Real-time alignment and calibration performance of LHCb with Run 3 data

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CERN

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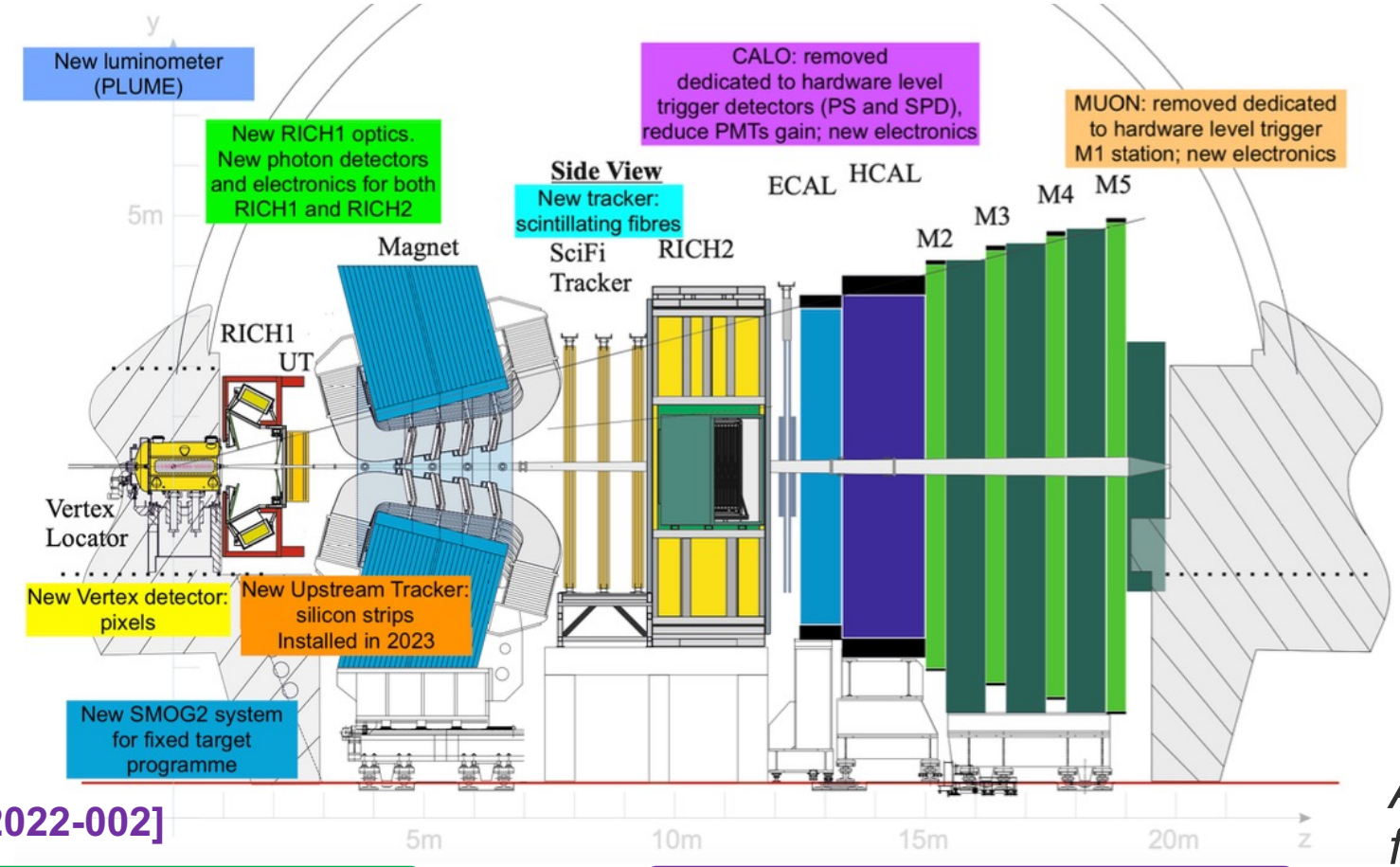
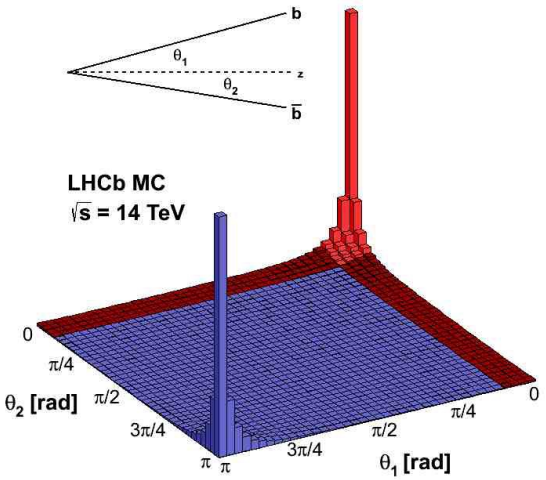
The LHCb detector in Run 3

