Novel Real-Time Calibration and Alignment at LHCb for Run II

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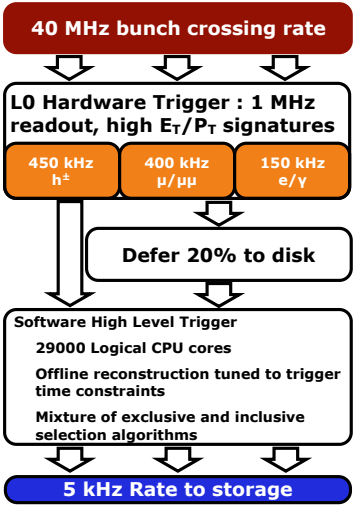
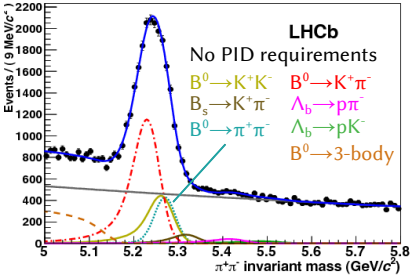
Run I Trigger Overview

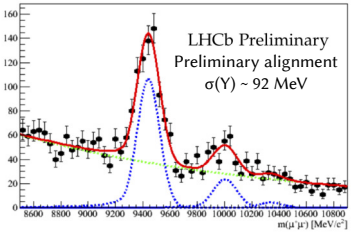
- LHCb detector read out at 1 MHz
- Hardware trigger (L0)
  - Based on multiplicity, calorimeters and muon detectors
  - Fixed latency of 4 μs
  - Reduces rate to 1 MHz
- Software trigger (HLT)
  - Runs on HLT farm
  - Split in two stages: HLT1 and HLT2
  - 20% of events buffered to allow processing out of fill
  - Output rate 5 kHz
  - Total time budget O(35) ms/event

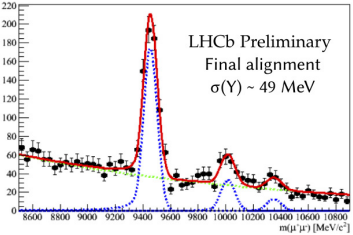


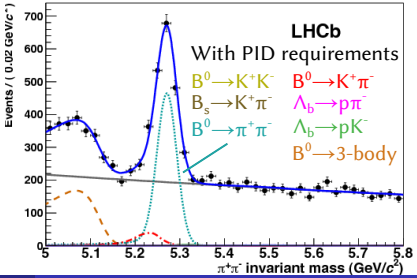
Improvements for Run II

- More effectively use disk buffers
- Make best quality PID and alignment available to HLT



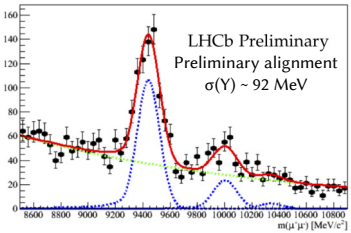


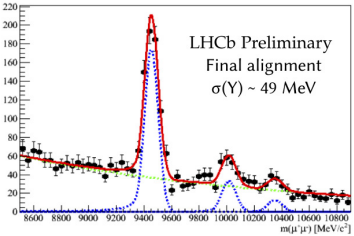


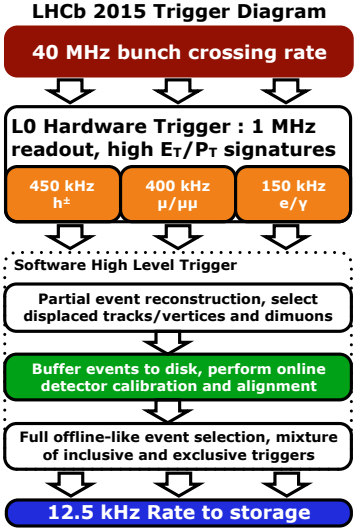


Improvements for Run II

- More effectively use disk buffers
- Make best quality PID and alignment available to HLT
- Put best-quality reconstruction in HLT2
- Need best-quality alignment and calibration
- Need data → use events accepted by HLT1

