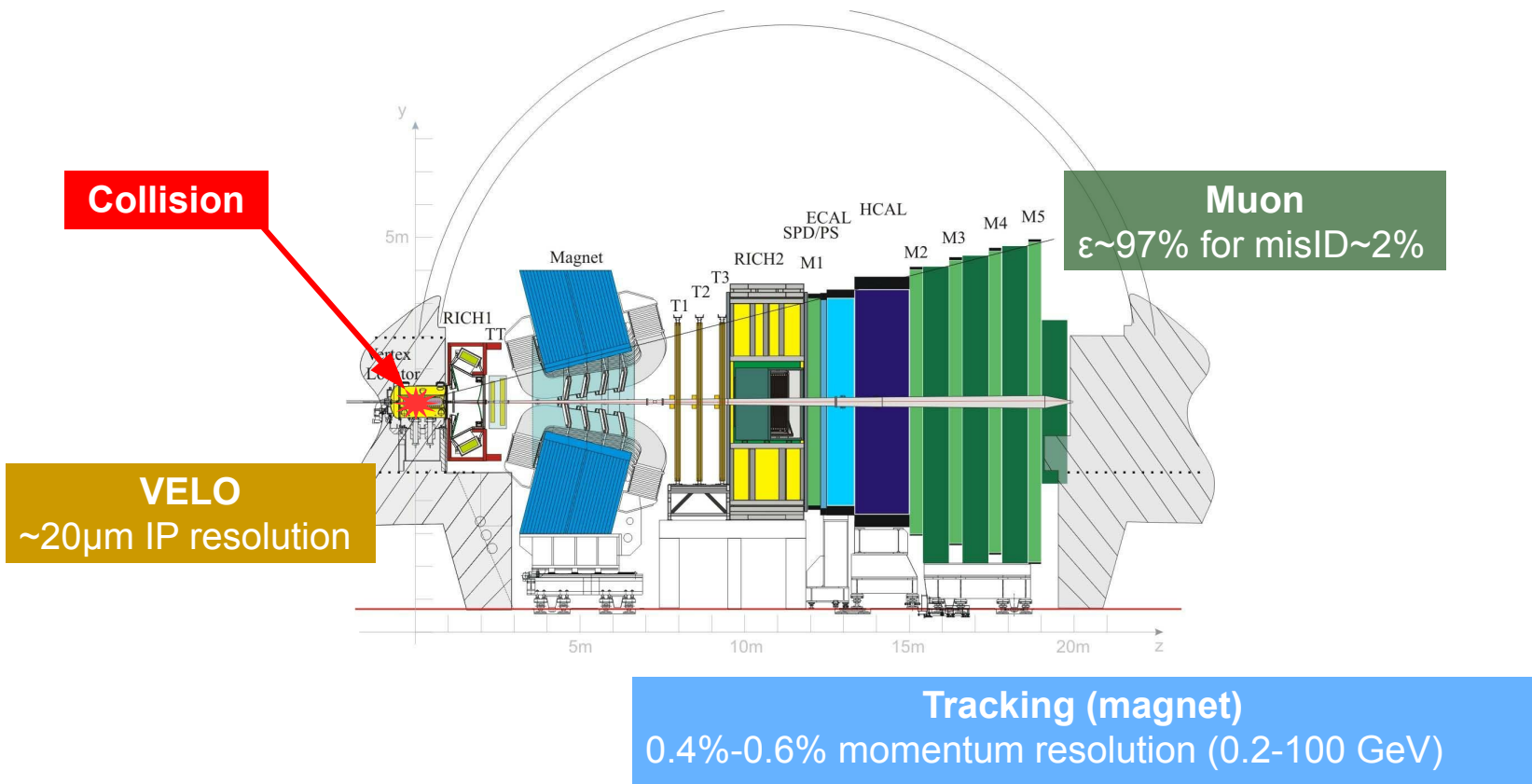


Reconstruction at 30 MHz for the LHCb upgrade

Murilo Rangel
on behalf of the LHCb Collaboration

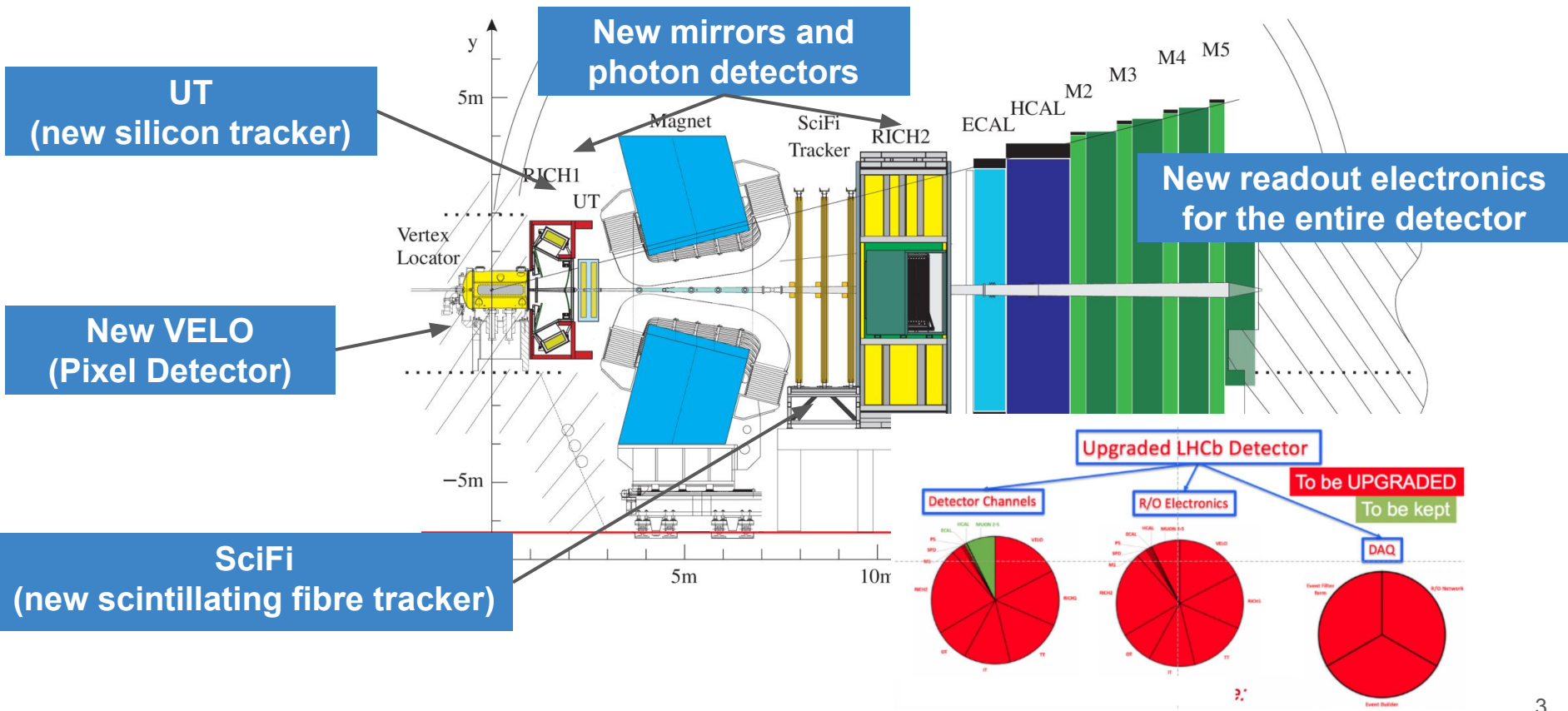


LHCb is a **single** arm spectrometer fully **instrumented** in the forward region ($2.0 < \eta < 5.0$)
