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# Global alignment of the LHCb SciFi Tracker and Vertex Locator

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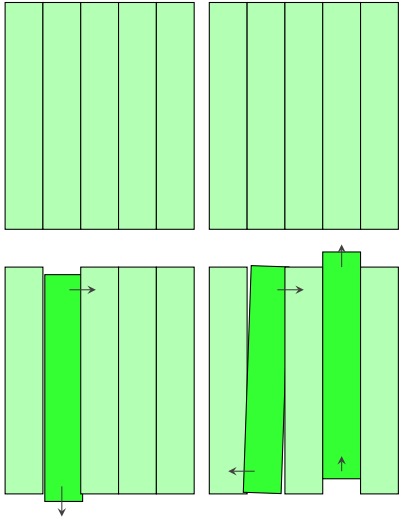
**04.03.2024**

DPG Conference, Karlsruhe

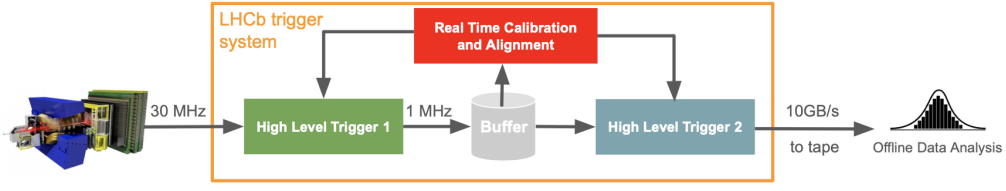
# Why do we need detector alignment?



- 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)
- $\chi^2$ 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 ($\alpha$) minimizing a global $\chi^2$:

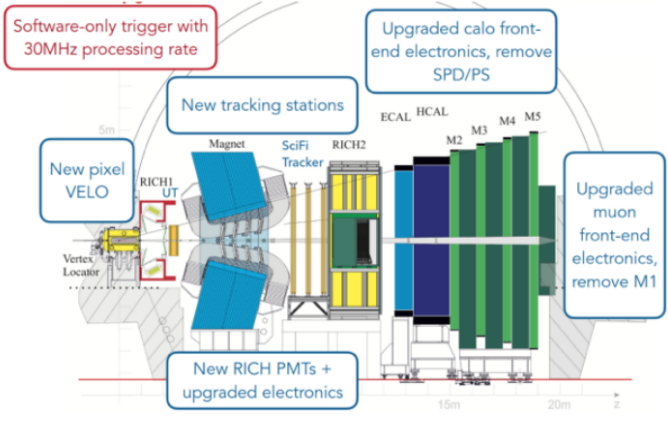
$$\alpha = \alpha_0 - \left(\frac{d^2\chi^2}{d\alpha^2}\right)^{-1}\Bigg|_{\alpha_0} \frac{d\chi^2}{d\alpha}\Bigg|_{\alpha_0}$$

Iterate until the $\chi^2$-difference is below a threshold

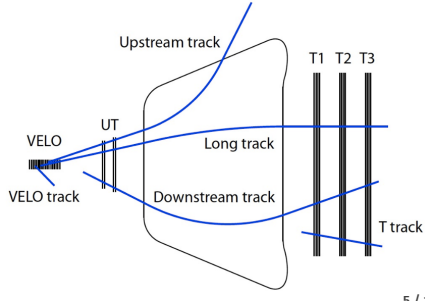
$r$: tracks residuals, $V$: covariance matrix, $R$: residuals' covariance matrix

