Novel real-time calibration and alignment procedure for LHCb Run II

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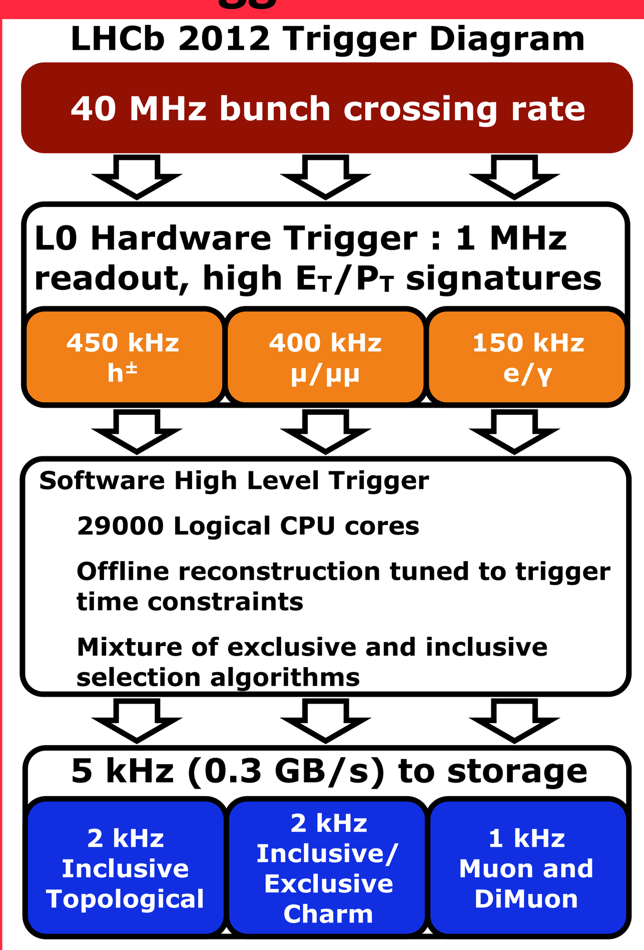
New challenges in Run II

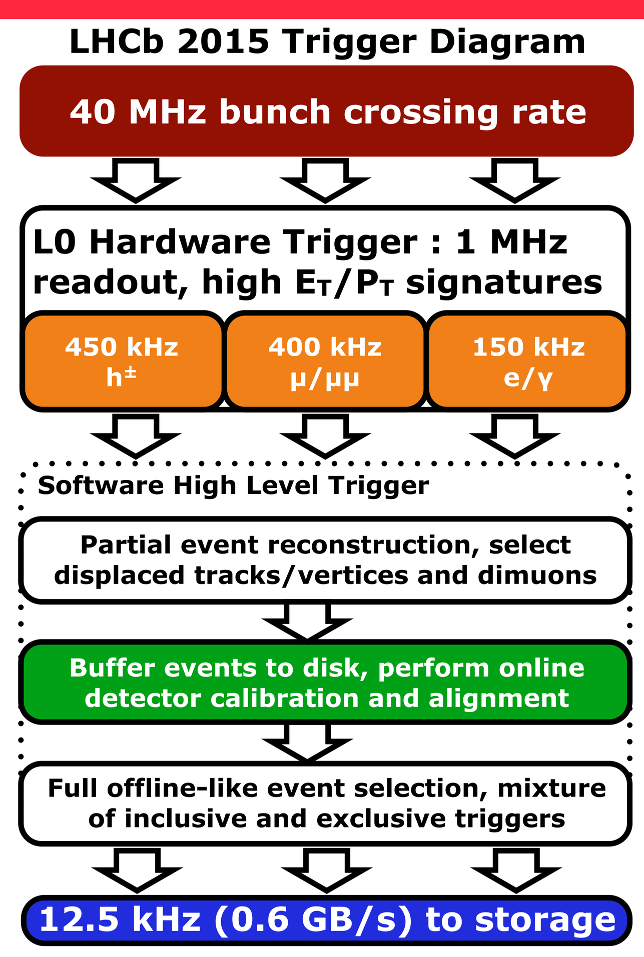
- Increase in energy: $\sqrt{s}$ = 7(8) TeV ⇒ 13 TeV
- 15% increase of inelastic collision rate
- 20% increase of multiplicity per collision
- 60% increase of $\sigma_{b\bar{b}}$ and $\sigma_{c\bar{c}}$
- Reduced bunch spacing: 50 ns ⇒ 25 ns

