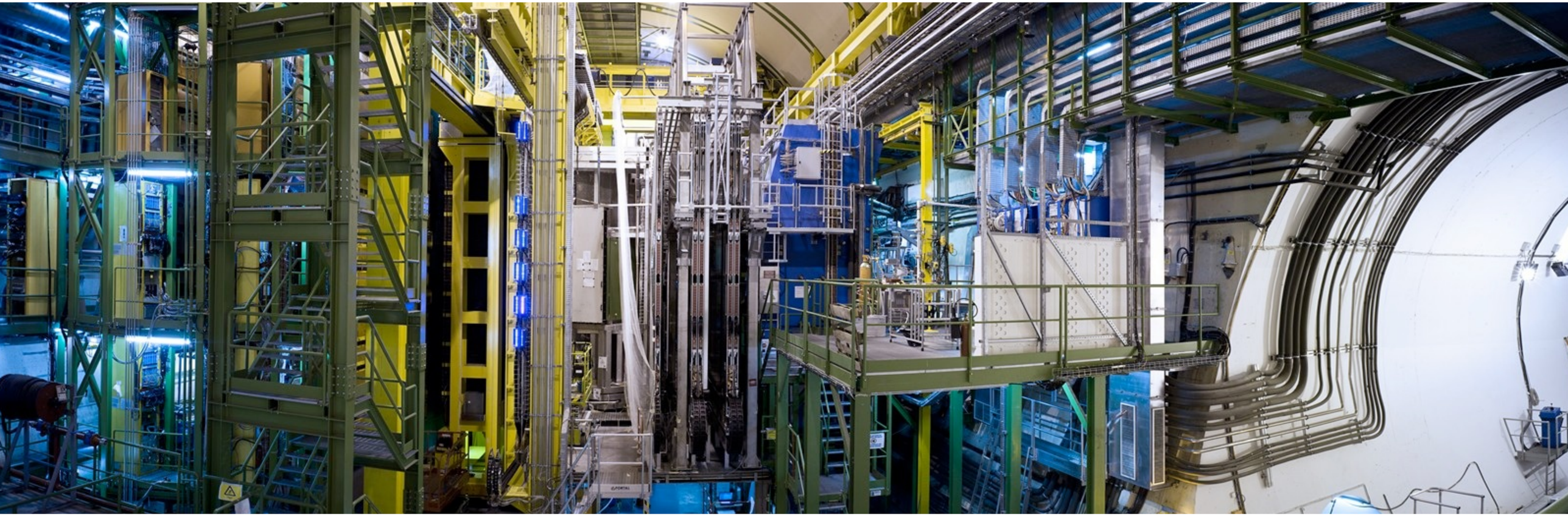
technische universität dortmund

FSP LHCb
Erforschung von Universum und Materie



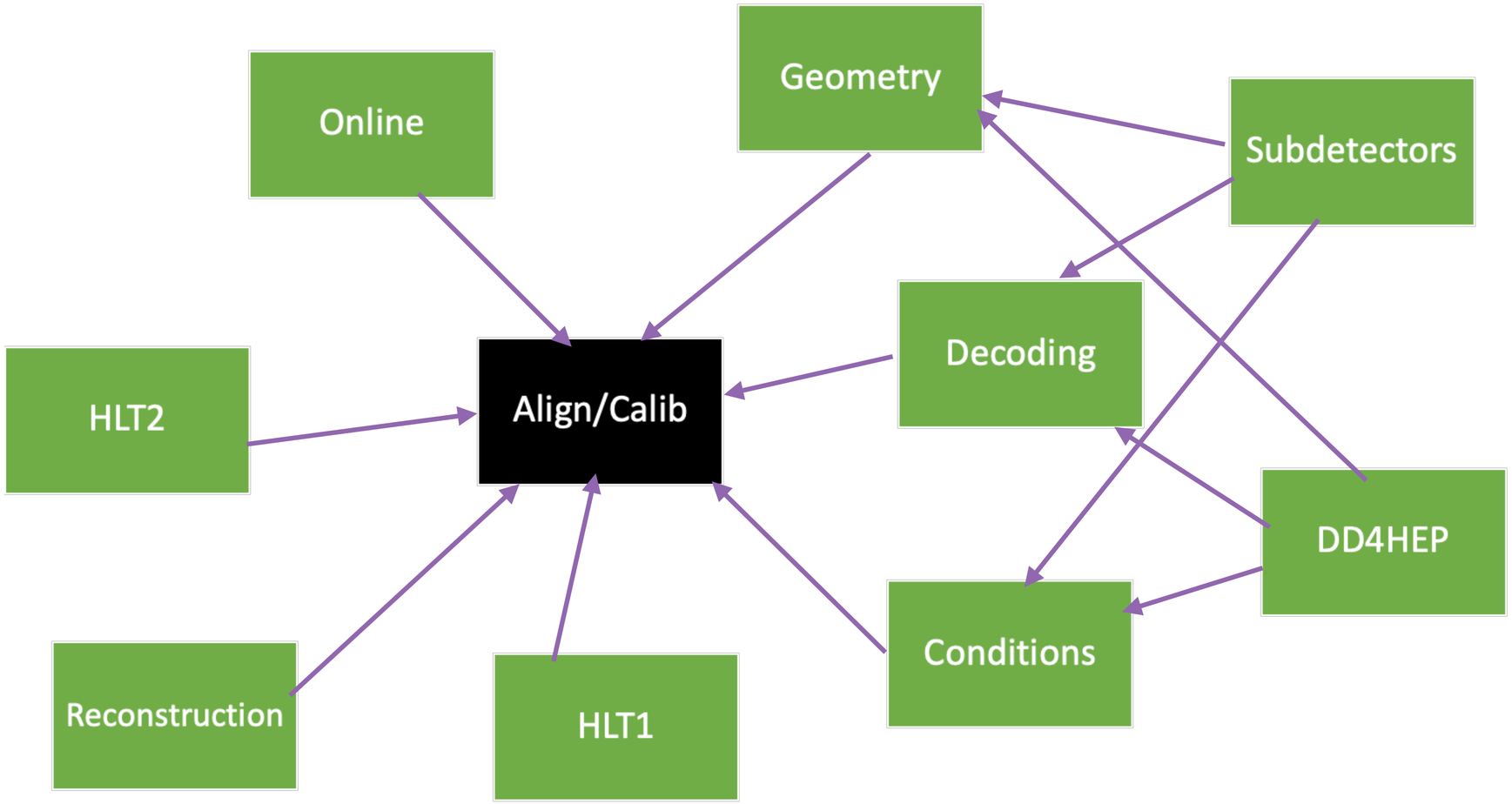
SciFi reconstruction and alignment

Sophie Hollitt

SciFi general at 106th LHCb Week - 5th Dec 2022

Reconstruction and alignment overview

- Lots of overlap between SciFi commissioning, reconstruction, and alignment in the past month or so



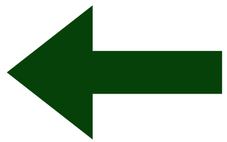
People working with SciFi align+calib:
Maria Vieites Diaz
Blake Leverington
Fred Blanc
Izaac Sanderswood
Nils Breer
Zehua Xu
Jessy Daniel
Louis Henry
Emmy Gabriel

People from other projects:
Laurent Dufour
Andre Gunther

+ lots of broad support from SciFi in general, RTA alignment & reconstruction during commissioning process

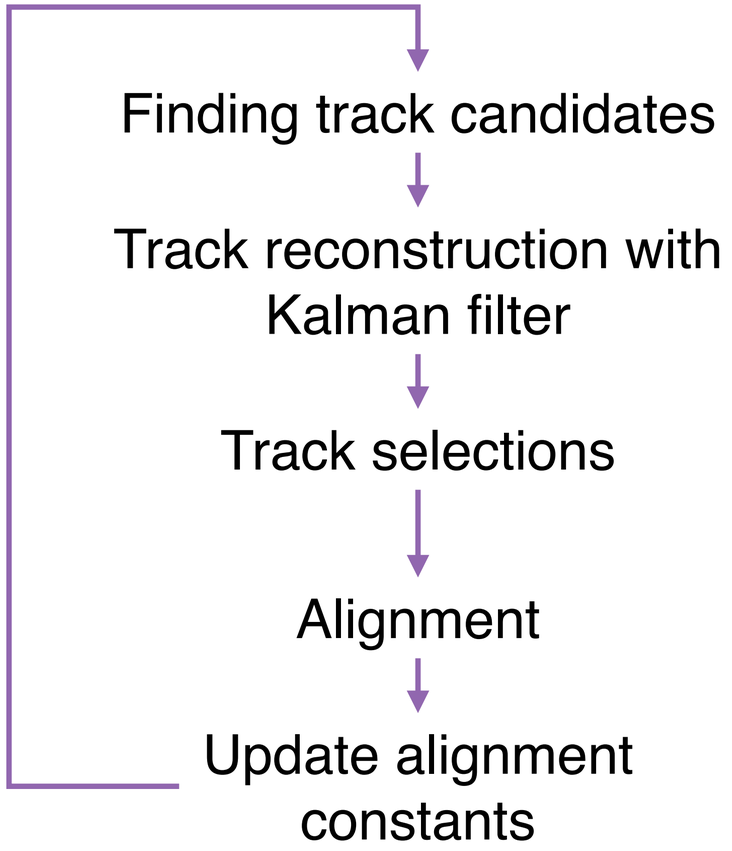
Reconstruction and alignment overview

- Tracking+reconstruction+alignment is a big area of interest
  - Lots more news/overviews in the Upgrade Computing and Software session today
  - VELO alignment is particularly relevant to us: crucial for long tracks
- Here we focus on:
  - SciFi alignment with long tracks
  - Tracking performance in SciFi
  - Hit efficiencies with long tracks
- This is a snapshot of our current positioning
  - Lots of planned work still to do with tracks/alignment over the next few months
  - Deep dives into specific aspects of recent data will be possible
  - Need to do a lot of preparations with online system (all alignments so far offline+manual+noDD4HEP)
- General principle:
  - **Step 1: understand big features**
  - Step 2: take a more precise look



We are here

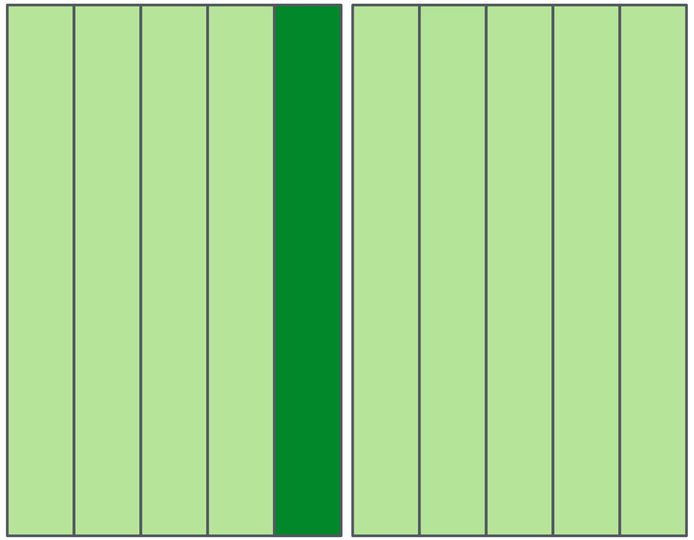
Process for running the alignment software

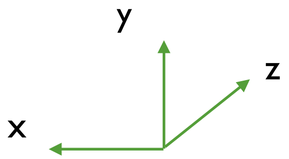


- The alignment is run iteratively
  - Use survey to set SciFi position for reconstruction in first iteration
- Track selections currently set from MC default
  - Planned: investigating different settings
- χ^2 constraints are used to:
  - align elements relative to a reference position (survey)
  - confine alignment of detector elements to their own local frame
- Currently running only manually/offline
  - Lots of room for tweaking settings

First alignments with long tracks

- First alignment calculated using Run 251342
  - Data recorded 27th October
- Applied in HLT1+2 from Run 252704
  - Improvements in tracking made this crucial to commissioning
- Configuration information:
  - Starting positions from SciFi survey (beam angle bug)
  - 200um uncertainty in survey positions inside alignment
  - Fix average Tx in back layer to fix momentum
  - **Long modules** aligned in TxRz degrees of freedom
  - Other degrees of freedom set from survey
  - VELO alignment for the same run used

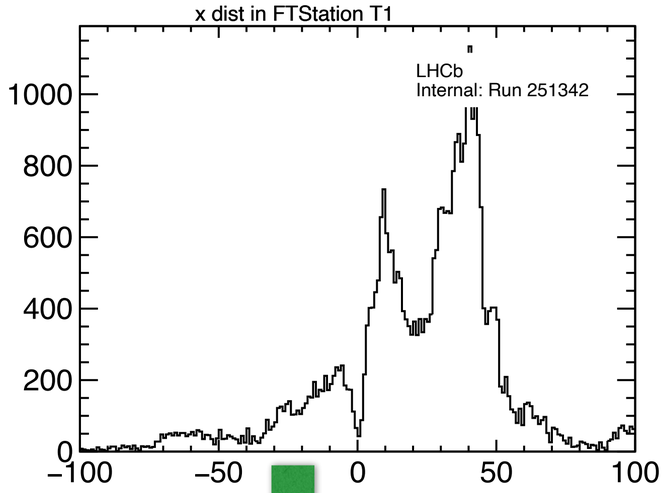


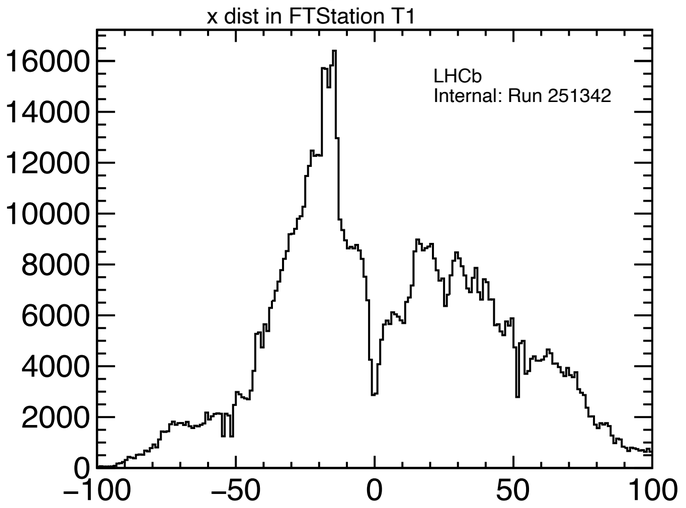


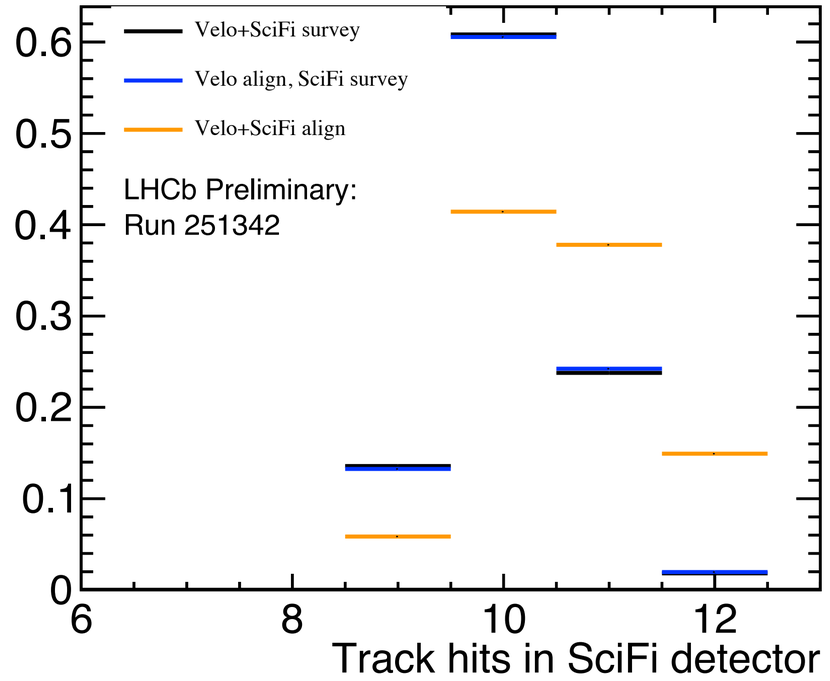
global LHCb coordinate system
(z along beam: looking from magnet toward CALO, MUON)

