







Understanding the Alignment of LHCb's Scintillating Fibre Tracker

Nils Breer, Biljana Mitreska, Sophie Hollitt, Johannes Albrecht **08.09.2023**

Maria Laach high energy physics school, Siegen









Overview

- The SciFi Detector Upgrade
- Importance of the SciFi and Alignment
- Understanding first alignments on 2022 data

• Stability measurements on 2022 data

N.Breer | 08.09.2023 2 / 20

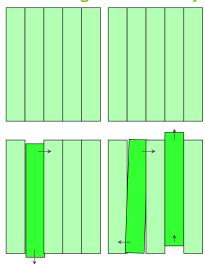








What is Alignment and why do we need it?



- Top: ideal detector, bottom: physical detector
- Surveys are used to find the rotation and position of each detector component
- →Starting positions for software alignment
- Building tracks accurately requires positions in reconstruction to be as similar as possible to real positions

N.Breer | 08.09.2023 3 / 20

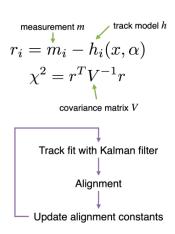








Alignment: track fits with the Kalman Filter



- Starting positions: positions from laser scans of detector objects (survey)
- Alignment: χ^2 minimization of track residuals
- Add measurements one-by-one to fit
- Prediction of next measurement →minimize residuals →redo until track complete
- Why Kalman Filter?
 - easily models material interactions as well as multiple scattering

N.Breer | 08.09.2023 4 / 20



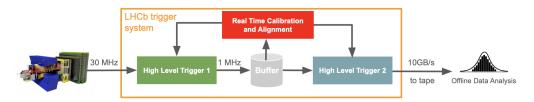






Importance of alignments

- 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



N.Breer | 08.09.2023 5/20

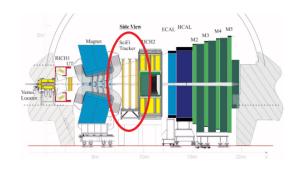




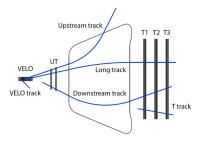




LHCb upgraded with the SciFi



- 3 stations: T1, T2, T3
- 4 layers per station: X1, U, V, X2
- Replaces former IT and OT to cope with the increased instantaneous luminosity



N.Breer | 08.09.2023 6 / 20

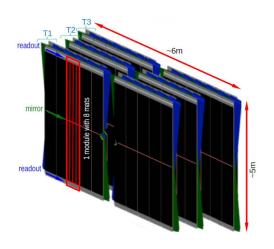








The Scintillating Fibre Tracker



- 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
- ullet \to Used for determining y-position of tracks by comparing hitposition at different angles

N.Breer | 08.09.2023 7/20



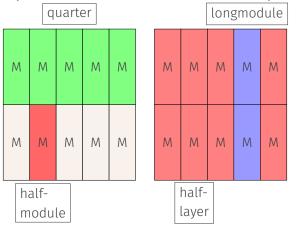






SciFi terminology

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



Q2	Q3
Q0	Q1
C-side	A-side

N.Breer | 08.09.2023 8 / 20



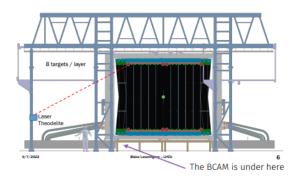






The survey: what is it and the different types

• Measure distance of some points on the detector with a laser



- Layer survey: find corners of layers
- Module survey: reflective stickers, calculate module plane
- Compare survey to simulation

N.Breer | 08.09.2023 9 / 20

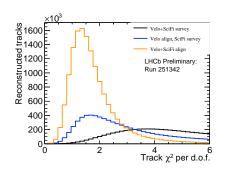








Alignment versions development in 2022



- V1: First ever alignments after upgrade
- Using first data sets
- Starting configuration: long modules, Tx Rz

- V2: Imroved configuaration from V1
- Half modules, Tx Rz, new time alignment

N.Breer | 08.09.2023 10 / 20



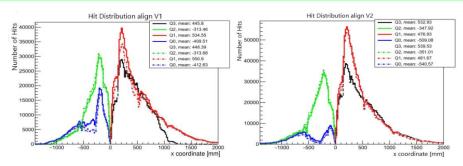






Hit distribution per quarter in V1 and V2 alignment on 2022 data

- V1 → V2: A-side better, C-side loosing some performance
- Performance discrepancies →quarter analysis
- χ2 per quarter →alignment performance per detector part
- Expectation for good alignment: symmetry and exponential hit distribution
- Scan quarters individually; find issues faster



N.Breer | 08.09.2023 11/20



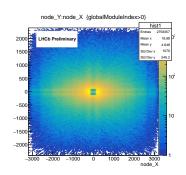


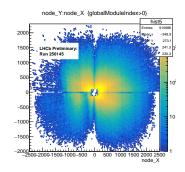




Track hits comparison of V2 and simulation

- Simulation: hits on **reconstructed** tracks fill whole detector
- A-side Track hits good!
- → Scan C-side quarters for possible issues in distinct layers





