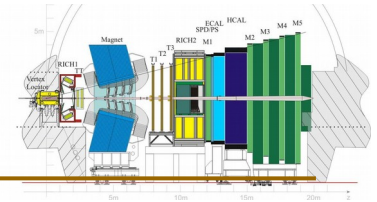


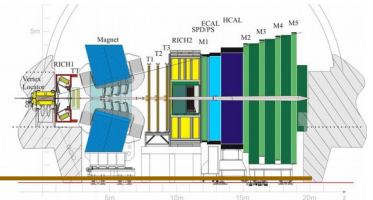
The LHCb High Level trigger in Run 2

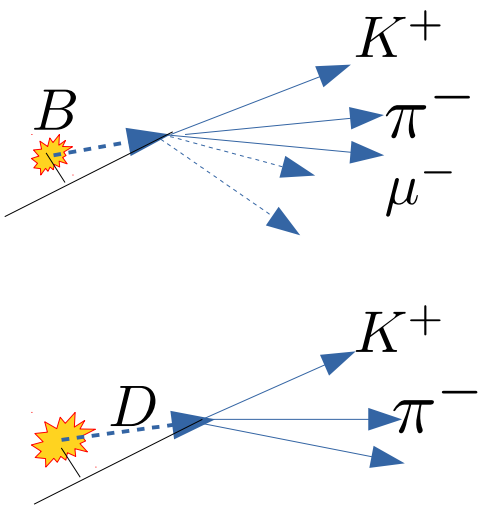
Sascha Stahl, CERN,

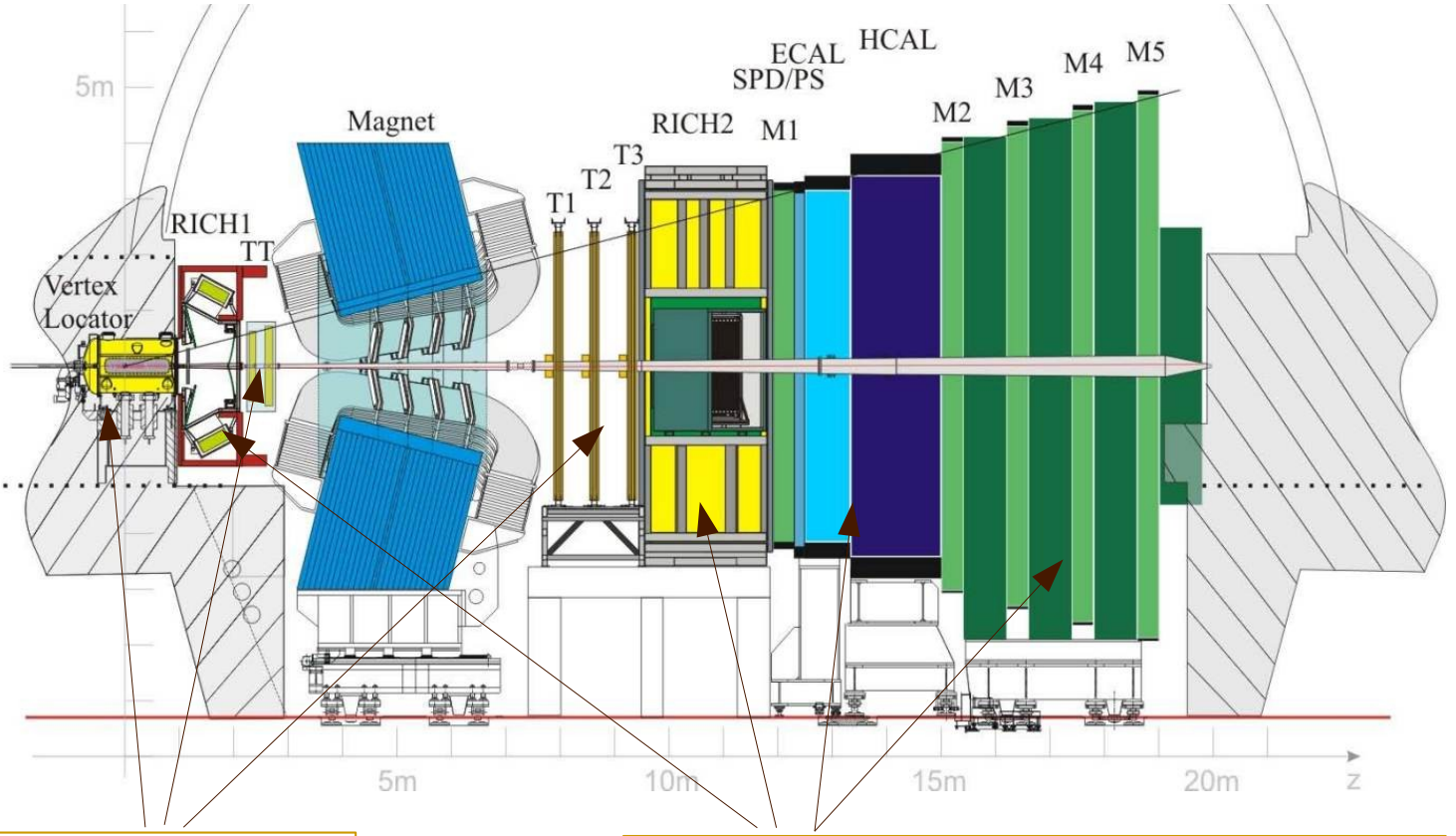
on behalf of the LHCb collaboration,

EPS-HEP, Vienna,
22.-27.7.2015

The LHCb experiment





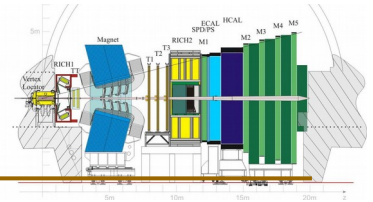


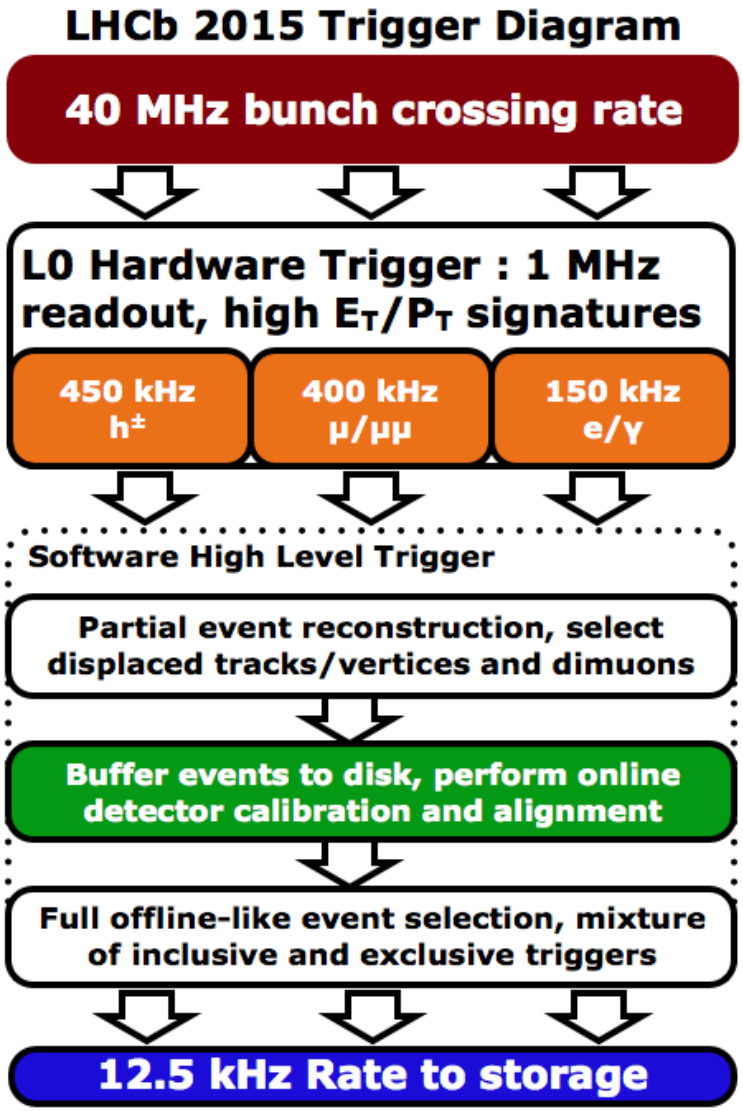
Vertex and track finding

Particle identification and first event trigger

