Novel Real-time Calibration and Alignment Procedure for LHCb Run II

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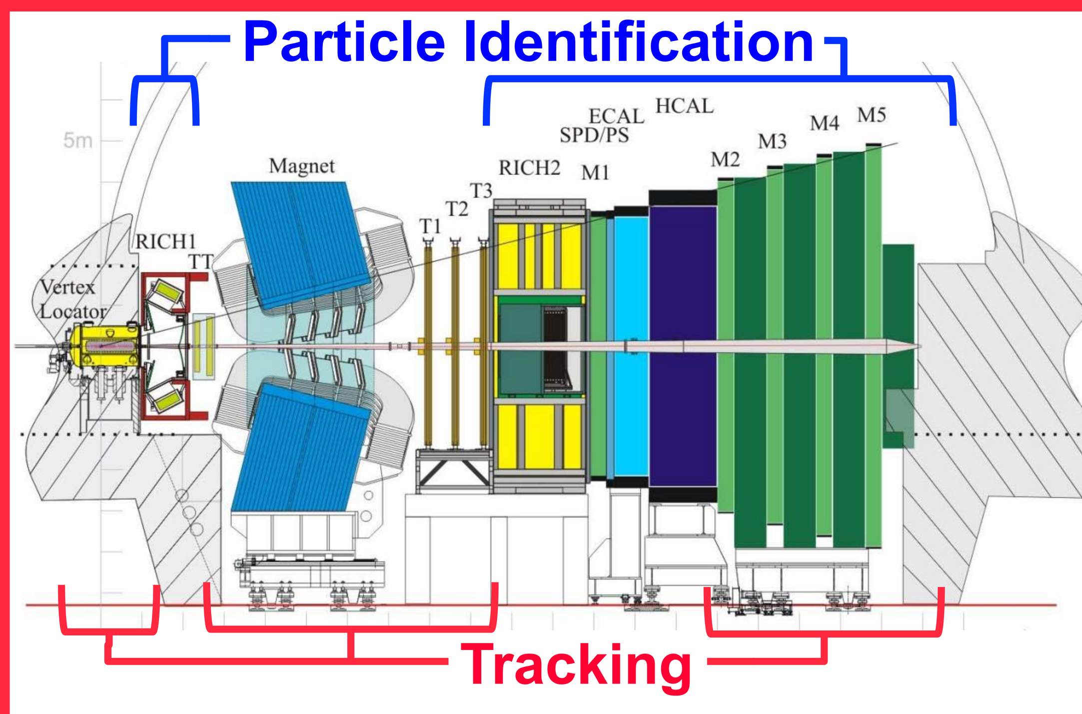
New challenges in Run II

- Increase in energy: $\sqrt{s}$ = 7(8) TeV ⇒ 13 TeV
- 15% increase of inelastic collision rate
- 20% increase of multiplicity per collision
- 60% increase of $\sigma_{b\bar{b}}$ and $\sigma_{c\bar{c}}$
- Reduced bunch spacing: 50 ns ⇒ 25 ns

Real Time Alignment and Calibration

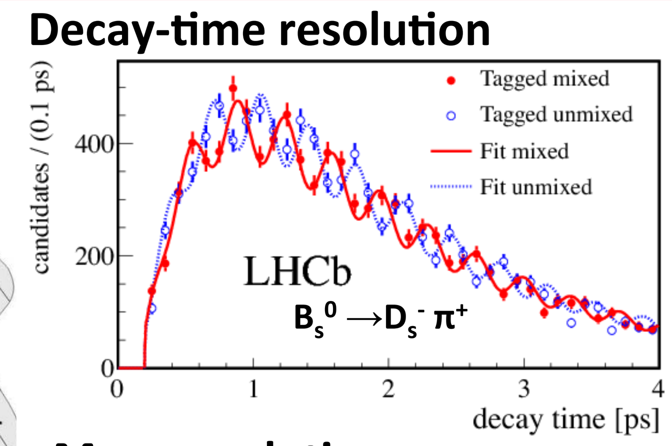
- Stable quality of alignment and calibration
- Particle identification useable in the high level trigger (HLT)
- Overall improved trigger efficiency
- No more differences between online and offline
- Physics analysis directly on trigger output (Turbo Stream)

