The LHCb Trigger

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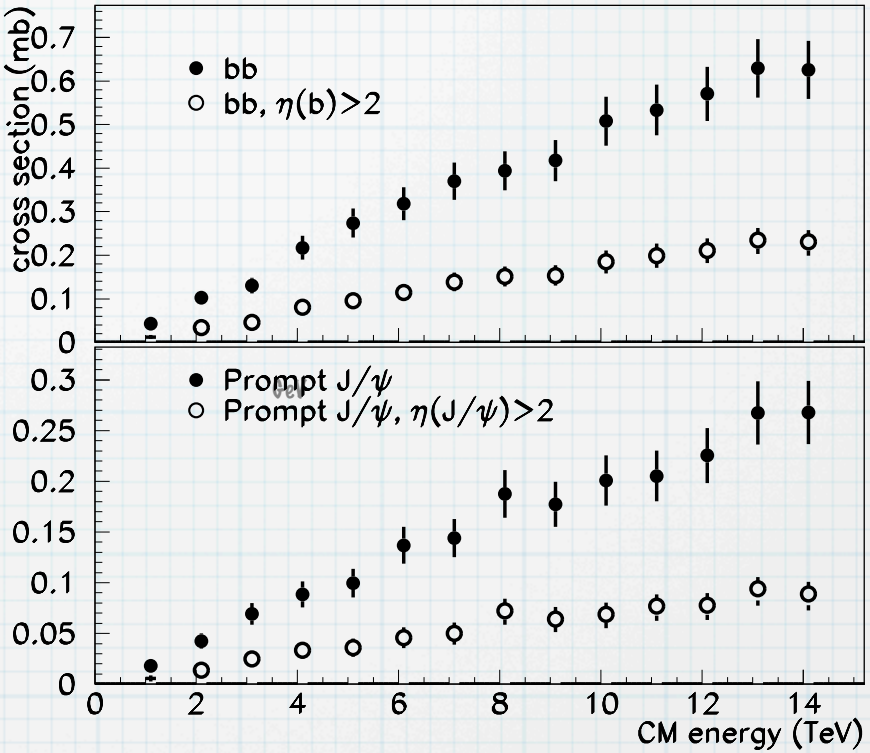
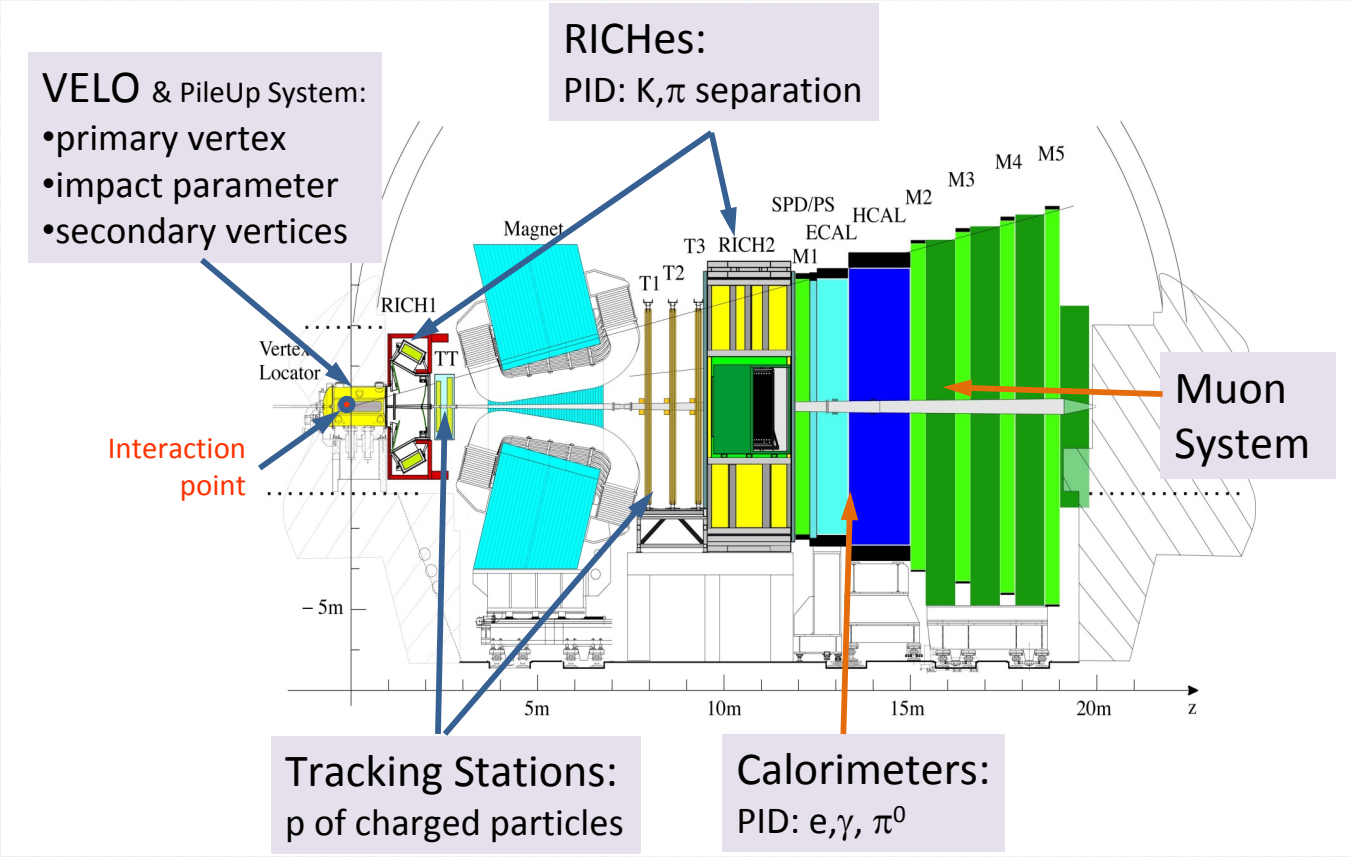
LHC environment

