

LHCb
LHCb



Highlight: LHCb Trigger and real-time analysis in Run 3

Louis Henry, on behalf of the LHCb collaboration
CERN, 07/06/2021

LHCbP2021
The Ninth Annual Conference on Large Hadron Collider Physics

7-12 June 2021 ~~Paris (France), Sorbonne Université~~ (IN2P3/CNRS, IRFU/CEA)

Online

D. Longieras / UCLouvain 2021

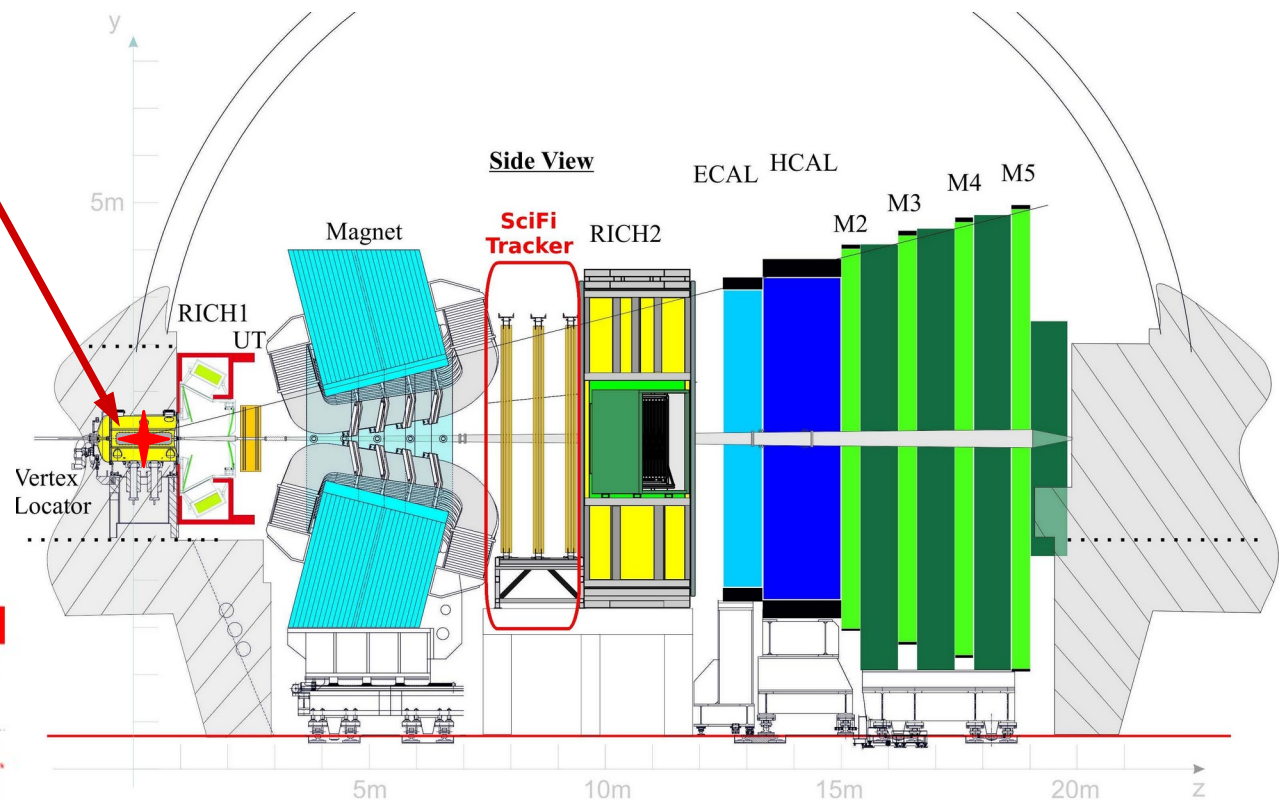
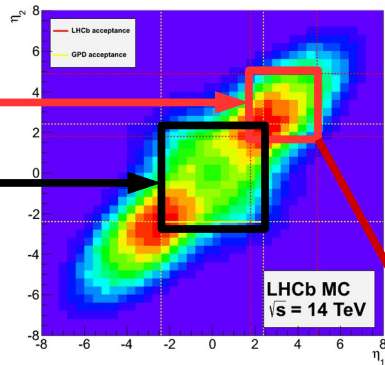
The banner features a stylized illustration of the Eiffel Tower on the left, a sign that says "Online", and a large, colorful particle detector structure on the right. The background is a gradient of yellow and orange.

The LHCb upgrade: a look from the outside

- LHCb: general-purpose detector specialised in beauty and charm hadrons.
- Upgraded from 2019 to 2022 to withstand larger luminosities.
 - Change nearly all subdetectors and channels, general geometry stays the same

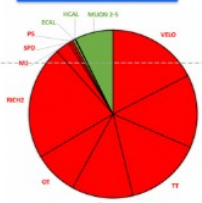
LHCb
(25% $b\bar{b}$)

ATLAS, CMS
(45% $b\bar{b}$)

