Real-time alignment and reconstruction: performance and recent developments at the LHCb experiment

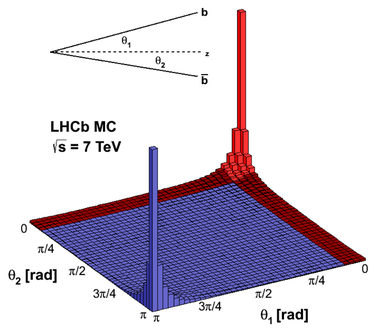
Agnieszka Dziurda[1], Lucia Grillo[2], Francesco Polci[3], **Michael Sokoloff[4]**

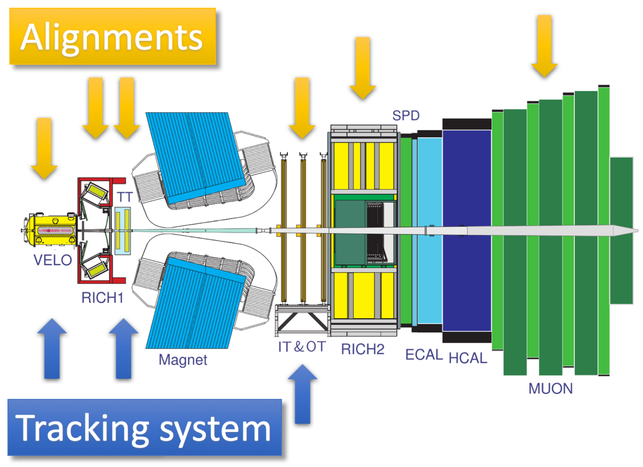
[1]CERN Geneva, [2]Universita & INFN Milano-Bicocca, [3]LPNHE Paris, [4]University of Cincinnati

On behalf of the Tracking and Alignment LHCb group

LHCb detector

- The LHCb detector is a single-arm forward spectrometer at LHC with a pseudorapidity η in the range $2 < \eta < 5$.
- Main attention: flavor physics studies.





JINST 3 (2008) S08005
Int. J. Mod. Phys. A 30, 1530022 (2015)

Outstanding physics results require an excellent detector performance

Reconstruction

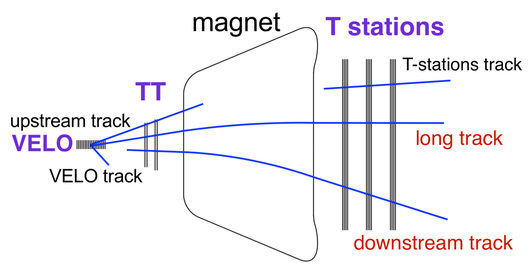
HLT1 sequence (35 ms)

- Offline VELO tracking with simplified Kalman Filter
- Primary Vertex finding
- VELO → TT: initial momentum estimate p_T>200 MeV
- TT → T stations with p_T>500 MeV
- Offline Kalman Filtering

Alignment and calibration

HLT2 sequence (650 ms)

- VELO → T stations no p_T threshold
- T-station standalone tracking
- Downstream tracking
- Matching tracking
- Offline Kalman Filtering and clone killing



Long tracks

- Hits at least in VELO, T stations
- Excellent momentum resolution
- Used in majority of analyses

Downstream tracks

- Hits in TT and T stations.
- Daughters of long lived particles

Introduced in Run II:
the same reconstruction in the trigger and offline.

Machine Learning in the tracking algorithms:

- Fake tracks killing
- Best candidate selection in track finding stage

New for 2017:
Downstream tracking reoptimization

Filter T stations tracks → Find matching TT hits → Select good downstream tracks

- Two Multivariate Classifiers
- Efficiency gain O(3-5)%
- Fake track reduction O(3-5)%

Alignment

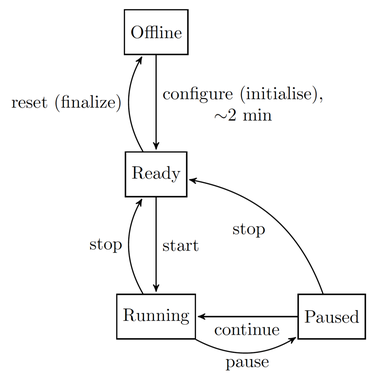
- **Alignment**: the calibration of the position and orientation of tracking detectors

Alignment varies due to:

- movement of the detector
- pressure, temperature,
- operation conditions:
  - magnetic field change
- mechanical intervention

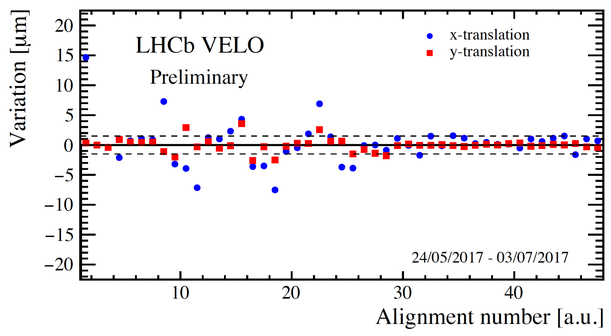
Direct impact to physics performance

- Primary Vertex resolution
- Decay-time resolution
- Impact Parameter resolution
- Invariant mass resolution
- Reconstruction efficiency and its asymmetry



For Run II (2015-2018)
the LHCb experiment introduced:

- **An automatic procedure** start at the beginning of each fill
- **The same alignment constants in the trigger as in the offline processing**

