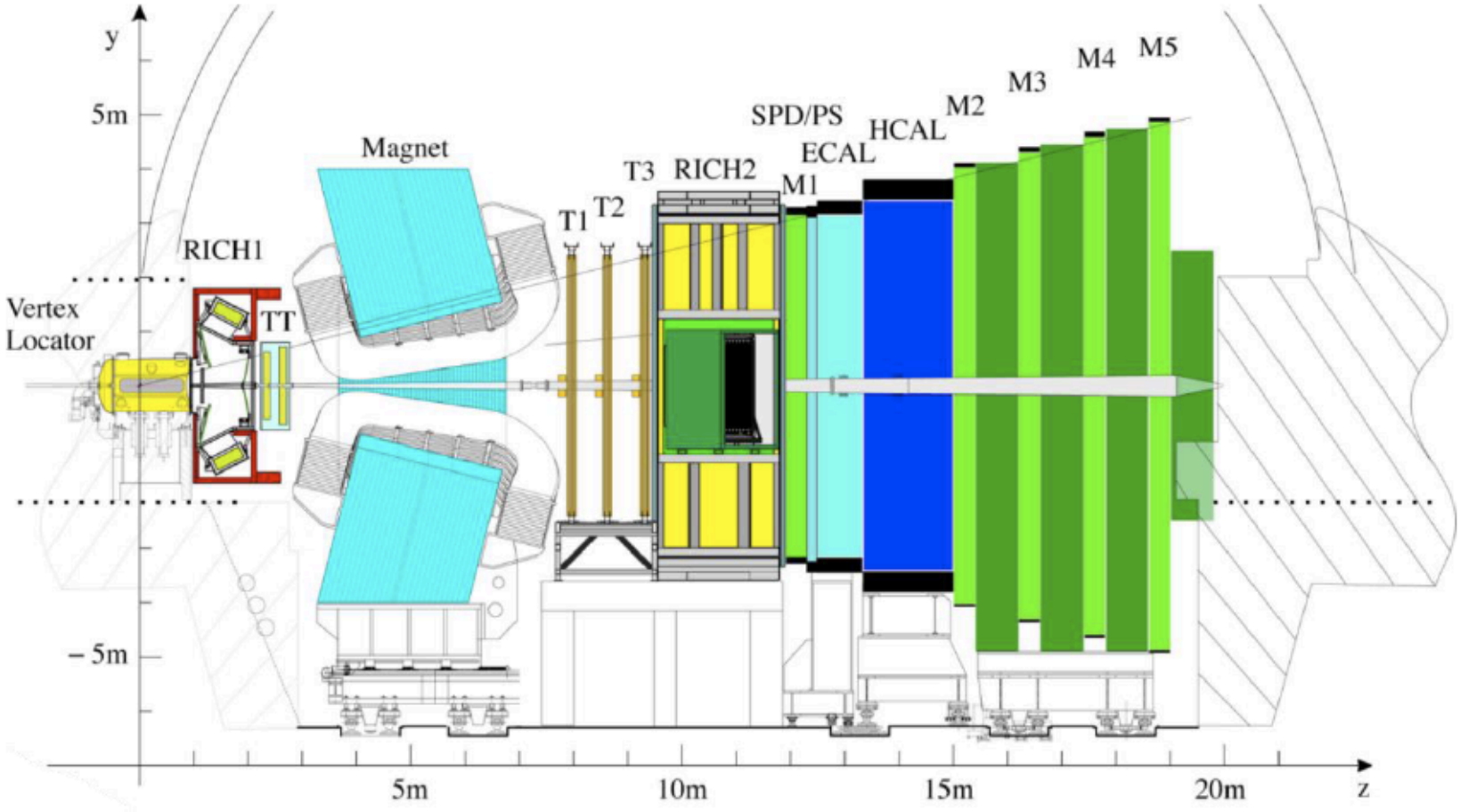
High Luminosity LHCb Challenges

Upgrade overview

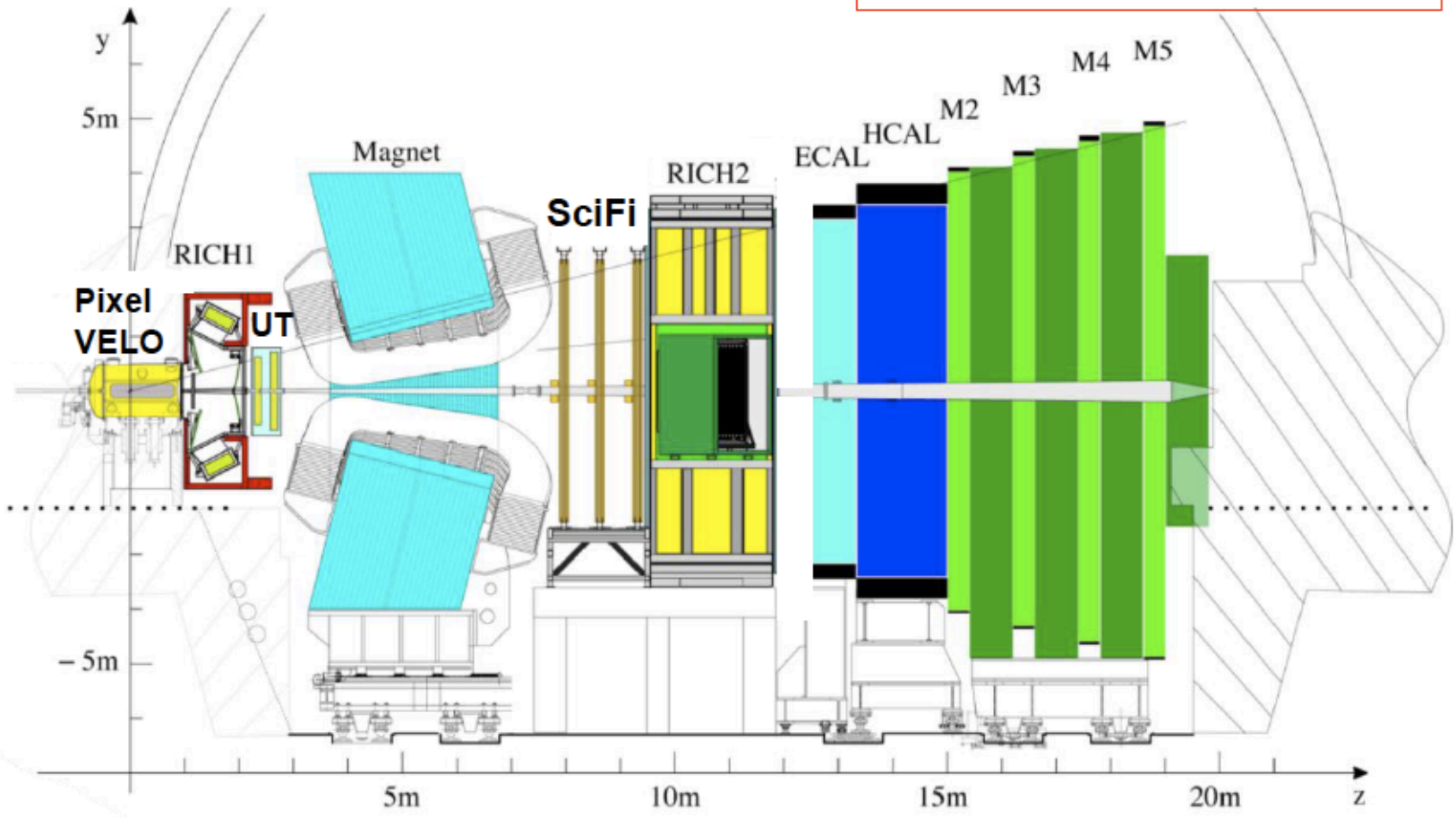
Current detector



Upgrade overview

Current detector → upgraded detector

