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FSP LHCb
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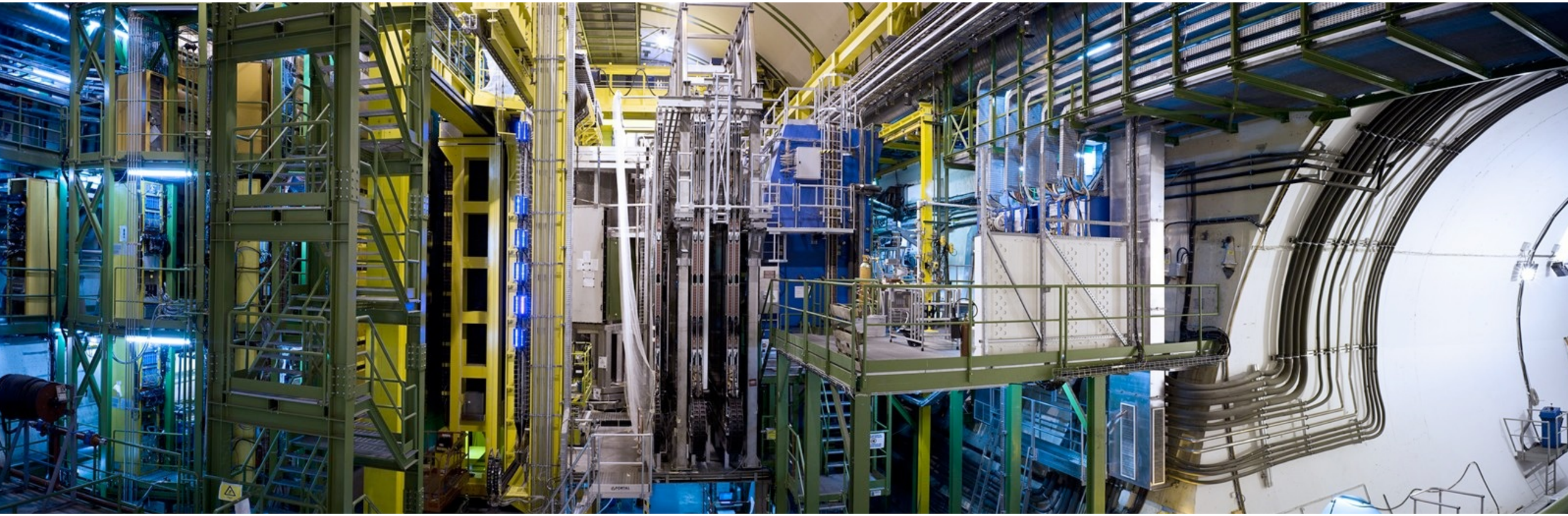


# SciFi Alignment summary

Sophie Hollitt for the SciFi alignment group
27th Feb 2023, SciFi General, 107th LHCb week

# Topic overview

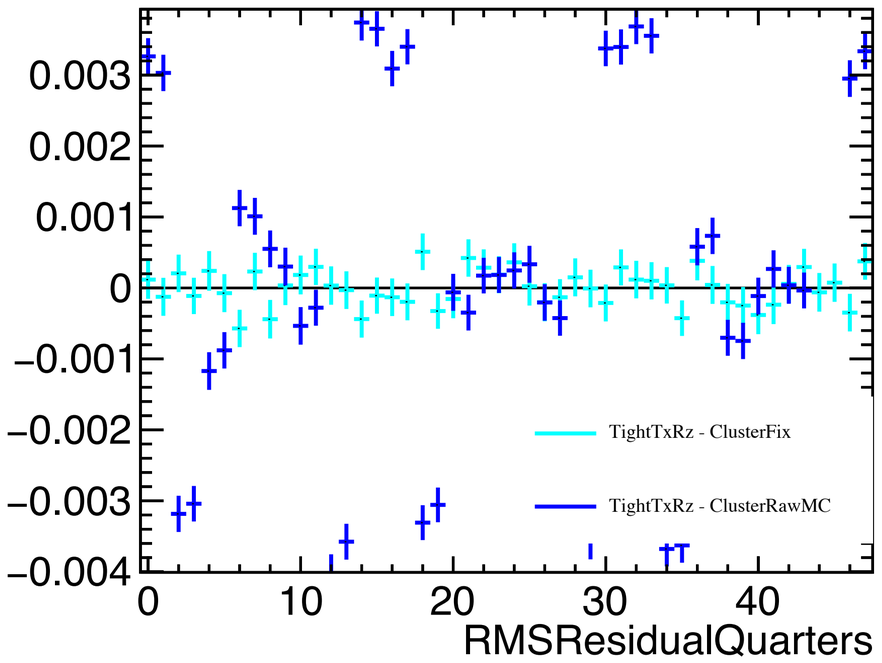
https://gitlab.cern.ch/lhcb/Alignment/-/issues/37

- ○ Debug/understand differences between SciFi v1 and v2 alignment ★
- ○ Setup SciFi dd4hep alignment ⋮
- ○ Test loose tracking for alignment with data to increase statistics in 1st iterations in outer modules ⋮
- ○ SciFi y alignment mechanical tests with magnet off MC ⋮
- ○ Repeat MC misalignment tests for SciFi when cluster-bias-fixed MC is available ★
- ○ Adjust SciFi survey implementation to constrain long modules (instead of short) ⋮
- ○ Determine size of effect of VELO drift/VELO misalignment on SciFi alignment (data+MC) ★
- ○ Mechanical test of (D0) particle reconstruction from HLT1 samples ⋮

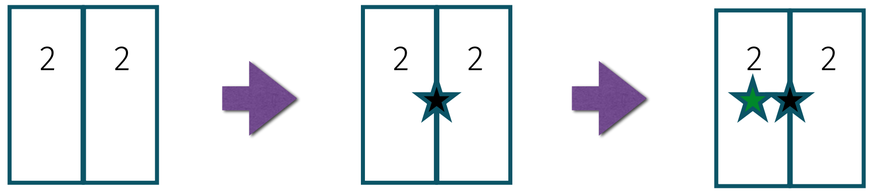
- Larger SciFi alignment + calib team this year:
  - Dortmund: Sophie Hollitt, Nils Breer, Biljana Mitreska
  - Heidelberg: Giulia Tuci, Miguel Ruiz Diaz
  - + Maria Vieites Diaz, Fred Blanc, Izaac Sanderswood
  - with further assistance from SciFi simulation & reconstruction group
- Allows us to pursue many more topics in parallel

# Reminder: what is the cluster bias?

- Effect seen in alignment:
  - Track residuals have a consistent pattern
  - Residuals cannot go to zero even after many iterations of alignment
  - Causes x displacements between top and bottom half and/or rotations of long modules
- This is the MEAN residual across all cluster types
  - Some individual cluster types have more
  - **The largest bias was seen from (2,2) symmetric clusters**
- Generate new MC with desired fix to check that this fixes the alignment issue