- Easily models material interactions as well as multiple scattering

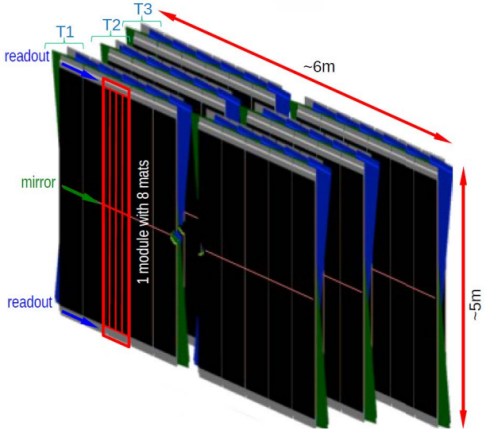
# The Run 3 LHCb detector




- 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



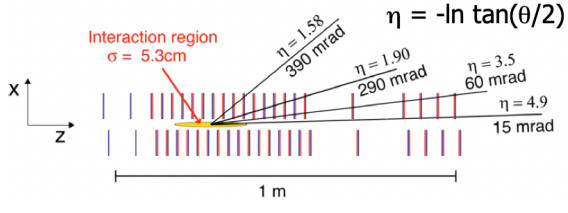
# The Scintillating Fibre Tracker

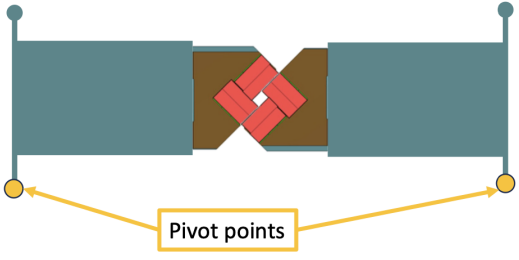


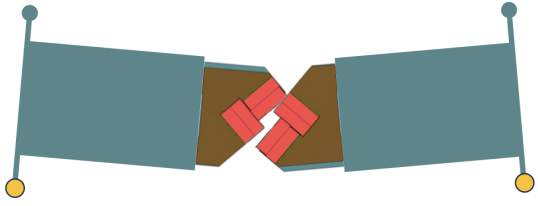

- 5 modules per side except for back T-station has 6
- X1, X2-layers are vertical and only yield x-position information
- U, V layers have a ∓5degree stereo angle respectively
  - → Used for determining y-position of tracks by comparing hitposition at different angles

# 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



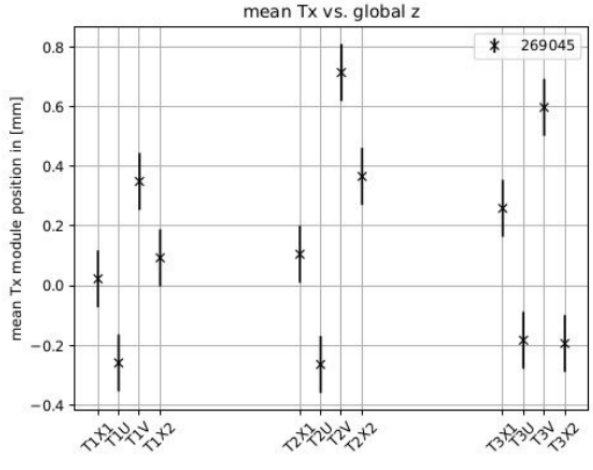



# Global alignment and motivation

## Global alignment

- Alignment of the VELO and SciFi simultaneously
- Motivation for global alignment
  - we can do the alignment seperately but ideally best alignment we achieve is the global one
  - Understanding the interplay between tracking systems
  - Rotations inside the VELO →weak modes inside SciFi (VELO twisting)

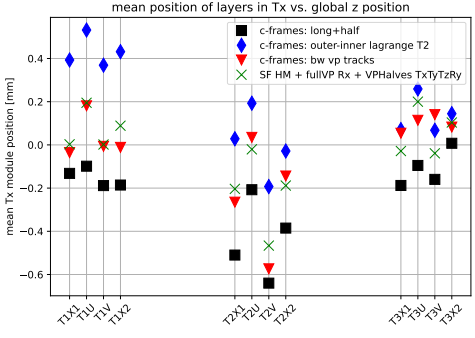
# SciFi alignment status and issues




- SciFi alignment quite good already
- Zig-zag pattern in stereo layers comes from global VELO Rx rotation
- Similar pattern in SciFi Tz →entangled problem between Tx and Tz

