Understanding the alignment of LHCb's SciFi Tracker

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Overview and Motivation

Motivation

- Studying permormance of different alignments on run 256145 data

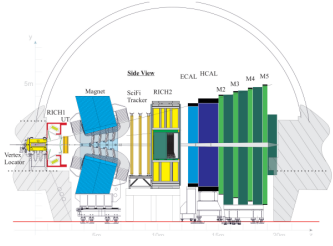
→ unexpected different results!

→ analysis of individual quarters

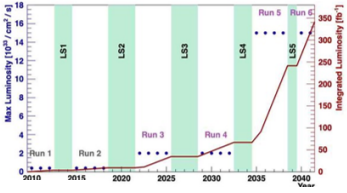
Overview

- The SciFi Detector Upgrade
- Alignment how to
- Analysis of SciFi quarters in different alignment versions

The Scintillating Fibre Tracker

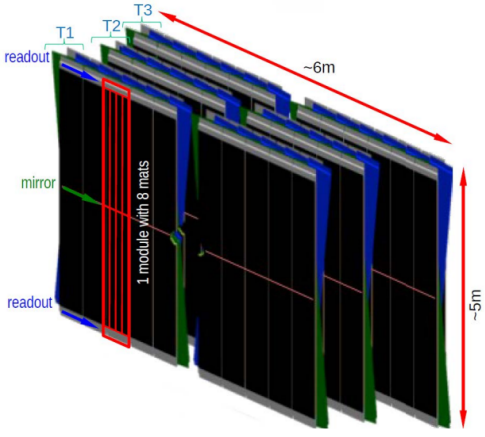


(a)



- Higher luminosity
  - detector must operate well with expected radiation damage
- detector readout electronics need to operate at 40 MHz, 25ns usable time per collision
- tracking efficiency and hit detection improvements aim for about 98% hit detection rate

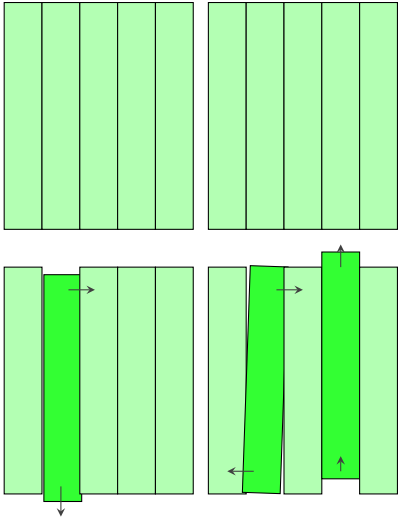
The Scintillating Fibre Tracker



- single detector type vs. IT + OT
- less timing information needed for readout
- less detector material
  - less multiple scattering and material interactions
- SiPM technology improvements yield better resolution and speed

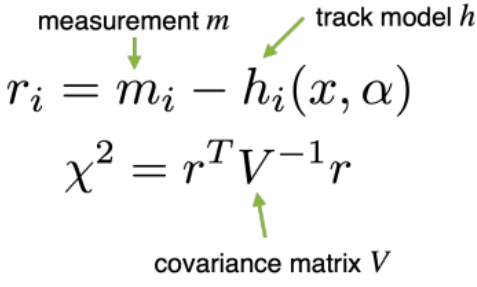
Abbildung: Visualization of the SciFi tracking

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 (this talk!)

Alignment: track fits with the Kalman Filter



- Minimise χ^2 with respect to the track parameters for the track fit
- Minimise χ^2 with respect to the alignment parameters α during the alignment
- Update the alignment constants α and repeat until convergence criterium for χ^2 is reached

Alignment versions in use

V1:

use full length Modules

alignable degrees of freedom: Tx Rz (x translation, rotation around z →beam pipe axis)

lowμ:

use half modules

uses VELO alignment on run 256145 data

μ = look it up

V2:

newest alignment version

half modules (top half and bottom half)

uses newest time alignment

utilizes VELO alignment from run 256145

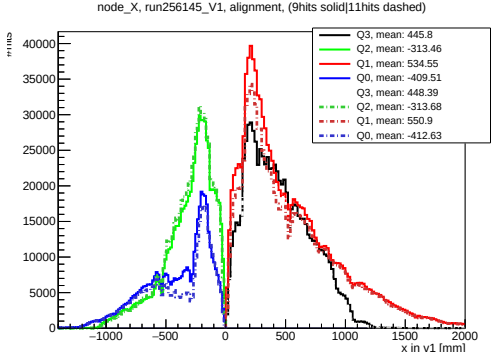
$\mu \approx 2.26$ (value taken from run database)

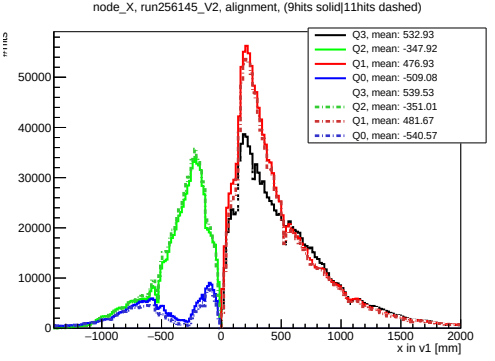
Why analyse the quarters separately?