- LHC at LHCb:
  - Bunch crossing 40 MHz
  - Luminosity **2 10^{32} $cm^{-2}s^{-1}$**
  - interactions/xsing $\nu \sim 1$
  - forward spectrometer **$4.9 > \eta > 1.9$**
  - B PT acceptance (1GeV)
  - Visible interactions **13 MHz**
  - σ bb / σ vis $\cong$ 10^{-2}
  - Relevant BR 10^{-4} 10^{-9}, rate **0(Hz)**
  - **2kHz** output rate, Data 35 kb/event, 10^7 s/year
  - Integrated luminosity @ 14 TeV: **$2fb^{-1}$ /year**



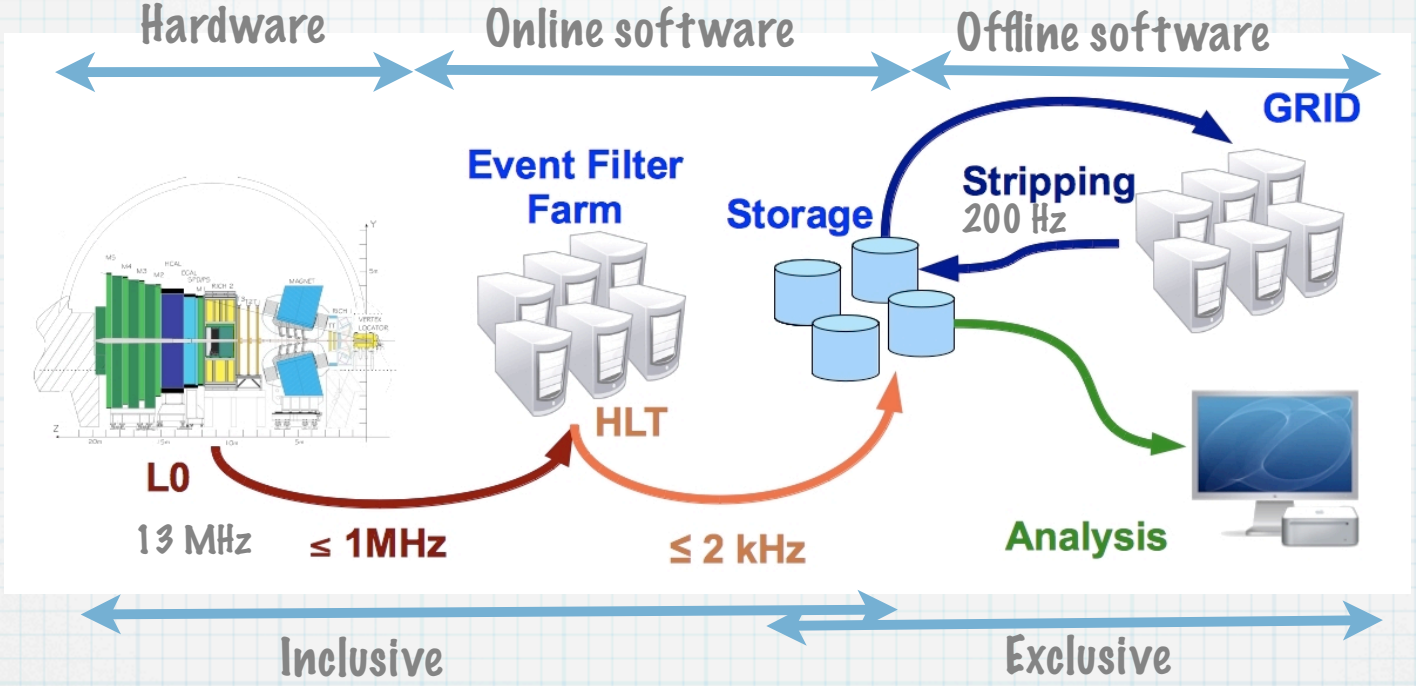
LHCb detector



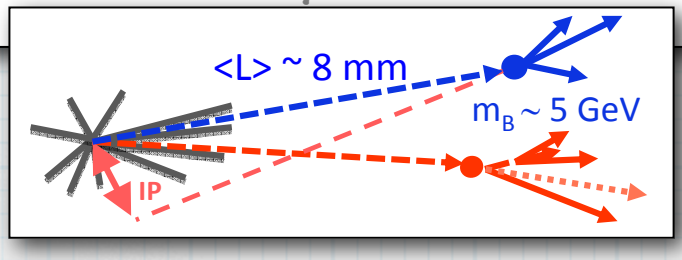
- Physics: Key channels
  - Rare: Bs->μμ,,B->K*μμ, Bs->Φ γ
  - CP Violation: Bs->J/ΨΦ,B->hh, B->DK

- PID
- Vertexing, IP
- momentum, mass resolution
- Flexible trigger

LHCb trigger overview

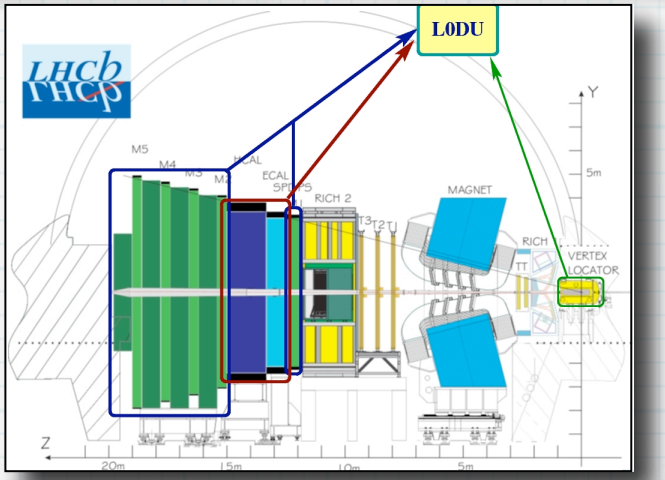


- B inclusive signal:
  - tracks with IP, PT,
  - detached secondary vertices

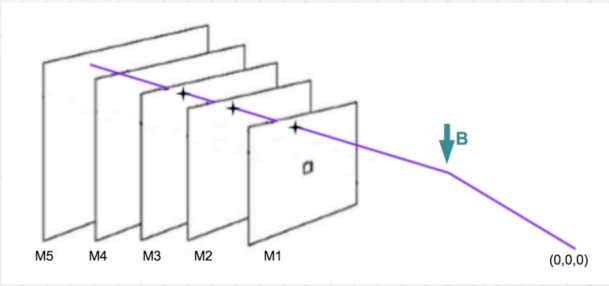


- Why an inclusive trigger and 2 kHz output?
  - Data mining
  - Large calibration sample (J/Ψ,D*)
  - Robustness:
    - On/offline reconstruction mismatch