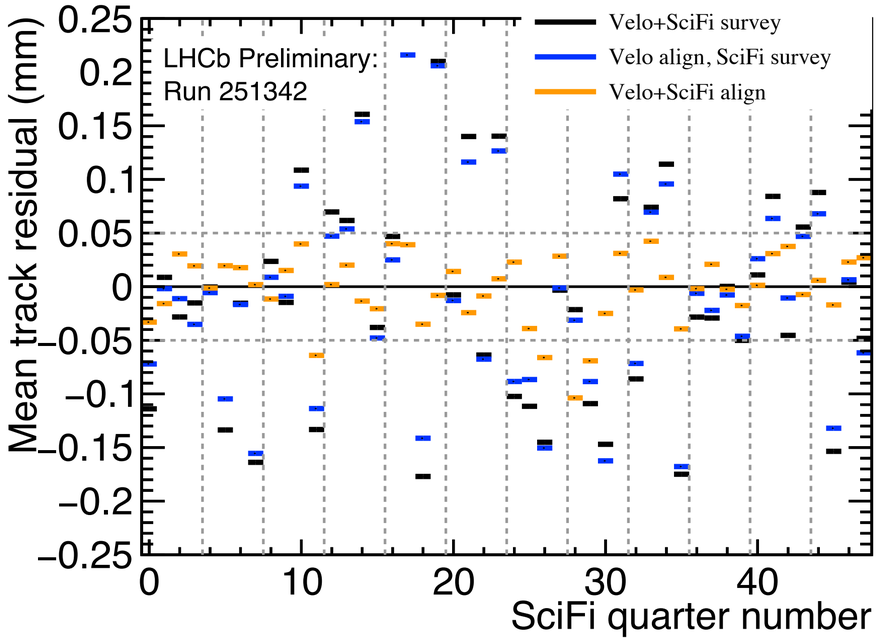
Performance of alignment for SciFi

- After first alignment:
  - More symmetrical distribution of track hits in SciFi (but still some puzzles)
  - Many more 11 and 12 hit tracks
  - Reduction of mean track residual in each SciFi quarter





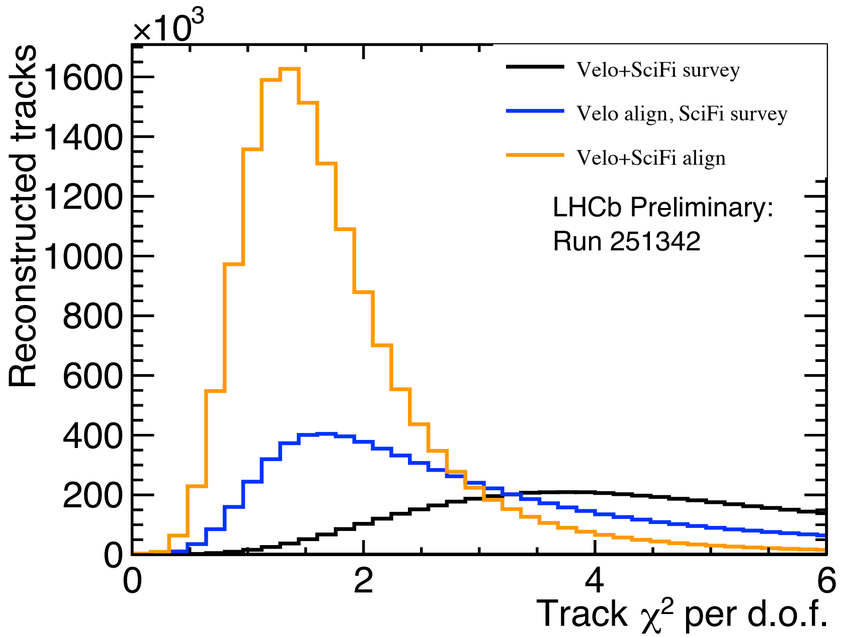


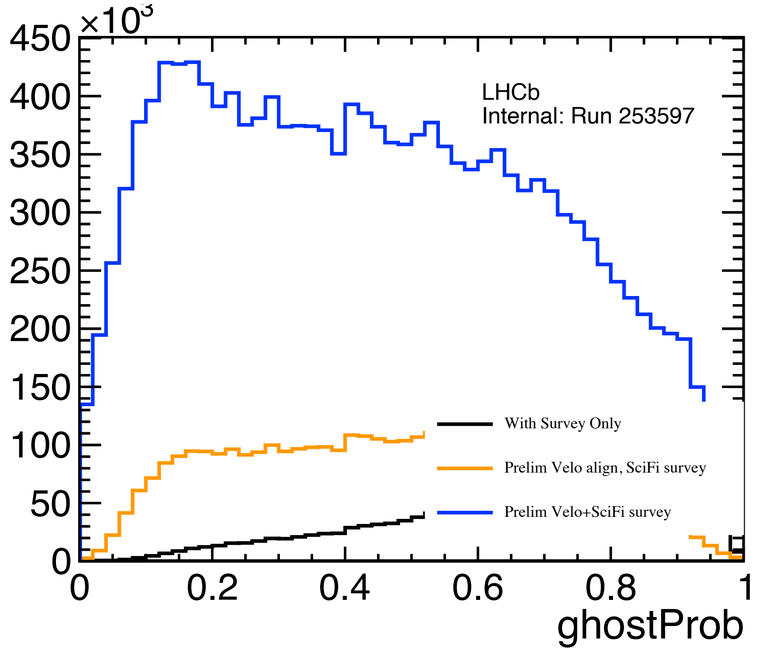


Performance of alignment for tracking

- After first alignment:
  - Lots more long tracks
  - Better track χ^2
  - Fewer ghosts
- But still: lots of puzzles to consider
  - Why was performance with survey so asymmetrical?
  - **Why a difference in efficiency for top and bottom half of detector?**
  - What can we do to improve the alignment in outer parts of the detector?

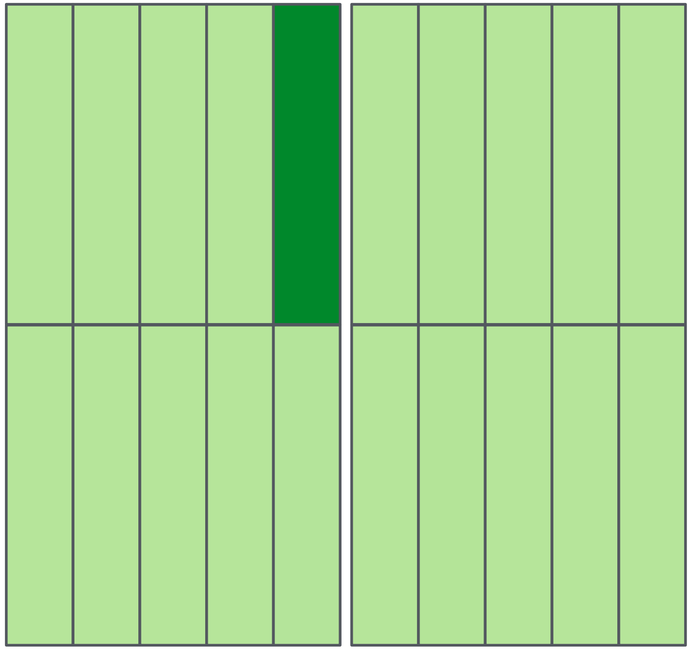
Track χ^2 and residuals per quarter in a Figure note

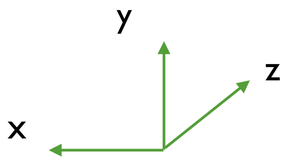




Incremental tests of alignment: looking at low mu sample

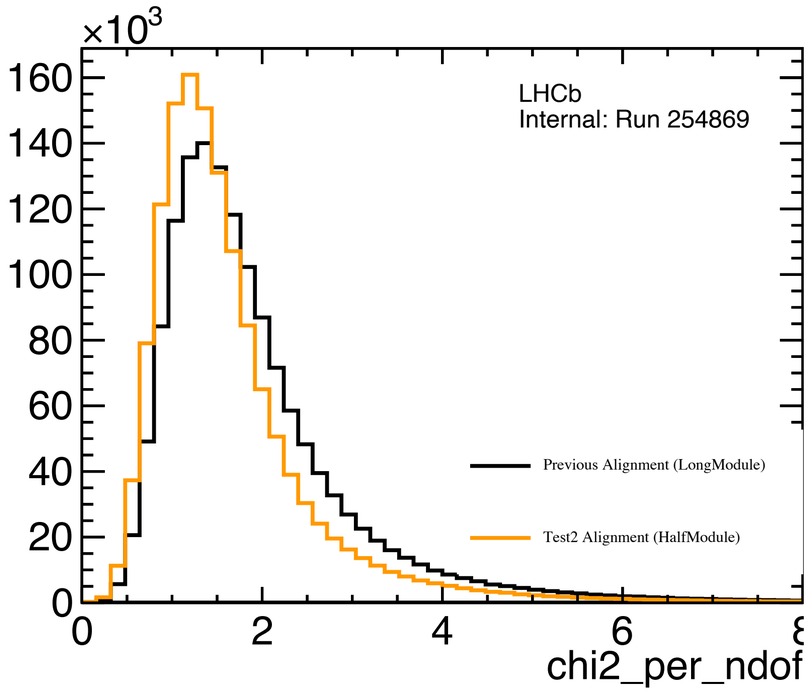
- Why low mu?
  - Some improvements to SciFi set up since first long tracks
  - Tracks are very clean in low luminosity sample
  - Dedicated VELO alignments available
- Configuration information:
  - Starting positions from SciFi survey (beam angle bug fixed)
  - 500um uncertainty in survey positions inside alignment
  - **Half modules** aligned in TxRz degrees of freedom
- Why half modules?
  - Use tracking alignment to correct for mismatch in top/ bottom half of SciFi long modules from survey (more on this next)

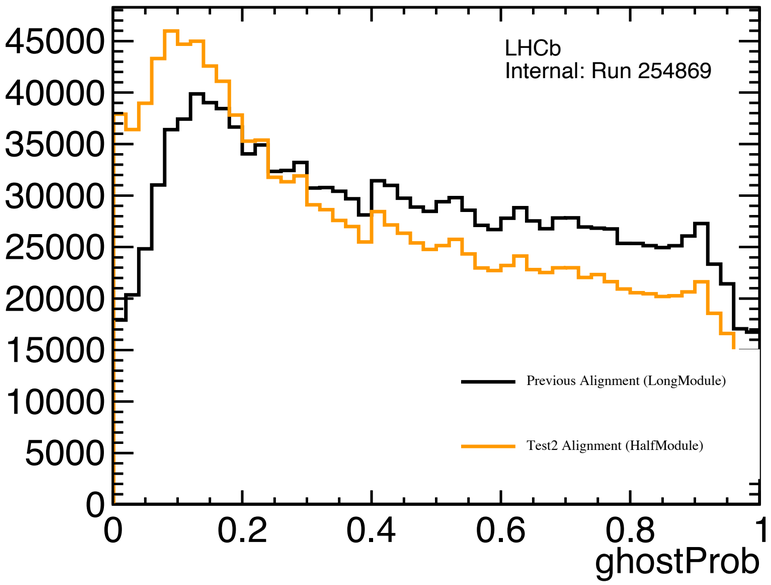


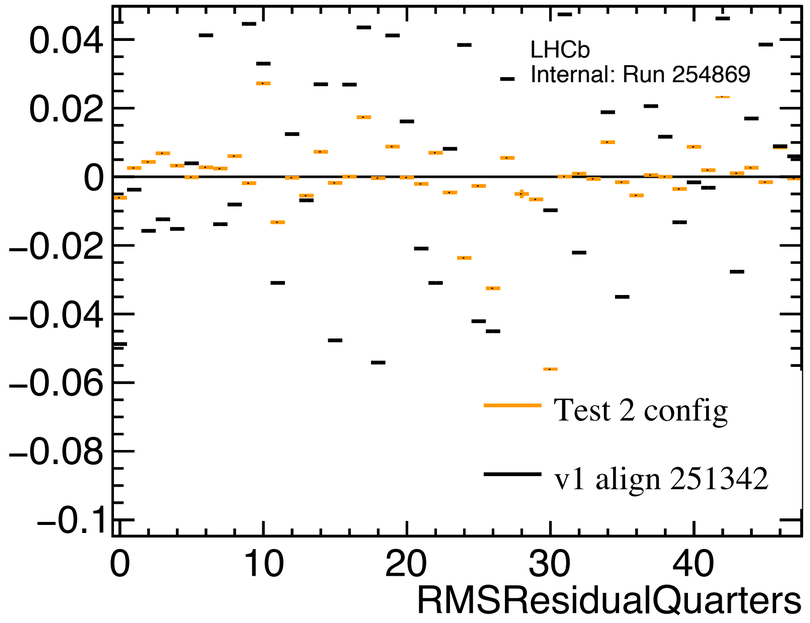


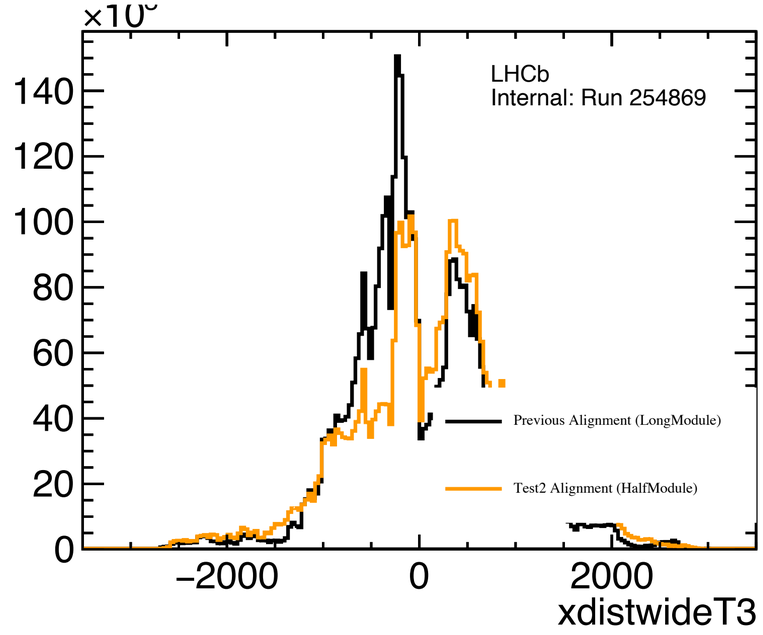
global LHCb coordinate system
(z along beam: looking from magnet toward CALO, MUON)

