


Track-based Muon Alignment: Updated Procedures, Tools, and Systematics Studies

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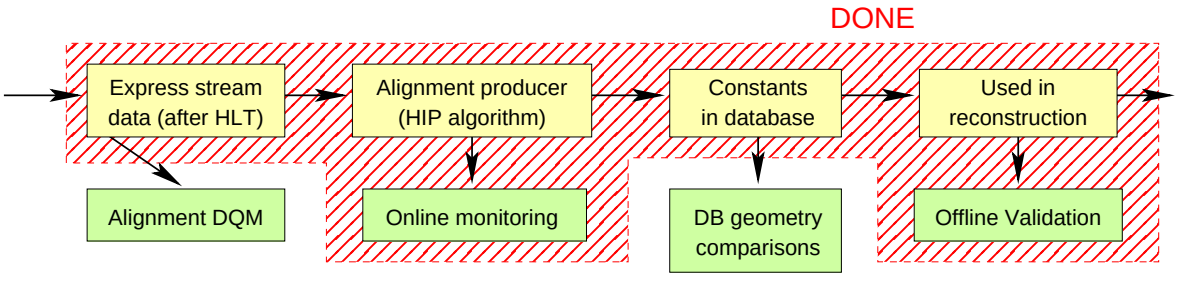
Overview

	Status
Infrastructure for online alignment 	Central path is done; work on DB monitor has resumed
Systematics studies	Some completed
Background studies; finalize cuts	CSA07 exercise
Beam-halo alignment (Karoly Banicz)	Checking feasibility
Cosmic ray and MTCC alignment (Alexey Kamenev)	Near future

What we're focusing on and why

Present

- Monitoring: to catch and fix mistakes quickly
- Systematics studies: quantify complicating effects and make sure they're not show-stoppers
- Beam-halo alignment: potential opportunity to align all CSC layers with tracks before first collisions

What we're focusing on and why

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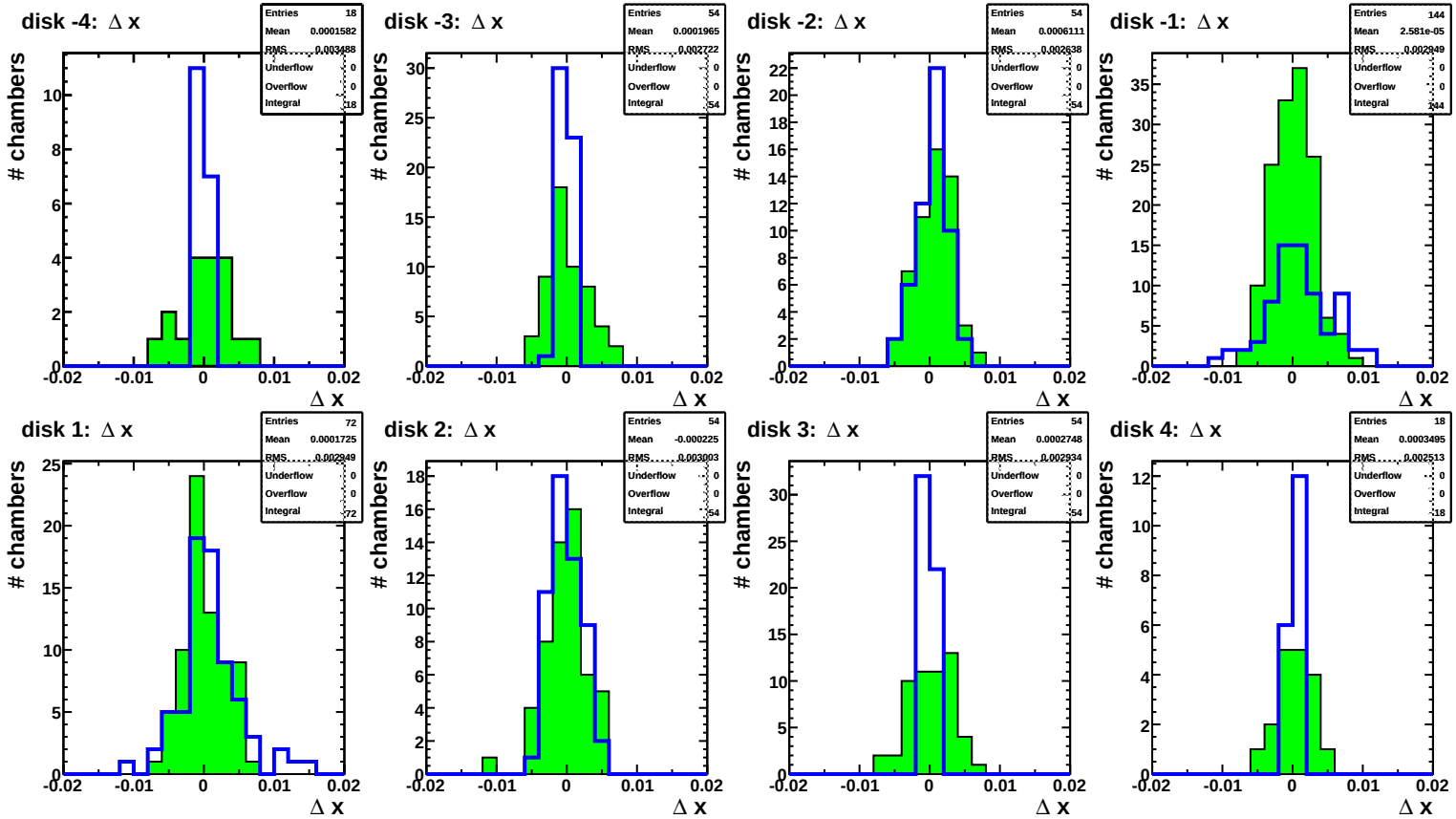
Near future

- Background studies: loosen event selection from $Z \to \mu\mu$ to an inclusive p_T cut. Requires a realistic event sample with all backgrounds, which we can get from CSA07.
- MTCC: real data, includes $\vec{B}(t)$ and an opportunity to connect track-based alignment with photogrammetry and laser system. Data must be re-processed in a 1_5_X+ release.

Monitoring alignment changes in the database

Examples from DB geometry comparison tool (1 of 2)

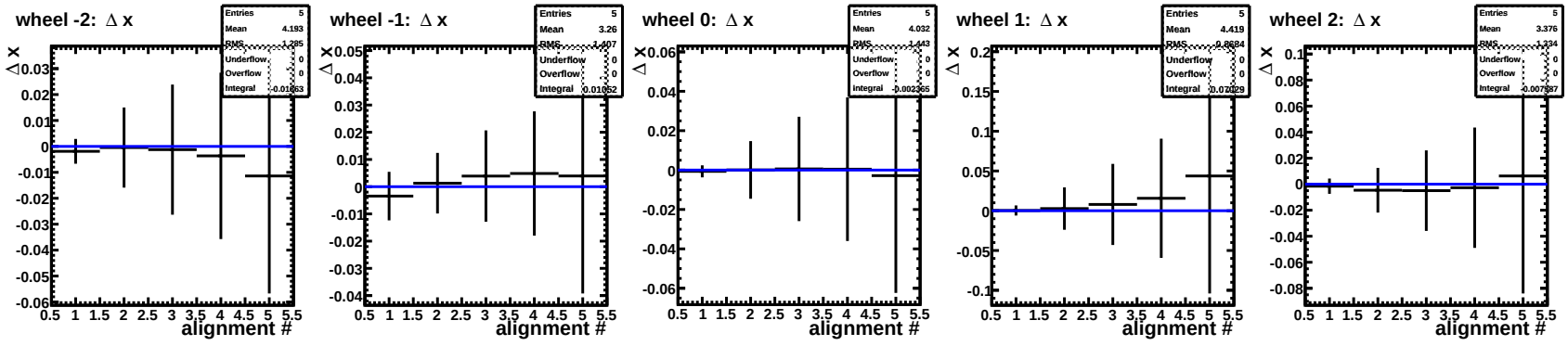
- Comparison of real alignment output (blue line) with a misalignment scenario (filled green)



