Reconstruction at 30 MHz

HL-LHC Trigger and Computing Workshop

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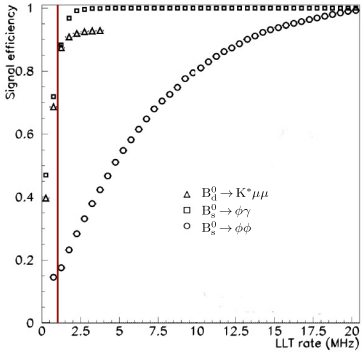
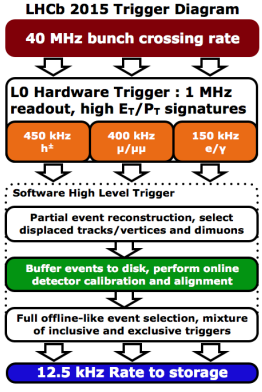
École Polytechnique Fédérale de Lausanne

7 September 2014

LHCb at 40MHz

At increased luminosity signals less well separated in L0 ⇒ we need to read out every event!



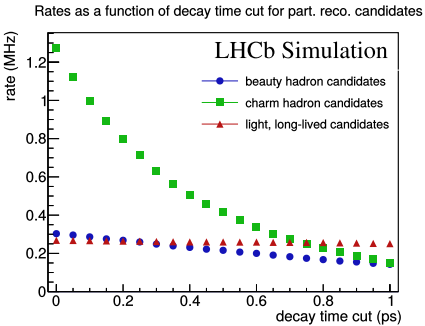


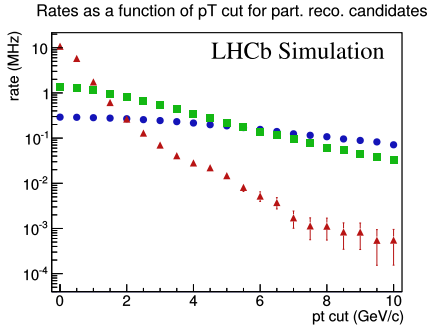
Upgrade readout to 40 MHz, full detector readout of all visible pp interactions

- Replace hardware L0 by software Low Level Trigger (LLT)

The Game has Changed

In the upgrade area there are no “boring” events, it is about classifying signal events!



