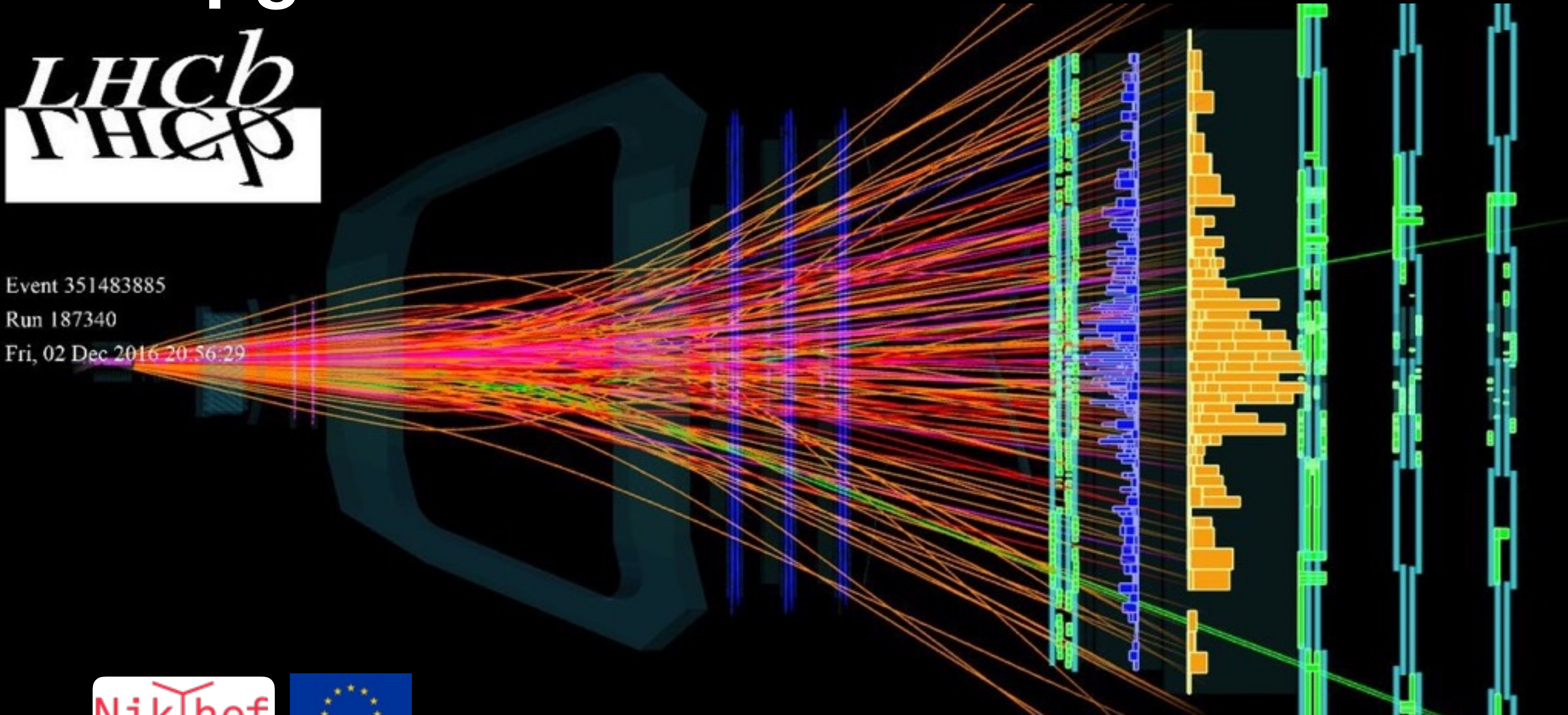
Real time analysis now and in the upgrade

