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Understanding the Alignment of LHCb's Scintillating Fibre Tracker

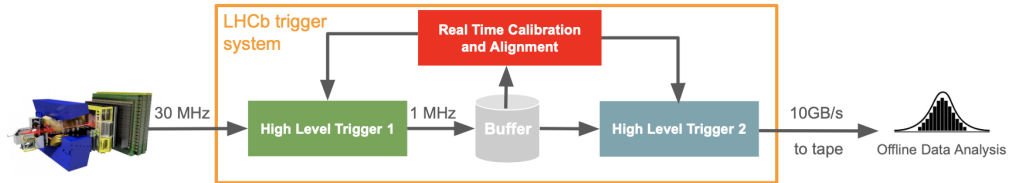**Nils Breer**, Sophie Hollitt, Johannes Albrecht
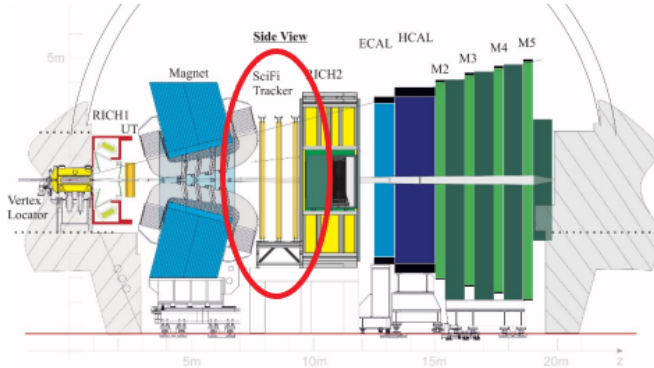
16.03.2023

DPG spring Conference, Dresden

Overview

- The SciFi Detector Upgrade

- Importance of the SciFi and Alignment

- Analysis of SciFi quarters

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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
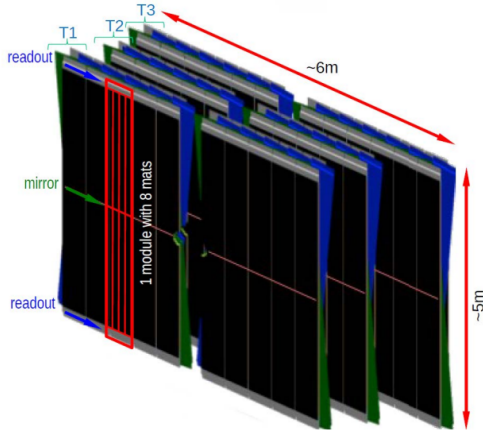 - best possible mass resolution

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LHCb upgraded with the SciFi

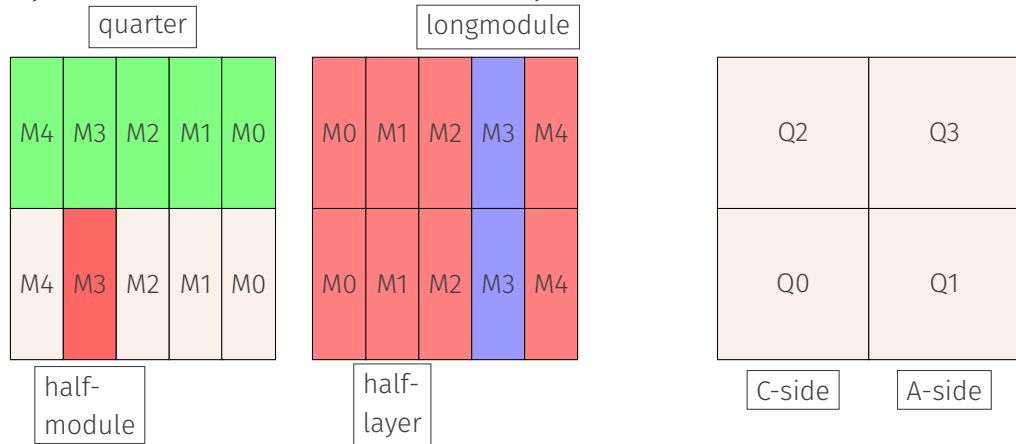- Consists of 3 stations: T1, T2, T3
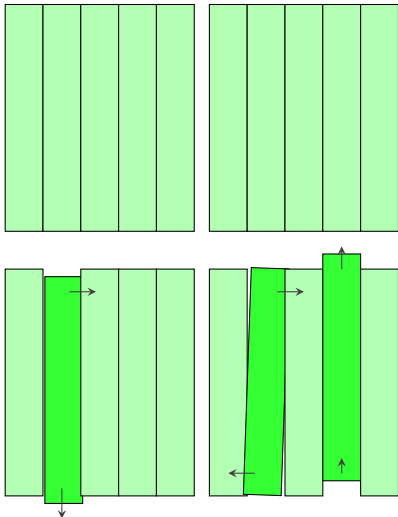- 4 layers per station: X1, U, V, X2

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

quarter

M4	M3	M2	M1	M0
M4	M3	M2	M1	M0

half-module

longmodule

M0	M1	M2	M3	M4
M0	M1	M2	M3	M4

half-layer

| Q2	Q3
Q0	Q1

C-side   A-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

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The survey: what is it and the different types

