CRAFT alignment from 3rd reprocessing

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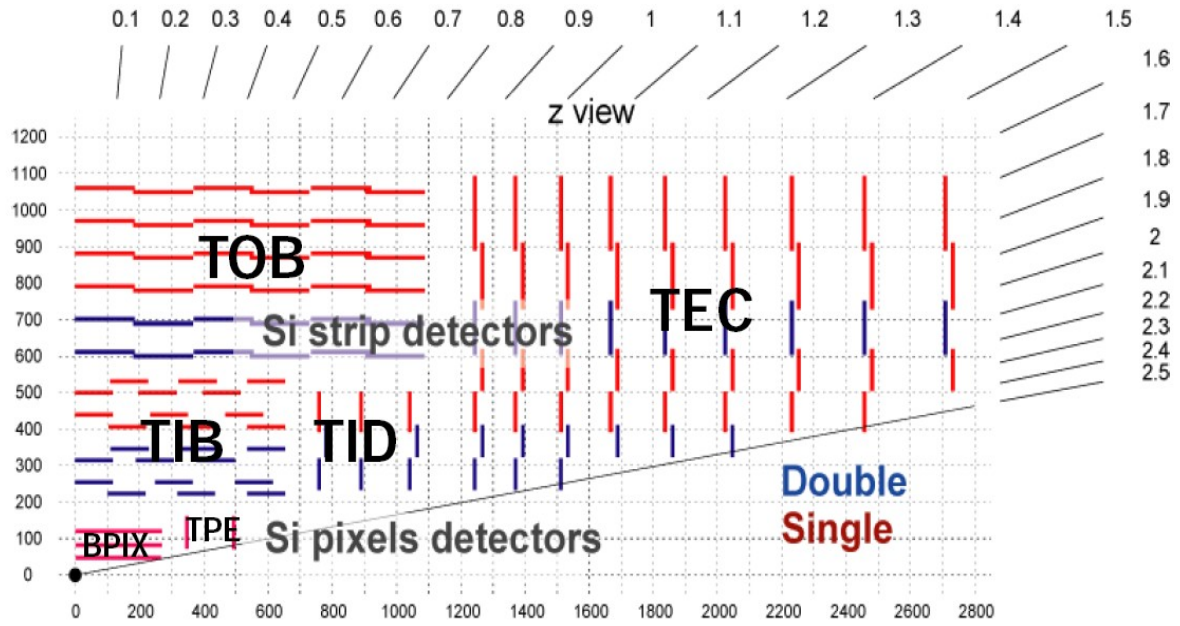
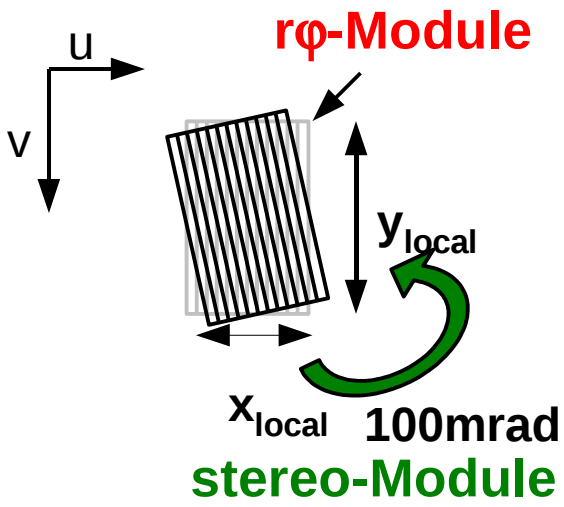
Outline

- Introduction
  - Terminology
  - Review Tracker Alignment and Millepede strategy
  - Current Millepede strategy ('**Adun**' (2/3 step))
- Tests with new Millepede strategy on simulated events (reversibility, weak modes)
- Data from 3rd reprocessing
- Latest alignment results on CRAFT data
- Conclusion & Outlook

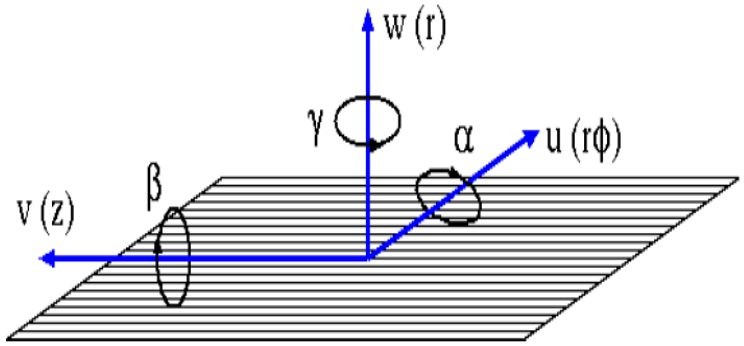
Terminology





- 1440 silicon pixel modules
- 15148 silicon strip modules
  - 1d-modules: sensitive coordinate in rφ (u)
  - 2d-modules: rφ- + stereo-module-unit rotated by 100mrad around local y

Alignment parameters per module



Millepede Alignment

- **Millepede II:** global approach to minimize track χ^2 taking into account correlations between alignment and track parameters
- **CSA08 strategy:** single sided module aligned in u, w, γ double sided & pixel modules in u, v, w, γ → total number of parameters: 44244 (Markus Stoye)
- **CRAFT promt reco:** following strategy from CSA08 + adjustments to data (Torino)

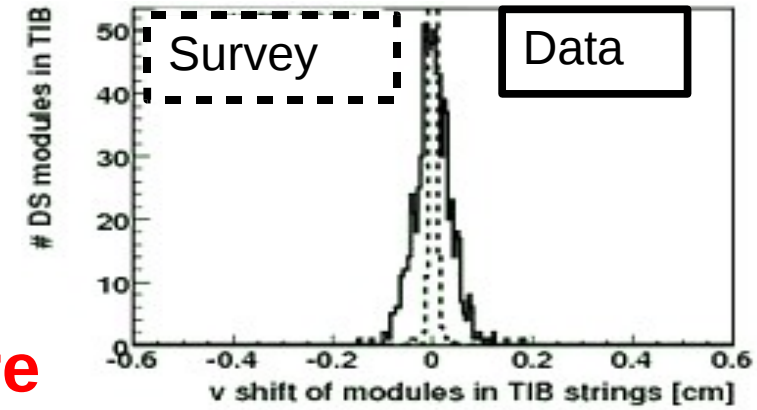
➔ Double sided modules treated as one unit!

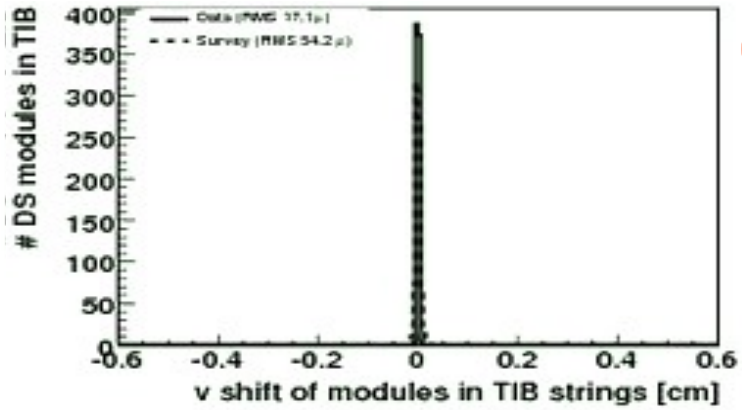
- **CRAFT re-reprocessing:** treatment of double sided modules as two separate module-units (Aachen)

Millepede Alignment Strategy: Review

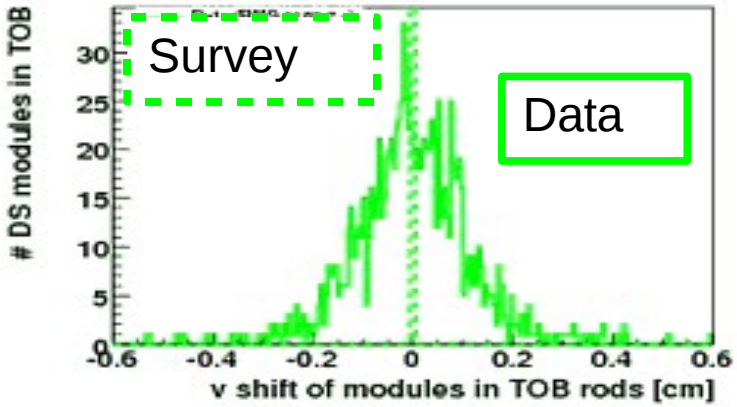
Aachen group

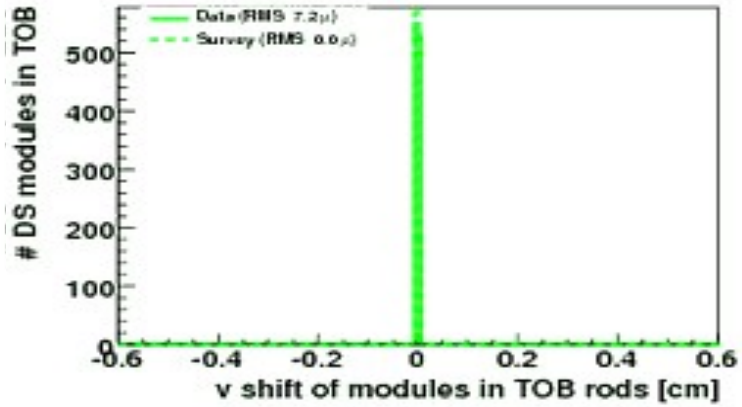
before





after





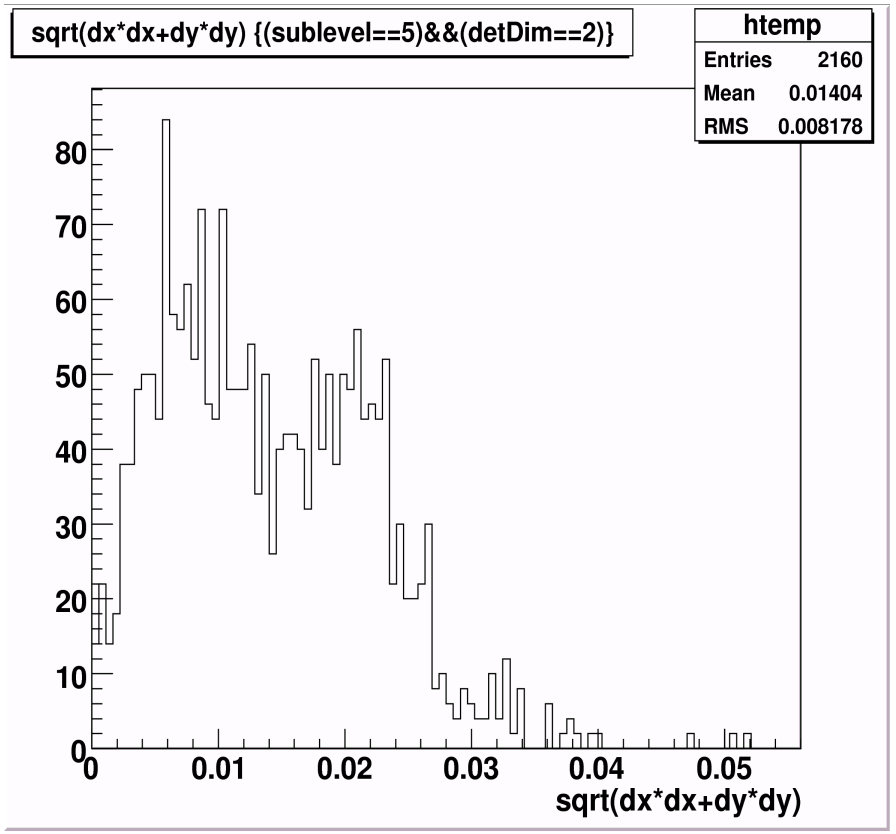
- 2d-modules aligned as one led to large movements of the modules within a string/rod compared to survey measurements

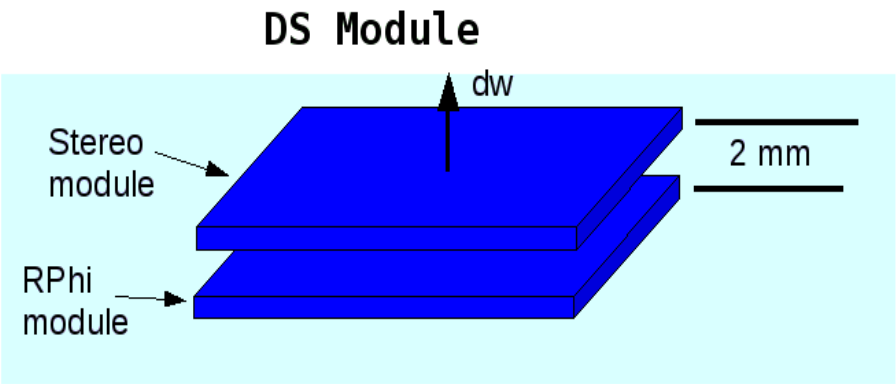
➔ Necessity of separate module-unit alignment for 2d modules

Millepede Alignment Strategy: Review

- Check that correction in dw of module-units in 2d-modules do not swap place (2mm in TOB, less in TIB)
- Not seen in CRAFT data

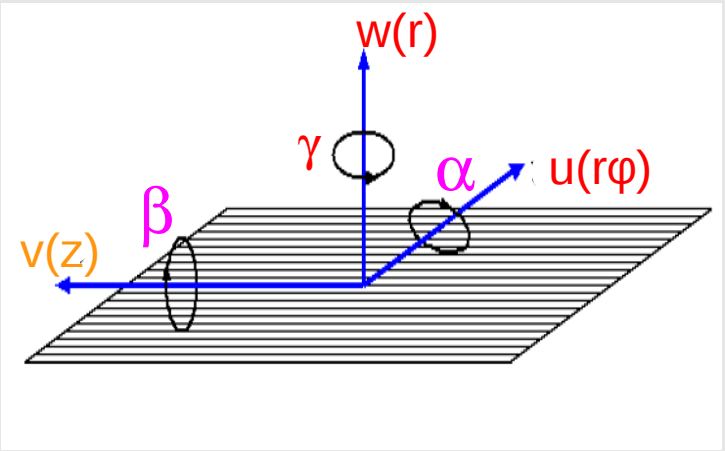
Aachen group





Current Millepede Alignment Strategy: 'Adun'

- Separated module-unit alignment of 2d-modules increases number of parameters to more than 55.000 (current pede limit (being fixed by V.Blobel) ~46.340 parameters)
  - ➔ 2 step approach due to limited number of parameters
  - ➔ Hard hit cut necessary to loose some modules and get below parameter limit
- **Adun 0**: module-unit alignment of 2d-modules in u,w and γ + large detector structures (all 6 degrees of freedom),(450 hits, 89% of the module units,~95% pixel modules)
- **Adun 1**: Single&Double sided module alignment in u,w and γ + α, β in TIB (150 hits, ~97% of modules aligned)
- Use of presigmas to suppress global movements/distortions



Adun Strategy on Simulated Events

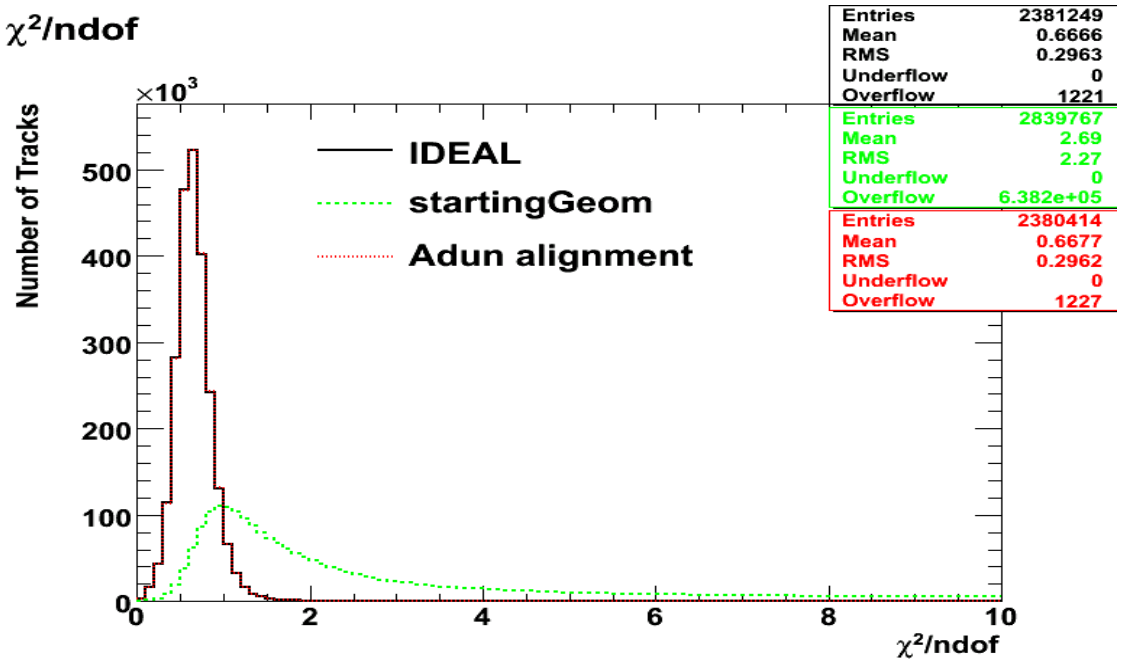
Adun Strategy from 'CRAFT Misalignment'

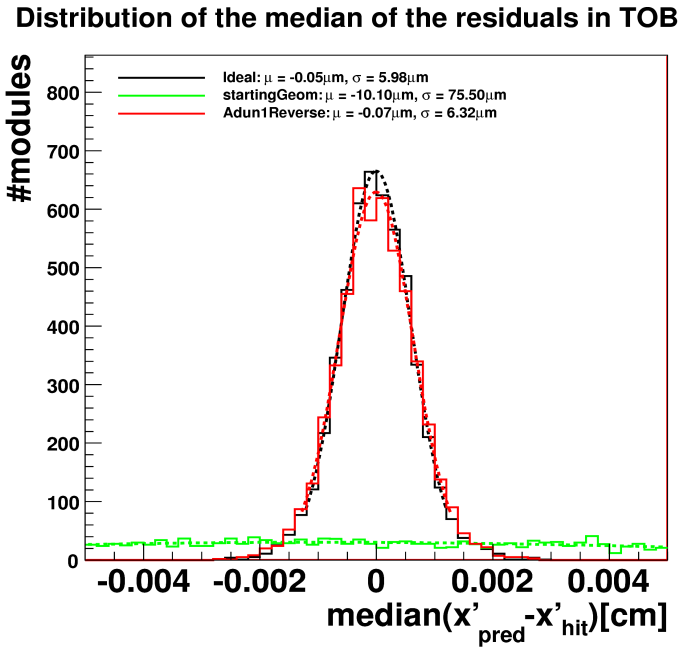
- Test Adun strategy on simulated events
- Start from **CRAFT Adun geometry** received from data as **misalignment** (only parameters misaligned that get aligned with Adun)
- Adun 0: required number of hits per strip module 450

  required number of hits per pixel module 25
- Adun 1: required number of hits per strip module 150

