Expected LHCb Trigger Performance

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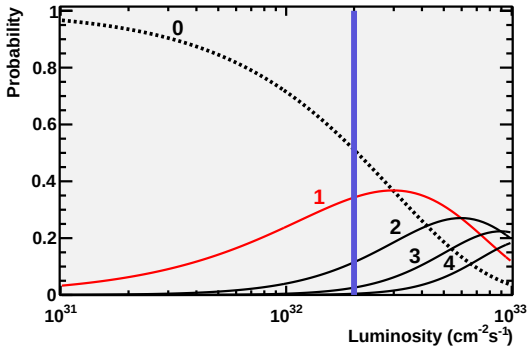
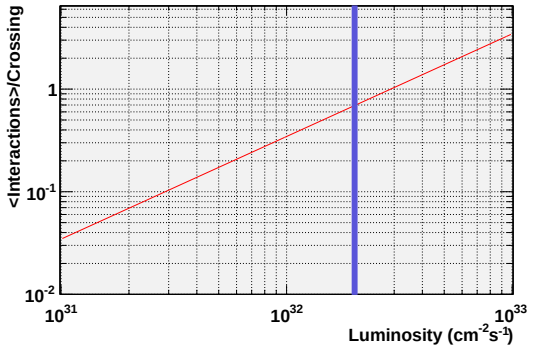
on behalf of the LHCb Collaboration

Expected LHCb Trigger Performance

Nominal Conditions

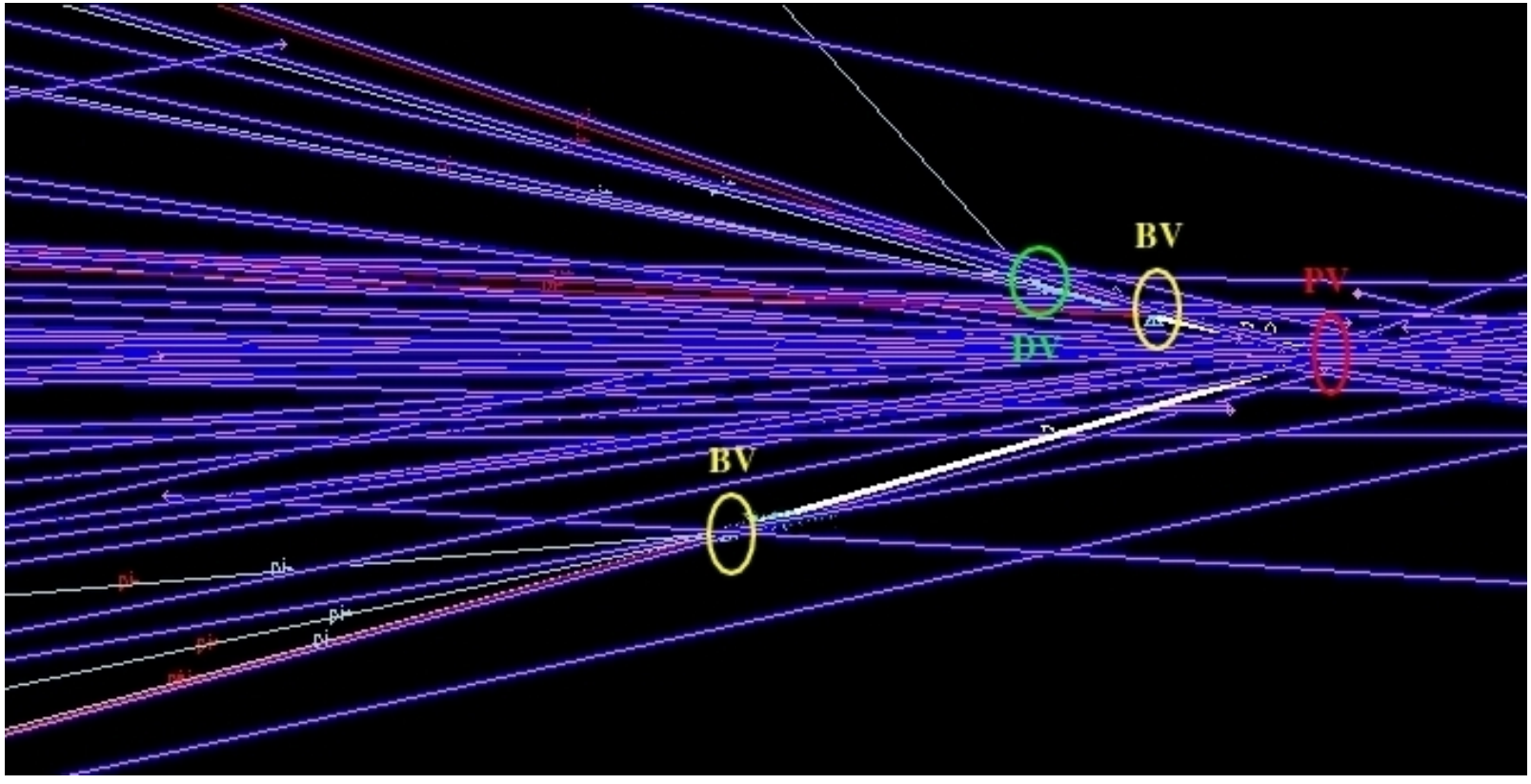
- pp colisions @ 14 TeV
  - $\mathcal{L} \sim 2 \times 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$
  - $< \frac{\text{Interactions}}{\text{Crossing}} > \lesssim 1$
- $b\bar{b}$ production
  - $\frac{b \text{ Events}}{\text{Visible Events}} \sim 10^{-2}$
- CPV Studies
  - $\mathrm{BR}(\mathrm{B_{CPV}}) - 10^{-4}$ to 10^{-9}
  - $\frac{\text{CPV Events}}{\text{Visible Events}} \lesssim 10^{-6}$



