Alignment of the DT chambers

Jim Pivarski

Alexei Safonov

Texas A&M University

29 January, 2009

Summary

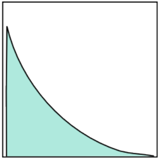
- We present alignment constants for the DT chambers, reducing misalignment from the 5–10 mm level down to the 1–2 mm level
  - links DT chambers to the tracker's coordinate system using globalMuons
  - compatible with the latest tracker description (geometry, APEs, Lorentz-angle), TIB and TOB only (best-aligned part)
  - this is an update to the CRAFT_ALL_V4 muon geometry description, updating only those chambers with adequate statistics, keeping previously-aligned layer and superlayer substructure
- Understanding of systematic effects
  - control of errors from $\vec{B}$-field mismodelling
  - for other systematic effects, see DT-DPG presentation `http://indico.cern.ch/conferenceDisplay.py?confId=51267`
- Validation plots: see DT-DPG "more information" for every chamber
  - a few examples shown here

Basic algorithm (very quickly)

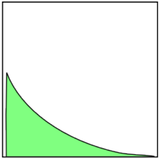
1. Refit globalMuon tracks with zero weight on the muon hits, so that the tracks are determined entirely by the tracker, yet contain muon hits
   - automatically in tracker's coordinate system
   - no coupling between track-fitting and alignment: convergence in one iteration (two performed)
2. Find the peak of the residuals distribution, note offset from zero
   - weighted-average 1-D hits in the same chamber on the same track, to properly account for their correlation
3. Apply corrections to move residuals to zero
   - DT local x (global $r\phi$) coordinate: offset of local x residuals
   - DT local y (global z) coordinate: offset of local y residuals
   - DT local ϕ_z (rotation in layer's plane): slope in local x versus local y
4. Follow-up with detailed validation plots

Effect of $\vec{B}$-field mismodelling

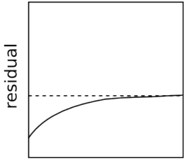
- Magnetic field is not properly described in reconstruction
- Track propagation is sensitive to integral of $\vec{B}$-field error along its path
- How can we get reliable residuals?



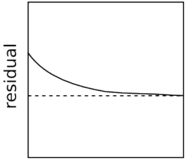
momentum spectrum
of positively-charged tracks



momentum spectrum
of negatively-charged tracks



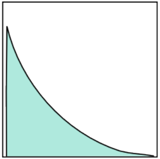
momentum of
positively-charged tracks



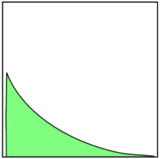
momentum of
positively-charged tracks

- Number of positively-charged and negatively-charged muons is not equal, but the momentum spectra are identical (fact used in charge ratio analysis)
- Small deviations of reconstructed track from average muon trajectory is antisymmetric with charge

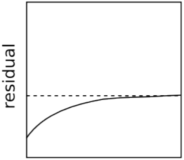
Effect of $\vec{B}$-field mismodelling



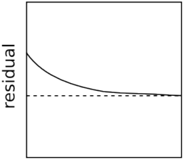
momentum spectrum
of positively-charged tracks



momentum spectrum
of negatively-charged tracks



momentum of
positively-charged tracks



momentum of
positively-charged tracks

- Measure residuals peak in two bins, one for each charge
- Non-weighted average is insensitive to $\vec{B}$-field errors

