Alignment update: CSA08 and CRUZET

Jim Pivarski, Alexei Safonov, Károly Banicz*

Texas A&M University, *US-CMS

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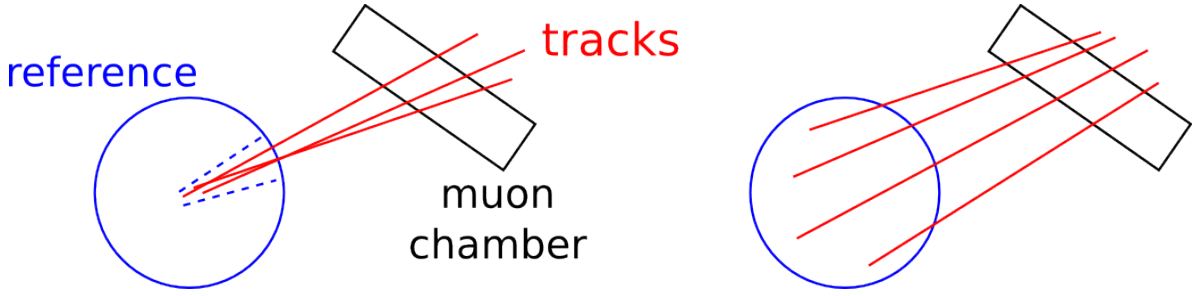
Main theme for this talk

Primary issue in alignment is not "being too many radiation lengths away from the reference system" (multiple scattering), the issue is "being too close" (dependence on fine details of the reference system)



- Symmetric multiple scattering can be defeated with statistics
- Dependence on reference can only be reduced by averaging over larger tracking volume

Outline of topics

- CSA08: results and lessons learned
- CSC Overlaps procedure: what works, what doesn't, and why
- Alignment with CRUZET data

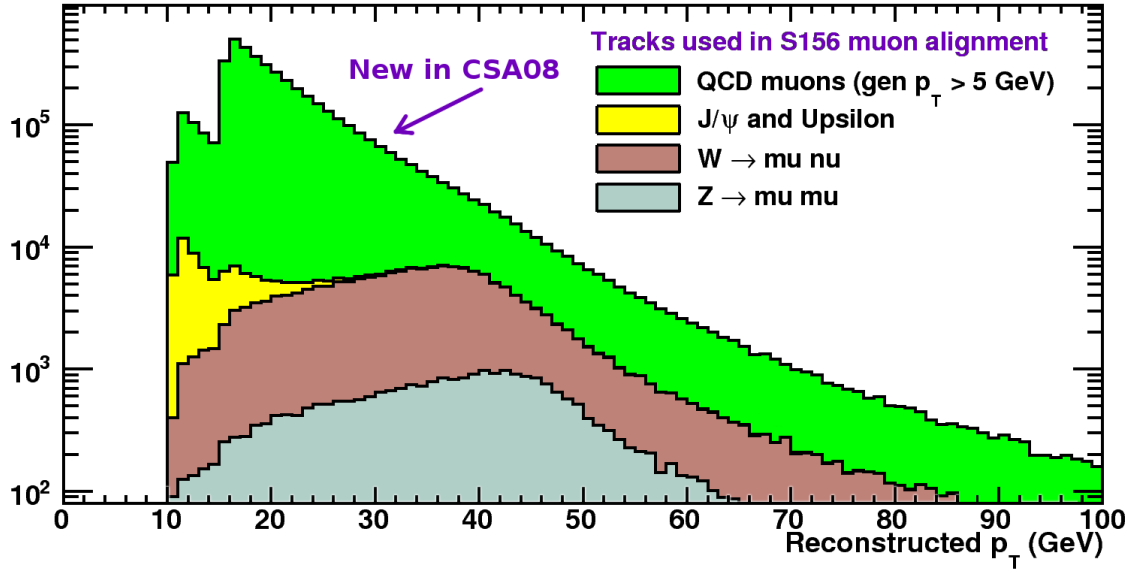
Last DPG presentation

Just before CSA08, things were changing quickly

- We found that the algorithm could be restored to a simpler state with improved resolution
- Pre-CSA08 test yielded surprising results (multiple scattering had not been implemented in the 1_8_4 FastSim production)