- perfomance in each quarter might be very different from one another
- $\rightarrow \chi^2$ per layer might be different from χ^2 per quarter
- v2 alignment shows improvements from v1 alignment but not across the whole SciFi
- find and resolve possible issues is easier

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), minimum hits (dashed lines)





Summary of Metrics from alignments in Quarter 0

This hints that something is not right in Q0

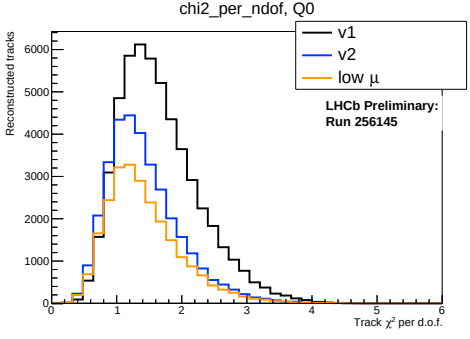


Abbildung: track χ^2 per dof comparing each alignment for Quarter 0.

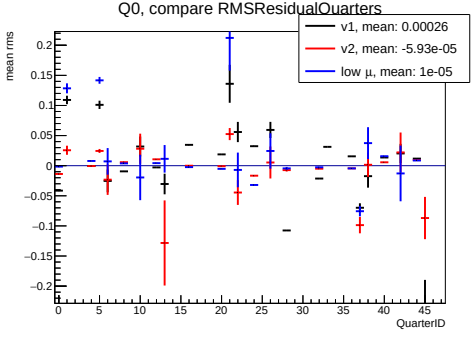


Abbildung: Residual in each module for each alignment in Quarter 0.

Summary of Metrics from alignments in Quarter 1

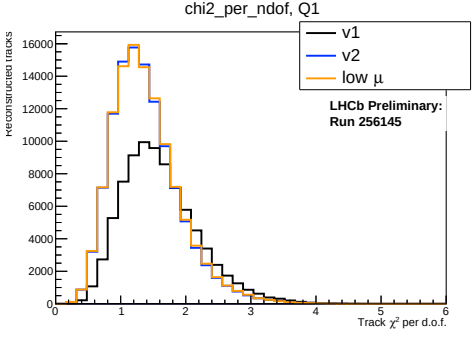


Abbildung: track χ^2 per dof comparing each alignment for Quarter 1.

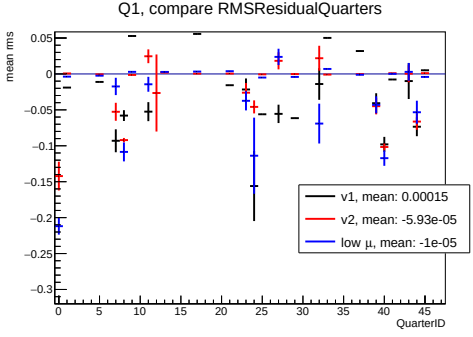


Abbildung: Residual in each module for each alignment in Quarter 1.

Summary of Metrics from alignments in Quarter 2

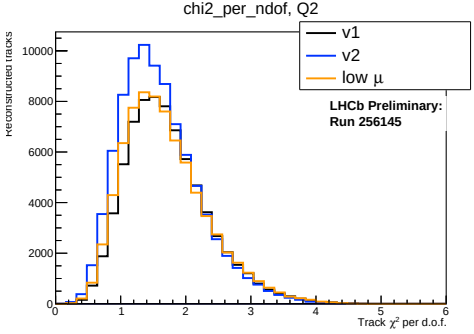


Abbildung: track χ^2 per dof comparing each alignment for Quarter 2.

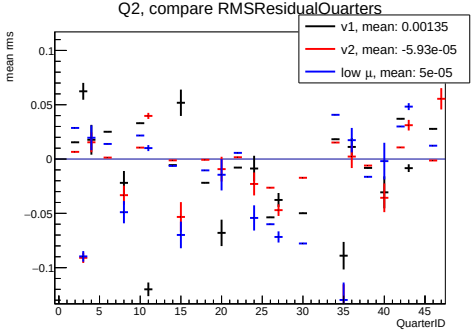


Abbildung: Residual in each module for each alignment in Quarter 2.