Comparing to the previous alignment









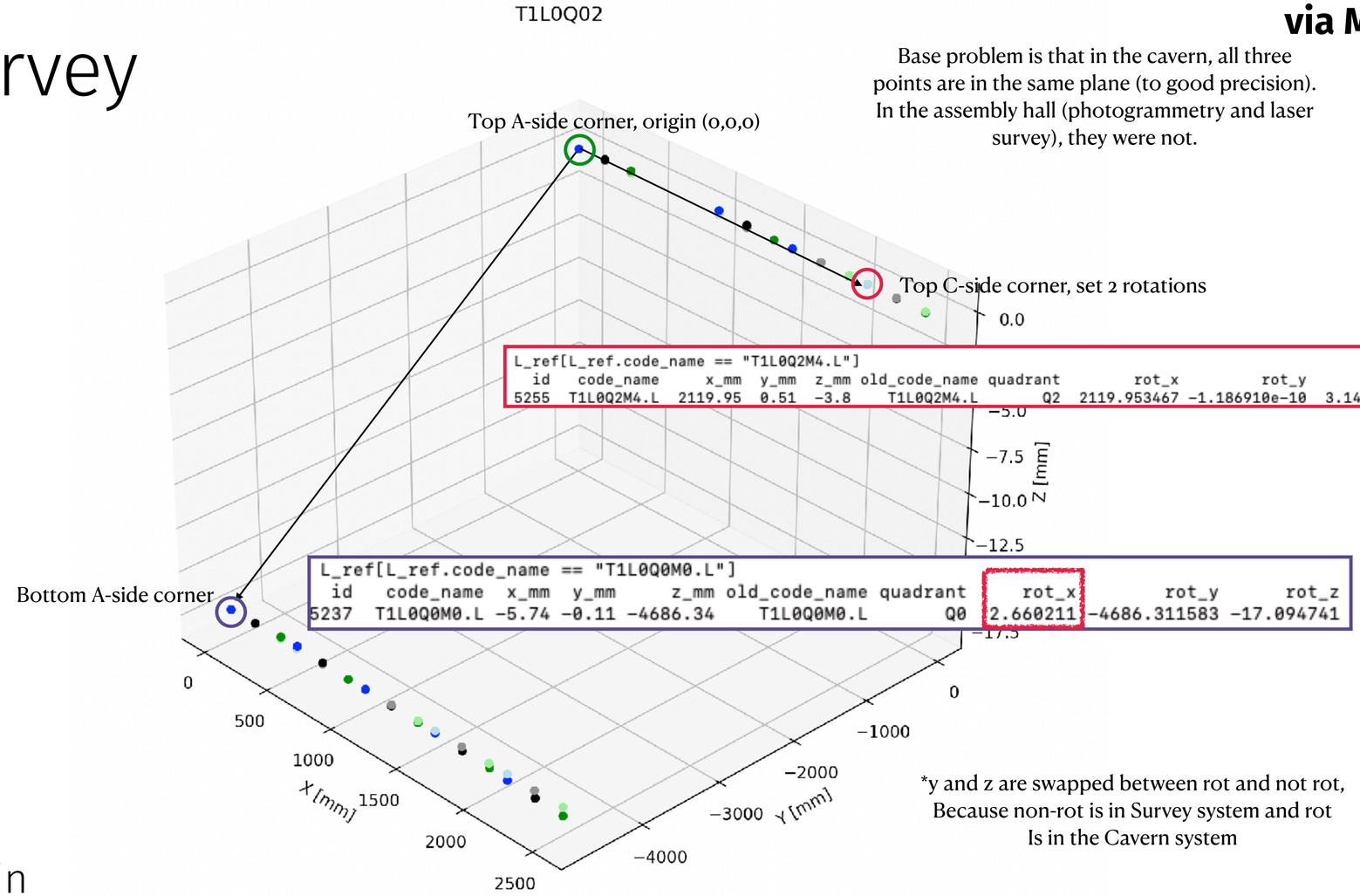
- Better track χ^2 and better residuals, but slightly fewer total tracks and a poorer distribution in x.
  - Alignment improved on the areas we could align
  - Good signs for future alignments IF we can get all half modules aligned
  - **…but 1/5 of all modules not realigned due to low statistics in test: issues with survey starting conditions?**

Checking the SciFi survey

- Current survey inputs: determined from photogrammetry in the Assembly hall.
- We suspect: frames and modules were less constrained in the test rig than they are in the cavern
  - Causes some twisting between reference points in top and bottom half: not in a single plane
  - Frames in cavern should not have this effect -> causes discrepancies in bottom half of detector between positions measured in the Assembly Hall and current position of detector.

via Maria

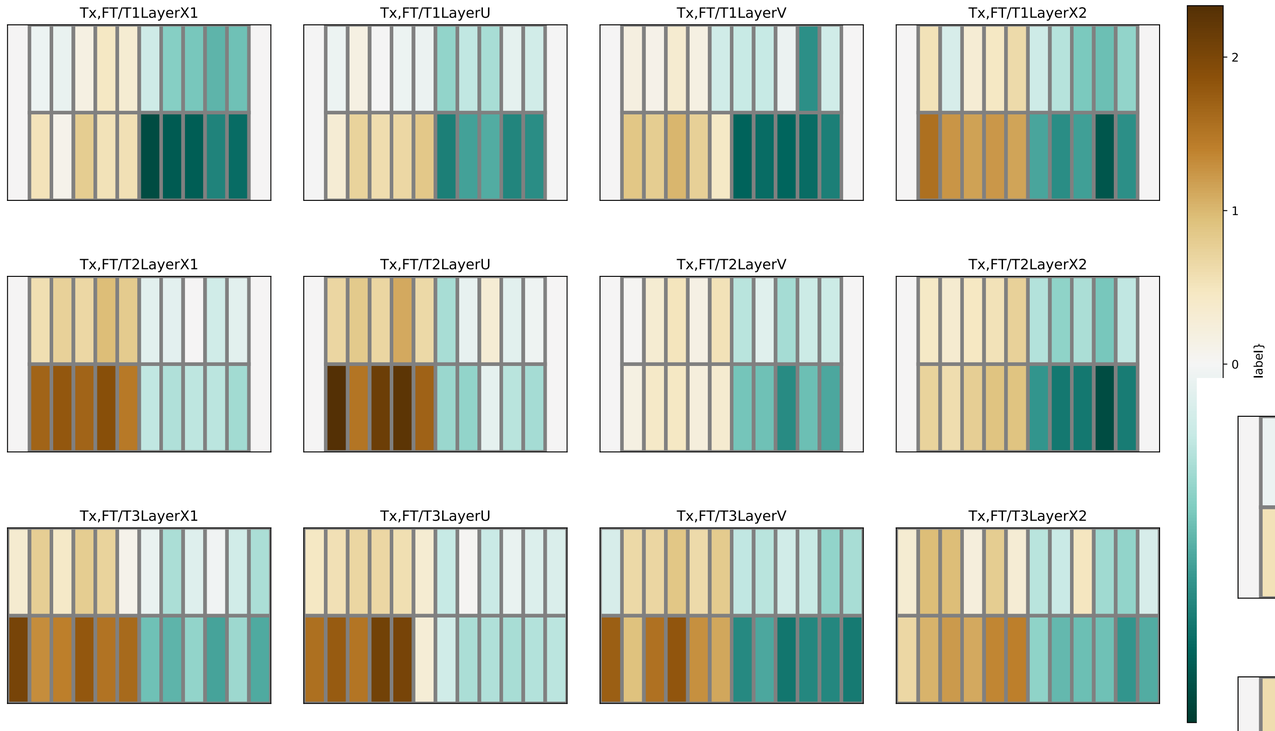
Base problem is that in the cavern, all three points are in the same plane (to good precision). In the assembly hall (photogrammetry and laser survey), they were not.



*y and z are swapped between rot and not rot, Because non-rot is in Survey system and rot Is in the Cavern system

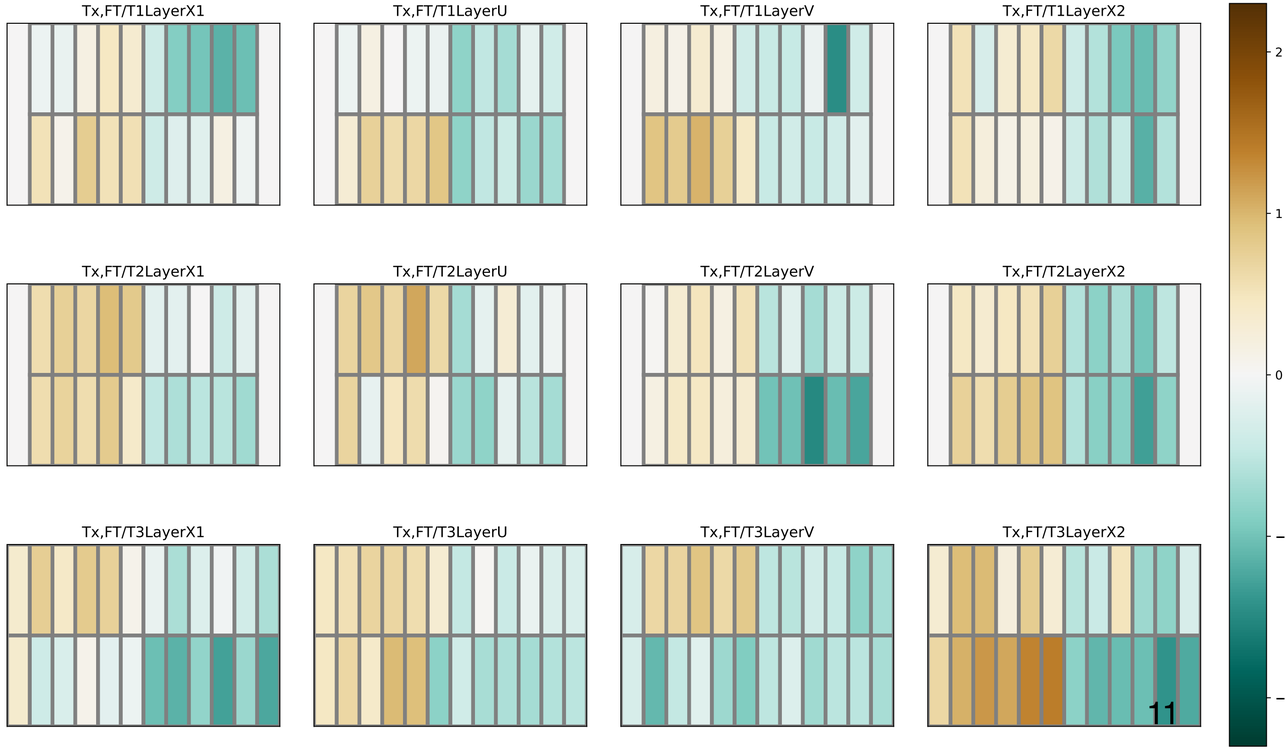
- New photogrammetry of modules planned for **January**, frames realigned/adjusted/surveyed for closing in **February**
- **This is crucial for alignment quality next year!**

Can we make any quick corrections to boost alignment power?



Shifting most extreme quarters only!
adjust so that A side edge used as survey reference matches on top and bottom half

Shifted 12 quarters in x (half of all the bottom quarters), and 4 in z



Will test these starting conditions/ constraints in next alignment
Best solution is still updated survey and photogrammetry

Current alignment status

- **Next week: alignment updates using newest data with best time alignment**
  - Use what we learned from low mu study/half module alignment
  - Use what we have learned about survey
  - Goal: Improved configuration for next round of reconstruction studies/HLT2 reprocessing

Other open SciFi reconstruction + alignment topics:

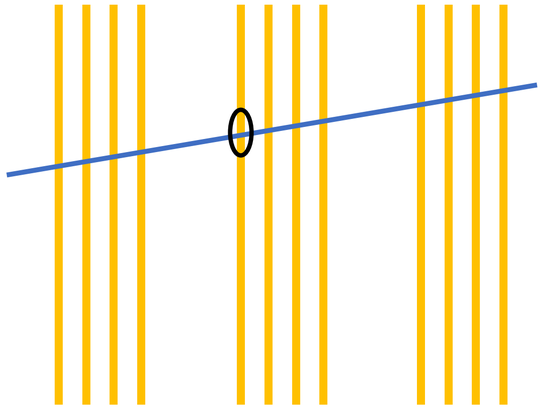
- SciFi coldbox calibration:
  - Reminder: cooling of SiPMs may bend the outer edges of fibres and move the reconstructed positions at the edge of each mat
  - Making updates to software to include parameters for these possible cooling effects
- Cluster bias effect:
  - Reminder: for some symmetrical cluster types, reconstructed centre is always pushed in the same direction.
  - Can cause (unphysical) rotation in alignment when top and bottom halves of SciFi push in opposite directions
  - **Current status: working on MC studies to justify firmware intervention.**

So, what have we learned about SciFi using the first alignment?

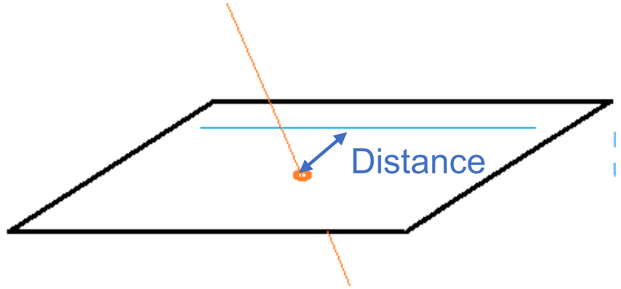
Looking at SciFi hit efficiency on long tracks

Hit efficiency studies

- Hit detection efficiency is a key indicator of tracker performance
  - Single hit efficiencies >98% expected in SciFi
  - Very interesting topic to follow as part of commissioning
- Hit efficiency depends on many factors
  - Time alignment of detector, hot channels, etc
  - Quality of VELO and SciFi spatial alignments (to get long tracks)
  - **No perfect precision information about efficiency in early stages due to changes of conditions: take a qualitative view**
- Calculating hit efficiency:
  1. Take a good track reconstructed WITHOUT your layer
  2. Use the track parameters to build the expected hit position in this layer
  3. Look at the decoded hits in this layer, compute the distance between them and the expected hit. If one is found within tolerance, consider it efficient



T2L0



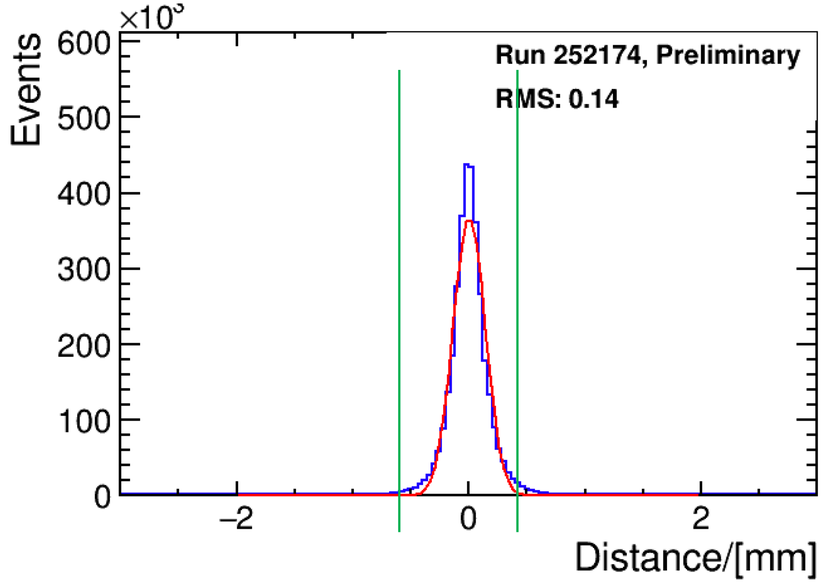
Hit efficiency studies

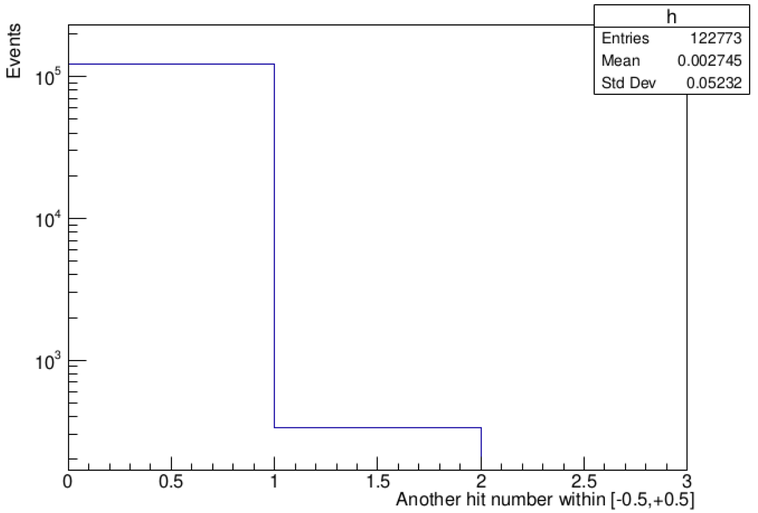
- Two approaches to hit efficiency studies so far
  - Hit efficiency in slices: per SiPM/module
  - Hit efficiency in a 2D distribution: FTHitEfficiencyChecker
- Hoping to combine the best of both approaches in the future
- Today: Start with Zehua's work on hit efficiency per SiPM, move onto the 2D plots from Laurent (comparison of older vs recent data!)

