Trigger Tracking for the LHCb Upgrade

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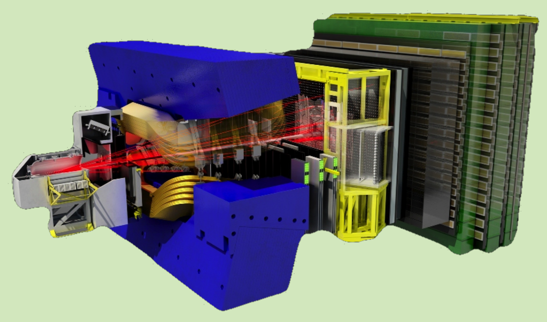
Motivation for the LHCb Upgrade [1] [2]

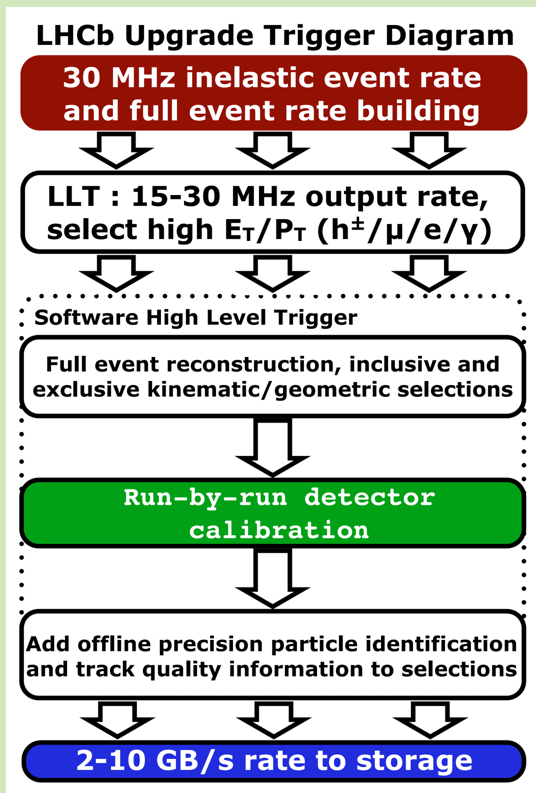
LHCb is a single-arm forward-spectrometer designed for high-precision tests of the Standard Model at the LHC.

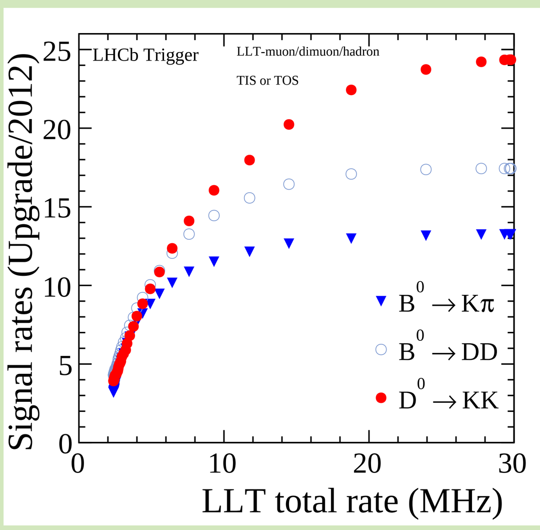


- Currently: $\mathcal{L} = 4 \times 10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
- Upgrade (in LS2, 2018-2020): $\mathcal{L} = 2 \times 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
  - → Replace VELO, trackers and RICH photodetectors
  - → Expect 0.5 MHz of $b\bar{b}$ and 6 MHz of $c\bar{c}$
  - → Trigger system needs to reject background but also discriminate between signal

The Upgrade Trigger

- Current LHCb trigger:
  - → L0 readout limited to 1 MHz
  - → Software trigger
    - → Partial event reconstruction @1 MHz
    - → Full event reconstruction offline @80 kHz
- Upgrade trigger:
  - → Remove 1 MHz bottleneck from L0
  - → Triggerless readout at full bunch-crossing rate
- **LHCb will run full event reconstruction at 30 MHz!**



