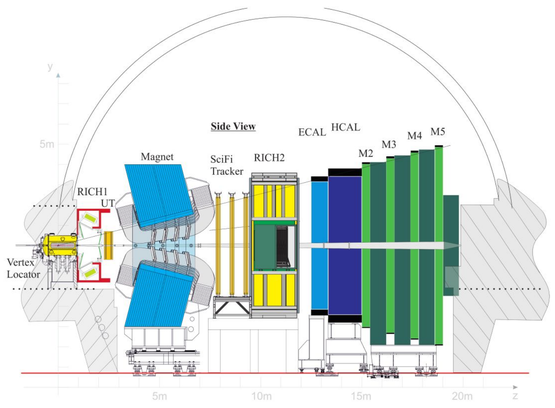
Real-time alignment of the LHCb detector in Run 3

Miguel Ruiz Díaz (miguel.ruiz.diaz@cern.ch), on behalf of the LHCb collaboration
Physikalisches Institut, Heidelberg University

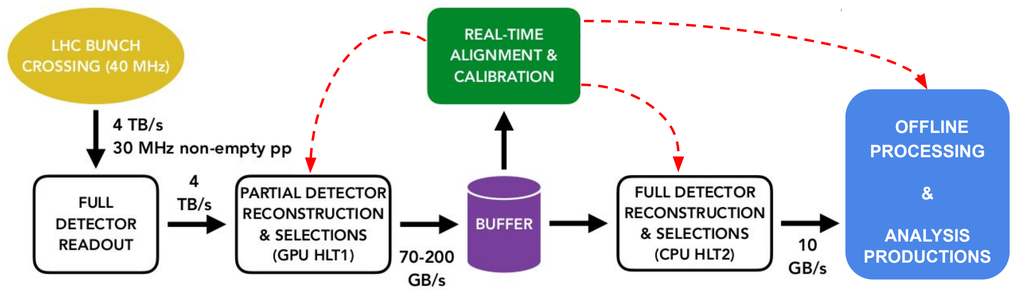
What is new for LHCb in Run 3?



[arXiv:2305.10515]

The LHCb detector has undergone a **big upgrade** for the new data-taking period:

- The **instantaneous luminosity is ~5 times larger** than in Run 2: $\mathscr{L} \sim 4 \times 10^{32}$ cm^{-2} s^{-1} → $\mathscr{L} \sim 2 \times 10^{33}$ cm^{-2} s^{-1}
- All components of the **LHCb tracker** (VELO, UT, and SciFi) are new
- The **read-out electronics and data acquisition system** have been upgraded to cope with the larger event rate
- New full-software **trigger system**

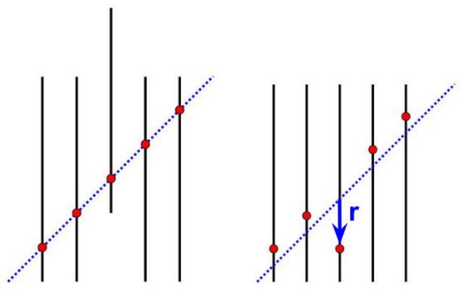


[LHCB-FIGURE-2020-016]

Real-time alignment and calibration play a critical role in the new Run 3 data flow. It is crucial to maximize the trigger efficiency and obtain good-quality data for offline analysis

Track-based alignment in short

Idea: use reconstructed tracks to extract information about the position of the detector and compute the necessary corrections



[CERN-THESIS-2022-105]

Transformations performed on the detector components are called **alignment constants**

The optimal values of the alignment constants are found by minimizing the **global track χ^2**

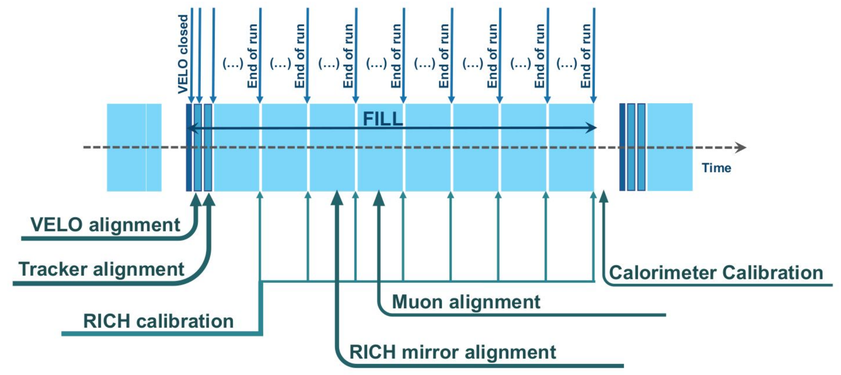
$$\chi^2 = \sum_i^{n_{\text{tracks}}} \chi_i^2(\mathbf{x}_i, \alpha)$$

$$\chi_i^2(\mathbf{x}_i, \alpha) = \mathbf{r}(\mathbf{x}_i, \alpha)^{\mathrm{T}} V^{-1} \mathbf{r}(\mathbf{x}_i, \alpha)$$

