Jet reconstruction and calibration at LHCb

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LHCb experiment overview – Run 2

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)]

Rich
ε(k→k)~95% for (π→k)~5%

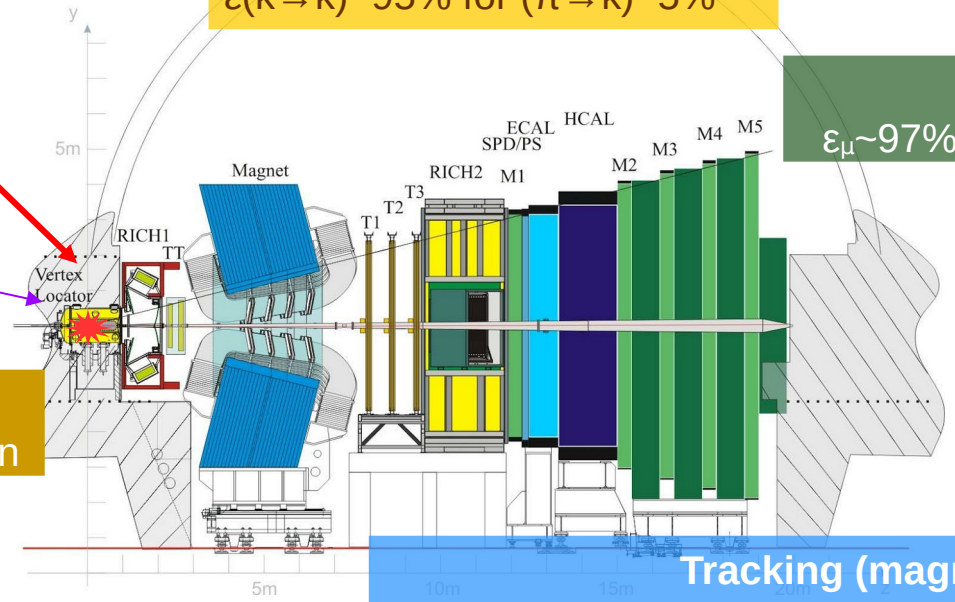
Collision

Muon
ε_μ~97% for misID~2%

SMOG
Fixed target

VELO
~20μm IP resolution

Herschel
Forward counters



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

Run 3 detector

CERN-LHCC-2012-007 LHCb-DP-2023-002

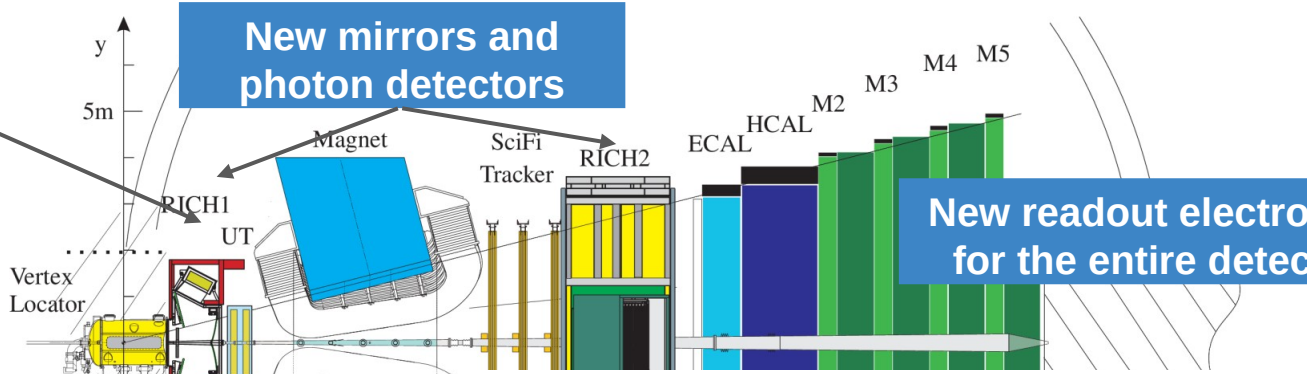
UT
(new silicon tracker)