Aligned − ideal local x in endcap

Examples from DB geometry comparison tool (2 of 2)

- Time series of increasing misalignment
- (Response to misalignment of tracker: we'll see more later)



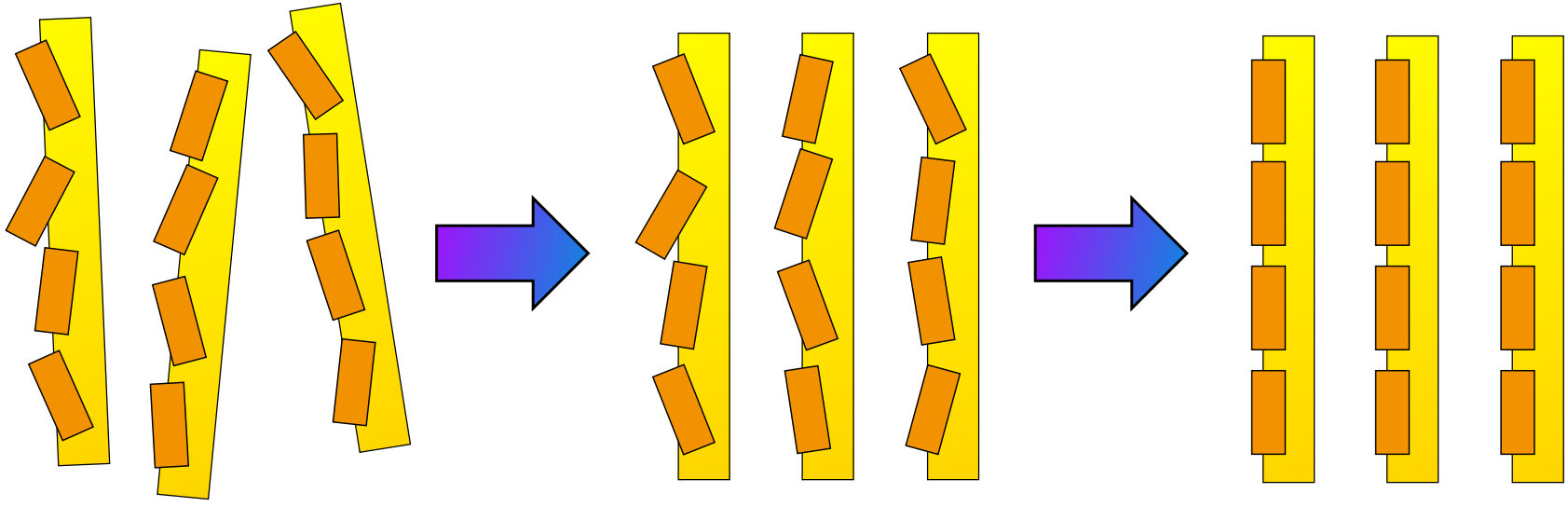
RMS of aligned − ideal global z in barrel

New student: Vadim Khotilovich

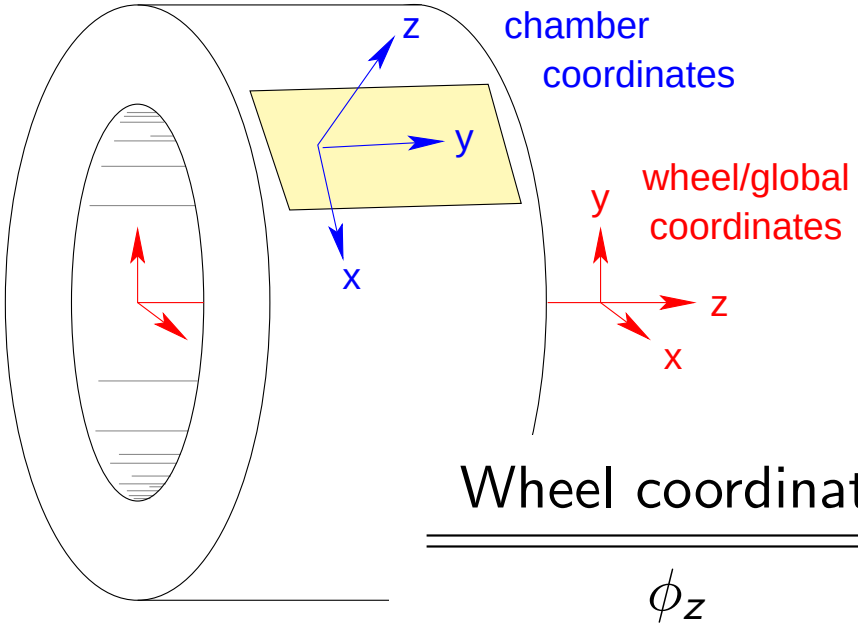
Optimized alignment procedure

Hierarchical 2–3 step process

1. Determine wheel/disk positions to 0.7 mm accuracy with a few hundred muons
2. Determine chamber positions to 100 μm with 10 pb^{-1}
3. Determine CSC layer positions, if necessary



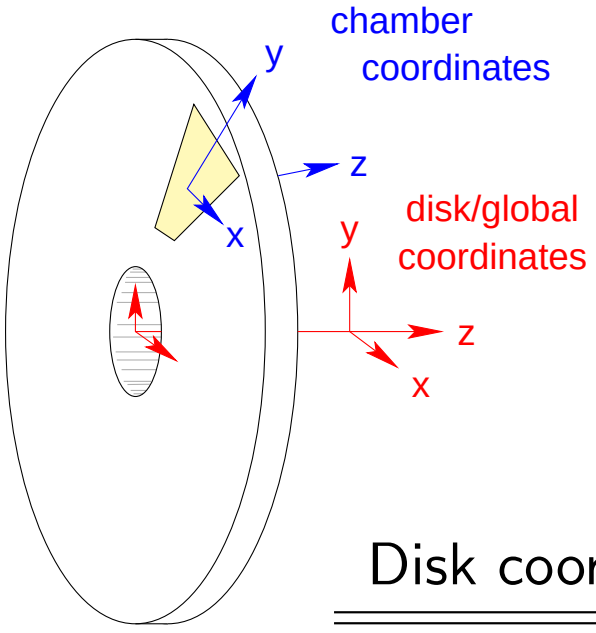
Degrees of freedom: barrel wheels



All 6 float in alignment

Wheel coordinate	Chamber residual
ϕ_z	x residual
x, y	linear combination of x and y
z	y residual
ϕ_y	left−right y differences
ϕ_y	top−bottom y differences

Degrees of freedom: endcap disks

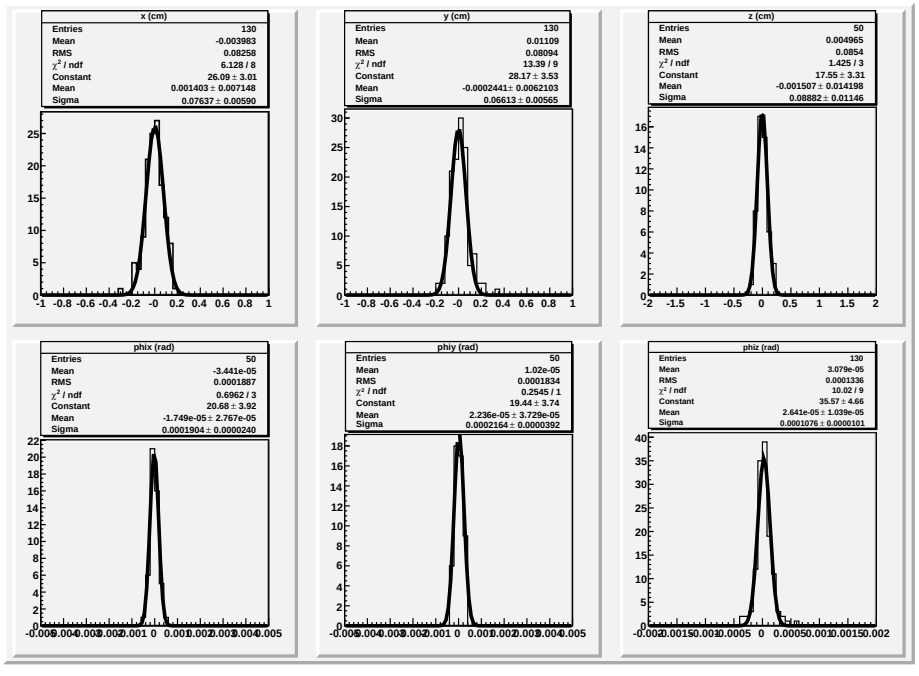


Only x, y, and ϕ_z float

Disk coordinate	Chamber residual
ϕ_z	x residual
x, y	linear combination of x and y
z	y residual differences... (weakly constrained)