A general detector specialized in beauty and charm hadrons





Huge production cross-section in LHCb acceptance

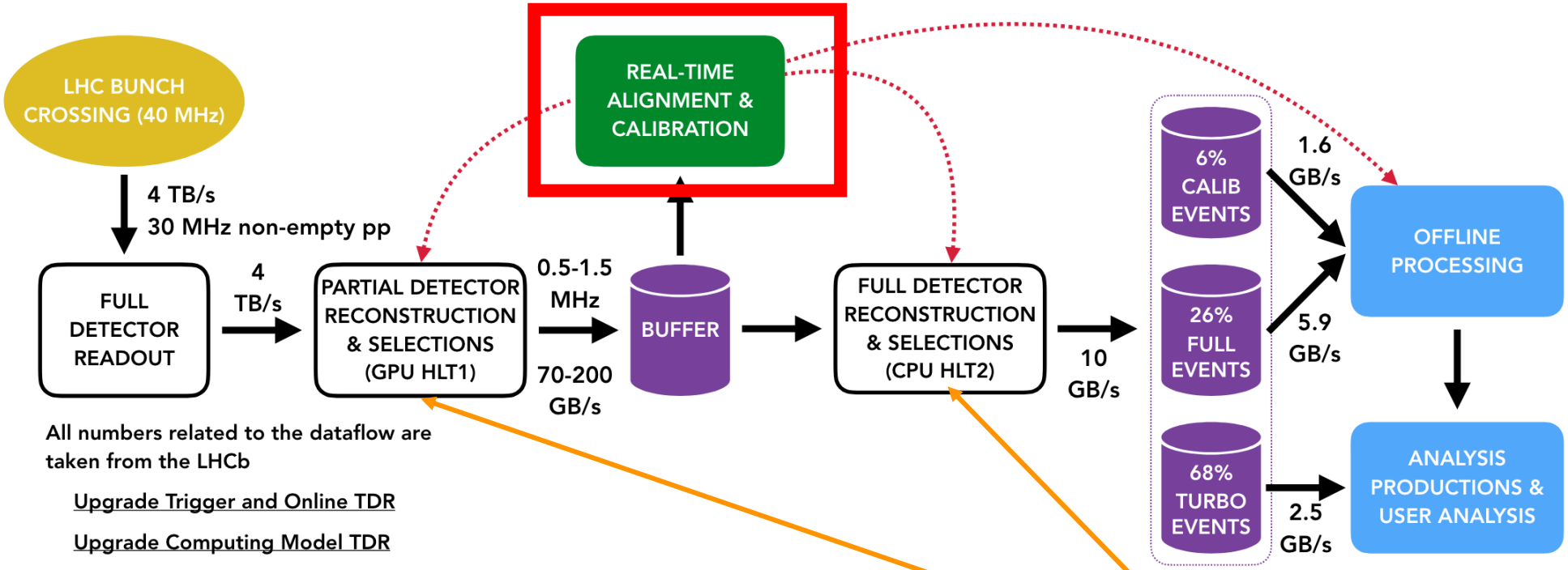
[LHCb-DP-2022-002]

Excellent momentum resolution

Excellent particle idenfication

Alignment & Calibration for better track quality & particle identification

The LHCb data flow



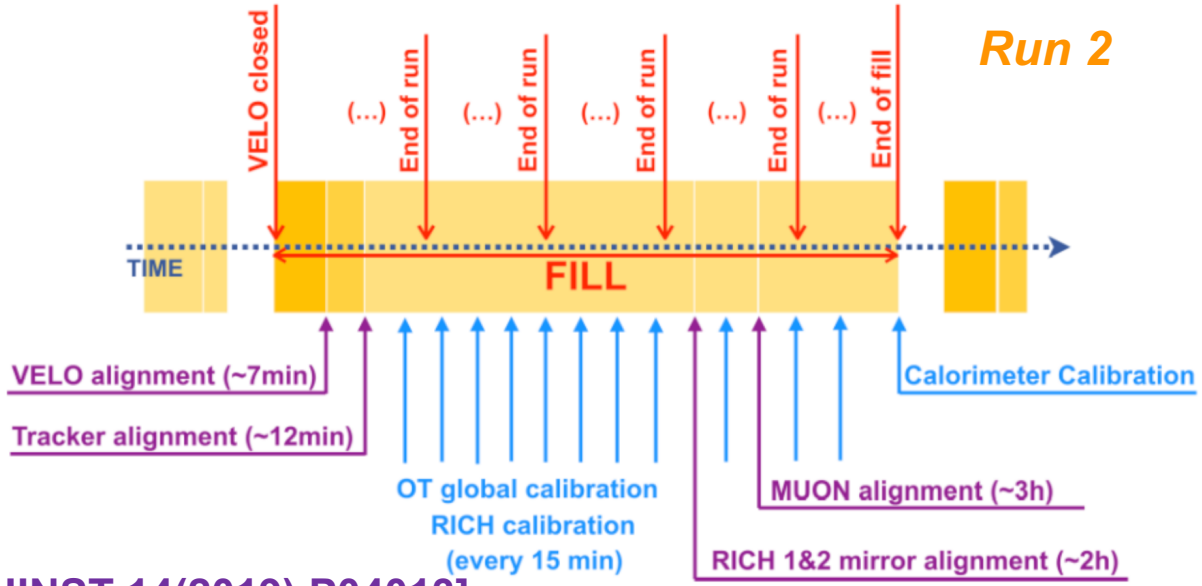
[LHCb-FIGURE-2020-016]

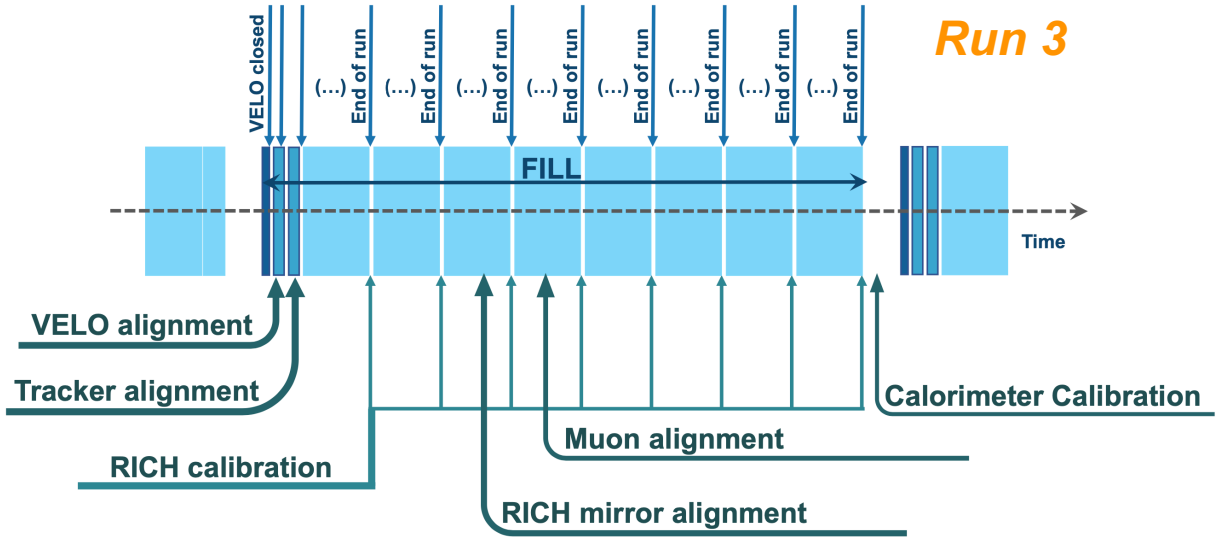
- Detector data @30 MHz received by O(500) FPGAs
- 2-stage software trigger, HLT1 & HLT2
- ***Real-time alignment & calibration***
- Results of alignment & calibration used for reconstruction at HLT1 & HLT2