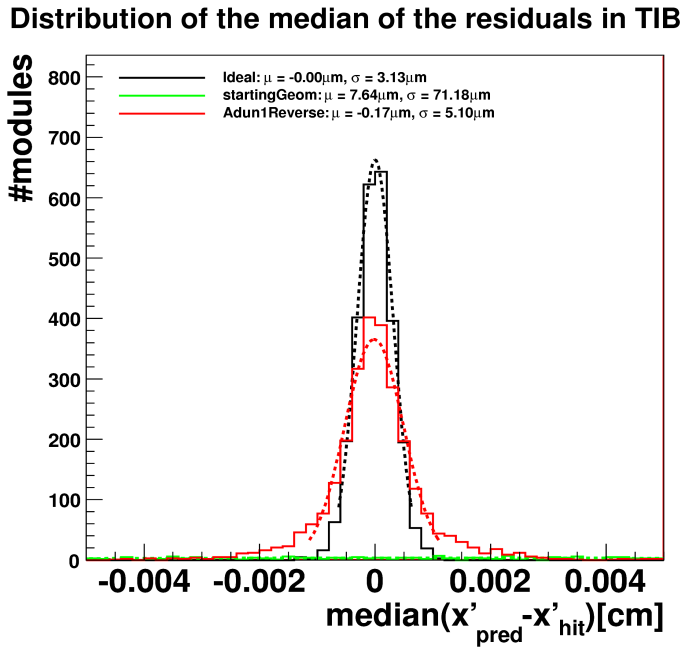
  required number of hits per pixel module 25
- Usage of pre-sigmas, no further fixation of reference system

Adun Studies on Simulated Events:Track Based Validation



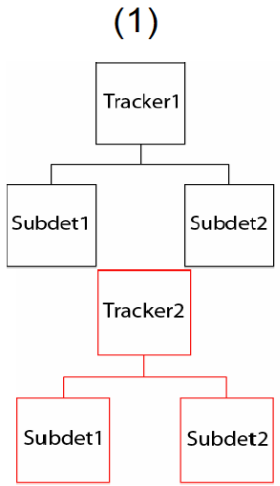


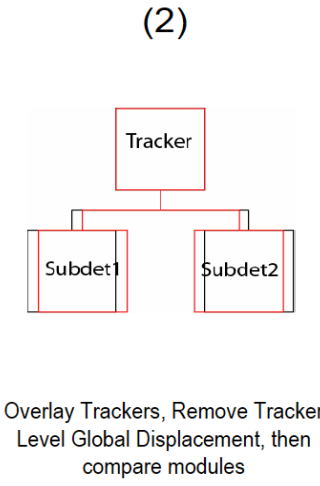
- Track based validation as estimator for the quality of the χ^2-minimization:
  - Nearly complete recovery in χ^2
- Distribution of median of the residuals on module similar to ideal geometry except in TIB ($\Delta\sigma$=2μm)

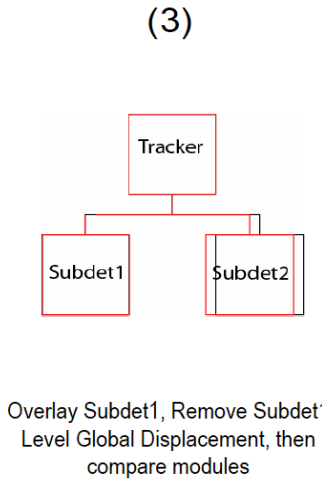


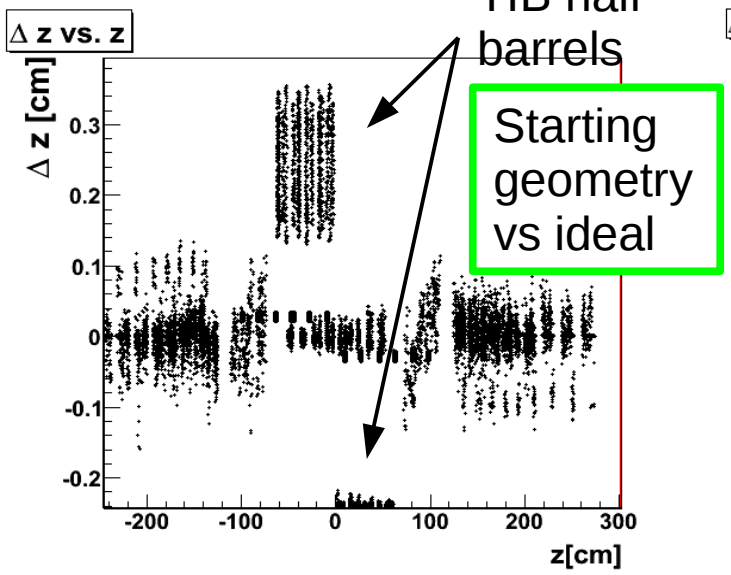
Geometry Comparison Adun1 vs Ideal/starting geometry

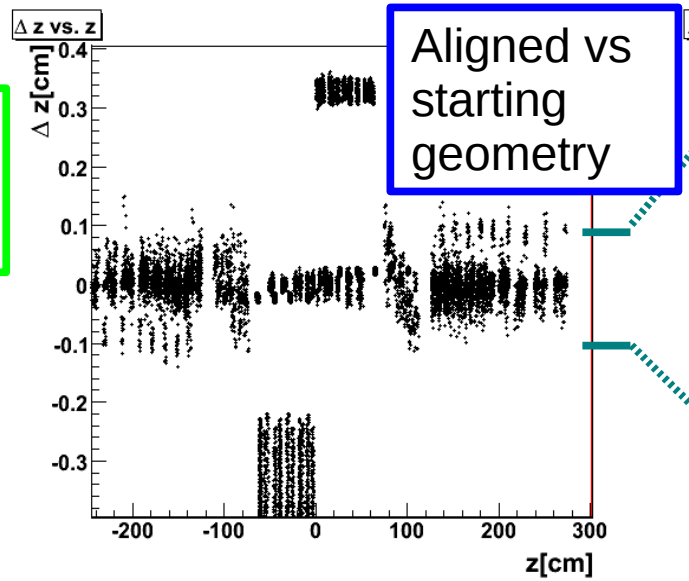
- Overlay detector, then subdetectors, remove global shifts to investigate module movement within the subdetector

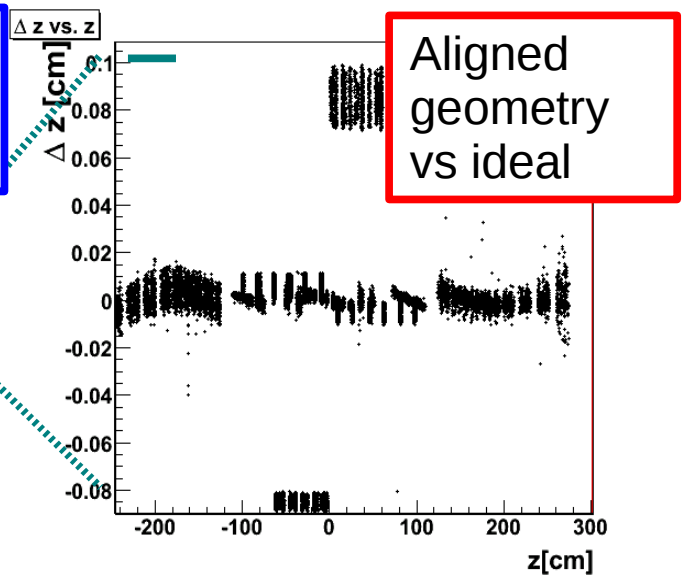












- Slight overcorrection of TIB half barrel movement in z

Adun Studies On Simulated Data

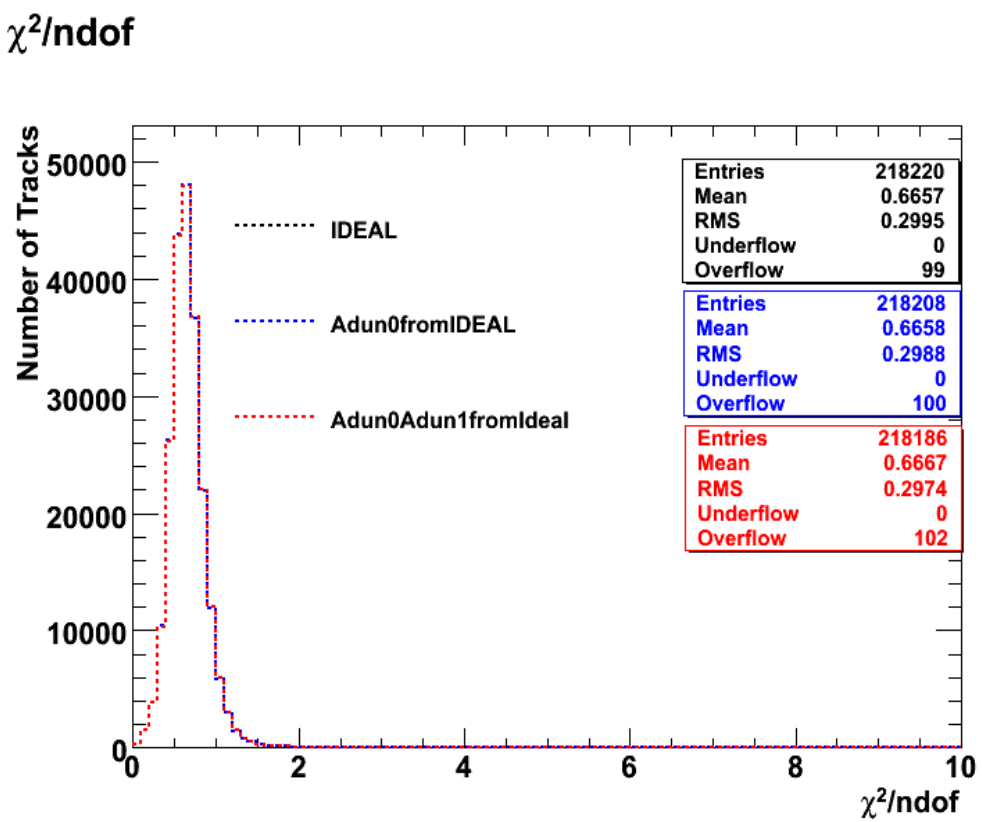
- Test Adun strategy on simulated events
- Start from **Ideal geometry → Adun0 → Adun1**
- Adun 0: required number of hits per strip module 450

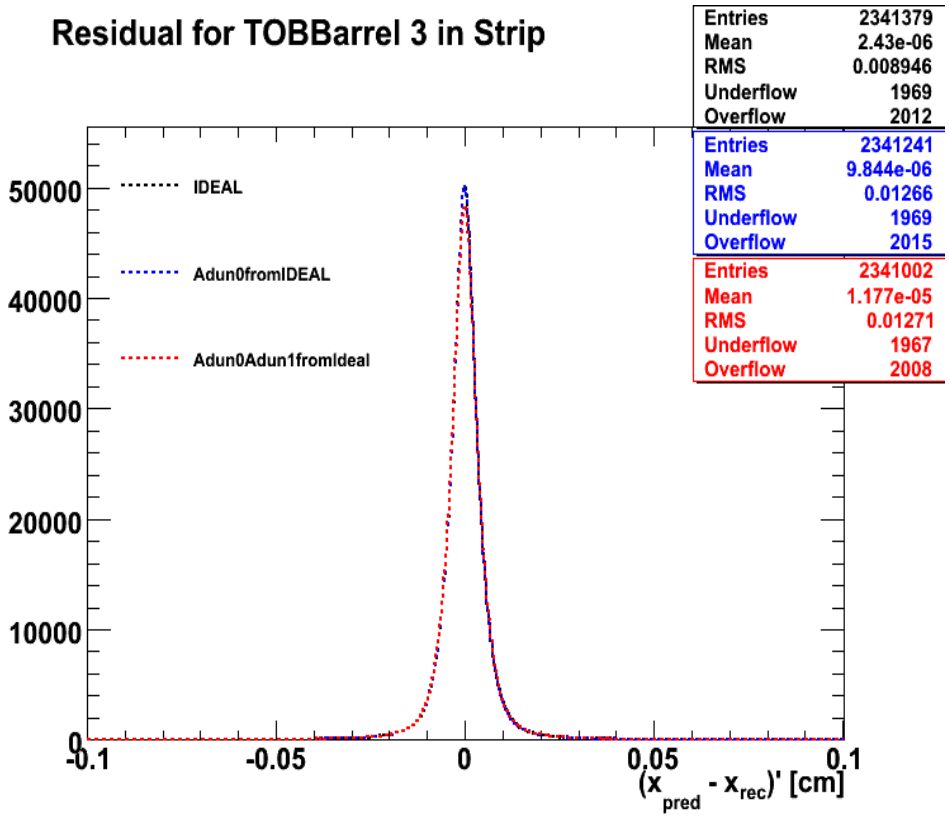
  required number of hits per pixel module 25
- Adun 1: required number of hits per strip module 150

  required number of hits per pixel module 25
- Usage of pre-sigmas, no further fixation of reference system

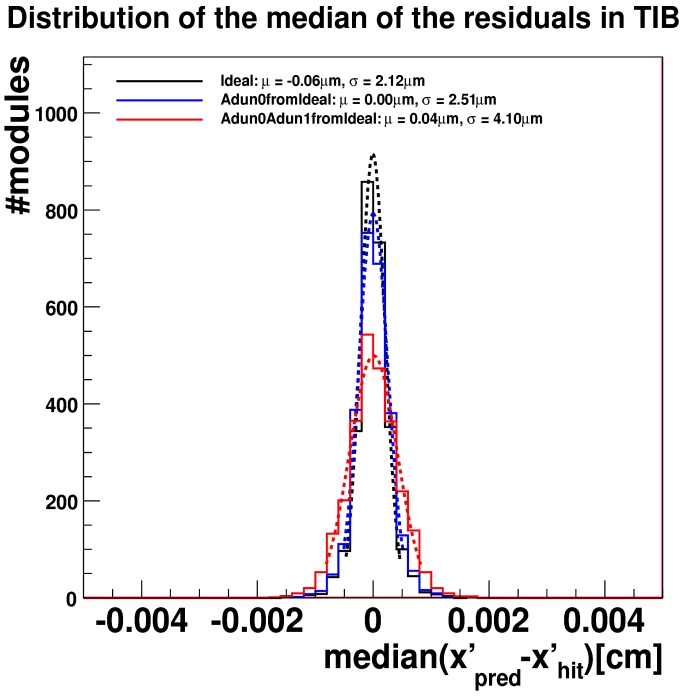
Track Based Validation: Adun Starting from Ideal

- Global χ^2 and the residuals on subdetector-level do not show a large changes

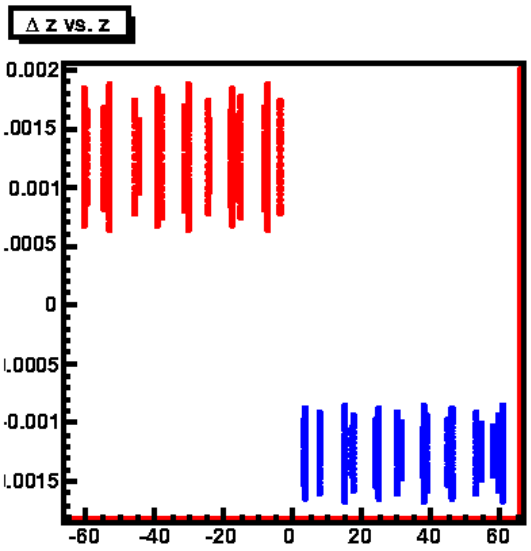




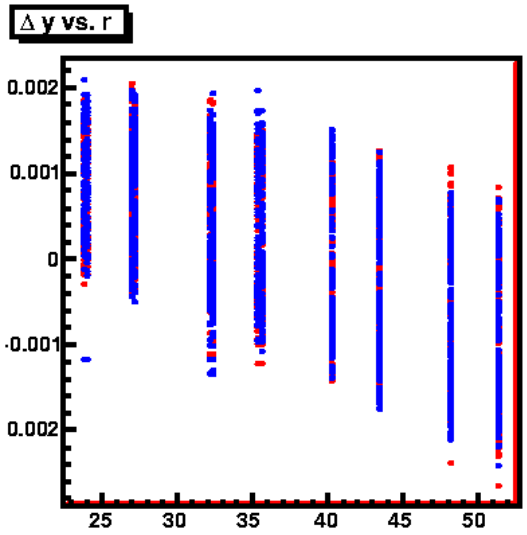
Geometry Comparison Adun1 vs Ideal: TIB

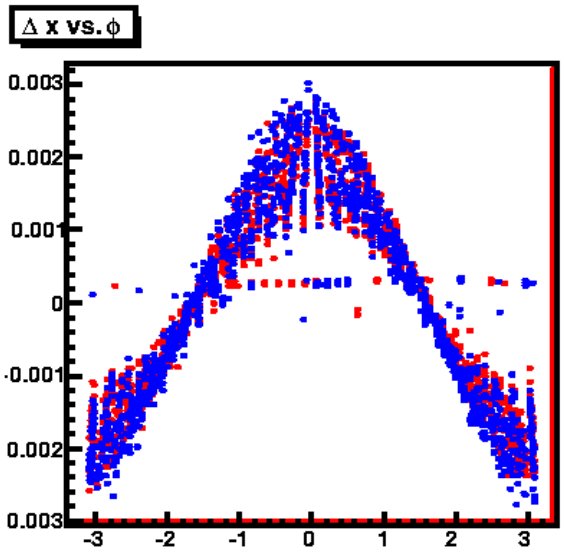


- Distribution of median of the residuals slightly worse for aligned than for ideal geometry in TIB
- Geometry comparison shows small z movement of TIB half barrels but also systematic effects in x,y