Wheel/disk alignment results × 10 trials

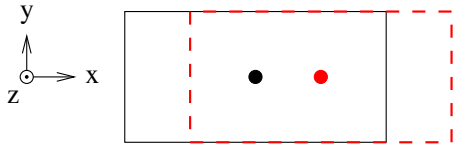
x, y positions	0.71 mm
z positions (barrel only)	0.89 mm
ϕ_x, ϕ_y angles (barrel only)	0.20 mrad
ϕ_z angle	0.11 mrad



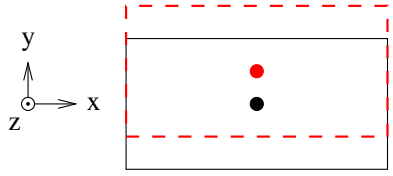
6 d.o.f. float in barrel
only x, y, ϕ_z in endcap

Independent of the number of muons ("brick wall" is ∼20 tracks)

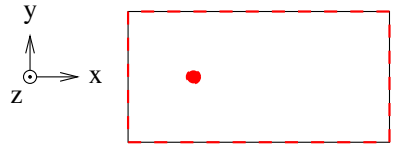
Chamber-by-chamber alignment



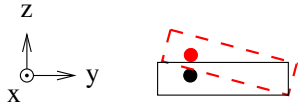
x: offset in r_x



y: offset in r_y

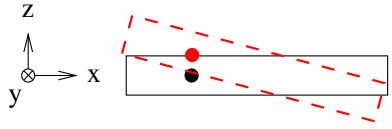


z: via angled tracks



ϕ_x: r_y linear in y

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



ϕ_y: r_x linear in x

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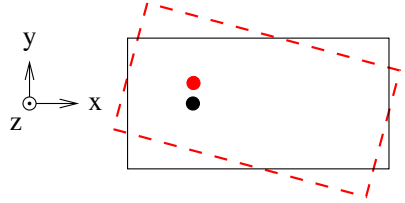
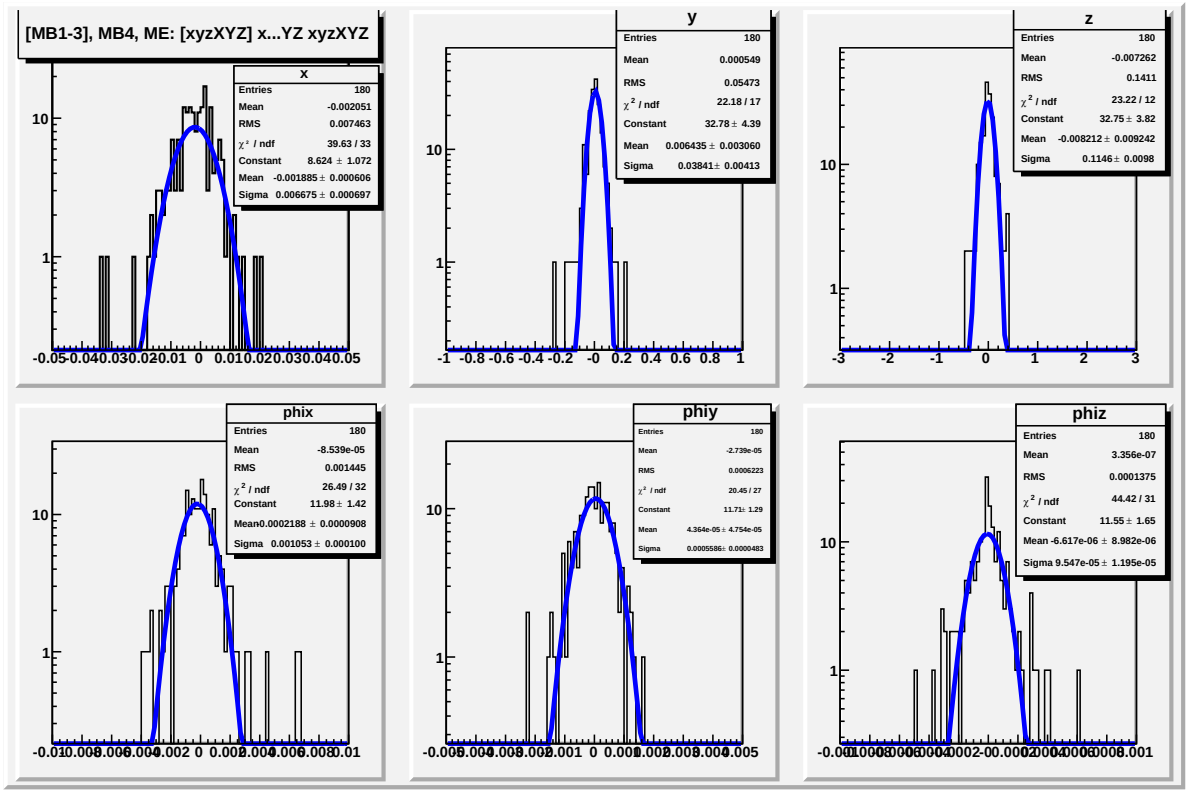


ϕ_z: r_x linear in y

(slope $\propto \sin\phi_z$)

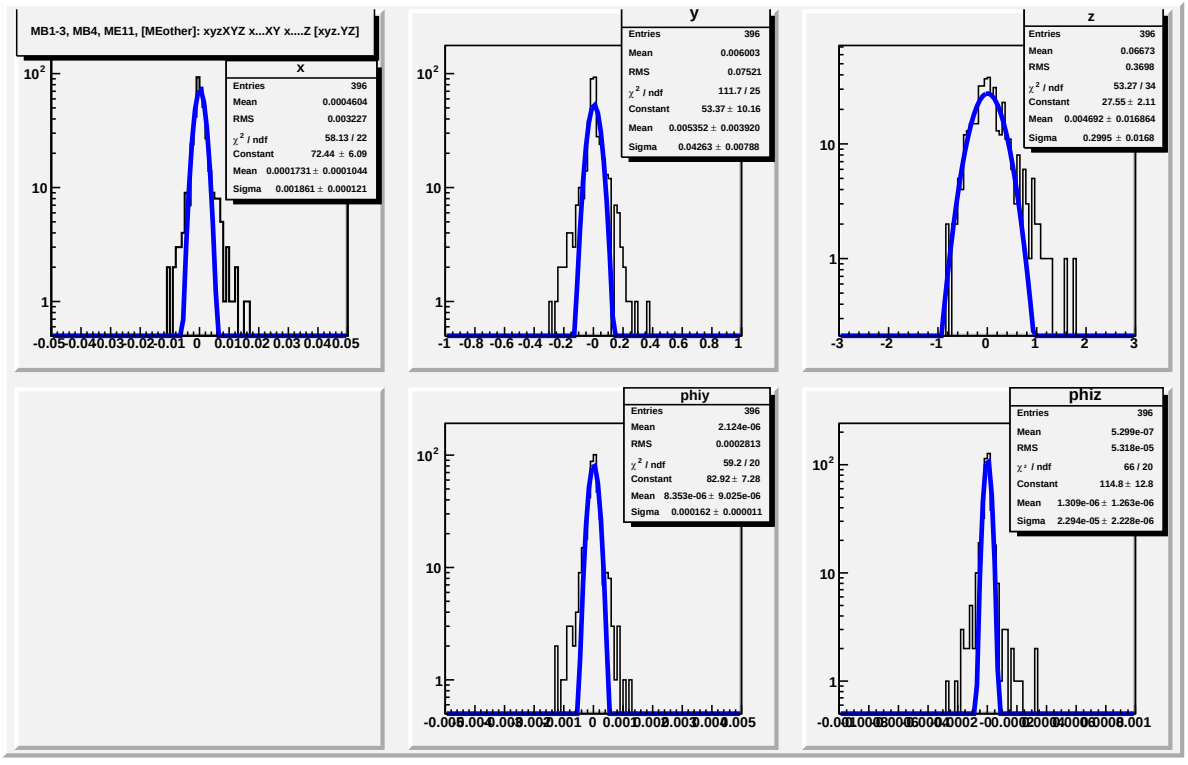
- Barrel stations 1–3: all 6 parameters float
- Barrel station 4 has no y measurement: x, ϕ_y, and ϕ_z only
- ME 1/1: could not find an optimal set— possible software bug
- Other endcap: all but ϕ_x

