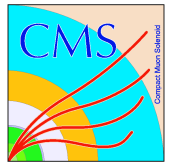


State of Muon Alignment and What Needs to be Done

Jim Pivarski

Texas A&M University

10 November, 2009

State of A&M muon alignment

The good news

- Our Reference-Target procedure seems to be recognized as the *de facto* track-based muon alignment method for CMS
- Hardware alignment system is being diagnosed via comparisons with our track-based data (rather than the other way around)
- Our CSC-Overlaps procedure has been conclusively demonstrated with last year's beam-halo, and has been successfully tested with this year's Monte Carlo (new)
- The 2008 beam-halo/CRAFT paper (09-016) has been accepted by the collaboration (this is our only documentation so far)
- Our Tracker-To-Ring alignment has been tested in CRAFT-2009 (CSC-Overlaps + Tracker-To-Ring is a complete endcap alignment)

What comes next

- Large quantities of beam-halo: must align all CSCs with beam-halo (CSC-Overlaps) and cosmic rays (Tracker-To-Ring)
- First collisions: must align all DTs with low-p_T muons (Reference-Target)

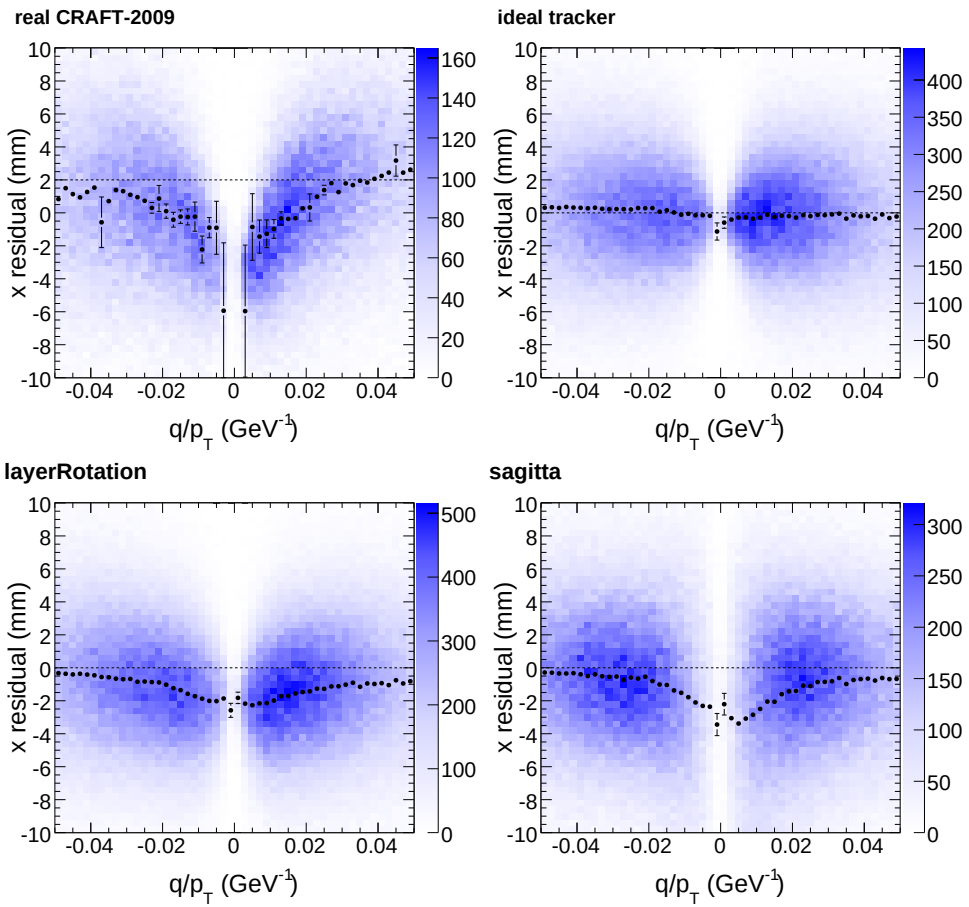
Problems and open questions

In order of importance

- Both DT and CSC alignments exhibit dependence on track p_T (hard)
  - cannot apply interim solution, a $p_T > 100$ GeV cut, with collisions (cosmics $\sim {p_T}^{-2.7}$, collisions $\sim \exp(-p_T)$)
  - DT problem: probably a global distortion of the tracker
  - CSC problem: p_T dependence alternates sign between chambers
- We don't know how alignment resolution depends on $\int \mathcal{L}\, dt$ (easy)
- findQualityFiles.py doesn't seem to work (?)
- Need to complete documentation
- Will eventually need the following new features:
  - alignment of ME1/1, 1/4 CSCs in rigid 2-chamber groups (physically the same chambers, independent units in software)
  - radial alignment of DTs in rigid 5-chamber groups (if pre-alignment is guaranteed by hardware system)
  - ability to align radial positions of CSCs (a very different project)
  - ability to align internal layers, especially in CSCs

DT p_T dependence

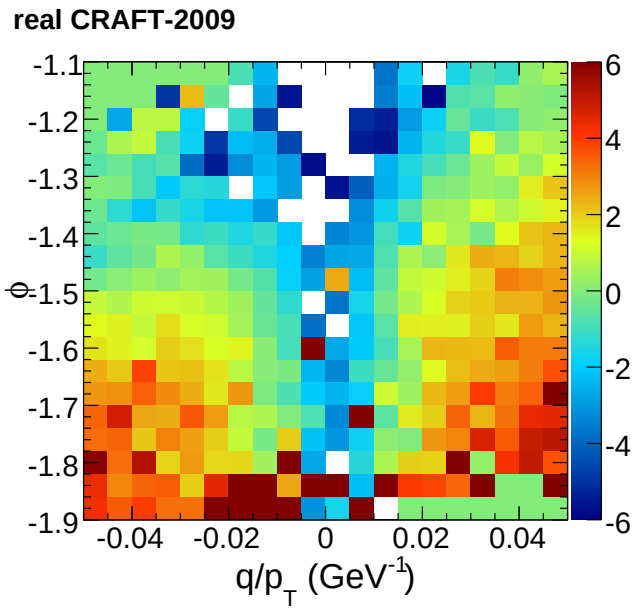
- Quick study: select a single DT layer (wheel, station, sector, layer: 0, 1, 10, 2) to avoid any dependence on internal muon misalignment
- Plot "unbiased residuals" as a function of q/p_T (curvature)
- Misalignment of the DT layer would be constant in q/p_T, magnetic field or material budget errors would be antisymmetric in q/p_T