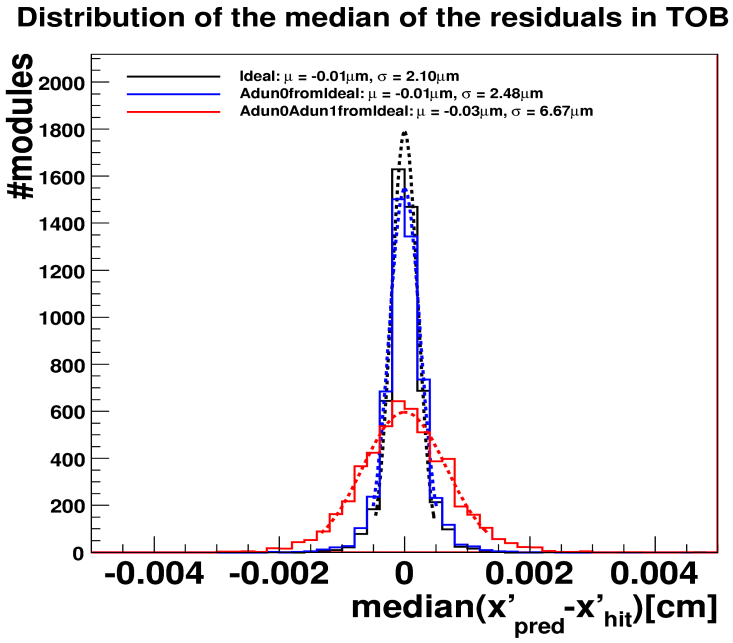


Effect in Δz much smaller 20μm, but additional effects in Δy and Δx

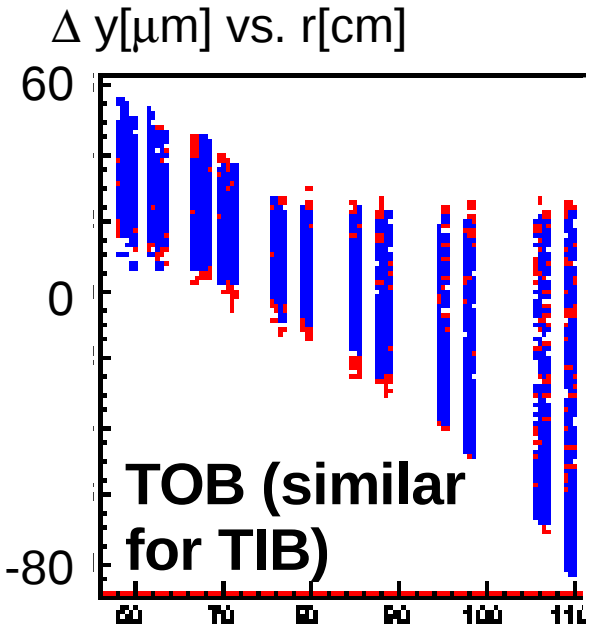


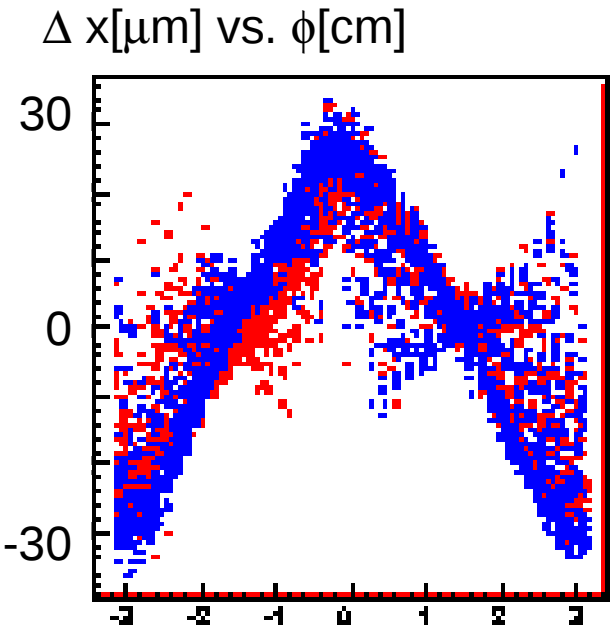


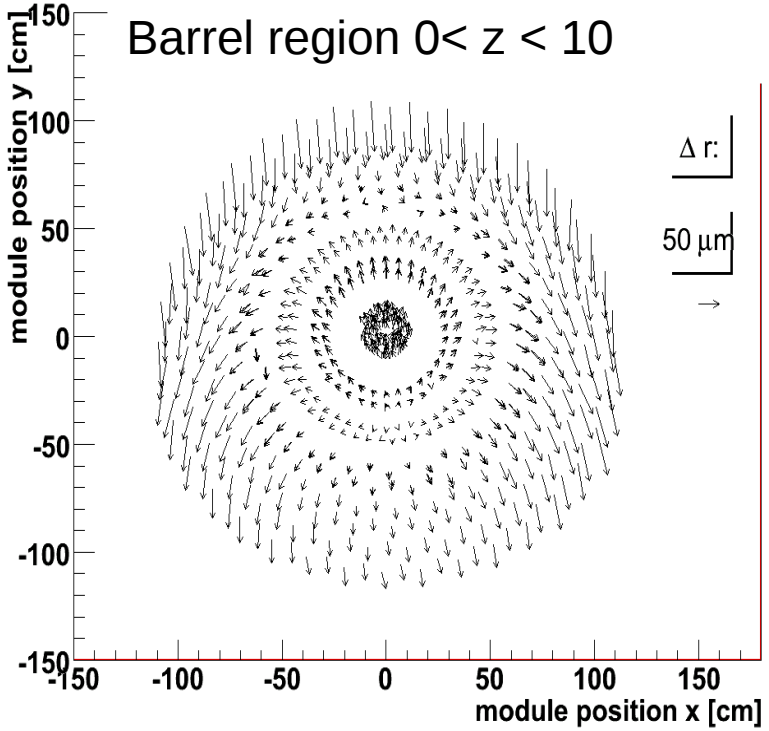
Geometry Comparison Adun1 vs Ideal: TOB



- Distribution of median of the residuals slightly worse in TOB as well
- Geometry comparison shows elliptical distortion in strip Barrel



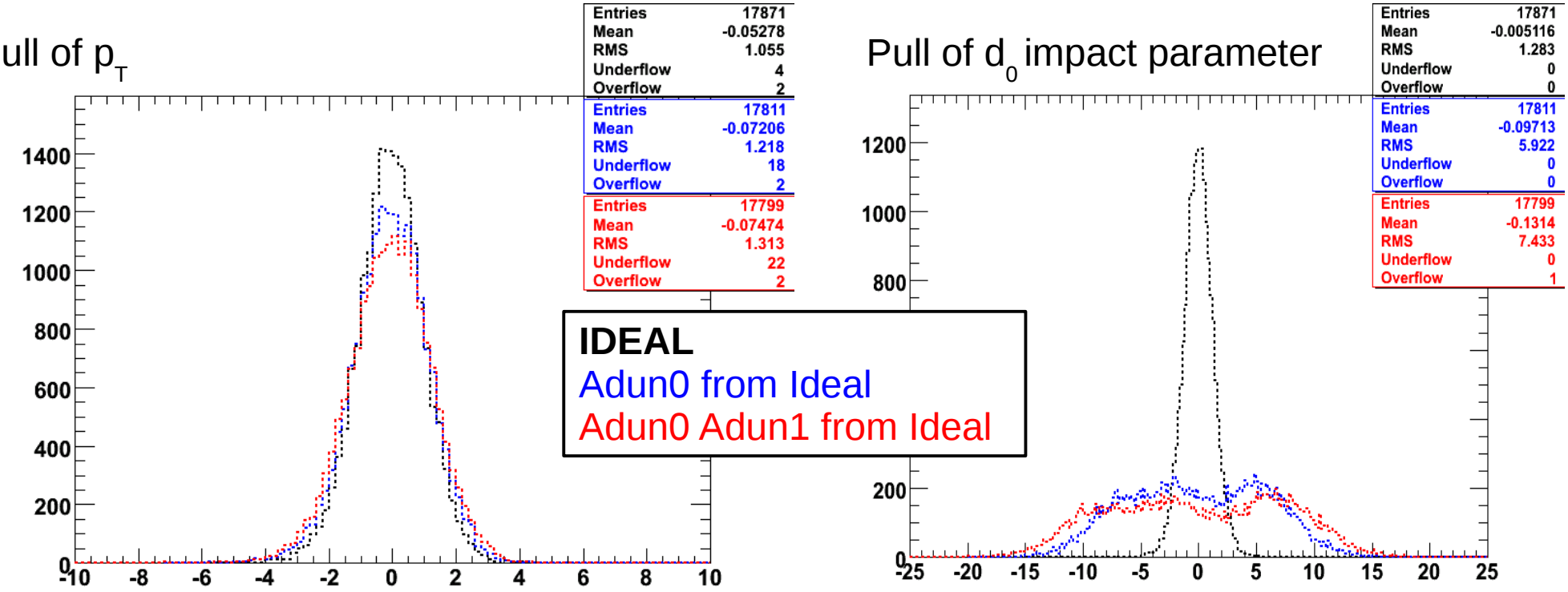




Systematic Distortions

- Consequences on tracking?
- Use tracks of high p_T muons to investigate influence of distorted tracker geometry on tracking parameters

Pull of p_T



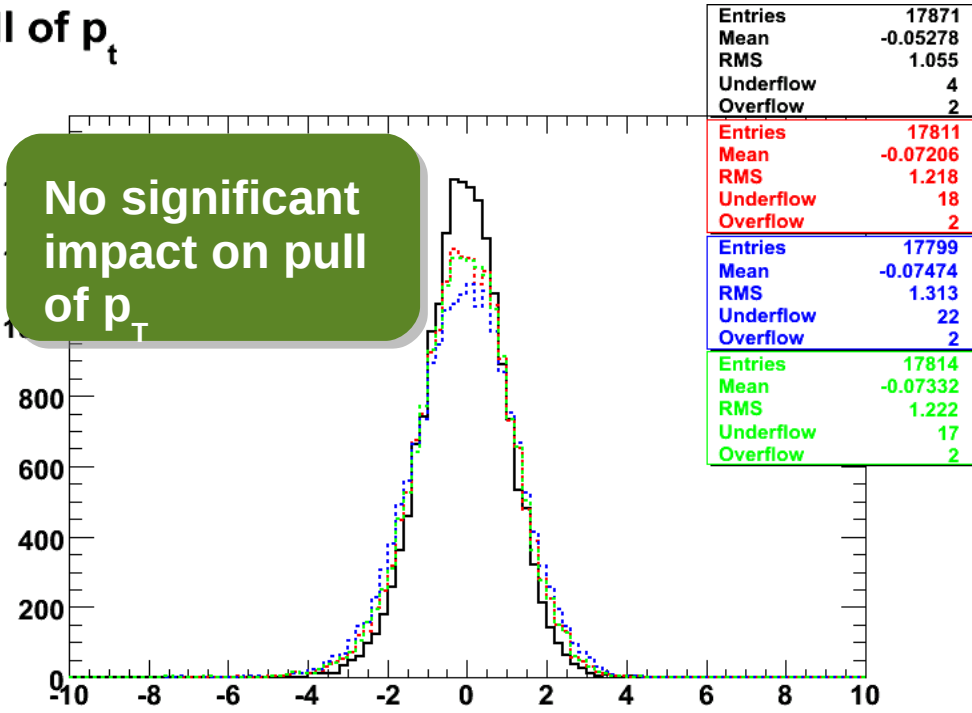
Pull of d_0 impact parameter

→ significant impact on d_0 parameter, p_T rather unaffected

Systematic Distortions: Fixing the Reference System

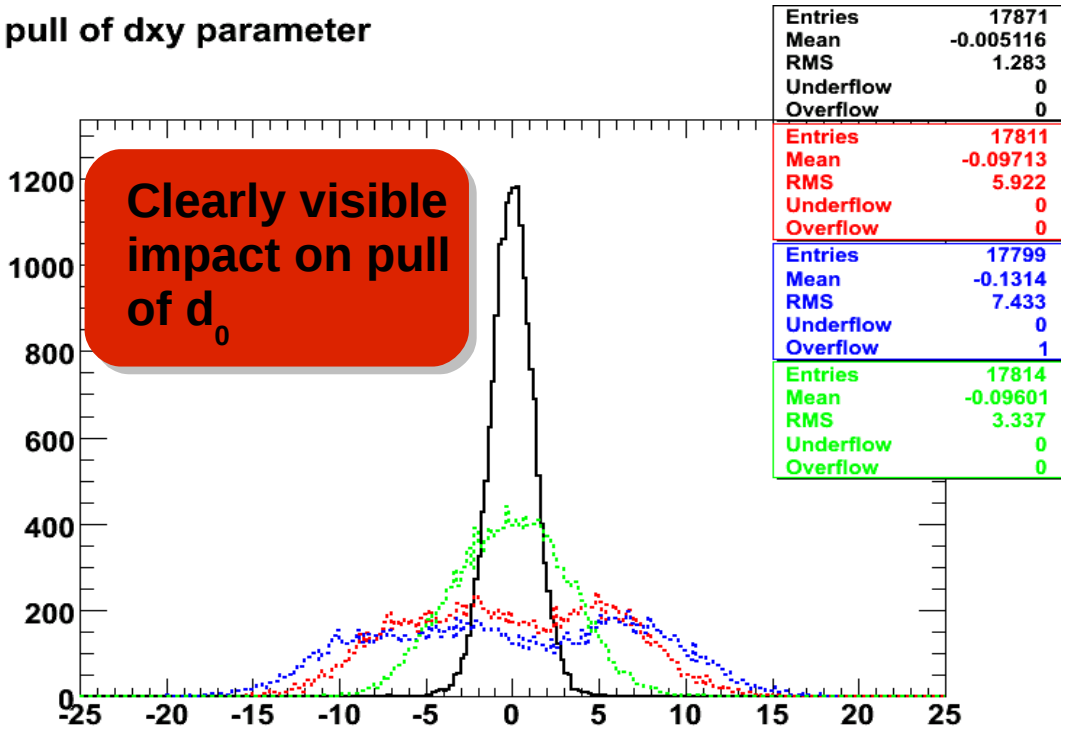
- constraining the overall movement of the TOB Half Barrels to define reference systems

pull of p_t



No significant impact on pull of p_T

pull of dxy parameter



Clearly visible impact on pull of d_0

IDEAL
Adun0 starting from IDEAL
Adun0 Adun1 starting from IDEAL
Adun0 starting from IDEAL TOB reference

Summary of Studies on Simulated Events

- Misalignment can nearly be recovered in terms of χ^2
- Only small sensitivity in z, half barrel movement of TIB recovered/slightly over-corrected
    - Even starting from ideal geometry half shells drift apart by 20 μm
- Elliptical distortions can be attenuated by fixing the reference system (TOB Barrel)

Adun Strategy on CRAFT Data

CRAFT Data From 3rd Reprocessing

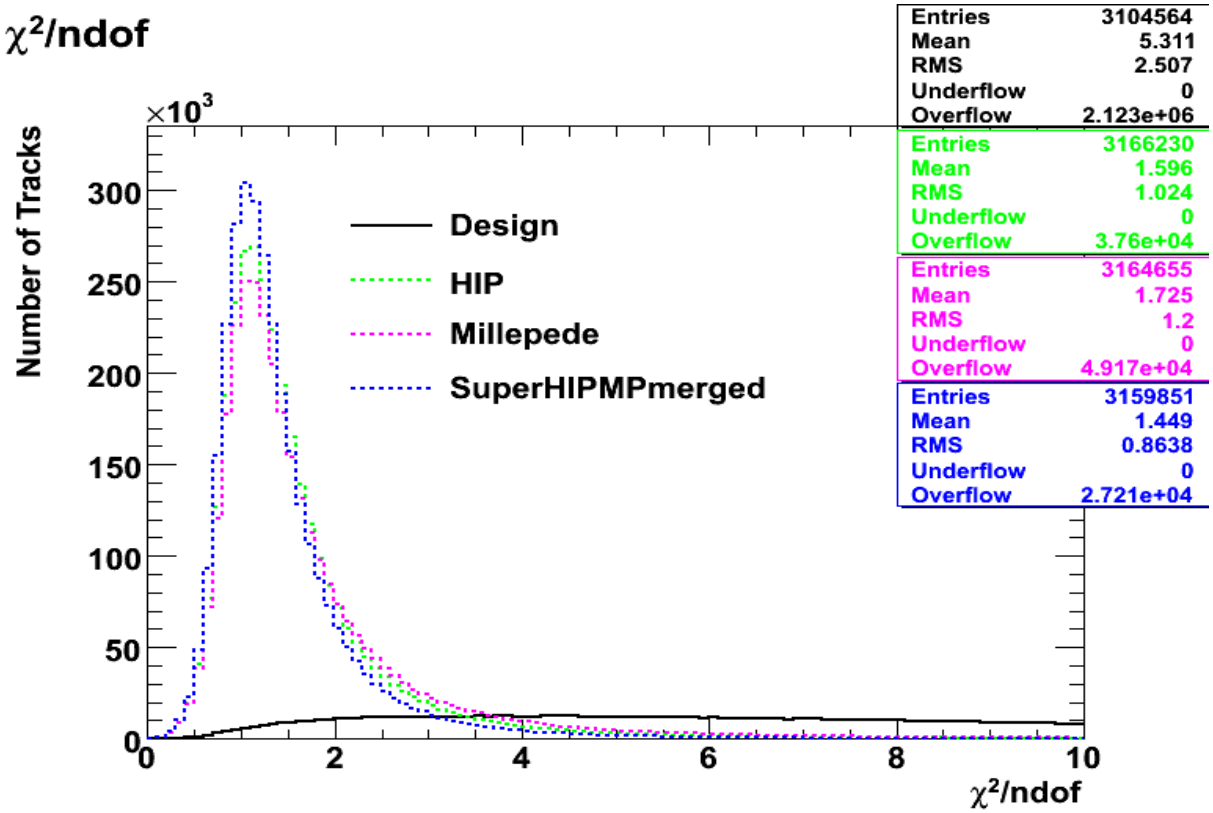
- Data of 3rd reprocessing shows better performance due to former alignment and calibration procedures
- + corrected cabling maps in TPE and TEC
- Increased number of pixel hits due to correction of Alignment Positioning Error (APE, important for pattern recognition) in Pixel, still only few hits in TPE (at least 20 hits)

➔ About 3Mio tracks after standard cuts:

  - At least 10 hits per track
  - 2 hits on 2d-modules
  - p_{min} = 5GeV

Track Based Validation

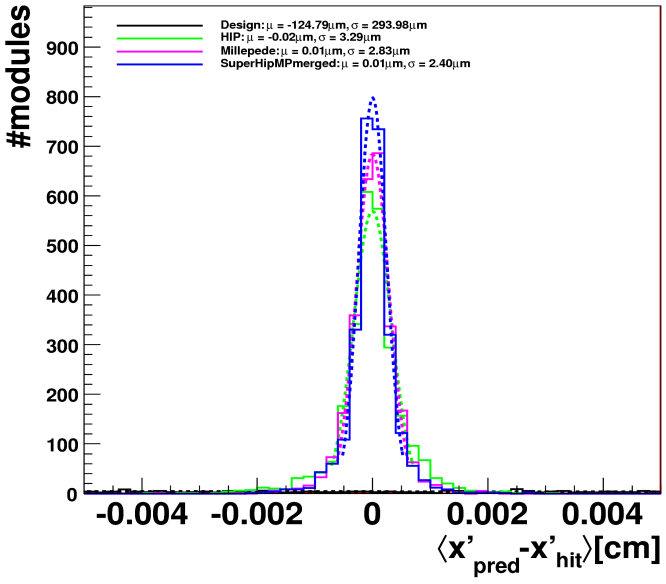
- MP aligning with Adun strategy (Aachen/Torino)
- HIP: local alignment done iteratively, all 6 degrees of freedom for all modules (Johns Hopkins)
- SuperHIPMPmerged: HIP alignment starting from MP Adun geometry