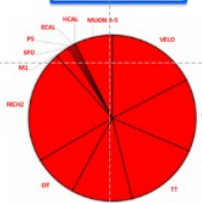


Upgraded LHCb Detector

Detector Channels



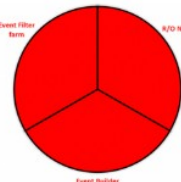
R/O Electronics



To be UPGRADED

To be kept

DAQ



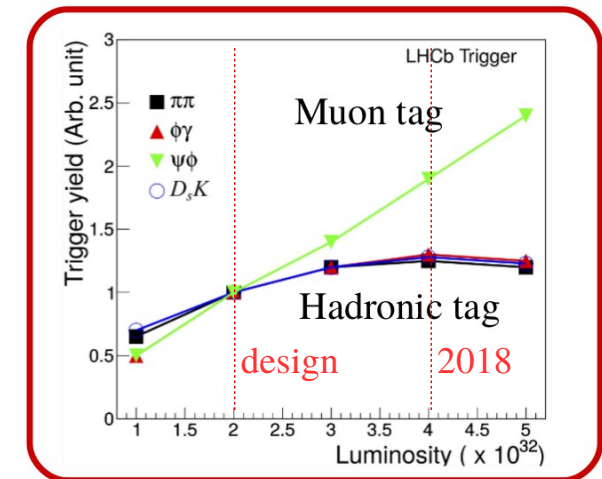
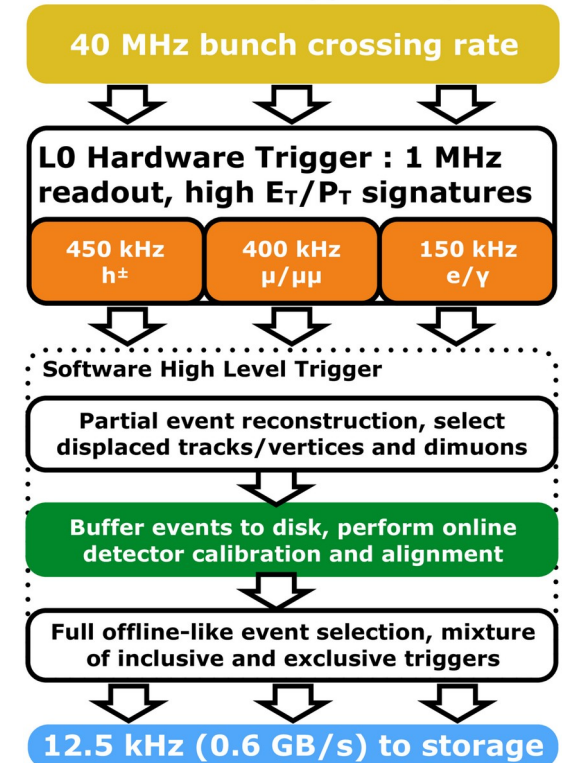
The LHCb upgrade: the challenge within

- Run 1+2 triggering in LHCb relied on two-stage trigger.
 - L0: hardware trigger on either muon tag or transverse energy
 - HLT: software trigger on displaced vertices, high transverse momentum signatures.
- Reduction factor needed to run the HLT as is would mean that L0 starts rejecting signal events at random: no benefit from higher luminosities.
 - Charm production is at 1MHz in Run3.
 - Need to remove the hardware trigger → **run a software trigger at 30 MHz.**
- Trigger is limited by the data rate and:

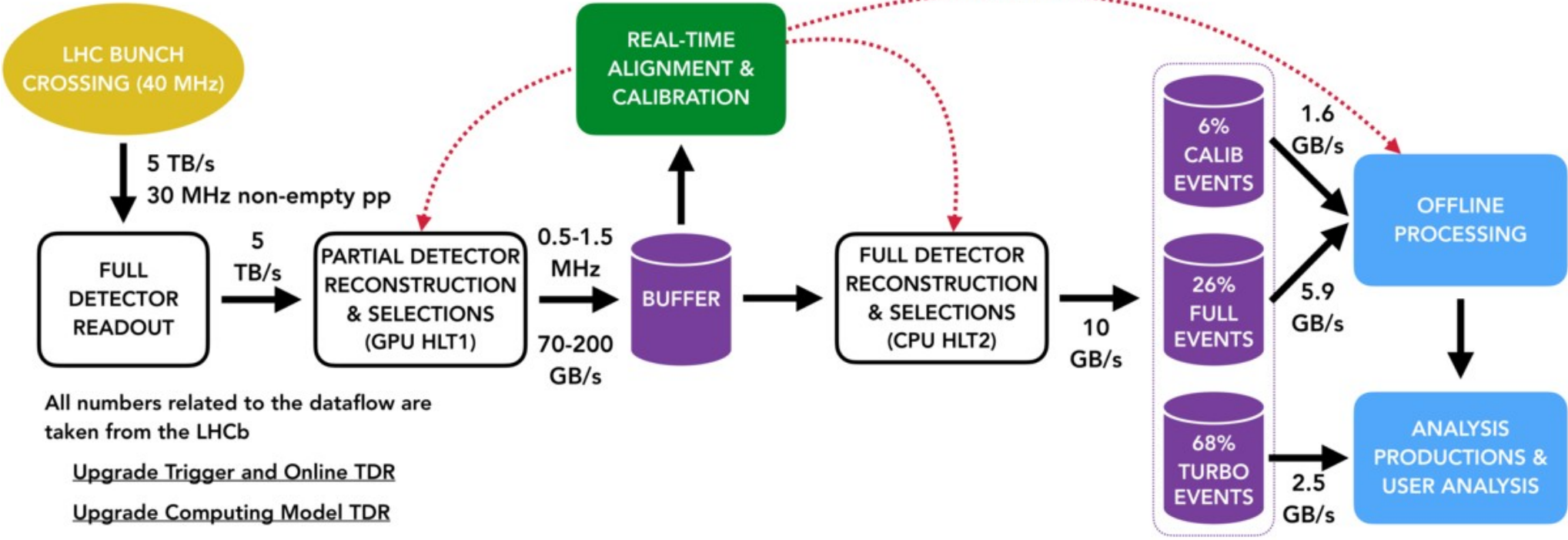
$$\text{Data rate} = \text{event size} * \text{event rate}$$
- Selecting events online with offline quality allows to reduce event size and so increase the event rate → **Turbo strategy.**