~45 kHz $b\bar{b}$ pairs and ~1 MHz $c\bar{c}$ pairs at 13 TeV and L = $4*10^{32}\,cm^{-2}\,s^{-1}$

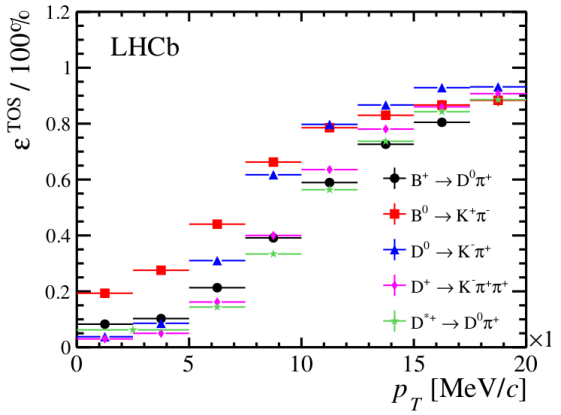
Event selection at LHCb

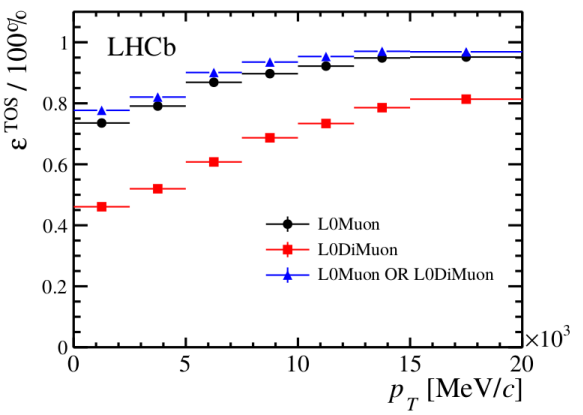




L0 efficiencies:

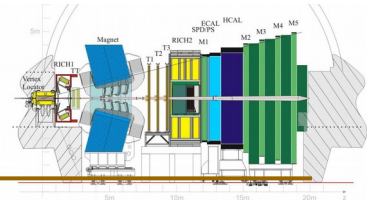
Int.J.Mod.Phys. A30 (2015) 1530022



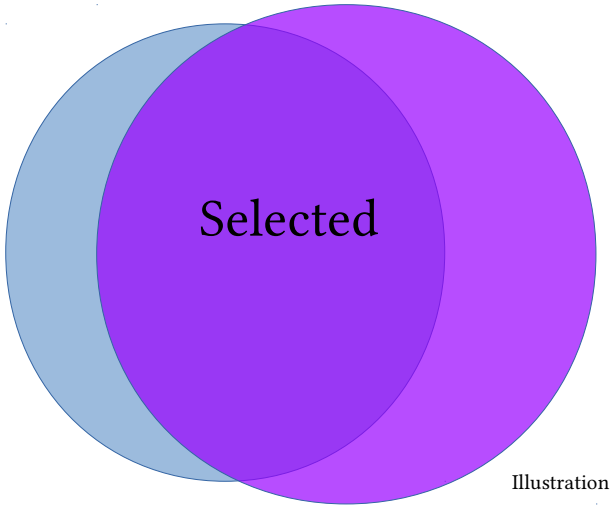


- HLT, software trigger:
  - Running on large farm
  - Split in HLT1 and HLT2
  - Selects events for offline analysis
- Physics analysis

