


Alignment of the Muon System with HIP

Jim Pivarski, Alexei Safonov

Texas A&M University

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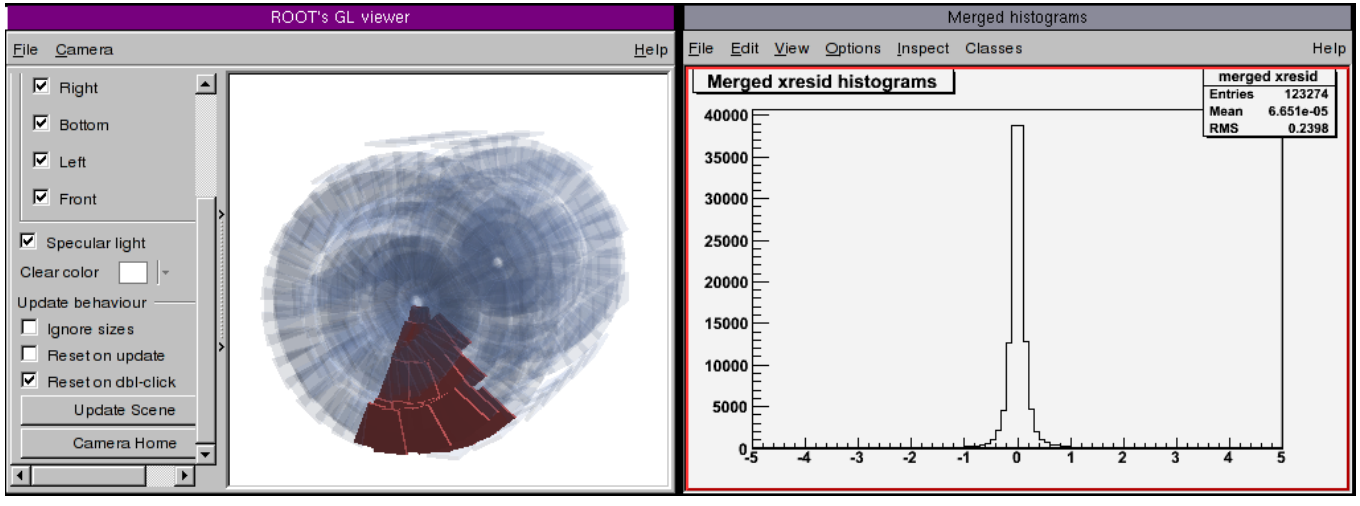
Introduction: monitoring tools (we'll be using it later...)

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



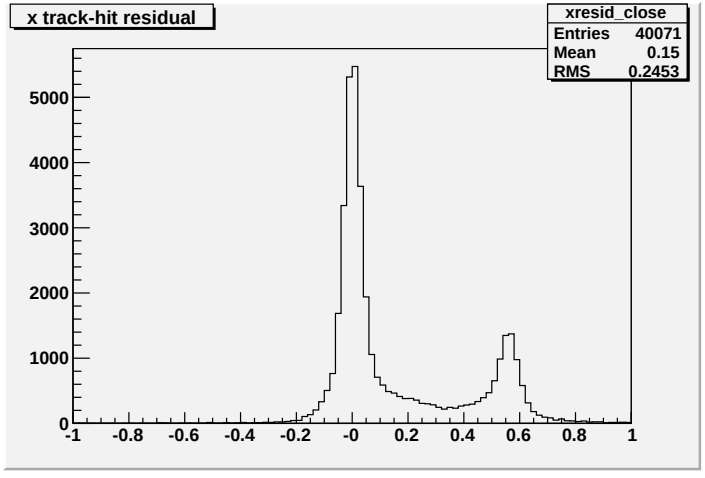
all of this will be in CVS early next week

Muon alignment simulation

- First full-scale muon alignment in AlignmentProducer
  - Large dataset: 10 pb^{-1} of muons from W and Z (simulated by Z only)
  - Full precision goals (200 μm)
  - Random misalignments with SurveyOnlyScenario (rather than moving all chambers in the same direction)
- 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

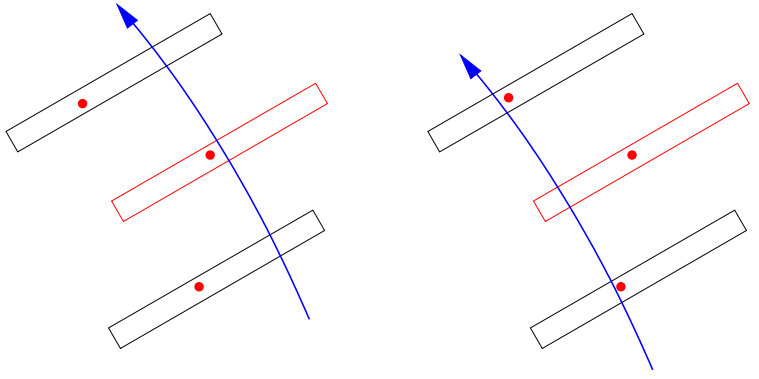
Aligning to the tracker

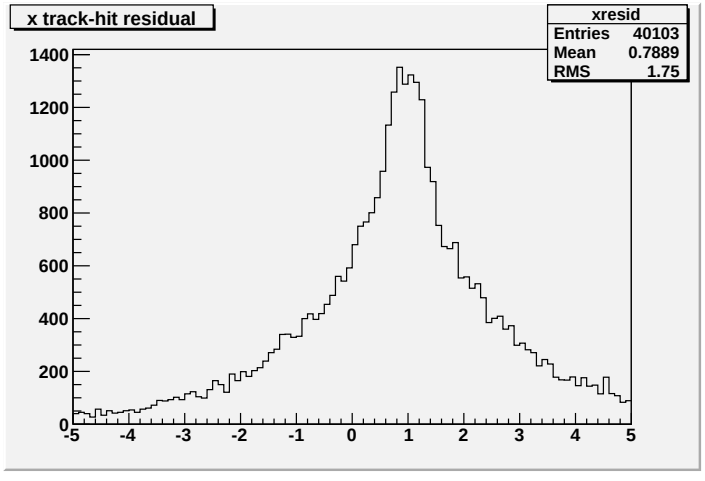
- Residuals from globalMuons have two peaks per chamber, due to track-fitting bias



