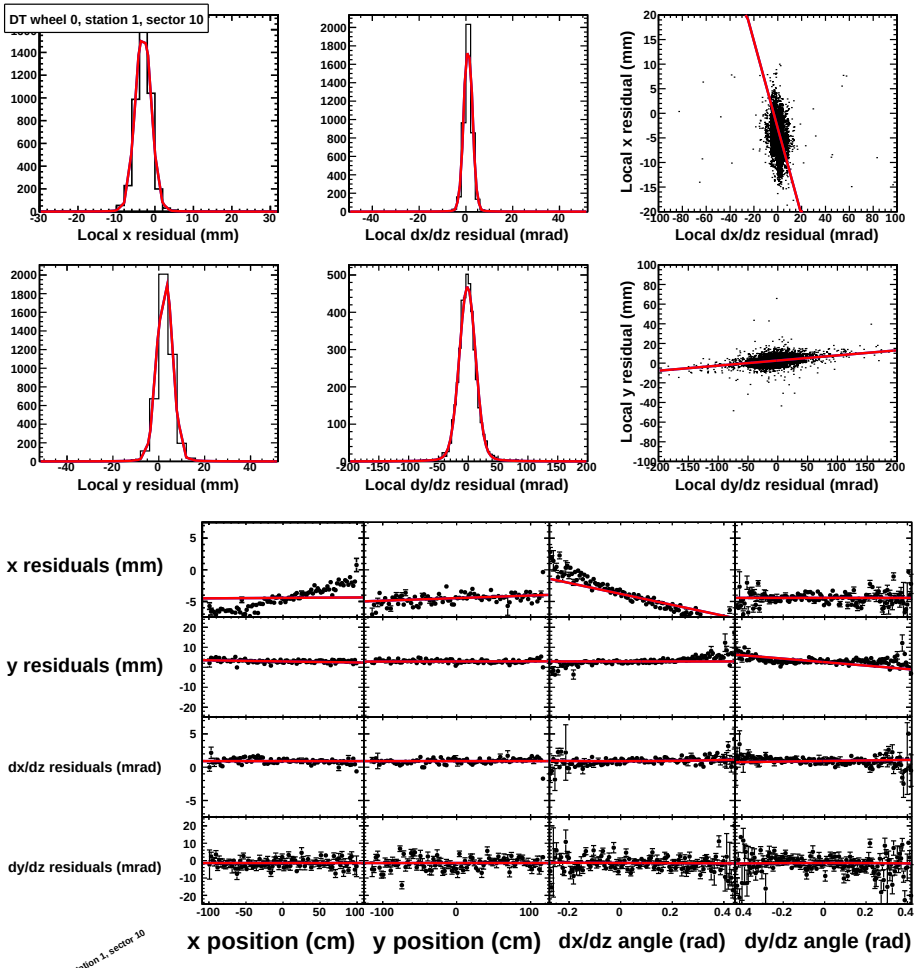
x	190 μm	ϕ_x	0.42 mrad
y	840 μm	ϕ_y	0.09 mrad
z	630 μm	ϕ_z	0.29 mrad

- Up-to-date alignment code in CVS (and 3_1_0 release)

