Status of Track-based Geometry in the Endcap

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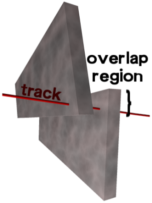
Outline

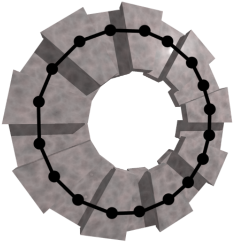
- CSC Overlaps results in more detail
- Plan to align endcap disks/rings with standAloneMuons, with cross-checks
- Proposed procedure for combining photogrammetry, hardware, and track-based results in the endcap

- Baseline alignment procedure shown to require 10–100 pb^{-1} for a few hundred micron precision
- Quicker alternative:
  1. relative alignment of chambers in each ring (CSC Overlaps)
  2. align whole ring with a small number of quality tracks
- Particularly good for layer alignment

Overlaps chamber alignment:

1. select tracks that pass through overlap of chambers in a ring
2. require consistency in pair of segments: slope and intercept
3. solve system



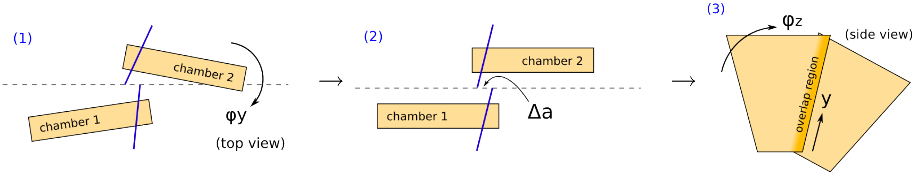


System is over-constrained: must be consistent with a circle ("closure")

Three-step procedure

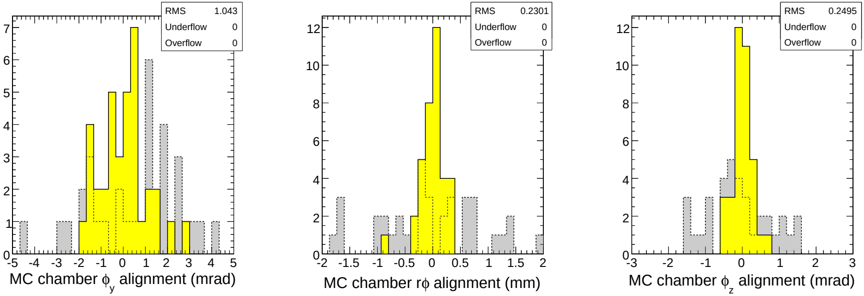
Interdependencies between alignment parameters are unidirectional

0. Fit segment of track in each chamber to $\phi(z) = a + bz$
1. Align φ_y angles (rotation around vertical axis) $\Delta b \rightarrow 0$
2. Align $r\phi$ positions (rotation around beamline) $\Delta a \rightarrow 0$
3. Align φ_z angles (rotation in the detector plane) $d(\Delta a)/dy \rightarrow 0$



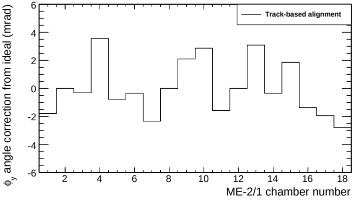
- Parameters decouple when aligned in this order (for example, φ_y depends only on Δb, but $r\phi$ depends on Δa and Δb)
- These are all of the rigid-body parameters accessible to overlaps tracks

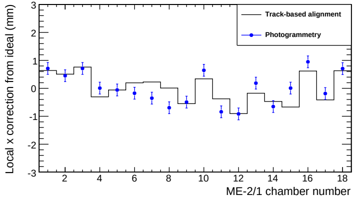
- Randomly misalign chambers and apply procedure using beam-halo Monte Carlo
  - statistics are roughly the same as September beam-halo
  - some chambers have more tracks, others less because ϕ distribution not perfectly modeled
- Plot aligned position minus true position in simulation (resolution)
- Unaligned is grey, aligned is yellow; one histogram entry per chamber
  - $\delta\varphi_y \sim 1$ mrad, $\delta r\phi \sim 230\ \mu$m, $\delta\varphi_z \sim 0.25$ mrad

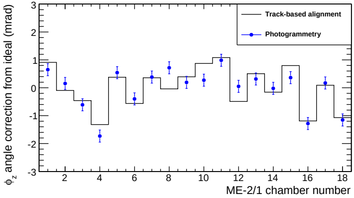


Alignment in real data

- Aligned ME$-2/1$ and ME$-3/1$ using beam-halo data
- Compared with photogrammetry
  - only track-based alignment sensitive to φ_y (only two alignment pins)
- Plot corrections relative to ideal geometry for each chamber
  - track-based: solid histogram
  - photogrammetry: blue points
- Physical misalignments are $\sim$2 mrad in φ_y, 1 mm in $r\phi$, and 1 mrad in φ_z
- Corrections from independent methods follow each other closely