Performance of LHCb Detector

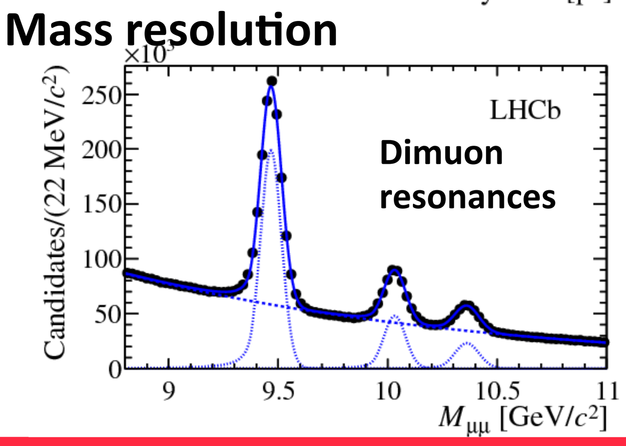


LHCb Detector Performance
Int. J. Mod. Phys. A30 (2015) 1530022
New J. Phys. 15 (2013) 053021

Decay-time resolution

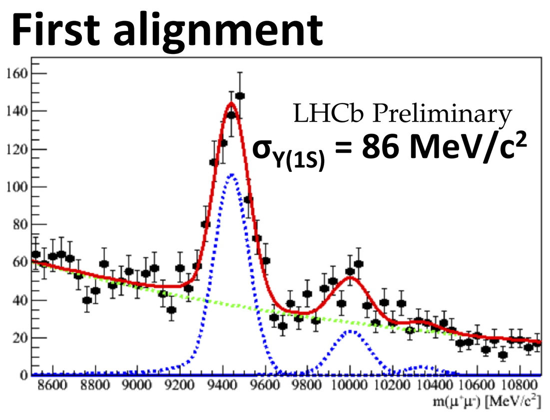


Mass resolution

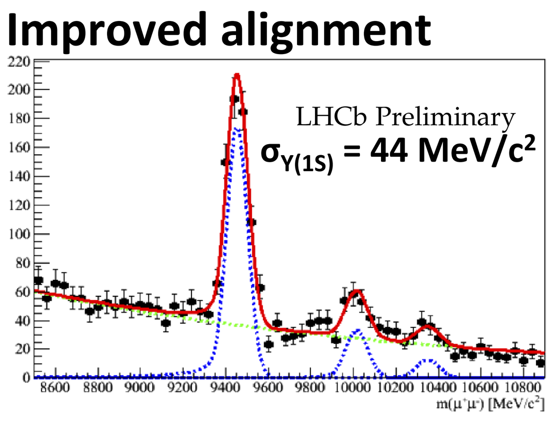