All sub-detectors read out at 40 MHz for software trigger



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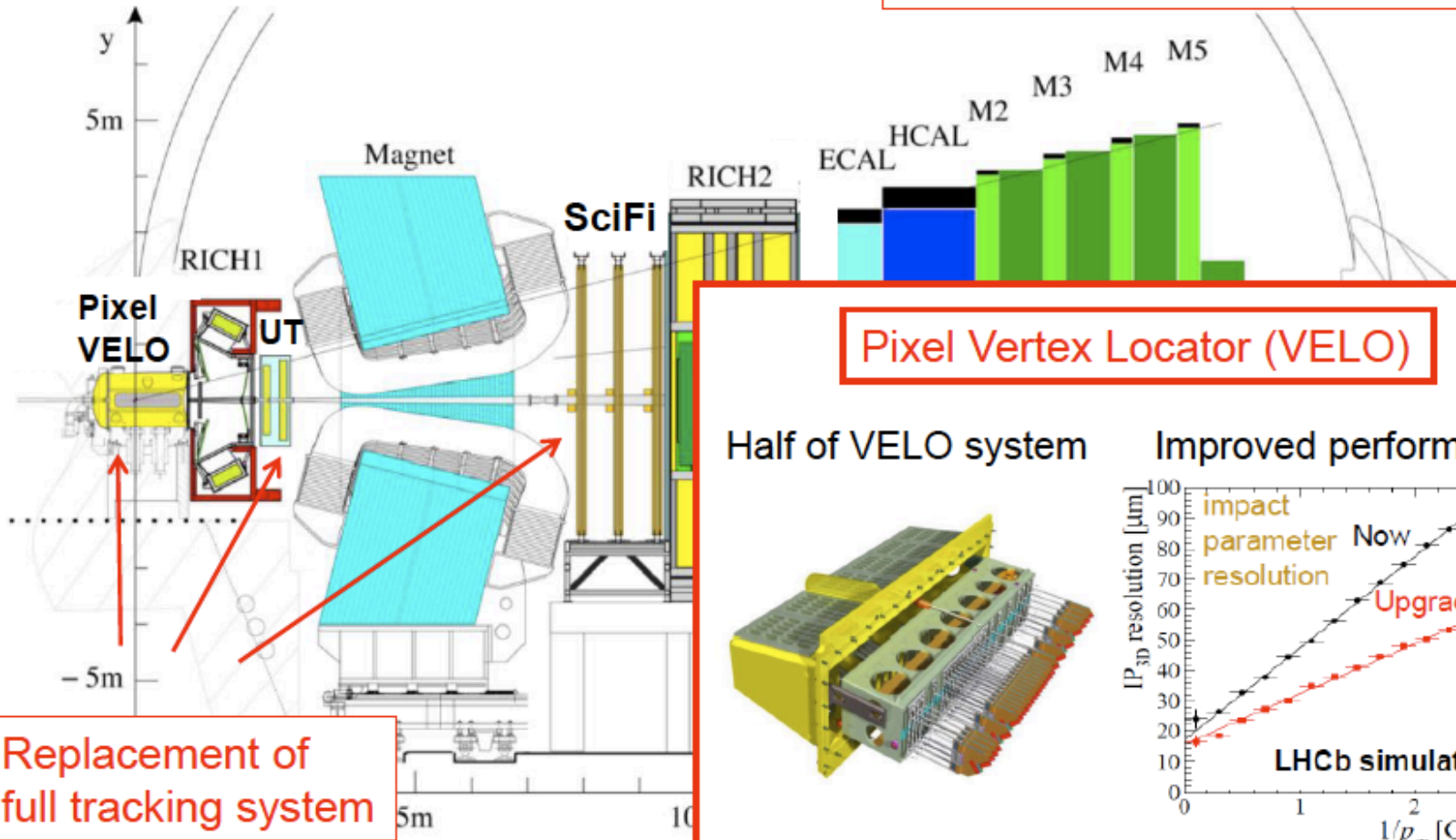


Replacement of full tracking system

Pixel Vertex Locator (VELO)