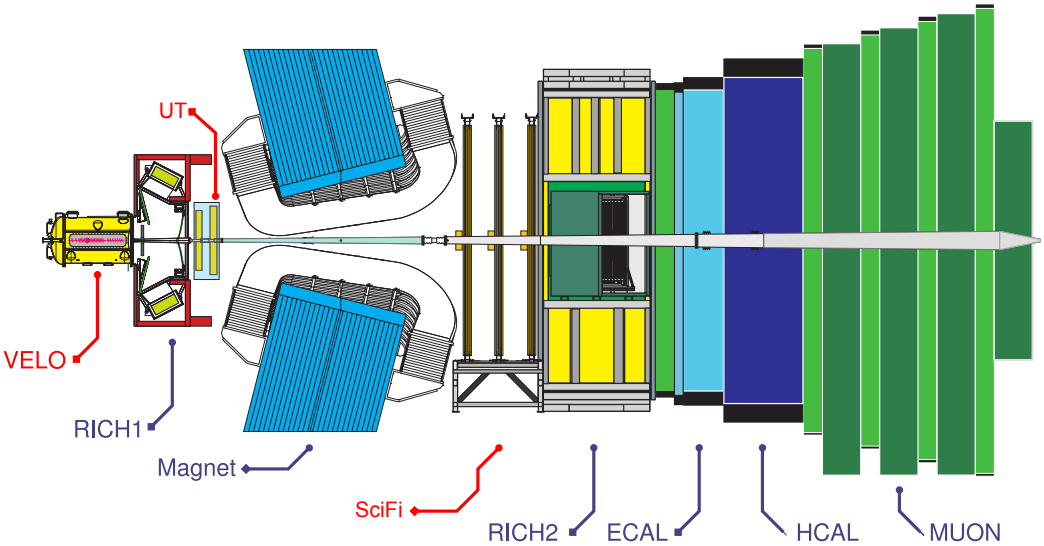


80 GB/s of reconstructible D hadrons, 27 GB/s of reconstructible B hadrons.

Compare to 10 GB/s allowed to tape

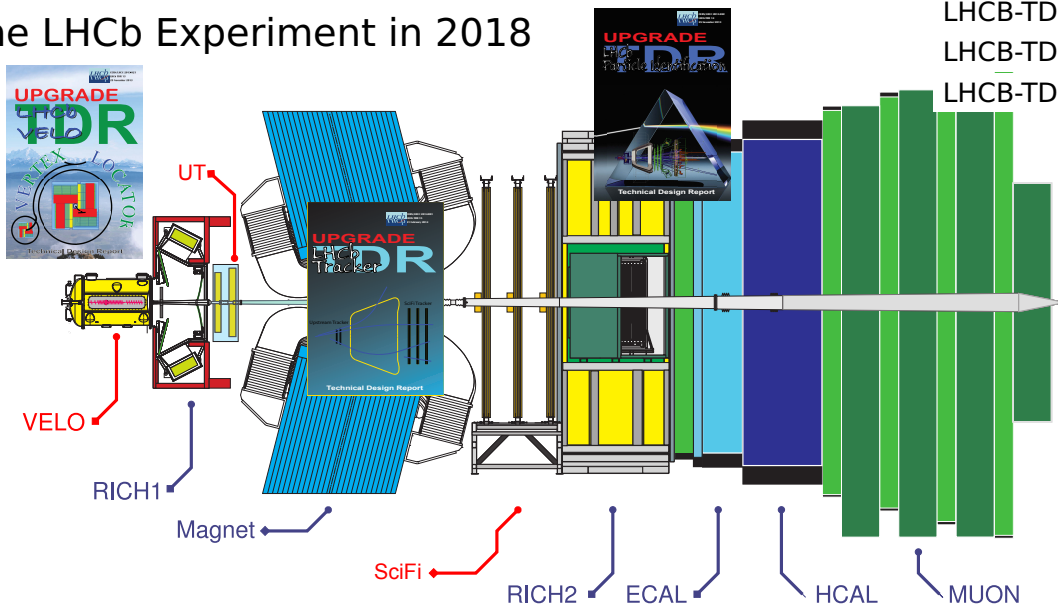
Details: LHCb-PUB-2014-027

The LHCb Experiment in 2018



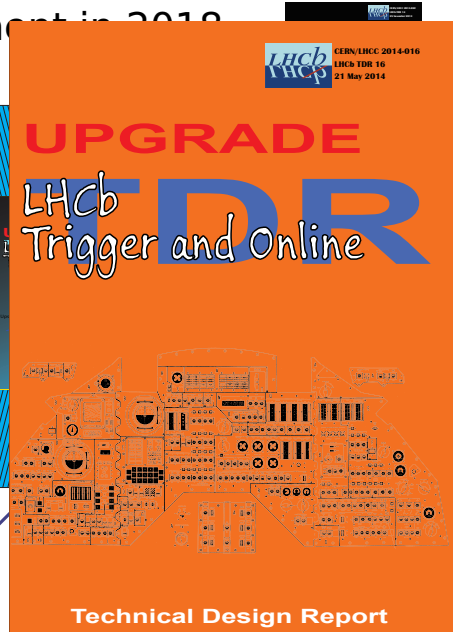
The LHCb Experiment in 2018

LHCB-TDR-013