Online and offline



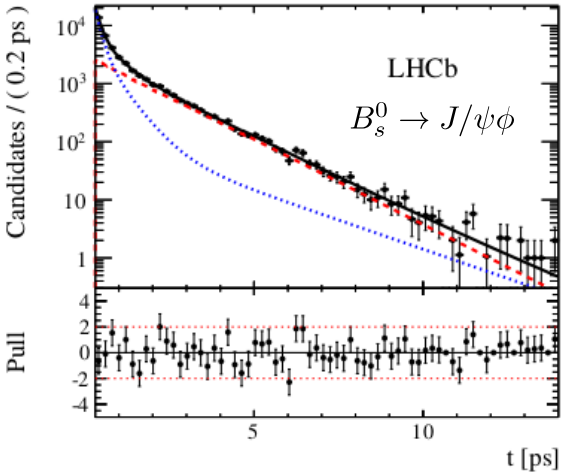
Online:
Compromise between performance and stringent timing requirements.



Illustration

Offline:
Best available performance without stringent timing requirements.

Example:
Lifetime measurement



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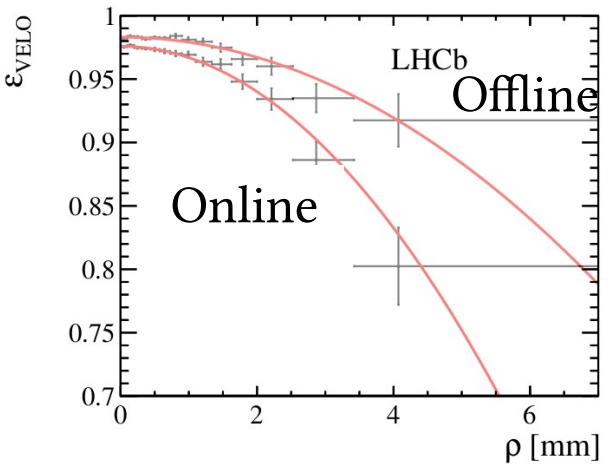
Differences:
Pattern recognition, detector alignment and calibration, candidate selection…



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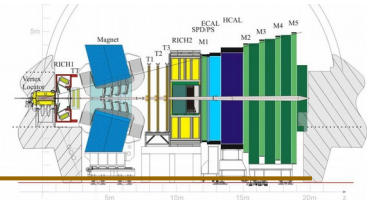
- Conclusion for Run 2:
  - Want online same reconstruction as offline.
  - Want calibrations and alignments immediately.

Deferred triggering

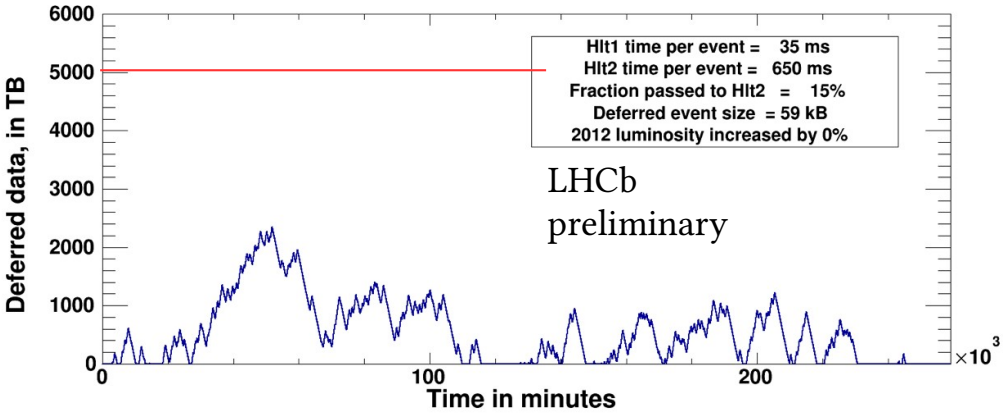


- Event Filter Farm doubled in Run 2:
  - 800 new nodes and 1000 old nodes, 50880 logical cores, 5 MCHF
- LHC stable beams 30% of time

  ⟶ 70% idle time
- Write data to disk,
  process between fills
  - 5000 TB in farm
- Run 1:
  Defer 20% of L0 accepted events

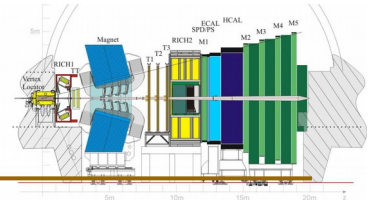
  ⟶ 25% more effective CPU power
- Run 2:
  Defer all HLT1 accepted events