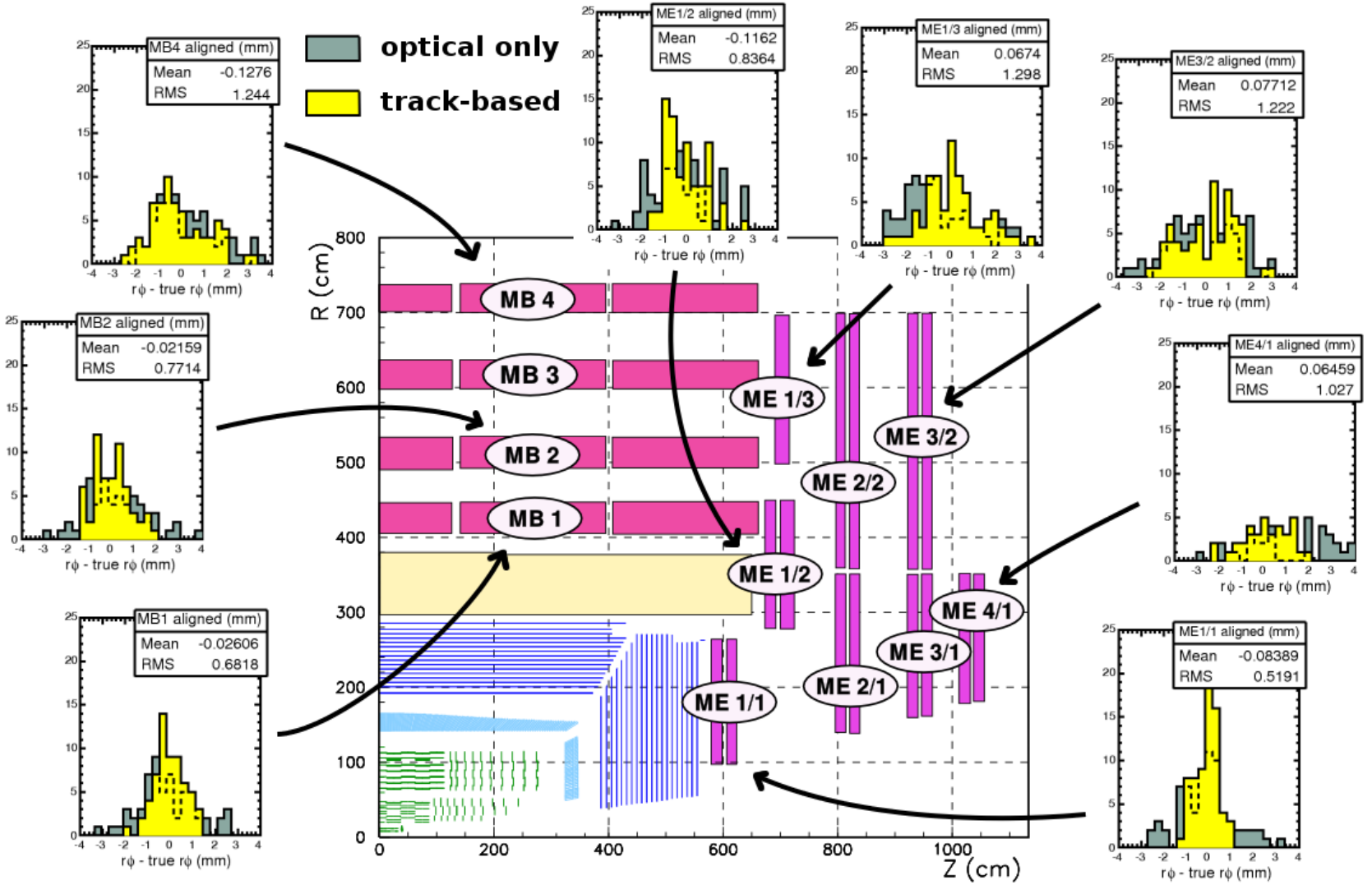
CSA08 exercise

- Included multiple scattering
- First inclusive spectrum of muons (right)
- First realistic tracker alignment → muon alignment workflow



10 pb^{-1} results

Histograms of aligned positions minus true positions in $r\phi$
MB1: 680 microns ME1/1: 520 microns ME1/2: 840 microns



Key result #1

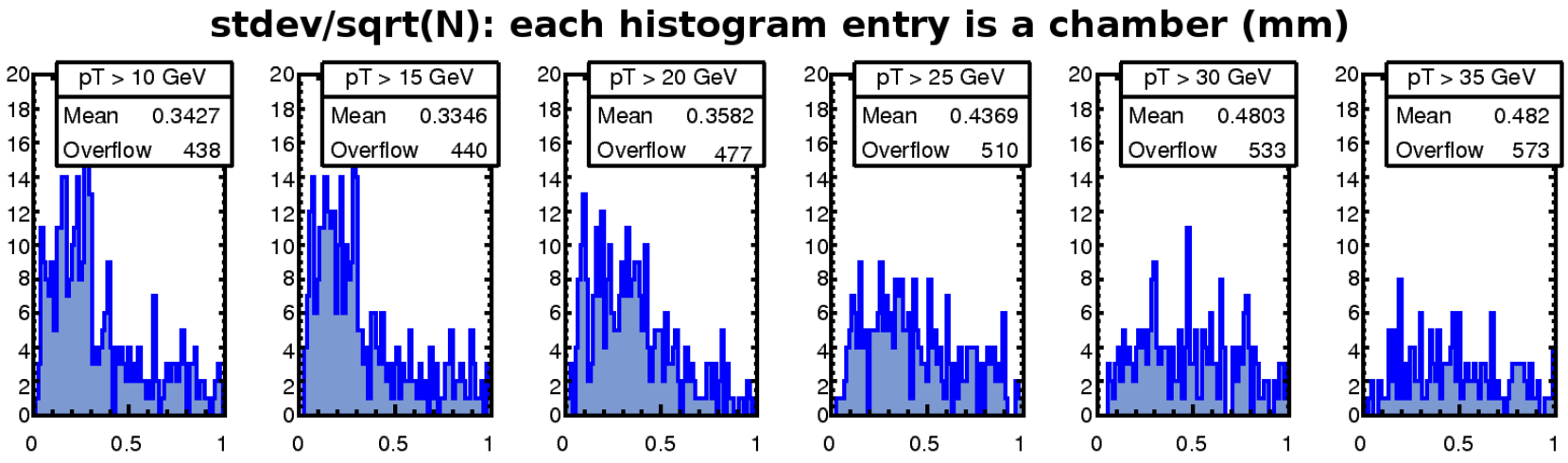
Long-standing question: is it better. . .