Tracking algorithm trusts the misaligned hit: peak at zero

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

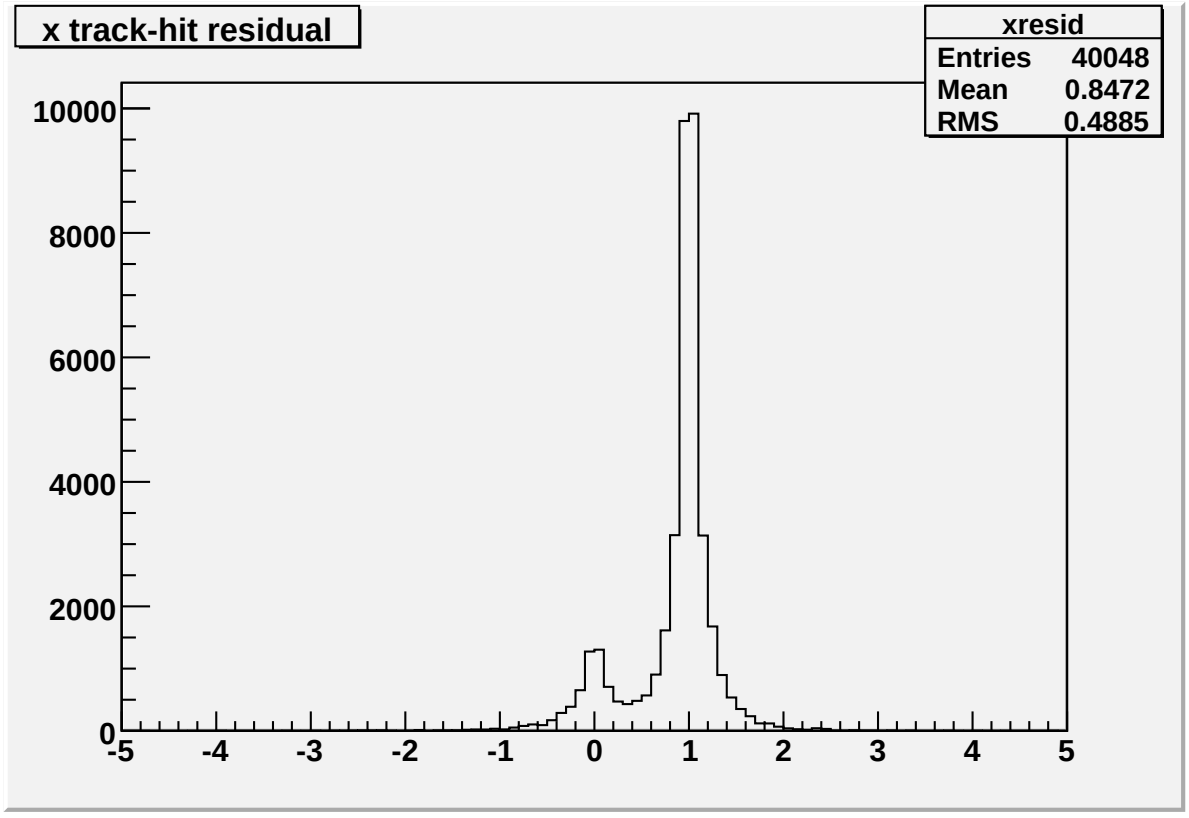




- Simply extrapolating a tracker track into the muon system removes the bias, but at a severe resolution cost (note wider scale)
- Neither is optimal

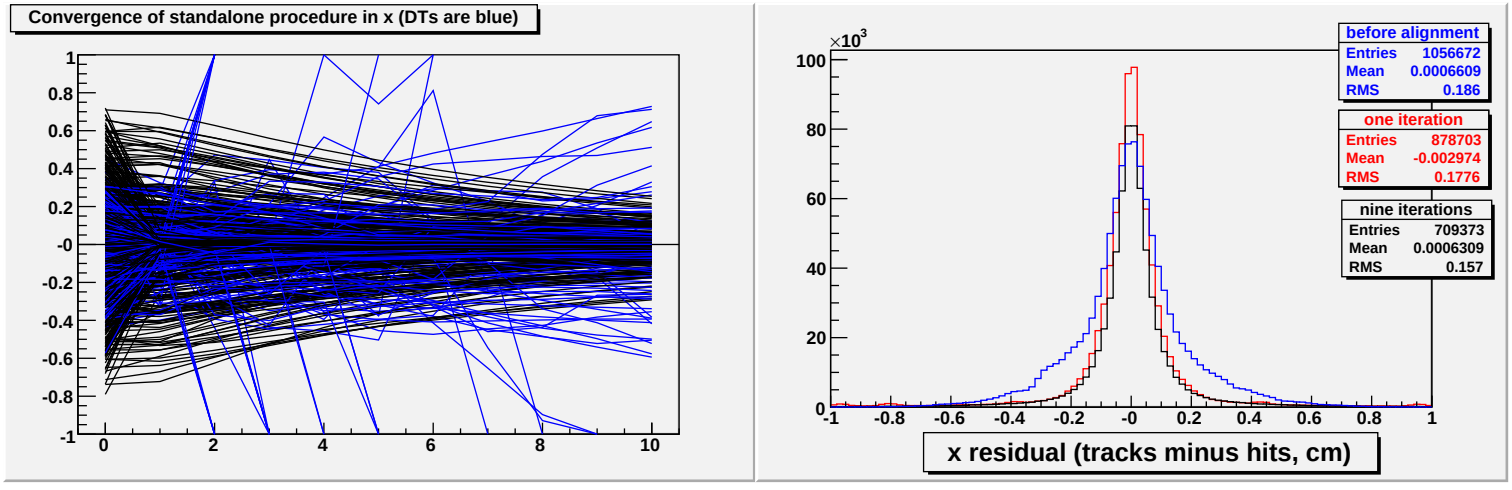
The "lowbias" method

- 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



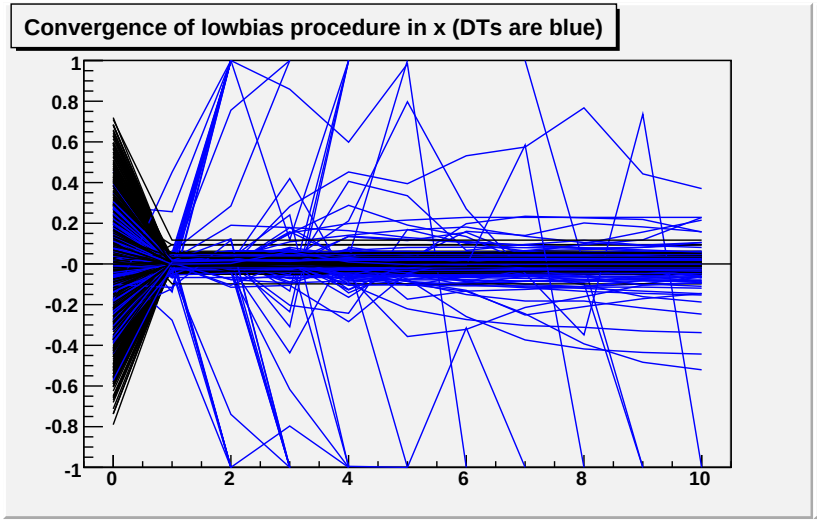
The "standalone" method

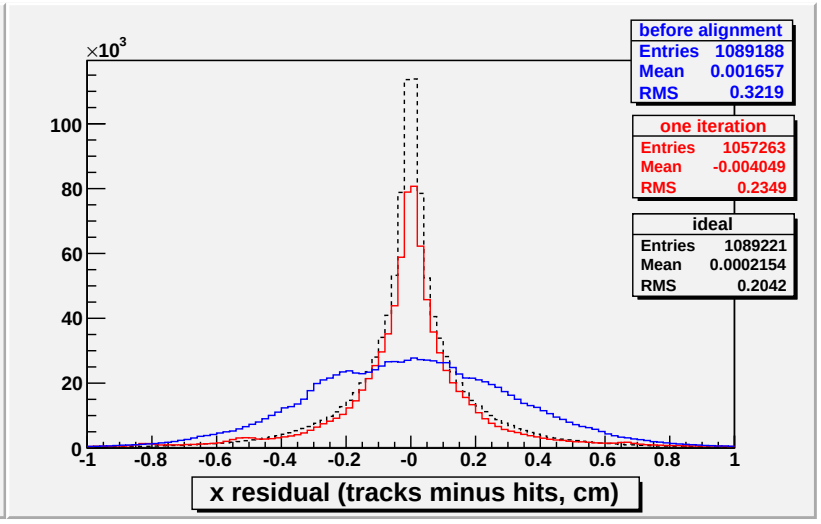
- standAloneMuons have the two-peak structure in residuals, and therefore need to iterate to decouple track-fitting from chamber alignment
- With a $|\text{residuals}| < 5$ cm cut, this method shows clear convergence for most chambers:



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

The same plots for "lowbias"