LHCb



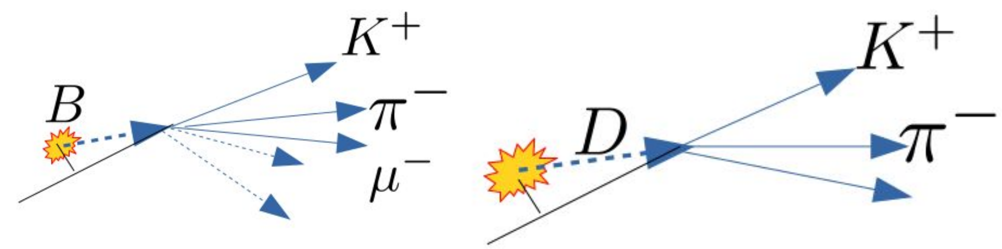
Nikhef

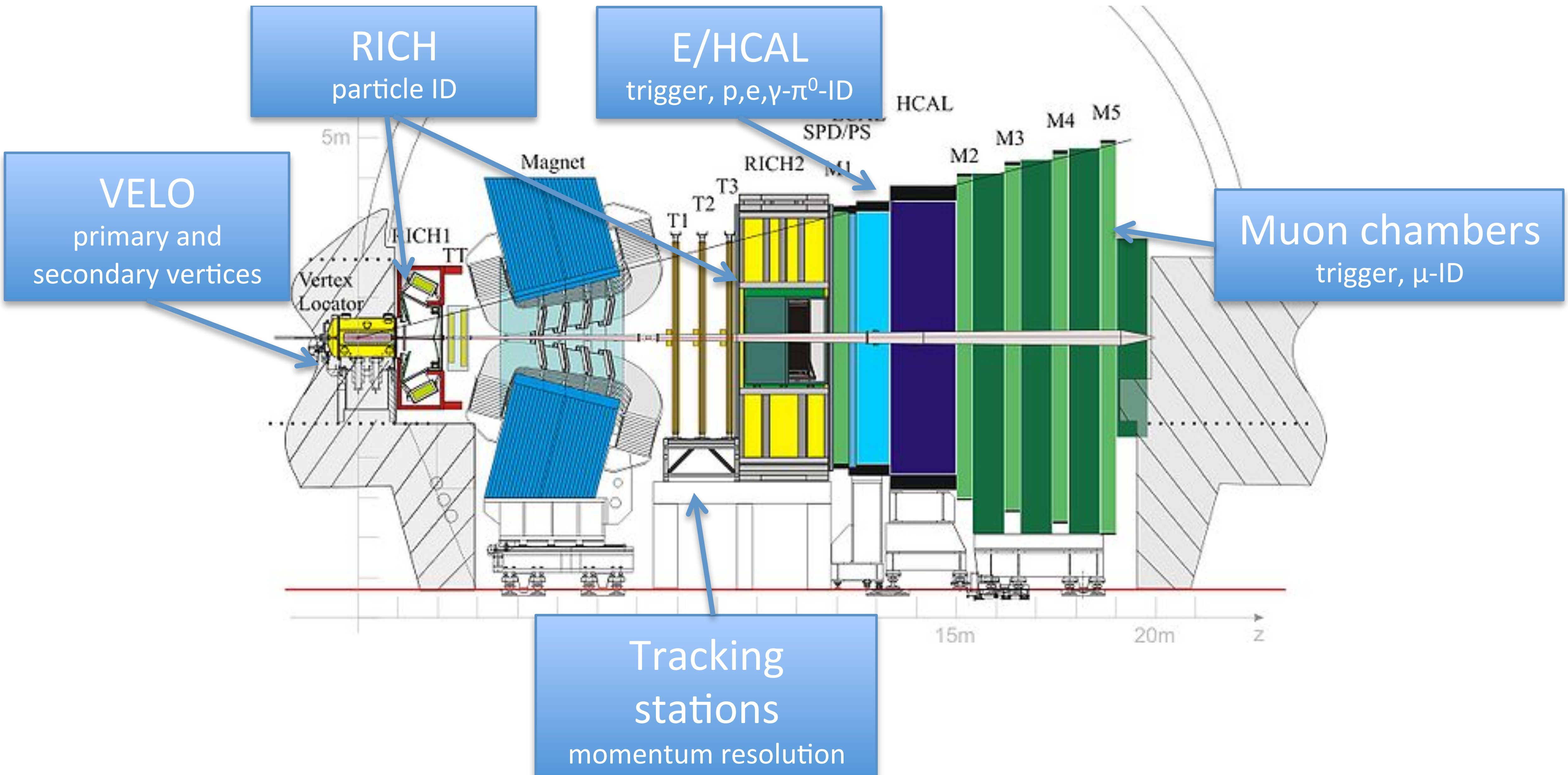
SEAN BENSON

LHCb now

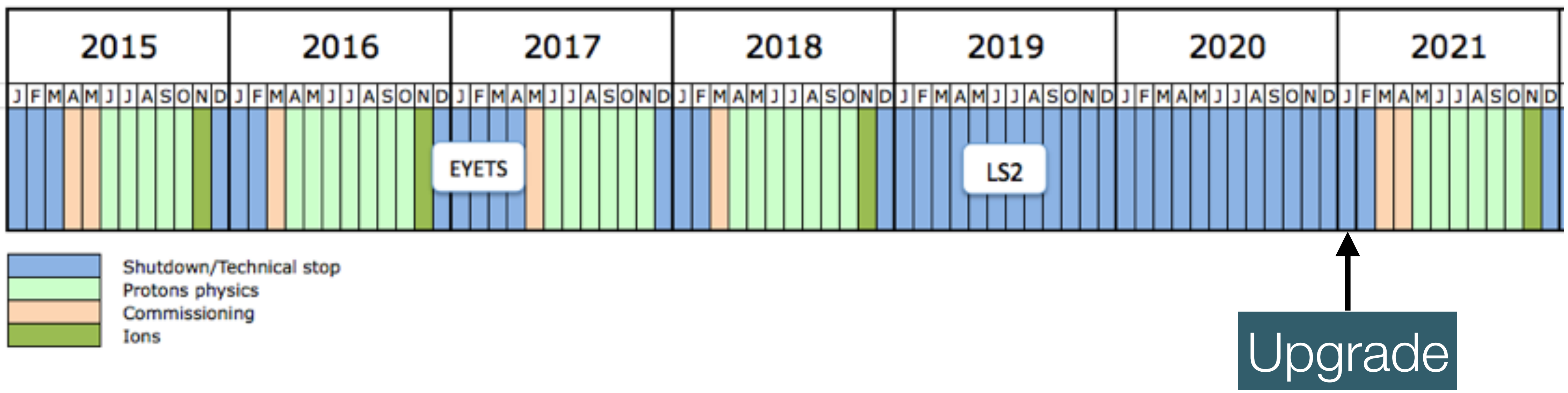
~45 kHz bb pairs and **~1 MHz** cc pairs

at 13 TeV and L = $4{\times}10^{32}$ cm^{-2}s^{-1}





LHCb in the future



Precision of many physics measurements at LHCb will be statistically limited at the end of Run II

- Upgrade to cope with 5× more luminosity (L = 2×10^{33} $cm^{-2}s^{-1}$)
  - Sub-detectors upgraded, front end electronics read out at collision rate
  - Triggerless read-out
  - Software trigger -> factor 2 efficiency improvement

LHCb in the future

A paradigm shift wrt Run II

- 24% (2%) of events contain a reconstructible charm (beauty) hadron.
  - 80 (27) GB/s worth of events usable for analysis.

We can only afford storing 2-10 GB/s offline

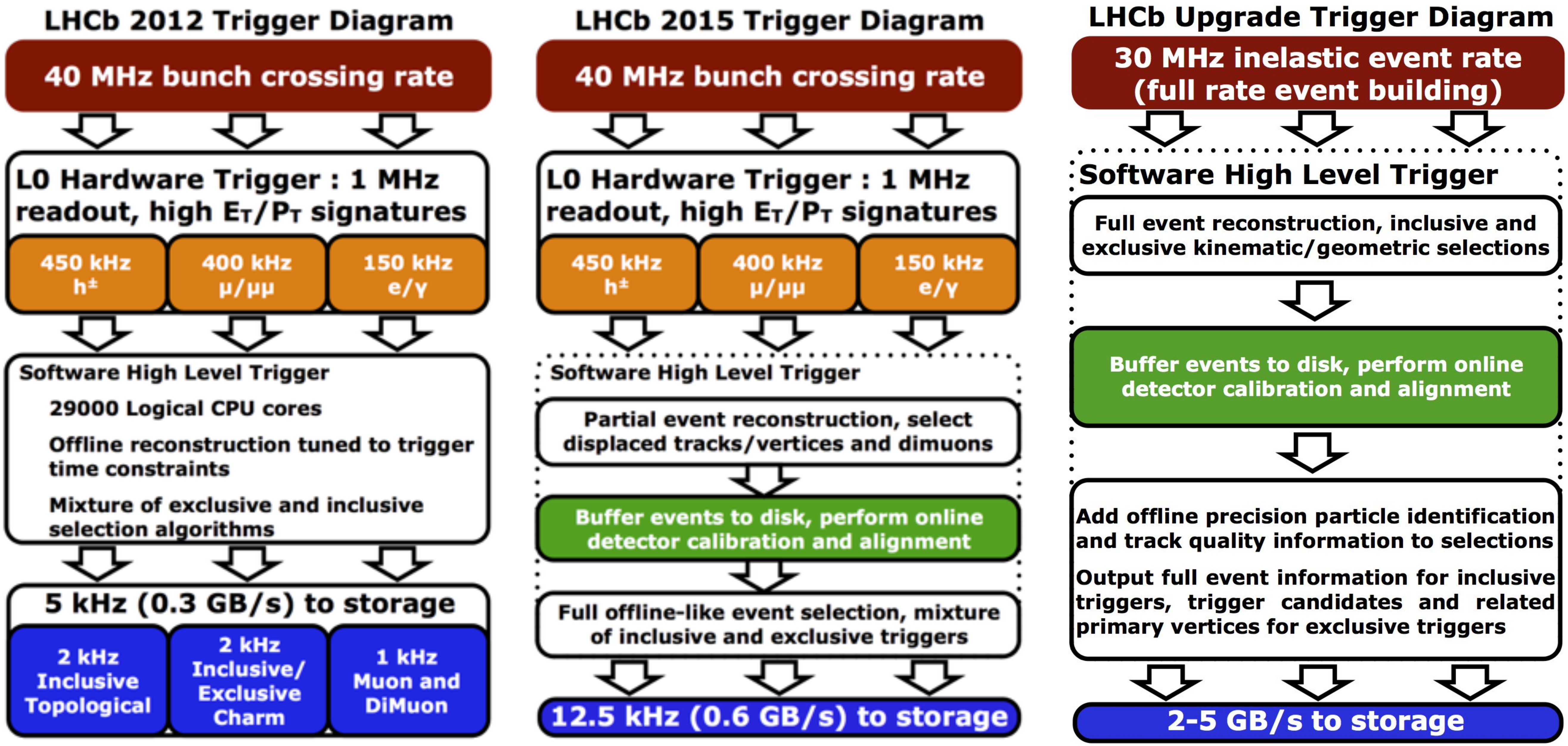
data rate rather than frequency is the most important

Not only separate signal and background decay topologies but effectively separate signal decays from other signal decays