Results with LHCb's 30MHz software trigger; in L. Calefice's talk

Alignment and calibration

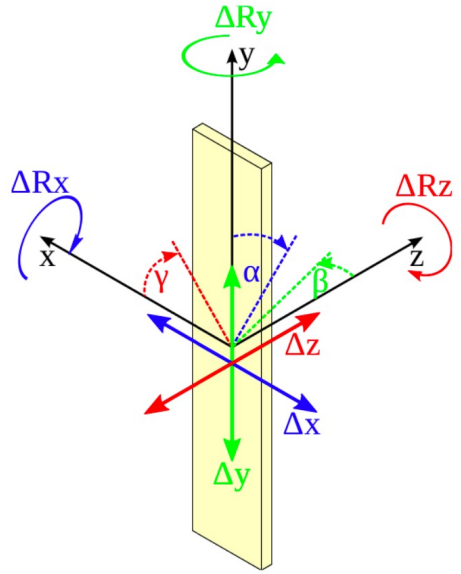
- Fully aligned and calibrated data needed before running HLT2
- Real time alignment and calibration pioneered in Run 2, crucial in Run 3
- Buffer capacity of O(40 PB), corresponds to O(days) of running, situated between HLT1 and HLT2
- LHCb distinguish two processes:
  - Alignment: *VELO, SciFi, UT, RICH mirrors, Muon*
  - Calibration: *RICH, ECAL, HCAL*





[JINST 14(2019) P04013]

Tracking system alignment



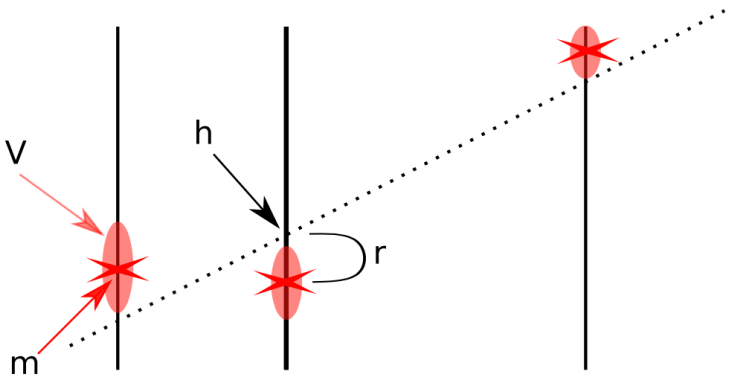
- Degrees of freedom μ for tracker alignment (alignment constants)
- The χ^2 of all tracks minimized with respect to the alignment parameters μ

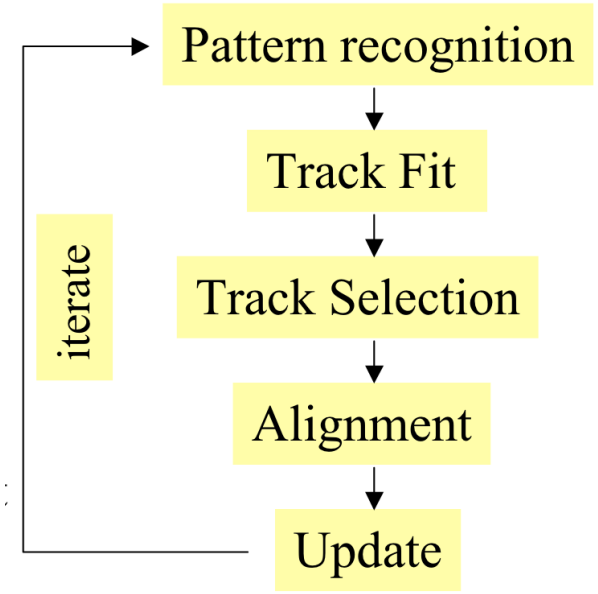
$$\chi^2 = [m - h(x)]^T V^{-1} [m - h(x)]$$

  - $m \rightarrow$ measurement; $h(x) \rightarrow$ measurement model; $x \rightarrow$ track parameters;
  - $V \rightarrow$ measurement covariance matrix from Kalman filter