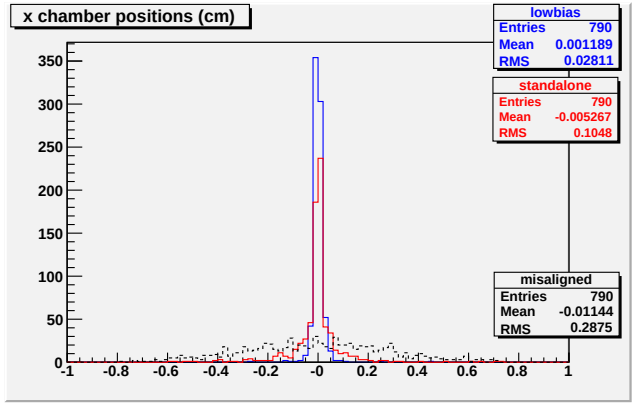




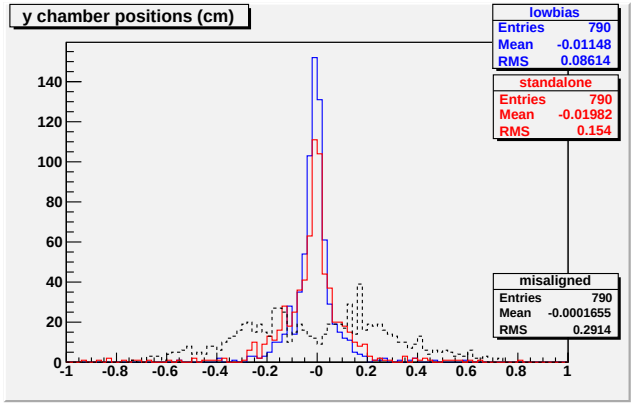
- Converges in one iteration
- Beyond that most chambers are stable, but a few DTs wander
- There's also a cumulative problem with hit efficiency

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)

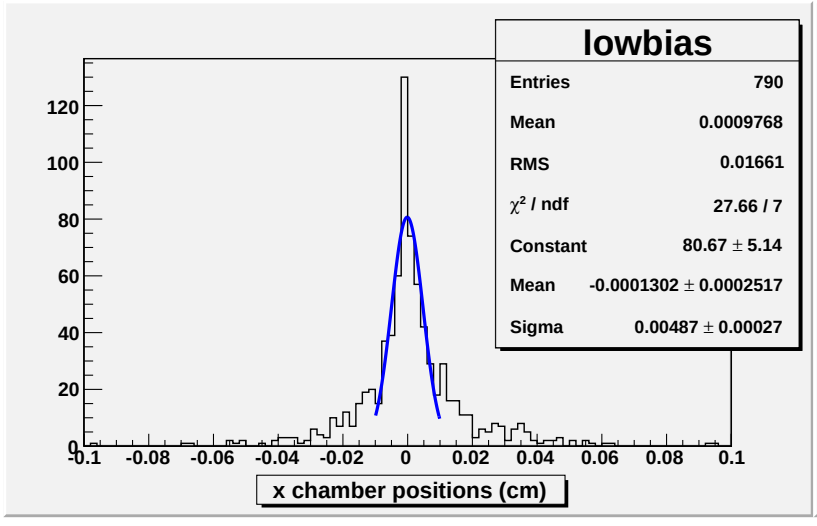
- Precision: alignment uncertainties are underestimated by a factor of 3–4 (pull distribution is wide)

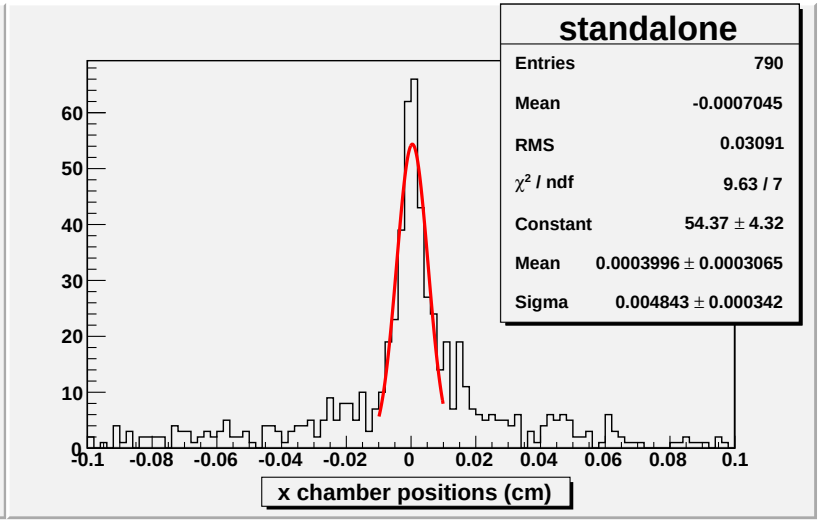
Figures of merit

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

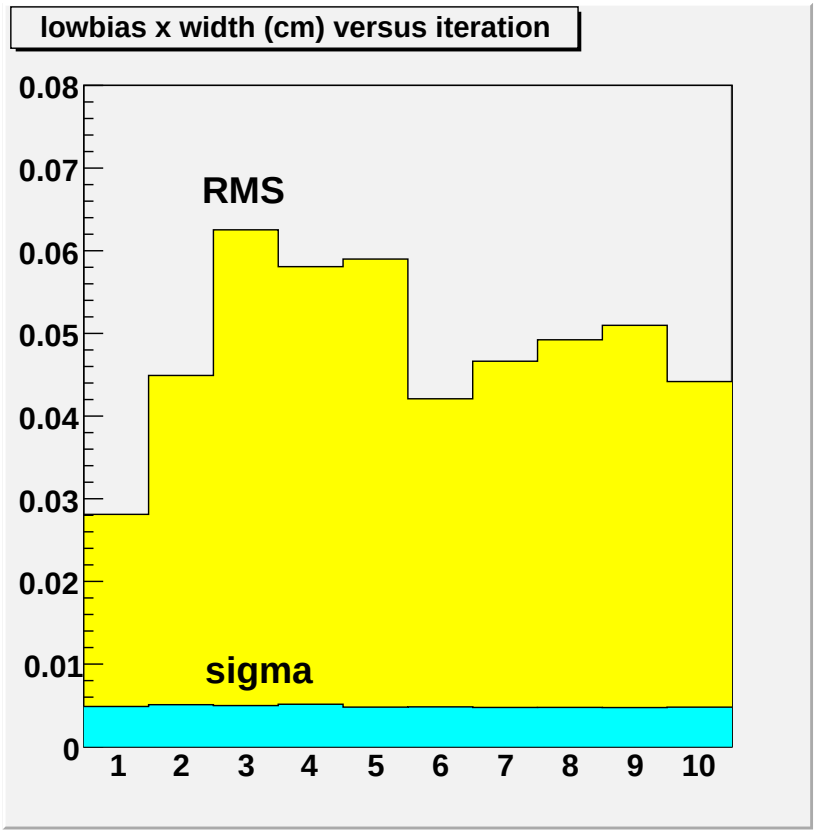
790 chambers	core σ	RMS	|max|
lowbias x	50	280	4500
lowbias y	270	860	6000
standalone x	50	1040	∞
standalone y	290	1540	34000