Real Time Alignment and Calibration

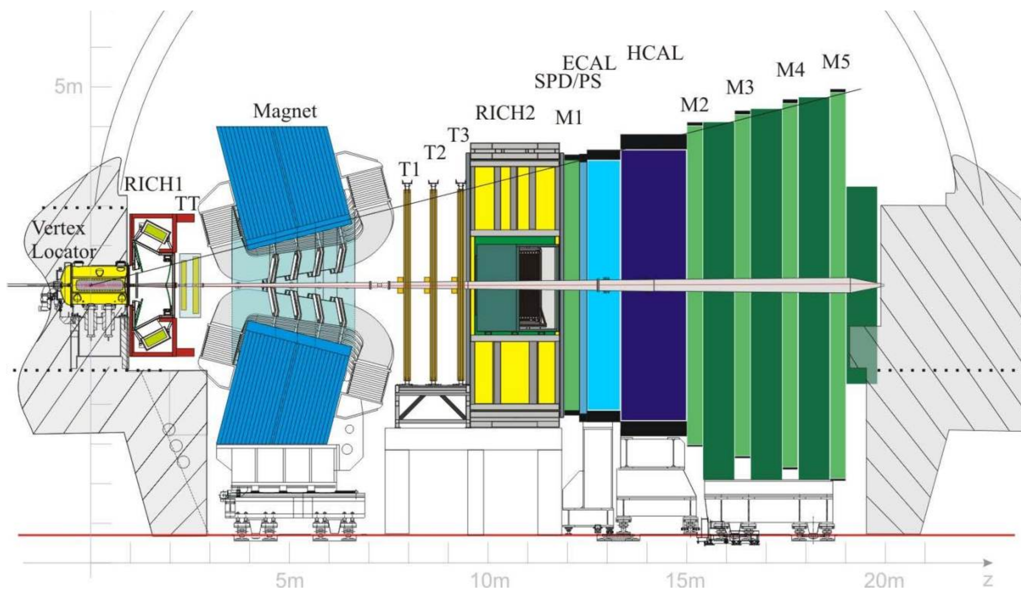
- Particle identification useable in HLT2
- Overall improved HLT2 efficiency
- Stable quality of alignment
- No more differences between online and offline