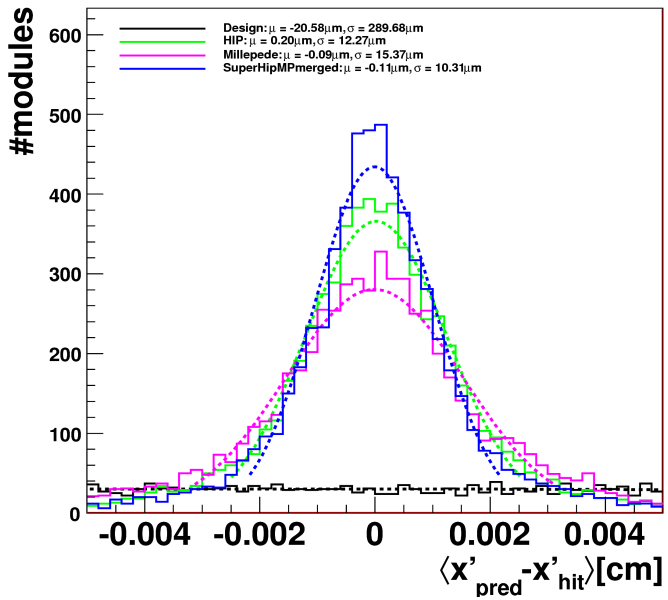
- **Best performance by SuperHIPMPmerged**
- **MP limited by number of parameters (not all modules aligned ~97%)**

Distribution of the Mean of the Residuals CRAFT

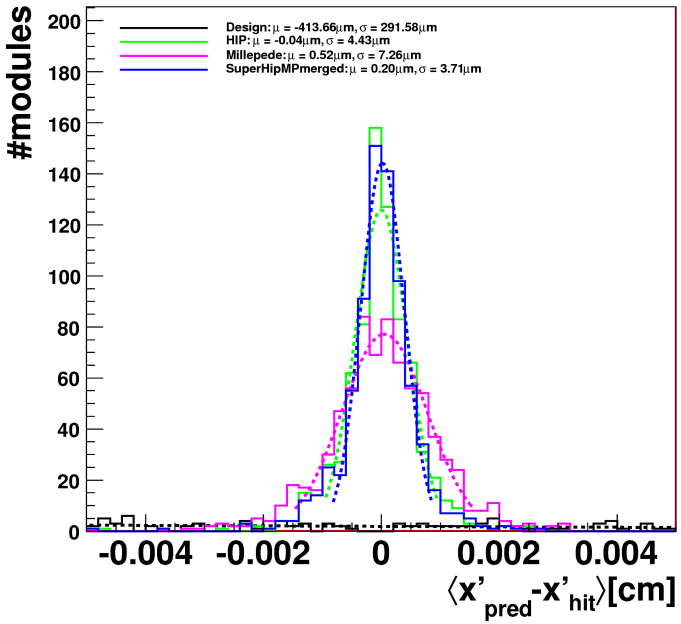
Distribution of the mean of the residuals in TIB



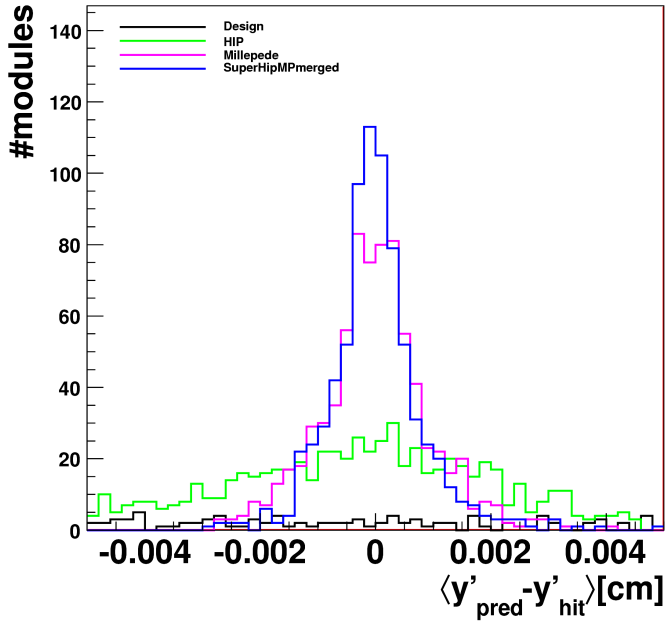
Distribution of the mean of the residuals in TEC



Distribution of the mean of the residuals in TPB



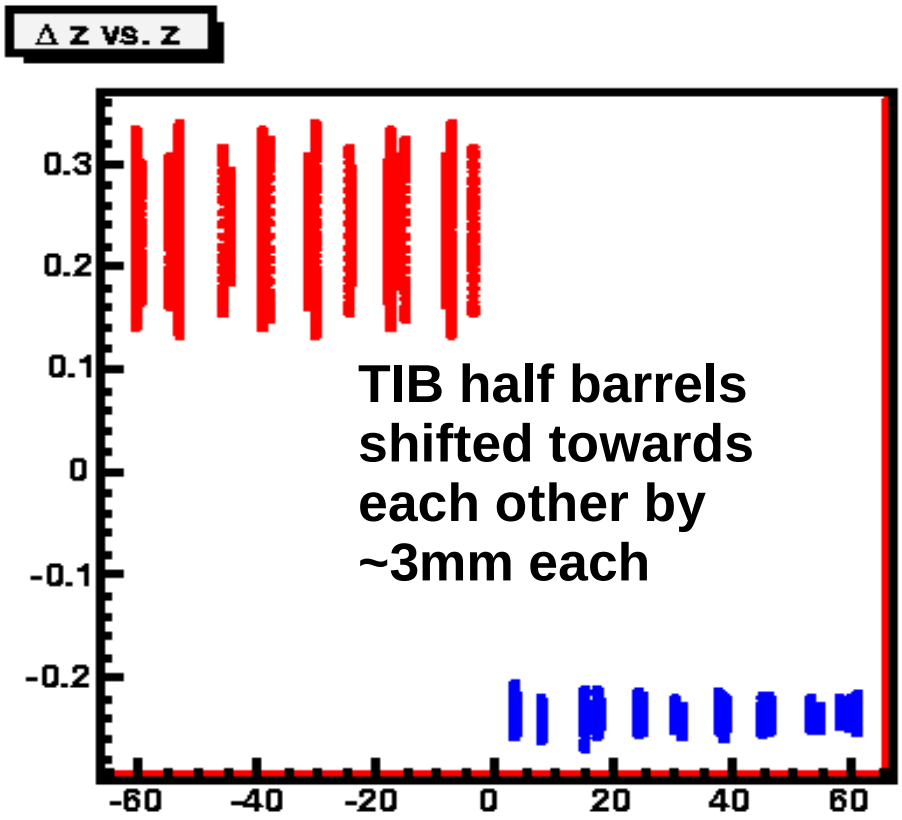
Distribution of the mean of the residuals in TPB

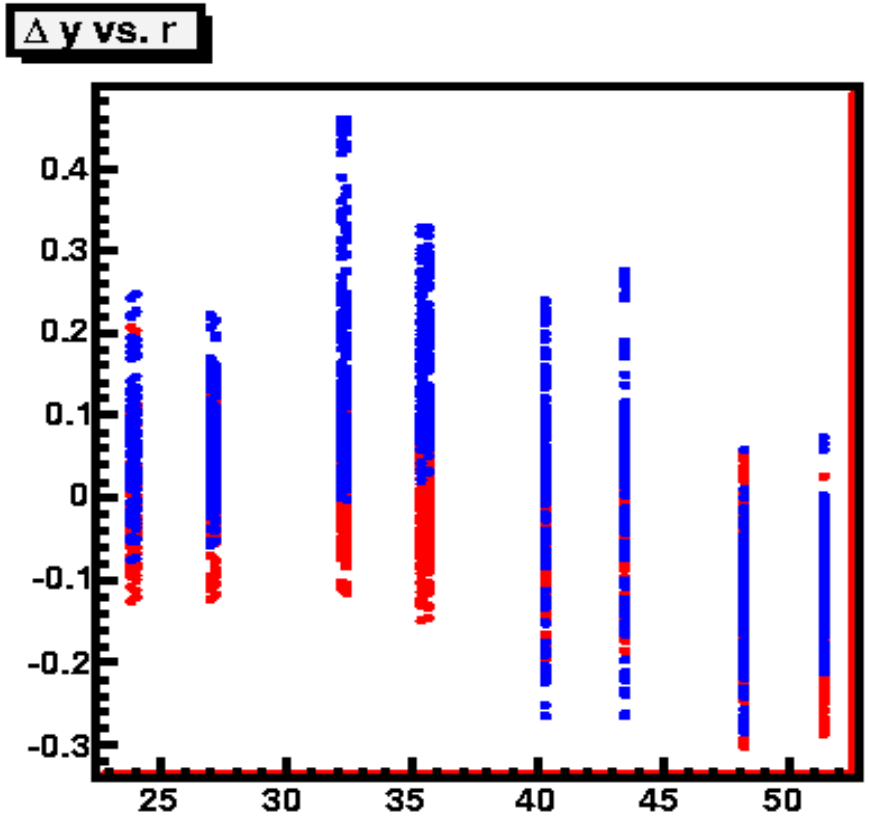


- MP looses some modules in the TEC due to harder hit cut (to decrease number of parameters) → performance in TEC slightly worse than HIP
- MP significantly better than HIP in Y residuals in TPB

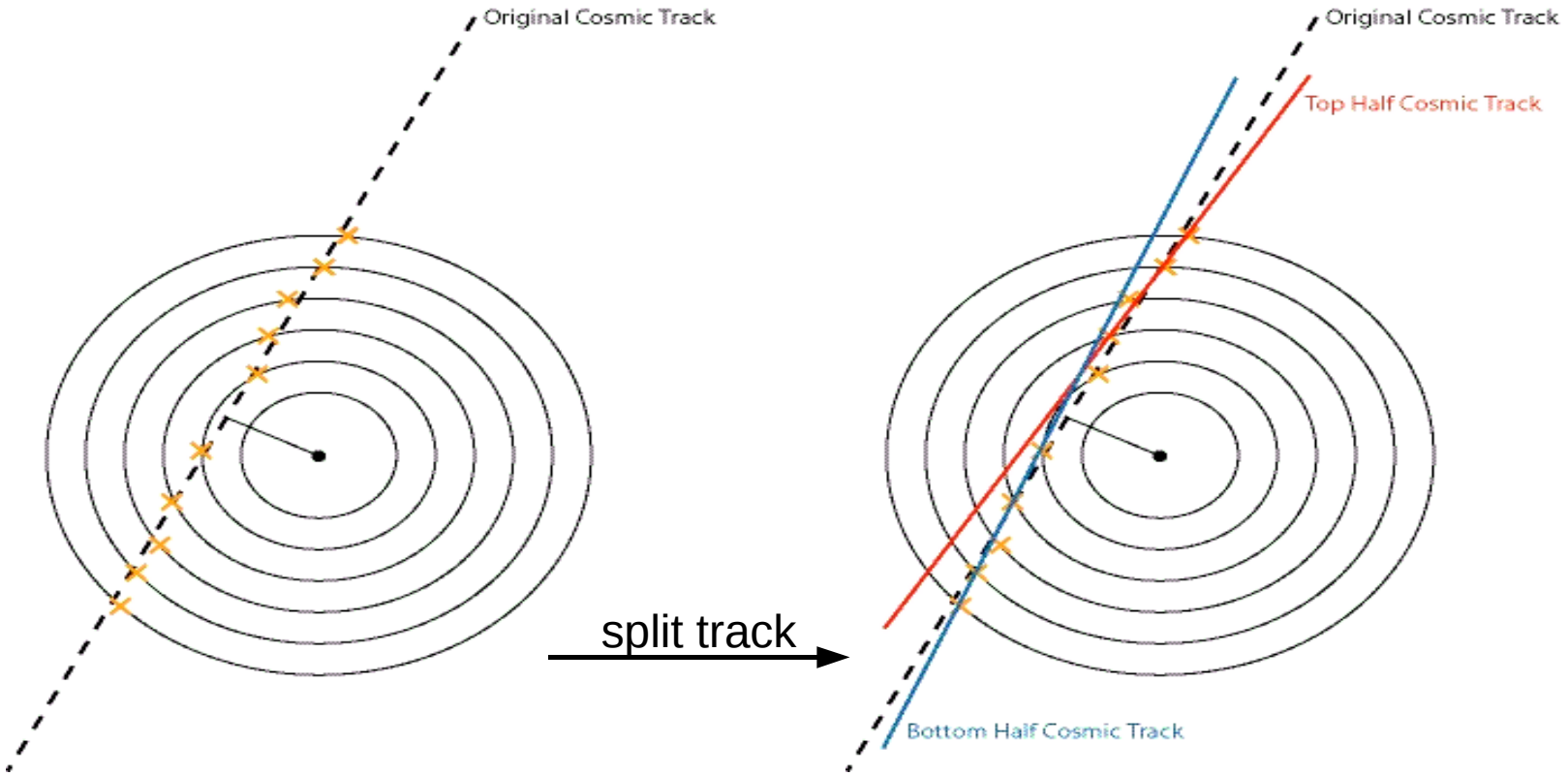
Geometry comparison CRAFT Adun

- Adun Alignment compared to Design (HIP sees the same but not that large ~2mm effect + correlated distortions in TPB)
- Movement of 2 TIB half barrels physical?
- Small quenching effect in y visible as before in simulation





CRAFT Validation: Track Splitting

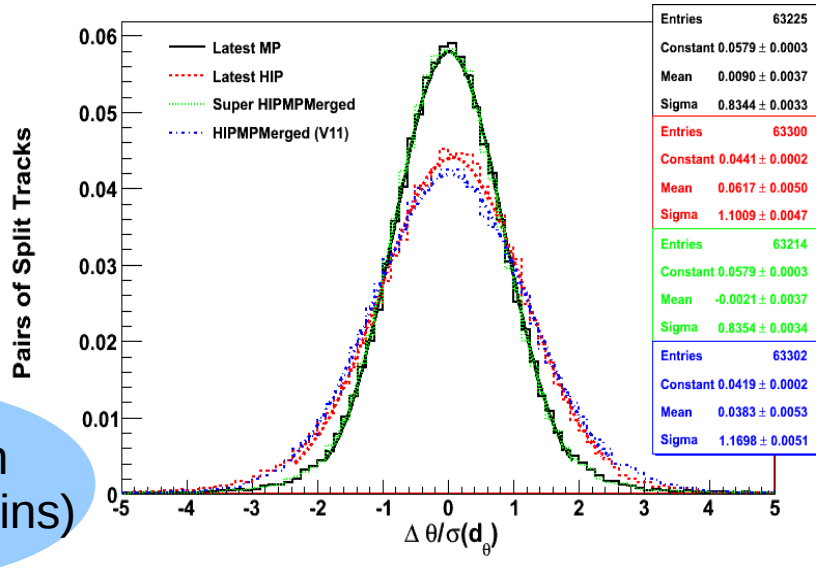


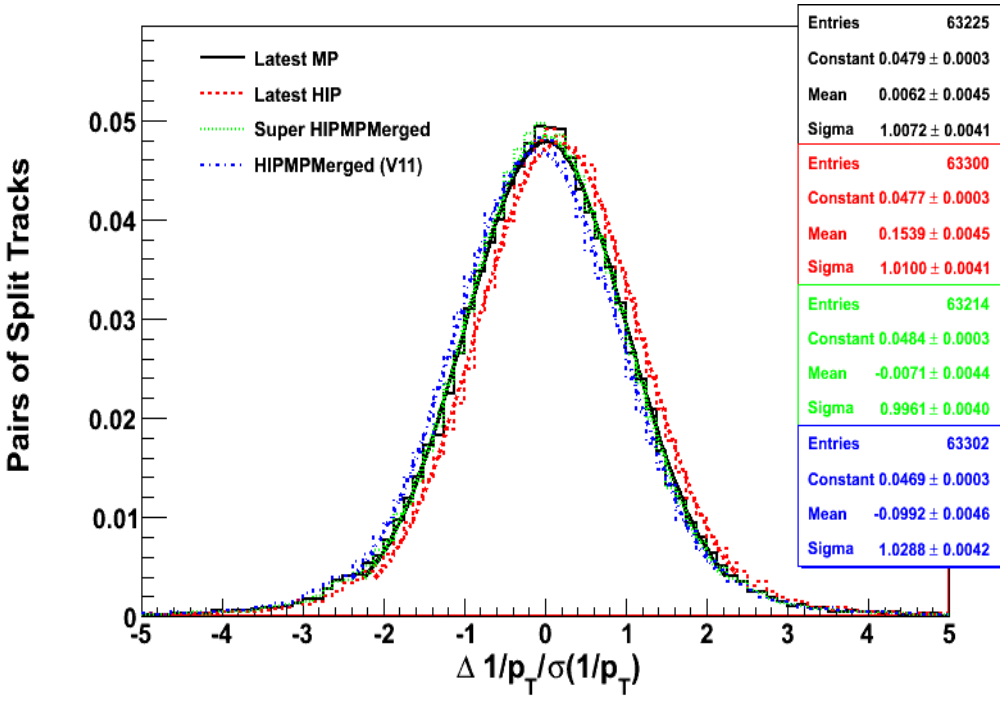
- Split cosmic track along distance of closest approach to beamline
- Fit top and bottom part separately and compare resulting track parameters

