technische universität dortmund

FSP LHCb
Erforschung von Universum und Materie

Bundesministerium für Bildung und Forschung

Performance of the SciFi Tracker alignment in 2024

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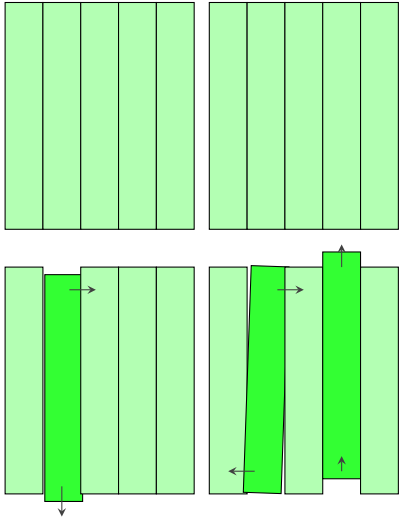
02.04.2025

DPG Conference 2025, Göttingen

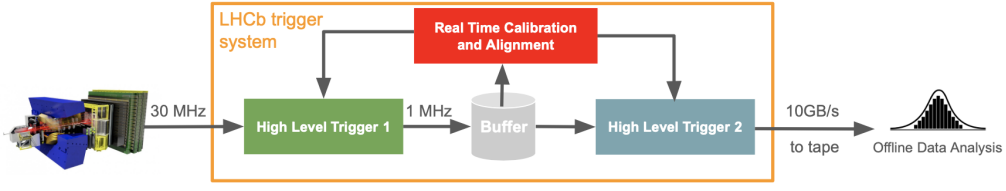
Why do we need detector alignment?



- Track reconstruction: detector position in reconstruction similar to real detector
- Top: ideal detector, bottom: physical detector
- Surveys: find the rotation and position of each detector component
- Surveyed measurements of detector: Input for alignment
- Alignment goal: achieve the best precision in the detector position

Importance of alignments

- Alignment is part of the LHCb trigger system
- Physics performance tied to alignment performance
- Good quality alignment contributes to:
  - → remove systematic biases for asymmetry measurements
  - Best possible mass resolution



Tracking alignment: track fit using Kalman filter

- Input sample: reconstructed tracks (HLT2)
- χ^2 minimization algorithm → determine detector element position

Reconstruct the tracks using the current alignment constants

$$\frac{d\chi^2}{d\alpha} = 2 \sum_{\text{tracks}} \frac{dr}{d\alpha}^T V^{-1} r$$

$$\frac{d^2\chi^2}{d\alpha^2} = 2 \sum_{\text{tracks}} \frac{dr}{d\alpha}^T V^{-1} R V^{-1} \frac{dr}{d\alpha}$$

Compute a new set of alignment constants (α) minimizing a global χ^2:

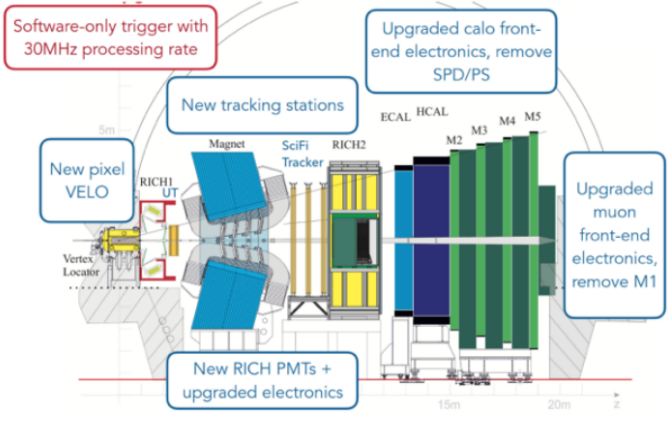
$$\alpha = \alpha_0 - \left(\frac{d^2\chi^2}{d\alpha^2}\right)^{-1}\Bigg|_{\alpha_0} \frac{d\chi^2}{d\alpha}\Bigg|_{\alpha_0}$$

Iterate until the χ^2-difference is below a threshold

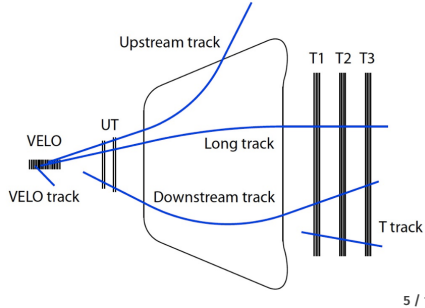
r: tracks residuals, V: covariance matrix, R: residuals' covariance matrix

