Global Muon Alignment

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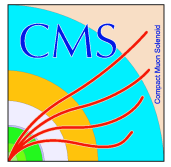
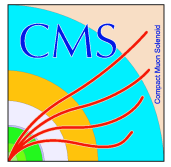
Outline



- 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

Changes since CRAFT-09



- Algorithmic
  - shape of residuals distribution
  - align only 4 most sensitive parameters: x, y, ϕ_y, ϕ_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.)

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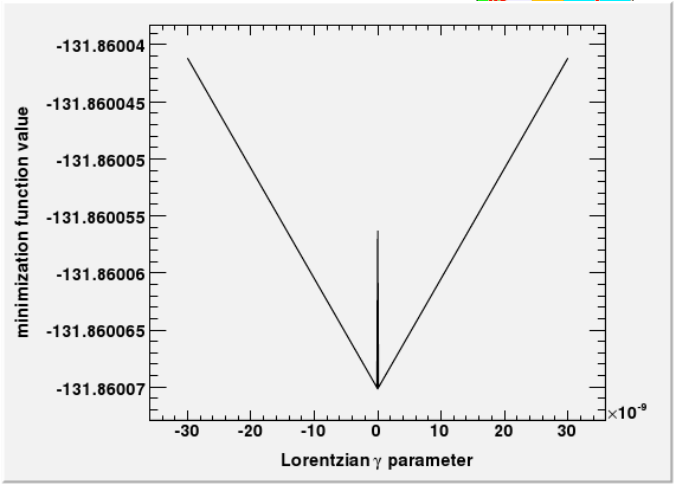
Shape of residuals distribution

- 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 ± 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

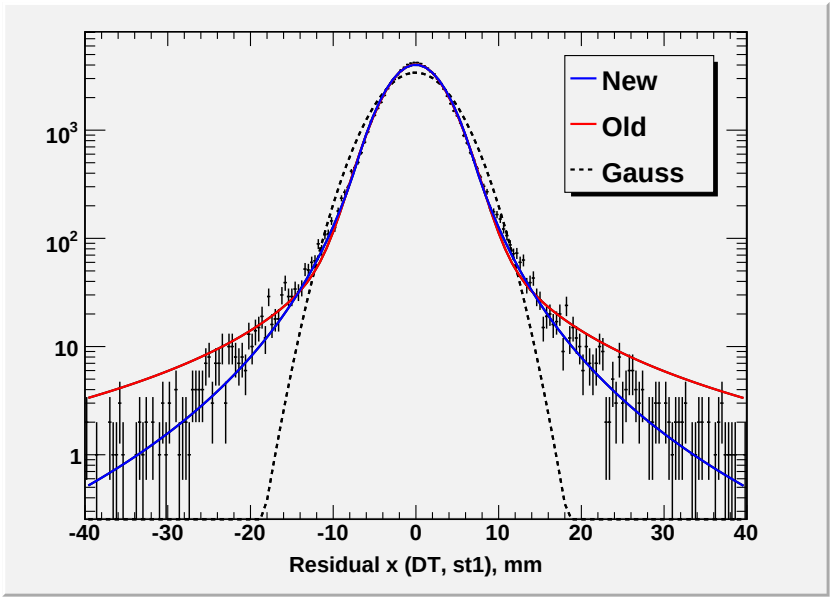
Shape of residuals distribution

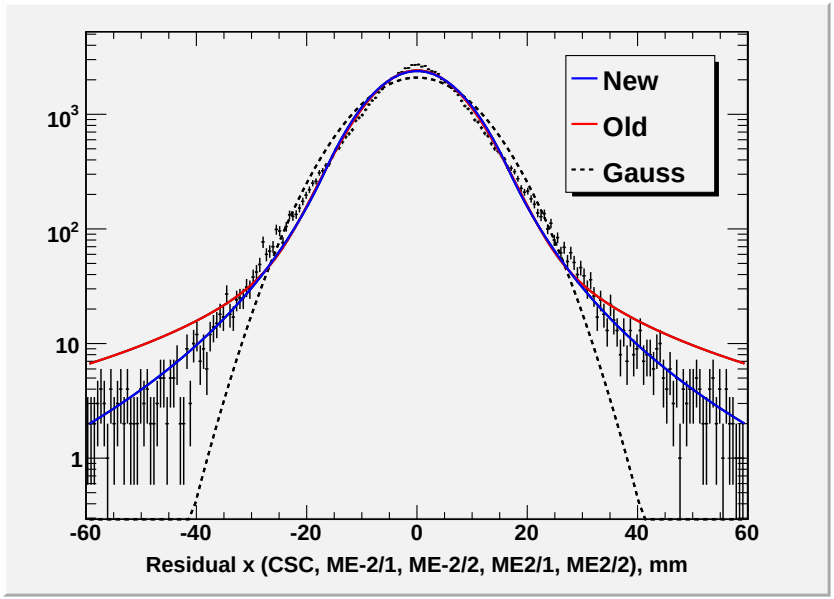
- Old function failed because $\mathcal{L}(\gamma)$ doesn't have a parabolic minimum in low-statistics (when $\gamma \ll \sigma$)
- New function:

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



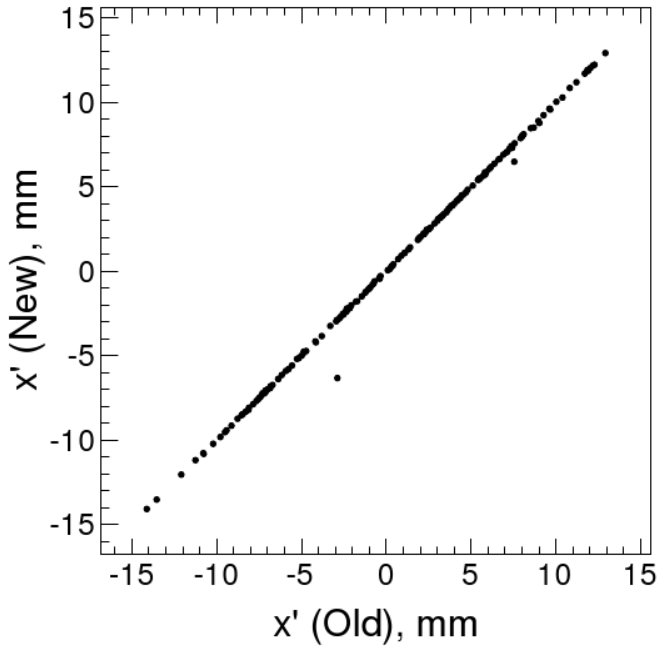
- Requiring normalization, continuity, and differentiability sets $m = 2\sigma$
- $1/x^4$ motivated by Rutherford scattering formula