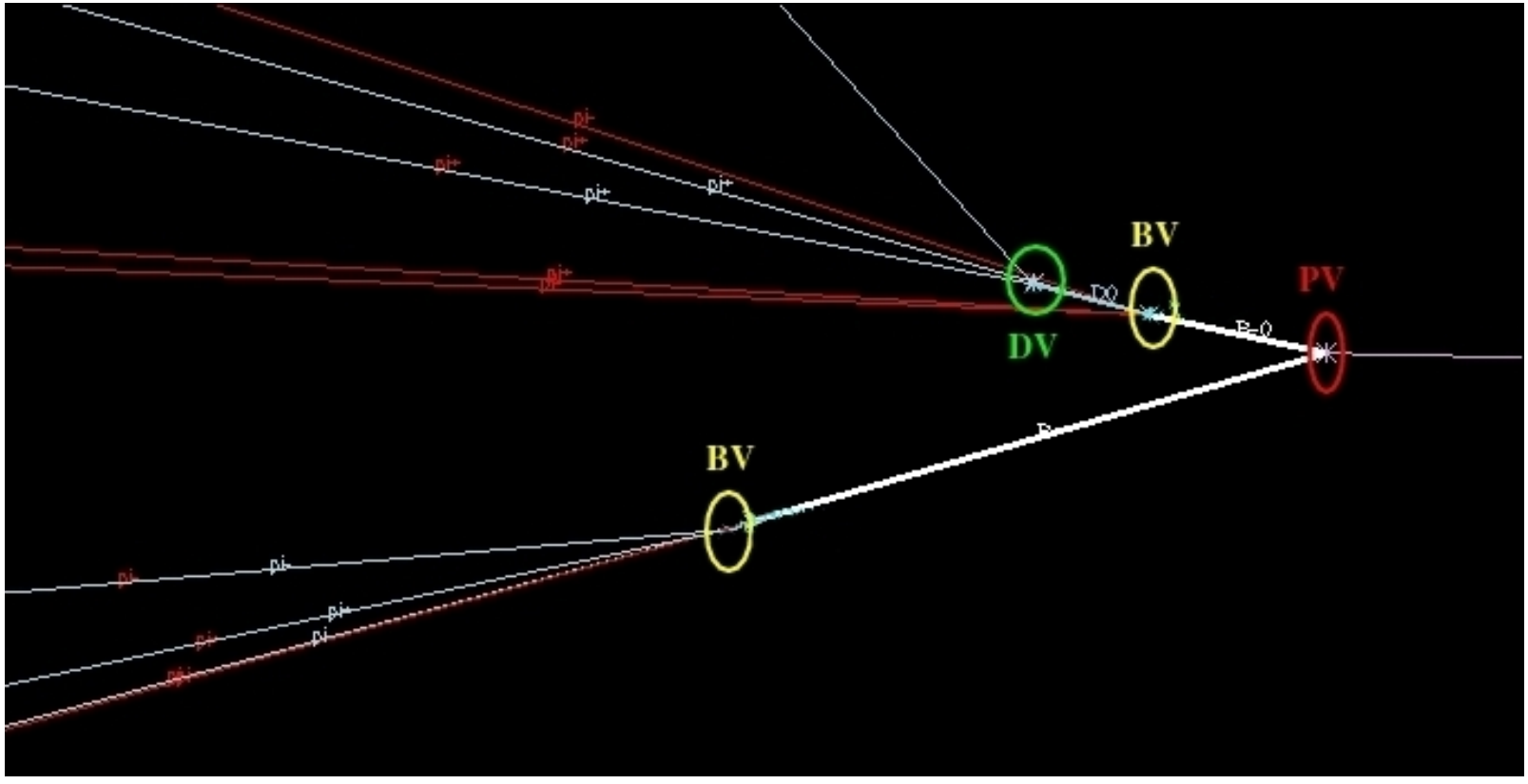


LHC Clock 40 MHz $\Rightarrow$ Possible Interaction 30 MHz $\Rightarrow$ Visible Event 15 MHz

