technische universität dortmund

FSP LHCb
Erforschung von Universum und Materie

Bundesministerium für Bildung und Forschung

Understanding the Alignment of LHCb's Scintillating Fibre Tracker

Nils Breer, Sophie Hollitt, Johannes Albrecht

16.03.2023

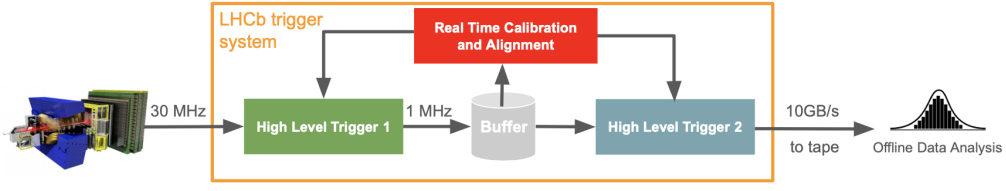
DPG spring Conference, Dresden

Overview

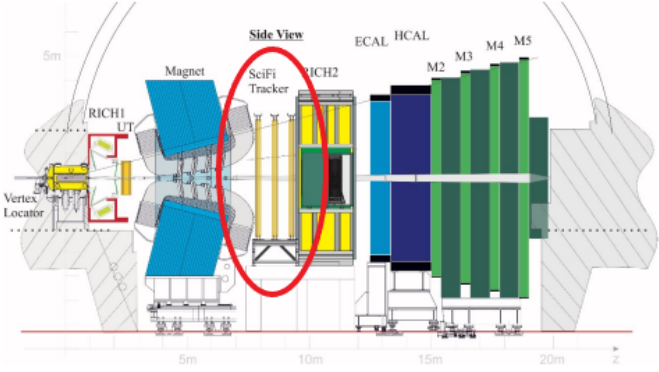
- The SciFi Detector Upgrade
- Importance of the SciFi and Alignment
- Analysis of SciFi quarters

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

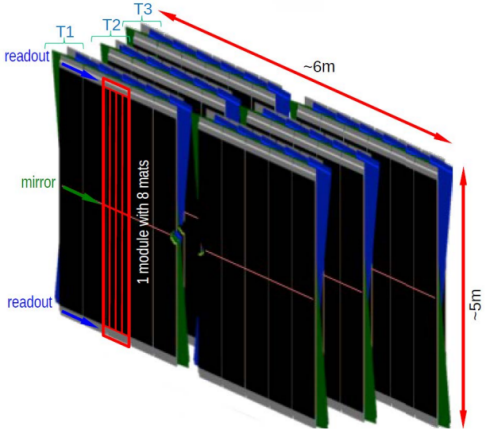


LHCb upgraded with the SciFi



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

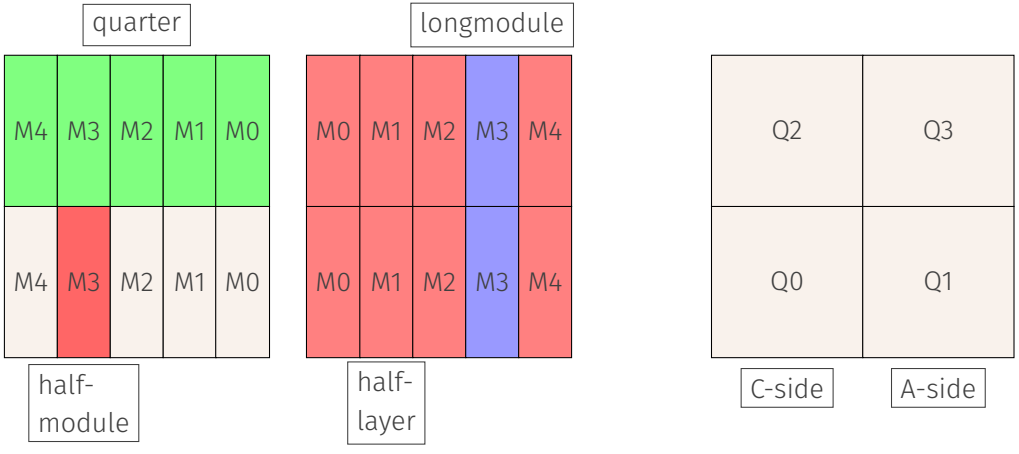
The Scintillating Fibre Tracker



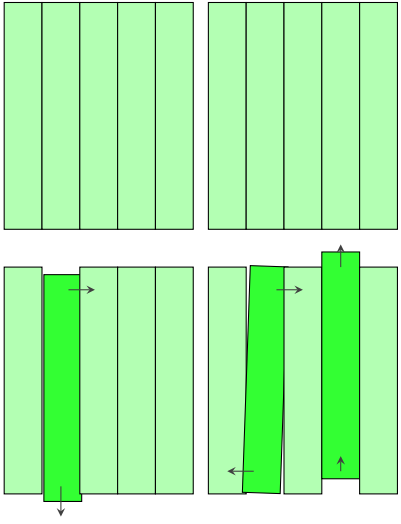
- Front two stations have 5 modules per side
- Back station has 6 modules on each side
- U, V layers have a **∓5 deg** stereo angle respectively
- → used for determining y-position of track by comparing hitposition at different angles

SciFi terminology

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



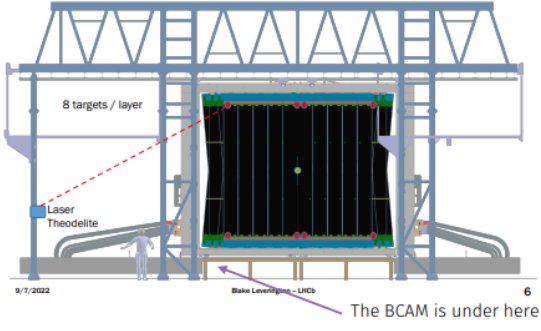
What is Alignment and why do we need it?