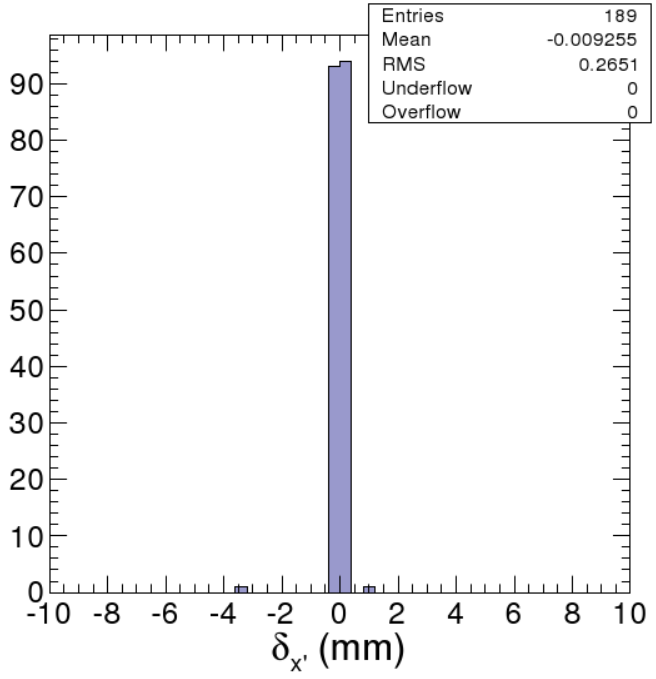




Validate algorithmic changes

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

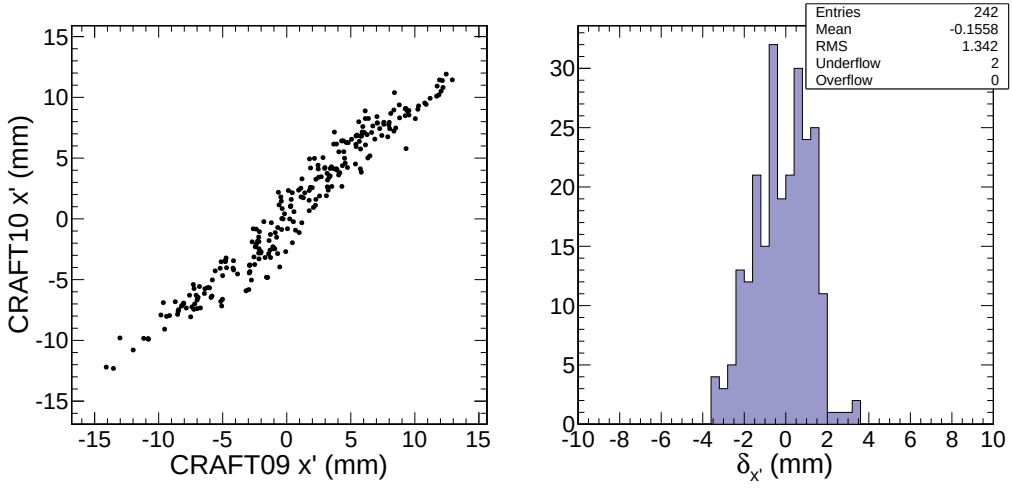


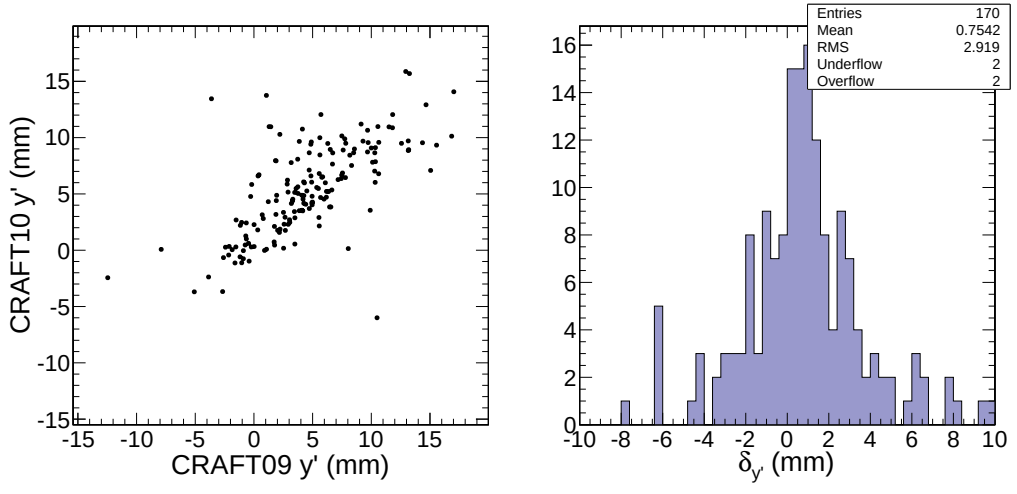


- RMS of 250 μm differences dominated by two chambers
  - they are low-statistics and did not reach a fixed point in old alignment (values still changing after 5 iterations)
- 189 chambers aligned in old algorithm, compared above
- all 250 chambers aligned in new algorithm