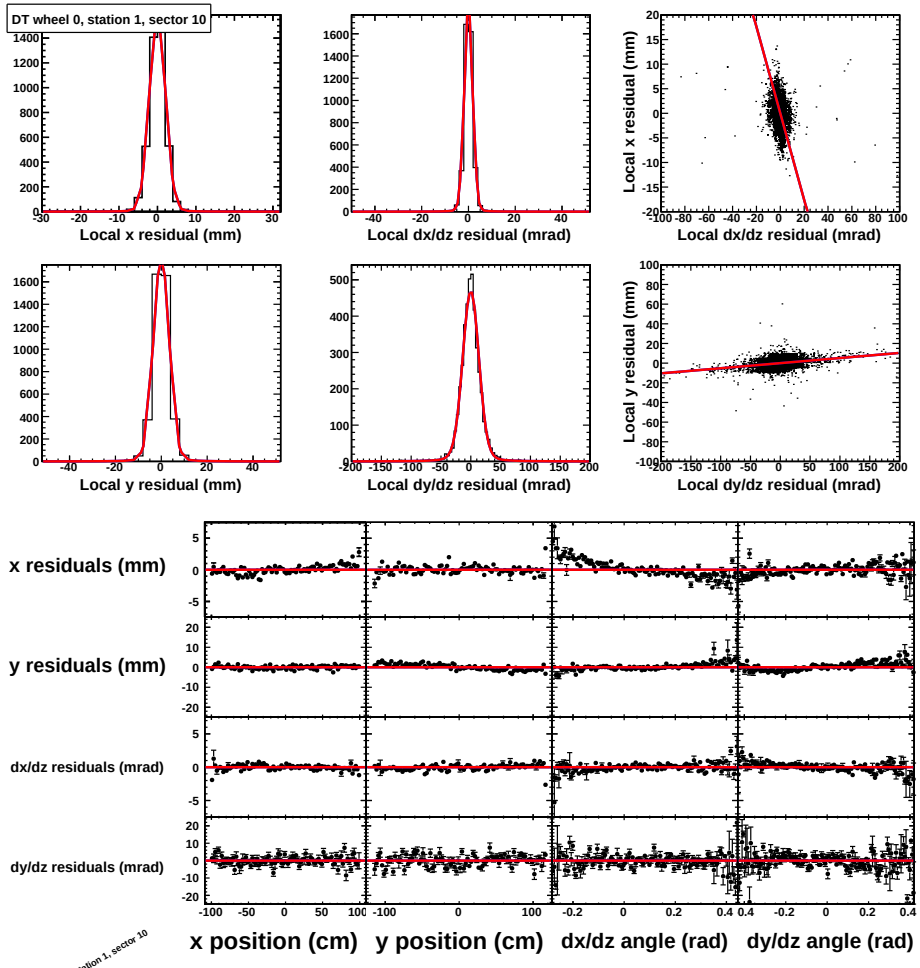
Example in real data

- Wheel 0, station 1, sector 10 (largest statistics, bottom of CMS)

Before (misaligned)