L0 algorithms and performance

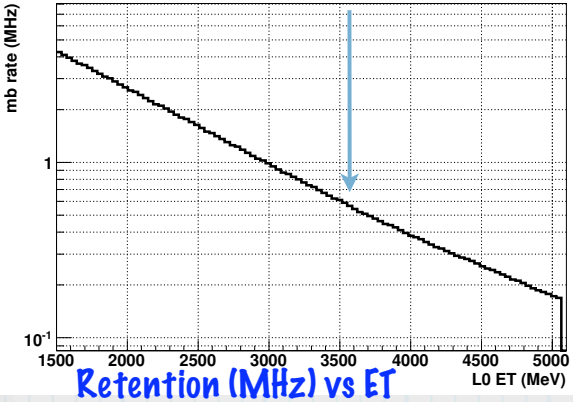


- L0 Muon, DiMuon triggers
  - M1-M5, projective
  - single and dimuon per quadrant
  - Latency 1 μs

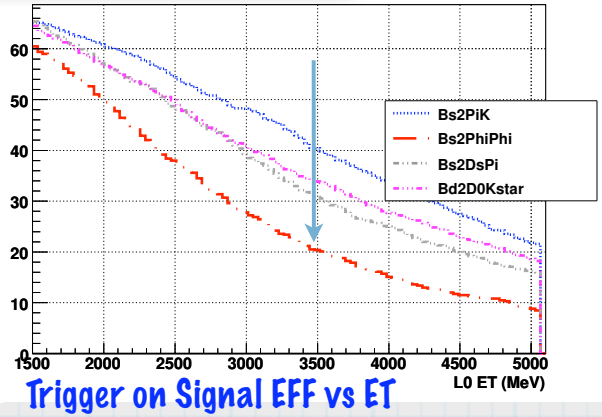


- Calorimeter triggers
  - ET (Had,ECal) 2x2 cells
  - Had or EM triggers
  - Latency 1 μs

L0 Hadron Trigger

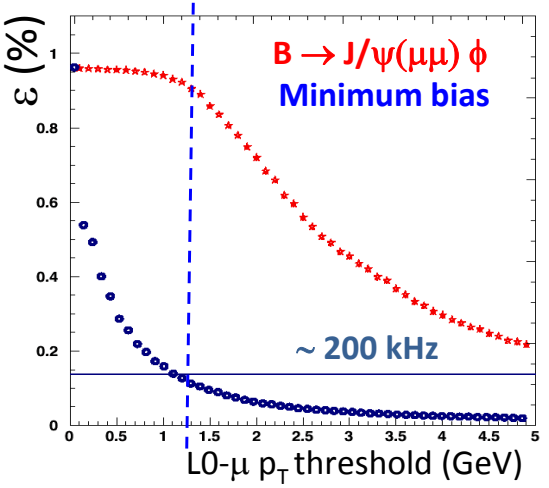


Retention (MHz) vs ET



Trigger on Signal EFF vs ET

L0 Muon Trigger



L0 performance

L0 Bandwidth Division

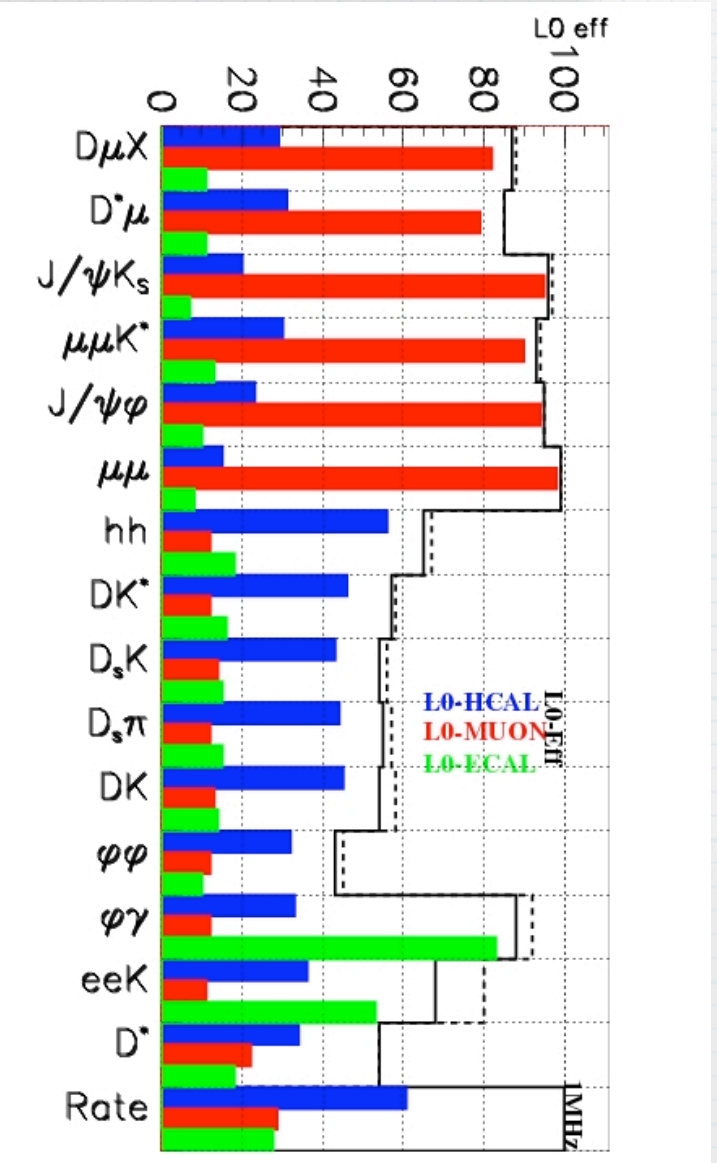
	μ	$\mu\mu$	h	$e^{\pm}$	γ	combined
E_T/p_T GeV	1.3	1.5	4.0	2.3	2.5	
rate (kHz)	280		630	180		1000