Comparison of 2009 with 2010

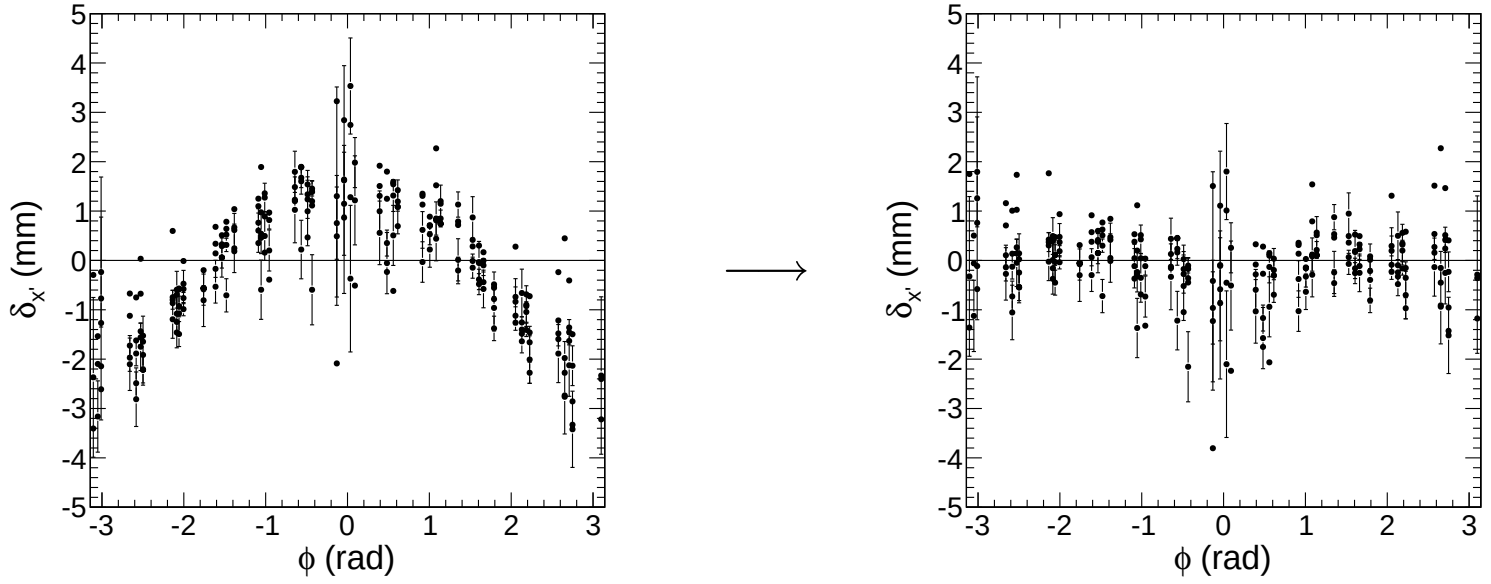
- Did chambers physically move during the winter shut-down?
- Plot CRAFT-09, CRAFT-10 differences





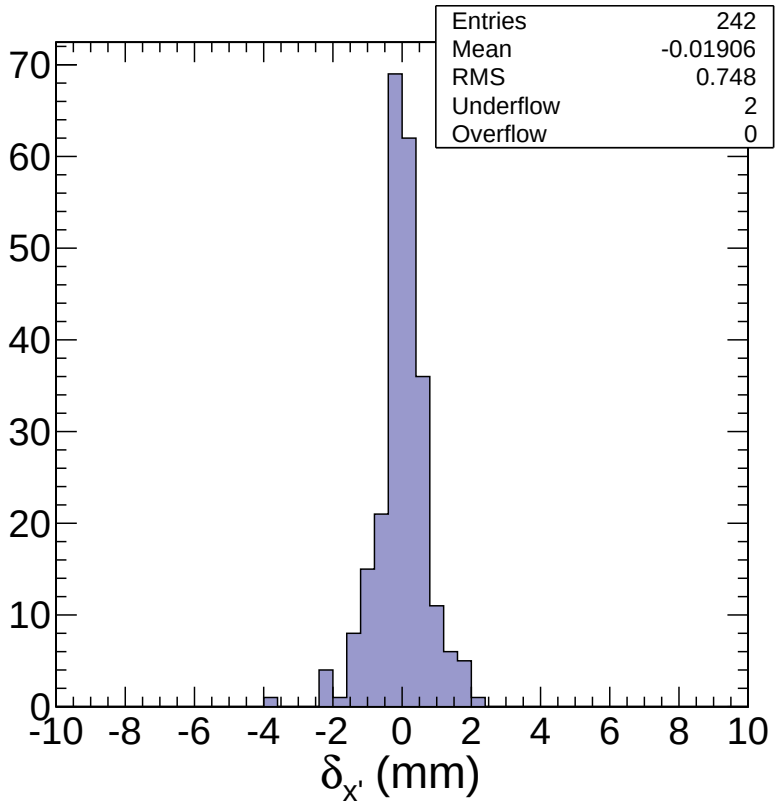
Comparison of 2009 with 2010

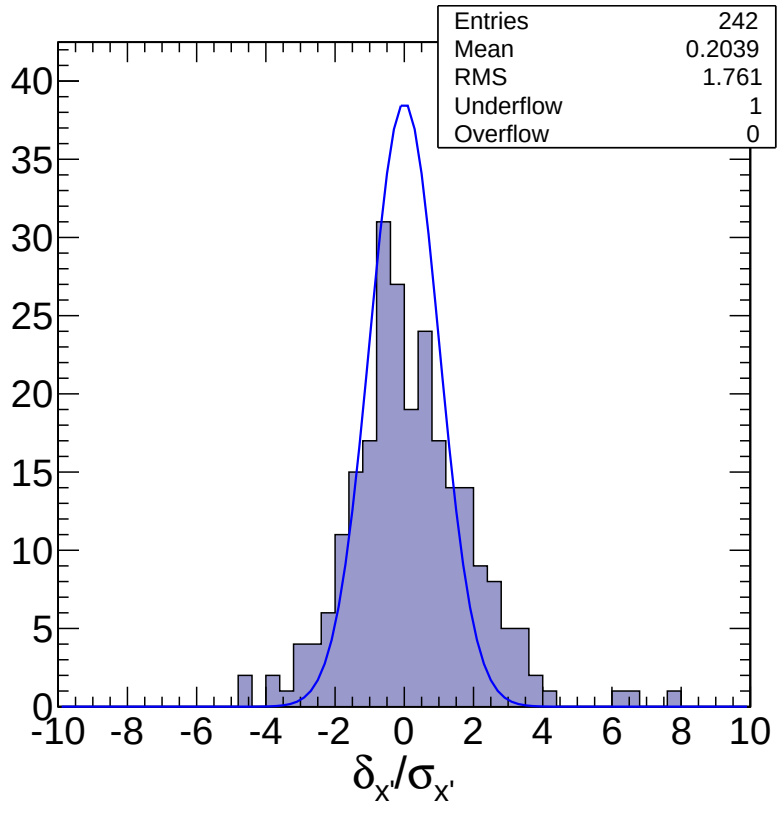
- Is there a pattern in these differences? Yes!



