# LHCb's Real-time Analysis Project and Development of Fast Tracking

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## LHCb's upgraded tracking system

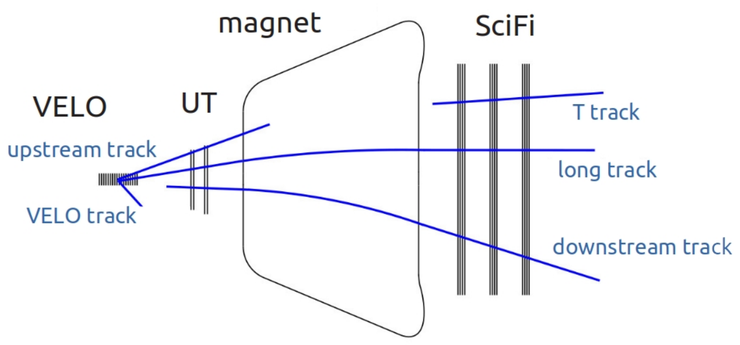
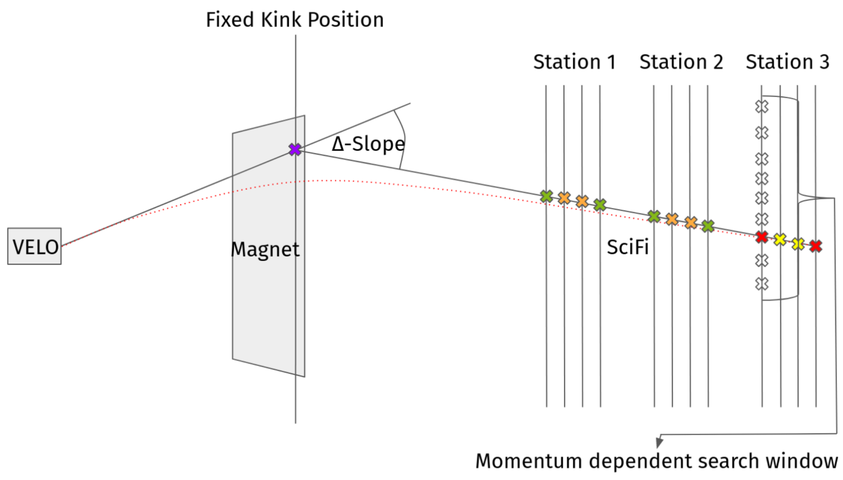



**Figure 3:** LHCb track types produced by different reconstruction algorithms. Long tracks have the best momentum estimate. [1]

