Update on Track-Based Alignment in CRUZET

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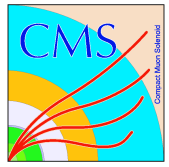
Outline



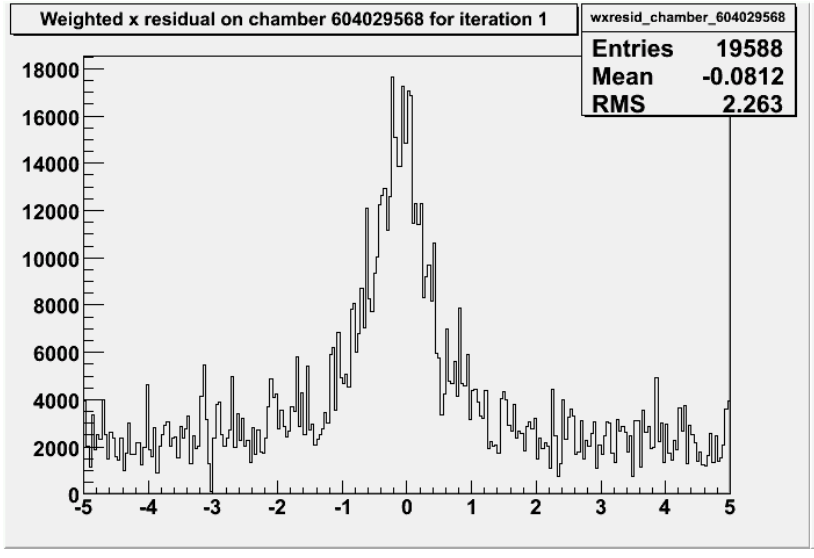
- Updates in CSC Overlap procedure in CRUZET
- Baseline procedure using StandAloneMuons in CRUZET-2

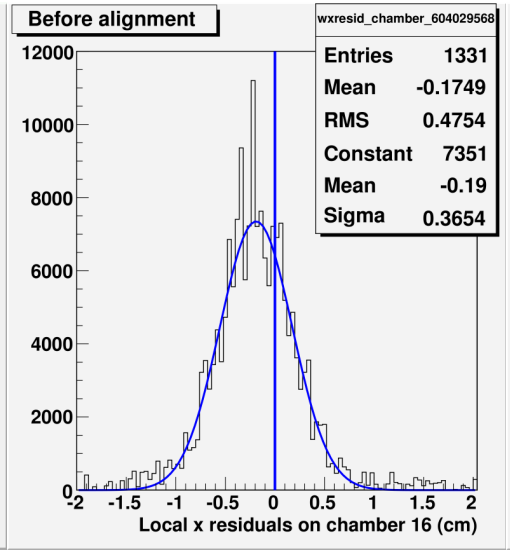
CSC Overlap procedure

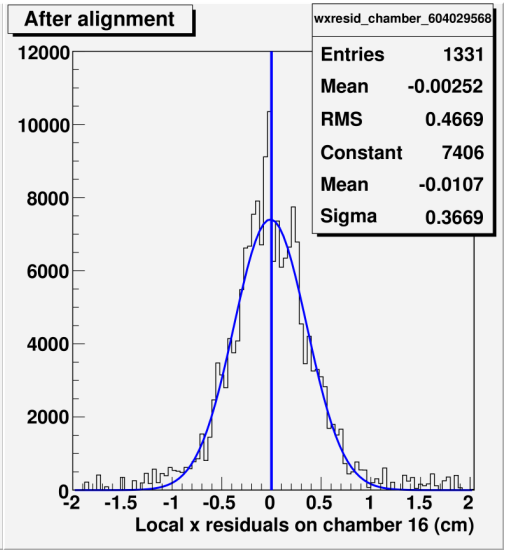
We have the residuals, we can minimize them, but is it *aligned?*

Plots of residuals on ME+4/1 chamber 16 from fit to chamber 15:

1. Any two segments in neighboring chambers
2. Exactly two segments, nearly collinear (linear fit has $\chi^2/\text{ndf} < 10$)
3. Applied alignment procedure