Impact on Physics

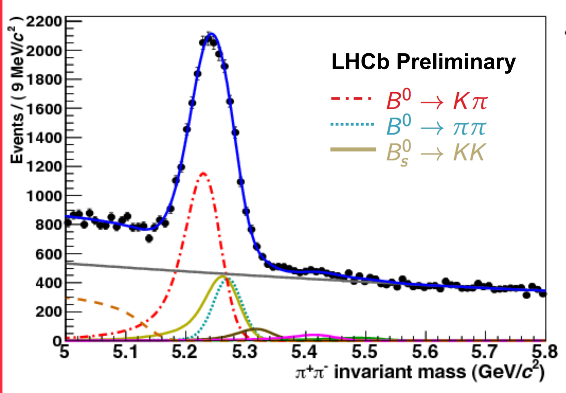
First alignment



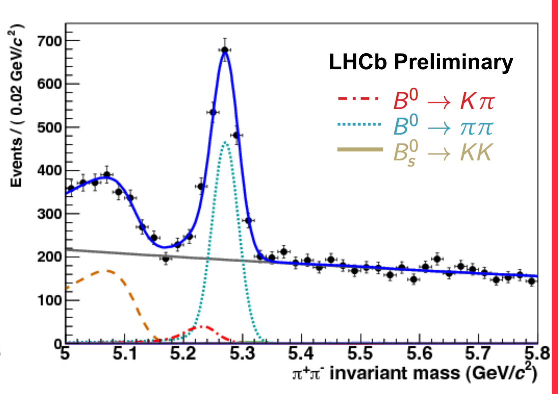
Improved alignment



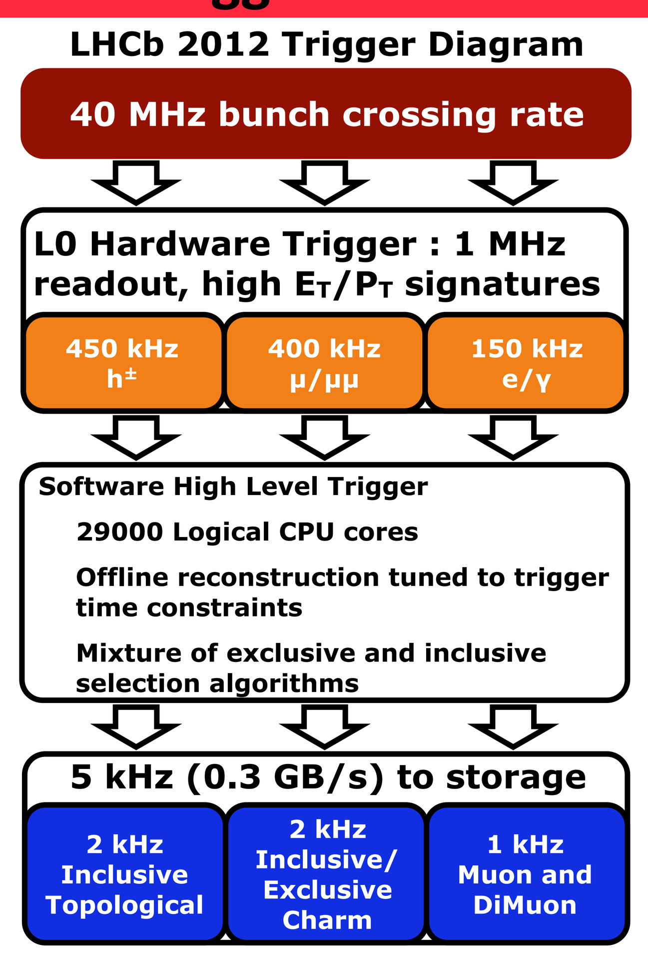
Without PID

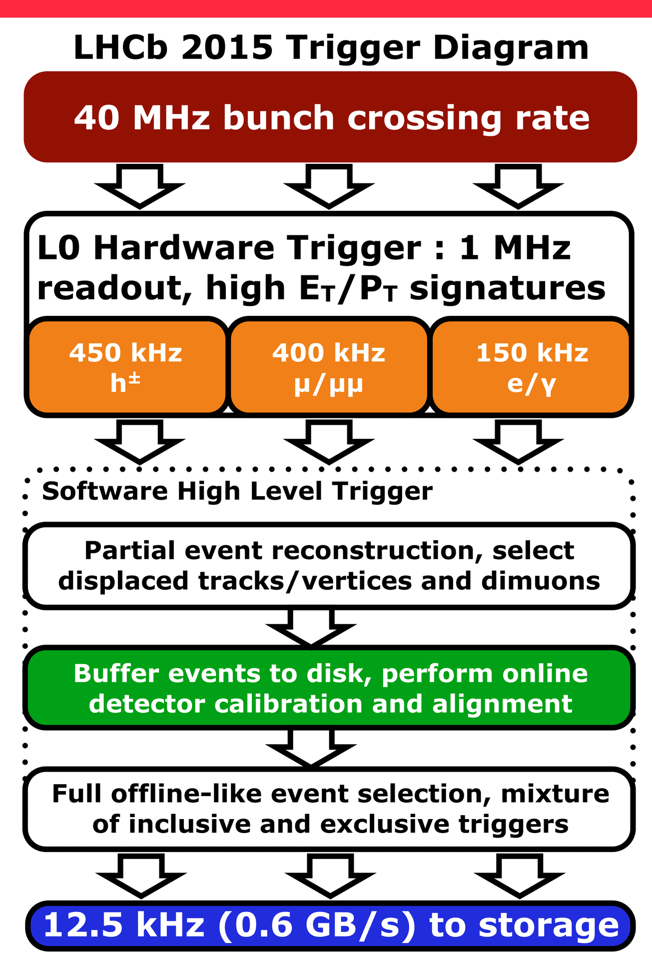


With PID



