Track-based Alignment of the Muon Chambers: Status and Schedule

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Comparison with Hardware Alignment

Track-based alignment: vary chamber positions to minimize

$$\sum |\text{residual}|^2 \text{ (that is, } \sum |\text{track} - \text{hit position}|^2\text{)}$$

- requires a large dataset ($\gg$ 2007 run, $\sim$a day full luminosity)

Hardware alignment: physical sensors on the chambers

- sensitive to short timescales

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- requires a large dataset ($\gg$ 2007 run, $\sim$a day full luminosity)
- insensitive to translations along line of sight from IP
- cannot recover trigger inefficiency due to misalignment
- the final alignment

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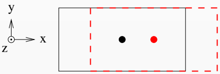
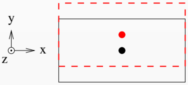
HIP: a Simple Alignment Algorithm

- Advantage: easy to see what's happening (diagnostic plots)

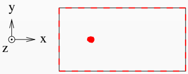
r_x = track−hit residual in local coordinate x



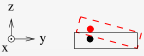
x: offset in r_x



y: offset in r_y

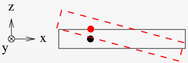


z: inaccessible



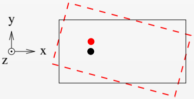
ϕ_x: r_y linear in y

(slope $= 1 - \cos\phi_x$)



ϕ_y: r_x linear in x

(slope $= 1 - \cos\phi_y$)

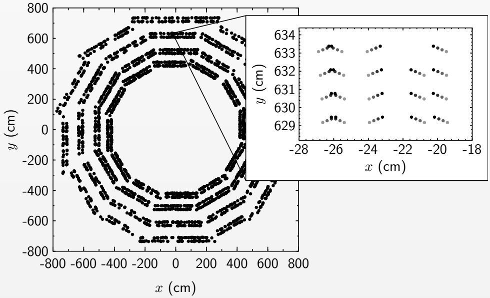


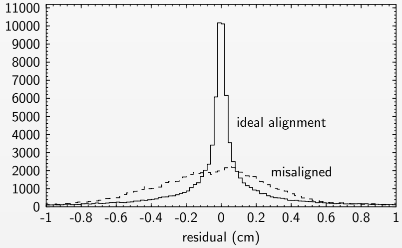
ϕ_z: r_x linear in y and r_y linear in x

(slope $= \sin\phi_z$)

History of Our Involvement

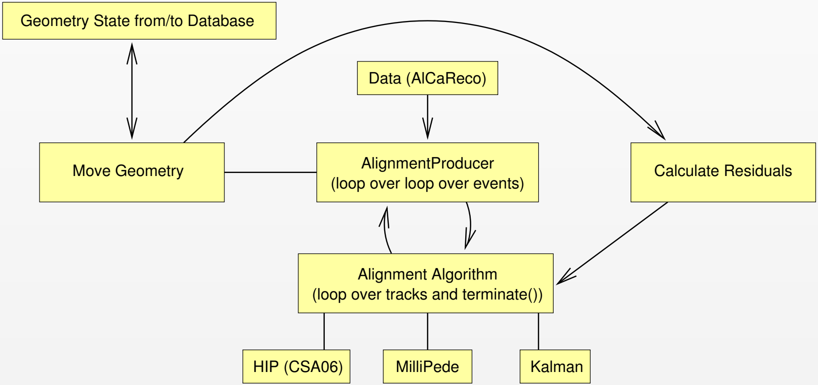
3 October:	Announced our involvement at Purdue EMU meeting
20 October:	Could arbitrarily move detector elements in CMSSW
22 October:	Could calculate residuals
26 October:	Proposed MuonAlignmentAnalyzer to AlCaReco
	They convinced us to extend CommonAlignment
13 November:	Presented at PRS/mu





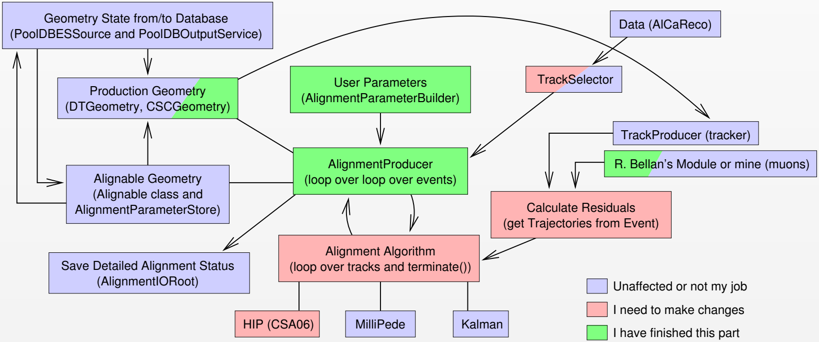
CommonAlignment

- Three alignment algorithms are sub-modules of CommonAlignment, including HIP (called CSA06Alignment)
- Designed for tracker and muon chambers, but only implemented for tracker



Current Status

- Can edit and update muon geometry (works in local area)
- Can calculate trajectory of tracker-fitted tracks at muon hits and put this into the Event in a standard way
- Need to modify CommonAlignment to get this object and use it to calculate residuals



Schedule through next year

Deadline	Task
1 Jan, 2007	Finish integrating muon chambers into alignment framework
1 Mar, 2008	Transition CSA06Alignment to HIPAlignment and develop low-level diagnostics suite
1 Apr	Prototype and study realistic alignment procedure, assuming a source of muons
1 May	Evaluate possible sources ($W \to \mu\nu$, $Z \to \mu\mu$, cosmics, or good muon) and finalize routine
1 Jun	Document everything

How much data do we need?