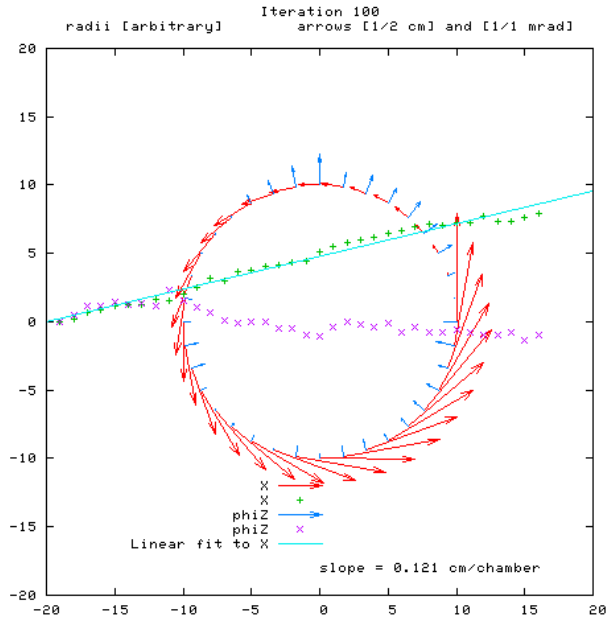




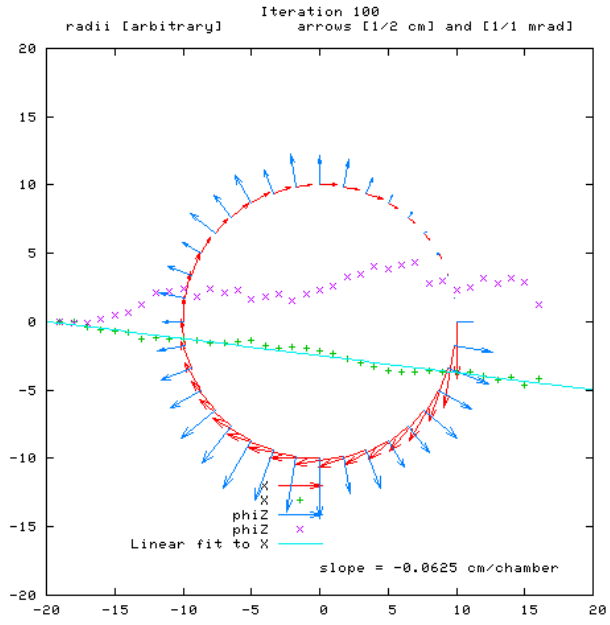


Rings do not close

ME+2/2 (CRUZET-1)



ME+3/2 (CRUZET-1)



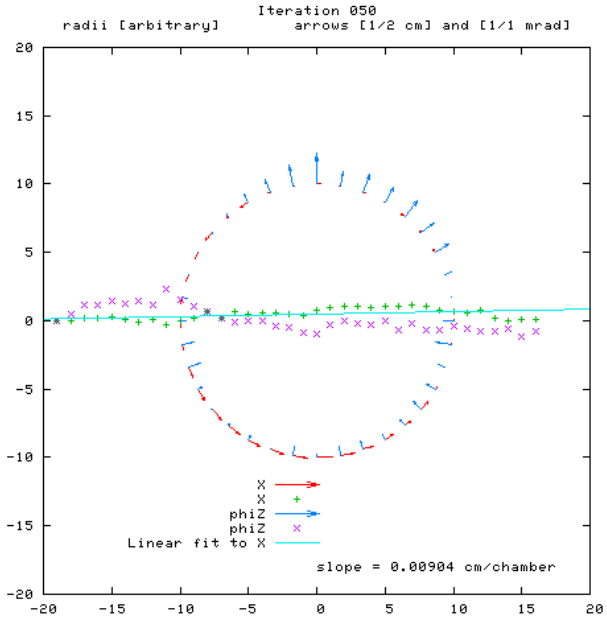
Average alignment correction per chamber (confirmed in CRUZET-2)

ring	ME+2	ME+3	ME+4
1	−0.5 mm	?	+1.0 mm
2	+1.2 mm	−0.6 mm	

Iteration-by-iteration animations from CRUZET-1 and -2 available in
https://banicz.web.cern.ch/banicz/CMS/alignment/CRUZET

Interpretations

ME+2/2 with $R+ = 6.6$ mm



Radial growth of the rings?

