Tracking in LHCb's 2020 HLT

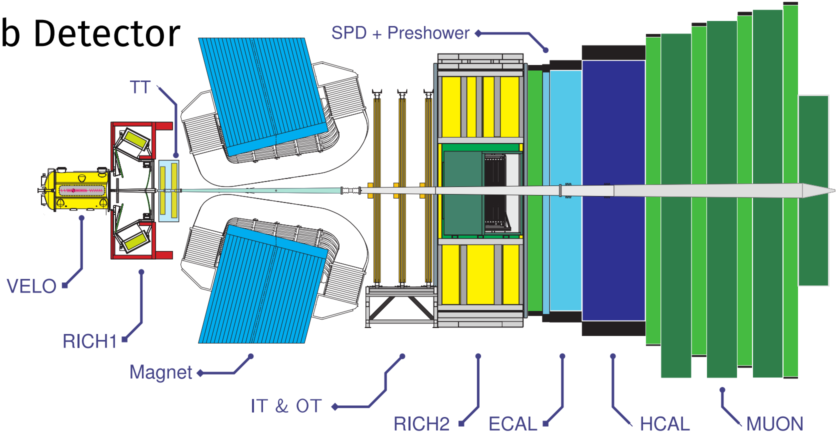
Connecting the Dots 2015

Tim Head, on behalf of LHCb

École Polytechnique Fédérale de Lausanne

9 February 2015

The LHCb Detector

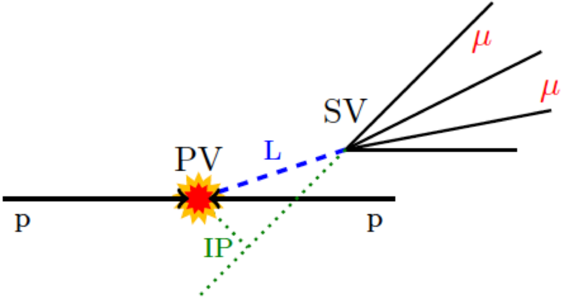


Eur.Phys.J. C71 (2011) 1645
Phys.Lett. B694 (2010) 209–216

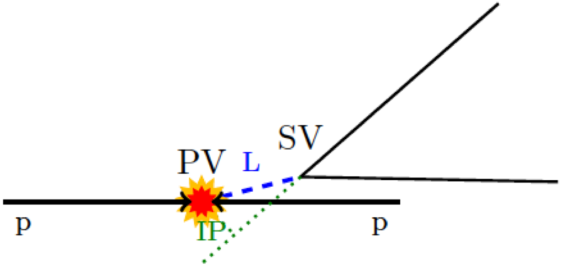
- LHCb is a single-arm ($2 < \eta < 5$) spectrometer at the LHC
  - Precision beauty and charm physics: CP violation, rare decays, heavy flavour production
- σ_{bb} and σ_{cc} are extremely large at the LHC
  - 30 kHz $b\bar{b}$ and 600 kHz $c\bar{c}$ in LHCb acceptance!

Heavy Flavour Signatures

Beauty hadrons



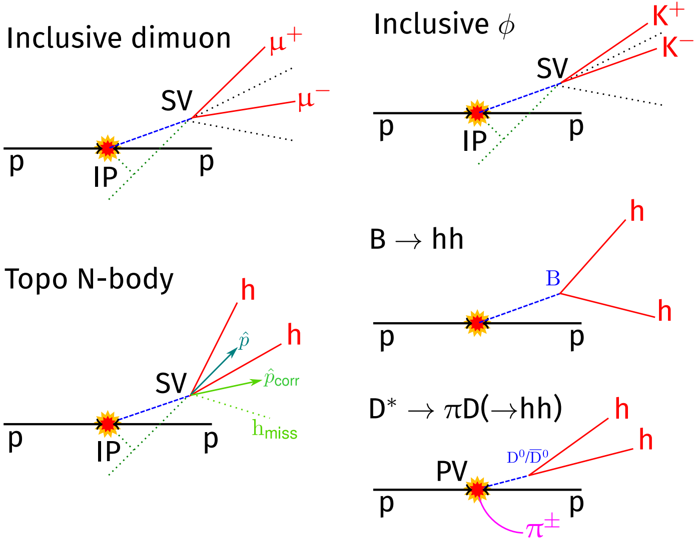
Charmed hadrons



- B^+ mass 5.28 GeV, daughter p_T $\mathcal{O}$ (1 GeV)
- lifetime $\approx$ 1.6 ps $\Rightarrow$ flight distance $\approx$ 1 cm
- common signature: detached $\mu\mu$