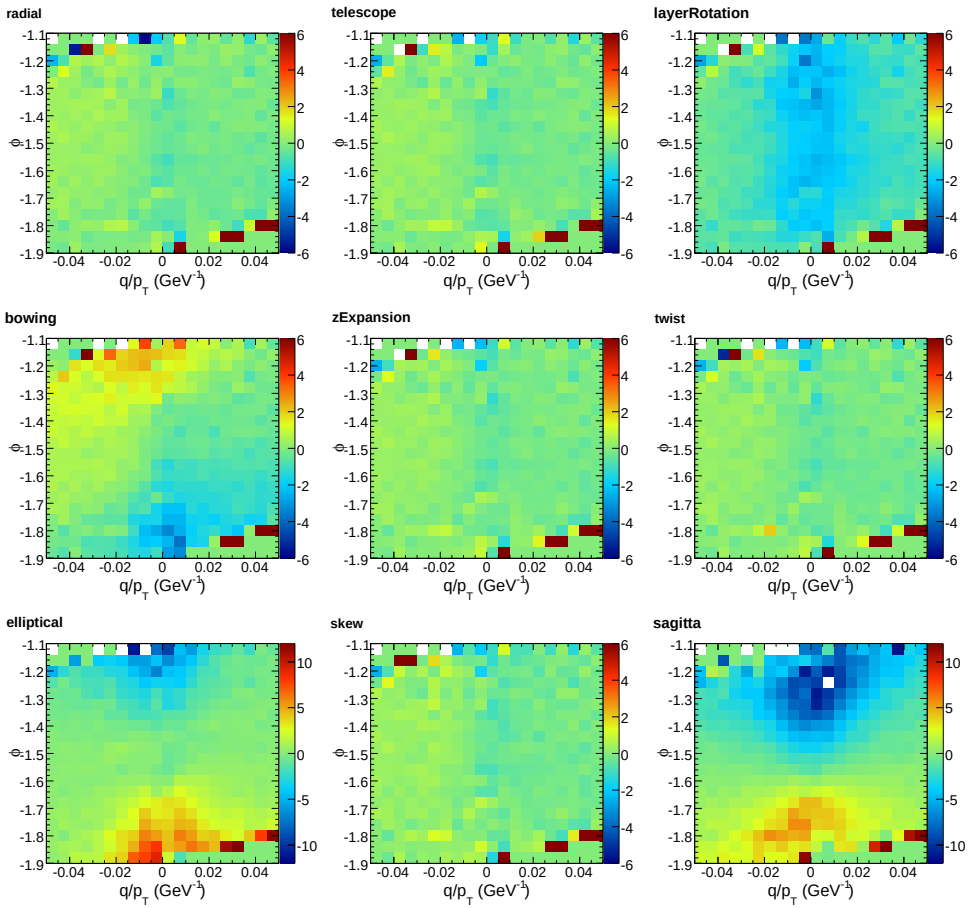


- Top-left: real data, CRAFT-2009 in 3_2_7 with the latest tracker alignment
- Others: Monte Carlo with different tracker geometries
- blues: 2-D distribution of residuals vs. q/p_T
- black points: profile (vertical mean by bin)