Barrel chamber results (MB4 not shown)



MB 1–3				MB 4			
x	67 μm	1.05 mrad	ϕ_x	x	28 μm		
y	384 μm	0.56 mrad	ϕ_y			0.57 mrad	ϕ_y
z	1.15 mm	0.095 mrad	ϕ_z			0.004 mrad	ϕ_z

Endcap chamber results (ME1/1 not shown)



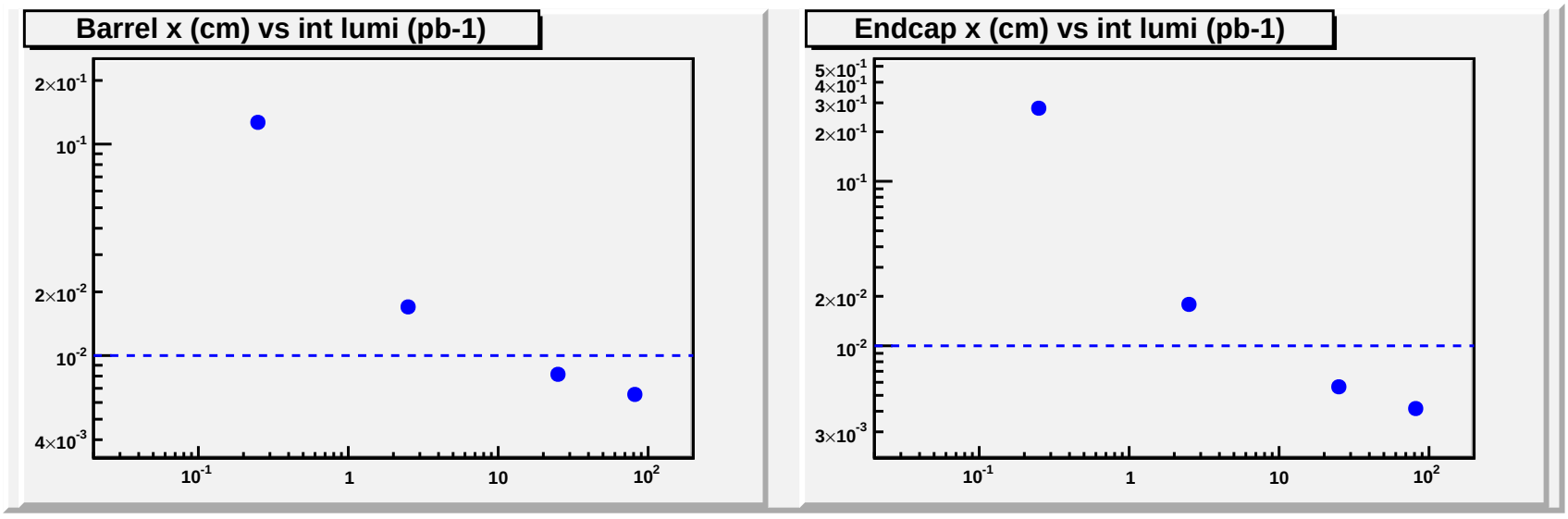
All but ME1/1

x	19 μm		
y	430 μm	0.16 mrad	ϕ_y
z	3.0 mm	0.03 mrad	ϕ_z

ME 1/1: possible software bug

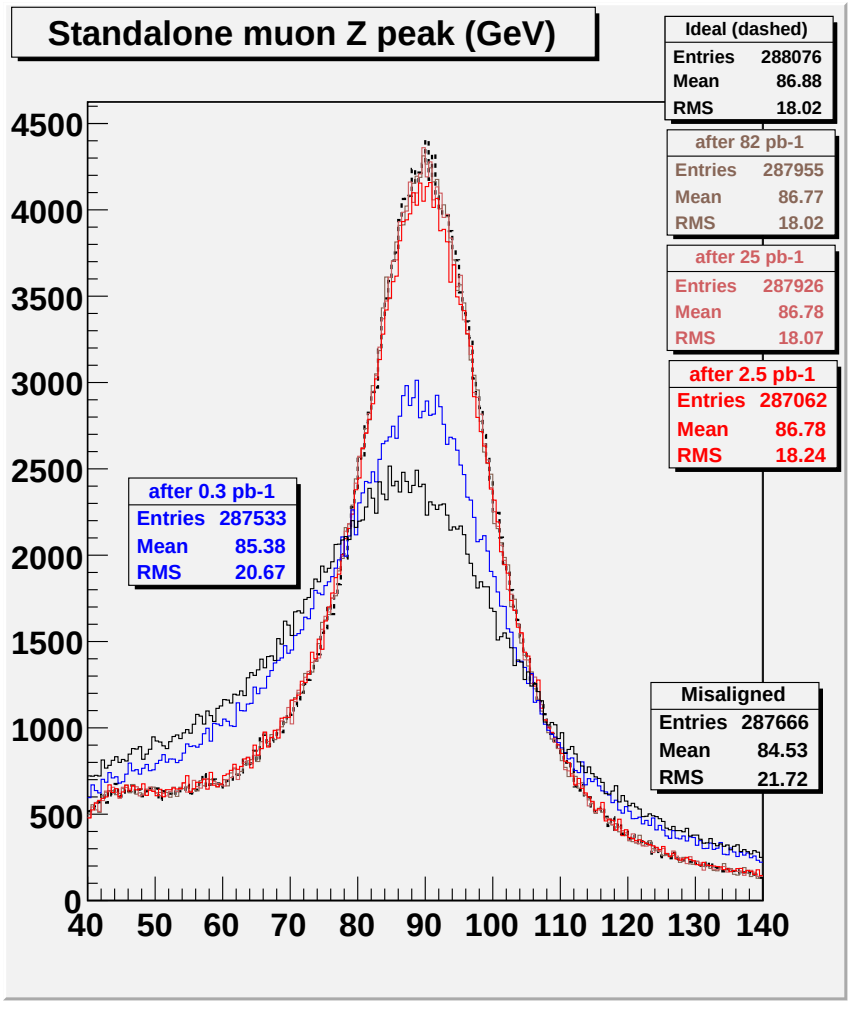
x	300 μm
y	2–6 mm asymmetry
angles	1 mrad or more