L0 Efficiencies for the Key Channels

$B_d \to \mu\mu K^*$	84%	31%	7%	88%
$B_s \to J/\Psi\Phi$	91%	27%	8%	92%
$B_s \to \mu\mu$	98%	17%	5%	98%
$B \to hh$	10%	60%	10%	65%
$B_u \to D^0(K_s\pi\pi)K$	11%	50%	7%	55%
$B_s \to \Phi\gamma$	10%	36%	72%	82%

b Events: 1% ⇒ 3%

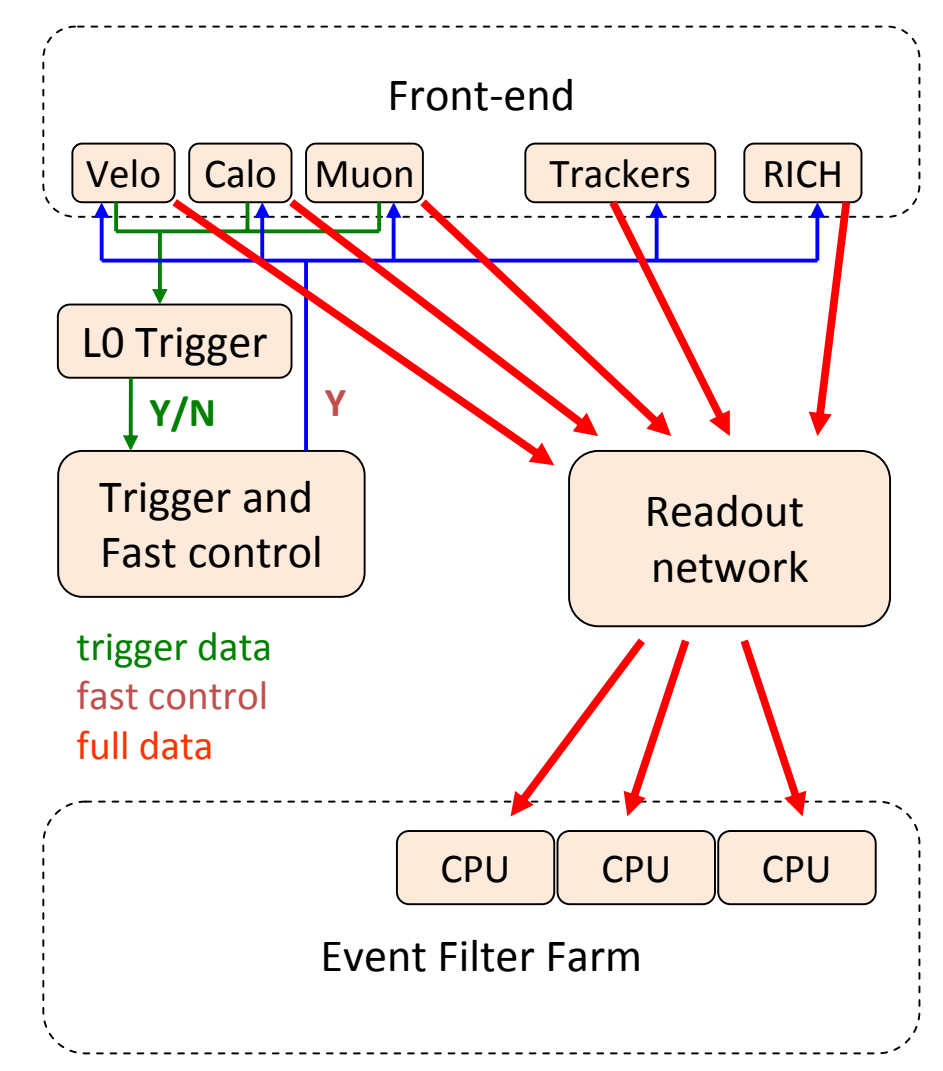
1 MHz



* eff vs offline selected events

DAQ arquitecture

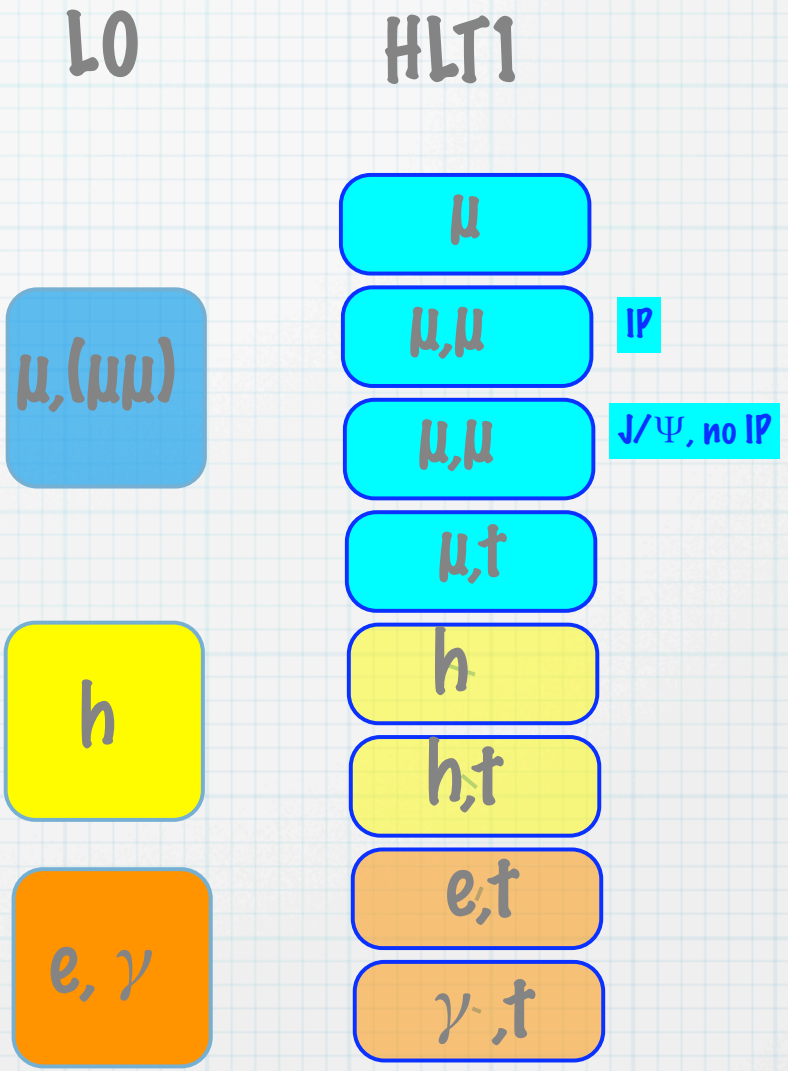
- Front End Electronic
  - Zero suppression
  - Buffer data
- Readout Network
  - 1MHz input
  - Gigabit Ethernet 50 Gb/s
- Event Filter Farm (EFF)
  - ~1000 boxes
  - ~50 subfarms
  - Intel Xeon 2.33 GHz
    - 8 cores
- Monitoring Farm