- to select high-momentum tracks and reduce multiple scattering (minimize standard deviation of residuals)
- or open the floodgates and let in all muons (maximize $\sqrt{N}$)?

Alignment correction is (roughly) mean of residual distribution,

$$\text{uncertainty} = \frac{\text{standard deviation}}{\sqrt{N}}$$

Answer: open the floodgates (minimum p_T of 10 GeV)



Key result #2

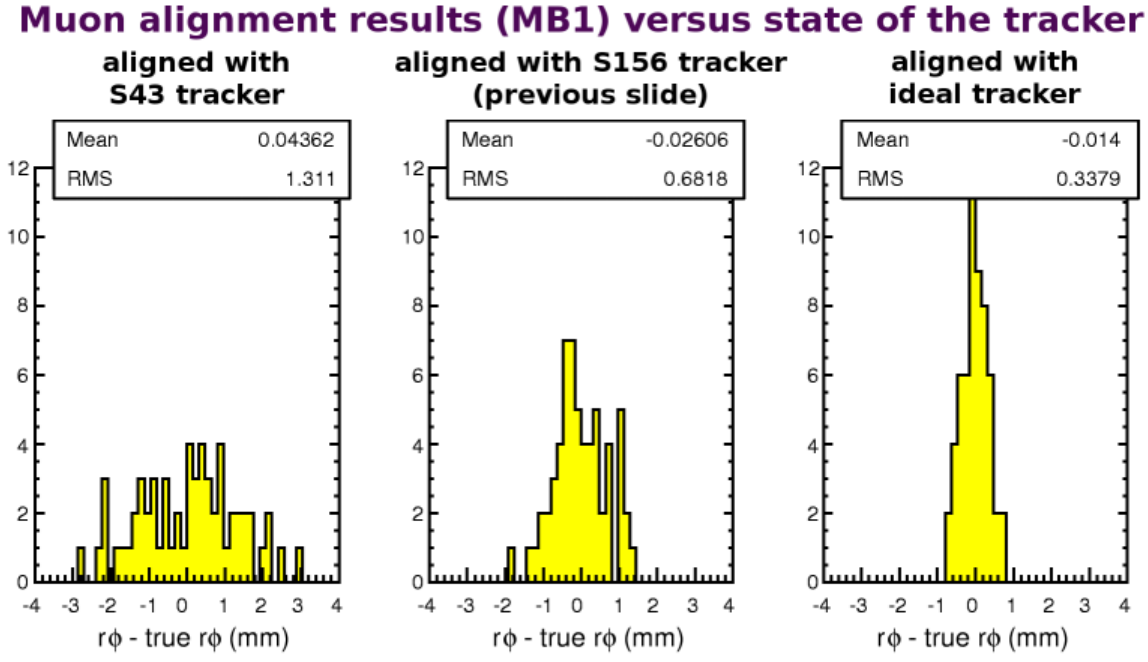
Strong dependence on tracker misalignment

Previous studies used randomly-generated tracker misalignment scenarios

models internal misalignment correlations expected from assembly

New study uses output of tracker alignment algorithm as input to muon alignment

includes correlations generated by tracker alignment attempt

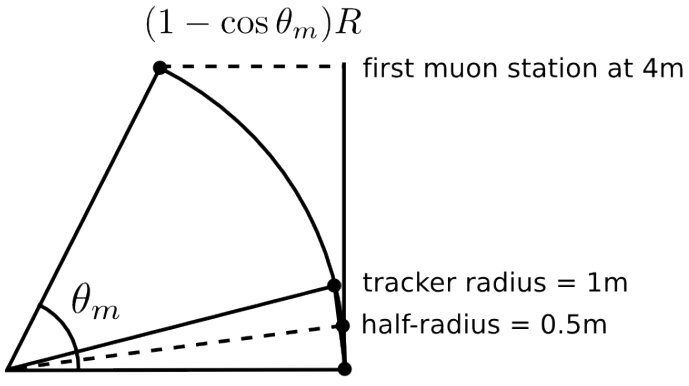


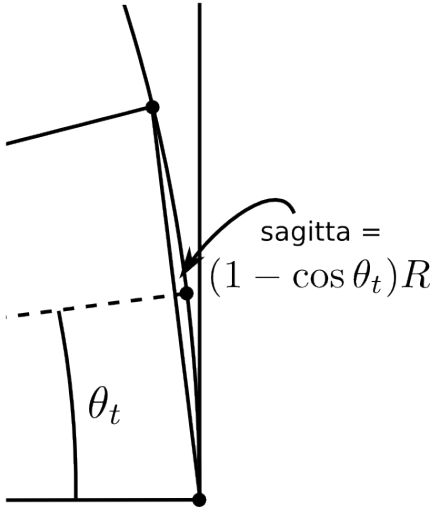
Analysis of #2

- Alignment performed using tracks from the interaction point
- Tracks that reach a given chamber all pass through the same slice of tracker (main theme)
- Tracker misalignments are $\mathcal{O}(10\ \mu\text{m})$, effect is 680 μm

Mismeasured ϕ or η: $10\ \mu\text{m} \left(\dfrac{\text{4 m inner muon station}}{\text{1 m tracker radius/half-length}} \right) = 14\ \mu\text{m}$