Designed for heavy flavour physics and also **exploited** for general purpose physics
[Int. J. Mod. Phys. A 30, 1530022 (2015)]

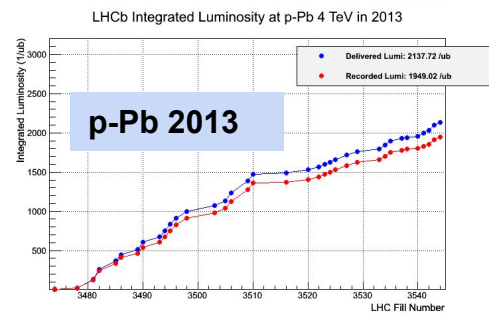
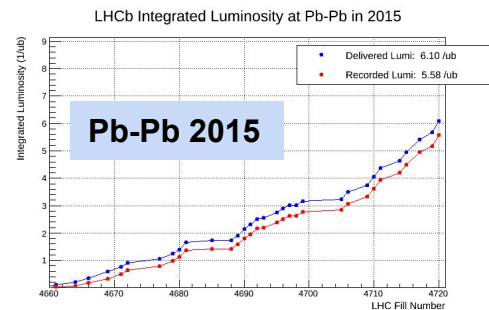
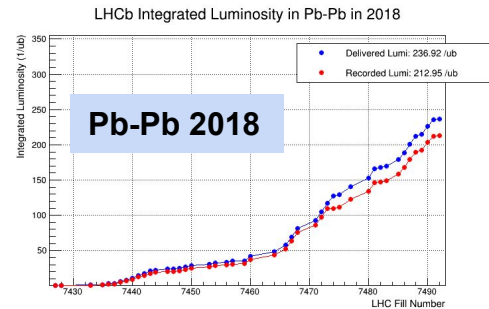
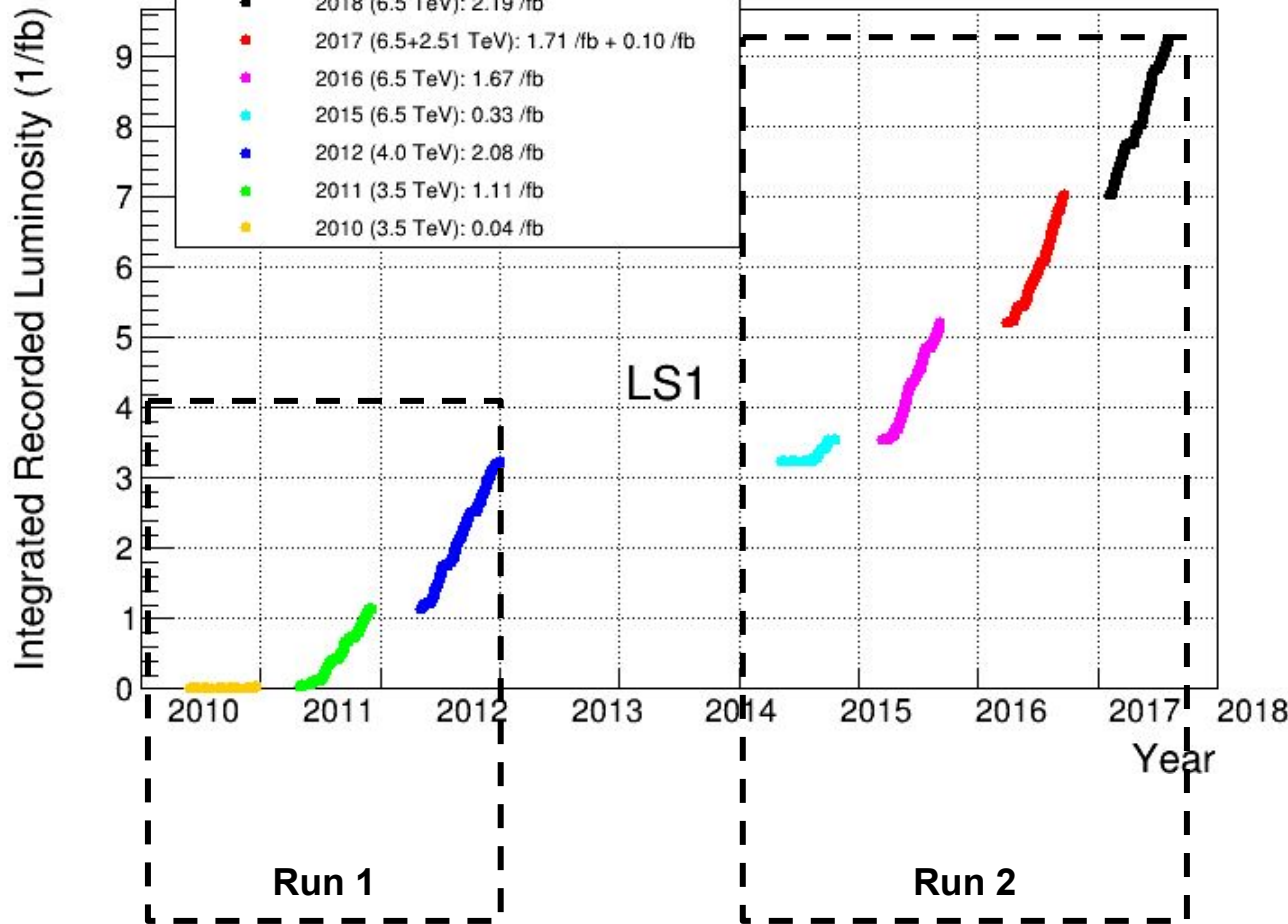