- D^0 mass 1.86 GeV, sizeable daughter p_T
- lifetime $\approx$ 0.4 ps $\Rightarrow$ flight distance $\approx$ 4 mm
- can be produced in B decays

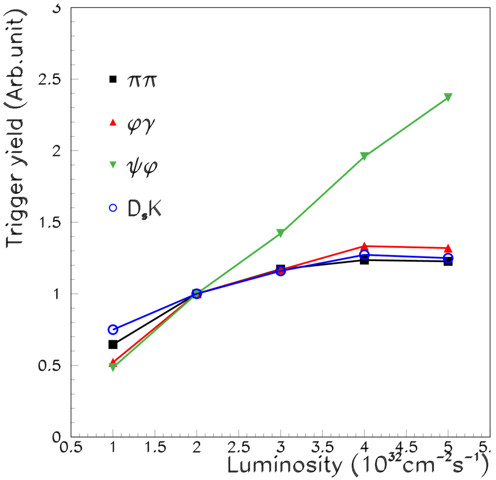
Actual Signatures



- Combining inclusive and exclusive selections
- Main trigger is a Bonsai BDT
- What you really need is offline like event reconstruction!
- Extremely powerful and flexible software environment

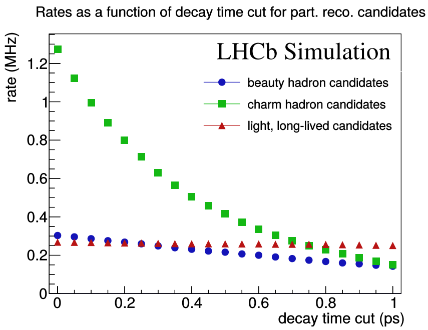
LHCb at 40MHz

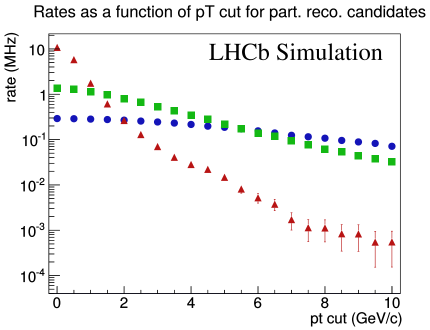
- In Run 2 LHCb will collect $\approx 8\,\text{fb}^{-1} \Rightarrow$ increase instantaneous luminosity
- At increased luminosity signals less well separated in L0 $\Rightarrow$ we need to read out every event!
- Upgrade readout to 40 MHz, full detector readout of all visible pp interactions
- Replace hardware L0 by software Low Level Trigger (LLT)
  - Acts as temporary ``handbrake'' during commissioning, 1 – 40 MHz scaleable output rate



The Game has Changed

In the upgrade area there are no ``boring'' events, it is about classifying signal events!





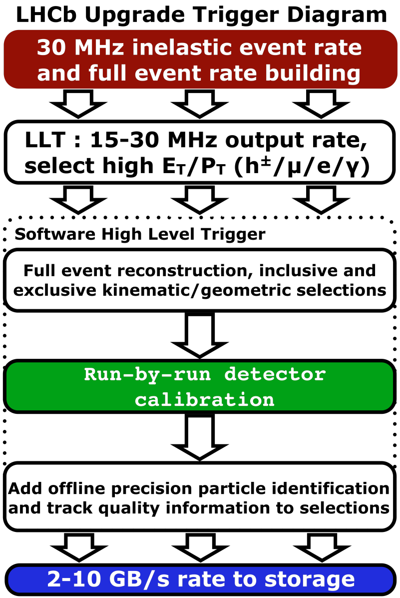
80 GB/s of reconstructible D hadrons, 27 GB/s of reconstructible B hadrons. Compare to 10 GB/s allowed to tape