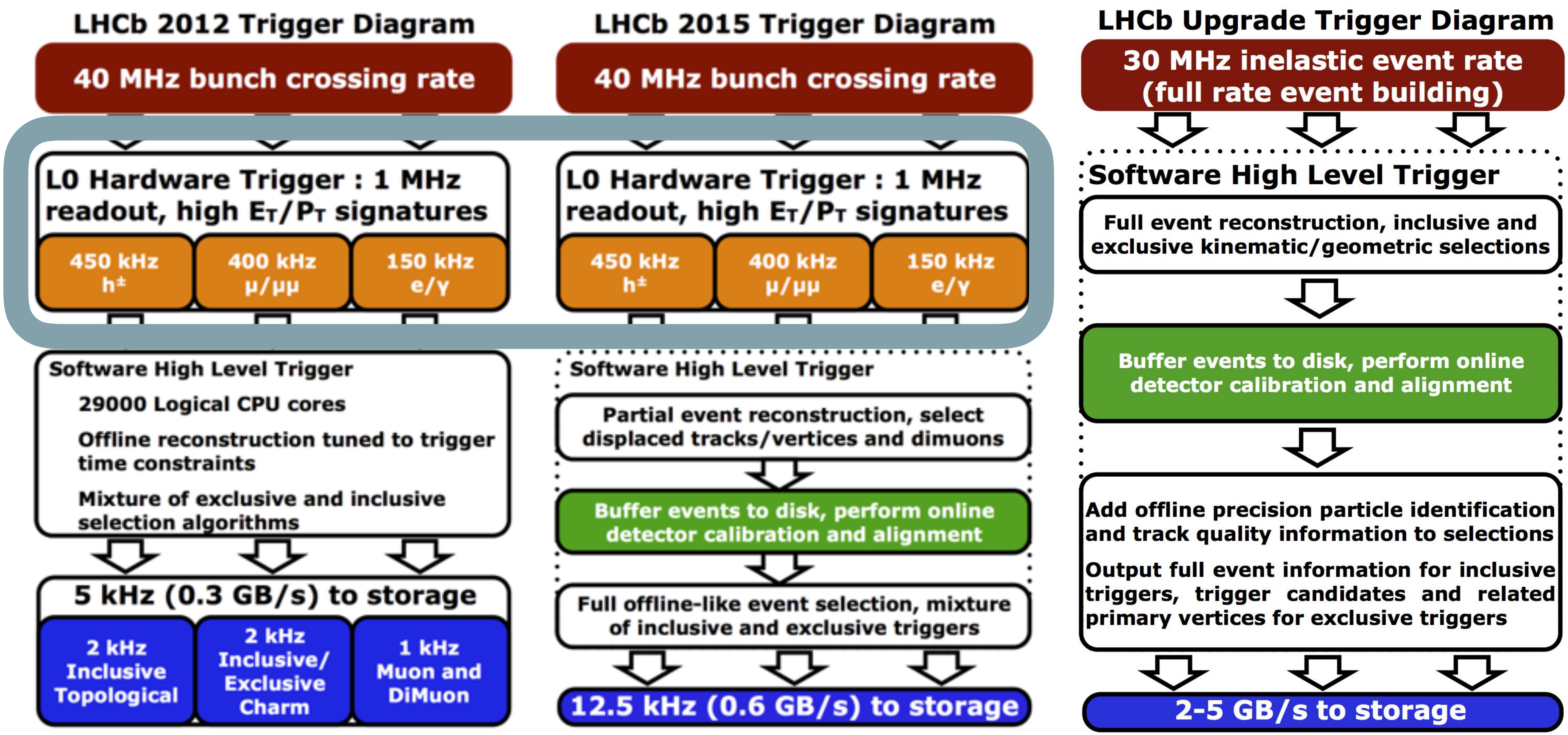
Triggers today

Triggers in the future

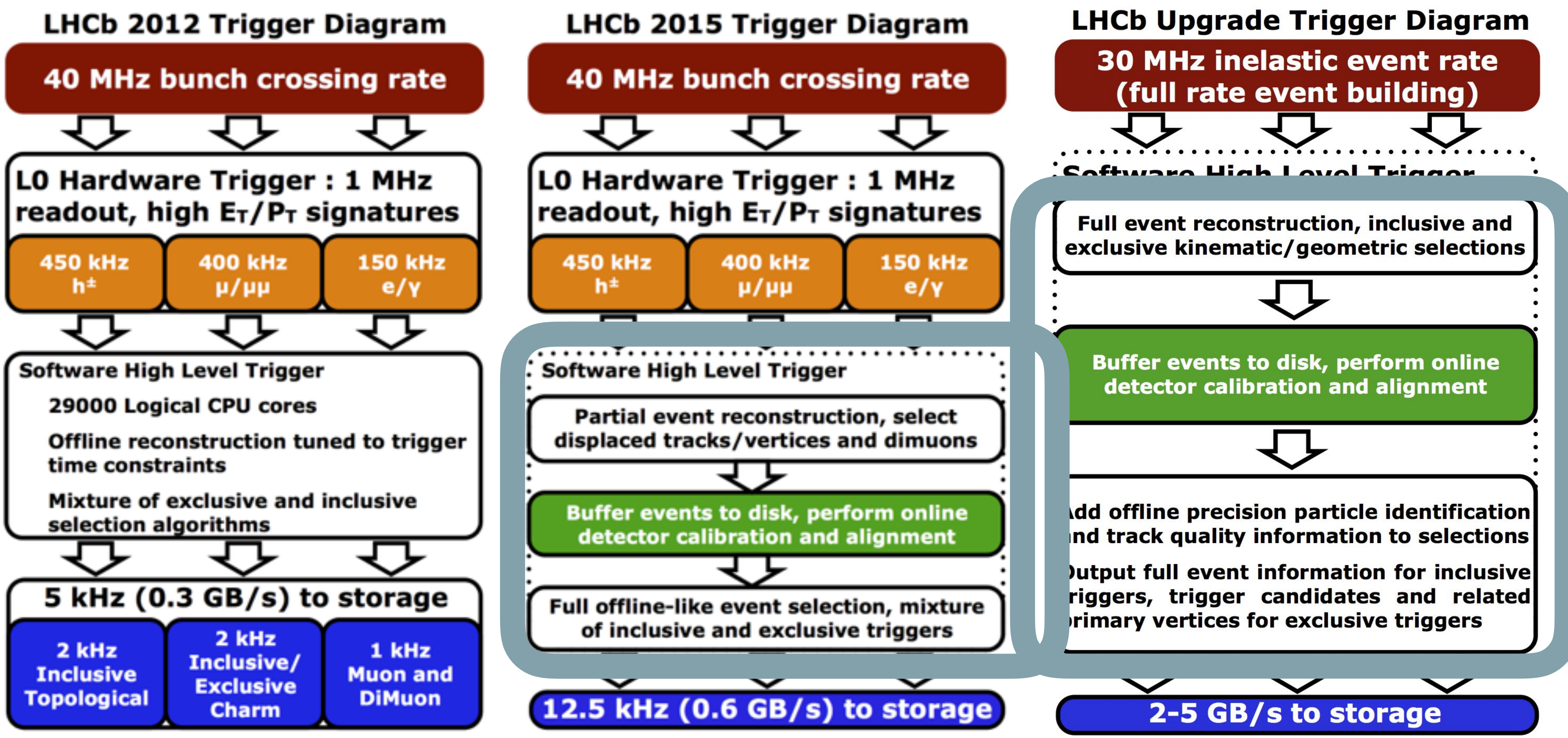
Evolution of the LHCb trigger



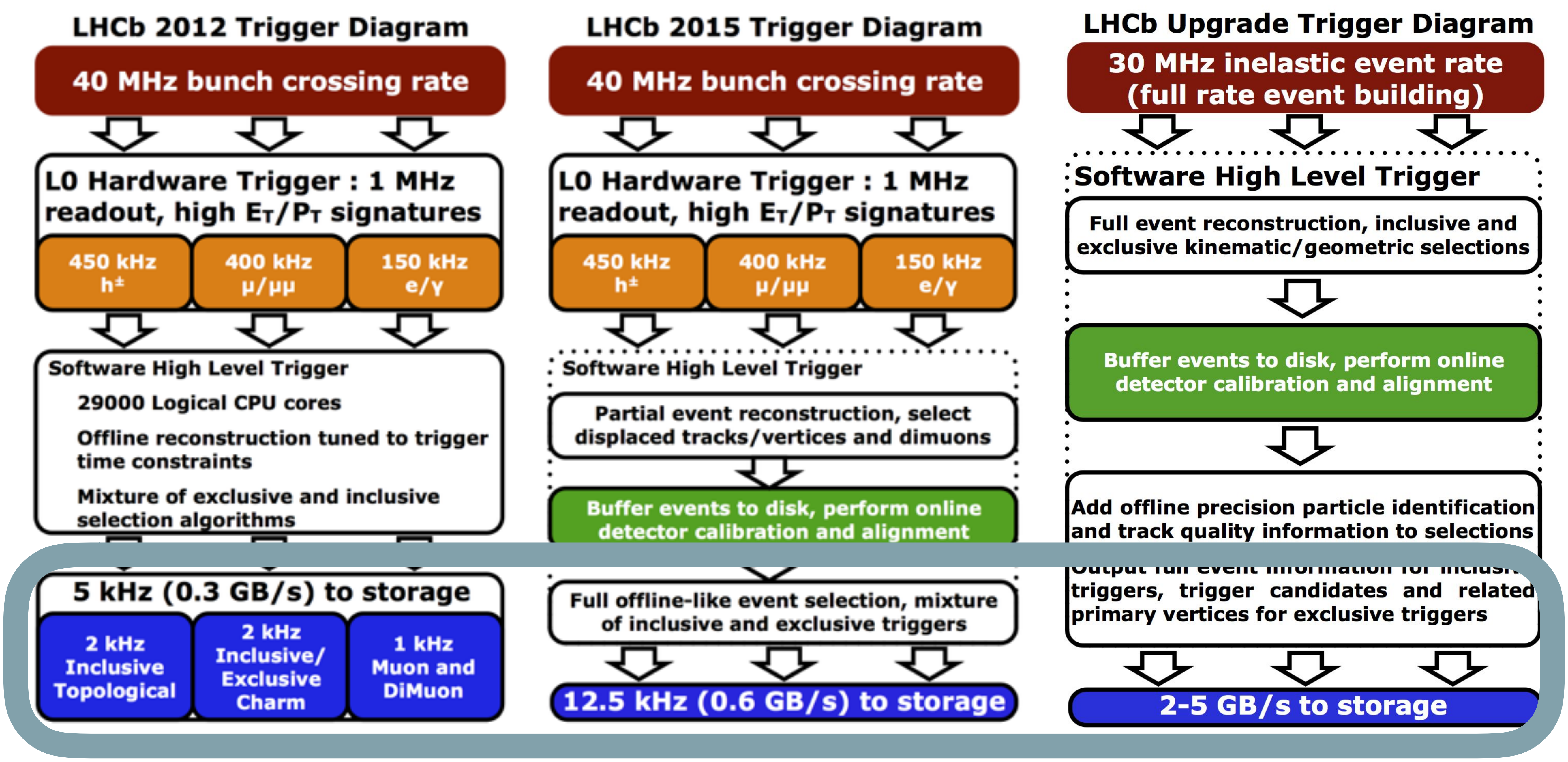
Evolution of the LHCb trigger



Evolution of the LHCb trigger

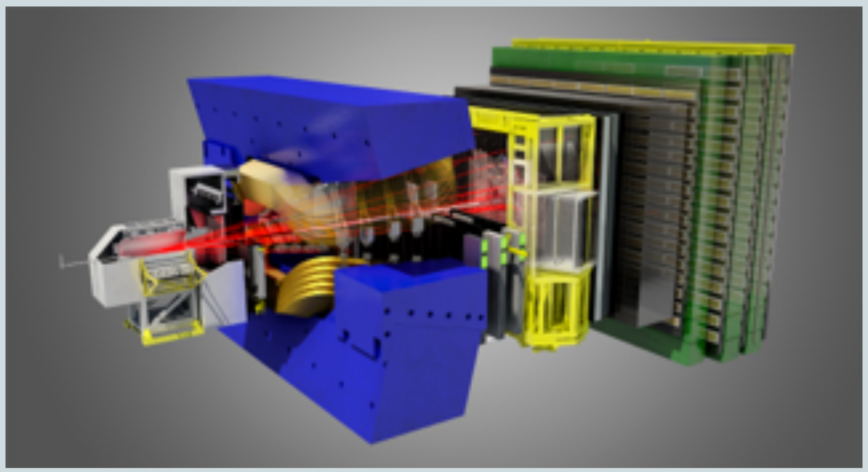


