Proposed Muon Alignment Constants Update

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Muon Alignment Group

9 August, 2010

Motivation

- Because of the constants roll-back in May, we have been using a muon geometry with known imperfections:
  - whole muon system is rotated 0.7 mrad around the beamline with respect to the tracker
  - endcap geometry is missing chamber corrections from photogrammetry (PG) and beam-halo

Proposed update

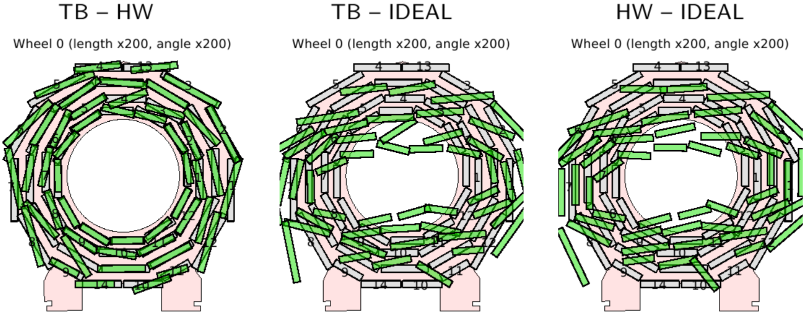
- GlobalPositionRcd (whole muon system coordinate frame): include the measurement derived from tracks (next page)
- DTAlignmentRcd (barrel chamber, superlayer, and layer positions): leave them as they are (hardware-derived), but note that track-based (TB) and hardware-derived (HW) results differ in systematically important ways (work in progress)
- CSCAlignmentRcd (endcap chamber and layer positions): use HW + beam-halo + PG update presented last time

Global position

- Connection of muon system coordinate frame to the tracker coordinate frame is difficult using HW-only measurements because some steps have mm-scale uncertainties
- Using tracks, this connection is straight-forward and does not require large datasets
- Alexander Spiridonov presented a robust method to determine the placement of a HW geometry with respect to the tracker

  http://indico.cern.ch/getFile.py/access?contribId=68&sessionId=9&resId=0&materialId=slides&confId=91797
- This is a full 6-DOF correction, but the parameter with the largest update is a 0.7 mrad rotation around the beamline
  - chamber-by-chamber TB corrections show the same trend
  - the measured-but-not-applied HW correction also agrees
- We use this for all TB-vs-HW studies in the rest of this talk, so that we study differences in the shape of the detector, not global offset
- We propose to update the GlobalPositionRcd to this one, so that the HW geometry already in the DB will become correctly centered

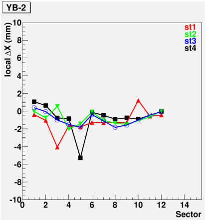
- Both methods have independently "found" the DT chambers at a level of at least a few mm in the sense that they are both substantial corrections relative to design and highly correlated with each other
- This picture shows geometry differences in 3 DOF for TB-minus-HW, TB-minus-design, HW-minus-design (all wheel 0)

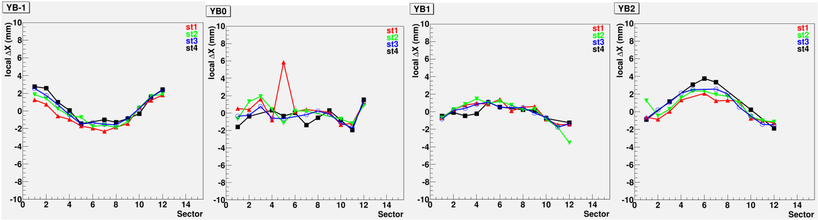


N.B. in this picture, displacements and angle differences have been exaggerated by 200×

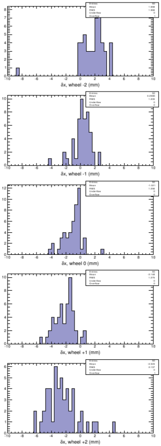
Zero-field PG—HW test

- Before going into detailed comparisons of HW with TB, note that zero-field HW reproduces in-wheel photogrammetry well
- Below: HW $r\phi$ differences versus sector number (ϕ) by wheel
- Within each wheel, differences have the form of a sine-curve, implying only a difference in global coordinate frame (whole-wheel translations and rotations transverse to the beamline)





Barrel TB and HW discrepancies



DT wheel -2
$\delta x = (1.7 \pm 2.0)$ mm

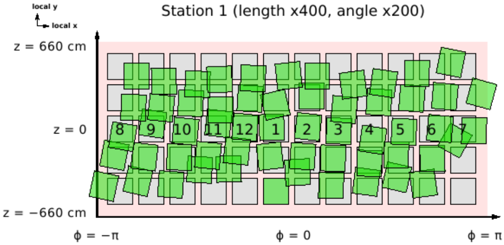
DT wheel -1
$\delta x = (0.3 \pm 1.2)$ mm

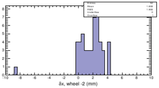
DT wheel 0
$\delta x = (-1.0 \pm 1.3)$ mm