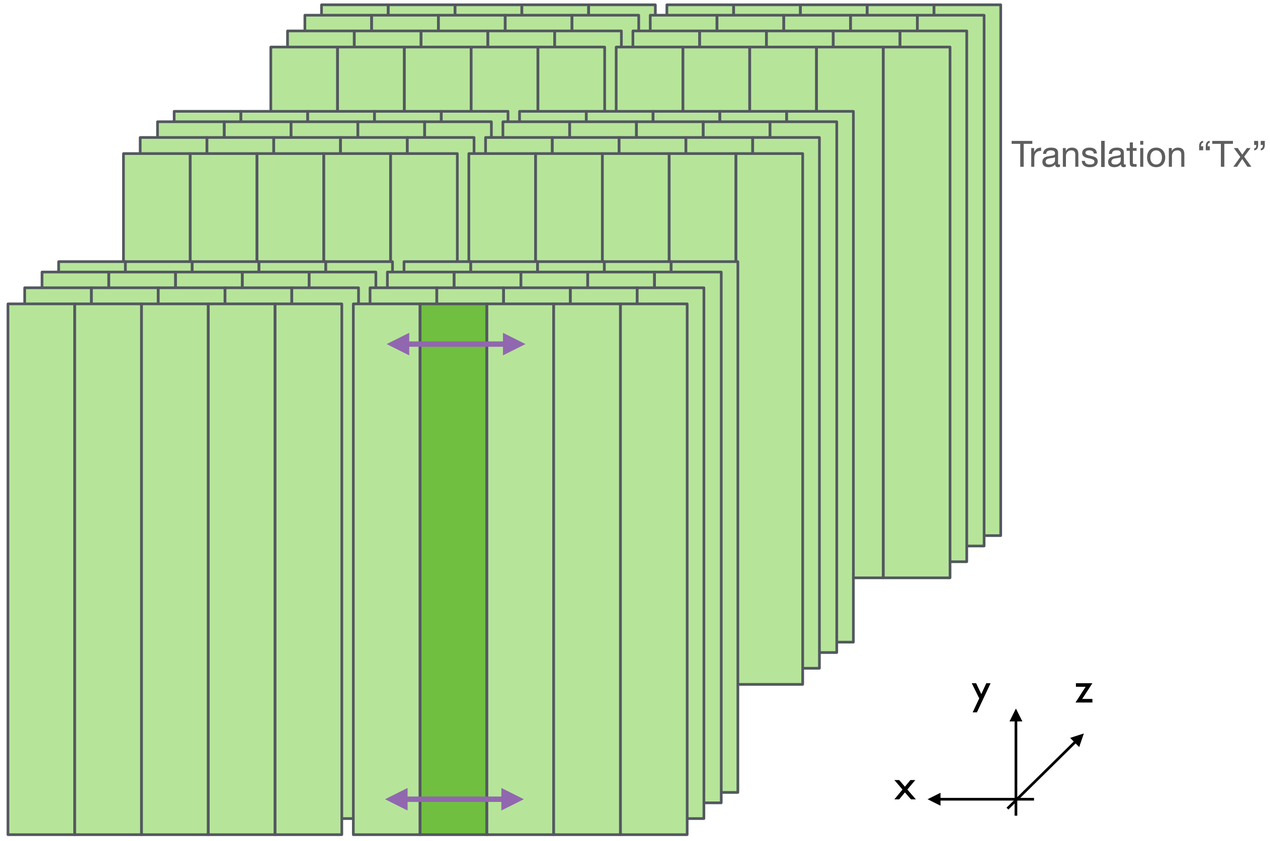

FPGA assigns a centroid position to each cluster, which is then converted to a channel position for the cluster (left or right half of channel)



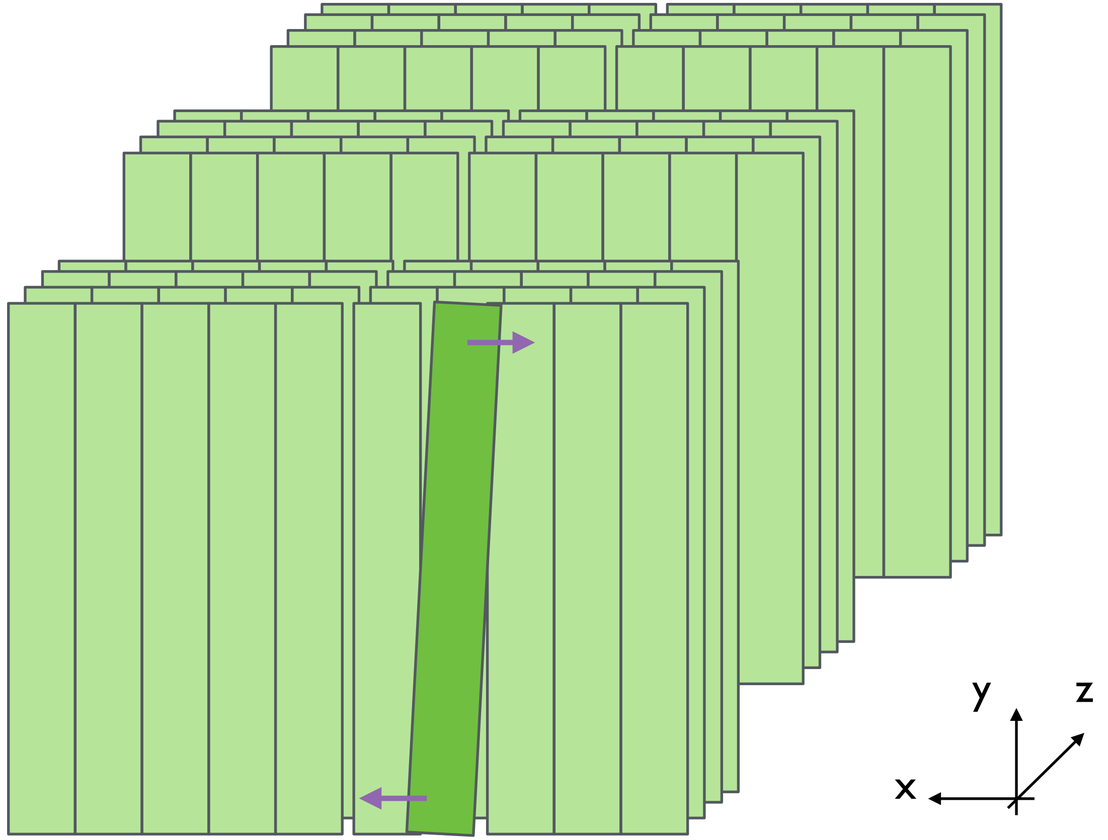
# Null tests for the simulated detector

1. Generate simulated events in a perfectly-aligned detector
2. Run the alignment on these events and look for movements away from 0

Translation “Tx”