- measure distance of some points on the detector with a laser
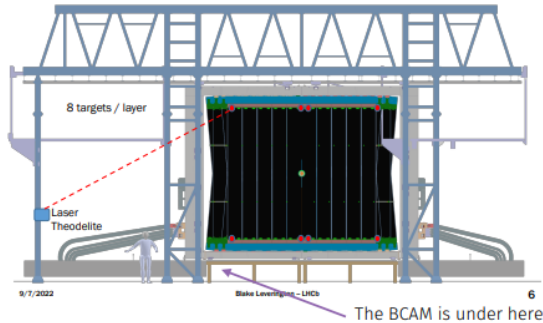
- 2022: photogrammetry was recorded in assembly hall → not quite perfect

- 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)

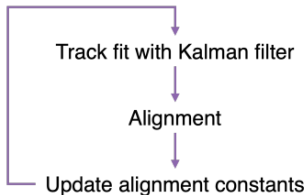- module survey: performed inside assembly hall sing reflective stickers keeping track of all positions

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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

Track fit with Kalman filter

Alignment

Update alignment constants

- 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
- easily models material interactions as well as multiple scattering
- propagation of nodes, minimization, smooth error sizes by back propagation

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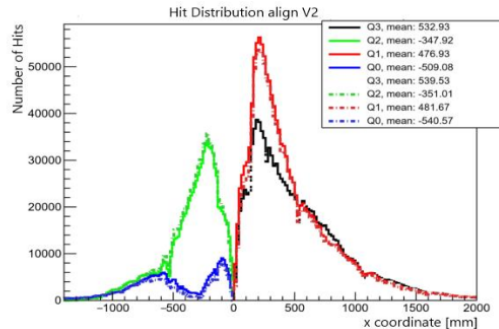für Bildung
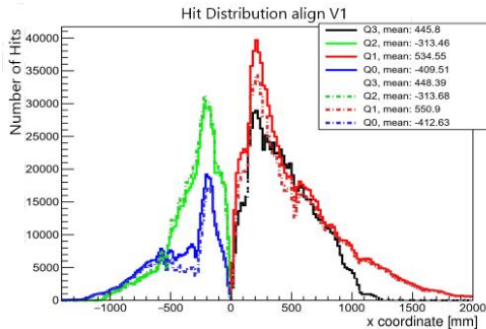und Forschung

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

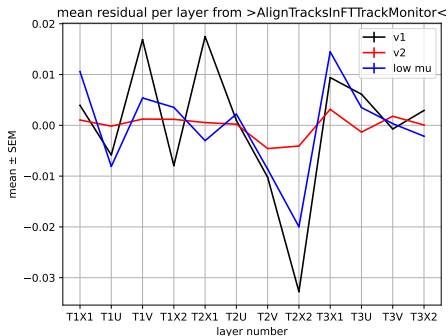- utilizes VELO alignment as well

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)

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Weighted residuals for V2 alignment

mean residual per layer from >AlignTracksInFTTrackMonitor<

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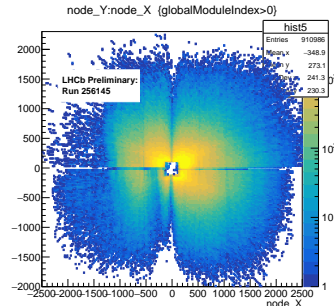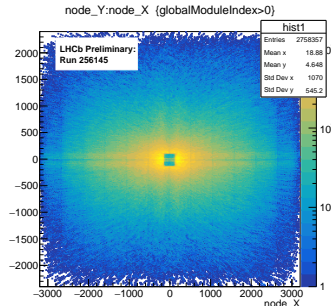$$\overline{Res}_L = \sum_{layer,quarter} \frac{\text{hits quarter of layer}}{\text{hits layer}}$$
- goal: residual around 0 per layer
- V2 alignment shows overall improvement in alignment quality in every layer of the SciFi
- Investigating why T2X2 has a larger mean residual than any other layer

→ V2 best performing alignment version for now, but still uses half modules → long modules as in the physical SciFi preferred in the long run
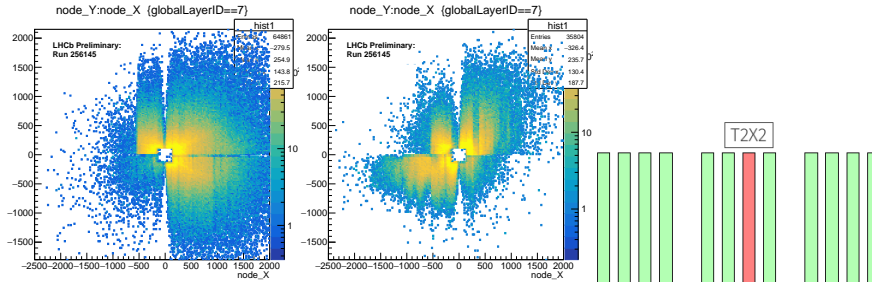
Track hits comparison of V2 and simulation

- MC: hits on **reconstructed** tracks
- C-side: negative x, A-side: positive x
- 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

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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

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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

- $\rightarrow$ 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!