- Easily models material interactions as well as multiple scattering

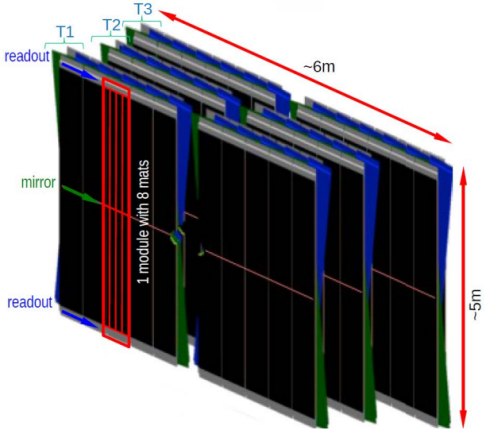
The Run 3 LHCb detector



- Brand new detector to maintain physics performance at more radiation harsh environment
- UT was not present during 2022-23 data taking →focus on SciFi and VELO



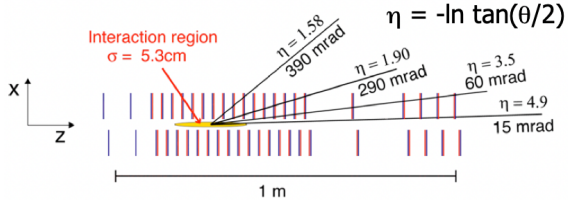
The Scintillating Fibre Tracker

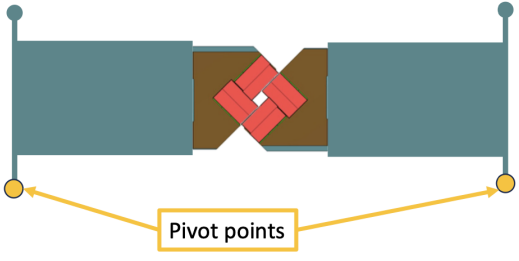


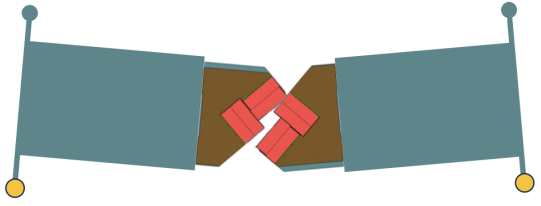
- 5 modules per side except for back T-station has 6
- X1, X2-layers are vertical and only yield x-position information
- U, V layers have a ∓5degree stereo angle respectively
  - → Used for determining y-position of tracks by comparing hitposition at different angles

VELO geometry

- Rotation Rz leading to shifts in x and y
- Half alignment sensitive to x shift
- Global movement in y
  - Can not be corrected for by half alignment







Global alignment and motivation for precision studies

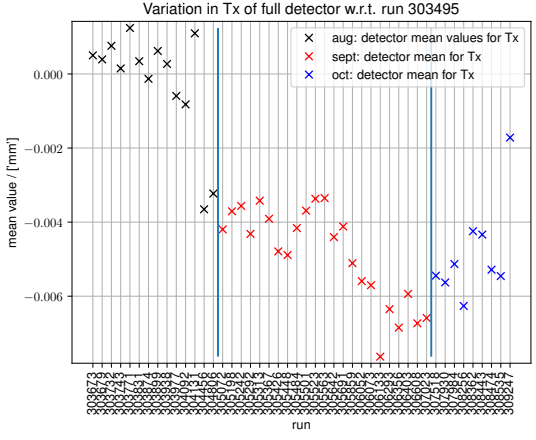
Global alignment

- Alignment of the VELO, SciFi and UT simultaneously
- Motivation for global alignment
  - Understanding the interplay between tracking systems
  - Rotations inside the VELO →weak modes inside SciFi (VELO twisting)

Precision studies

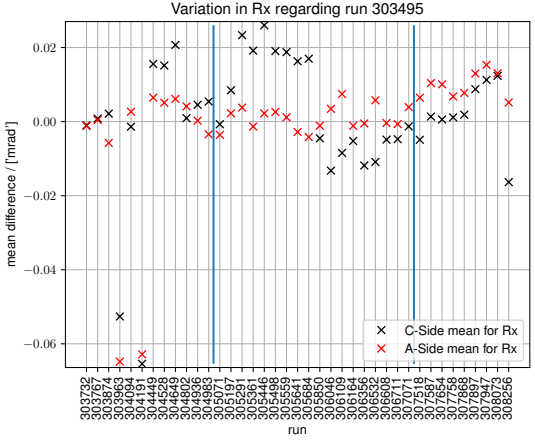
- Analyzing the precision of the SciFi tracker on 2024 data
  - Obtain precision by running over a set of runs throughout the year →automatic uptdate threshold
  - Exceeding this threshold triggers an alignment update