DT wheel +1
$\delta x = (-2.2 \pm 1.3)$ mm

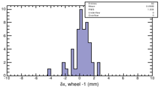
DT wheel +2
$\delta x = (-2.5 \pm 2.1)$ mm

- Primary TB-minus-HW differences:
    - 5-chamber groups from wheel -2 to wheel $+2$ seem to be coherently rotated: about 4 mm end-to-end
    - barrel compressed in z by about 4 mm end-to-end
    - $\mathcal{O}(1.3 \text{ mm})$ individual-chamber variations after that

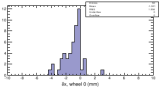




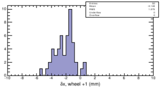
DT wheel -2
$\delta x = (1.7 \pm 2.0)$ mm



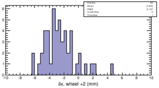
DT wheel -1
$\delta x = (0.3 \pm 1.2)$ mm



DT wheel 0
$\delta x = (-1.0 \pm 1.3)$ mm

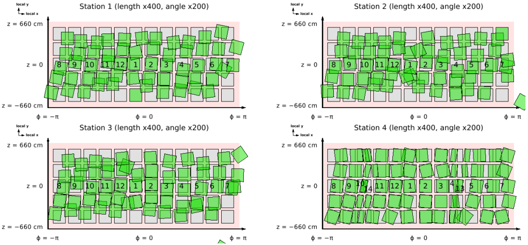


DT wheel +1
$\delta x = (-2.2 \pm 1.3)$ mm



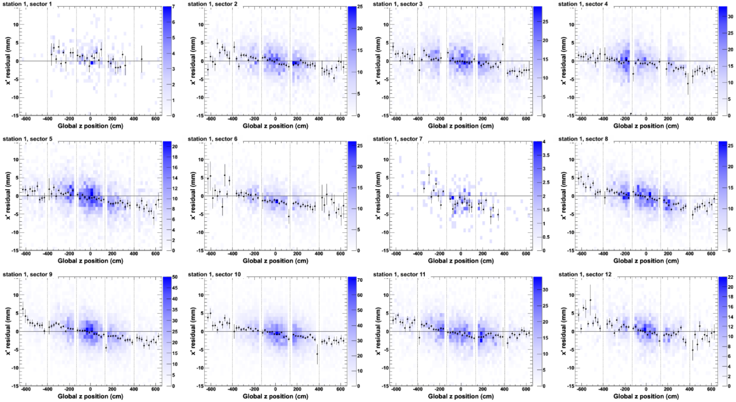
DT wheel +2
$\delta x = (-2.5 \pm 2.1)$ mm

- Primary TB-minus-HW differences:
  - 5-chamber groups from wheel -2 to wheel $+2$ seem to be coherently rotated: about 4 mm end-to-end
  - barrel compressed in z by about 4 mm end-to-end
  - $\mathcal{O}(1.3\text{ mm})$ individual-chamber variations after that
- Same trends for all stations



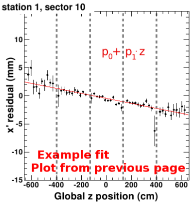
Barrel TB and HW discrepancies

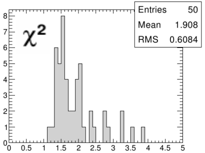
- Also seen at the level of residuals: these are $r\phi$ residuals vs. z in each 5-chamber group; dashed lines are boundaries between chambers
- Smooth transitions between chambers could be due to a coherent rotation in HW or a tracking bias in TB: inconclusive test

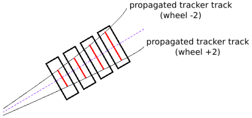


N.B. Vertical scales are ± 15 mm, horizontal scales span the barrel (± 660 cm)

- If the effect were due to a bias in input tracks, e.g. a global distortion of the tracker leading to z-dependent $\Delta\phi$ errors, then its magnitude would scale with distance from the tracker

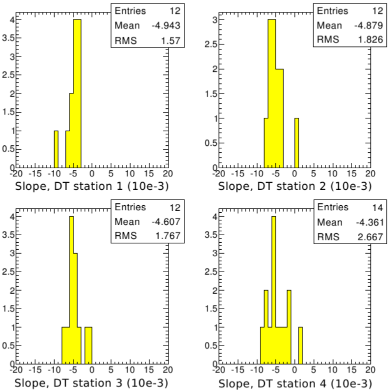






- Test: fit each 5-chamber group of residuals to a straight line (50 in all) and make histograms of the resulting slopes

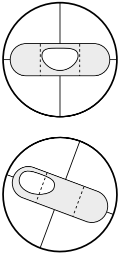
- Result: strongly peaked at the same slope for all four stations, though station 4 has almost twice the radius of station 1



Tiltmeter test

- The end of each HW measurement device in the barrel (MAB) is equipped with a tiltmeter to sense rotation with respect to gravity

Liquid with a monitored bubble



- Each MAB is equipped with a tiltmeter which measures the angle wrt gravity:
  - One can combine PG orientation of YB2 wheels with tiltmeter variation between 0T and 3.8T:

Δphi_Z Tilt (μrad)	MAB195	MAB255	MAB315	MAB15	MAB75	MAB135
YB+2	+48.8	+78.6	-69.9	-57.8	-56.5	--
YB-2	--	100.3	12.8	-40.3	-57.3	--

Phi_Z Angle (μrad)	YB+2	YB-2
Absolute PG	227	169
Δphi_Z from tilts compatible with 0	0±100*	0±100*
Total = PG + Δ from 0T to 3,8T	227±100	169±100
Link Fit @ 3.8T	349	244

PG+Tilt is compatible with lasers (lasers more precise)

* VERY conservative uncertainty

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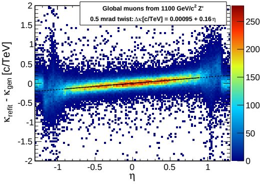
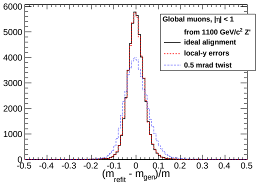
- Constraint from gravity direction + PG: 110 $\pm$ 140 μrad $\rightarrow$ 0.47 $\pm$ 0.63 mm at barrel ends, in contraction with TB's 4 mm
- Independent of barrel HW procedure: TB is the one out of three independent measurements which differs

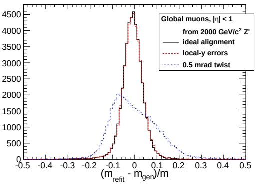
- We have two independent geometries, HW and TB, which agree in the major corrections with respect to design, but disagree in the details
- Primary difference: 4 mm end-to-end rotation and scaling trends with respect to wheel (global z)
  - simple explanations have been ruled out, and we still have contradictory evidence among TB, HW, and the tiltmeters
  - zero-field PG-vs-HW is consistent with this picture but doesn't imply any new constraints because wheel-to-wheel PG has $\mathcal{O}$(mm) uncertainties
  - we don't have a proof that either TB or HW is more trustworthy, and hence will leave the geometry in the DB as it is until we sort this out
- Proposal: unchanged HW-derived DTAlignmentRcd

DT alignment uncertainty

- We now have a handle on DT alignment systematic uncertainty: the TB-minus-HW difference
- The known shape and magnitude of the discrepancy can be used to quantify systematic uncertainties in track parameters and physics observables
- Left: track curvature error vs. η with a 4 mm end-to-end twist of the barrel (tracks from Z' with $m_{Z'} = 1100$ GeV$/c^2$)
- Right: smearing of 1100 and 2000 GeV$/c^2$ Z' mass distributions with no bias (black), z-scaling (red), and twist (blue) (with $|\eta| < 1$)



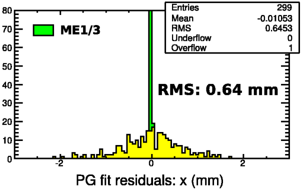




- Full details belong in a different talk

- Endcap has fewer points of comparison between TB and HW
  - HW measures disk-bowing and z-compression toward solenoid; TB does not (with much precision)
  - TB measures $r\phi$ positions and rotations-in-transverse plane of all chambers; HW only monitors six chambers in each ring
- Systematic HW-minus-TB comparision is in development, but because there are so few points of comparison, it is harder to distinguish measurement differences from coordinate frames
- We do have a geometry which combines orthogonal degrees of freedom (next page)
- Currently in the database: only disk-bowing and z-compression from CRAFT-08, no information from tracks or even PG

1. HW provides disk-bowing and z-compression toward solenoid
2. Beam-halo tracks measure $r\phi$ and ϕ_z of chambers relative to their neighbors; this is used to build a complete geometry of each disk
3. Any missing beam-halo information is filled in by photogrammetry in a combined fit
   - beam-halo uncertainties $\ll$ photogrammetry uncertainties, except for chambers with electronics issues and the shadow in the beam-halo distribution due to the LHC floor
   - photogrammetry is consistent with the combined fit at the level of 0.6 mm



4. Correct disk positions in the transverse plane (global x, y, ϕ_z) with cosmic ray tracks from the tracker (using new GlobalPositionRcd)

Locations of new constants

- Updated GlobalPositionRcd:

  /afs/cern.ch/user/s/spiridon/public/JUN6_MuBarrelHW_Tracker_ichep10_GlobalPositionRcd.db

- DT HW alignment: offline DB tag "DTAlignment_2009_v4_offline"

- Updated CSC combined alignment:

  `/afs/cern.ch/user/p/pivarski/public/JUN5_CSC_beamhalo-PG-diskXYphiZ.db`

  (note: still waiting on final disk-z corrections to CSC geometry or will fall-back to a default set)

Conclusions

- Significant improvements to the muon geometry currently in the database are available
- Comparisons between track-based and hardware alignments in the barrel are not in sufficient agreement, but the discrepancies are systematic, suggesting a single surmountable problem
- With two independent measurements of the barrel alignment, we can quantify alignment systematic uncertainties in a way that can be propagated to analyses
- TB-minus-HW comparisons are more difficult in the endcap, but TB-minus-PG is precise