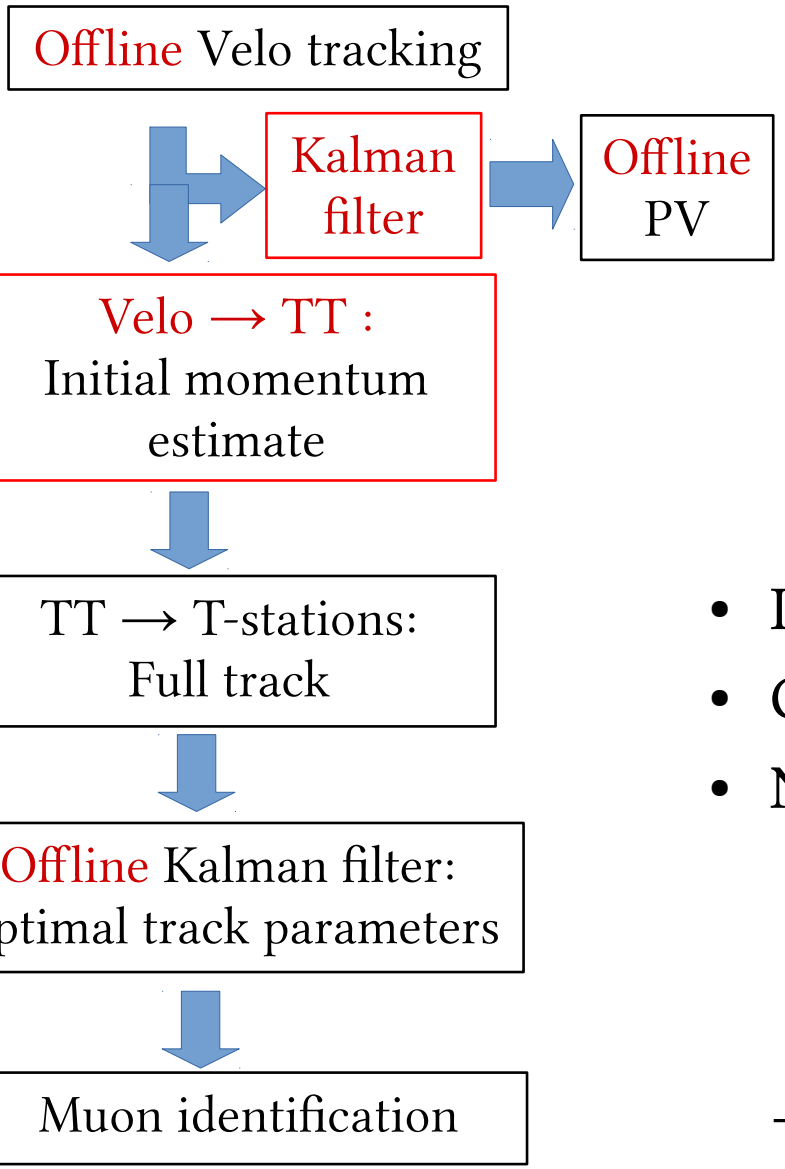
  ⟶ Fewer events

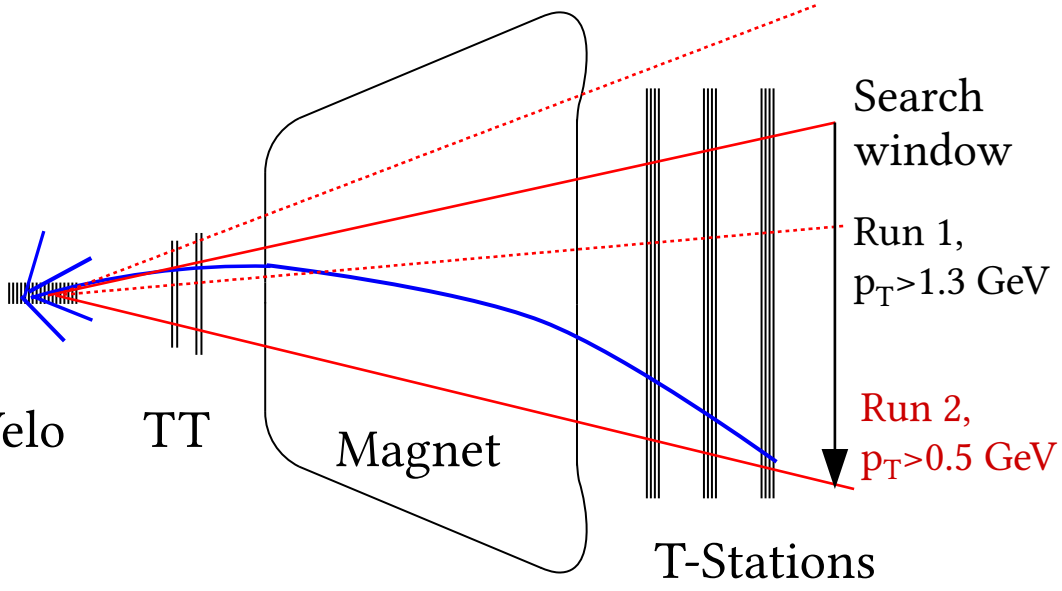


- More time for reconstruction
- Calibration between
  HLT1 and HLT2 possible

HLT1 event reconstruction



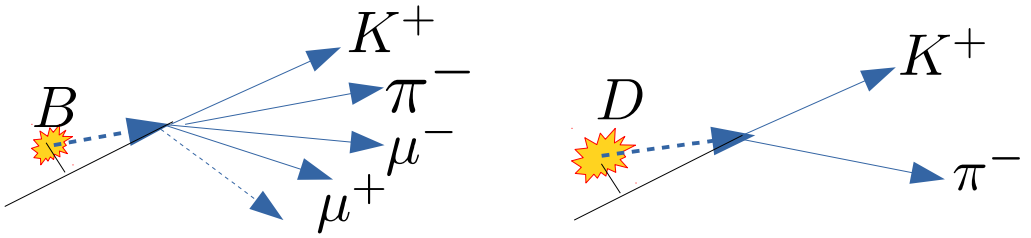




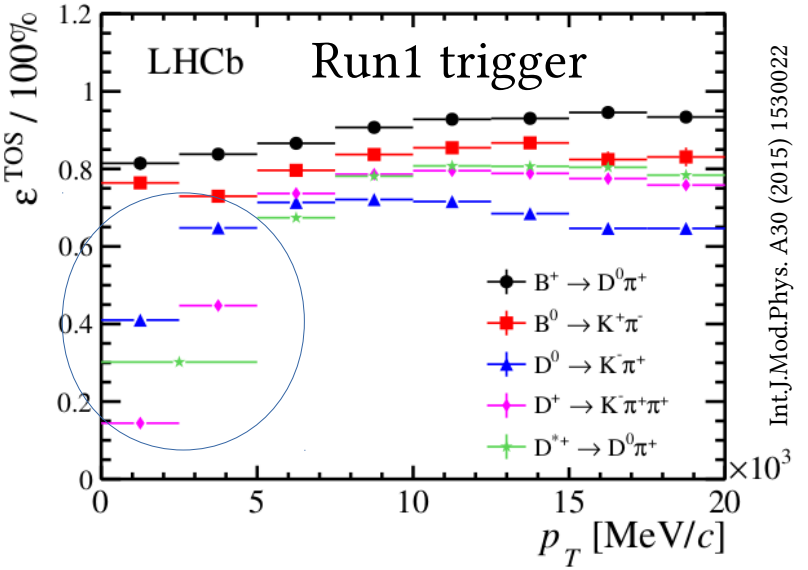
- Improved sequence (Velo → TT)
- Code optimization
- New offline:
  - PV fit only with Velo tracks
  - Kalman filter with fast geometry description
  - No performance degradation