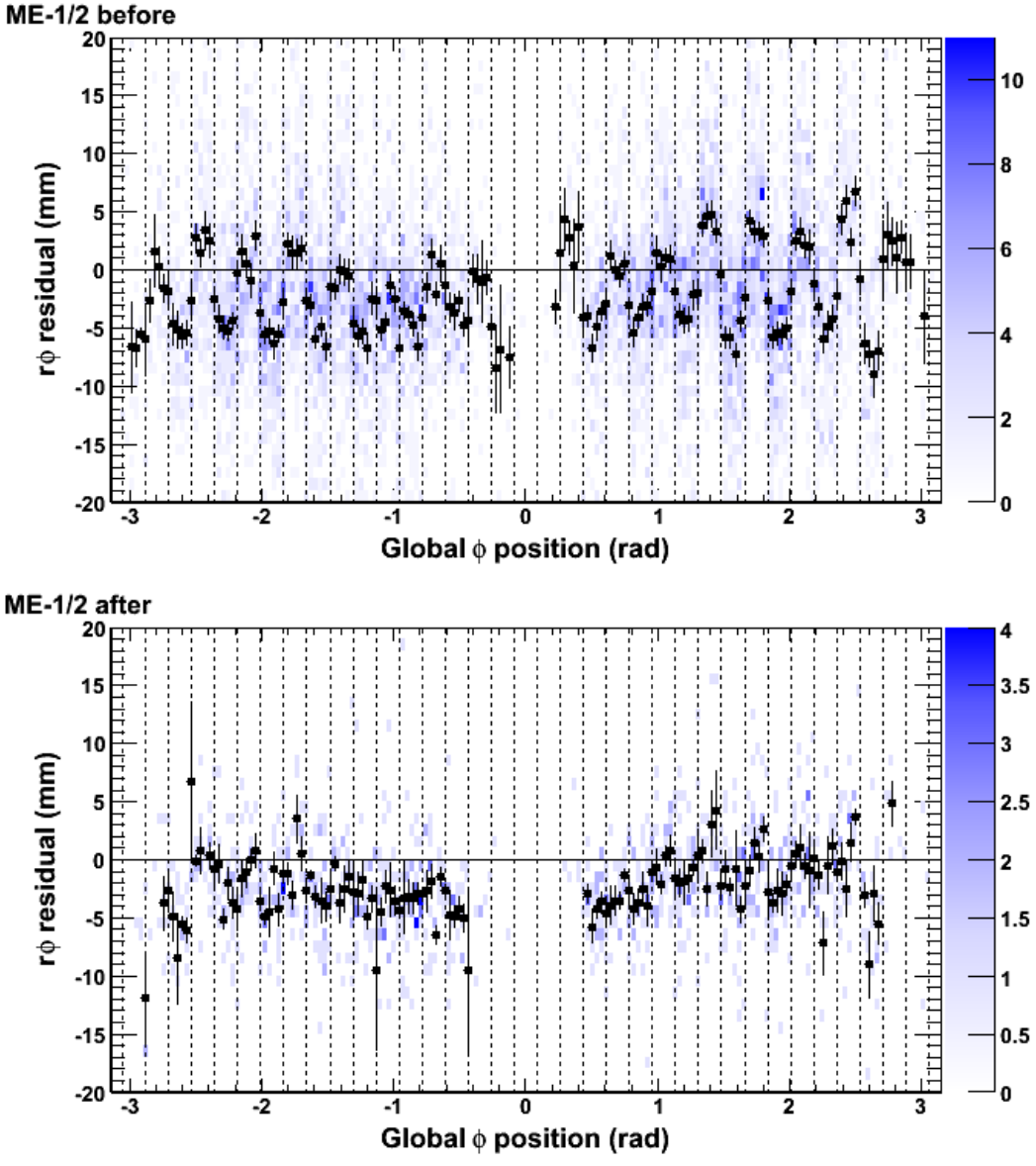
DT residual vs. ϕ and q/p_T

- 2-D profiles: color scale is average residual (mm) in each 2-D bin
- None of the 9 example tracker distortions has exactly the same shape as data
- This is a tracker alignment issue; shown in tracker alignment meeting



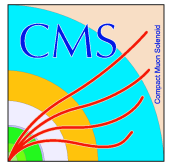


CSC p_T dependence



- Alternation of residuals from one chamber to the next
- Non-physical: the chambers wouldn't move like that
- $p_T > 40$ GeV cut $\rightarrow$ $p_T > 100$ GeV suppresses the effect
- Not observed in RecHits (overlaps)
- Unclear what the effect is (not $\vec{B}(\vec{x})$, as that wouldn't alternate)

Who should work on this?



- DT p_T dependence: likely a tracker alignment issue, may be solved by tracker alignment with early collisions, resonances, etc.
  - I'm trying to get someone to use the method I presented to diagnose the tracker
  - Not for our group (tracker alignment is not our scope)

- CSC p_T dependence: I might be able to figure something out by comparing overlapping CSCs (beam-halo) with tracks from the tracker (cosmics)
  - very open-ended problem, because symptoms don't make sense
  - CSC-DPG is aware of it, I'm encouraging others to look at it

Dependence on $\int \mathcal{L}\, dt$