ME+2/2	ME+3/2
+6.6 mm	−3 mm

- ME2/2 and ME3/2 are identical: how can these be in opposite directions?
- Hard to imagine a transcription error or a physical effect which can do this

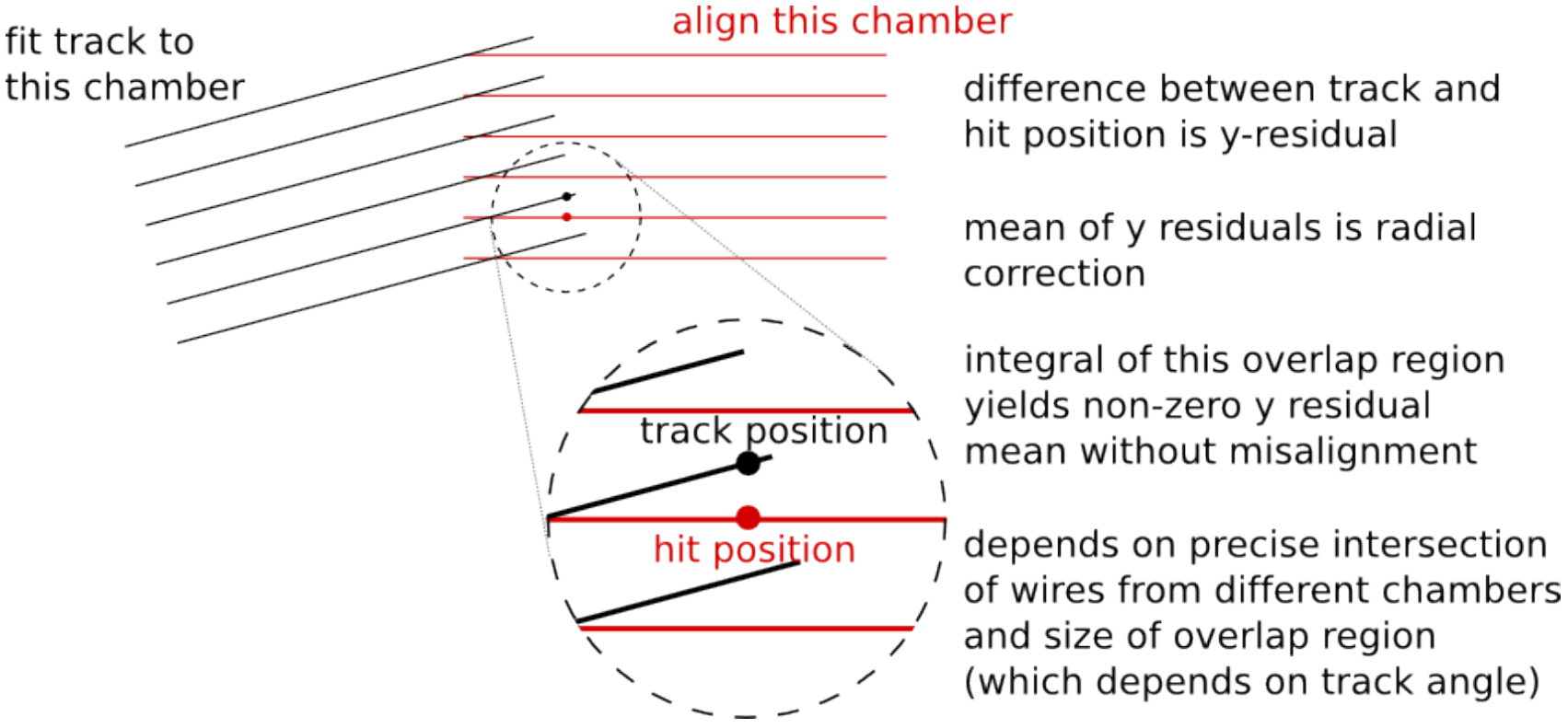
However, Oleg and I have found that our narrow-end alignment pin positions in ideal DDD and ideal detector drawings do not agree.