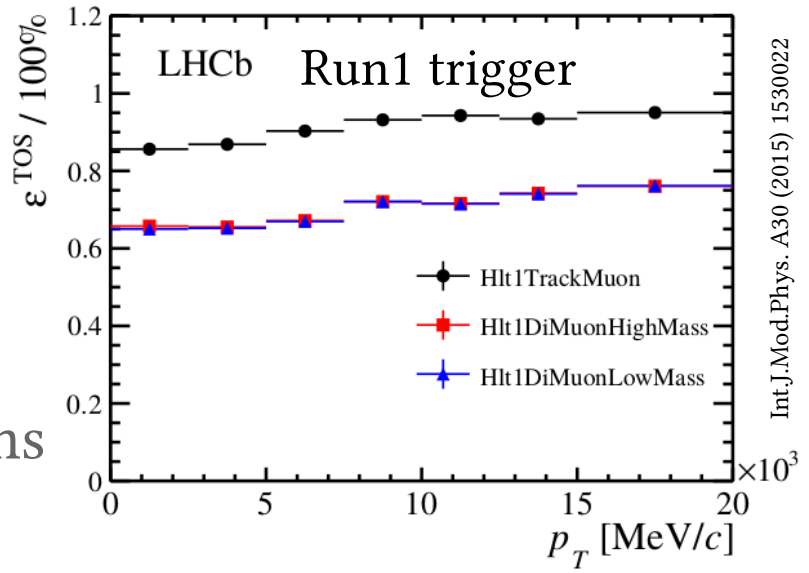
→ Consistent PV and track parameters

HLT1 trigger

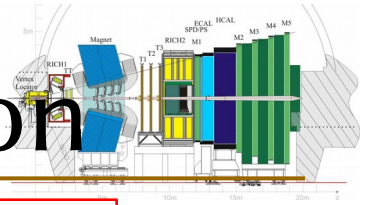


- Inclusive charm and beauty triggers:
  - Single and two track MVA selections
    $\longrightarrow$ ~100 kHz
- Inclusive muon triggers:
  - Single and dimuon selections
  - Special low p_T track reconstruction
  - $\longrightarrow$ ~40 kHz
- Exclusive triggers:
  - New lifetime unbiased trigger selections for hadronic charm and beauty decays





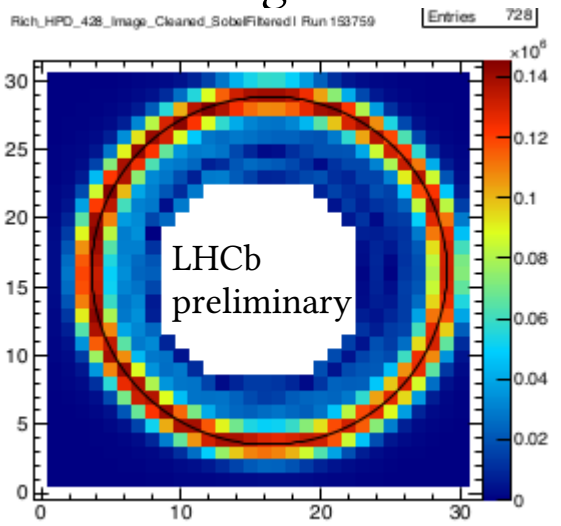
Real-time alignment and calibration



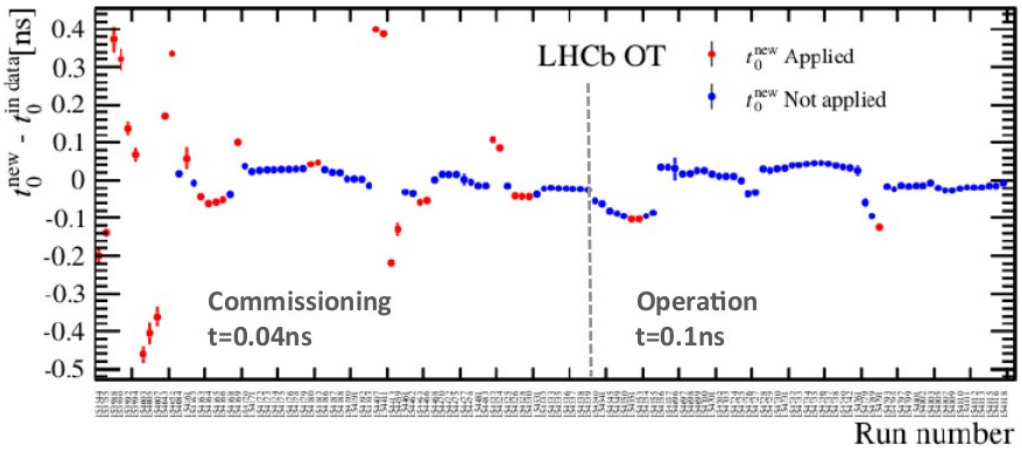
More details: P. Seyfert, Friday 27.7.,
"Novel real-time calibration & alignment and tracking performance for LHCb Run II"