LHCb Upgrade

CERN-LHCC-2012-007

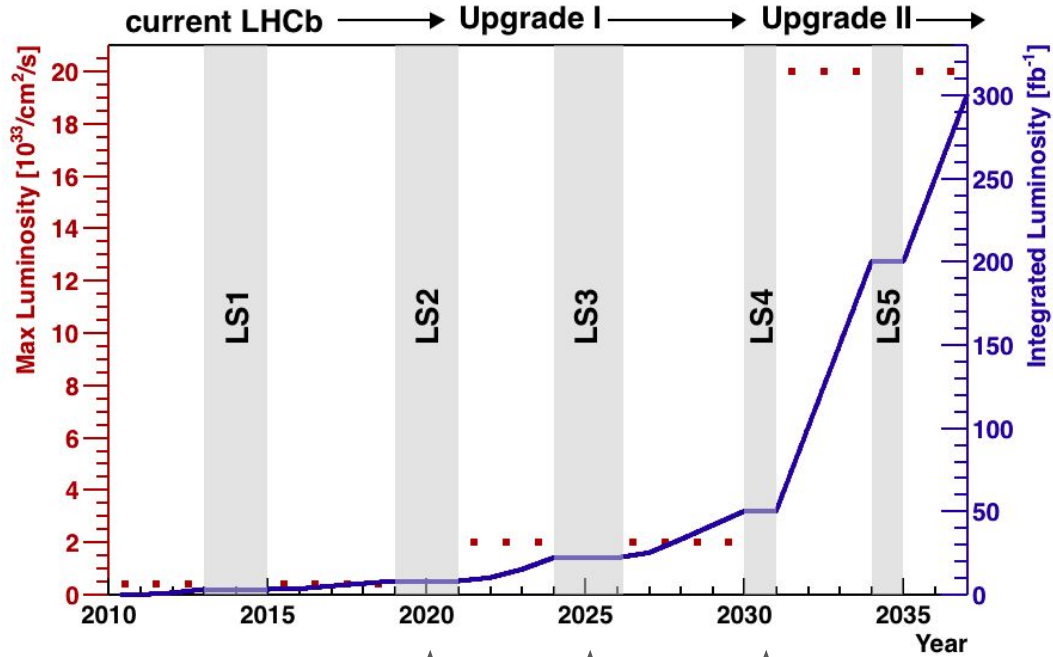


LHCb Cumulative Integrated Recorded Luminosity in pp, 2010-2018



LHCb Upgrade

[arXiv:1808.08865 \[hep-ex\]](https://arxiv.org/abs/1808.08865)



Run 1+Run 2: 9.1/fb
Run 3: 25/fb

Upgrade

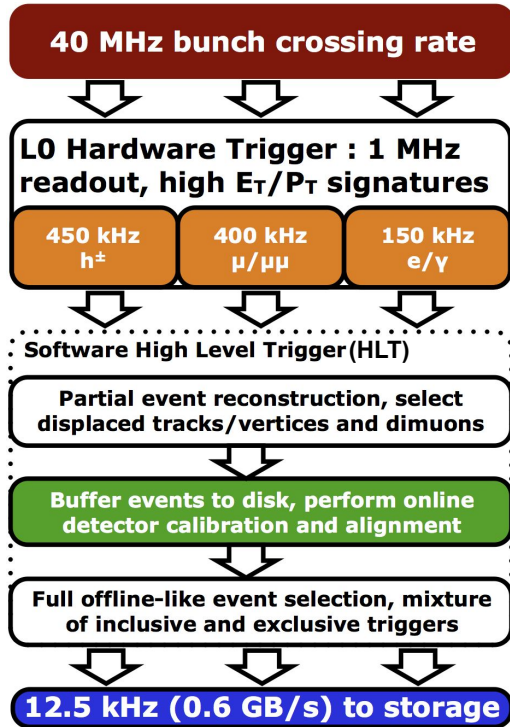
I

Ib

II

Run 2 trigger

LHCb Run II Trigger Diagram (2015 - 2019)

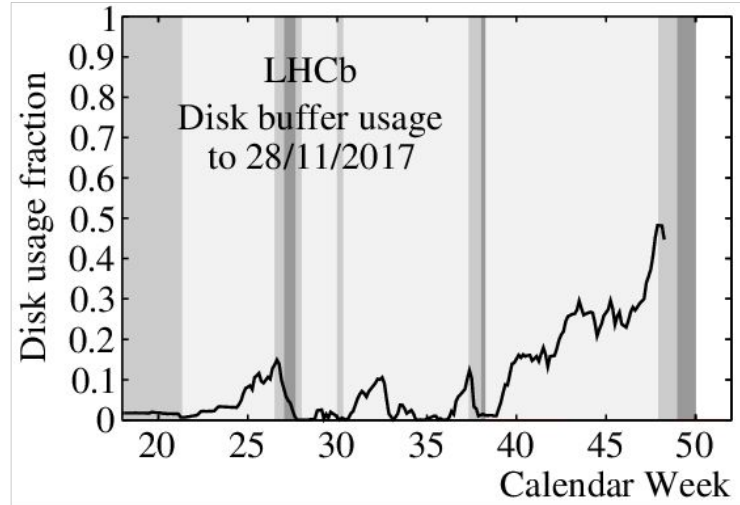
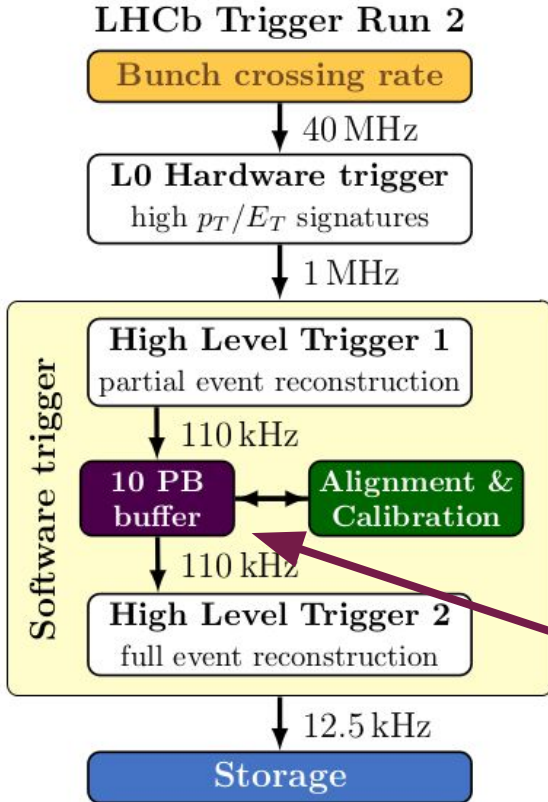


Trigger structure:

Hardware: energies deposited in calorimeters and muon stations hits are used to bring 40 MHz to 1 MHz