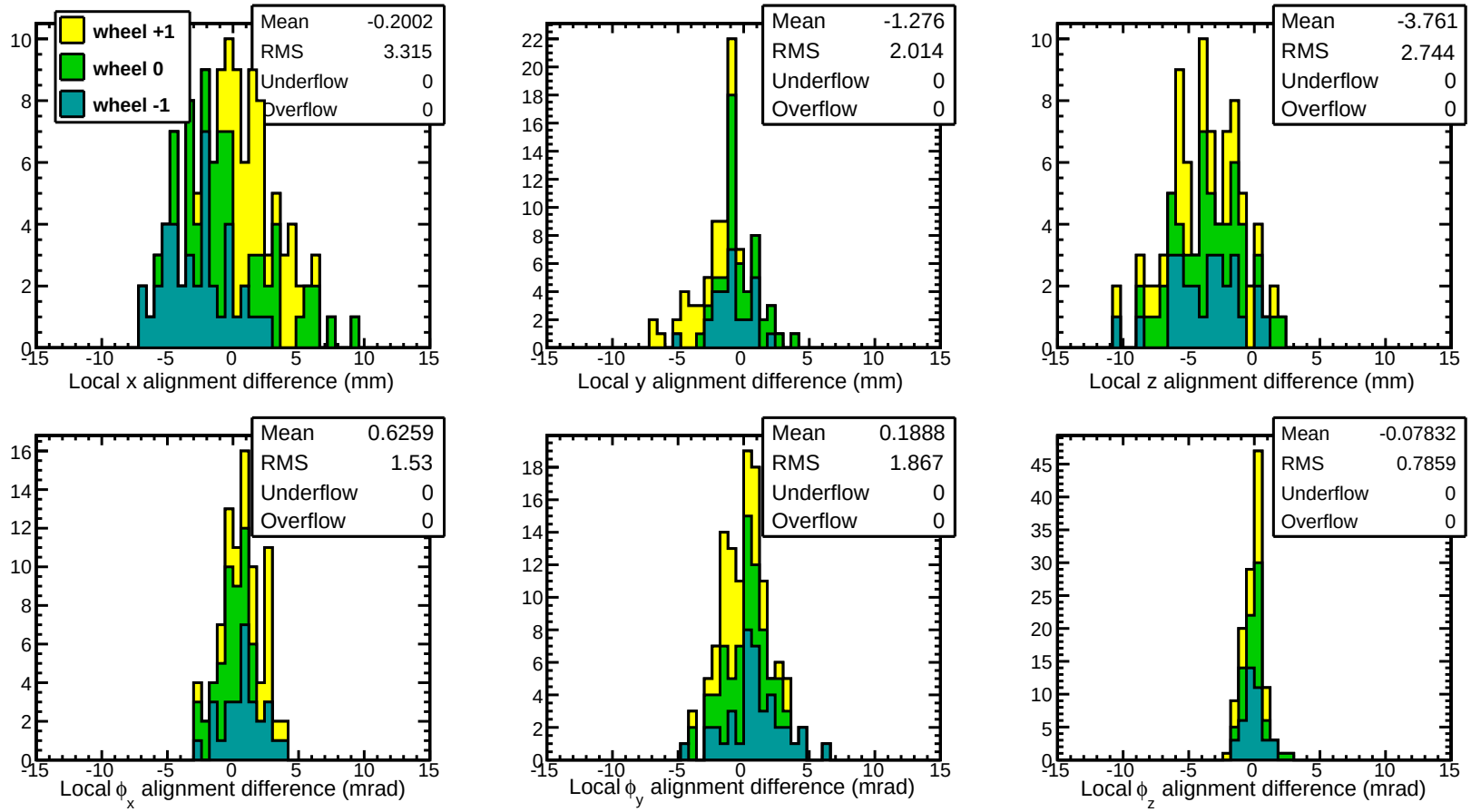


After (aligned)



Parameter updates

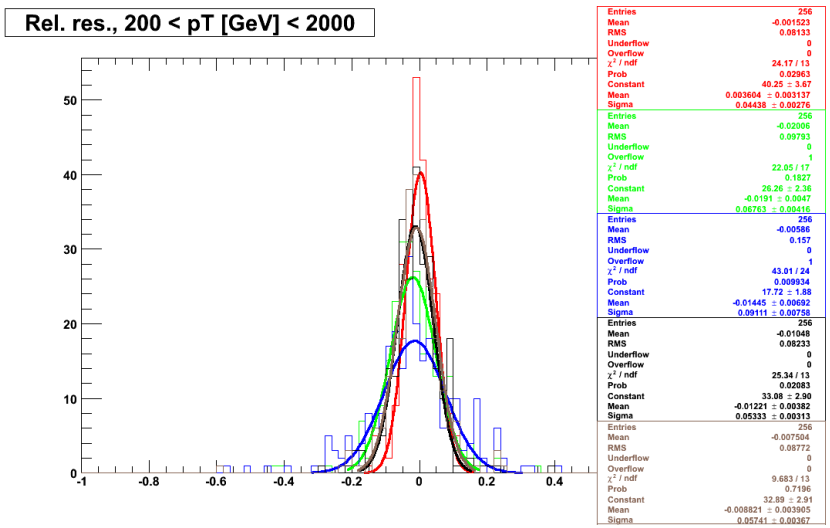
- Differences between proposed constants and previous (CRAFT_ALL_V5–12) shown below
- Systematic rotation of wheels is due to low-p_T tracks used in previous alignment



