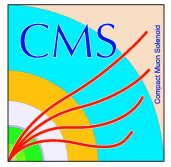


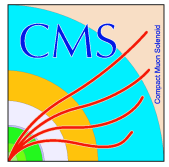
Muon and Tracker Alignment at Start-Up

Jim Pivarski

Texas A&M University

8 December, 2009

Status of alignments

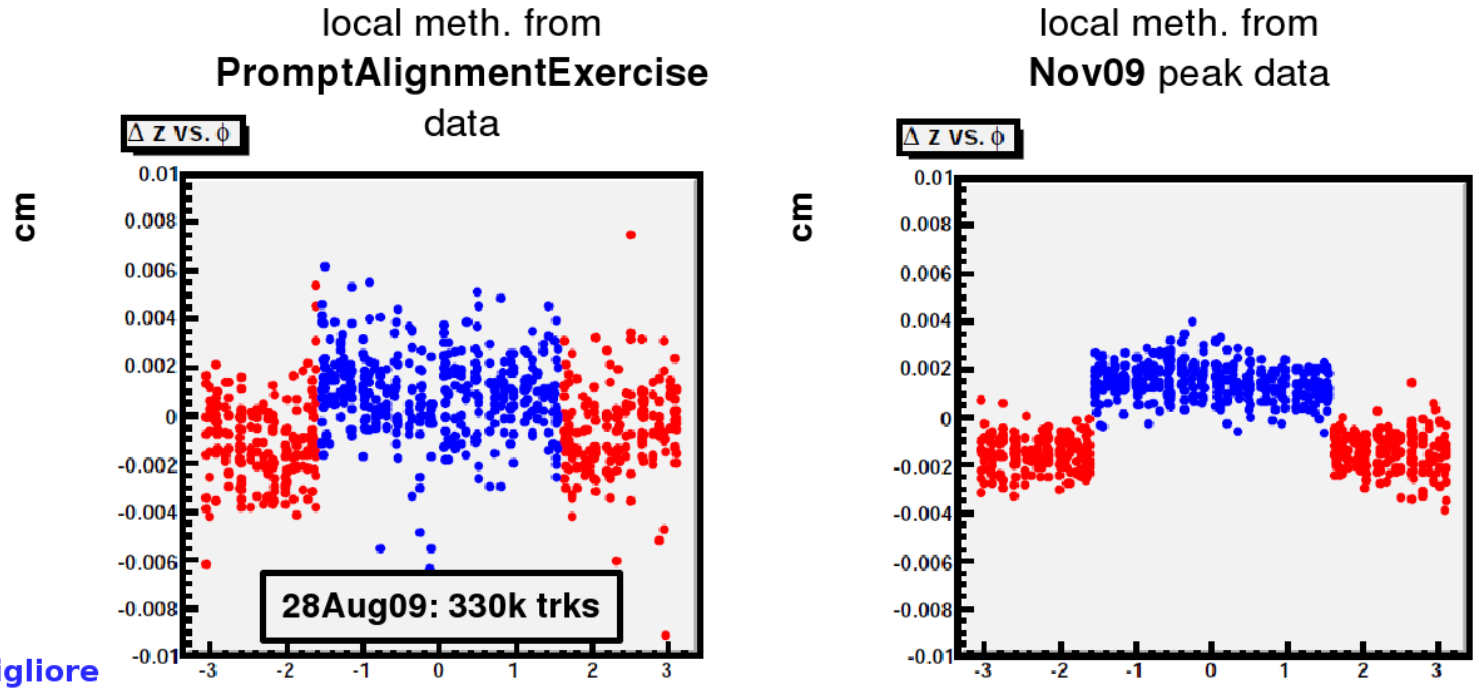


- Tracker alignment
  - CRAFT-09: repeated CRAFT-08 exercise, introduced prompt workflow (frequent, automated, low-statistics alignment)
  - Cooling incident: physically moved pixel half-shell 30 μm in z
  - Re-aligned using November cosmic rays, this is startup
- DT alignment
  - CRAFT-09: repeated CRAFT-08 exercise with tighter bounds on alignment uncertainties, this is startup
  - Barrel hardware alignment is now producing alignments; testing with tracks
- CSC alignment
  - CRAFT-09: corrected few-mm disk position errors with tracks, hardware system providing missing degrees of freedom, this is startup
  - New LHC runs provide too few beam-halo tracks for alignment

Tracker cooling incident

- Below: module position differences before and after cooling incident
- Left: "after" = prompt alignment performed immediately after incident (low statistics, but pinpoints the motion in time)
- Right: "after" = full-statistics November cosmic ray alignment

BPIX after TIB cooling accident: wrt Aug09pk_r1



E. Migliore

Tracker alignment statistics

- Month-long CRAFT: ∼3 million tracks after quality cuts
- November cosmics (startup): ∼2 million
  - roughly the same quality in strip tracker
  - pixel (smaller target for cosmic rays): 2–2.5 μm (nearly ideal) in CRAFT but 3–4 μm in startup alignment
    (RMS of distribution of median of residuals, measure of local precision)
- About 10 M quality minbias tracks needed to improve alignment

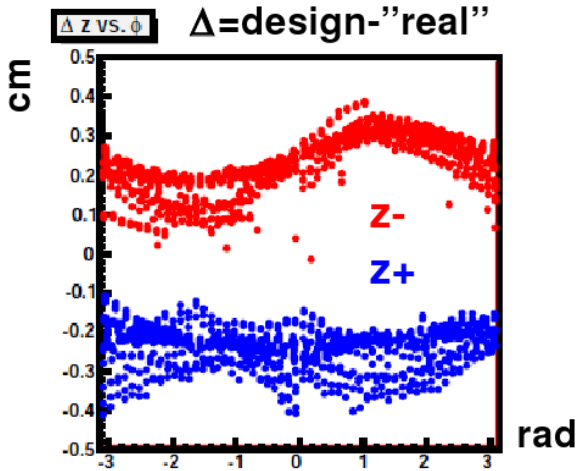
Tracker alignment systematics

- Combining data with different topologies (minbias, cosmics) and introducing new constraints (primary vertex, resonances) yields qualitatively new information on the global shape of the tracker

Other outstanding tracker issues

- 5 mm gap between two half-cylinders of TIB (known since first alignments at the Tracker Integration Facility)
- Want to see if tracks from collisions confirm the observation

- Compare the "real" (from combined meth.) to the design geometry
  - TIB: 5 mm shift of the two HalfBarrels along z-axis (two halves shifted apart)
  - confirmed by optical survey
  - remaining scatter: indication of "skew"?

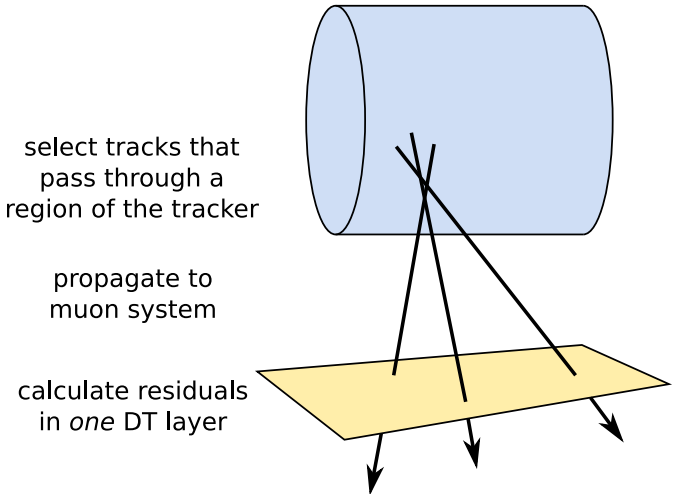


E.Migliore Univ.Torino/INFN

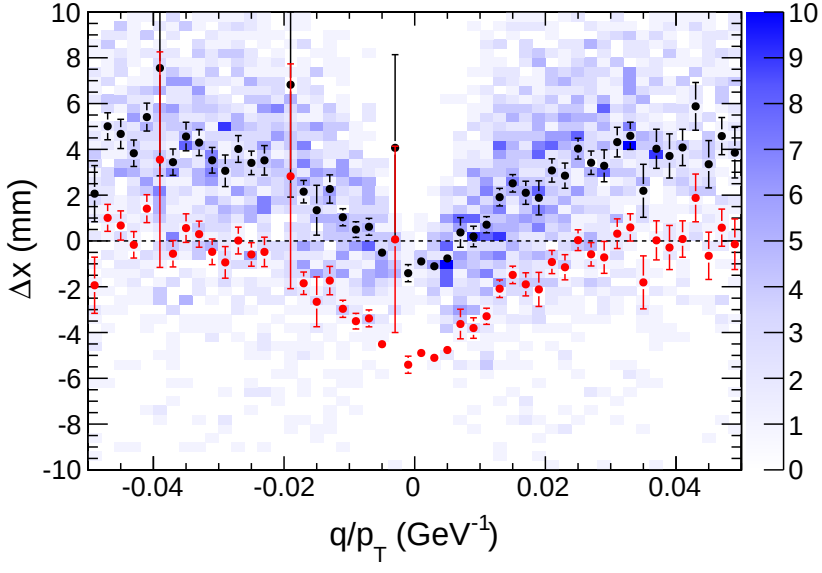
- Minbias illuminate the tracker endcaps better than cosmics
  - the last TEC disk is used to connect tracker to muon hardware alignment system
  - improved tracker endcap → improved hardware alignment global position

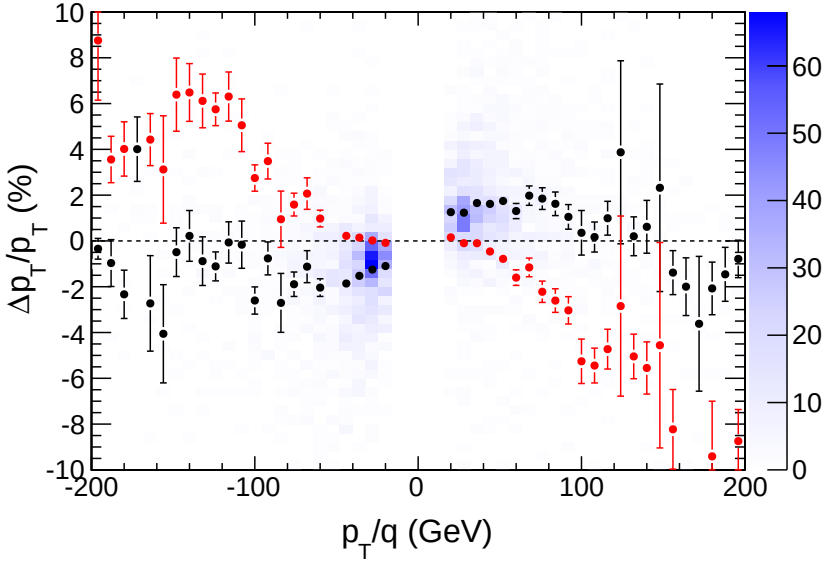
https://twiki.cern.ch/twiki/bin/view/CMS/TrackerAlignmentWithBeams2009

Studying tracker with muon hits



- As an external detector, the muon system can analyze global distortions in the tracker
- Select one DT layer to simplify and minimize dependence on muon alignment
- Varying DT layer position maps a family of curves for tracker momentum error ($\Delta p_T / p_T$)



