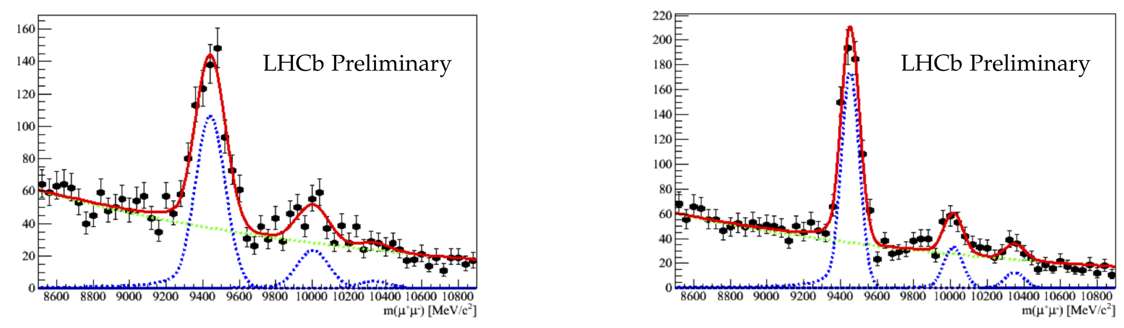
# Real-time alignment and calibration of the LHCb Detector in Run II


Giulio Dujany[1], Barbara Storaci[2] on behalf of the LHCb collaboration
[1] School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
[2] Physik-Institut, Universität Zürich, Zürich, Switzerland

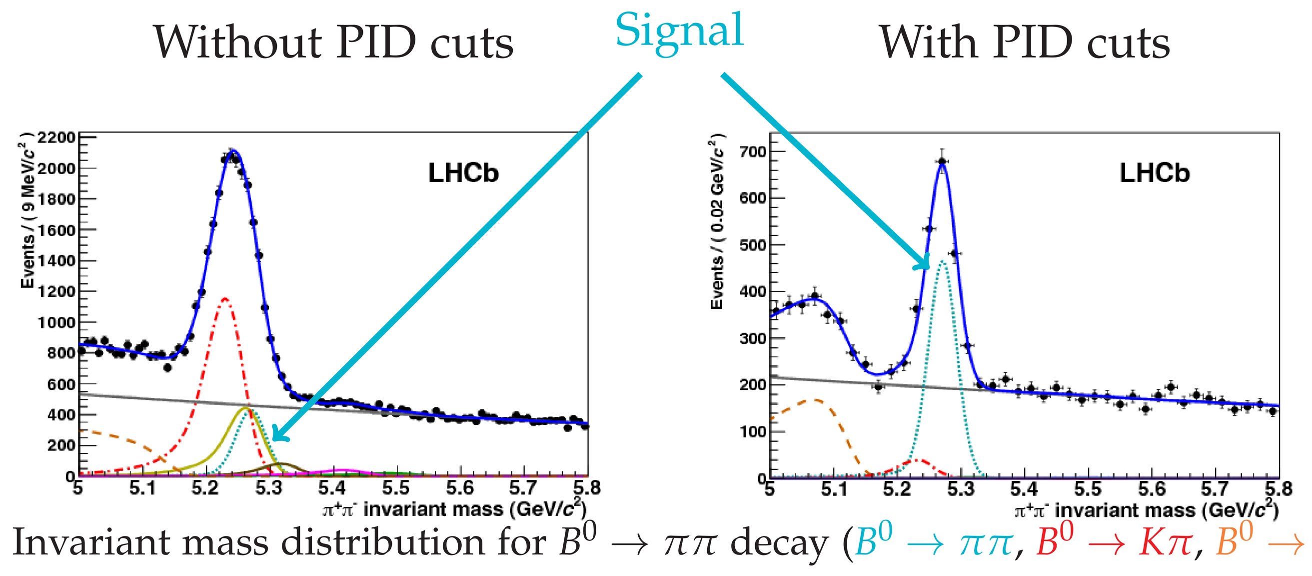

## Importance of alignment and calibration

- The spatial alignment of the detector and the accurate calibration of its subcomponents are essential elements to achieve the best physics performance, e.g. mass and impact paramenter resolution.
- The complete calibration of RICH detectors allows an exclusive selection using particle identification criteria.

First alignment $\sigma_\Upsilon = 92$ MeV/c$^2$ | Better alignment $\sigma_\Upsilon = 49$ MeV/c$^2$




Invariant mass distribution for $\Upsilon \to \mu\mu$ [5].




Invariant mass distribution for $B^0 \to \pi\pi$ decay ($B^0 \to \pi\pi$, $B^0 \to K\pi$, $B^0 \to$ 3-bodies, $B_s \to KK$, $B_s \to K\pi$, $\Lambda_b \to pK$, $\Lambda_b \to p\pi$) [1].