LHCb-FIGURE-2020-016

LHCb Run 2 Trigger Diagram

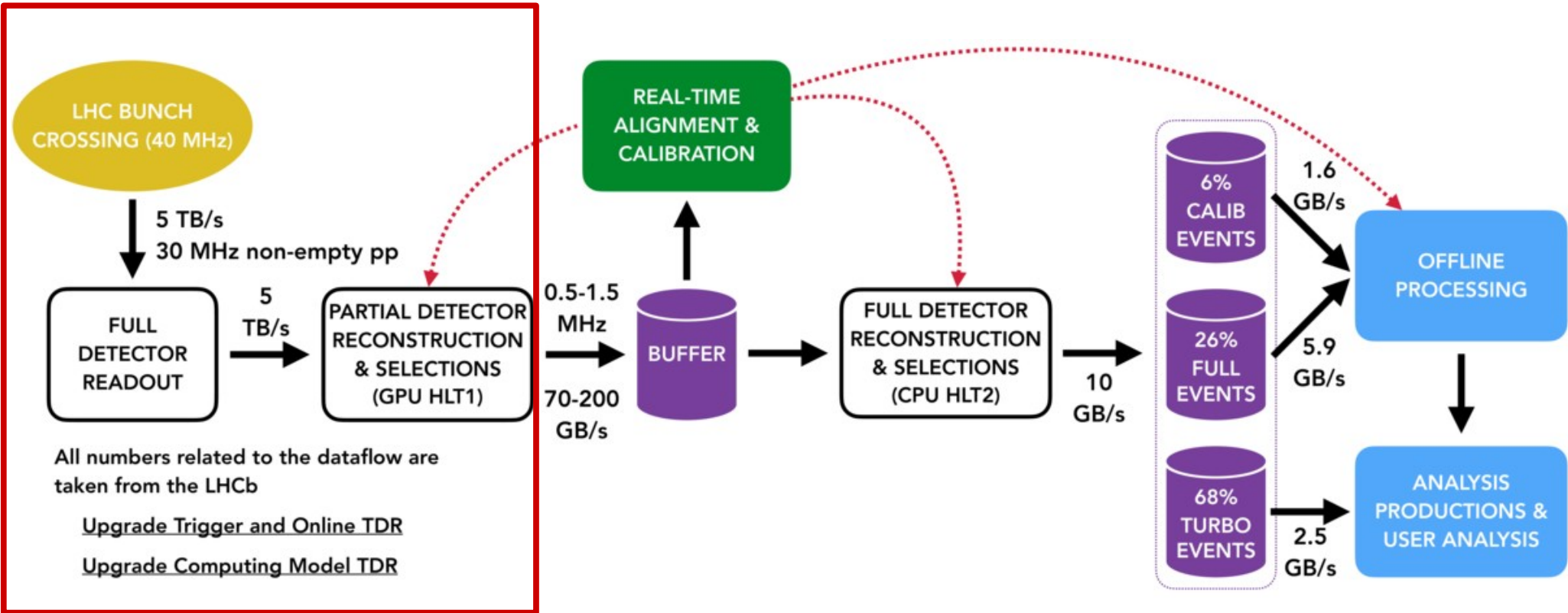


The new LHCb data flow



LHCb-FIGURE-2020-016

Data preparation & HLT1

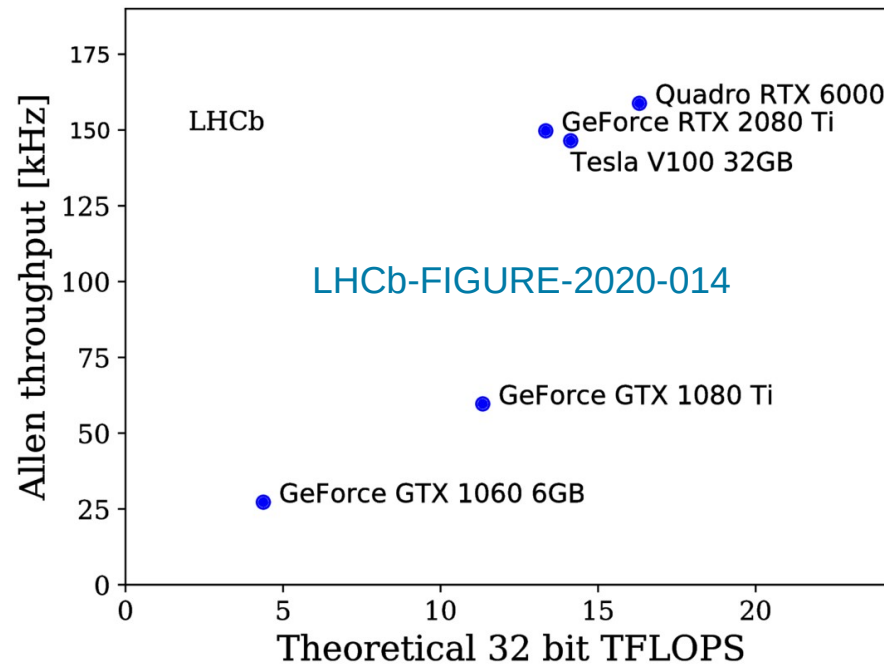


LHCb-FIGURE-2020-016

HLT1: concept and challenges

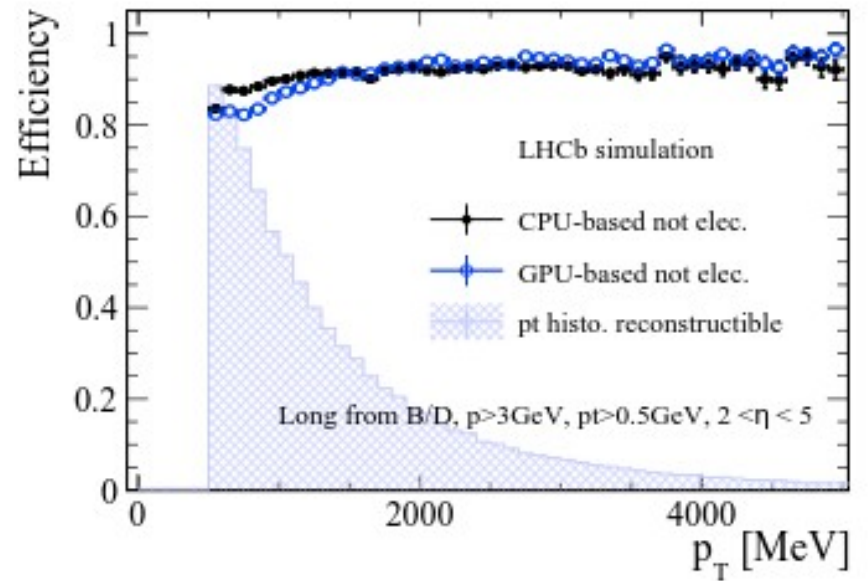
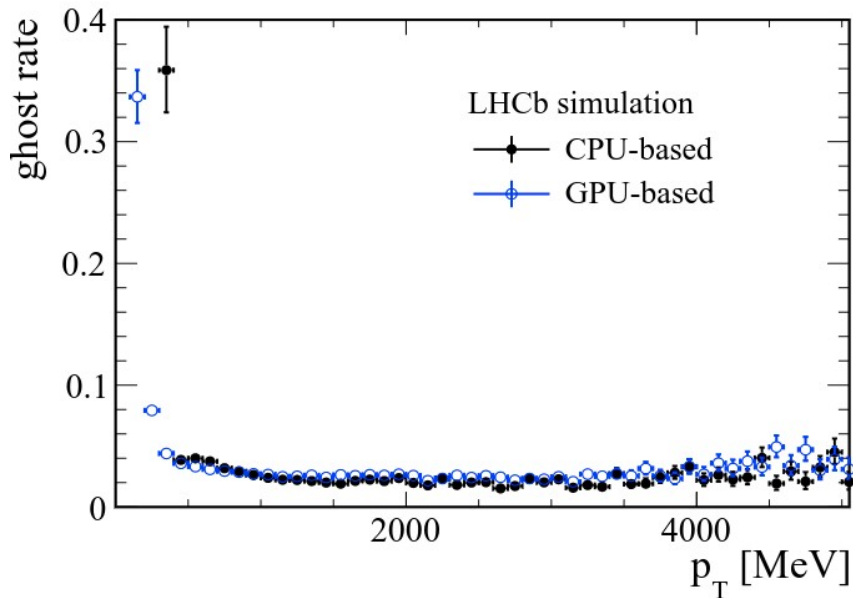
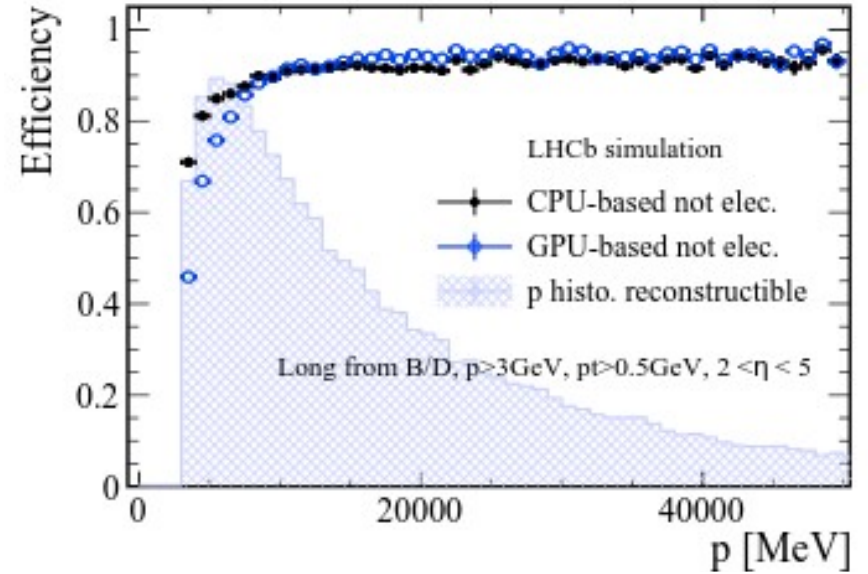
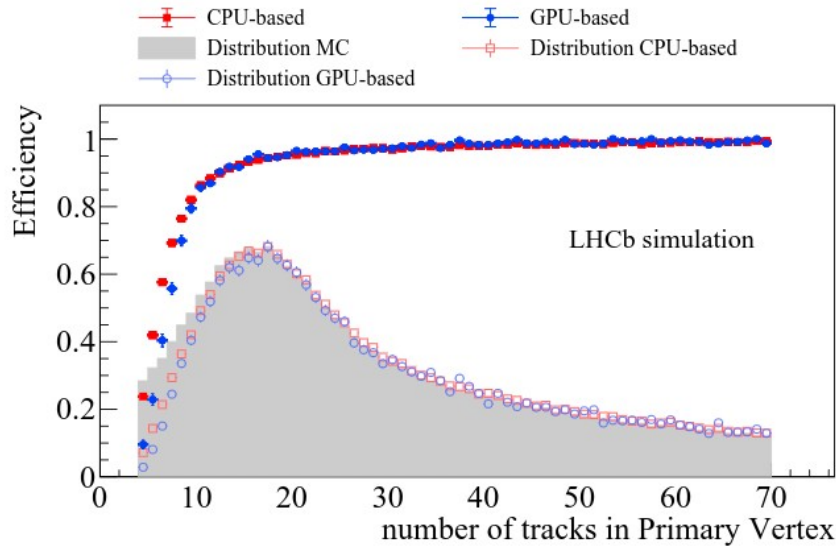
- Due to increased luminosities and cross-sections, simple signatures (transverse energy and momentum) not enough to select signal efficiently.
 - “rare signal over abundant background” does not hold anymore: era of abundant signals.
- Better signatures require tracking algorithms to be run at 30 MHz of inelastic collisions.
- Focus of a lot of work by LHCb over past years (see V. Gligorov’s talk at [CPAD](#)).
 - Chosen solution: [GPU-based HLT1](#), selecting over similar signatures as in Run 2.
 - Takes advantage of the highly-parallel nature of the task

Process HLT1 on fewer than 500 state-of-the-art GPUs.