## HLT1 Long Track Reconstruction

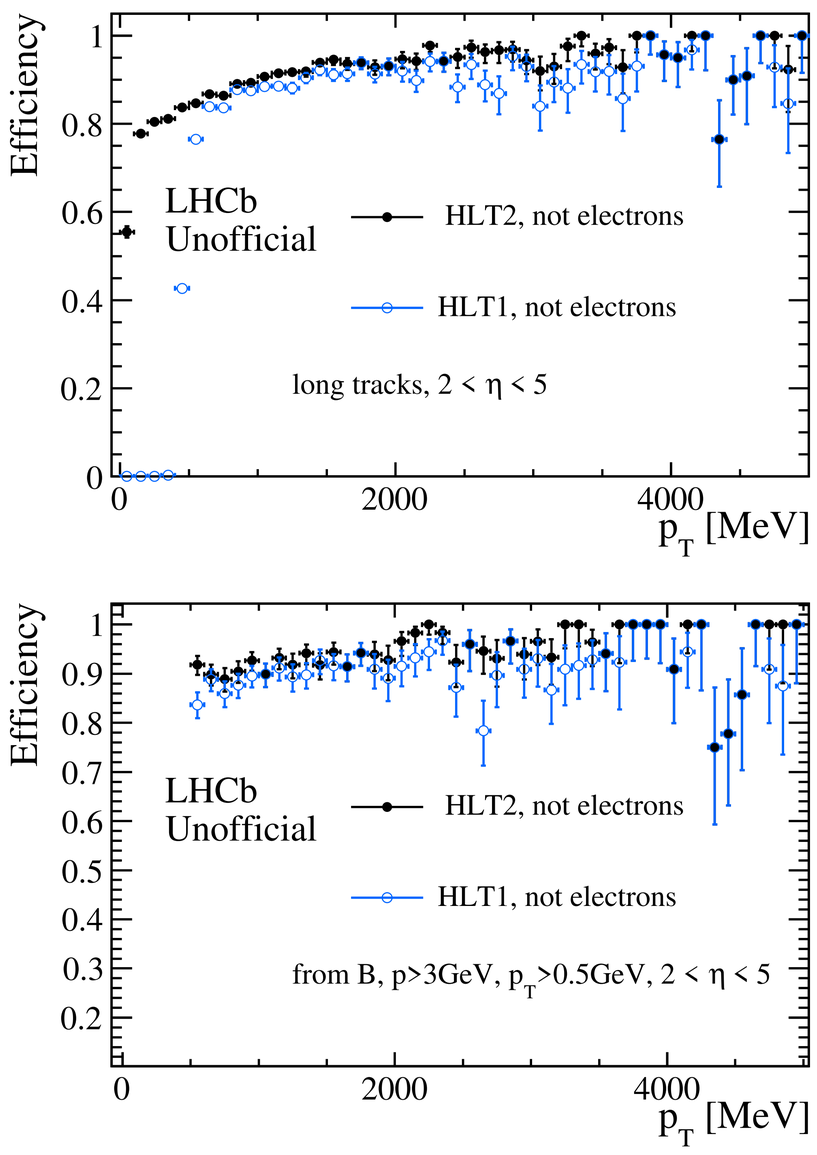



- focuses on reconstruction efficiency of high-momentum long tracks from $B$ mesons
- is able to reconstruct tracks at 30 MHz event rate

**Idea:** almost no magnetic field within last SciFi station

- use momentum estimate from upstream track to open search window
- find hit doublet on straight line (red)
- extrapolate to other SciFi stations
- collect hits close to extrapolated position
- perform fit of candidate

## Tracking Efficiency on Simulation




## Main Upgrade Challenge: An Efficient Trigger

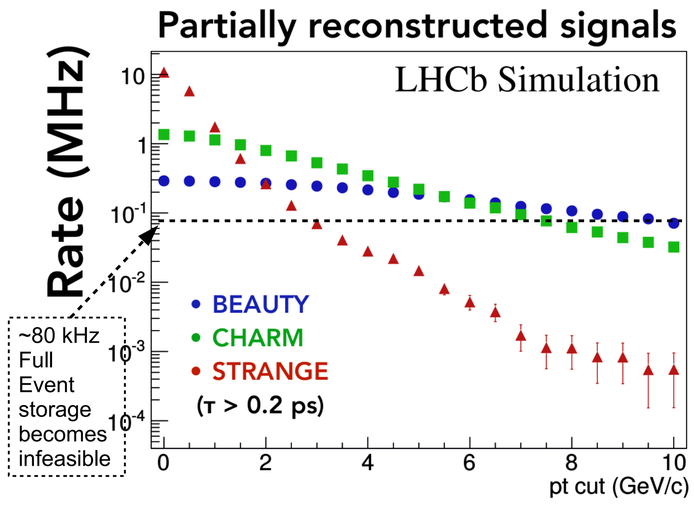



**Figure 1:** Signal rates of two-track combinations reconstructed by the Software Trigger as a function of transverse momentum cuts. Adapted from LHCB-PUB-2014-027.

- signal rates alone higher than current raw data storage capability
- hardware trigger selection (e.g. transverse momentum cut) not effective anymore
- partial and full event reconstruction needed to efficiently select interesting $pp$ collisions
  $\rightarrow$ 40 MHz read-out (40$\times$ Run II rate) + Software Trigger with Real-time Analysis
- reduced event model necessary
  $\rightarrow$ selectively store event information with Turbo persistence model

## Real-time data processing @ LHCb

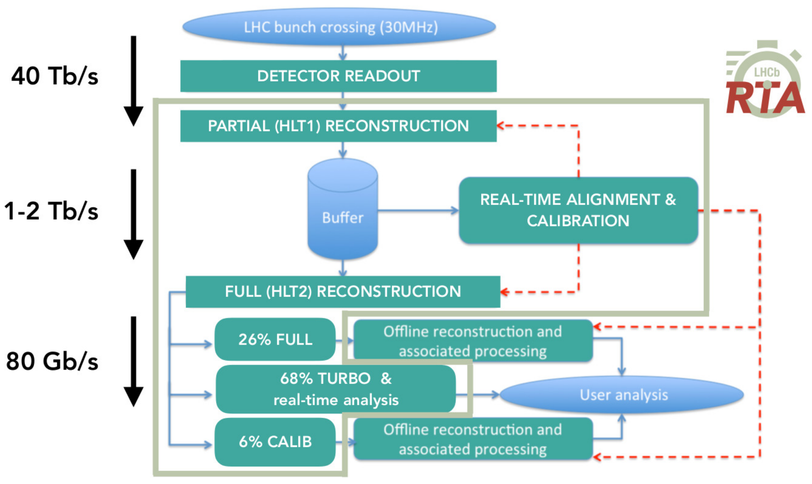



**Figure 2:** LHCb data processing scheme during Run III.

- "real-time" means period between collisions and permanent data storage
- first trigger stage (HLT1) performs partial event reconstruction
- online detector calibration and alignment
- second trigger stage (HLT2) provides offline-like reconstruction quality