Evolution of the LHCb trigger



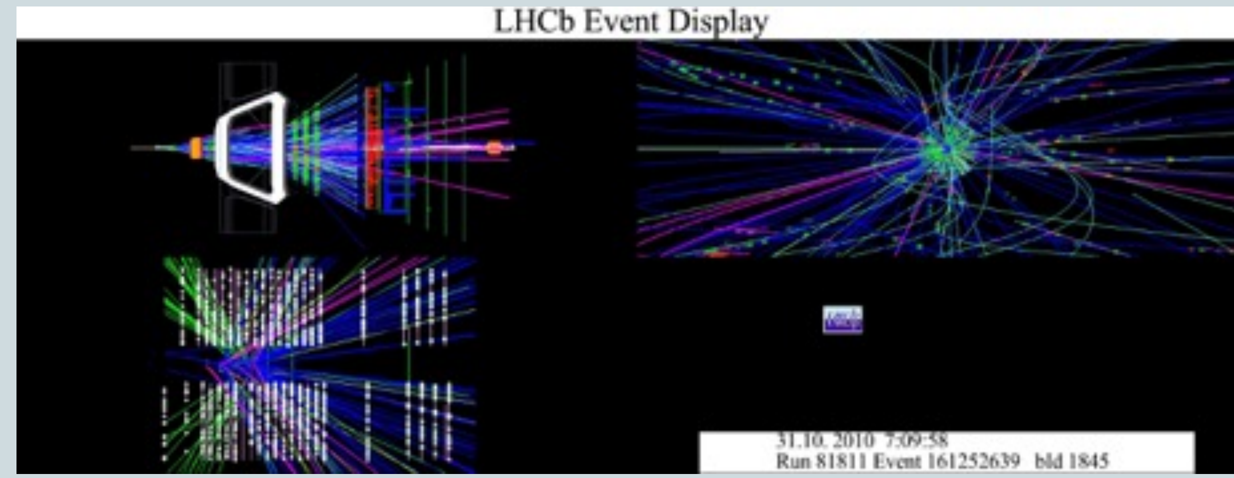
LHCb data collection strategy (pre-historic)

1



LHCb receives ~30M proton-proton collisions a second

2

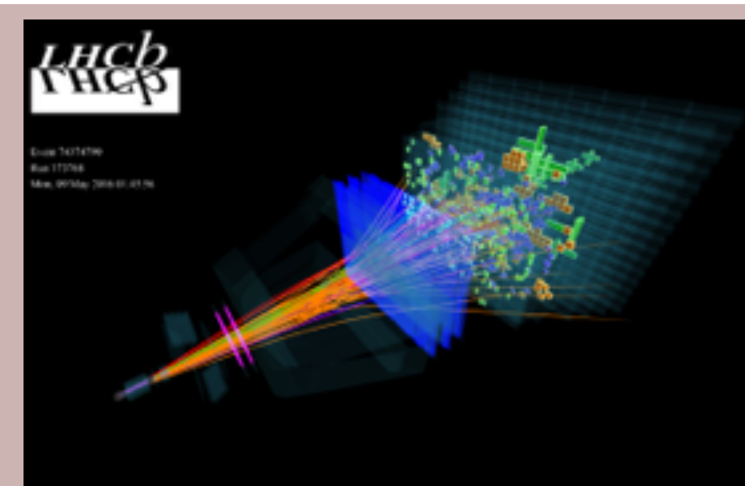


Fast reconstruction of raw data, looking for displaced vertices (classic signs of our signal)