- 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

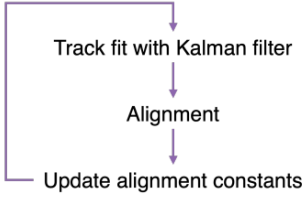
Alignment: track fits with the Kalman Filter

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

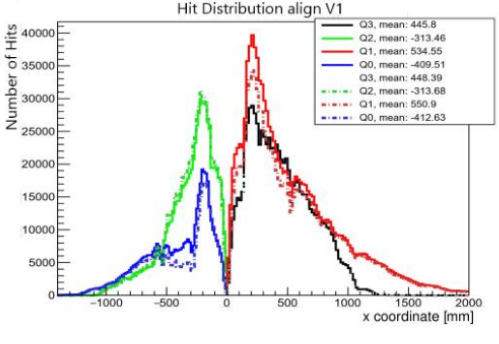
- V2: Updated alignment version with what we learned from V1 (hard work from detector experts)
- aligned using half modules
- uses newest time alignment
- used for HLT2 reprocessing
- utilizes VELO alignment as well

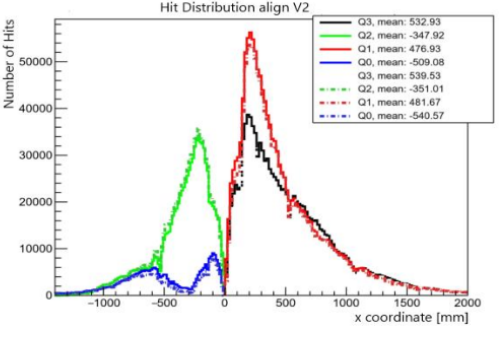
Why analyse the quarters separately?

- perfomance 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 seperately makes finding possible issues easier

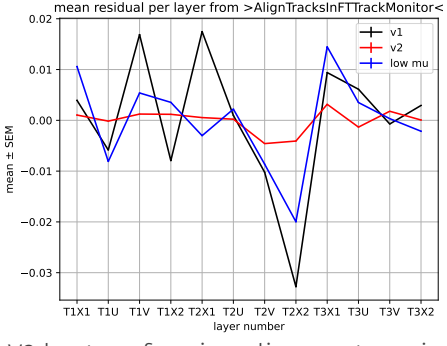
Hit distribution per quarter in V1 and V2 alignment

- 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

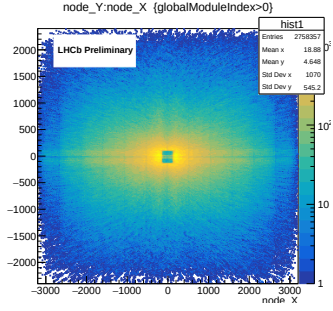


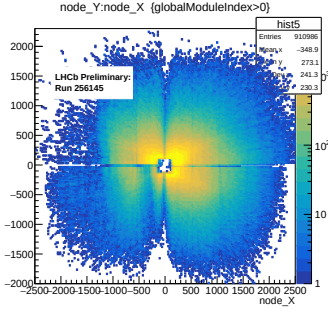
- mean residual per quarter weighted: $\overline{Res_L} = \sum_{layer,quarter} \frac{\text{hits quarter of layer}}{\text{hits layer}}$
- goal: residual around 0 per layer
- V2 alignment shows overall improvement in alignment quality in every layer of the SciFi
- Investigating why T2X2 has a larger mean 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

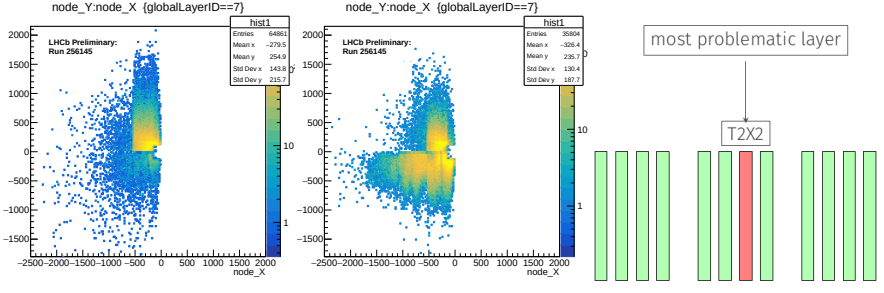
- MC: hits on **reconstructed** tracks
- C-side: negative x, A-side: positive x
- data: quite homogenous distribution of tracks throughout the whole A-side
- C-side tracks are not filled into the most outer modules
- information of all layers per quarter added on top of each other





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 corectly 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!