Details: LHCb-PUB-2014-027

Triggers today

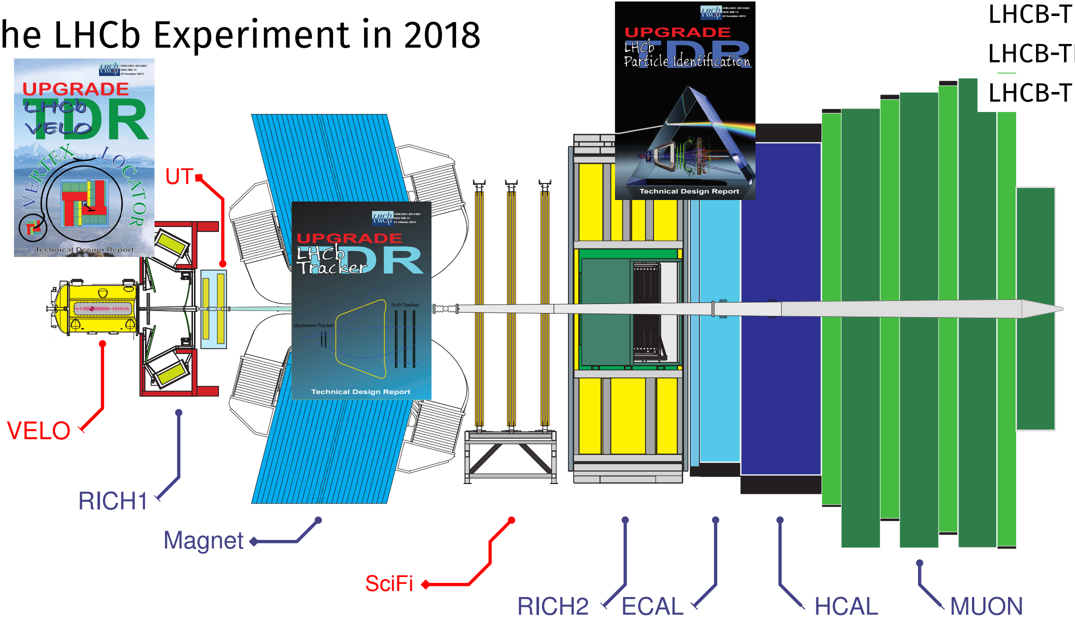
Triggers in the future

Real Time Analysis

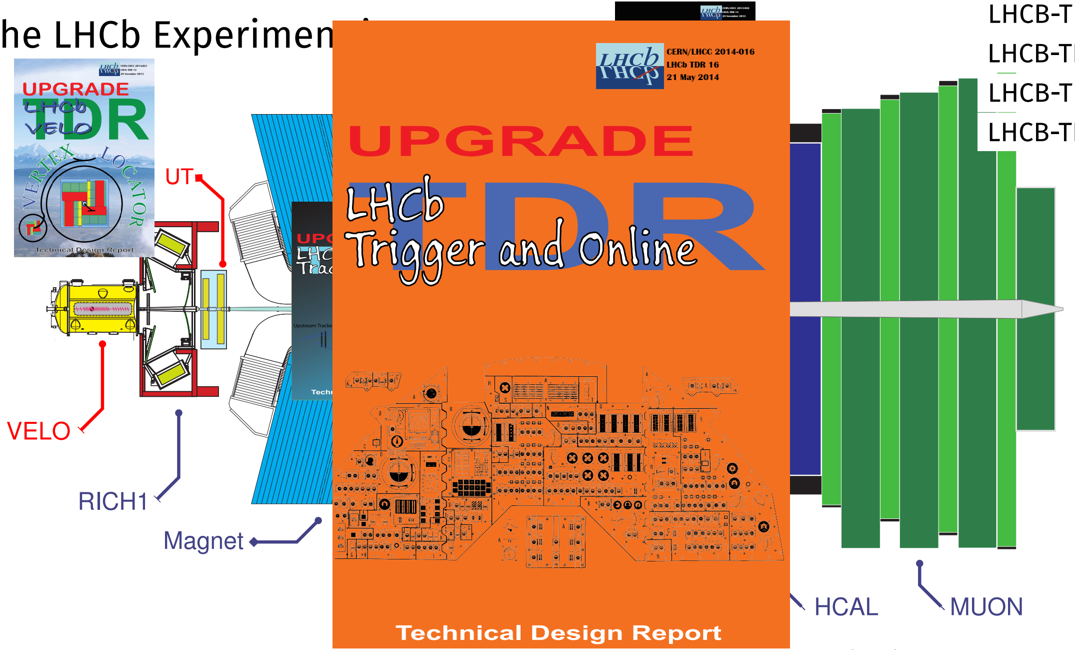


The LHCb Experiment in 2018

LHCB-TDR-013
LHCB-TDR-014
LHCB-TDR-015

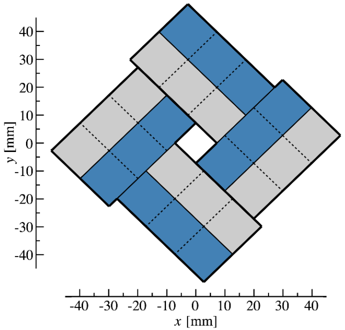


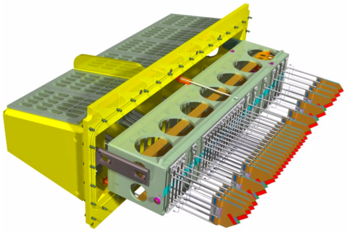
The LHCb Experimen

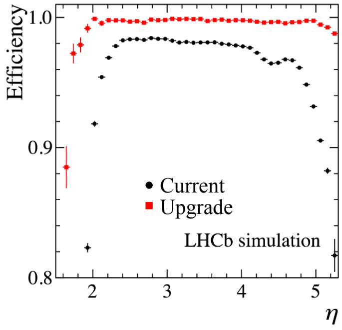


LHCB-TDR-013
LHCB-TDR-014
LHCB-TDR-015
LHCB-TDR-016

Vertex Locator (VELO)



