
Understanding the Alignment of LHCb's Scintillating Fibre Tracker

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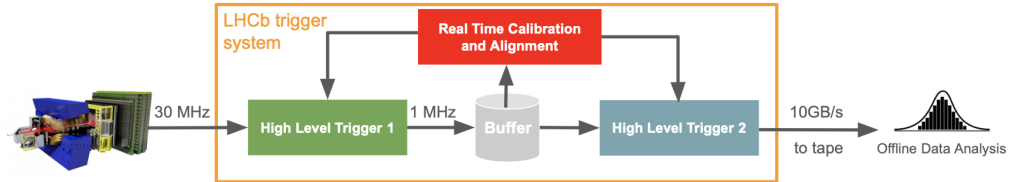
DPG spring Conference, Dresden

Overview

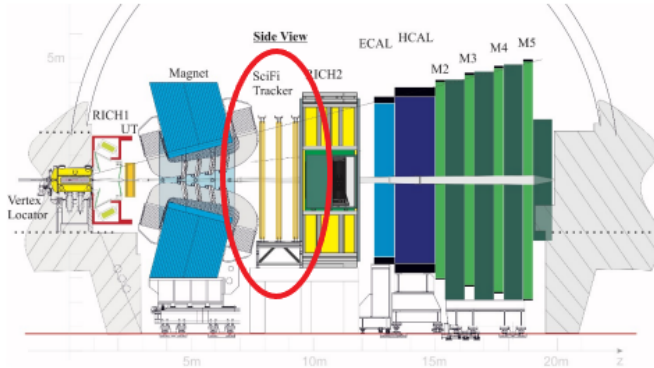
- The SciFi Detector Upgrade
- Importance of the SciFi and Alignment
- Analysis of SciFi quarters

Importance of the SciFi

- Alignment is part of the LHCb trigger system
- Physics performance tied to alignment performance
- with optimal alignment:
 - → remove systematic biases for asymmetry measurements
 - best possible mass resolution