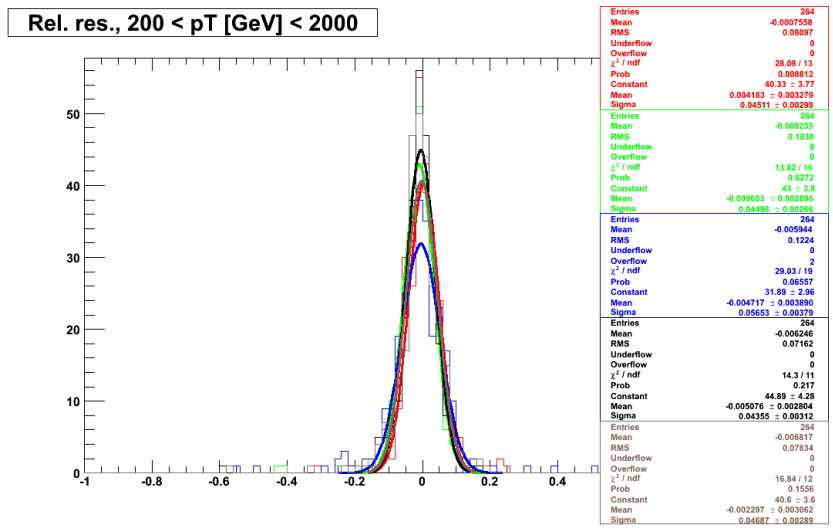
Momentum in split cosmics

- $\frac{(1/p_T)_{\text{top}} - (1/p_T)_{\text{bot}}}{\sqrt{2}\,(1/p_T)_{\text{bot}}}$ (equal to $\frac{(p_T)_{\text{top}} - (p_T)_{\text{bot}}}{\sqrt{2}\,(p_T)_{\text{bot}}}$ if Gaussian)
- $200 < p_T < 2000$ GeV tracks (not used in the alignment)
- Key: tracker-only, sometimes with station 1, with station 1, all stations

CRAFT_ALL_V5–12



new constants



- Tracker-only: 4.51%
- Tracker and sometimes station 1: 5.33 → 4.36%
- Tracker and muon station 1: 6.76 → 4.50%
- Tracker and all muon stations: 9.11 → 5.65%

J. Tucker

DT alignment and 2008 MC

- 2008 MC $\frac{(1/p_T)_{\text{meas}} - (1/p_T)_{\text{gen}}}{\sqrt{2}\,(1/p_T)_{\text{gen}}}$ tracker + station 1 resolution:

  IDEAL: 2%, CSA08 10 pb^{-1}: 3%, STARTUP: 6% at 200 GeV

- Cosmic splitting $\frac{(1/p_T)_{\text{top}} - (1/p_T)_{\text{bot}}}{\sqrt{2}\,(1/p_T)_{\text{bot}}}$ (same reco): 4.5% at 200 GeV

