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

Roel Aaij

CERN, Geneva,
on behalf of the LHCb collaboration

August 5th 2016

ICHEP, Chicago
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 $O(35) \text{ ms/event}$

---

40 MHz bunch crossing rate

L0 Hardware Trigger: 1 MHz readout, high $E_T/P_T$ signatures

- 450 kHz $h^\pm$
- 400 kHz $\mu/\mu\mu$
- 150 kHz $e/\gamma$

Defer 20% to disk

Software High Level Trigger
- 29000 Logical CPU cores
- Offline reconstruction tuned to trigger time constraints
- Mixture of exclusive and inclusive selection algorithms

5 kHz Rate to storage
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

**LHCb 2015 Trigger Diagram**

- 40 MHz bunch crossing rate
- L0 Hardware Trigger: 1 MHz readout, high $E_T/P_T$ signatures
  - 450 kHz $h^\pm$
  - 400 kHz $\mu/\mu$
  - 150 kHz $e/\gamma$
- Software High Level Trigger
  - Partial event reconstruction, select displaced tracks/vertices and dimuons
  - Buffer events to disk, perform online detector calibration and alignment
  - Full offline-like event selection, mixture of inclusive and exclusive triggers
- 12.5 kHz Rate to storage
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.

Roel Aaij (CERN)  
ICHEP 2016  
August 5th 2016  
3
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.
VELO
Primary vertices
Impact parameter

LHCb Vertex Locator

Roel Aaij (CERN)

ICHEP 2016
August 5th 2016
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

Magnet

Vertex Locator

Tracker

P of charged particles
Once the Velo alignment has completed, the tracker alignment is performed automatically.

A sample of tracks from 100 k $D^0 \rightarrow K^- \pi^+$ decays selected by HLT1 is used.

An improved alignment is put in production automatically.

Plots are produced for the shifters to check.
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
The muon station alignment runs after completion of the tracker alignment.

A sample of tracks from 250 k events containing $J/\psi \rightarrow \mu^+ \mu^-$ 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.
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.
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.

Cherenkov angle resolution [rad]

Roel Aaij (CERN)
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.
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.

LHCb preliminary
\[
\langle \sigma_{\Delta \theta} \rangle = 0.666 \text{ mrad}
\]

Roel Aaij (CERN)
ICHEP 2016
August 5th 2016
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