


Track-based Alignment of the Muon System

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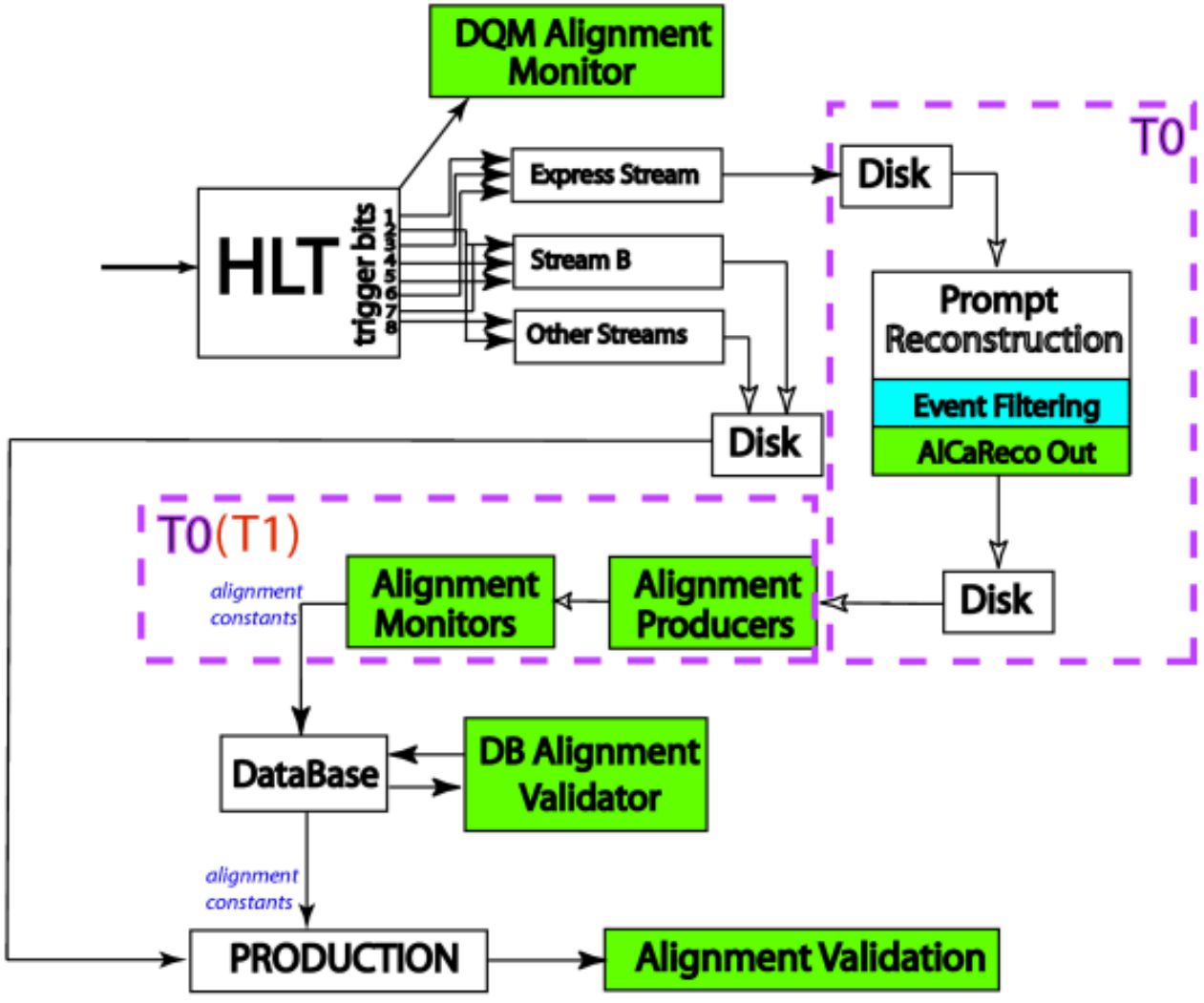
Introduction and Overview

- Development of infrastructure: ready for CSA07
- Survey measurements (used as constraints for track-based alignment)
- MC: developing the procedure
- Alignment results in MC
- MTCC: early attempts on real data

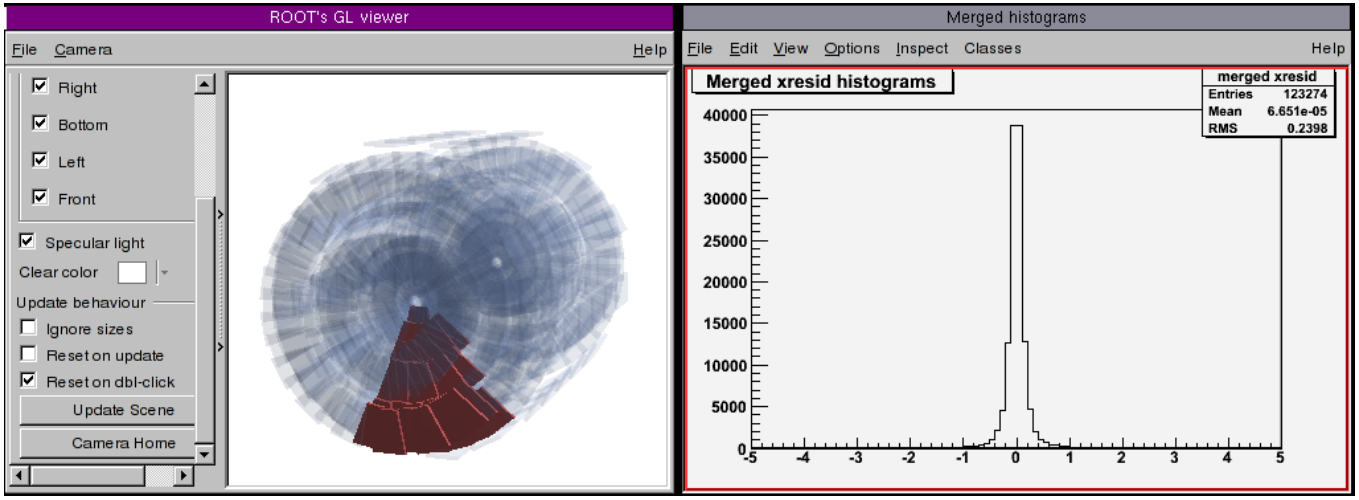
Infrastructure



- Defined data path and triggers
- Defined data format for muon alignment stream
- Developed monitoring tools
- Ready for CSA07

Alignment Monitor Tool

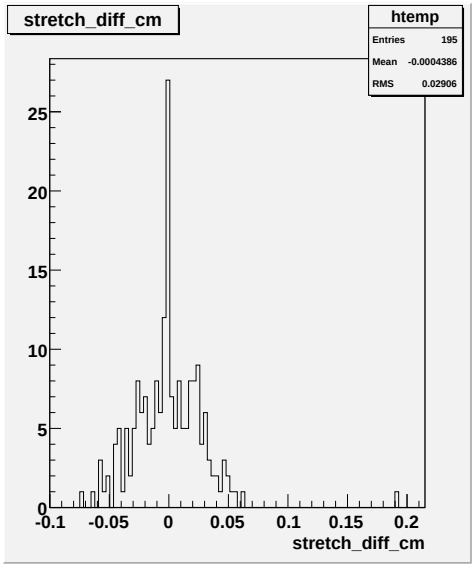
1. CommonAlignmentMonitor: general plotting package integrated into AlignmentProducer
   - Manages iteration, collection after parallel processing
2. AlignmentMonitorMuonHIP outputs histograms for every chamber (or every layer): residuals versus everything
3. pyROOT script merges histograms on the fly