Summary of Metrics from alignments in Quarter 3

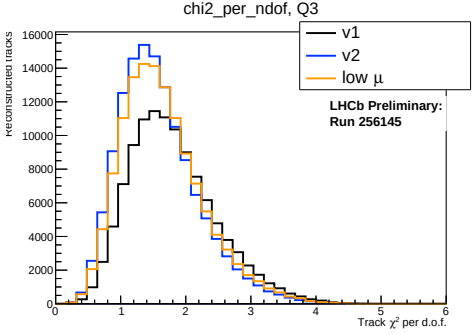


Abbildung: track χ^2 per dof comparing each alignment for Quarter 3.

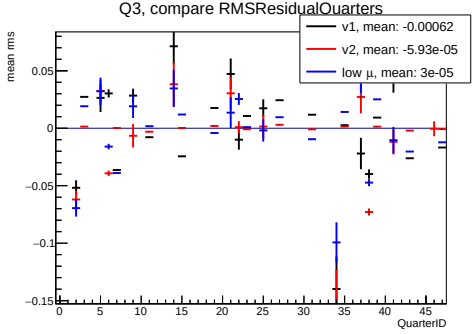


Abbildung: Residual in each module for each alignment in Quarter 3.

X^2 against ϕ angle distribution in V2 alignment

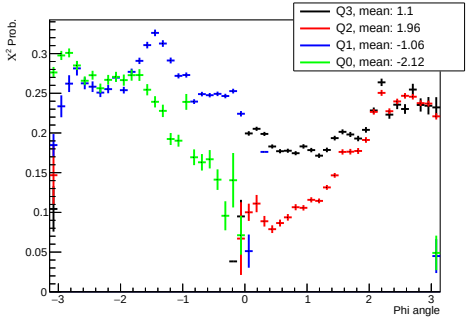
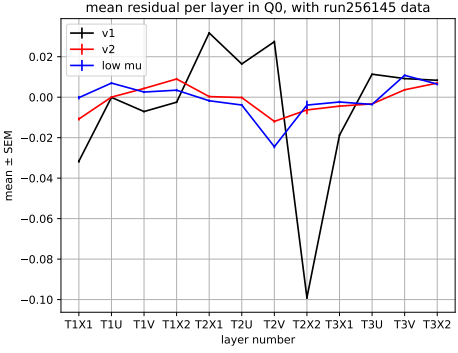


Abbildung: X^2 against ϕ distribution for each quarter for V2 alignment.

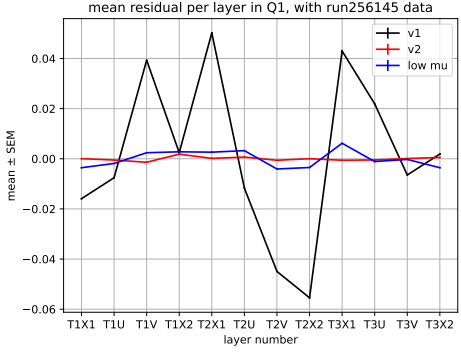
- X^2 against ϕ distribution for each quarter in V2
- information of layers are combined for each quarter
  → information of problematic layer in given quarter hidden
- aim: flat distribution across all angles
- A-side quarters (Q1: blue, Q3: black) quite flat
- C-side quarters (Q0: green, Q2: red) have small X^2 around 0

Track residuals in bottom half SciFi quarters

- left: Quarter 0, right: Quarter 1
- use cuts on LayerID to extract information about each layer



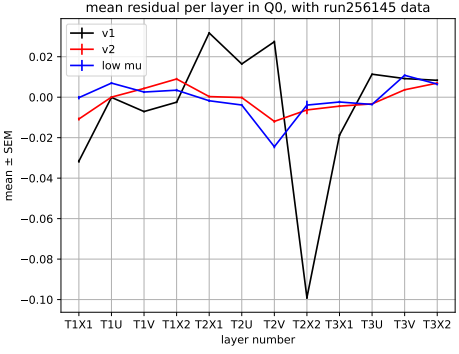
(a) Quarter 0



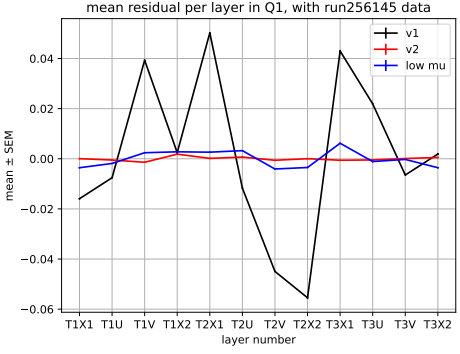
(b) Quarter 1

Track residuals in top half SciFi quarters

- left: Quarter 2, right: Quarter 3
- use cuts on LayerID to extract information about each layer