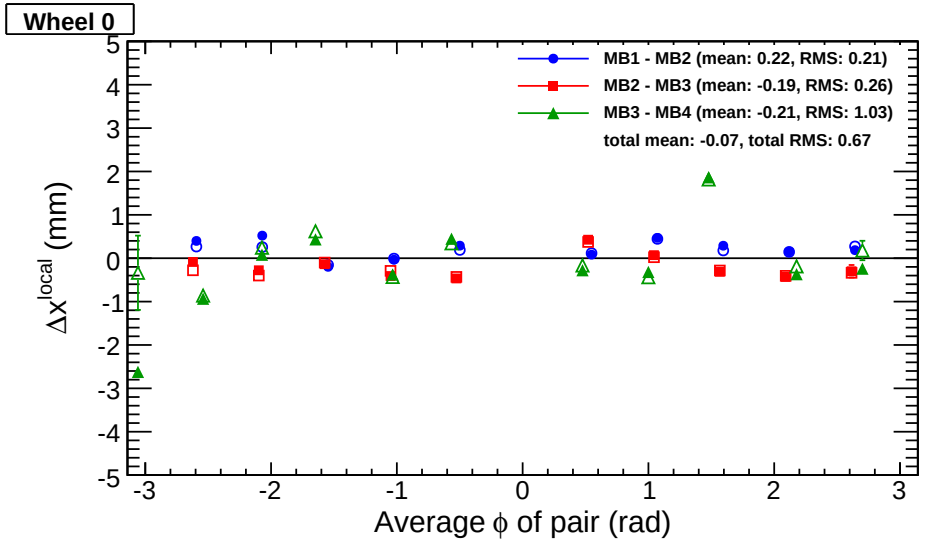


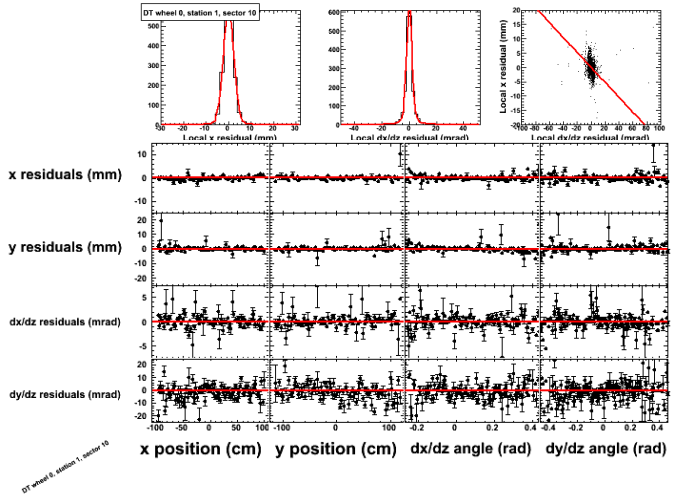
- More details in the Alignment & Calibration meeting today

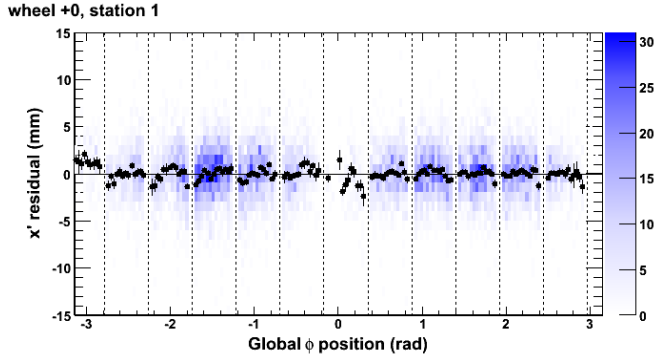
DT startup from CRAFT-09

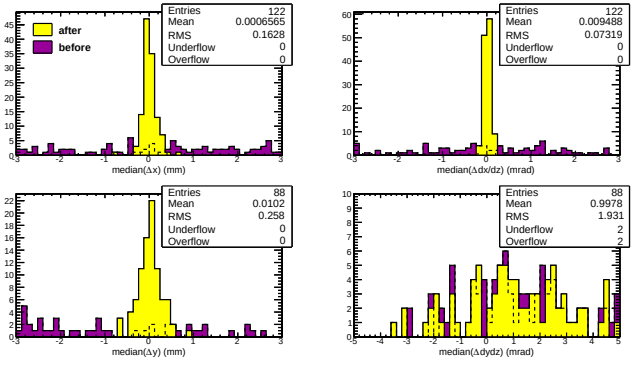
Repeated all checks developed for CRAFT-08

- Right: lots of plots
- Below: local segment cross-check
  - now includes full propagation between stations (not linear)
  - 0.70 mm upper bound on local alignment error $\longrightarrow$ 0.35 mm for stations 1–3

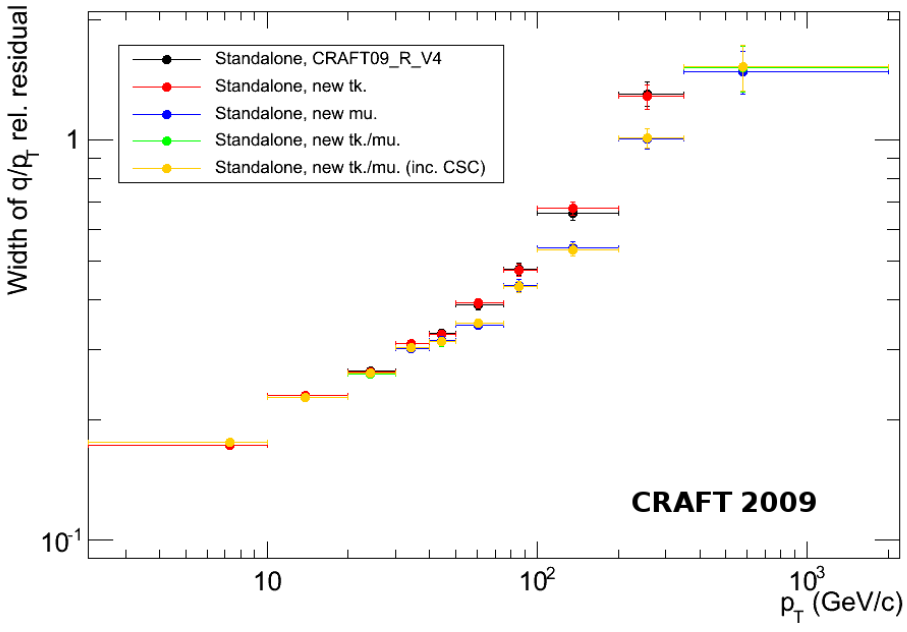


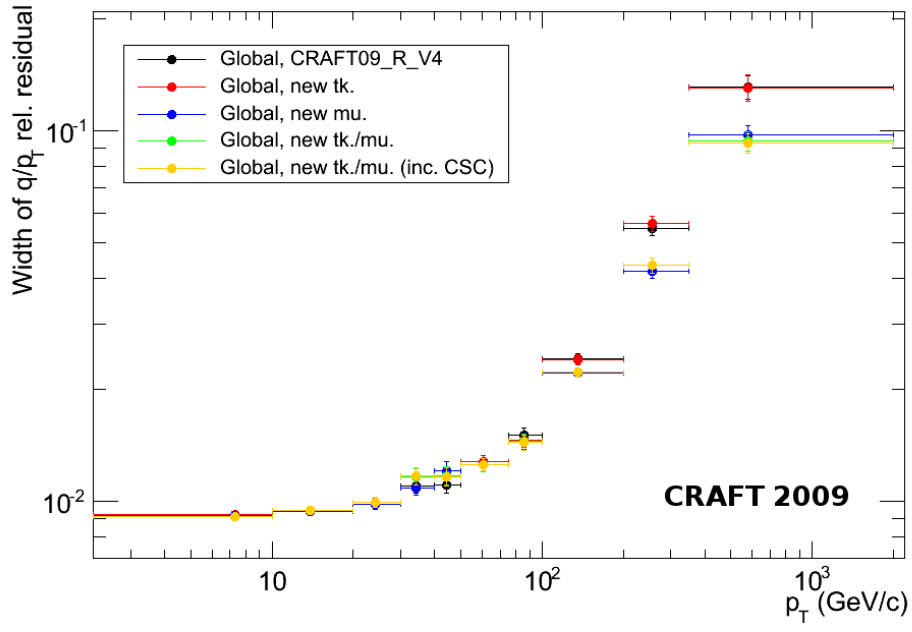






Cosmic splitting results

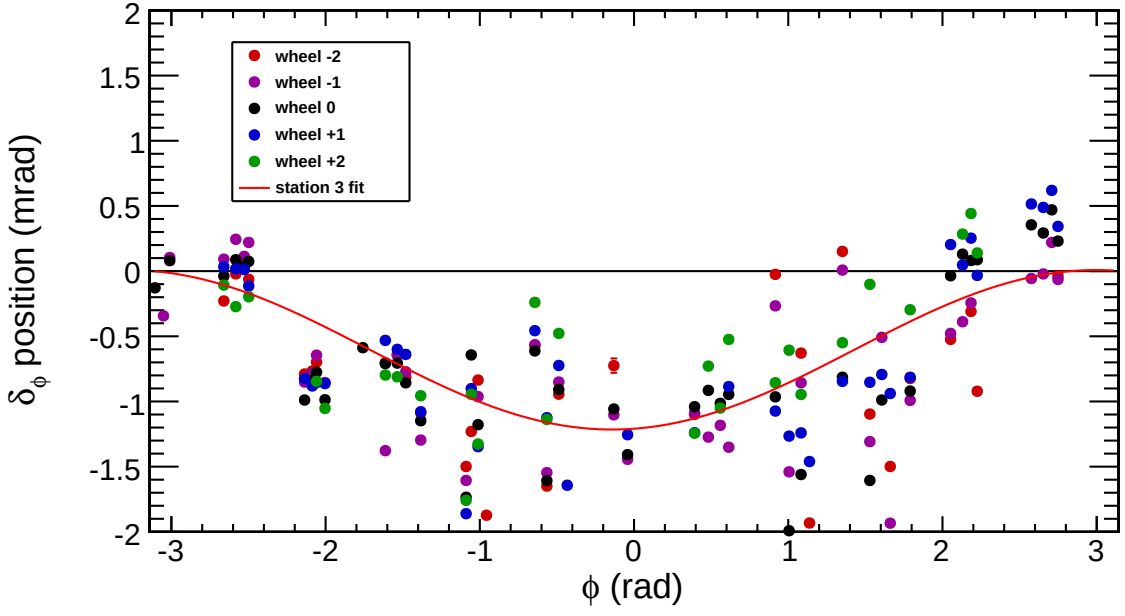


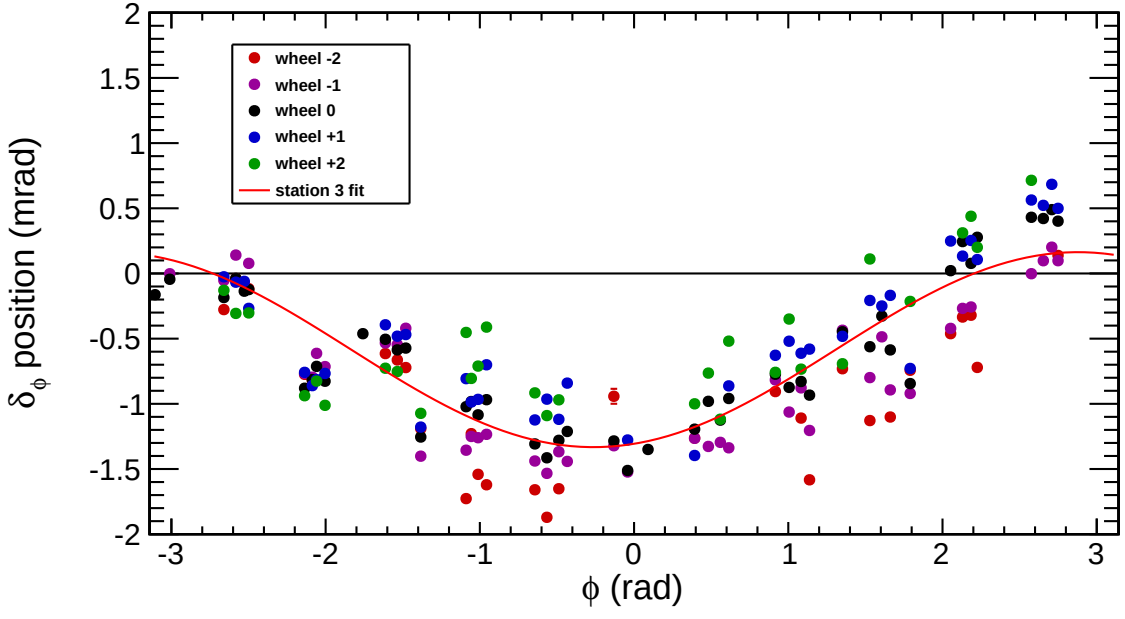


J. Tucker

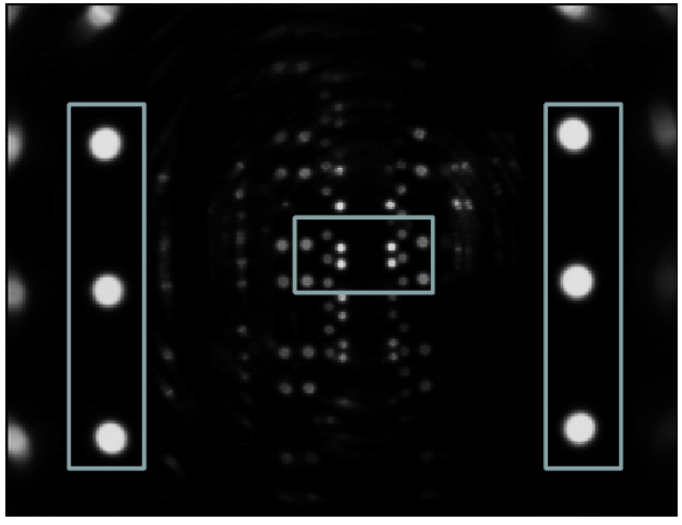
- DT alignment yields clear improvement in standAloneMuons (left) and globalMuons (right), with little difference between globalMuon and FirstMuonStation (4.2% vs. 4.0% at 200 GeV)
- standAloneMuon resolution is still valid
- muon alignment may need to be repeated to regain globalMuon resolution