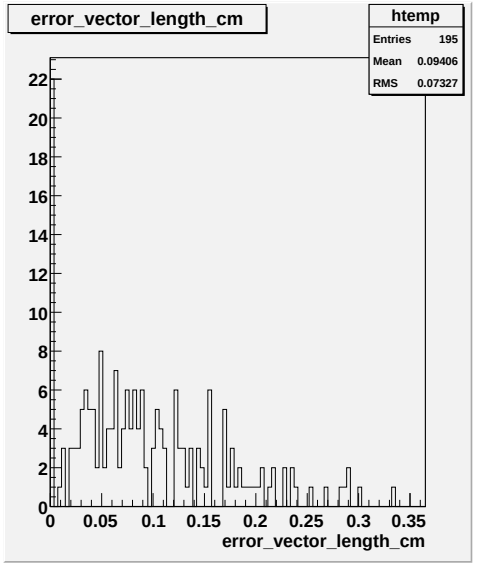
- Offline Alignment Validation, the last step in monitoring, sees changes in p_T, Z' resolution (Javier Fernandez)

Survey measurements

- This is the initial geometry used in track-based alignment
- Can also be used as a constraint on track-based alignment
- Positions of optical targets are measured by photogrammetry and later transformed into chamber positions/orientations
- CSC measurement is good; transformation contains an error



Measurement resolution: $\sim$300 μm



Consistency check: $\sim$1 mm

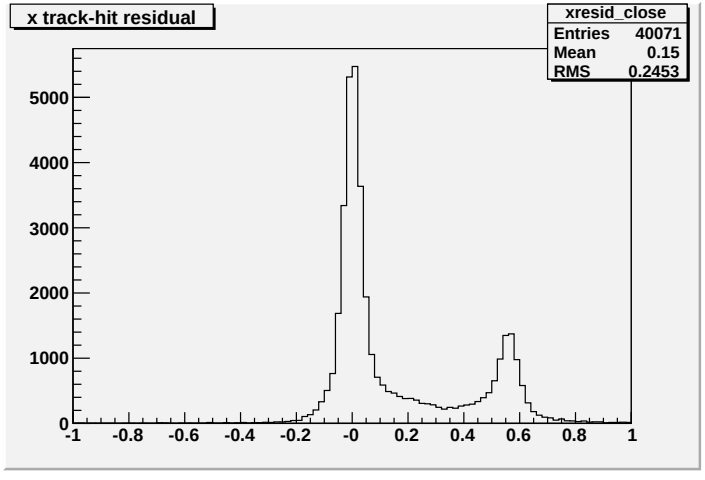
Testing the alignment system in MC

MC: developing the procedure

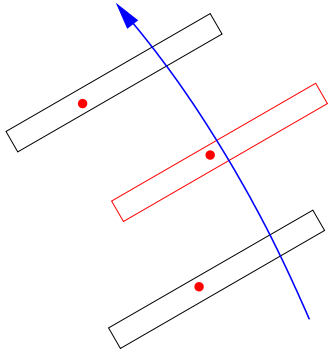
- More realistic than this spring's test-run (presented at UCLA)
  - Large datasets: 10 pb^{-1} and 100 pb^{-1} of muons from W and Z (simulated by Z only)
  - More ambitious precision goals (200 μm, rather than 1 cm)
  - Random misalignments with SurveyOnlyScenario (rather than moving all chambers in the same direction)
  - First attempt at muon system self-measurement
- Two major approaches, developed simultaneously
  - Align the muon system to the tracker (globalMuons)
    - converges more quickly
  - Align the muon system to itself (standAloneMuons)
    - independent of the tracker

Aligning to the tracker

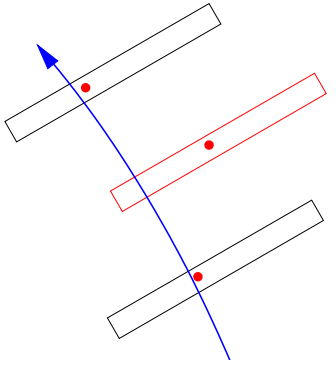
- Residuals from globalMuons have two peaks per chamber, due to track-fitting bias