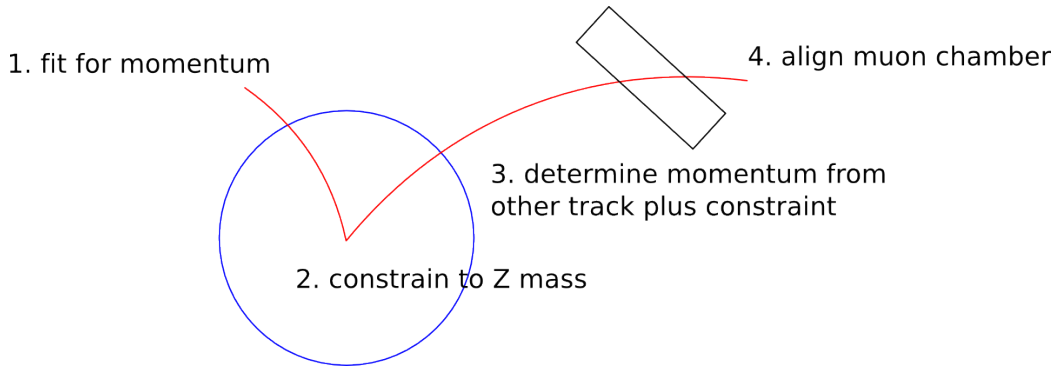
Mismeasured curvature: $10\ \mu\text{m} \left(\dfrac{\text{4 m inner muon station}}{\text{0.5 m tracker half-radius}} \right)^2 = 640\ \mu\text{m}$



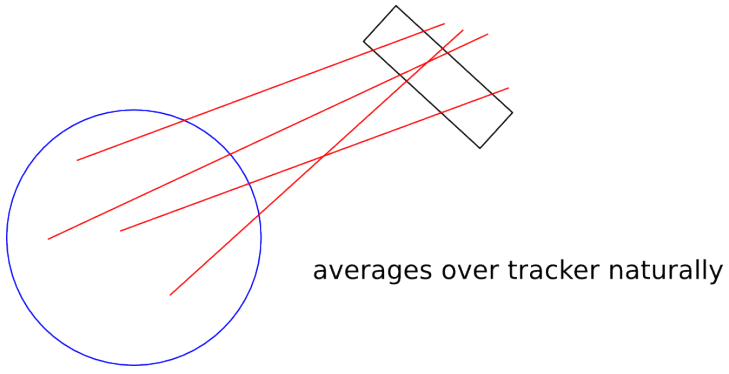


What to do about it

1. Wait for tracker alignment to improve their curvature measurement (cosmic rays under-utilized in CSA exercise)
2. Improve tracker with muon system in combined fit (tentatively discussed)
3. Average over tracker with $Z \longrightarrow \mu\mu$ constraint

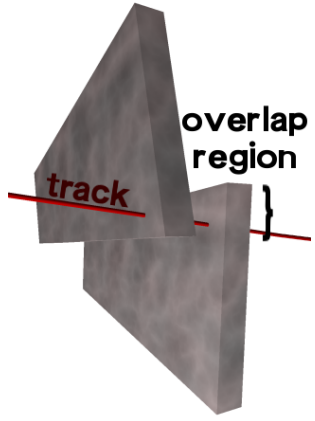


4. Align with cosmic rays! (guaranteed high statistics, best option for now)



CSC Overlaps procedure

Basic idea: with Karoly Banicz



- Relative alignment of pairs of CSCs using tracks that pass through the overlapping edges
- Whole CSC rings can be aligned (internally) by propagating corrections around the ring

History: (* = discussed on subsequent slides)

Old idea: chambers designed with overlap for this purpose

This spring: beam-halo identified as a good source of tracks

Many technical details, such as trigger & AlCa paths to get these events

Beam-halo MC AlCaReco descoped from CSA08 production, we reconstructed it ourselves

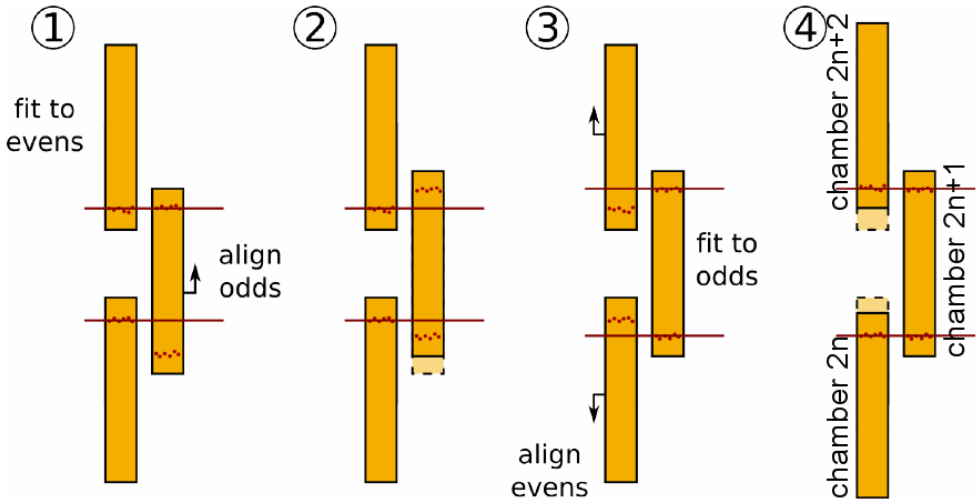
* Instability in "even-odd" procedure, replaced with "one-sided" procedure