Event



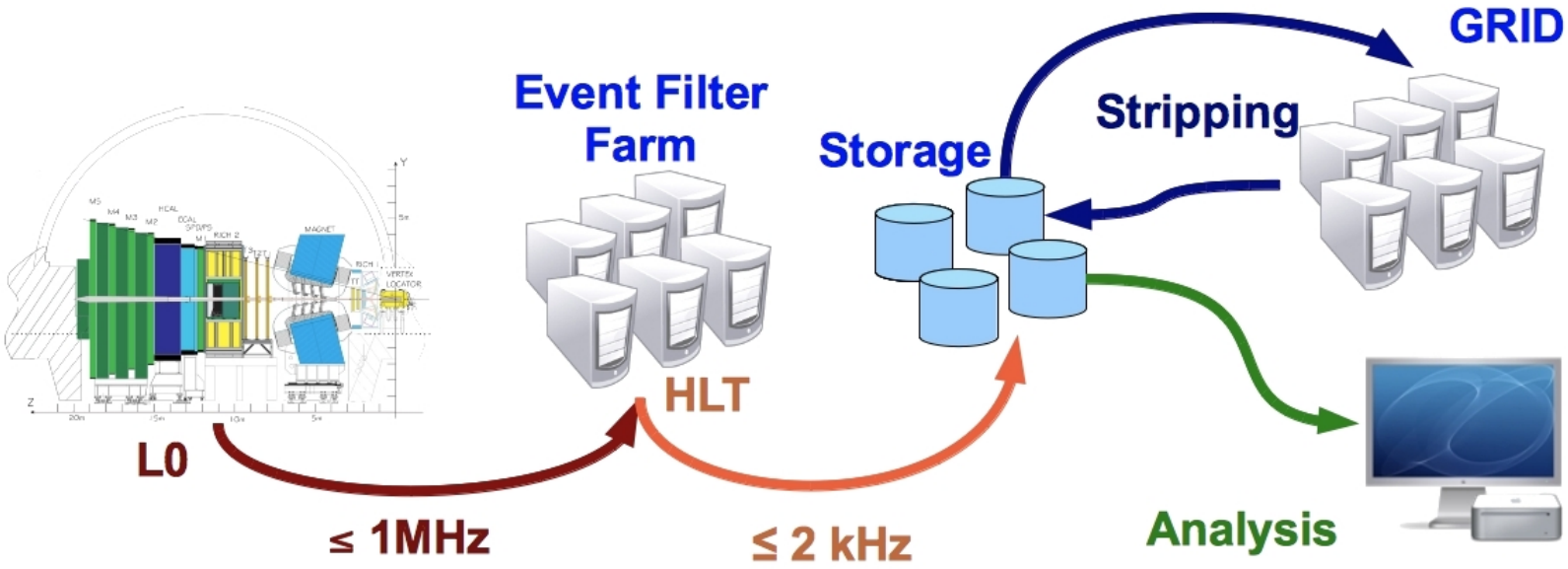
Event



Signature of B-decays

- $p_T(b - products) > p_T(pp)$
- B decay length $\sim$ 7 mm - σ(PV) $\sim$ 50μm

Data Flow



Constraints

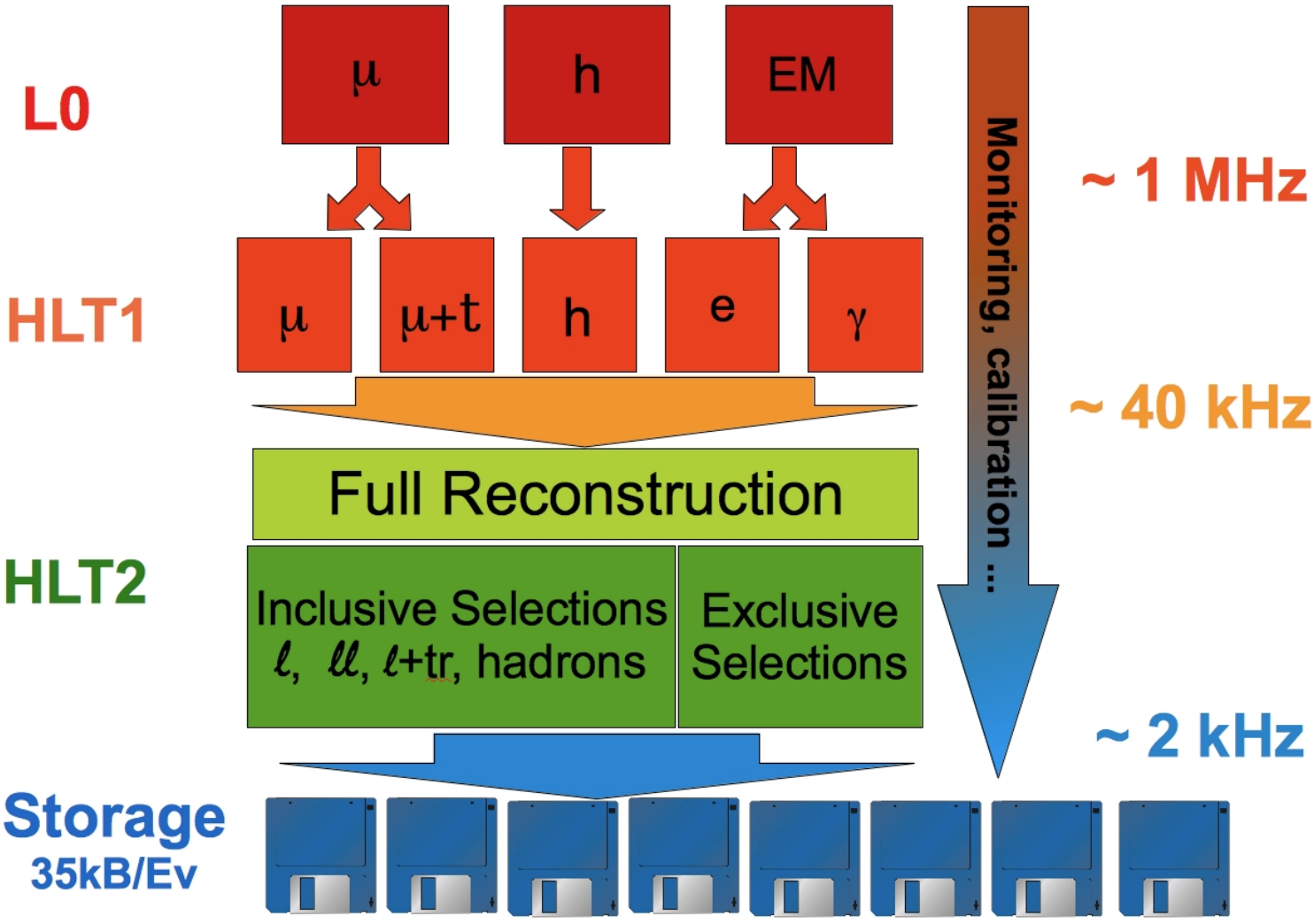
- Front-End Readout
- Write to File
- Data set too big