3

If we see something? Save it.
Can save ~0.01% of the collisions

4

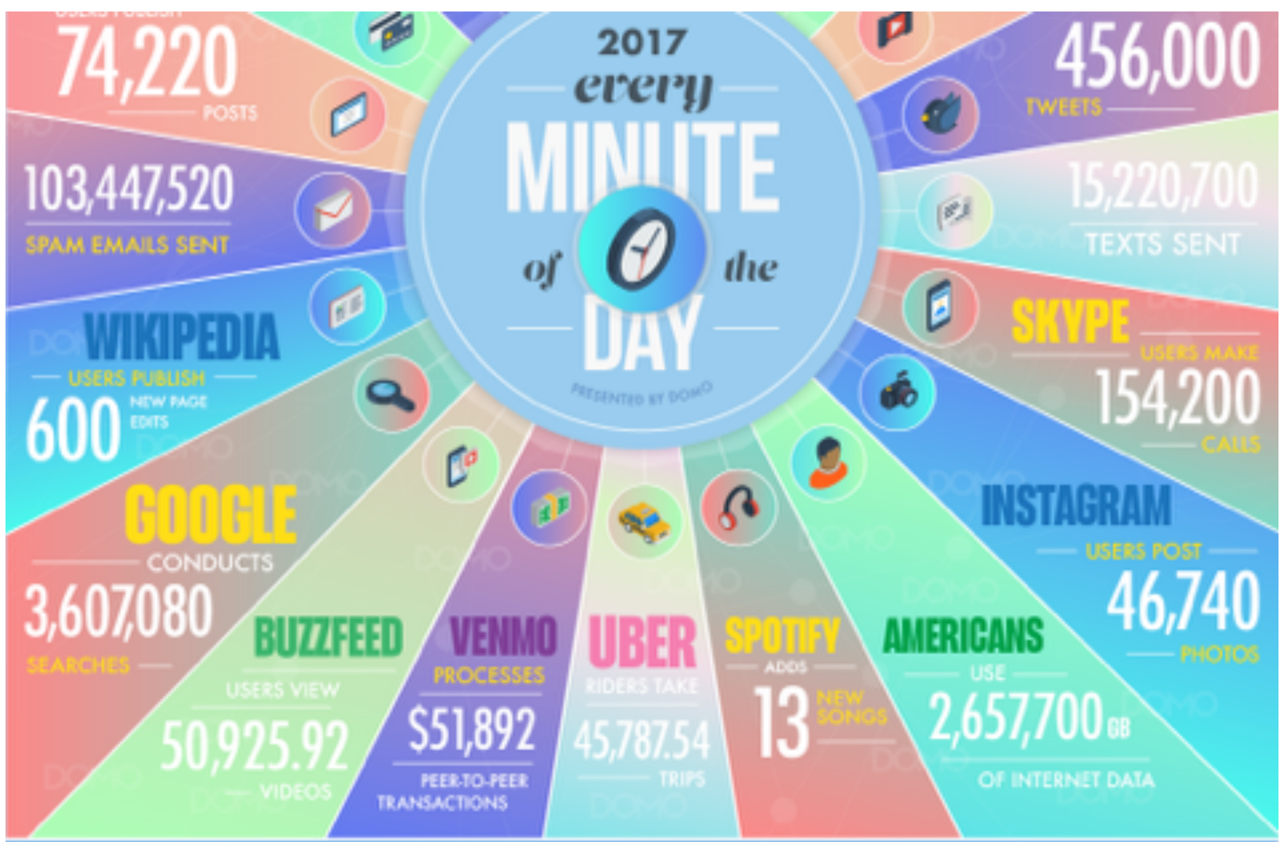


Detailed reconstruction of the data <u>from scratch</u> offline => make measurements.

LHCb local computing resources

Storage

12 PB - 20 days HLT1 output or
~5minutes American internet usage

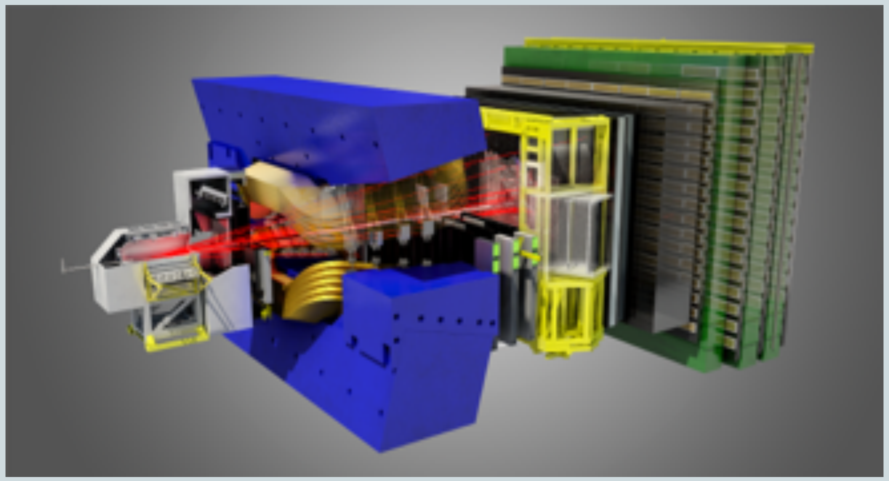


Processing powe

55000 logical cores

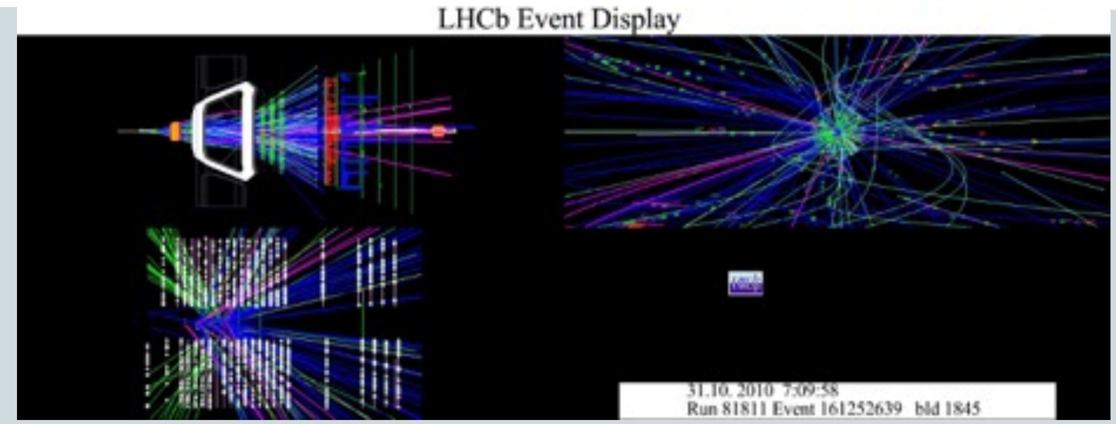
LHCb data collection strategy (now and in the future)

1



LHCb receives ~30M proton-proton collisions a second

2

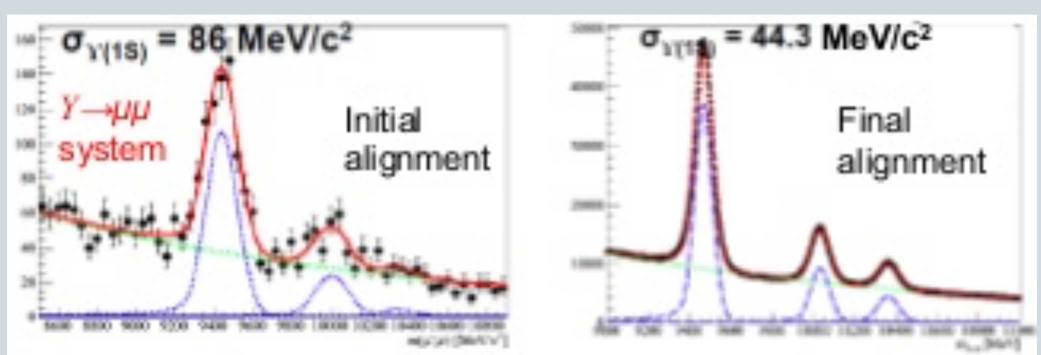


Fast reconstruction of raw data, looking for displaced vertices (classic signs of our signal)

3

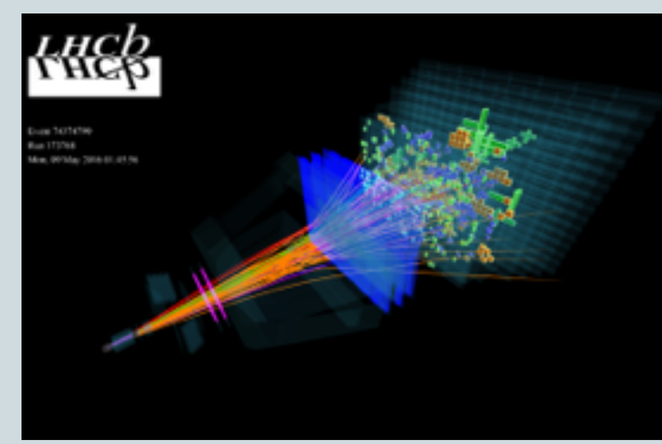
Buffer all of the data, passed by step 2 (buffer size: 13PB)

4



Use a tiny subset of the data to calibrate the detector, resulting in final quality calibrations