### Why Online?

- Minimize the difference between online and offline performance.
- More effective trigger selection.
- Stability of the alignment quality, hence physics performances.
- Some analysis performed directly on the trigger output.

## New procedure during Run II

### General strategy

- Automatic evaluation at regular intervals, eg. beginning of the run, fill, or less frequently depending on the task.
- Dedicated data sample to perform alignment or calibration collected with a specific trigger selection line for each task.
- Compute the new alignment or calibration constants in a few minutes.
- Update the constants only if needed.
- The same new alignment or calibration constants will be used both by the trigger and the offline reconstruction.

### Outer Tracker and RICH calibration

- Evaluation of the new parameters by fitting monitoring histograms.
- Evaluated as an online analysis task on a single CPU.

### Tracking alignment and RICH mirror alignment

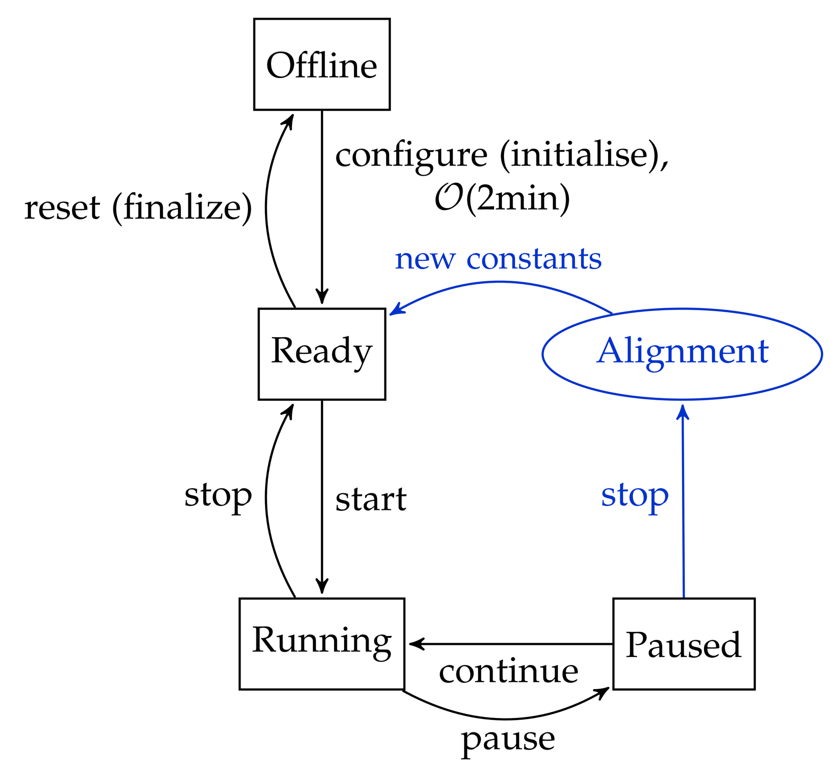
- Based on an iterative procedure: a fit to the residuals distributions, for the RICH mirror alignment, or a procedure based on the Kalman track fit residuals, for the tracking detectors.

Reconstruct the tracks using the current alignment constants. ⇄ Compute a new set of alignment constants minimizing a global $\chi^2$.

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

- Two kinds of alignment tasks defined:
  - Analyser: perform the track reconstruction based on the alignment constants computed by the iterator. Many instances run in parallel on $\sim$ 1700 nodes of the HLT farm.
  - Iterator: collects the output of the analysers and minimizes the $\chi^2$ computing the alignment constants for the next iteration. It runs on a single node.

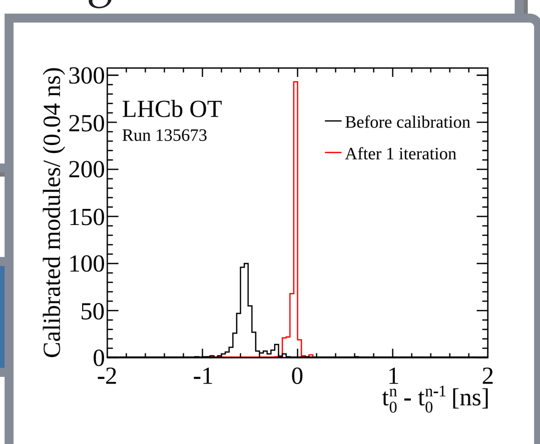
Finite State Machine:




## Key elements

### Global time alignment of the Outer Tracker (OT)

- Time calibration evaluated by the distance of the track to the wire.
- A single condition which accounts for the global time alignment.
- Executed for each run.
- Updated every few weeks.