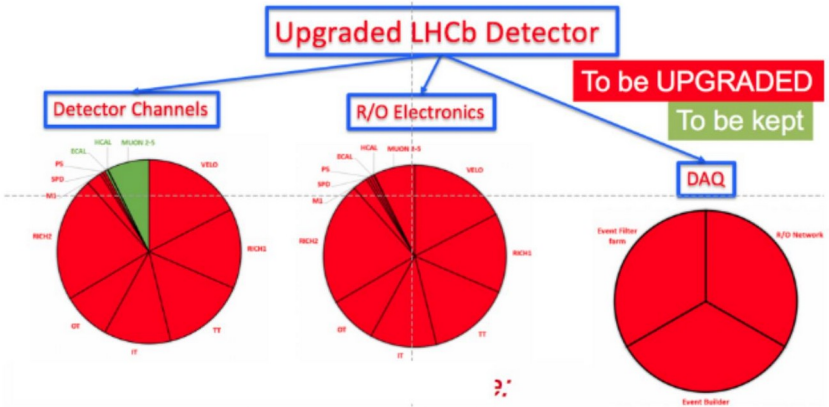
New mirrors and photon detectors

New readout electronics for the entire detector

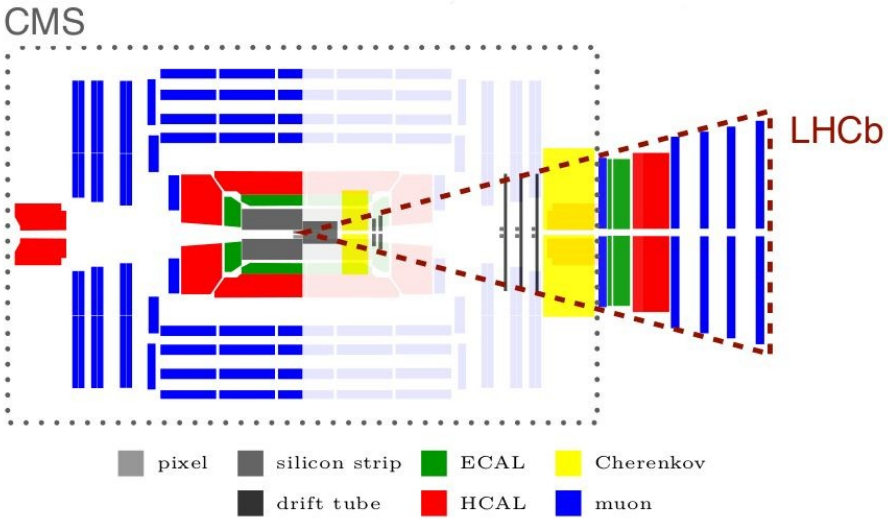
New VELO
(Pixel Detector)

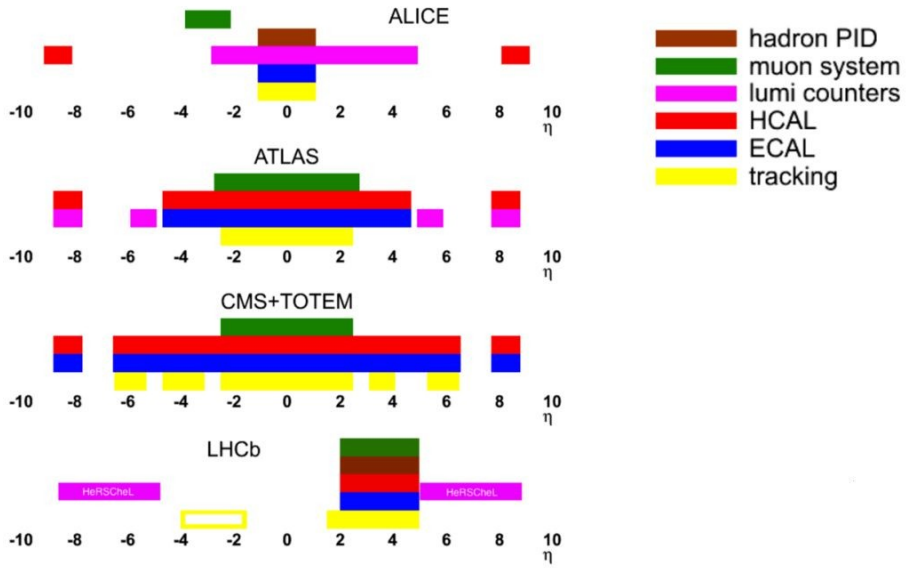
SciFi
(new scintillating fibre tracker)