- DDD is 7 mm too far from beamline in ME2/2 and ME3/2
- 9.53 mm in all other stations (except ME1/1) very consistently
- ME1/1 chambers have no alignment pins

Wire group granularity?

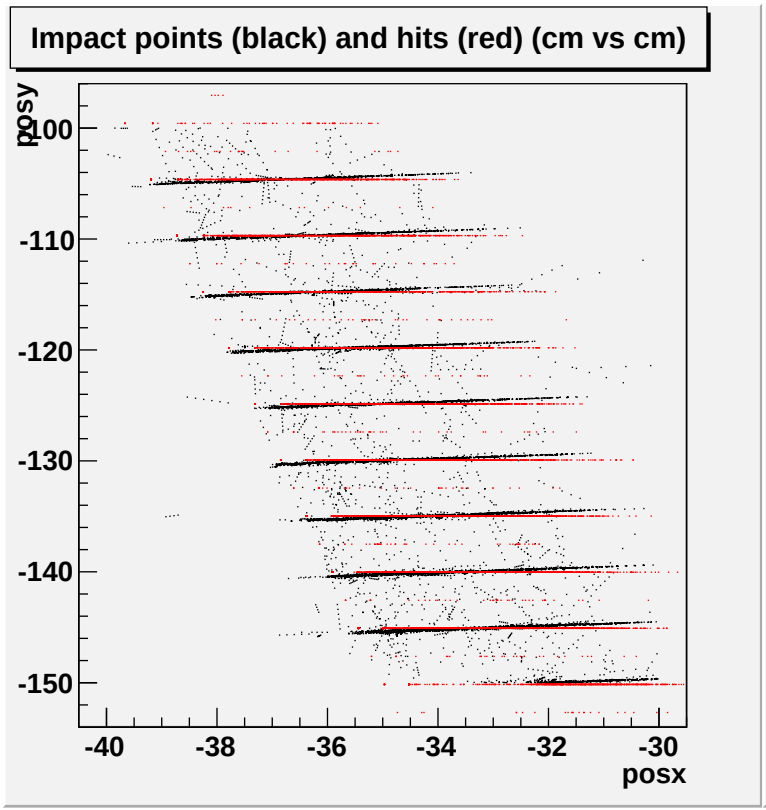
Discreteness of wire groups can cause an apparent radial shift

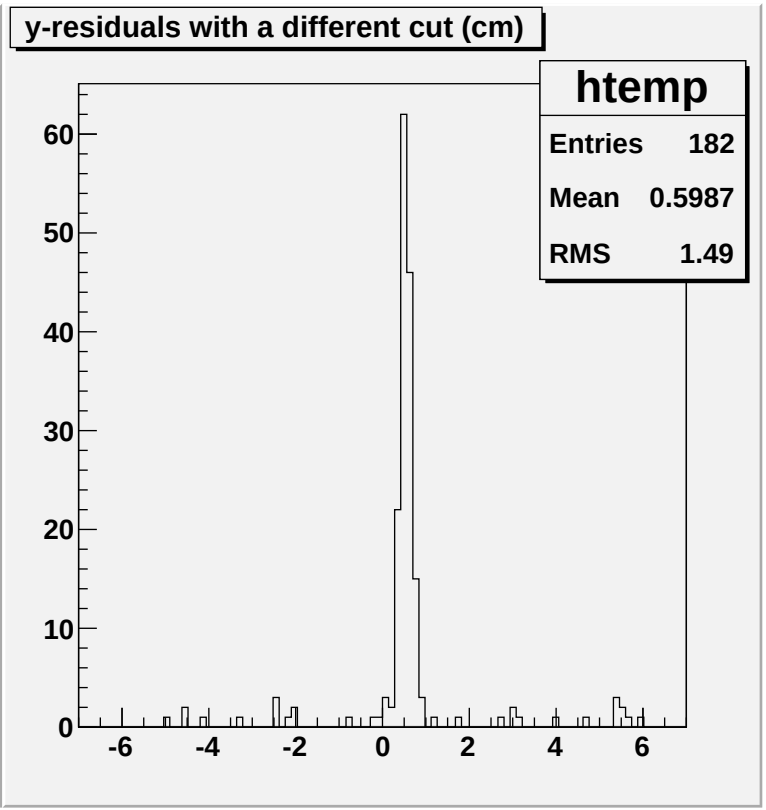
- for most hits, reconstructed y is the nearest wire group center
- at the edge of the chamber, y is needed to resolve x position, propagating effect to x