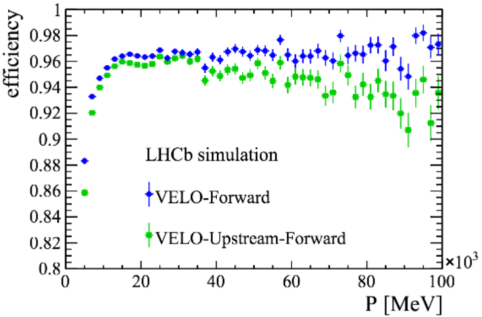


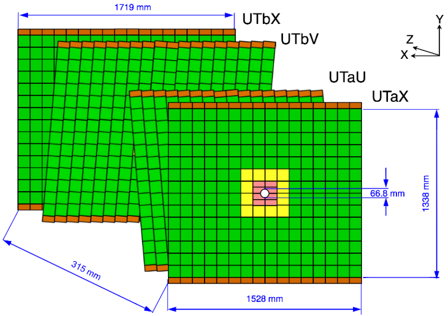


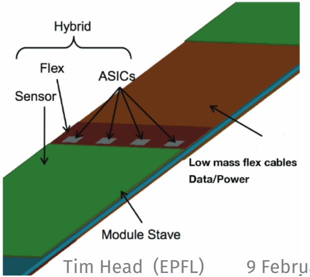
- Hybrid pixel detectors, two moveable halves, active edge at 5.1 mm from beam
- Basic building blocks are $14 \times 14\,\text{mm}^2$ pixel chips, three chips in a row share silicon sensor
- Micro-channel CO_2 cooling

Upstream Tracker

- Single-sided silicon strip detector
- Four layers (x, u, v, x) (5° stereo angles)
- Finer segmentation around beam-pipe
- 250 μm thin sensors
- New read-out chip (SALT)
- Bi-phase CO_2 cooling