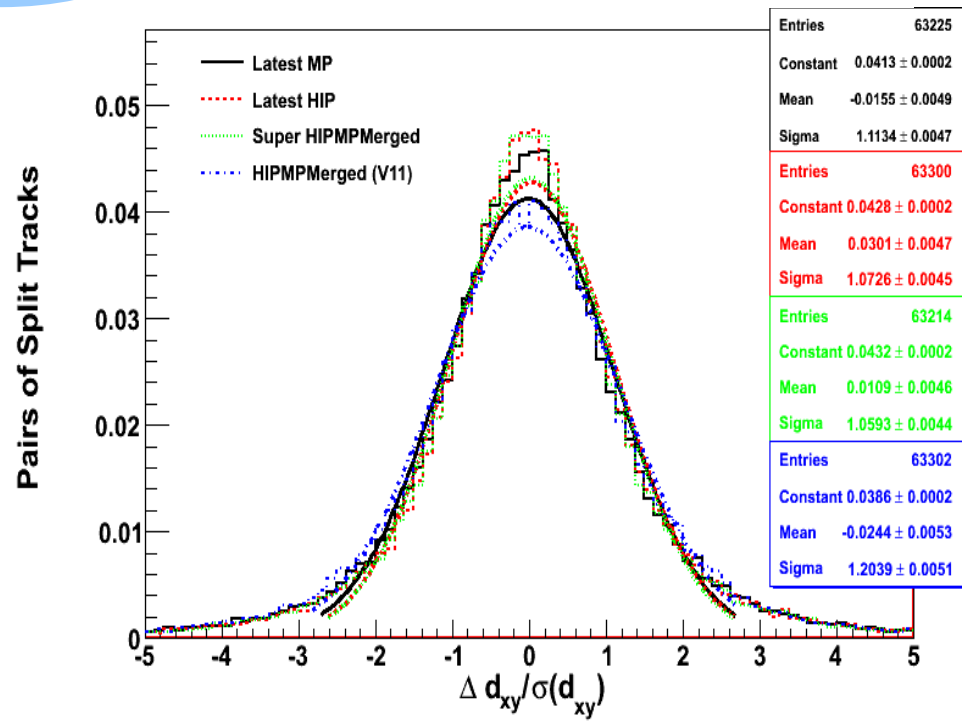
Track Splitting Results

- Very similar behaviour of difference in track parameters except for $\Delta\theta$ → MP and SuperHIPMPmerged have larger z-movement of half barrels in TIB

Nhan Tran
(Johns Hopkins)







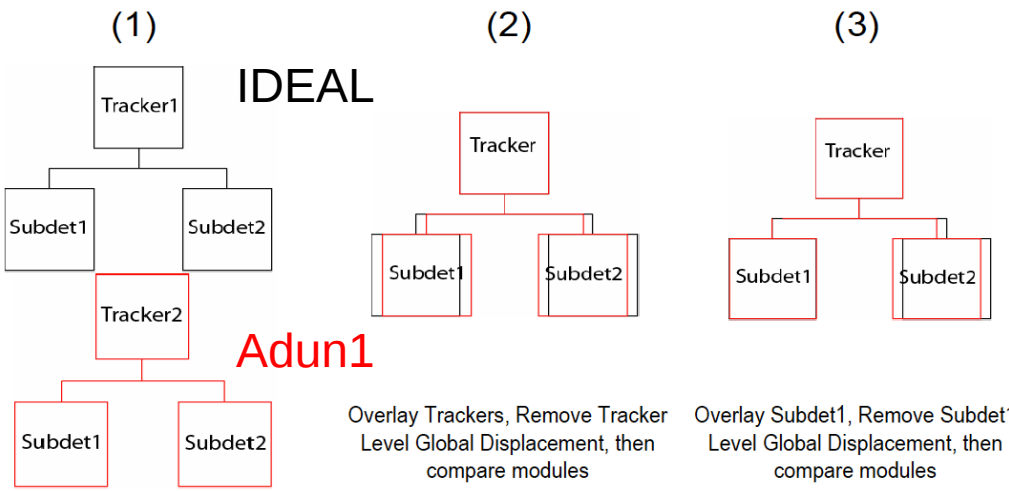
Conclusion/Outlook

- Stand alone alignment with about 3.9 Mio. tracks from cosmic muons already allows a good alignment in most of the detector regions
- Separate alignment of 2d-module units improves the alignment results a lot and is integrated in both alignment strategies
  - Posing problem in due to parameter limit in current pede executable (being fixed by Blobel)
- Coherent results from both algorithms (HIP and MP) + best performance achieved by combining the two (SuperHIPMPmerged)
    - in terms of χ^2 and residuals, no statistical limitation in strip barrel region

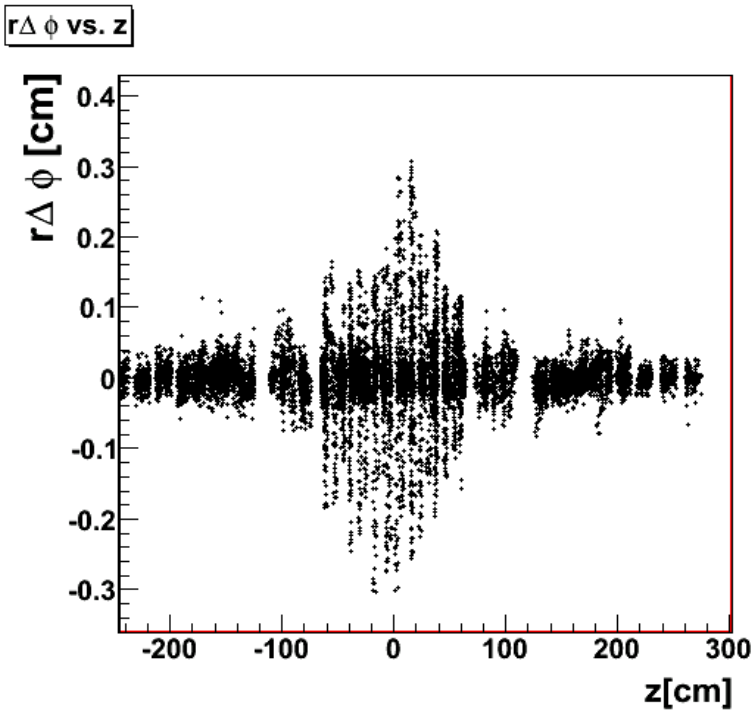
Conclusion/Outlook

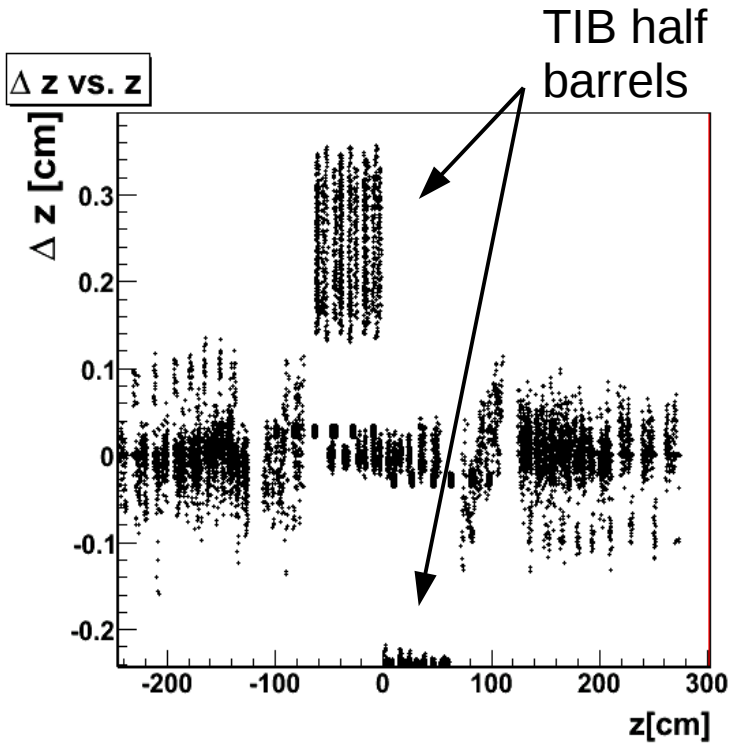
- χ^2 invariant modes:
  - Simulation: for Adun starting from misalignment TIB half barrel movement over-corrected by 1 mm in non-sensitive coordinate z
  - simulation: elliptical distortion using MP Adun starting from IDEAL → fixing reference system can help
    - Check also trajectory model
  - Data: large movements of the TIB half barrels → seen by both algorithms: real or fake?
  - Track splitting shows no big differences between the algorithms except for $\Delta\theta$ which is correlated to the z movements in TIB
- Redo exercise for CRAFT09 coming soon
- Need of complementary data coming from the beamspot

Geometry Comparison Starting Geometry vs Ideal



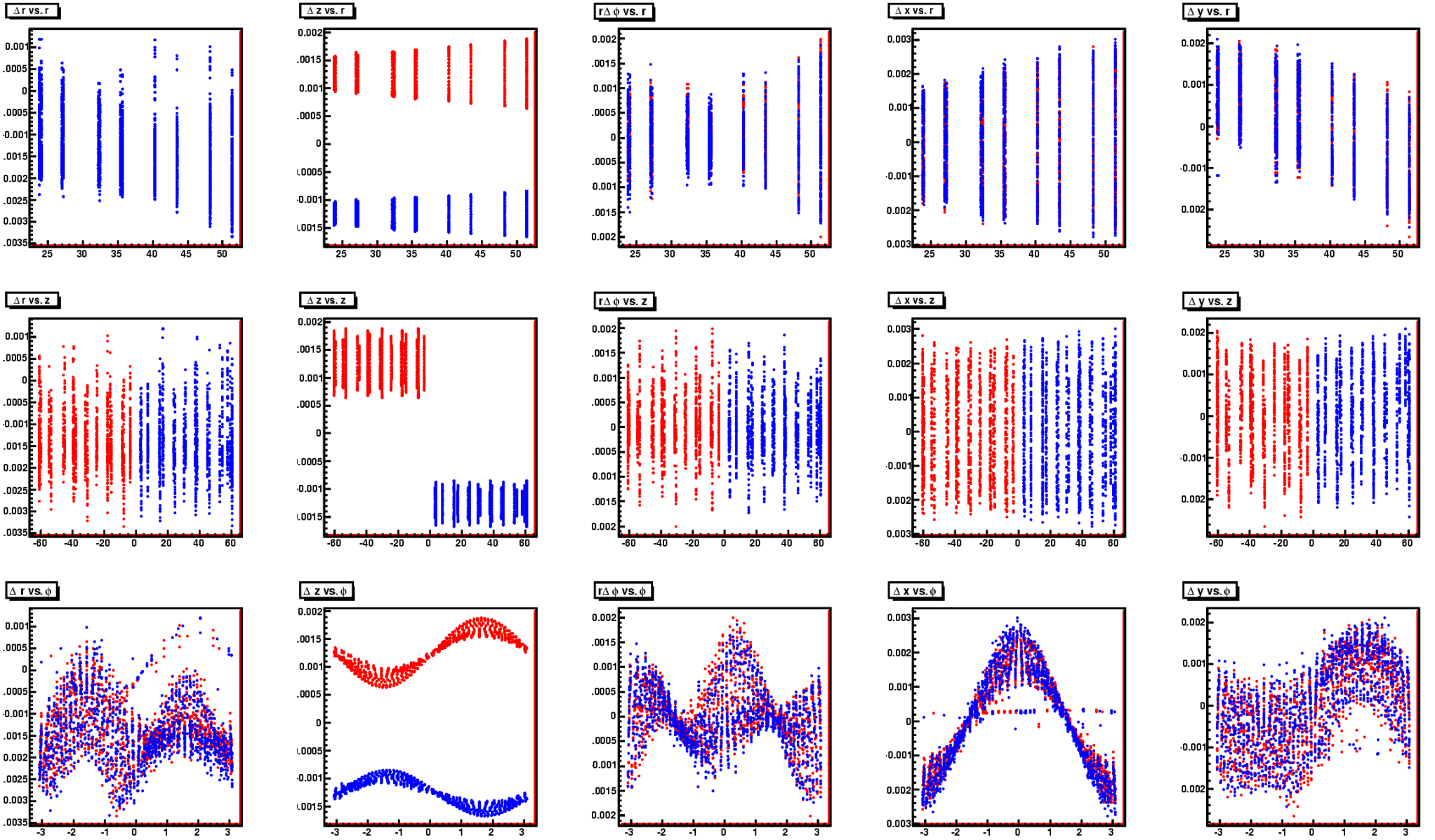
- Overlay detector, then subdetectors, remove global shifts to investigate module movement within the subdetector



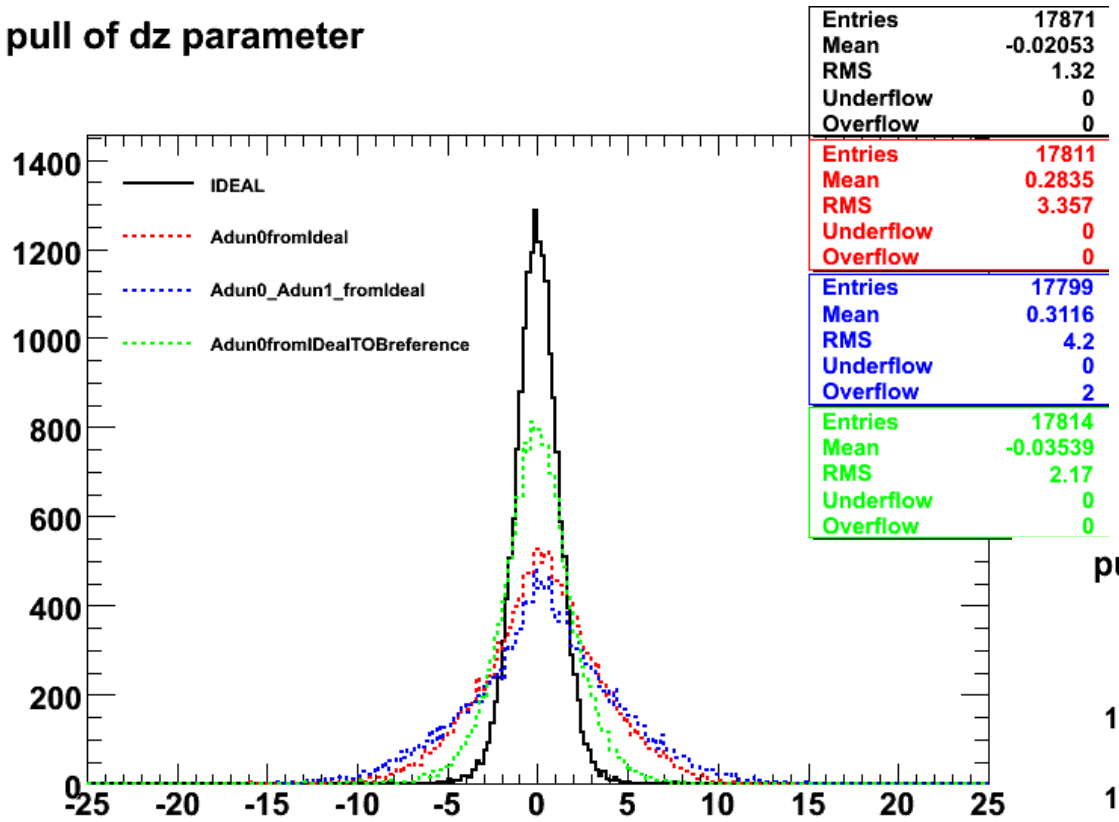


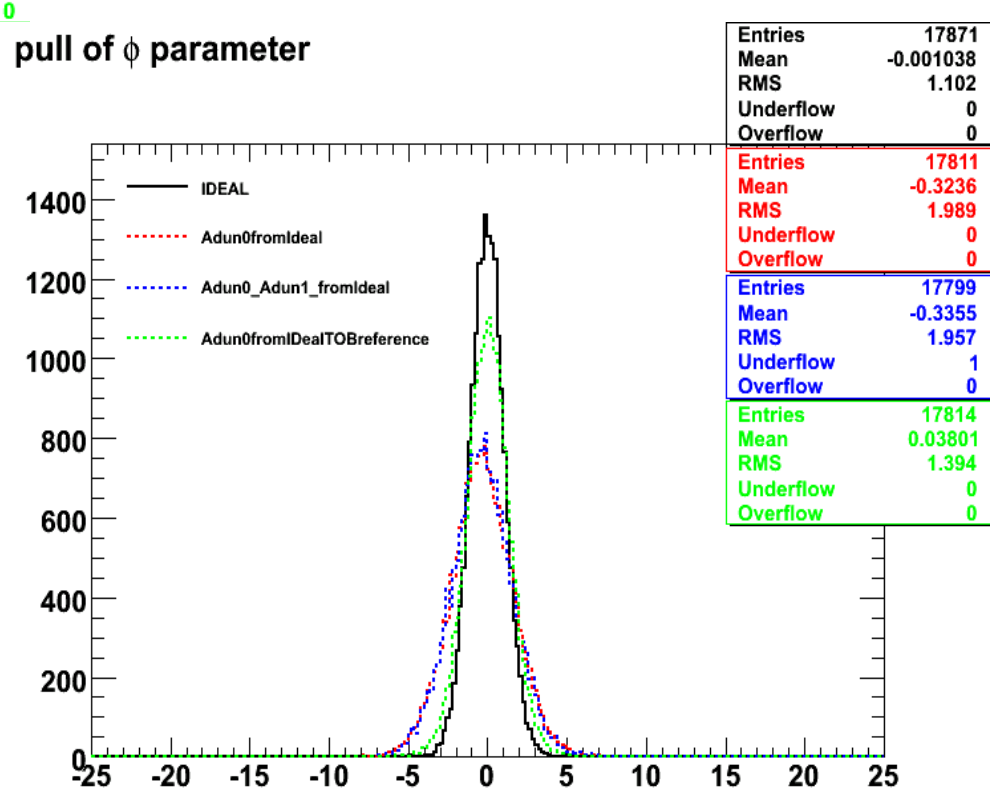
- Starting Geometry: rΔphi-misalignment of up to 3 mm in TIB, else <1mm
- Shift in Δz of the 2 TIB half barrels towards each other