### Tracking alignment

- Procedure based on the Kalman track fit residuals.
- Mass and vertex constraints used to minimize shearing effects.

**Vertex Locator (VELO)**

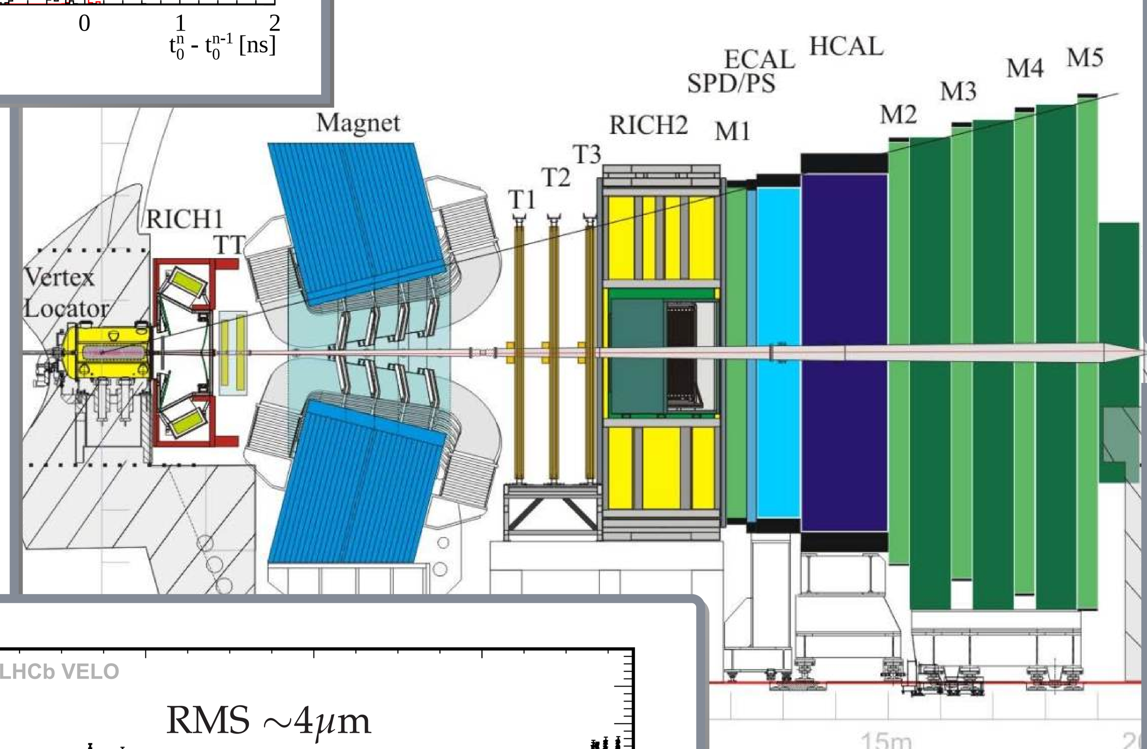
- Retracted by 29 mm for each fill.
- Alignment evaluated at the beginning of each fill $\mathcal{O}(1$ min).
- Update immediately if needed.
- Update expected often but not for each fill.

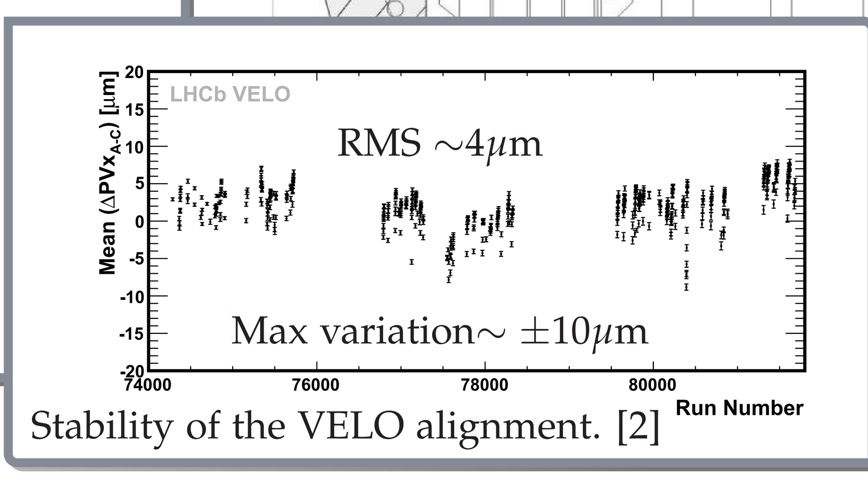
**Tracker (TT, IT, OT)**

- Run after the VELO for each fill.
- Update expected every few weeks.