Hit efficiency studies (with an eye on SiPMs)

via Zehua Xu

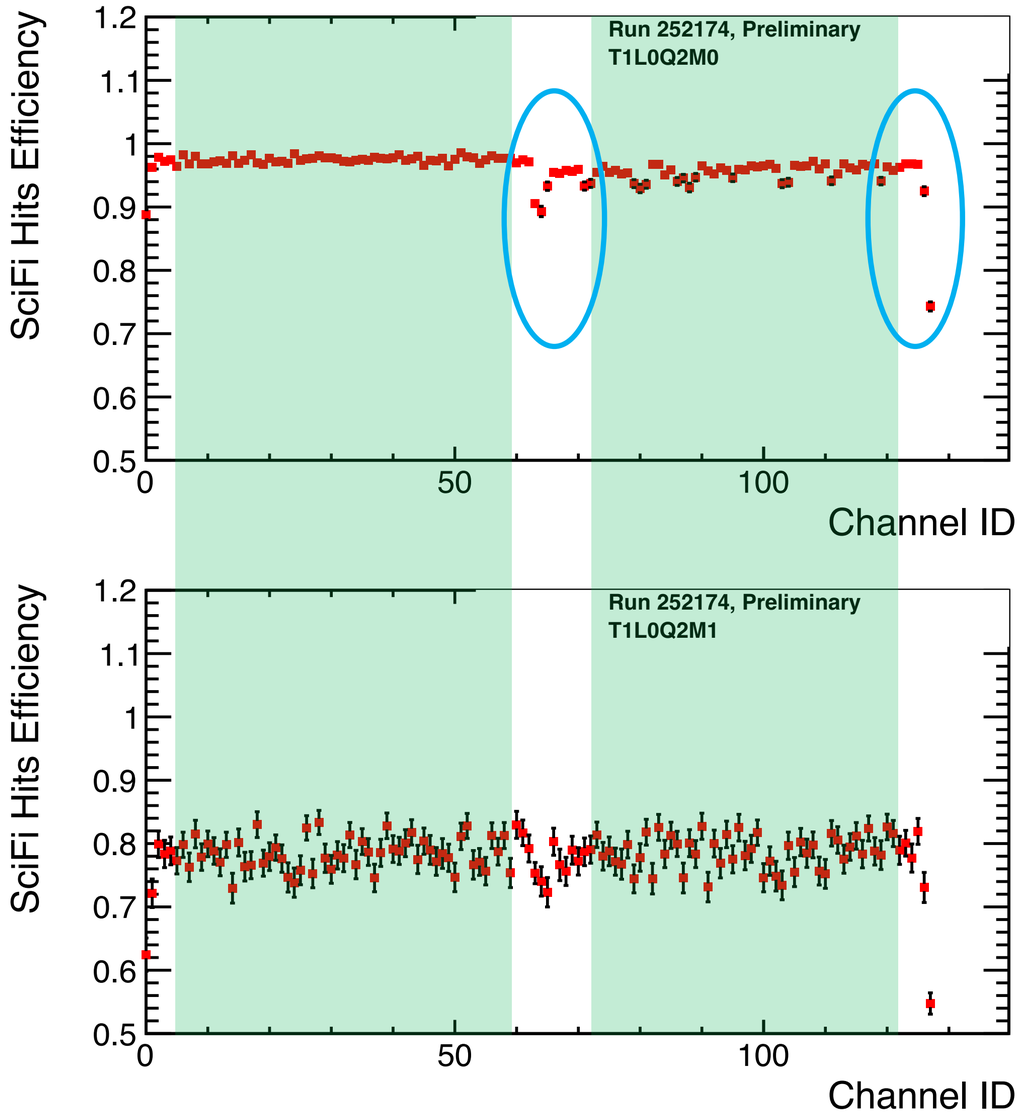
- Studies on Run 252174 (3rd November)
  - Many more slides from overview on 29th November
- Consider long tracks with
  - nSciFiHits>8
  - p > 3 GeV, pT > 0.3 GeV
  - χ^2/ndof in SciFi < 2.5
- 1D distance between track and cluster channel considered: <0.5mm
  - Less than 0.1% of tracks have a hit outside this window
  - Mean unbiased residual per module in data is usually < 150um
- Are there contributions in this window from other tracks?
  - Studied high luminosity MC sample
  - Possibility of more than 1 hit in ± 0.5mm region: <0.3% in inner module

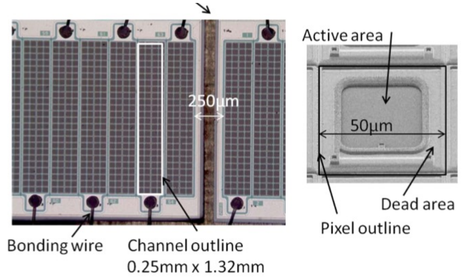




via Zehua Xu

Regions used in SiPM hit efficiency



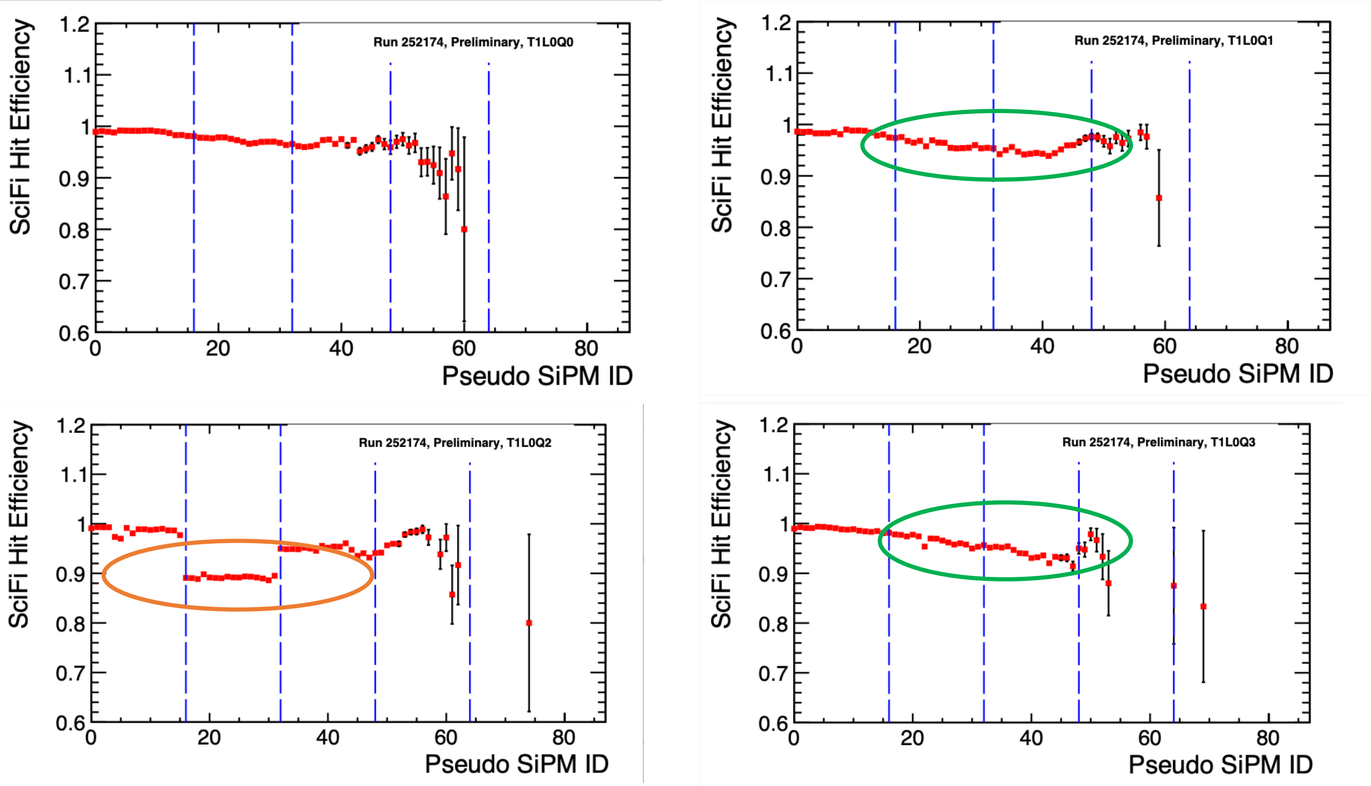


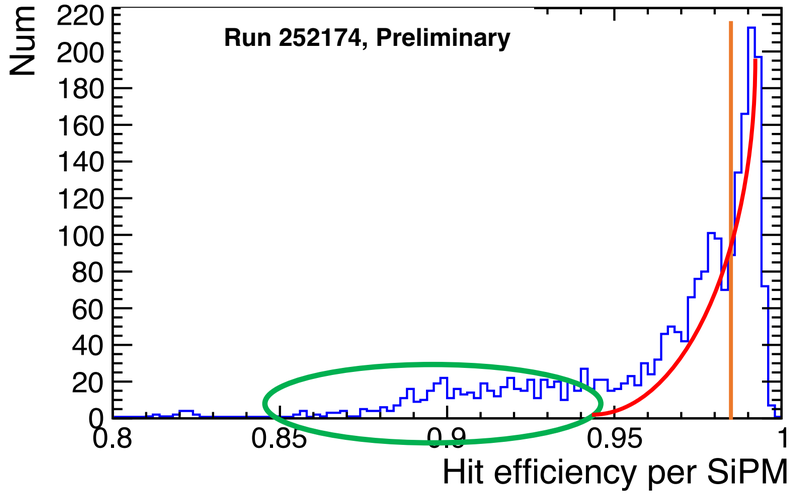
- Single hit : channels out of dead/gap area
- Using single hit efficiency to define SiPM efficiency
- Average hit efficiency per channel in T2L0Q2M0 > 98% (Single hit efficiency)

via Zehua Xu

Hit efficiency studies (with an eye on SiPMs)

Single hits efficiency per SiPM (T1L0)



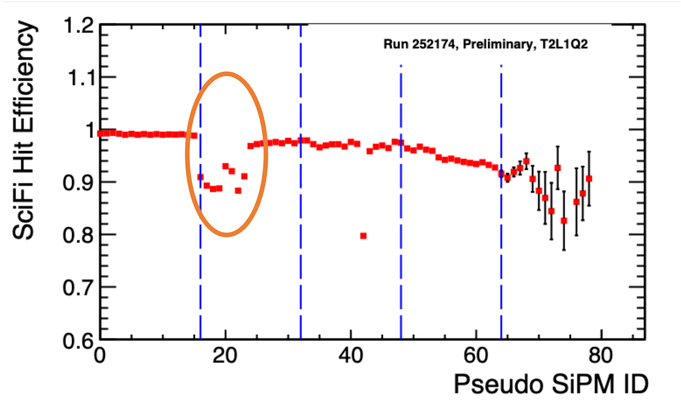


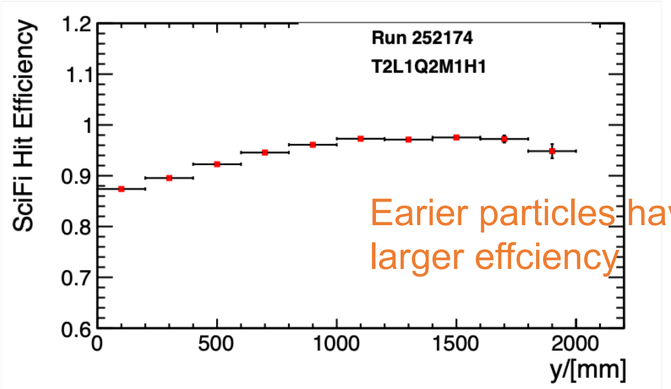
- Hit efficiency per SiPM, for all SiPM in M0,M1,M2
- Circled region of SiPM with lower efficiency:
  - Inefficient channels?
  - Imperfect time alignment?

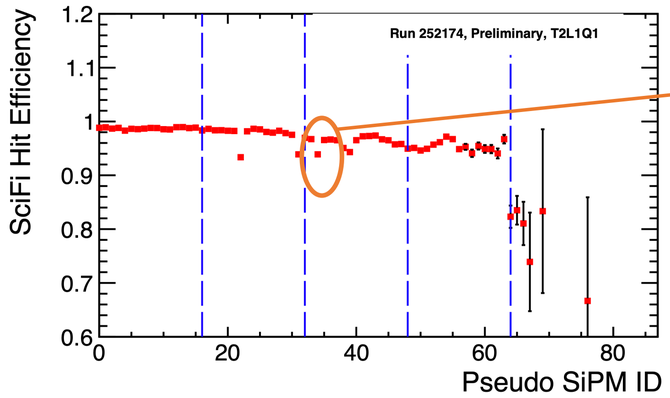
- After archiving Most signal hit efficiency $> 95\%$
- Monitor lost module
- Possible to improve efficiency with better time alignment

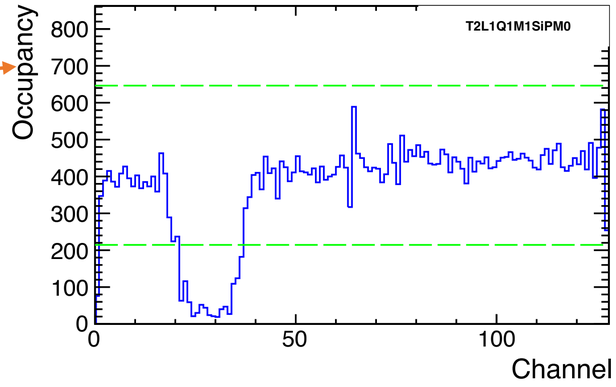
Hit efficiencies and SciFi monitoring

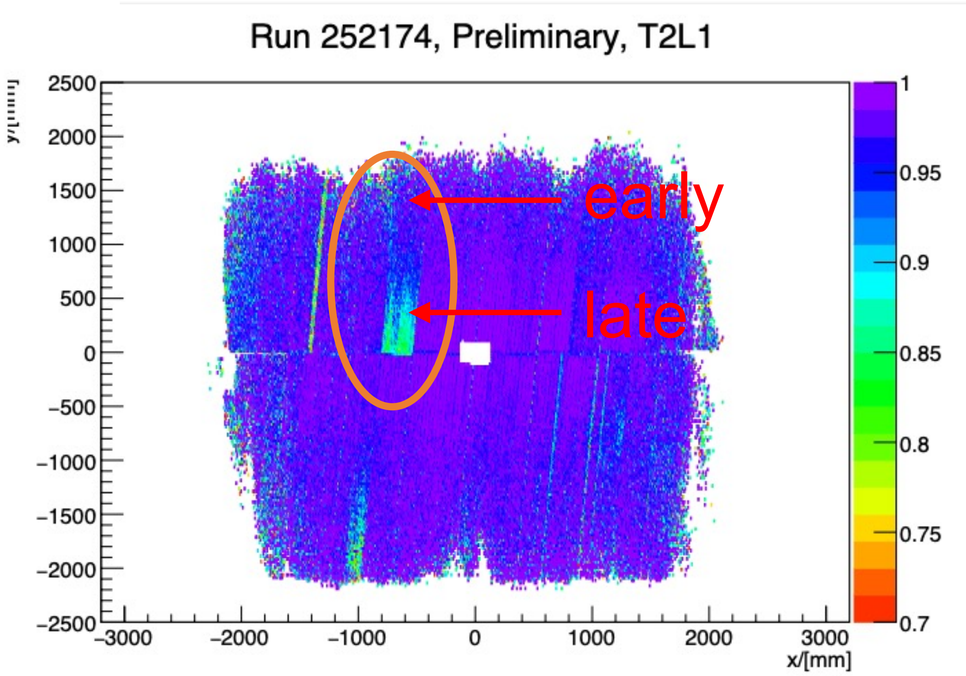
- Single hit efficiency by SiPM can show us:
  - Detector regions where the time alignment is inefficient
  - SiPMs that have channels with poor efficiency











Discussion topic: would it be feasible/useful to run timing or threshold scans layer by layer using this monitoring as a reference to optimise hit efficiency?