- Most of the variation is in a $\sin\phi + \cos\phi +$ 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

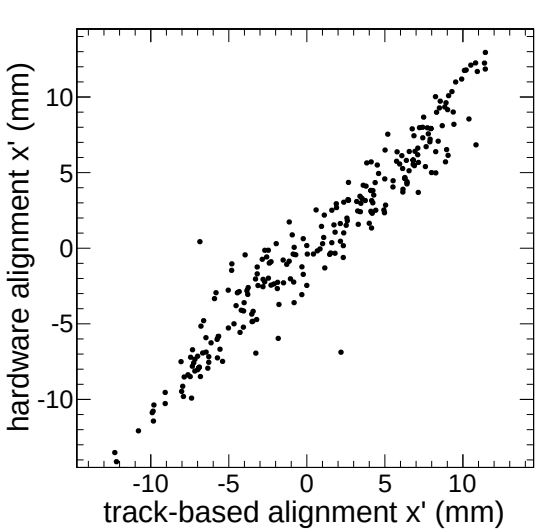


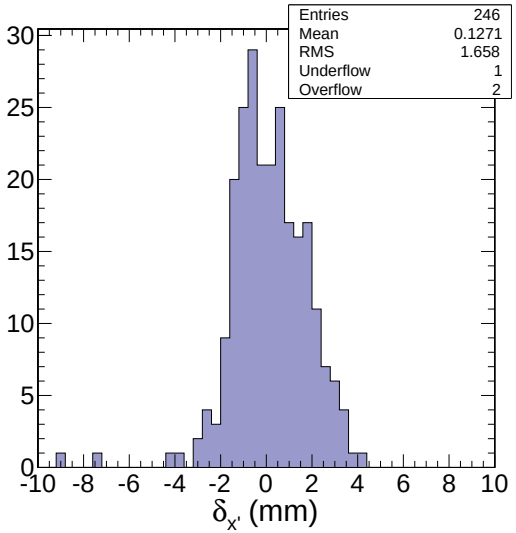


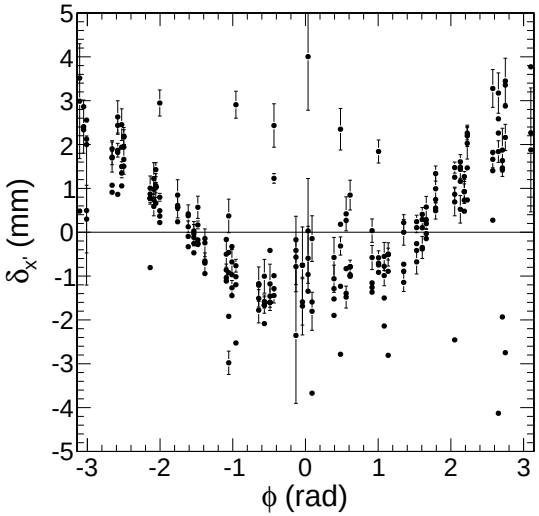
- Random variations around the $\cos\phi$ curve are 0.75 mm wide and almost pure statistics

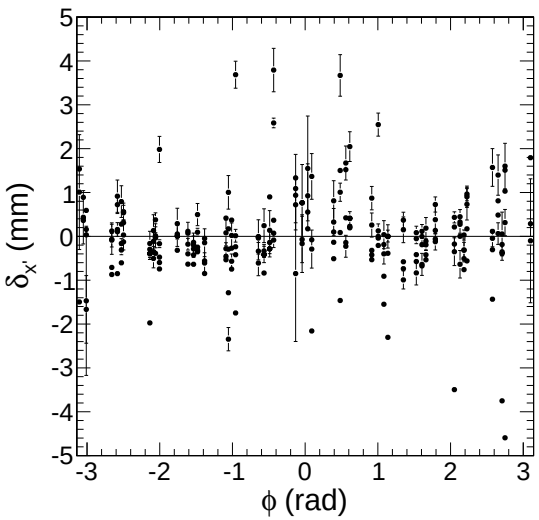
2010 hardware alignment

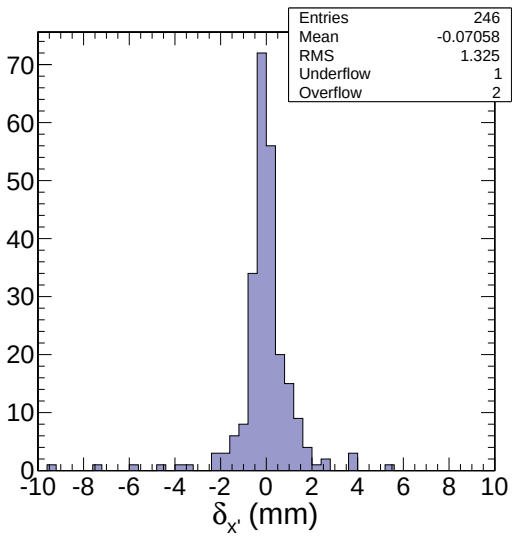
- How do hardware and track-based alignments compare in 2010? Use same method of comparison (also dominated by $\cos\phi$)