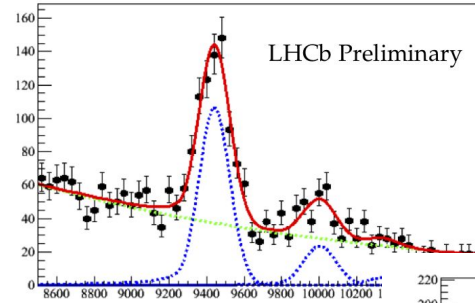
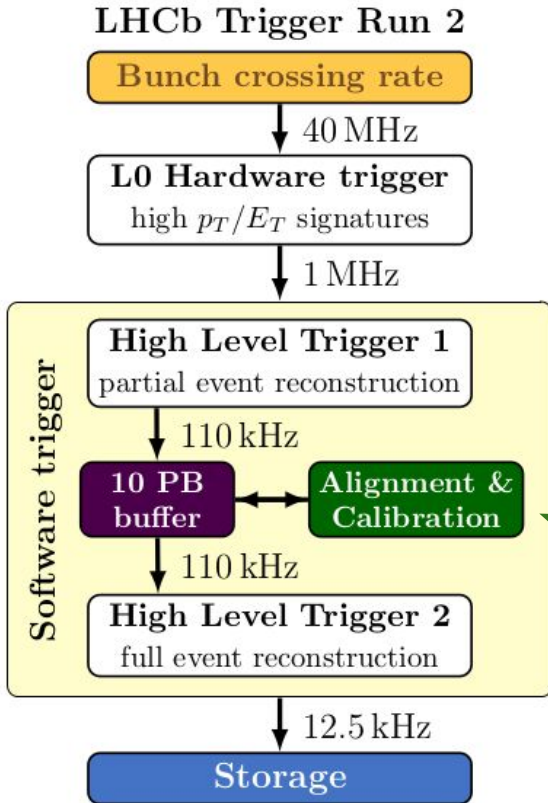
Software: events built at 1 MHz (~27000 physical cores)
HLT1: fast tracking and inclusive selections
1 MHz to 100 kHz
HLT2: complete event reconstruction and selections

Run 2 trigger

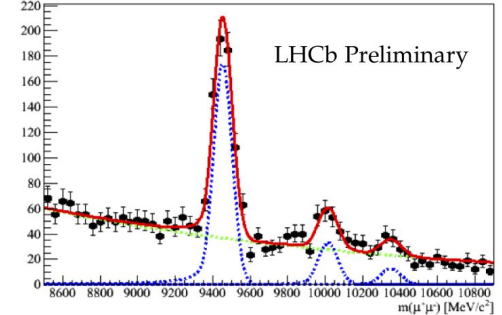


- # HLT Farm with 10 PB disk space
- # At an average event size of 55 kB with 100 kHz: up to 2 weeks before HLT2 has to be executed
- # 2x trigger CPU capacity since Farm is used twice for HLT (excess used for simulation)

Run 2 trigger



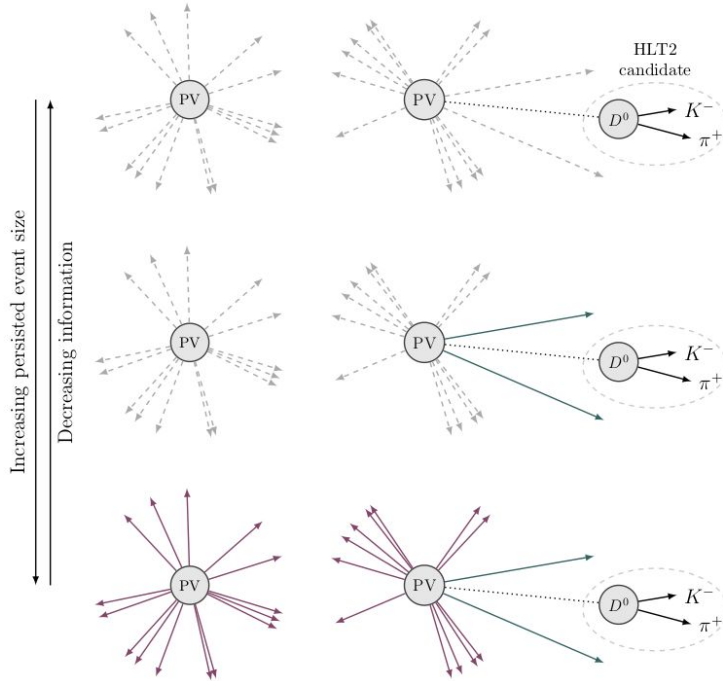
~50% improvement in mass resolution



- # Real-time alignment and calibration
- # Dedicated HLT1 trigger lines supply samples for the alignment
- # Alignment & calibration tasks run in parallel while events are being processed by HLT1

Run 2 trigger: Turbo

$$\text{Bandwidth [GB s}^{-1}] \propto \text{Trigger output rate [kHz]} \times \boxed{\text{Average event size [kB]}}$$



Turbo data processing model

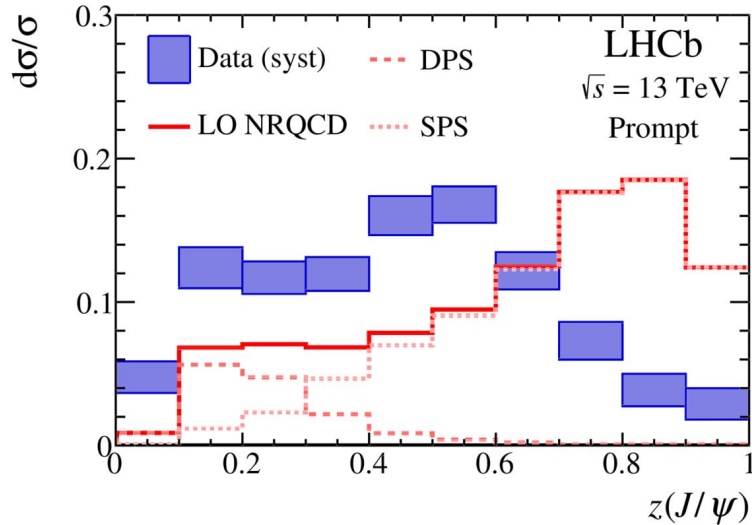
- # Analyses that can be done using trigger objects can profit of reduced event size and higher trigger rate.
- # Event size can be reduced from 70 kB to 7 kB depending on the persistence level
- # Calibration samples increased, reducing systematic uncertainties on efficiency measurements
- # 50% of HLT2 trigger lines are Turbo counting 10% of the bandwidth