Barrel hardware alignment

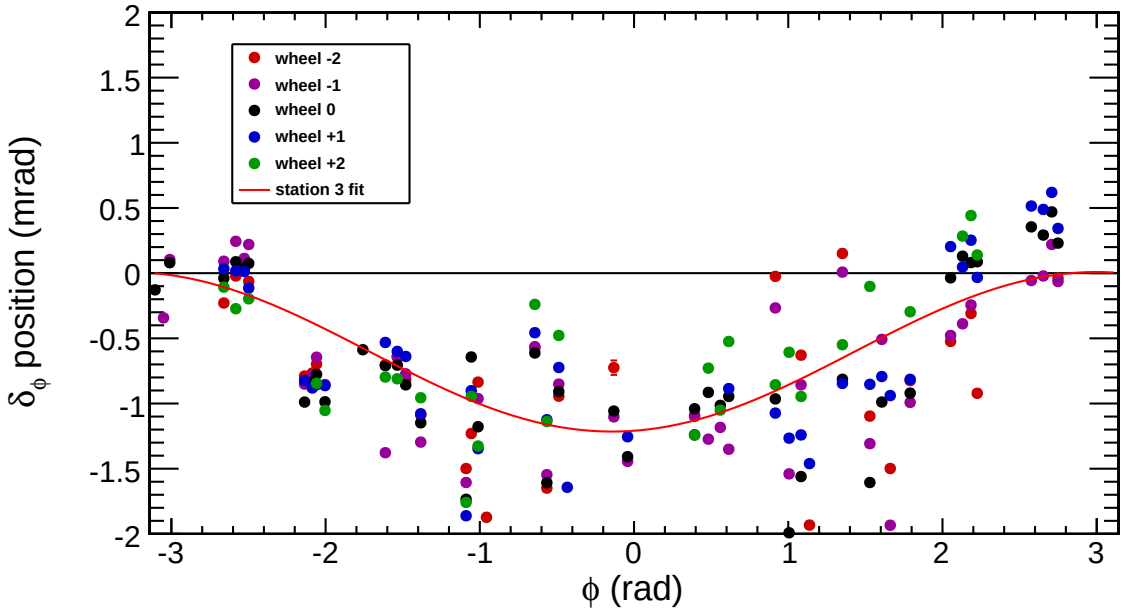


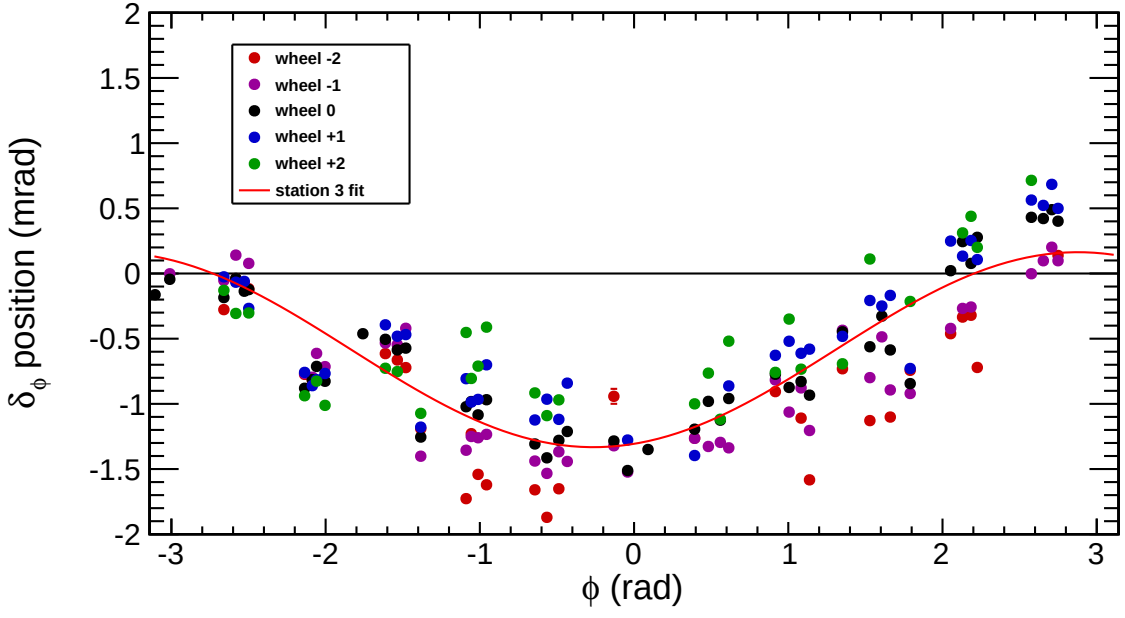


- Differences in chamber positions between hardware and track-based geometries
- Top-left: reconstruction was following some LED reflections
- Bottom-left: corrected

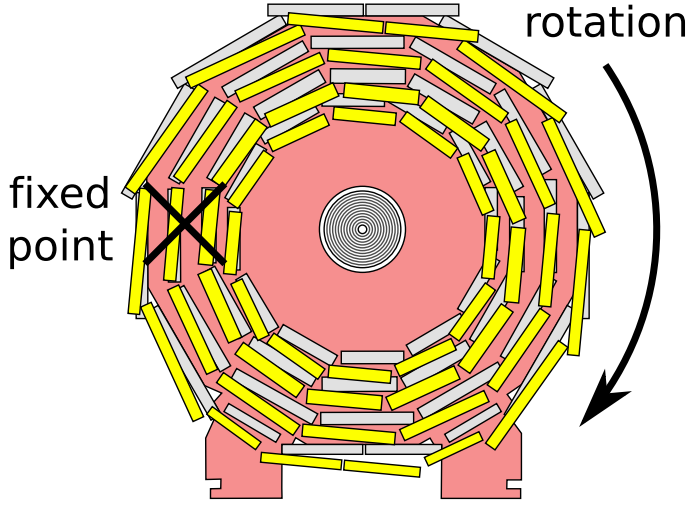


Barrel hardware alignment



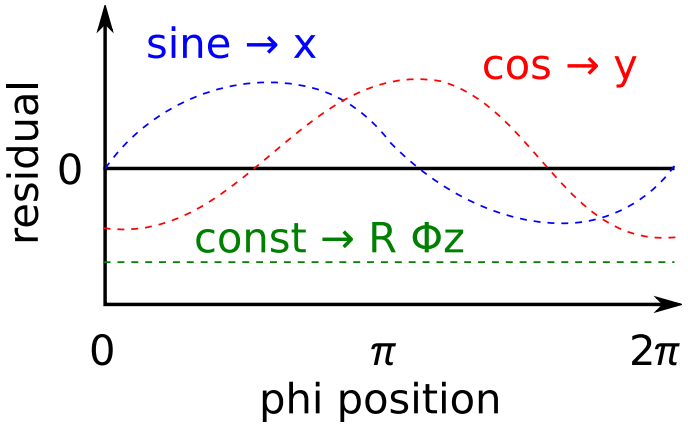


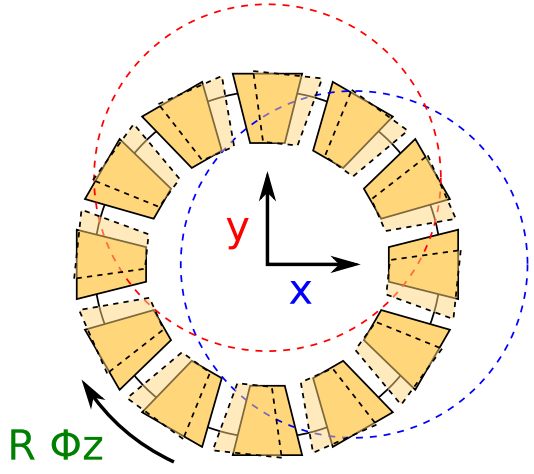
- Differences in chamber positions between hardware and track-based geometries
- Sine curve: global position with respect to tracker
  - $x \longrightarrow 1.2$ mm
  - $y \longrightarrow 4.5$ mm
  - $\phi_z \longrightarrow 0.58$ mrad

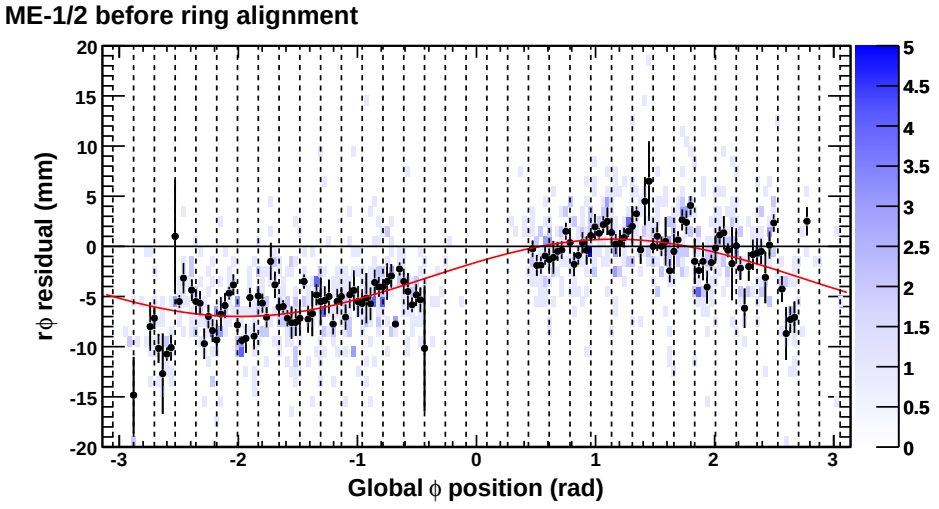


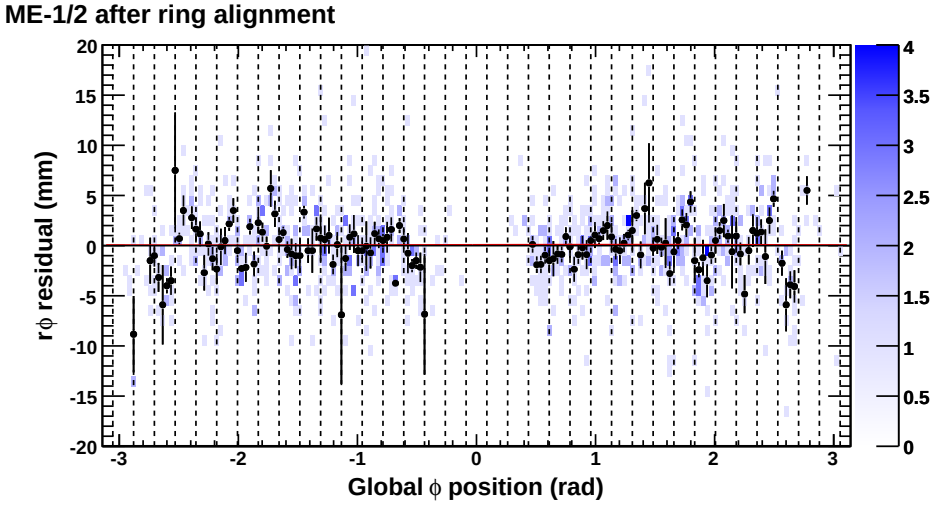
CSC startup from CRAFT-09

- Largest correction: positions of disks after closing
- Important step after beam-halo alignment, to locate internally-aligned rings with respect to tracker