CSC alignment overview

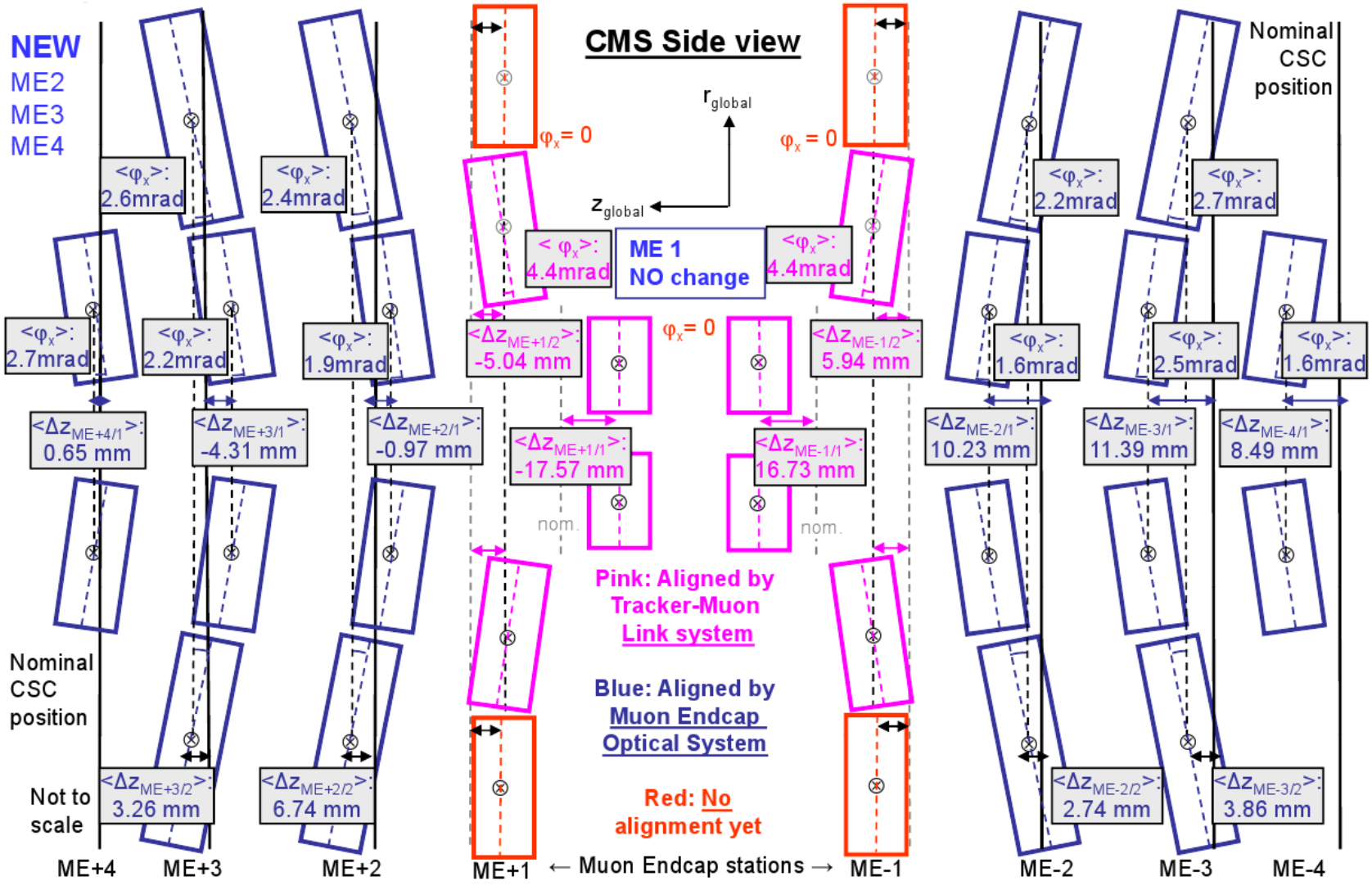
- Photogrammetry + disk-bending (lasers) + disk positions (tracks)

CSC photogrammetry

- Describes individual chamber positions relative to their disks (300 μm resolution)
- Not expected to move in x and y during 0 T $\rightarrow$ 3.8 T

