Physics exploration with the LHCb experiment

List of the interested scientists in the community

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José Helder Lopes	UFRJ
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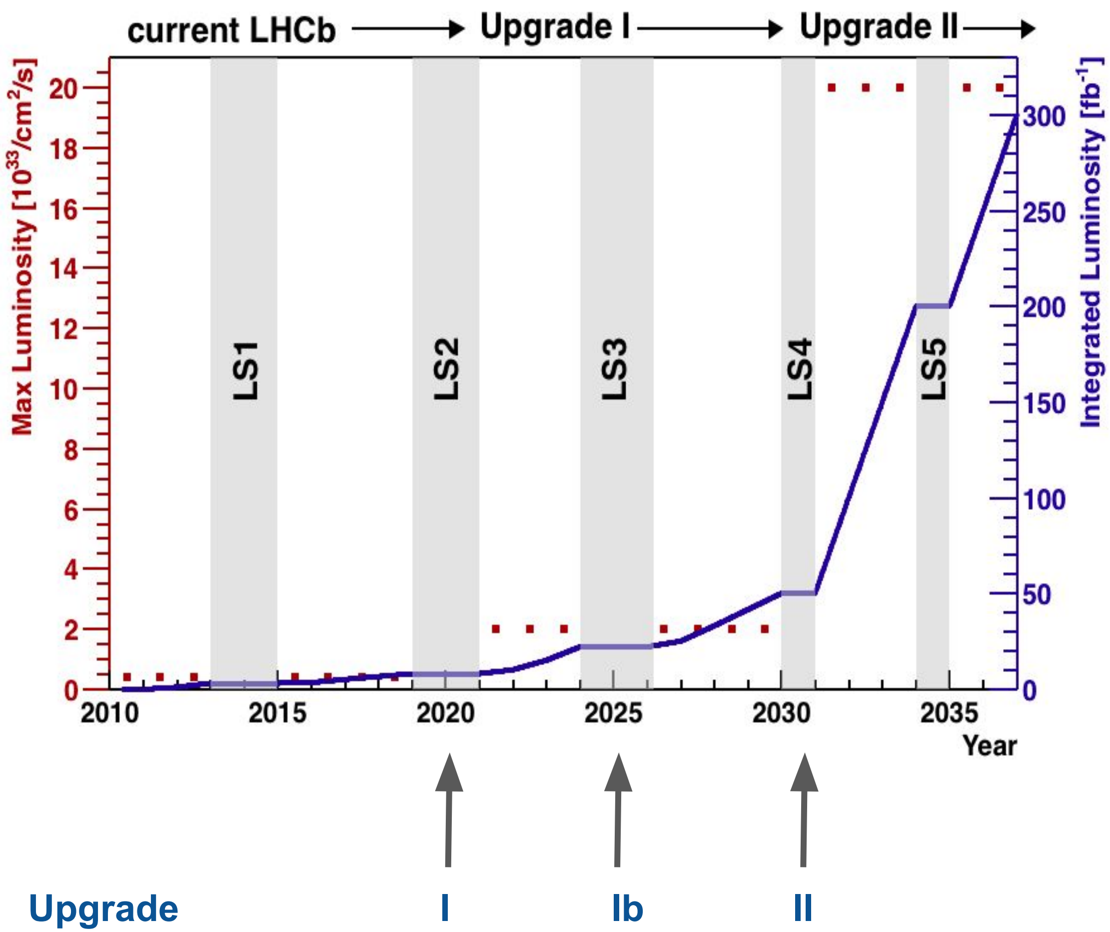
This document summarizes the participation of the Brazilian institutes in the LHCb experiment during the next 15 years. We focus on the expected challenges and costs to maintain and improve these contributions.

arXiv:1808.08865 [hep-ex]



Run 1+Run 2: 9.1/fb
Run 3: 25/fb
Run 4: 50/fb

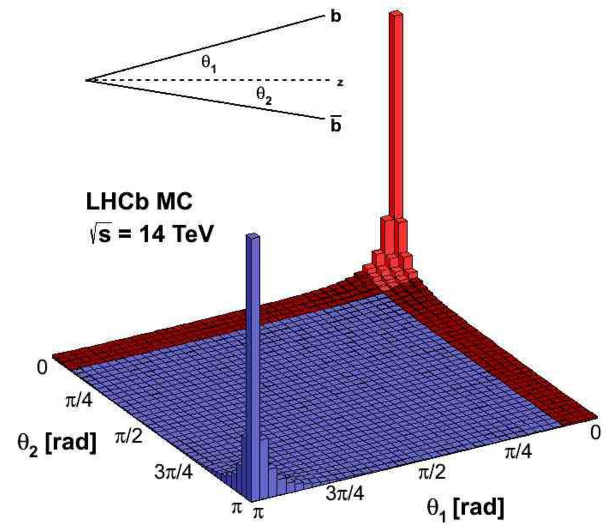
Why LHCb?

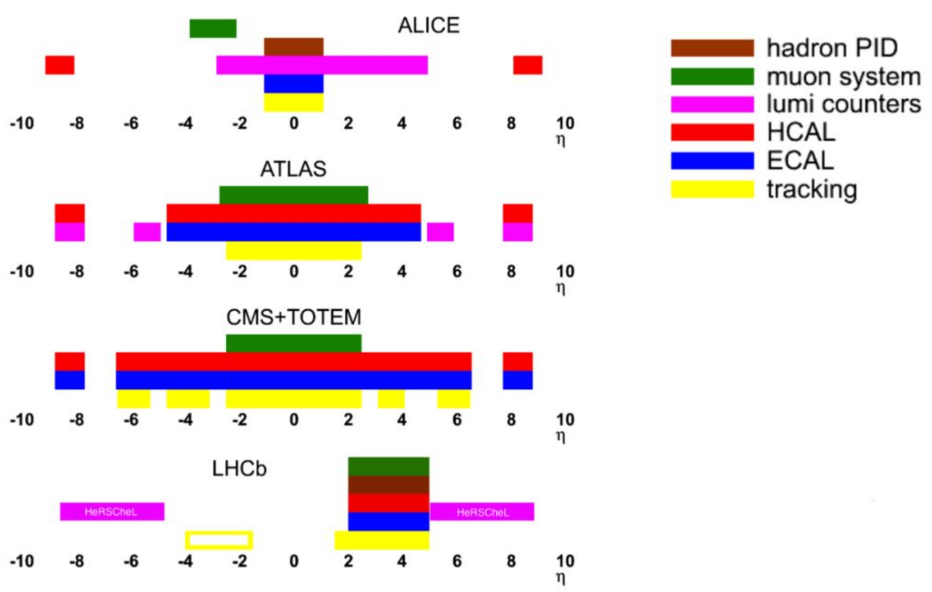
++ Dedicated heavy flavour experiment at LHC
 -- CP-violation in b/c-sector
 -- Rare b/c-hadron decays

++ Indirect searches for unknown Physics

++ Electroweak, QCD, direct searches and heavy ion

>>> General Purpose Detector in forward region





Why Upgrade?