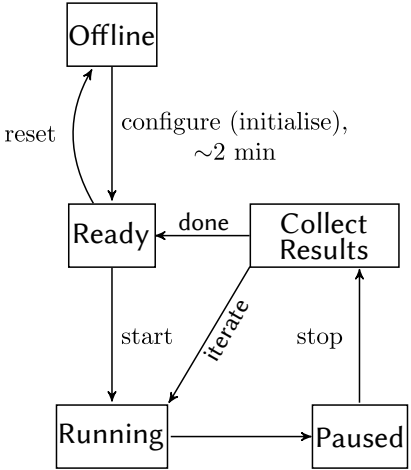






Alignment Controls

- A master process steers the iterations
- O(1800) worker processes
- Once a sufficient number of suitable events has been collected, an alignment starts
- An initial set of constants is calculated
- Workers process their events with the given constants and make their results available
- Individual results are combined
- A new set of constants is calculated
- Iterate until converged, O(5) min.



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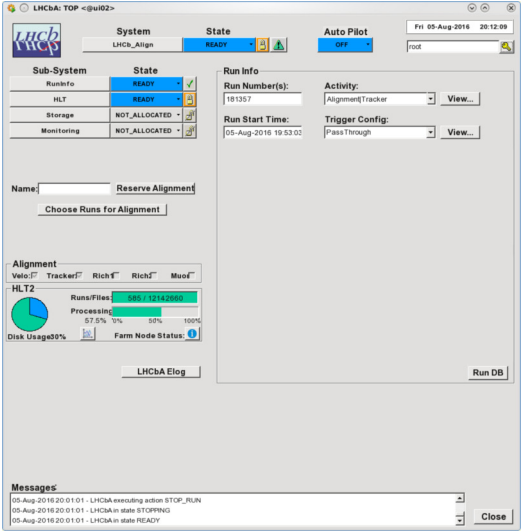
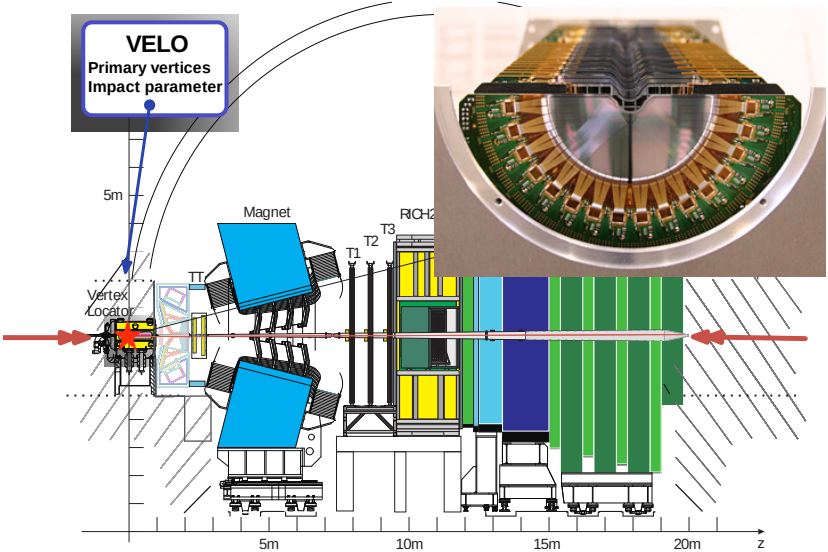


