



# Global Muon Alignment

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- ▶ Improvements to the algorithm since CRAFT-09
- ▶ Alignment with CRAFT-10 (cosmic rays from February onward)
  - ▶ comparison of CRAFT-09 with CRAFT-10
  - ▶ comparison of hardware and track-based in CRAFT-10
- ▶ Residuals quality of CRAFT-10 alignment
- ▶ Alignment strategy



- ▶ Algorithmic
  - ▶ shape of residuals distribution
  - ▶ align only 4 most sensitive parameters:  $x$ ,  $y$ ,  $\phi_y$ ,  $\phi_z$
  - ▶ truncate  $\Delta \frac{dy}{dz}$  residuals to control shape
  - ▶ “motion policy” for selecting which chamber alignments to publish to the database
- ▶ Many framework updates (more diagnostic output, automation, etc.)



- ▶ Algorithmic
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## Shape of residuals distribution

- ▶ Motivation: with old residuals shape (Voigt distribution), MINUIT fails for some low-statistics chambers
  - ▶ in CRAFT-09, this affected 61 chambers, mostly in sectors 1&7, wheels  $\pm 2$
  - ▶ becomes a serious issue in early collisions alignments, where whole detector is low-statistics
  - ▶ in low-statistics cases, we want a result with appropriate error bars, not a MINUIT failure

# Shape of residuals distribution

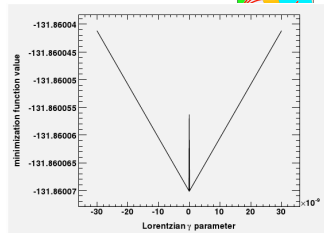
Jim Pivarski 5/19



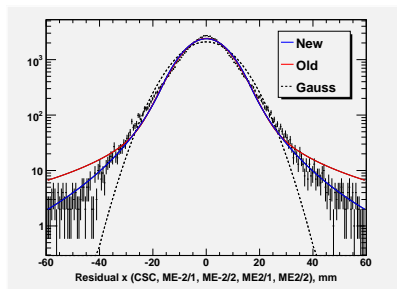
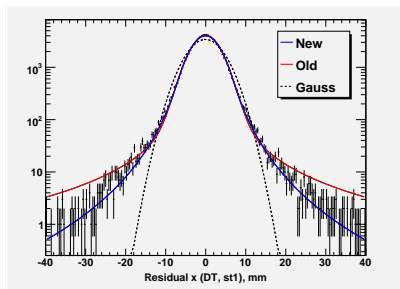
- ▶ Old function failed because  $\mathcal{L}(\gamma)$  doesn't have a parabolic minimum in low-statistics (when  $\gamma \ll \sigma$ )

- ▶ New function:

$$f(x) = \begin{cases} \exp\left(-\frac{x^2}{2\sigma^2}\right) & \text{if } |x| \leq m \\ 1/x^4 & \text{if } |x| > m \end{cases}$$

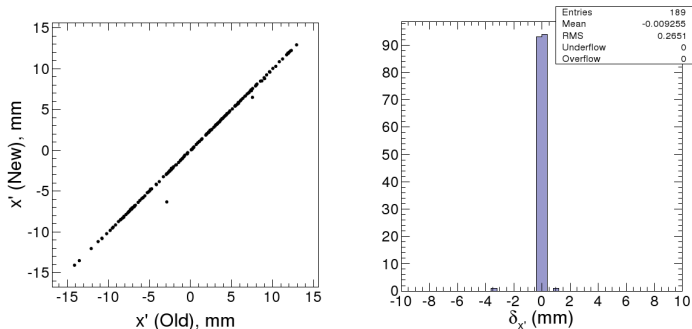


- ▶ Requiring normalization, continuity, and differentiability sets  $m = 2\sigma$
- ▶  $1/x^4$  motivated by Rutherford scattering formula





- ▶ Verify that new algorithm produces the same alignment results as old algorithm for CRAFT-09:



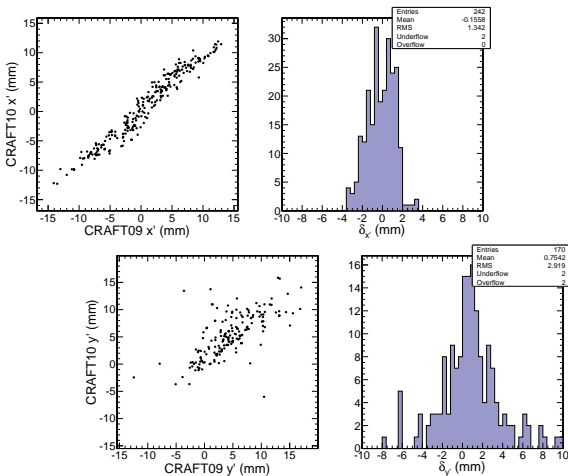
- ▶ RMS of  $250 \mu\text{m}$  differences dominated by two chambers
  - ▶ they are low-statistics and did not reach a fixed point in old alignment (values still changing after 5 iterations)
- ▶ 189 chambers aligned in old algorithm, compared above
- ▶ all 250 chambers aligned in new algorithm

# Comparison of 2009 with 2010

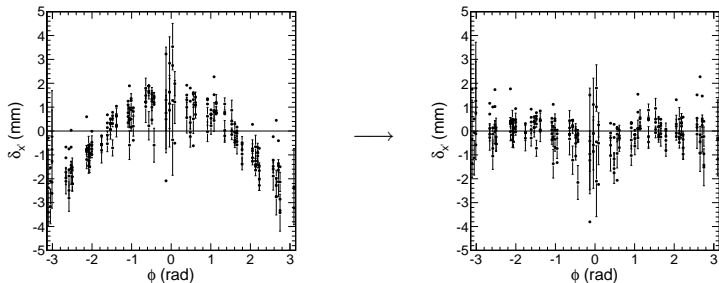
Jim Pivarski 7/19



- ▶ Did chambers physically move during the winter shut-down?
- ▶ Plot CRAFT-09, CRAFT-10 differences



- Is there a pattern in these differences? Yes!

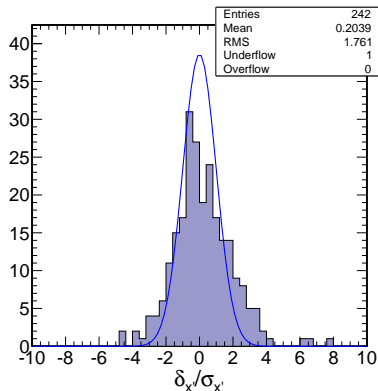
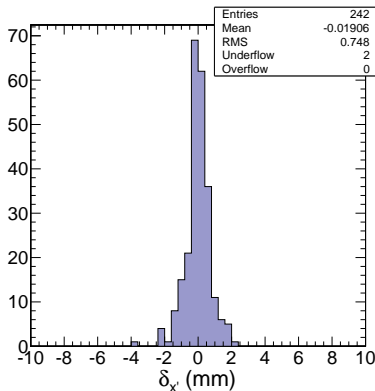


- Most of the variation is in a  $\sin \phi + \cos \phi + \text{const}$  trend (mostly  $\cos$ )
- These bulk trends only reflect changes in global position (possibly a GlobalPositionRcd issue)
- Subtract out this trend so that we can analyze only internal alignment of the muon system