Performance of the HLT1: tracking and PV reconstruction

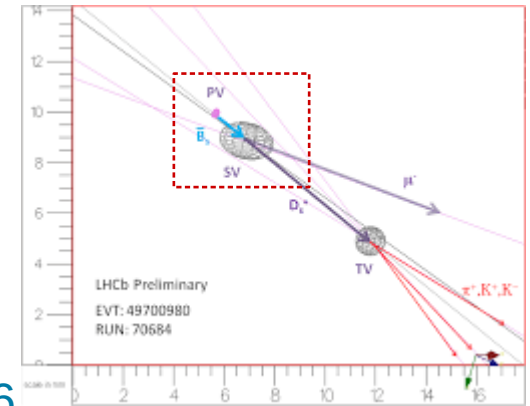
LHCb-DP-2021-003



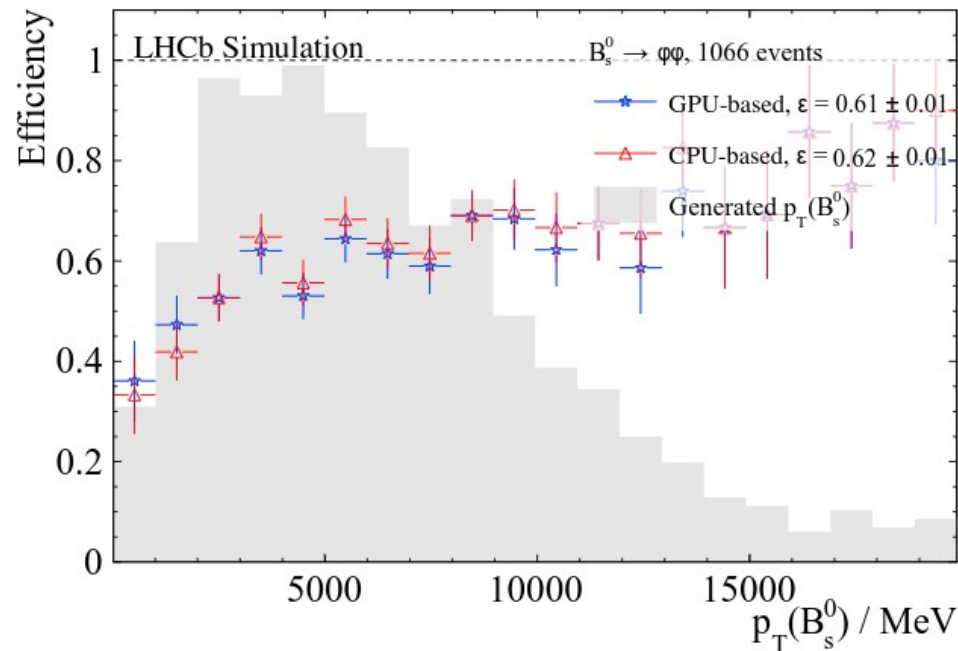
HLT1: selection efficiency

- HLT1 trigger criteria depend mainly on displaced vertices, muon-tagged tracks, and exclusive charm decays.
- Already a reasonable rate in implemented selection, for $>50\%$ efficiency on signal.
- Selections are not yet tuned completely as it also depends on final choices (including in HLT2).

CERN-LHCC-2020-006

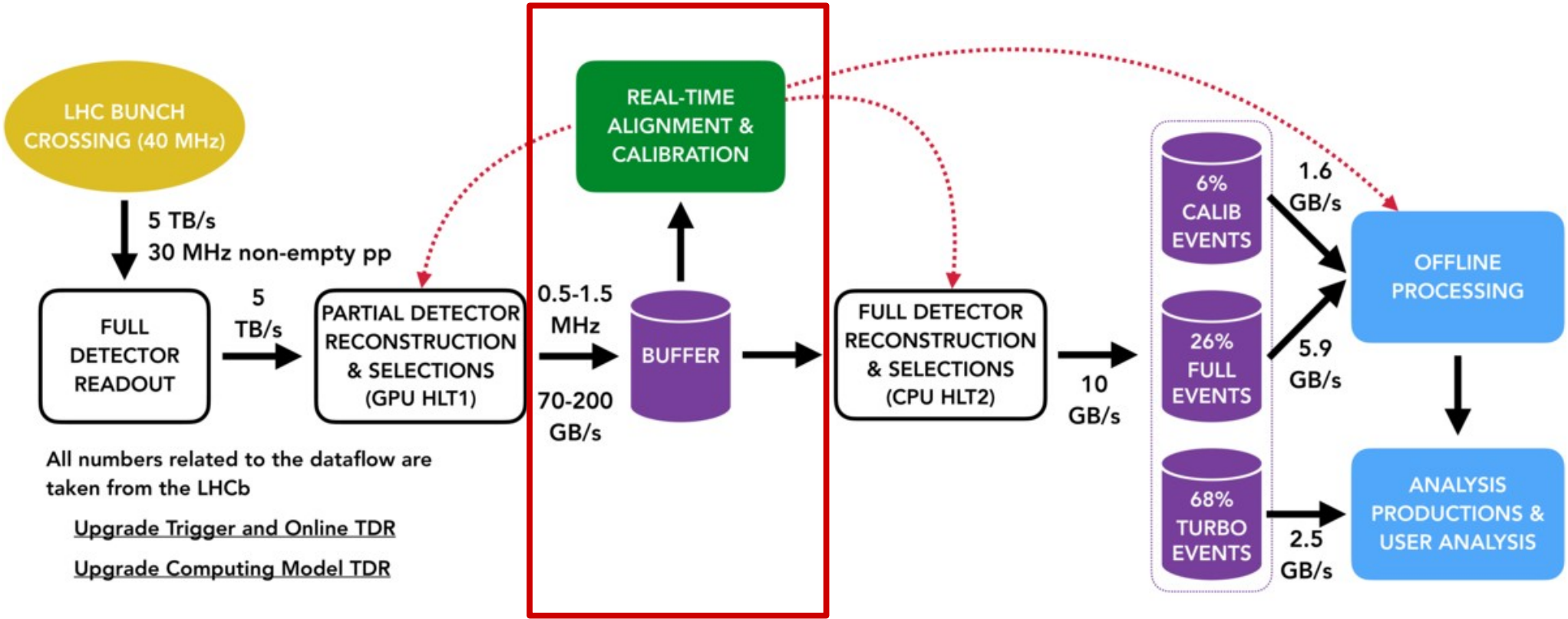


LHCb-DP-2021-003



Trigger	Rate [kHz]
ErrorEvent	0 ± 0
PassThrough	30000 ± 0
NoBeams	32 ± 3
BeamOne	0 ± 0
BeamTwo	0 ± 0
BothBeams	0 ± 0
ODINNoBias	0 ± 0
ODINLumi	0 ± 0
GECPassthrough	27862 ± 25
VeloMicroBias	29 ± 3
TrackMVA	379 ± 11
TrackMuonMVA	24 ± 3
SingleHighPtMuon	5 ± 1
TwoTrackMVA	498 ± 12
DiMuonHighMass	125 ± 6
DiMuonLowMass	156 ± 7
DiMuonSoft	5 ± 1
D2KPi	98 ± 5
D2PiPi	41 ± 4
D2KK	77 ± 5
Total w/o pass through lines	1115 ± 18