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

Real-time alignment and calibration

Alignment and calibration of different sub-detectors is performed at different stages during the LHC fill. **Alignment constants** are **automatically updated** if the change in their values exceeds a set of **thresholds** evaluated from precision studies performed before the data-taking period

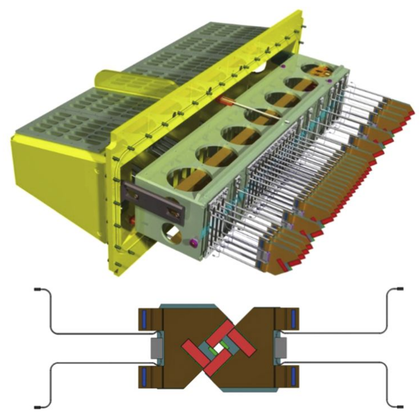


[arXiv:2305.10515]

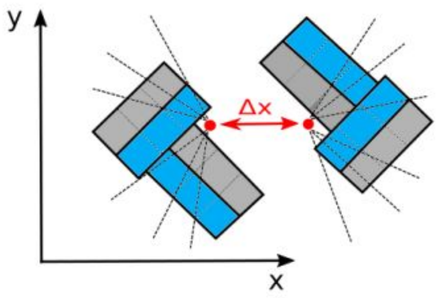
The **updated values** of the alignment and calibration constants are propagated in real time to **HLT1 and HLT2** and employed in the rest of the fill

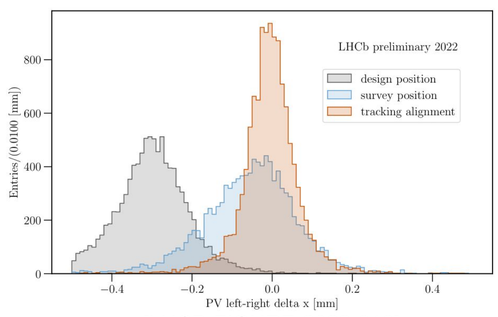
Alignment of the VELO

- The tracking alignment is not sensitive to the position of the **VELO global motion system**, it is evaluated offline from a material scan
- The position of **VELO modules and module sensors** is also evaluated offline during the commissioning period since they are not expected to move
- The **real time alignment** updates the constants corresponding to rotations and translations of the two VELO halves



[arXiv:2305.10515]



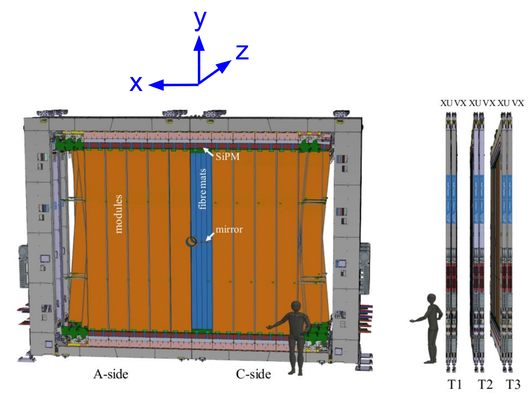


[LHCB-FIGURE-2022-016]

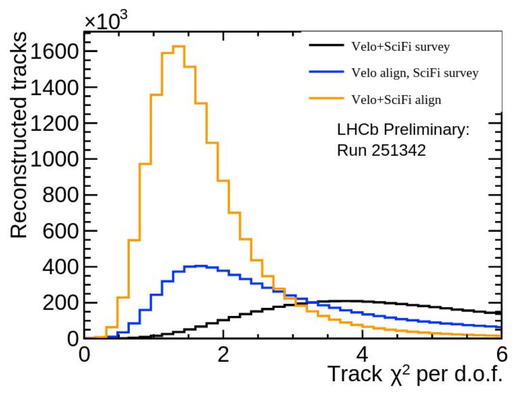
The alignment is **monitored in real-time**, studying the difference between the position of primary vertices reconstructed independently from each of the two VELO halves