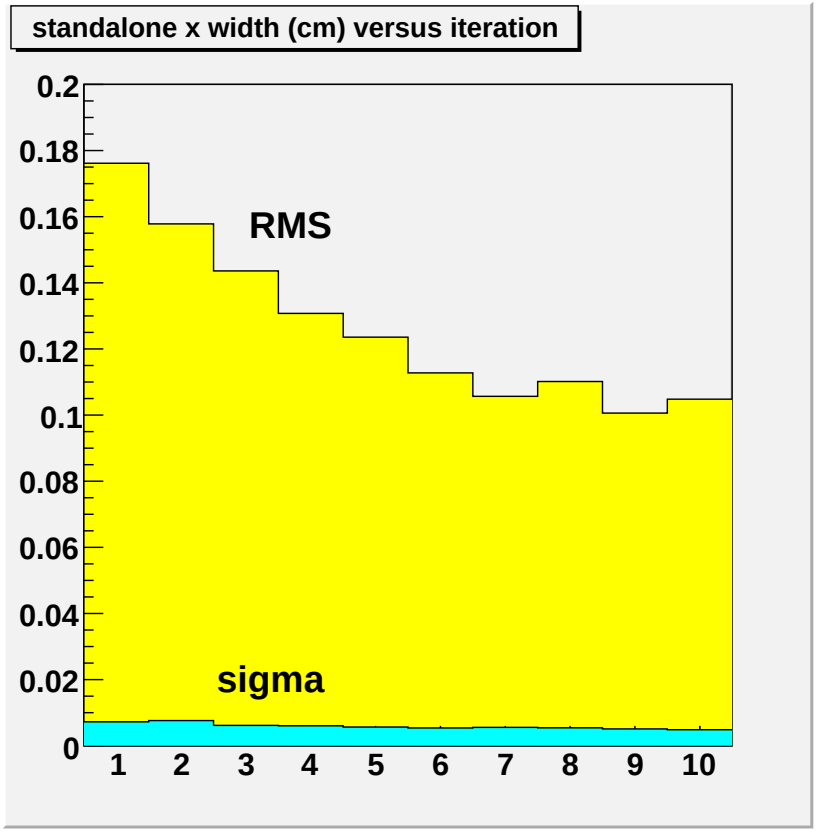
microns





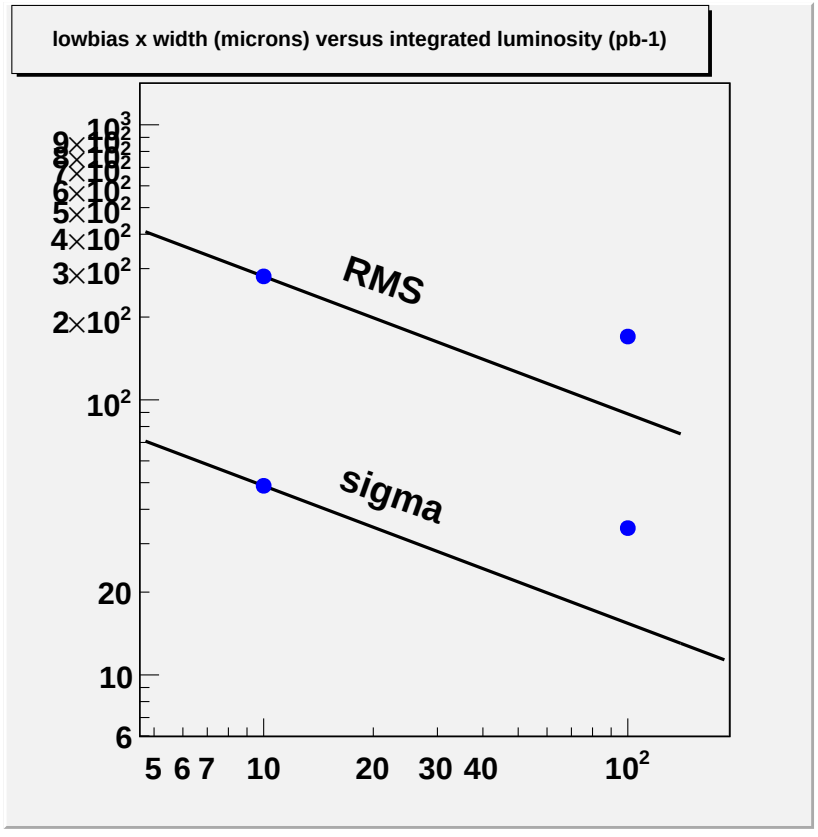
Figures of merit versus iteration

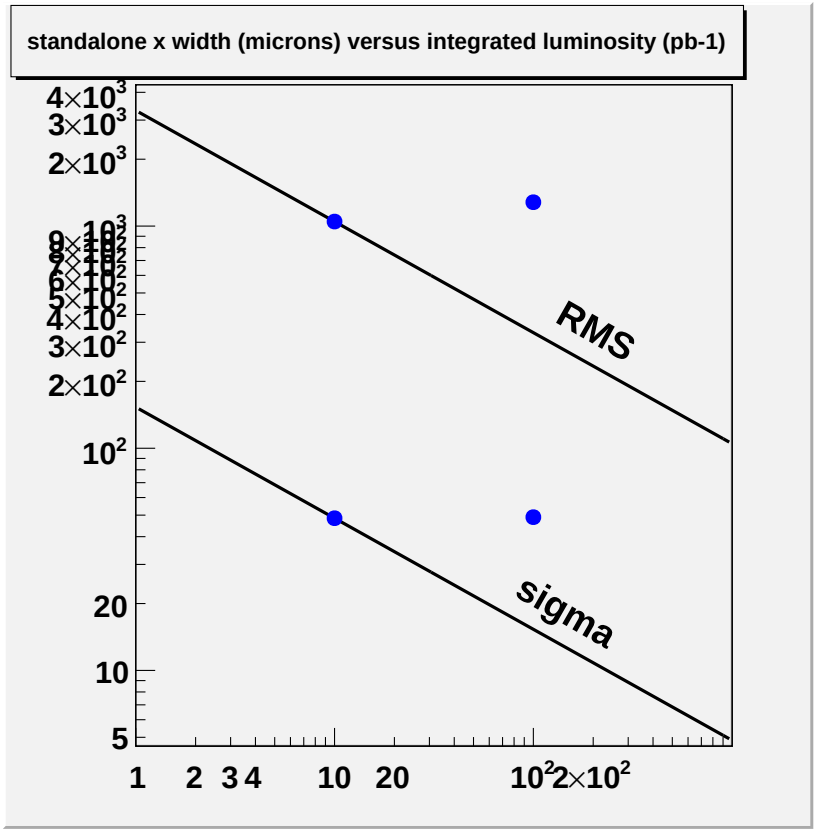




- Core σ largely unchanged after first iteration
- standalone method requires 7 iterations