- We're starting to get questions about when we'll be able to provide a first alignment of all chambers (cosmic ray alignment only covers top and bottom, where the cosmic rays are)
- Usual answer of 20–50 pb^{-1} is no longer acceptable (50 pb^{-1} is no longer considered a small amount of data)
- Natural conclusion of "October Exercise" study:
  - split sample into non-overlapping samples: 5, 10, 20, 50 pb^{-1} or something
  - run procedure (correctly) on each
  - quote results

findQualityFiles.py not working

- I tried to use it to select within a run range, it selected zero runs
- I was in a hurry, so I did it by hand
- It needs to be made robust, at least in a stand-alone CMSSW directory

Documentation

- We're building up new a tree (starting summer 2008) under

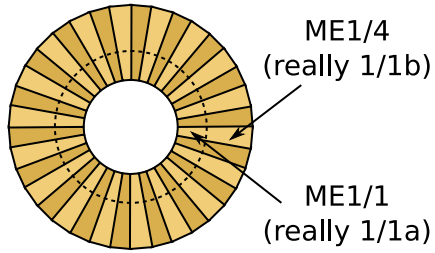
  `https://twiki.cern.ch/twiki/bin/view/CMS/SWGuideMuonAlignment`

- findQualityFiles.py should become a separate page, not in the flow of the Reference-Target documentation

Who should work on this?

- Clearly, I have to write the first draft of each topic
- But it would be very helpful if you could expand, polish, or otherwise make it more useable as you try to use it
  - our e-mail discussions have made SWGuideMuonAlignReferenceTarget out-of-date