- Alignment and calibration of detectors crucial for optimal physics performance
  - E.g. RICH particle identification
    $$D^0 \to K^-\pi^+ \text{ vs. } D^0 \to K^-K^+$$
- Automatic real-time procedures:
  - RICH calibration between HLT1 and HLT2
  - Tracker alignment during running, O(min)
  - Calorimeter calibration, RICH and Muon alignment monitored
  - Apply updates if necessary
- Minimizes time with suboptimal alignments and calibrations
- Online same alignments and calibrations as offline

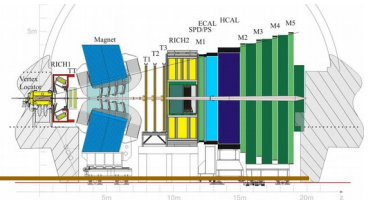
RICH image calibration:

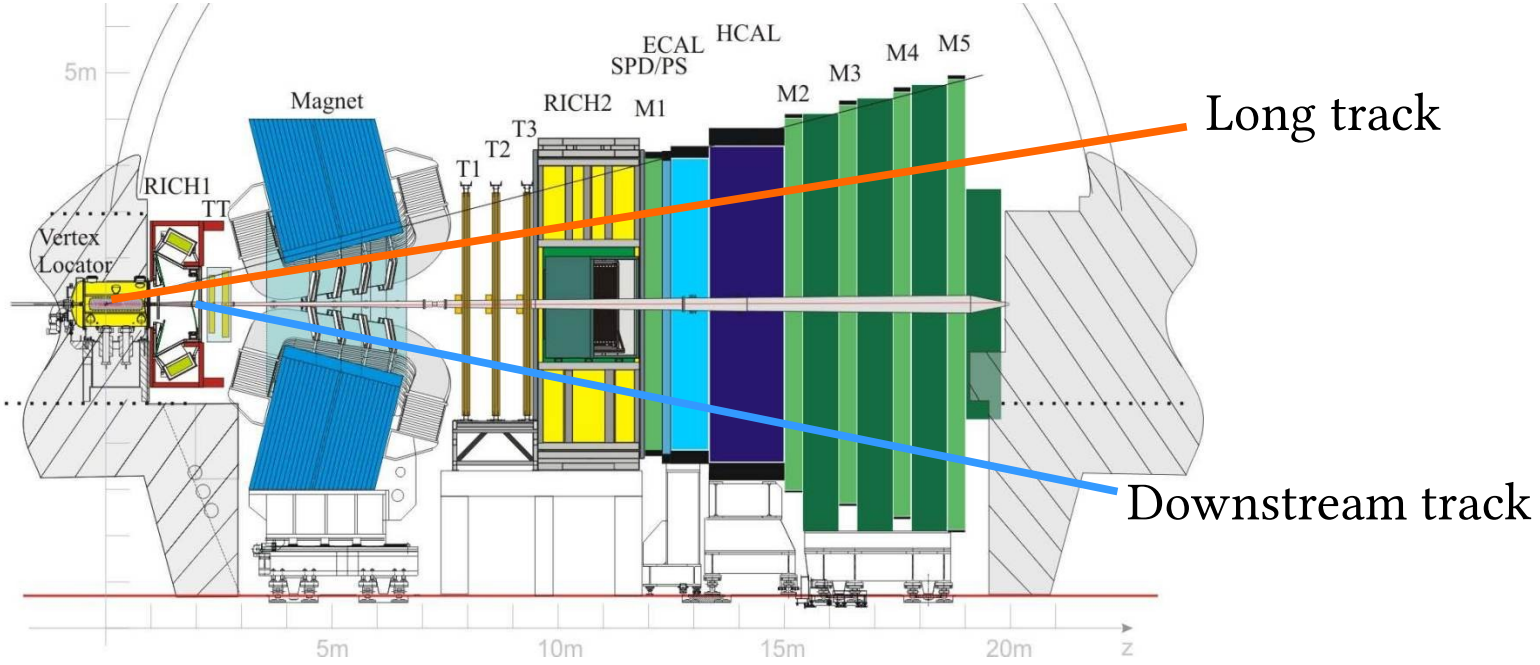


Outer Tracker drift-time calibration:



HLT2 event reconstruction

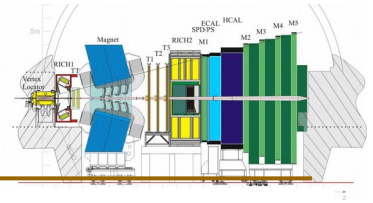




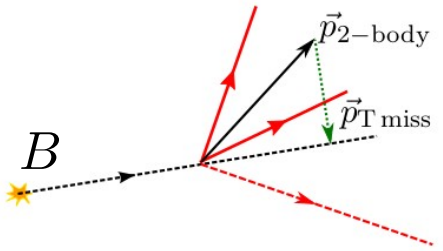
- Full event reconstruction:
  - 1. Start from HLT1 vertices and tracks
  - 2. Reconstruct all tracks
    (Run 1 p_T>300 MeV, no redundancy)
  - 3. Full particle identification
    for long tracks (new)
- Same strategy as offline

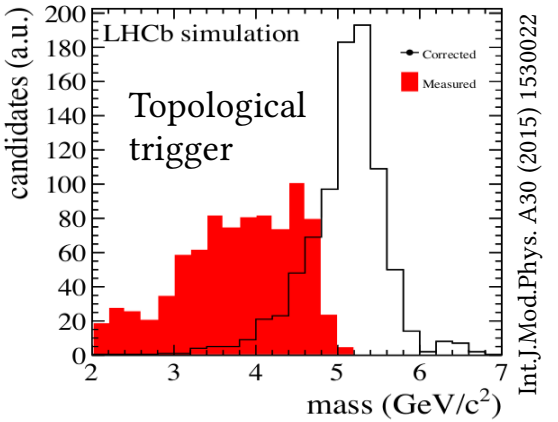
Algorithm	Time	Run 1
Total HLT1	~ 35 ms	~ 20 ms
Track finding	~ 200 ms	
Full track fit	~ 100 ms	
RICH reconstruction	~ 180 ms	
Calo reconstruction	~ 50 ms	
Muon ID	~ 2 ms	
Total Hlt2	~ 650 ms	~ 150 ms