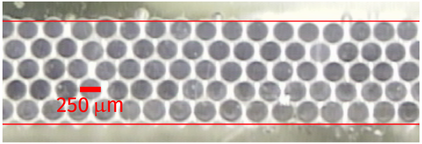


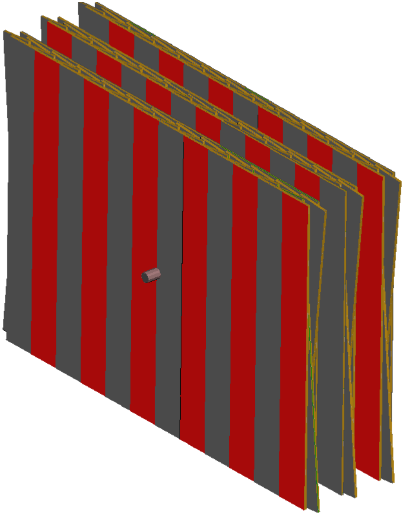




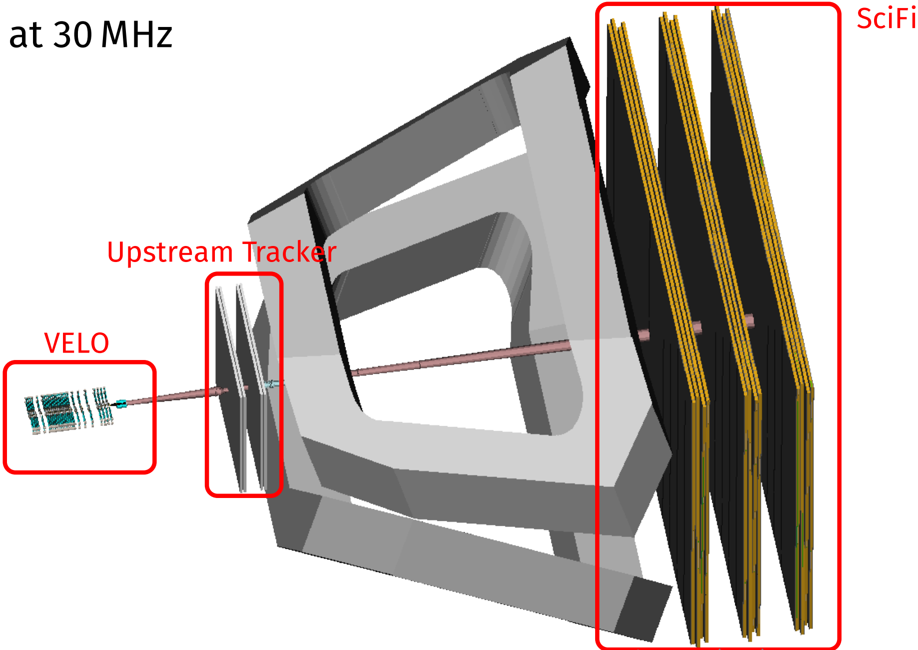
Scintillating Fibre Tracker

- Scintillating fibres
  - 250 μm diameter, 2.5 m long
- Three stations with four (x, u, v, x) layers each
- Read out by Silicon Photomultipliers
  - inside light-tight read-out box
  - cooled to −40 °C
- New ASIC for read-out (PACIFIC)



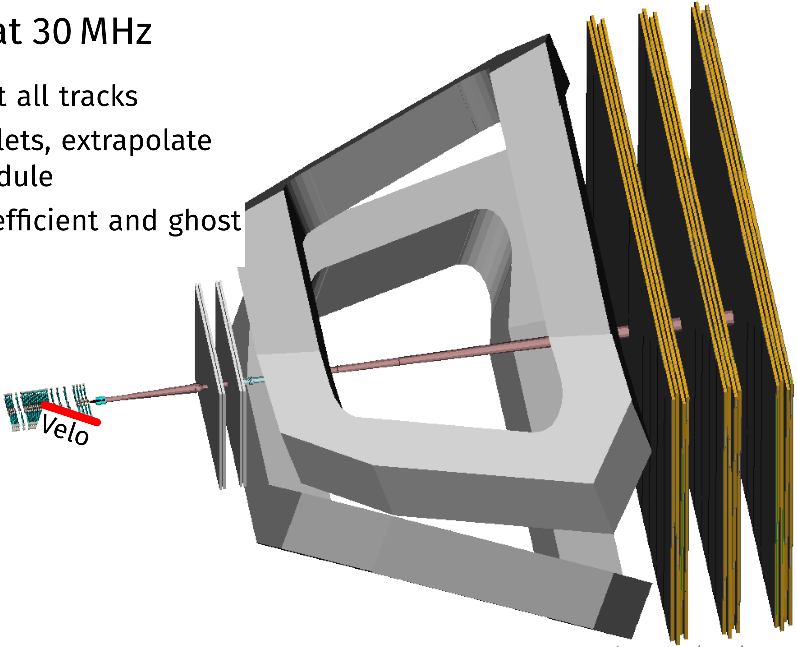


Tracking at 30 MHz

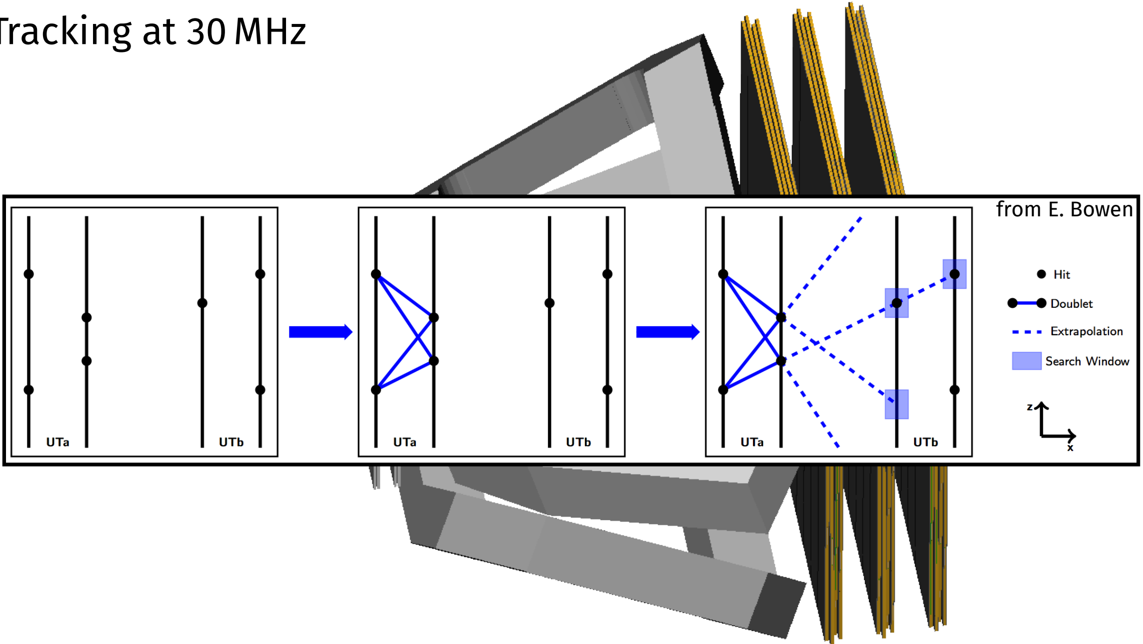


Tracking at 30 MHz

- Reconstruct all tracks
- Build doublets, extrapolate to next module
- Extremely efficient and ghost free