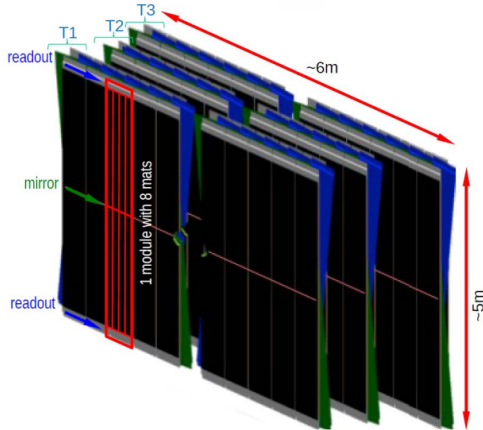


LHCb upgraded with the SciFi



- Consists of 3 stations: T1, T2, T3
- 4 layers per station: X1, U, V, X2

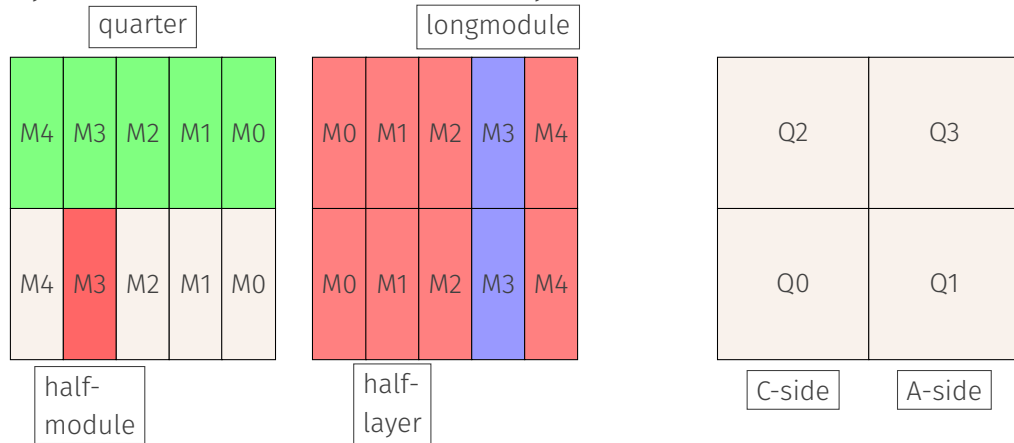
The Scintillating Fibre Tracker



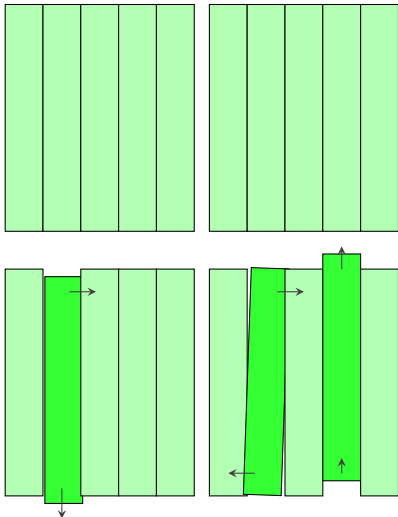
- Front two stations have 5 modules per side
- Back station has 6 modules on each side
- U, V layers have a $\pm 5^\circ$ stereo angle respectively
- → used for determining y-position of track by comparing hitposition at different angles

SciFi terminology

layers are divided into two halves commonly labeled as A-side and C-side



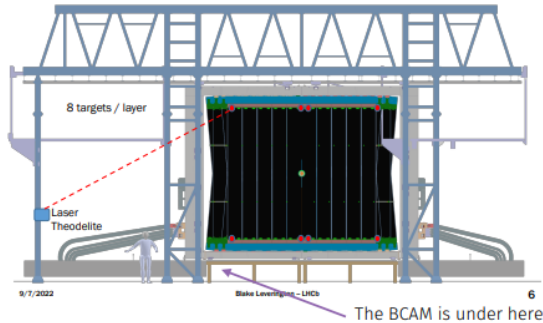
What is Alignment and why do we need it?



- 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
- Building tracks accurately requires positions in reconstruction to be as similar as possible to real positions

The survey: what is it and the different types

- measure distance of some points on the detector with a laser



- 2022: photogrammetry was recorded in assembly hall → not quite perfect
- 2023: photogrammetry will be recorded in cavern
- relative angles and positions between points are compared to simulation
- layer survey: performed in the cavern on the layer n the front in closed state (both halves together)
- module survey: performed inside assembly hall sing reflective stickers keeping track of all positions

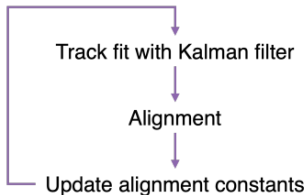
Alignment: track fits with the Kalman Filter

measurement m track model h

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

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

covariance matrix V



- Use survey information as starting point
- aligning the detector by minimizing the residuals of the track hits
- basically a χ^2 minimization problem with alignment parameters α
- Why Kalman Filter?
 - easily models material interactions as well as multiple scattering
- propagation of nodes, minimization, smooth error sizes by back propagation

Alignment versions in use

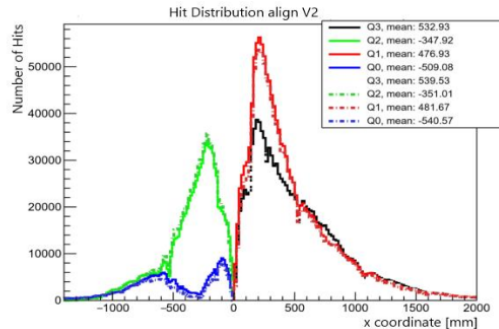
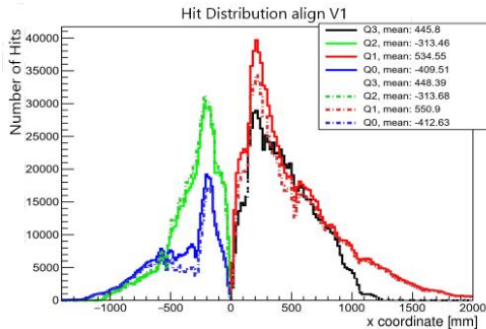
- V1: First ever SciFi alignments for the upgraded LHCb detector, which is using early tracks from comissioning
 - use full length modules
 - alignable degrees of freedom: Tx Rz (x translation, rotation around z → beam pipe axis)
 - utilizes VELO alignment
- V2: Updated alignment version with what we learned from V1 (hard work from detector experts)
 - aligned using half modules
 - uses newest time alignment
 - used for HLT2 reprocessing
 - utilizes VELO alignment as well

Why analyse the quarters separately?