++ Hints of beyond SM phenomena
 … Lepton flavour (non-)universality?
 … Deviations in angular analysis

++ Precision tests with very rare decays

++ Several complementary studies w.r.t. GPD

++ Higher luminosities and more efficient triggers

The Brazilian institutes have been contributing to the LHCb experiment in different projects and in the best way possible. Although it would be fair to list the successful results of these contributions despite the adversities, we will describe below only the expected challenges.

We plan to participate in the experiment operations until 2031. If the LHCb Upgrade II is approved to collect data during the High Luminosity LHC (HL-LHC) operational period, the timeline would be extended by at least five years.

Challenges and costs

** formalize commitments to LHC experiments

** infrastructure and engineering capabilities to perform detector research and development (R&D) in the institutes

… properly train our students in the local institutes

** financial support for mission trips to CERN

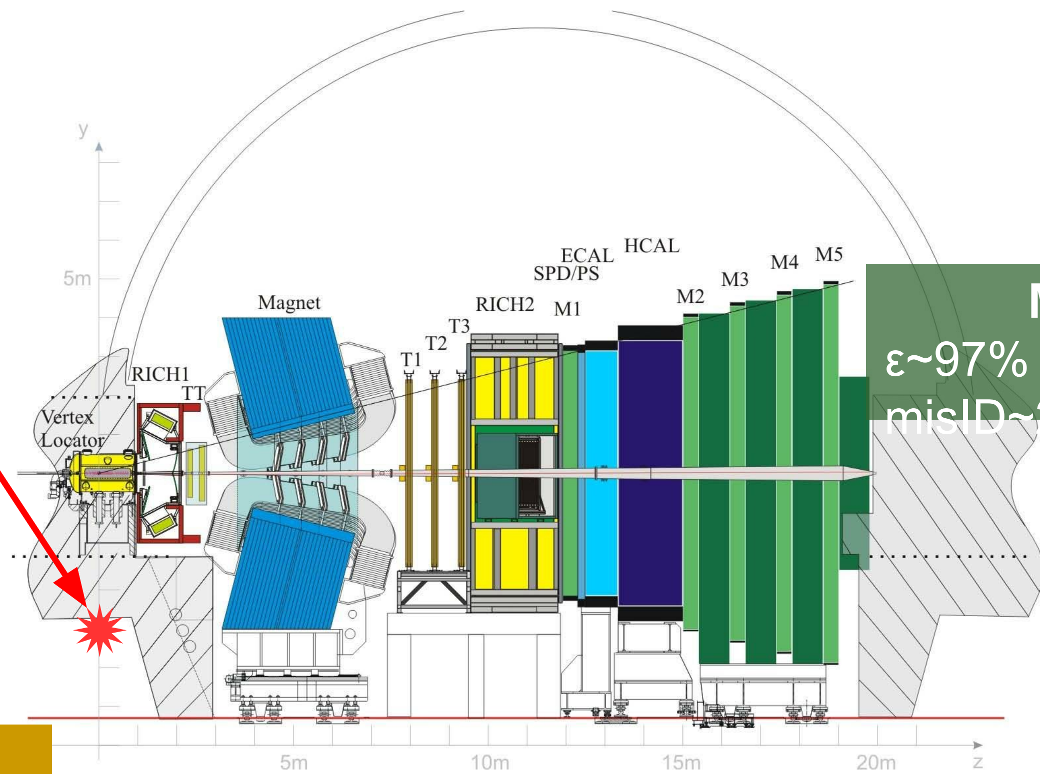
In summary, the costs to maintain a fruitful collaboration with the LHCb experiment, the Brazilian institutes need 2855 kCHF in the next 15 years.

Backup

LHCb is a single arm spectrometer fully instrumented in the forward region (2.0<η<5.0)

Designed for heavy flavour physics and also exploited for general purpose physics

[Int. J. Mod. Phys. A 30, 1530022 (2015)]



Collision

Muon
ε~97% for misID~2%

VELO
~20μm IP resolution

Tracking (magnet)
0.4%-0.6% momentum resolution (0.2-100 GeV)

LHCb

→ Unique coverage complementary to ATLAS/CMS

→ Soft trigger and forward acceptance

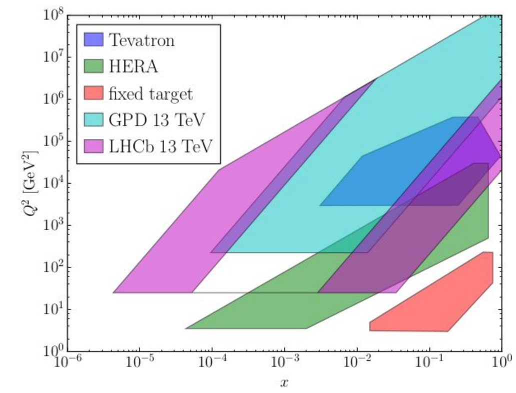
→ lower masses reach

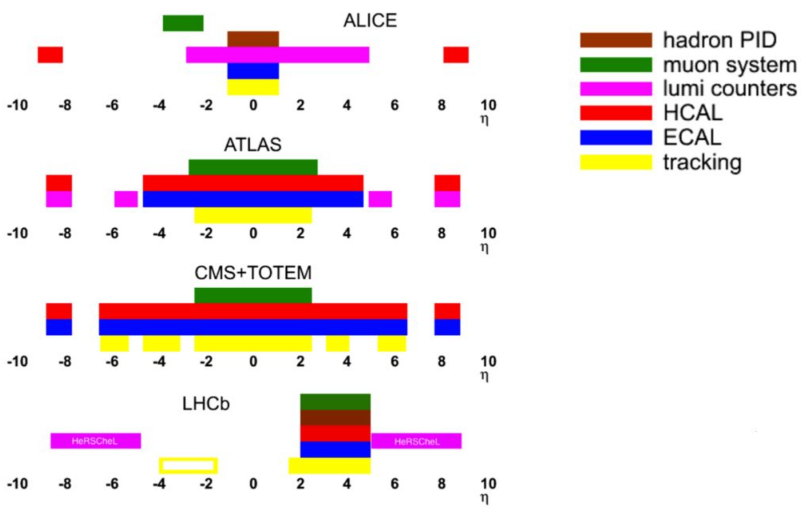
→ Excellent secondary/tertiary vertex reconstruction

