
Understanding the alignment of LHCb's SciFi Tracker

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Overview and Motivation

Motivation

- Performance studies of alignments on run 256145 data
 - unexpected different results!
 - analysis of individual quarters

Overview

- The SciFi Detector Upgrade
- Alignment how to
- Analysis of SciFi quarters in different alignment versions

The Scintillating Fibre Tracker

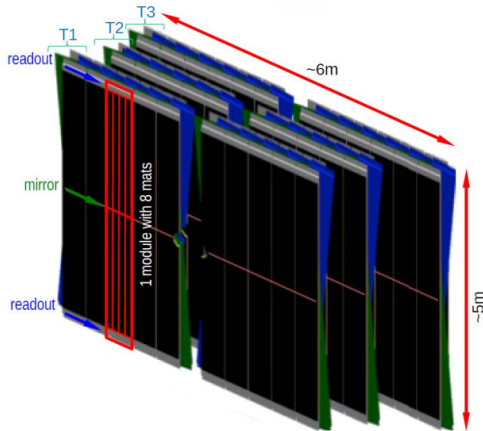
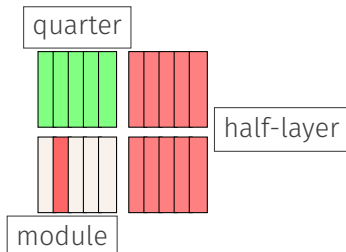


Abbildung: Visualization of the SciFi tracking

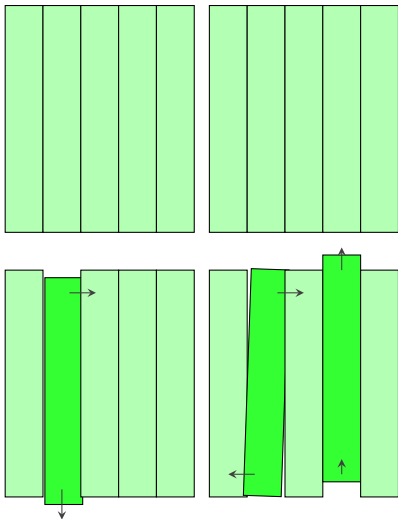
- Consists of 3 stations (T1, T2, T3) with 4 layers each (X1, U, V, X2)
- Front two stations have 5 modules per side
- Back station has 6 modules on each side
- U, V layers have a $\mp 5^\circ$ stereo angle respectively
- → used for determining y-position of track by comparing hitposition at different angles

SciFi terminology



- Long modules have the full height of the SciFi
- Half modules only span across one quarter
- each layer is divided into two halves labeled as A-side and C-side
 - A-side: side from which the cavern is accessed
 - C-side: side of the cryogenic lab
- each layer can be described with four quarters, two per half layer

What is Alignment?



- top: ideal detector, bottom: physical detector
- Surveys are used to find the rotation and position of each detector component
- Are used as starting positions for software alignment (this talk!)

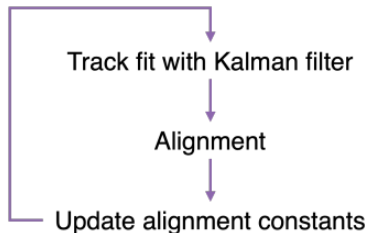
Alignment: track fits with the Kalman Filter

measurement m track model h

$$r_i = m_i - h_i(x, \alpha)$$

$$\chi^2 = r^T V^{-1} r$$

covariance matrix V



- Minimise χ^2 with respect to the track parameters for the track fit
- Minimise χ^2 with respect to the alignment parameters α during the alignment
- Update the alignment constants α and repeat until convergence criterium for χ^2 is reached

Alignment versions in use

V1:

- use full length modules
- alignable degrees of freedom: Tx Rz (x translation, rotation around z → beam pipe axis)

low μ :

- uses half modules
- uses VELO alignment on run 256145 data
- Tx Rz

V2:

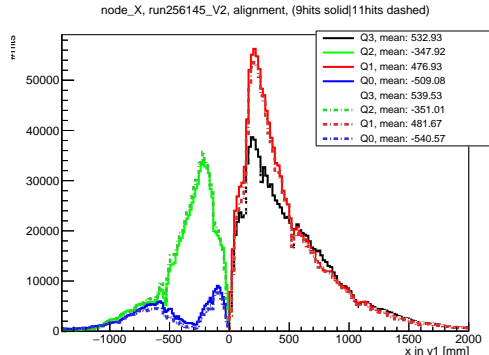
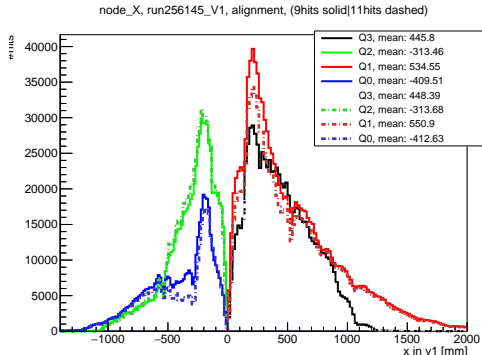
- newest alignment version
- half modules (top half and bottom half)
- uses newest time alignment
- utilizes VELO alignment from run 256145
- used for HLT2 reprocessing
- $\mu \approx 2.26$ (run database)

Why analyse the quarters separately?