(a) Quarter 2



(b) Quarter 3

Conclusion

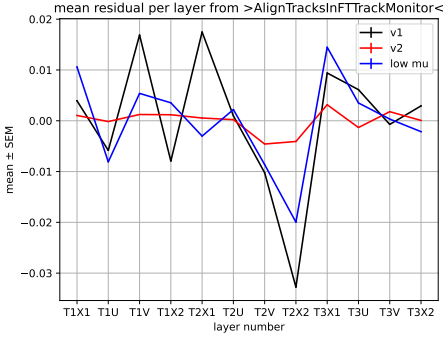


Abbildung: mean Residual per layer weighted with quarter hits.

mean residual per quarter weighted:

$\bar{Res}_Q = \sum_{\text{layer,quarter}} \frac{\text{hits quarter of layer}}{\text{hits layer}}$

goal: residual around 0 per layer

V2: quite good except second C-frame in T2

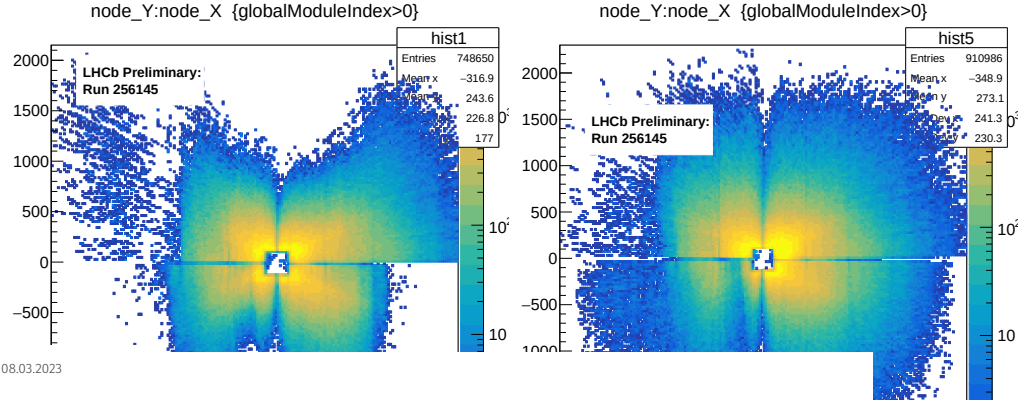
V1: everywhere worse than V2

low μ: quite ok except for back T2

→ V2 best performing alignment version for now, but still uses half modules → long modules

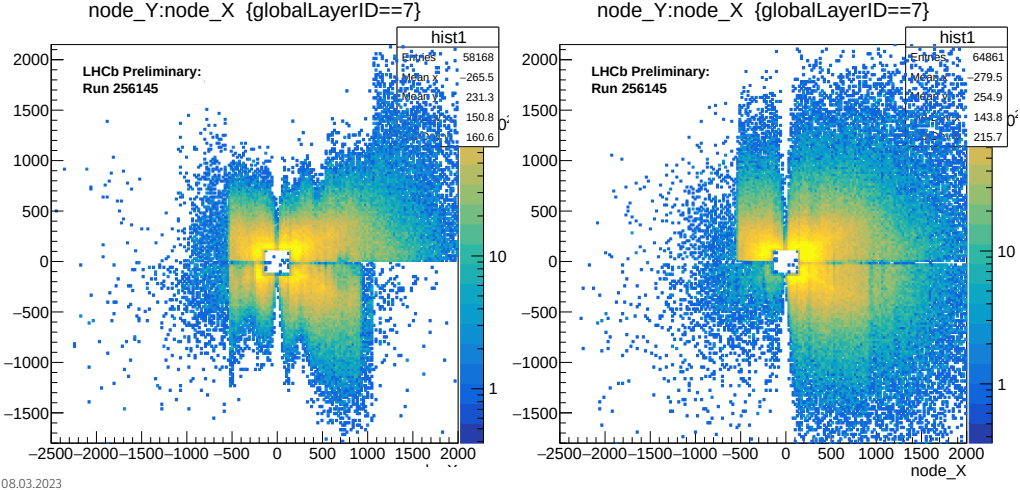
Track residuals in top half SciFi quarters

- V1: left, V2, right
- Hits on tracks as XY distribution resembling SciFi Layers
- C-side: negative x, A-side: positive x
- information of all layers are combined for each quarter → hard to see whats going on



Track residuals in top half SciFi quarters

- V1: left, V2, right



Conclusion

- text

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/