$$\text{alignment} = \frac{R_+ + R_-}{2}$$

- Difference is maximally sensitive

$$\text{error tracer} = \frac{R_+ - R_-}{2}$$

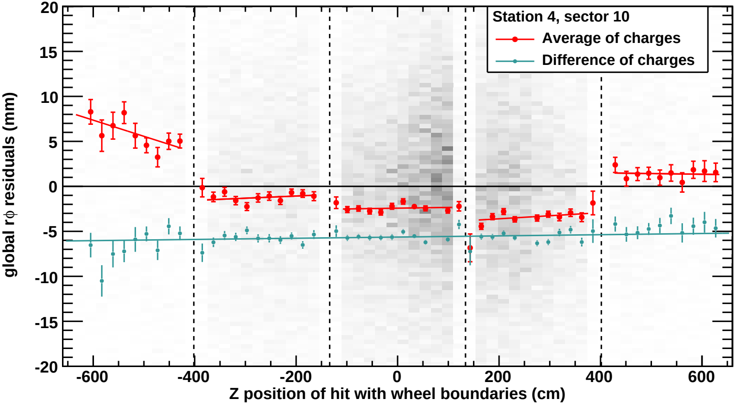
- Effectively scales up negatively-charged muon statistics such that the two curves cancel
- Systematic error $=$ (error tracer) $\times$ (charge mismeasurement) $\times \dfrac{0.3}{2.3}$

$$\sim \text{(error tracer)} \times \text{(a few percent or less)}$$

Effect of $\vec{B}$-field mismodelling

- Demonstration in station 4 (largest $\vec{B}$-field errors):
  - despite large $(R_+ - R_-)/2$ difference ("error tracer"),

    the $(R_+ + R_-)/2$ average cleanly breaks at chamber boundaries

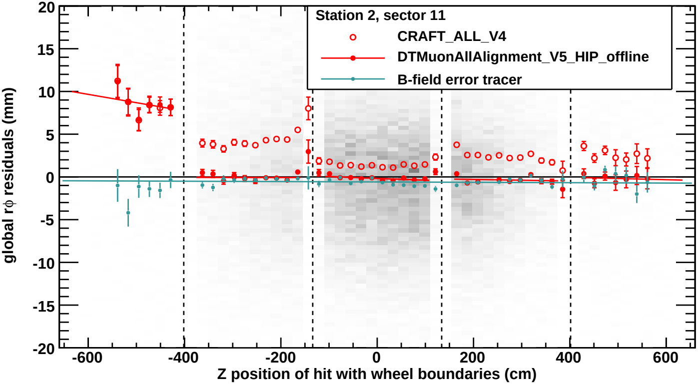


grey background is the raw 2-D residuals distribution

linear fits are only a guide for the eye: not used in alignment!

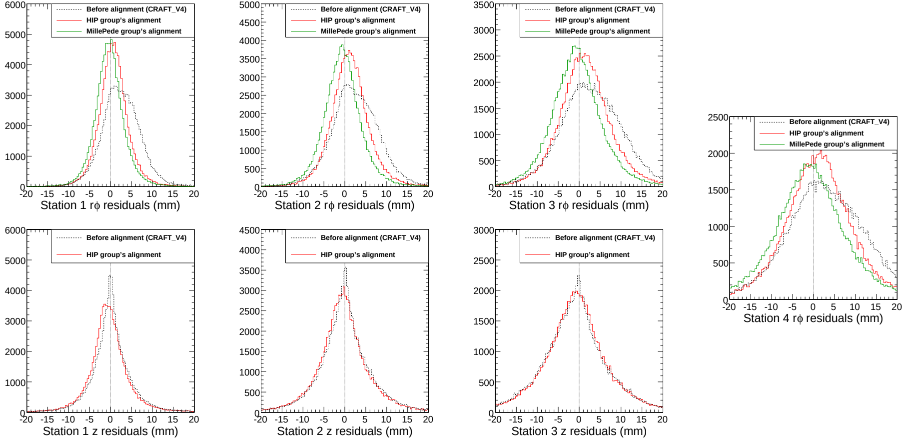
Track-based validation

- Plot residuals with more detail than the alignable level
  - dataset is divided such that you're only ever looking at one chamber at a time
  - grey background is the raw 2-D residuals distribution
  - linear fits are only a guide for the eye, not used in alignment
  - example of unaligned chamber: wheel -2, station 2, sector 11
  - see DT-DPG Indico page "more information" for 152 pages