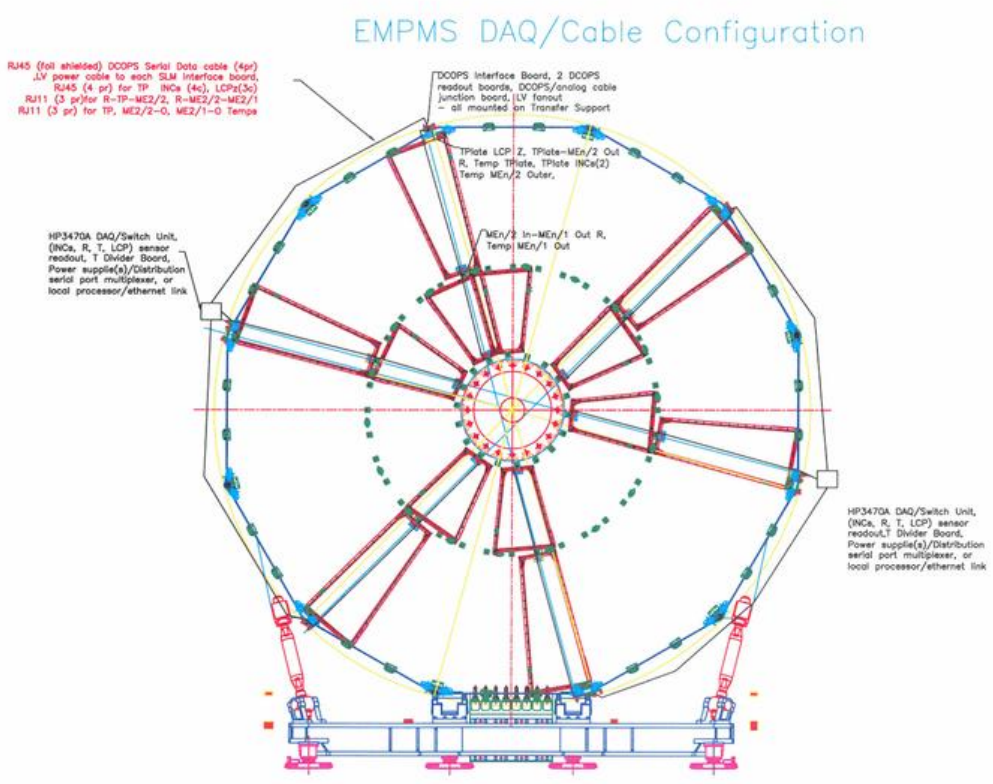




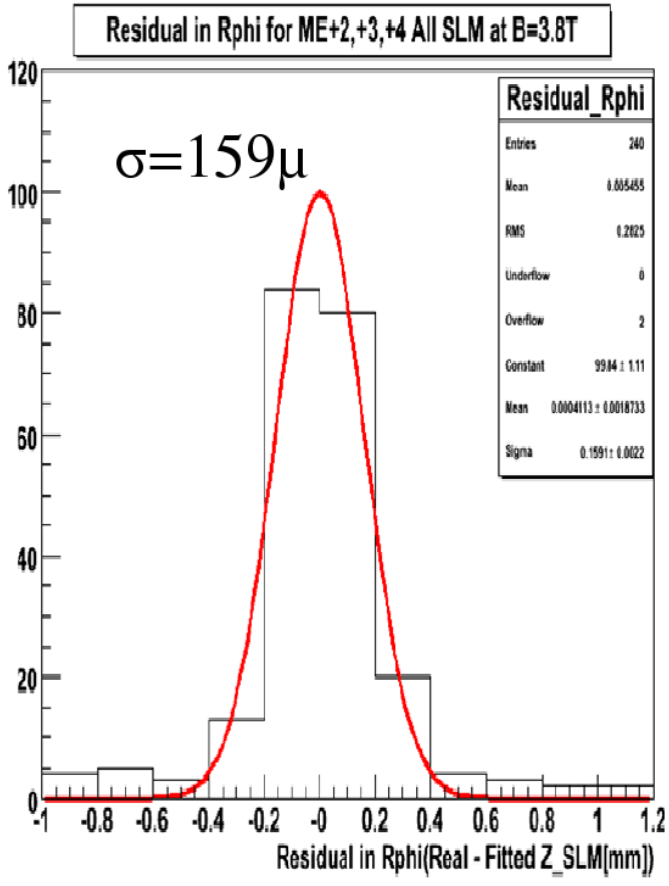


Endcap hardware alignment

- Hardware geometry provides z and ϕ_x (tracks are insensitive to these)
- Reconstruction recently extended to transfer lines (inter-disk) and $r\phi$ positions of monitored chambers
- Opportunity to compare $r\phi$ with tracks

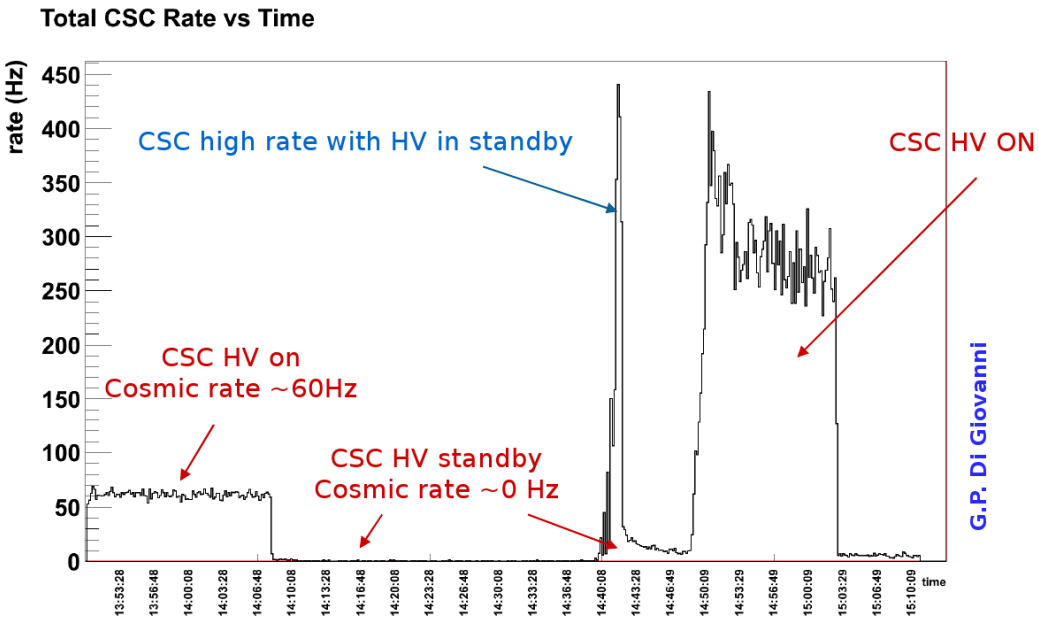


Laser line residuals: internal consistency of hardware alignment

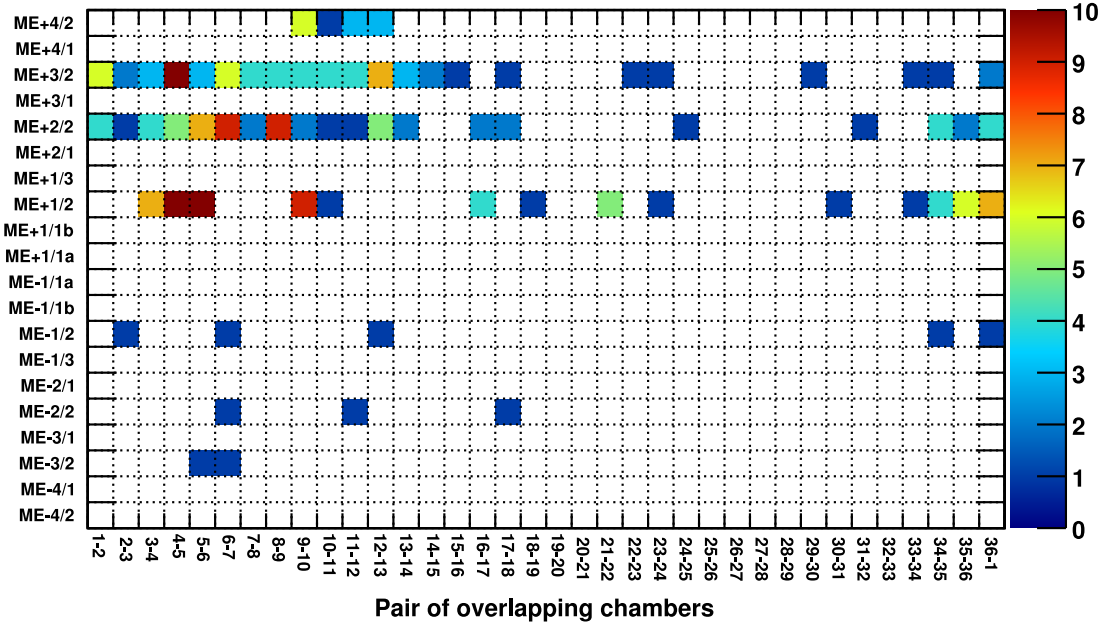


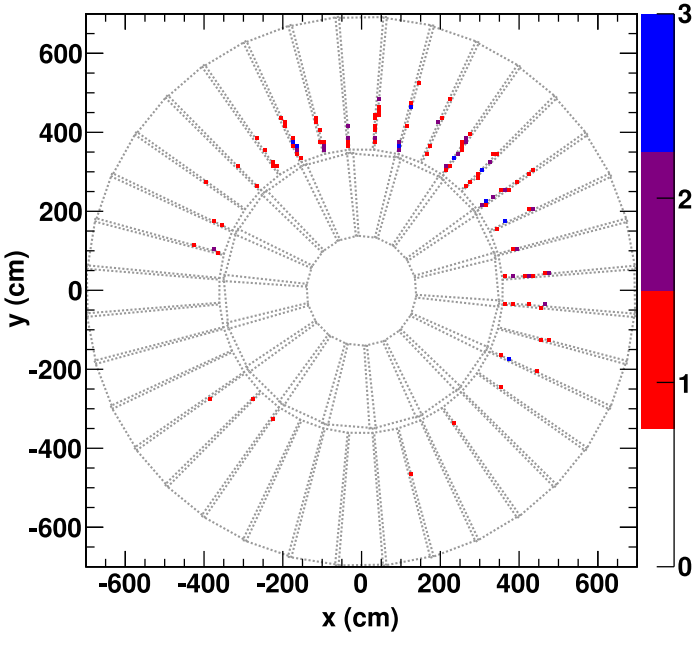
Himali Kalakhety

Beam-halo! But not many...

