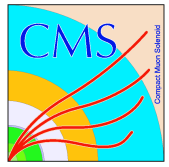

Alignment Combination Plans with Contingencies

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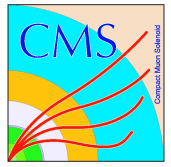
Outline



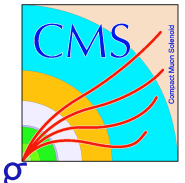
- Expanded version of the CSC alignment combination procedure I presented last CMS Week
- Emphasis: each procedure must input and output CSCAlignmentRcds, modifying only the parameters they best measure
- Similar idea for DT alignment

Available CSC Procedures

(all parameters are local: e.g. x is $r\phi$, y is radial)

$\surd$	Chamber Photogrammetry	x, y, z, ϕ_x, ϕ_z chambers relative to disks	100% valid at $\vec{B} = 0$ T, some parameters are invalid when $\vec{B} > 0$ (mostly y, z, ϕ_x)
	Transfer lines and/or cavern photogrammetry	6 dof for disks	puts chamber coordinates into global frame, but need to connect physical measurements with (a) chamber centers and (b) the tracker
$\surd$	DCOPS/SLM disk bending	average z and ϕ_x for rings	corrects for large deviations due to $\vec{B}$-field
	StandAloneMuon cosmics alignment	6 dof for disks or x, z, ϕ_y, ϕ_z for chambers	barrel (reference) needs to be better aligned, track refitter may need more debugging
$\surd$	Beam-halo Overlaps alignment	x, ϕ_y, ϕ_z relative to ring	needs beam-halo (Aug–Oct)
$\surd$	Collisions muon alignment	6 dof for disks or x, z, ϕ_y, ϕ_z for chambers	needs collisions ($\geq$ Nov)

Combining what we have now



(1) Chamber photogrammetry → (2) DCOPS/SLM disk bending

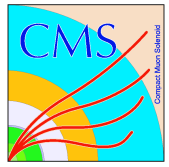
- Realistic local x positions (assume effect of $\vec{B}$-field is in z and stretching is radial, as symmetry implies)
- Realistic z bulge and radial bending (at least the ϕ_x part, if not y)
- But: no alignment of whole disks in CMS coordinates, which reduces the usefulness of the new local alignment

Ways to improve this before collisions

Any one of the following would improve the alignment; more than one would provide cross-checks:

- Add a photogrammetry-relative-to-cavern alignment at the beginning (step 1.5)
  - and again assume that the $\vec{B}$-field effects are ϕ-symmetric
  - still doesn't connect to the tracker
- Add a transfer line measurement at the end (step 3)
  - need to propagate tracker coordinate system through the TEC
- Add a standAloneMuon cosmics alignment at the end (step 3 or 4)

Combining steps: implementation



- Every alignment step should do the following:
  1. read an input geometry in CSCAlignmentRcd format (except chamber photogrammetry because it's first)
  2. apply corrections to the parameters the procedure can measure; don't modify the parameters that were better determined by previous steps
  3. write a modified geometry in CSCAlignmentRcd format
- If using XML tools, `<moveglobal>`, `<movelocal>`, and `<rotatelocal>` provide this functionality
- This creates a chain of working alignment procedures in which the best information is passed through to the end
- Much easier to understand the results than a global fit that includes different methods in a single χ^2 minimization

Redundant measurements

- Tracks measure CSC x and z parameters, but not with equal precision because they're determined in rather different ways:
  - x is essentially an average of the whole residuals distribution
  - z is a linear trend in that distribution
- DCOPS measure CSC x and z parameters directly, with ∼equal precision because they're measured the same way: laser cross-hair
- Example:
  - suppose track x accuracy is 0.3 mm and z is 3 mm (and assume this was determined by comparing different track methods)
  - suppose DCOPS reproduces x with 1 mm and z with 3 mm
  - in this case, tracks provide 0.3 mm resolution in x and DCOPS provide 1 mm resolution in z
- Cross-checks (e.g. DCOPS x above) are not wasted measurements: they go into the physics analysis as tighter MC alignment scenarios, because we're more confident in the geometry (in z in this case)

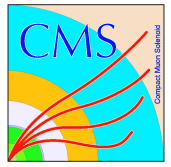
Available DT procedures

(all parameters are local: e.g. x is $r\phi$, y is along the beamline, z is radial)

$\surd$	Photogrammetry/ survey	6 dof (stand-alone)	100% valid at $\vec{B} = 0$ T, much less $\vec{B}$ distortion than endcap
$\surd$	MillePede algorithm	6 dof (stand-alone)	with survey constraint, it's a tracks/survey average: what are the weights?
	Hardware alignment	6 dof (stand-alone)	I see that progress is being made
$\surd$	GlobalMuon alignment	now: x, y, ϕ_z soon: 6 dof	cosmic rays don't provide complete coverage
	StandAloneMuon cosmics alignment	same 6 dof	more complete coverage, using aligned chambers as reference

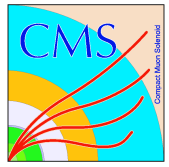
- We've exercised (1) Survey + MillePede $\rightarrow$ (2) GlobalMuon using DTAlignmentRcds for communication
- I don't yet know which of the 6 parameters will be better determined by which procedure

Methods to determine accuracy



- When hardware and track-based alignments agree, they're both right (RMS of chamber-by-chamber differences is the sum in quadrature of the accuracies of the two methods)
- When they disagree, one or both is wrong (pattern of systematic disagreement can be a useful clue)
- Disagreement or lack of comparison forces us to use internal cross-checks to determine accuracy independently
- Internal cross-checks for track-based alignment:
  - agreement between tracks from different directions and checking consistency of $A - B$, $B - C$, $A - C$ triangles
  - correlation of residuals within chambers, discontinuities at borders
  - computing same parameter from different kinds of residuals
  - closure conditions for circular rings of chambers
  - Monte Carlo studies with a given set of systematics
- I expect that hardware and photogrammetry have methods of internally determining accuracy of each parameter, too
- They'll be necessary to objectively decide which to use from each

Conclusions



- The *technical* problem of merging alignment results can be solved by each procedure reading and writing in AlignmentRcd format, and only modifying best-measured parameters
  - can be done with existing XML tools
- Deciding which alignment procedures have the best measurement of a given parameter will require internal cross-checks (determining track accuracy using only tracks and determining hardware accuracy using only hardware)
- For the endcaps, we already have enough resolution data to know what the combined procedure will probably look like:

  (1) Photogrammetry $\rightarrow$ (2) DCOPS disk bending $\rightarrow$ (3) Transfer line disk position? $\rightarrow$ (4) GlobalMuon alignment in x, ϕ_y, ϕ_z
  - opportunity to cross-check DCOPS and track-based in x and z