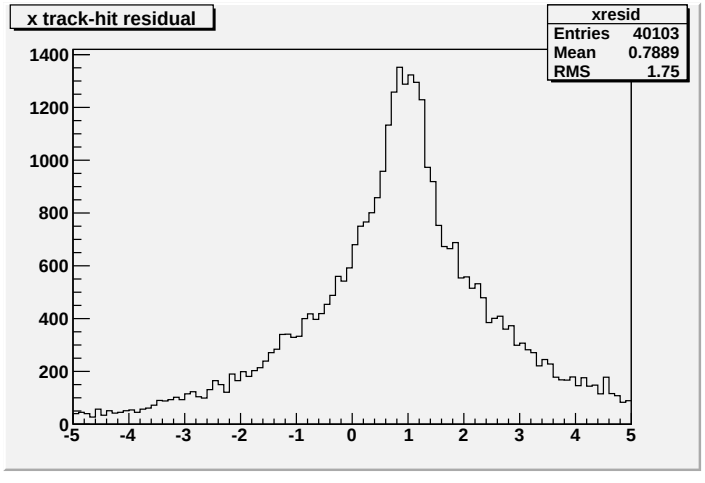


Tracking algorithm trusts the misaligned hit: peak at zero



Tracking algorithm avoids the misaligned hit: peak near $-\Delta x$

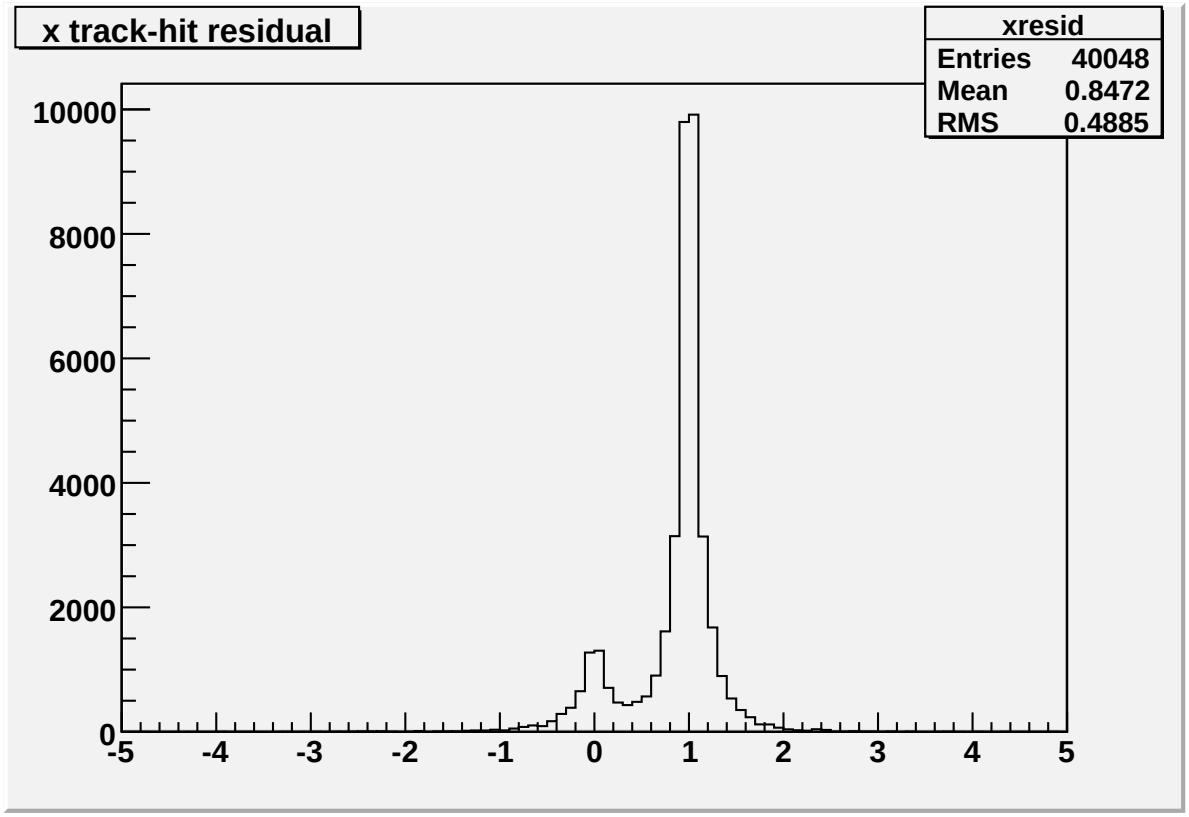




- Simply extrapolating a tracker track into the muon system removes the bias, but at a severe resolution cost (note wider scale)
- Neither is optimal

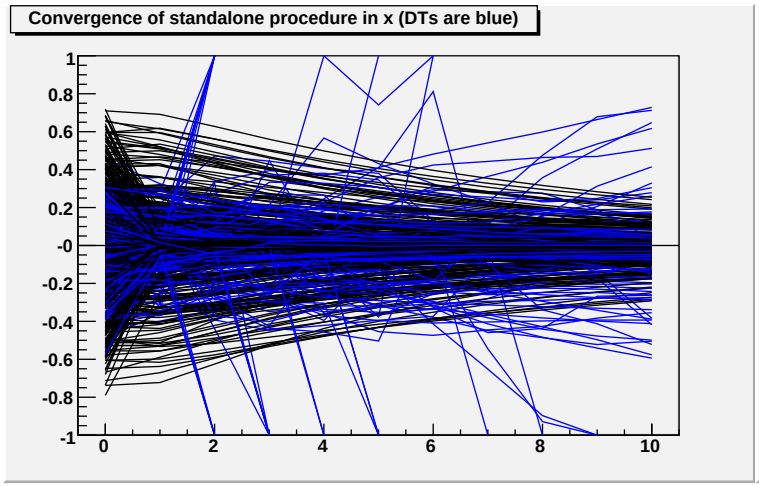
The "lowbias" method

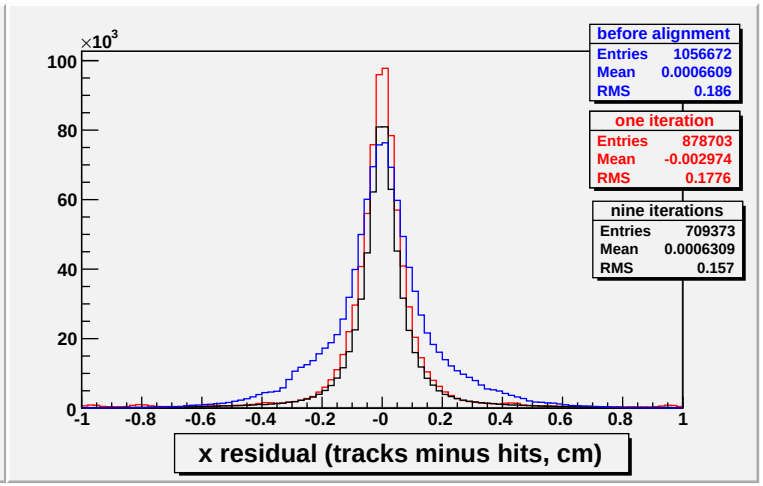
- Re-fit globalMuon tracks with inflated hit uncertainties in the muon system
- Resulting tracks are determined mostly by the silicon tracker, but they "know" about scattering in the muon system



The "standalone" method

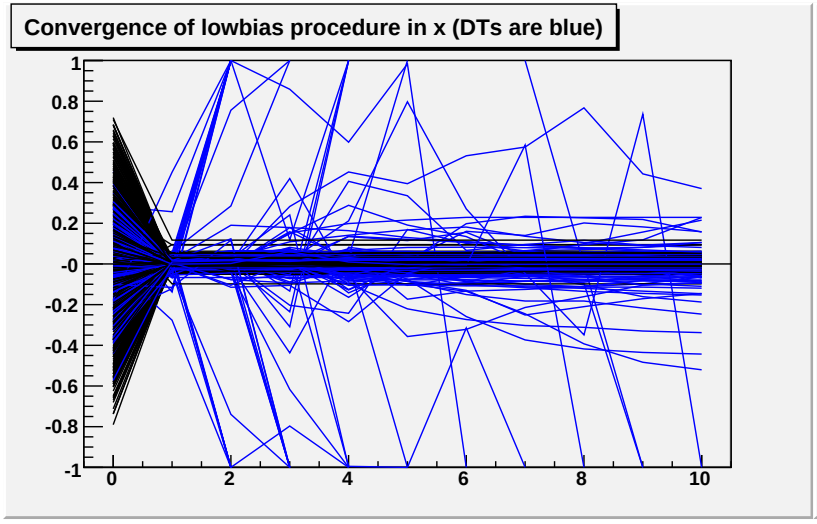
- standAloneMuons have the two-peak structure in residuals, and therefore need to iterate to decouple track-fitting from chamber alignment
- With a $|\text{residuals}| < 5$ cm cut, this method shows clear convergence for most chambers:

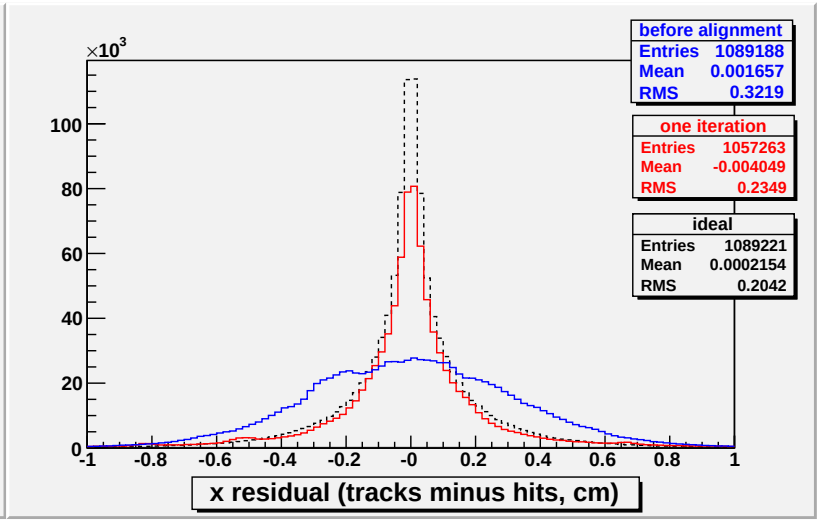




- We are keenly interested in saving the tails. . .