New features 1

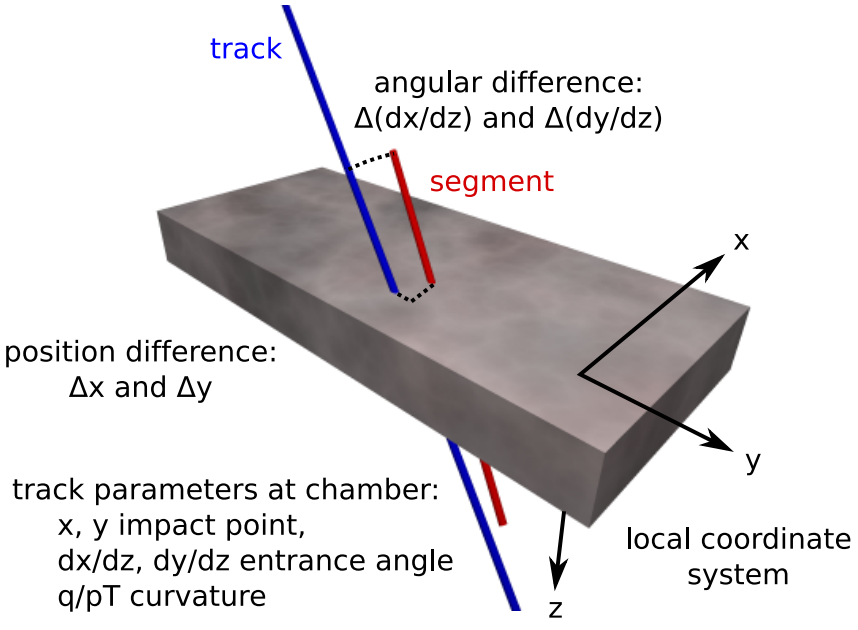


- CMSSW makes a distinction between the 1/1a half and the 1/1b half of ME1/1 chambers (models them as separate chambers)
- They are physically part of the same frame; we should treat them as rigid bodies for alignment
- I implemented this in Reference-Target, but it seemed to not be working, so it is off by default
- It has not been implemented in CSC-Overlaps, but it needs to be

Who should work on this?

- I should just find and fix the bug
- But I may ask for your help in testing (i.e. run a simulated collisions alignment to check that it was handled properly)
- I'll need to copy the implementation into CSC-Overlaps

New features 2: DT radial



- Radial (local z) alignment of DTs is only weakly determined by tracks
  - δ_z correction is effectively the slope of Δx residuals versus $\frac{dx}{dz}$ entrance angle or Δy residuals versus $\frac{dy}{dz}$ entrance angle
  - distributions of entrance angles are narrow, limiting the precision of the slope

- $\Delta x / \frac{dx}{dz}$ and $\Delta y / \frac{dy}{dz}$ can be antisymmetric with q/p_T, just like magnetic field and material budget errors: normal trick doesn't work
- If we could assume that 5-chamber groups spanning all 5 wheels are at *the same* z position, we would gain a much broader expanse of $\frac{dy}{dz}$ by aligning them together as rigid bodies (in z only; for the other parameters, we do normal single-chamber alignment)

New features 2: DT radial

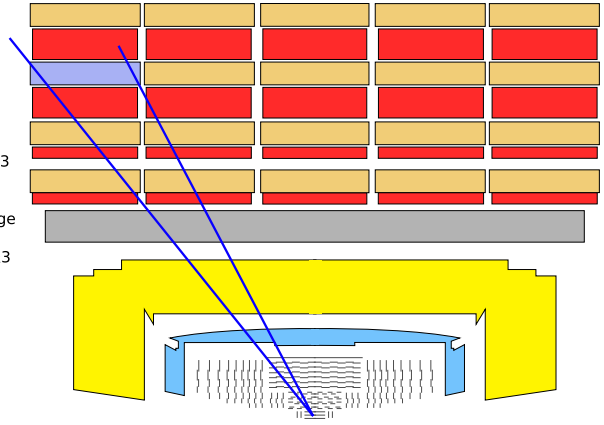
Jim Pivarski

Single chamber fit:
dy/dz range: about 0.15 rad
and can be asymmetric
dx/dz range: about 0.5 rad
but symmetric

$\Delta z = \Delta y$ / (dy/dz) from SL2
$\Delta z = \Delta x$ / (dx/dz) from SL1&3

Overconstrained: final z position is a weighted average of z determined from SL2 and z determined from SL1&3