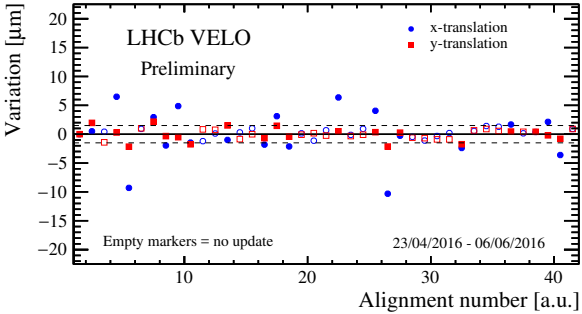
LHCb Vertex Locator

2008 JINST 3 S08005



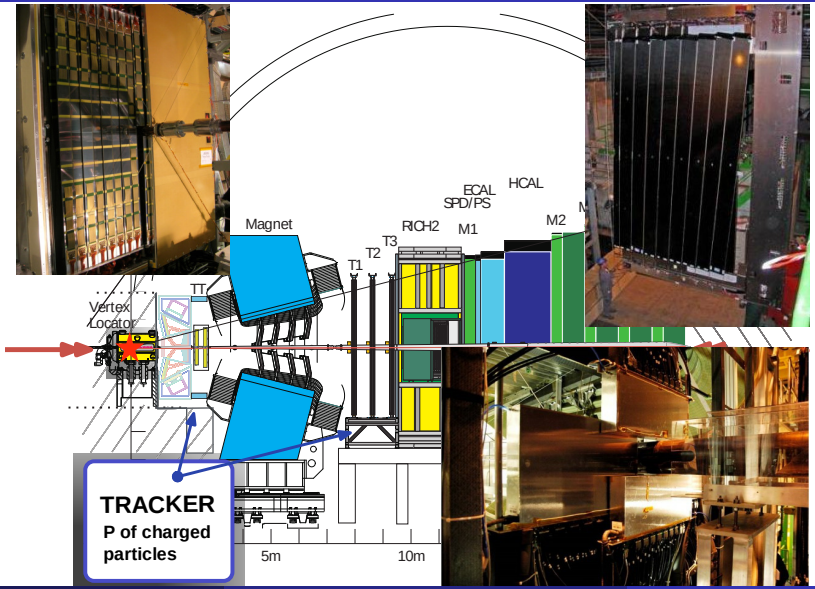
Velo Alignment

- Once stable beams are declared, the LHCb Vertex Locator detector moves 30 mm closer to the beams.
- The Velo halves are aligned shortly (10 min) afterwards.
- An improved alignment is put in production automatically.
- Plots are produced for the shifters to check.
- Further alignment of all Velo sensors is checked regularly and updated if needed.



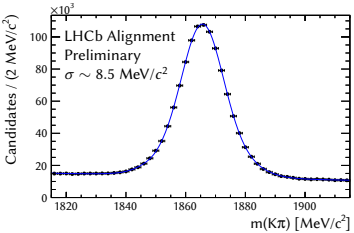
LHCb Tracker

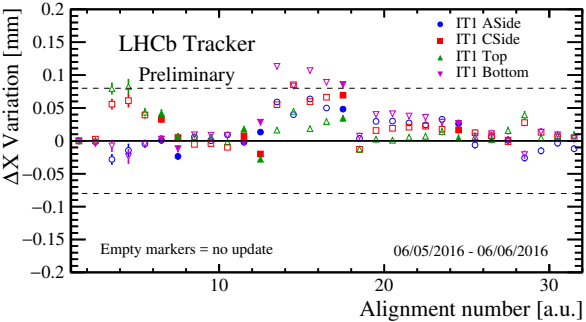
2008 JINST 3 S08005



Tracker Alignment

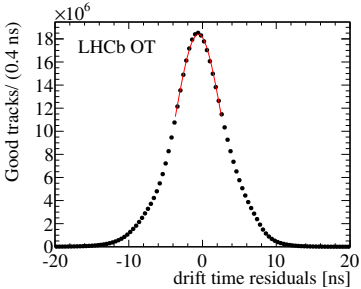
- Once the Velo alignment has completed, the tracker alignment is performed automatically
- A sample of tracks from 100 k $D^0 \to K^-\pi^+$ decays selected by HLT1 is used.
- An improved alignment is put in production automatically.
- Plots are produced for the shifters to check.