Half of VELO system

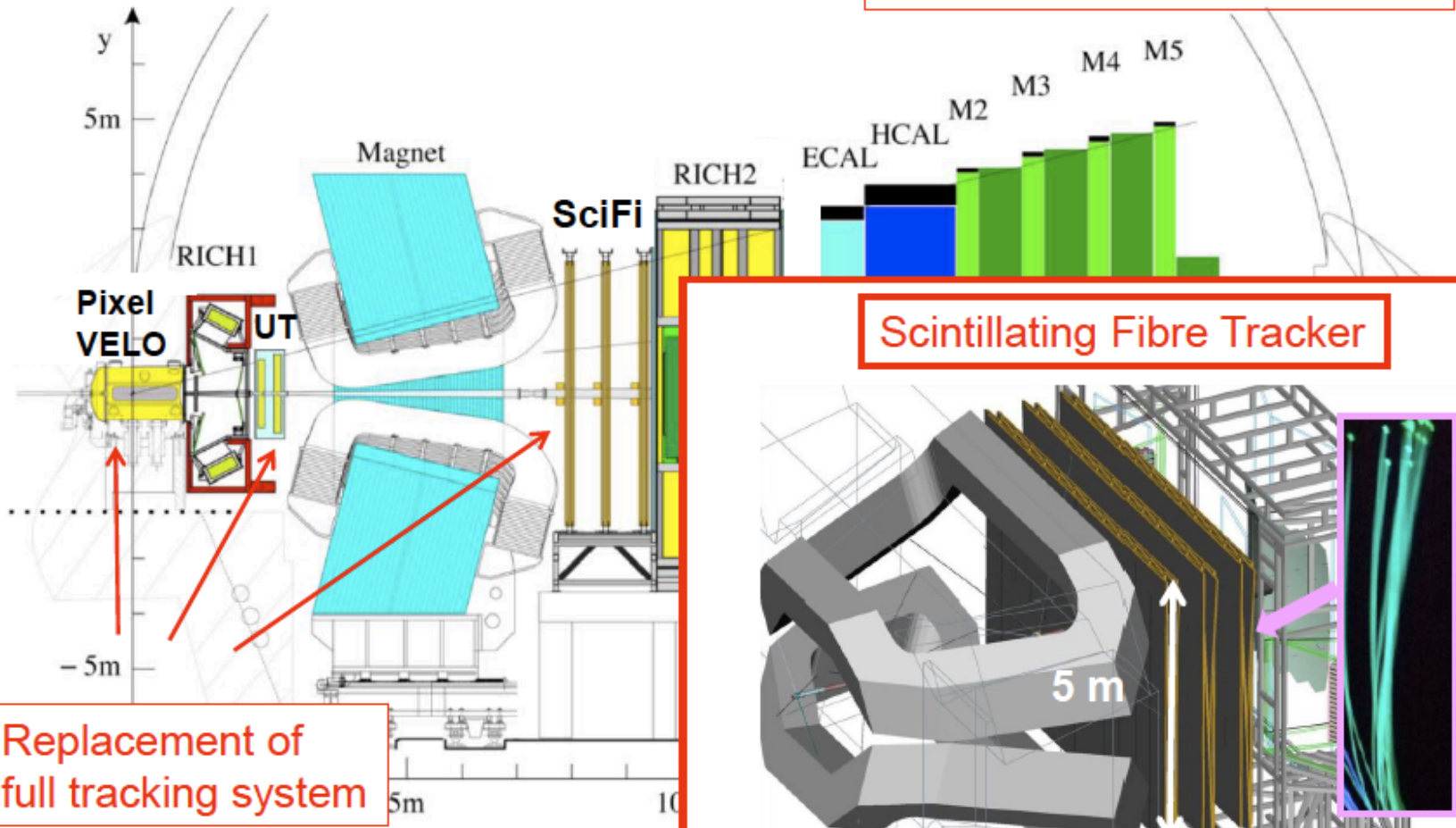
Improved performance

('UT' = 'Upstream tracker', a high performance Si strip detector)

Upgrade overview

Current detector → upgraded detector

All sub-detectors read out at 40 MHz for software trigger



Replacement of full tracking system

Scintillating Fibre Tracker

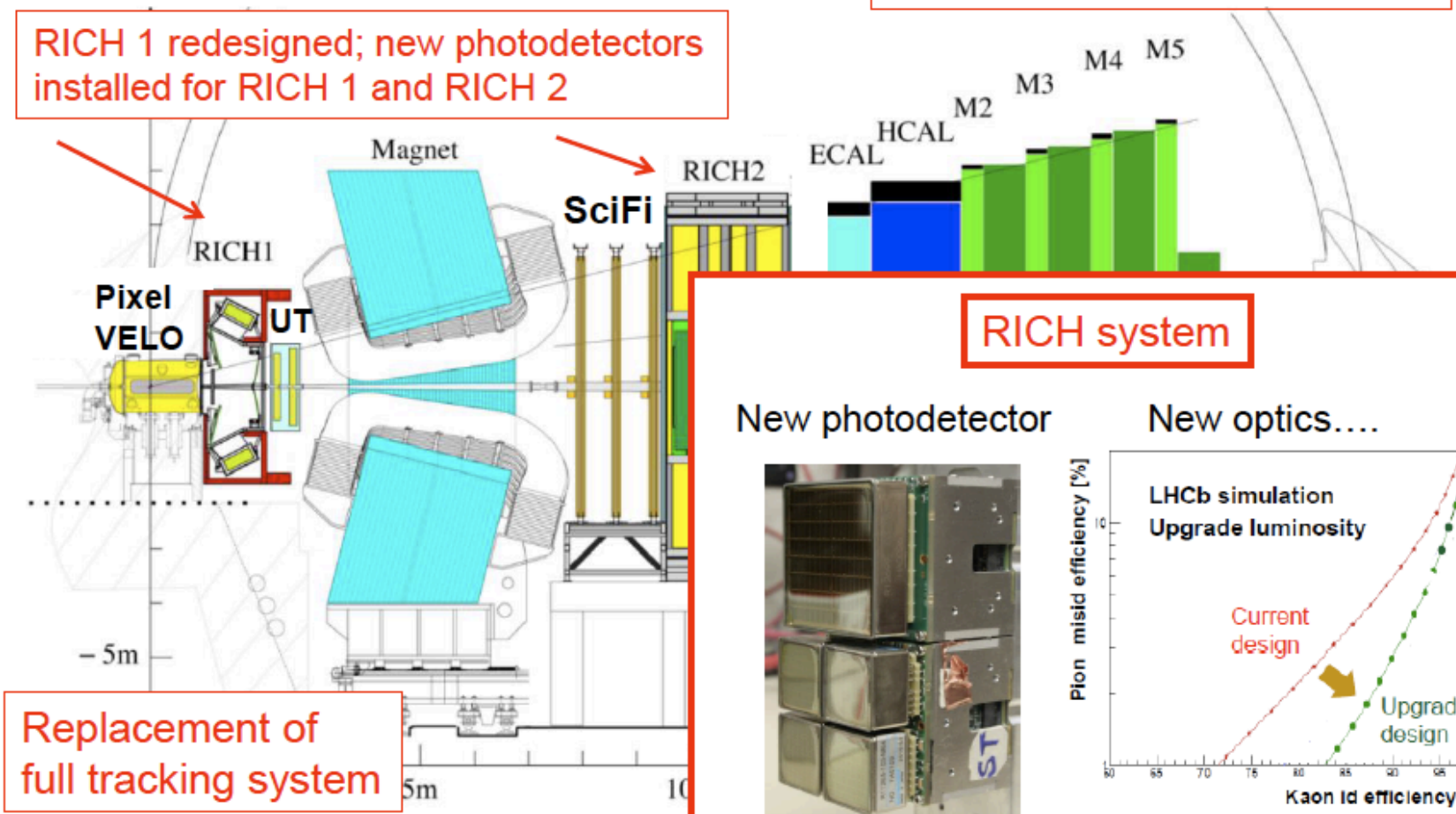
Large scale system (~12,000 km of fibres)

