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# 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

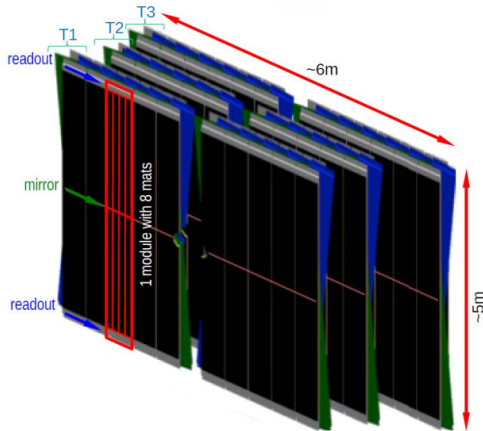
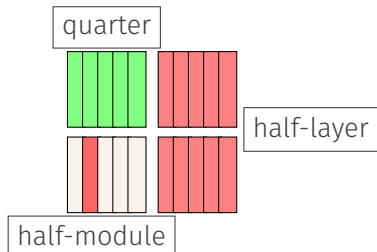


Abbildung: Visualization of the SciFi tracking

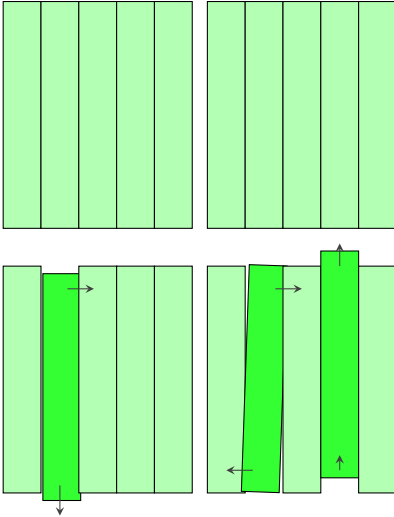
- Consists of 3 stations (T1, T2, T3) with 4 layers each (X1, U, V, X2)
- Front two stations have 5 modules per side
- Back station has 6 modules on each side
- U, V layers have a  $\mp 5^\circ$  stereo angle respectively
- → used for determining y-position of track by comparing hitposition at different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

## SciFi terminology



- Long modules have the full height of the SciFi
- Half modules only span across one quarter
- layers are divided into two halves commonly 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 split into four quarters, two per half layer

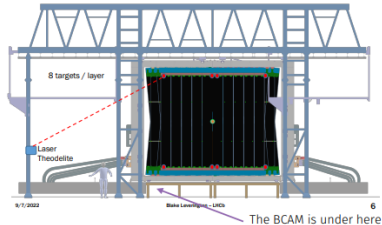
## What is Alignment?



- 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

## The survey: what is it and the different types

- measure distance of some points on the detector with a laser
- → relative angles and positions between points are compared to simulation



- 3 types:
- BCAM survey: over time, the BCAM monitors the positions of reference points on each layer
- module survey: performed inside assembly hall using reflective stickers keeping track of all positions
- layer survey: performed in the cavern on the layer in the front in closed state (both halves together)

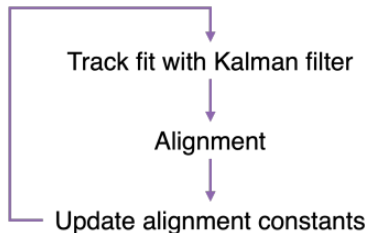
## Alignment: track fits with the Kalman Filter

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
- Minimise  $\chi^2$  with respect to the track parameters for the track fit
- Minimise  $\chi^2$  with respect to the alignment parameters  $\alpha$  during the alignment
- Update the alignment constants  $\alpha$  and repeat until convergence criterium for  $\chi^2$  is reached
- validate alignment quality using  $\chi^2$

## Alignment versions in use

V1:

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

low  $\mu$ :

- 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)