- Residual (r) is defined as :

$$r = m - h(x, \alpha)$$

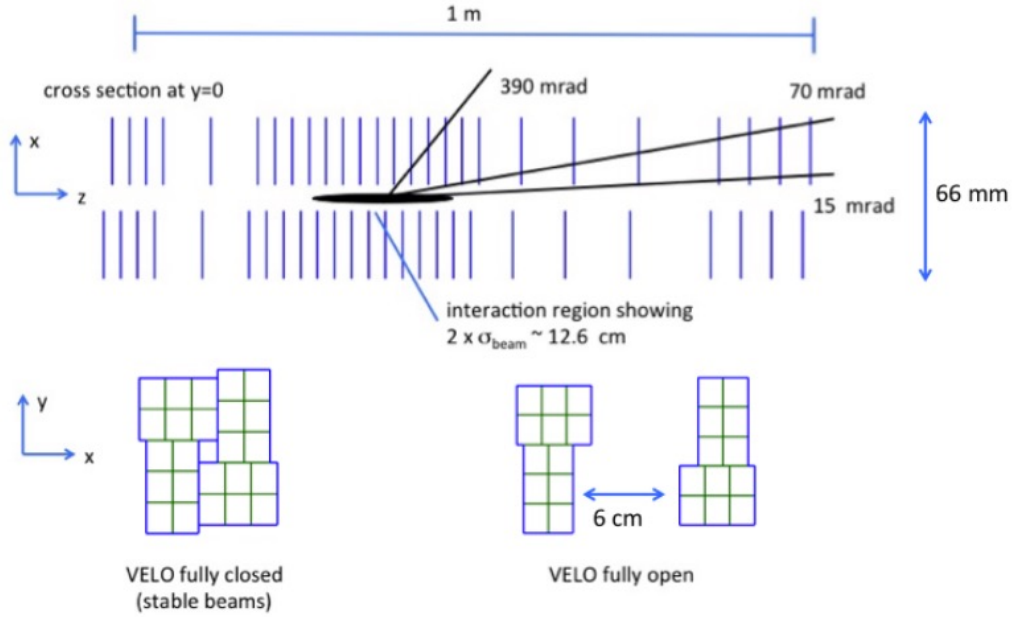


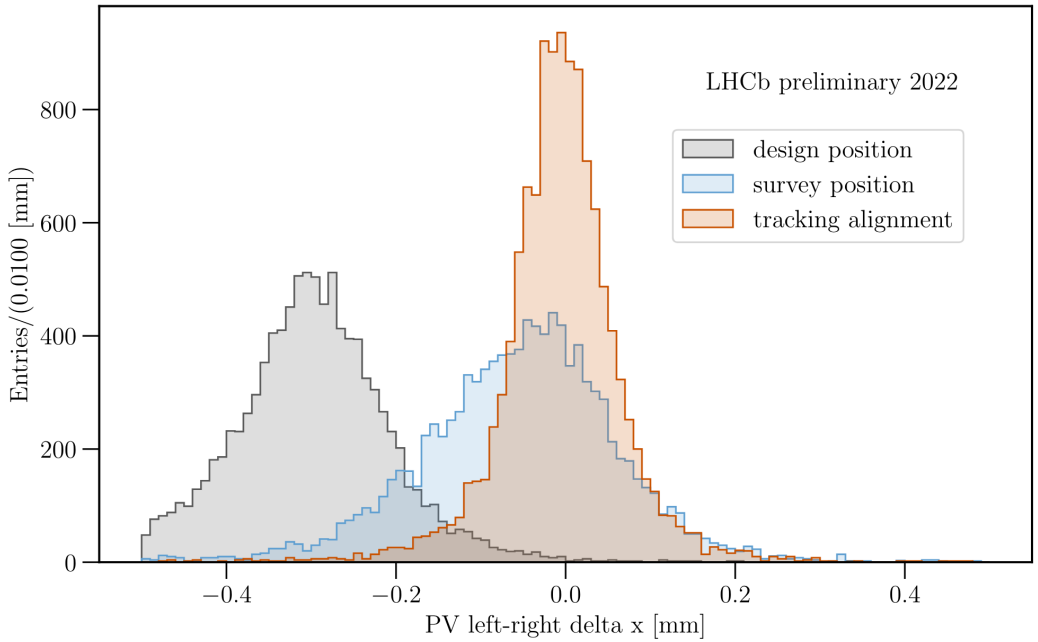


[Nucl. Instrum.Meth.A 600 (2009) 471-477]

Velo alignment

- VELO closed at the begin of stable beam collision
- VELO alignment quality from measurement of the distance of the PV position reconstructed using only tracks in the right or left half ➔ Bias indicates misalignment