- performance in each quarter might be very different from one another
- $\rightarrow \chi^2$ per quarter can provide more insights about the performance in each detector part
- v2 alignment shows improvements from v1 alignment but not across the whole SciFi
- find and resolve possible issues is easier

Hit distribution per quarter in V1 and V2 alignment

- V1(left)- and V2(right) alignment on 20000 events with run 256145 data
- C-side: negative x direction, A-side: positive x
- plotted is x-coordinate against number of hits in each quarter coded by colour.
- 9 minimum hits per quarter (solid lines), 11 minimum hits (dashed lines)



Summary of Metrics from alignments in Quarter 0

This hints that something is not right in Q0

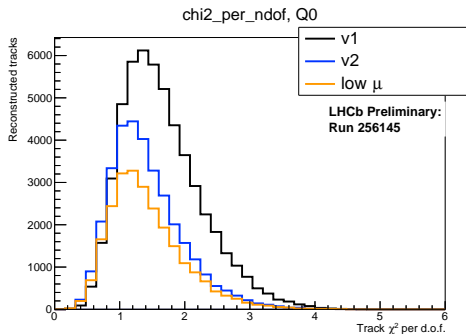


Abbildung: track χ^2 per dof comparing each alignment for Quarter 0.

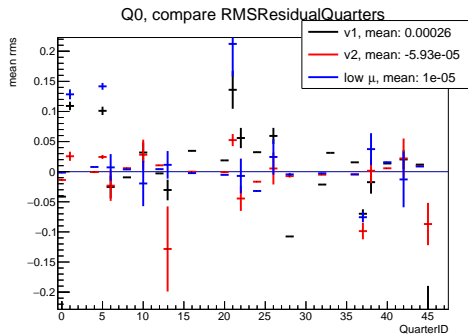


Abbildung: Residual in each module for each alignment in Quarter 0.

Summary of Metrics from alignments in Quarter 1

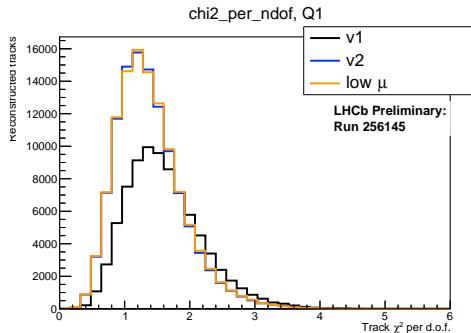


Abbildung: track χ^2 per dof comparing each alignment for Quarter 1.

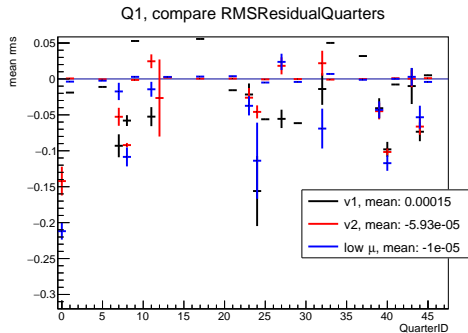


Abbildung: Residual in each module for each alignment in Quarter 1.

Summary of Metrics from alignments in Quarter 2

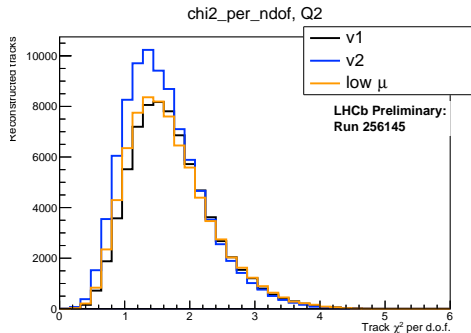


Abbildung: track χ^2 per dof comparing each alignment for Quarter 2.

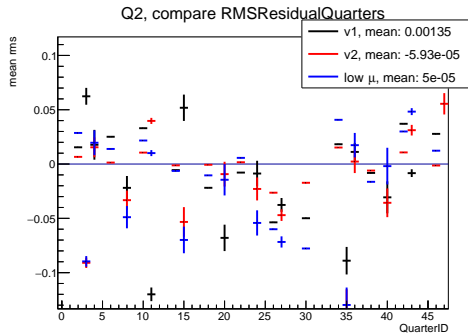


Abbildung: Residual in each module for each alignment in Quarter 2.