# Comparison of 2009 with 2010

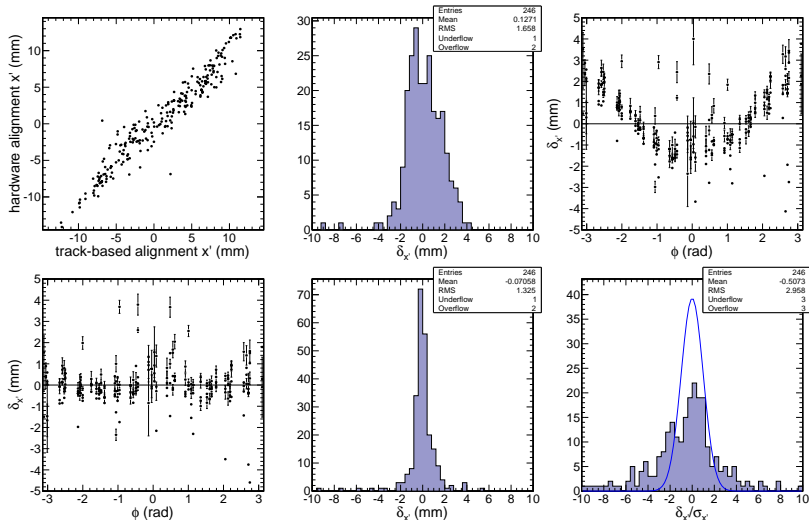
Jim Pivarski 9/19

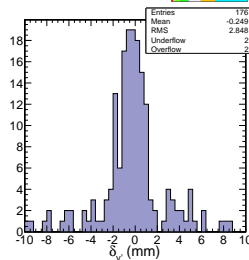
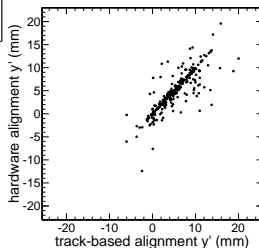
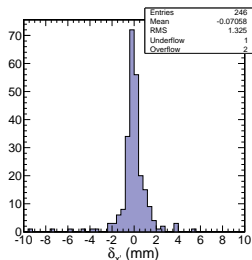


- Random variations around the  $\cos \phi$  curve are 0.75 mm wide and almost pure statistics



- How do hardware and track-based alignments compare in 2010?  
Use same method of comparison (also dominated by  $\cos \phi$ )





- ▶ Track-based and hardware alignments *agree* for most chambers: central core width of about 1 mm or less in  $x$ , 2 mm in  $y$
- ▶ Different global positions, we should check GlobalPositionRcd (which will be updated next week)
- ▶ Outliers listed below ( $|x'| > 2$  mm): they might be the chambers that were not accessible to the hardware alignment

(wheel, station, sector): (-2, 1, 2) (-2, 1, 7) (-2, 1, 11) (-2, 1, 12) (-2, 2, 2) (-2, 2, 3) (-2, 2, 7) (-2, 3, 1) (-2, 3, 7)  
 (0, 1, 12) (2, 1, 1) (2, 1, 3) (2, 1, 6) (2, 2, 1) (2, 2, 5) (2, 3, 6) (-1, 4, 11) (2, 4, 6) (2, 4, 9)



A snapshot of the alignment quality browser for this alignment:

Runs

Run	Analyzed on
GaussPowerTailsWholeSample	10-03-15 04:32:02
mmal_test_Monitor	11-39 2010-02-25
NOV4DT_PASS3noweight_TkHIP	09-13 2010-02-03
p105	20-22 2010-03-01
p110	13-36 2010-03-02
p120	14-18 2010-03-02
craft10-not-final_20100412231618	10-04-12 23:16:18
craft10-apr25_20100425170432	10-04-27 20:01:01
craft10-res_slope_y_less_200mrad	10-04-30 08:03:46

Tests

Common

[+] medians distribution

DT

Chamber

[+] residuals distributions

[+] residuals relations to misalignments

CSC

Options

Plot Height: - 600 +

☐ Show 1st iteration

☐ Open in External Window

SlideShow

Tests: Custom Folders: Selected Only

< Start Stop Reset >

5

Log

Clear ALL

Date/Time	Level	Message
07/05/2010 02:49:57	INFO	Run craft10-res_slope_y_less_200mrad: Found 306 CSCs, 324 DTs

System View

CSCs Table DTs Table Summary Report

Run Number: craft10-res\_slope\_y\_less\_200mrad [ROOT file]