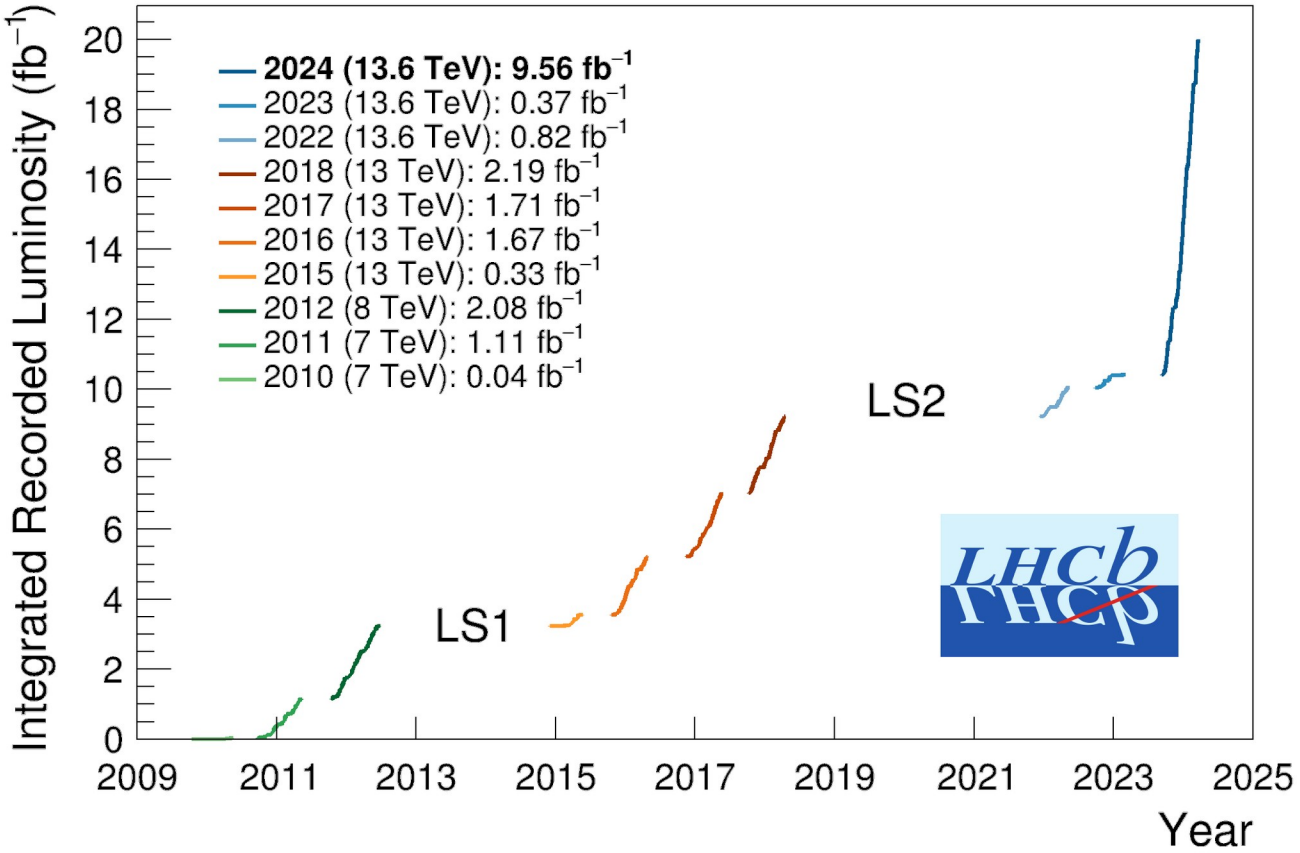


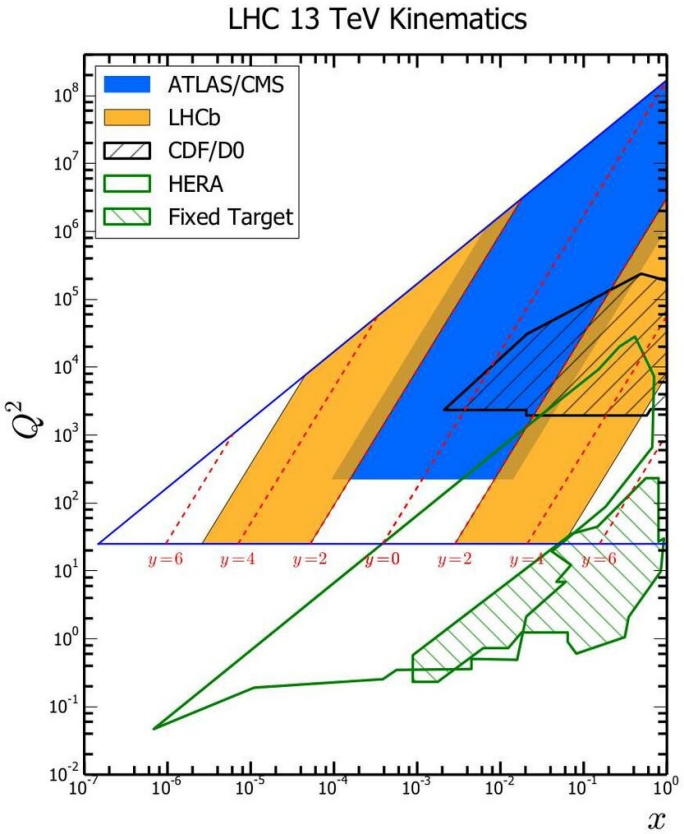


LHCb compared other experiments (outdated version)