**Muon stations**

- Run for each fill.
- Variation not expected but used as monitoring.




Stability of the VELO alignment. [2]

### RICH calibration

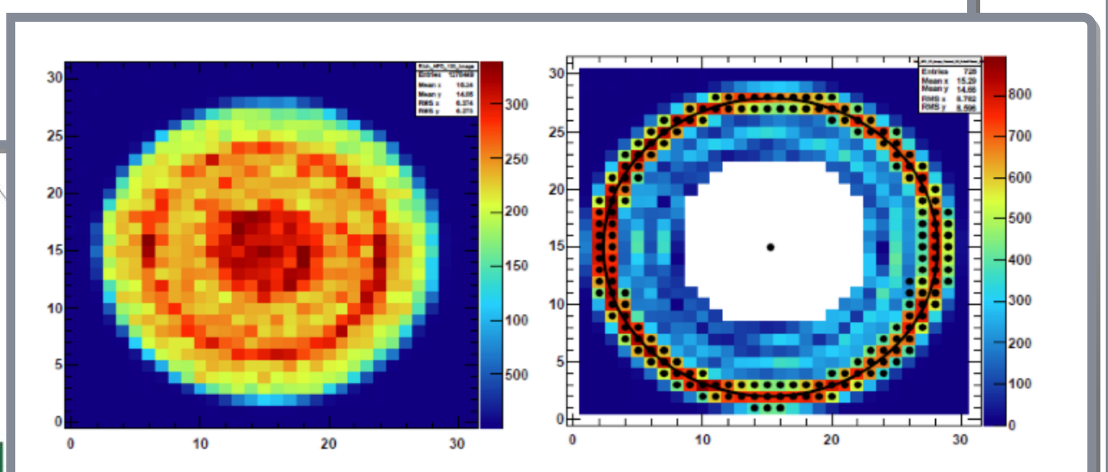
Evaluated and updated every run

**Refractive index**

- The refractive index depends on the gas mixture, temperature and pressure.
- Calibrated by fitting expected Cherenkov angles.

**HPD image**

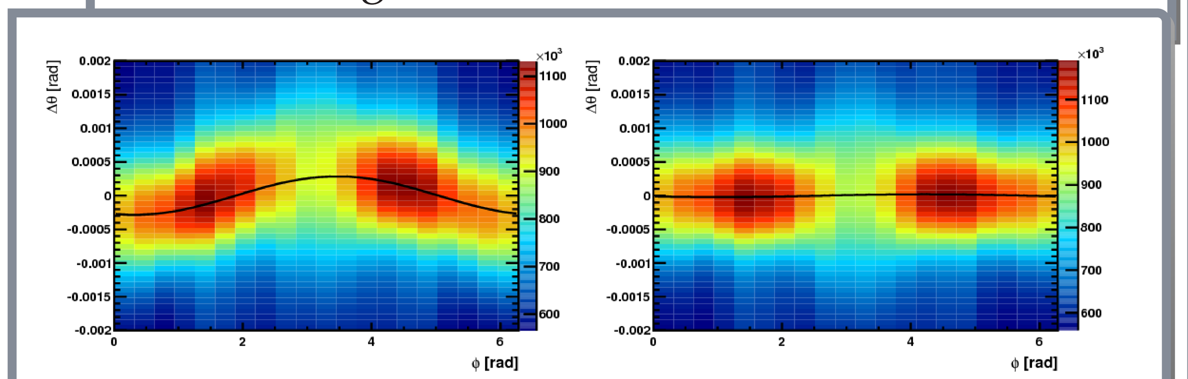
- Affected by magnetic/electric fields.
- Anode images cleaned, Sobel filter used to detect edge.



Anode images, before and after cleaning and Sobel filter.

### RICH mirror alignment

- Fit the variation of the Cherenkov angle as a function of the mirrors' alignment constants.
- Run for each fill.
- Variation not expected but used as monitoring.



Cherenkov angle residuals VS the azimuthal angle before (left) and after (right) the mirror alignment [4].

## Bibliography


[1] R. Aaij et al., J. High Energy Phys. 10, 037 (2012).
[2] R. Aaij et al., JINST 9, 09007 (2014).
[3] R. Aaij et al., Int. J. Mod. Phys. A30, 1530022 (2015)
[4] M. Adinolfi et al., Eur.Phys.J. C73, 2431 (2013).
[5] J. Amoraal et al., Nucl. Instrum. Meth. A712, 48 (2013).
[6] W. Hulsbergen, Nucl.Instrum.Meth. A600, 471 (2009).