The same plots for "lowbias"

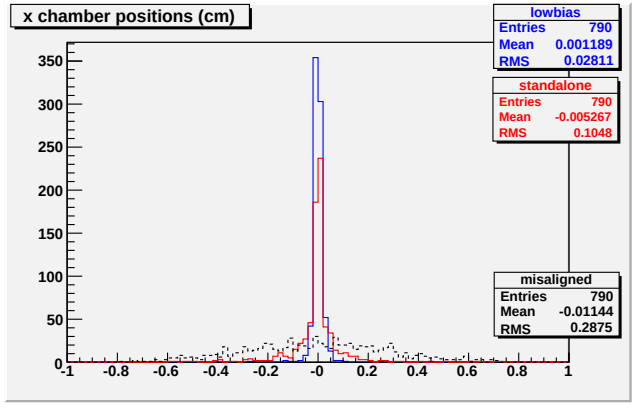




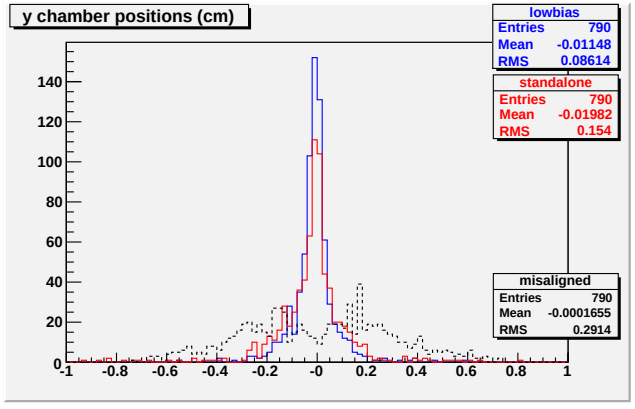
- Converges in one iteration
- Beyond that most chambers are stable, but a few DTs wander
- There's also a cumulative problem with hit efficiency

Alignment Results (10 pb^{-1})

- Starting from MuonSurveyOnlyScenario: positions misaligned 2.5 mm, ϕ_z misaligned 0.25 mrad
- Five degrees of freedom in alignment: x, y, ϕ_x, ϕ_y, ϕ_z
- Accuracy: one iteration lowbias, ten iterations standalone



$x_{\text{aligned}} - x_{\text{true}}$ (cm)



$y_{\text{aligned}} - y_{\text{true}}$ (cm)

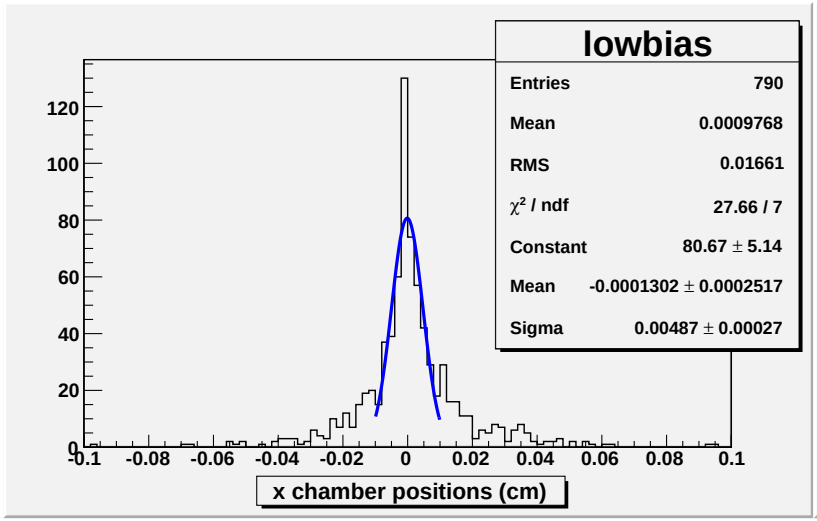
- Precision: alignment uncertainties are still underestimated by a factor of 3–4

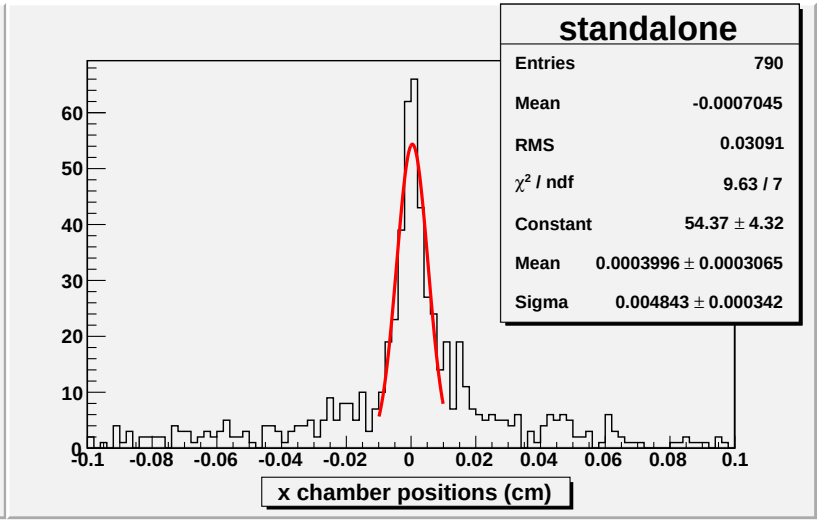
Figures of merit

1. σ of core Gaussian (best-measured chambers)
2. RMS, cut at 1 cm
3. |max| (worst outlier)