Backup: Geometry comparison MC Adun 1 vs Ideal:TIB



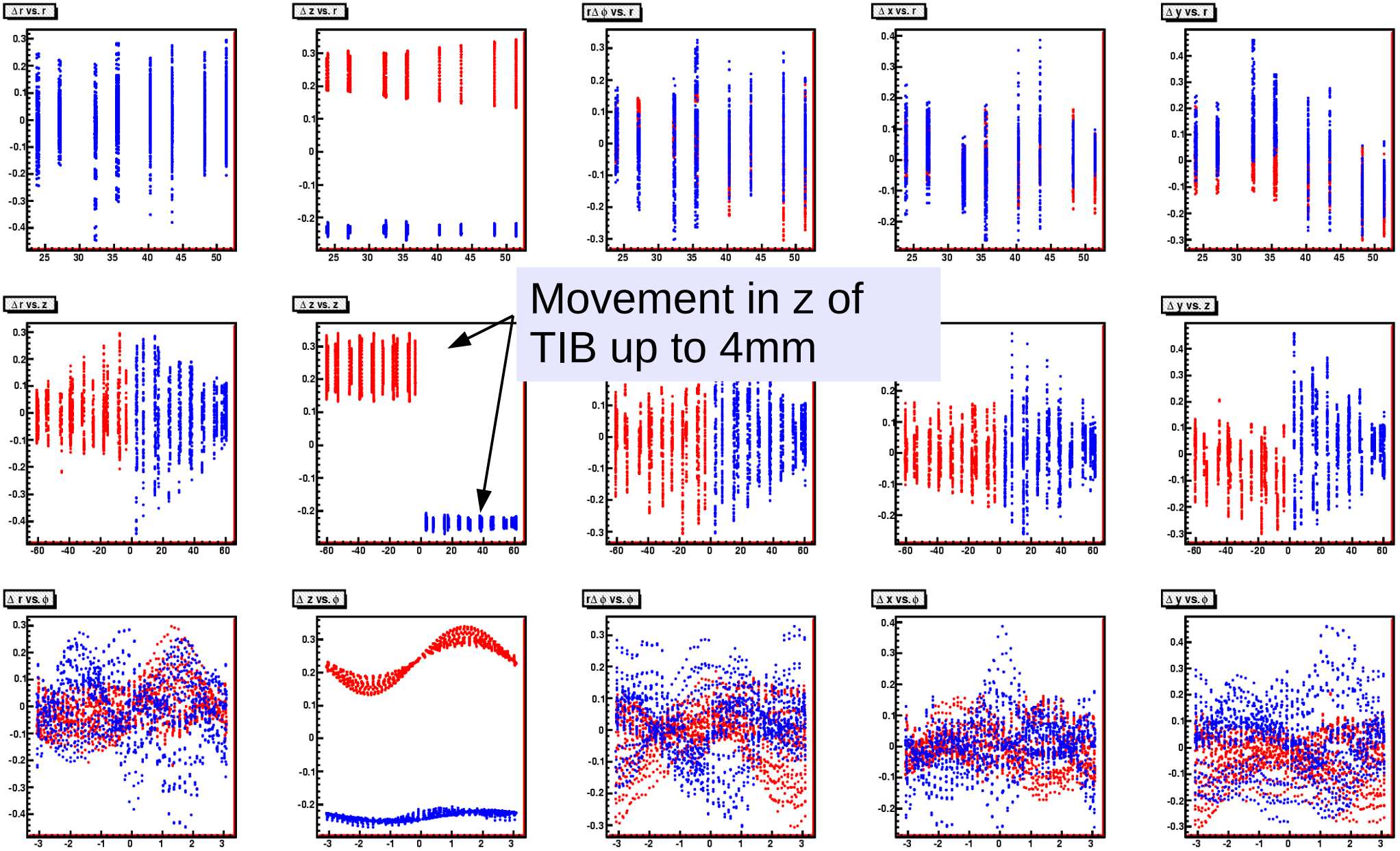
Backup: MC Validation Adun strategy



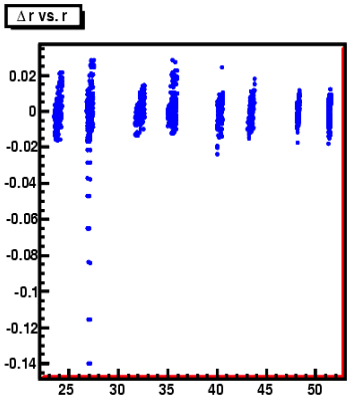


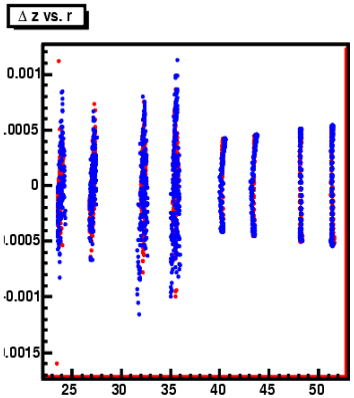
Impact also on pull of dz and pull of phi parameter

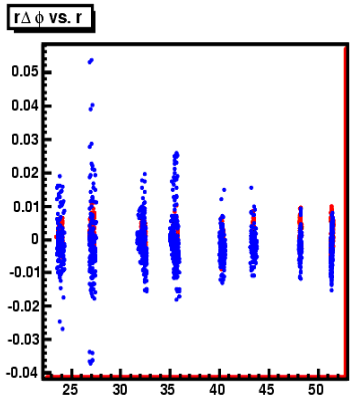
Backup: Adun1 vs Design (Common subdets):TIB

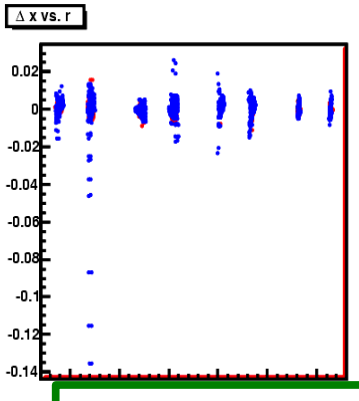


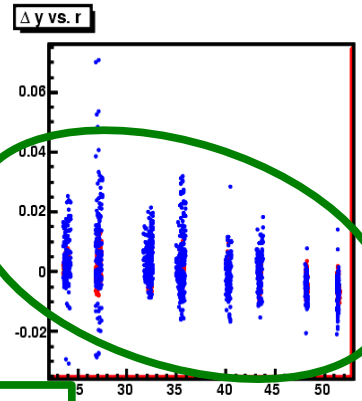
Backup: Adun1 vs Adun0 (Common SubDets): TIB



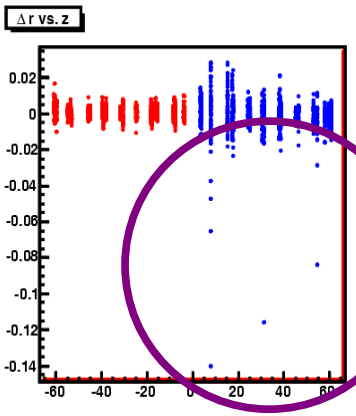


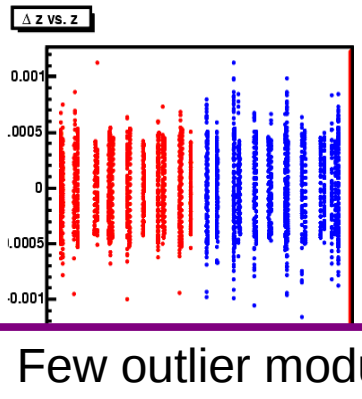


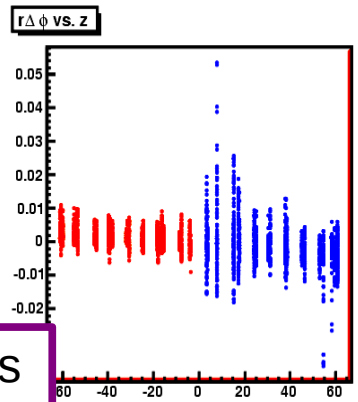


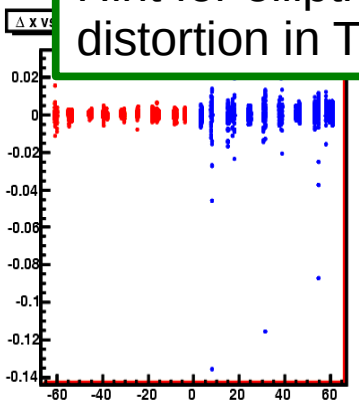


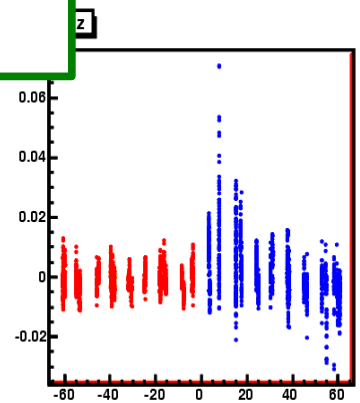
Hint for elliptical distortion in TIB



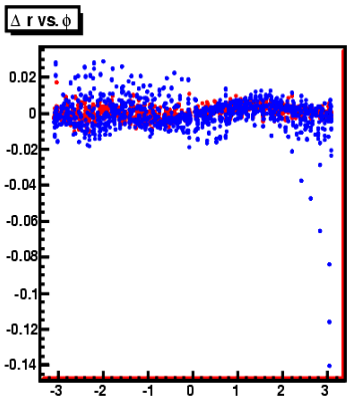


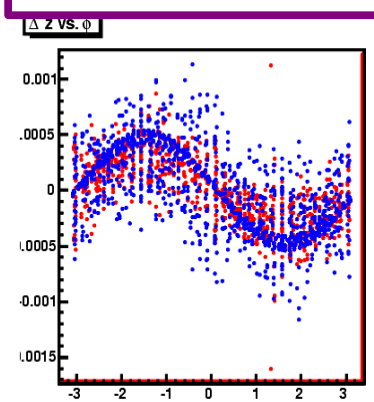


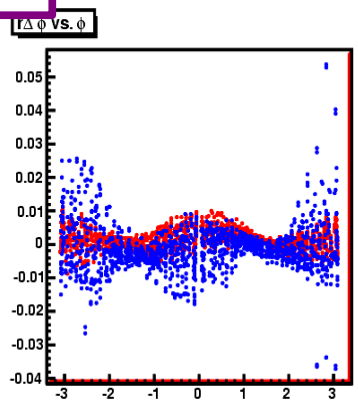


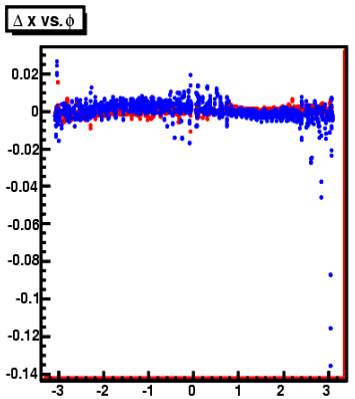


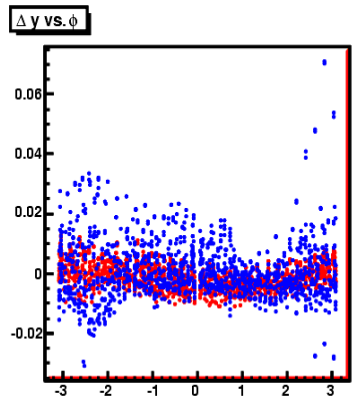
Few outlier modules introduces in step 1



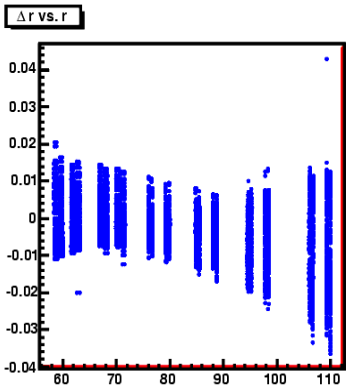


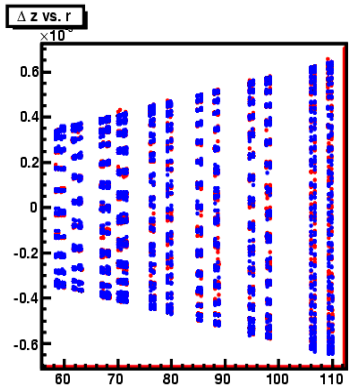


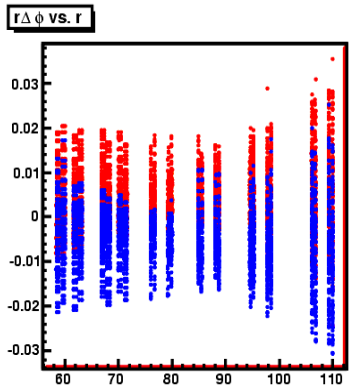


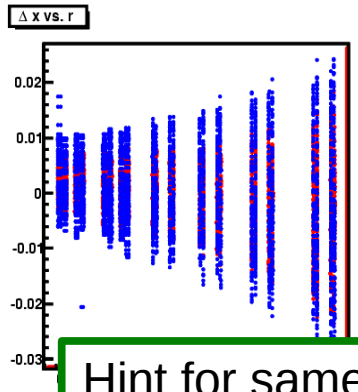


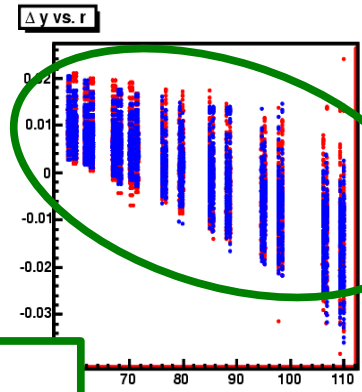
Backup: Adun1 vs Adun0 (Common SubDets): TOB

