# A Validation Suite/Simple Alignment Algorithm for Muon Chambers

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# Context

Three sophisticated alignment algorithms have been developed over the past 3 years:

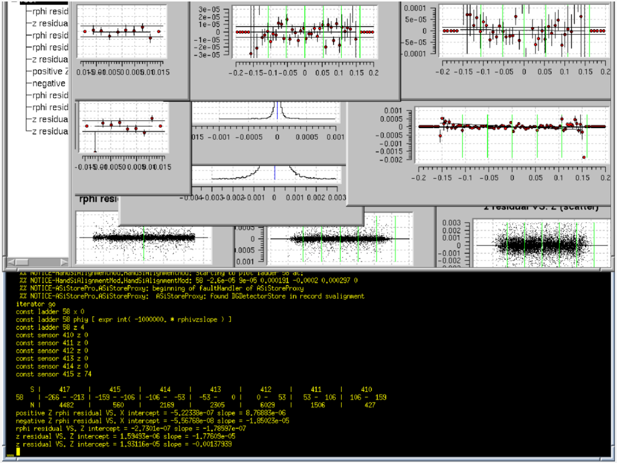
| | |
|---|---|
| HIP | iterative $\chi^2$ minimization of residuals |
| Millepede | matrix inversion, at least in spirit |
| Kalman | coupled track-fitting and alignment |

Possible disadvantage: they are all global fits, it may be hard to diagnose problems with individual chambers

Misalignment distribution may be very non-Gaussian due to static friction: some chambers stick while others slip...

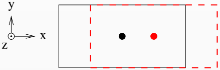
# Si-Vertex Alignment at the CLEO Experiment

- Global fit did not reliably reduce $\chi^2$
- Plotted residuals for and corrected each wafer individually

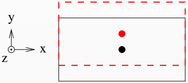


# Five Degrees of Freedom from a 2D Sensor

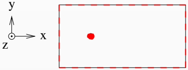
$r_x$ = track−hit residual in local coordinate $x$



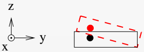

$x$: offset in $r_x$




$y$: offset in $r_y$

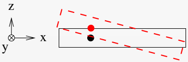



$z$: inaccessible



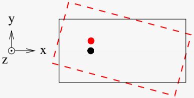

$\phi_x$: $r_y$ linear in $y$

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




$\phi_y$: $r_x$ linear in $x$

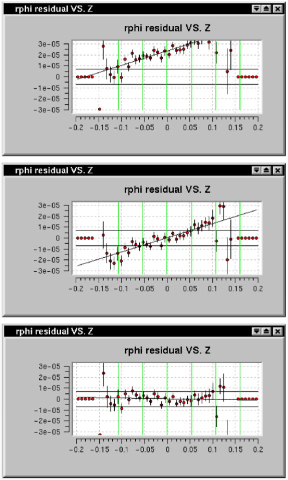
(slope $= 1 - \cos\phi_y$)




$\phi_z$: $r_x$ linear in $y$ and $r_y$ linear in $x$

(slope $= \sin\phi_z$)

# Example from CLEO

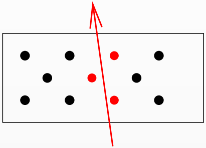



Take this plot to be $r_x$ versus $y$ (ignore the different axis label convention)

1. Linear fit to profile plot
2. Shift $x$ position to correct offset
3. Rotate $\phi_z$ to correct slope
4. Apply similar corrections to the degrees of freedom not shown
5. Iterate to resolve correlations

Not an efficient or an elegant alignment procedure, but you can see what's happening

# Muons: Simpler with Segments?



Muon code reconstructs local 4D segments (2D position + 2D direction)

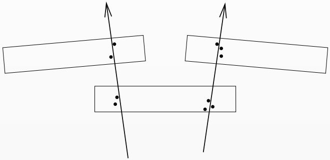
Angular track−segment difference in $x$-$z$ plane is $\phi_y$
Angular track−segment difference in $y$-$z$ plane is $\phi_x$

Replace weak $\mathcal{O}(\phi^2)$ dependencies!

**But,**

- need to propagate to segment's local coordinate system (center of chamber, not the layer plane)
- may require substantial re-working of CommonAlignment
- other subtleties I don't understand yet...

# Another Useful Diagnostic



Local consistency of the overlap regions (track has hits in two chambers in the same layer)

Easy way to implement: $\text{residual}_{\text{chamber 1}} - \text{residual}_{\text{chamber 2}}$

(track cancels, effectively a "ruler" curved in the $\vec{B}$ field)

**But,**

- hard to interpret as a correction: diagnostic only
- low statistics

# Possible Future Timeline

1. Test Residuals Algorithm in MuonAlignmentAnalyzer

1. Add muon chambers to CommonAlignment

2. Incorporate Residuals Algorithm into CommonAlignment

3. Apply Residuals Algorithm to early data, possibly only the largest outliers

3. Use it to debug global fits, if necessary

4. Use residuals plots to monitor global fits, which do the real alignment