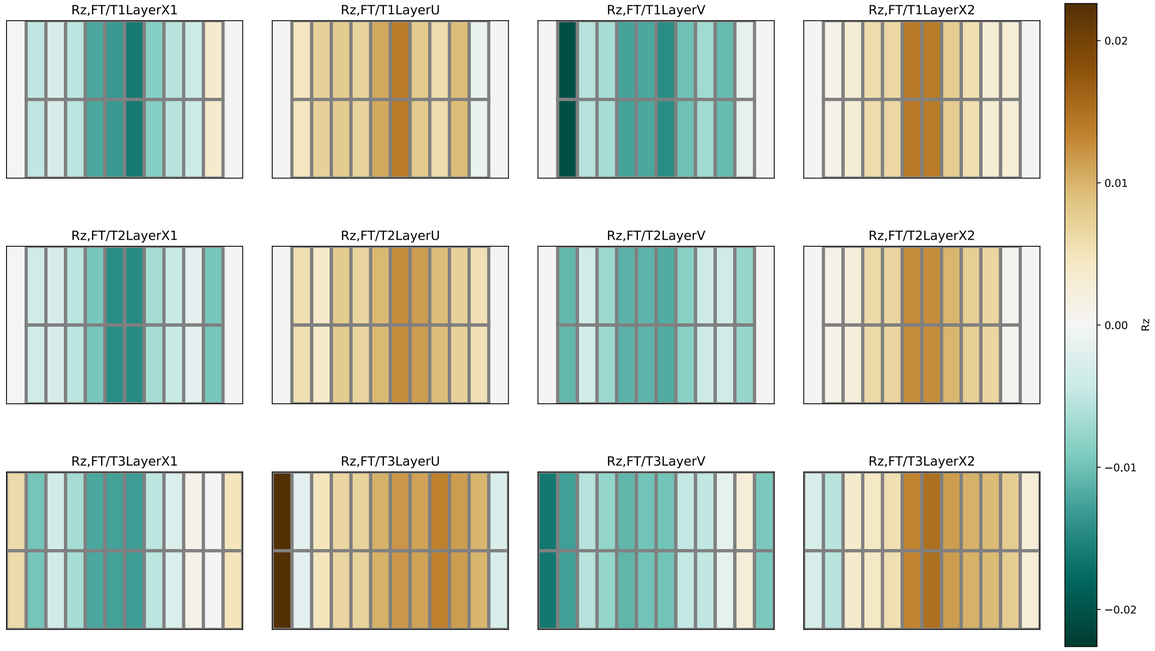


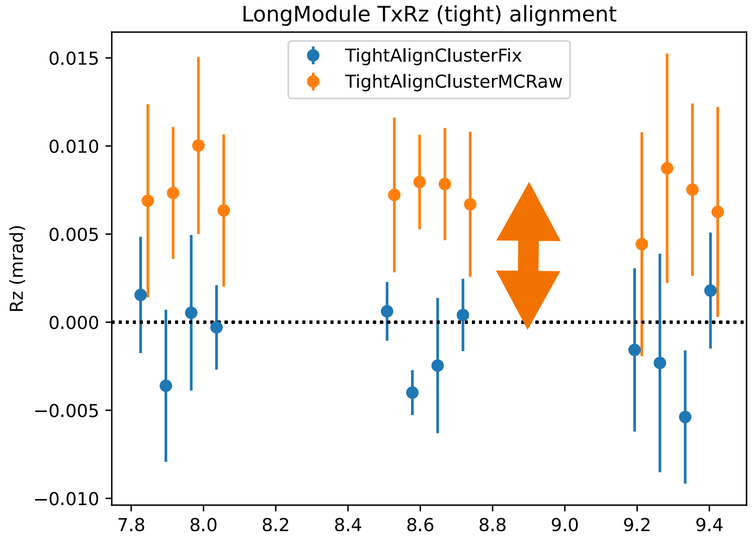

Rotation “Rz”



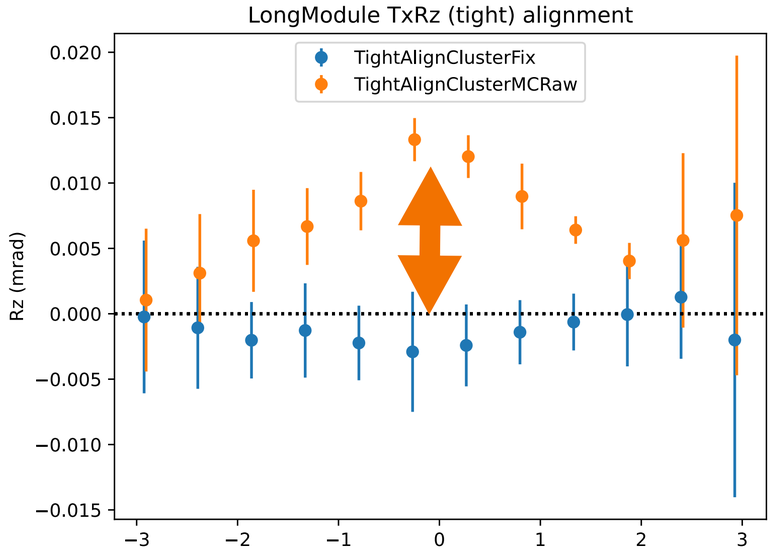
# Results from “tight” alignment:

Rz distribution on standard biased MC (global frame)




This plot: average rotation in each layer, flattened across all modules (local frame direction)

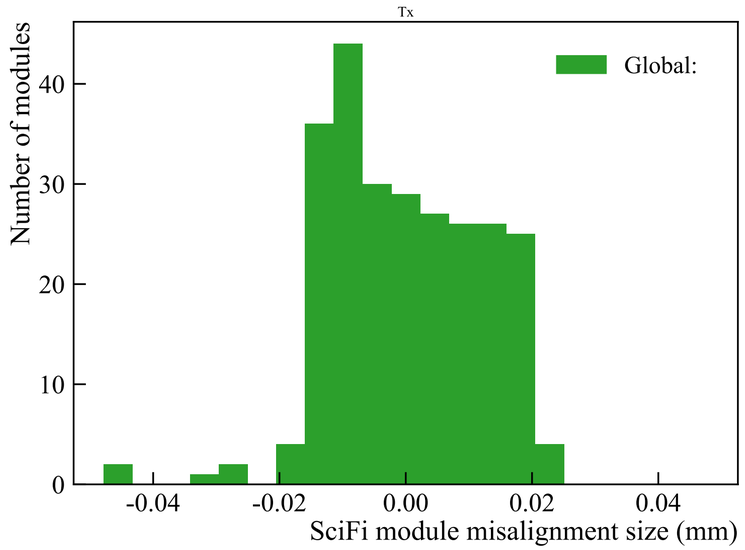



This plot: average rotation in each module, flattened across all layers

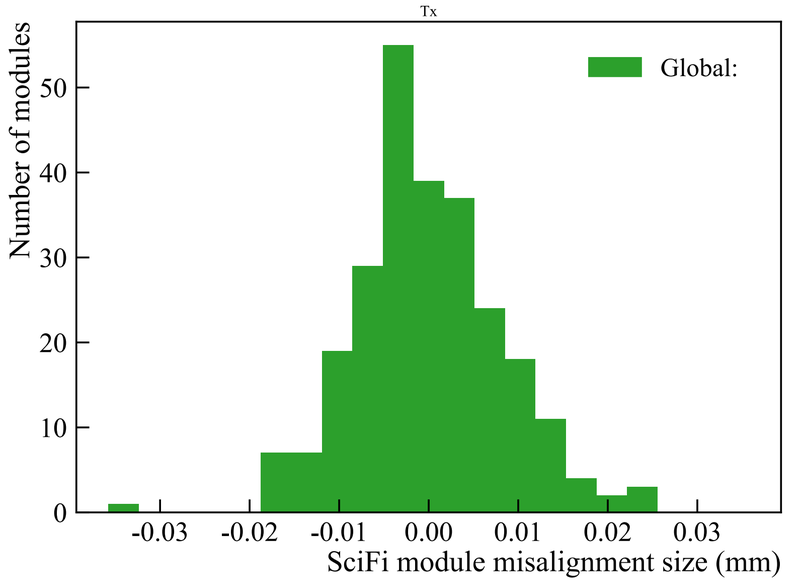
Cluster bias effect on rotation
IS SOLVED by these changes!