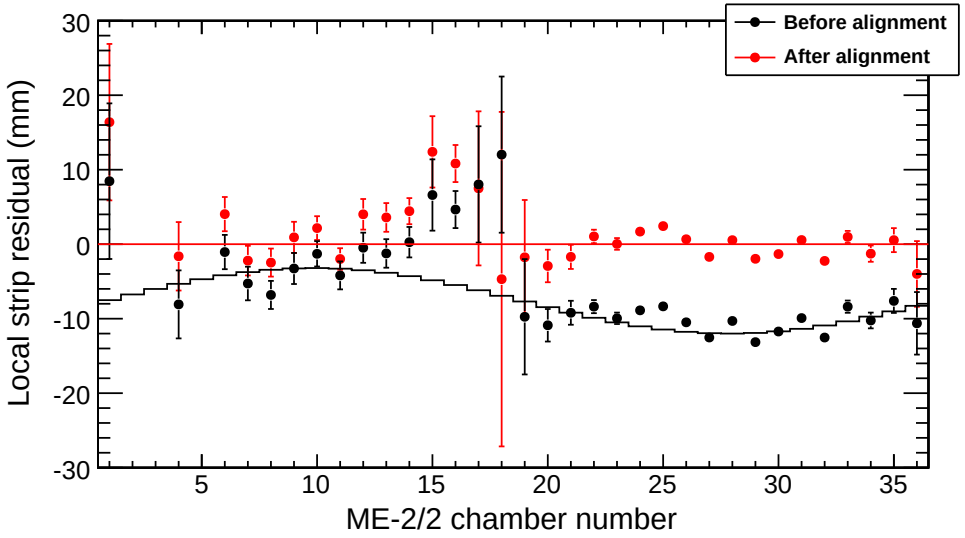
Disk-bending measurements

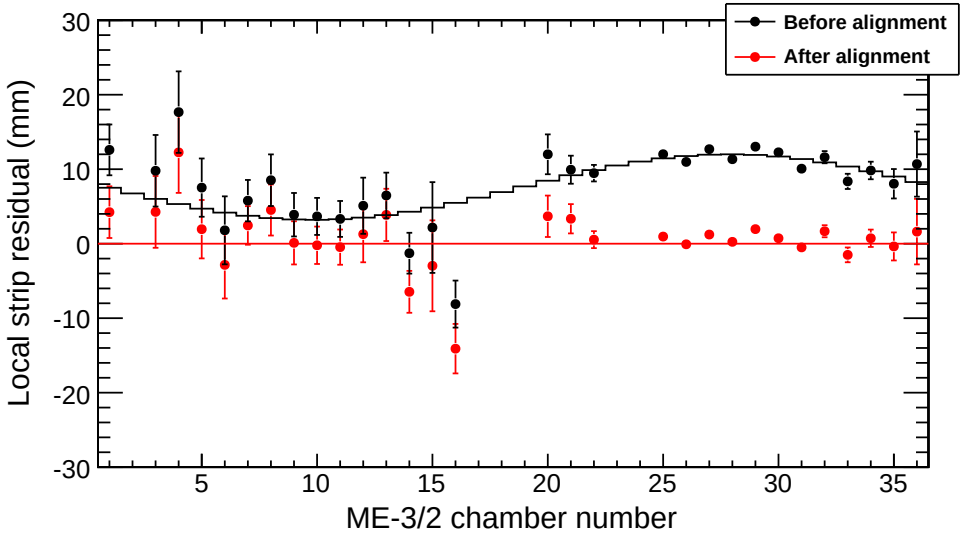
- From Straight Line Monitor lasers and the Link System



Disk positions

- Local cathode strip residuals ($\approx r\phi$) as a function of chamber
- Fit ME1/2 (2/2) to global x, y, ϕ_z, cross-check with ME1/3 (3/2)





