# 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

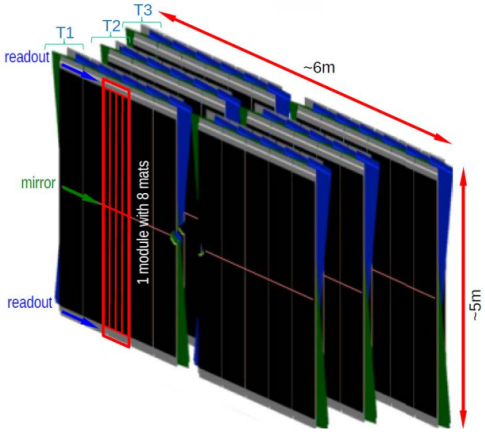
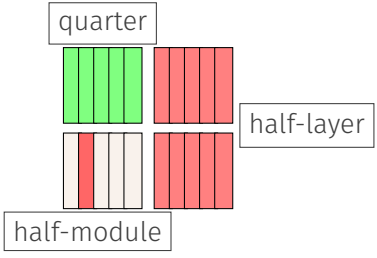



Abbildung: Visualization of the SciFi tracking

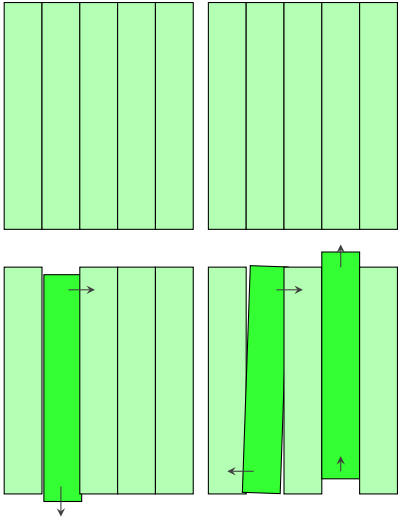
- Consists of 3 stations (T1, T2, T3) with 4 layers each (X1, U, V, X2)
- Front two stations have 5 modules per side
- Back station has 6 modules on each side
- U, V layers have a **∓5 deg** stereo angle respectively
- → used for determining y-position of track by comparing hitposition at different angles

## 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

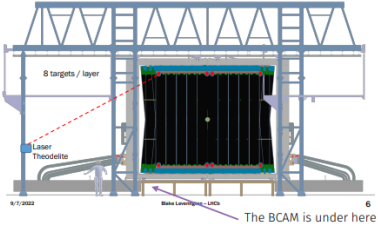
## What is Alignment?



- 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

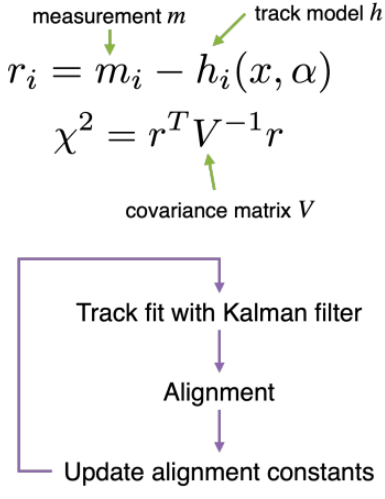
## The survey: what is it and the different types

- 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 assebly 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




- 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 →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)

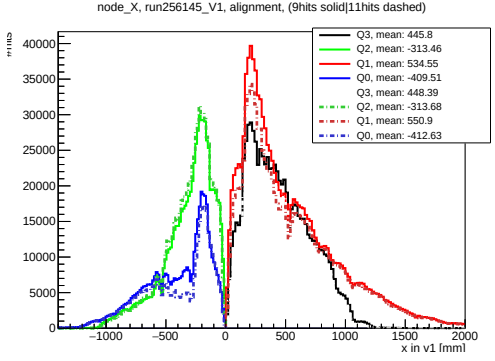
## Why analyse the quarters separately?

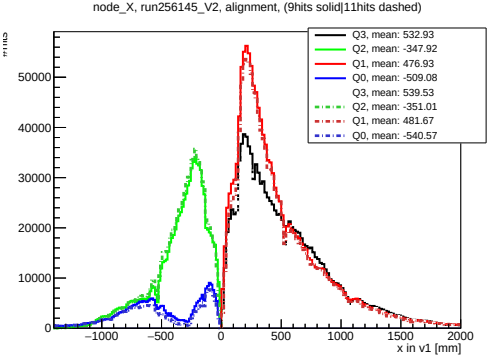
- perfomance in each quarter might be very different from one another
- $\rightarrow \chi^2$ per quarter can provide more insights about the performance in each detector part
- v2 alignment shows improvements from v1 alignment but not across the whole SciFi
- find and resolve possible issues is easier

$\rightarrow$ 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

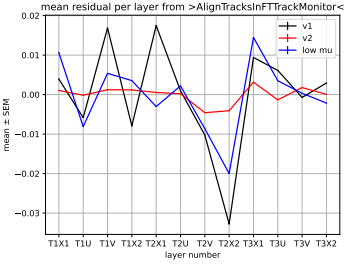


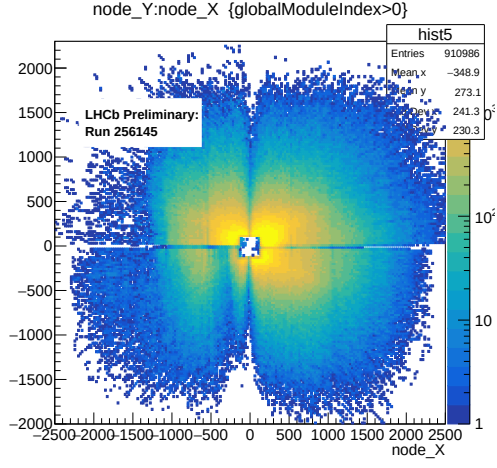

Abbildung: mean Residual per layer weighted with quarter hits.

- 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

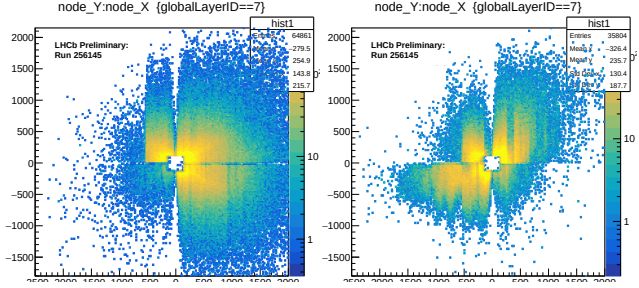
## Track hits comparison of alignment versions

- 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 looking at worst performing layer: T2X2



## New Q0 positions in T2X2 layer

- changes based on V2 alignment positions
- manually scan rotations/positions of T2X2Q0 and register alignment tracks
- original V2 alignment has little to no tracks in Q0 because parts of the SciFi are too far out of alignment
- mean per quarter subtracted from V2 conditions xml in T2X2 now yielding tracks in M0 and M1



## 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:
- Test these starting condition in alignment + compare to current survey
- More investigation for T2X2Q2 as well configuration

## 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/
- BCAM https://accelconf.web.cern.ch/ipac2018/papers/wepaf067.pdf