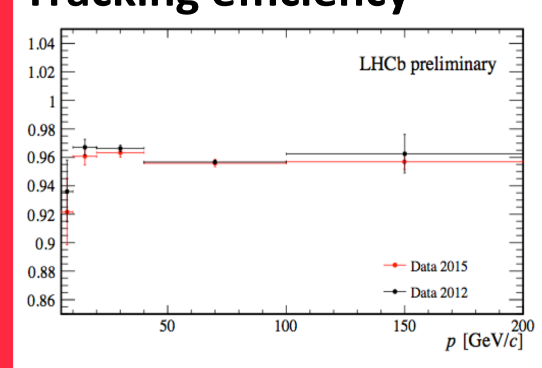
LHCb Trigger Schemes



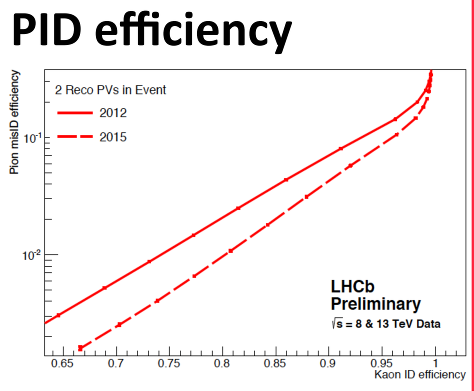


Performance in Run II

Tracking efficiency

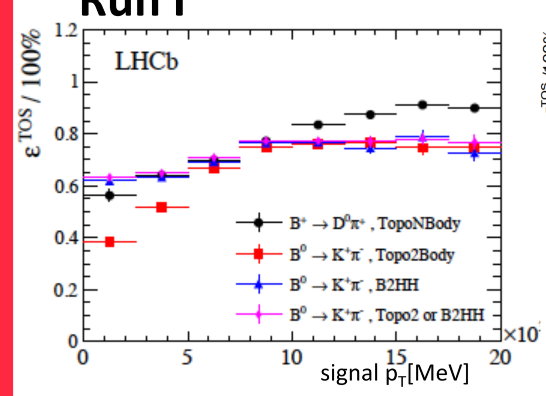


PID efficiency

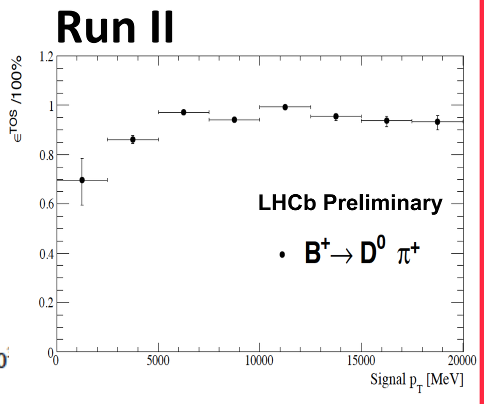


Trigger efficiency:

Run I



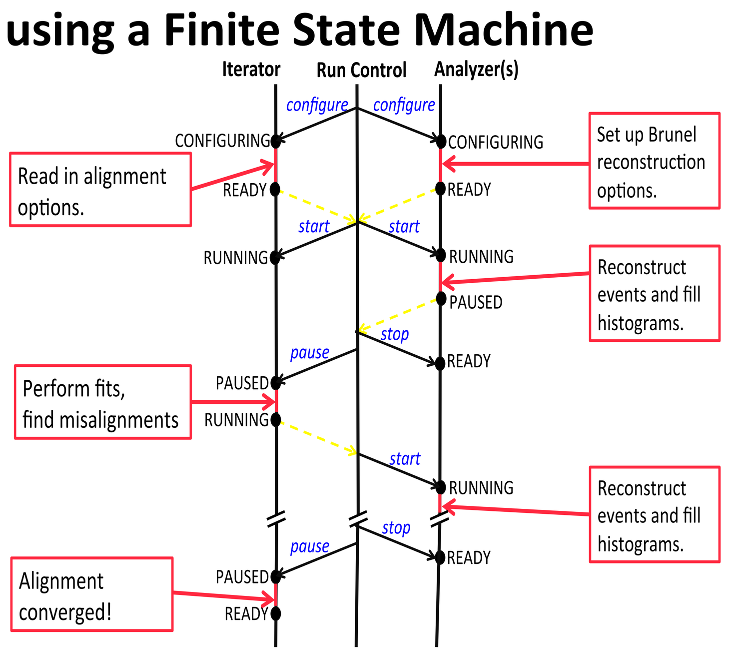
Run II



Dedicated Framework and Procedure

- Alignments performed for each fill
- Dedicated trigger line for each task
- Event reconstruction parallelised on *analysers* (1700 nodes), computing of alignment constants by *iterator* (1 node)
- Calibrations on monitoring histograms
- VELO, Tracker & calibrations: automatic update of the constants if they differ by a given value
- RICH alignment & Muon alignment: monitoring mode

Example of alignment sequence using a Finite State Machine



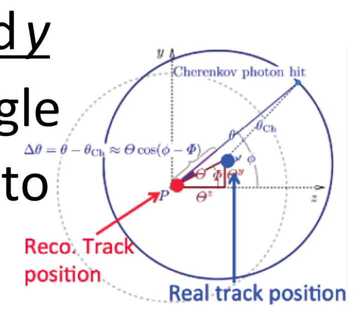
RICH Mirror Alignment

<u>Orientation of the RICH mirrors in *x* and *y*</u>

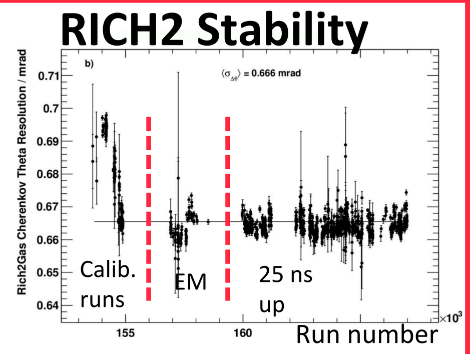
- Fit the variation of the Cherenkov angle Δθ as a function of the polar angle φ to extract the misalignments on the detector plane (Θ_x, Θ_y)

$$\Delta\theta = \Theta_x \sin\varphi + \Theta_y \cos\varphi$$

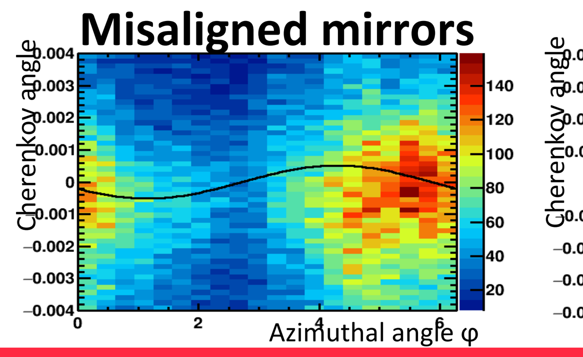
- Updated $\mathcal{O}(10)$ times a year
- ~30 minutes per task



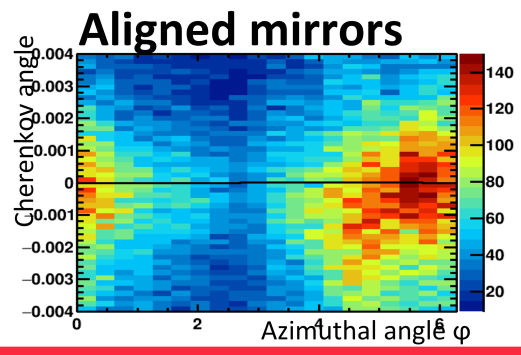
RICH2 Stability



Misaligned mirrors



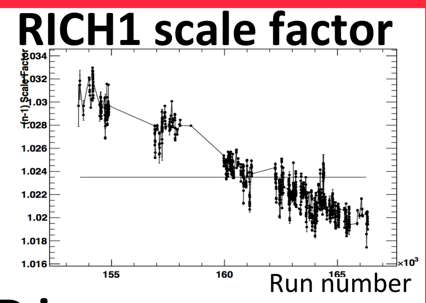
Aligned mirrors



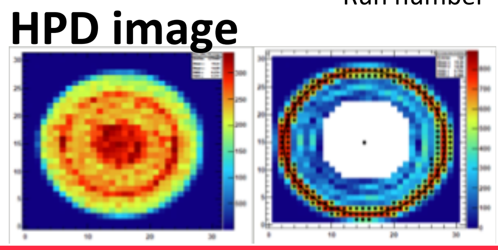
RICH Calibration

- <u>Refractive index calibration:</u> Fit to the reconstructed-expected Cherenkov angle yields scale factor for the refractive index
- <u>HPD image calibration:</u> Sobel filter applied to each HPD and used to provide calibration
- Updated every run