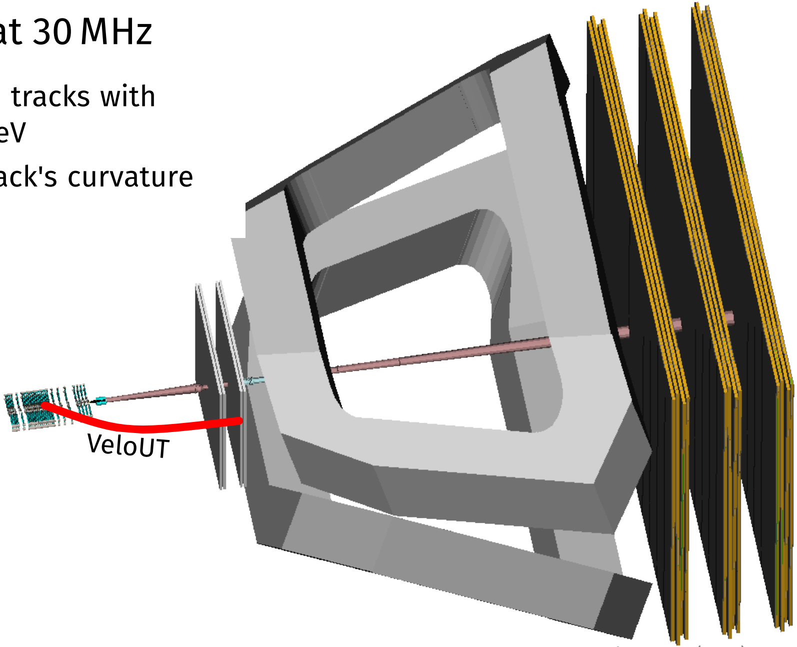


Tracking at 30 MHz

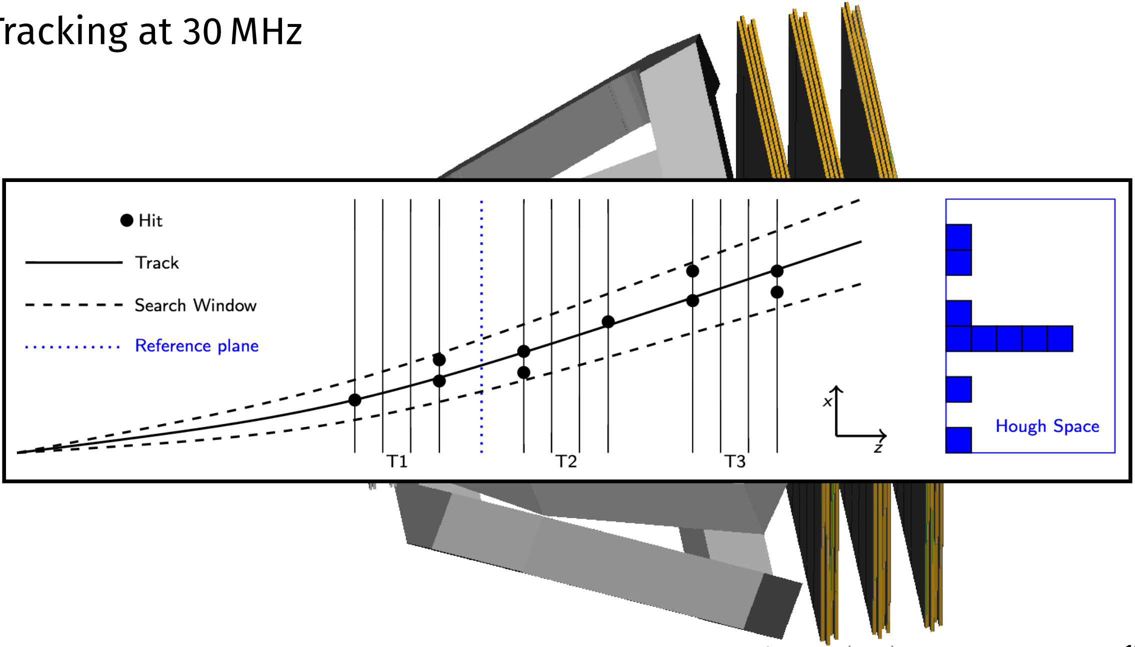


Tracking at 30 MHz

- Extrapolate tracks with $p_T > 200\,\text{MeV}$
- Measure track's curvature
- $\sigma p/p \approx 15\%$

