Muon alignment update: full procedure results

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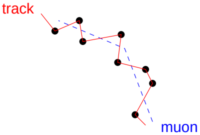
Overview

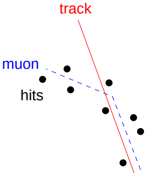
- The key issue in muon alignment: track fits are too flexible!
- New 9-pass alignment scheme
- How the parameters were tuned
- Alignment quality

Flexibility of track fits

- Tracks for alignment need to be somewhat independent of the hits; that's why we project from the tracker
- With small Alignment Parameter Errors (APEs), tracks follow the hits too closely, presumably by assuming scattering between each station
- With large APEs, extrapolation from the tracker is $\mathcal{O}(1\ \mathrm{cm})$, presumably because the muons really do scatter



Small APEs



Large APEs

Potential solutions:

- large APEs, infinite statistics, and hope real scattering is symmetric
- minimize extrapolations and optimize APEs

Method for minimizing extrapolations, using existing tools

Align one station at a time: e.g. for station 2,

- Set APE = 0 in tracker and station 1
- Set APE = medium in station 2
- Set APE = large in stations 3 onward
- Fit tracks through whole detector, only align station 2

Pro: track fit is dominated by extrapolation through only one layer of iron

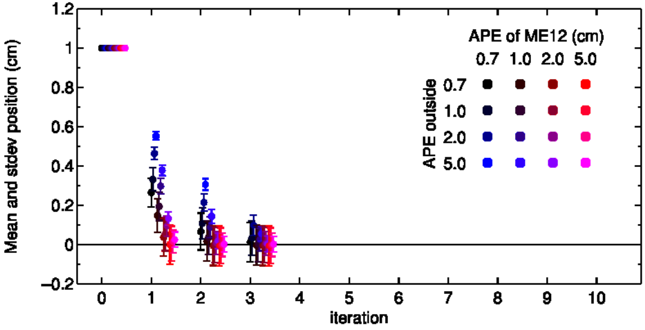
Con: Very CPU intensive

Two parameters need to be optimized for most stations: "medium" and "large"

Optimizing APEs

Simplified to a 1-dimensional case

- All chambers start 1 cm from the correct position; they need to find their way back to zero
- If APE is too large, they will spread (large stdev (errorbar))
- If APE is too small, they will converge too slowly (large mean)



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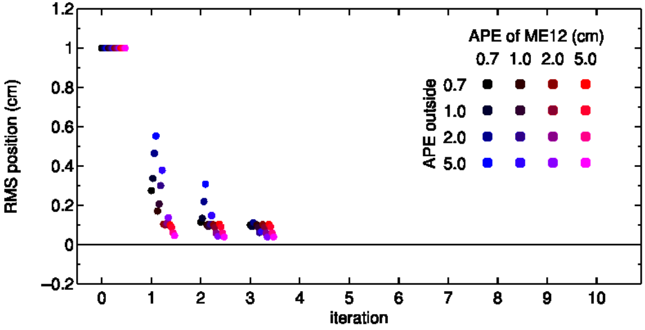
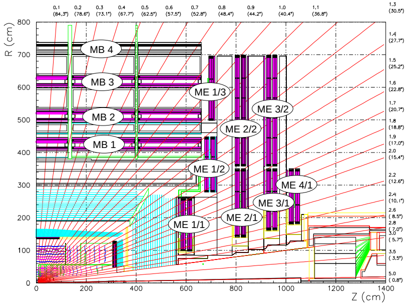


Optimized values

	"medium" (cm) (APE of aligned)	"large" (cm) (APE outside)
MB1	2	5
MB2	0.5	0.5
MB3	0.5	0.5
MB4	0.7	
ME1/1	0.5	0.5
ME1/2	5	5
ME1/3	0.5	0.5
ME2/1	0.5	0.5
ME2/2	0.7	0.7
ME3/1	0.5	0.5
ME3/2	0.7	
ME4/1	0.5	



Which degrees of freedom?

- With 6-dof misalignments, we want to align as many degrees of freedom as possible
- Constraints:
  - MB1–3 measures z and ϕ_x worst, unclear which
  - MB4 does not measure y or ϕ_x at all
  - ME measures ϕ_x worst, then unclear between z and ϕ_y
- 8 parameter combinations to try in the barrel, 6 in the endcap
- Tested all combinations with TeV track resolution
- Marginal best case: let everything float (except MB4 y and ϕ_x)
- But ME z and ϕ_x distributions were not improved, so I chose to fix them, too

Full procedure

Each pass has 5 iterations

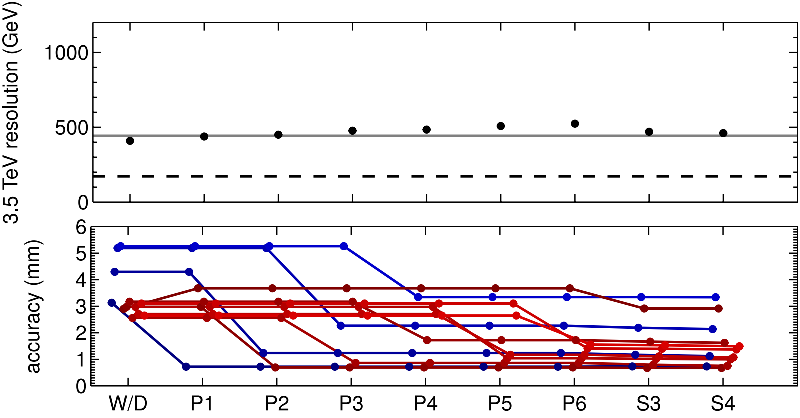
1. Align superstructures: wheels and disks
2. Pass 1: align MB1 and ME1/1 (large APEs: 2–5 cm)
3. Pass 2: align MB2 and ME1/2 (small APEs: 0.5–0.7 cm)
4. Pass 3: align MB3 and ME2/1
5. Pass 4: align MB4 and ME1/3
6. Pass 5: align ME2/2 and ME3/1
7. Pass 6: align ME3/2 and ME4/1
8. "Stage 3": re-align everything with 500 μm APEs
9. "Stage 4": re-align everything but MB1, ME1/1, and ME1/2 (first step in the muon system) to improve relative alignments