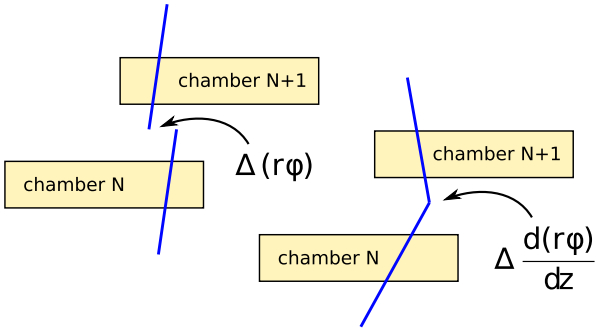


- Longest period of true beam-halo: 13 min in run 122294
- Overlaps track yield: 229 in outer ring after sensible cuts
- Not enough for alignment

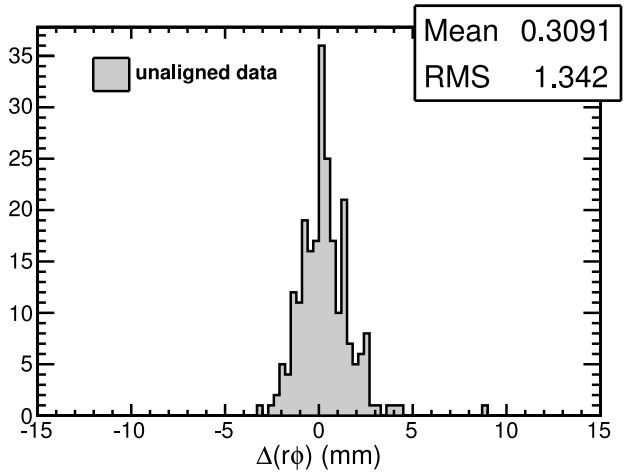


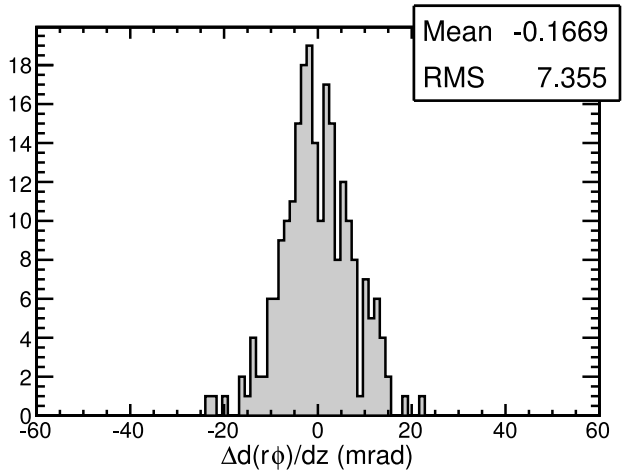


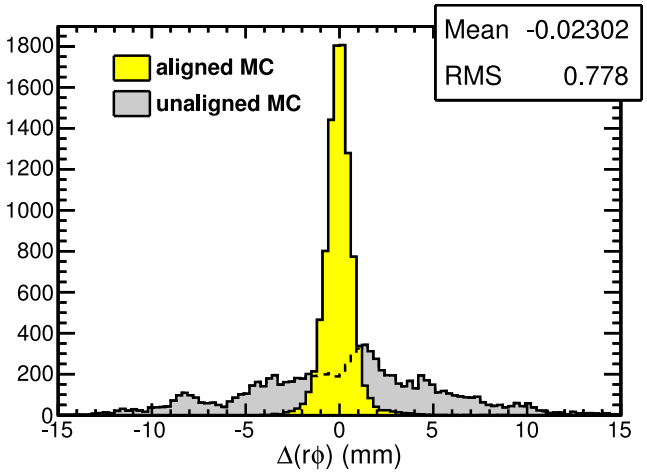
New beam-halo residuals

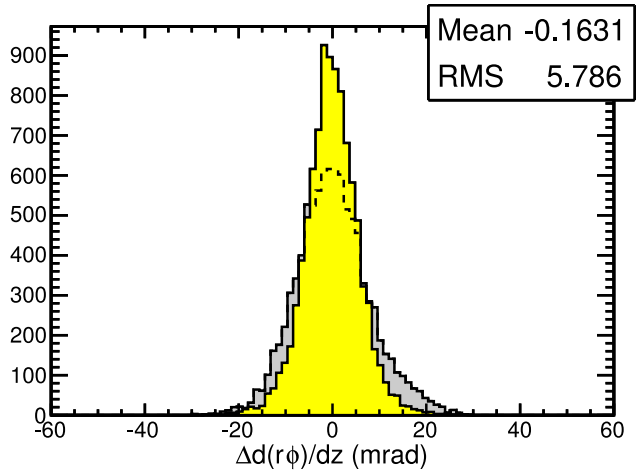


- Two types of residuals: continuity ($\Delta r\phi$) and differentiability ($\Delta \frac{d(r\phi)}{dz}$)
- Outer ring consistent with ∼1 mm RMS misalignment

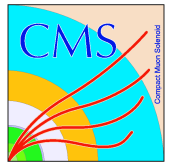








Upcoming alignment steps



Very soon (this year?)

- Tracker: combine cosmics and minbias with primary vertex constraint, beam-halo
- DT: continue aligning with cosmic rays
- CSC: align chambers relative to ring with beam-halo, rings relative to tracker with cosmics

Larger datasets ($\sim$5 pb^{-1})

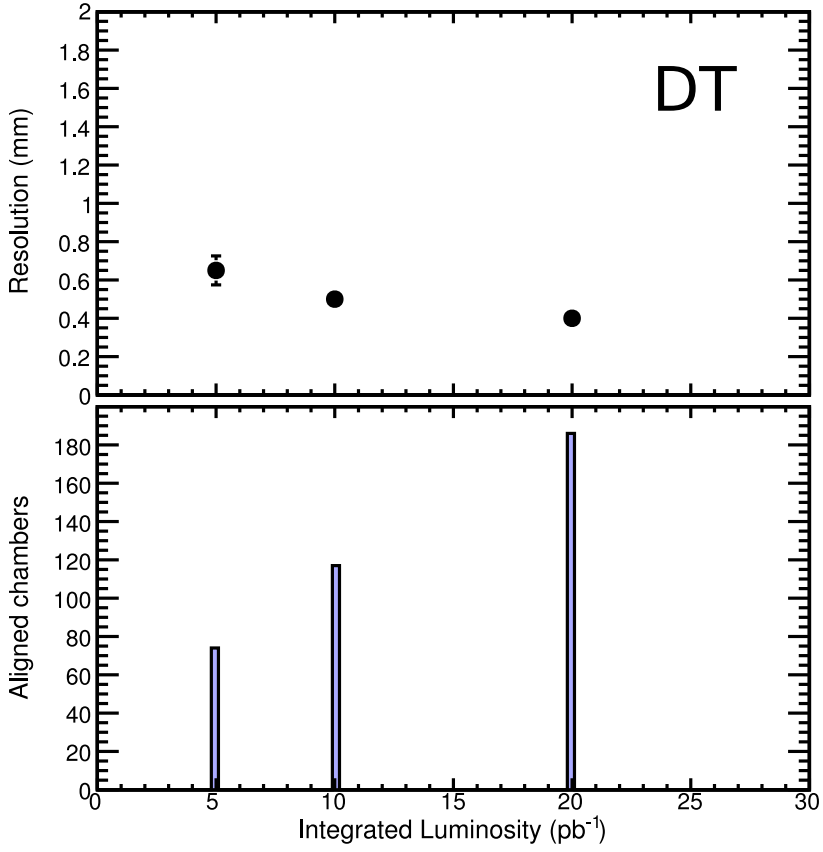
- Tracker: add isolated muon, J/ψ, Υ
- DT: combine cosmics and collisions muons
- CSC: use collisions for chambers-in-ring and tracker-to-ring (cross-checks)

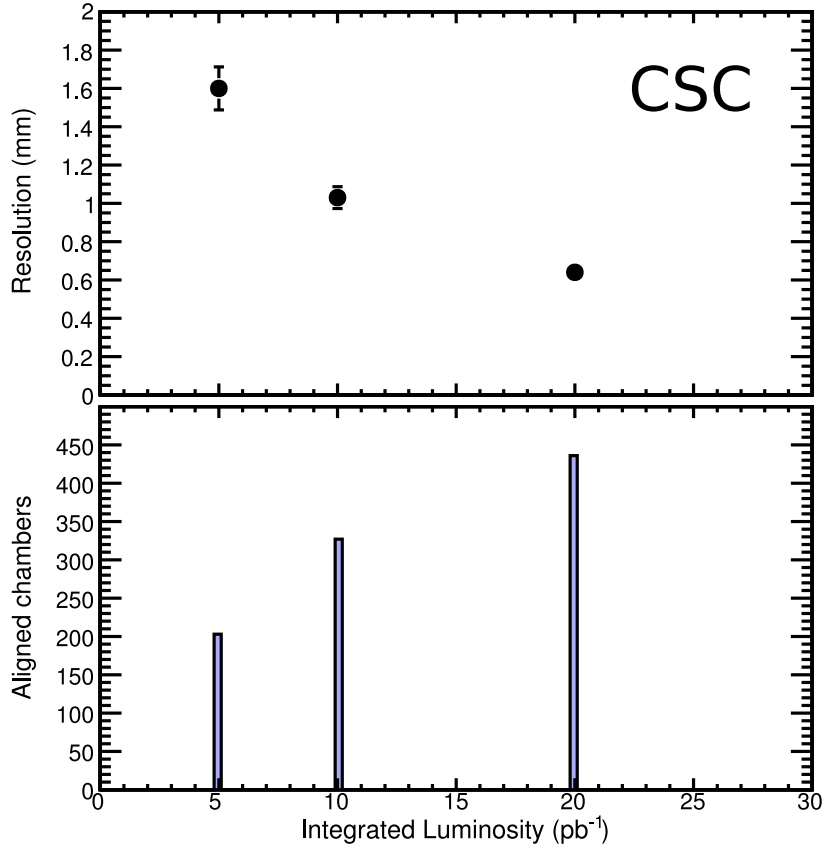
Even larger

- DT and CSC together, using standard algorithm

MC studies of alignment reach

- Aysen Tatarinov (TAMU), new muon alignment expert in training
- Studied alignment resolution as a function of integrated luminosity using standard algorithm
  - aligning all chambers with more than 30 tracks
  - RMS $r\phi$ resolution *for the aligned chambers*
  - see backup for full results

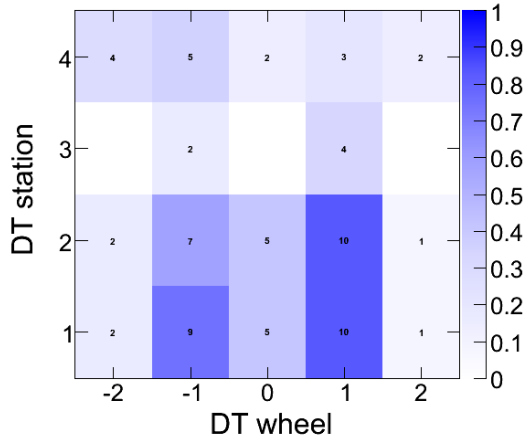


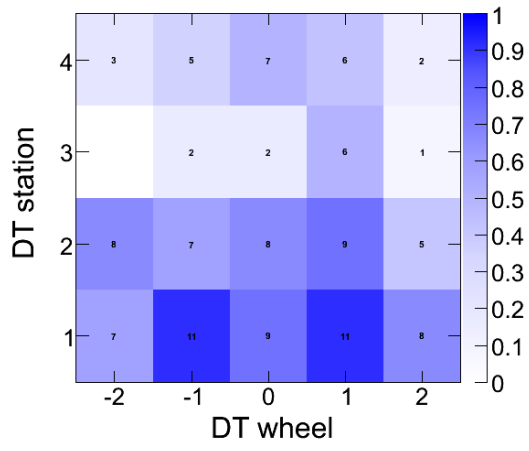


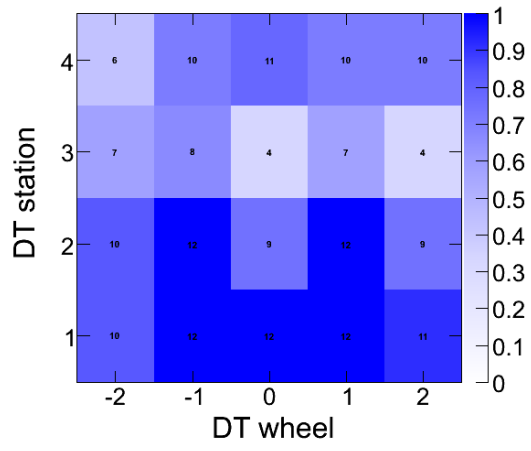
Distribution of aligned chambers

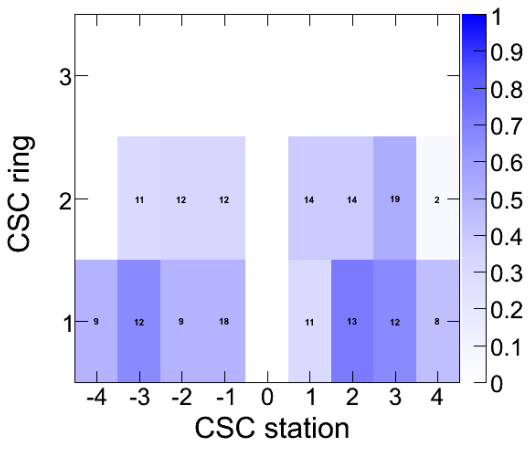
- The alignment fitter succeeds for more chambers as integrated luminosity is added
- Complements chambers accessible with cosmic rays