Run 2 Trigger: Turbo Analyses

Study of J/ψ Production in Jets

R. Aaij *et al.* (LHCb Collaboration)
Phys. Rev. Lett. **118**, 192001 – Published 8 May 2017

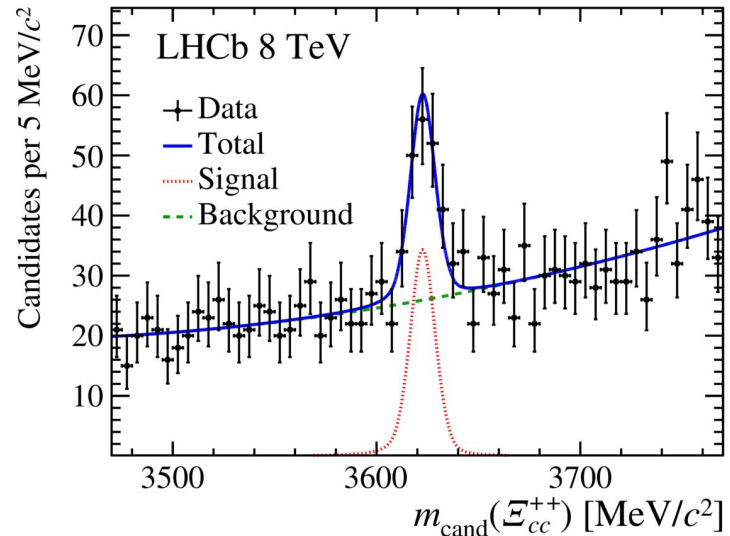
Physics See Viewpoint: [Probing Quarkonium Production in Jets](#)



Observation of the Doubly Charmed Baryon Ξ_{cc}^{++}

R. Aaij *et al.* (LHCb Collaboration)
Phys. Rev. Lett. **119**, 112001 – Published 11 September 2017

Physics See Viewpoint: [A Doubly Charming Particle](#)

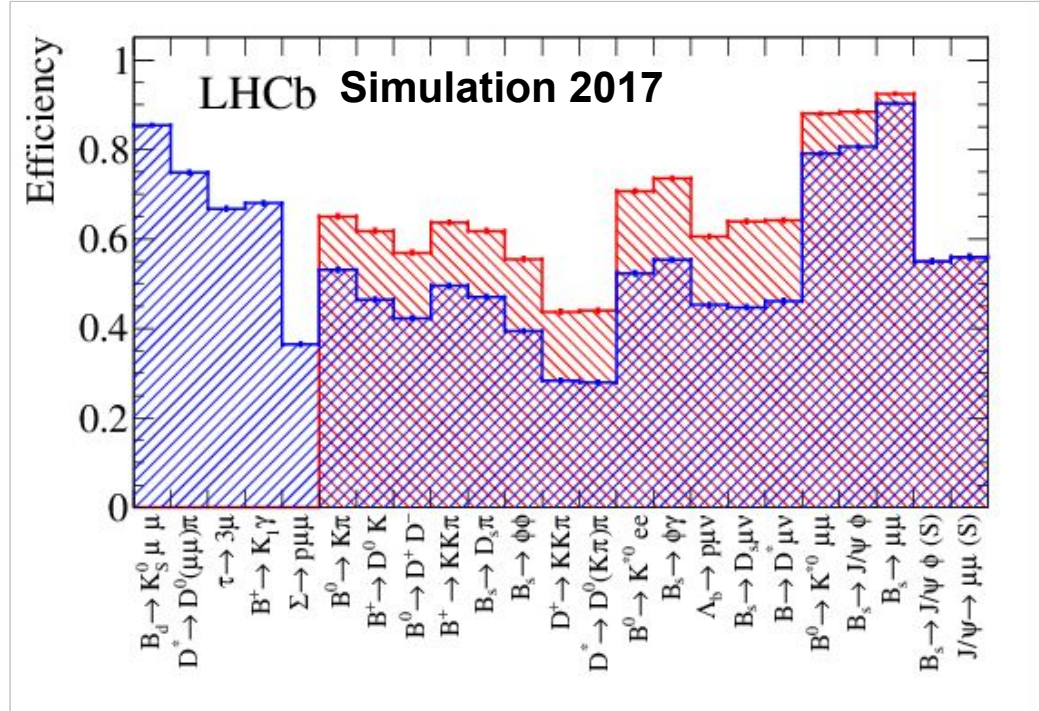


Run 2 trigger: Efficiencies

$$\epsilon = \frac{N(\text{TOS and TIS})}{N(\text{TIS})}$$

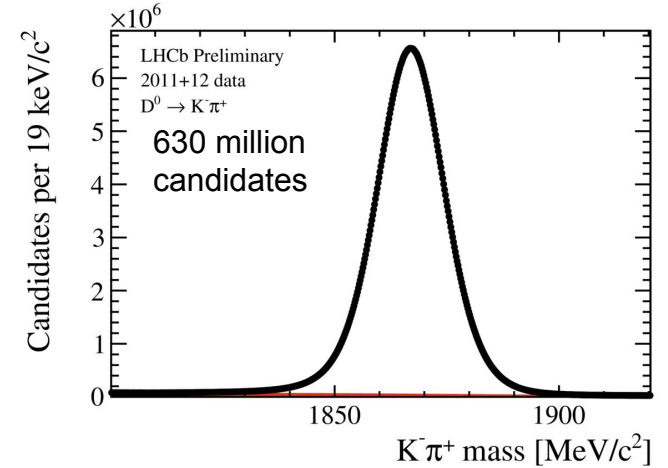
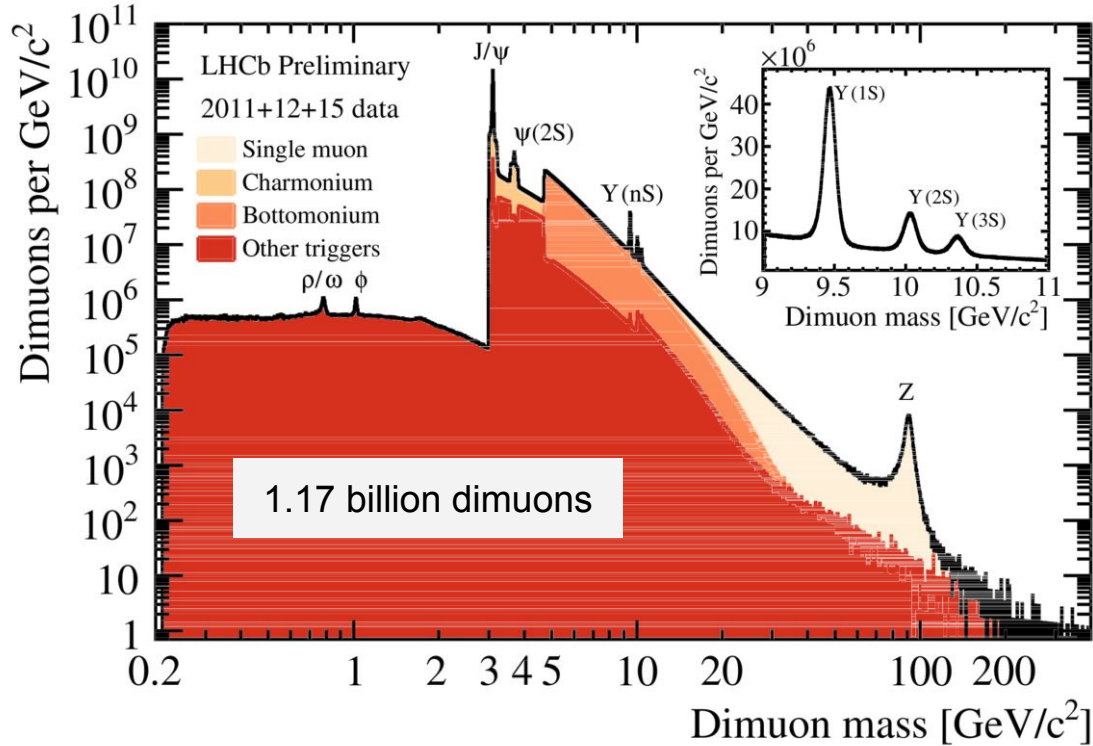
TOS: events triggered on the signal
TIS: events triggered independently of the presence of the signal