LHCb Trigger Schemes



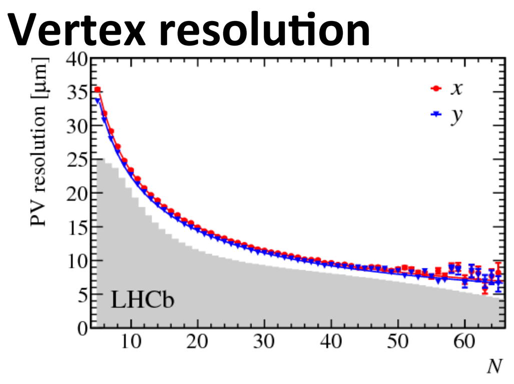


The LHCb Detector

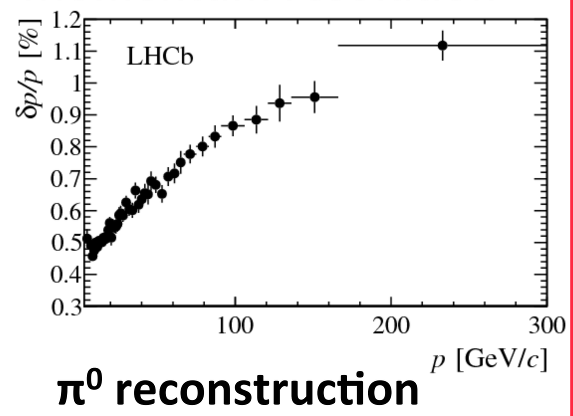


2.4 · 10^{12} B hadrons in LHCb detector acceptance in 2011 + 2012

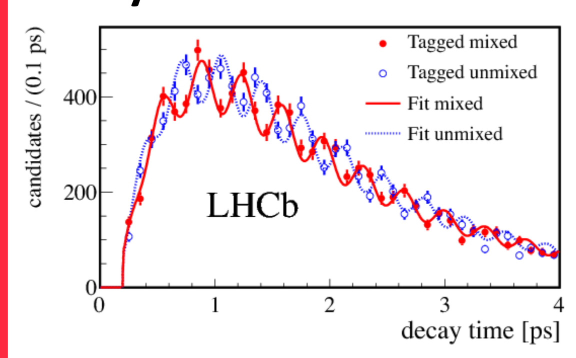
Vertex resolution



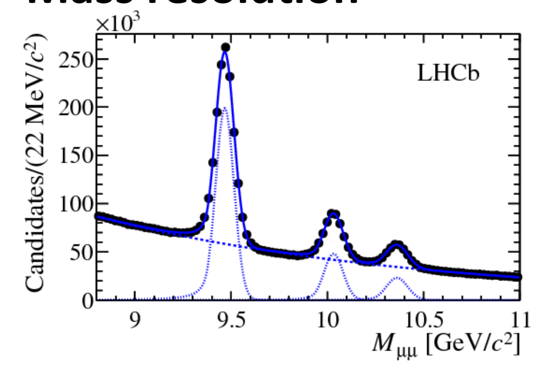
Momentum resolution



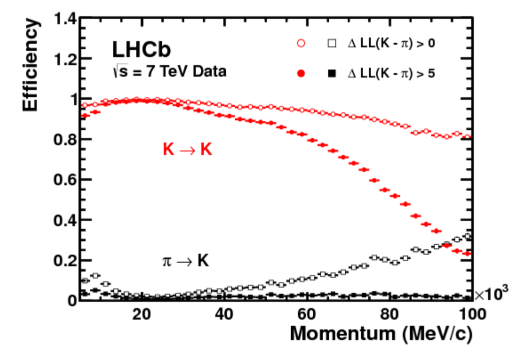
Decay-time resolution



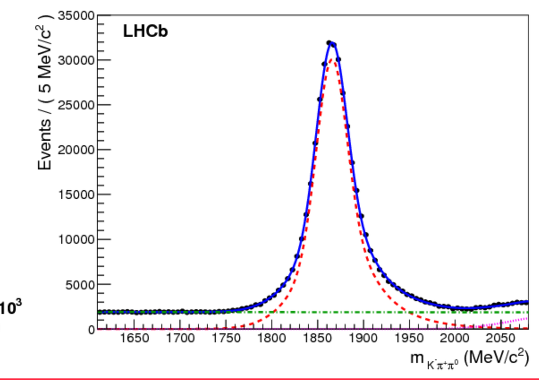
Mass resolution



PID efficiency

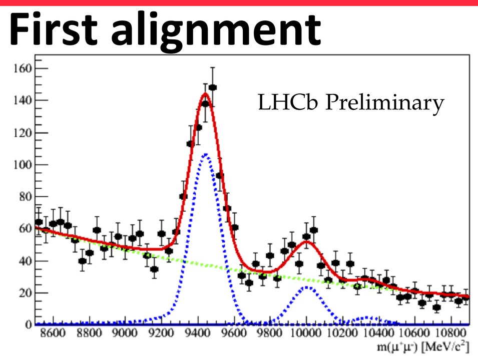


π^0 reconstruction

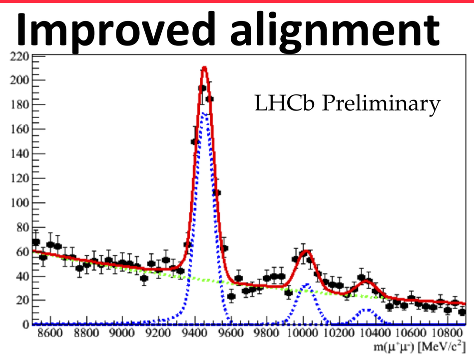


Performance and Impact on Physics

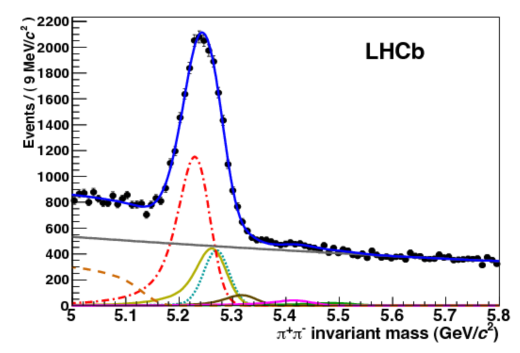
First alignment

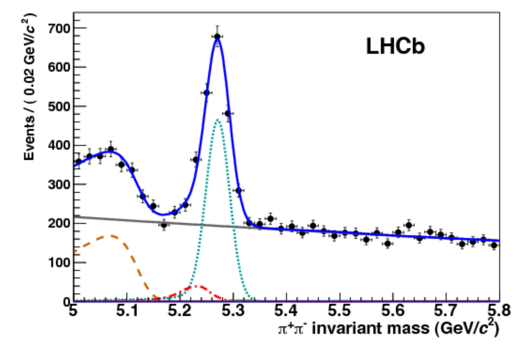


Improved alignment



Task	Used by
Velo alignment	HLT1, HLT2 and offline
tracker alignment	HLT1, HLT2 and offline
muon alignment	L0 Muon and monitoring