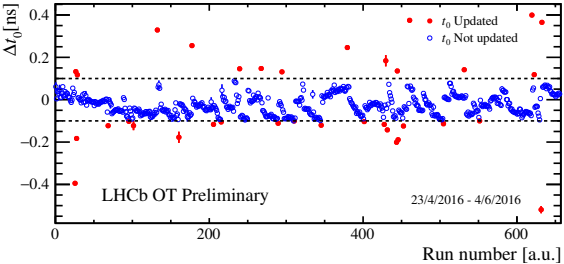




Outer Tracker Calibration

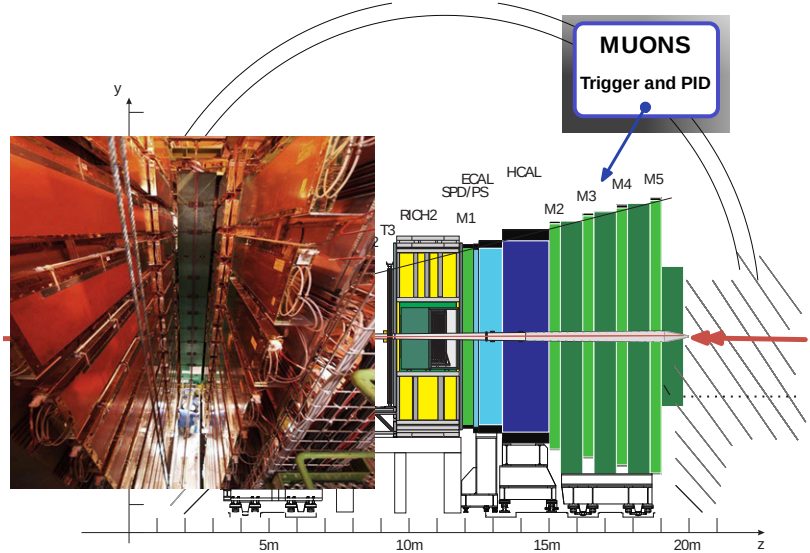
- The LHCb Outer Tracker consists of 55 k, 4.9 mm diameter, gas-filled straws.
- Measured time consists of
  - Particle time-of-flight
  - Drift-time
  - Signal propagation time
  - $t_{off} = t_0 + t_{FE}$
- The global offset with respect to the LHC clock, t_0, varies during the year and is calibrated run by run.
- The per front-end offsets are calibrated a few times per year.