N.Breer | 08.09.2023 12 / 20



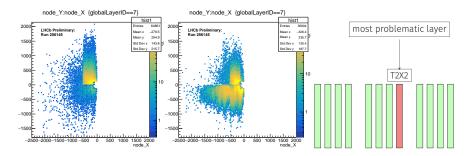






Improved Q0 positions in T2X2 layer with V2 alignment

- Compare good vs. poor performing layers
- ullet Q0(bottom left quarter) modules too far out of alignment ullet less tracks reconstructed in these objects
- Fix manually and rerun alignment



N.Breer | 08.09.2023 13 / 20









Stability tests on 2022 data

- How much does the SciFi move between runs?
- Does the magnet polarity impact playa role in the alignment?

- Perform alignment for each of the runs on the list
- Sort the runs in ascending run number
- Compare the difference in module position for subsequent
- Where are the modules in the local frame in all runs?

N.Breer | 08.09.2023 14 **/ 2**0



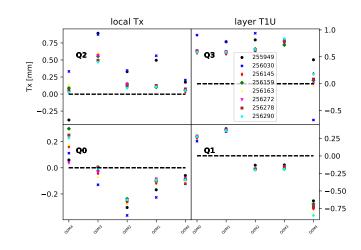






Module Positions in local half module frame

- Runs 255949 + 256030 problematic →issues known!
- Optimal fine timing implemented in 256145 (afterwards)
- Both magnet polarities comparable results



N.Breer | 08.09.2023 15 / 20



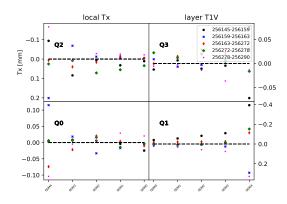






Reduced dataset: removed pre timing update runs

- Comparison of module positions of 2 runs each
- Outer modules →low statistics
 →difficult for the alignment →large movement
- Inner modules: movement around
 150µm allowed



N.Breer | 08.09.2023 16 / 20









stability tests: Conclusion

- Timing changes have big impact on module alignment
- Upper limit of module movement: 150μm
- →manually update
- Magnet polarity no major impact
- A possible choice of an automatic update would be if variations of > 200 μm occur.

N.Breer | 08.09.2023









Summary

- Source of complications: SciFi parts too far out of alignment to be correctly updated, corrected now with new alignment version and photogrammetry
- Correct module positions by hand: working procedure for singular low-efficiency modules
- stability tests show no substantial difference in alignment quality from magnet polarity

• sufficient statistics: 150µm movement; rerun manually if this is exceeded

N.Breer | 08.09.2023









Backup

Loose Tracking config and D0 selection

```
2 # (c) Copyright 2022 CERN for the benefit of the LHCb Collaboration
4 # This software is distributed under the terms of the GNU General Public
5 # Licence version 3 (GPL Version 3), copied verbatim in the file "COPYING".
6 #
7 # In applying this licence, CERN does not waive the privileges and immunities #
8 # granted to it by virtue of its status as an Intergovernmental Organization #
9 # or submit itself to any jurisdiction.
   from PvConf.Algorithms import (PrForwardTrackingVelo, PrMatchNN)
   from Moore import options, run_reconstruction
   from RecoConf.standalone import standalone hlt2 light reco without UT
14 from RecoConf.hlt2 tracking import (
       make_PrKalmanFilter_noUT_tracks,
16
       make_TrackBestTrackCreator_tracks,
18 from RecoConf.early_data import (
19
       get_loose_PrForwardTrackingVelo_params,
28
       get_loose_PrMatchNN_params,
21
       get_loose_PrKalmanFilter_params,
       get_loose_TrackBestTrackCreator_params,
23 )
24
   with PrForwardTrackingVelo.bind(**get_loose_PrForwardTrackingVelo_params()), \
        PrMatchNN.bind(**qet_loose_PrMatchNN_params()), \
26
        make_PrKalmanFilter_noUT_tracks.bind(**qet_loose_PrKalmanFilter_params()), \
        make_TrackBestTrackCreator_tracks.bind(**qet_loose_TrackBestTrackCreator_params()):
28
       run_reconstruction(options, standalone_hlt2_light_reco_without_UT)
```

```
pt_{min} = 800 MeV
pion, kaon required to have min pt and
IPCut = 60 \mu m
mass hypothesis [1760 MeV, 1960 MeV]
vertex \chi^2 < 10
```

N.Breer | 08.09.2023 19 / 20









Backup: stability dataset

- Dataset contains magnet-up and magnet-down samples from 2022 labeled as "good" from EMTF
- Good: > 90% of datalinks are good
- Includes runs from fills: 8489, 8491, 8496 List of randomly chosen runs: 255949, 256030, 256145, 256159, 256163, 256272, 256278, 256290
- V3 Alignment from tag (loose tracking, half module alignment TxTz + Mat alignment, back layer fixed) from conditions database

N.Breer | 08.09.2023 **20 / 20**