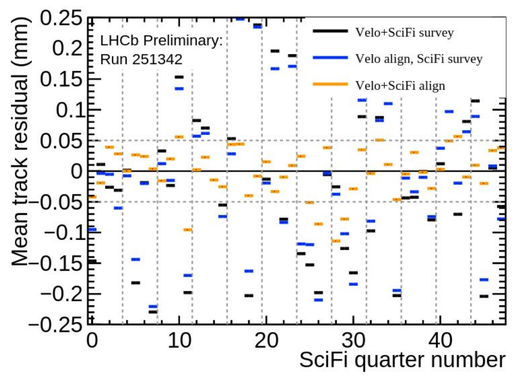
Alignment of the SciFi tracker

- **Degrees of freedom:** translations in x and rotations around z of SciFi modules and rotations around x of module halves
- Transformations at the level of **CFrames, layers, and fiber mats** are evaluated offline before the data-taking period
- The **real-time alignment** is run on a collected sample of tracks from $D^0 \to K\pi$ and $J/\psi \to \mu\mu$ candidates. **Mass and vertex constraints** are applied in the minimization to correct the momentum of tracks



[arXiv:2305.10515]

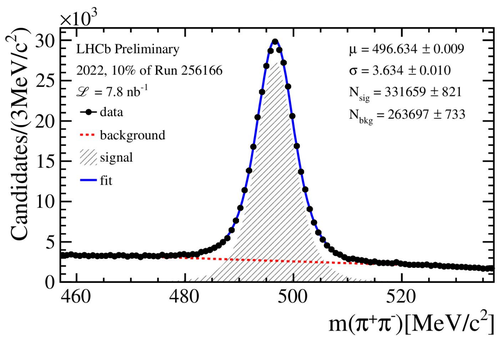




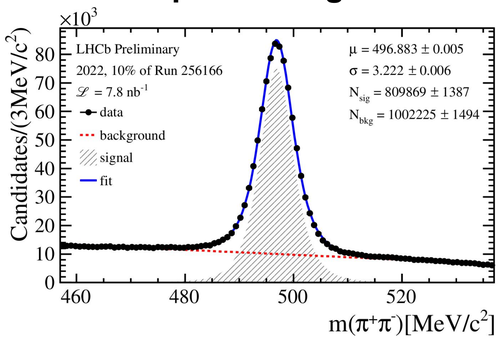
[LHCB-FIGURE-2022-018]

Impact on mass distributions

Early alignment

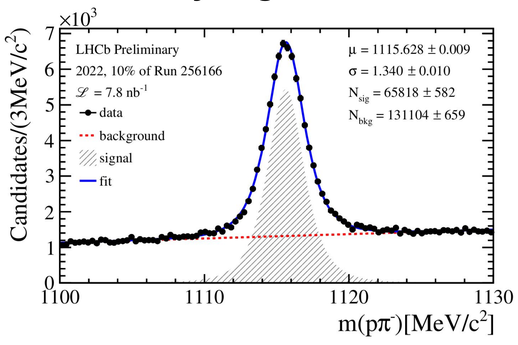


Improved alignment

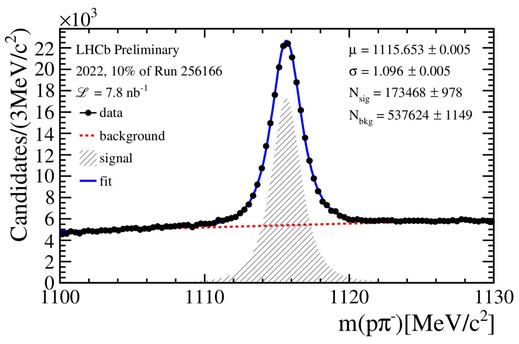


$K_s^0 \to \pi^+\pi^-$

Early alignment



Improved alignment



$\Lambda^0 \to p\pi^- / \bar{\Lambda}^0 \to \bar{p}\pi^+$

Early commissioning Run 3 results already show a **factor ~2.5 increase in the signal yield** of K_s^0 and Λ^0 reconstructed candidates with a clear improvement in the **mass resolution** between two preliminary alignment versions. The main difference between the two versions is the inclusion of the alignment constants to correct the position of the **SciFi mats**. Further improvements on momentum and mass resolution are expected when the UT is commissioned and included in the reconstruction sequence

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386