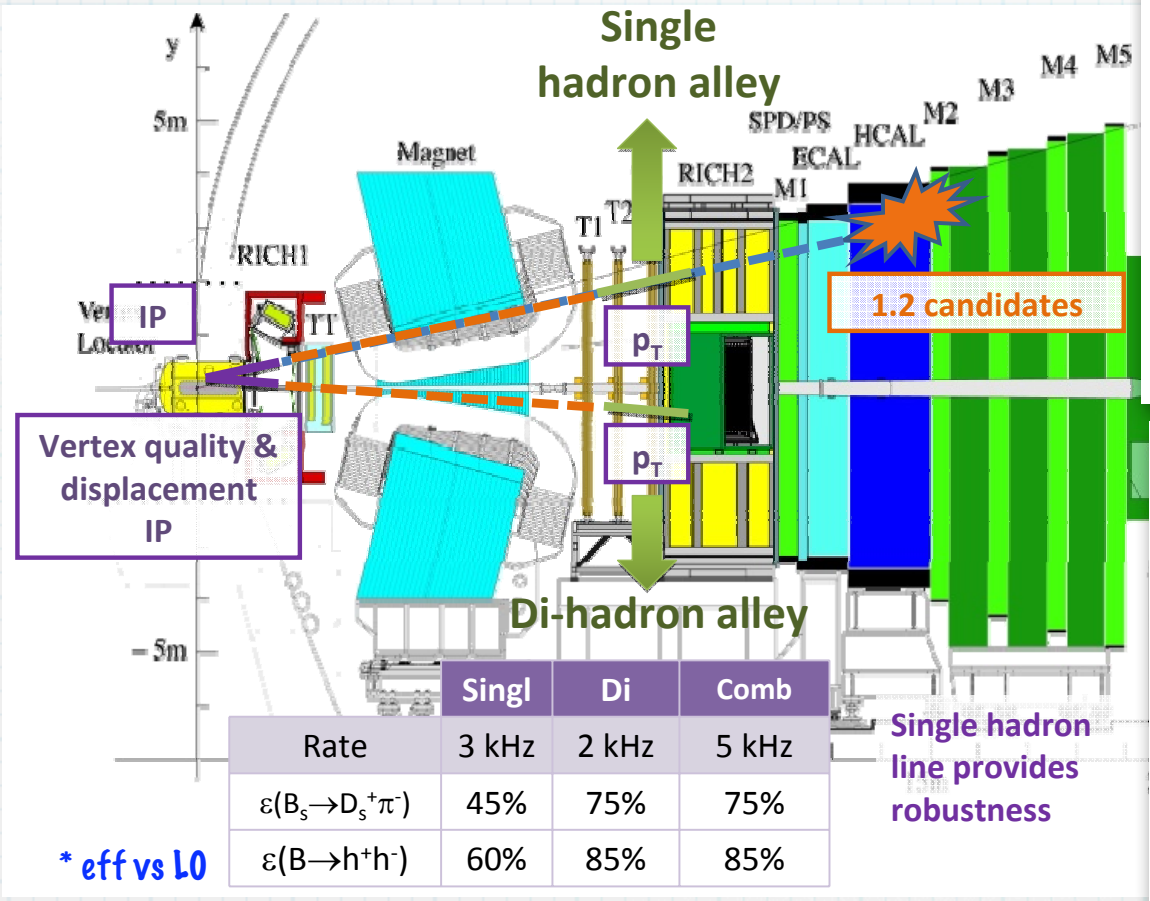
1/3 of the EFF installed end 2009

HLT1 strategy

- Reduction factor (30)
- Partial reconstruction of the event
- Inclusive B search (IP, PT..)
  - Few particles
- Design in lines, each gives a trigger
  - Independent and scalable
  - Start from a L0 trigger
  - Follow few candidates!
  - Define few knobs per line
  - Study eff, rate, time
  - Monitor, summary