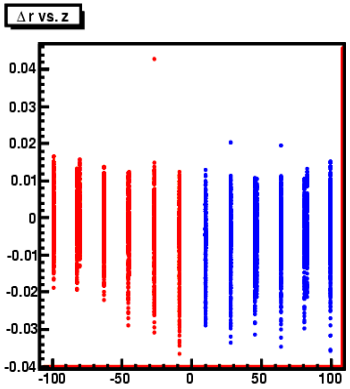


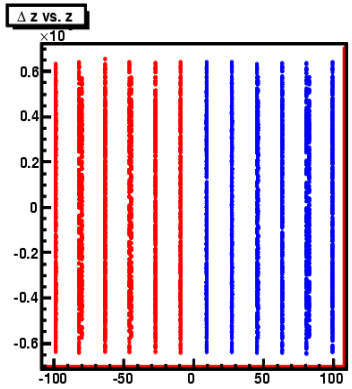


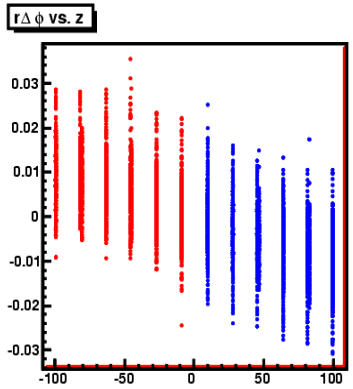


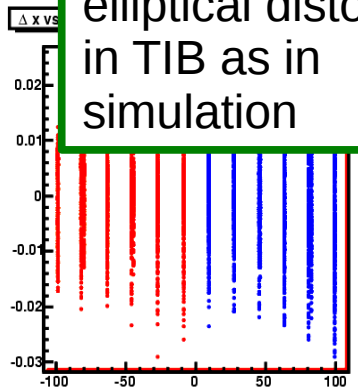


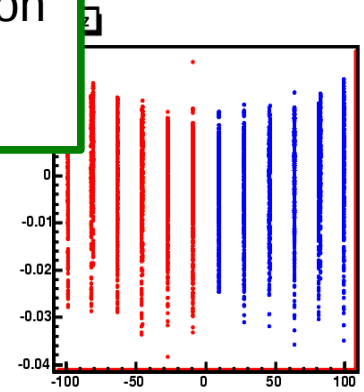


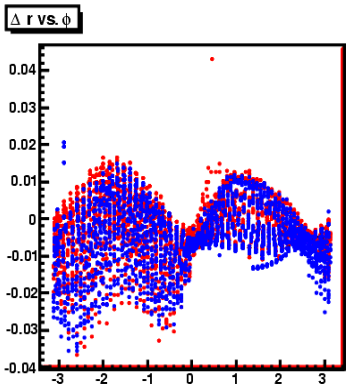


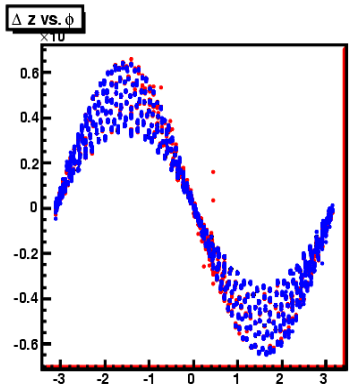


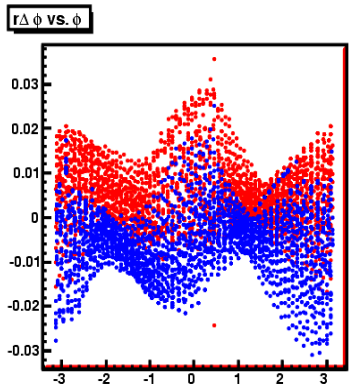


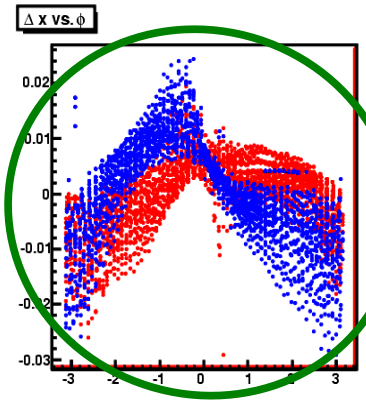


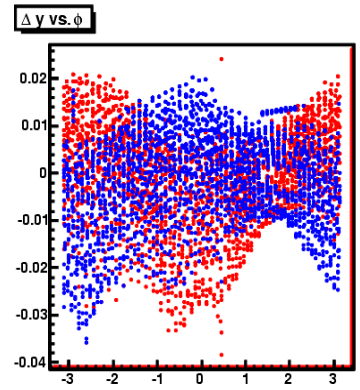






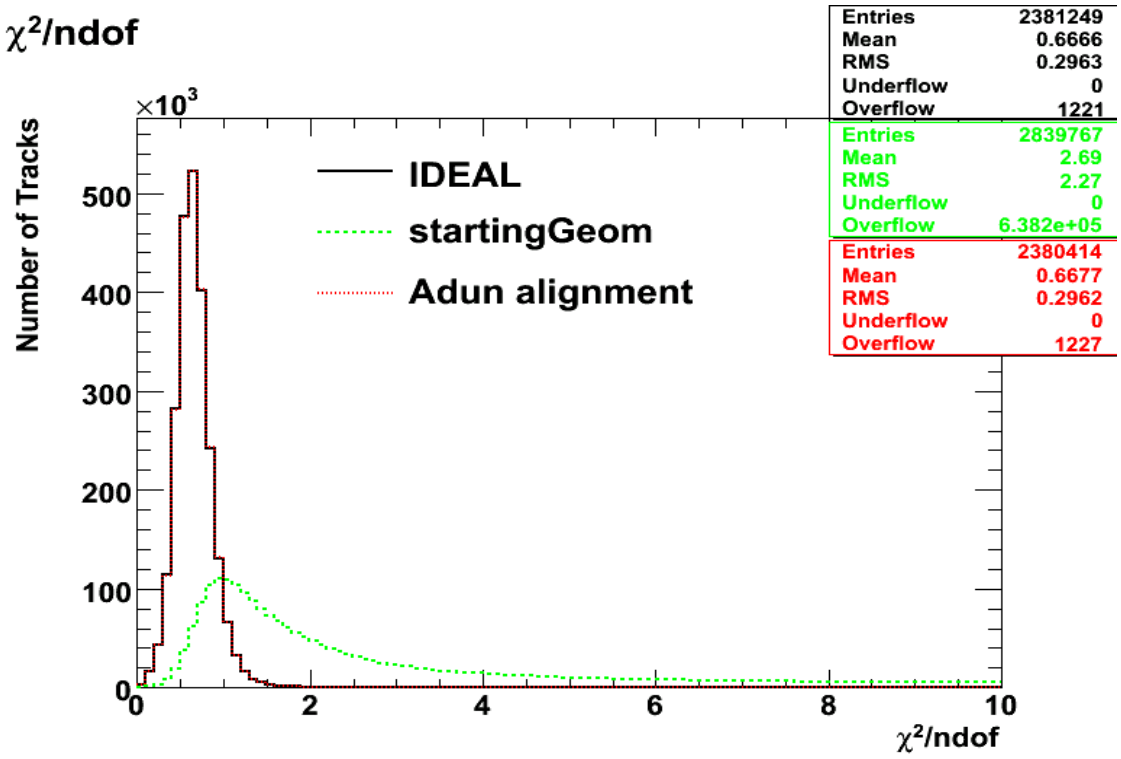


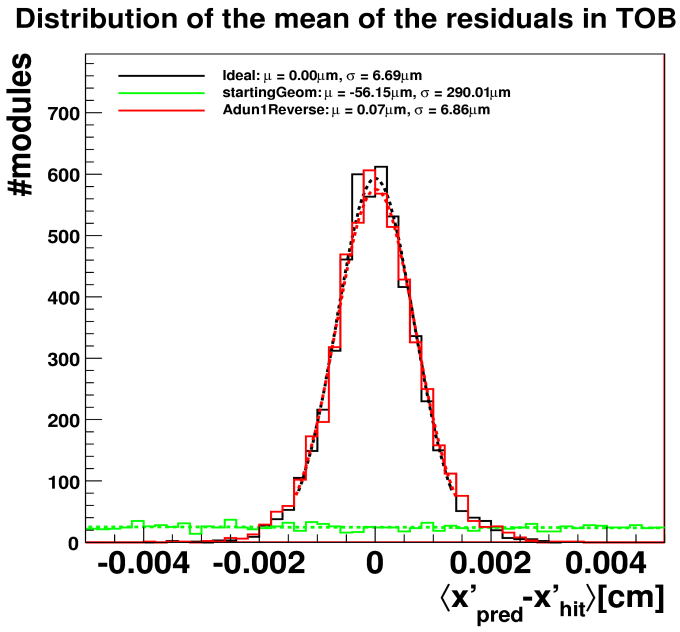


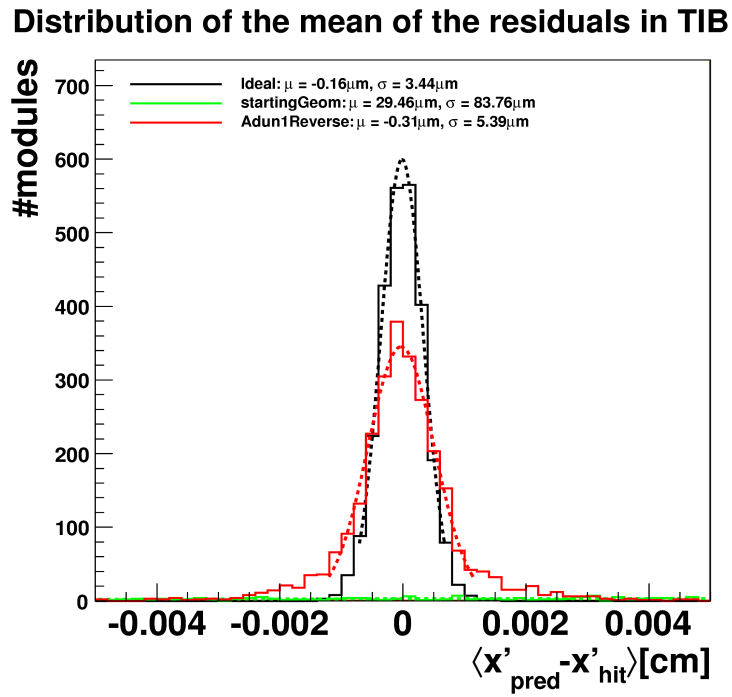


Hint for same elliptical distortion in TIB as in simulation

Backup: Adun Studies on Simulated Data

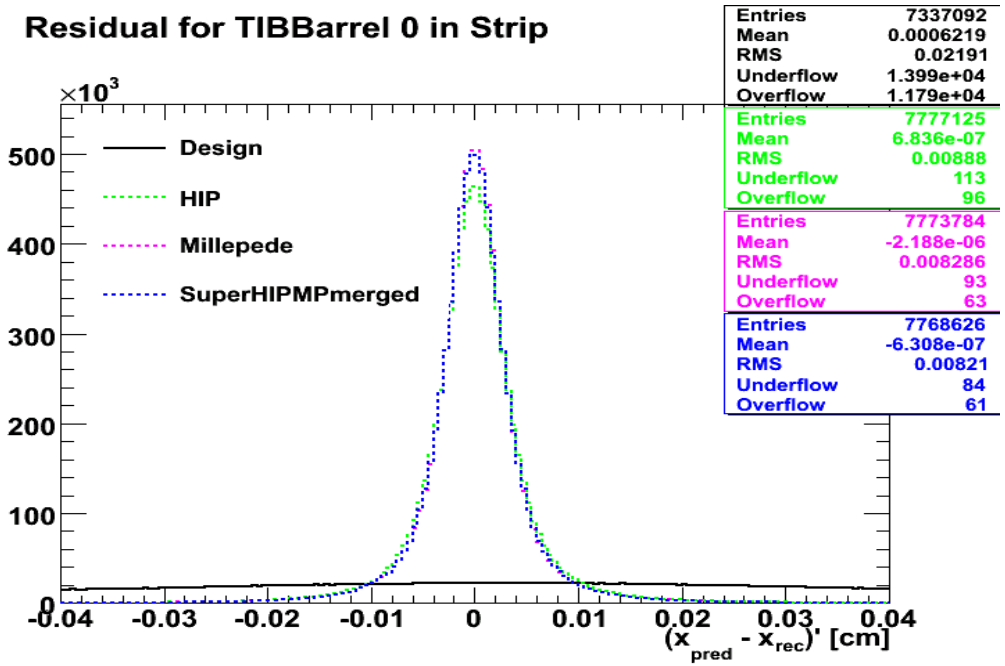


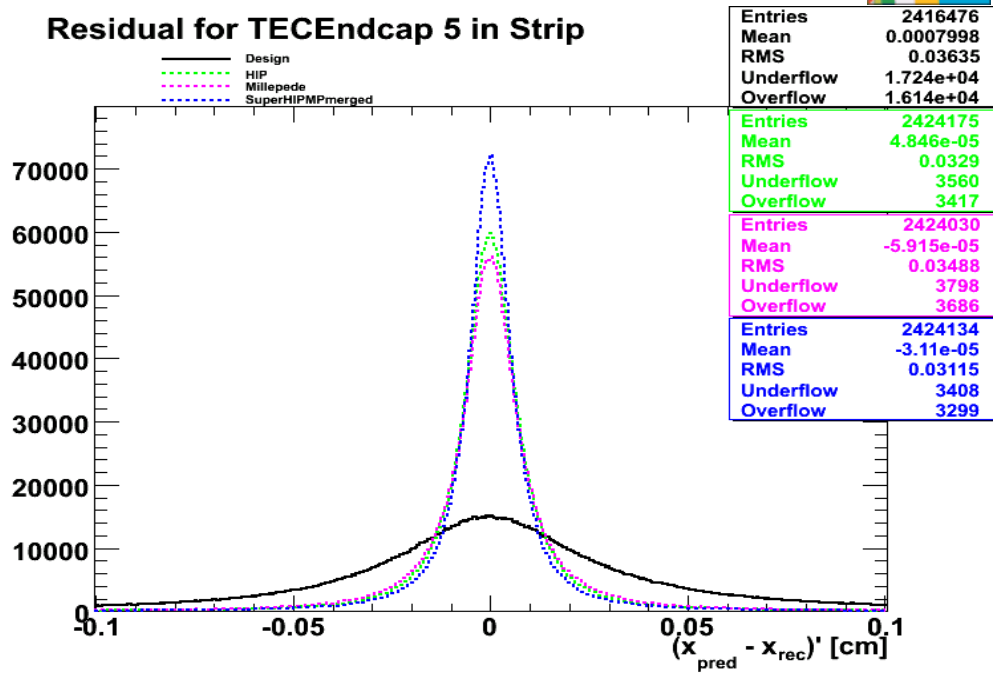


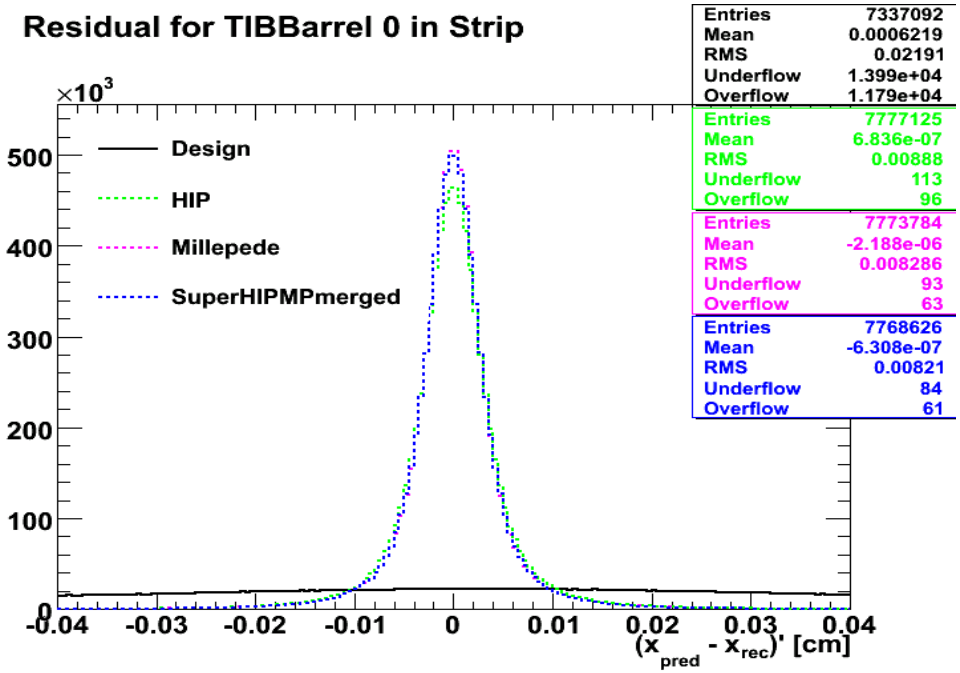


- Nearly complete recovery in χ^2
- distribution of mean of the residuals on module level differs significantly in TIB for IDEAL and aligned object ($\Delta\sigma$=2μm)

Residual Distributions on Subdetector Level

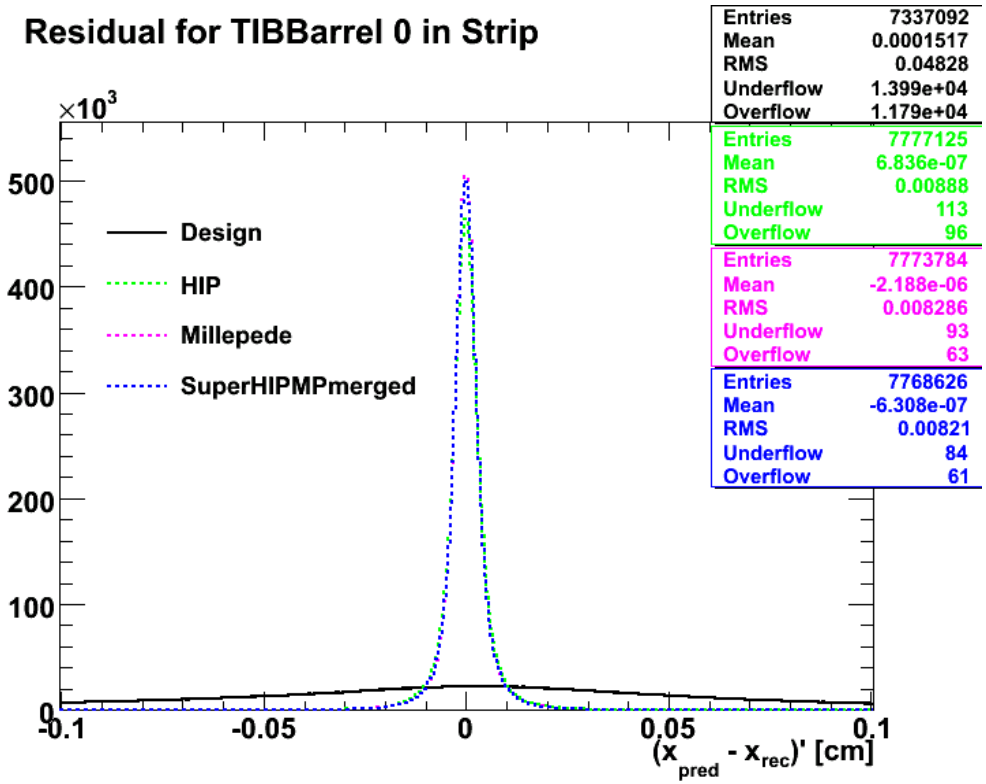


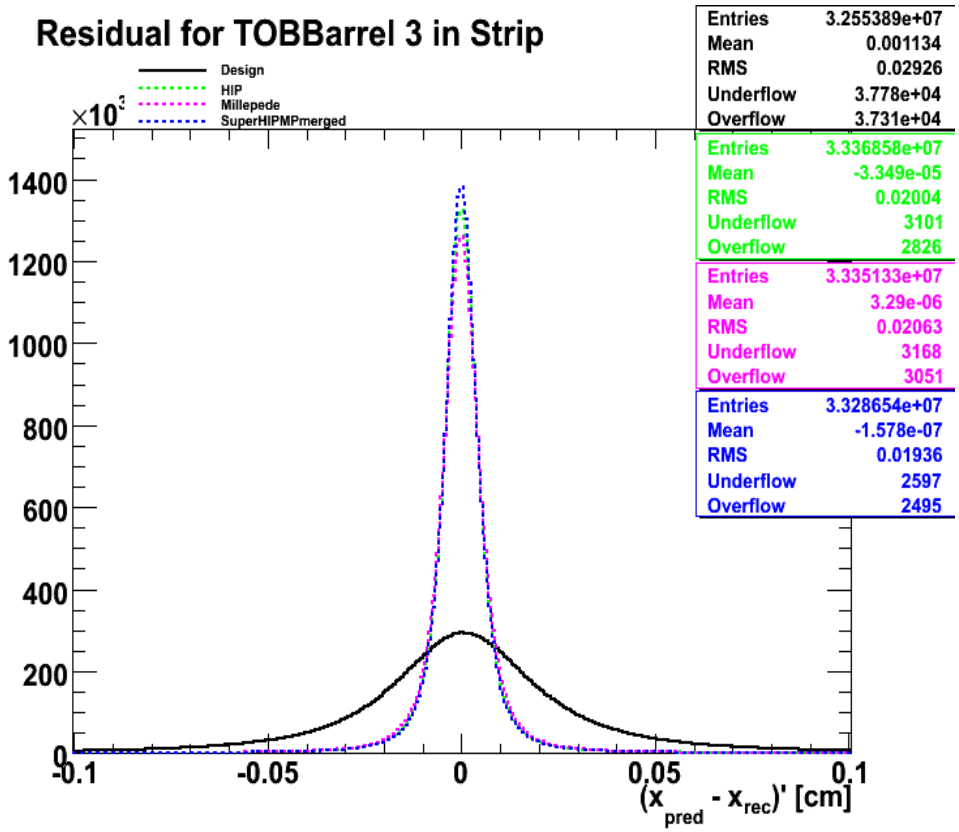




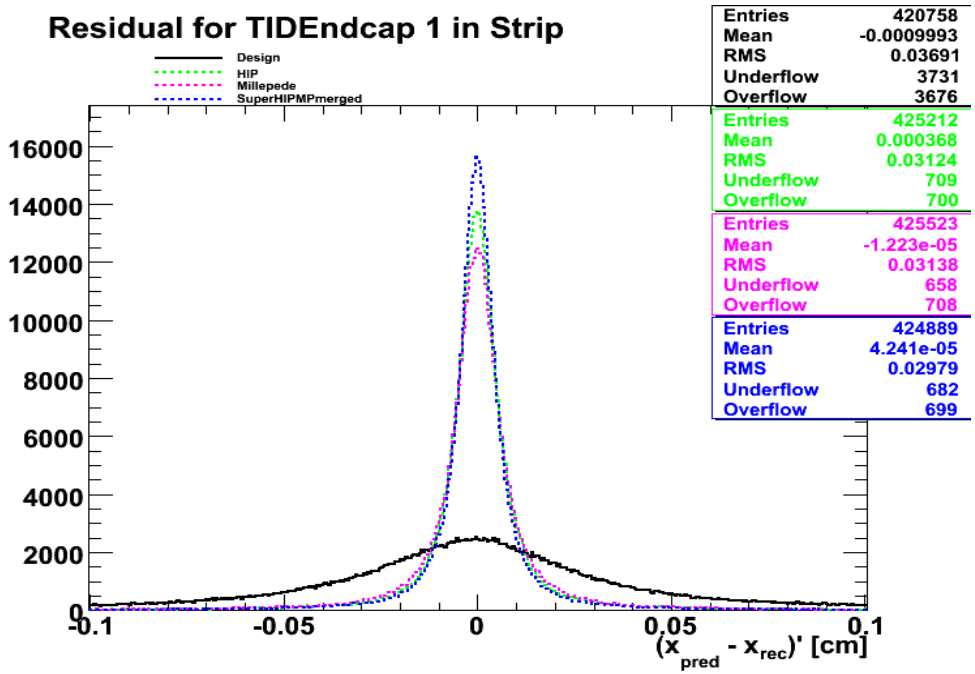
- RMS in barrel region ~ 70-80µm
- RMS in endcaps ~ 300µm
- best performance of SuperHIPMPmerged object, especially in endcaps (TID and TEC)
- Slightly better performance of MP in TIB (all 6 dof aligned by both algorithms)