# Extra visualisations of tight alignment

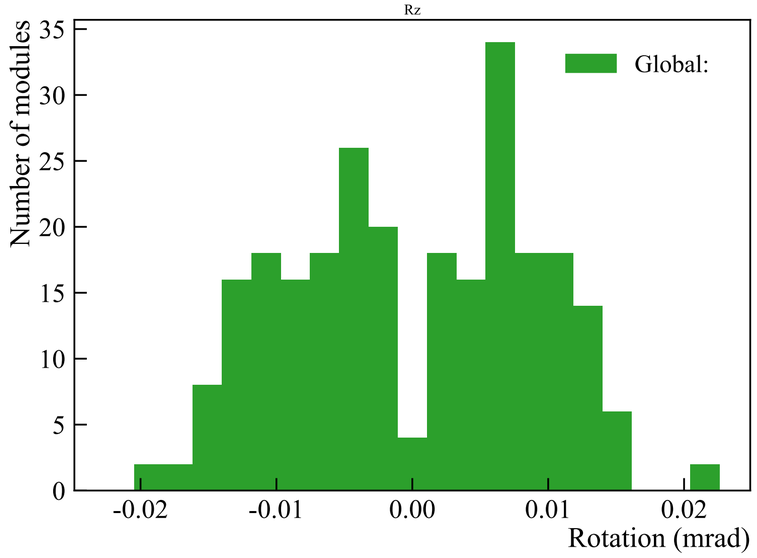
After alignment: standard biased MC

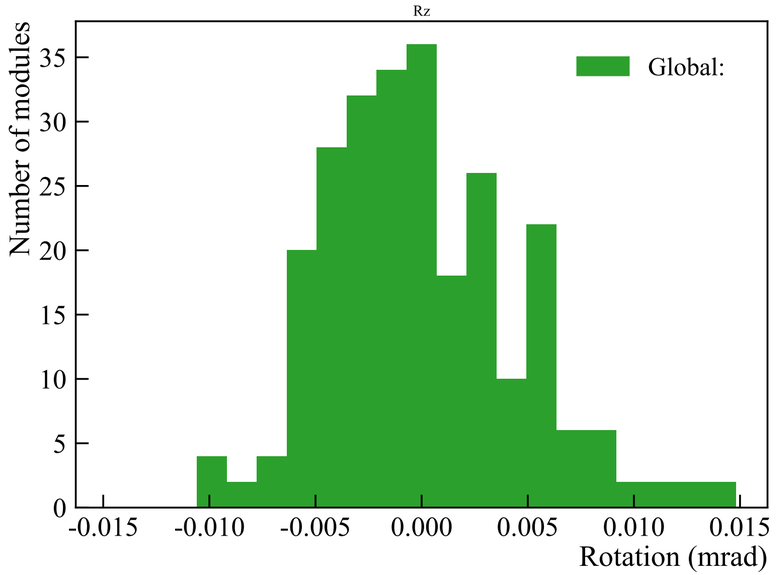



After alignment: cluster fixed MC




Distribution much more Gaussian

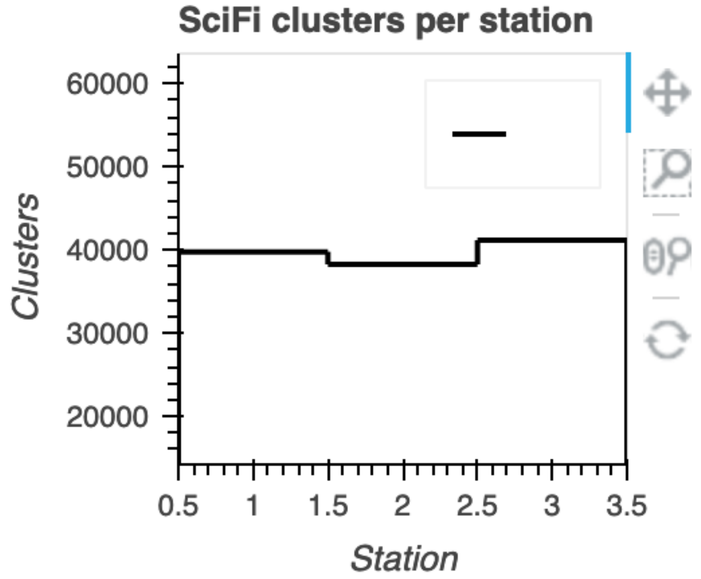


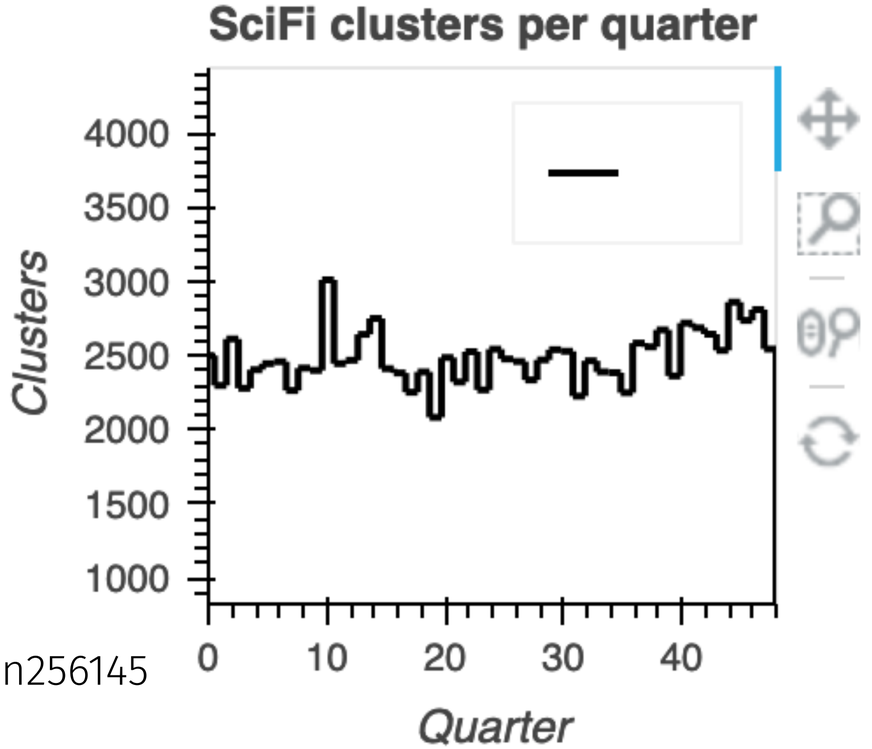




Distribution much more Gaussian, centred on 0

# Understanding 2022 alignments

- Summary of 2022 alignments in commissioning:
  - Uses TxRz degrees of freedom on either long or short module units
  - Alignment starting from VELO halves alignment, uses GoodLongTracks
  - Current best alignment (v2) uses short modules, calculated on a run with best SciFi timing (256145)
  - Still some known issues:
    - survey input is not quite right for cavern conditions:
      - known that T2X1 and T2U have some extra sun heating on the modules.
      - known that the frames might be a bit less constrained during photogrammetry than they are in the assembly hall
    - **A side alignment quality improved a lot from v1 to v2, C side performance still lags, especially in Q0.**