- Start with CMS NOTE 2006/016 toy MC ("for illustrative purposes only!")
- Distinguish between barrel and endcap: intrinsic resolutions, overlapping geometry, η distribution of $W \to \mu\nu$ and $Z \to \mu\mu$
- Simulate multiple scattering, non-uniform $\vec{B}$, propagated from tracker (30% effect)

2 days of 10^{30}/cm^2/s at 0.9 TeV:

4–6 mm resolution in barrel, 3–4 mm in endcap

10^{33}/cm^2/s at 14 TeV:

17 hours for 200-300 μm in barrel (410,000 muons),
10 hours for 100-150 μm in endcap (220,000 muons)

Summary

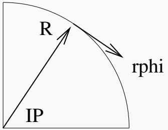
- We are implementing a simple, robust alignment algorithm that provides opportunities for diagnostics
- Software development is progressing smoothly (well-designed infrastructure)
- Conservative schedule has an alignment routine ready on time
- Track-based alignment cannot be precise with 2 days of low-energy, low-luminosity data
- At full energy and luminosity, track-based can be sensitive to timescales as short as a day

How much data do we need?

MB1 alignment resolution *per track* (scales with $1/\sqrt{N_{\text{track}}}$)

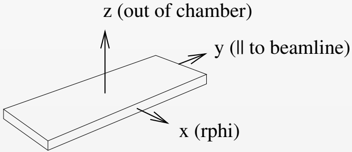
global translations:

rphi	*R*	*z*
8 mm	80 mm	8 mm



local rotations:

ϕ_x	ϕ_y	ϕ_z
70 mrad	50 mrad	10 mrad



*direct effect on tracking

How much data do we need?

$$\left.\begin{array}{rcl} rphi & \rightarrow & \text{8 mm } x\text{-residual} \\ \phi_z \times L_y & \rightarrow & \text{25 mm } x\text{-residual at chamber edge} \\ \text{global } z & \rightarrow & \text{8 mm } y\text{-residual} \\ \phi_z \times L_x & \rightarrow & \text{20 mm } y\text{-residual at chamber edge} \end{array}\right\} \text{15-20 mm}$$

for all barrel chambers (independent of chamber lengths)

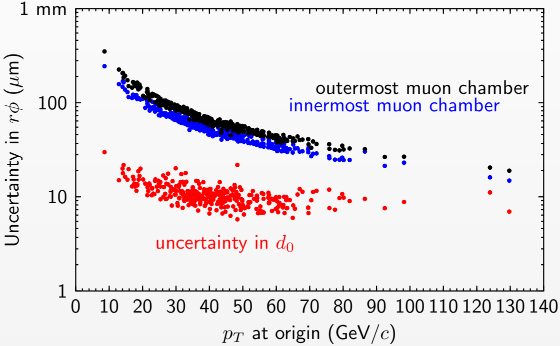
Intrinsic resolutions of $\frac{\text{endcap}}{\text{barrel}} = \frac{50\ \mu\text{m}}{170\ \mu\text{m}}$

(E. Torassa, *Review of the CMS Muon Detector System*)

5-6 mm for all endcap chambers

How much data do we need?

Toy MC was for innermost muon chamber: what about resolution loss in outer chambers? Full simulation:



Multiple scattering, non-uniform $\vec{B}$, propagated from tracker $\Rightarrow$ 30% widening of distribution

How much data do we need?

To get 200-300 μm in barrel and 100-150 μm in endcap,

$$\left(1.3\,\frac{20\text{ mm}}{300\ \mu\text{m}}\right)^2 = 6800\,\frac{\text{muons}}{\text{DT}} \qquad \left(1.3\,\frac{6\text{ mm}}{150\ \mu\text{m}}\right)^2 = 2700\,\frac{\text{muons}}{\text{CSC}}$$

$\times$ 60 non-overlapping = 410,000 barrel $\qquad\times$ 80 = 220,000 endcap

At 0.9 TeV:

$$\begin{aligned} 2\times\sigma(Z)\times\mathcal{B}(\mu\mu)\times\epsilon(\eta) &= 0.14\text{ nb (barrel), }0.060\text{ nb (endcap)} \\ \sigma(W)\times\mathcal{B}(\mu\nu)\times\epsilon(\eta) &= 0.67\text{ nb (barrel), }0.29\text{ nb (endcap)} \end{aligned}$$

At 14 TeV:

$$\begin{aligned} 2\times\sigma(Z)\times\mathcal{B}(\mu\mu)\times\epsilon(\eta) &= 1.2\text{ nb (barrel), }1.2\text{ nb (endcap)} \\ \sigma(W)\times\mathcal{B}(\mu\nu)\times\epsilon(\eta) &= 5.4\text{ nb (barrel), }5.4\text{ nb (endcap)} \end{aligned}$$