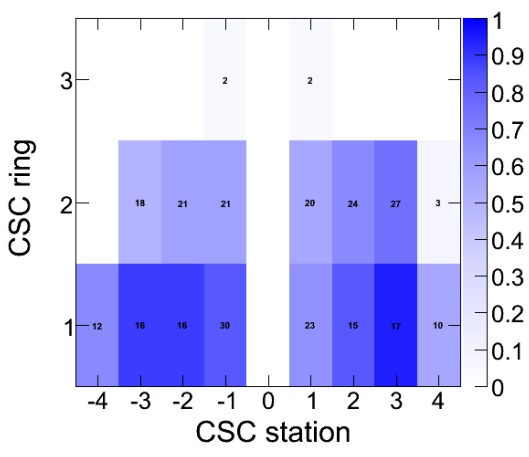
5 pb^{-1} 10 pb^{-1} 20 pb^{-1}

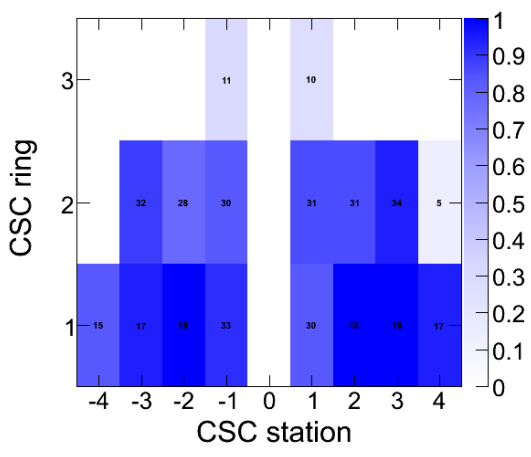








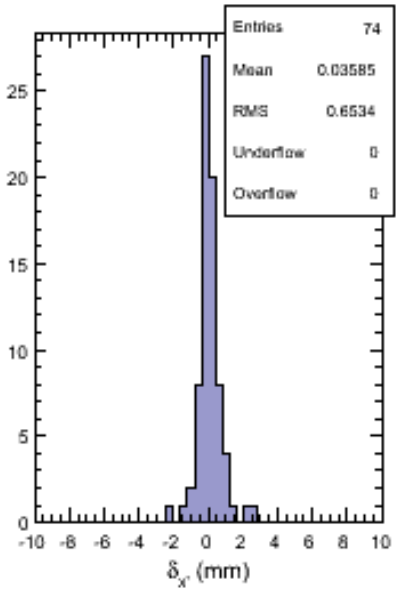


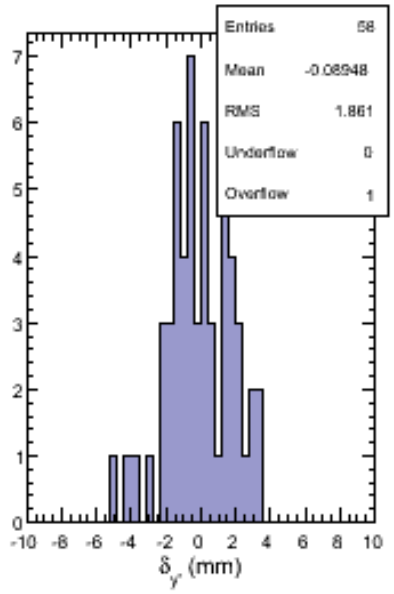


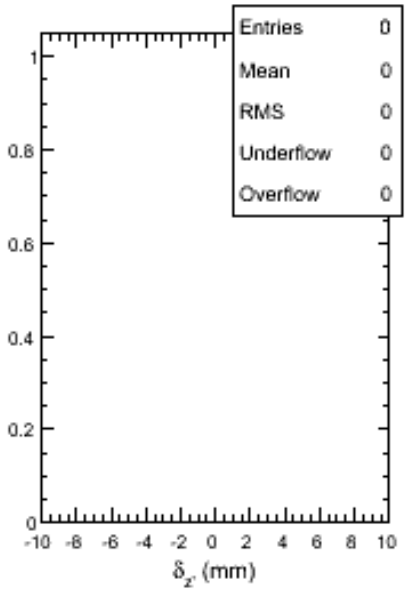
Conclusions

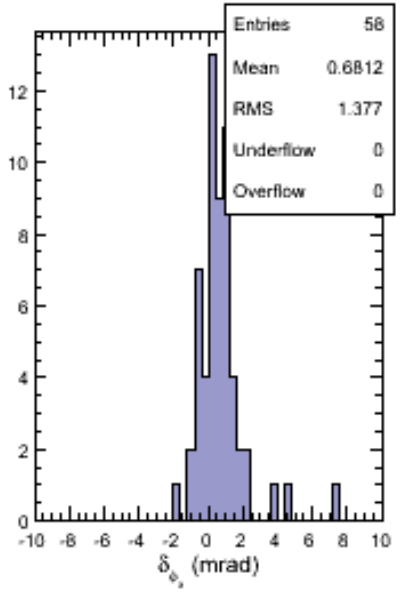
- Tracker CRAFT alignment is precise, but cooling incident moved things; current alignment is post-incident
  - new project: analyzing tracker global distortions with the muon system; if you're interested, more details in Alignment & Calibration meeting
- Current DT + CSC alignments based on CRAFT-09
- Hardware geometry is being studied with tracks (right now for barrel and soon for endcap)
- Too few beam-halo muons for alignment, but the tracks we do see have the right distributions
- Aysen: new aligner in the group, quantifying resolution with low-lumi samples

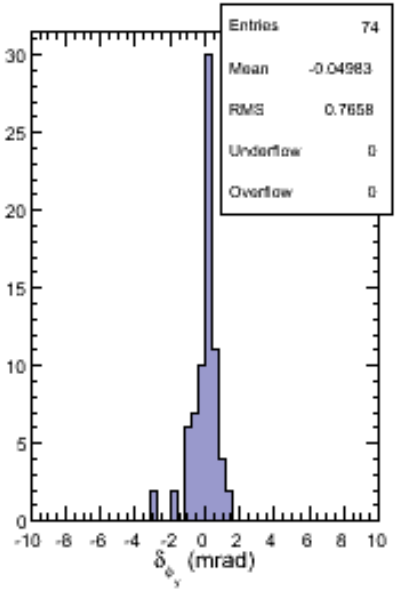
DT 5 pb^{-1}

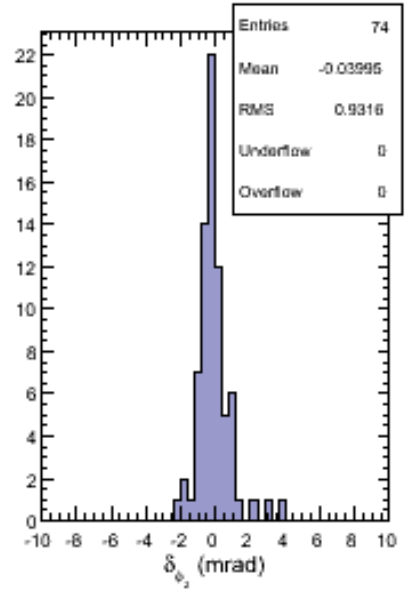

Entries 74
Mean 0.03585
RMS 0.6534
Underflow 0
Overflow 0
$\delta_{x'}$ (mm)


Entries 58
Mean -0.08948
RMS 1.861
Underflow 0
Overflow 1
$\delta_{y'}$ (mm)

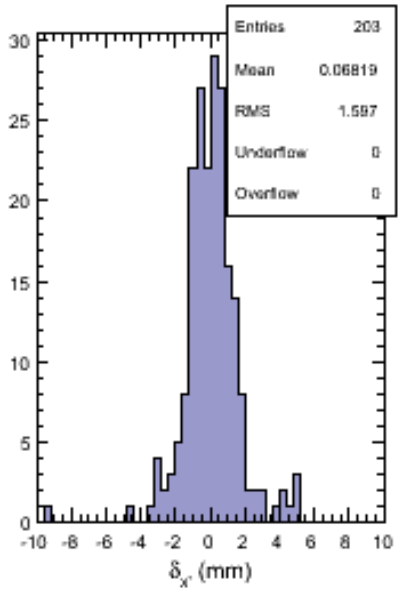

Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{z'}$ (mm)

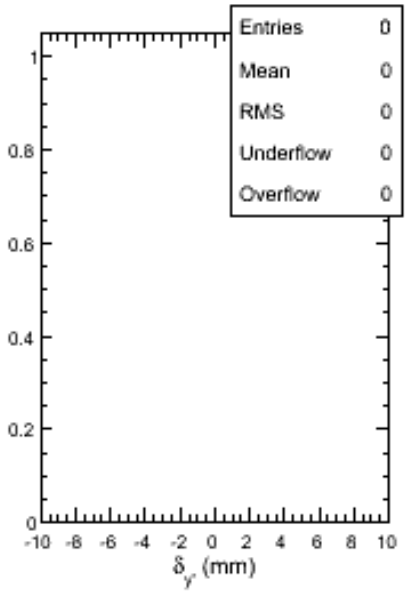

Entries 58
Mean 0.6812
RMS 1.377
Underflow 0
Overflow 0
δ_{ϕ_x} (mrad)

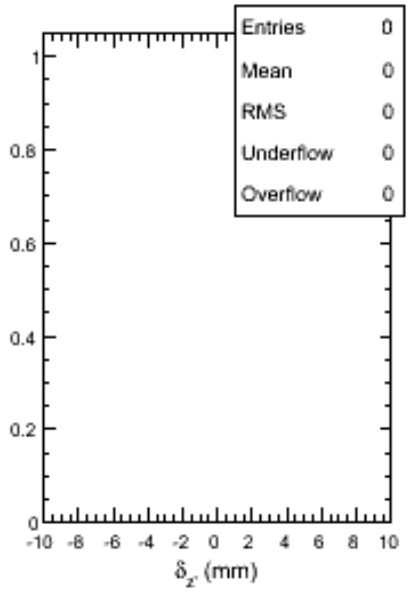

Entries 74
Mean -0.04983
RMS 0.7658
Underflow 0
Overflow 0
δ_{ϕ_y} (mrad)

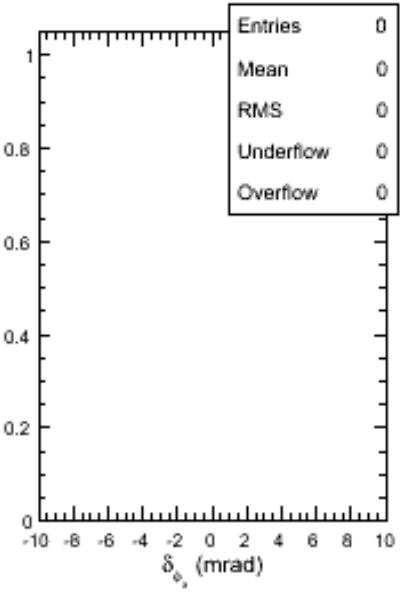

Entries 74
Mean -0.03995
RMS 0.9316
Underflow 0
Overflow 0
δ_{ϕ_z} (mrad)