Level 0 Trigger

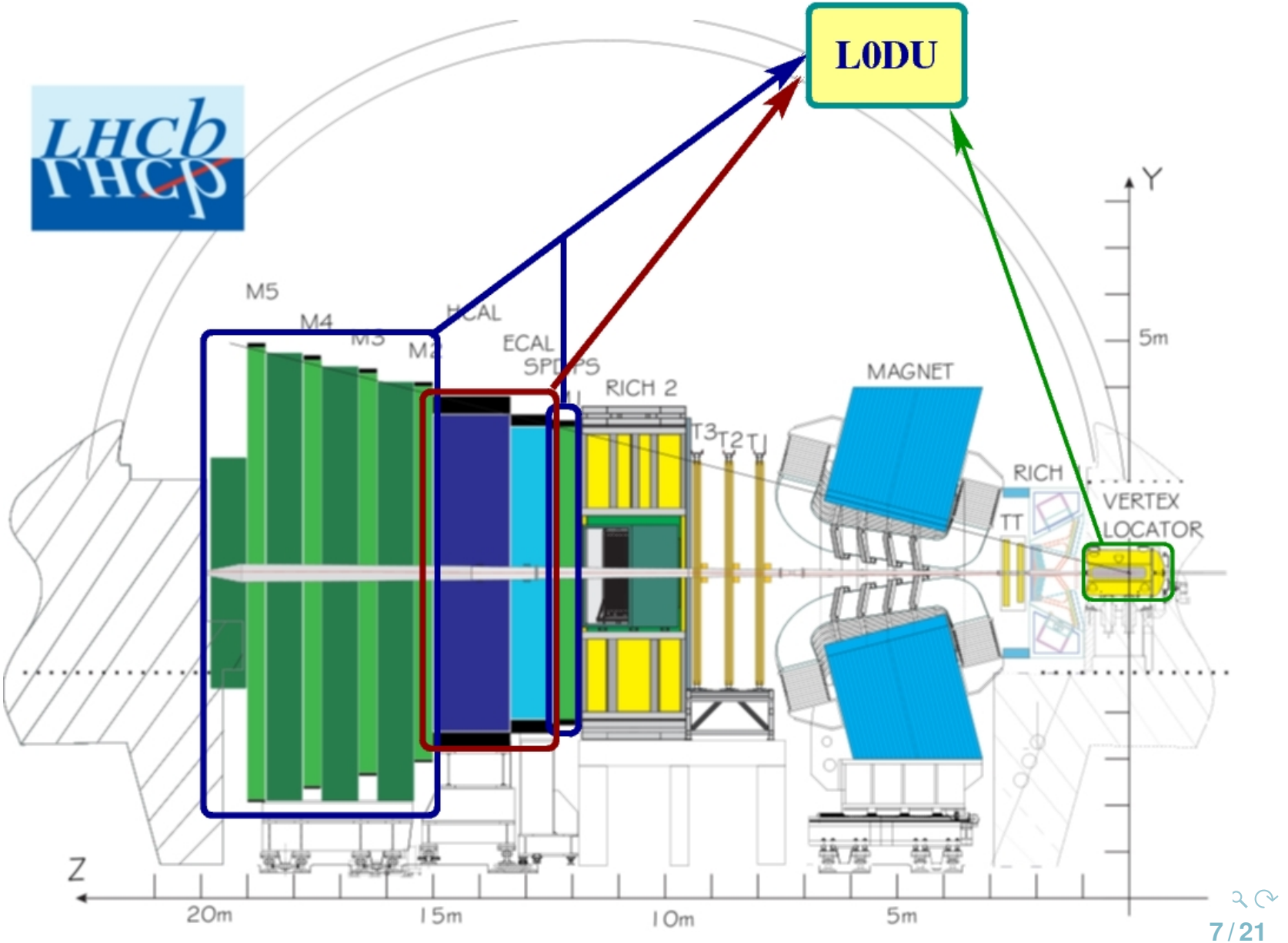
High Level Trigger: HLT1, HLT2

Stripping (HLT2-like)