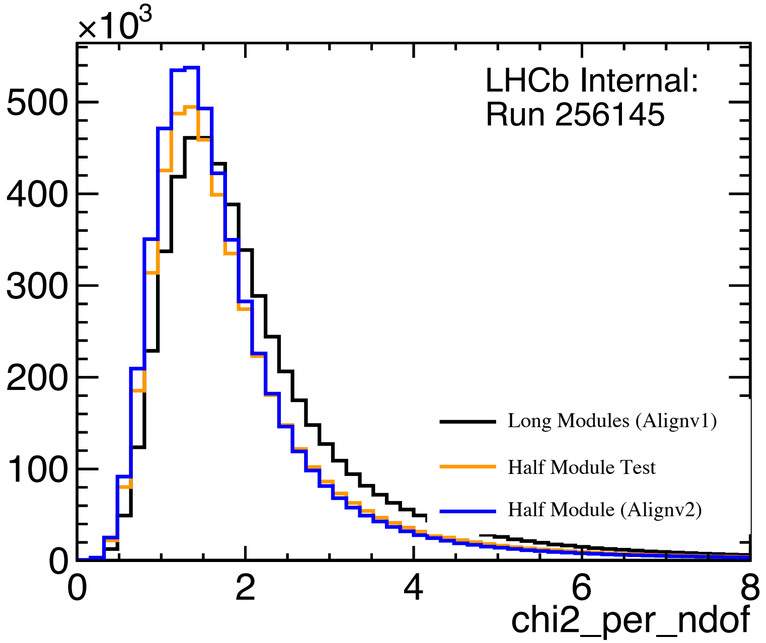


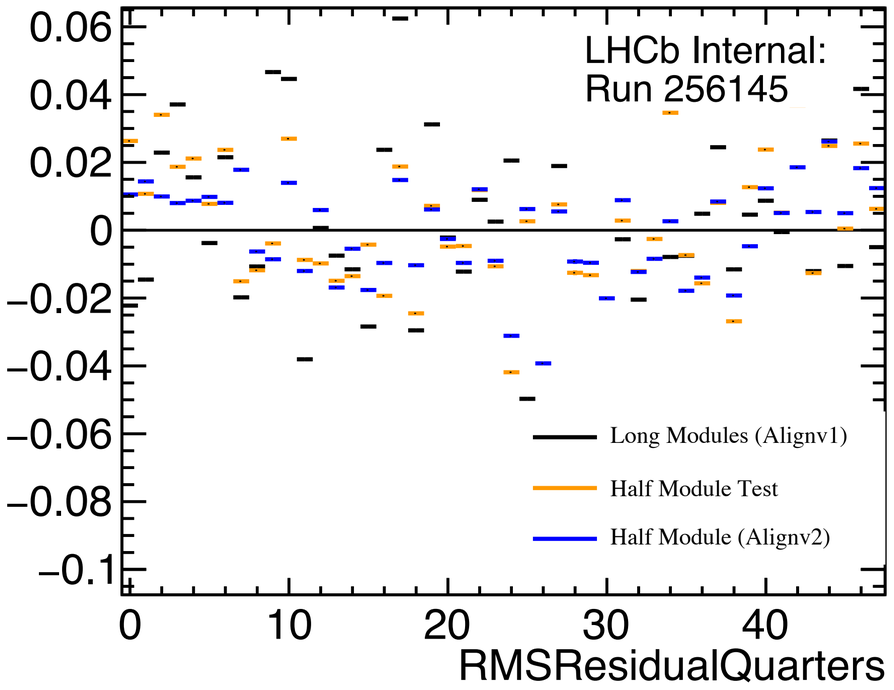



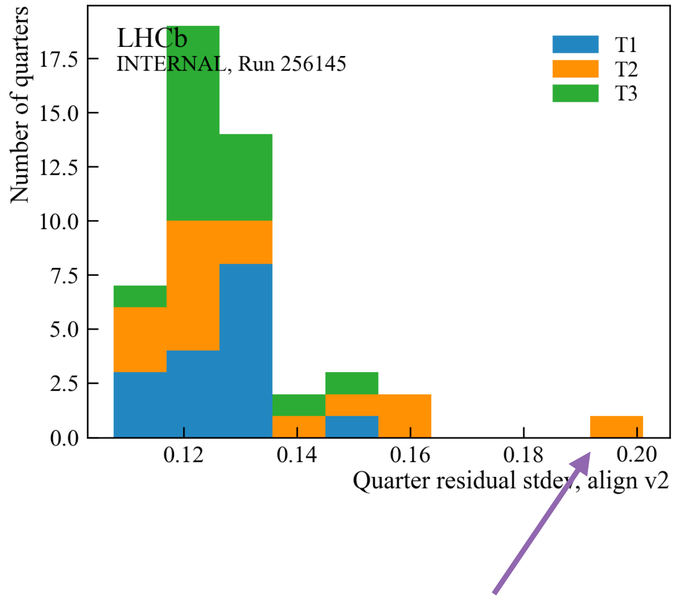

Monitoring for Run256145 in Monet

# Quick summary: Alignment v2 conditions

- Uses Run 256145 (first run with updated/best SciFi timing)



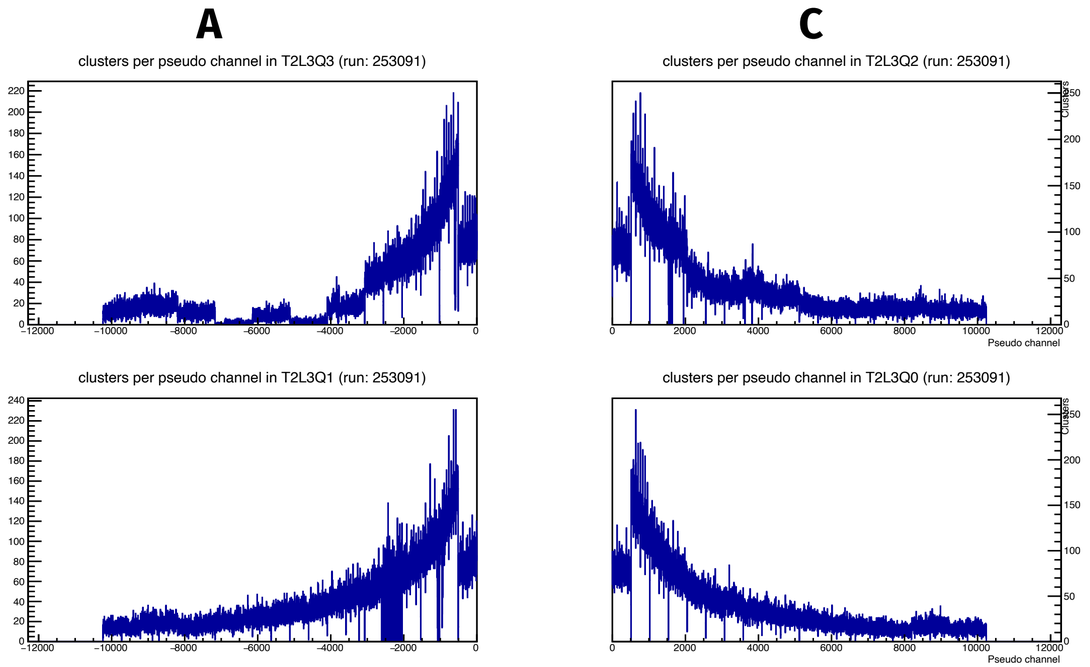




The widest track residual distributions are from quarters in Station 2

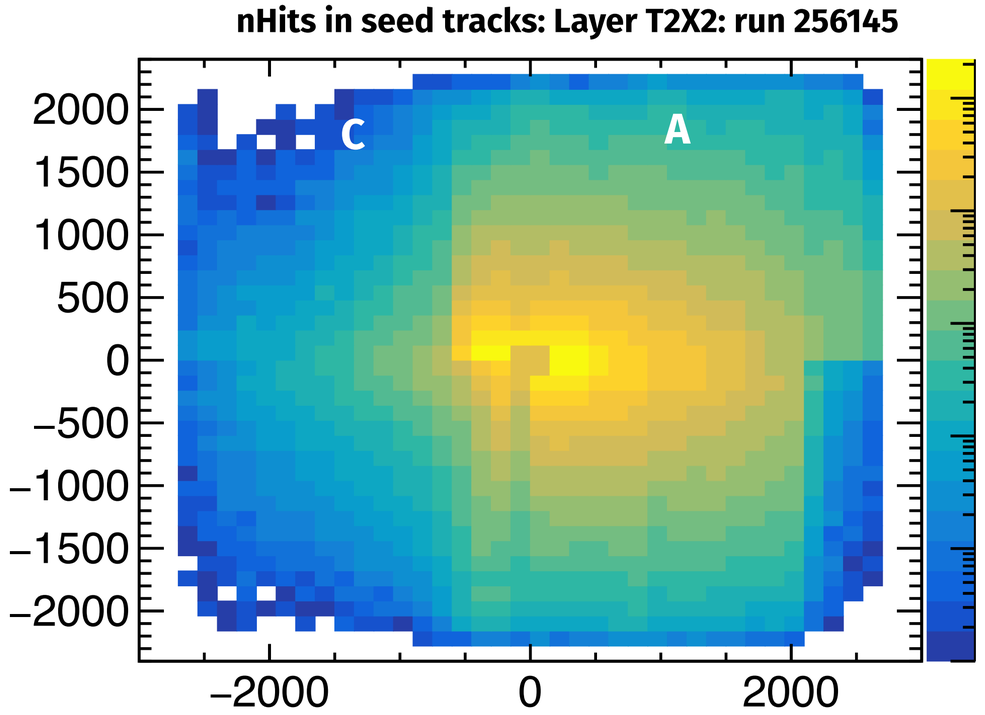
When averaged across the whole SciFi, Alignv2 has the best tracking performance so far

# Understanding 2022 alignments: SciFi C side

- SciFi has a nice, fairly even distribution of clusters in all quarters in all layers
  - Something is going wrong when clusters are combined into tracks
- Suspicion: one or more parts of the C side are quite far out of alignment using survey information
  - Limits the number hits in this region
  - May be blocking changes to other parts of C side by “requiring” alignment tracks to go through a small area.