ECAL calibration	update of ECAL high voltages
RICH mirror alignment	HLT2 and offline
RICH calibrations	HLT2 and offline
OT calibration	HLT1, HLT2 and offline

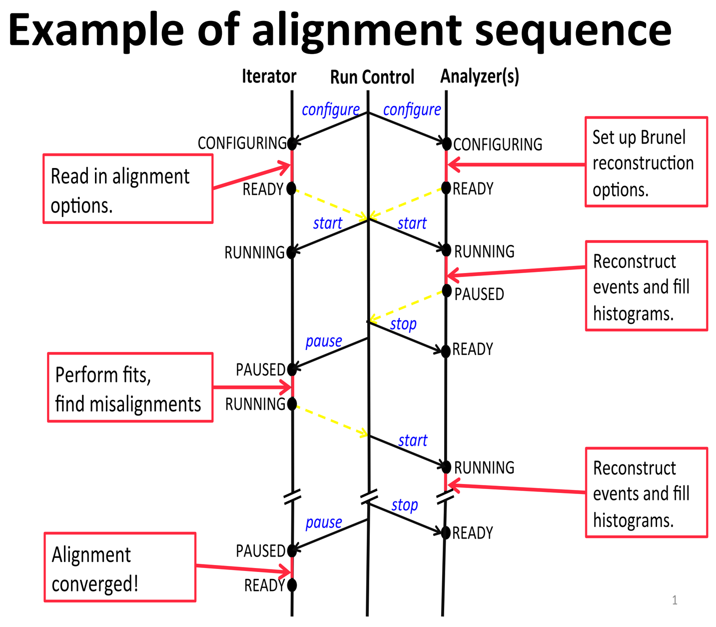




Alignment Farm and Framework

- Alignments performed for each fill
- HLT farm with 1700 nodes
- HLT1 line for each task
- Event reconstruction parallelised
- 1 iterator + 1700 analysers
- Steered by the run control using a Finite State Machine
- VELO, Tracker + Calibrations: automatic update of the constants if they differ by a given value
- RICH alignment + Muon System: monitoring mode

Example of alignment sequence

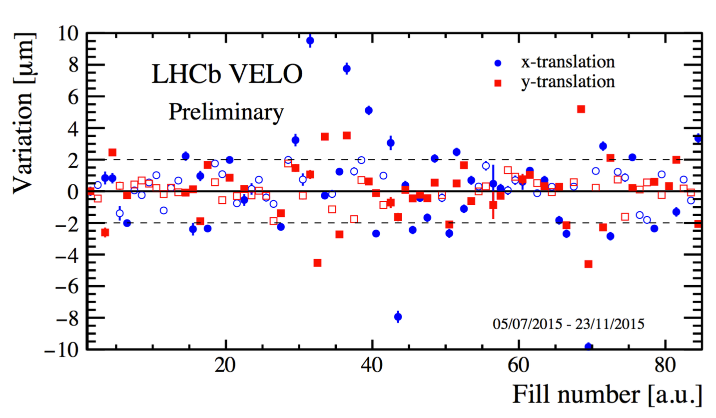


Tracker Alignment: VELO, Tracker, Muon System

Position of the tracking elements in x and y

- Minimisation of residual of Kalman track fit using additional constraints (e.g. magnetic field, particle masses)