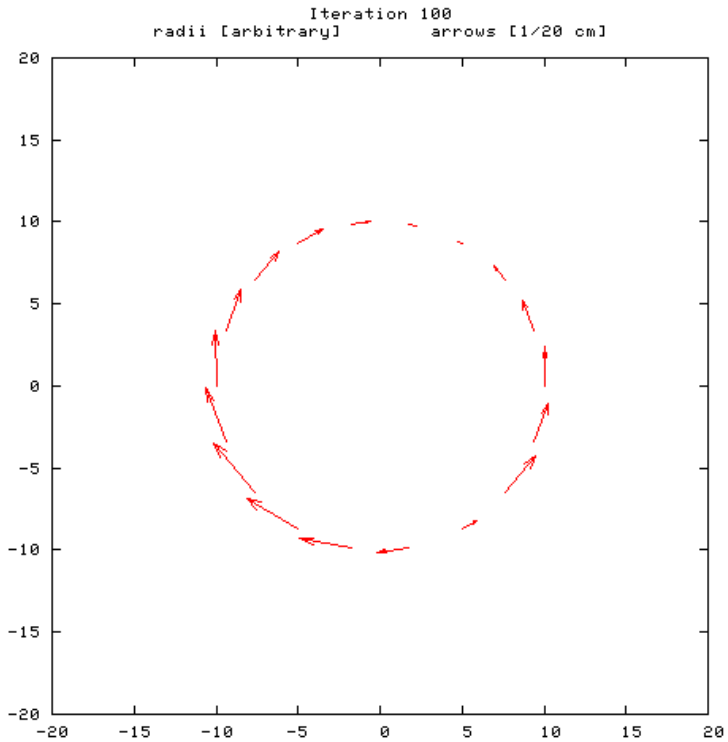
* Specialized "minitrack" building in CRUZET data for efficiency

* CRUZET and MC converge, but rings do not close

* Granularity of wire groups might be responsible

Even-odd procedure

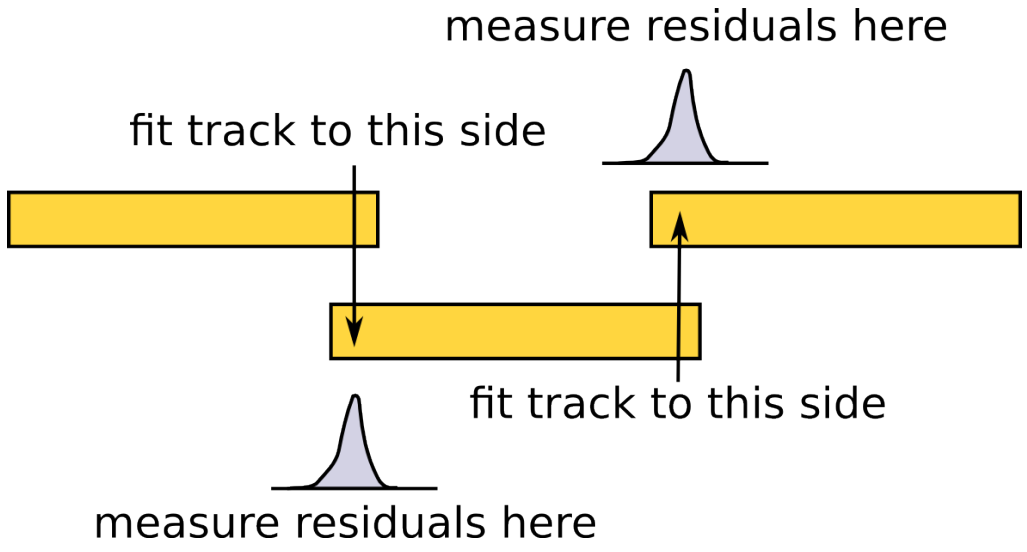




- Instability grows in ideal-geometry MC
- This "weak mode" minimizes the mean by balancing left-edge residuals and right-edge residuals

One-sided procedure

Don't mix left-edge residuals with right-edge residuals, and also align everything at once:



Reverse direction to quantify asymmetry

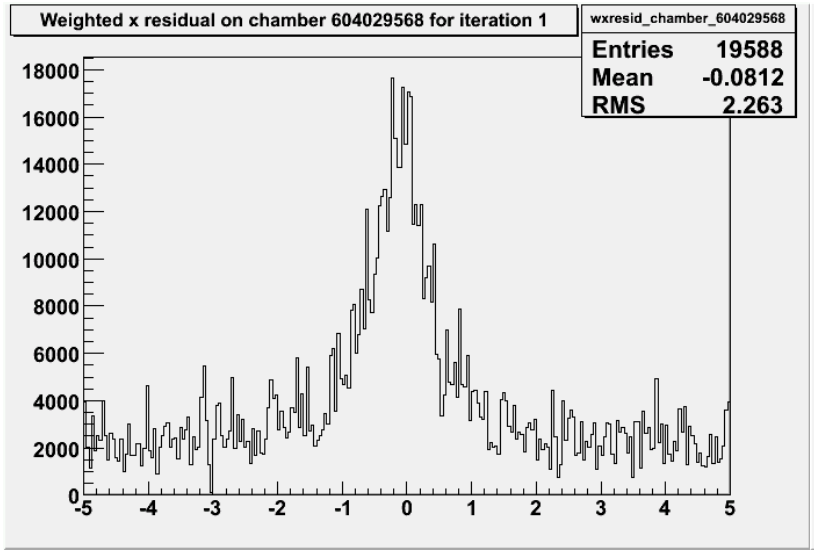
This procedure converges in data and MC
(meaning: residuals are minimized and alignment stops)