DT Summary

	1	2	3	4	5	6	7	8	9	10	11	12			
MB+2	MB+2/1	1	2	3	4	5	6	7	8	9	10	11	12		
	MB+2/2	1	2	3	4	5	6	7	8	9	10	11	12		
	MB+2/3	1	2	3	4	5	6	7	8	9	10	11	12		
	MB+2/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12
MB+1	MB+1/1	1	2	3	4	5	6	7	8	9	10	11	12		
	MB+1/2	1	2	3	4	5	6	7	8	9	10	11	12		
	MB+1/3	1	2	3	4	5	6	7	8	9	10	11	12		
	MB+1/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12
MB-0	MB-0/1	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-0/2	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-0/3	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-0/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12
MB-1	MB-1/1	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-1/2	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-1/3	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-1/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12
MB-2	MB-2/1	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-2/2	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-2/3	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-2/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12
MB-ALL	MB-ALL/1	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-ALL/2	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-ALL/3	1	2	3	4	5	6	7	8	9	10	11	12		
	MB-ALL/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12

Severity legend: NONE UNCERT05 UNCERT075 UNCERT1 LOWSTAT TOLERABLE SEVERE CRITICAL

Report Status

Plots



A snapshot of the alignment quality browser for this alignment:

**Runs**

Run	Analyzed on
GaussPowerTailsWholeSample	10-03-15 04:32:02
mmal_test_Monitor	11-39 2010-02-25
NOV4DT_PASS3noweight_TkHIP	09-13 2010-02-03
p105	20-22 2010-03-01
p110	13-36 2010-03-02
p120	14-18 2010-03-02
craft10-not-final_20100412231618	10-04-12 23:16:18
craft10-apr25_20100425170432	10-04-27 20:01:01
craft10-res_slope_y_less_200mrad	10-04-30 09:03:45

**Tests**

**Common**

☒ medians distributions

**DT**

**Chamber**

☒ residuals distributions

☒ residuals relations to misalignments

**CSC**

**Options**

Plot Height: - 600 +

☐ Show 1st iteration

☐ Open in External Window

**SlideShow**

Tests: Custom Folders: Selected Only

< Start Stop Reset > 5

Log Clear ALL

Date/Time	Level	Message
07/05/2010 02:49:57	INFO	Run craft10-res_slope_y_less_200mrad: Found 306 CSCs, 324 DTs

**System View**

CSCs Table DTs Table Summary Report

Run Number: craft10-res\_slope\_y\_less\_200mrad [ROOT file]

**DT Summary**

DT	1	2	3	4	5	6	7	8	9	10	11	12
MB+2	1	2	3	4	5	6	7	8	9	10	11	12
MB+2/2	1	2	3	4	5	6	7	8	9	10	11	12
MB+2/3	1	2	3	4	5	6	7	8	9	10	11	12
MB+2/4	1	2	3	13	4	5	6	7	8	9	14	10
MB+1	1	2	3	4	5	6	7	8	9	10	11	12
MB+1/2	1	2	3	4	5	6	7	8	9	10	11	12
MB+1/3	1	2	3	4	5	6	7	8	9	10	11	12
MB+1/4	1	2	3	13	4	5	6	7	8	9	14	10
MB-0/1	1	2	3	4	5	6	7	8	9	10	11	12
MB-0/2	1	2	3	4	5	6	7	8	9	10	11	12
MB-0/3	1	2	3	4	5	6	7	8	9	10	11	12
MB-0/4	1	2	3	13	4	5	6	7	8	9	14	10
MB-1	1	2	3	4	5	6	7	8	9	10	11	12
MB-1/2	1	2	3	4	5	6	7	8	9	10	11	12
MB-1/3	1	2	3	4	5	6	7	8	9	10	11	12
MB-1/4	1	2	3	13	4	5	6	7	8	9	14	10
MB-2	1	2	3	4	5	6	7	8	9	10	11	12
MB-2/2	1	2	3	4	5	6	7	8	9	10	11	12
MB-2/3	1	2	3	4	5	6	7	8	9	10	11	12
MB-2/4	1	2	3	13	4	5	6	7	8	9	14	10
MB-ALL1	1	2	3	4	5	6	7	8	9	10	11	12
MB-ALL2	1	2	3	4	5	6	7	8	9	10	11	12
MB-ALL3	1	2	3	4	5	6	7	8	9	10	11	12
MB-ALL4	1	2	3	13	4	5	6	7	8	9	14	10

Severity legend: NONE UNCERT05 UNCERT075 UNCERT1 LOWSTAT TOLERABLE SEVERE CRITICAL

**Report Status**

**Plots**

low statistics  
(expected in sectors 1&7  
for cosmic rays!)