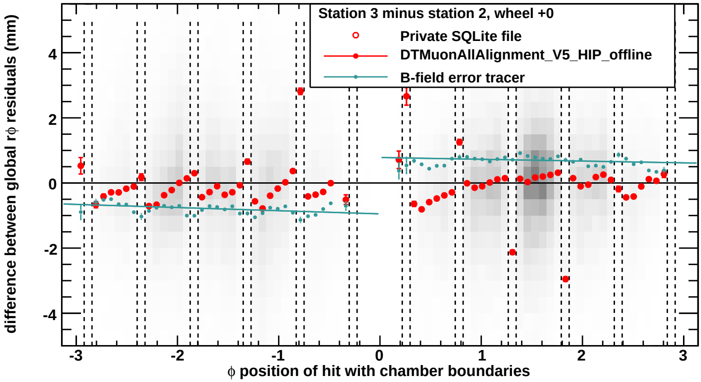


Summary of residuals

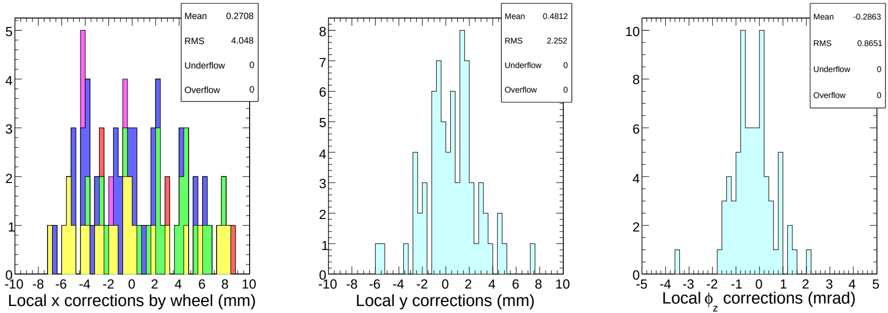
- To summarize, project all residuals ($p_T > 80$ GeV, all chambers)
  - like the tracker's χ^2/N_{dof} plot, but unweighted
  - less sensitive measure of alignment, but convenient
- Residuals in plots are calculated the same way as residuals in alignment



- Linearly-independent test: residuals differences between pairs of stations
  difference = (st. 3 track − st. 3 hit) − (st. 2 track − st. 2 hit)
  - shows *relative* positions of chambers; globalMuon is just a ruler
  - therefore, this is a real consistency check
  - note zoomed vertical scale: accuracy is 1–2 mm
  - also shows $\vec{B}$-field error between the stations, not integrated



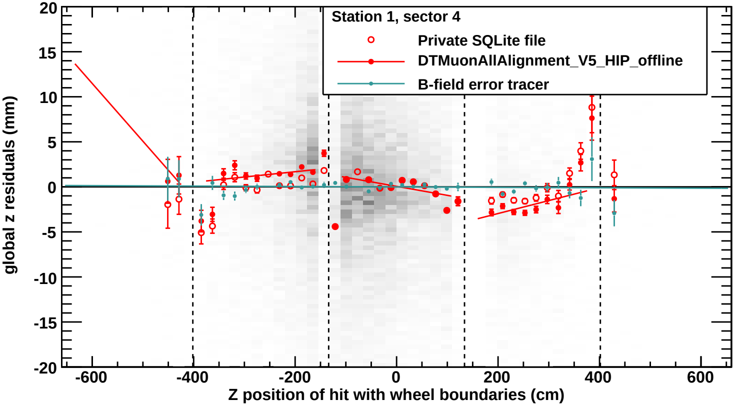
Values of the corrections



- 5–10 mm changes in $r\phi$ positions, and they don't correspond to an overall rotation of the wheels
- A scan of residuals differences plots suggests that remaining misalignment is on the order of 1–2 mm

Constants in database

- Constants were successfully uploaded to the database, but an additional 2 mm $\times$ wheel number was applied to the z positions
  - track residuals do not prefer this additional translation
  - but z residuals still have other effects on the same order, so the resolution is about 2 mm anyway
  - see Muon Alignment Hypernews for full SQLite-DB comparison



Conclusions

- New DT chamber alignment, in the same coordinate system as the tracker, reduces misalignment from the 5–10 mm level down to the 1–2 mm level
- Covers mostly wheels -1, 0, and $+1$ (wherever statistics was sufficient)
- Controls for systematics, not a blind minimization of residuals
  - see DT-DPG for more
- Constants are in the database, but with an extra z translation that worsens the average z residual