Alignment of the CMS Muon System with the HIP Algorithm

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1 Introduction to the HIP algorithm and the geometry of the muon system

(I copied the following from https://twiki.cern.ch/twiki/bin/view/CMS/SWGuideMuonAlignAlgos. The CMS Note introduction won't be quite as short and technical— it will either be longer or contain less detail.)

The HIP algorithm (Hits and Impact Points) is an iterative algorithm for aligning detectors. It decouples the correlation between track-fitting and detector alignment by alternating between the two, hopefully converging to a solution that optimizes both. The alignment step of the HIP algorithm is very simple: chambers are moved in such a way as to make the weighted mean of their residuals distribution zero before refitting. (A residual is the difference between the local position of a hit and the track's extrapolation to the detector surface, called the impact point.) In the one-dimensional case, an x alignment correction is equal to the negative of the weighted mean of the x residual distribution. In general, x and y residuals (if the latter are available) are transformed to the 6-dimensional space of parameters x, y, z, phix, phiy, and phiz (assuming all 6 parameters are selected for alignment), through a 6x2 Jacobian matrix. The weighted mean generalizes into a matrix equation involving a matrix inversion that is at most 6x6, for every detector. Most of the computational effort is in re-fitting tracks and producing updated residuals distributions between each iteration. (See CMS NOTE 2006/018.)

The muon system forms a barrel and an endcap around the CMS detector composed of 790 large (meter-scale) independently-alignable sensors. Disks and wheels are the largest independently-alignable structures (tens of meters), each of which holds dozens of chambers. Alignment of the 6-12 layers and superlayers inside the chambers must also be considered, though probably only once, with high statistics. More detail about these issues and progress in solving them will be available at SomePageThatDoesntExist?; the following is an introduction to a software system that can compute these alignments, given a dataset in CMSSW.

2 Nominal procedure

default, standard of comparison

10 pb^{-1} of high p_T tracks (from Z's and W's)

number of hits cuts on tracks, pull cut on hits

Initial misalignment: the Muon10InvPbScenario with residual layer misalignments (to be determined from layer alignment studies) chamber-by-chamber (CSC and DT) x, phiy, phiz float? can we relax this, letting y and phix float, too? Not for DT station 4, of course...

globalMuon APE scheme: starts large, descends rapidly, converges in a few iterations

standAloneMuon APE scheme: less steep, but relevant

3 Accuracy and Precision

output alignment parameter uncertainties (are they broken? why are they $\sim$4 times too big?): do they scale with residual misalignment?

if not, is there any other way to identify chambers with poor convergence? do they have fewer hits?

4 Performance issues

How does this scale with number of tracks (convert to pb^{-1} of W, Z, and if possible, a generic muon sample with a cut)

How much computer time does this take? (per iteration, and how many iterations are necessary?)

5 Special alignments

5.1 Quick disk alignment

how much data do we need to do this if the chambers and layers are also misaligned? (With ideal chambers, it's very quick! :)

MC and MTCC (compare with known x = 7 mm, y = 1 mm in MTCC phase II)

5.2 CSC Layer alignments

what is the nominal procedure, what degrees of freedom can we align, and how much data do we need to do it?

MC and MTCC

this will probably include Karoly's work: his plots with our results overlaid

6 Beam halo alignment of CSC layers

will we have this before data-taking?

New information from Karoly: no problem for inner ring, outer ring may have 0.8 million muons, though heavily emphasizing the inner radius part

7 Systematics studies

7.1 Dependence on tracker alignment

How does the globalMuon strategy depend on tracker alignment? (Initial studies suggest that the dependence is *very* weak. Is there anything wrong with my studies?)

New information: it looks like my procedure is working. Dependence on tracker alignment is probably *very weak!* I need to pull this together into a coherent story, with plots.

7.2 Dependence on momentum

How does resolution depend on the momentum of the input tracks? Use J/ψs to do an alignment if you have enough; otherwise, just compare width of the residuals distributions.

7.3 Dependence on fitting parameters

What happens if we use different sets of fitting parameters? I don't see much difference yet, but I haven't tried dropping "y" degrees of freedom.

7.4 Correlation between alignment and calibration

How well does alignment fare if we have a miscalibrated detector?

7.5 "Dependence on tracking algorithm"

7.5.1 Uncertainty in material distribution

Change the distribution of material in track-fitting but not in SimHit generation to simulate incorrect material description

7.5.2 Uncertainty in magnetic field

Same for magnetic field modeling

7.5.3 Dependence on track charge

How does alignment differ between positive and negative tracks? Can we cancel the effect by requiring equal populations?

7.5.4 Depdence on the actual algorithm used in tracking

If I'm very adventurous, I may try plugging in different tracking algorithms. I don't know how easy that is.

7.6 Background studies

Align with realistic backgrounds from CSA07

What are the optimized track quality cuts?

8 Conclusion

It works very, very, very well.