Upgrade overview

Current detector → upgraded detector

All sub-detectors read out at 40 MHz for software trigger

RICH 1 redesigned; new photodetectors installed for RICH 1 and RICH 2



Replacement of full tracking system

RICH system

New photodetector

New optics….

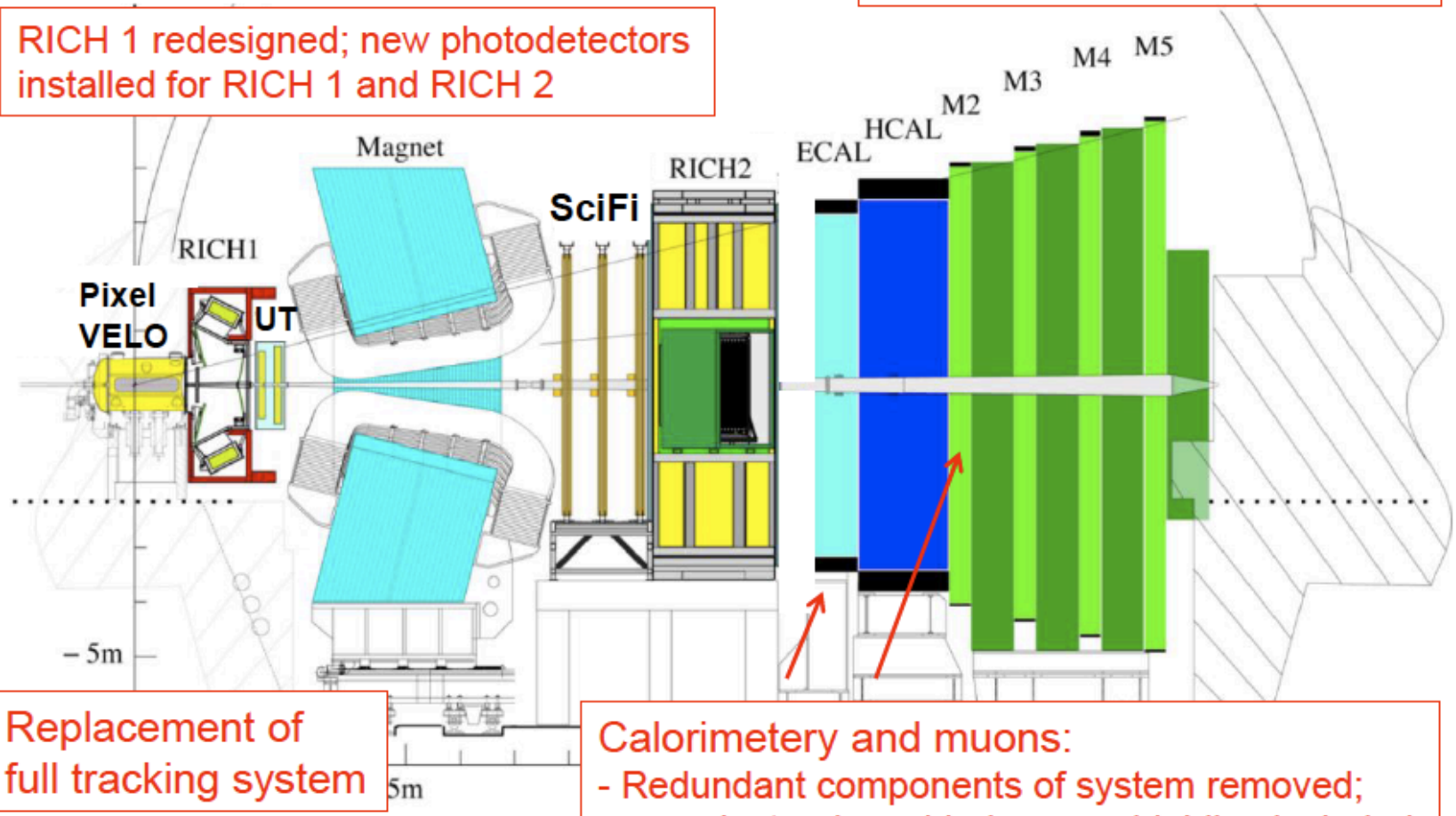
…good performance at high luminosity

Upgrade overview

Current detector → upgraded detector

All sub-detectors read out at 40 MHz for software trigger

RICH 1 redesigned; new photodetectors installed for RICH 1 and RICH 2



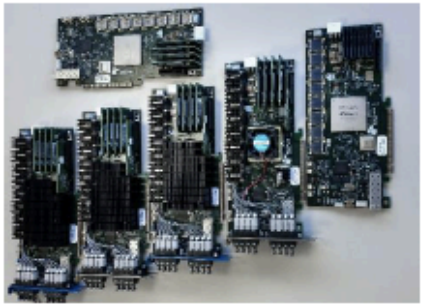
Replacement of full tracking system

Calorimetery and muons:
- Redundant components of system removed; new electronics added; more shielding included

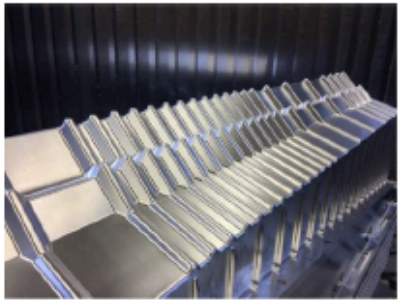
Upgrade overview

Excellent progress on all aspects of the Upgrade project.