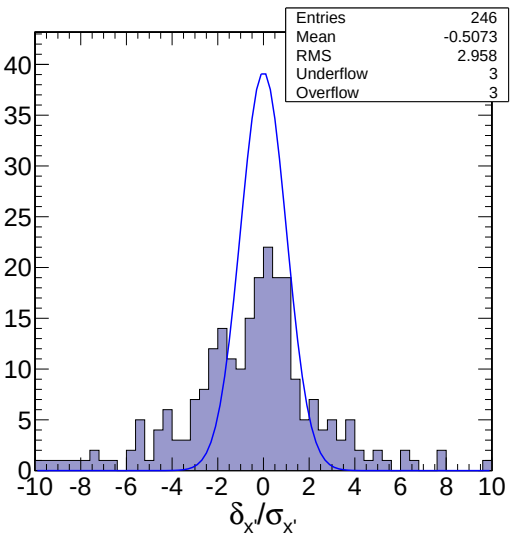




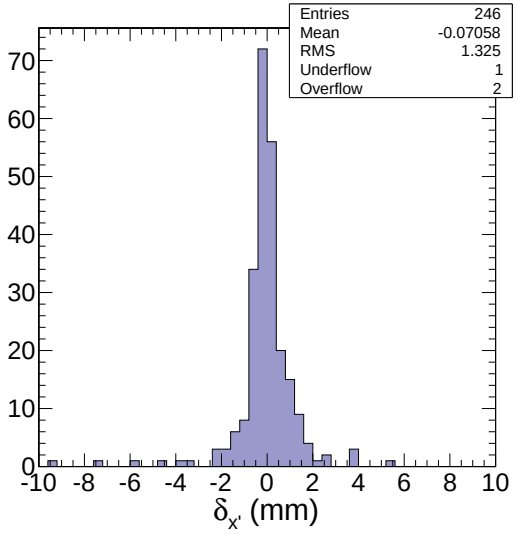


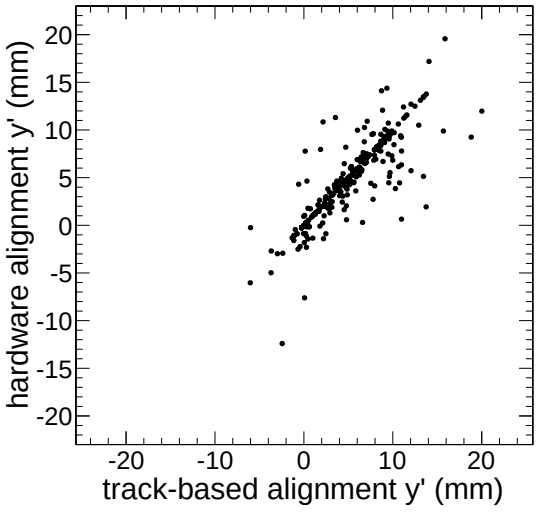


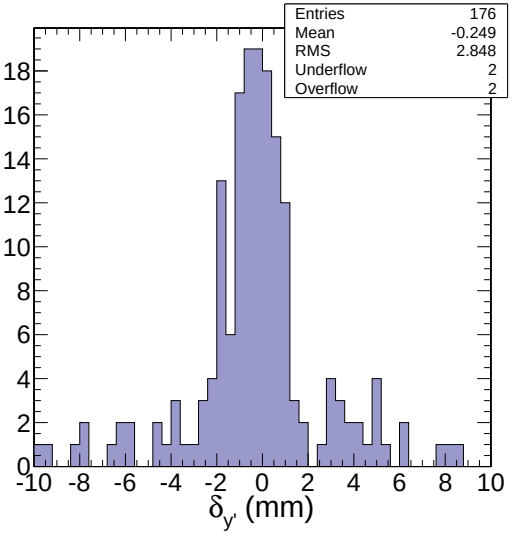




2010 hardware alignment







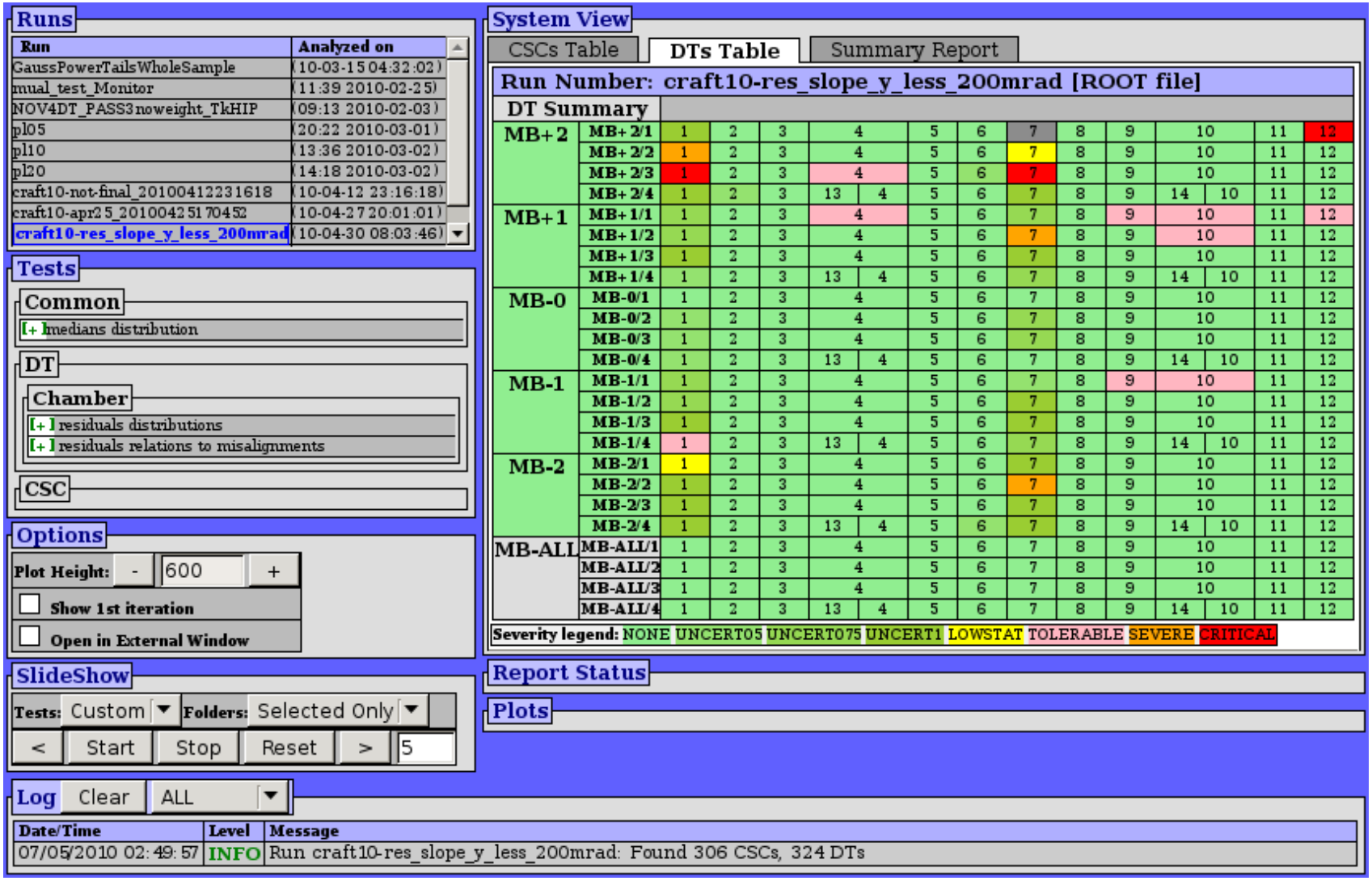
- Track-based and hardware alignments *agree* for most chambers: central core width of about 1 mm or less in x, 2 mm in y
- Different global positions, we should check GlobalPositionRcd (which will be updated next week)
- Outliers listed below ($|x'| > 2$ mm): they might be the chambers that were not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

Residuals quality

A snapshot of the alignment quality browser for this alignment:



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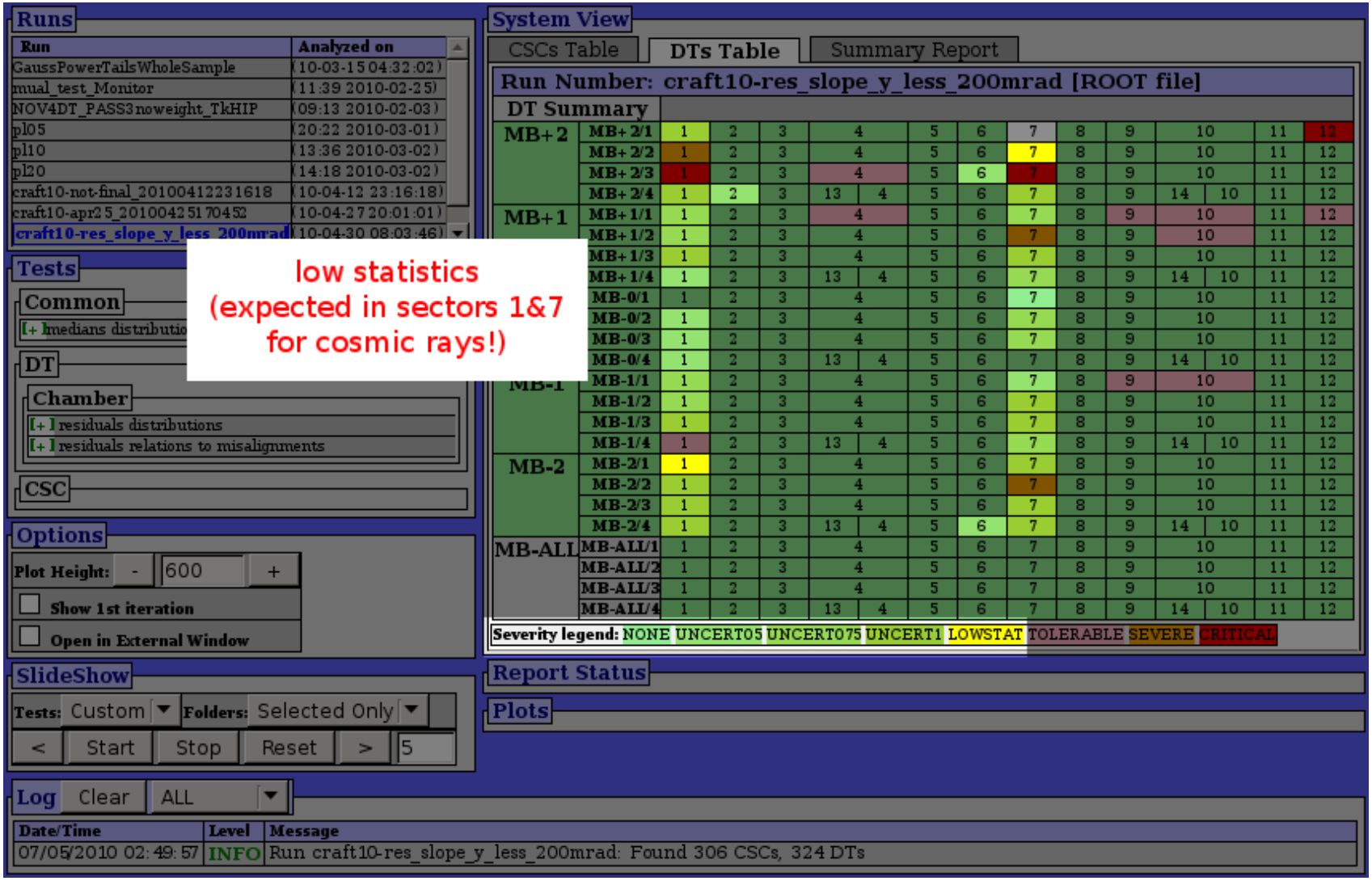

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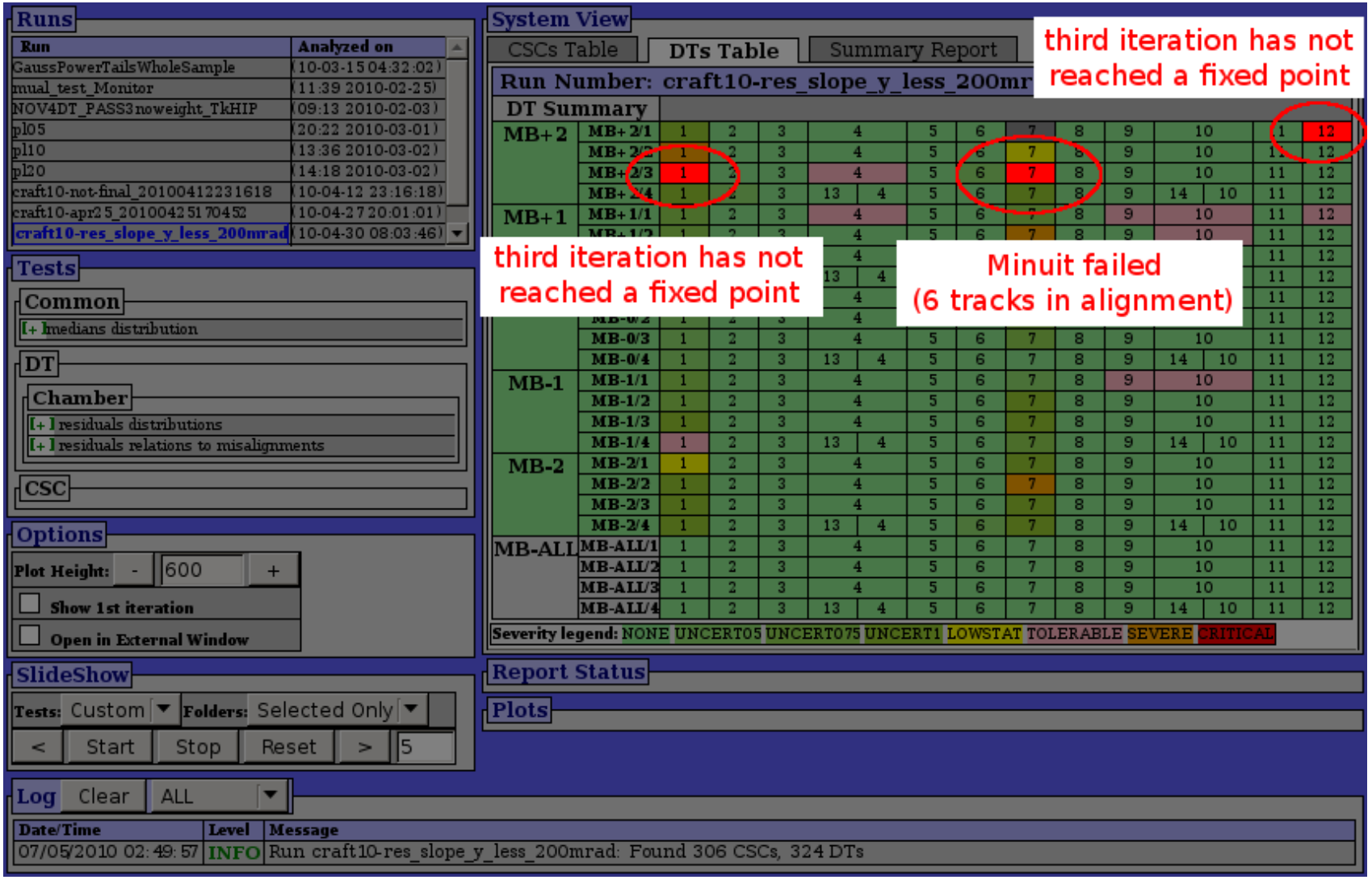