LHCB-TDR-014
LHCB-TDR-015



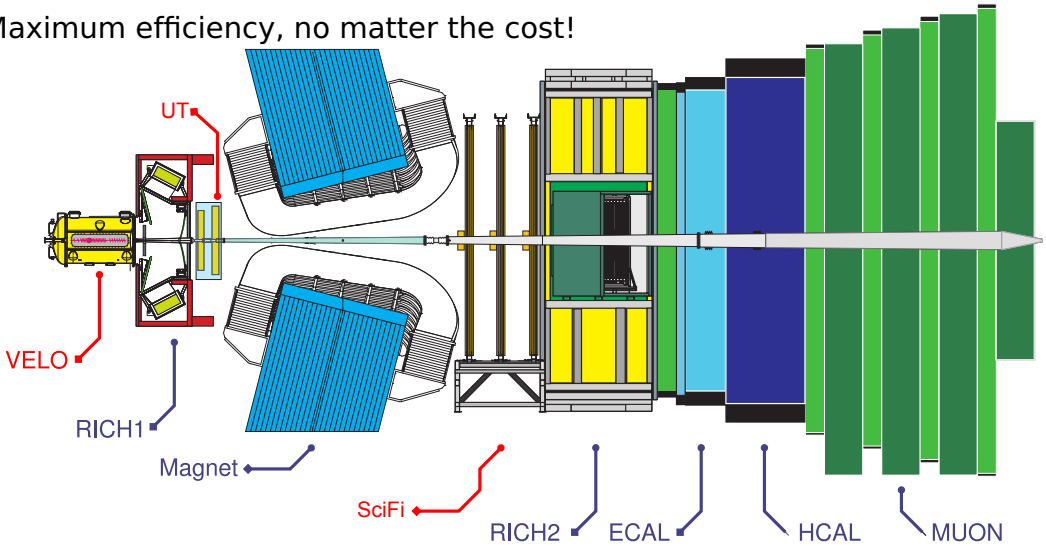
The LHCb Experiment in 2018

LHCB-TDR-013
LHCB-TDR-014
LHCB-TDR-015
LHCB-TDR-016



Offline Tracking

Maximum efficiency, no matter the cost!



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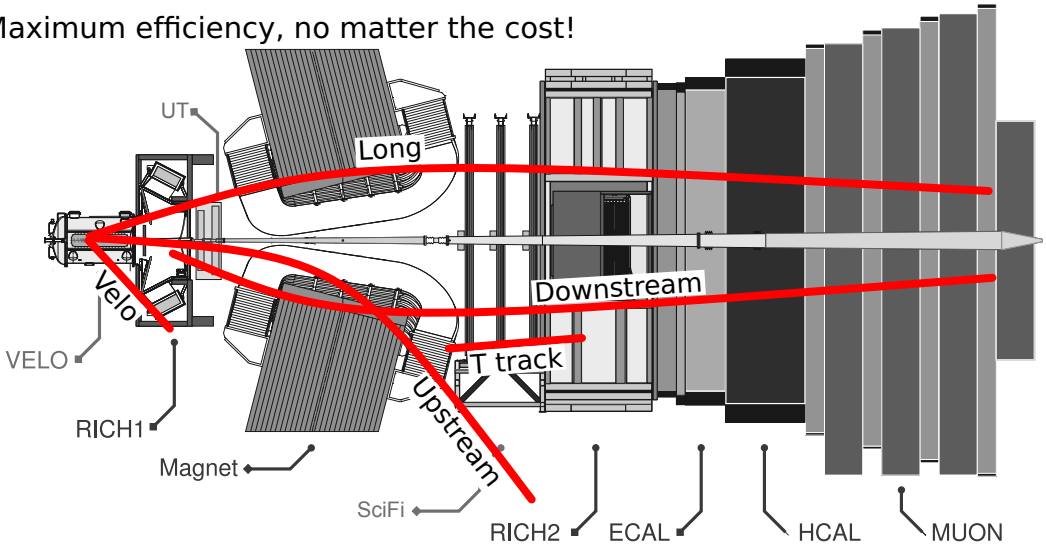
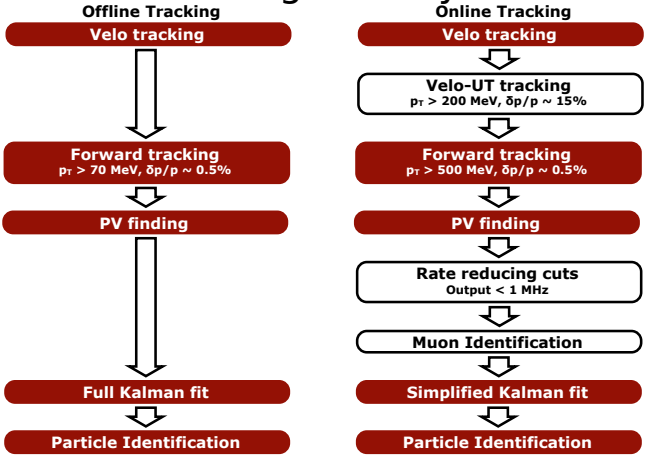