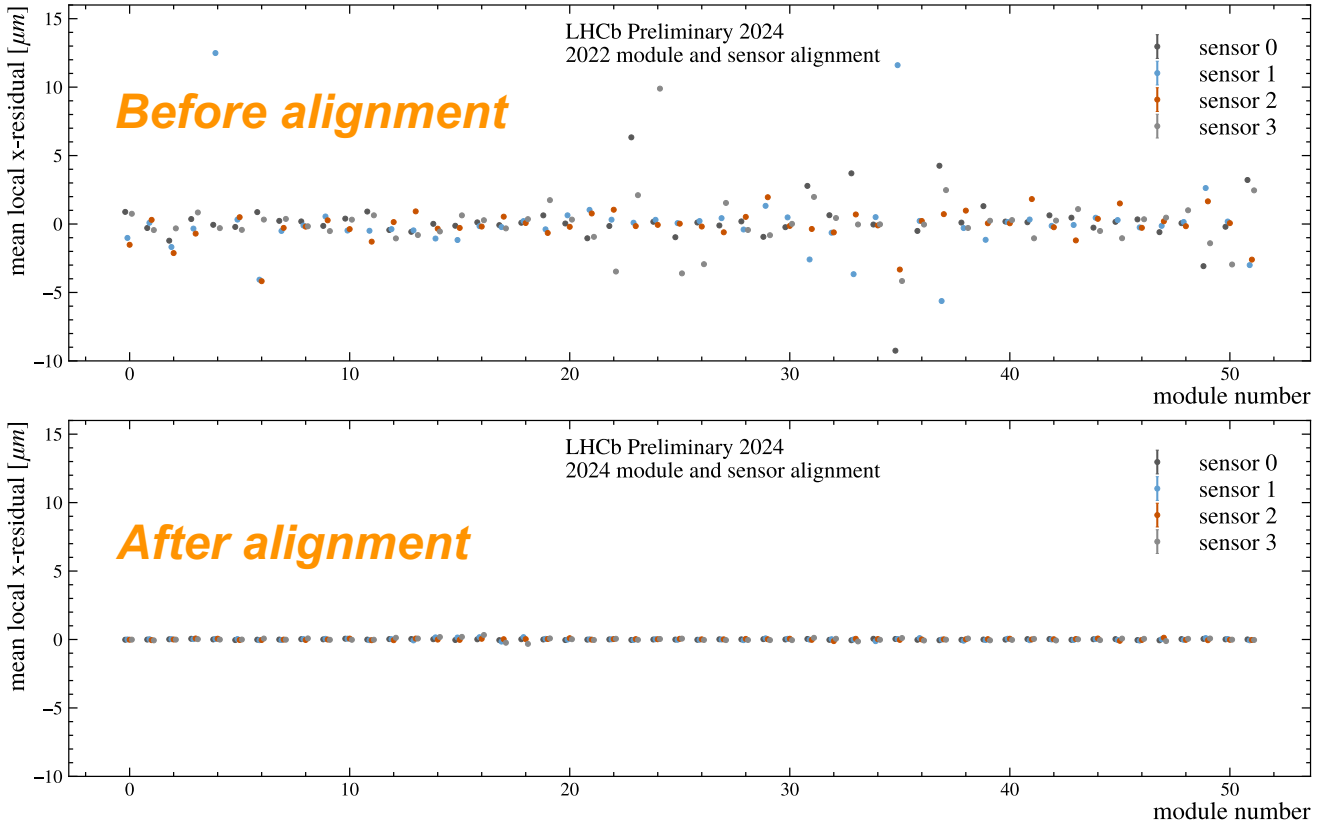




[LHCb-FIGURE-2022-016]

Velo alignment cont.

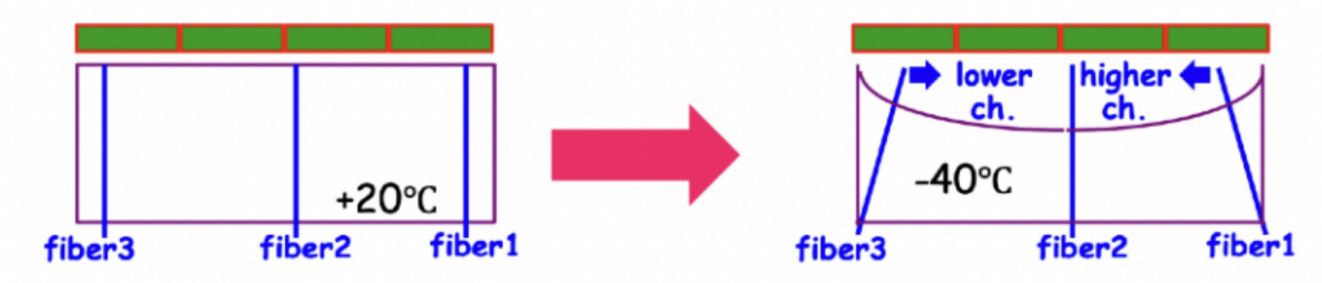
- The modules aligned: (T_x, T_y, T_z) and (R_x, R_y, R_z); The sensors are aligned (T_x, T_y, R_z)
- The mean of the residuals ~ 0 after alignment

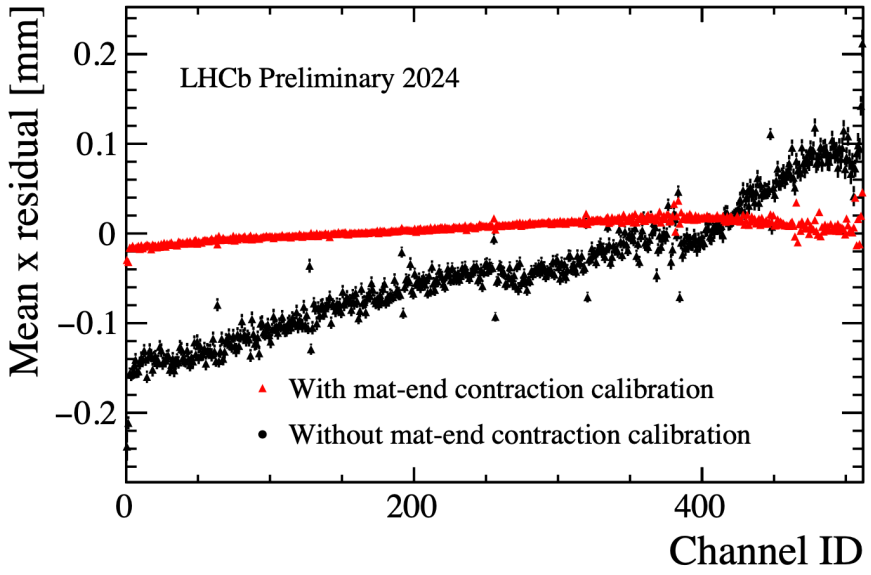


[LHCb-FIGURE-2024-009]