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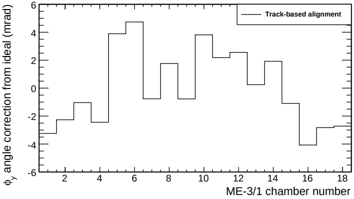
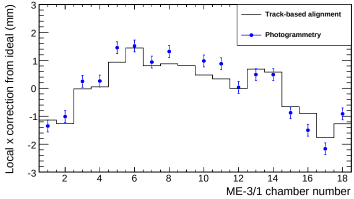
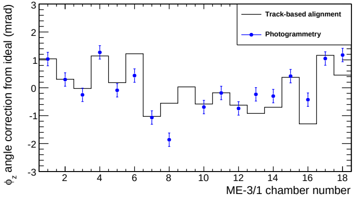
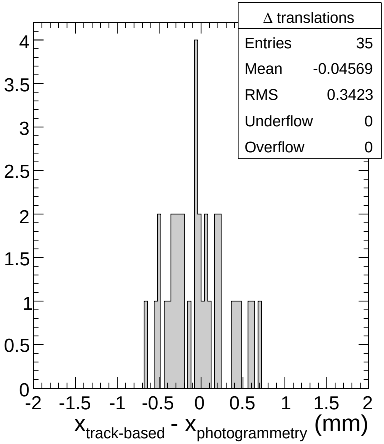


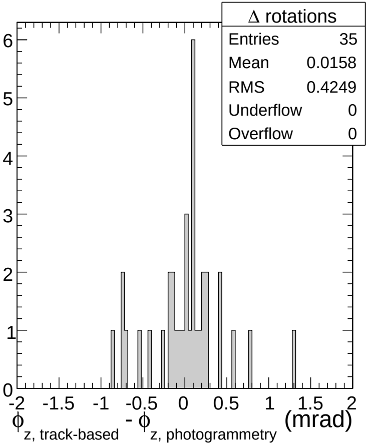




Determine accuracy from PG

- RMS difference between track-based and PG: 340 μm, 0.42 mrad
- Photogrammetry $r\phi$ uncertainty is $(300/\sqrt{2})$ μm $= 210$ μm
- $r\phi$ errors in track-based method alone $= \sqrt{340^2 - 210^2} = 270$ μm
- φ_z errors $= \sqrt{0.42^2 - (0.3 \cdot \sqrt{2}\ \mathrm{mm}/1.85\ \mathrm{m})^2} = 0.35$ mrad





Ring consistency (closure)

- Each residual distribution represents the difference in alignment between two chambers
- Must sum to zero: $(x_1 - x_2) + (x_2 - x_3) + \ldots + (x_N - x_1) = 0$
- φ_y and φ_z residuals have always summed to zero ("closed")
- $r\phi$ residuals closed in MC, but not in data
- Agreement with photogrammetry ruled out possibility of alignment mistake; pointed to error in CMSSW chamber description
  - active volume of chambers is 2.5 mm closer to beamline, *or*
  - active volume is 800 μm wider than in description
- Oleg found 10 μm rounding error in strip width description
  - multiplied by $\sim$80 strips $\approx$ 800 μm wider active volume
- Implemented correction; ME$-$2/1, $-$3/1 closure is now perfect!

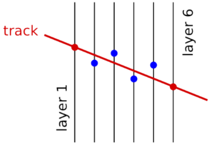
$$\sum_{\text{chamber } i} (r\phi_i - r\phi_{i+1})$$

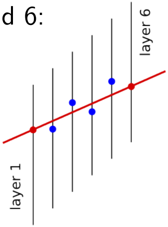
	before (mm)	after (mm)
ME$-$2/1	+14.30	-0.72 $\pm$ 0.42
ME$-$3/1	+15.90	-0.36 $\pm$ 0.51

- Strip geometry correction will go into CMSSW_3_0_X (where it won't introduce an error into the existing MC)
- CSCOverlapsAlignmentAlgorithm will go into the new Alignment/MuonAlignmentAlgorithms directory for CMSSW_3_0_X
- Triggers and AlCa paths have been defined to collect overlaps data from beam-halo and collisions events
  - we'll probably keep using it into the collisions era, at least until globalMuon methods are fully validated
  - like the hardware system, it can provide quick monitoring (in $r\phi$, φ_z, and to a lesser extent, φ_y)
  - not likely to work with a cosmic ray track source, but we only need something known to work with beam
  - these results are from 62232 (9 minutes of beam-2)

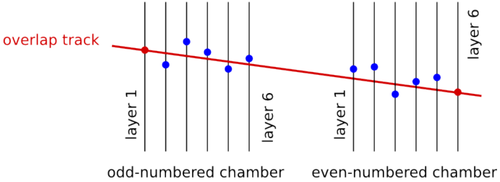
CSC layer alignment

- *First* first look at layer alignment by Karoly in MTCC
- Internal chamber data can only simultaneously determine four layers and a straight track, insensitive to shear
  - method of fixing track to layers 1 and 6:





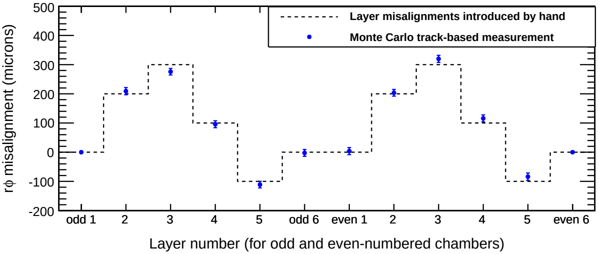
- Overlap events allow us to add one degree of freedom per chamber
  - five layers is enough to describe complete internal alignment



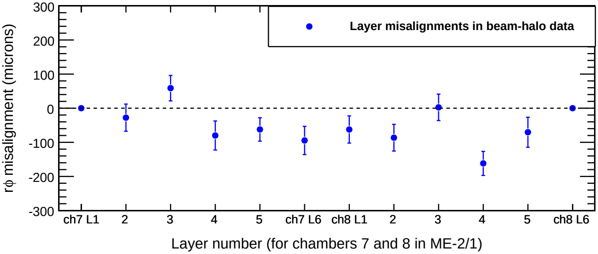
Plots of layer residuals

Test in Monte Carlo with 36× statistics (folded all pairs)

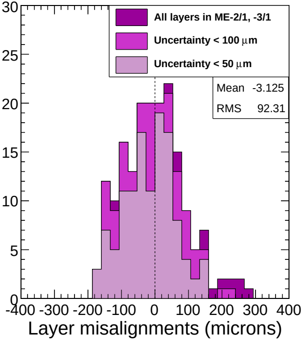
- residuals (blue points) reproduce misalignment pattern (histogram)



Example in data: chamber 7, layer 1 and chamber 8, layer 6 are fixed



Typical scale and resolution

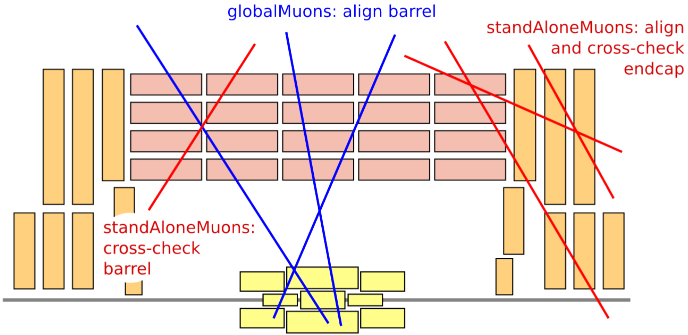


- Observed $\sim$100 μm layer misalignments in ME$-2/1$ and $-3/1$
  - technique requires chambers to be previously aligned
  - (and must be followed by a chamber re-alignment)
- About half as large as misalignments observed in MTCC (which was ME$+$)
- Resolution with full beam-halo run is 40–100 μm, hard to see misalignments
- I have not cross-checked these with FAST measurements yet

Status

- Not yet integrated into an alignment routine: just illustrative plots
- Layers only need to be aligned once
- Definitive CSC layer alignment will probably be done with early collisions

- globalMuon statistics are very poor in the endcap, and the tight geometric cuts implied by the requirement that they pass through the tracker might be a source of bias
- When we have a standAloneMuon refitter, this is what I have in mind for CRAFT:



- These are the cross-checks that we did in CRUZET, with the addition of linking the barrel to the tracker

Proposed combining procedure

The following makes the best use of all available endcap data:

Alignment step	Parameters updated	Responsible
1. Photogrammetry	all but φ_y for most chambers	Karoly & Oleg
2. Straight-line monitors	$r\phi$, z, φ_x, φ_z for monitored chambers, averages for the rest	Florida Tech
3. CSC Overlaps	$r\phi$, φ_y, φ_z for all chambers, keeping average of monitored chambers fixed	Texas A&M
4. Disk alignment	whole-disk 6 d.o.f.	Texas A&M

- In the end, photogrammetry supplied the radial positions, SLMs provide z and ϕ_x of disk-bulging and the $r\phi$ connection between rings, Overlaps provide $r\phi$, φ_y, and φ_z of individual chambers, and Disk alignment connects to the tracker (or barrel if there are still globalMuon issues)
- Communication at each step proceeds through CSCAlignmentRcds

Conclusions

- CSC Overlaps procedure is in good shape
- CSC layer alignment can be done with many of the same tools
- StandAlone refitter for cosmics will allow us to do deeper cross-checks of globalMuons and align the endcap disks
- Proposed a procedure for combining results from our complimentary alignments