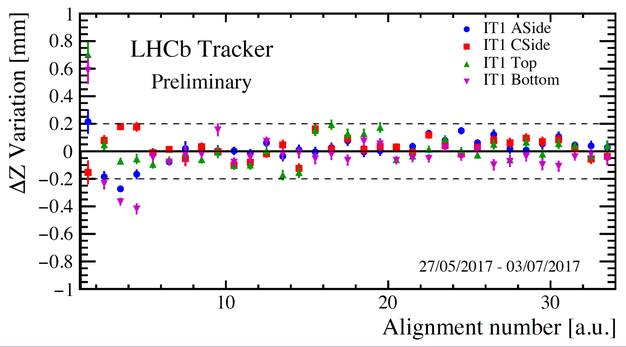


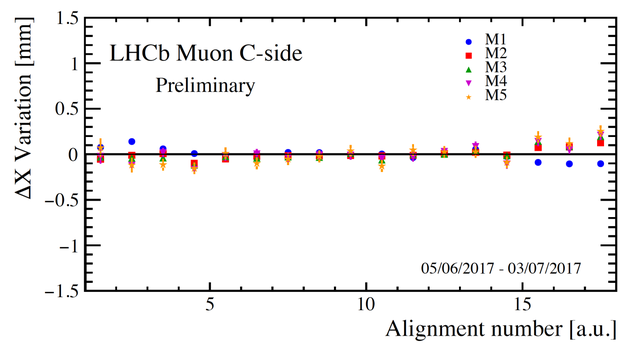
VELO: VErtex LOcator

- The closest detector to the beam: ~8 mm
- VELO moves: opened during the injection, closed at the beginning of each fill,
- Based on Kalman method with iterations
  10.1016/j.nima.2008.11.094, 10.1016/j.nima.2012.11.192
- Fully automatic since 2015
- Time: ~7 min

Tracker (TT, IT, OT)

- Uses reconstructed tracks from $D^0 \to K\pi$
- Aligned with respect to VELO
- Based on Kalman method
- ~700 elements to be aligned
- Time: ~12 min
- Good stability

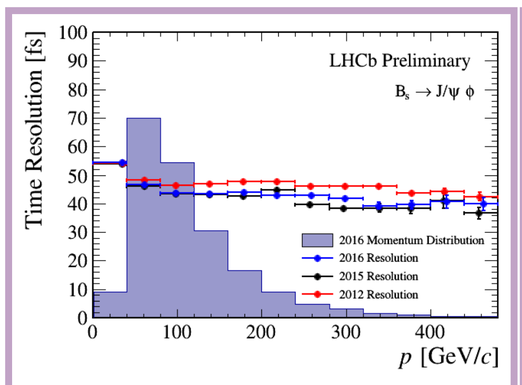




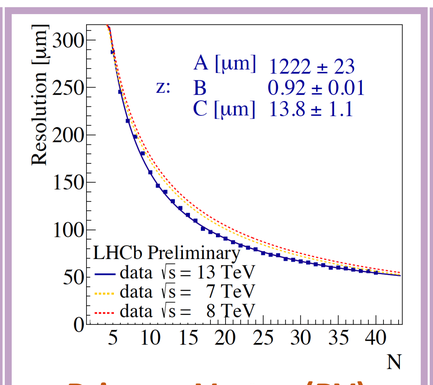
MUON

- Uses reconstructed tracks from $J/\psi \to \mu\mu$
- Aligned with respect to VELO and Tracker
- Based on Kalman method
- Very stable: an update applied only after mechanical intervention
- Serves as a monitoring

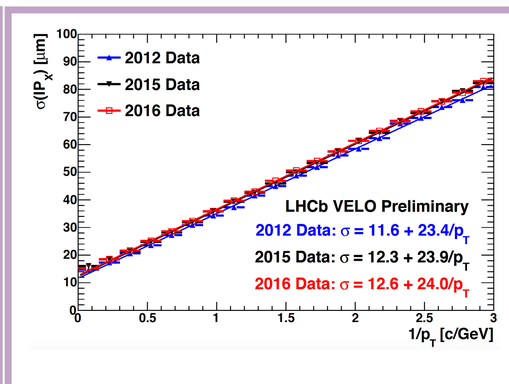
Performance



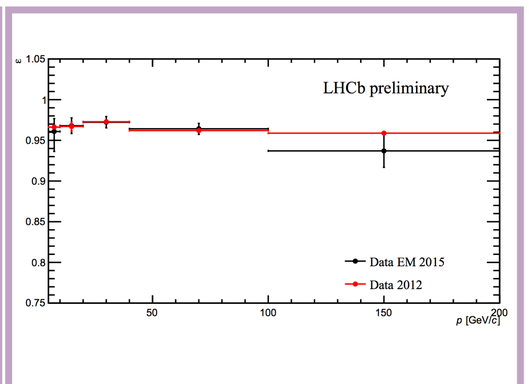
Decay-time resolution:
~45 fs,
for a 4-track vertex



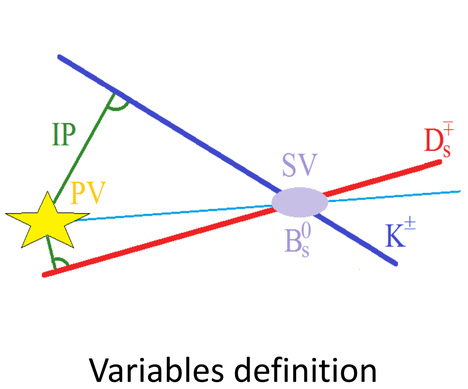
Primary Vertex (PV) resolution :
~77 μm in z direction,
for PV with 25 tracks



Impact Parameter (IP) resolution: ~13 μm,
for high p_T and IP_x component



Average tracking efficiency: >96%



Variables definition on the example of:
$B_s^0 \to D_s^{\mp} K^{\pm}$ decays

The best quality achieved already in the trigger! Analyses can be performed directly on the trigger output!