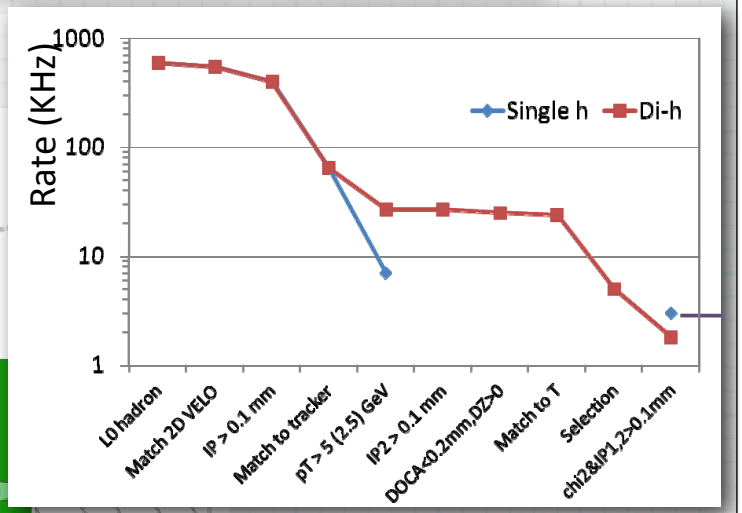
HLT1 Hadron lines, an example

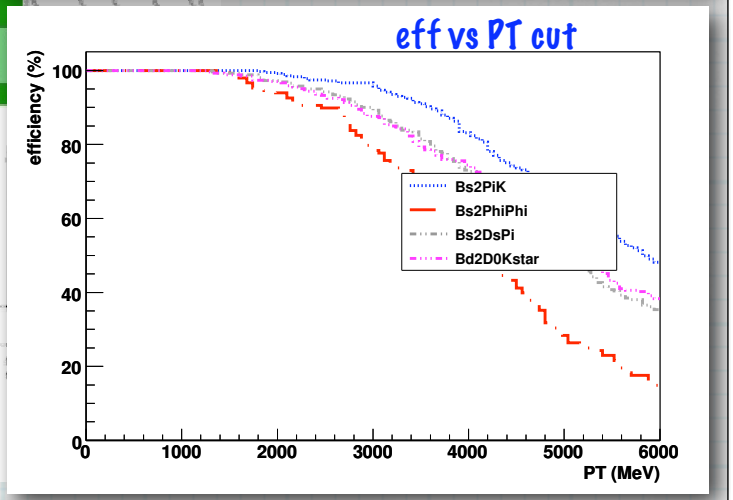


	Singl	Di	Comb
Rate	3 kHz	2 kHz	5 kHz
$\varepsilon(B_s \to D_s^+ \pi^-)$	45%	75%	75%
$\varepsilon(B \to h^+ h^-)$	60%	85%	85%

* eff vs L0

Single hadron line provides robustness





- Each line define some knobs (cuts):
- Single: IP, PT
- DiHadron: IP, PT; Vertex: Pointing, Δz

- What triggers the Hadron HLT1?
- 60% are ghost tracks
- Use fit to reduce the rate 1/2

HLT1 bandwidth division

- Use key channels
- Fix Output rate (40 kHz)
- Minimize χ^2

$$\chi^2 = \sum_{channels} \left(1 - \frac{\epsilon^{channel}}{\epsilon^{channel}_{max}}\right)^2$$

HLT1 Bandwidth Division

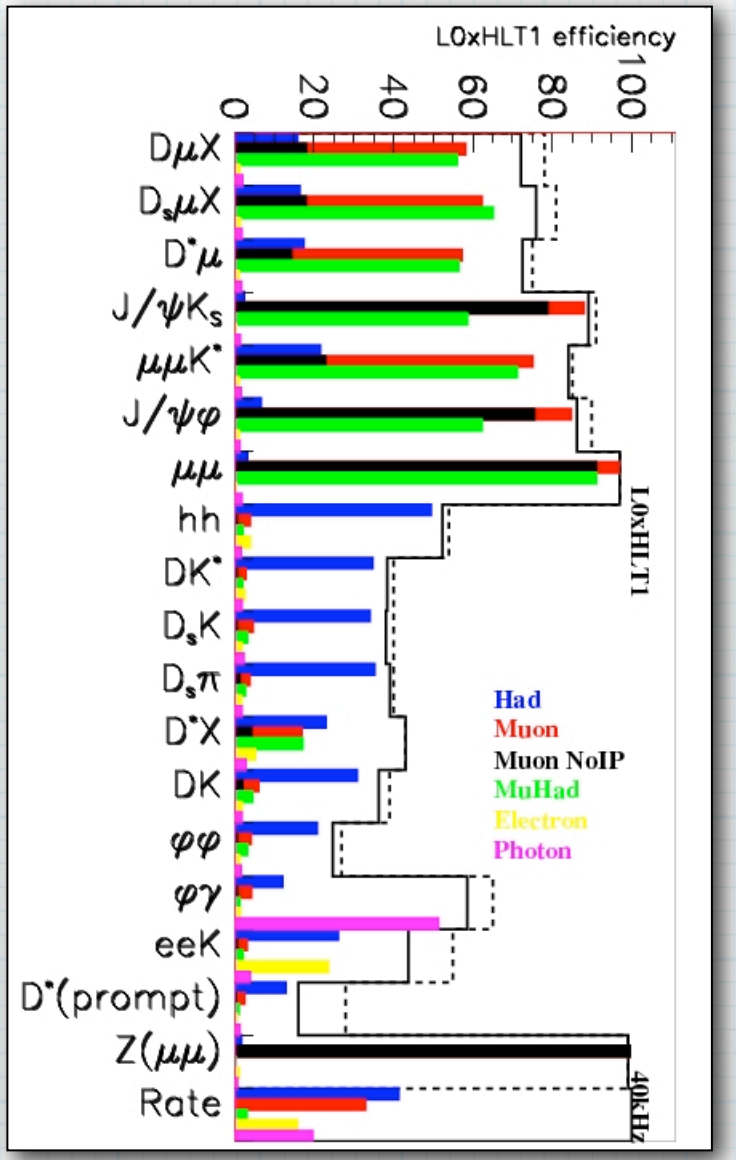
Alley	h	μ	μ+Tr	e	γ	combined
rate (kHz)	17	13	2	6	8	38

L0×HLT1 Efficiencies for the Key Channels

$B_d \to \mu\mu K^*$	17%	77%	73%	1%	2%	83%
$B_s \to J/\Psi\Phi$	7%	84%	62%	1%	1%	86%
$B_s \to \mu\mu$	3%	97%	91%	0%	2%	97%
$B \to hh$	49%	4%	2%	4%	1%	52%
$B_u \to D^0 K$	31%	6%	4%	2%	2%	36%
$B_s \to \Phi\gamma$	12%	4%	1%	1%	51%	58%

b Events: 3% ⇒ 16%

~40 kHz



* eff vs offline selected events

HLT2 strategy and performance

- **Scenarios**: leptonic, hadronic, democratic
- Reduction factor (5-20)
- **Full reconstruction** of the event
- **Inclusive B** search
  - Several particles: 2->4
- Exclusive B search possible