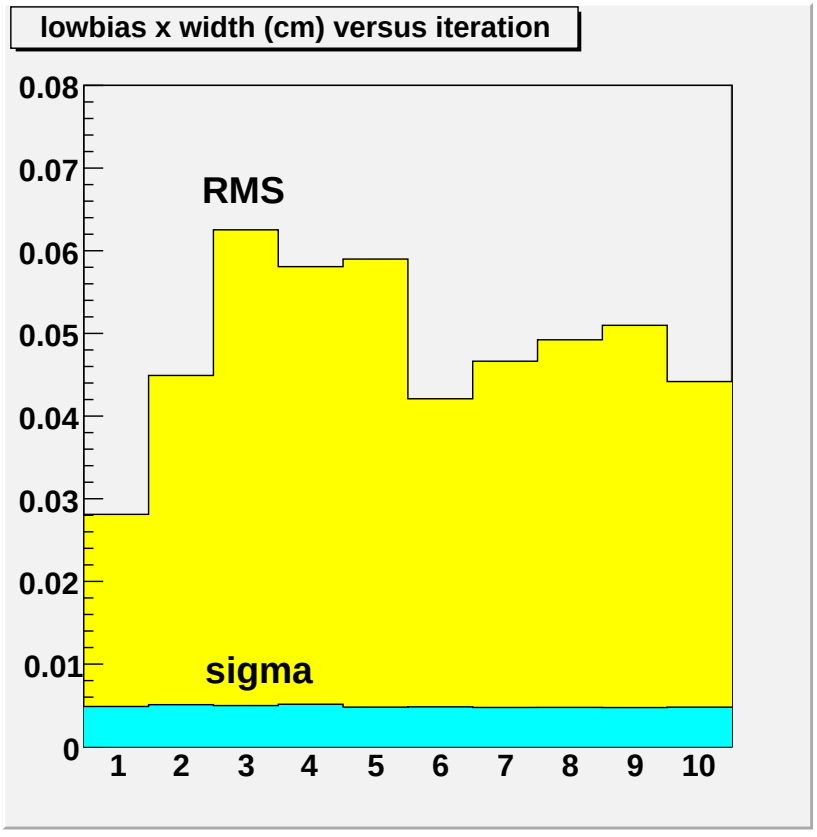
790 chambers	core σ	RMS	|max|
lowbias x	50	280	4500
lowbias y	270	860	6000
standalone x	50	1040	∞
standalone y	290	1540	34000

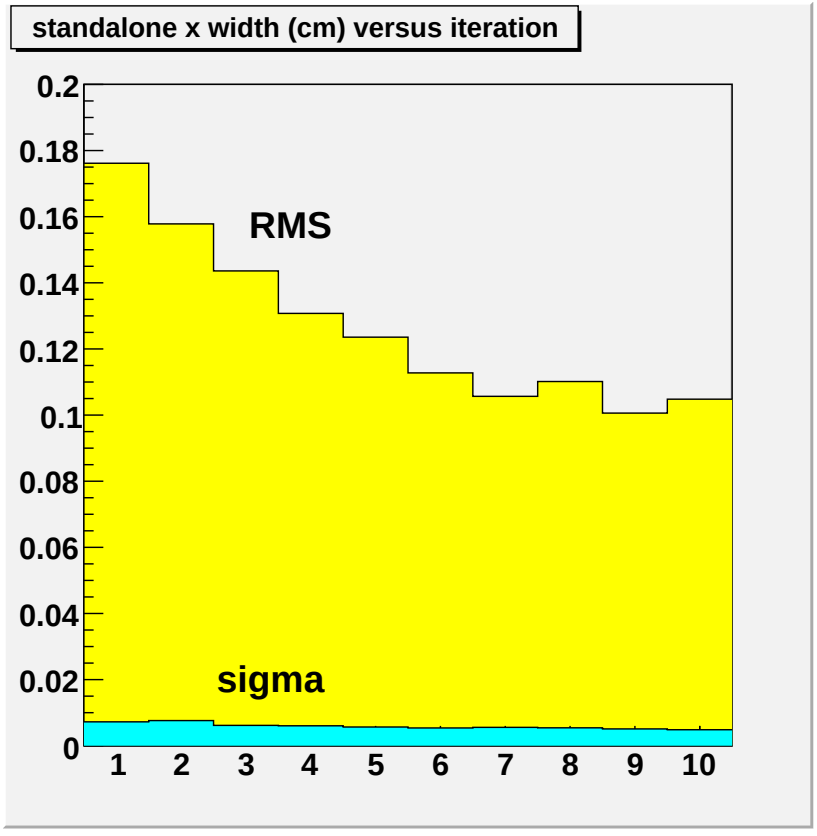
microns





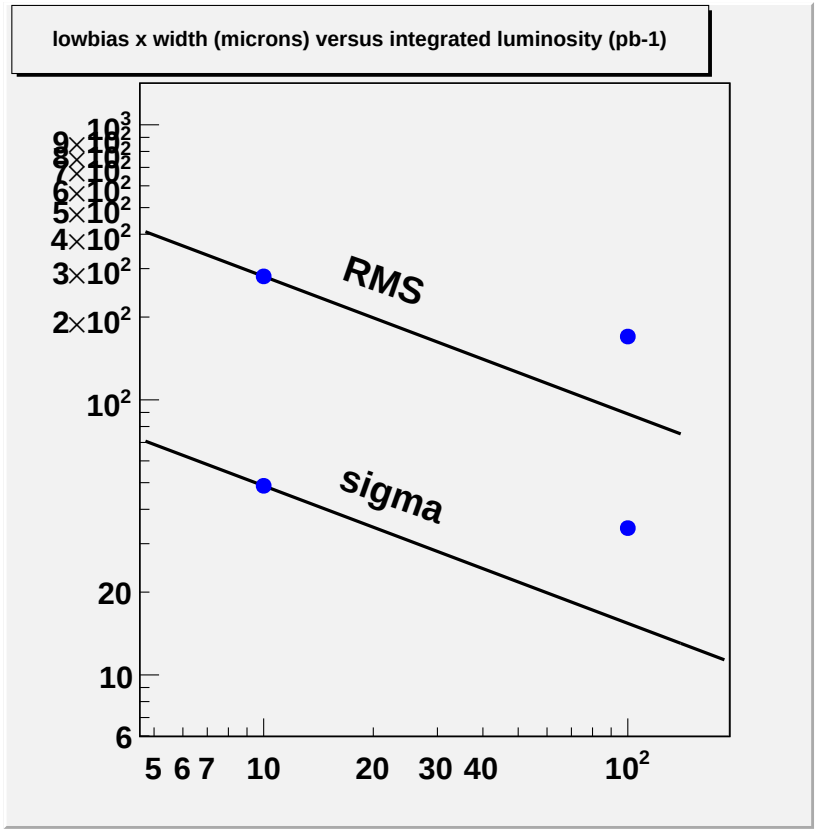
Figures of merit versus iteration

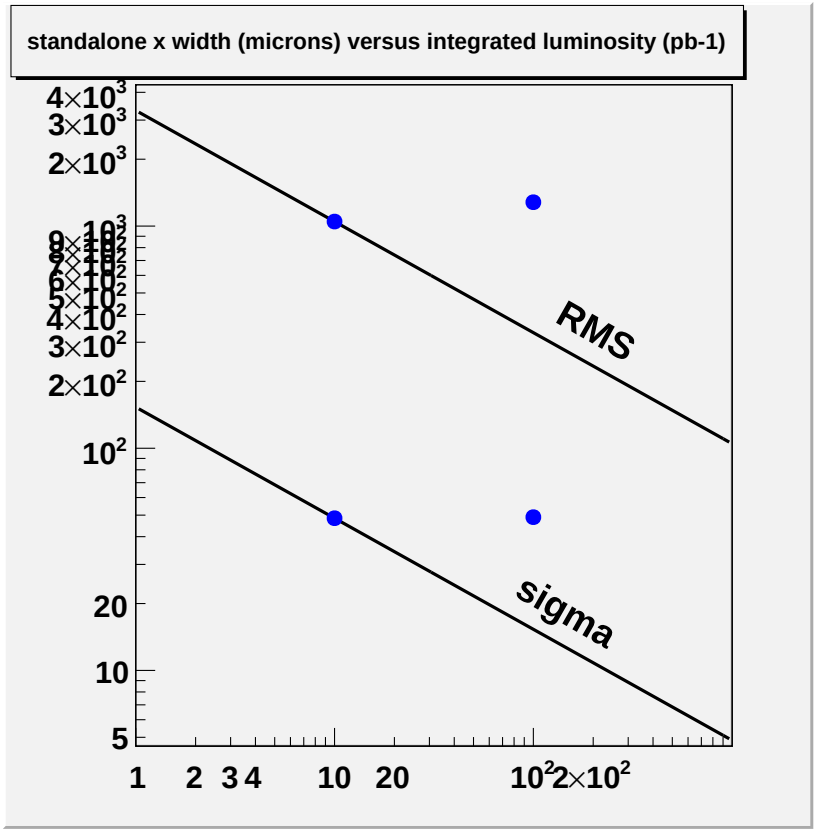




- Core σ largely unchanged after first iteration
- standalone method requires 7 iterations