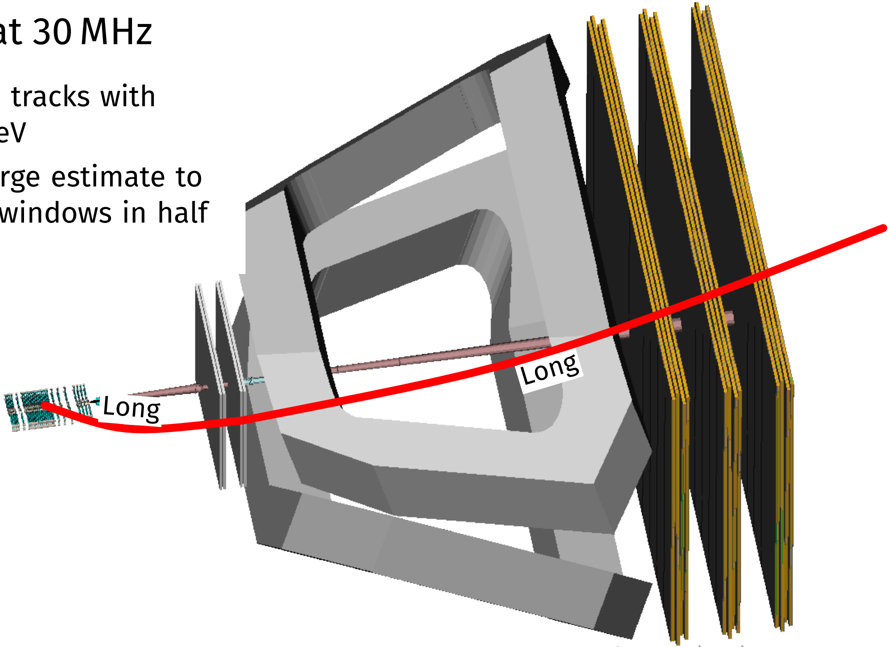


Tracking at 30 MHz

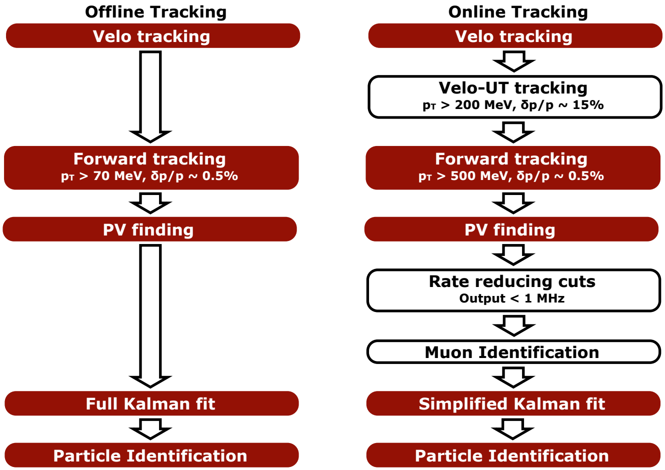


Tracking at 30 MHz

- Extrapolate tracks with $p_T > 500\,\text{MeV}$
- Use UT charge estimate to cut search windows in half
- $\sigma p/p \approx 0.5\%$



Full Track Reconstruction on all Events



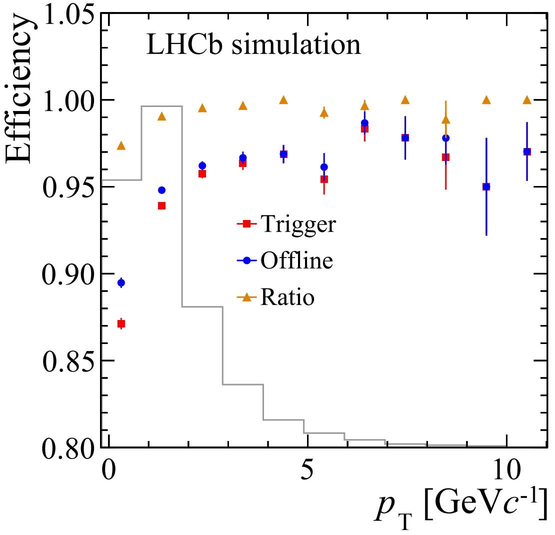
- Maximum flexibility and robustness
- Details: LHCb-PUB-2014-028
- LHCb will be the first hadron collider experiment to operate a software only trigger at full event rate!