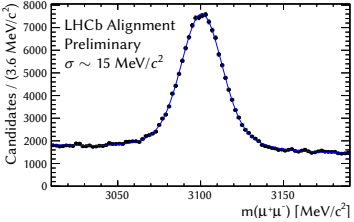
LHCb Muon Detector

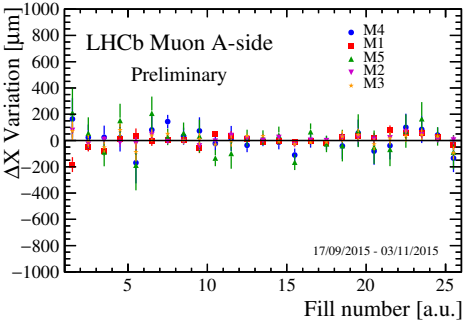
2008 JINST 3 S08005



Muon Alignment

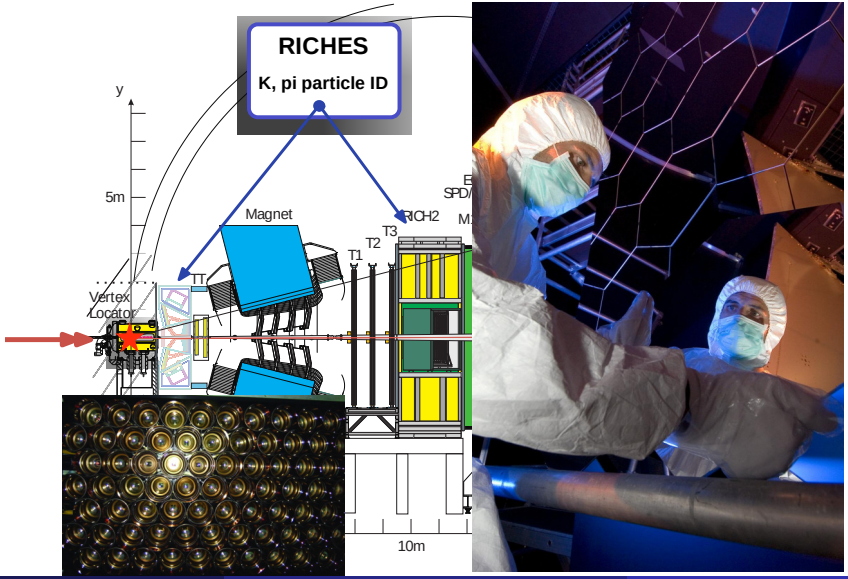
- The muon station alignment runs after completion of the tracker alignment.
- A sample of tracks from 250 k events containing $J/\psi \to \mu^+\mu^-$ decays selected by HLT1 is used.
- Due to the relatively large size of the muon detector pads, the muon alignment is most important to the muon-based L0 triggers.





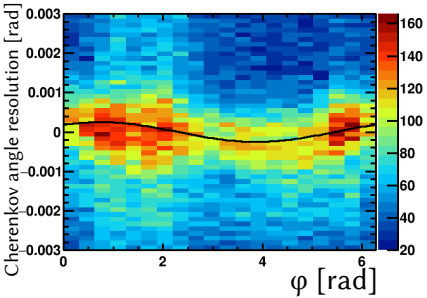
LHCb RICH Detectors

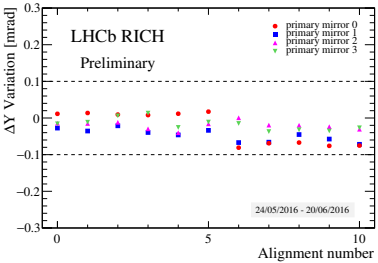
2008 JINST 3 S08005

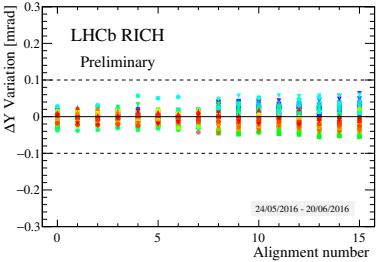


RICH Mirror Alignment

- Mirror tilts result in shift of Cherenkov rings with respect to the tracks they belong to
- RICH1 and RICH2 primary and secondary mirror planes consist of many mirrors, aligned in pairs
- Mirror tilts are obtained by minimising $\Delta\theta$
- 1092 constants in total