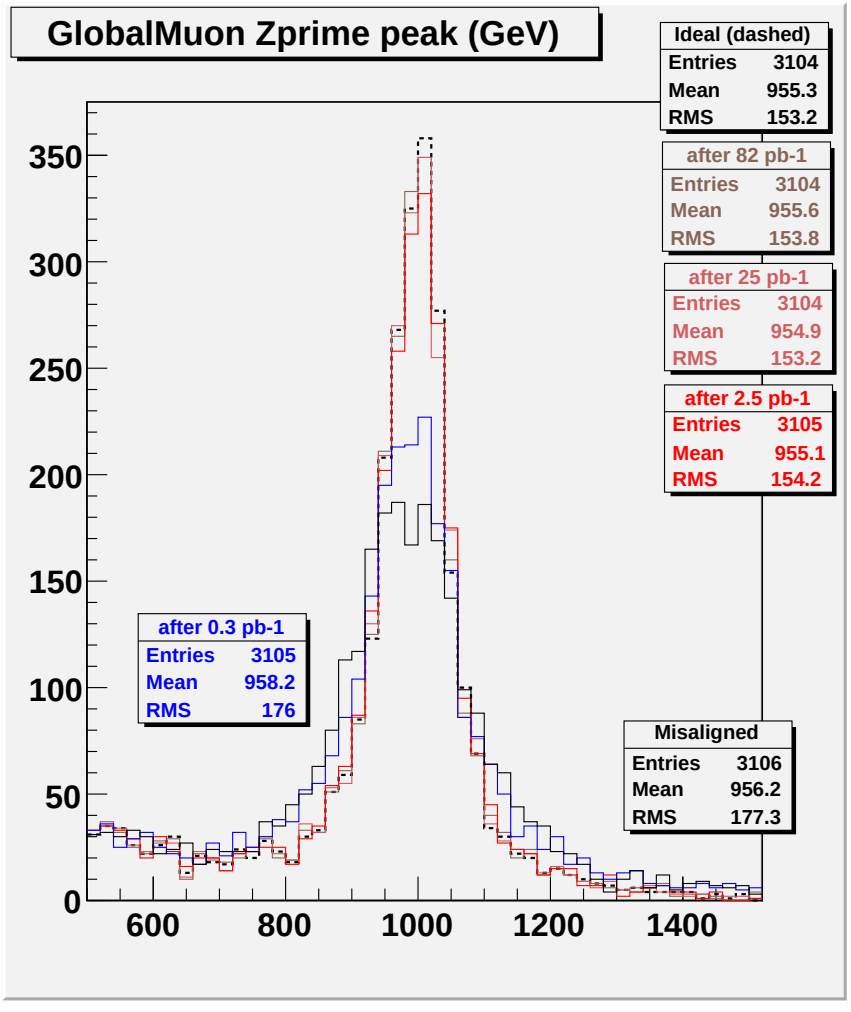
Dependence on integrated luminosity: accuracy



- Points: RMS of distribution, Line: 100 μm
- x accuracy reaches 100 μm with 10 pb^{-1}

Dependence on integrated luminosity: Z, Z' resolution



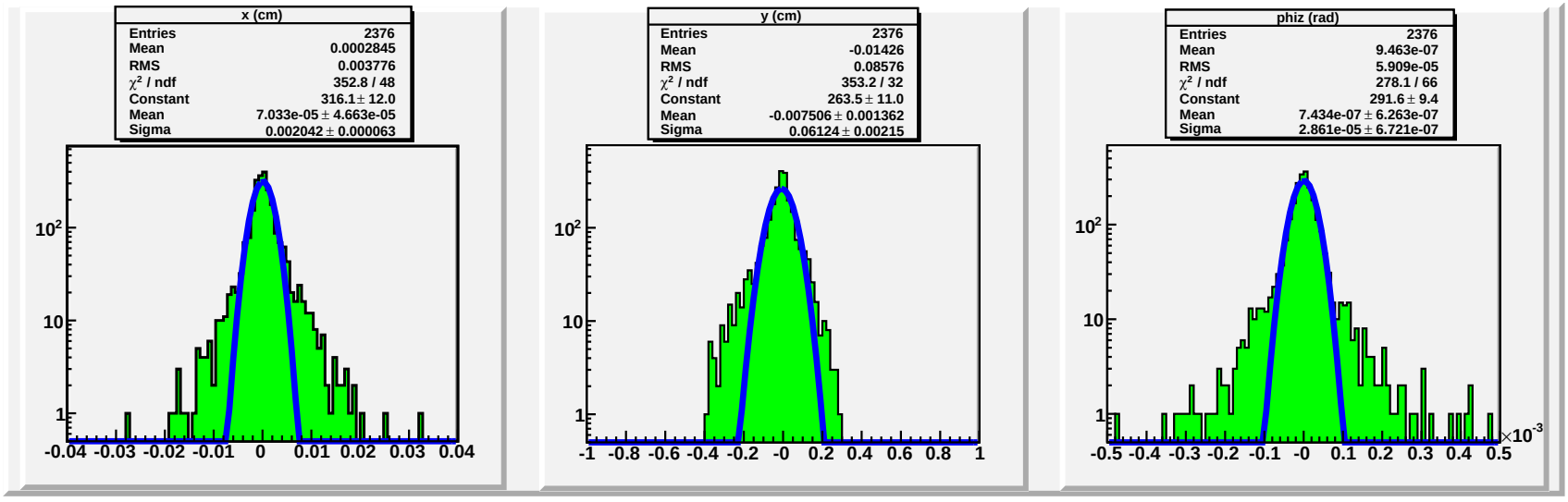


- To do: higher moments of distribution— Drell-Yan smearing

CSC layer-by-layer alignment

- CSC layers known to be misaligned (Karoly, Andrey, Oleg. . .)

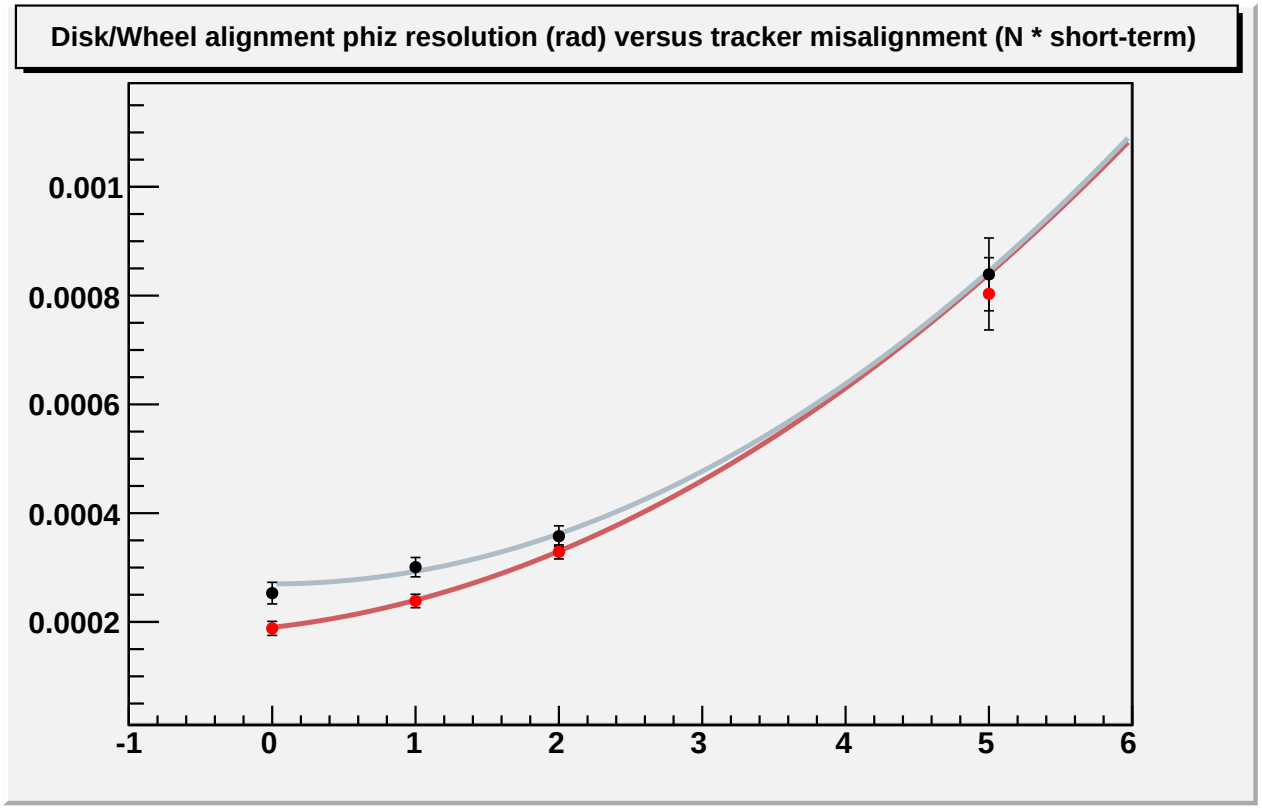
	current (RMS)	after 82 pb^{-1} alignment (RMS)
x	190 μm	38 μm
y	340 μm	860 μm
ϕ_z	0.04 mrad	0.06 mrad