2D hit efficiency maps (from a tracking perspective)

- Current hit tolerance: 2.5mm (but in 3D)
- Currently considering: long tracks with p> 5GeV, pT> 400 MeV
- **New Gaudi algorithm for this: FTHitEfficiencyMonitor**
  - Updated from software for OT procedure
- Have a comparison of older vs newer runs today!

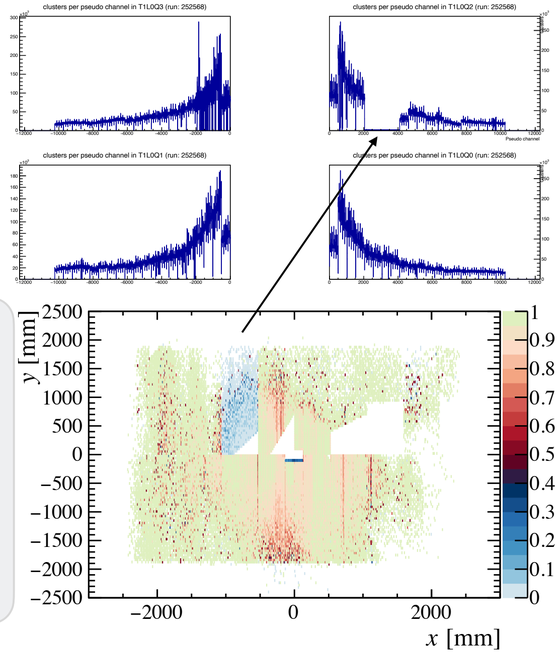
Upcoming plots from Laurent Dufour
Thanks to Wouter + Andre for assistance with the software

2D hit efficiency maps: with Run 252568

- This Run is from 5th November, seen in Laurent's presentation on 15th November
  - Very early VELO alignment
  - Earlier version of fine time alignment
- Lots of modules with poor efficiency
  - Spatial alignment? Time alignment?

White patches: either no hits in 2.5mm OR no tracks passing through this region when this layer is not included

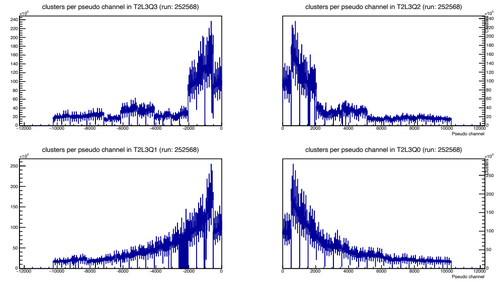
T1L0

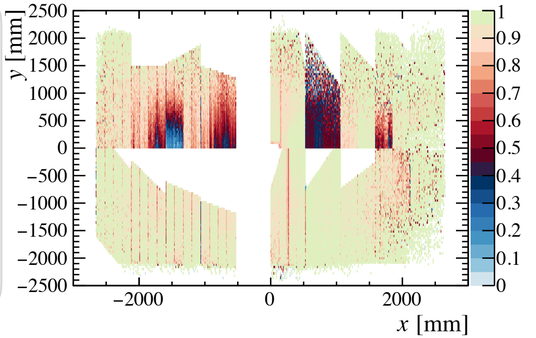


See lower efficiency around mirror point for some modules?

Genuine effect? Matter of thresholds?

T2L3

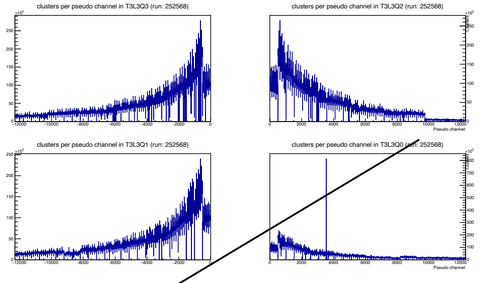


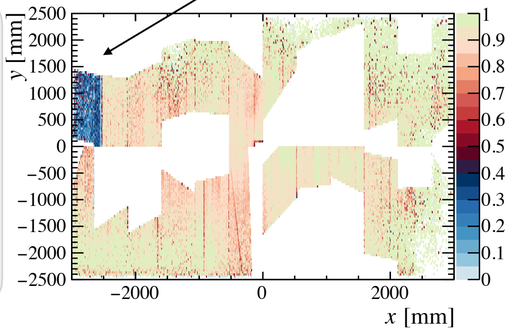


Few modules a bit poor, again seemingly more poor around mirror point

Performance agrees somewhat with that of cluster histogram

T3L3



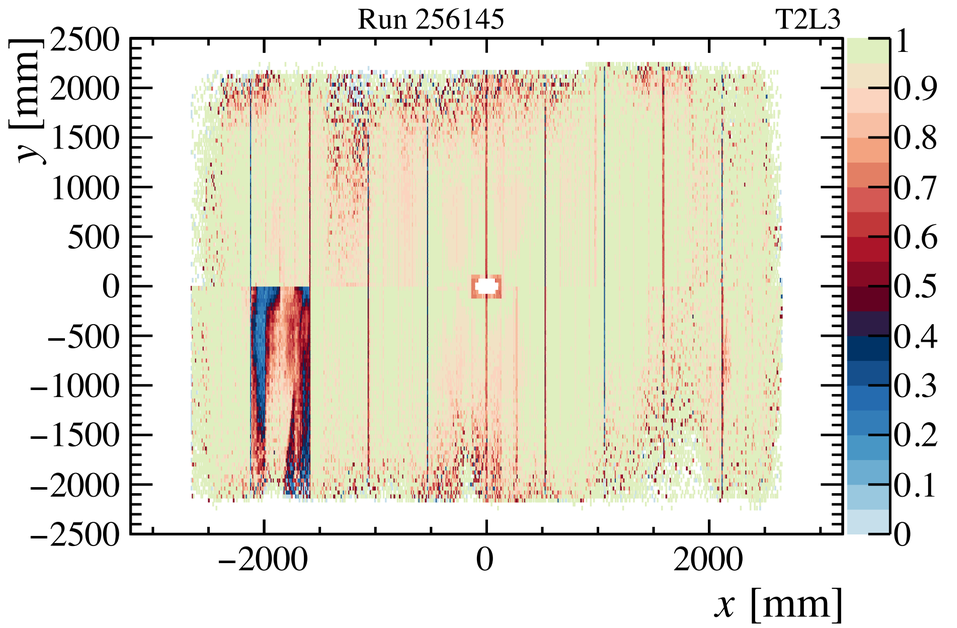


One module poor

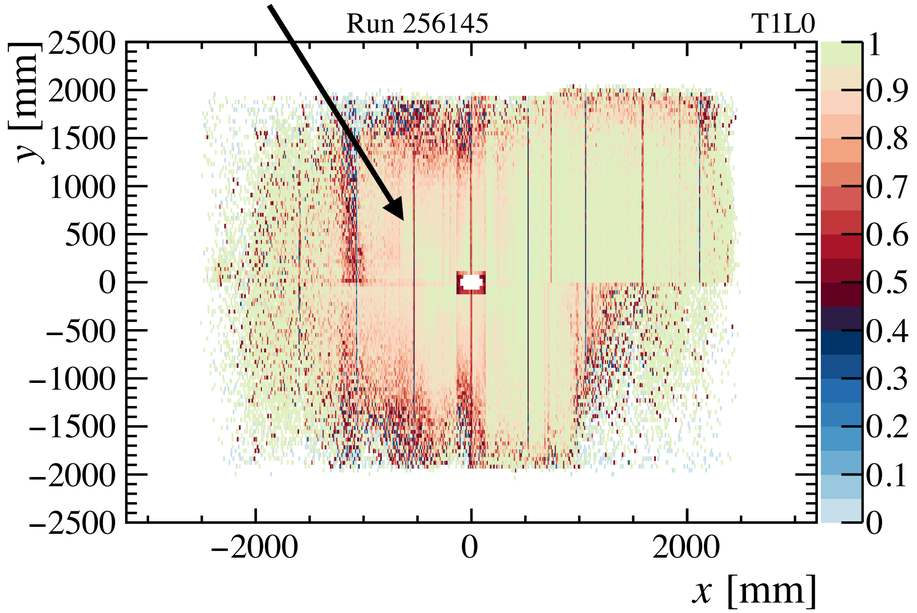
What's going on with the diagonal line around y < 0 and x ~ -500mm?

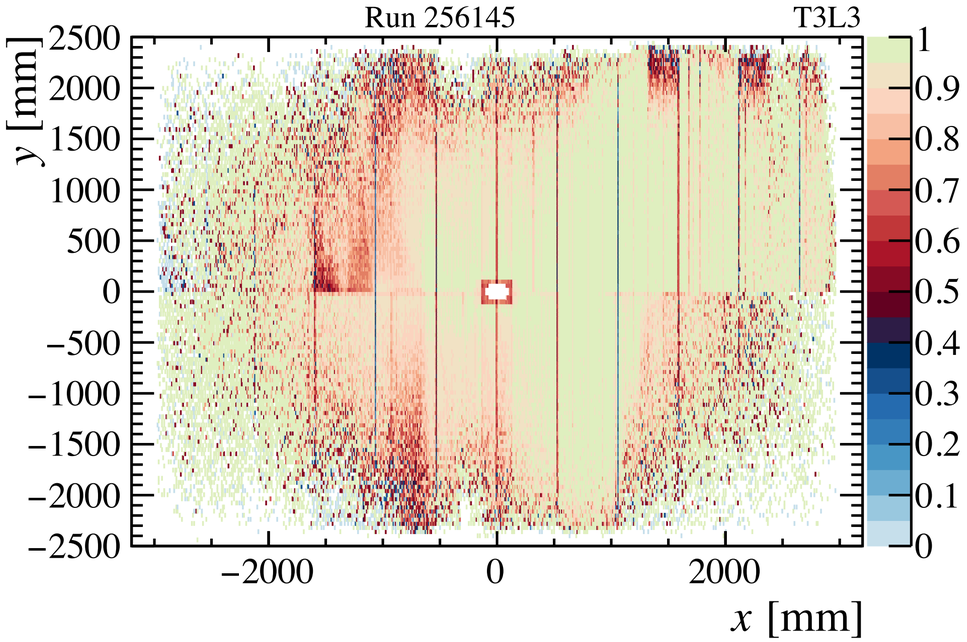
2D hit efficiency maps: with Run 256145

- This Run is from 27th November
  - Best SciFi time alignment so far
  - Dedicated alignment of VELO halves
  - Same SciFi alignment
- Huge thank you to everyone who made this possible!

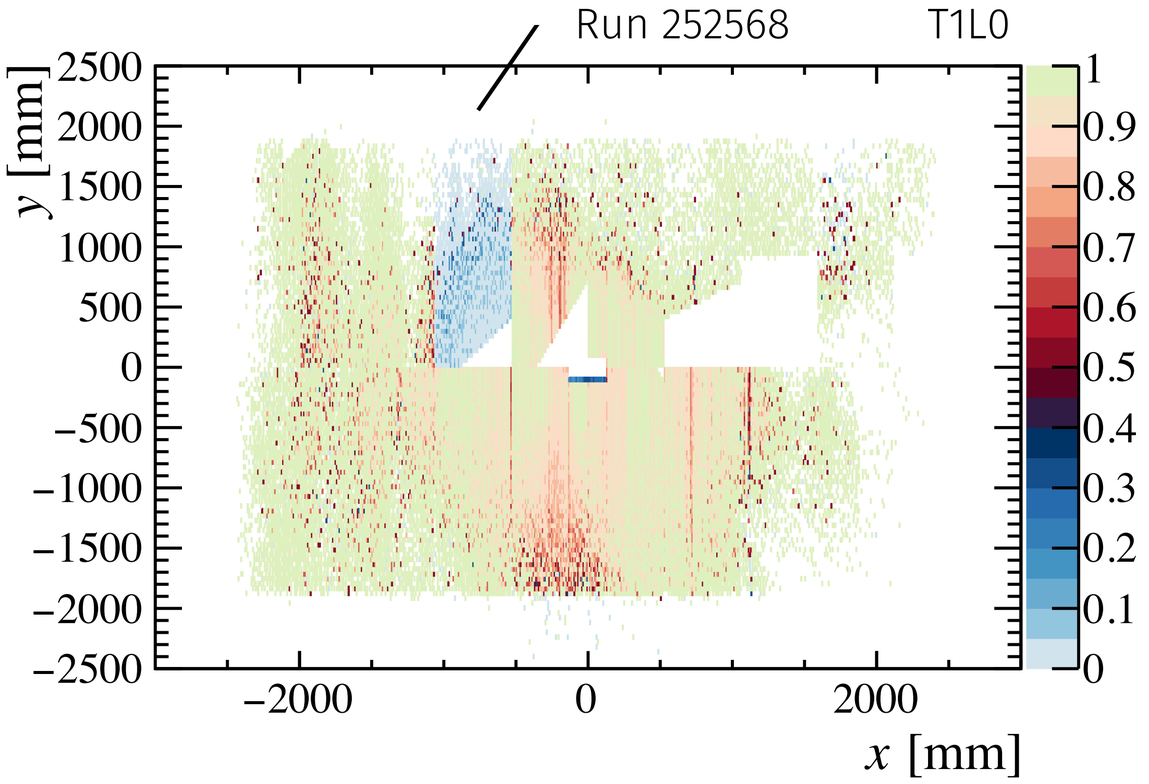


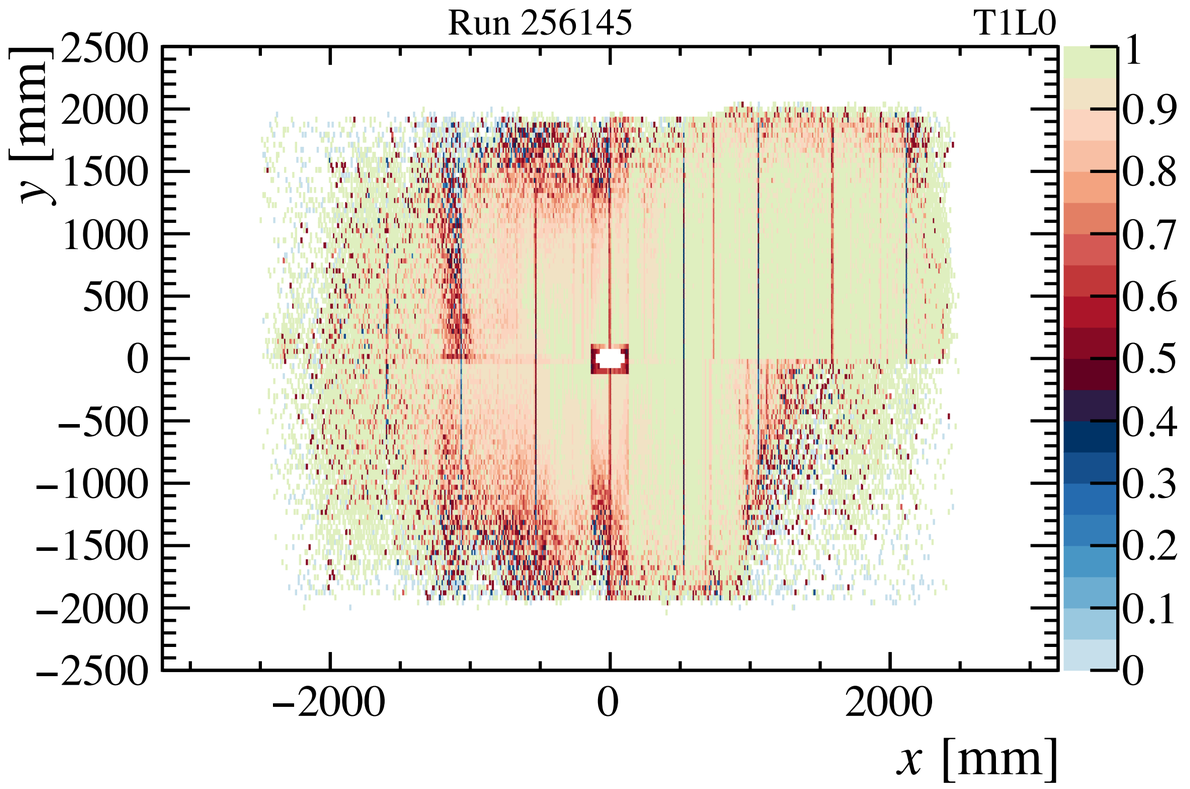
Now receiving clusters in this module





Side by side:





- Top/bottom differences in tracking performance are now easier to spot
  - Performance still looks quite good for an alignment produced with an older timing configuration!
  - Looking forward to studying how this behaves in newer alignments

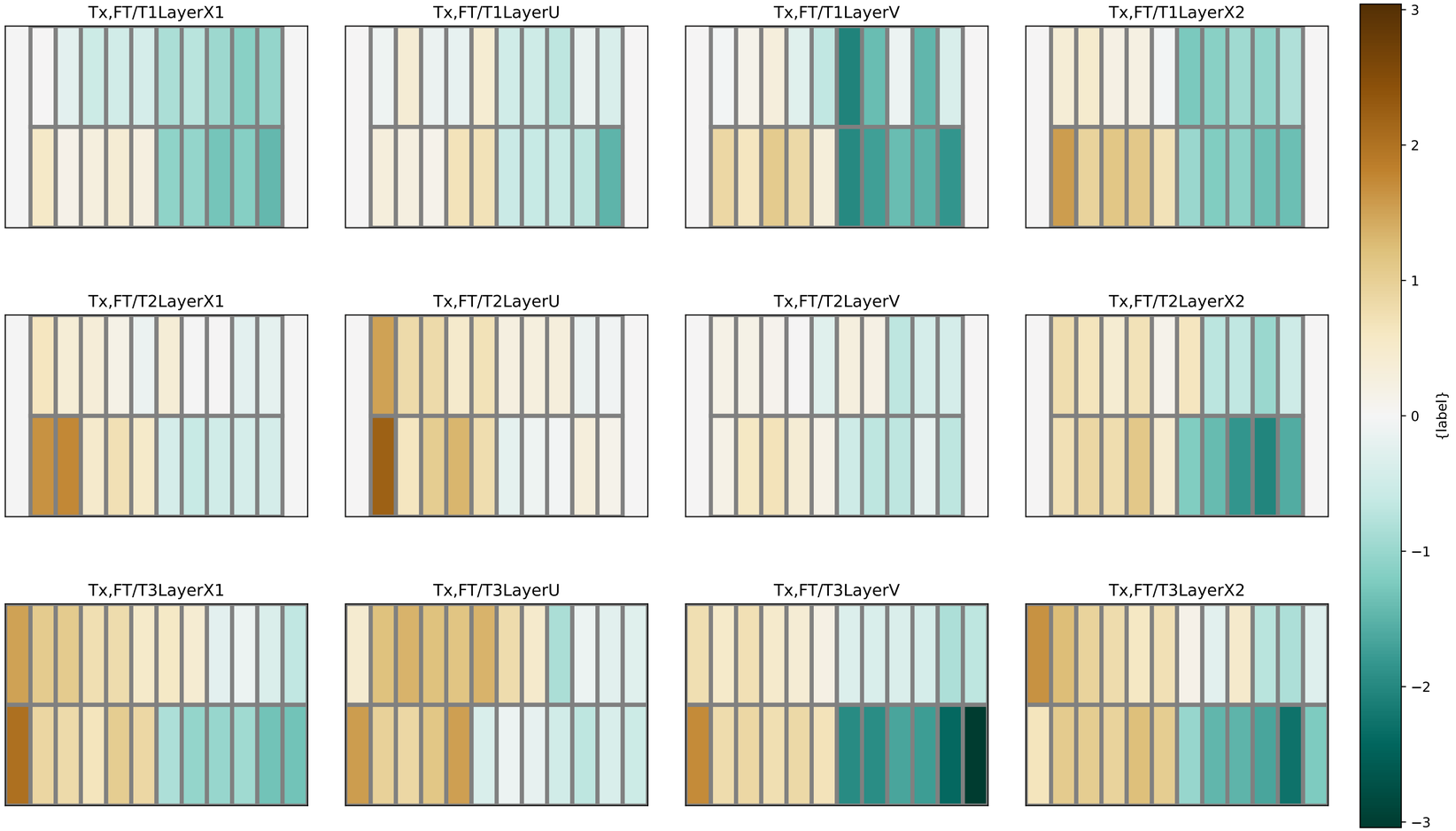
Summary:

- **We have had ~ 1 month of data with long tracks:**
  - First alignment was included in HLT1+HLT2
  - Have tested multiple possible alignment updates, but haven't had a configuration yet that provides improved track quality AND a good spatial distribution of tracks in SciFi
  - We have all the ingredients for an improved alignment now: **coming very soon**
- More steps in YETS: additional incremental improvements
  - Tests using magnet off sample
  - Use SciFi + RTA expertise to look more at tracking under different conditions, including 2D hit and tracking efficiency in SciFi and search for further improvements
- Thanks to everyone who's jumped in to help study long tracks so far
  - The extra person-power during this crunch period has provided a lot of extra information
  - Hit efficiency studies look very promising and have been a great partner to spatial alignment + SciFi timing studies
  - Lots of ideas for new areas of study/self-contained project areas, and
- **Looking forward to lots of studies to prepare us for the next data samples**

Backup

Test 2: half-module alignment, new survey, loose uncertainty

Run 254869, 1M events last iteration (iter #7)



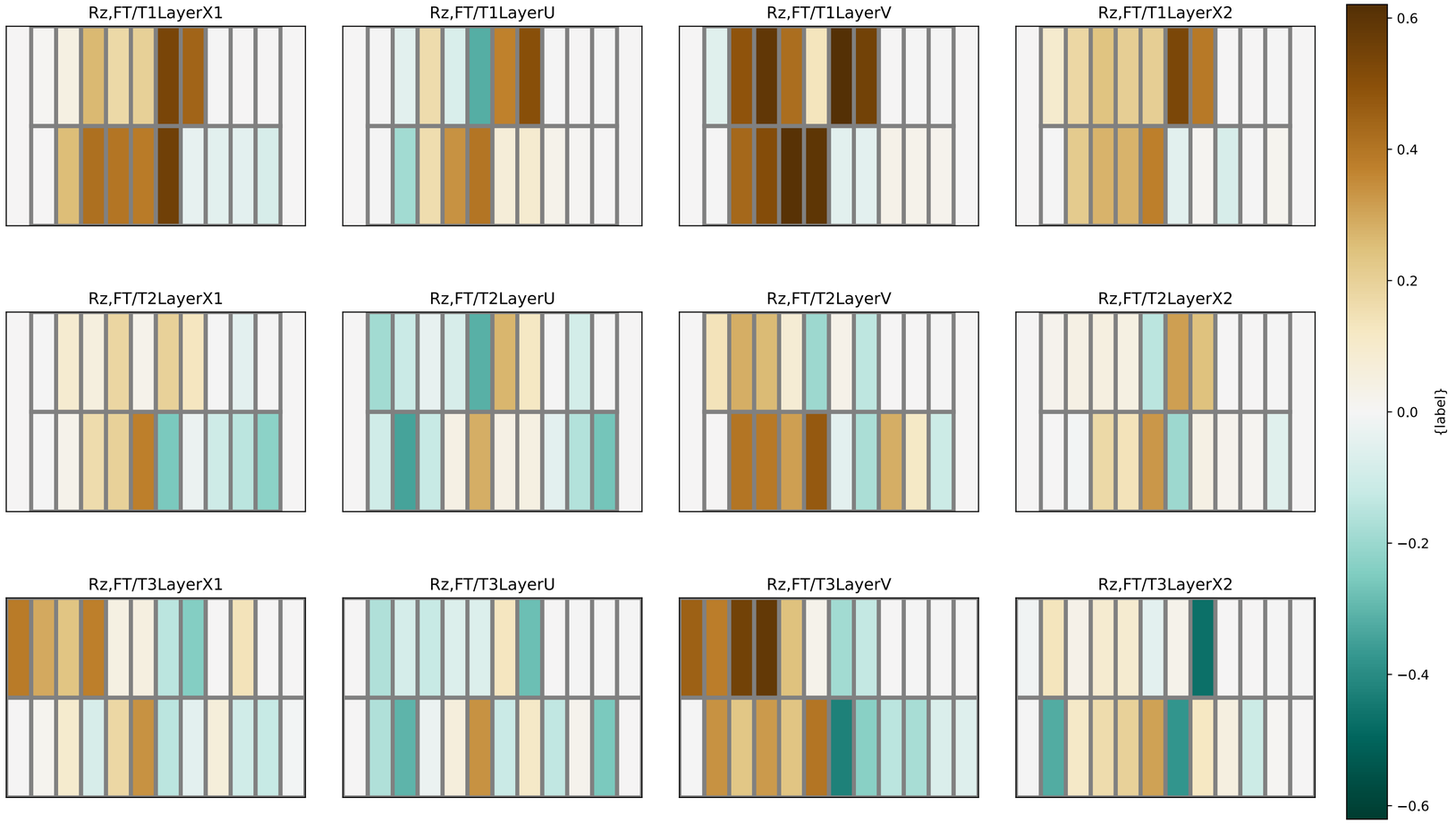
Reduction of top-bottom differences

Still differences A side vs C side

T3LayerV C side seems to have not been realigned
- low statistics?
- affected by fixing T3X2 in place?

Test 2: half-module alignment, new survey, loose uncertainty

Run 254869, 1M events last iteration (iter #7)



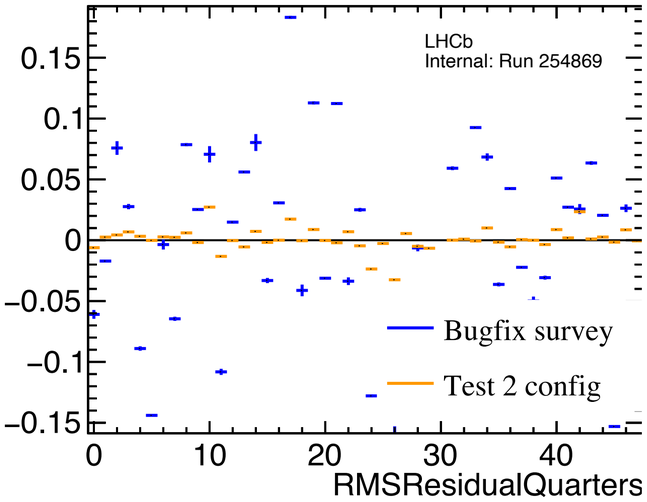
Survey starts with almost 0 rotation in z

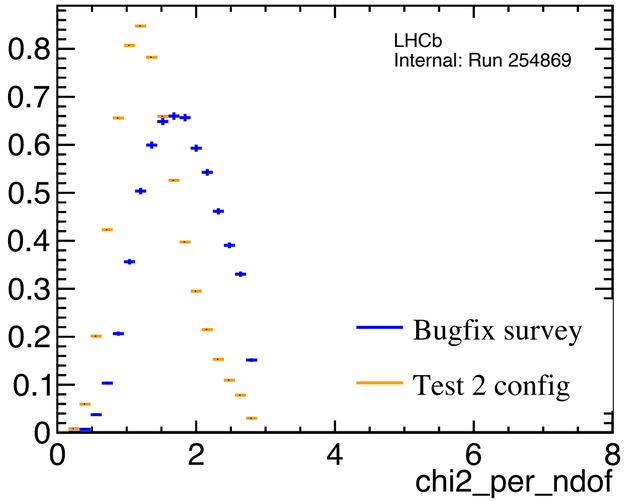
Shearing in x converted into rotation of long module by alignment

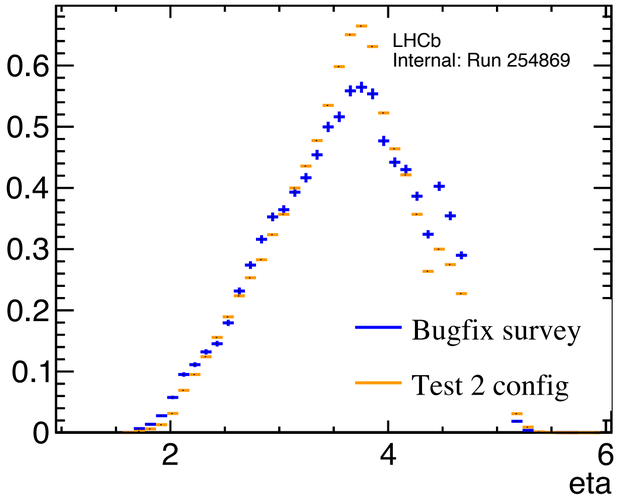
Is this physical? Or not? More study needed

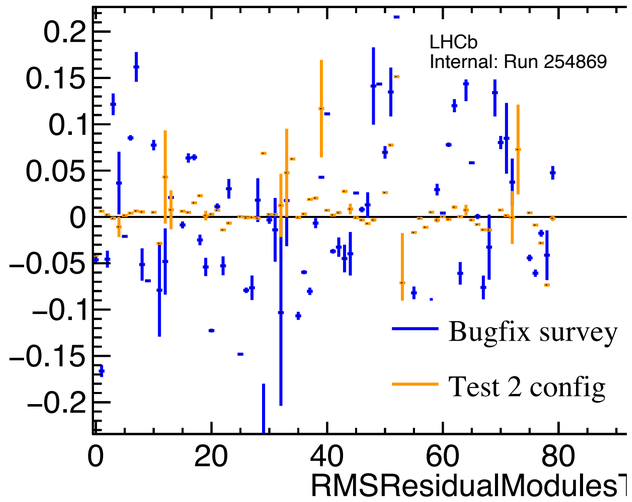
Test 2: half-module alignment, new survey, loose uncertainty

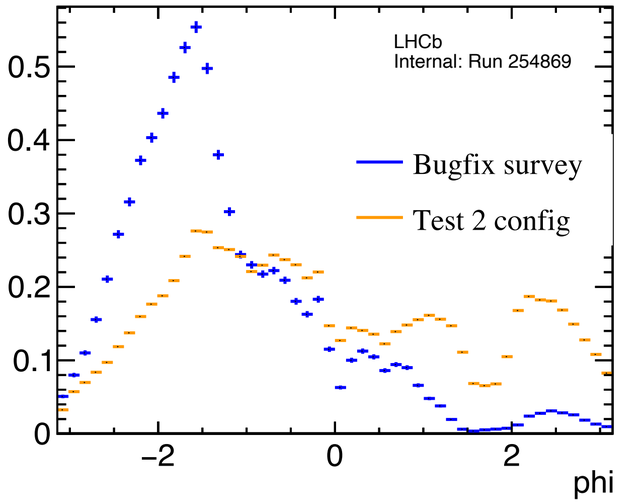
Run 254869, 1M events last iteration (iter #7)