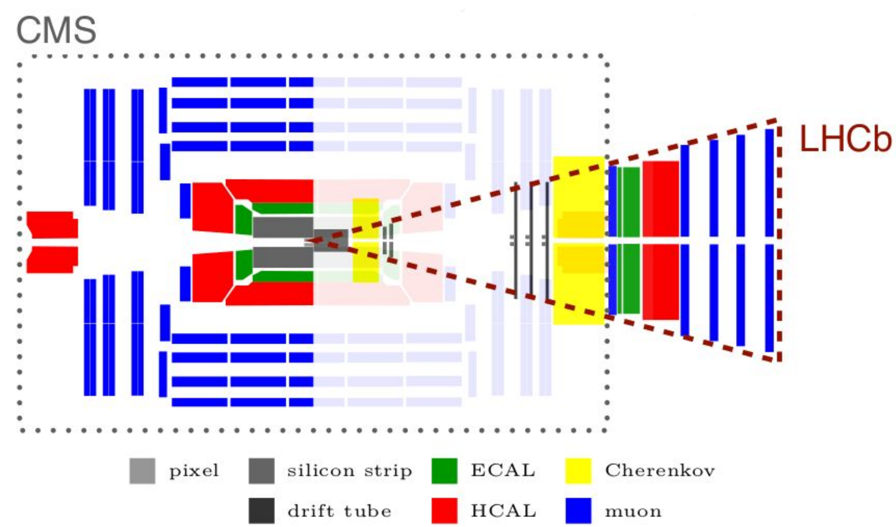
→ lower lifetimes reach (~ 1 ps).

→ Fixed target physics program

$$\sigma = \int xfx(f_1, x_1, Q^2)\, xfx(f_2, x_2, Q^2)\, \hat{\sigma}\, \mathrm{d}x_1 \mathrm{d}x_2, \quad Q^2(x) = e^{\pm 2y} x^2 s$$