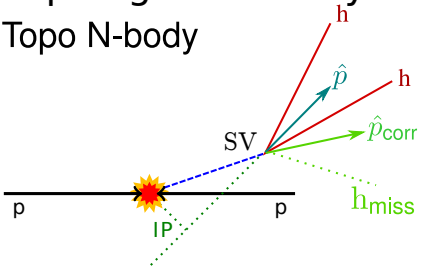
Offline Tracking Already Online

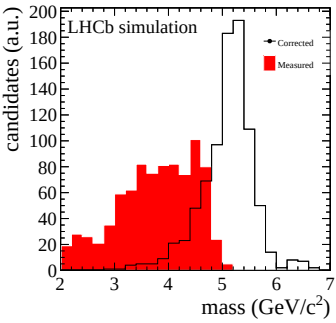


- Maximum flexibility and robustness
- Details: LHCb-PUB-2014-028
- LHCb will be the first hadron collider experiment to operate a software only trigger at full event rate!

Offline quality tracking at 30 MHz in software is possible!

Topological *N*-Body Trigger



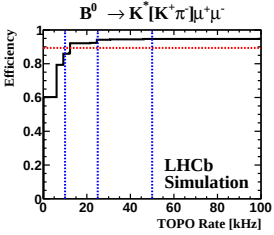


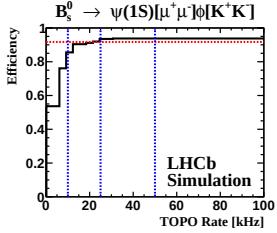
- Main trigger for B decays is based on a Boosted Decision Tree
- Inclusive trigger for 2, 3, 4-body detached vertices
- Preselect tracks based on distance to PV, scalar and vector sum of p_T
- BDT inputs: p_T, IP_{χ^2}, flight distance χ^2, mass and corrected mass:

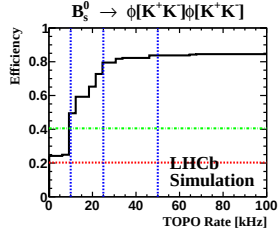
$$m_{corr} = \sqrt{m^2 + \left|p_{T_{miss}}\right|^2} + \left|p_{T_{miss}}\right|$$

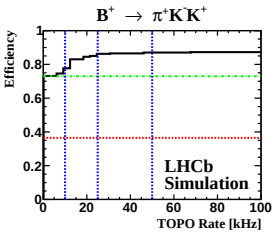
Upgrade Topological *N*-Body Trigger

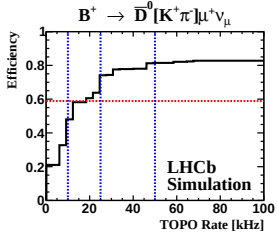
- Same principle and technique as in Run I, preselect tracks using $\sum p_T$
- The only question: how much better do we want to do?
- Details: LHCb-PUB-2014-031

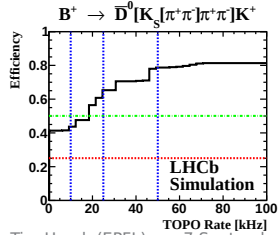






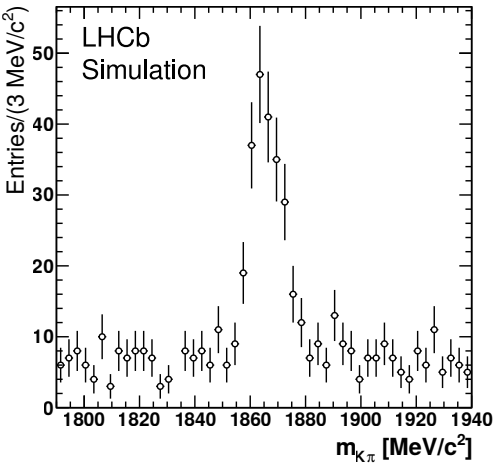






Lifetime Unbiased

- Lifetime acceptances are very hard to measure ⇒ systematic uncertainties
- Instead select directly on lifetime, not proxy variables
- No need to evaluate lifetime resolution or acceptance functions