Integrated Recorded Luminosity (fb^{-1})
Year
2024 (13.6 TeV): 9.56 fb^{-1}
2023 (13.6 TeV): 0.37 fb^{-1}
2022 (13.6 TeV): 0.82 fb^{-1}
2018 (13 TeV): 2.19 fb^{-1}
2017 (13 TeV): 1.71 fb^{-1}
2016 (13 TeV): 1.67 fb^{-1}
2015 (13 TeV): 0.33 fb^{-1}
2012 (8 TeV): 2.08 fb^{-1}
2011 (7 TeV): 1.11 fb^{-1}
2010 (7 TeV): 0.04 fb^{-1}
LS1
LS2
LHCb
0
2
4
6
8
10
12
14
16
18
20
2009
2011
2013
2015
2017
2019
2021
2023
2025



• LHCb measurements are tests of pQCD in a interesting phase space

→ PDFs and proton structure can be studied in two different kinematic regions:

- At high-x values that can be compared with other experiments
- At low-x values and high Q^2, unexplored by other experiments

N.B. LHCb coverage in heavy ions collisions not discussed.

Jet reconstruction at LHCb

→ Particle flow approach including neutral recovery
  Charged particles: mass hypothesis depends on the PID variable
  Photons: Calorimeter based (isolated from tracks)
  Pi0s: Resolved or merged
  Calorimeter clusters associated to tracks: Energy recovery → E/p subtraction (Run 1-2)

→ Reconstruction: anti-k_T with R=0.5 (other radius studied)

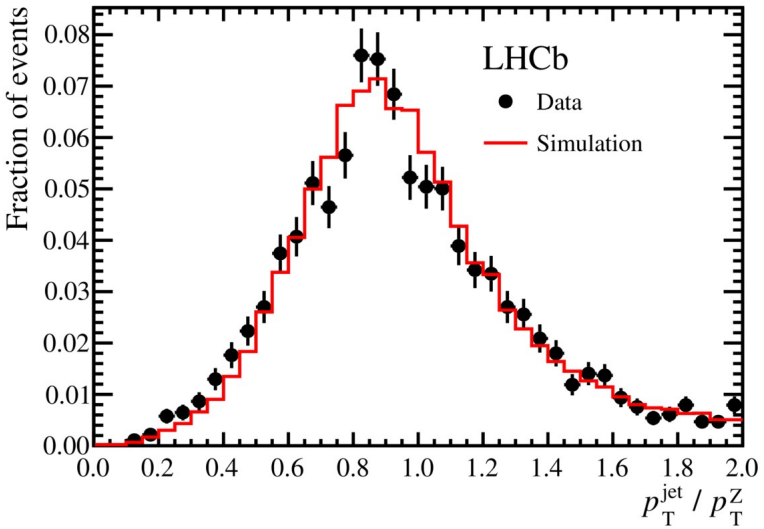
→ Energy calibration performed using simulation (Run 1-2)
  f(p_T) in regions of η, charge particle fraction (cpf) and number of primary vertices

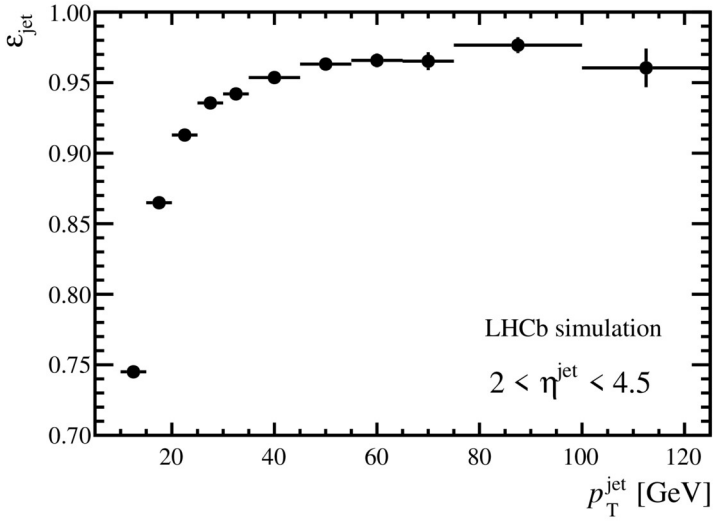
→ Jet identification requirements based on the number of charged particles, leading charged particle p_T and cpf.

OBS: The group working on LHCb jet measurements is small.