If entire L0 bandwidth is granted
 If there is bandwidth division



Run 2 trigger: Plots

[LHCb-CONF-2016-005](#)



Rare events: high efficiency
Copious production: high purity

LHCb Upgrade I

✳ Increase instantaneous luminosity:
 $4 \times 10^{32} \rightarrow 2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

✳ Replacement of tracking detectors
finer granularity to cope with higher particle density
new front-end electronics compatible with 30 MHz readout

✳ Remove hardware trigger stage and operate software trigger at 30 MHz input rate with 5 x more pileup than Run 2.

✳ **HLT1 output:** from 100 kHz to 1 MHz
Disk buffer contingency: from weeks to days
HLT2 output: from 0.6 GB/s to 10 GB/s

LHCb Upgrade Trigger Diagram

**30 MHz inelastic event rate
(full rate event building)**

Software High Level Trigger

Full event reconstruction, inclusive and exclusive kinematic/geometric selections

Buffer events to disk, perform online detector calibration and alignment

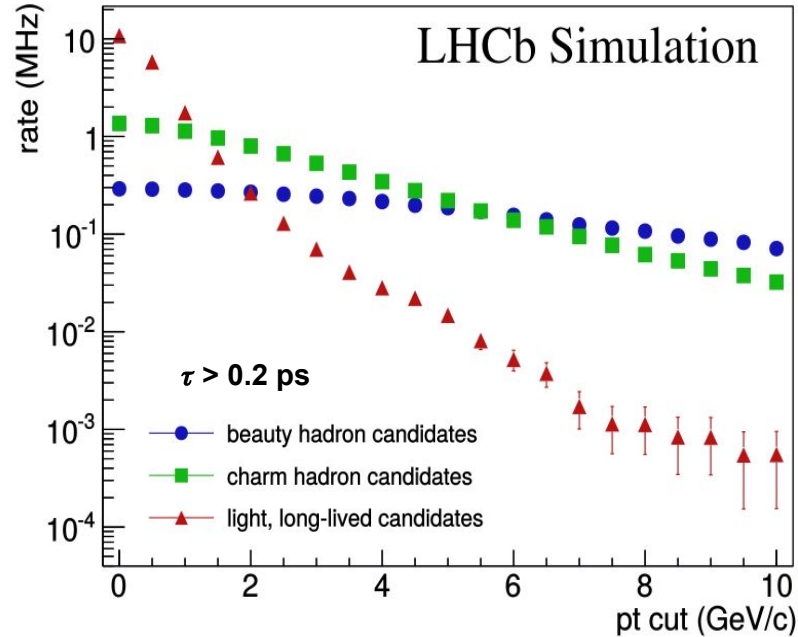
Add offline precision particle identification and track quality information to selections
Output full event information for inclusive triggers, trigger candidates and related primary vertices for exclusive triggers

2-5 GB/s to storage

Run 3 Trigger

[LHCb-PUB-2014-027](#)

Rates as a function of pT cut for part. reco. candidates



2018

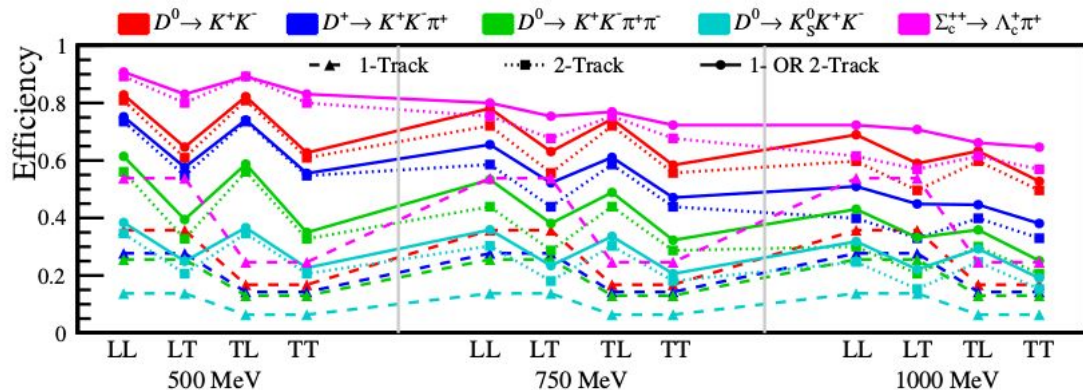
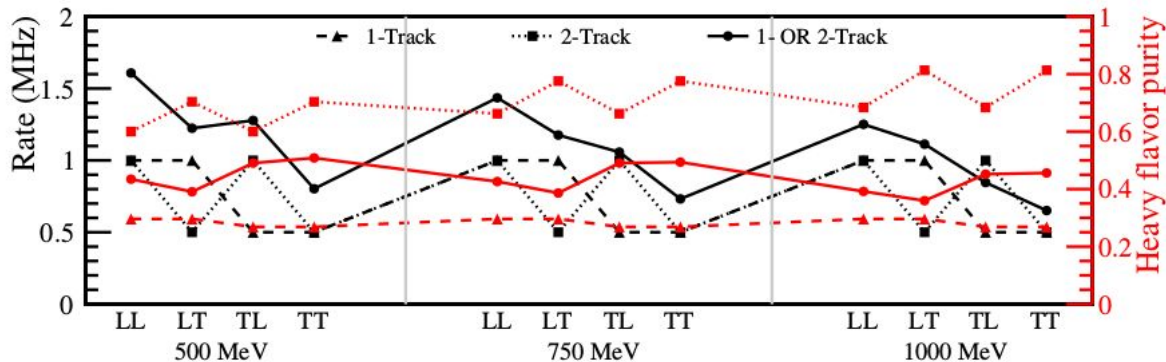
stream	event size (kB)	event rate (kHz)	rate fraction	throughput (GB/s)	bandwidth fraction
FULL	70	7.0	65%	0.49	75%
Turbo	35	3.1	29%	0.11	17%
TurCal	85	0.6	6%	0.05	8%
total	61	10.8	100%	0.65	100%