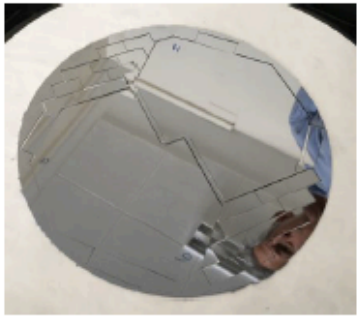
Prototype readout boards



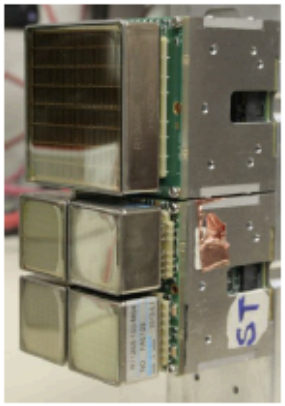
RF box for VELO



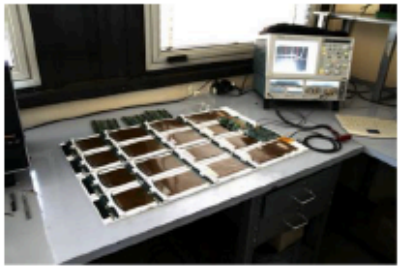
Diced wafer with microchannel cooling substrates for VELO



RICH photodetectors



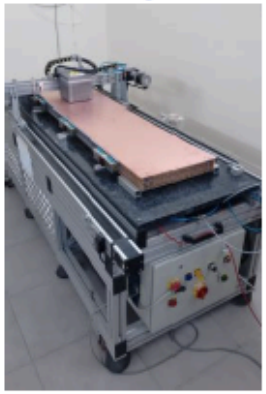
Testing Upstream Tracker 'flex cables'



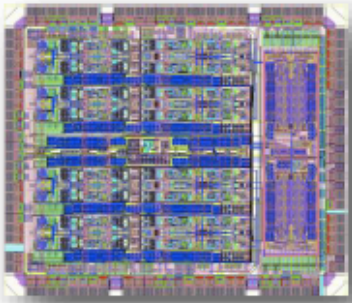
Delivery of tracker scintillating fibres (SciFi)

First batch of SciFi modules arriving at IP8

MWPC for muon system

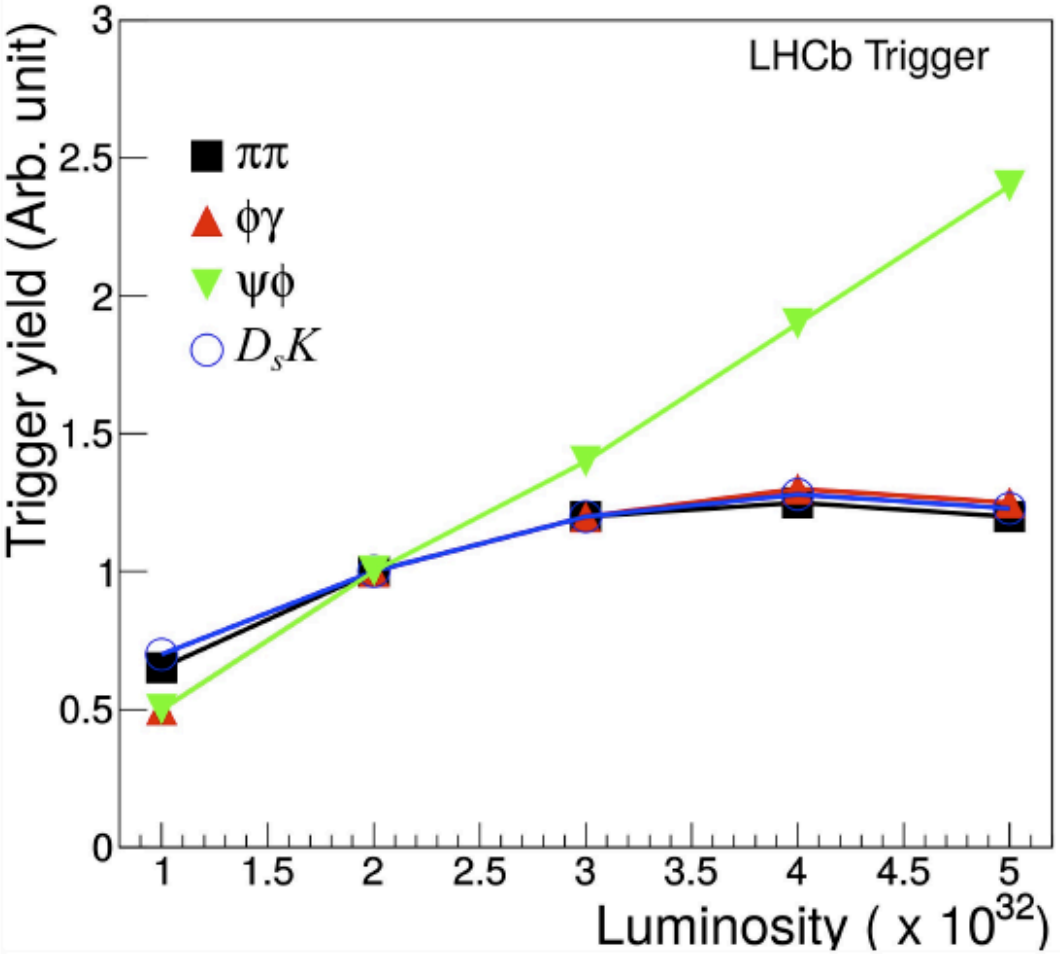


ECAL front-end ASIC



Timescale tight, but still on-track for installation in LS2.