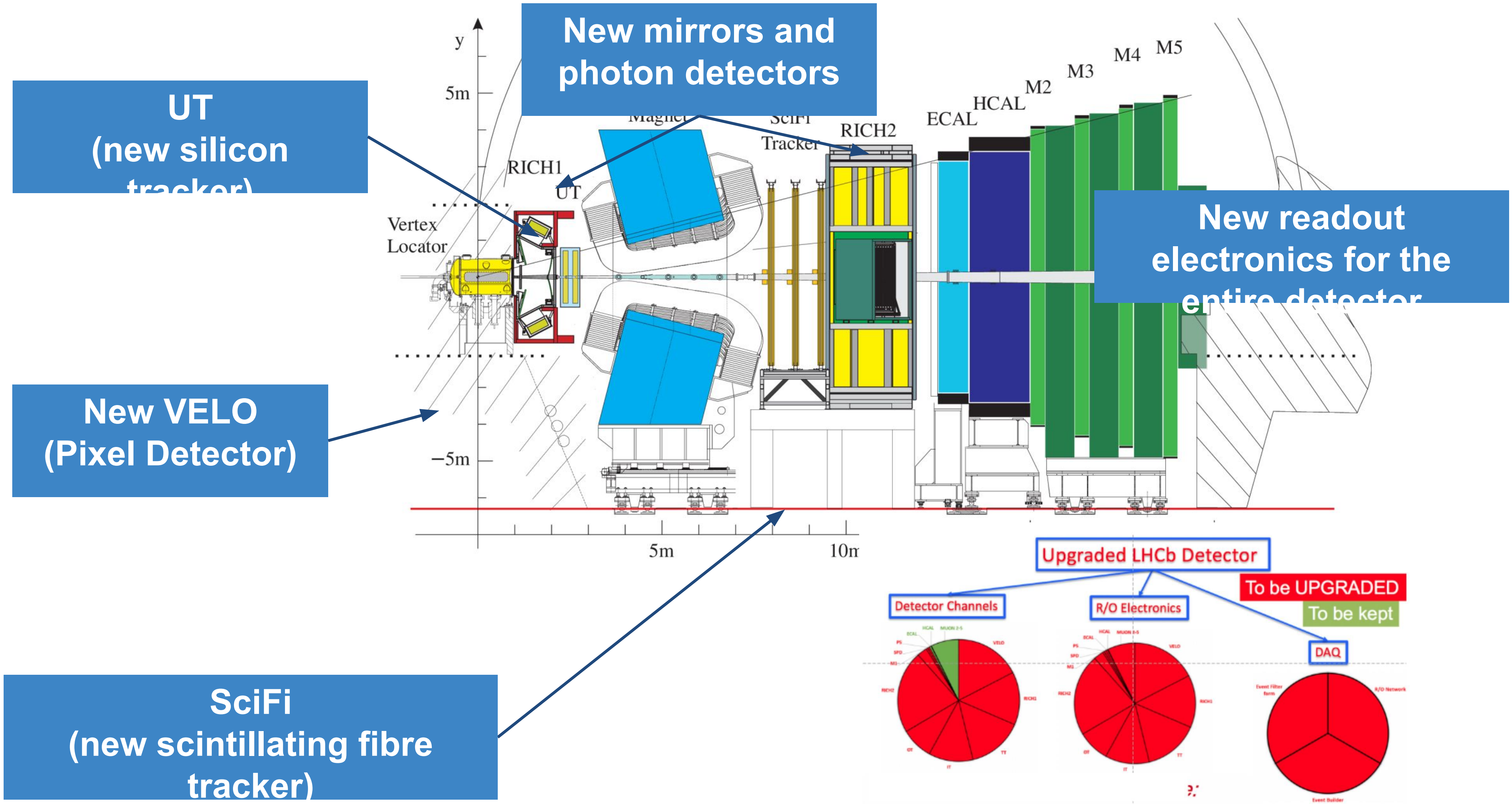


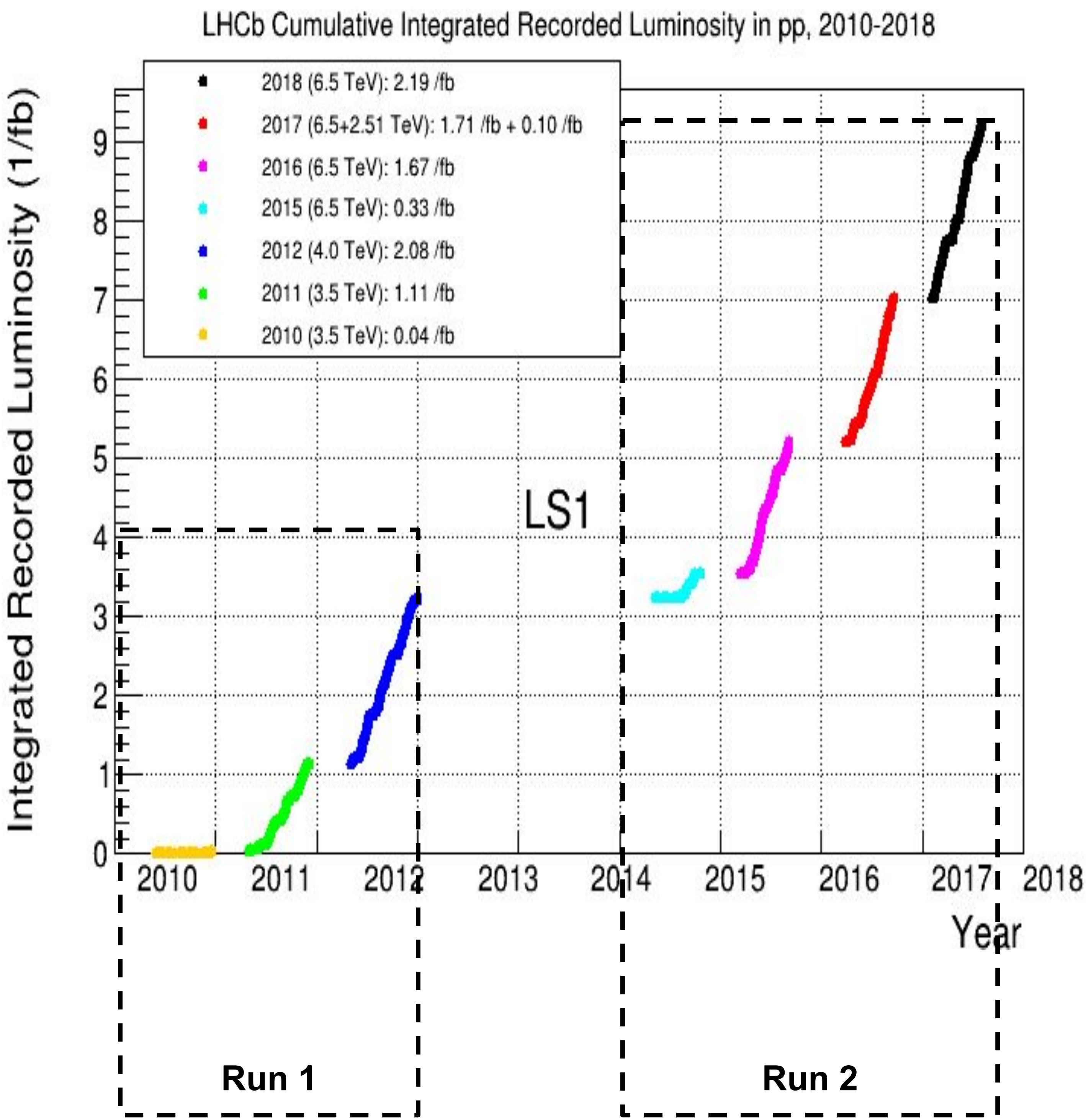




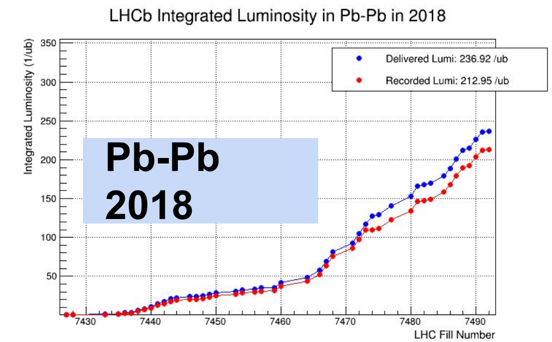
LHCb Upgrade

CERN-LHCC-2012-007

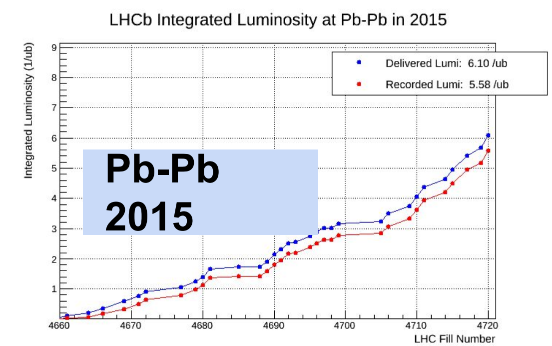




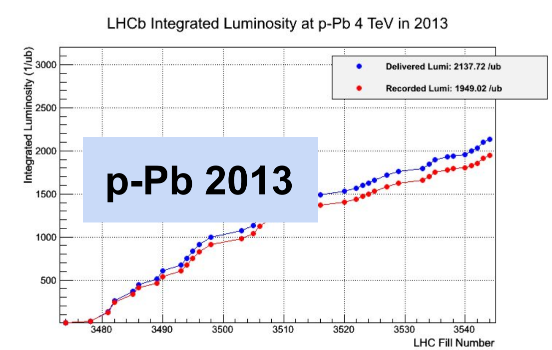
LHCb Cumulative Integrated Recorded Luminosity in pp, 2010-2018
2018 (6.5 TeV): 2.19 /fb
2017 (6.5+2.51 TeV): 1.71 /fb + 0.10 /fb
2016 (6.5 TeV): 1.67 /fb
2015 (6.5 TeV): 0.33 /fb
2012 (4.0 TeV): 2.08 /fb
2011 (3.5 TeV): 1.11 /fb
2010 (3.5 TeV): 0.04 /fb
Integrated Recorded Luminosity (1/fb)
LS1
Year
Run 1
Run 2



LHCb Integrated Luminosity in Pb-Pb in 2018
Delivered Lumi: 236.92 /ub
Recorded Lumi: 212.95 /ub
Integrated Luminosity (1/ub)
LHC Fill Number
Pb-Pb 2018



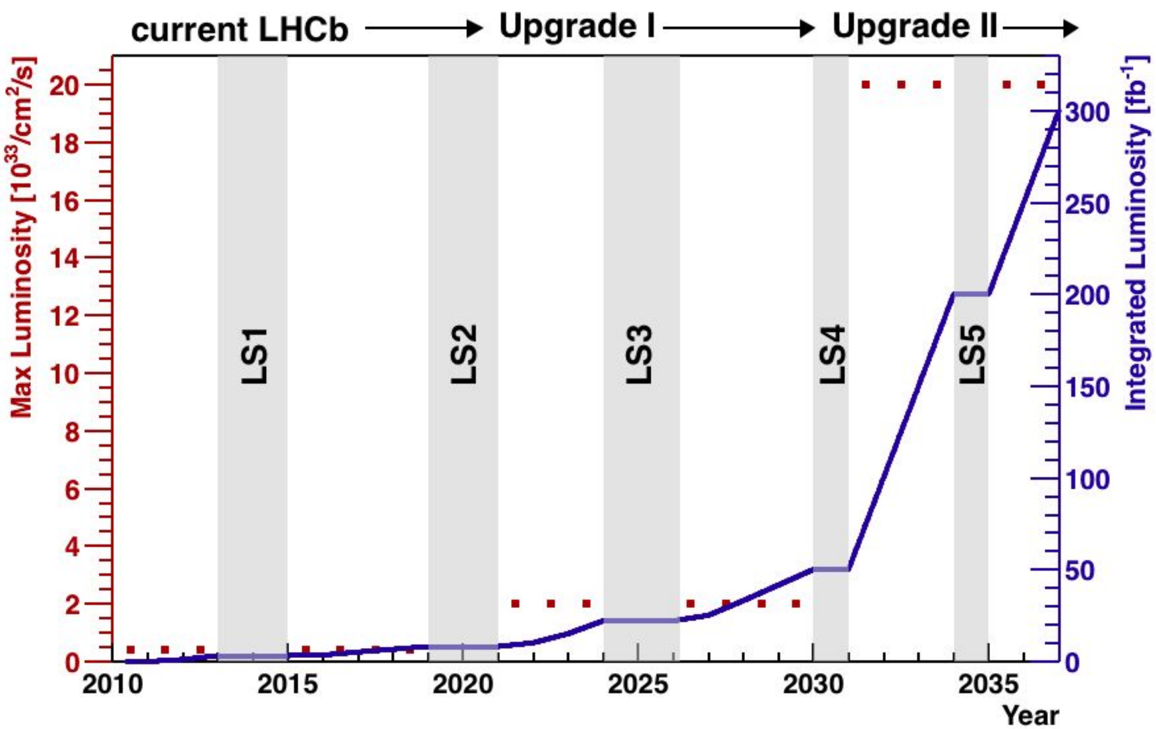
LHCb Integrated Luminosity at Pb-Pb in 2015
Delivered Lumi: 6.10 /ub
Recorded Lumi: 5.58 /ub
Integrated Luminosity (1/ub)
LHC Fill Number
Pb-Pb 2015