Systematics studies

Effect of tracker misalignment (1 of 3)

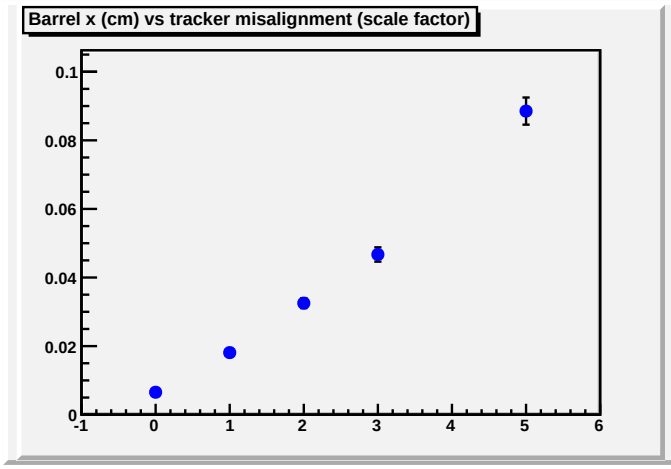
- Wheel/disk procedure: becomes significant when tracker is misaligned 2–3 times worse than "short-term scenario"

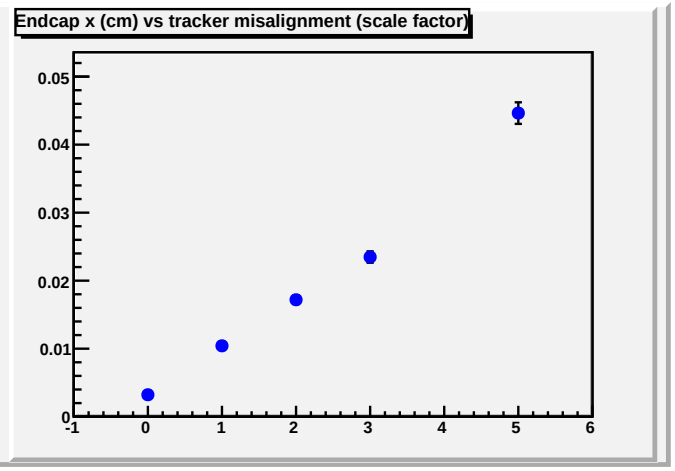


- Black: wheels/disks include large chamber misalignments
  Red: chambers are perfectly aligned on wheels/disks

Effect of tracker misalignment (2 of 3)

- Most sensitive parameters: x and ϕ_z
- Accuracy versus $N \times$ tracker "short-term" scenario (ST)