Trigger Overview



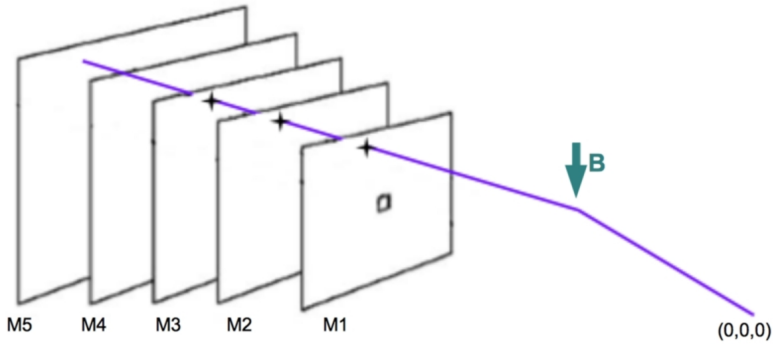
The Detector



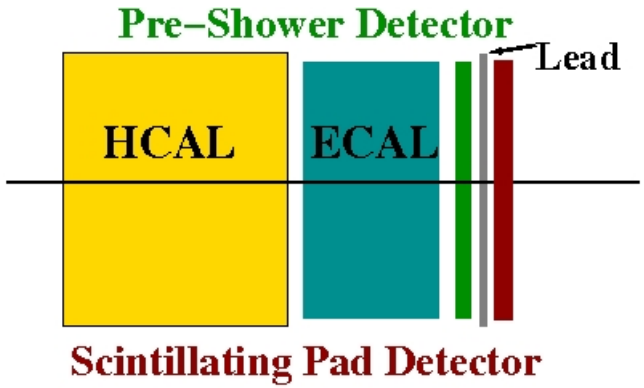
Hardware Trigger - L0

Physics Triggers

- Muon Objects
  - Single-μ and Di-μ
  - No PV information
  - $\Delta p/p \sim 20\%$



- Calorimeter Objects
  - γ, π^0, $e^{\pm}$ and hadrons
  - Eletromagnetic objects ID: SPD and PS
  - E_T: ECAL and HCAL

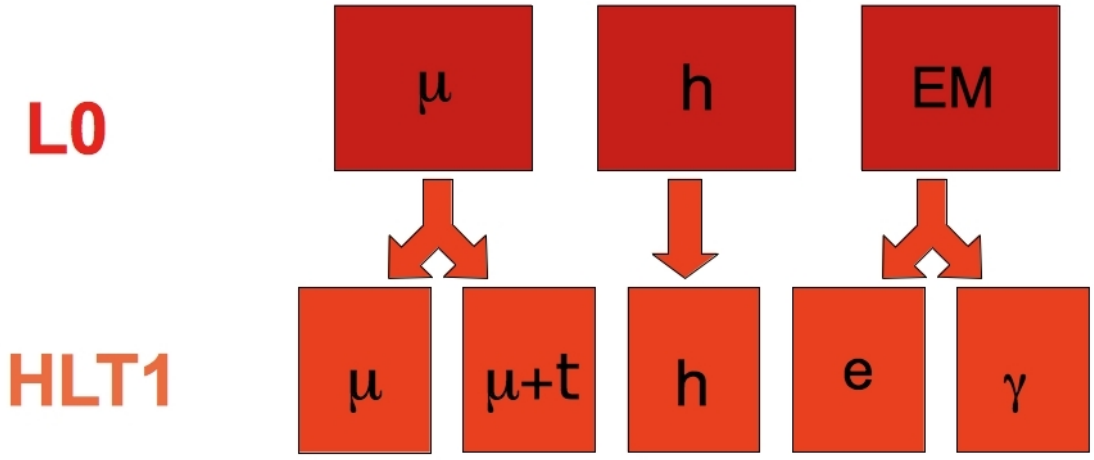


L0 output rate

- All detector information @ $\sim$ 1 MHz

Software Trigger - HLT1

- HLT1 - High Level Trigger - First step
  - Muon, Muon+Track, Hadron, Electron and Photon Alleys
  - Confirm L0 decision - tracking system
  - Partial reconstruction (fast tracking)
  - Trigger on simple signatures



HLT1 output rate: 30-40 kHz

Software Trigger - HLT2

- HLT2 - High Level Trigger - Second step
  - Event full reconstruction
  - Particle ID: muon system, calorimeters
  - Inclusive and exclusive selections
    - RICH @ low rate
    - Inclusive selections: Signatures of b decays
      Single-ℓ, di-ℓ, J/Ψ, ℓ+track, Φ, topological ...
    - Exclusive Selections: full decay reconstruction