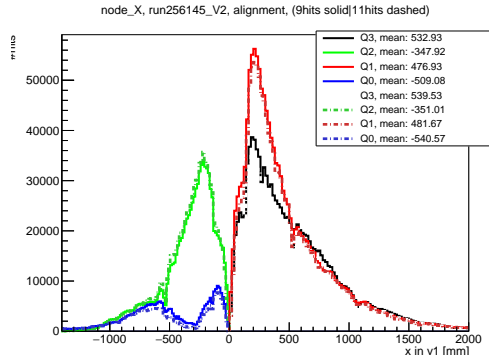
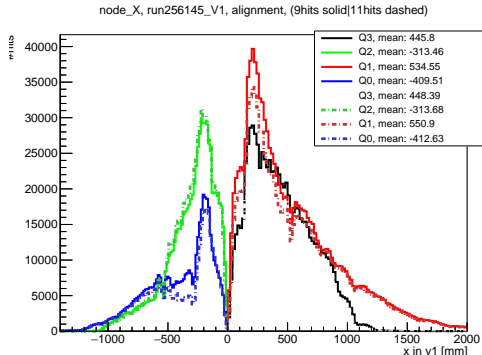
## Why analyse the quarters separately?

- 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

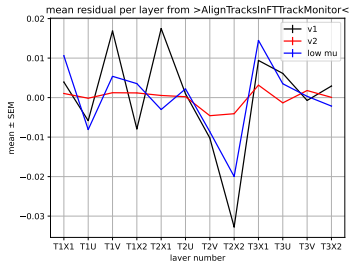
$\rightarrow$  data from run 256145 is being used because at this point the current best alignment version v2 was in use

## 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)



## 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:

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

goal: residual around 0 per layer

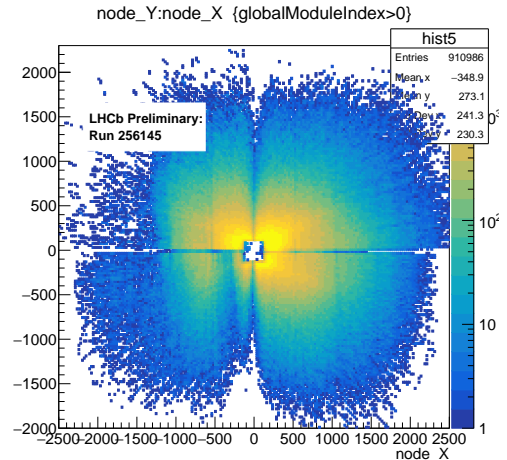
V2: quite good except second C-frame in T2

V1: everywhere worse than V2

low  $\mu$ : quite ok except for back T2

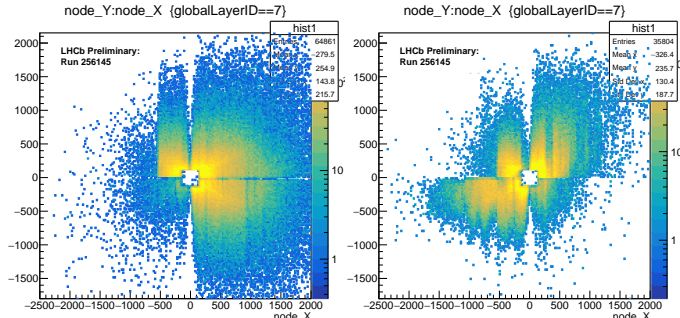
## Track hits comparison of alignment versions

- V2 alignment with run 256145 data
- Hits on tracks as X-Y distribution with all layer information used
- 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
- → track distribution becomes clear when looking at the worst performing



## 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

- Trying to solve a puzzle with tracking alignment regarding C-side especially Quarter 0
- Source of complications: parts of the SciFi being too far out of alignment to be corrected
- → An improvement of the alignment track hits in T2X2Q0 was achieved which results in more tracks in additional modules. Further investigation needed.
- A-side showed an improvement from V1 to V2
- Next steps: adding changes into the survey and running alignments on the new configuration

## Sources

- SciFi Conference Talk:  
[https://twiki.cern.ch/twiki/pub/LHCb/SciFiConference/fee\\_2018.pdf](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/>