Summary of Metrics from alignments in Quarter 3

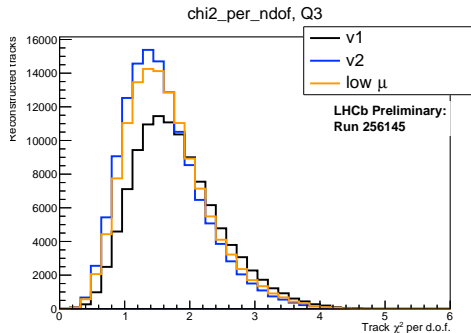


Abbildung: track χ^2 per dof comparing each alignment for Quarter 3.

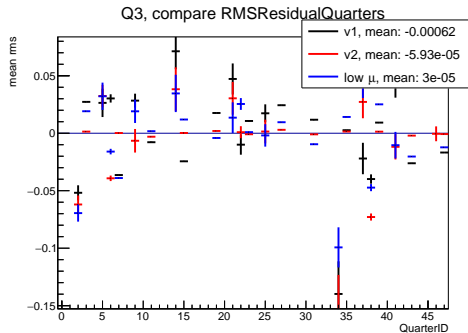


Abbildung: Residual in each module for each alignment in Quarter 3.

χ^2 against ϕ angle distribution in V2 alignment

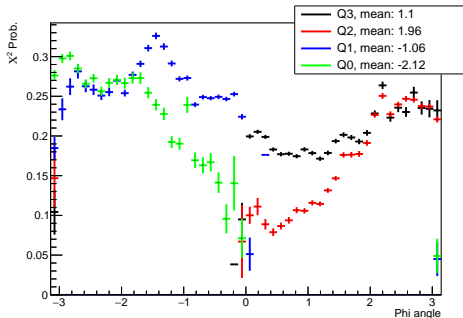
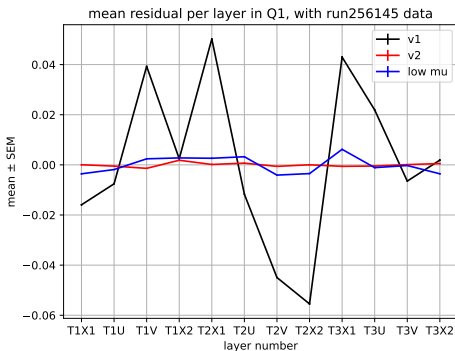
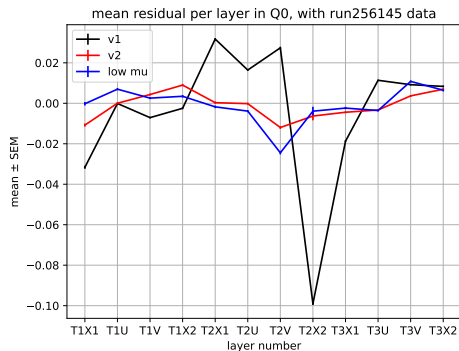


Abbildung: χ^2 against ϕ distribution for each quarter for V2 alignment.

- χ^2 against ϕ distribution for each quarter in V2
- information of layers are combined for each quarter
 - information of problematic layer in given quarter hidden
- aim: flat distribution across all angles
- A-side quarters (Q1: blue, Q3: black) quite flat
- C-side quarters (Q0: green, Q2: red) have small χ^2 around 0

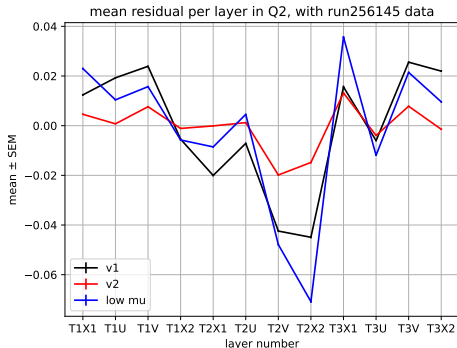
Track residuals in bottom half SciFi quarters

- V1: Q0 quite bad residual in T2X2 as seen in previous plots
- V1: T2X1 and T2U overshooting because of photogrammetry
- V2: nice in Q1, Q0 still some differences in T2

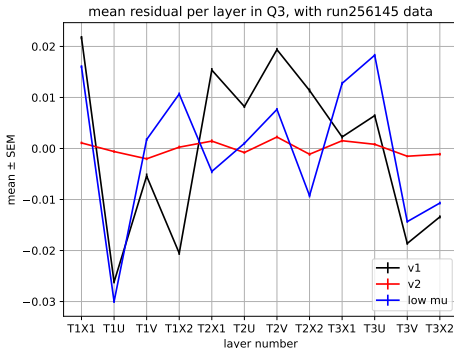


Track residuals in top half SciFi quarters

- Q2: quite bad performance overall; V2 not as bad
- Q3: V2 performs quite well; oder alignments far worse