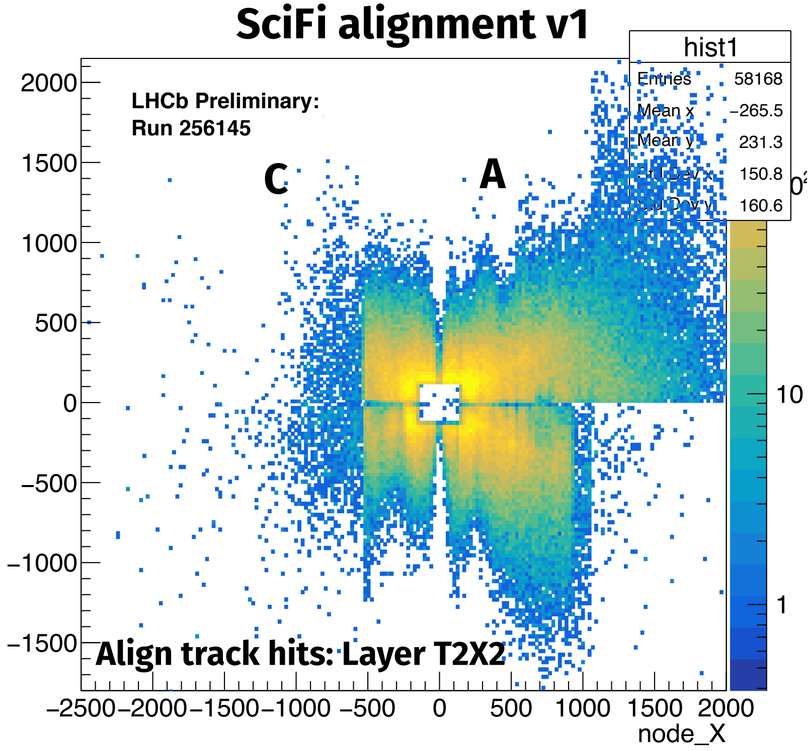

**nClusters: Layer T2X2**

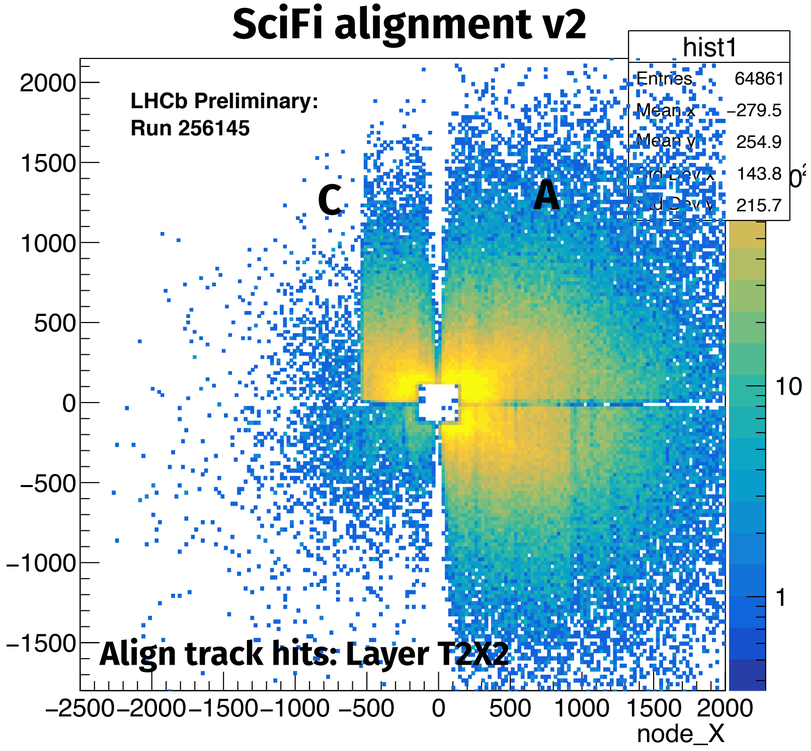



log (nHits)

# Understanding 2022 alignments: SciFi C side

- SciFi has a nice, fairly even distribution of clusters and seed tracks
  - Something is going wrong with the long tracks for alignment
- Suspicion: one or more parts of the C side are quite far out of alignment using survey information
  - Limits the number of GoodLongTracks/hits in this region
  - May be blocking changes to other parts of C side by “requiring” alignment tracks to go through a small area.



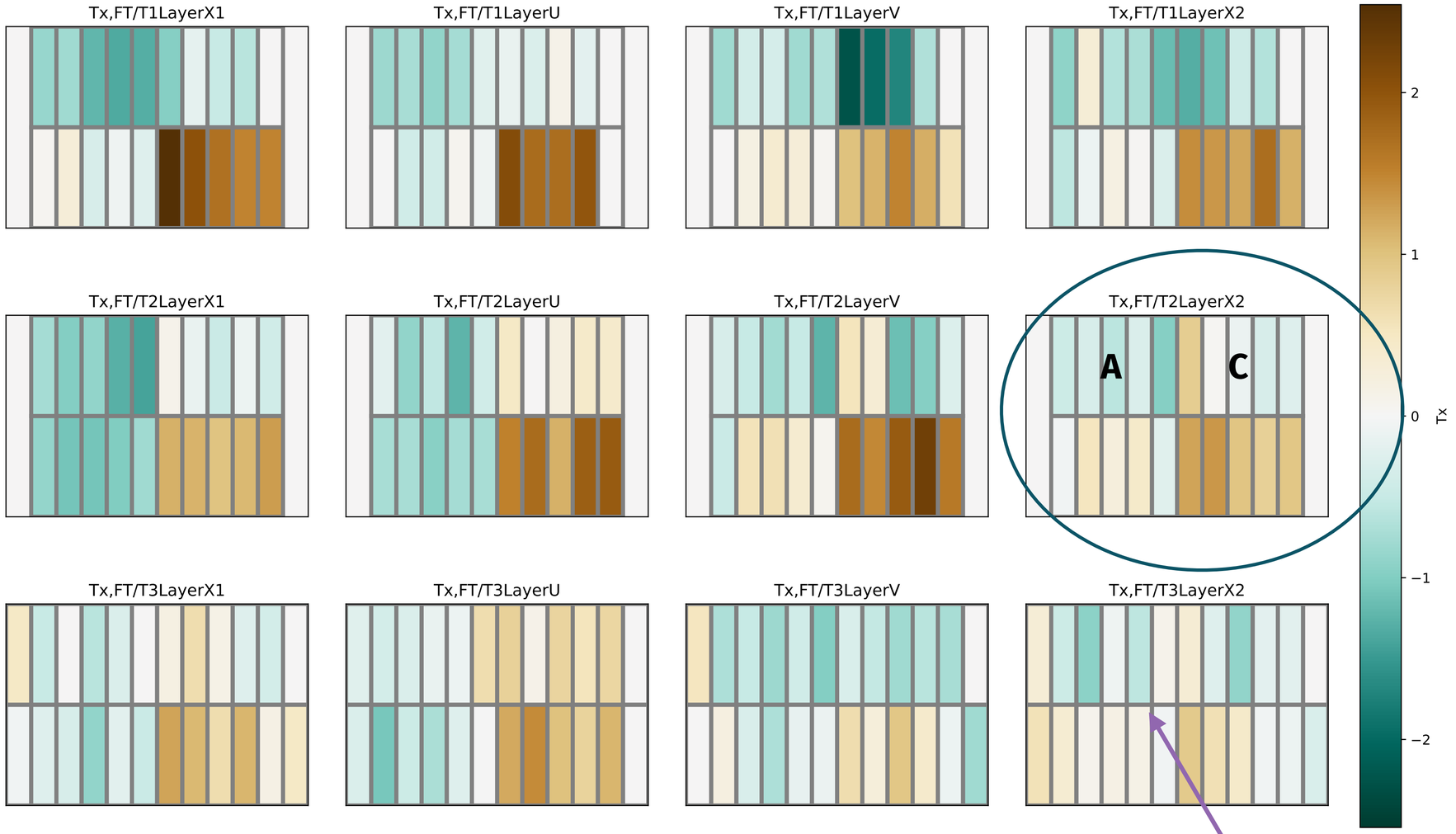




Shown: worst performing layer, T2X2 (back of station 2)

Can we find a reason for this difference in Q0 the alignment coefficients for this layer or a neighbouring layer?