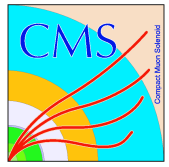
Generating 6 mm shifts

- Beam-halo MC with ideal alignment
- Overlay track extrapolated from reference (black) and hit (red)
- Vertical difference between black and red is the y-residual
- Can create a 6 mm y-residual by changing the degree of overlap (with cuts); cosmic rays have broader overlap due to incidence angles





Baseline procedure in CRUZET



Motivation: to look for the radial shift from further away, unaffected by wire granularity (because you get to average over imperfections in the reference tracking volume)

Method: fit tracks in muon barrel or one endcap station, project them to another endcap station and align

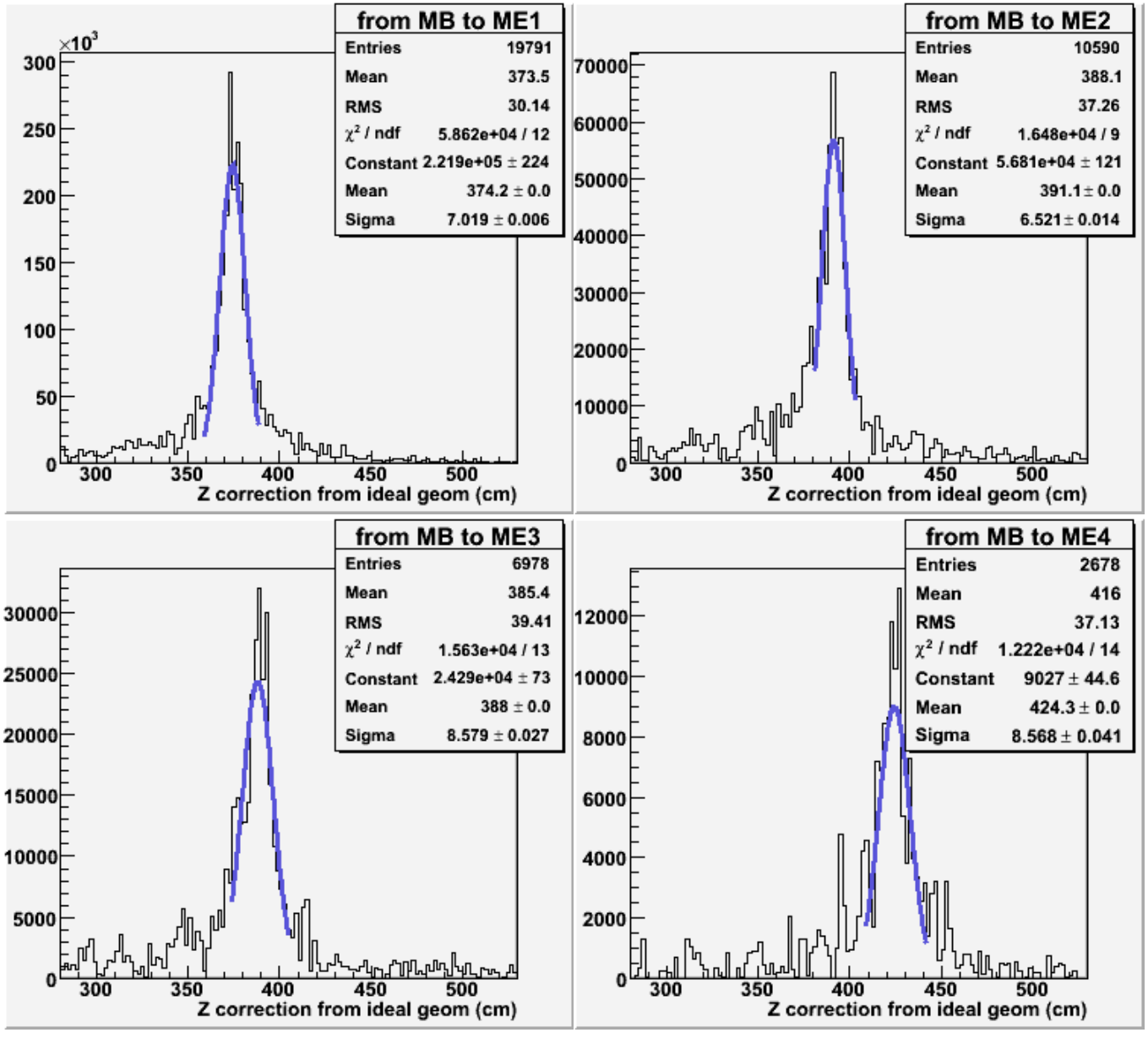
Using HIP derivatives, we can get each hit to tell us where it thinks the whole disk is (in z for instance)