A snapshot of the alignment quality browser for this alignment:

**Runs**

Run	Analyzed on
GaussPowerTailsWholeSample	10-03-15 04:32:02
mmal_test_Monitor	11-39 2010-02-25
NOV4DT_PASS3noweight_TkHIP	09-13 2010-02-03
pD5	20-22 2010-03-01
pD10	13-36 2010-03-02
pD0	14-18 2010-03-02
craft10-not-final_20100412231618	10-04-12 23:16:18
craft10-apr25_20100425170432	10-04-27 20:01:01
craft10-res_slope_y_less_200mrad	10-04-30 09:03:46

**Tests**

**Common**

☒ medians distribution

**DT**

**Chamber**

☒ residuals distributions

☒ residuals relations to misalignments

**CSC**

**Options**

Plot Height: - 600 +

☐ Show 1st iteration

☐ Open in External Window

**SlideShow**

Tests: Custom Folders: Selected Only

< Start Stop Reset > 5

Log Clear ALL

Date/Time	Level	Message
07/05/2010 02:49:57	INFO	Run craft10-res_slope_y_less_200mrad: Found 306 CSCs, 324 DTs

**System View**

CSCs Table DTs Table Summary Report

Run Number: craft10-res\_slope\_y\_less\_200mrad

**DT Summary**

DT	1	2	3	4	5	6	7	8	9	10	11	12		
MB+2	1	2	3	4	5	6	7	8	9	10	11	12		
MB+2/1	1	2	3	4	5	6	7	8	9	10	11	12		
MB+2/2	1	2	3	4	5	6	7	8	9	10	11	12		
MB+2/3	1	2	3	4	5	6	7	8	9	10	11	12		
MB+2/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12
MB+1	1	2	3	4	5	6	7	8	9	10	11	12		
MB+1/1	1	2	3	4	5	6	7	8	9	10	11	12		
MB+1/2	1	2	3	4	5	6	7	8	9	10	11	12		
MB+1/3	1	2	3	4	5	6	7	8	9	10	11	12		
MB+1/4	1	2	3	4	5	6	7	8	9	10	11	12		
MB-1	1	2	3	4	5	6	7	8	9	10	11	12		
MB-1/1	1	2	3	4	5	6	7	8	9	10	11	12		
MB-1/2	1	2	3	4	5	6	7	8	9	10	11	12		
MB-1/3	1	2	3	4	5	6	7	8	9	10	11	12		
MB-1/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12
MB-2	1	2	3	4	5	6	7	8	9	10	11	12		
MB-2/1	1	2	3	4	5	6	7	8	9	10	11	12		
MB-2/2	1	2	3	4	5	6	7	8	9	10	11	12		
MB-2/3	1	2	3	4	5	6	7	8	9	10	11	12		
MB-2/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12
MB-ALL	1	2	3	4	5	6	7	8	9	10	11	12		
MB-ALL/1	1	2	3	4	5	6	7	8	9	10	11	12		
MB-ALL/2	1	2	3	4	5	6	7	8	9	10	11	12		
MB-ALL/3	1	2	3	4	5	6	7	8	9	10	11	12		
MB-ALL/4	1	2	3	13	4	5	6	7	8	9	14	10	11	12

Severity legend: NONE UNCERTOS UNCERT07S UNCERT1 LOWSTAT TOLERABLE SEVERE CRITICAL

**Report Status**

**Plots**

third iteration has not reached a fixed point

third iteration has not reached a fixed point

Minuit failed  
(6 tracks in alignment)