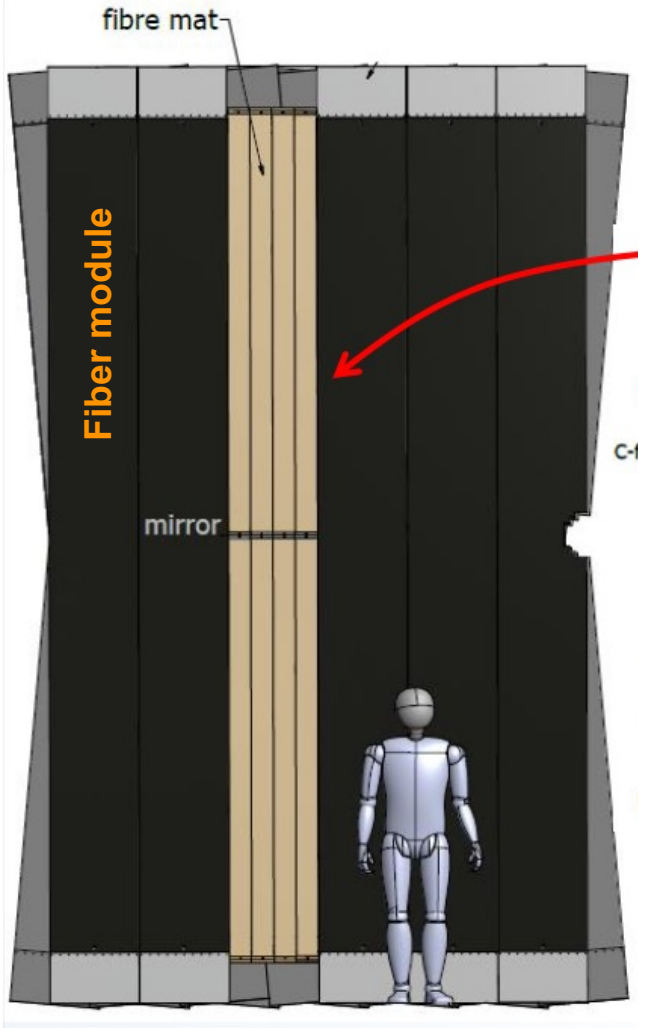
SciFi alignment

- SciFi fibre module hanged on frame; Fibre mats glued together to construct module
- Mat contraction effect due to SiPM cooling





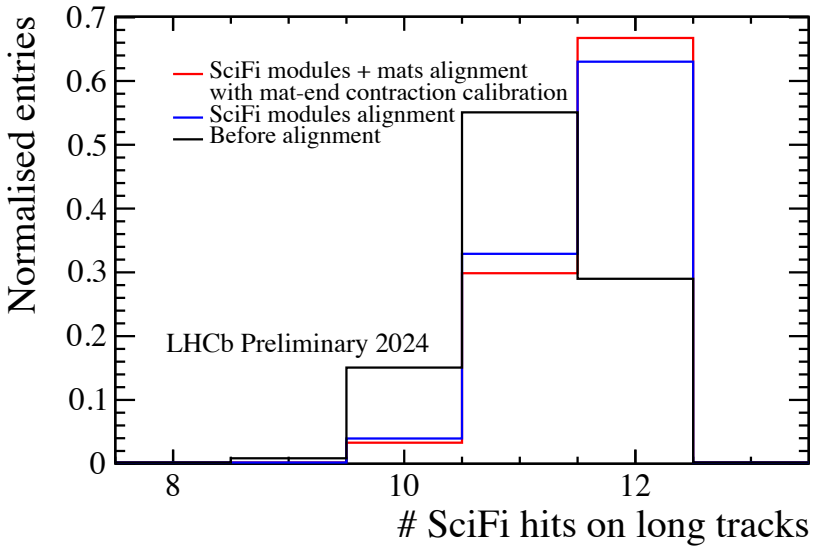
[LHCb-FIGURE-2024-009]

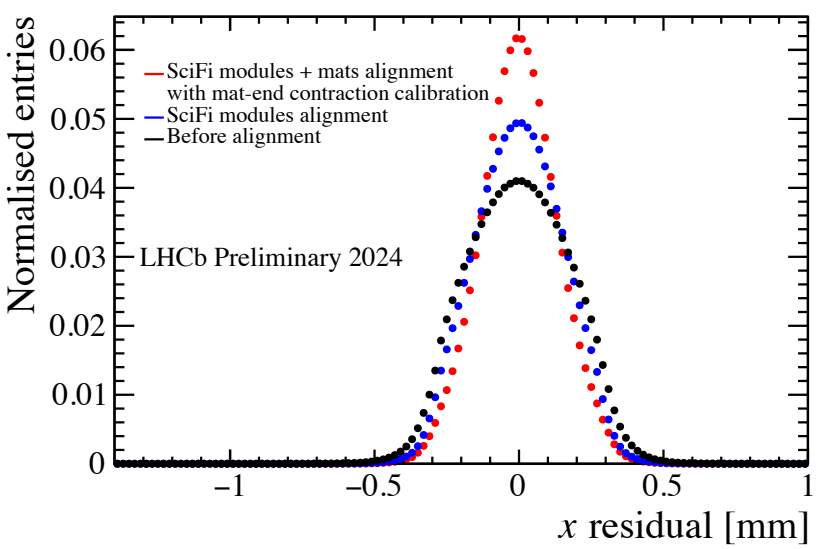


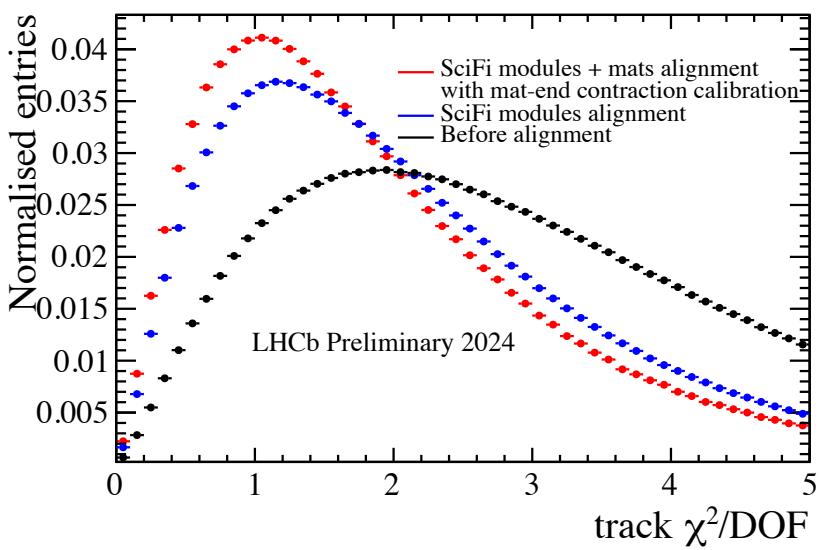
SciFi alignment cont.