Jet reconstruction – Run 1

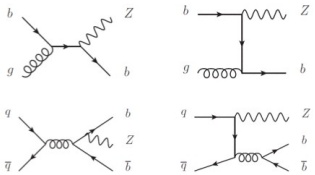
→ Simulation models well Z+jet data (JHEP 01 (2014) 33)



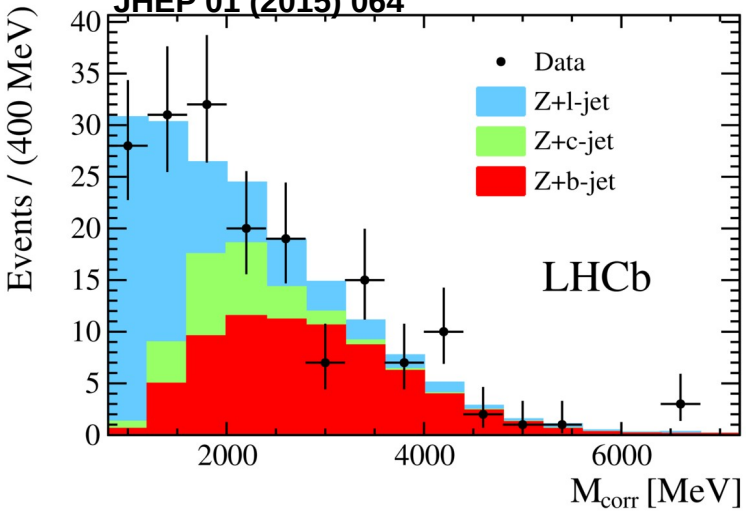


Jet reconstruction – Run 1-2

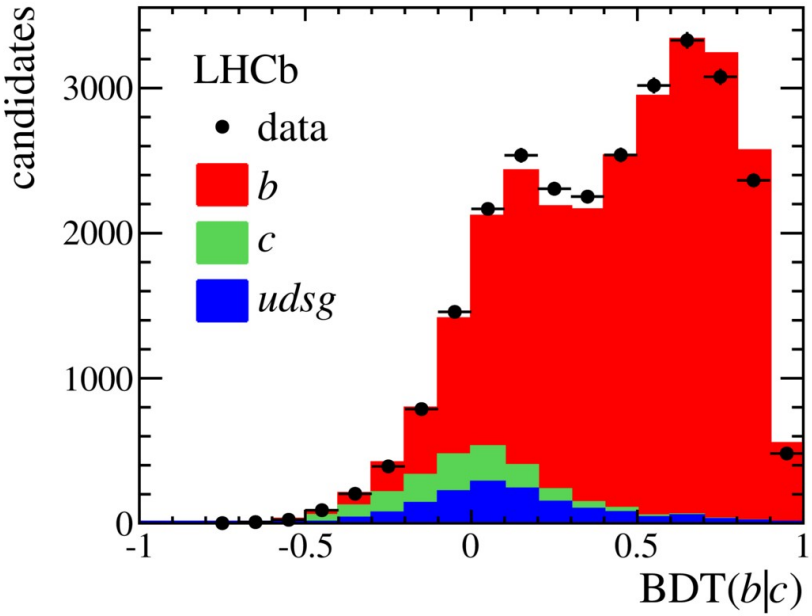
→ Heavy-flavor tagging working well since first studies