Upgrade trigger



what doesn't work

- increased luminosity

→ events passing hardware trigger

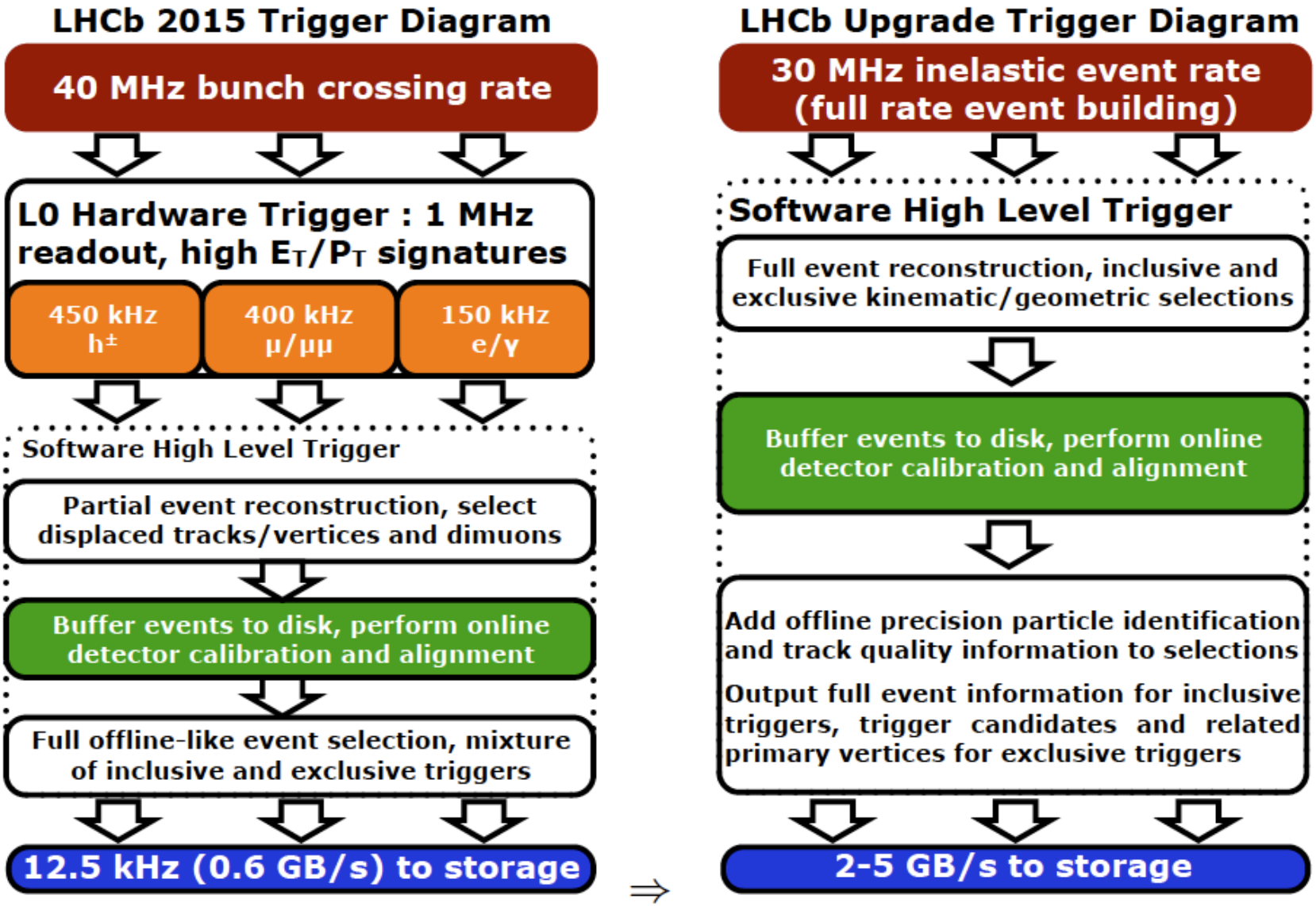
→ saturating bandwidth

→ tighten thresholds

→ loss in efficiency

⇒ no increase in statistics for analyses (depending on the decay channel)

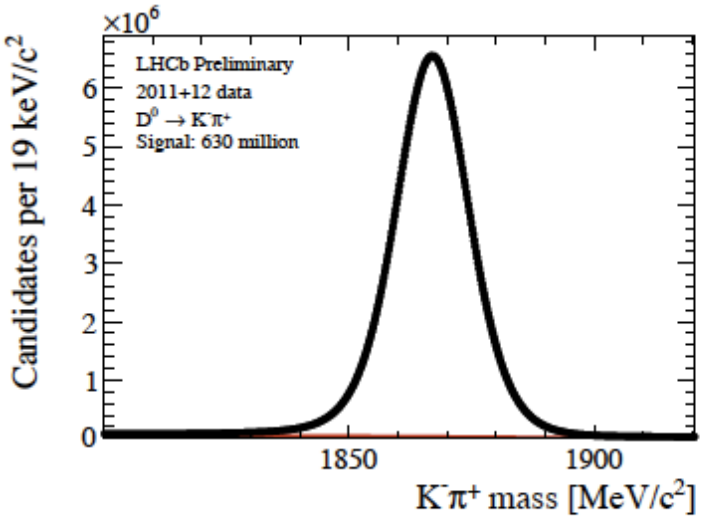
Upgrade trigger



Upgrade trigger

Triggers today

Real-time data analysis tomorrow



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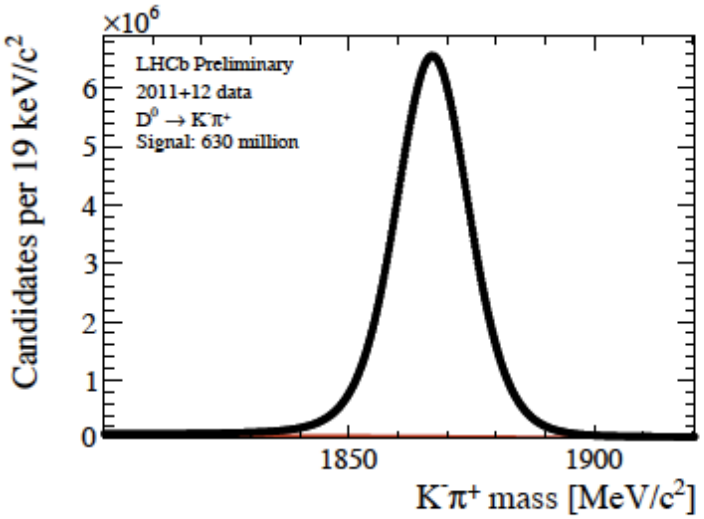
- Selecting and storing full events could work for rare signal
- When dealing with "millions" of good signal events, rejecting background isn't enough to stay within processing bandwidths