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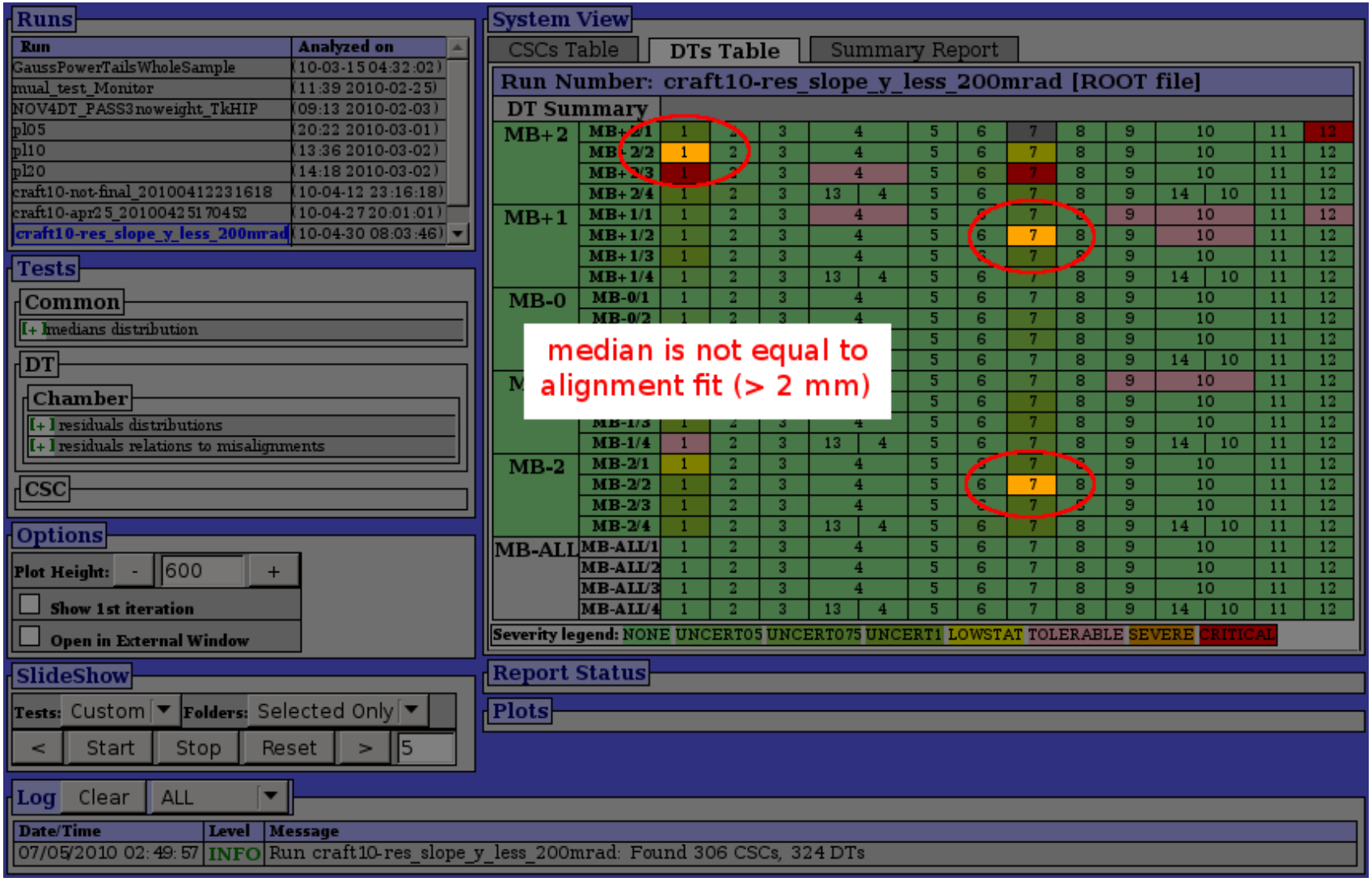