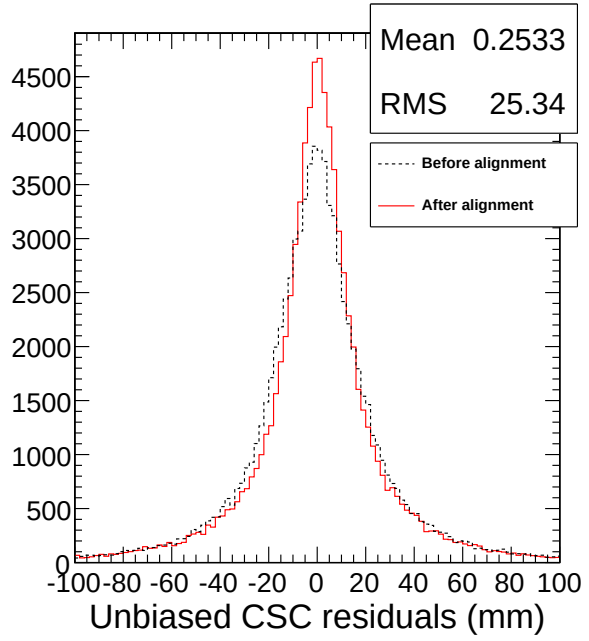
- Biggest correction: ME−2 and ME−3

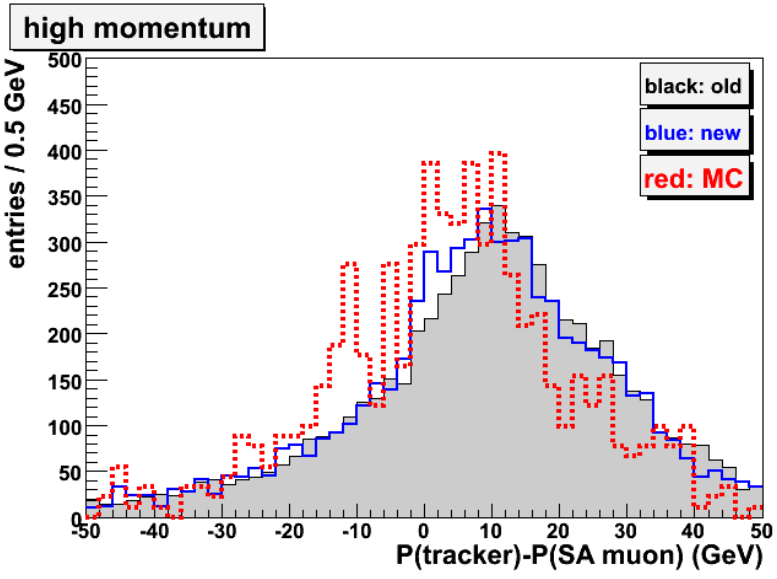
  ϕ_z: 1.44 mrad
  x: 4.4 mm
  y: −0.1 mm

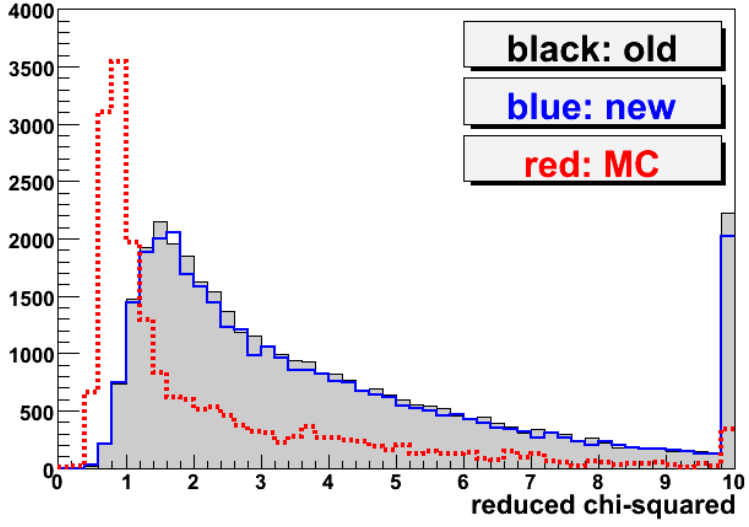
- ME−2/2 fit (top) is a good match to ME−3/2 (bottom)

Cross-checks for CSCs

- Raw globalMuon residuals (what we used for alignment): improved by construction
- $p_{\text{tracker}} - p_{\text{standAlone}}$ and standAlone χ^2: no significant improvement (blue is data)
- We're continuing these studies, to align *individual* CSCs with tracks (difficult because of the angular distribution of cosmic rays)



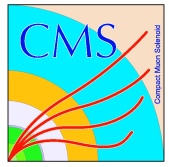




MC scenario

- DT/CSC STARTUP misalignment scenario currently in the database describes the February CRAFT alignment (V5–12)
- Since then...
  - more chambers have been aligned, with more degrees of freedom (within wheels -1, 0, $+1$)
  - resolution has improved due to updated algorithms
  - knowledge about resolution has improved: split cosmics techniques, $p_{\text{tracker}}/p_{\text{globalMuon}}$, relative position checks, Monte Carlo study
- We've prepared a new geometry describing the state after CRAFT
  - random-generator sigmas are explicitly derived from the cross-checks, alignment corrections, and MC study
  - unaligned chambers (wheels ± 2 and sectors 1 and 7) still have large misalignments
- Appropriate for cosmic ray MC but not for physics: for physics analyses, we will align with collisions data (and therefore reach all chambers)

Summary



- DTAlignmentRcd for CRAFT (2_2_X format)

  `/castor/cern.ch/user/p/pivarski/DTCRAFTiter03_withCenteredTracker.db`

- CSCAlignmentRcd for CRAFT (2_2_X format)