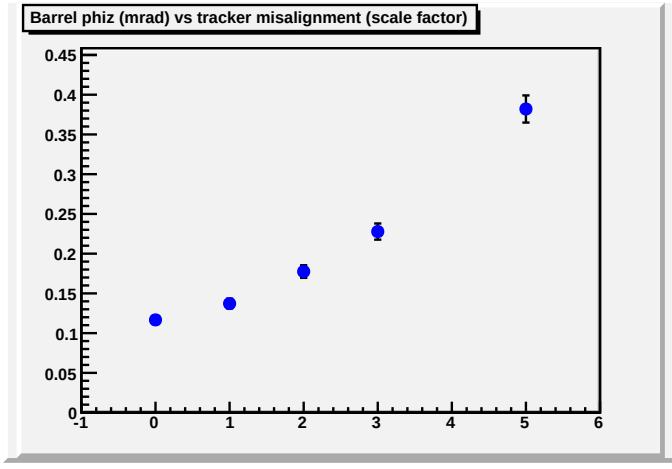


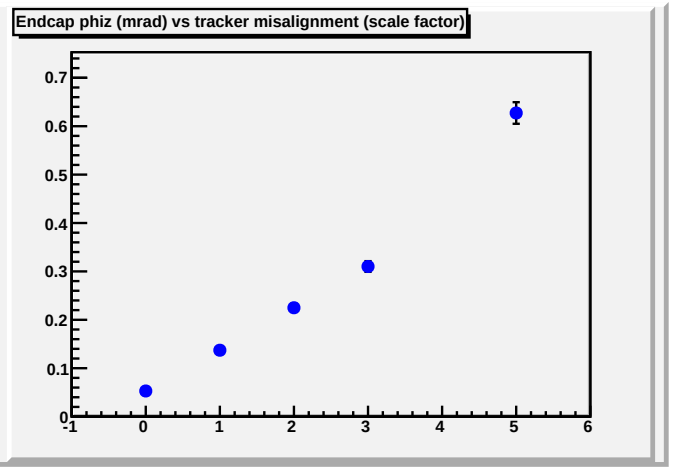
Barrel x:
200 μm/ST

Endcap x:
100 μm/ST

Barrel ϕ_z:
0.5 mrad/ST

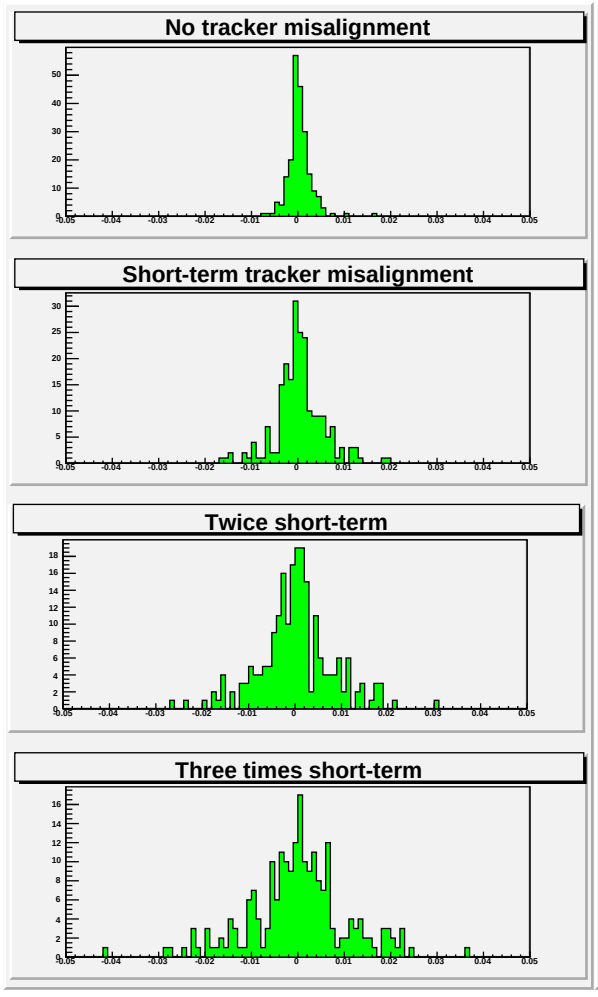
Endcap ϕ_z:
1 mrad/ST



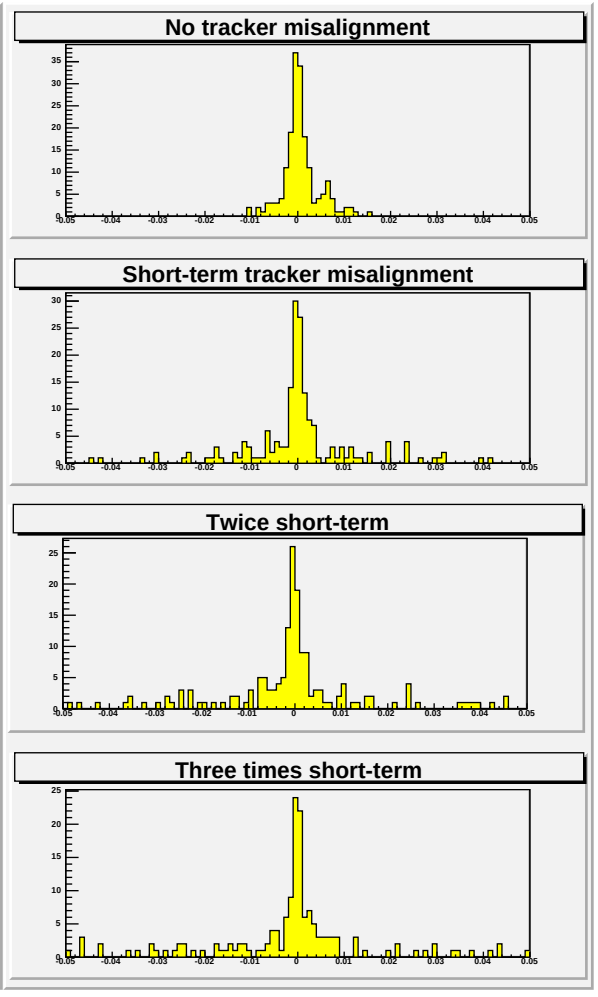


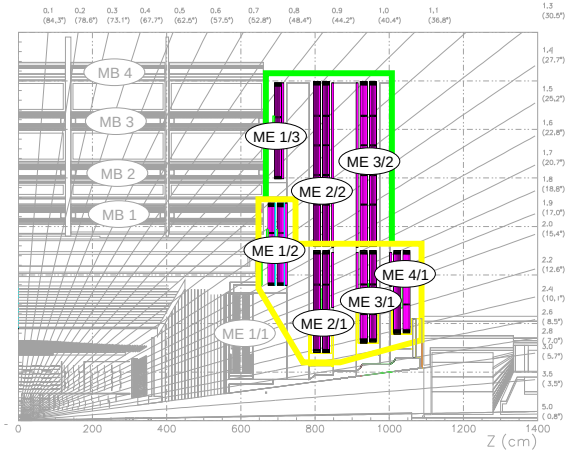
Effect of tracker misalignment (3 of 3)

Outer endcap



Inner endcap



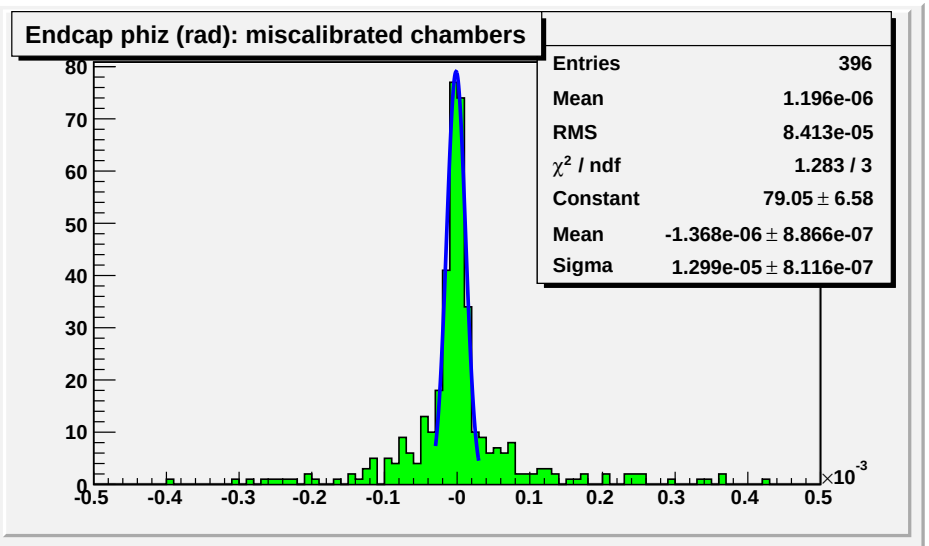


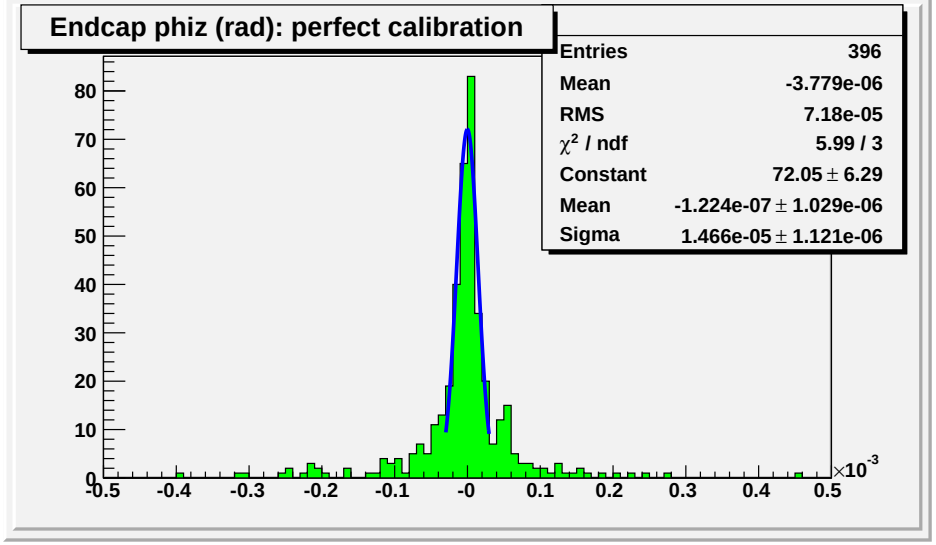
Outer endcap (1/3, 2/2, 3/2) only widens

But inner endcap (1/2, N/1) gets more outliers

May need to apply standalone procedure to these, if tracker is bad

Effect of miscalibration





- 10 pb^{-1} miscalibration scenario
- Small influence on tails

Barrel (Δ RMS)

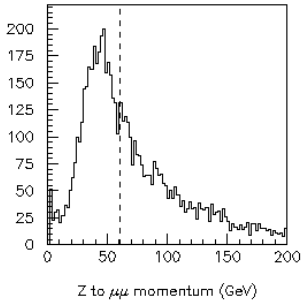
x	6%	0%	ϕ_x
y	1%	3%	ϕ_y
z	0%	10%	ϕ_z

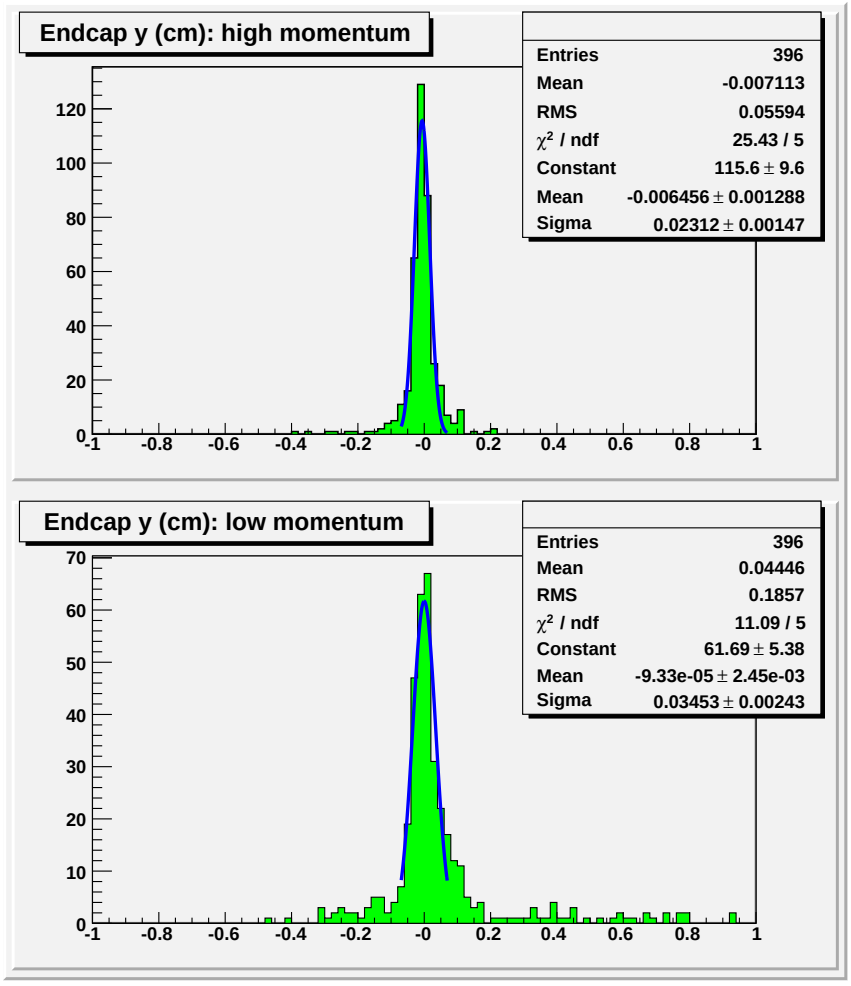
Endcap (Δ RMS)