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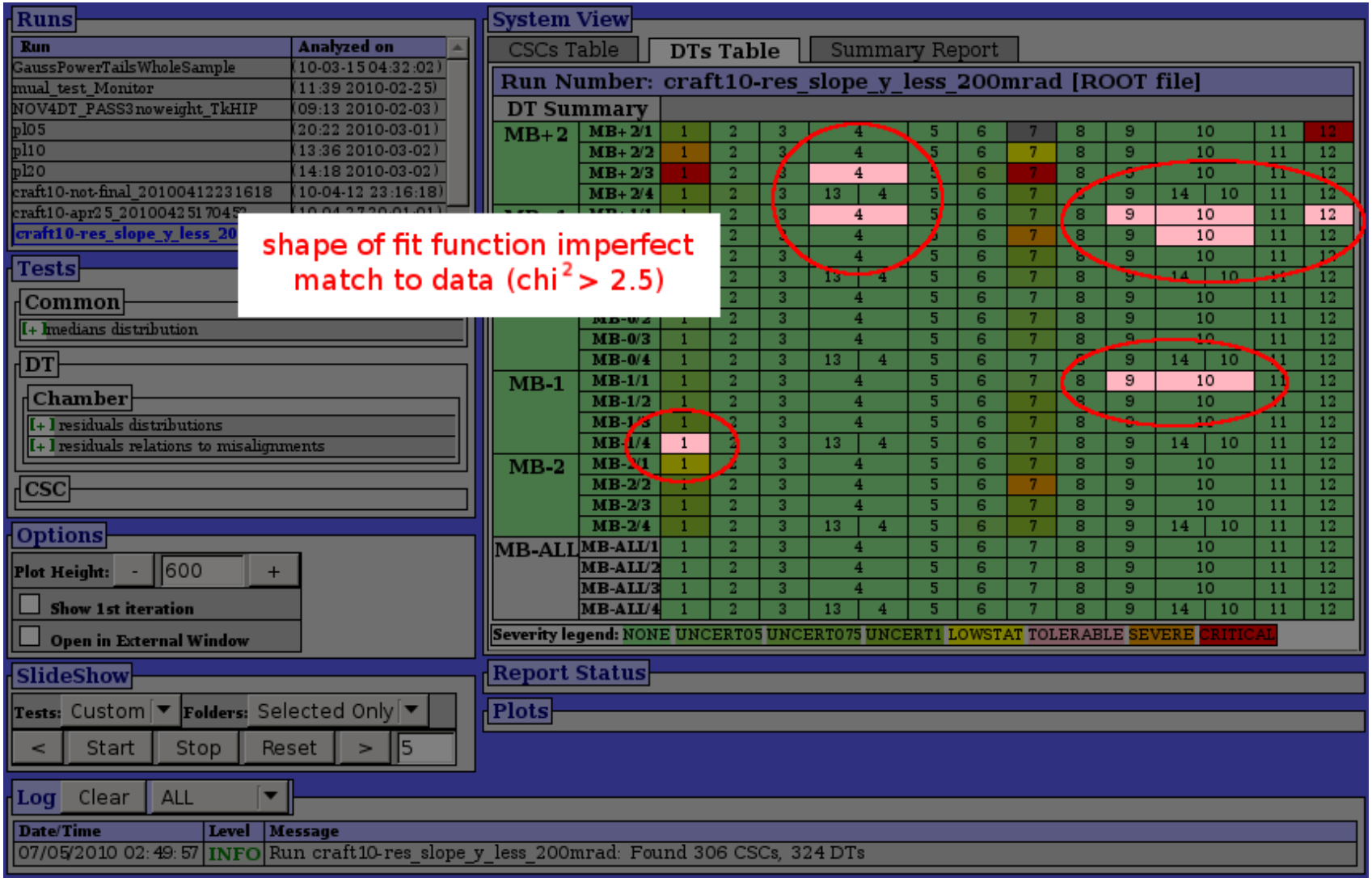

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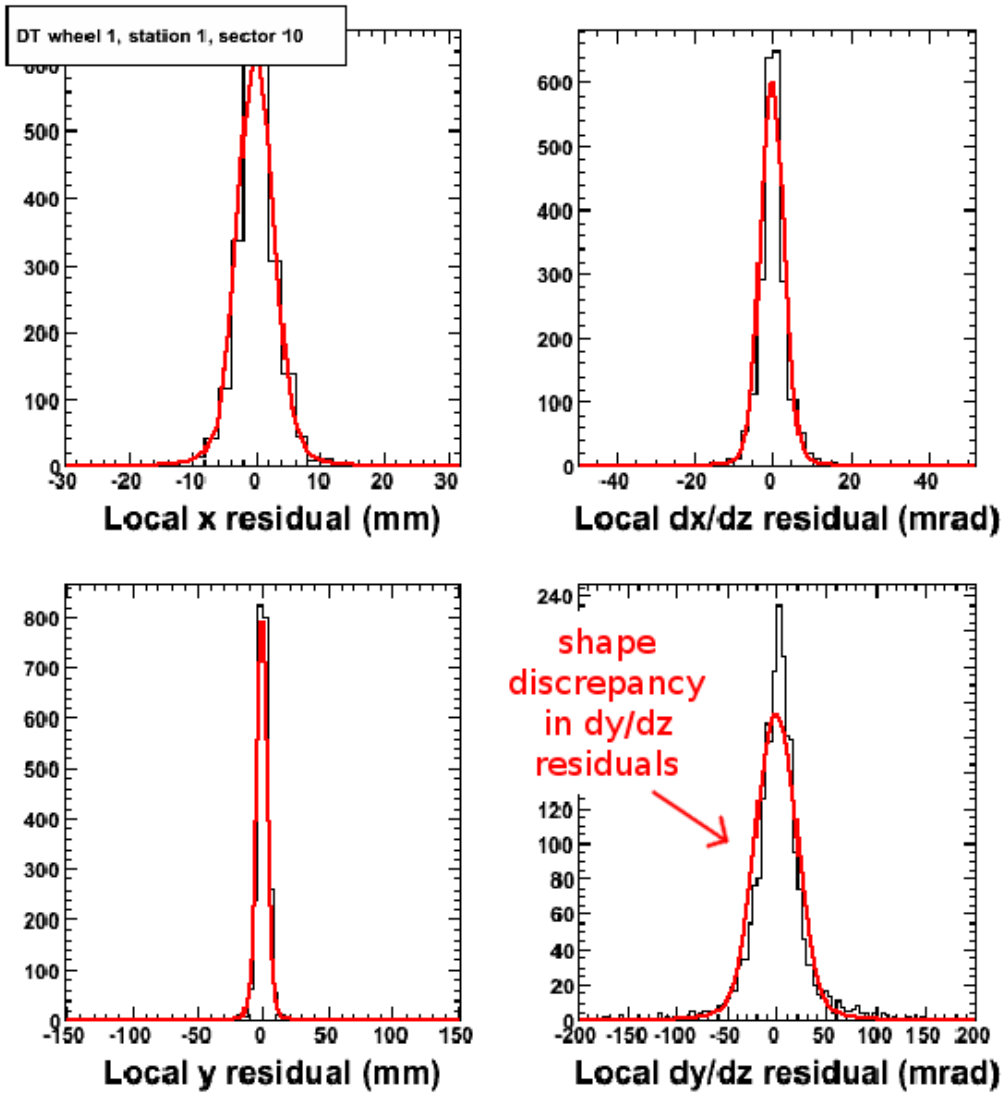


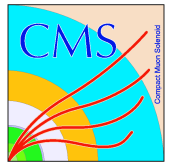
- Selected one of the pink (tolerable) errors: a high-statistics chamber showing a shape discrepancy between fit and data
- $\Delta\frac{dy}{dz}$ differs from general residuals shape
- For now, truncating distribution at 200 mrad and not aligning corresponding parameter ($\Delta\frac{dy}{dz}$ corresponds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

Alignment strategy

- Procedure:
  1. start with hardware alignment
  2. apply global position correction
  3. replace hardware result with track-based if $|x_{\mathrm{TB}} - x_{\mathrm{HW}}| > 2\sigma_{\mathrm{TB}}$

- 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 $2\sigma_{\mathrm{TB}}$ (after global position correction) and would be preserved in the final geometry

Conclusions



- Reference-Target algorithm has been made more robust, but alignment results are unchanged
- Physical displacement of DT chambers from 2009 $\longrightarrow$ 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