RICH1 scale factor



HPD image



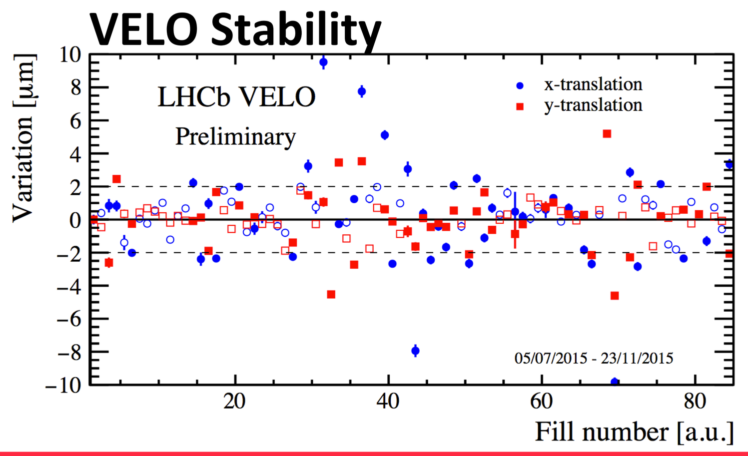
Tracker Alignment: VELO, Tracker, Muon System

<u>Position and orientation of the full tracking system</u> (700 elements)

Minimisation of residual of Kalman track fit using additional constraints

- Independent alignments:
  - VELO: updated every $\mathcal{O}(1)$ fills
  - Tracker: updated every $\mathcal{O}(1)$ weeks
  - Muon: updated $\mathcal{O}(1)$ per year
  - ~7 minutes per task

VELO Stability



Calorimeter Calibration

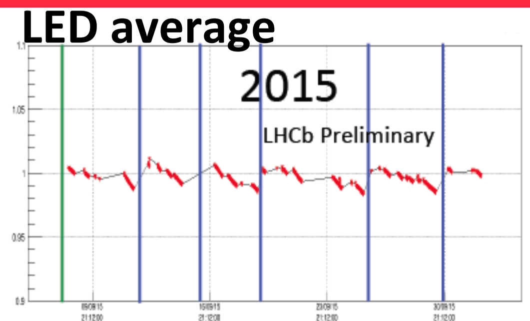
<u>Relative calibration for each cell</u>

- Occupancy method and LED monitoring system: adjustment of high voltage settings to compensate for the aging of the detector
- Updated per fill

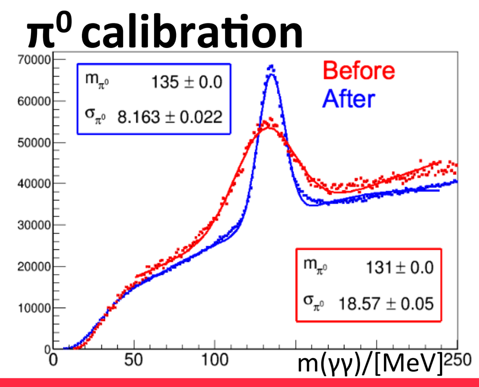
<u>Calibrate to the neutral π mass</u>

- Fit the π^0 mass distribution for each cell for $\pi^0 \to \gamma\gamma$
- Run on the HLT-farm during TS

LED average



π^0 calibration



Outer Tracker Calibration

<u>Global time alignment for all modules</u>

- Fit the residual of the drift time to extract the global time delay t_0 caused by readout electronics $t_{meas} = t_0 + t_{flight} + t_{drift} + t_{prop}$
- Updated every $\mathcal{O}(10)$ runs

OT Stability