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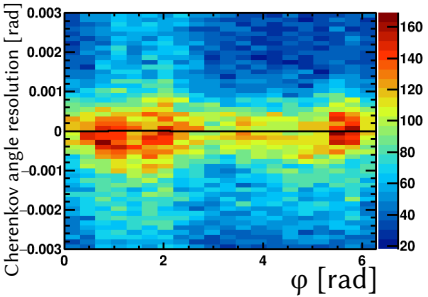
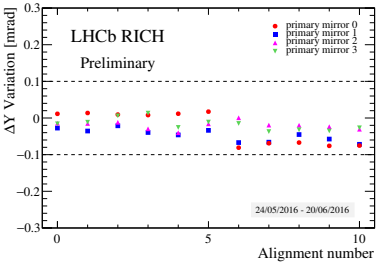
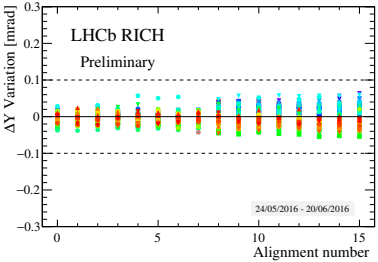
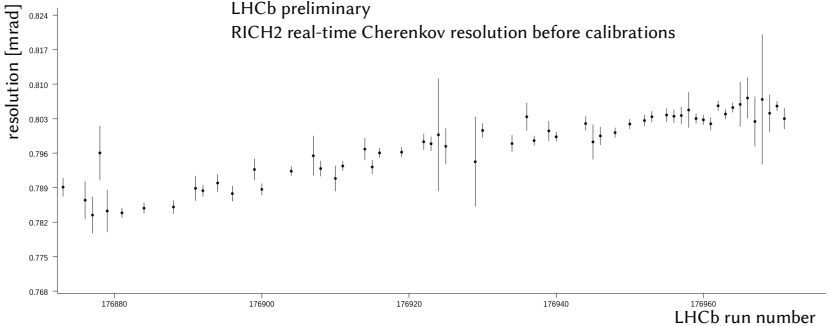


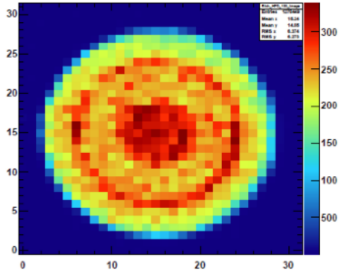


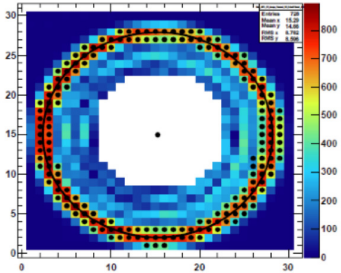


RICH Calibration

- Data available O(5) minutes after collection of data
- Refractive index calibration is obtained from a fit to the distribution of $\Delta\theta = \theta_{\text{reco}} - \theta_{\text{exp}}$
- HPD image centres are obtained from a fit to individual HPD images after edge finding with a Sobel filter.







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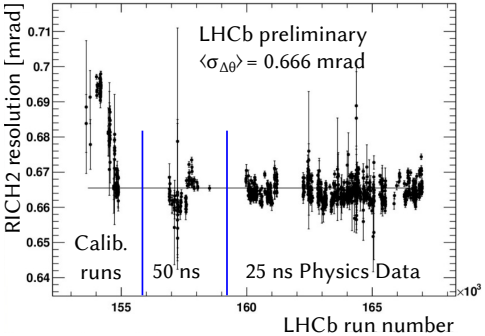

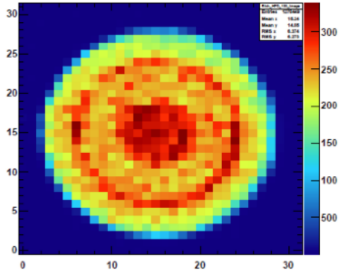

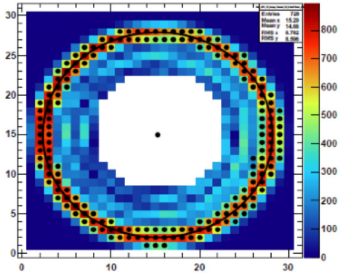

Summary

- Run II HLT reoptimised to allow buffering after HLT1
- Best quality alignment and calibrations available to HLT
- All alignment and calibration procedures fully commissioned and running automatically from 2016's start of data taking
- Alignment and calibration quality stable for all sub-detectors
- Complete best-quality reconstruction available online
- Improves purity of HLT selections and enables physics analysis on HLT output, see talk by B. Sciascia on Turbo stream