Figures of merit versus integrated luminosity

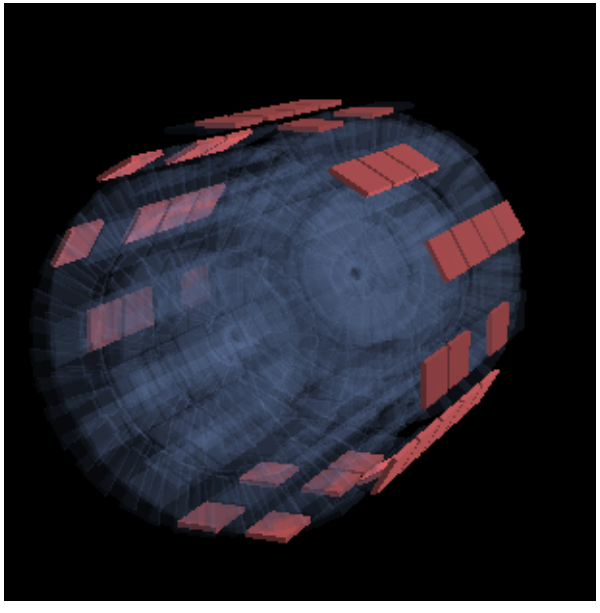


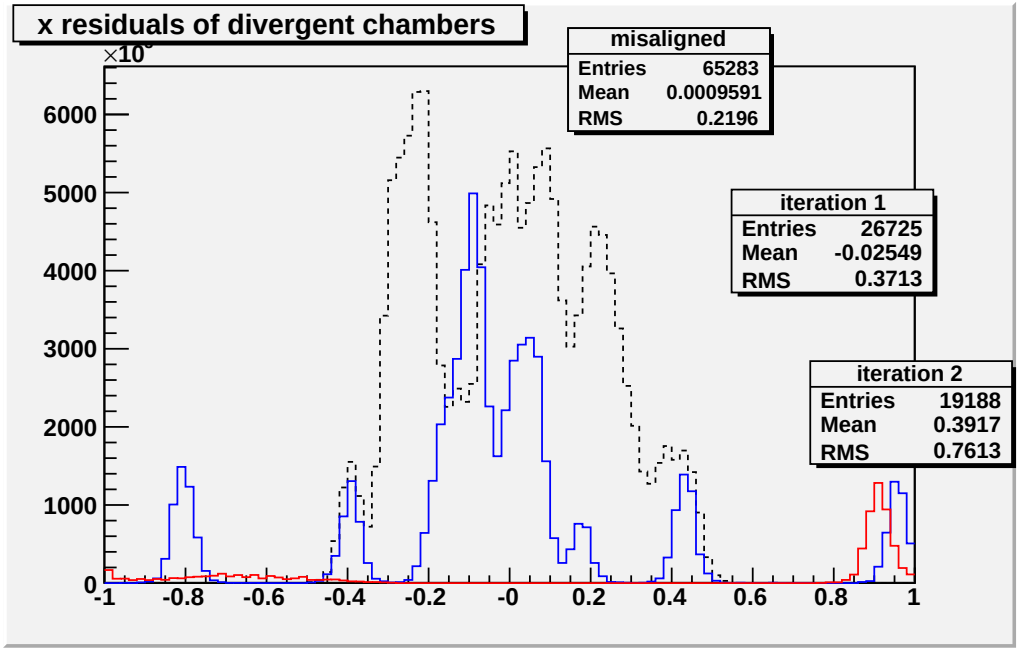


- lowbias reaches sensitivity limit between 10 and 100 pb^{-1}
- standalone technique reaches limit below 10 pb^{-1}

Initial diagnostics of the outliers

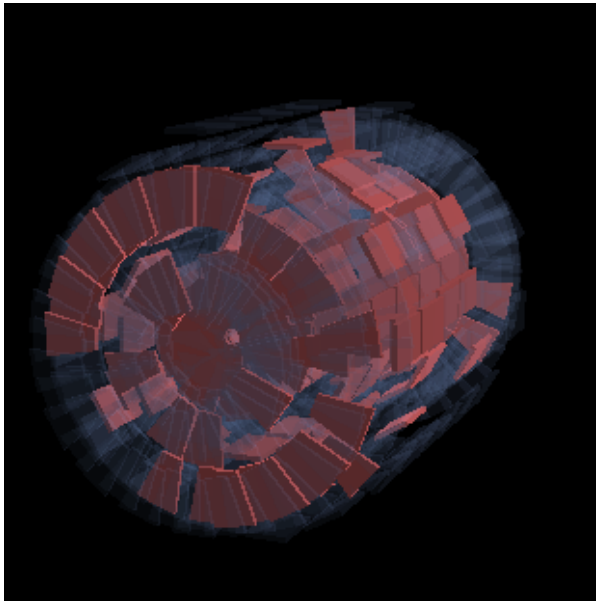
- Just apply the tool to the chambers that diverge
- x beyond 0.8 cm in the second iteration (standalone):

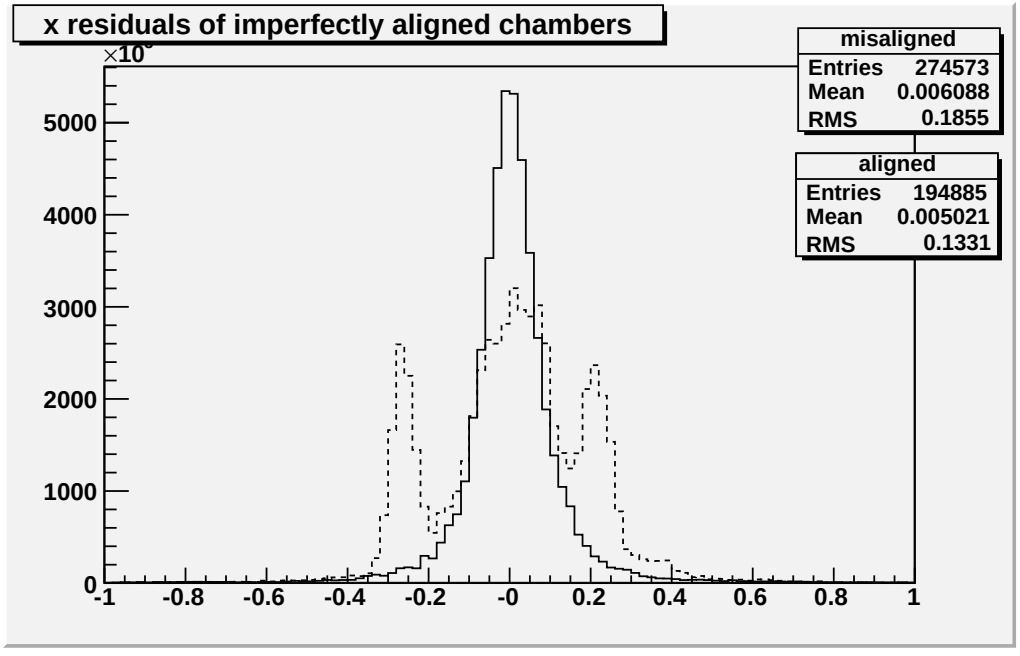




The imperfectly-aligned chambers

- x between 0.02 and 0.1 cm in the tenth iteration (standalone):





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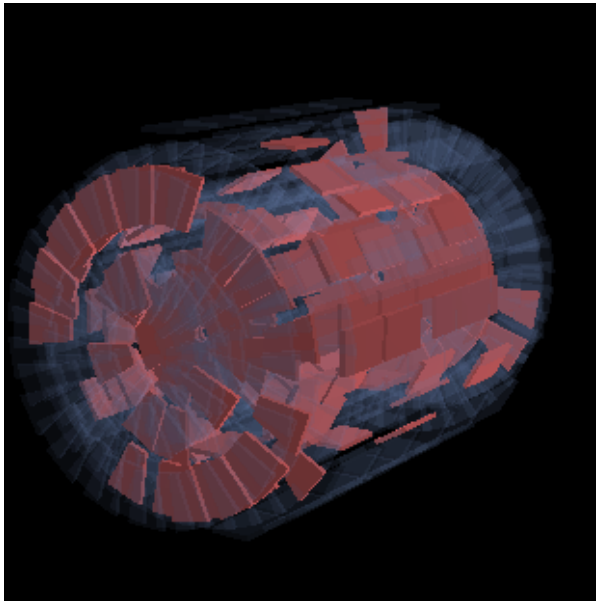