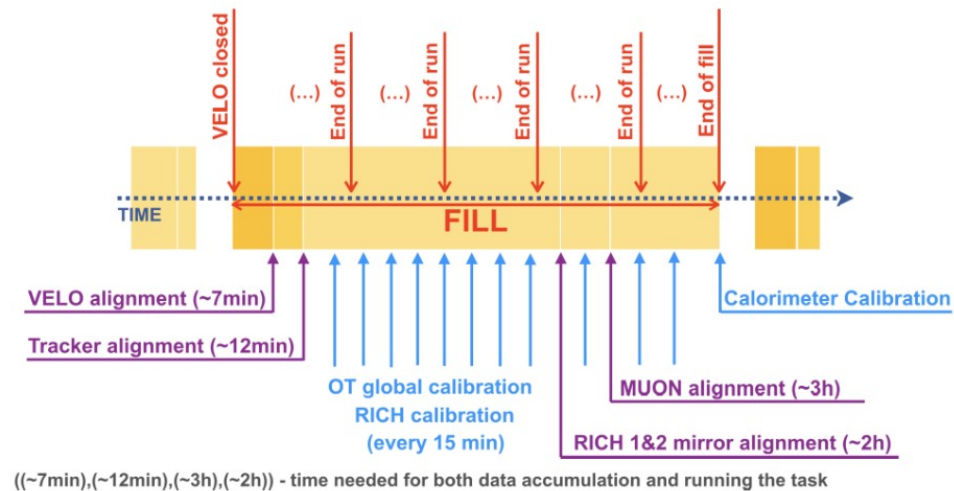
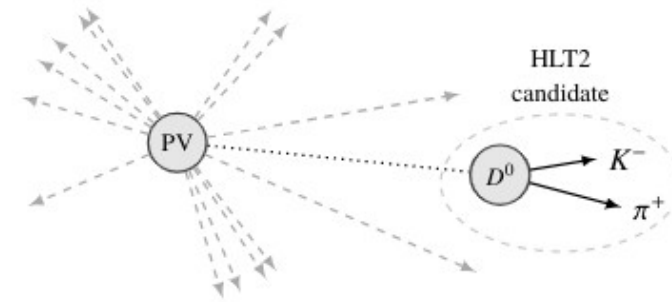
Real-time alignment and calibration