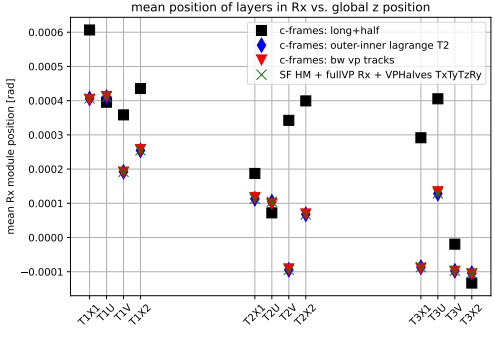
## Comparison to global alignment tests

| | C-FRames | Halfmodules | full VELO | VELO halves |
|---|---|---|---|---|
| DoF | RxRz | TxRxRz | RxRz | TxTyTz |




- Black: first align Longmodules then Halfmodules
- Blue: constraining (X1|X2) and (U|V) layers
- Red: added backwards VELO tracks
- Green: only Rx in full VELO alignment

# global alignment: rotation studies




- Observe rotation around Rx through T-stations
- This effect only shows when running SciFi and VELO together

## Outcome of the study and next steps

- ongoing investigation of zig-zag pattern with VELO Rx

→similar pattern in Tz →cannot fix one without the other

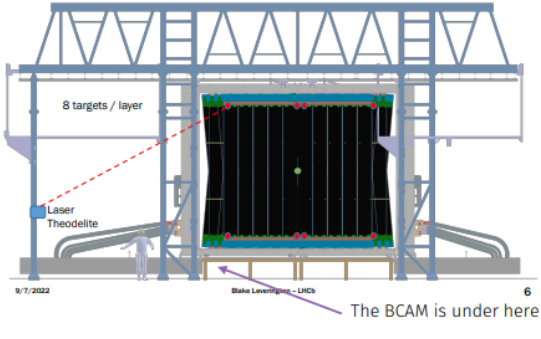
- global VELO Rx might be overthrown by survey constrains acting on Rx →Rx not being picked up in the alignment
- Testing different survey uncertanties to study the impact on global VELO rotation
- Testing different settings in the alignment on stereo layers in Tx
- make sure VELO Rx is being picked up in the alignment
- Include the VELO + SciFi configuration during data-taking

## Summary

- global alignment improving the SciFi alignment
- survey constraints counteract the global VELO Rx
- A lot more tests to do until data taking which look promising
- **Thank you for your attention!**

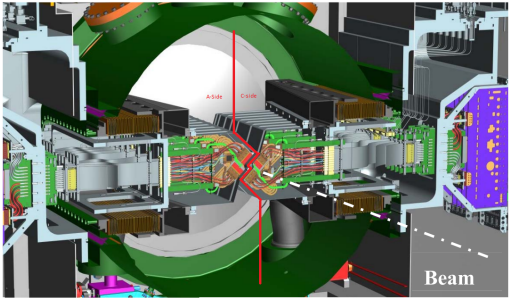
## The survey: what is it and the different types

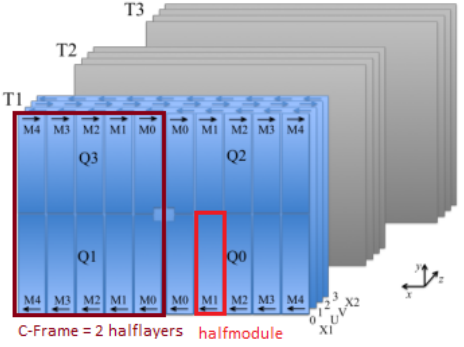
- Measure distance of some points on the detector with a laser




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

# Alignables for the global alignment



## Links

Wouter's paper on the Kalman Filter

Real time Alignment and calibration presentation