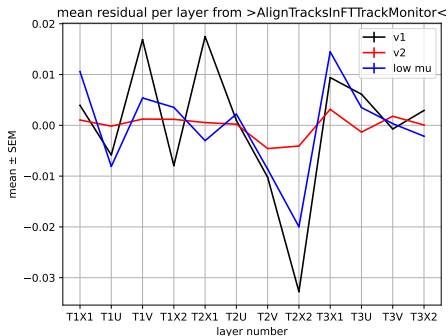
- performance in each quarter might be very different from one another
- $\rightarrow \chi^2$ per quarter can provide more insights about the performance in each detector part
- v2 alignment shows improvements from v1 alignment but not across the whole SciFi
- analysis of each quarter separately makes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

Hit distribution per quarter in V1 and V2 alignment

- V1(left)- and V2(right) alignment on 20000 events
- C-side: negative x direction, A-side: positive x
- 9 minimum hits per quarter (solid lines), 11 minimum hits (dashed lines)



Weighted residuals for V2 alignment



- mean residual per quarter weighted:

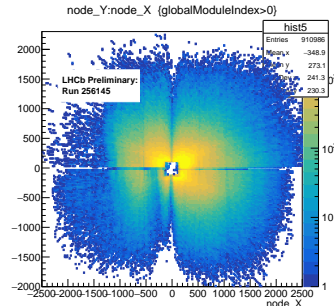
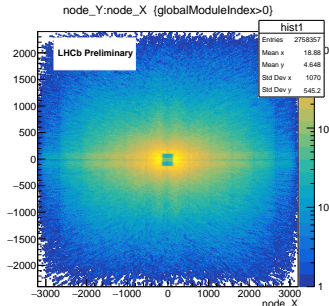
$$\overline{\text{Res}}_L = \sum_{\text{layer, quarter}} \frac{\text{hits quarter of layer}}{\text{hits layer}}$$

- goal: residual around 0 per layer
- V2 alignment shows overall improvement in alignment quality in every layer of the SciFi
- Investigating why T2X2 has a larger mean residual than any other layer

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

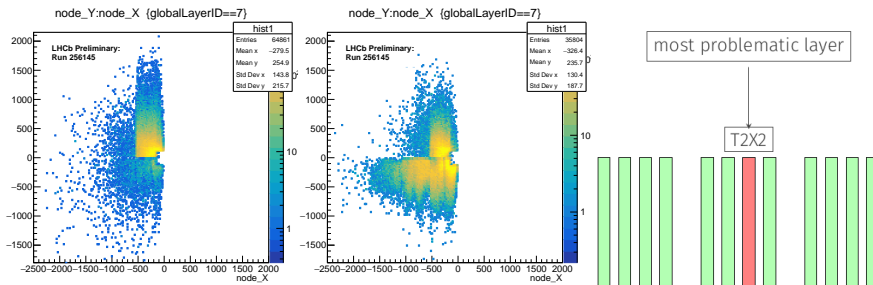
Track hits comparison of V2 and simulation

- MC: hits on **reconstructed** tracks
- C-side: negative x, A-side: positive x
- data: quite homogenous distribution of tracks throughout the whole A-side
- C-side tracks are not filled into the most outer modules
- information of all layers per quarter added on top of each other



New Q0 positions in T2X2 layer

- Changes based on V2 alignment positions
- test incremental shifts of position/rotation until we found an improvement
- rotations are with regard to the local frame of the module
- positions: translations relative to the nominal position for each module
- V2 alignment has only few tracks in Q0 because parts of the SciFi are too far out of alignment



Summary

- Trying to solve a puzzle on unexpected lower number of alignment tracks on the C-side
- Source of complications: SciFi parts too far out of alignment to be correctly updated
- → Varying the positions and rotations of Q0 modules yielded more tracks in more modules
- Feeding this back into tracking alignment to get the fine tuning right
- new survey/photogrammetry in progress to improve alignment starting conditions this year

Thank you for your attention!