Figures of merit versus integrated luminosity





- lowbias reaches sensitivity limit between 10 and 100 pb^{-1}
- standalone technique reaches limit below 10 pb^{-1}

Planned systematics studies

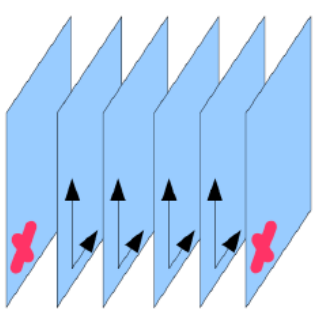
- Dependence of lowbias on tracker alignment — in progress
- Dependence on fitting constraints — in progress
- Dependence on survey constraints
  - obtain survey geometries and apply constraints
- Dependence on tracking algorithm
  - Uncertainty in distribution of material
  - Uncertainty in $\vec{B}(\vec{x})$
- Background studies in CSA07
  - Multiple scattering in low-p_T muons
    - Alignment with $J/\psi \to \mu\mu$
  - Effect of fake muons in the alignment stream
    - Obtain realistic background samples from CSA07
    - Finalize track quality cuts

Testing the alignment system in MTCC

Karoly Banicz's (re-)discovery of layer offsets

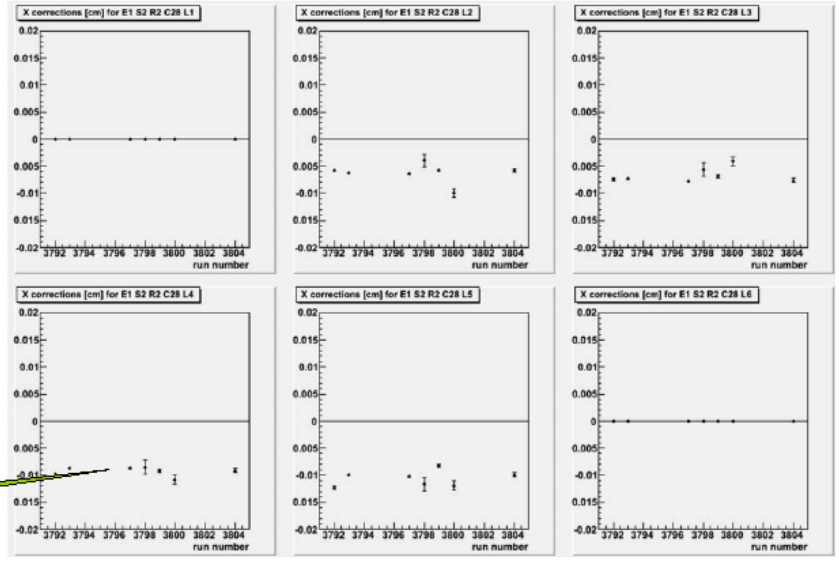
- Agrees with FAST site measurements
- We want to reproduce this study in AlignmentProducer

- Pick good segments, fix end-points and look at residuals in intermediate layers:



- Example:
  - ME2/28:

~ 100 microns



120 aligned layer positions	mean	stdev	|max|
x	-55 μm	190 μm	670 μm
y	110 μm	330 μm	1.2 mm
ϕ_z	0.01 mrad	0.04 mrad	0.15 mrad

Preliminary MTCC alignment with AlignmentProducer

- Alignment attempts were beset by random crashes
- A single standalone iteration survived; not enough for a reliable alignment, but enough for order-of-magnitude

102 semi-aligned layer positions	mean	stdev	|max|
x	8 μm	192 μm	440 μm

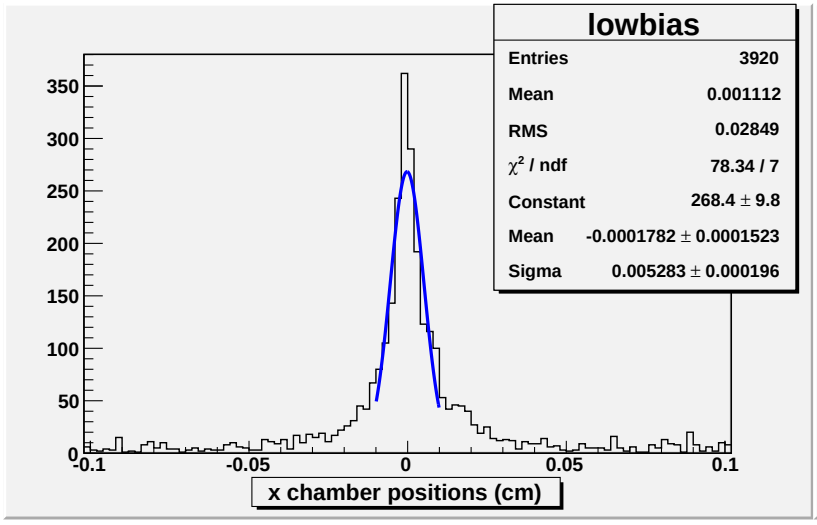
- in rough agreement with Karoly's results
- We'll need more data and more robust computation
- Likely to get both with MTCC 1_5_0 re-reconstruction

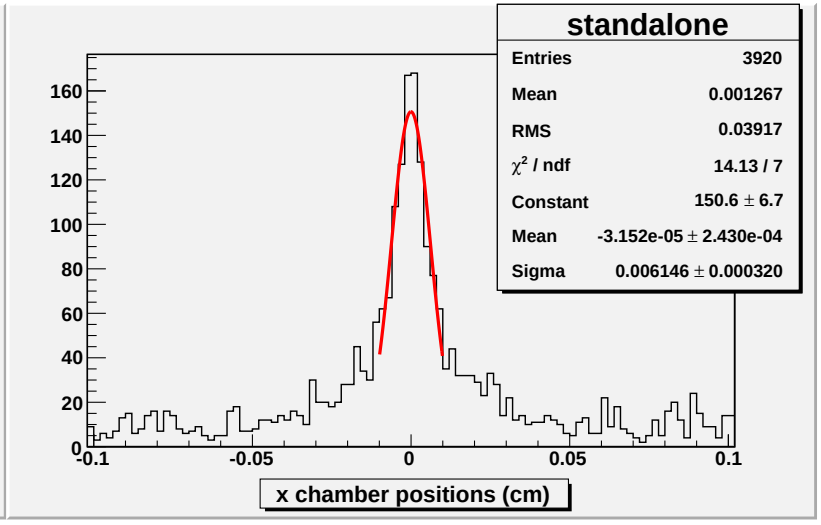
How well can we do layer-by-layer alignments anyway?