Key challenges: combinatorics and output rate

- B^0, $D^0 \to h^+h^-$
  - Timing: 0.13 ms

$B^0 \to h^+h^-$	~ 1 kHz
$D^0 \to K^-\pi^+$	~ 20 kHz
$D^0 \to K^+\pi^-$, $\pi\pi$	~ 40 kHz
$D^0 \to KK$	~ 2 kHz

- $B_s \to \phi(\to KK)\,\phi(\to KK)$
  - Timing: 0.1 ms, Rate: ~ 12 Hz

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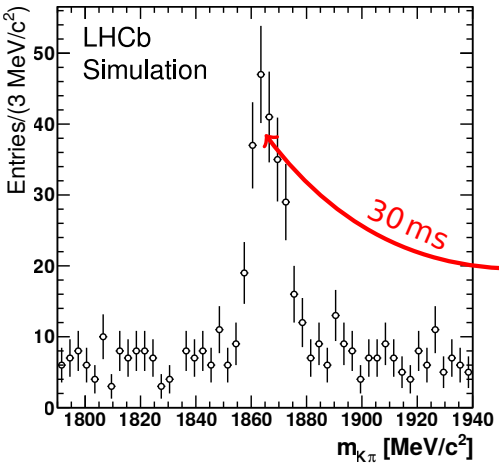

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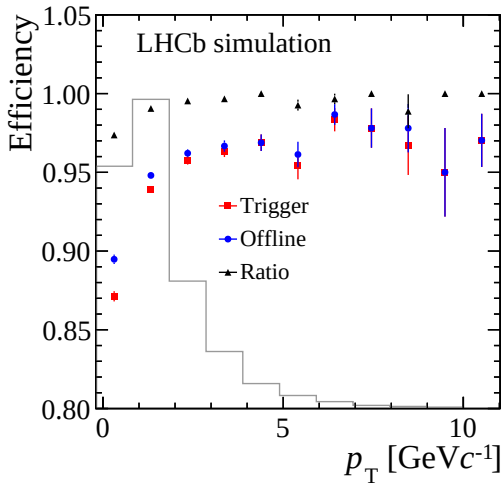
Where to put all the Data?

- The HLT output rate is limited by available offline computing
- What really counts is GB/s not Hz
- Several scenarii considered in the TDR: 2, 5 or 10 GB/s
  - translates to: 20, 50 or 100 kHz
- Unless, you write out less information
- If everything is already reconstructed in the trigger, can write out only a subset of the event information

Efficiency

- Compared to “offline” the HLT tracking sequence is 98.7% efficient
- In addition tracks with $p_T < 0.5\,\text{GeV/c}$ are available with lower momentum resolution

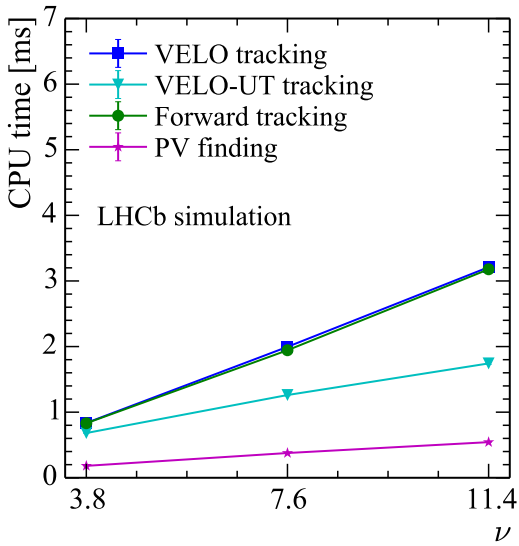
	Efficiency [%] HLT	relative
long, from B	72.8	80.3
long, $p_T > 0.5\,\text{GeV/c}$	87.4	97.2
long, from B, $p_T > 0.5\,\text{GeV/c}$	92.5	98.7