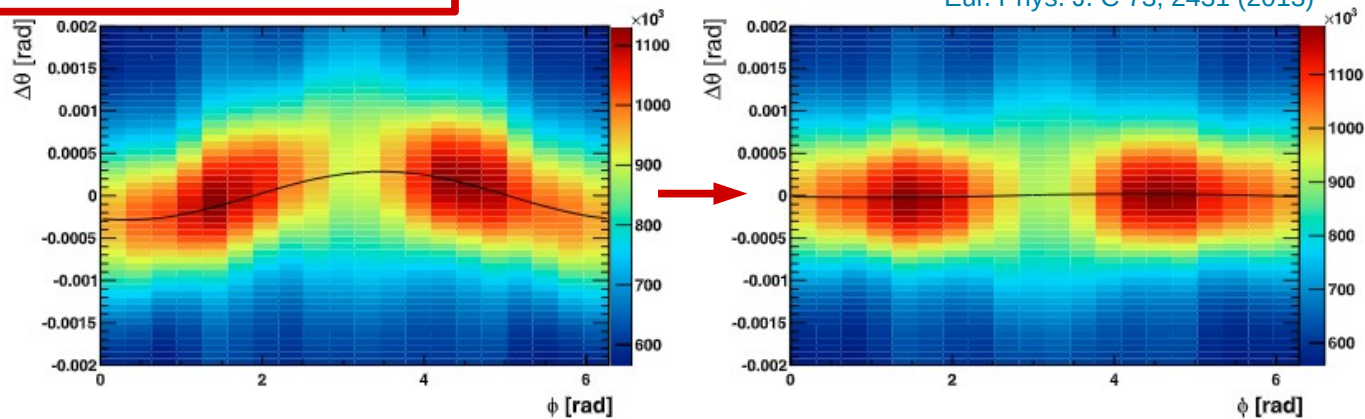
LHCb-FIGURE-2020-016

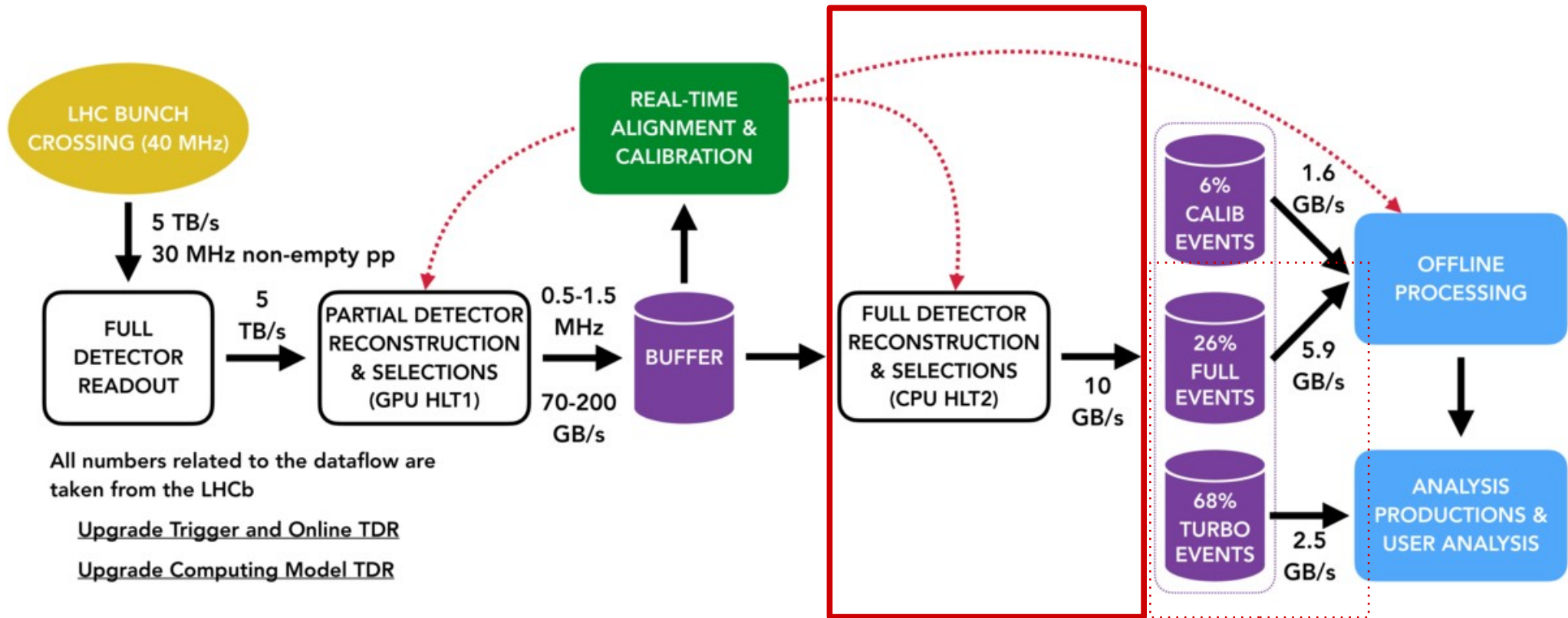
Real-time alignment and calibration

- Increased share of the Run 2 “Turbo” strategy: statistics for abundant modes can be increased if decision is taken at trigger level to only write part of the event.
 - This is what requires real-time alignment and calibration as aim is to have offline-quality quantities to take the decision on.
 - See Vitalii Lisovskyi’s talk on Thursday [[link](#)] for more precision.
 - See also N. Skidmore talk at ICHEP 2020 [[link](#)]



Example from Run1: RICH mirrors

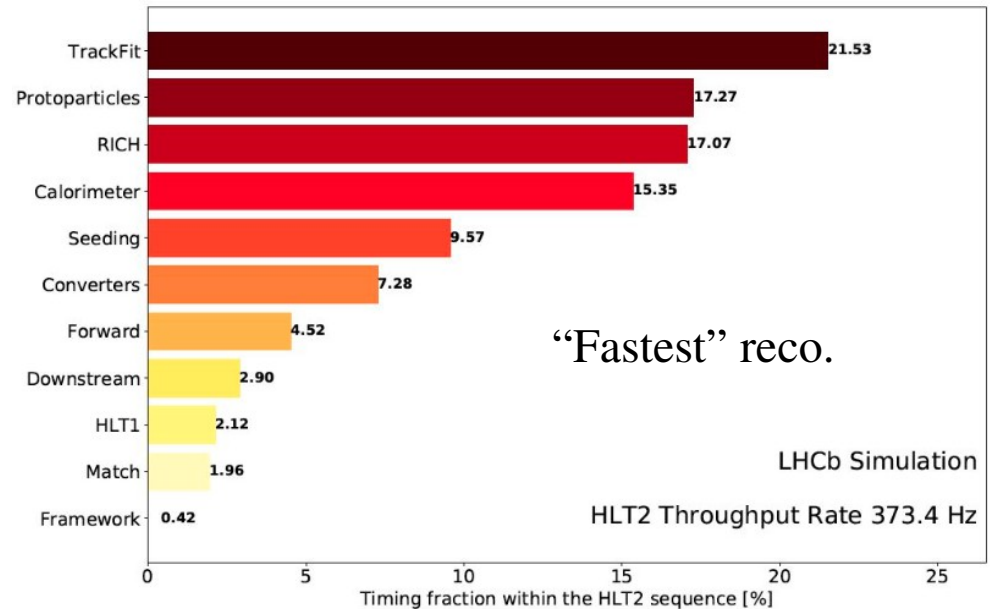
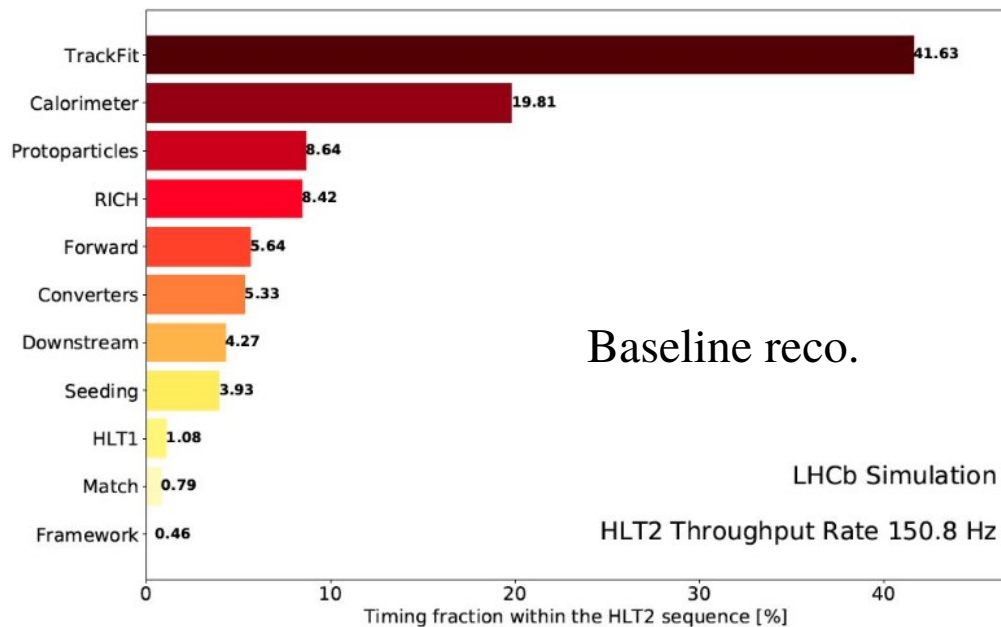