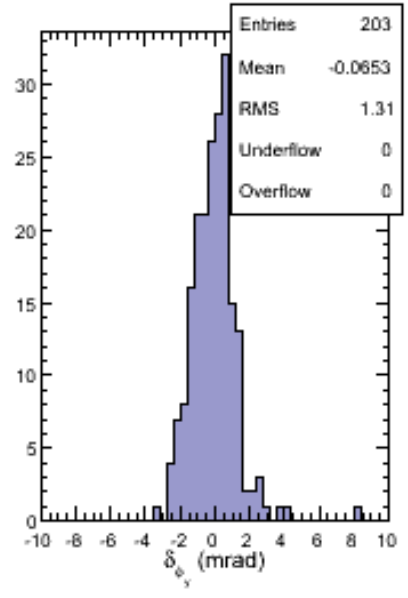
CSC 5 pb^{-1}

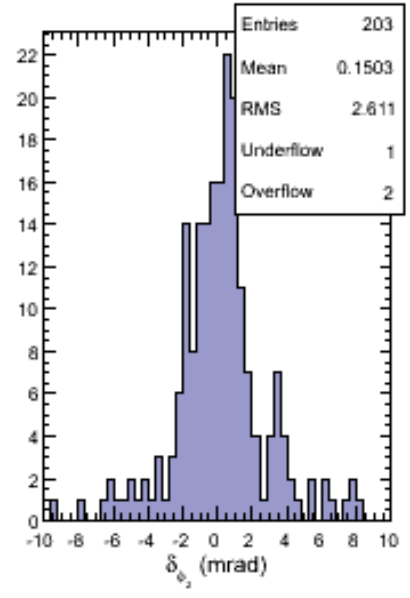

Entries 203
Mean 0.06819
RMS 1.597
Underflow 0
Overflow 0
$\delta_{x'}$ (mm)


Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{y'}$ (mm)

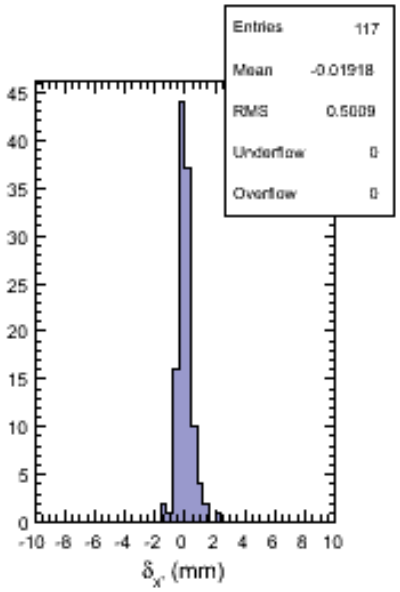

Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{z'}$ (mm)

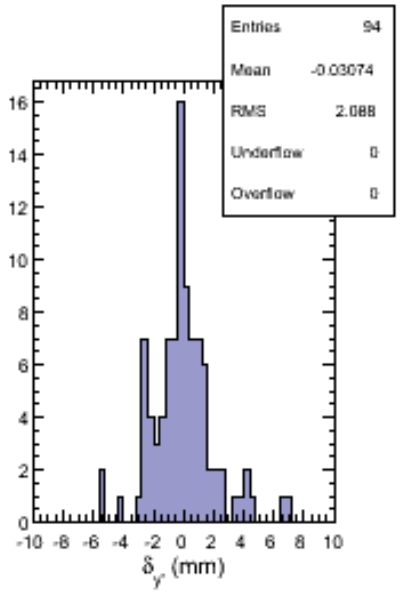

Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
δ_{ϕ_x} (mrad)

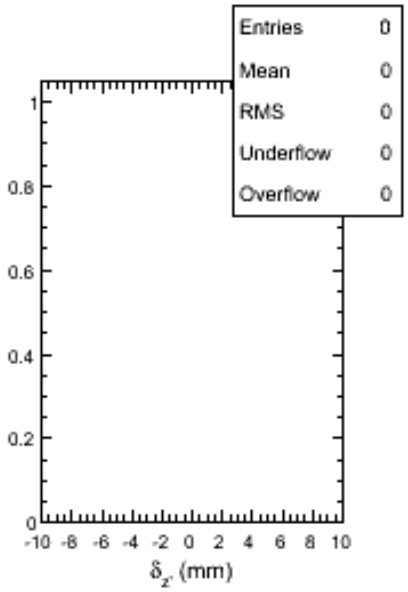

Entries 203
Mean -0.0653
RMS 1.31
Underflow 0
Overflow 0
δ_{ϕ_y} (mrad)

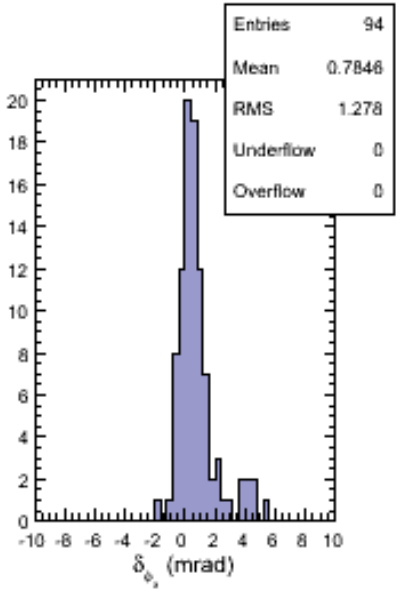

Entries 203
Mean 0.1503
RMS 2.611
Underflow 1
Overflow 2
δ_{ϕ_z} (mrad)

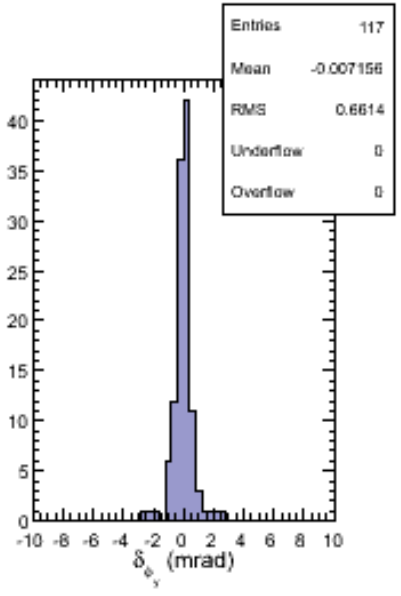
DT 10 pb^{-1}

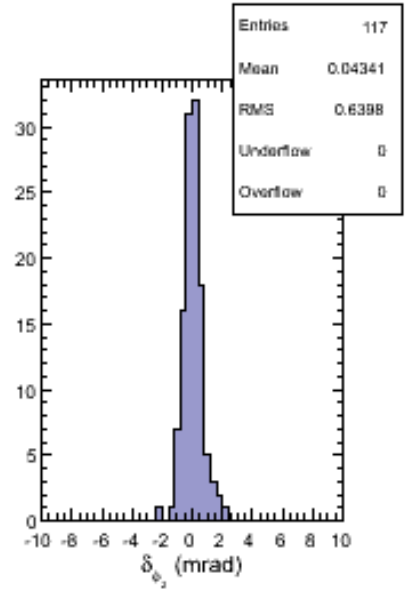

Entries 117
Mean -0.01918
RMS 0.5009
Underflow 0
Overflow 0
$\delta_{x'}$ (mm)


Entries 94
Mean -0.03074
RMS 2.088
Underflow 0
Overflow 0
$\delta_{y'}$ (mm)

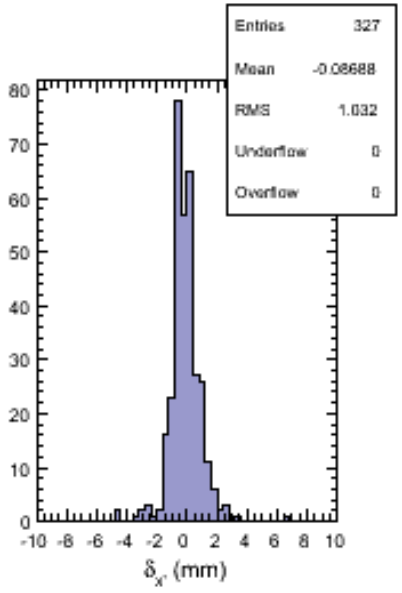

Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{z'}$ (mm)

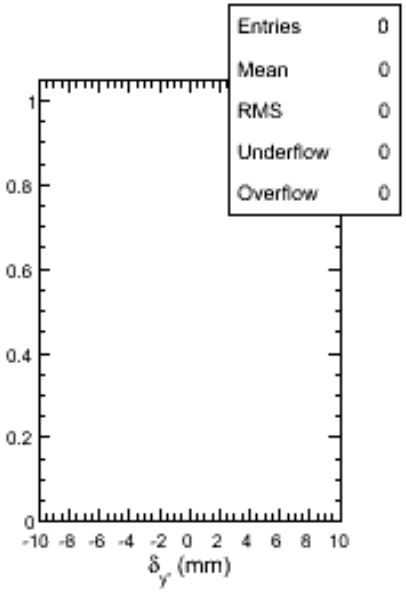

Entries 94
Mean 0.7846
RMS 1.278
Underflow 0
Overflow 0
δ_{ϕ_x} (mrad)

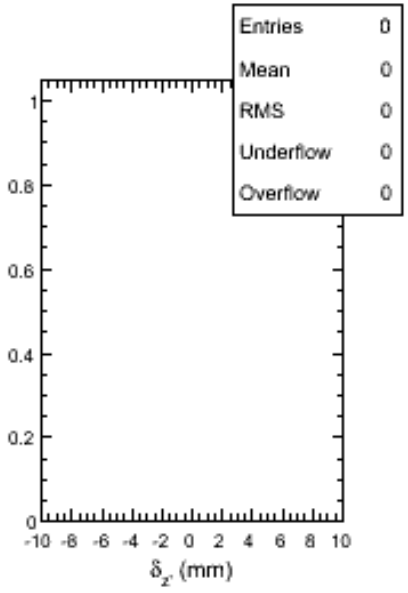

Entries 117
Mean -0.007156
RMS 0.6614
Underflow 0
Overflow 0
δ_{ϕ_y} (mrad)

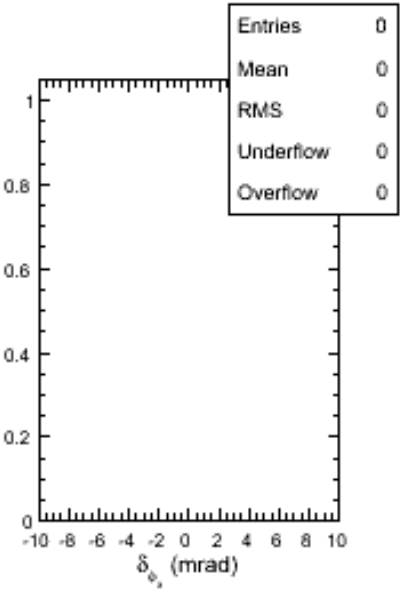

Entries 117
Mean 0.04341
RMS 0.6398
Underflow 0
Overflow 0
δ_{ϕ_z} (mrad)

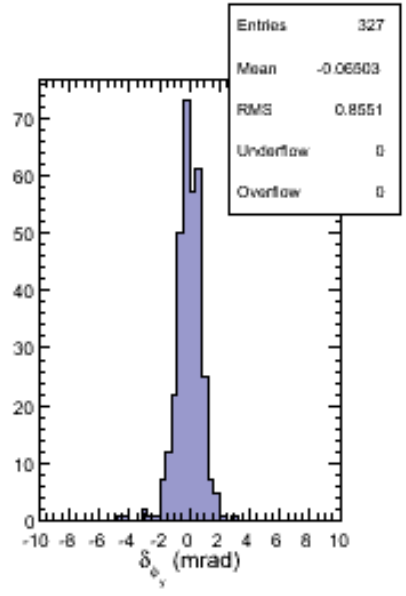
CSC 10 pb^{-1}

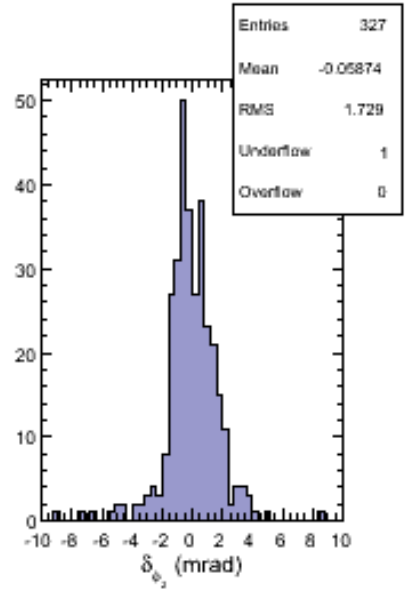

Entries 327
Mean -0.08688
RMS 1.032
Underflow 0
Overflow 0
$\delta_{x'}$ (mm)


Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{y'}$ (mm)

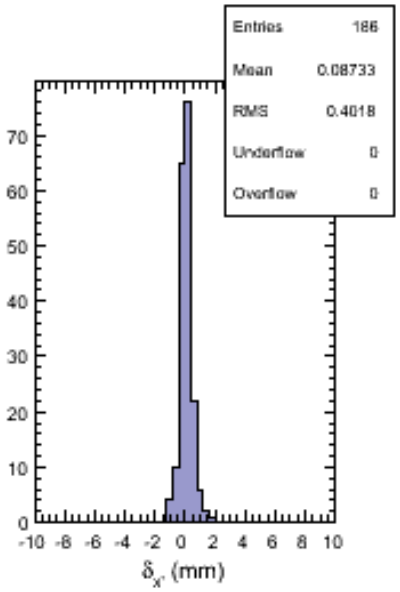

Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{z'}$ (mm)

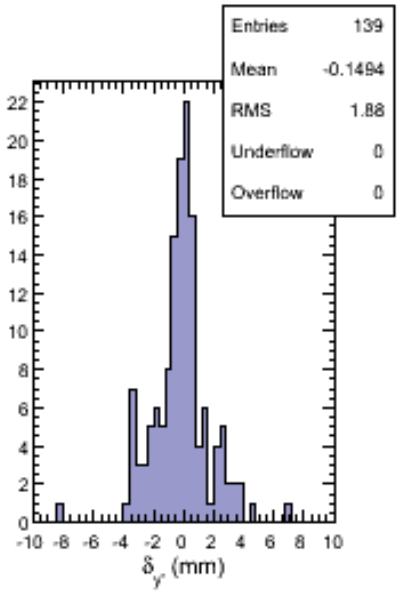

Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
δ_{ϕ_x} (mrad)

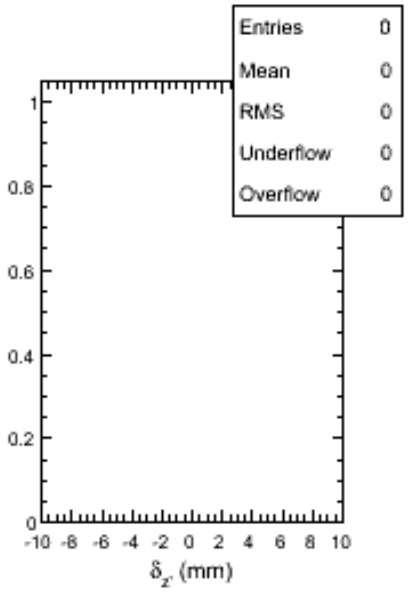

Entries 327
Mean -0.06603
RMS 0.8551
Underflow 0
Overflow 0
δ_{ϕ_y} (mrad)

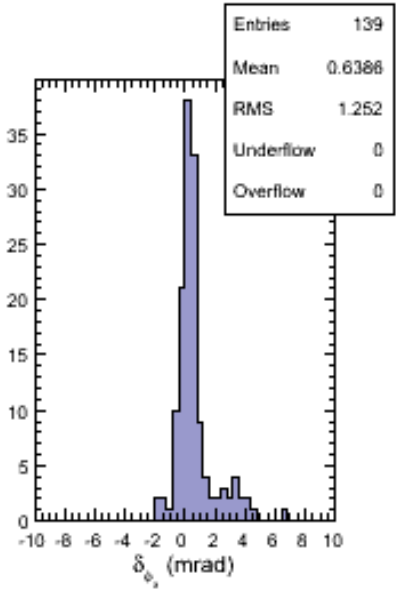

Entries 327
Mean -0.05874
RMS 1.729
Underflow 1
Overflow 0
δ_{ϕ_z} (mrad)

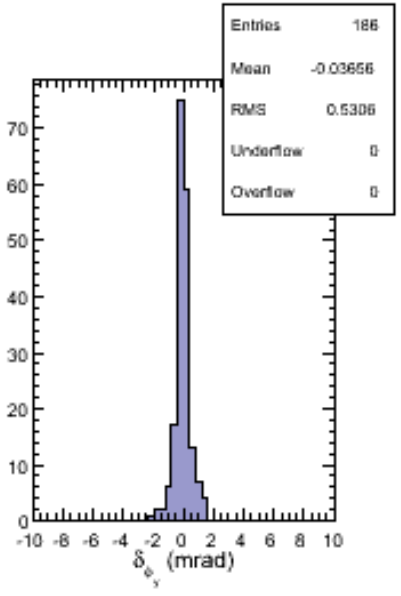
DT 20 pb^{-1}

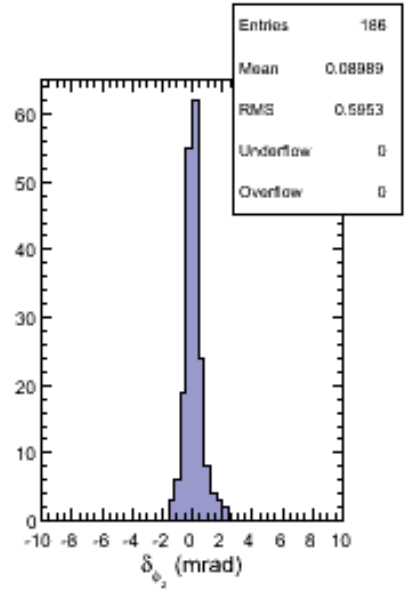

Entries 186
Mean 0.08733
RMS 0.4018
Underflow 0
Overflow 0
$\delta_{x'}$ (mm)


Entries 139
Mean -0.1494
RMS 1.88
Underflow 0
Overflow 0
$\delta_{y'}$ (mm)

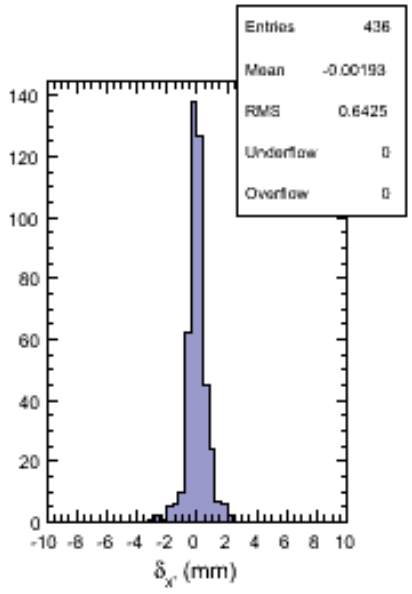

Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{z'}$ (mm)

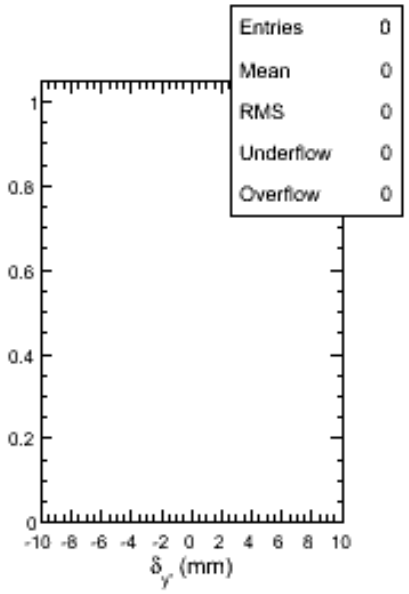

Entries 139
Mean 0.6386
RMS 1.252
Underflow 0
Overflow 0
δ_{ϕ_x} (mrad)

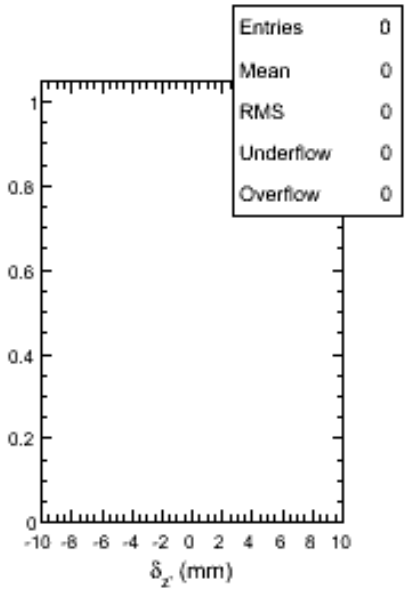

Entries 186
Mean -0.03656
RMS 0.5306
Underflow 0
Overflow 0
δ_{ϕ_y} (mrad)

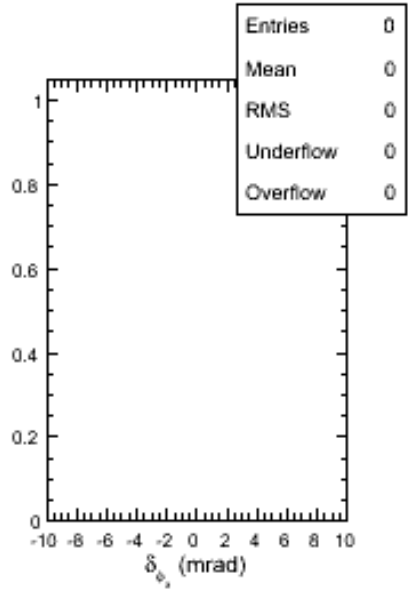

Entries 186
Mean 0.08989
RMS 0.5953
Underflow 0
Overflow 0
δ_{ϕ_z} (mrad)

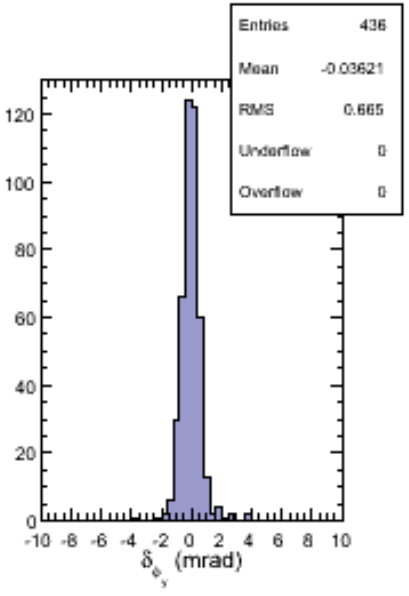
CSC 20 pb^{-1}

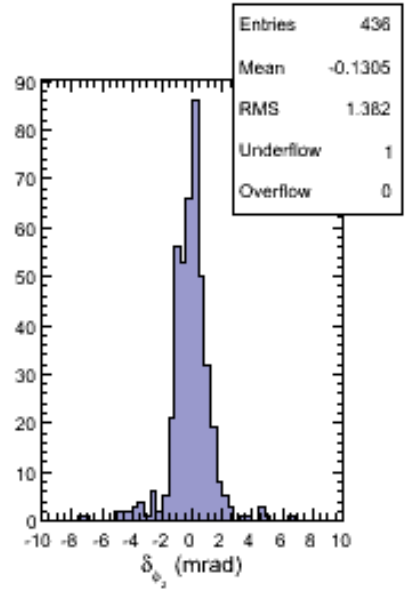

Entries 436
Mean -0.00193
RMS 0.6425
Underflow 0
Overflow 0
$\delta_{x'}$ (mm)


Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{y'}$ (mm)


Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
$\delta_{z'}$ (mm)


Entries 0
Mean 0
RMS 0
Underflow 0
Overflow 0
δ_{ϕ_x} (mrad)


Entries 436
Mean -0.03621
RMS 0.665
Underflow 0
Overflow 0
δ_{ϕ_y} (mrad)


Entries 436
Mean -0.1305
RMS 1.382
Underflow 1
Overflow 0
δ_{ϕ_z} (mrad)