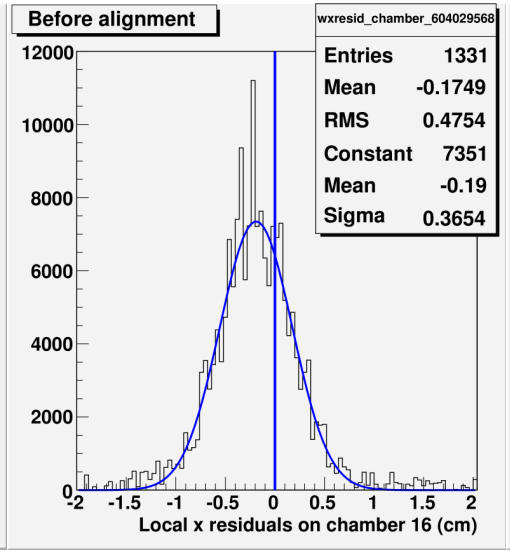
"Minitracks" in CRUZET

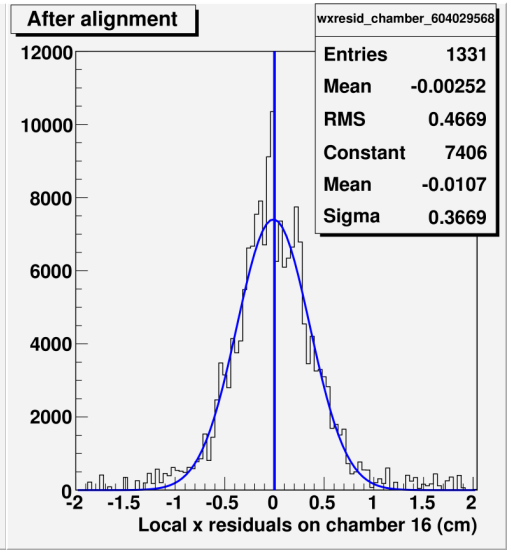
- Overlap regions are narrow; cut has low acceptance
- Full station-traversing muon tracks are not necessary, only need to match pairs of segments in overlapping chambers

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. Aligned

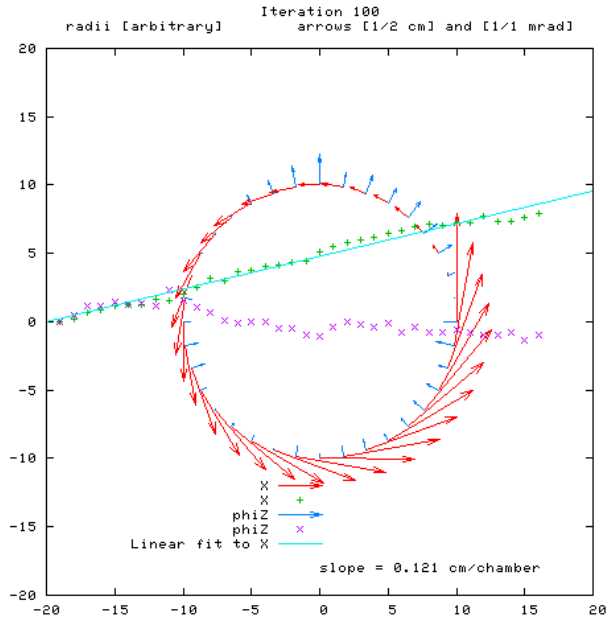




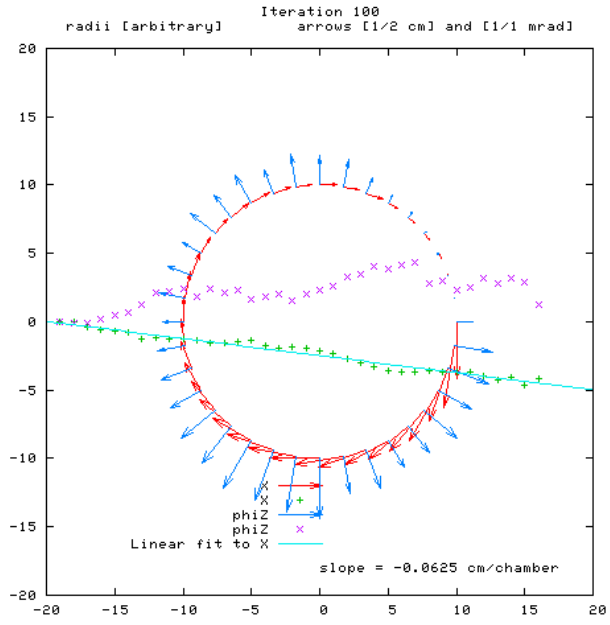


Rings do not close

ME+2/2 (CRUZET-1)



ME+3/2 (CRUZET-1)



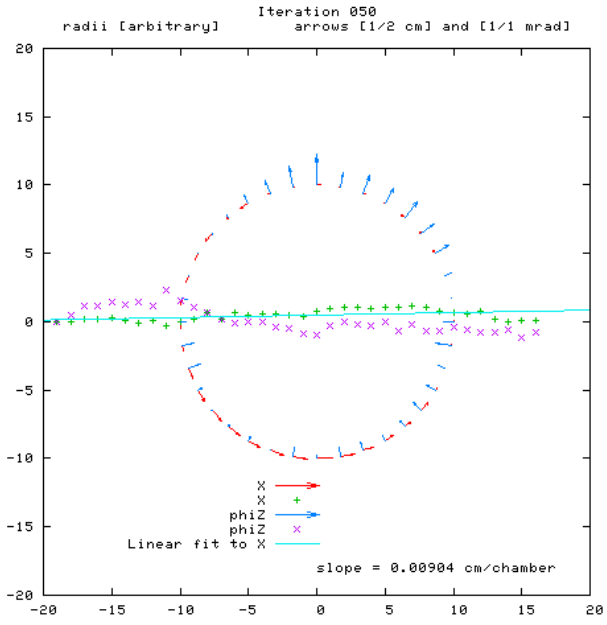
Average alignment correction per chamber (confirmed in CRUZET-2)

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 shift of all chambers in a ring?