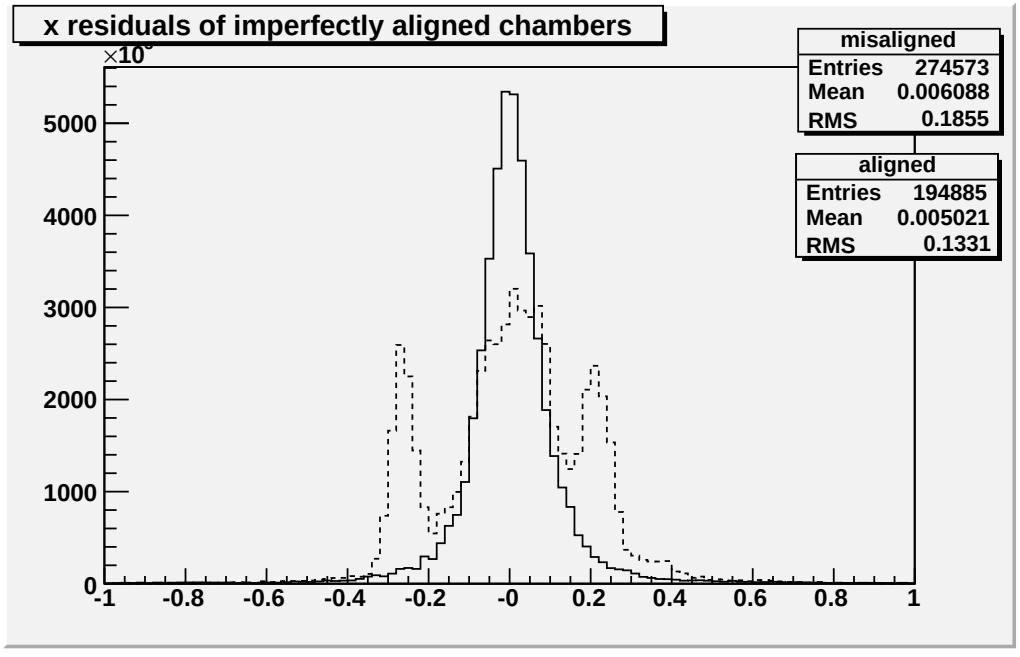

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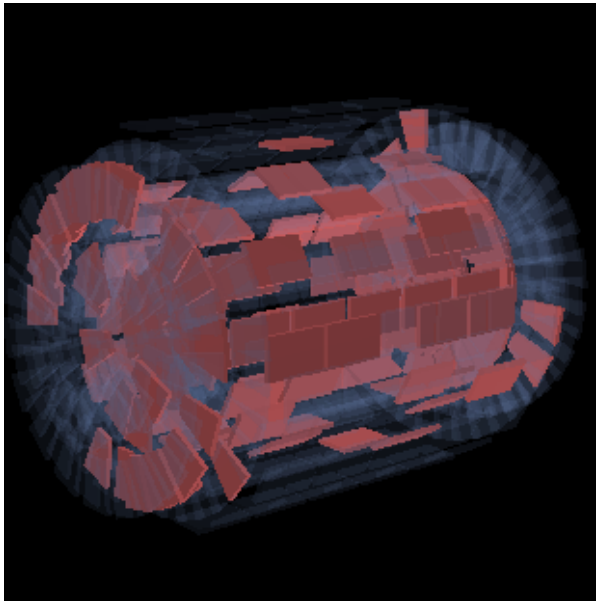

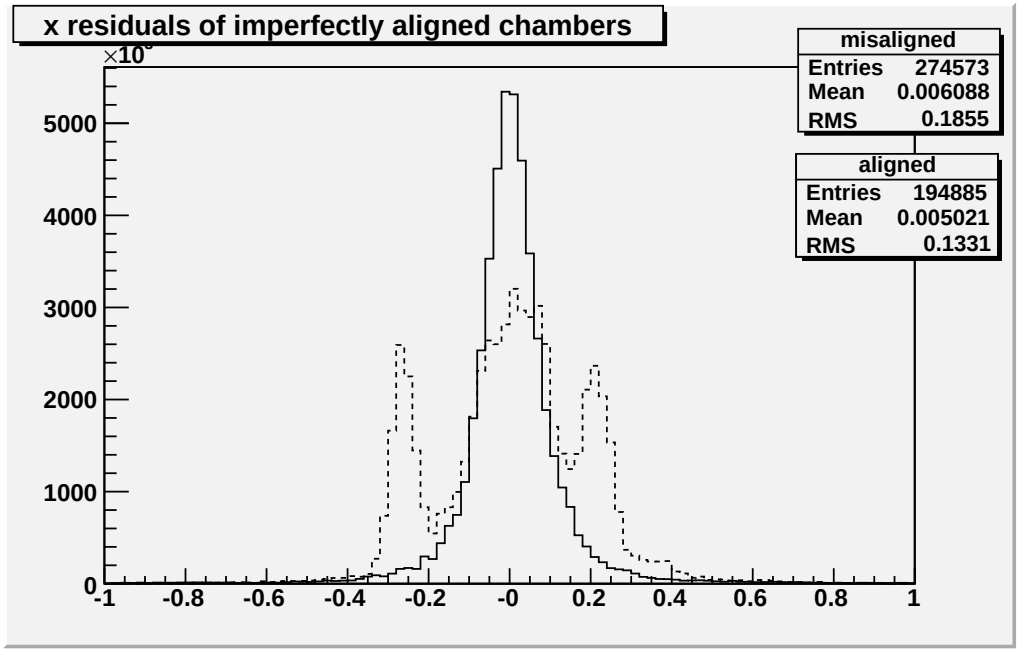

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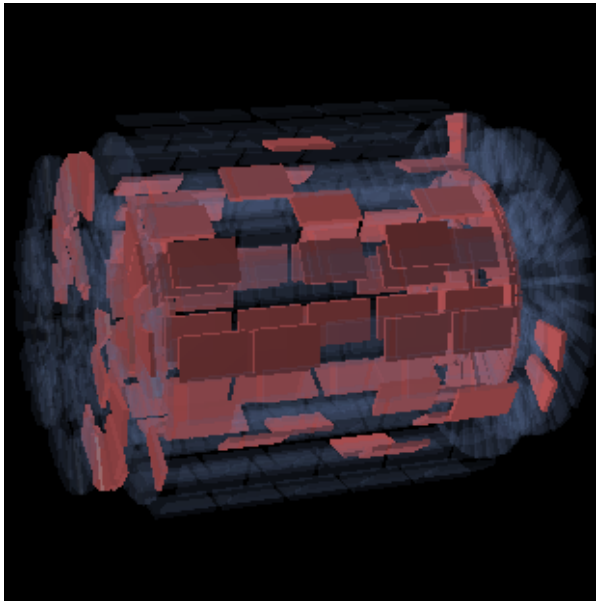