Detectorposition in 2024



- Aligning SciFi CFrames in Tx and modules in Tx
- mean module constant for the whole SciFi w.r.t. reference run from 2024 alignment update
- distinct edges at points of interest (hardware, machine development)
- The movements may not always come from the SciFi →related to the VELO position

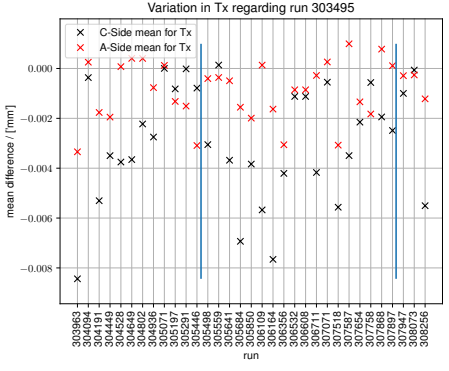
Detectorposition in 2024, halfmodules Rx alignment

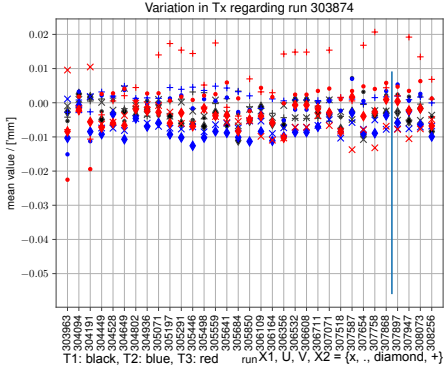


- Rerunning the test with halfmodule alignment in Rx (here) as well as TxRz and CFrames in Tx
- Fluctuation is seen in the SciFi C side
  - VELO constants follow the same trend until ”edges” seen in the constants →not the cause for this effect
  - Related to the alignment of the VELO halves

Detectorposition in 2024, halfmodules TxRz alignment

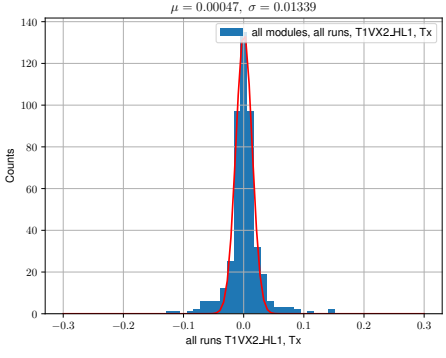
- Halfmodules aligned in TxRz and CFrames in Tx
- C-side objects move a little more w.r.t. to reference but still small →expected
- Per layer, movement looks consistent over all runs →expected

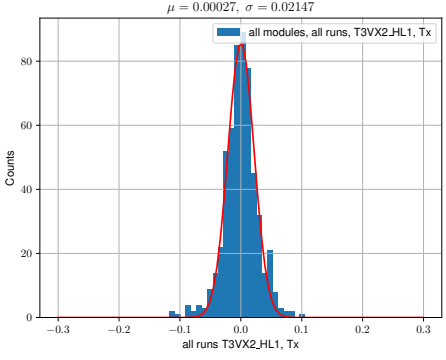




Detectorposition in 2024

- Width of the distribution is a wider in the last station →also seen on Monte Carlo
- Overall centered and width is comparable to MC values



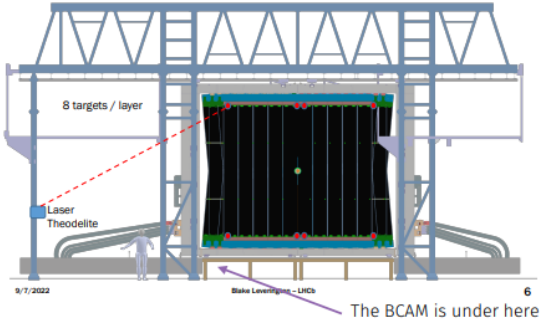


Summary

- The precision study for the 2024 data since the v21 alignment update looks consistent and shows expected behavior →data taken in 2024 is good!
- Better than the single hit resolution of the SciFi of 100 µm
- Comparison to Monte Carlo is consistent
- Still need to understand the difference seen between spread in SciFi stations
- **Thank you for your attention!**

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

Alignables for the global alignment