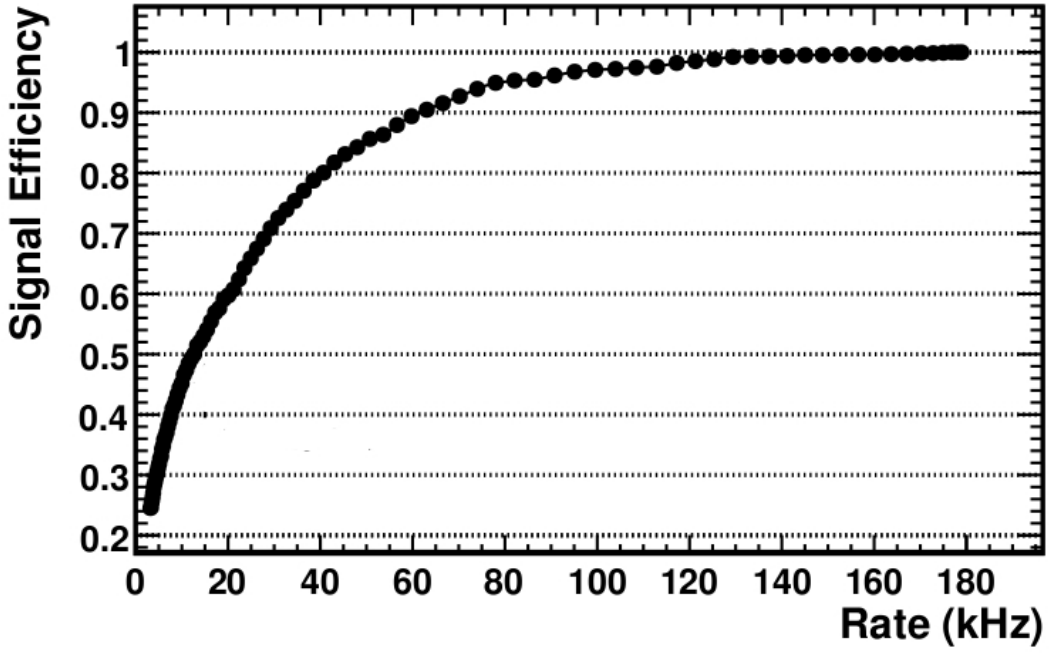
HLT2 output rate $\sim$ 2 kHz

Trigger Implementation

- Define Key Channels
- Design Trigger Lines
- Identify Knobs

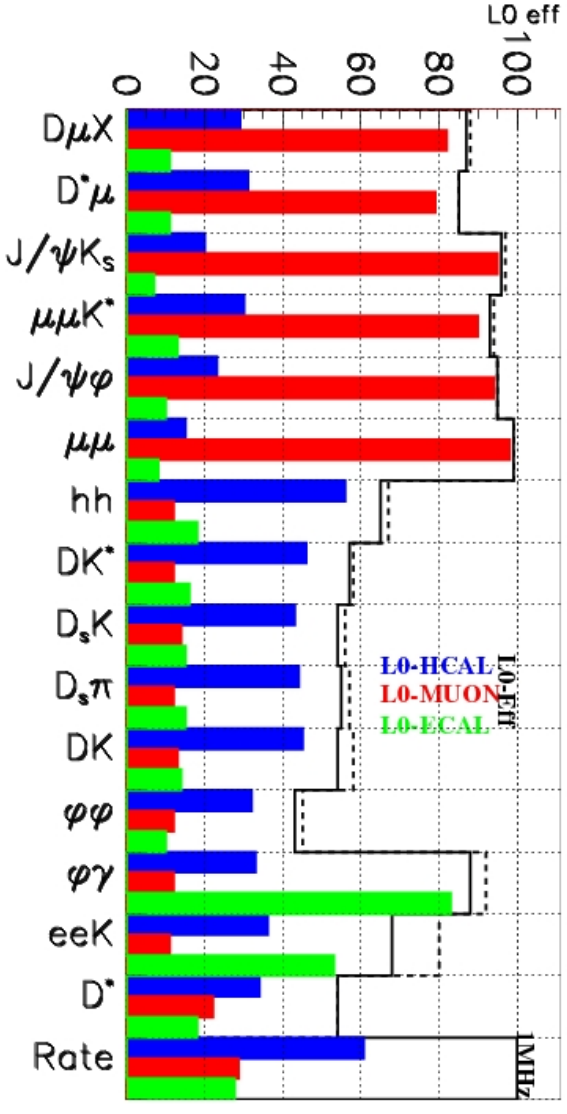
- Rate $\times$ Channel Efficiency
- Robustness, bias ...

An example: $B_s \rightarrow J/\Psi\Phi \Rightarrow \mu$ line $\Rightarrow$ knob: $\mathbf{P}_T$



L0 Bandwidth Division

- L0 Decisions
  - L0-Muon
  - L0-HCal
  - L0-ECal
- Optimized for Key Channels
  - $B_d \rightarrow \mu\mu K^*$
  - $B_s \rightarrow J/\Psi\Phi$
  - $B_s \rightarrow \mu\mu$
  - $B \rightarrow hh$
  - $B_u \rightarrow D^0(K_s\pi\pi)K$
  - $B_s \rightarrow \Phi\gamma$
- Robustness, Bias
- All efficiencies w.r.t. offline selected events