x	15%		
y	9%	3%	ϕ_y
z	2%	17%	ϕ_z

Dependence on muon momentum

- Divide $Z \rightarrow \mu\mu$ sample along 60 GeV median



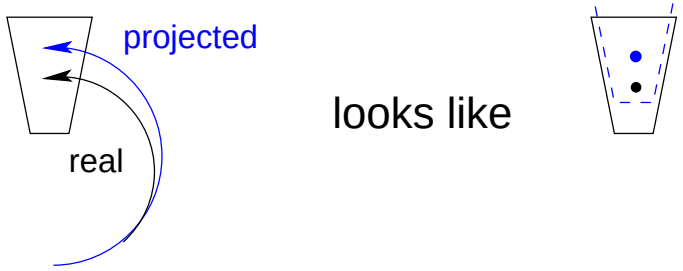


Δ Resolution

Barrel: $< 5\%$ in each parameter

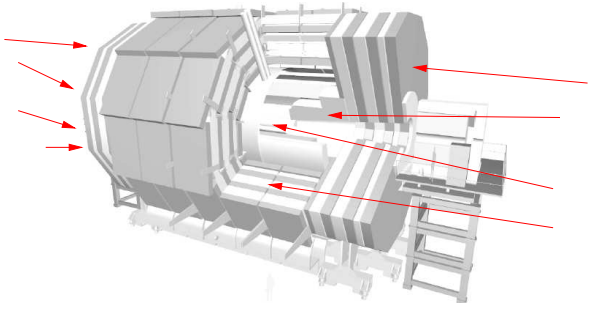
		core	RMS
Endcap:	x	$\times 1.5$	$\times 3$
	y	$\times 1.5$	$\times 3$
	z	$\times 3$	$\times 3$
	ϕ_y	$\times 1.6$	$\times 3.5$
	ϕ_z	$\times 1.2$	$\times 2$

Note asymmetric tail in y!



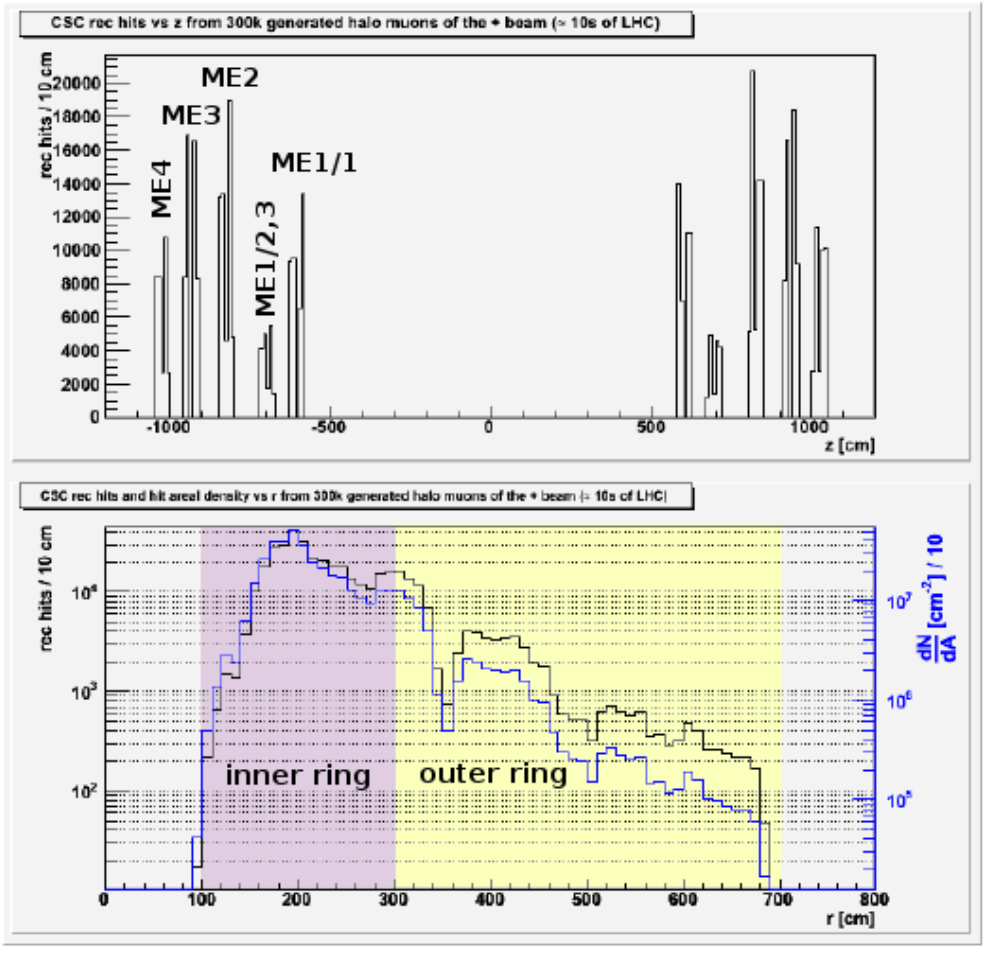
Beam-halo studies (Karoly)

Alignment plans with beam-halo



- Before first collisions
  - Accumulate beam-halo muons from accelerator studies with constant conditions (constant $\vec{B}(t)$, detector positions)
  - Align CSC layers; remains valid even after chambers/disks move
  - Will the rate be high enough? To be determined...
- With collisions
  - Combine muons from the vertex with beam-halo muons: requires a new trigger (under discussion)
  - Alignment will be improved by more orthogonal tracks

Beam-halo illumination

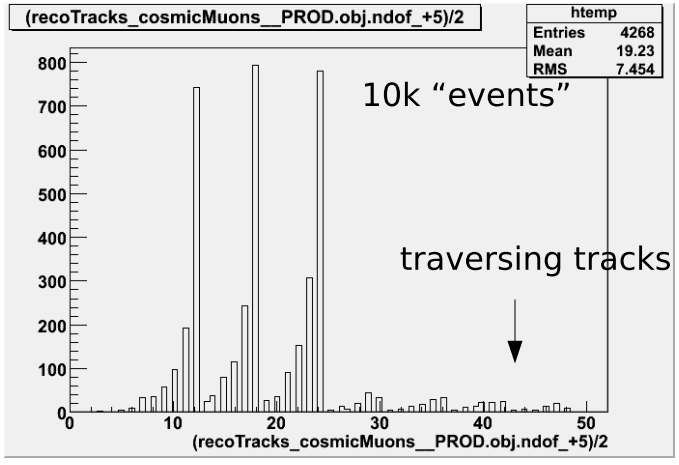


Top: z (cm) Bottom: r (cm)

All four stations covered

Chambers in outer rings will get uneven statistics

A few tracks connect both sides



Number of hits


Conclusions

- Basic infrastructure is in place for CSA07 and beyond; we are developing monitors
- Continuing to improve the baseline procedure
- Problem with ME1/1, possible software bug
- Learning quantitative relevance of systematic effects, some of which are responsible for outliers
  - Tracker misalignment — important if worse than "short-term"
  - Chamber miscalibration — only small effects
  - Muon momentum — degradation in endcap with 20–60 GeV
- Karoly is making great progress with beam-halo alignment feasibility studies
- MTCC/alignment with cosmic rays is a high priority