LHCb Trigger

Outlook:

- Introduction: the experiment and the trigger
- L0 trigger (hardware)
- HLT (software): the alleys
- Trigger monitoring
- Summary

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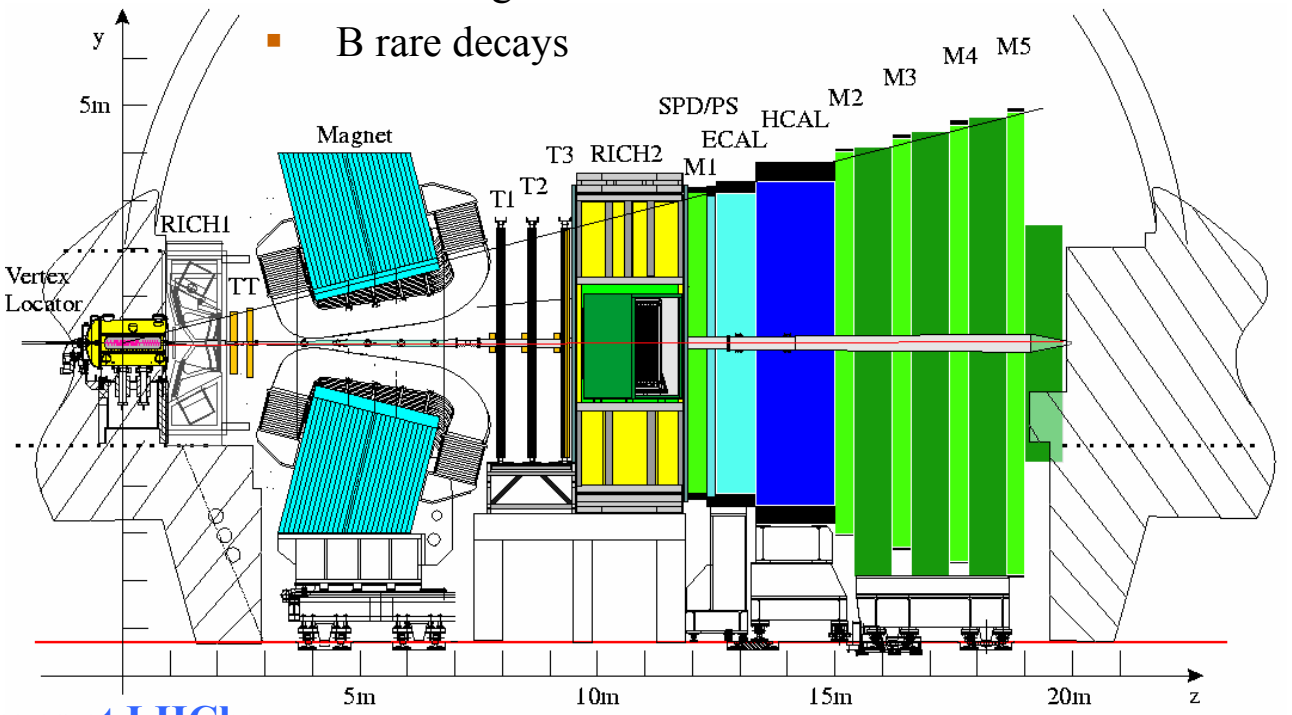
Physics at LHC, 07/07/06