- After alignment:
  - Average number of SciFi hit improved
  - Better resolution
  - Better track fit quality

➔ To achieve better track momentum resolution



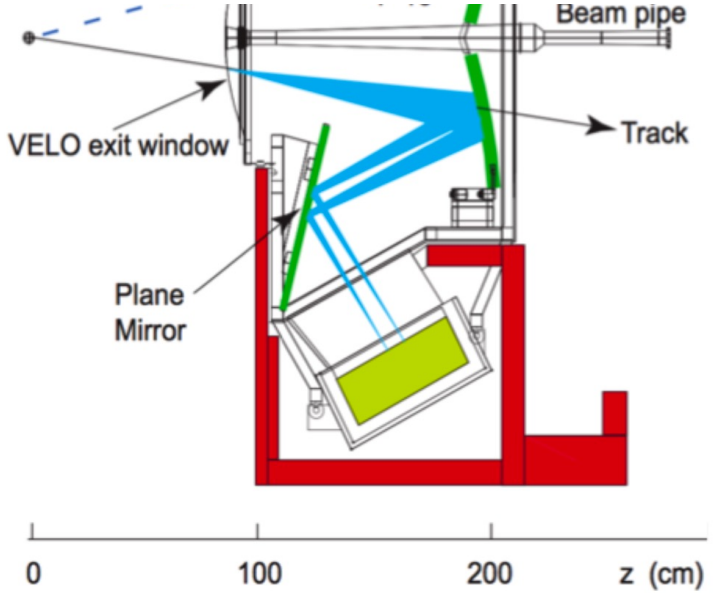


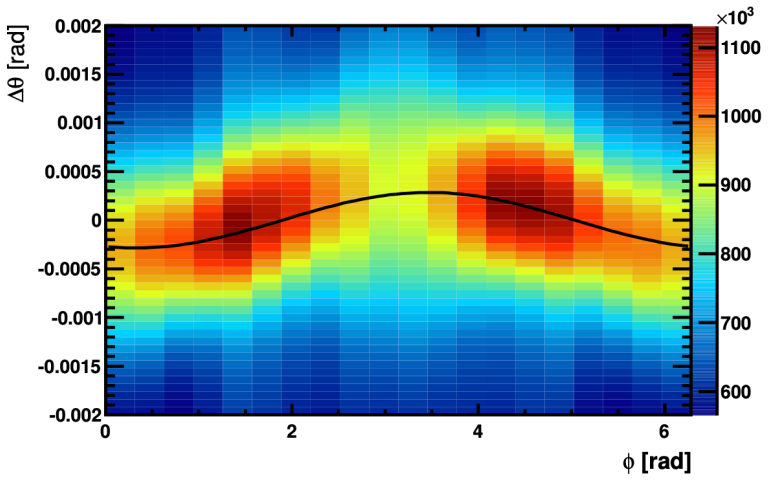


[LHCb-FIGURE-2024-009]

RICH mirror alignment

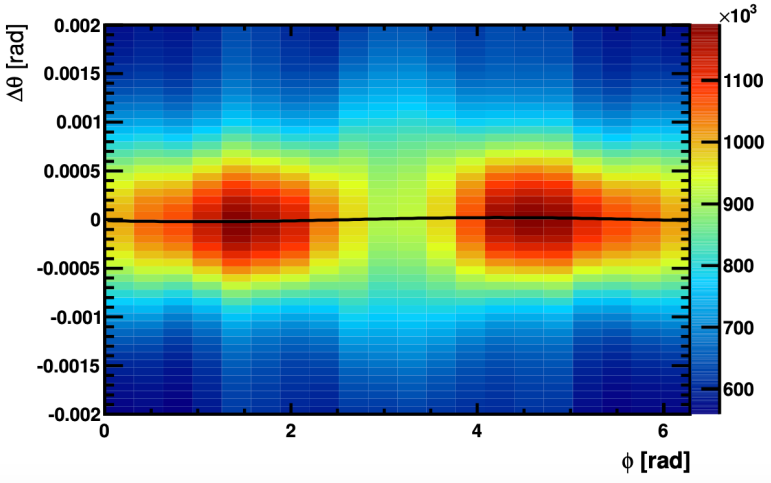
- The centre of Cherenkov ring would not correspond to the intersection point of the charged track
- Alignment for each mirror: by the fit of the Cherenkov angle difference as a function of the azimuthal angle on the ring
- Better single-photon resolution ➔ better identification



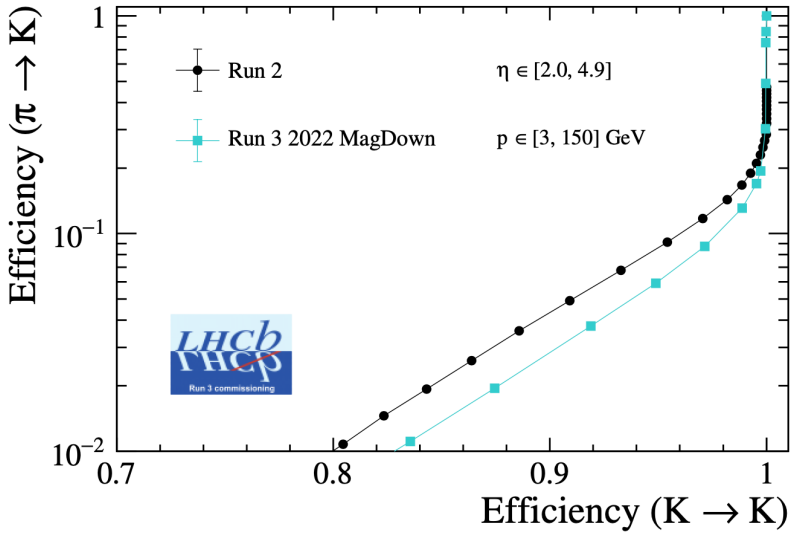


Before mirror alignment

[Eur. Phys. J. C 73 (2013) 2431]