5

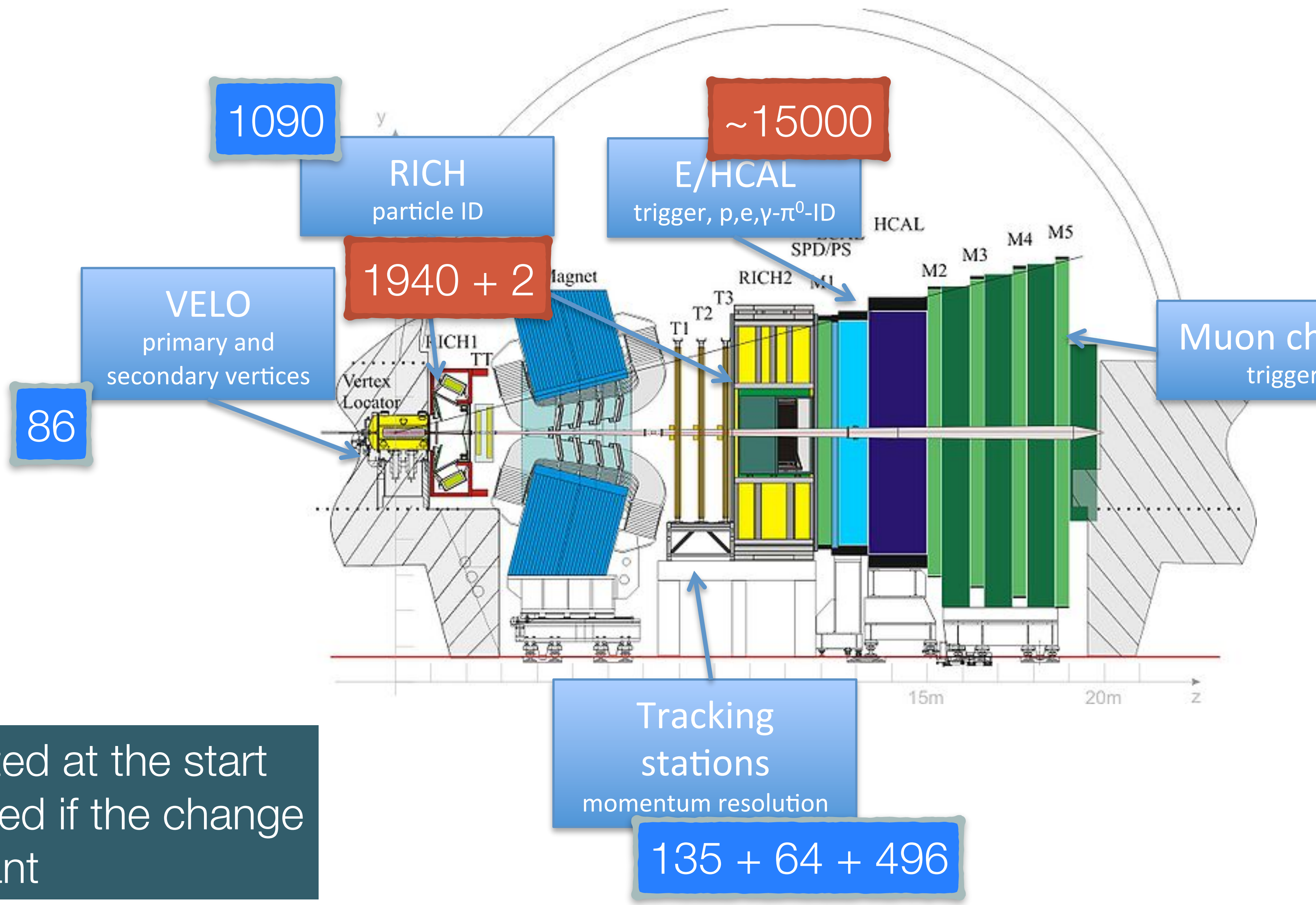


Calculate final quality information and use this directly for analyses (no additional reconstruction required)

Detector calibration in real time

alignment # params

calibration # params



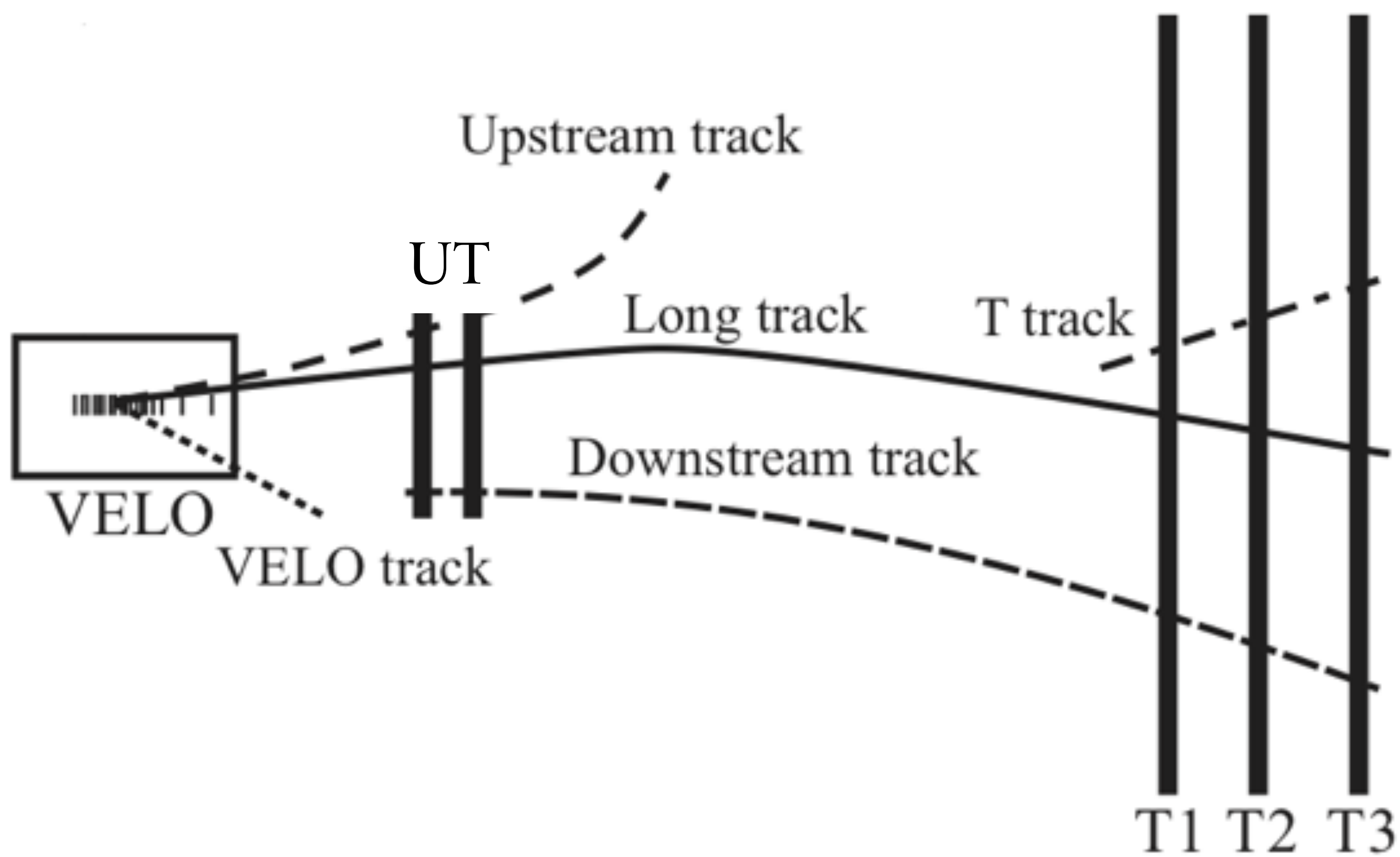
Real data used collected at the start of a fill, constants updated if the change is significant

Event reconstruction in real time

Take advantage of the Run II trigger strategy

- Perform a fast reconstruction and selection (HLT1)
  - mainly tracking, vertex finding and inclusive selections
  - buffer events on disk and perform detector alignment and calibration

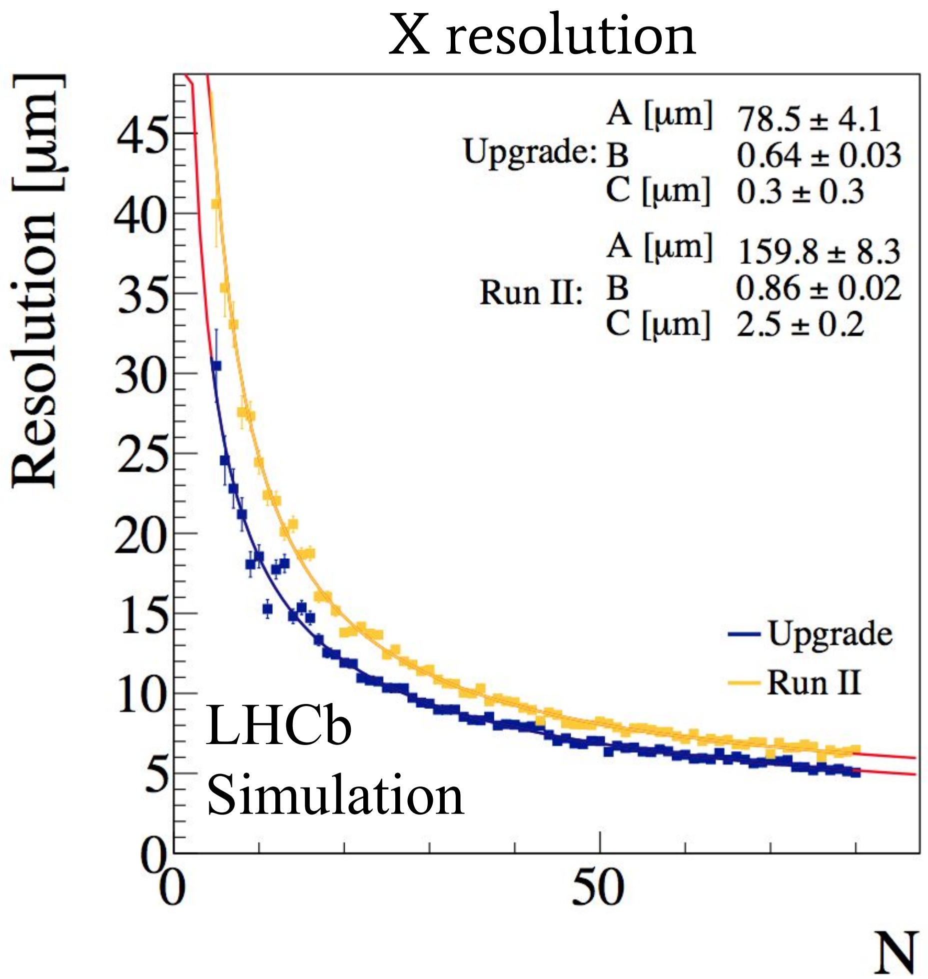
- Perform the full reconstruction and selection (HLT2)
  - ultimate track quality and particle identification