ME+2/2	ME+3/2
+6.6 mm	−3 mm

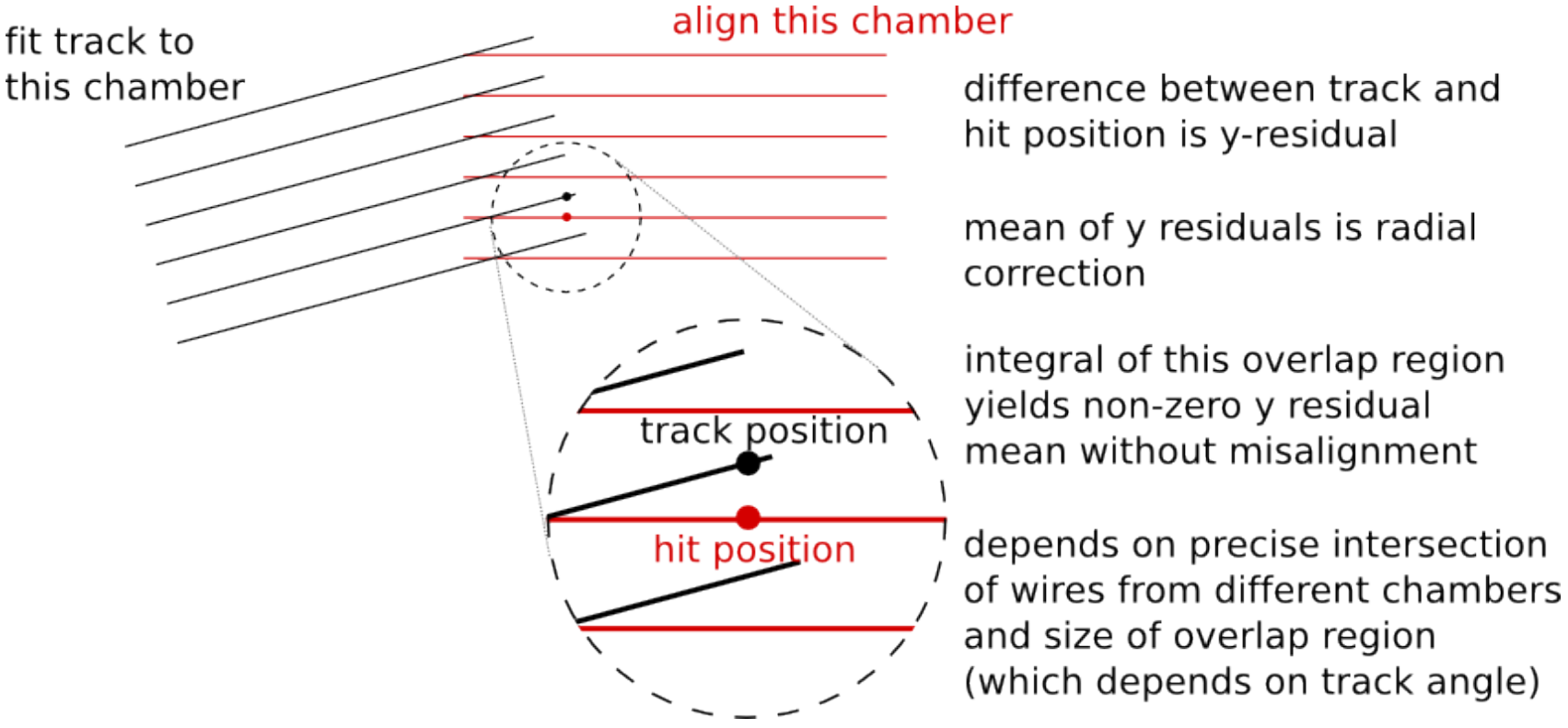
- How can these be in opposite directions?
- Hard to imagine a transcription error or a physical effect which can do this

- Even less likely that all chambers are "randomly" misaligned by this same amount

Wire group granularity?