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

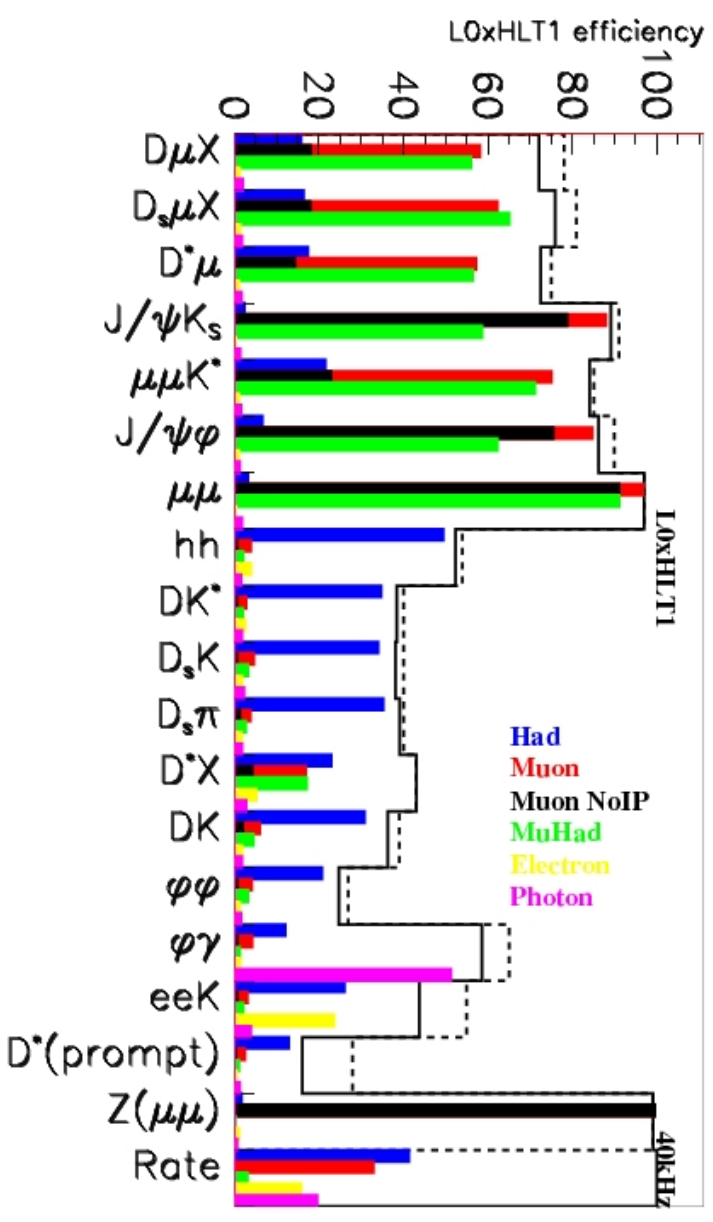
L0 Efficiencies for the Key Channels

$B_d \to \mu\mu K^*$	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% $\Rightarrow$ 3%

HLT1 Bandwidth Division

- 5 Alleys
  - hadron
  - μ
  - μ+track
  - electron
  - photon
- L0$\times$HLT1 Efficiencies



Hlt1 Performance

HLT1 Bandwidth Division

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

L0$\times$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% $\Rightarrow$ 16%

HLT2 Bandwidth Division

HLT2 Lines

- Inclusive
  - Leptonic
    - Single Lepton
    - Lepton + Track
    - Di-Leptons
  - Topological
    - beauty
    - charm
  - Φ
- Exclusive

➥Different Running Scenarios

Line	Bandwidth (Hz)
Leptonic	400 - 1200
Topological-b	400 - 1000
Topological-c	200 - 800
Φ	100 - 200
Inclusive	1800
Exclusive	200

➥HLT2 $\rightleftarrows$ Stripping

Hlt2 Performance

Possible HLT2-Inclusive Bandwidth Division

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

L0$\times$HLT1$\times$HLT2-Inclusive Efficiencies

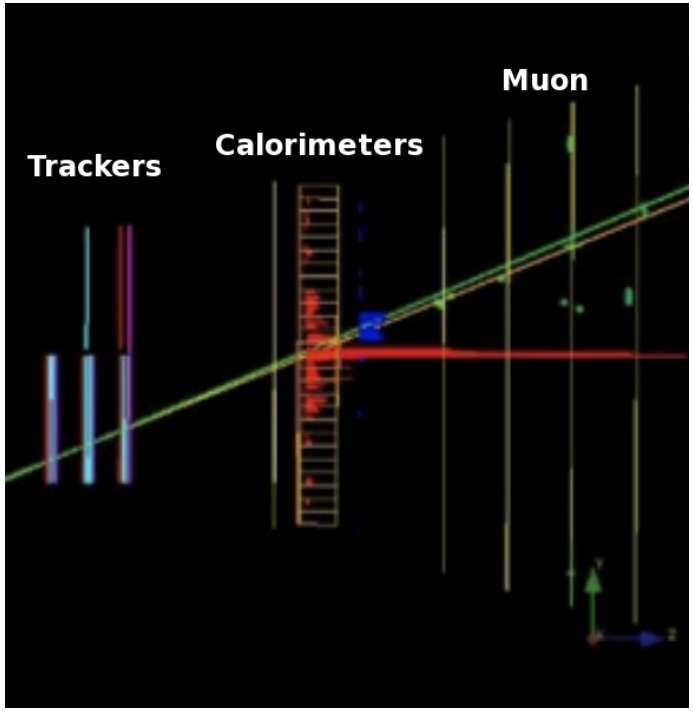
$B_d \to \mu\mu K^*$	70%	59%	-	-	74%
$B_s \to J/\Psi\Phi$	82%	34%	3%	38%	84%
$B_s \to \mu\mu$	94%	80%	-	-	95%
$B \to hh$	2%	42%	-	-	42%
$B_u \to D^0 K$	4%	18%	-	-	21%
$B_s \to \Phi\gamma$	1%	1%	-	50%	51%

b Events: 16% $\Rightarrow$ 50%

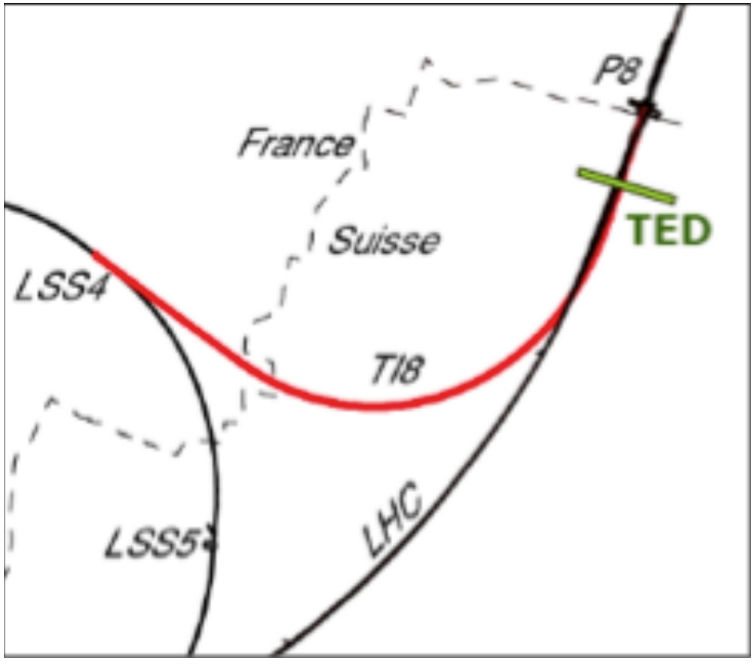
L0 Commissioning

L0 has been commissioned using:

- Cosmics

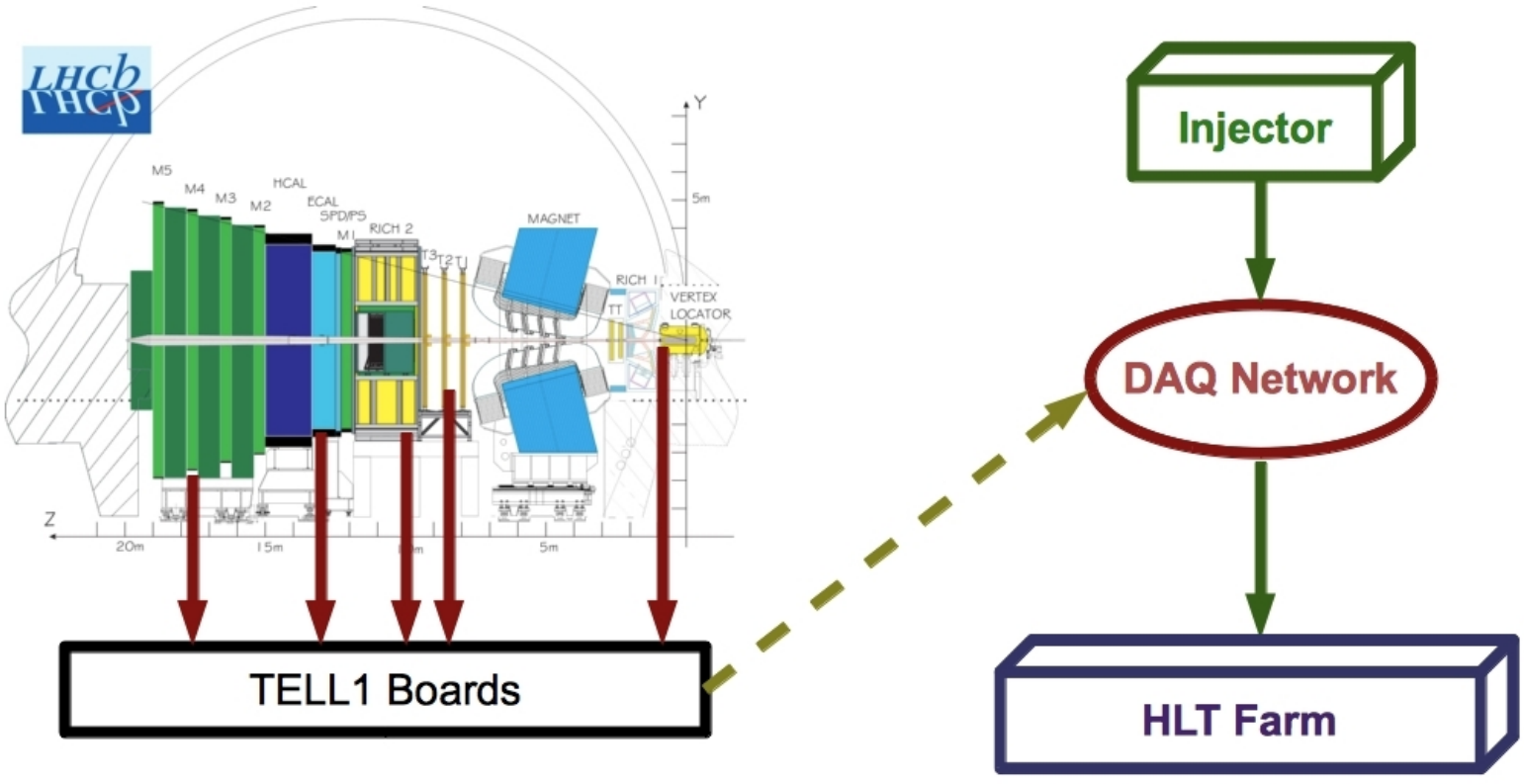


- Transition-line End Dump



HLT Commissioning

Full Experiment System Test



➥ HLT1 Timing $<$ 5 ms/event

Running Conditions

- Many possible running conditions: E_{beam}, $\mathcal{L}$ ...
  ➥ For each scenario
  - Define Physics goals - Key Channels
  - Reoptimize Bandwidth Division
- One of 2010 possible running scenarios
  - 68 colliding bunches @ 7 TeV
  - $\mathcal{L} \sim 10^{31} cm^{-2} s^{-1}$
    - Charm can be included in key channels
    - L0×HLT1 Efficiency for prompt charm 70% (15% @ nominal conditions)

Trigger Performance

- LHCb trigger has been commisioned
  - L0 with cosmics and TED
  - HLT with FEST
- For LHC nominal conditions it has been optimised using Key Channels
  - Signal Efficiencies
    - Leptonic: $\sim$ 70% - 90%
    - Radiative: $\sim$ 50%
    - Hadronic(b): $\sim$ 20% - 50%
- A procedure to setup the Trigger for different running conditions was established