LHCb experiment

LHCb will study B physics at LHC

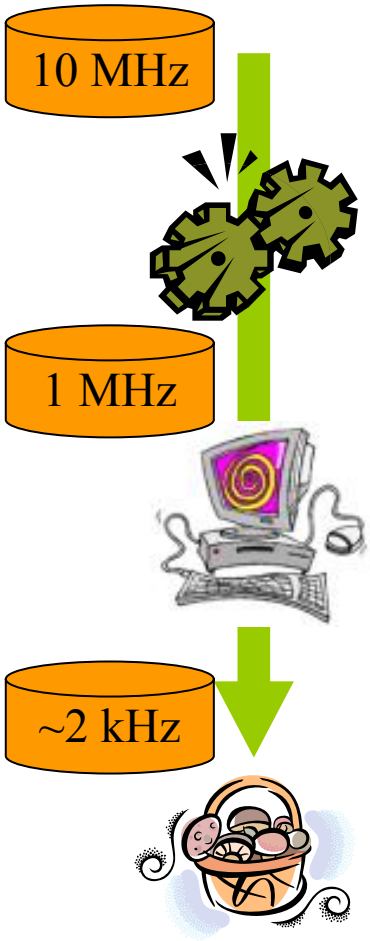
- Study the Unitary Triangle of the CKM matrix
- Bs mixing
- B rare decays



B mesons at LHCb:

- Luminosity 2 10^{32} cm^{-2} s^{-1} → 100 kHz bb @ 10 MHz of visible interactions
- bb are produced backward/forward region → LHCb is one arm spectrometer
  15% bb at least one B in the acceptance $1.9<\eta<4.9$
- Small interesting B branching ratios: 10^{-3} 10^{-9} → O(10) Hz

LHCb trigger



Visible collisions
$L = 2\ 10^{32}\ cm^{-2}\ s^{-1}$

L0: [hardware]
high Pt particles
calorimeter + muons
4 μs latency

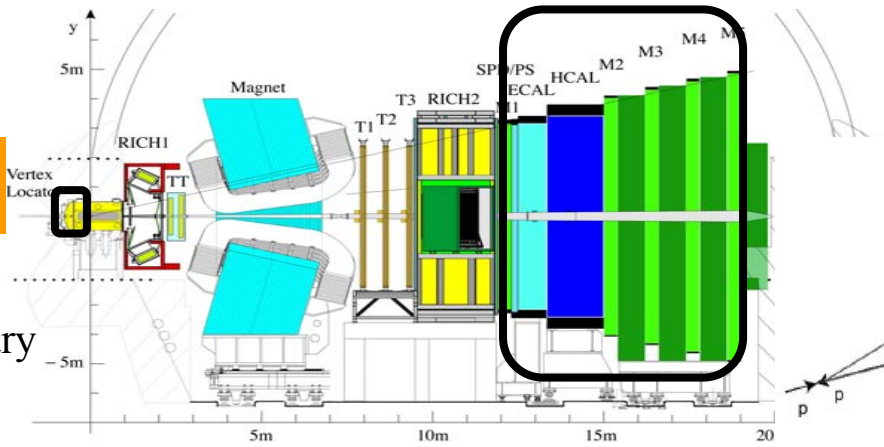
HLT [software]
1 MHz readout
~1800 nodes farm

On tape:
Exclusive selections
Inclusive streams

LHCb trigger:

- Two trigger levels:
  - L0: hardware
  - HLT: software
- Trigger Strategy:
  - Enhance the b content in sample
    High Pt particles,
    Displaced tracks
    Increase b content: 1% → ~50-60%
  - Follow seed particles of the decays
    Trigger divided in alleys
  - Favor inclusive channels

L0 strategy

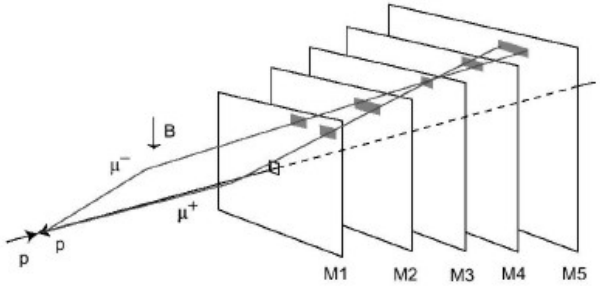


Veto

Strategy:

- Number Primary Vertices

Muon



Muon Stations:

- M1-M5 stations

Strategy:

- 2 highest Pt muons per quadrant:
  - (σ_p/p~20%)

Latency: 1 μs

Hadron

ECal (γ,π^0,e):

The LHCb calorimeter:

- SPS, ECAL, HCAL:

Trigger strategy:

- Largest Et candidate for had,e,γ,π^0
- Global variables:
  - Total Et and SPD multiplicity

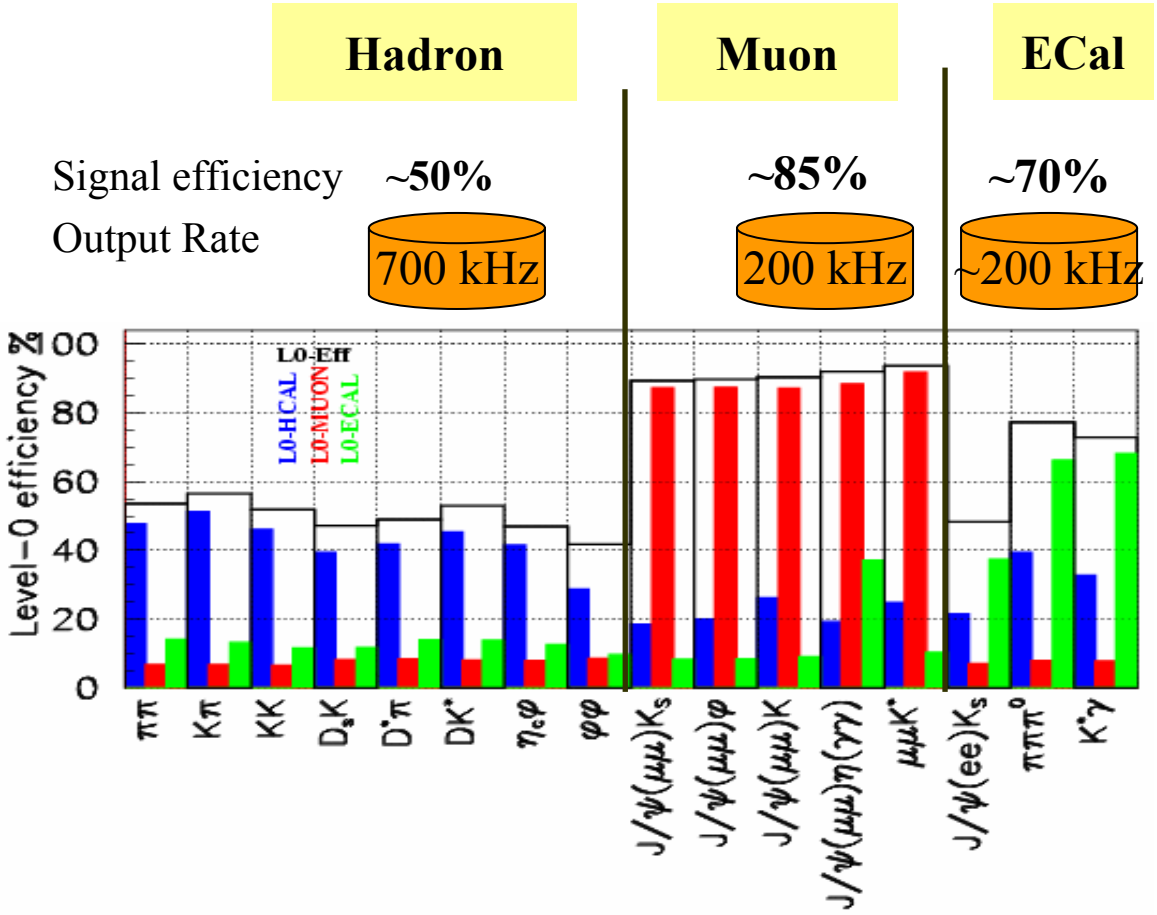
Latency: 1 μs

LO decision unit

L0 performance

L0 performance:

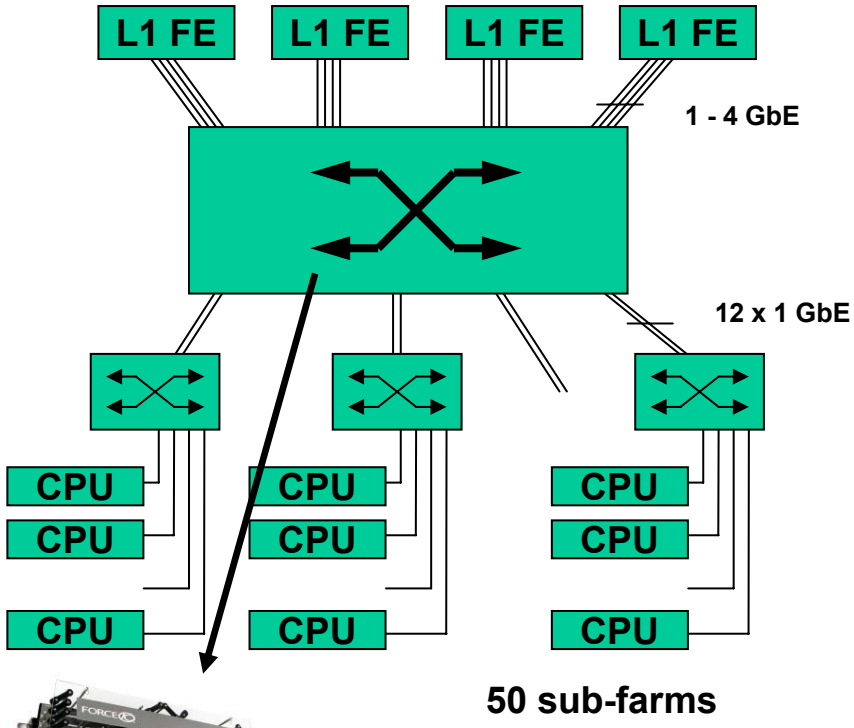
- Efficiency: trigger selected events/offline selected events
- Good for muons, acceptable for hadrons
- *b content:*
  - *1% → 2.5 % (hadron), 4.5 % (muons)*



Type	Thresh (GeV)
Hadron	3.6
Electron	2.8
Photon	2.6
π^0 local	4.5
π^0 global	4.0
Muon	1.1
Di-muon Σp_T^{μ}	1.3