At LHC, flavour physics has no background: almost every event contains signal candidates

Upgrade trigger

Triggers today

Real-time data analysis tomorrow



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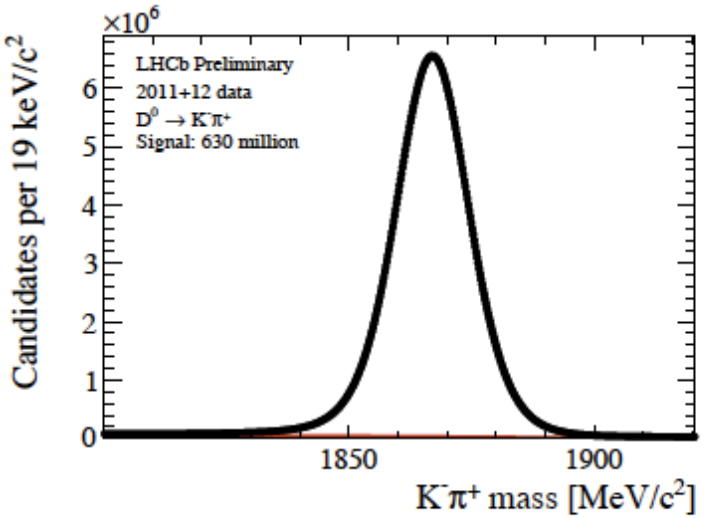
The TURBO approach

- once a decay is reconstructed (mass, decay time, Dalitz plot) no need to access raw data for analysts
- once a decay is reconstructed in the trigger no need to re-reconstruct offline
- (unaffordable to study raw data for millions of events anyway)

Upgrade trigger

Triggers today

Real-time data analysis tomorrow



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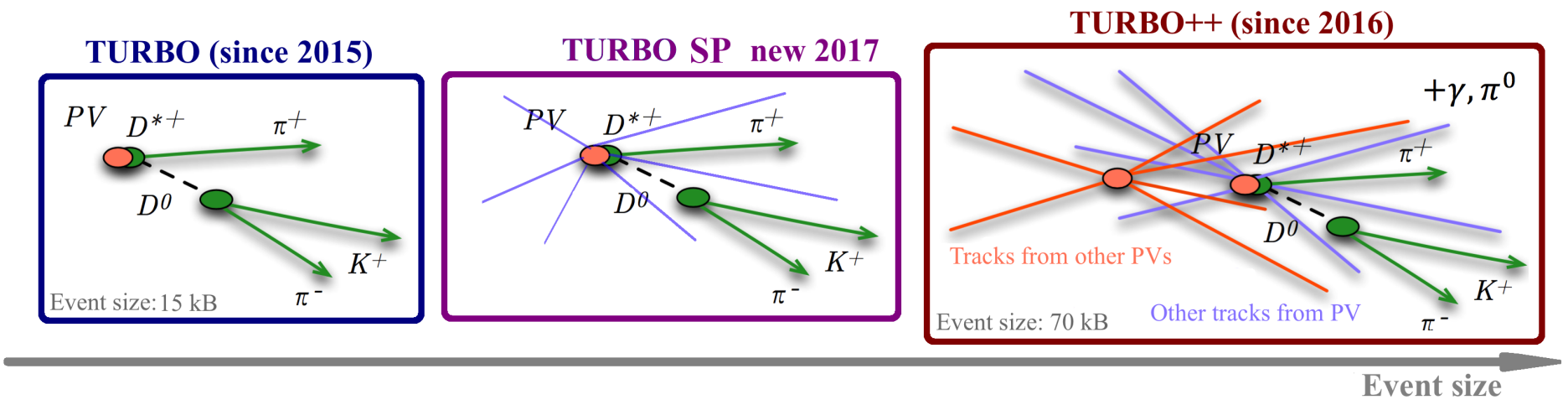
The TURBO approach

- once a decay is reconstructed (mass, decay time, Dalitz plot) cannot afford to store all raw data offline
- once a decay is reconstructed in the trigger cannot afford to re-reconstruct all data offline
- **Finite budget for offline computing resources**

Upgrade trigger

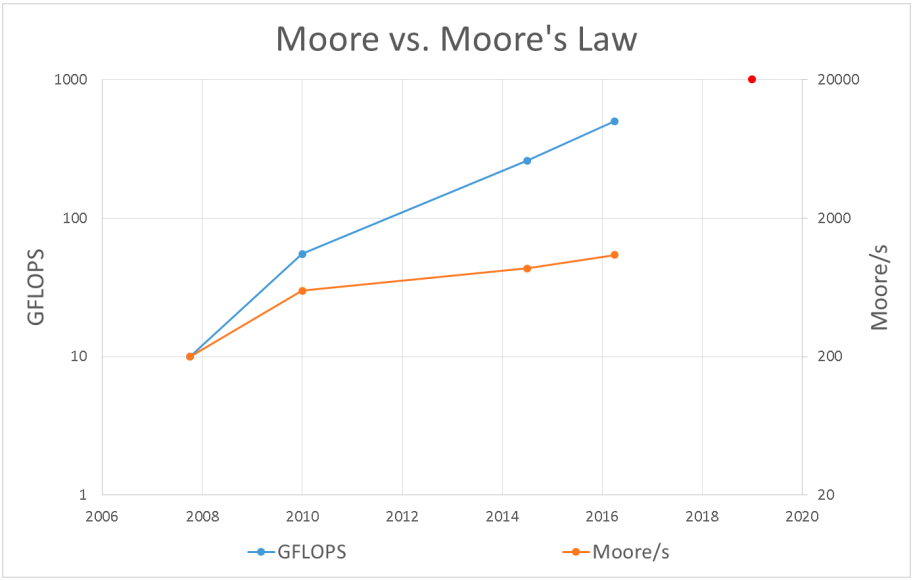


per trigger line storage definition

- only decay and nothing else
- decay and selected reconstructed objects
- all *reconstructed* objects (no raw data)
- full raw event