Offline-quality tracking at 30 MHz in software is possible!

Efficiency

- Compared to ``offline'' the HLT tracking sequence is 98.7% efficient
- In addition tracks with $p_T < 0.5\,\mathrm{GeV}/c$ are available with lower momentum resolution

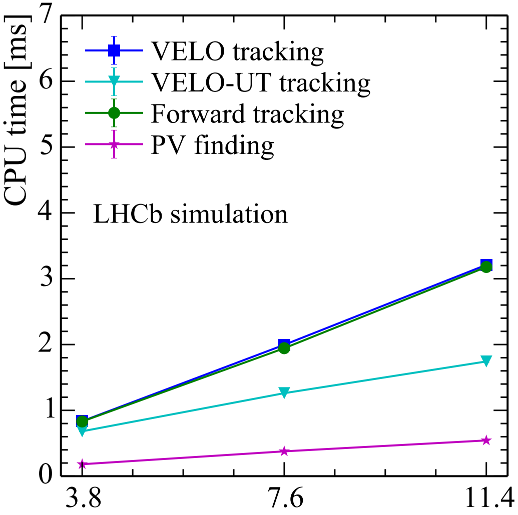
	Efficiency [%]	
	HLT	relative
long, from B	72.8	80.3
long, $p_T > 0.5\,\mathrm{GeV}/c$	87.4	97.2
long, from B, $p_T > 0.5\,\mathrm{GeV}/c$	92.5	98.7



Timing

- At nominal luminosity reconstruction uses less than half the budget (13 ms)
- CPU time does not ``explode'' at higher luminosity

Algorithm	CPU time [ms]
VELO	2.0
VELO-UT	1.3
Forward	1.9
PV finding	0.38
Total	5.4



(ν =average number of interactions)

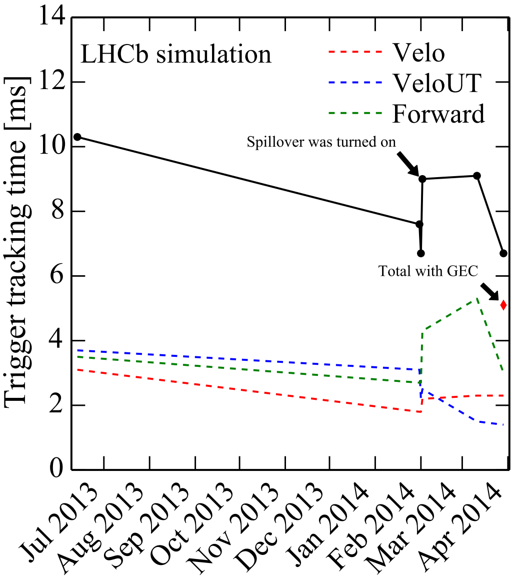
Conclusion

- The LHCb trigger has been very successful in 2011 and 2012
  - using BDTs as the main trigger
- 2020 will see a truly upgraded trigger
- Tracking at 30 MHz in software is possible
- Allows very diverse, efficient triggers that minimally bias the physics observables
  - lifetime unbiased hadronic triggers
- Run 2 will be our ``test beam'', testing many techniques which will be needed for 2020:
  - run-by-run calibration and alignment
  - Turbo stream: analysis without offline reconstruction

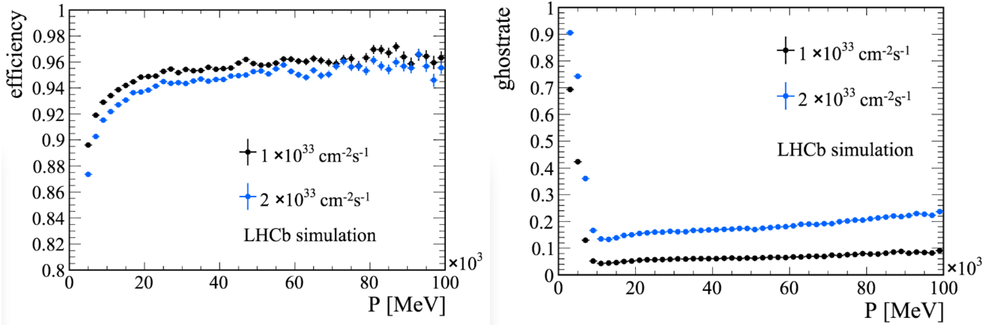
One more thing …

HLT1 Tracking Time

- Making the whole tracking sequence faster is hard work
- Some competition is good as nobody wants to be the slowest
- A dedicated group of people, working together is needed



SciFi Track Reconstruction



- Forward track reconstruction algorithm efficiency and ghostrate
- Taken from LHCB-TDR-015