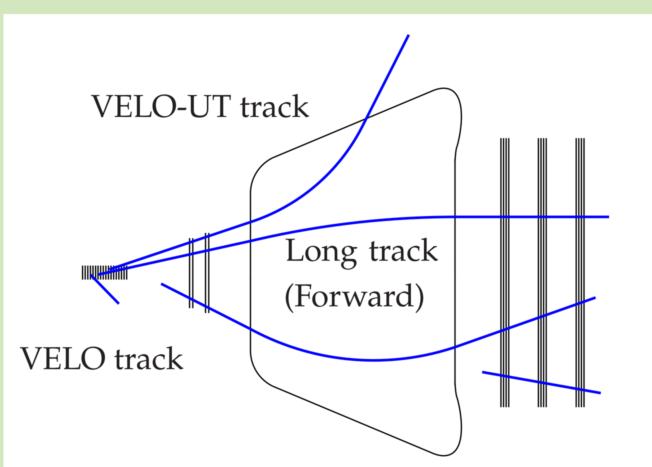


- Initial phase (only partial EventFilterFarm + DAQ):
  - → LowLevelTrigger (LLT)
    - → Hardware trigger to reduce rate
    - → Rate tunable to match farm size
- Once full farm is installed: remove LLT

Estimated per-event timing budget on the 3.125 MCHF upgrade farm: 13.3 ms on today's CPUs.

Tracking [3] [4]

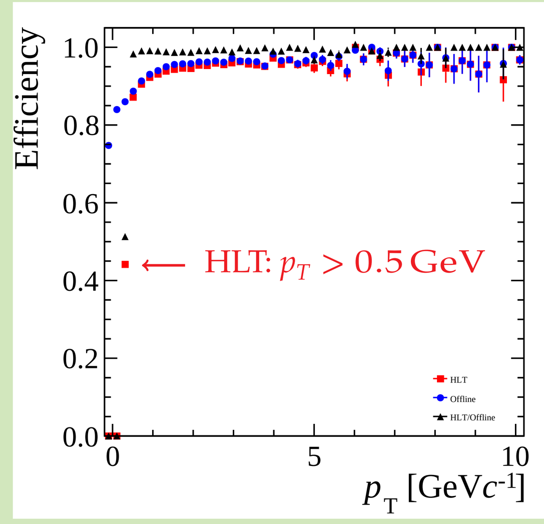
- Upgraded LHCb: Track reconstruction at 30 MHz
  - → Use offline-algorithms with reduced search windows
  - → Intermediate confirmations of VELO tracks with UT
    - → Running VELO+Forward is too slow; we can use the UT to quickly get charge and momentum information which makes running the Forward possible
- Tracking consists of three steps:
  - (1) VELO tracking
  - (2) VELO-UT tracking $\sigma_p/p \approx 15\,\%$
  - (3) Forward tracking $\sigma_p/p < 0.5\,\%$
- Tracks only reconstructed with p_T above:
  - → VELO-UT tracking: $p_T > 200\,\mathrm{MeV/c}$
  - → Forward tracking: $p_T > 500\,\mathrm{MeV/c}$



Performance: Efficiencies

- Typical B daughter-track has $p_T > 0.5\,\mathrm{GeV}$
- Absolute efficiencies measured using MC truth
  - → "Good trigger track": Long, from B, $p_T > 0.5\,\mathrm{GeV}$

	Cumulative Efficiency [%]	
	Offline	HLT
VELO tracking	99.8	99.8
VELO-UT tracking	–	97.9
Forward tracking	94.3	93.2
Ghost rate	40.0†	7.4

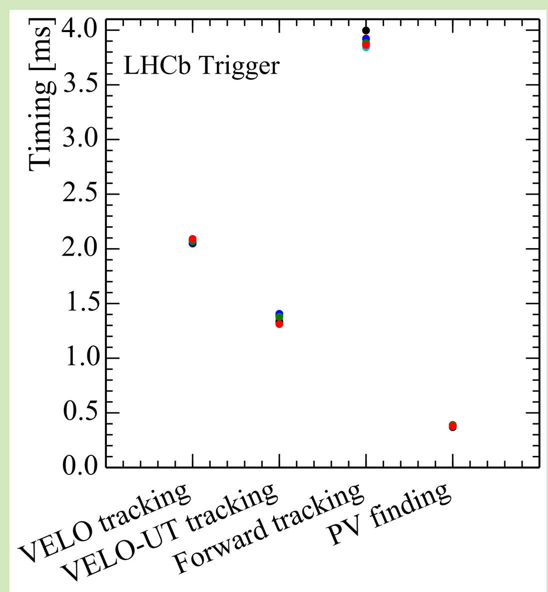


- HLT and offline tracking largely identical, relative efficiency 98.8 % (forward tracks)