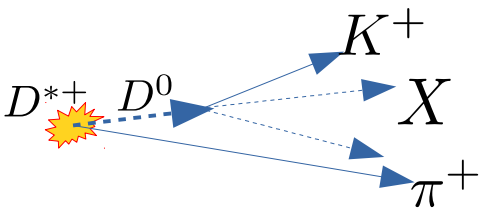
HLT2 trigger selection



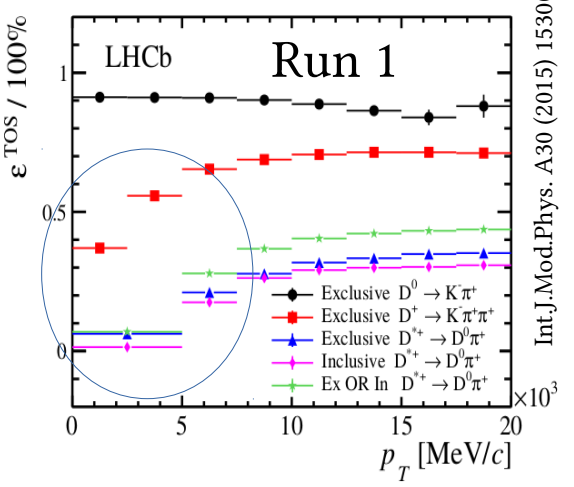
- Inclusive beauty trigger:
  - MVA based inclusive selection of 2,3,4 body detached vertices
  - Di muon triggers for B⟶ J/Ψ X
- Exclusive beauty trigger:
  - E.g. B ⟶ ΦΦ, B ⟶ γγ (new) etc.
- Charm trigger:
  - Inclusive trigger on D* resonance
  - Many exclusive lines using particle identification
- Electroweak trigger
- …
- Almost 400 different trigger selections
- Total output to storage 12.5 kHz (twice as in Run 1)



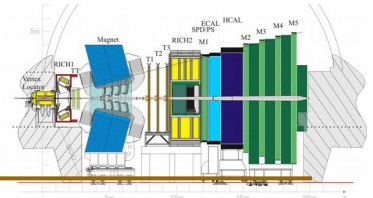




Charm efficiency:



Turbo stream

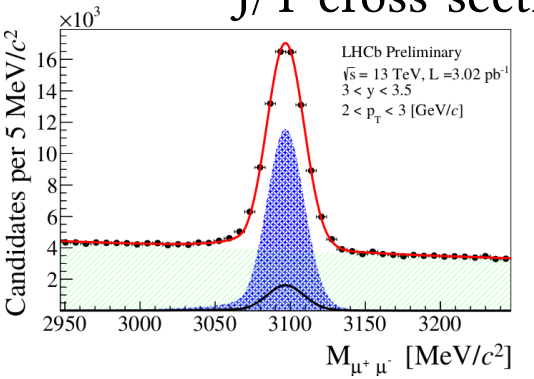


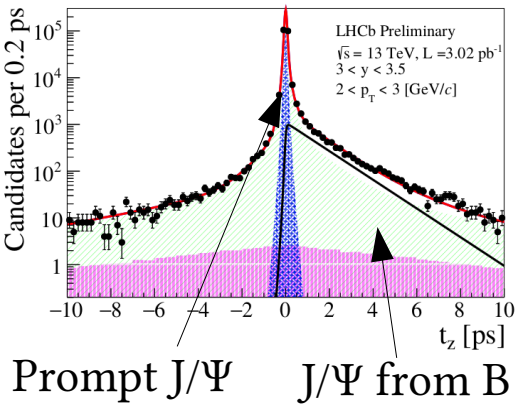
- Online has offline quality
  → use it for physics analyses
- Turbo stream:
  - Write out full information of trigger candidates
  - Throw away raw event data

  → Saves a lot of space
- Ideal for analyses with very high signal yields (millions)
- Extremely quick turn around

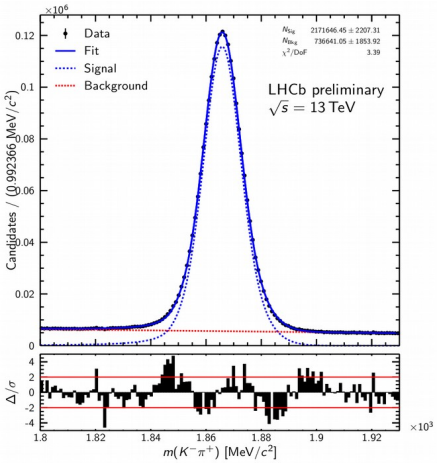
Measurement of differential J/Ψ cross-section:

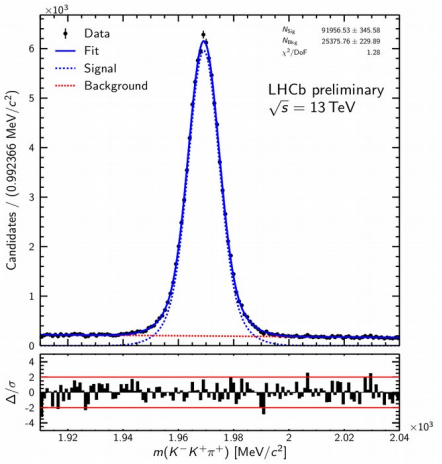
LHCb-PAPER-2015-037





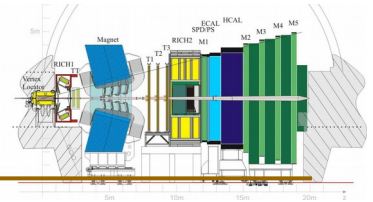
Measurement of differential charm cross-section:





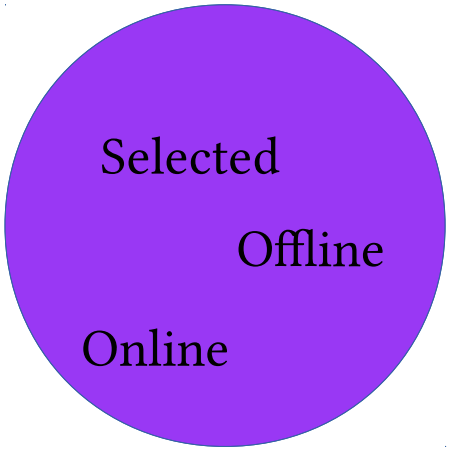
I. Komarov, QCD 24.7., "First LHCb results from the 13 TeV LHC data"

Conclusion

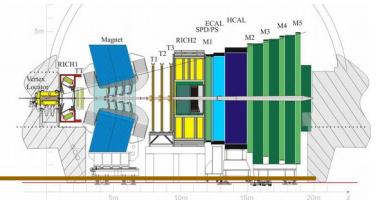


- Larger farm, lots of hard work and smart ideas
- Online full event reconstruction including particle identification
- Consistent reconstruction online and offline
- Real-time calibration new to detectors of this scale

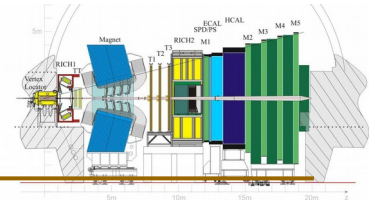
  $\longrightarrow$ Much better trigger in Run 2 than in Run 1



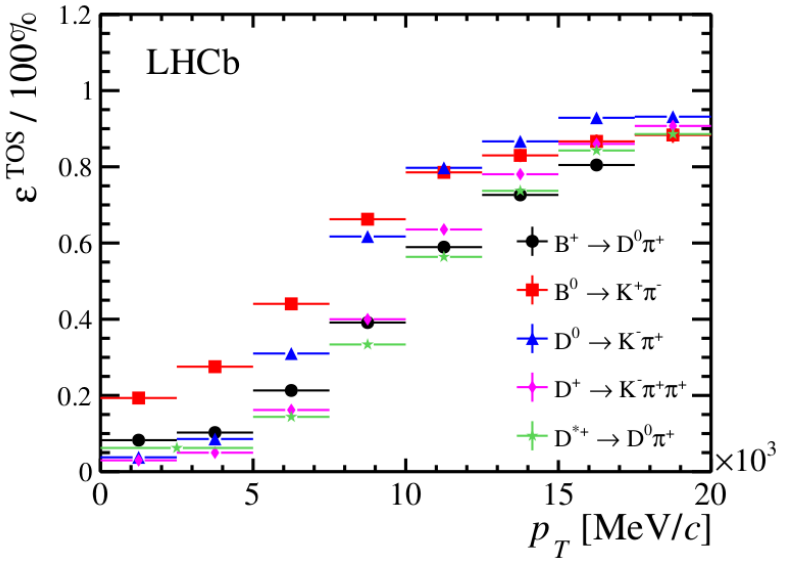
- We still have more ideas…

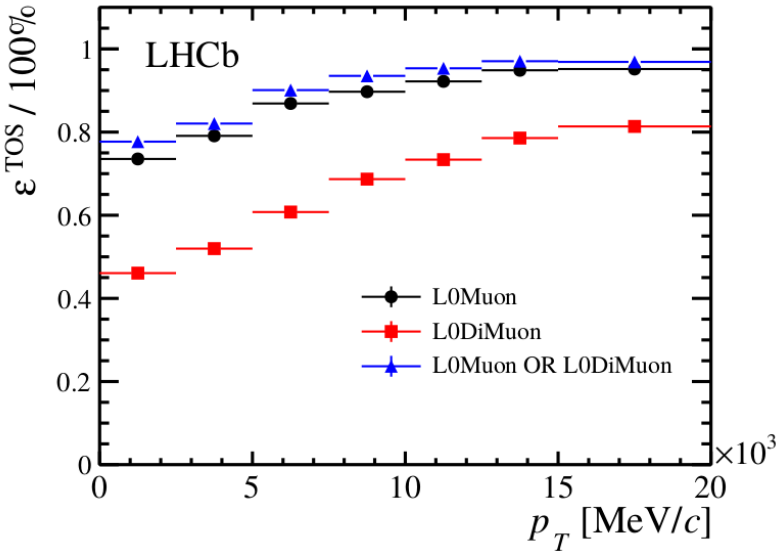

Magnet
RICH1
RICH2
ECAL
HCAL
SPD/PS
M1
M2
M3
M4
M5
T1
T2
T3
Vertex
Locator
5m
10m
15m
20m
z

Hardware trigger (L0)

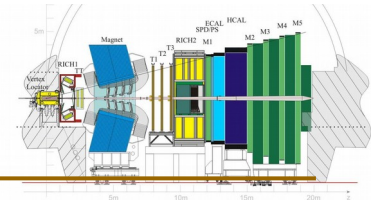


- Reduce bunch crossing-rate to ~1 MHz
- Calorimeter trigger:
  - Hadrons:
    ET > 3.7 GeV, rate 500 kHz
  - Photons and electrons:
    ET > 3 GeV, rate 150 kHz
- Muon trigger
  - Single Muon: pt>1.76 GeV
  - Di Muon: (pt1*pt2) 1.6 GeV2
  - Rate 400 kHz
- Filters out very complex events
- Low multiplicity triggers





Event filter farm



- 900 nodes with 2TB disks, 800 nodes with 4TB disks
  - 900 Intel x5650, 100 AMD 6272, 800 Intel E5-2630v3 (new)
- 27040 physical cores, 50880 logical cores
- Almost doubled the performance from Run1 to Run2

Deferred triggering, Run1 and Run 2