Upgrade

stream	rate fraction	throughput (GB/s)	bandwidth fraction
FULL	26%	5.9	59%
Turbo	68%	2.5	25%
TurCal	6%	1.6	16%
total	100%	10.0	100%

Run 3 Trigger: HLT1

[LHCb-PUB-2017-006](#)



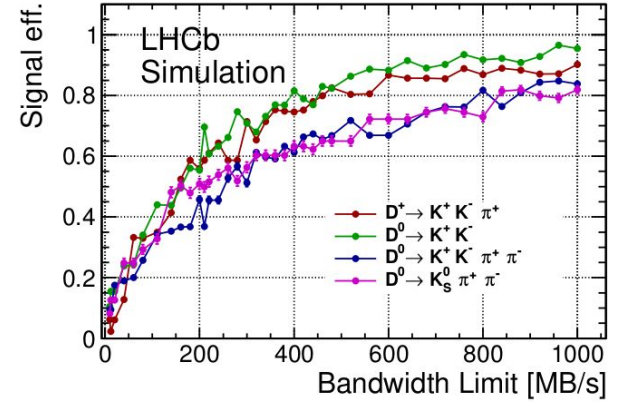
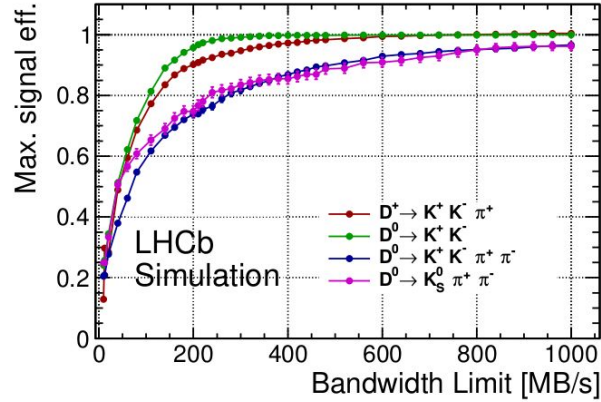
Loose (L) track selection: 1 MHz
 # Tight (T) track selection: 0.5 MHz

Inclusive selection using combination of Loose (L) and Tight (T) with different p_T thresholds

Optimisation for both selections is expected using more realistic ghost rate

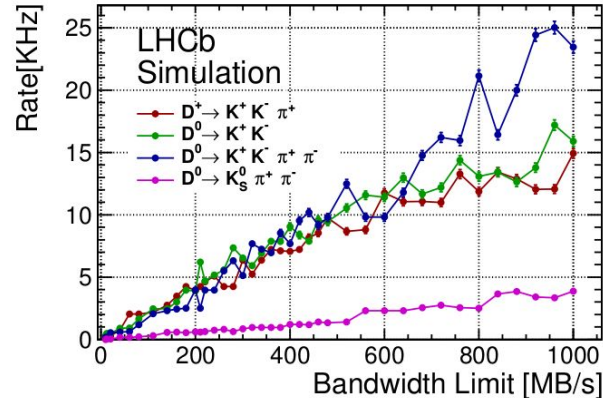
Run 3 Trigger: HLT2

[LHCb-PUB-2017-006](#)



Same strategy as in Run 2 **increasing** Turbo stream usage

To cope with many (> 500) trigger lines, a genetic-algorithm based on bandwidth division is used.



Summary

- # Success of Run 2 trigger paved the way to design Run 3 Trigger
- # No hardware trigger will allow great improvement in the trigger efficiencies
Genetic-algorithm to cope with many (> 500) trigger lines
- # Larger use of reduced event size changes the trigger performance parameters
rate \mapsto bandwidth
signal efficiency \mapsto analysis sensitivity
- # Great potential for LHCb Run 3 physics program \mapsto Great challenge to achieve it