JHEP 01 (2015) 064

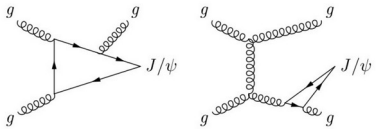


JINST 10 P06013

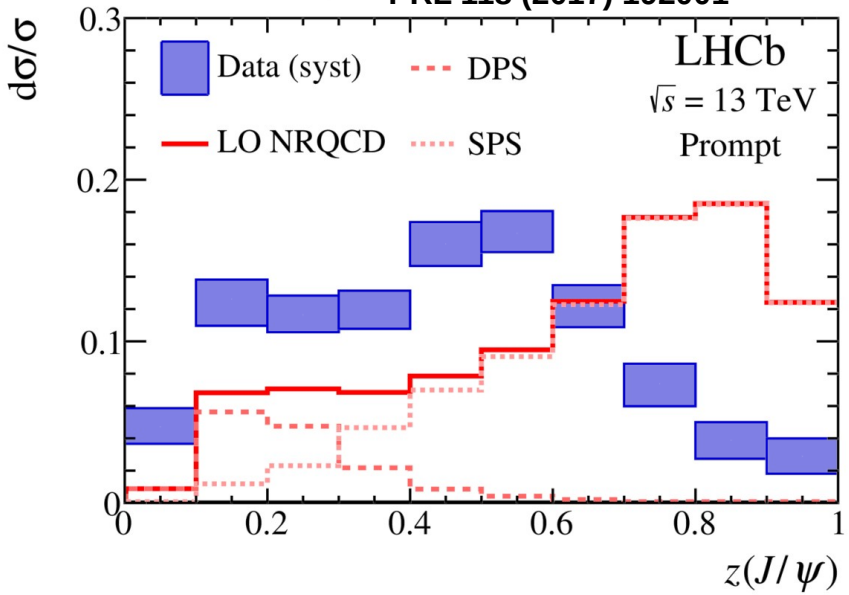


Jet reconstruction – Run 2

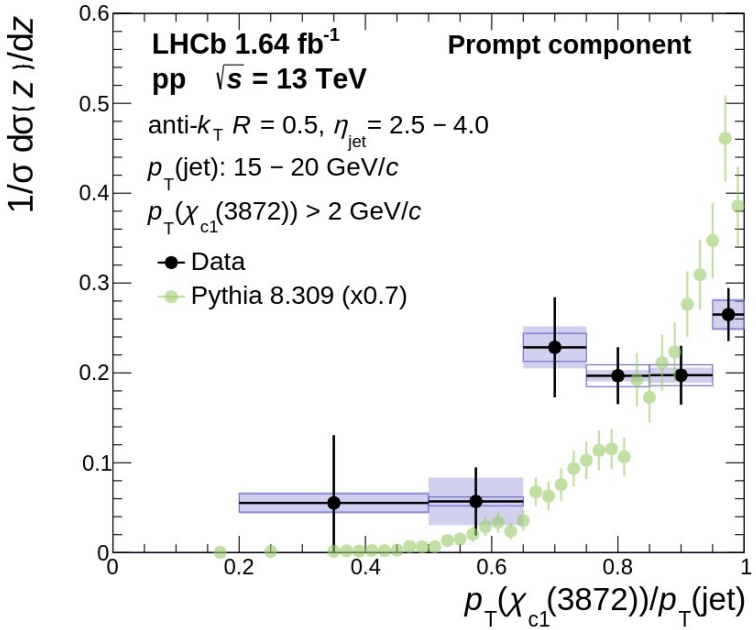
→ Meson tagging studies performed with great success



PRL 118 (2017) 192001



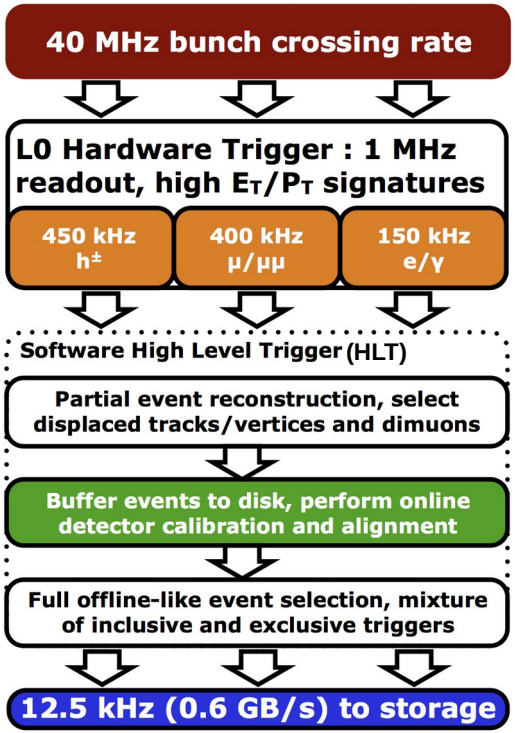
arXiv:2410.18018



Jet reconstruction in trigger

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

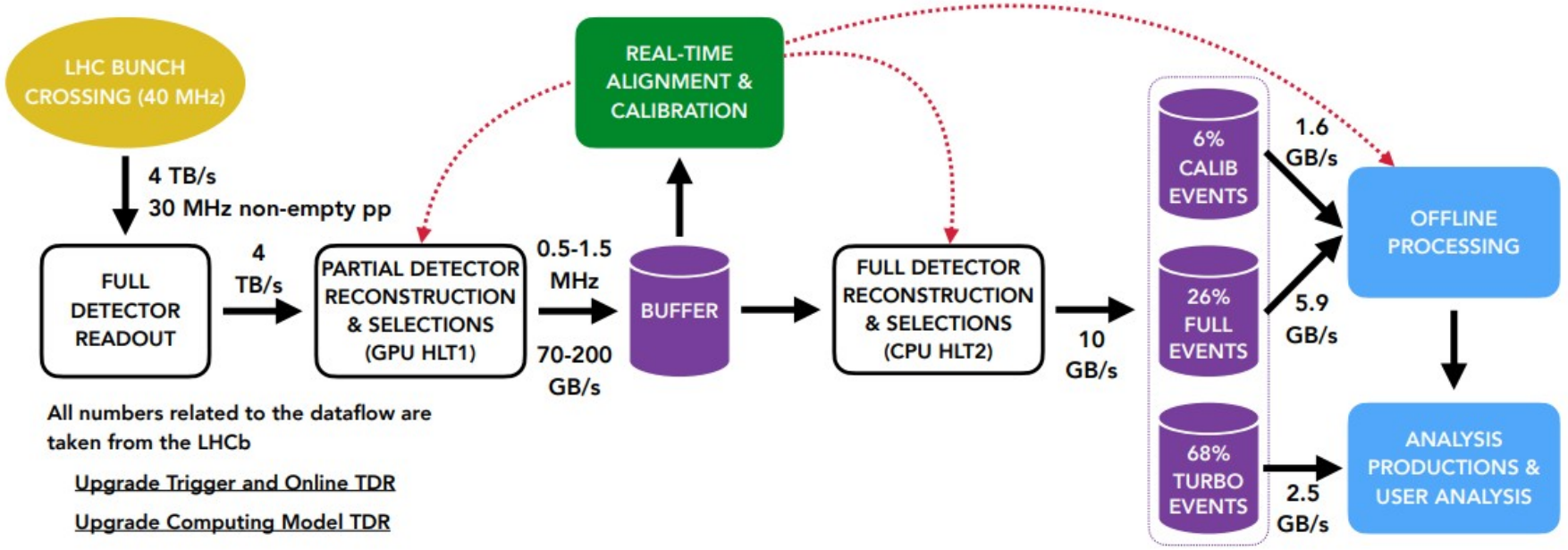
♯ Software: events built at 1 MHz (~27000 physical cores)