Local coordinates for chambers depicted

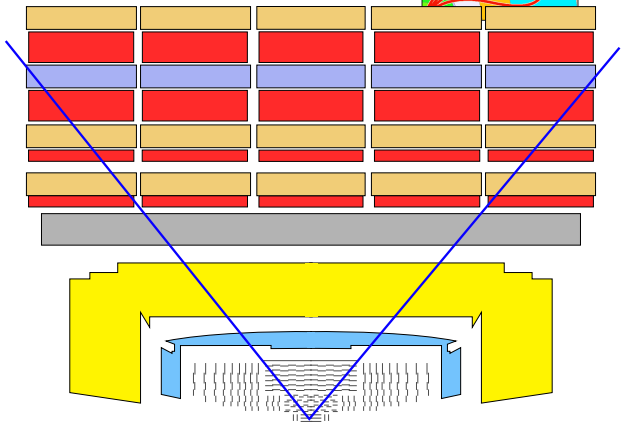


SemiSuperSector fit:
dy/dz range: about $\pi/2$
and symmetric

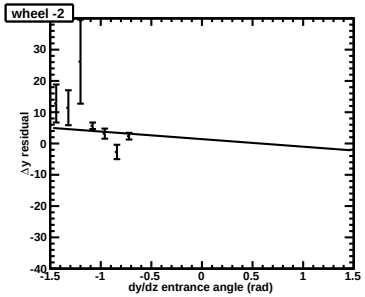
$\Delta z = \Delta y$ / (dy/dz) from SL2

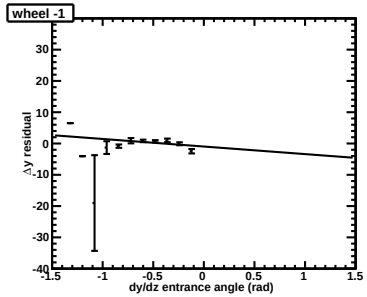
Final z position comes from SL2 only. Correct placement of SL1&3 depends on internal DT alignment.

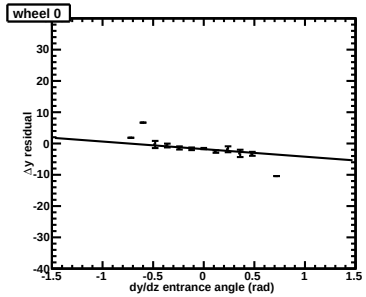
Local coordinates for chambers depicted

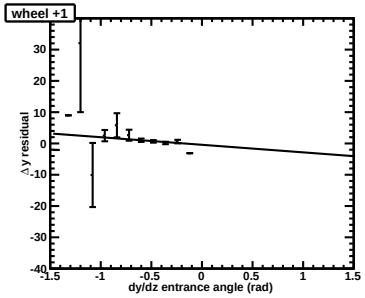


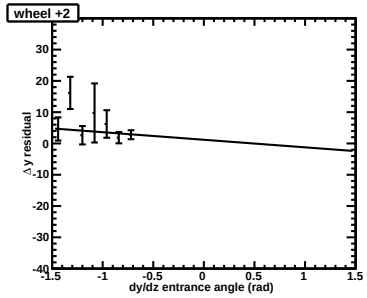
- Hacked together a test, and it does seem that the hardware alignment provides relatively consistent z positions