† Offline, this gets reduced by a Kalman filter based track fit

How to Measure Timings

- Measurement of small times is problematic
  - → CPU can be used by other users/processes
  - → CPU's speed depends on many unknowns (e.g. temperature)
  - → Absolute numbers not comparable between different machines
- Solutions
  - → Fixed set of identical machines (HLT farm) reserved for this purpose only
  - → Multiple runs over many events (reduce fluctuations, estimate uncertainty)
  - → Typical reproduceability ~ 0.05 ms



10 runs each; spread gives an estimate of uncertainty

Performance: Timing

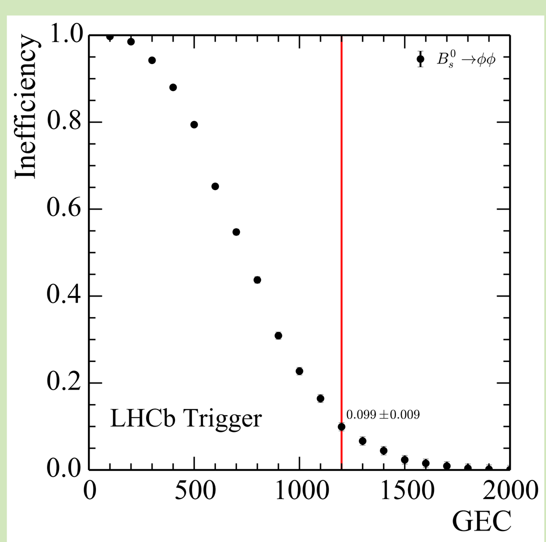
Estimated budget: 13.3 ms

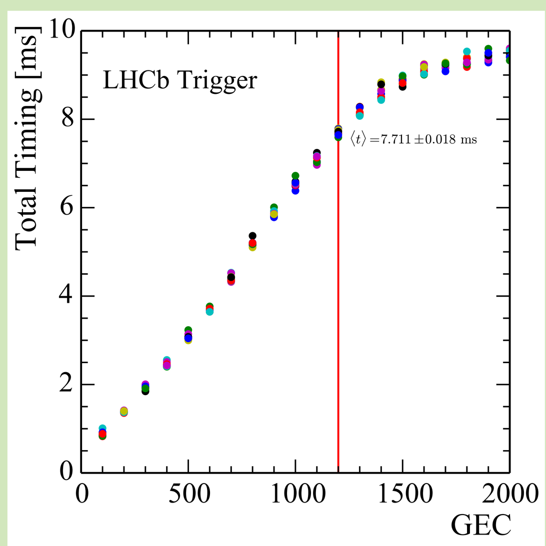
Tracking Algorithm	Timing [ms] No GEC	GEC = 1200
VELO tracking	2.3	2.1
VELO-UT tracking	1.5	1.4
Forward tracking	5.3	3.9
PV finding	0.41	0.38
Total	9.5	7.7

- At full bunch crossing rate of 30 MHz
  - → All tracks with $p_T > 500\,\mathrm{MeV}$ available in offline quality
  - → $p_T > 200\,\mathrm{MeV}$: lower momentum resolution (VELO-UT)
- Only 58 % of the budget!
  - → Rest available for staged reconstruction (Kalman fit, RICH PID, …) and selections

Global Event Cuts (GEC)

- High multiplicity tails take up disproportionally much CPU time
  - → Operationally safer to run tracking with GEC
- GEC are an excellent handle to control reconstruction time
- Occupancies in the various sub-detectors are correlated with each other





References

[1] I. Bediaga *et al.*, 'Framework TDR for the LHCb Upgrade: Technical Design Report', CERN, Geneva, Tech. Rep. CERN-LHCC-2012-007. LHCb-TDR-12, Apr. 2012.

[2] 'Letter of Intent for the LHCb Upgrade', CERN, Geneva, Tech. Rep. CERN-LHCC-2011-001. LHCC-I-018, Mar. 2011.

[3] J. Albrecht, K. Dungs and T. Head, 'Track finding scenarios for the software trigger of the upgraded LHCb experiment ', CERN, Geneva, Tech. Rep. LHCb-PUB-2014-xx, Apr. 2014, in preparation.

[4] A. A. Alves *et al.*, 'LHCb Tracker Technical Design Report', CERN, Geneva, Tech. Rep. LHCb TDR 15, Feb. 2014.