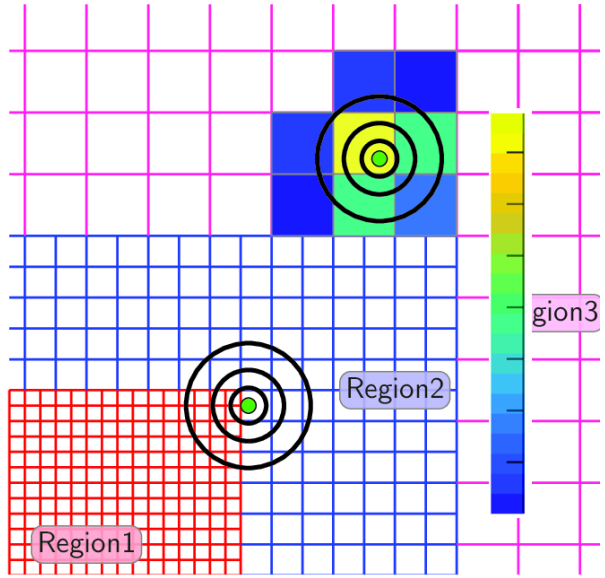
After mirror alignment

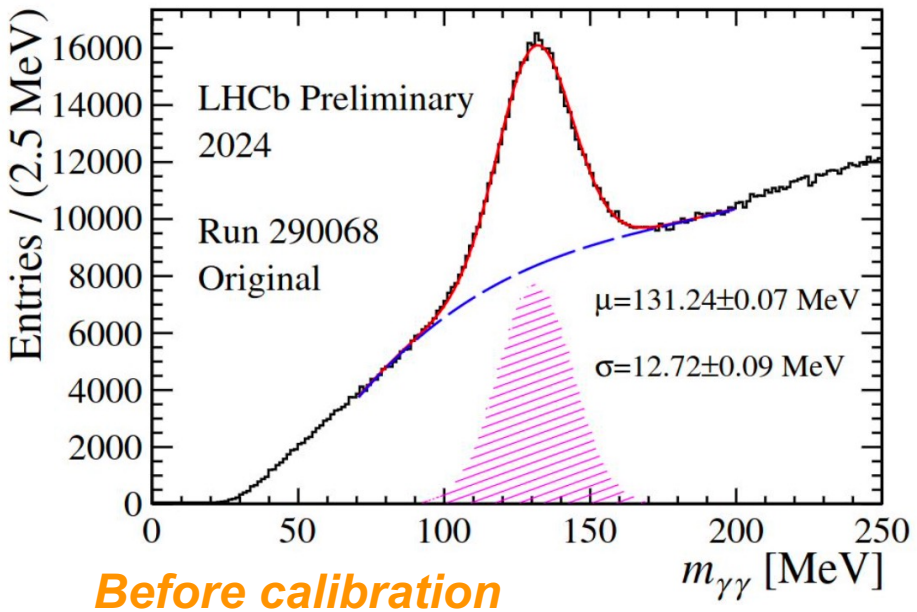


[LHCb-FIGURE-2023-019]

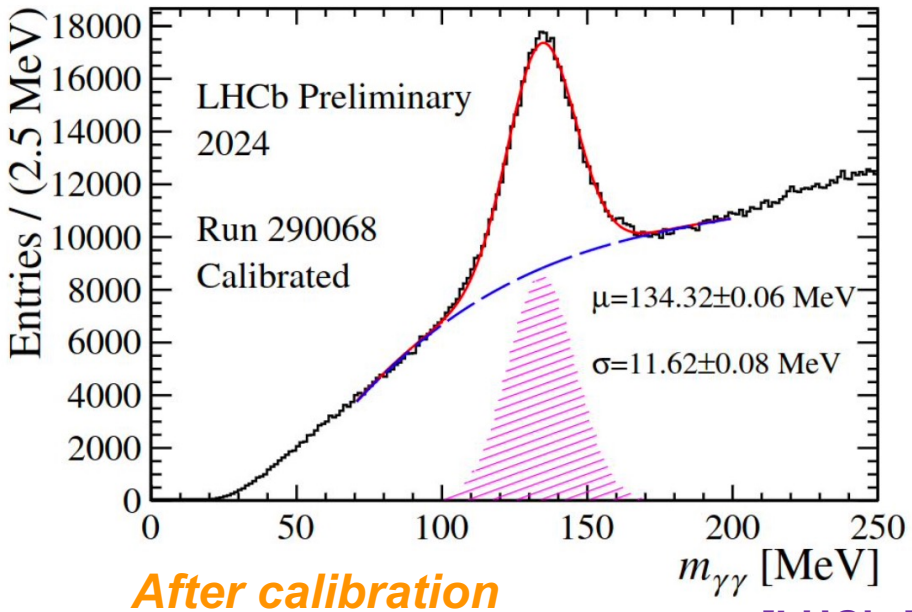
Electromagnetic calorimeter calibration

- A set of corrections for each of the 6016 cells of ECAL
- The energy corrections for each cell obtained using the reconstructed π^0 mass
- π^0 mass resolution improved after calibration





Before calibration



After calibration

[LHCb-FIGURE-2024-009]

Summary

- **The framework real-time alignment and calibration at LHCb works for Run 3**
  - fully automated real-time alignment pioneered for Run 2
  - for Run 3 new detector and fully software-based trigger
- **Alignment and calibration improve the tracking quality and particle identifications to complete an offline quality reconstruction**
- **Tune system and refine the alignment & calibration over time with the feedback from taking data**

Thanks for your attention

Backup

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