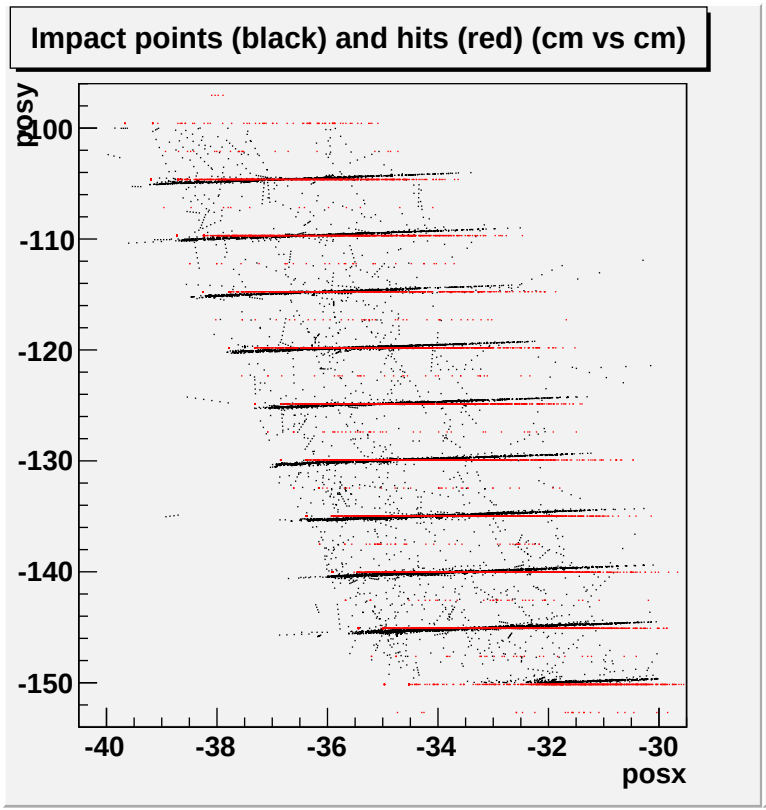
Perhaps the apparent radial shift is due to discrete wire groups

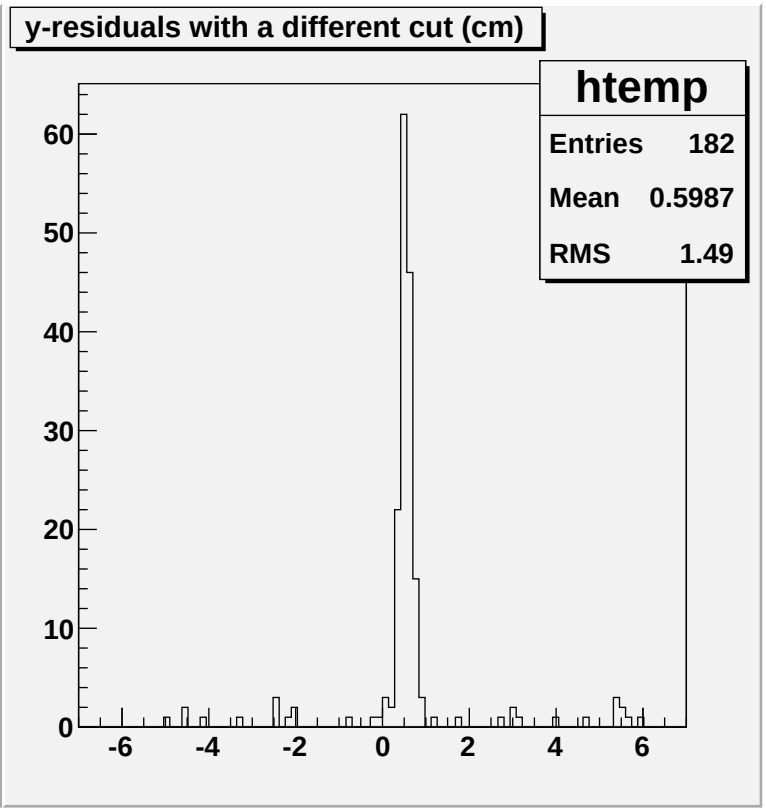
- for most hits, reconstructed y is the nearest wire group center
- at the edge of the chamber, y is needed to resolve x position, propagating effect of granularity to $r\phi$



Generating 6 mm shifts

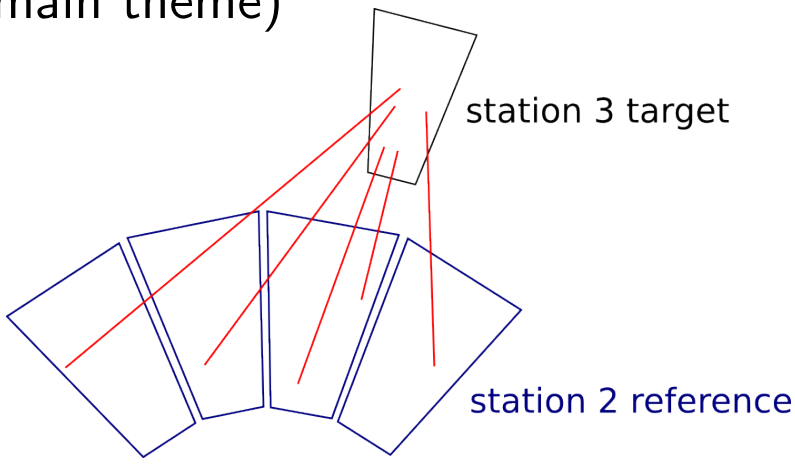
- Beam-halo MC with ideal alignment
- Overlay track extrapolated from reference (black) and hit (red)
- Vertical difference between black and red is the y-residual
- Can create a 6 mm y-residual by changing the degree of overlap (with cuts); cosmic rays have broader overlap due to incidence angles





Next steps

- Apply baseline procedure to standAloneMuons in CRUZET-1/2 to look for the "radial shift" effect
  - more affected by multiple scattering, but less affected by detailed structure of CSCs because we'll average over more chambers (main theme)



- Ultimately, globalMuons from CRUZET-3 would have the least bias

Conclusions

- Settled final open MC questions in CSA08 exercise
- Actively pursuing real-data alignments with CSC-overlaps procedure, will test surprising outcome with the robust baseline procedure