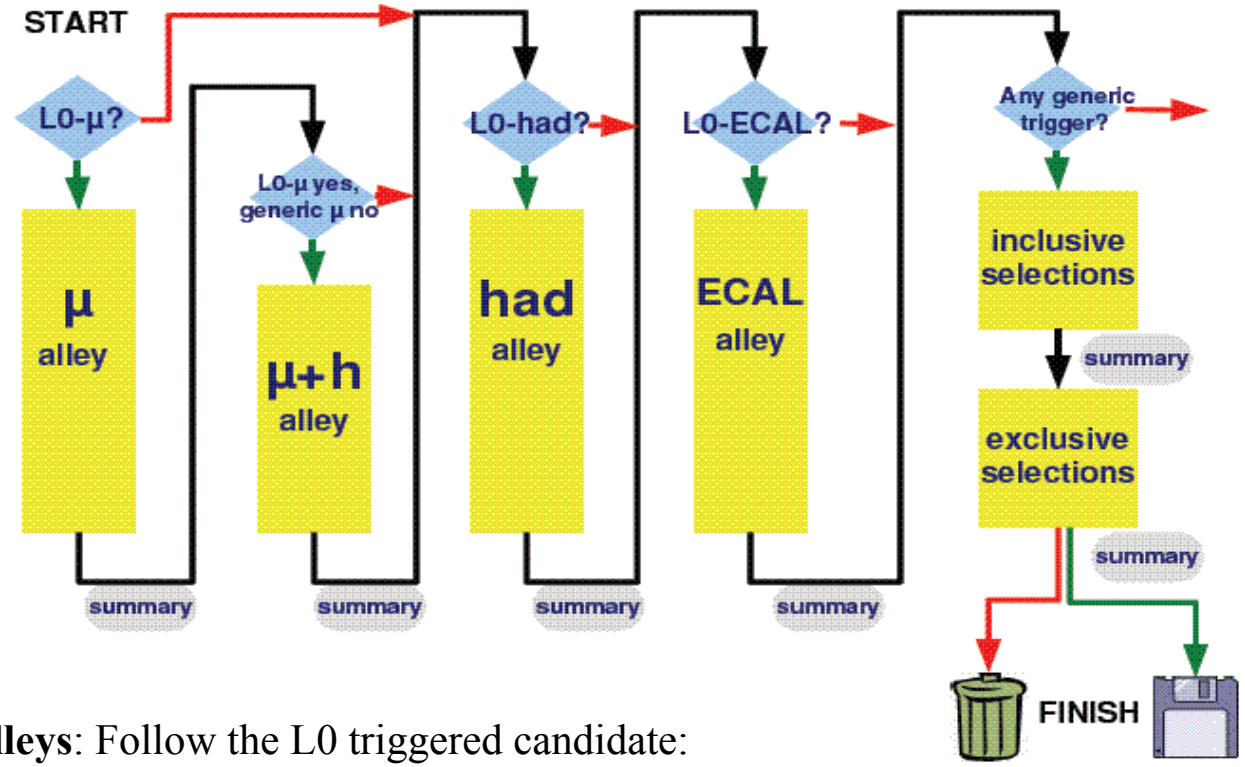
DAQ Farm

- **Front Ent Electronic board**
  - Performs zero suppression
  - Event formatting for DAQ
  - ~300 L1 front-end modules
- **Readout at 1 MHz:**
  - Gigabit Ethernet from Level-1 to farm
    - Single core router ~750 input links
  - Total throughput: 50 GB/s
- **Event Filter Farm**
  - ~1800 nodes
    - (estimated from 2005 Real-Time Trigger Challenge results)
    - 50 in sub-farms of up to 44 nodes