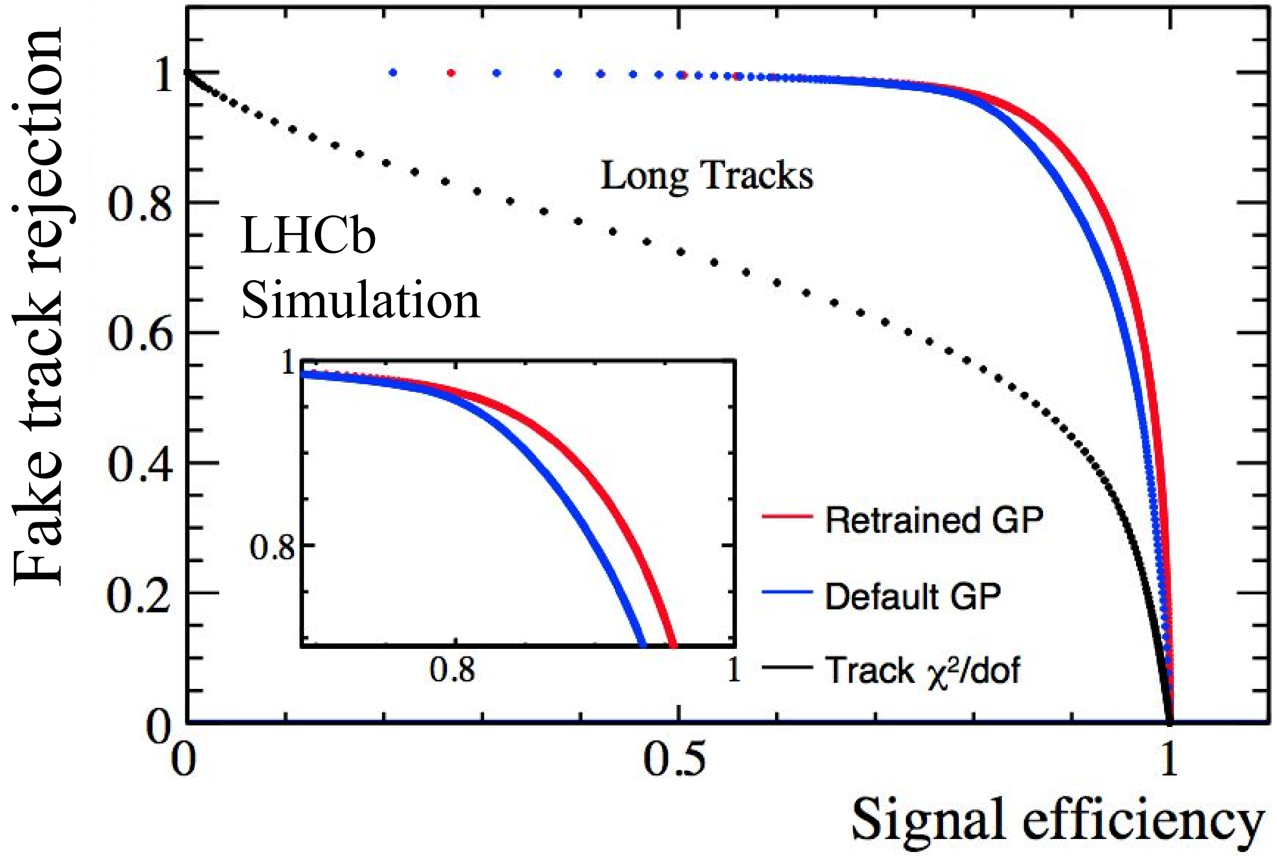


Event reconstruction in real time - performance

The event topology is more complex at the upgrade conditions

- 3-4 times more primary vertices and 2-3 times higher track multiplicity
- Challenging to keep good physics performance and to lower processing time





Event reconstruction in real time - performance

	Eff. (%)	Eff. (%) TDR
Fakes	5.6	10.9
Long tracks	92.5	92.3

	Timing (ms)	Timing (ms) TDR
Forward tracking	2.3	1.9
PV finding	1.1	0.4

Figures in the tables from single-threaded current architecture

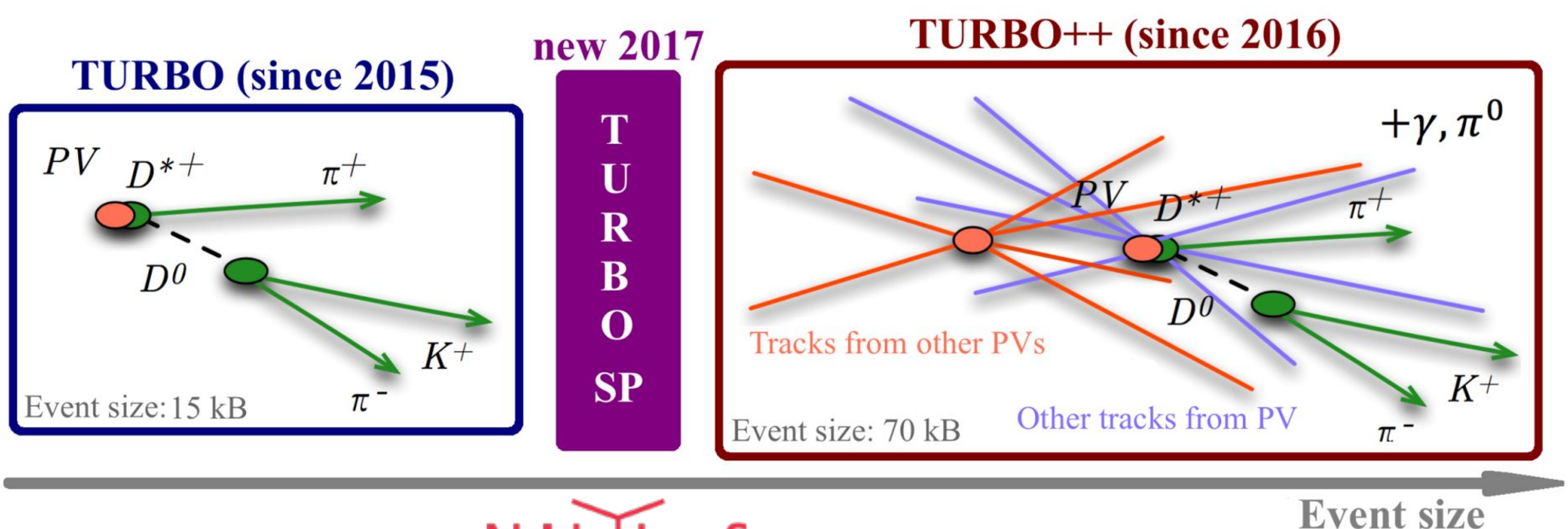
Throughput performance targets challenging to meet

- Hardware performance growth at equal cost is slowing dramatically
- Timing above measured using the software designed a decade ago
- A lot of work on new software underway Core framework (Gaudi): built-in thread safety, flexible scheduling, functional C++, etc.
- Experiment software: major redesign of algorithms
- Central Nikhef role to this

Analysis objects in real-time

Turbo: analysis with the trigger output

- Save offline storage by removing raw and uninteresting data
- Crucial for analyses needing large samples
- Real-time data reduction ⇒ be flexible in monitoring quality and updating