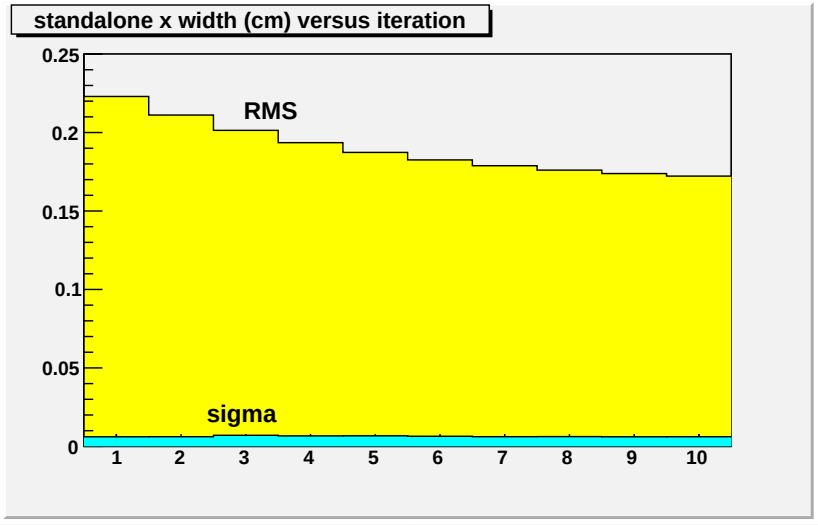
Back to MC...

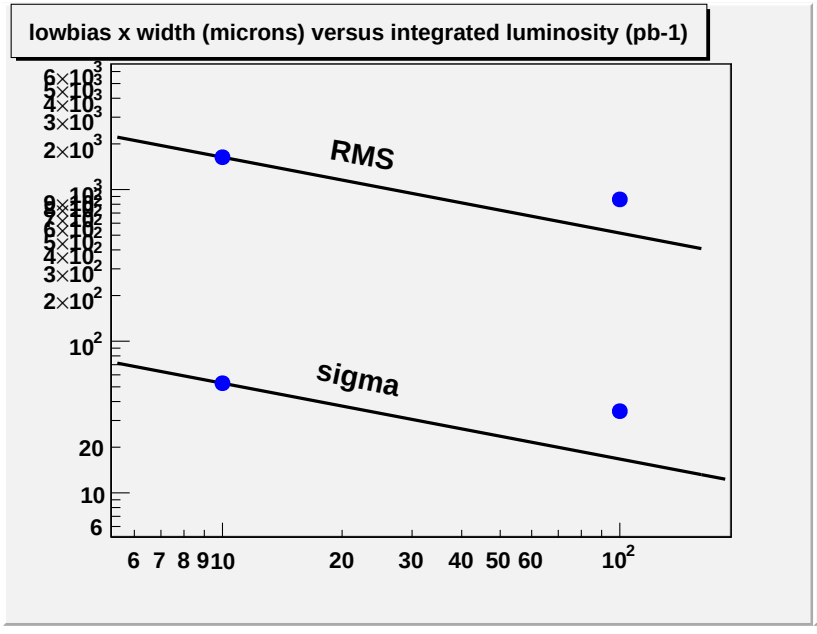
3920 layers	core σ	RMS	|max|
lowbias x	50	1630	6600
lowbias y	360	1830	13000
standalone x	60	1720	6600
standalone y	380	1970	6400

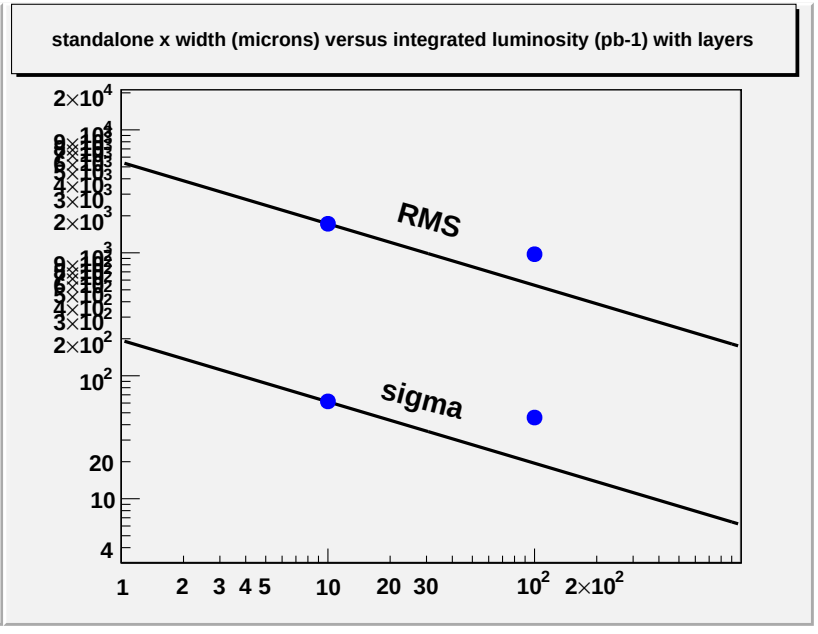
microns






standalone x width (cm) versus iteration
0.25
0.2
0.15
0.1
0.05
0
RMS
sigma
1
2
3
4
5
6
7
8
9
10


lowbias x width (microns) versus integrated luminosity (pb-1)
RMS
sigma
6
7
8
9
10
20
30
40
50
60


standalone x width (microns) versus integrated luminosity (pb-1) with layers
RMS
sigma
1
2
3
4
5
10
20
30