  `/castor/cern.ch/user/p/pivarski/CSCCRAFT_HardwareAndPGAndDisk2.db`

- Updated STARTUP Scenario for Monte Carlo

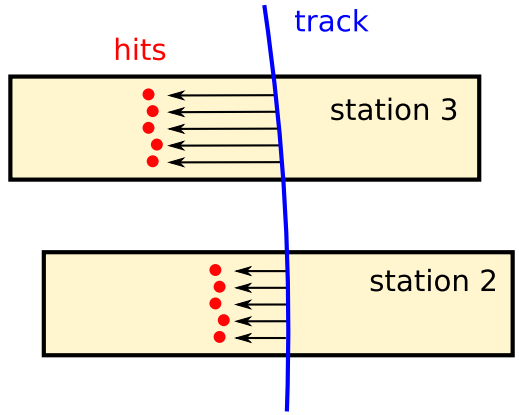
  `/castor/cern.ch/user/p/pivarski/MCScenario_CRAFT1_22X_V02-09-04.db`

  `/castor/cern.ch/user/p/pivarski/MCScenario_CRAFT1_31X_V02-09-04.db`

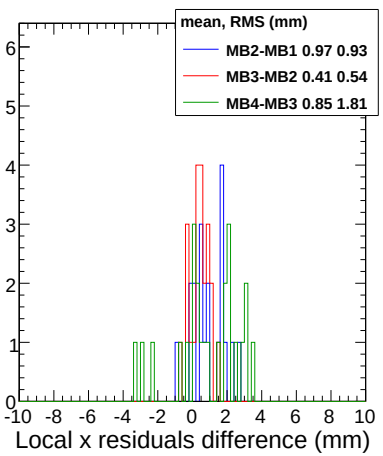
Backup: relative DT positions

- Alignment determined positions of each chamber individually from the tracker
- Cross-check with relative chamber positions
- Measured from difference of residuals with respect to an unbiased track:

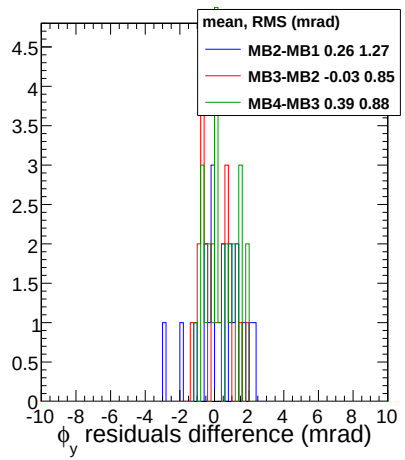
  (track − station 3 hit) − (track − station 2 hit)



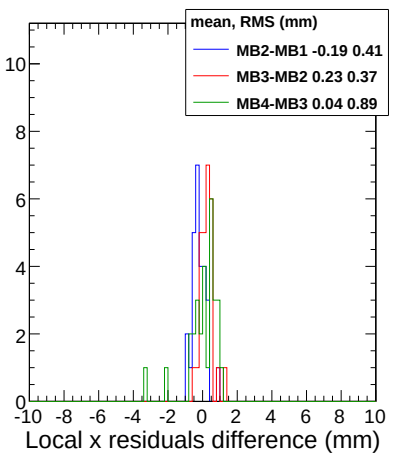
V5–12 x



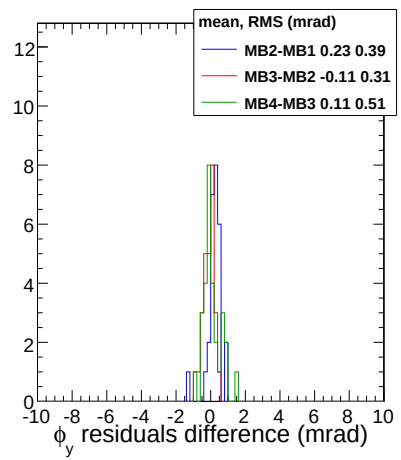
V5–12 ϕ_y



new x



new ϕ_y



- New x resolution: 400 μm, with the exception of station 4, sector 4 chambers (which have internal structure, under investigation)
- New ϕ_y resolution: 0.3–0.5 mrad