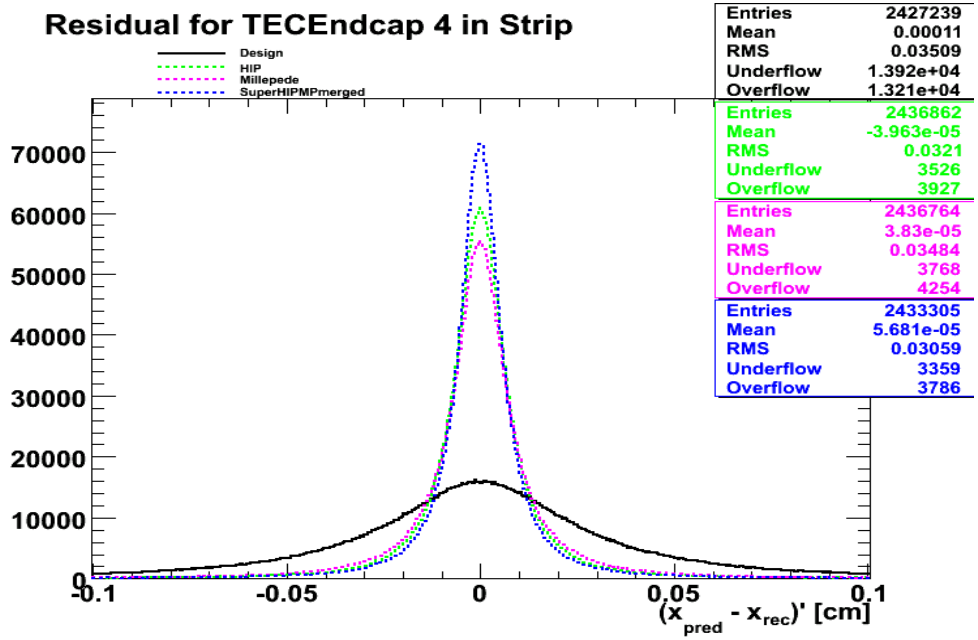
Backup: Strip Barrel Residuals CRAFT

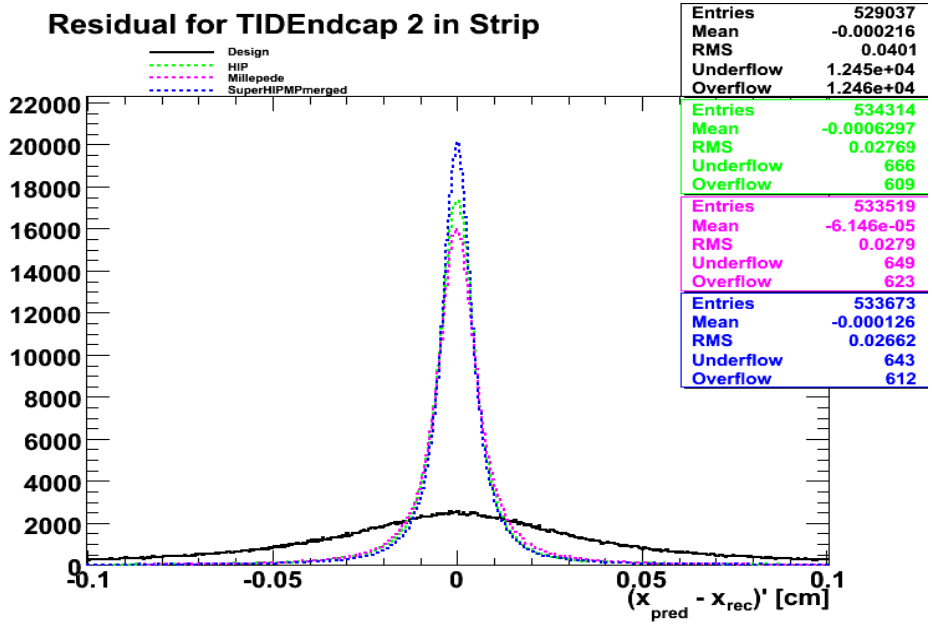


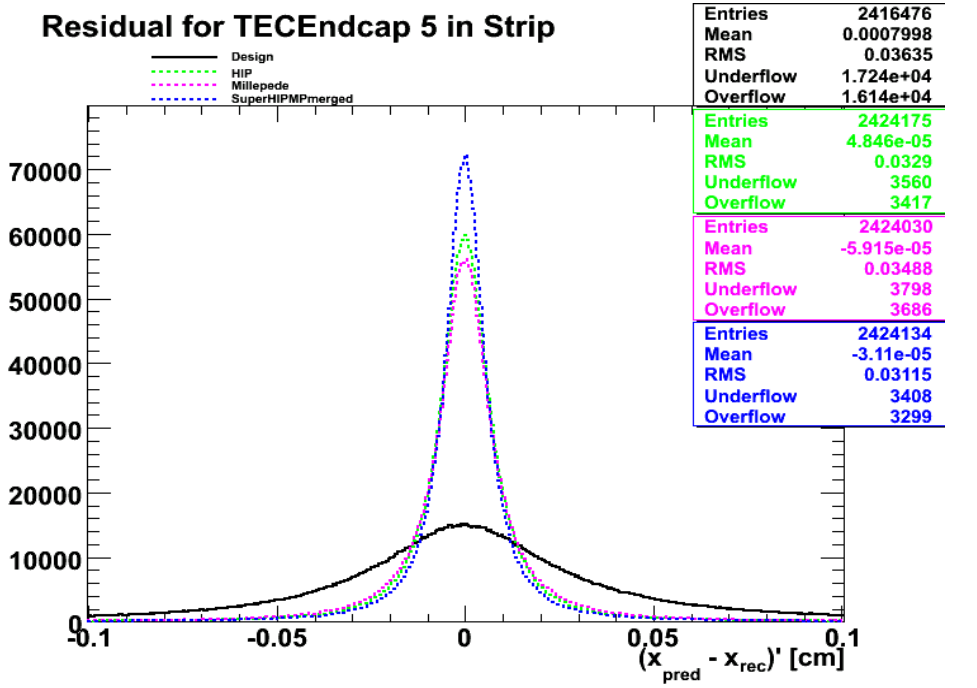


Backup: Endcap Residuals

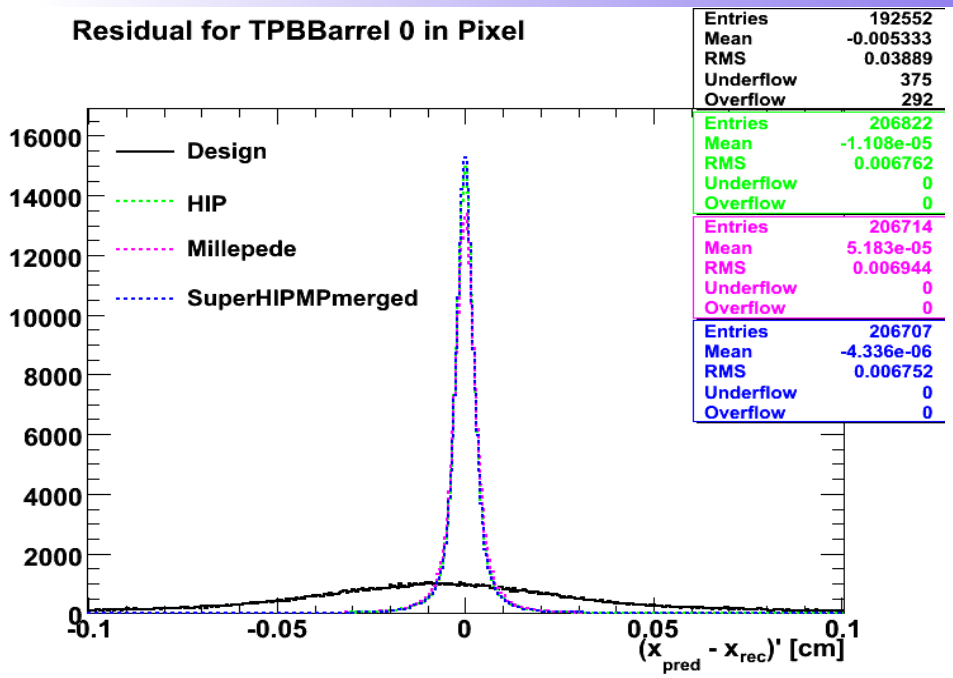


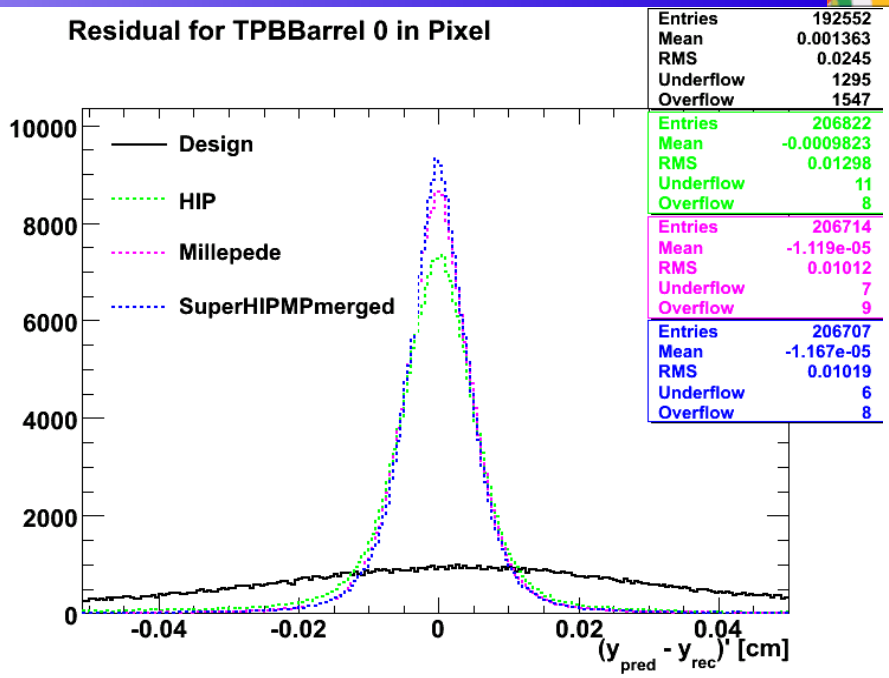


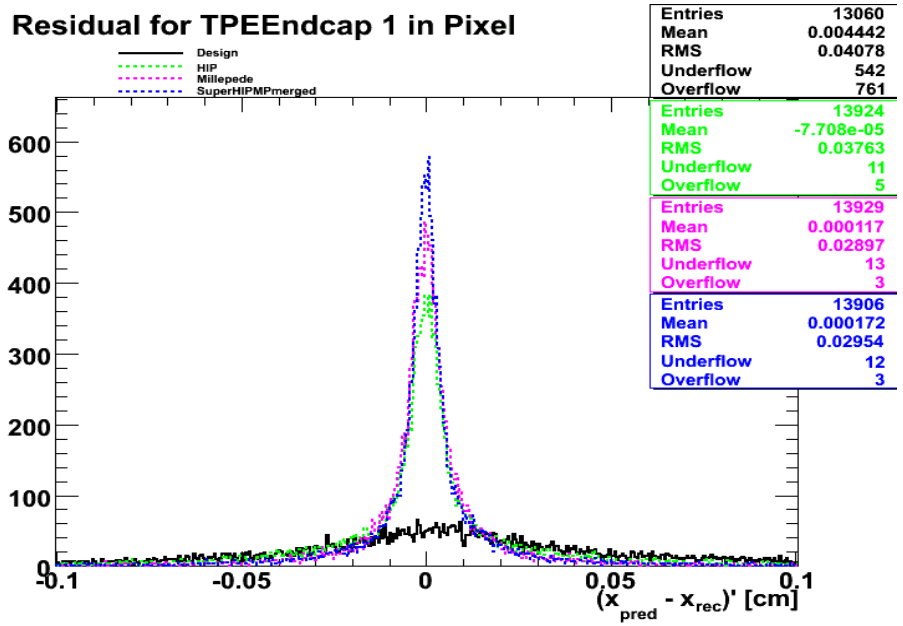


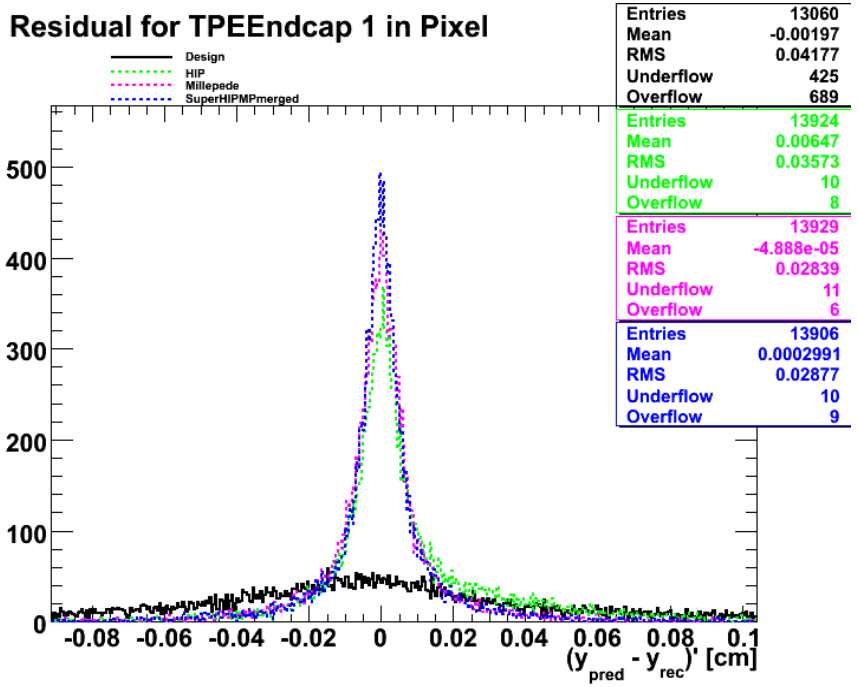


Backup: Pixel Barrel residuals

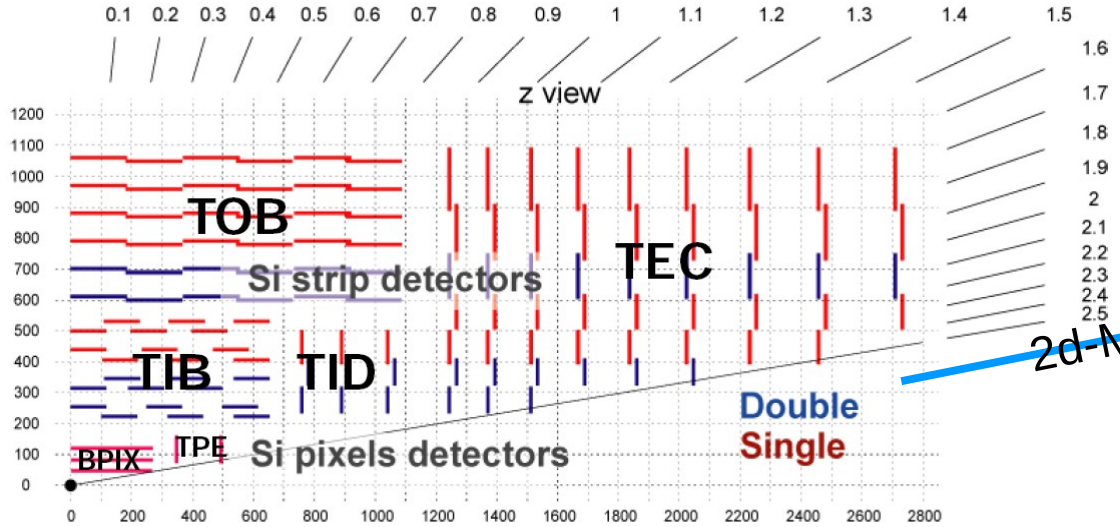


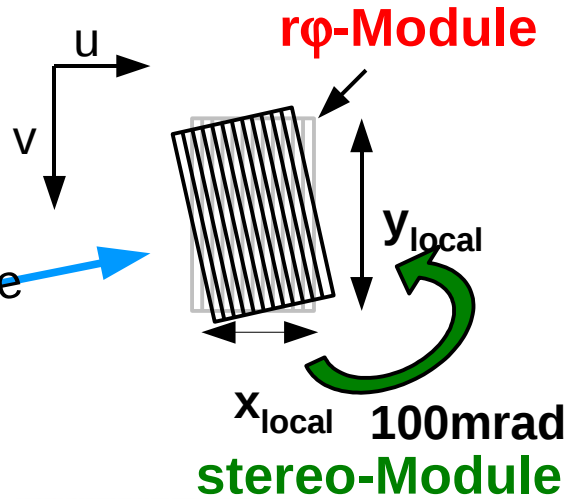


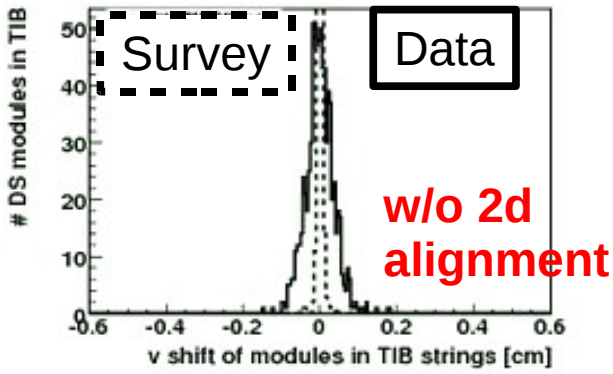


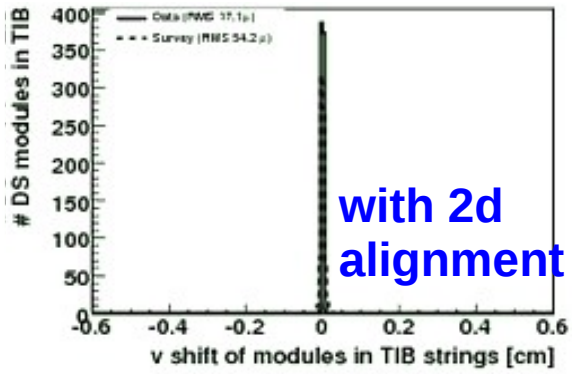


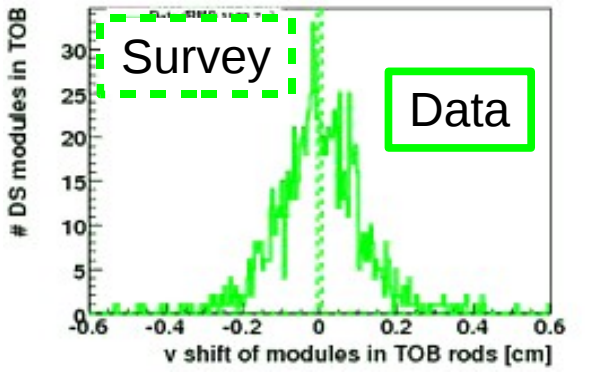
Millepede Alignment Strategy Adun

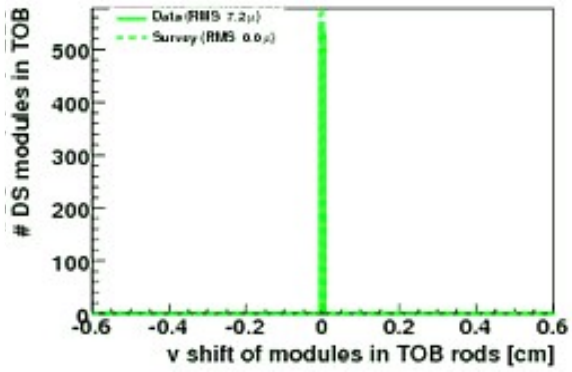












- 2d-modules aligned as one led to large movements of the modules within a string/ rod compared to survey measurements
- ➔ Necessity of separate det unit alignment for 2d modules