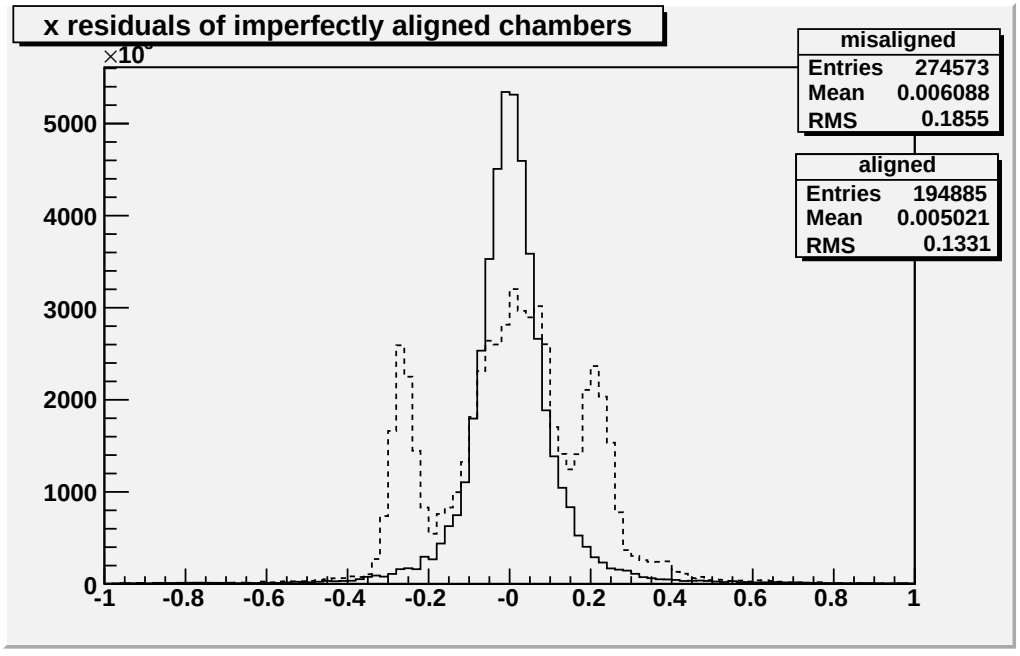

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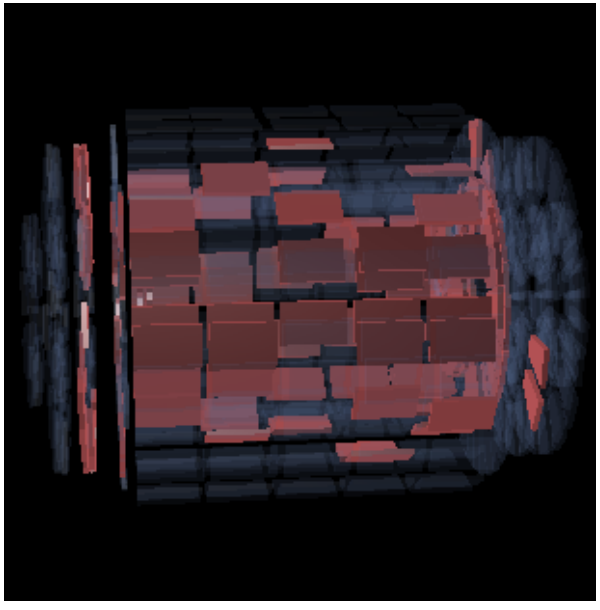
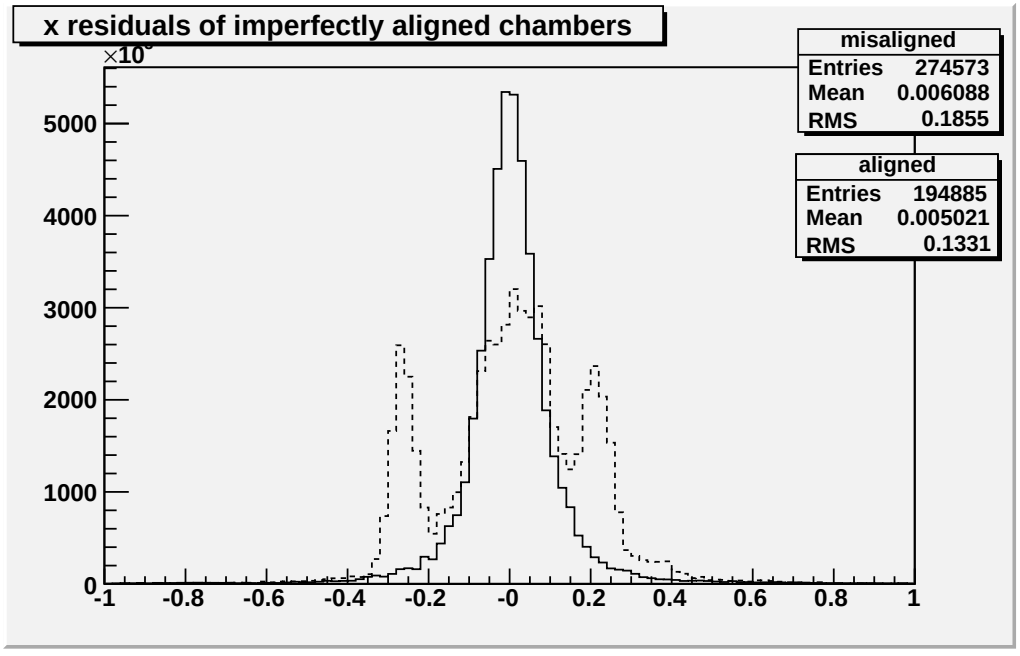
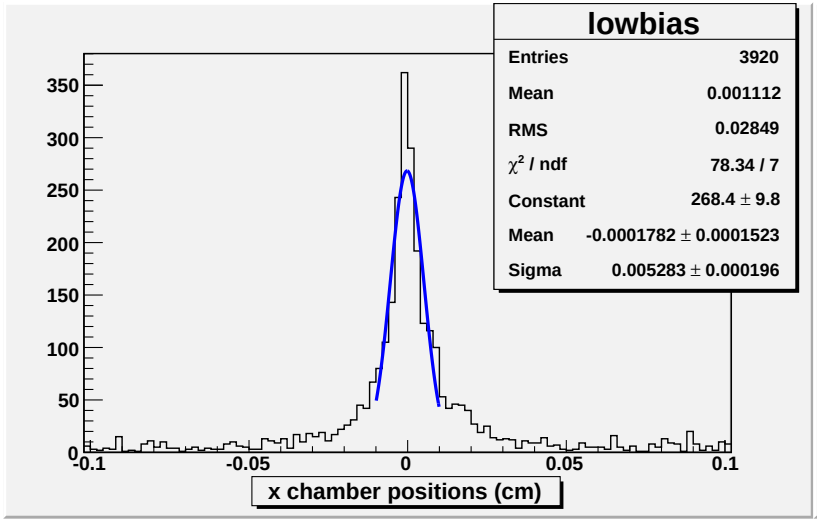
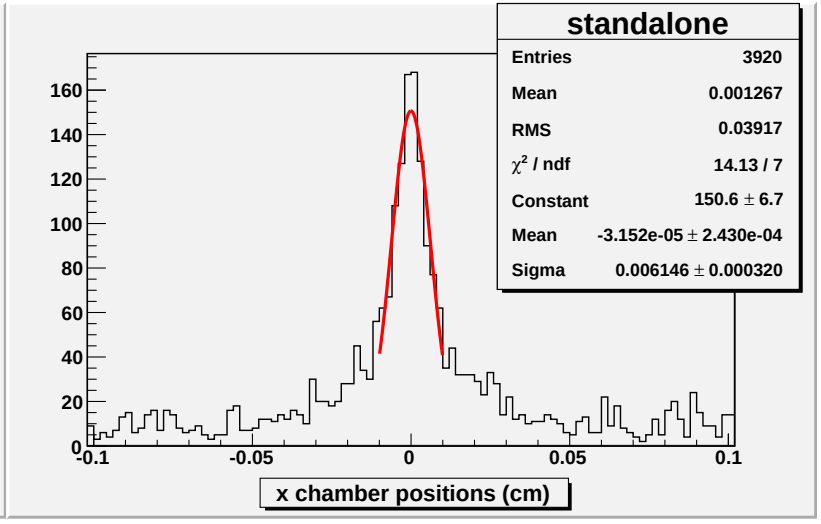