Possible HLT2-Inclusive Bandwidth Division

Line	lepton	topo-b	topo-c	ϕ	combined
rate (Hz)	900	650	200	150	1800

L0×HLT1×HLT2-Inclusive Efficiencies

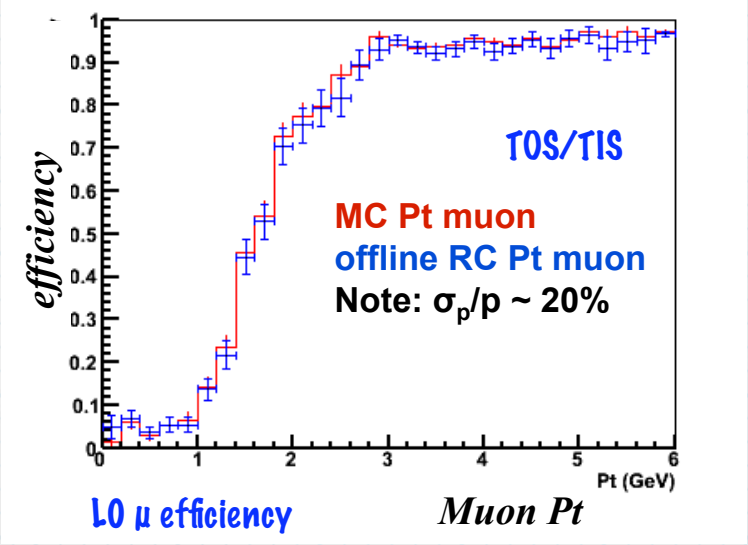
$B_d \to \mu\mu K^*$	70%	59%	-	-	74%
$B_s \to J/\Psi\Phi$	82%	34%	3%	38%	84%
$B_s \to \mu\mu$	94%	80%	-	-	95%
$B \to hh$	2%	42%	-	-	42%
$B_u \to D^0 K$	4%	18%	-	-	21%
$B_s \to \Phi\gamma$	1%	1%	-	50%	51%

b Events: 16% ⇒ 50%

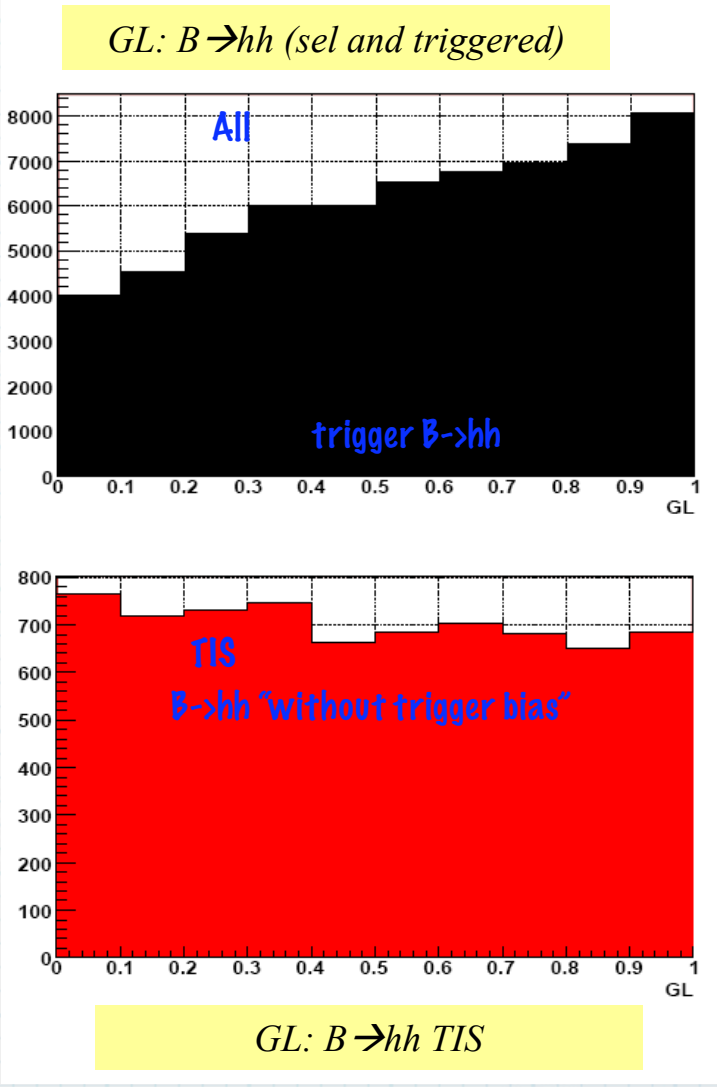
~2 kHz

Understanding the trigger

- Trigger Configuration Key (**TCK**)
  - Unique per event
  - Define lines of L0xHLT1xHLT2
- **HLT Summary** stored in raw event
  - Line decisions and candidates
- Trigger On (Independent of) Signal (**TOS** and **TIS**)
  - TIS events "trigger unbias" (**4%**)
  - Understand trigger bias and efficiencies