HLT1: fast tracking and inclusive selections

1 MHz to 100 kHz

HLT2: complete event reconstruction and selections

Run 3 trigger



All numbers related to the dataflow are taken from the LHCb

Upgrade Trigger and Online TDR

Upgrade Computing Model TDR

Jet reconstruction – Run 2 trigger

→ Implemented in HLT2 without energy recovery
→ No identification requirement – no energy correction

Jet reconstruction – Run 3 trigger/offline

→ implemented in HLT1 for inclusive jet lines

→ Implemented in HLT2 (no energy recovery)
  → Same as offline reconstruction
  → Simple identification requirement – no energy calibration
  → Inclusive, dijet and sV+jets with and without SV tags

Discussion

Run 1-2

→ successful jet program with papers in the pipeline, but …

-- missing performance paper

-- missing inclusive jet measurement

-- missing jet studies in heavy-ion collisions (PbPb, pPb, p-A, Pb-A)

Run 3 jet reconstruction – common issues

** Major rewrite of the Run 2 code. Strategy is similar.

→ Preliminary studies are promising

Ongoing/future studies

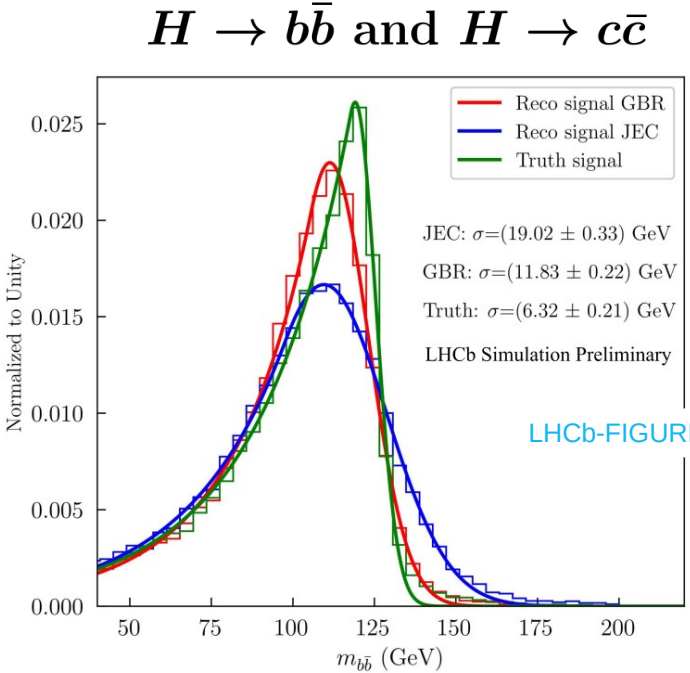
→ Studies to cope with higher inst. Luminosity

→ Performance studies with Z+jets and B/D+jets

Discussion

Space for improvements

- new techniques: analysis orie
  - → Higgs
  - → gluon/quark discriminati
  - → ...



LHCb-FIGURE-2023-029

Figure 1: Fitting of the three invariant mass peaks (truth level and reconstruction level with default correction and GBR correction) to the crystal-ball function.