LHCb Integrated Luminosity at p-Pb 4 TeV in 2013
Delivered Lumi: 2137.72 /ub
Recorded Lumi: 1949.02 /ub
Integrated Luminosity (1/ub)
LHC Fill Number
p-Pb 2013

LHCb Upgrade

arXiv:1808.08865 [hep-ex]

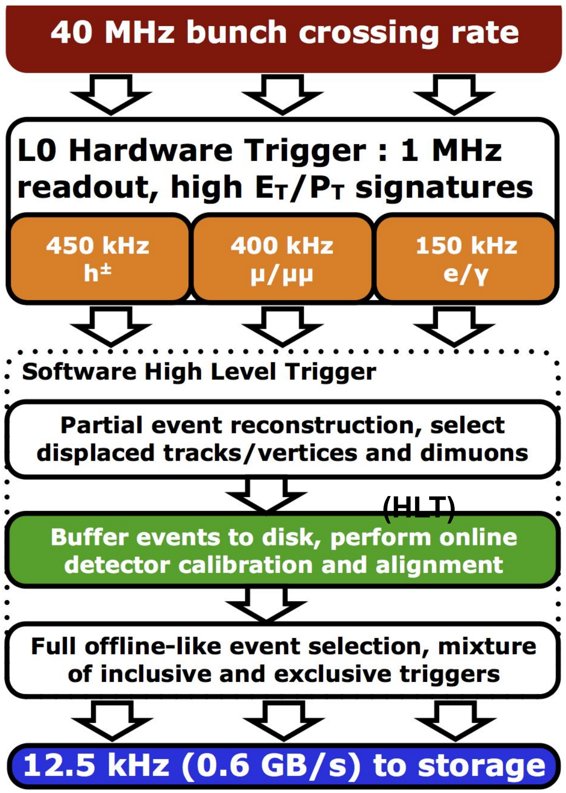


Run 1+Run 2: 9.1/fb
Run 3: 25/fb

Upgrade **I** **Ib** **II**

Run 2 trigger

LHCb Run II Trigger Diagram (2015 - 2019)



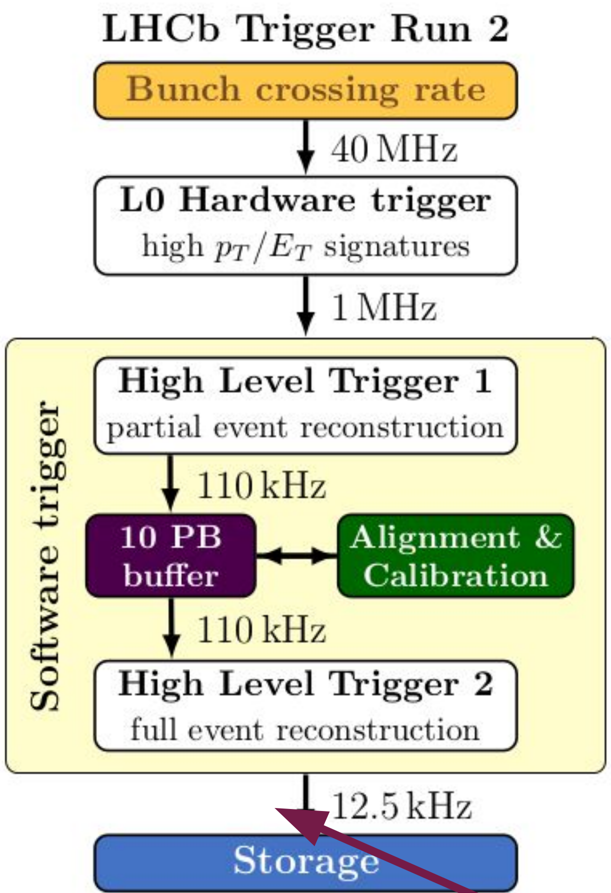
JINST 14 (2019) no.04, P04013

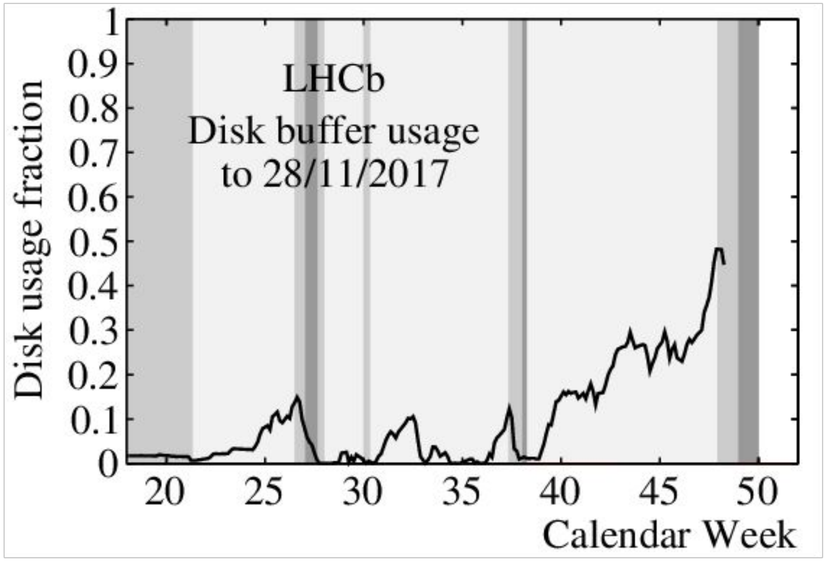
Trigger structure:

- 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

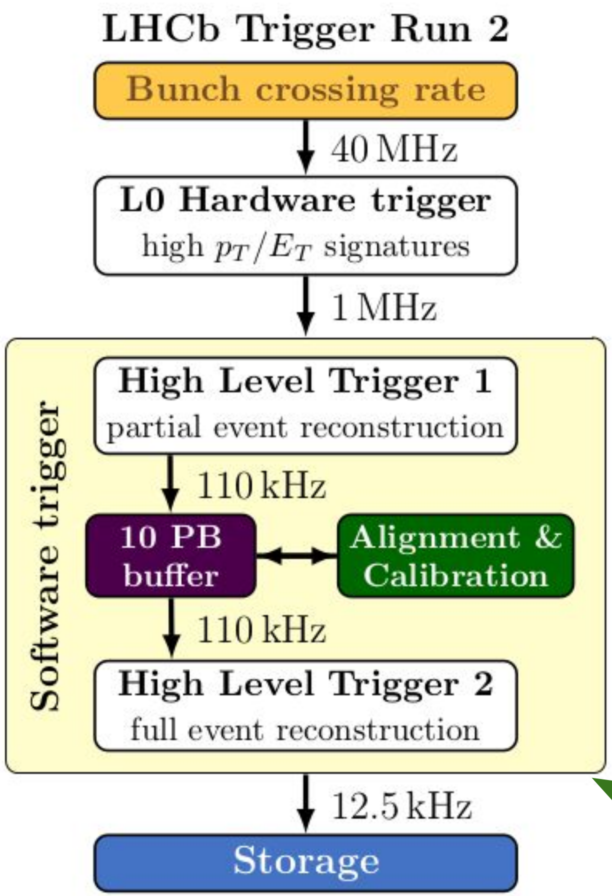


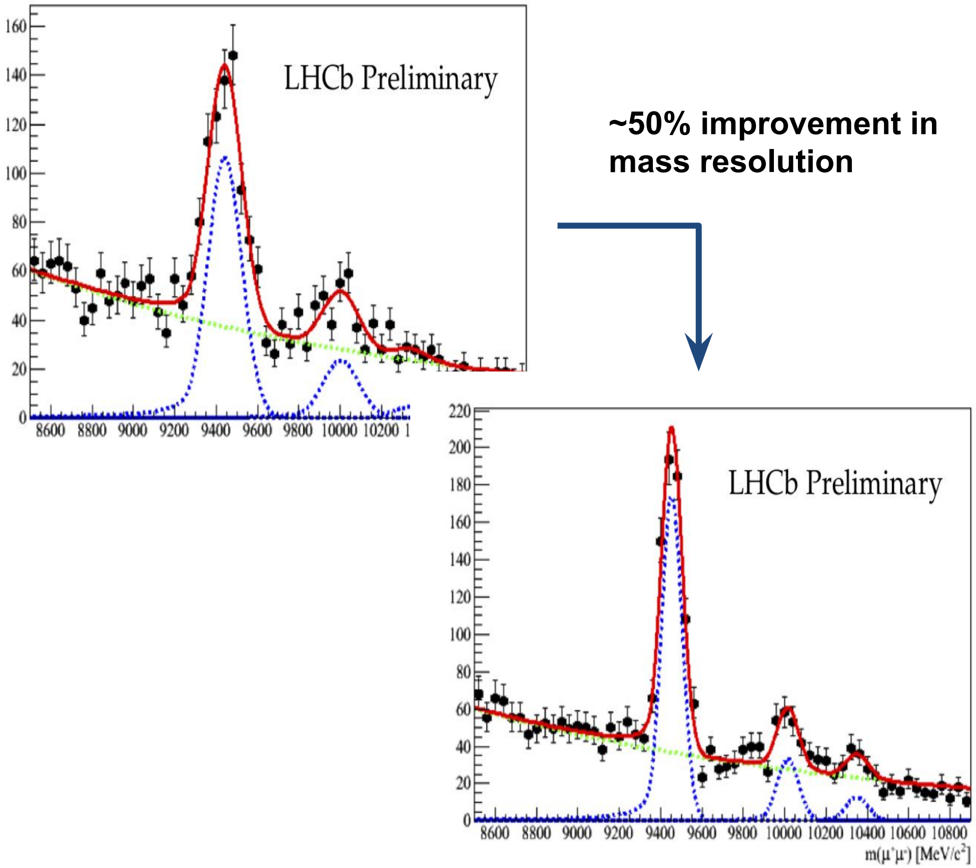


♯ HLT Farm with 10 PB disk space
♯ At an average event size of 55 kB with 100 kHz: up to 2 weeks before HLT2 has to be executed
♯ 2x trigger CPU capacity since Farm is used twice for HLT (excess used for simulation)

JINST 14 (2019) no.04, P04013

Run 2 trigger



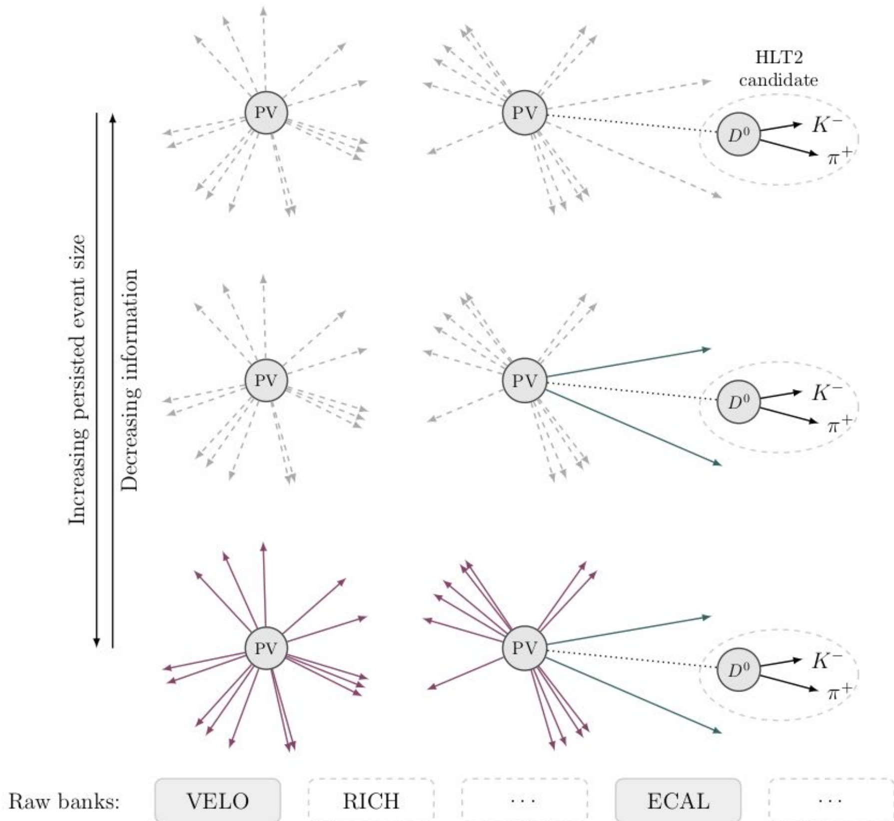


♯ Real-time alignment and calibration
♯ Dedicated HLT1 trigger lines supply samples for the alignment
♯ Alignment & calibration tasks run in parallel while events are are being processed by HLT1