**-> In progress**

# Understanding 2022 alignments: SciFi C side




Differences in Tx between v2 and survey.

Large movements in Q0 in most layers still with poor tracking efficiency: alignment configuration might be “stuck” in a local best configuration

T2X2 highlighted from previous slide

Average position of this layer fixed in alignment

# Improving 2022 alignments: continuing plans

- Planned tests:
  - Use information from first alignment to subtract/adjust “large offsets” from 2022 survey quarter-by-quarter
  - Vary starting position elements in T2X2 C-side manually to “scan” alignments?
  - Test performance with different sources of alignment tracks:
    - loose tracking setup (more VELO+seed tracks matched to long tracks)
    - alignment with high momentum SciFi seed tracks for first few iterations of alignment
  - Return to using Tz degree of freedom in studies/release restrictions on SciFi back layer
    - Benefit: survey Tz is not perfect, moving T3 may allow us to find better tracks in T2
    - Risk: curvature bias if aligning without particle constraints
  - Rerun with newest photogrammetry+survey when possible

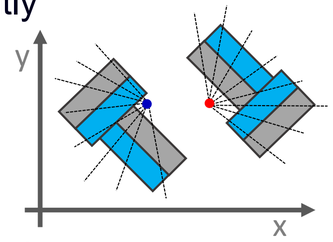
**Goal: 2022 Alignment v3 with better C side performance for end of March/ early April**

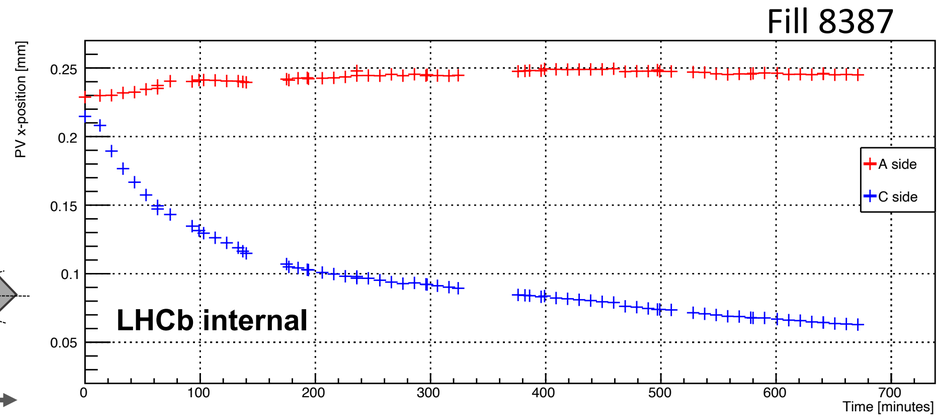
# VELO motion effects on SciFi

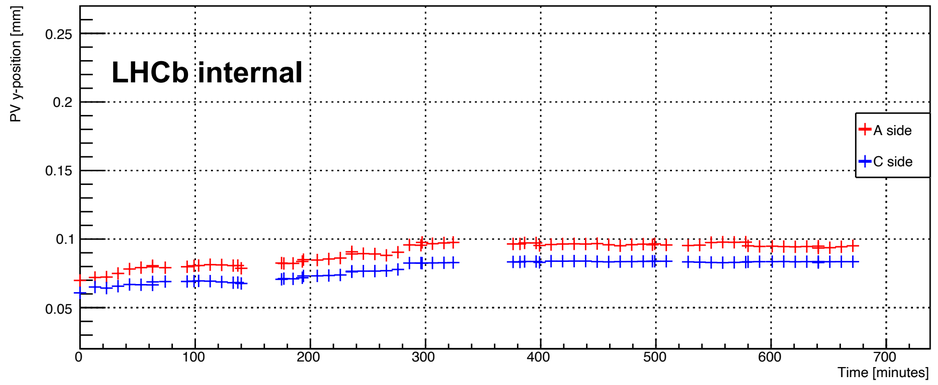
VELO drift report at last LHCb week

## Drift of VELO C side

- Two VELO halves could act as separated detector
- PV position reconstructed independently by each half should be at the same position
  - Difference of PV position is a relative misalignment between the two halves
- Some drift of PV is expected due to LHC beam movement (e.g. luminosity levelling)
- PVx position versus time shows a large and unexpected drift of the C-side
- Effect is (almost) reproducible for several fills with the VELO fully close and opened by 1 mm (e.g. during VdM scans)



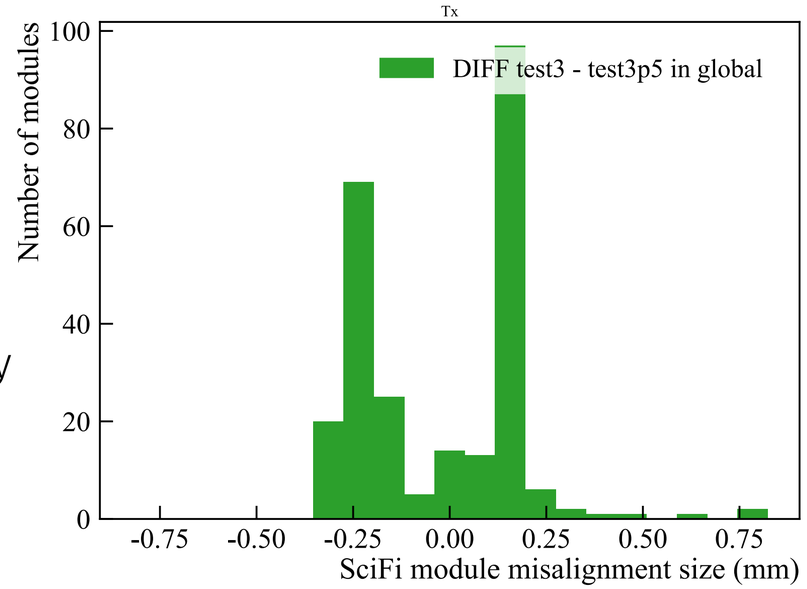




- SciFi alignment uses long tracks and PVs
- How much could this affect us?