This is complimentary to Riccardo's geometric approach

Plots from CRUZET-2

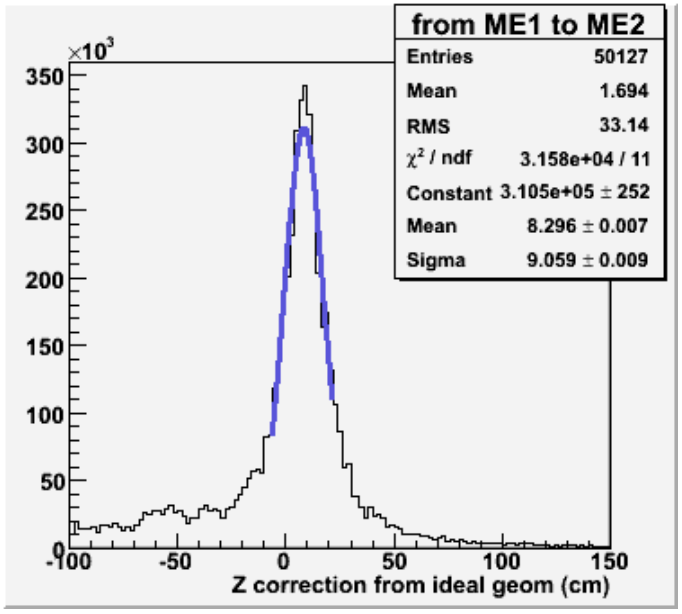
Finding the endcaps

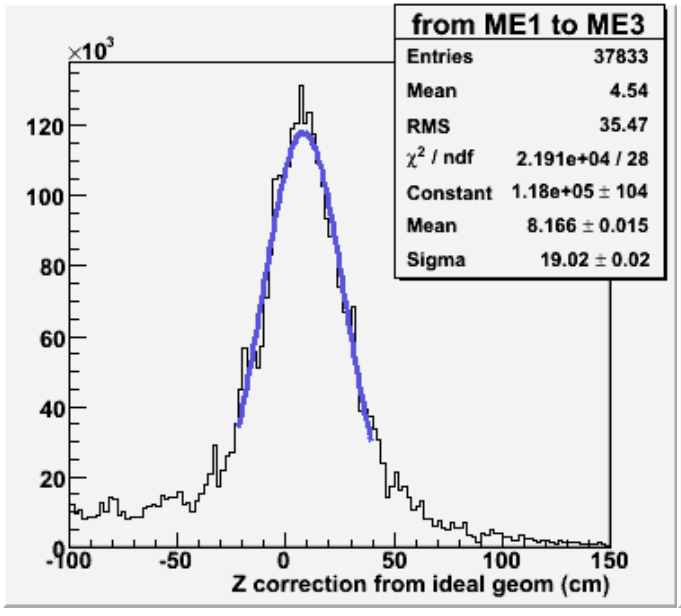
Fit tracks in the barrel, align endcap stations