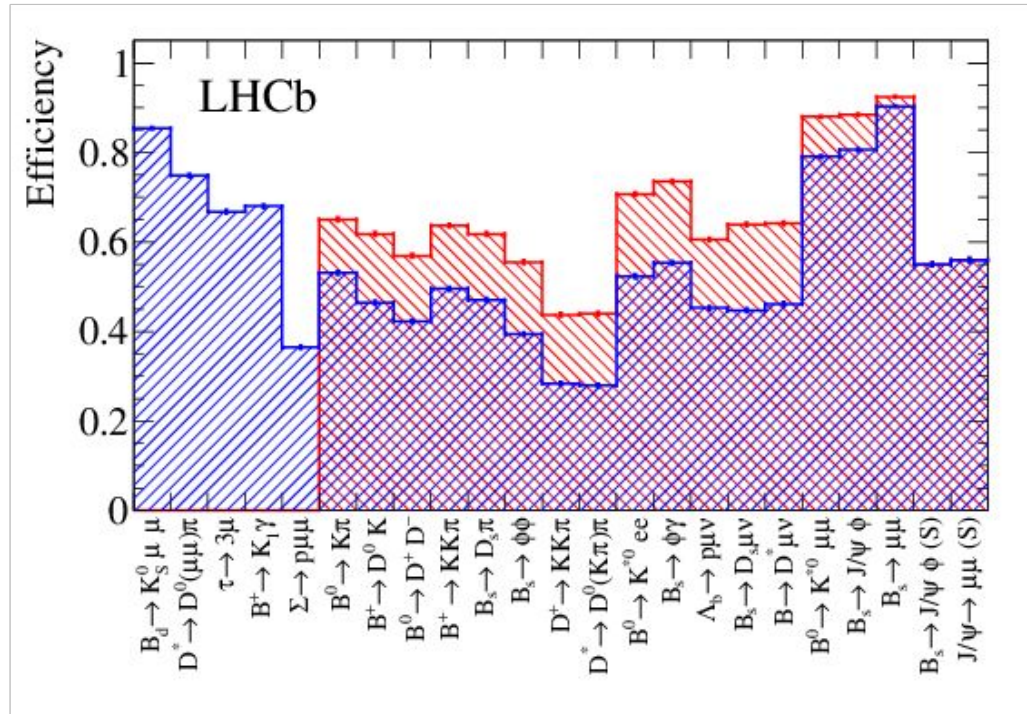


LHCb Real Time Analysis Project

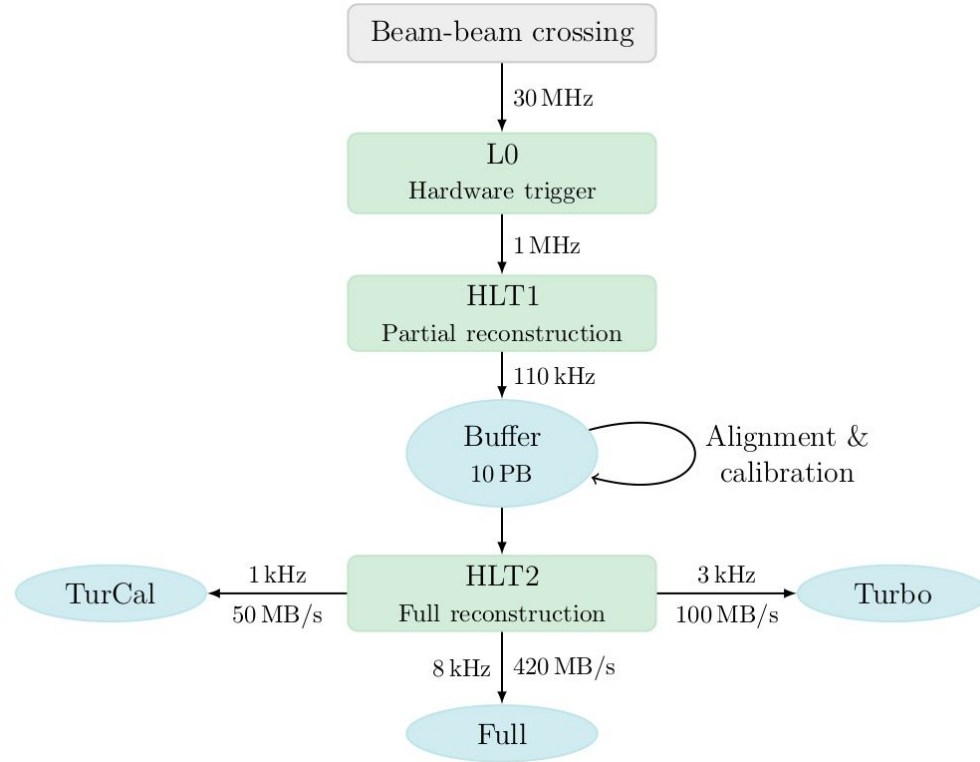
THANK YOU!!!!!!

|

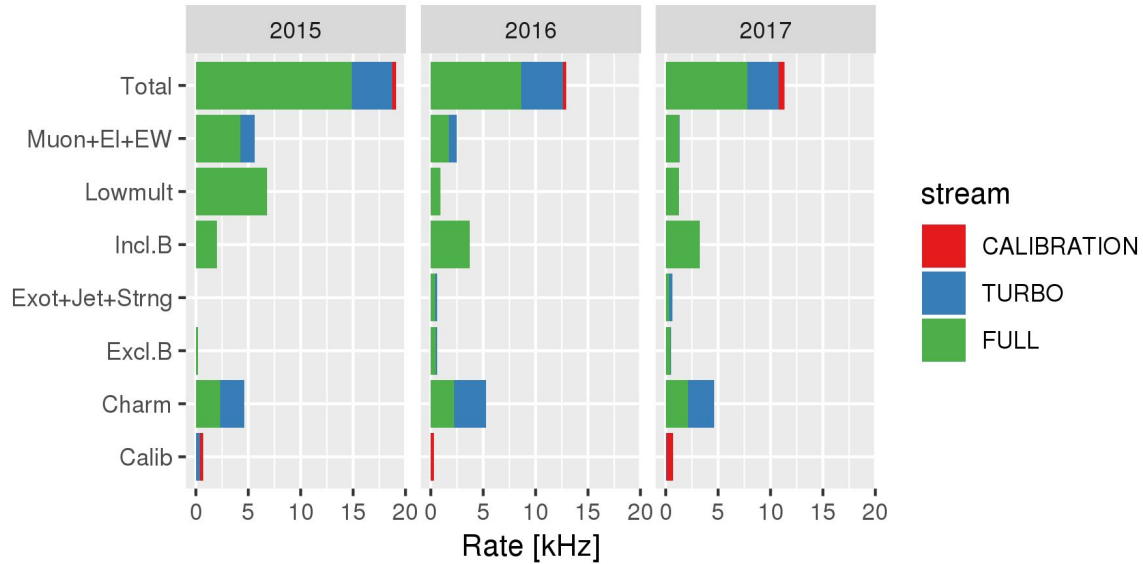
Run 2 trigger: Efficiencies



LHCb Run II trigger

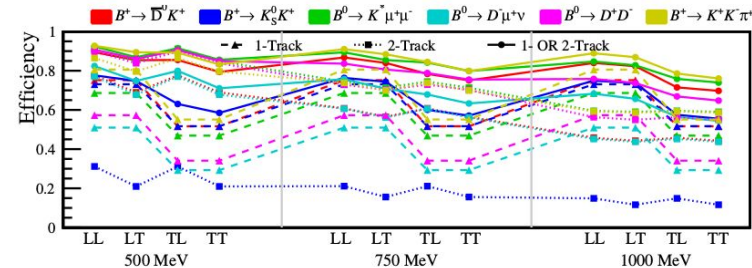
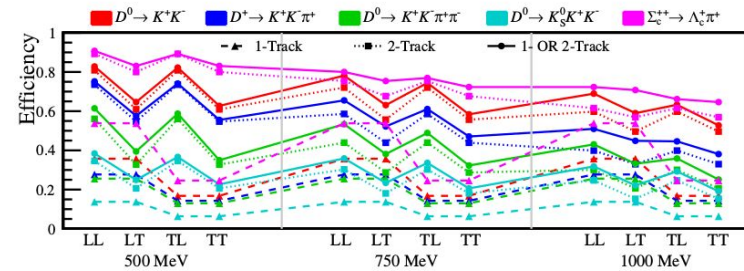
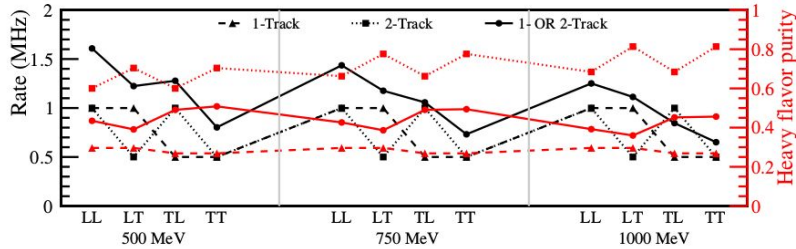


Turbo



Run 3 Trigger: HLT1

[LHCB-PUB-2017-006](#)



- # Loose (L) track selection: 1 MHz
- # Tight (T) track selection: 0.5 MHz

Inclusive selection using combination of Loose (L) and Tight (T) with different p_T thresholds

Optimisation for both selections is expected using more realistic ghost rate

Run 2 trigger: Real-time alignment