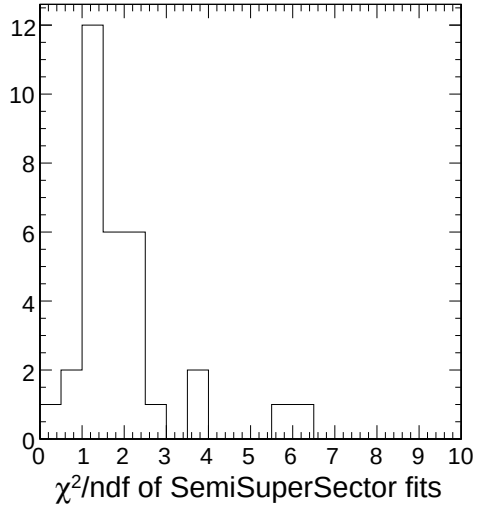


Station 1, sector 05

slope = $\Delta z'$ =

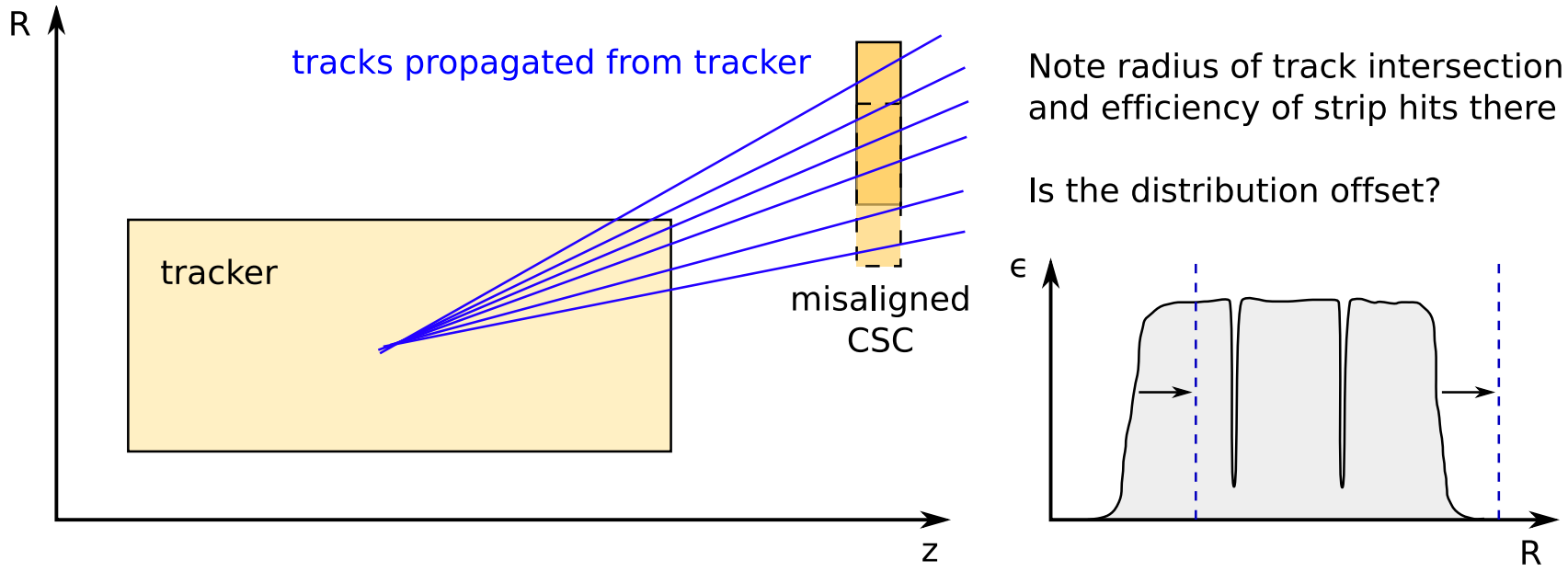
2.42007 ± 0.539568 mm

χ^2/ndf = 62.8884/41 = 1.53386

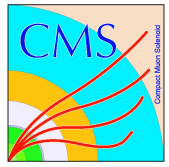


New features 3: CSC radial

- CSC wire measurements are not good for alignment: huge granularity (several cm) yields non-bell-curve residuals
- Both Reference-Target and CSC-Overlaps use strip data only; very little sensitivity to radial positions (local y)
- Can identify radial position by observing location of inefficiencies at regular intervals on the chambers, instead of residuals
- This would be a very different kind of project, separate framework

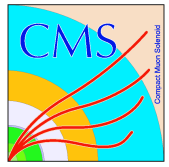


New features 4: layer alignment



- Track-based layer alignment has the best resolution when using only local linear segments
- Our chamber geometries (N parallel layers) have serious weak modes when doing so (especially shear of the chamber and all segments)
- Using overlapping tracks in the CSCs only turns this into a ring-wide problem
- One could develop a hybrid procedure where the slope of the segment is derived from a track propagated from the tracker and the intercept is from locally-fitted data
  - track angles propagated from the tracker are unambiguous
  - segment positions from a local fit are precise
- We have stayed out of DT layer alignment, and should continue to do so for the foreseeable future
- CSC layers appear to be well aligned already (in ME$-2/1$, $-3/1$)
- Oleg's hardware alignment of CSC layers has the same weak modes (by coincidence)

Conclusions



- Lots to do!
- We should figure out short/long-term goals and who does what in this meeting