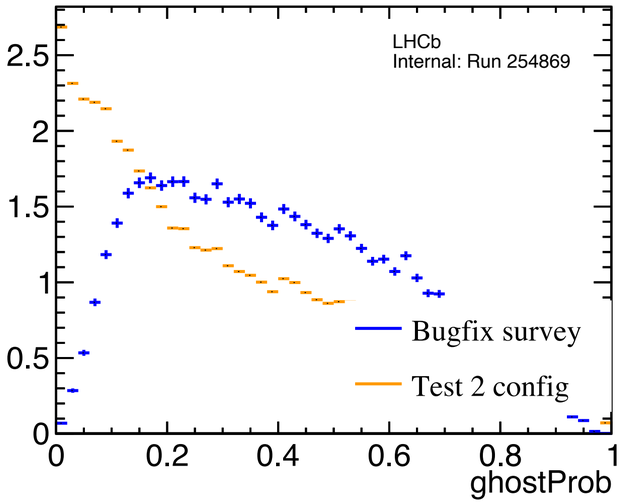




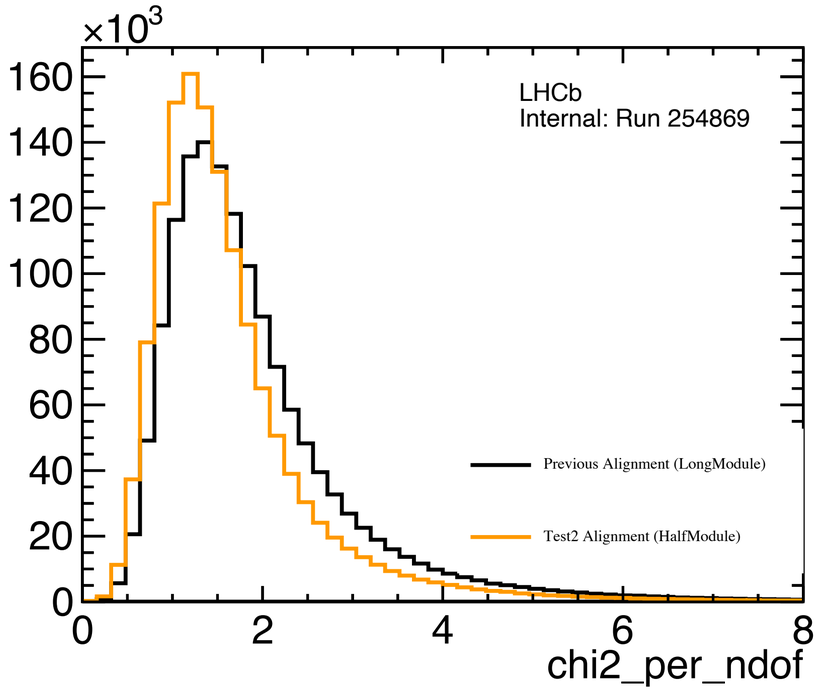


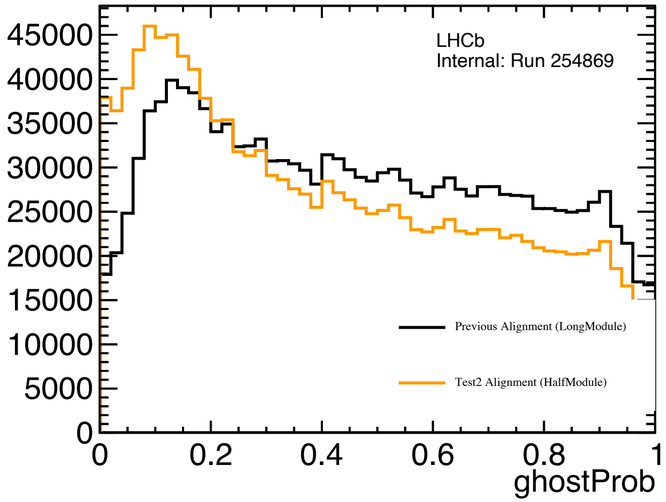


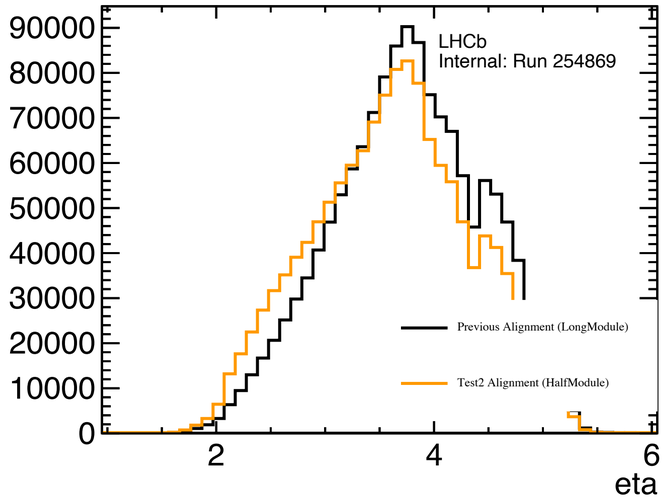


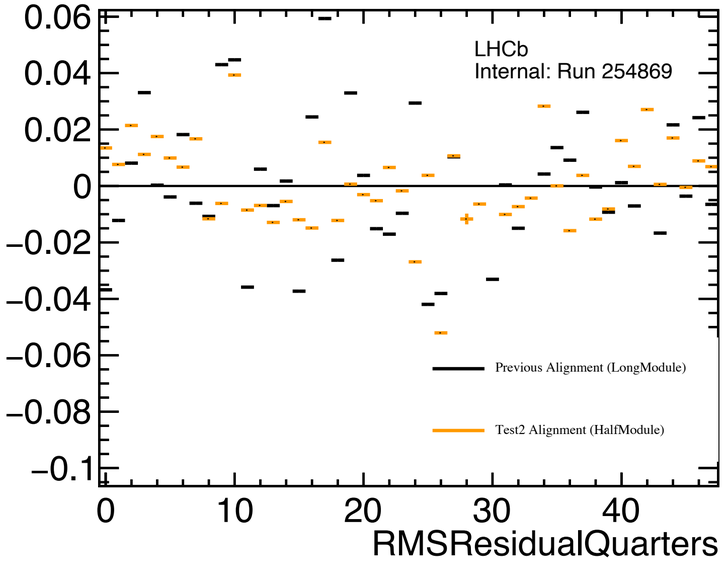


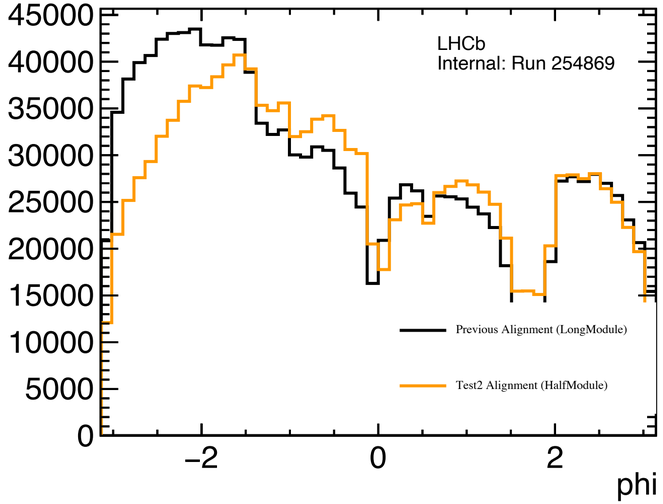
Half-module alignment vs First alignment on Run 254869



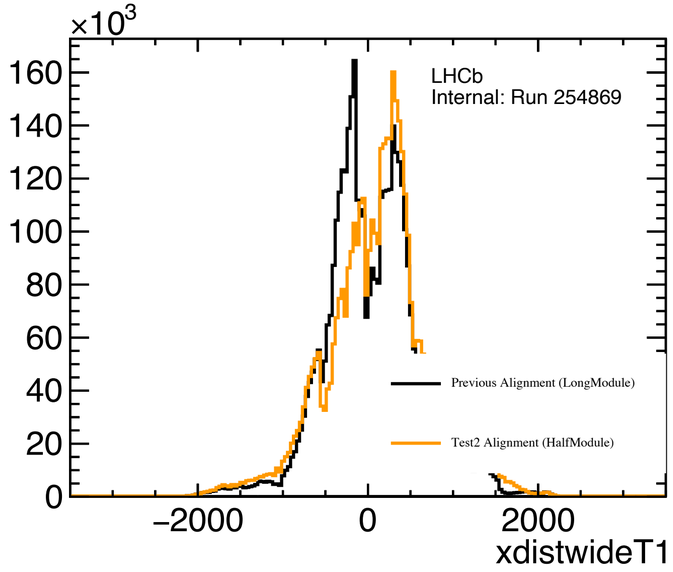


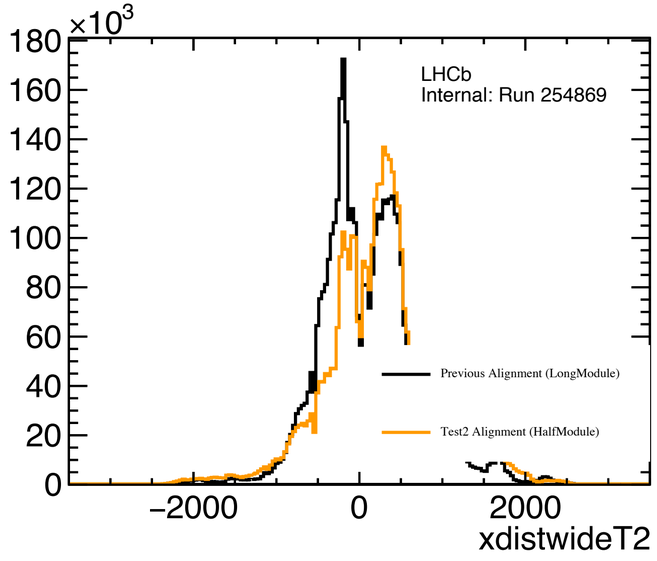


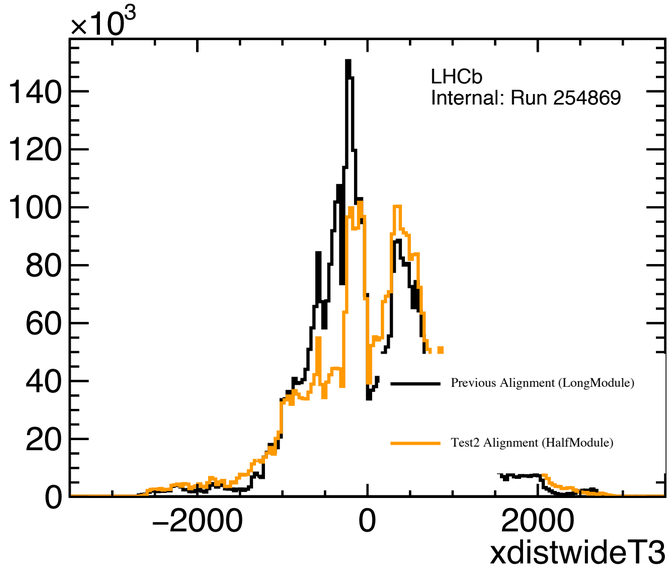


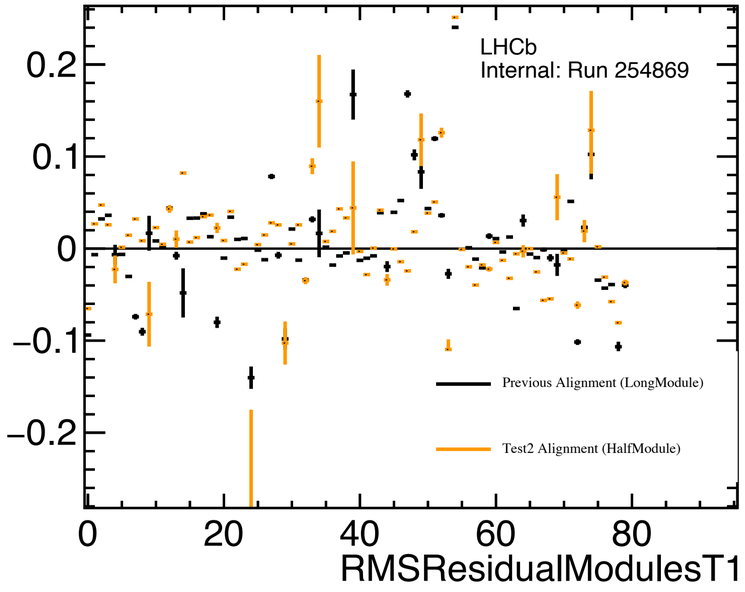


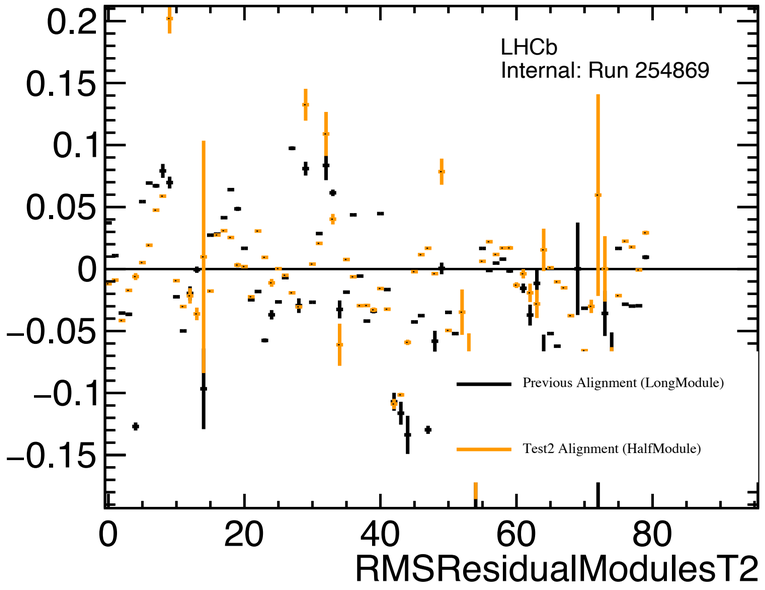
Half-module alignment vs First alignment on Run 254869