## Turbo persistence model

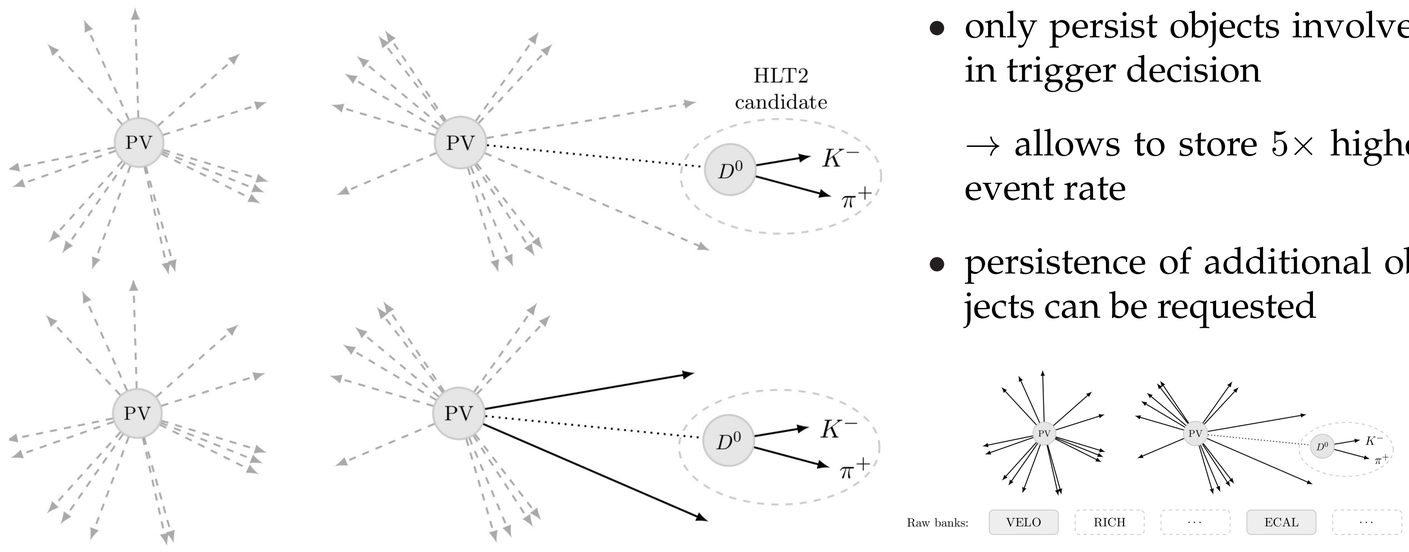



**Figure 4:** Turbo persistence model with different levels of persistence. [3, 4]

- only persist objects involved in trigger decision
  $\rightarrow$ allows to store 5$\times$ higher event rate
- persistence of additional objects can be requested

## HLT2 Long Track Reconstruction - Forward Tracking

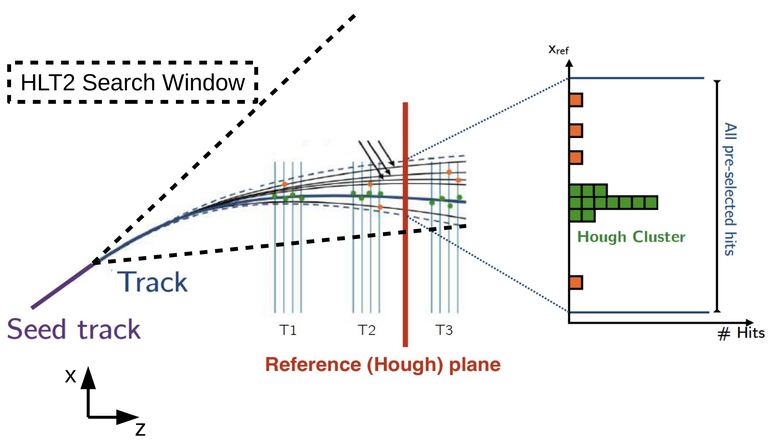



**Figure 5:** Sketch of the track reconstruction in the SciFi stations. [2]

- focuses on long track reconstruction efficiency
- provides tracks with best momentum resolution
- **event throughput has to be improved!**

**Algorithm:**

- extrapolate VELO tracks to SciFi stations
- open symmetric hit search window and collect hits
- project hits onto reference plane
- select hit clusters (track candidates)
- perform fit of candidate

**Improvements:**

- more precise VELO track extrapolation
  $\rightarrow$ collect less wrong hits
  $\rightarrow$ 20% event throughput increase
- store hits in "struct-of-array" memory layout
  $\rightarrow$ use SIMD CPU instructions
  $\rightarrow$ 15% event throughput increase

## Contact and References

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[1] LHCB-TDR-015
[2] LHCb-PUB-2014-001
[3] LHCb-DP-2019-002
[4] LHCB-TDR-018