TURBO triggers must be a default for many analyses

Upgrade trigger:CPU power

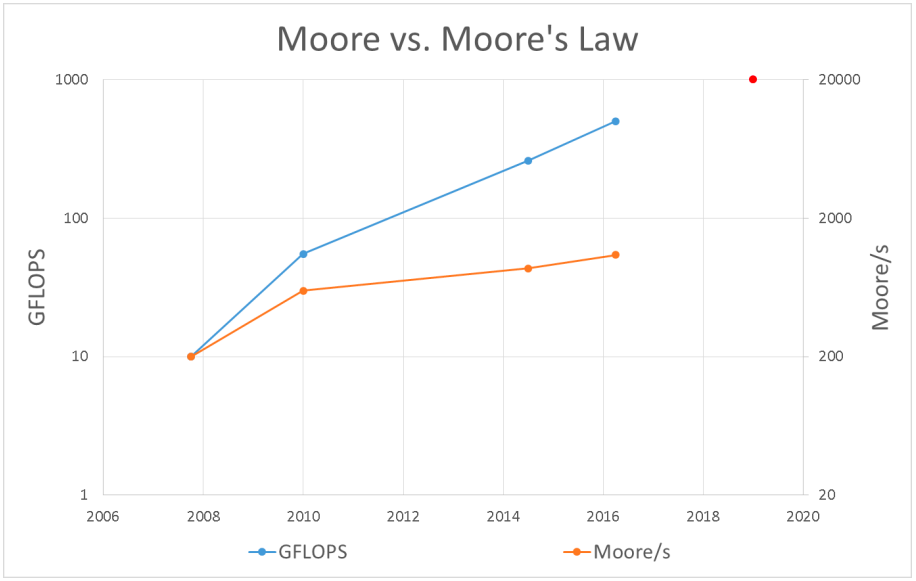


- theoretical computing power of CPUs increases (per second, per Watt, per CHF)
- observed computed trigger decisions does not follow that increase

reasons from a CPU's point of view I/II

- modern vector units process 2, 4, or 8 inputs at a time
  $\rightsquigarrow$ our software often didn't use these
  $\rightarrow$ 7/8 of the silicon unused!

Upgrade trigger:CPU power



- theoretical computing power of CPUs increases (per second, per Watt, per CHF)
- observed computed trigger decisions does not follow that increase

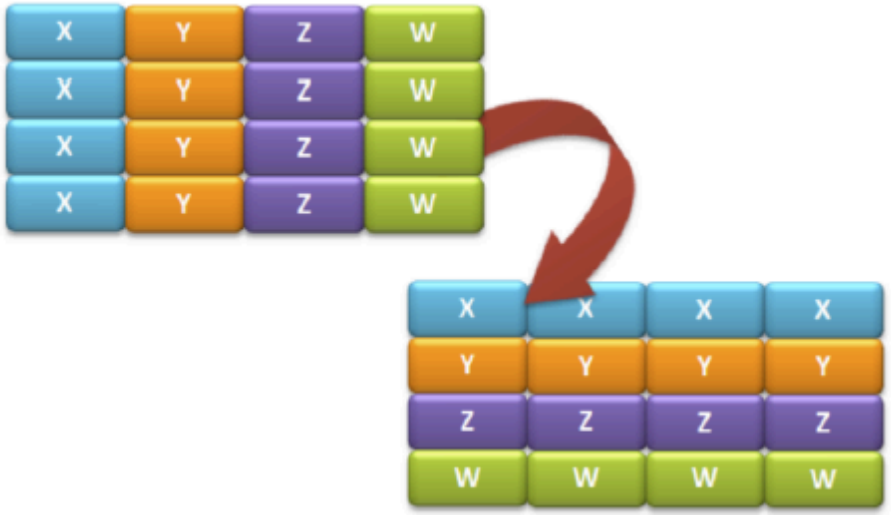
reasons from a CPU's point of view II/II

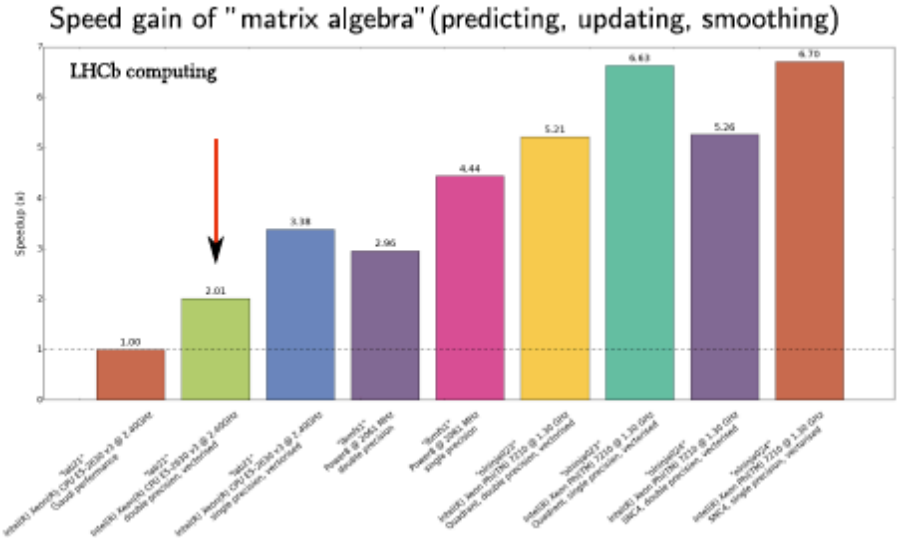
- software not parallelised (just start multiple processes on a multicore machine)
  - $\rightsquigarrow$ processes compete for memory
  - $\rightsquigarrow$ even multiple instances of the same data (detector geometry)
  - $\rightarrow$ CPU waits for data instead of computing

New computing techniques R&D

Example: track fitting

- track fit one of the big CPU time consumers
- written for sequential adding of hits
- but different tracks can be fitted independent of each other (thread parallelisable)
- matrix operations are always the same (vectorisable)





conclusions

- The main challenge for future HEP experiments is data handling and computing resources
- LHCb upgrade will implement a new paradigm for trigger and computing
- Only novel trigger and analysis concepts (e.g. TURBO stream) will make data analysis affordable in future HEP experiments
- LHCb is pioneering these concepts
- LHCb will change completely the way HP experiment will be made
- R&D in computing nowadays as (if not more) important as detector R&D