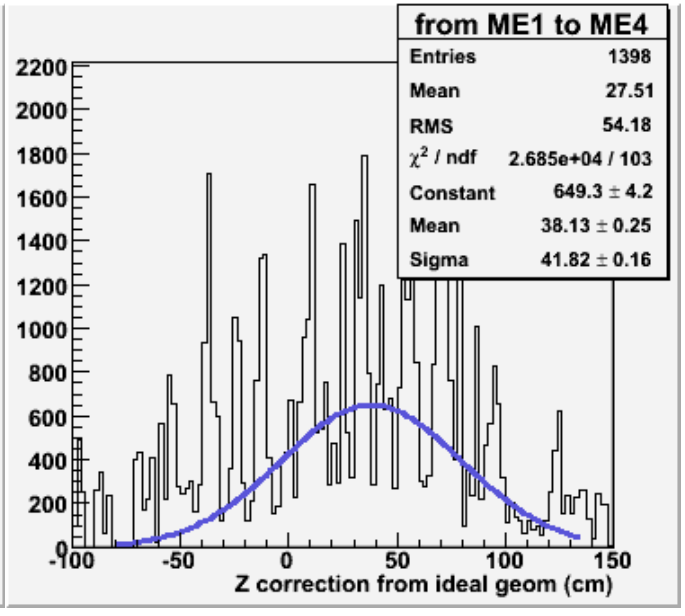


Finding the endcaps

Fit tracks in ME1, align other endcap stations

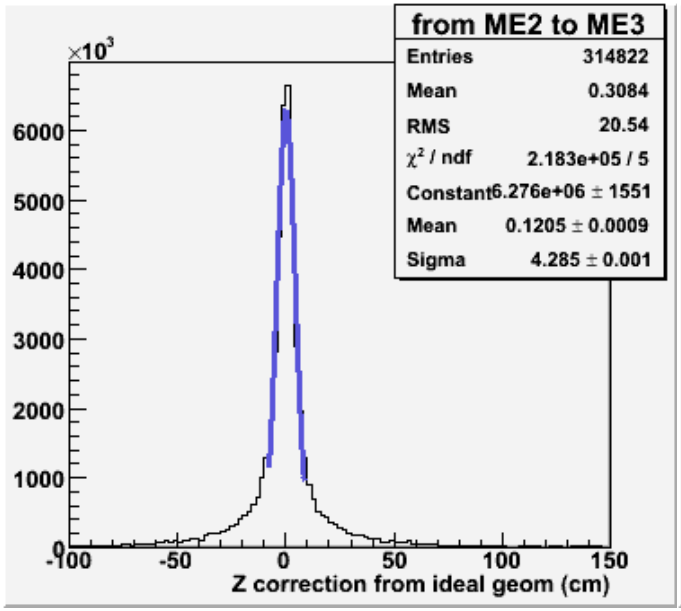


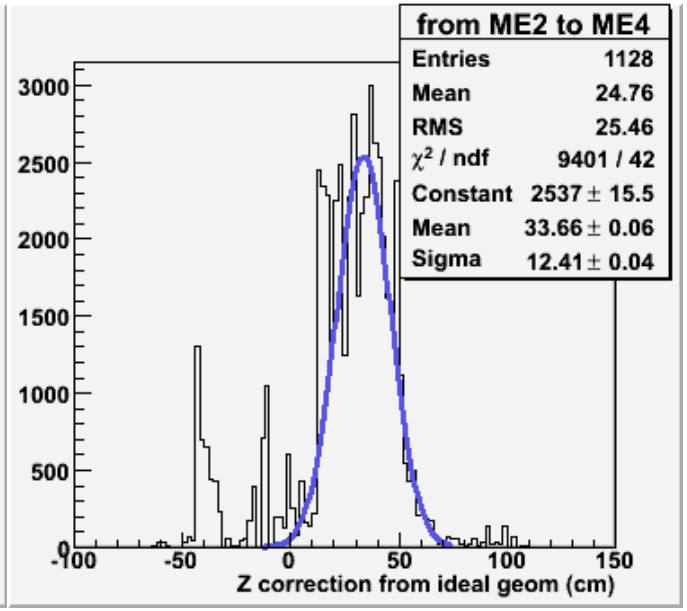




Finding the endcaps

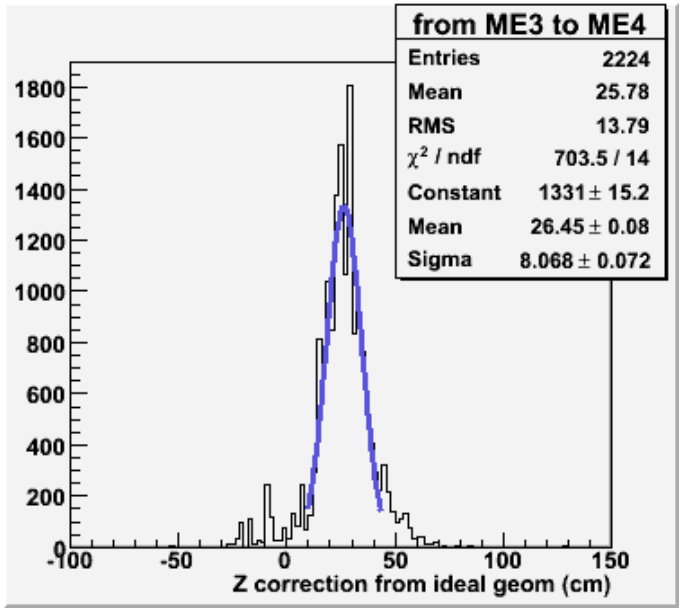
Fit tracks in ME2, align other endcap stations





Finding the endcaps

Fit tracks in ME3, align other endcap stations



Consistency

- ME1
  - 374.178 cm
- ME2 ($\Delta = 8.6$ cm)
  - 391.11 cm
  - ME1 + 8.296 cm = 382.474 cm
- ME3 ($\Delta = 5.7$ cm, 3.2 cm, 8.9 cm)
  - 388.00 cm
  - ME1 + 8.16 cm = 382.34 cm
  - ME2 + 0.1205 cm = 391.23 cm or 382.59 cm
- ME4 ($\Delta = 12$ cm, 0.43 cm, 9.9 cm, 12 cm, 2.2 cm, 10 cm)
  - 424.34 cm
  - ME1 + 38.1 cm = 412.3 cm
  - ME2 + 33.66 cm = 424.77 cm
  - ME3 + 26.45 cm = 414.45 cm

About 10 cm consistency, but it really depends where the track comes from (size of tracking volume, closeness to target, number of tracks)

ME2 and ME3 are linked?

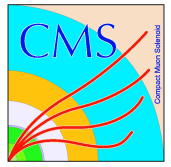
I haven't been able to verify this, but I'm pretty sure ME2 and ME3 are on opposite sides of the same yoke

All parameters agree to high precision (unlike other pairs)

Position of ME3 relative to ME2:

- Δx, Δy, Δz = -0.26 mm, -0.36 mm, 1.52 mm
- $\Delta\phi_x$, $\Delta\phi_y$, $\Delta\phi_z$ = 0.75 mrad, -0.78 mrad, 0.075 mrad

Conclusions, what to do next



- CSC Overlaps procedure either discovered a radial offset in ideal geometry or suffers from a problem due to wire granularity or both
- Migrate CSC Overlaps procedure from local x to raw strip measurements (6 mm RMS $\longrightarrow$ 200 μm) in both track-fits and hit measurements; removes sensitivity to wires altogether
- That will require a little infrastructure work
- Baseline procedure can find stations using StandAloneMuon tracking
- But it doesn't look like it will find radial positions with sufficient precision
- I should apply Pablo's barrel alignment in this study, but wheel positions are key
- I will, however, be able to align individual chambers in ME2 and ME3 due to the high statistics in the ME2 $\leftrightarrow$ ME3 sample (not relative to barrel)
- Statistics pointing to ME4 are poor: if comparison with hardware must be in ME4 (as we planned) we'll need to wait for improvements to CSC Overlaps procedure
- CRUZET-3 tracker-to-muon alignment