Test for alignment quality

- Using 66000 muons from 10 pb^{-1} of W decays (85% of the muons from W and Z combined)
- Starting with complete misalignment: $\pm$5 mm, $\pm$5 mrad at all levels (chamber and wheel/disk)
- Includes known layer misalignments in CSCs (which we won't improve with this procedure)
- Two cases:
  - Ideal tracker
  - 10 pb^{-1} misaligned tracker
- Two methods to judge quality:
  - Dimuon resolution for 3.5 TeV Z' (where muon alignment matters most)
  - Stdev of local x (global $r\phi$) residual misalignment, for each station

Ideal tracker case

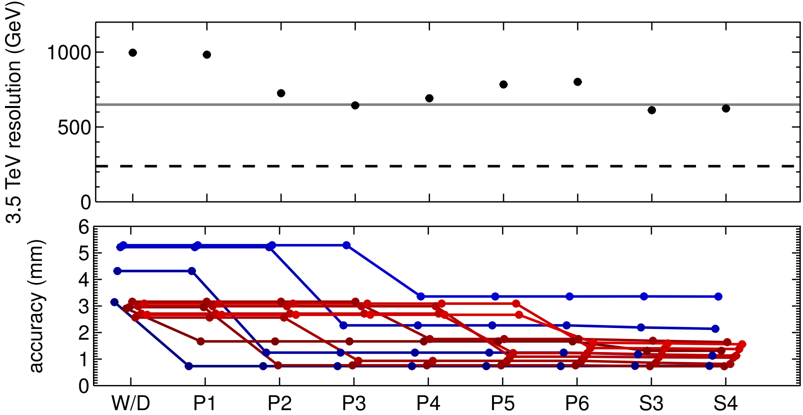
Dashed line: perfect muon system alignment (best-case goal)
Grey line: official 10 pb^{-1} scenario (not a mean)



Reds: endcap stations, Blues: barrel stations

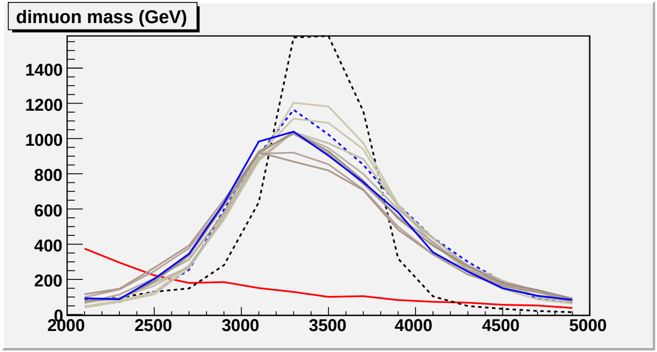
Misaligned tracker case

Dashed line: perfect muon system alignment (best-case goal)
Grey line: official 10 pb^{-1} scenario (not a mean)



Reds: endcap stations, Blues: barrel stations

Shown as a dimuon spectrum (ideal tracker case)



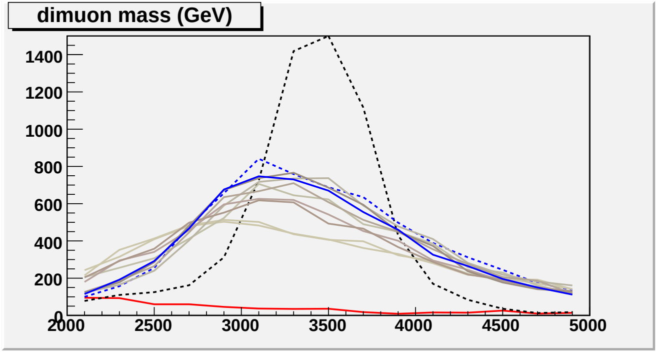
Red: before alignment (peaks at 1 TeV)

Darkening shades of gray: alignment passes, ending in blue

Dashed blue: official 10 pb^{-1} scenario

Dashed black: perfect muon system alignment

Shown as a dimuon spectrum (misaligned tracker case)



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Darkening shades of gray: alignment passes, ending in blue

Dashed blue: official 10 pb^{-1} scenario

Dashed black: perfect muon system alignment

Inverted hierarchy?

- Wheels and disks are better aligned than the chambers
  - wheel/disk (after first pass): 1 mm in x and y, 0.3 mrad in ϕ_z (corresponds to 0.4–2.5 mm in $r\phi$)
  - chambers (after all passes): 0.7–3.2 mm in $r\phi$
- Official scenario has the opposite: 2–3 mm wheel/disks and 0.5 mm chambers
- Our method is particularly good at aligning large structures globally, we need to work on chambers within stations

Other tests in progress

- Robustness: same procedure with a statistical ensemble of 8 starting scenarios (are we looking at a lucky case?)
- Full scale: 100 pb^{-1}
- Simplification: replace pass1 – pass6 with a single pass that aligns all stations at once (to see if those extra steps are helping at all)

Ideas for improving the algorithm

- If $10\times$ statistics improves by $\sqrt{10}$, we will try as many QCD muons as possible
- Use CSC overlaps to align chambers locally? (requires modifications to the track-fitter)

Conclusions

- Post-bugfix, this is the first fully realistic test of the system
- We want to improve the performance
- But this is a demonstration that we can at least reach the standard set by the official scenarios