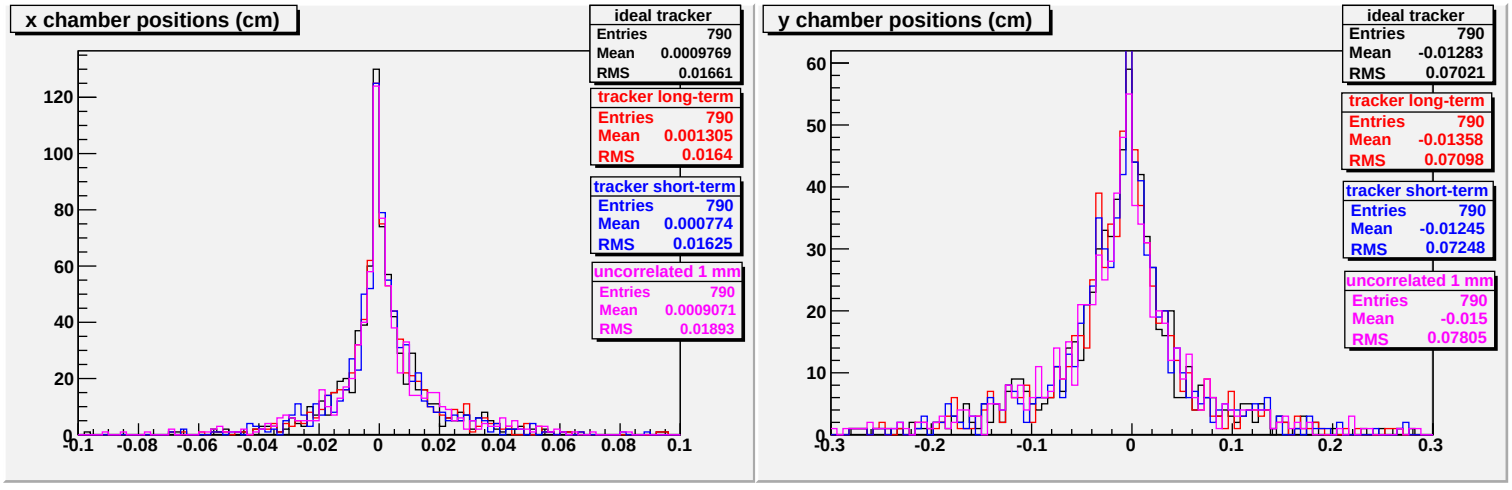
Summary

- Overall scheme and infrastructure components are now mature
- Entering the era of precision alignment studies
- Procedure is ready for CSA07, some updates need to be checked into CVS
- We have taken a first glance at MTCC data and are ready to apply our software to 1_5_0 re-reconstructed data
- Concrete list of systematics studies planned for CSA07
- The software is available for cosmic ray/beam halo studies...
- We're starting to write a CMS Note

Backup Slides

Dependence of lowbias on tracker alignment

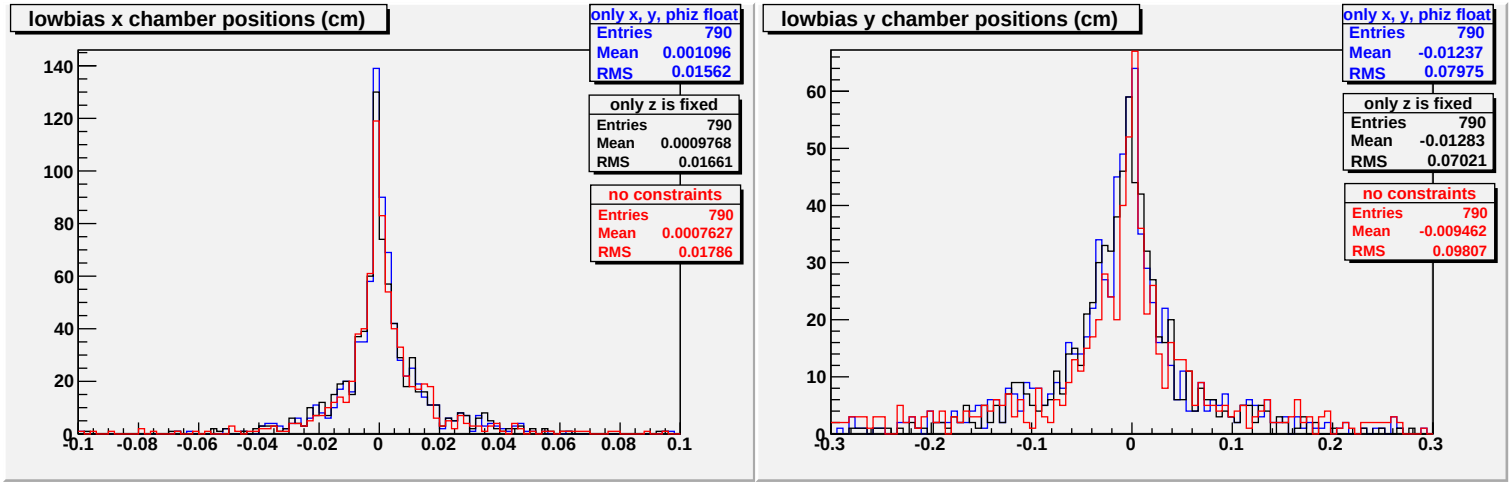
- The lowbias technique aligns the muon system using tracks which were fitted to the silicon tracker
- How does muon alignment depend on the tracker's alignment?



- Differences between alignment scenarios appears to be weak

Dependence on fitting constraints

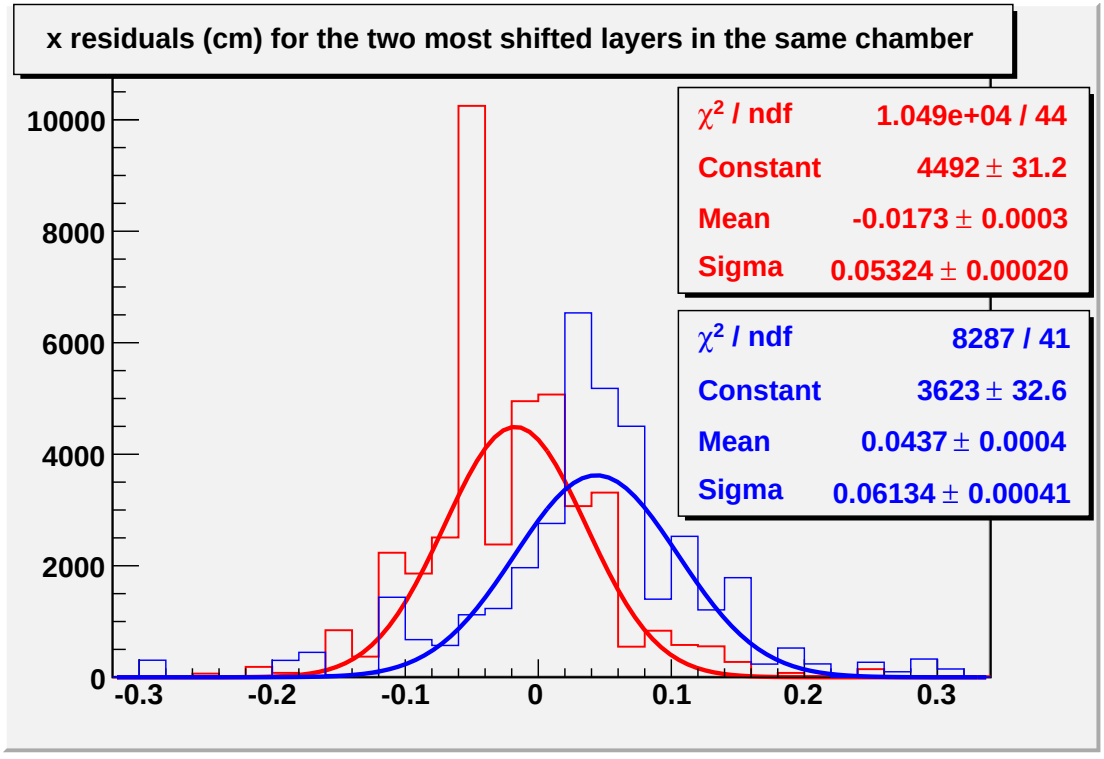
- Reducing the number of degrees of freedom should improve convergence



- Again, dependence is weak

Are the MTCC layer offsets real?

- Or are we under-reporting our uncertainties?
- Can we find a pair of divergent layers in the same chamber?



- red is layer 3, blue is layer 6 in chamber 27 in ME+3/2