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



- Independent alignments:
  - VELO & Tracker: every $\mathcal{O}(1)$ fills
  - Tracker: every $\mathcal{O}(1)$ weeks
  - Muon system: XXX

Outer Tracker Calibration

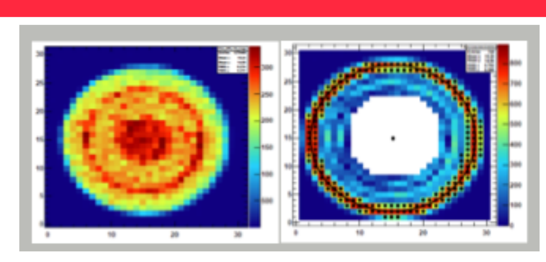
Global time alignment for all modules

- Fit the residual of the drift time to extract the global time delay t_0 caused by readout electronics

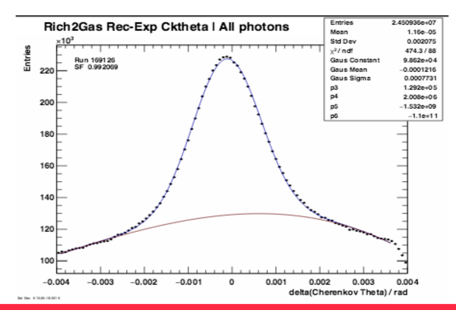
$$t_{meas} = t_0 + t_{flight} + t_{drift} + t_{prop}$$

- Update triggered every $\mathcal{O}(10)$ runs

RICH Calibration



- HPD image calibration: Sobel fit performed for each HPD and used to provide calibration for each anode element.



- Refractive index calibration: Fit to the reconstructed-expected Cherenkov angle yields (n-1) scale factor.
- Updated every run.

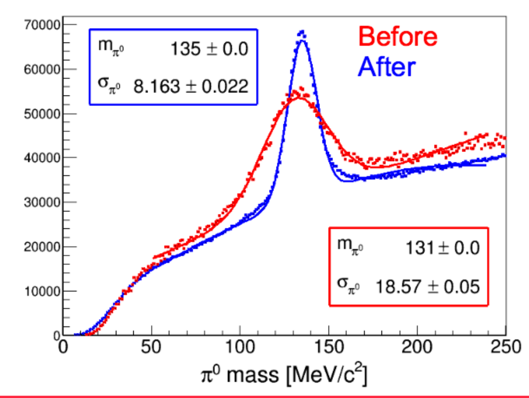
Calorimeter Calibration

Occupancy calibration for each cell

- Scale the High Voltage by factor α to keep the gain stable by evaluating the variation of the occupancy $O = \frac{\sum^{ADC>thresh.} N_{events}}{\sum N_{events}}$
- Updated per fill

Calibrate to the neutral π mass

- Fit the π^0 mass distribution for each cell for $\pi^0 \to \gamma\gamma$, one γ has its seed in the cell and use the offset to the nominal π^0 mass as calibration
- Run on the HLT-farm during TS

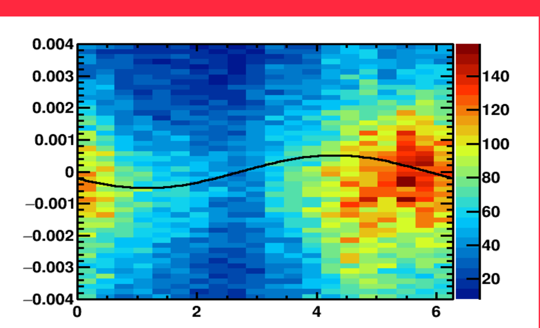


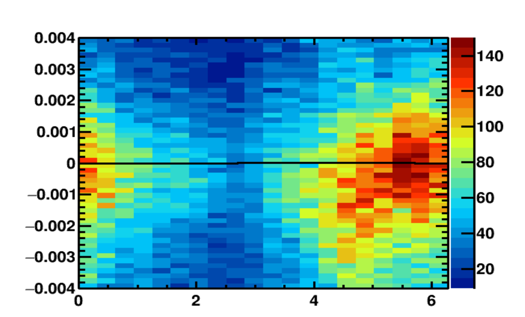
RICH Mirror Alignment

Orientation of the RICH mirrors in x and y

- 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):

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





- Monitoring mode, update $\mathcal{O}(10)$ times a year