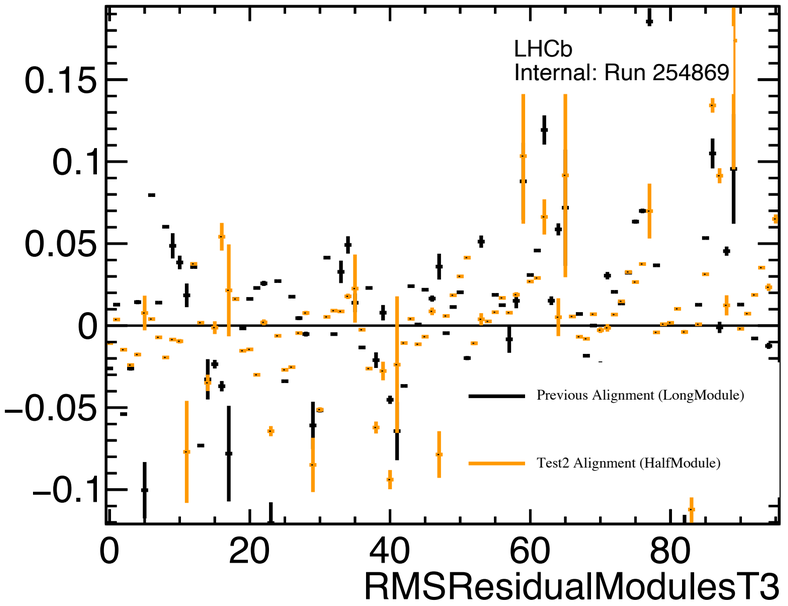








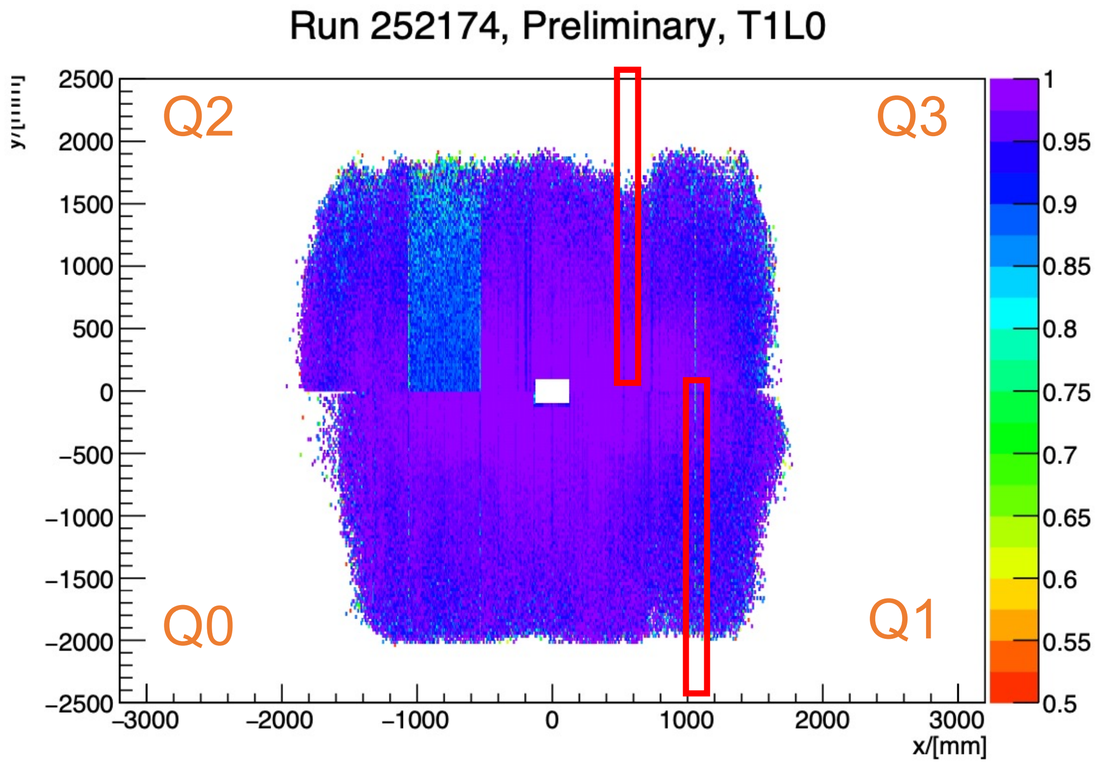


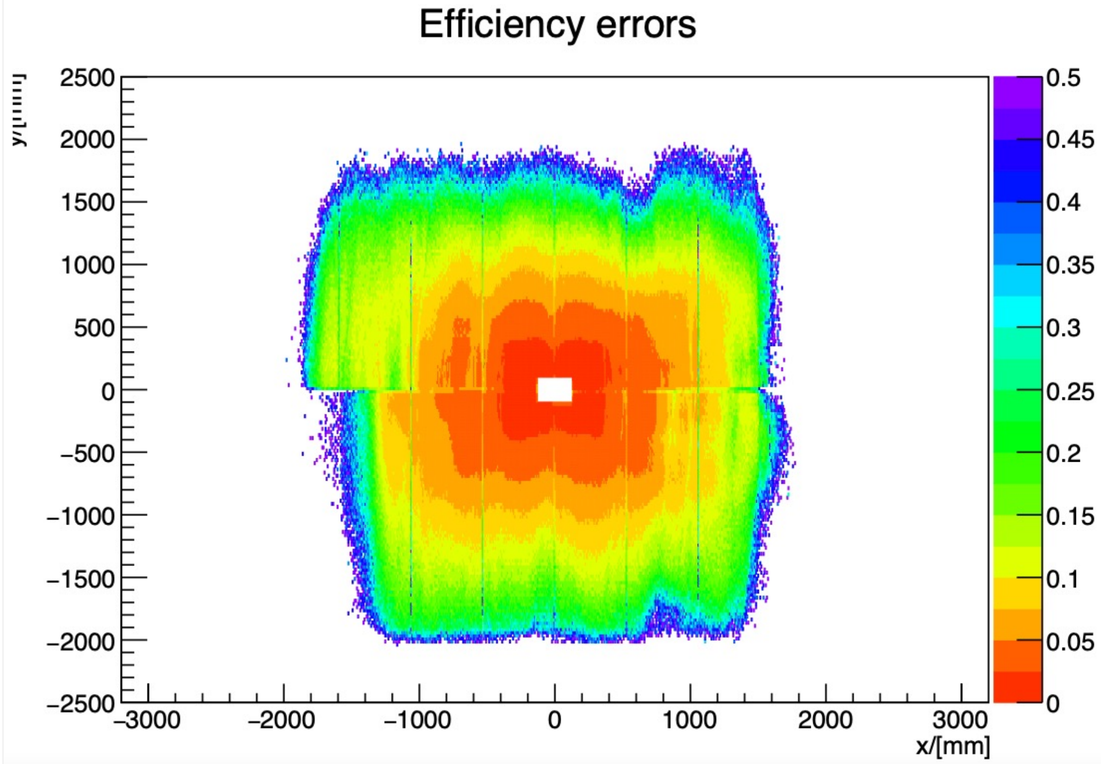


via Zehua Xu

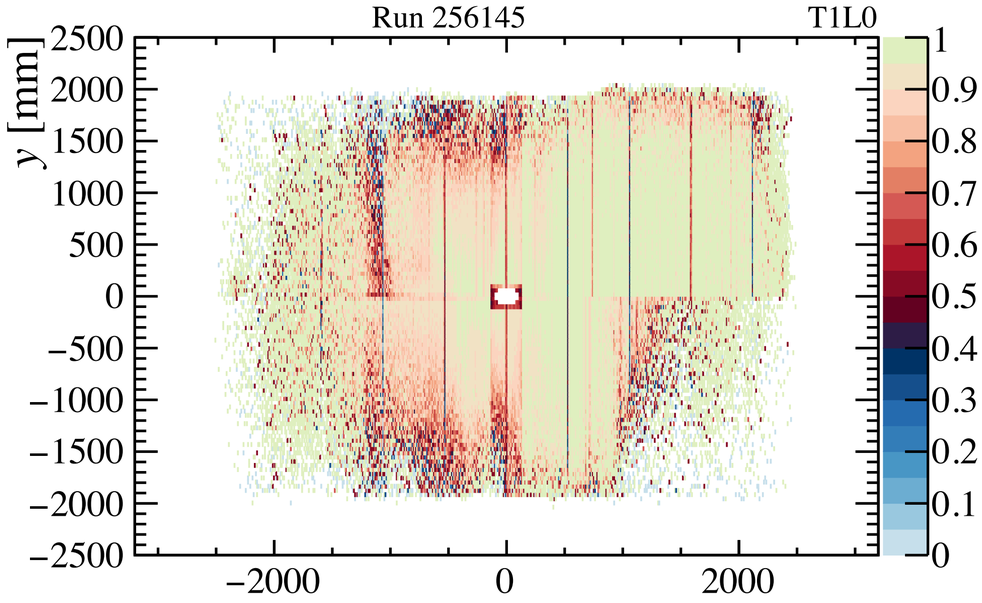
Hit efficiency studies (with an eye on SiPMs)

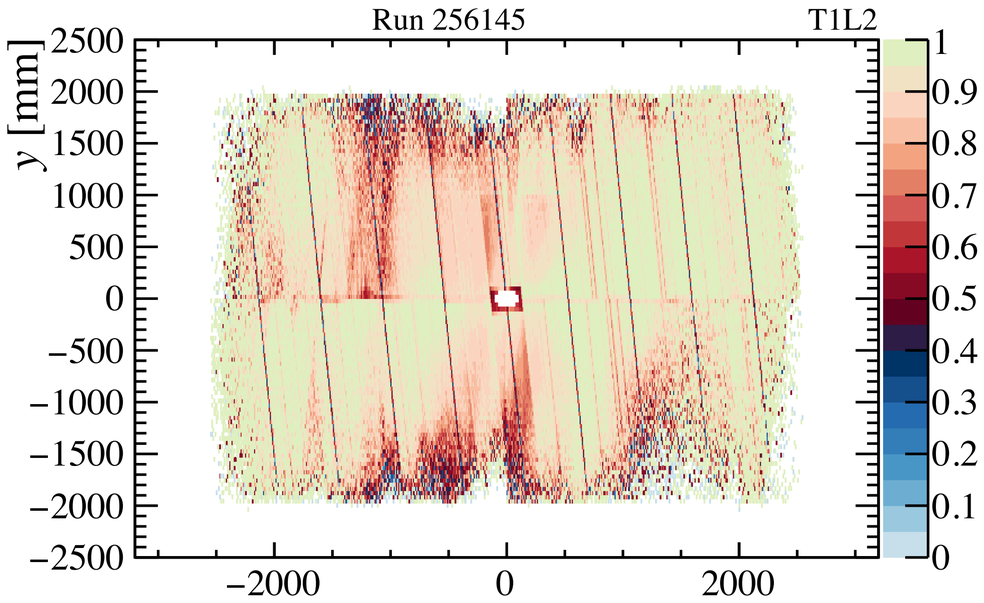
- Studies on Run 252174 (3rd November)
- Not enough statistics in M3,M4,(M5) with early data samples for detailed studies by SiPM

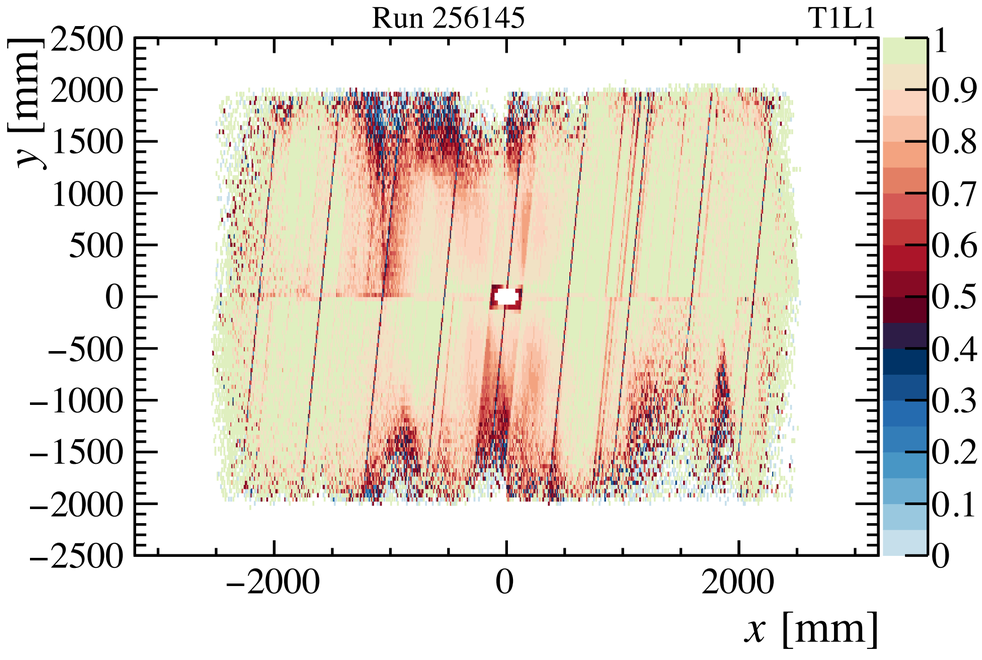


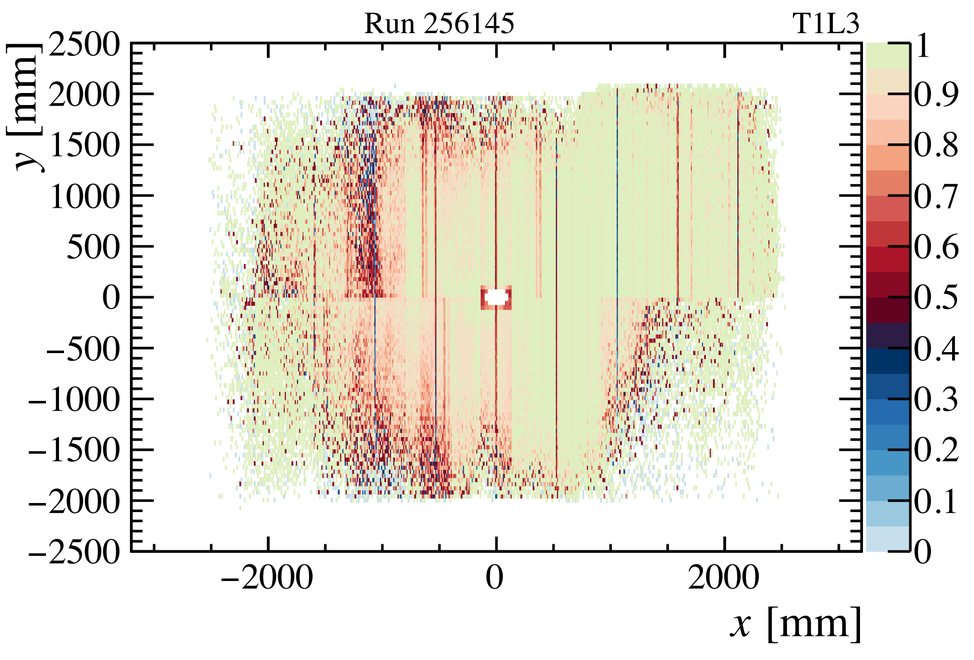


More 2D efficiencies on Run 256145



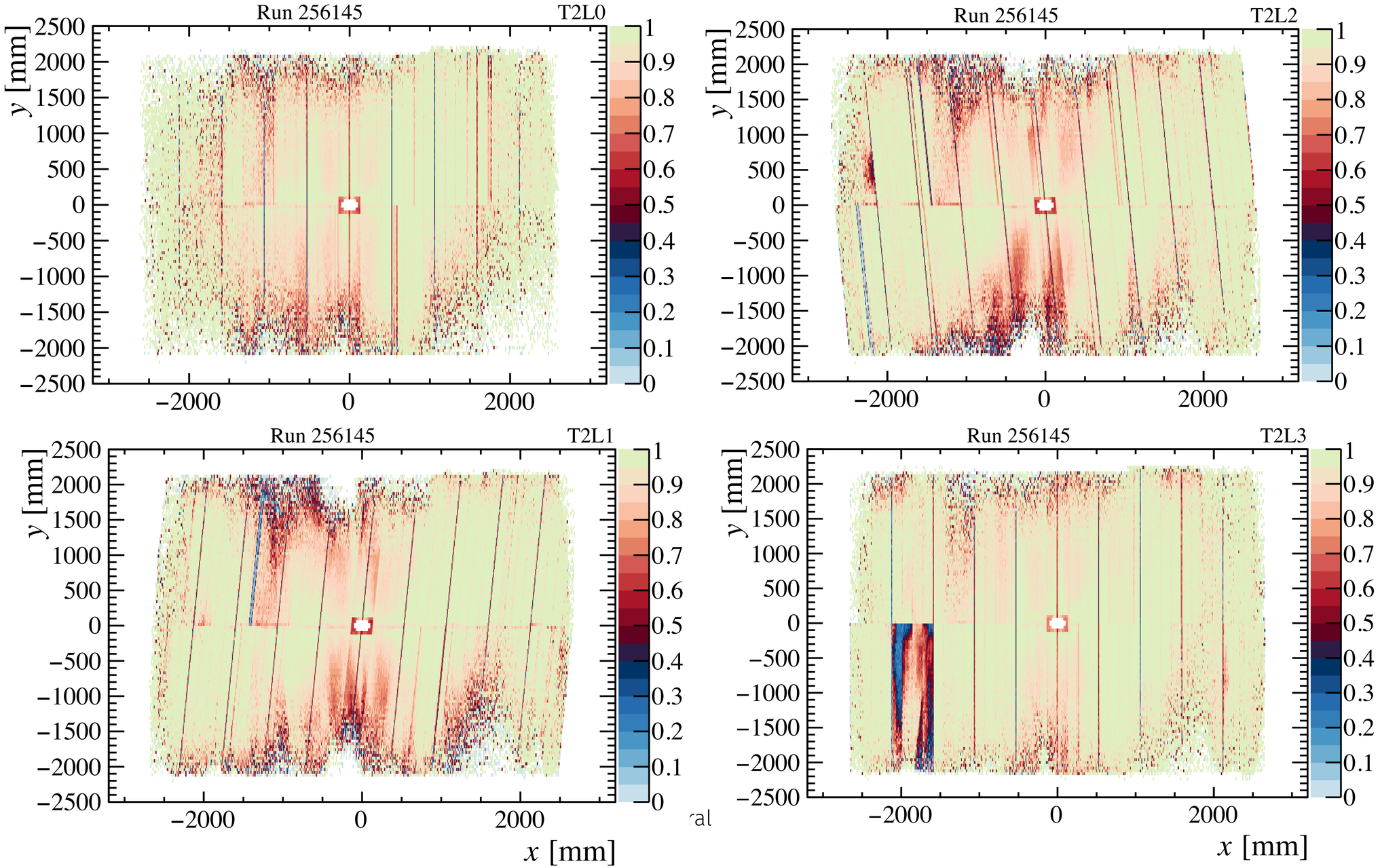






"shadows" of modules in other layers

More 2D efficiencies on Run 256145



More 2D efficiencies on Run 256145