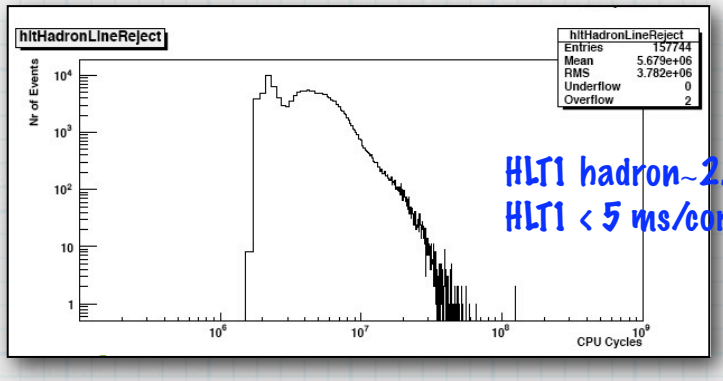


L0 B->hh as control channel of the Bs->μμ

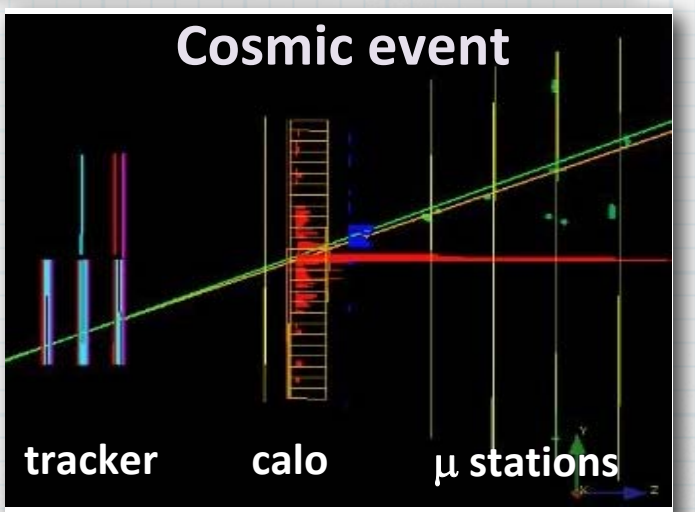


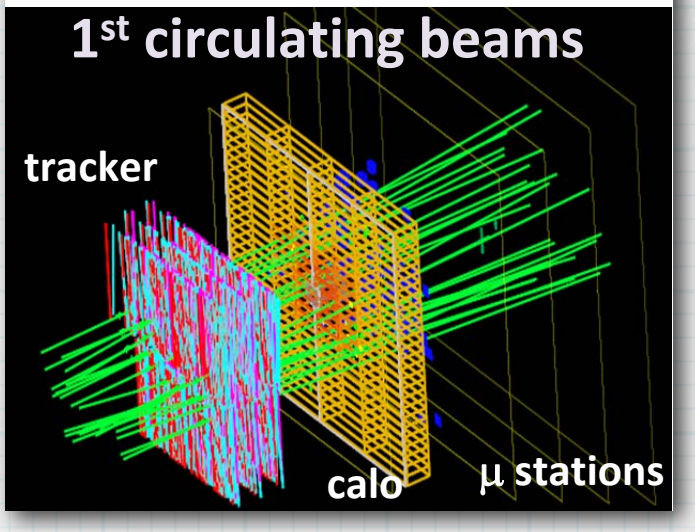
Commissioning the trigger

- Cosmic
  - ECal+Hcal coincidences
  - Synchronization and comparison with emulation
- Beam dump (TED) 350 m upstream
  - compare L0 muon and raw banks
- FEST
  - Replace detector by a MC data injector!
  - Exercise DAQ and online
  - TCK configuration, data base, EFF monitoring, time measurements



HLT1 hadron~2.4 ms/core
HLT1 < 5 ms/core



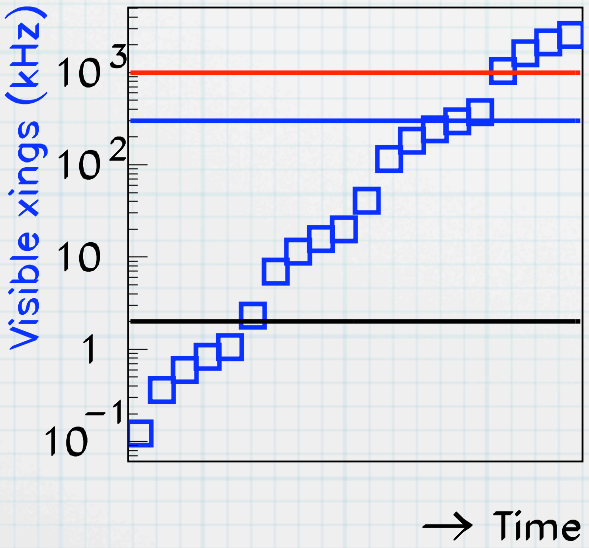


First run conditions

- Visible collisions from few kHz to 2.7 MHz
- Scenario : 68 bunches, 7 TeV, 330 kHz, 10^{31} cm^{-2}s^{-1}
- Soft L0 to 300 kHz (30% of EFF)
- HLT1 nominal reduction factor 30
- HLT2 reduction factors (5-20)
- Output 2kHz

$\epsilon_{\mathrm{L0\times Hlt1}} = 0.03$

Threshold	DC06 MeV, mm	MC09 MeV, mm
L0-h	3840	860
L0-μ	1200	120
L0-e,γ	2800	2800
Hlt1-h: p_{T}, IP	1600, 0.09	250, 0.06
Hlt1-μ: p_{T}	6200	1000
Hlt1-e,: p_{T}, IP	2820, 0.13	2820, 0.13
Hlt1-γ: p_{T}, IP(t)	2800, 0.15	2800, 0.15



>1 MHz L0:harder cuts, Hlt1×Hlt2: nominal values

.3-1 MHz L0: depends on farm size,
Hlt1: nominal, Hlt2: looser

<.3 MHz L0-loose, Hlt1: nominal,
Hlt2: absent, very loose

< 2 kHz Just L0-mbias+random trigger.

Conclusions

- The trigger of the LHCb selects inclusively **B decaying into muons, hadrons, photons,** electrons, from **13 MHz** of visible interactions to **2 kHz** of output rate
- The different levels of the trigger are **efficient** (>80%) except the L0 hadron trigger (50%)
- Large **contribution** of the spanish Institutions (**USC, UB**)
  - In the design and implementation of the HLT1 (**hadron, muon+track**)
  - In the design and implementations of HLT2 (topological, muons)
  - **HLT1 infrastructure**
  - How to understand trigger biases using **TIS events**
- LHCb trigger commissioning well advanced
- Conditions for the first run being established
- Eagerly waiting for the data!