LHCB-FIGURE-2020-016

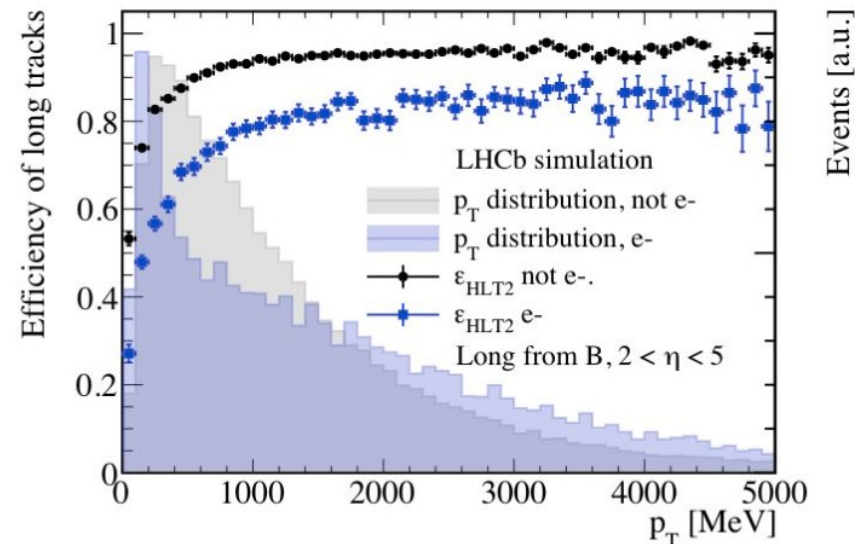
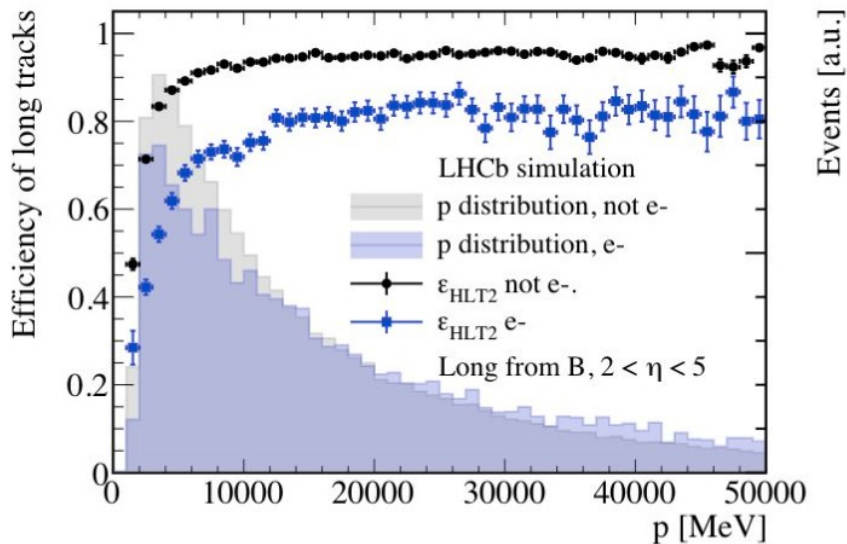
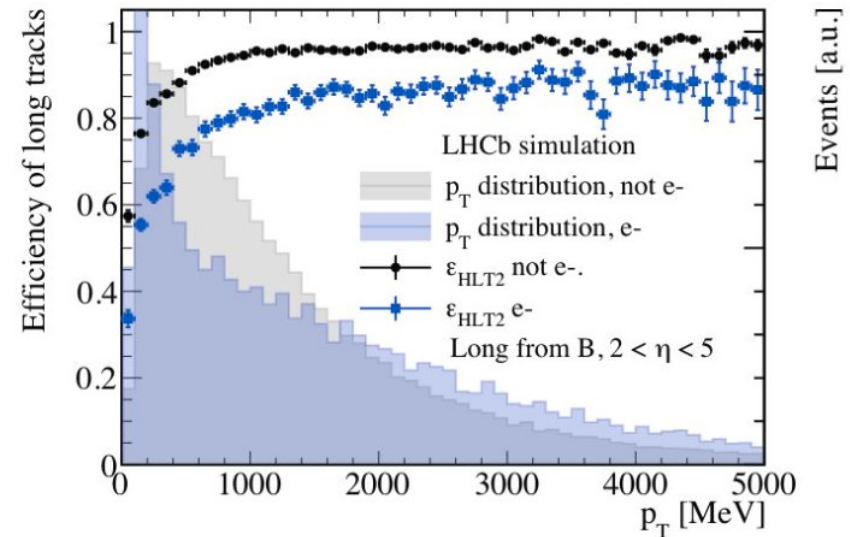
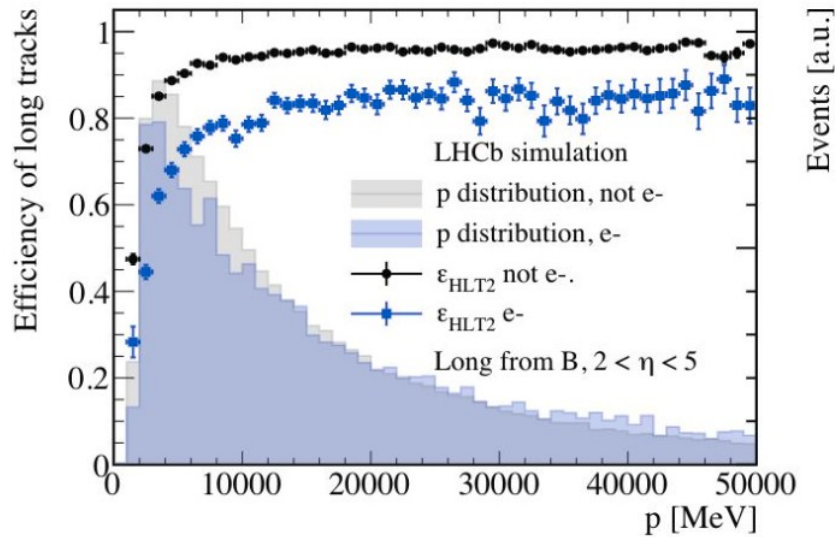
HLT2: timing

- While dealing with a much reduced data flow compared to HLT1, HLT2 must do much more:
 - Full reconstruction with offline-quality resolution
 - Hundreds of exclusive decay lines
- Previous (LHCP 2020) throughput was at 133 Hz/node on baseline configuration.
- New configuration: “fastest” → limited use of track fit, less overlap between tracking algorithms, selective matching of tracks ↔ ECAL clusters.
- 300Hz is already a milestone throughput for HLT2.



HLT2 efficiencies

- Baseline reconstruction (top) vs fastest reconstruction (bottom).



Conclusion

- The LHCb data flow has been overhauled for the upgrade
 - Essential to perform data analysis at the same level of precision or better with the increased luminosity.
 - Full software trigger
 - Increased share of the Turbo stream → real-time calibration + selective persistence.
- HLT1:
 - Throughput already compatible with operations
 - Efficiency on long tracks on par with Run 2
 - Trigger lines already have reasonable rates, need to be tuned.
- HLT2:
 - Throughput has progressed since a year, possible to remove some of the reconstruction
 - Efficiency on all tracks satisfactory
 - Trigger lines already being written using completely reformulated framework (not shown).
- And now?
 - Writing more lines
 - Get ready for commissioning.