Discussion

Heavy-ion opportunity

Prog.Part.Nucl.Phys. 127 (2022) 103990

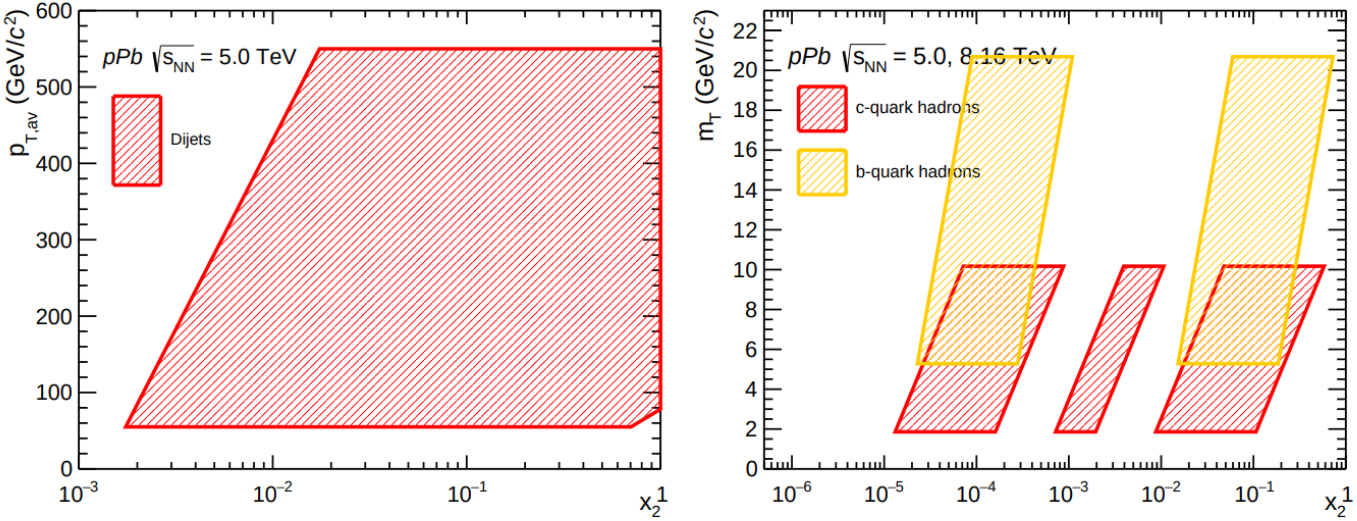


Figure 4: Simple estimates of measurement sensitivity to probe nuclear PDFs with pPb collisions: left dijet measurement case by CMS [53], right open heavy-flavor measurements selection with lowest transverse momentum coverage by LHCb [54, 55] and ALICE [56].

Discussion

Heavy-ion opportunity

Prog.Part.Nucl.Phys. 127 (2022) 10399
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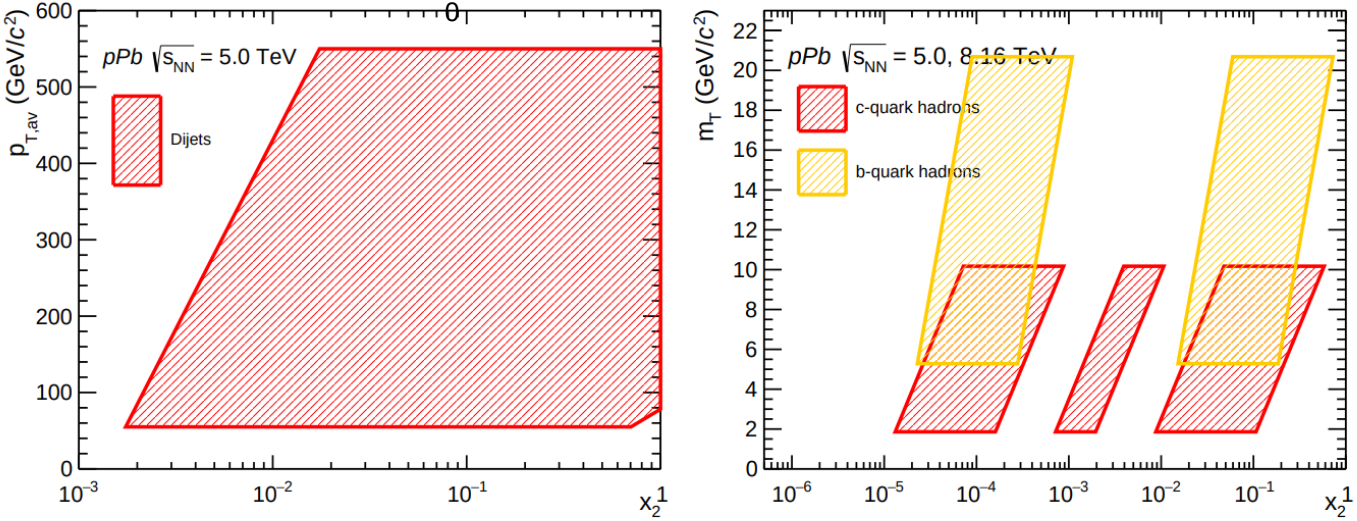

Figure 4: Simple estimates of measurement sensitivity to probe nuclear PDFs with pPb collisions: left dijet measurement case by CMS [53], right open heavy-flavor measurements selection with lowest transverse momentum coverage by LHCb [54, 55] and ALICE [56].

Summary

--- Jet program at LHCb has been very successful

--- Many opportunities and challenges for Run 3

+ one of our main challenge is the FTE available for activities to support jet measurements

--- Other measurements not shown can be found https://lbfence.cern.ch/alcm/public/analysis

THANK YOU