A snapshot of the alignment quality browser for this alignment:

**Runs**

Run	Analyzed on
GaussPowerTailsWholeSample	10-03-15 04:32:02
mutual_test_Monitor	11-39 2010-02-25
NOV4DT_PASS3noweight_TkHIP	09-13 2010-02-03
p105	20-22 2010-03-01
p110	13-36 2010-03-02
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craft10-not-final_20100412231618	10-04-12 23:16:18
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<b>craft10-res_slope_y_less_200mrad</b>	10-04-30 08:03:46

**Tests**

Common

☒ median distribution

DT

Chamber

☒ residuals distributions

☒ residuals relations to misalignments

CSC

**Options**

Plot Height: - 600 +

☐ Show 1st iteration

☐ Open in External Window

**SlideShow**

Tests: Custom Folders: Selected Only

< Start Stop Reset > 5

**Log** Clear ALL

**System View**

CSCs Table DTs Table Summary Report

Run Number: craft10-res\_slope\_y\_less\_200mrad [ROOT file]

**DT Summary**

DT	1	2	3	4	5	6	7	8	9	10	11	12
MB+2	1	2	3	4	5	6	7	8	9	10	11	12
MB-2	1	2	3	4	5	6	7	8	9	10	11	12
MB+2/1	1	2	3	4	5	6	7	8	9	10	11	12
MB+2/2	1	2	3	4	5	6	7	8	9	10	11	12
MB+2/3	1	2	3	4	5	6	7	8	9	10	11	12
MB+2/4	1	2	3	4	5	6	7	8	9	10	11	12
MB+1	1	2	3	4	5	6	7	8	9	10	11	12
MB+1/1	1	2	3	4	5	6	7	8	9	10	11	12
MB+1/2	1	2	3	4	5	6	7	8	9	10	11	12
MB+1/3	1	2	3	4	5	6	7	8	9	10	11	12
MB+1/4	1	2	3	4	5	6	7	8	9	10	11	12
MB-0	1	2	3	4	5	6	7	8	9	10	11	12
MB-0/1	1	2	3	4	5	6	7	8	9	10	11	12
MB-0/2	1	2	3	4	5	6	7	8	9	10	11	12
N	1	2	3	4	5	6	7	8	9	10	11	12
MB-1	1	2	3	4	5	6	7	8	9	10	11	12
MB-1/1	1	2	3	4	5	6	7	8	9	10	11	12
MB-1/2	1	2	3	4	5	6	7	8	9	10	11	12
MB-1/3	1	2	3	4	5	6	7	8	9	10	11	12
MB-1/4	1	2	3	4	5	6	7	8	9	10	11	12
MB-2	1	2	3	4	5	6	7	8	9	10	11	12
MB-2/1	1	2	3	4	5	6	7	8	9	10	11	12
MB-2/2	1	2	3	4	5	6	7	8	9	10	11	12
MB-2/3	1	2	3	4	5	6	7	8	9	10	11	12
MB-2/4	1	2	3	4	5	6	7	8	9	10	11	12
MB-ALL	1	2	3	4	5	6	7	8	9	10	11	12
MB-ALL/1	1	2	3	4	5	6	7	8	9	10	11	12
MB-ALL/2	1	2	3	4	5	6	7	8	9	10	11	12
MB-ALL/3	1	2	3	4	5	6	7	8	9	10	11	12
MB-ALL/4	1	2	3	4	5	6	7	8	9	10	11	12

Severity legend: NONE UNCERT05 UNCERT075 UNCERT1 LOWSTAT TOLERABLE SEVERE CRITICAL

**Report Status**

**Plots**

**Date/Time** **Level** **Message**

07/05/2010 02:49:57 INFO Run craft10-res\_slope\_y\_less\_200mrad: Found 306 CSCs, 324 DTs



A snapshot of the alignment quality browser for this alignment:

**Runs**

Run	Analyzed on
GaussPowerTailsWholeSample	10-03-15 04:32:02
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p110	13-36 2010-03-02
p120	14-18 2010-03-02
craft10-not-final_20100412231618	10-04-12 23:16:18
craft10-apr25_20100425170457	10-04-25 17:04:57
craft10-res_slope_y_less_200	10-04-25 17:04:57

**System View**

CSCs Table | DTs Table | Summary Report

Run Number: craft10-res\_slope\_y\_less\_200mrad [ROOT file]

DT Summary

DT	MB+2	MB+2/1	MB+2/2	MB+2/3	MB+2/4	MB-1	MB-1/1	MB-1/2	MB-1/3	MB-1/4	MB-2	MB-2/1	MB-2/2	MB-2/3	MB-2/4	MB-ALL	MB-ALL/1	MB-ALL/2	MB-ALL/3	MB-ALL/4
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
8	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
9	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
11	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
12	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
13	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
17	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
18	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

shape of fit function imperfect match to data ( $\chi^2 > 2.5$ )

**Tests**

Common

Median distribution

DT

Chamber

residuals distributions

residuals relations to misalignments

CSC

**Options**

Plot Height: - 600 +

☐ Show 1st iteration

☐ Open in External Window

**SlideShow**

Tests: Custom | Folders: Selected Only

< Start Stop Reset > 5

**Log** Clear ALL

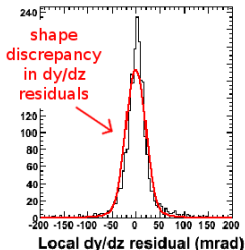
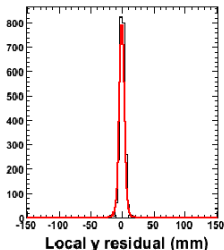
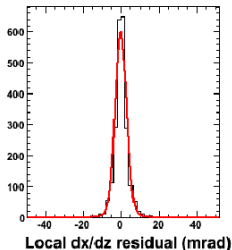
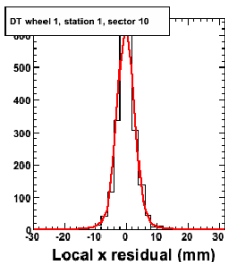
**Report Status**

**Plots**

**Log**

Date/Time	Level	Message
07/05/2010 02:49:57	INFO	Run craft10-res_slope_y_less_200mrad: Found 306 CSCs, 324 DTs





- ▶ Selected one of the pink (tolerable) errors: a high-statistics chamber showing a shape discrepancy between fit and data
- ▶  $\Delta \frac{dy}{dz}$  differs from general residuals shape
- ▶ For now, truncating distribution at 200 mrad and not aligning corresponding parameter ( $\Delta \frac{dy}{dz}$  corresponds to  $\delta_{\phi_x}$ )
- ▶ Verified that applying this cut has negligible impact on the 4 aligned parameters



- ▶ Procedure:
  1. start with hardware alignment
  2. apply global position correction
  3. replace hardware result with track-based if  $|x_{\text{TB}} - x_{\text{HW}}| > 2\sigma_{\text{TB}}$
  
- ▶ Step 3 is the “motion policy” recommended by our resolution projections note:
  - ▶ it guarantees that a superior prior geometry will not be replaced by statistical fluctuations in track-based alignment at the 95% confidence level
  - ▶ but clear track-based measurements of chamber misalignments *would* be corrected
  - ▶ more than half of the hardware constants are within  $2\sigma_{\text{TB}}$  (after global position correction) and would be preserved in the final geometry



- ▶ Reference-Target algorithm has been made more robust, but alignment results are unchanged
- ▶ Physical displacement of DT chambers from 2009  $\rightarrow$  2010 in  $x$  is barely statistically significant
- ▶ Most hardware and track-based results agree well, but there are enumerable outliers
- ▶ Residuals in 2010 indicate what you'd expect: some problems related to low statistics in sectors 1&7
  - ▶ automated algorithm catches anomalies; we don't need to flip through thousands of plots
- ▶ The “motion policy” publishes the best of a prior geometry and observed track-based measurements