JINST 14 (2019) no.04, P04013

Run 2 trigger: Turbo

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



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

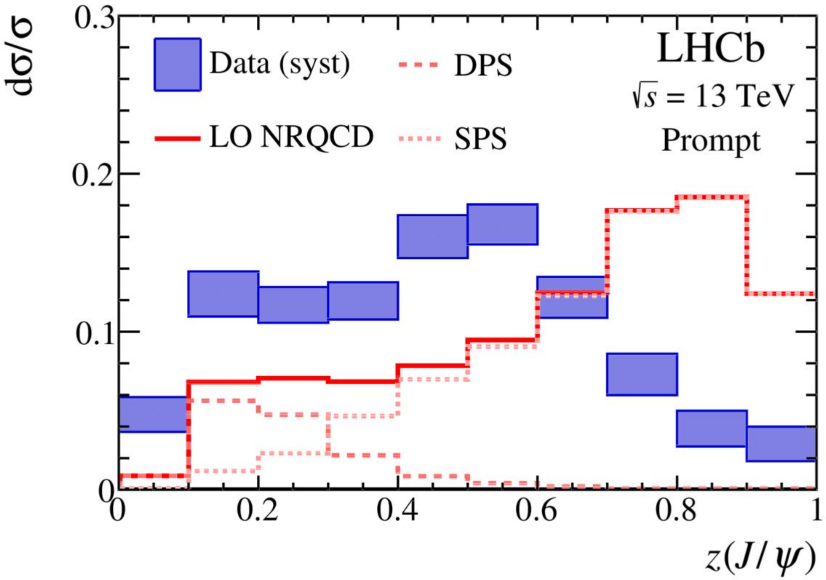
JINST 14 (2019) no.04, P04006

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

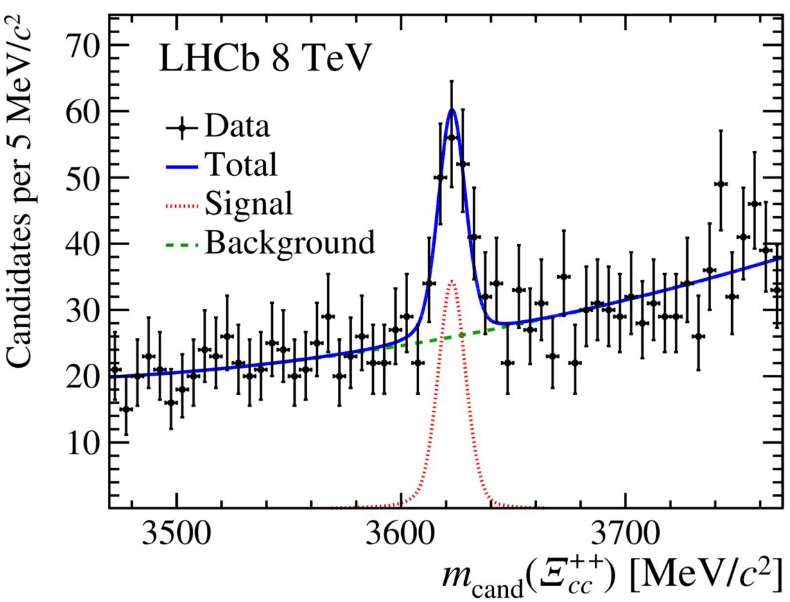
Physics See Viewpoint: Probing Quarkonium Production in Jets