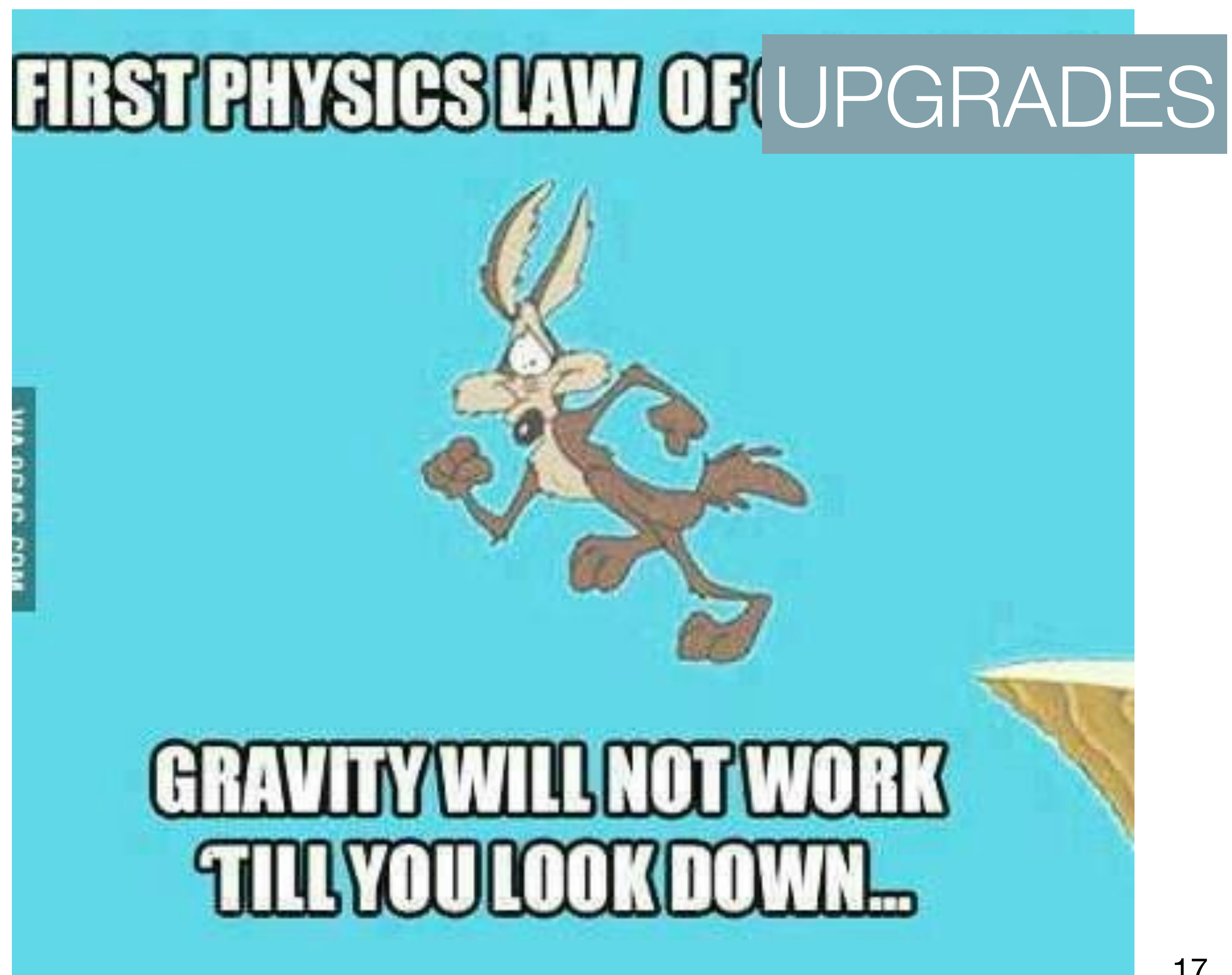
Summary

Unprecedented challenges posed by the LHCb upgrade

Many of the improvements proposed for the upgrade successfully prototyped and expanded

- Turbo
- Turbo SP

We have a computing mountain to climb and Nikhef is playing a central role

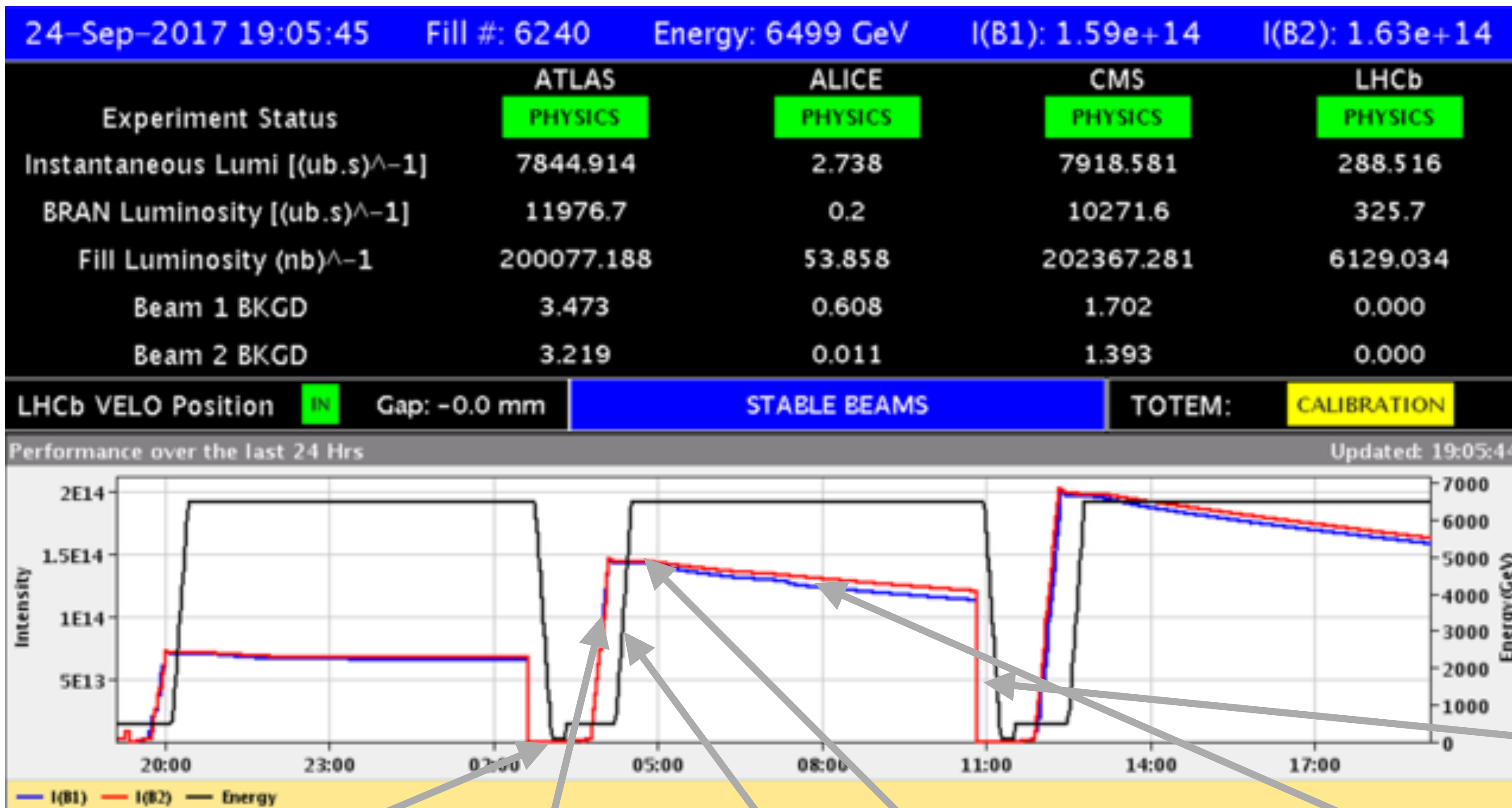


Summary


FIRST PHYSICS LAW OF CARTOONS
GRAVITY WILL NOT WORK
'TILL YOU LOOK DOWN...

Backup

The LHC



only time experiments are collecting data, usually between 35-45% of the time (including LHC testing weeks)

prepare proton injection

inject proton bunches

increase beam energy to 6.5TeV

prepare collisions

stable beams

dump beam, de-ramp dipole magnets