(a) Quarter 2



(b) Quarter 3

Weighted residuals for V2 alignment

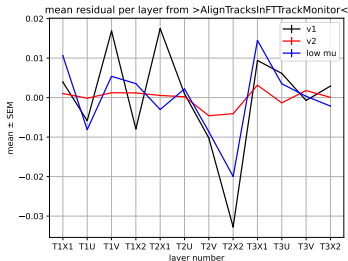


Abbildung: mean Residual per layer weighted with quarter hits.

→ V2 best performing alignment version for now, but still uses half modules → long modules as in the physical SciFi preferred in the long run

mean residual per quarter weighted:

$$\overline{\text{Res}}_Q = \sum_{\text{layer, quarter}} \frac{\text{hits quarter of layer}}{\text{hits layer}}$$

goal: residual around 0 per layer

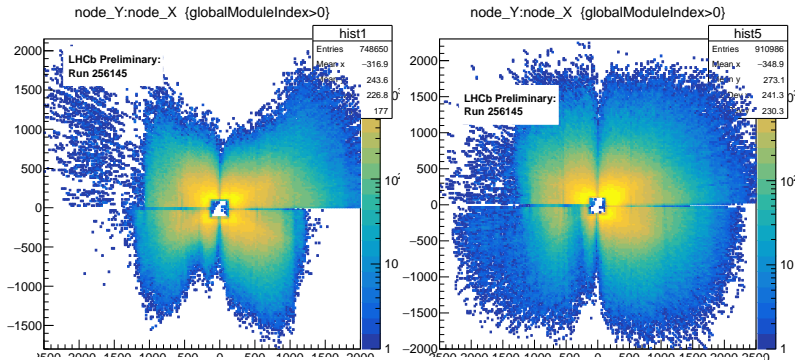
V2: quite good except second C-frame in T2

V1: everywhere worse than V2

low μ : quite ok except for back T2

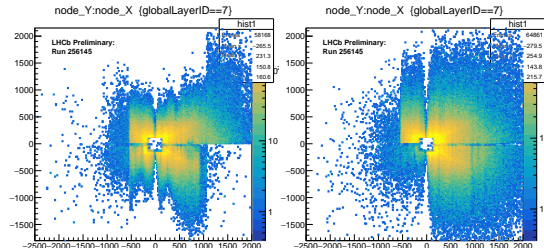
Track hits comparison of alignment versions

- V1: left, V2, right
- Hits on tracks as XY distribution resembling SciFi Layers
- C-side: negative x, A-side: positive x
- information of all layers are combined for each quarter → hard to see whats going on



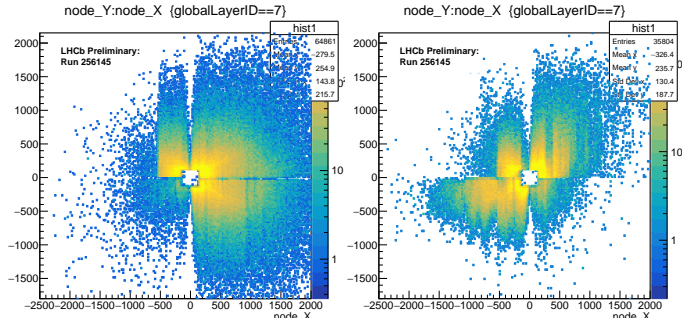
Track hits in V2 alignment

- T2X2 showed worst performance on C-side
- SciFi clusters and seed tracks are nicely distributed → the issue at the long tracks in the alignment
- hypothesis: some parts are out of alignment using the current survey
 - reduction in GoodLongTracks and hits for that part
 - Difference in Q0: some parts blocking tracks from going through a module and pushing them into a different ones.



New Q0 positions in T2X2 layer

- changes based on V2 alignment positions
- manually scan rotations/positions of T2X2Q0 and register alignment tracks
- Upcoming:
 - Test these starting condition in alignment + compare to current survey
 - More investigation for T2X2Q2 as well



Summary

- Analysis of alignment versions discovered poor performing C-side; especially Q0
- Source of complications: parts of the SciFi being too far out of alignment
- A-side showed an improvement from V1 to V2
- An improvement of the alignment track hits in T2X2Q0 was achieved but further investigation is needed for top half

Sources

- SciFi Conference Talk:

https://twiki.cern.ch/twiki/pub/LHCb/SciFiConference/fee_2018.pdf

- LHCb SciFi: From performance requirements to an operational detector:

<https://indico.cern.ch/event/1163878/>