Timing

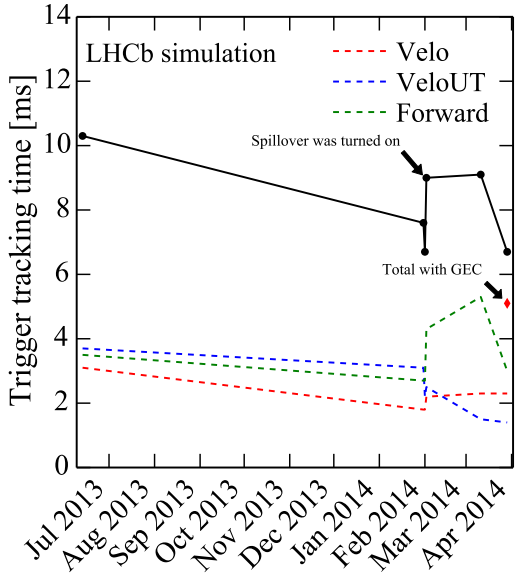
- At nominal luminosity reconstruction uses less than half the budget (13 ms)
- CPU time does not “explode” at higher luminosity

Algorithm	CPU time [ms]
VELO	2.0
VELO-UT	1.3
Forward	1.9
PV finding	0.38
Total	5.4



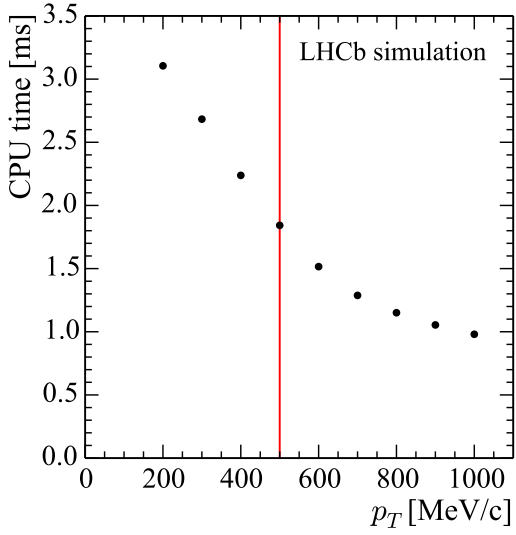
Time Evolution

- Making the whole sequence faster is hard work
- Some competition as nobody wants to be the slowest
- A dedicated group of people is needed



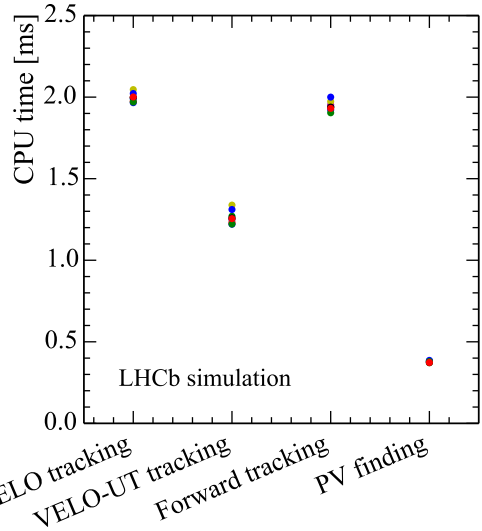
Spare Time

- Extra CPU time can be “used up” by reducing the p_T requirement in the Forward tracking



How Good is Your Watch?

- Measuring very short times is difficult
- We spent some time building tools
- An improvement of 0.1 ms saves LHCb ≈ 20 000 CHF



Take Home Messages

- For 2020 LHCb will have a truly upgraded trigger
  - full software trigger for the first time at a collider!
- Take a global view and optimise the “whole chain”
  - from front-end data format to sequence of tracking algorithms
- Reconstruction in the trigger is of “analysis” quality
  - no need for dedicated offline reconstruction, record *the* legacy charm dataset

- Run II will be our “test beam”, trialing many techniques which we will need for 2020:
  - run-by-run calibration and alignment
  - turbo stream/analysis without offline reconstruction