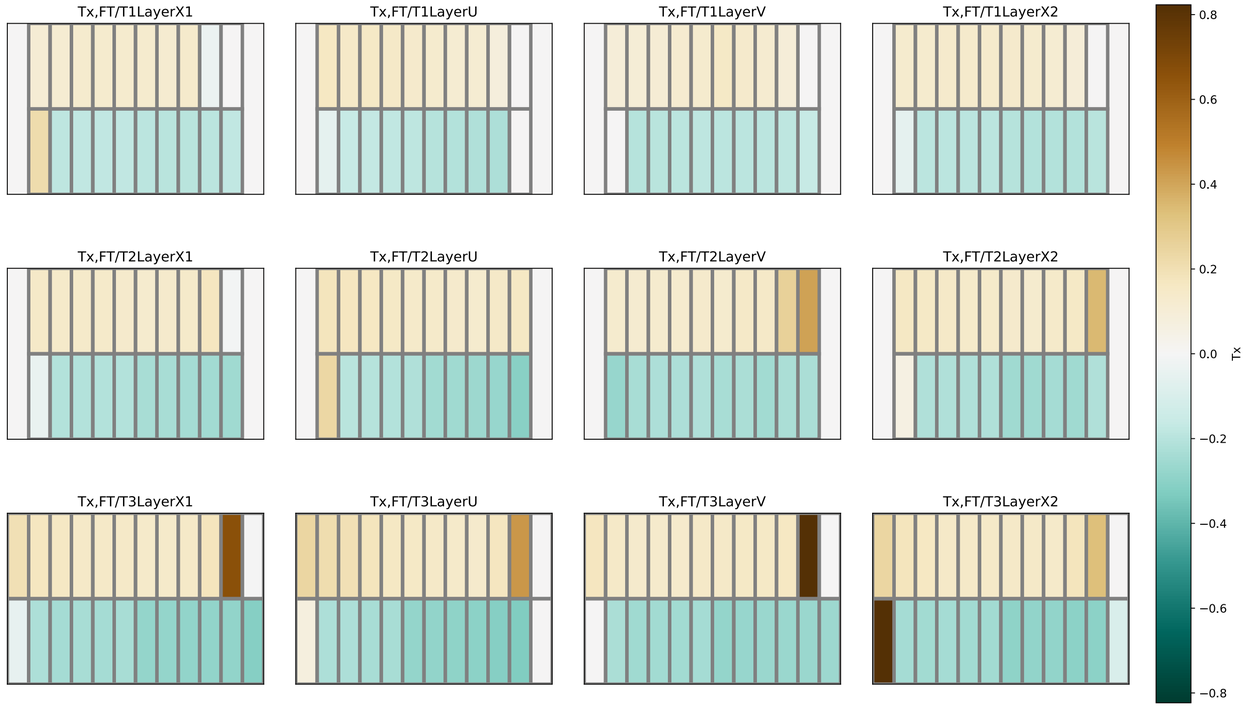
# VELO motion effects on SciFi

- Quick data study: how does SciFi alignment with long tracks change by turning VELO motion read-in on/off?
  - Much larger change in position than expected from VELO drift over time
  - Same starting conditions
  - 4 iterations, 200k events
- Very nice consistent pattern across SciFi from change: SciFi top half moves left (+x) and bottom half moves right (-x)
  - Modules not matching pattern: insufficient hits to align on one alignment or the other
- At first glance: VELO motion is included properly/global shifts on SciFi translation from VELO translation are relatively small

When VELO moves by 1mm, SciFi moves by <250um




Difference in alignment conditions with VELO motion on vs off



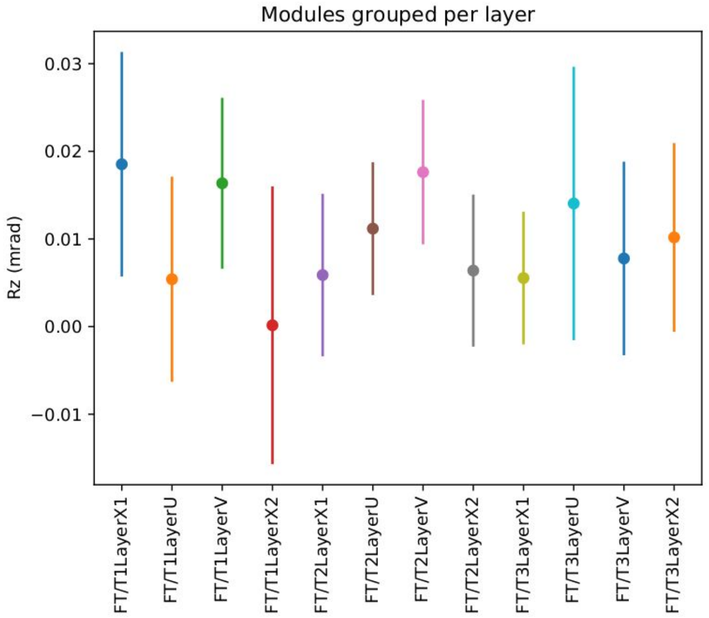
# VELO motion effects on SciFi: MC studies

- Ongoing MC studies to also look an effect in the SciFi alignment based on VELO C side drift
- Realistic parameters from VELO experts:
  - 180um drift in Velo Tx on C side
  - **220urad drift in Velo Ry on C side**
- Study being repeated on MC without cluster bias effect to double-check size of rotation effects.

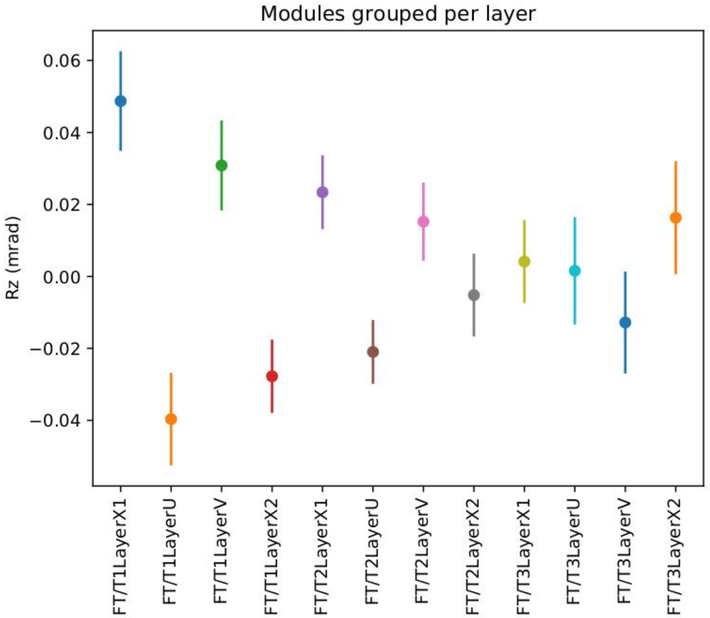
Some signs of rotations of SciFi modules based on VELO half rotations in small first-look study

(2-3x larger than rotation from cluster bias)

**Default conditions**




**Modified Velo conditions**



# Extra topics not mentioned in detail:

- Mechanical test of D0 with HLT1 data
  - Goal: confirm D0 particles can be reconstructed from 2022 HLT1 sample. Debug alignment reconstruction if needed
  - Current status: reconstructing D0 candidates, cuts on ETA need to be debugged to improve candidate quality
- Preparations for alignment with DD4HEP/online
  - DD4HEP configuration for alignment software was just merged last week
  - Can now add SciFi updates/test compatibility of alignment in DetDesc and DD4HEP
- SciFi coldbox calibration
  - Placeholder SciFi coldbox parameters merged to conditions
  - Can now work on generating MC to predict the amount of bending at different temperatures
- SciFi y-alignment checks with magnet off MC/data
  - Current task: talk to reconstruction experts about best method for projecting straight tracks/ finding missing hits
  - Temporarily on hold, photogrammetry/survey is priority

# Summary

- Lots of people on the SciFi alignment team this year, especially from RTA/software side
- Current dual focus:
  - Understanding alignments from 2022 and preparing the best starting conditions for 2023
  - Improving software and preparing for online alignments with dd4hep
- I believe we are on track to have everything ready for data taking
  - At worst, we will have older survey information for the first few weeks
  - But we are working on making sure we have the best alignment starting conditions and can also get the most out of the existing survey information for this early period

# BACKUP

# Settings for null tests

- Alignment on 14k MinBias events
  - Use MDF and VELO Retina clusters to speed up testing
  - UT in MC but not used in track reconstruction sequence
- Tested with 2 different configs for alignment constraints: one tight, one loose
  - Loose: LongModules aligned in TxRz, sum(change in Module Tx or Rz in CFrame)=0
  - Tight: LongModules aligned in TxRz, sum(change in Module Tx or Rz in whole SciFi)=0, Sxz=0, sum(change in Module Tx in T3X2)=0
- Alignment converges at 1 iteration or less