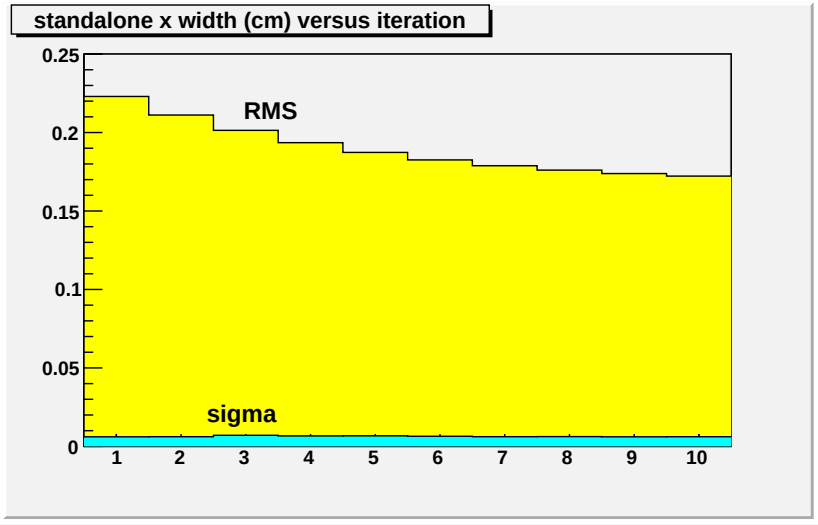
Aligning individual layers

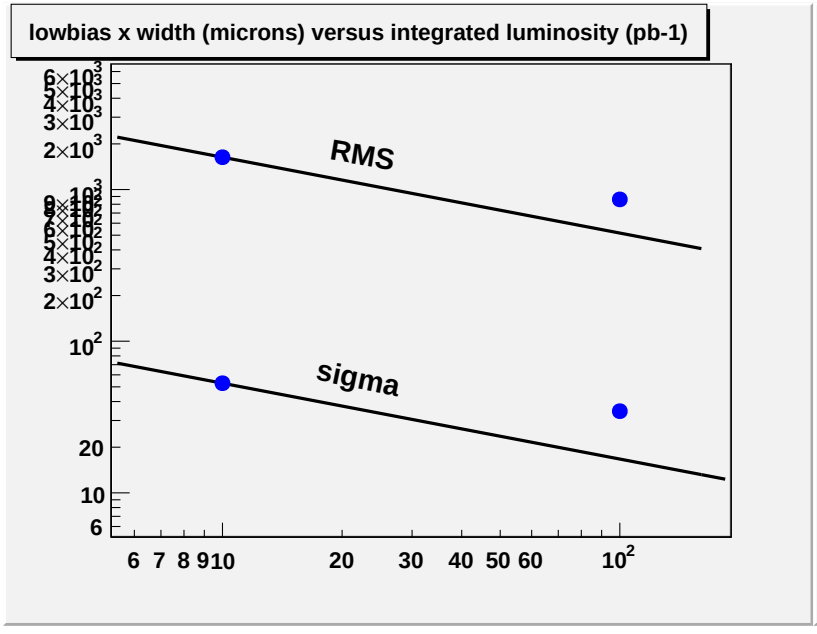
- CSC chambers known to have 100-300 μm offsets (MTCC)
- The near-tails are bigger (this is 100 pb^{-1}, x, y, ϕ_z only)

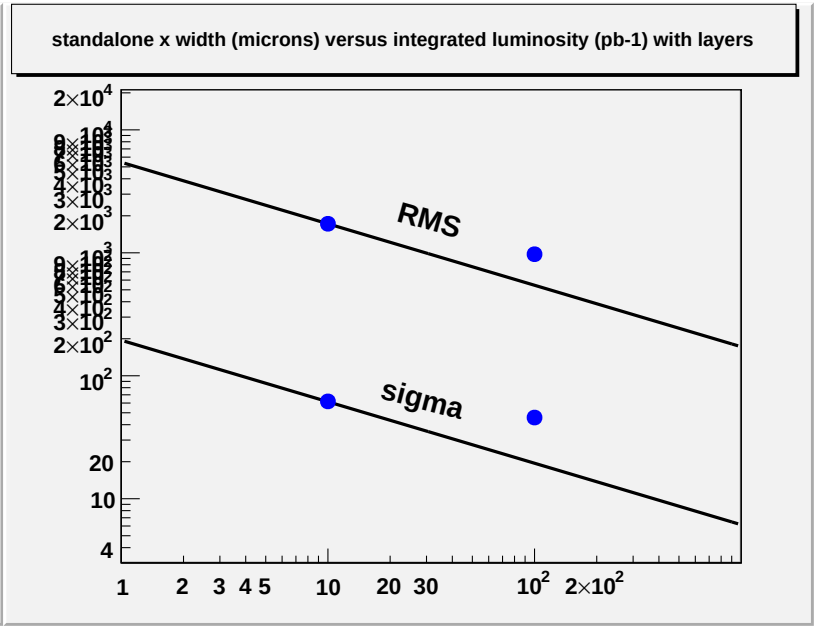




3920 layers	core σ	RMS	|max|
lowbias x	50	1630	6600
lowbias y	360	1830	13000
standalone x	60	1720	6600
standalone y	380	1970	6400
			microns

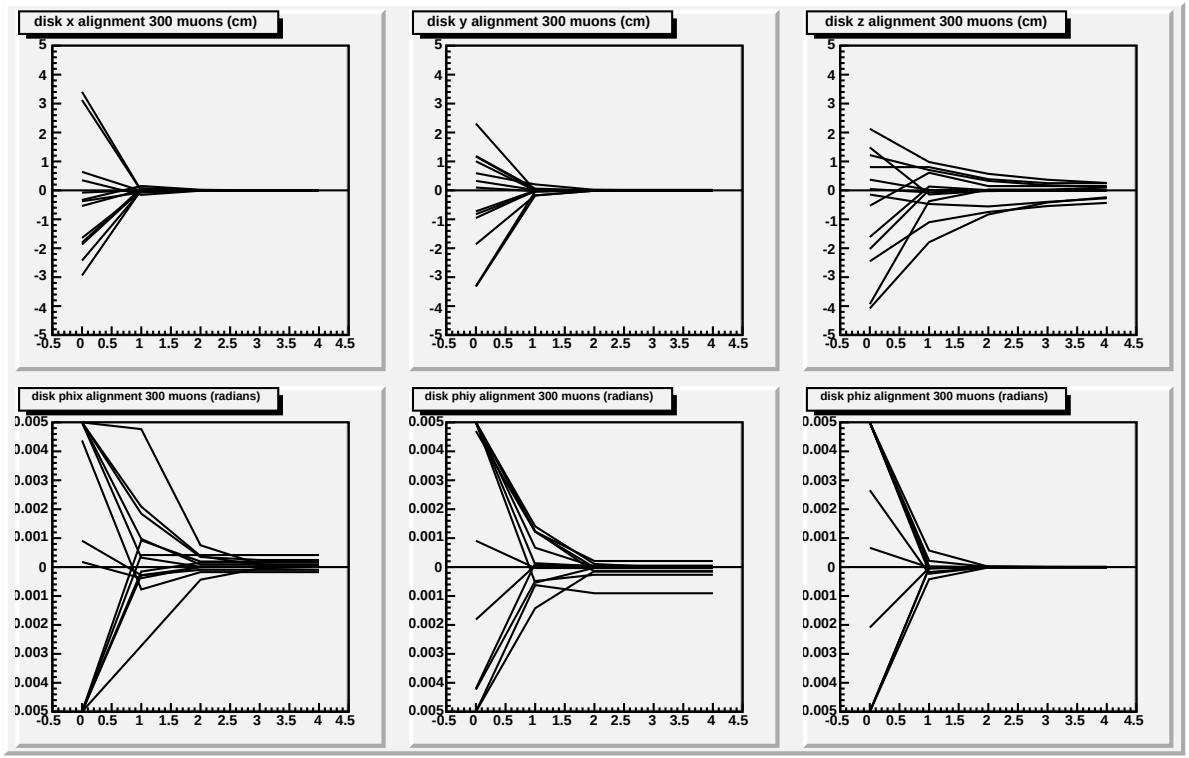

standalone x width (cm) versus iteration
0.25
0.2
0.15
0.1
0.05
0
RMS
sigma
1
2
3
4
5
6
7
8
9
10


lowbias x width (microns) versus integrated luminosity (pb-1)
RMS
sigma
6 7 8 9 10
20
30
40
50
60
10²


standalone x width (microns) versus integrated luminosity (pb-1) with layers
2×10⁴
RMS
sigma
20
10
4
1
2
3
4
5
10
20
30
10²
2×10²

Whole-disk/wheel alignment is also important

- 0.7 cm disk misalignment observed in MTCC phase 2
- How many tracks does HIP need?
- Not many: x,y to 800 μm with 300 tracks



top row: x, y, z (cm), bottom: ϕ_x, ϕ_y, ϕ_z (rad)

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