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



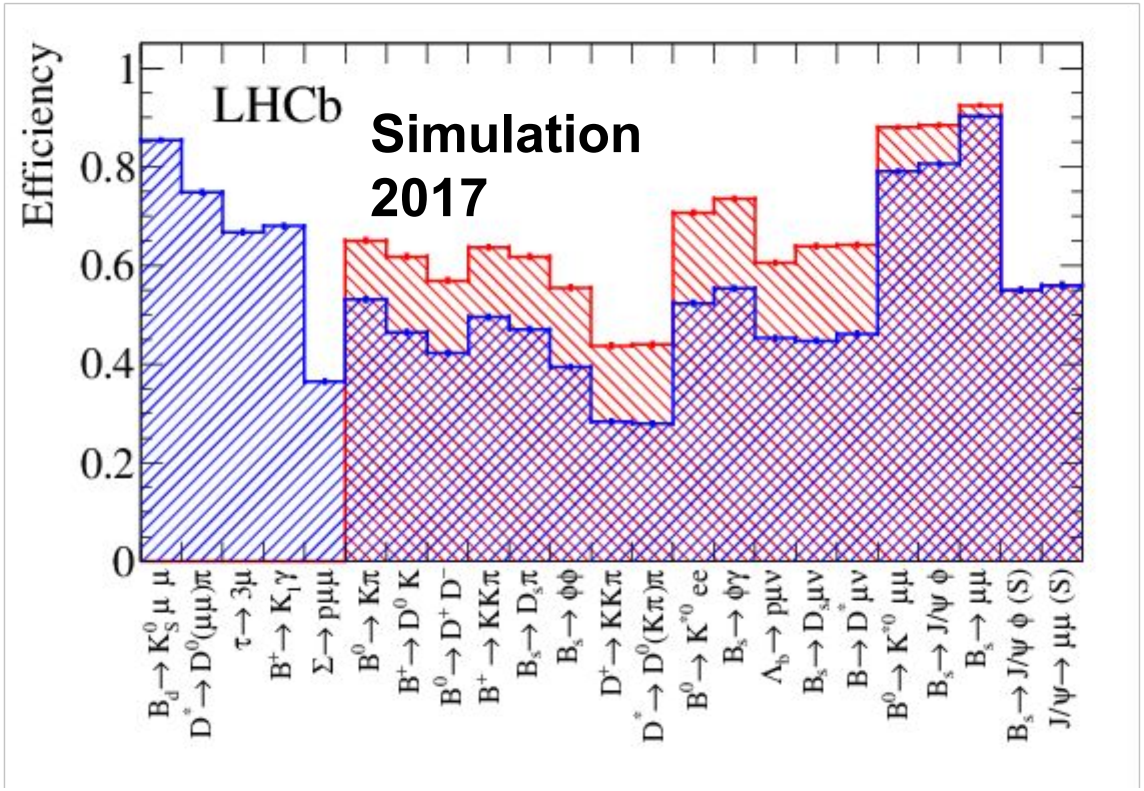
Phys.Rev.Lett. 118 (2017) no.19, 192001

Phys. Rev. Lett. 119, 112001

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

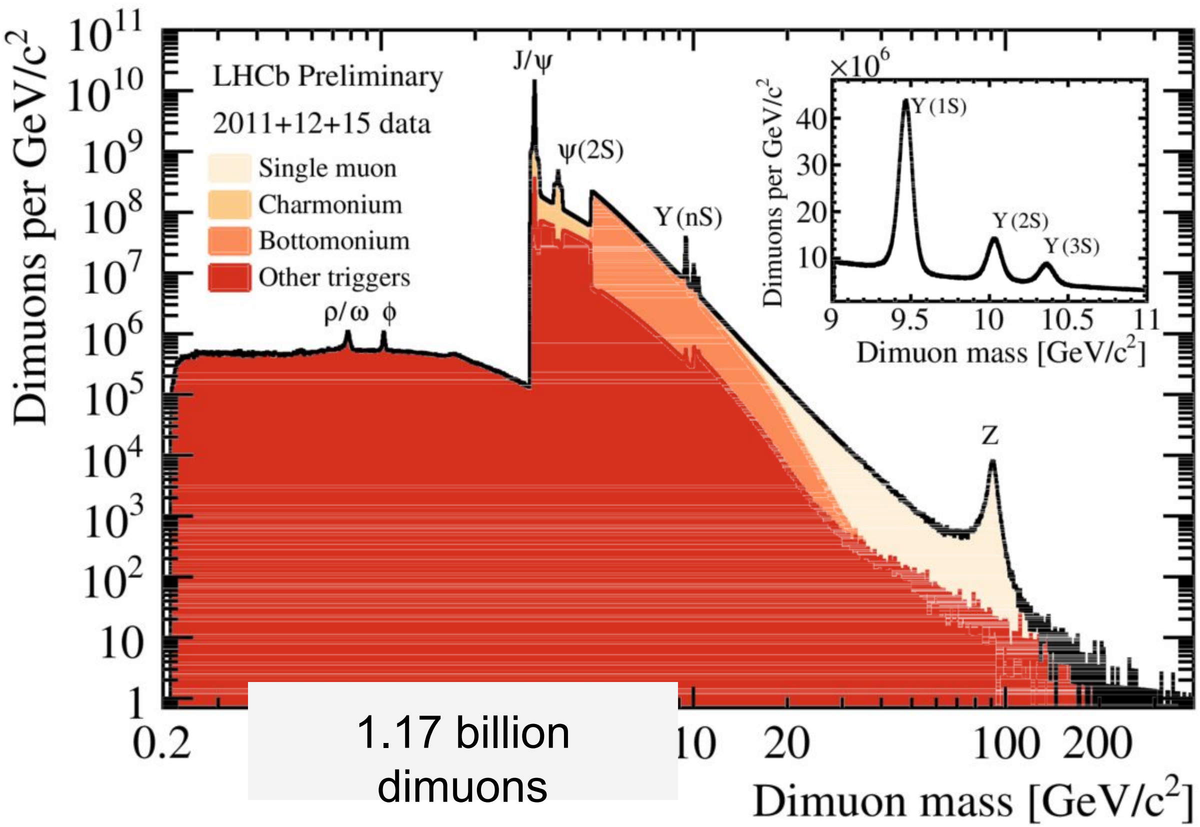


If entire L0 bandwidth is granted
If there is bandwidth division

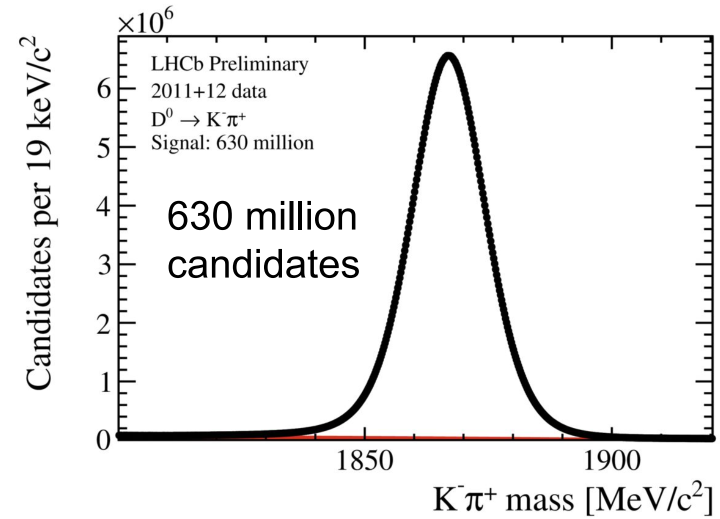
JINST 14 (2019) no.04, P04013

Run 2 trigger: Plots

LHCb-CONF-2016-005



1.17 billion dimuons



Rare events: high efficiency
Copious production: high purity

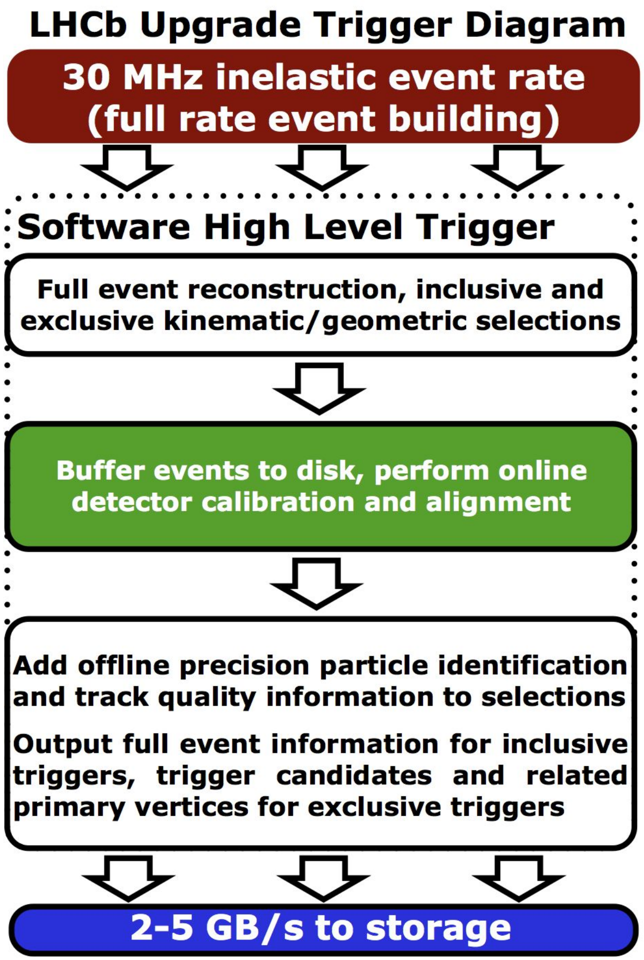
LHCb Upgrade I

❈ Increase instantaneous luminosity:
$4 \times 10^{32} \rightarrow 2 \times 10^{33}$ cm^{-2} 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-PUB-2014-027