Force10 E1200, 1260 GbE ports

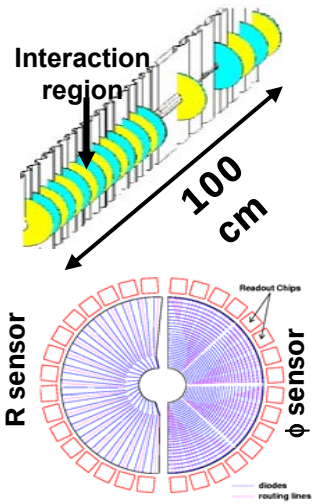
HLT Alleys

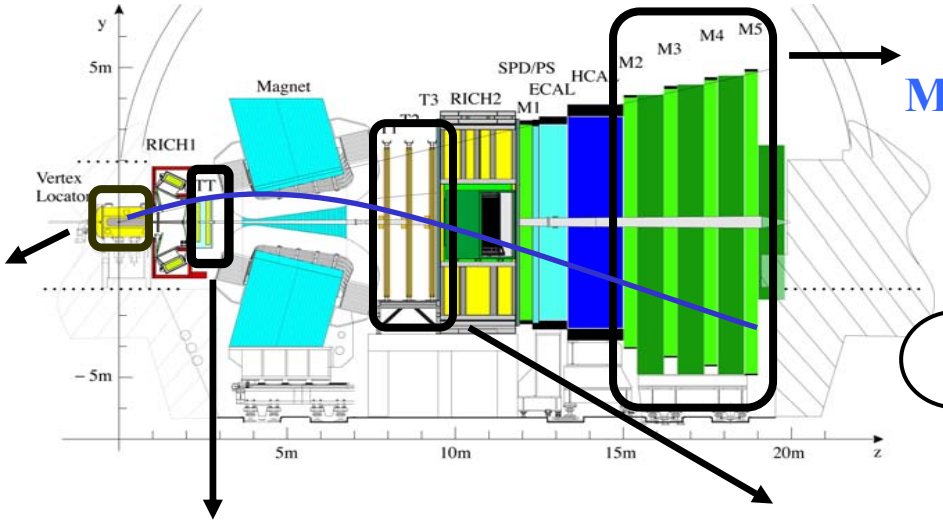


➢ Strategy

- **Independent alleys**: Follow the L0 triggered candidate:
  - Muon, Muon+Hadron, Hadron, ECal
- ***Partial Reconstruction***:
  - Select few tracks per alley, full reconstruction is done at the end of the alleys
- Produce a summary:
  - With the information of how we triggered the event!

HLT:tracking





Muon stations:

$\sigma_p/p \sim 20\%$ standalone

$\sigma_p/p \sim 5\%$ matched with Velo tracks

~0.2 ms

Standalone muons

VELO:

RΦ geometry

All tracks

~1 ms

Trigger Tracker (TT):

$\sigma_p/p \sim 20\text{-}40\ \%$

Use B field before magnet!

few selected tracks

~0.5 ms

Tracker stations (T):

σ_p/p ~1%

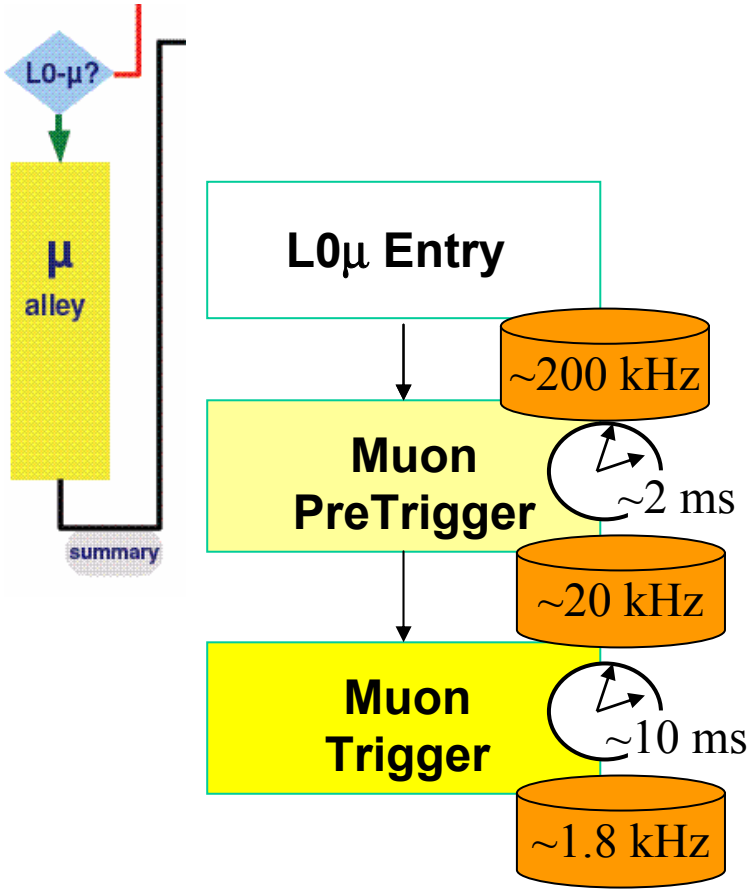
few displaced tracks

~8 ms

➢ Reconstruction strategy:

- Do reconstruction with Velo and select tracks with Impact Parameter
- Fast Measurement of Pt (use TT or match Velo tracks with the muon stations)
- Refine Pt measurement (use T stations)

Muon Alley: strategy



Muon PreTrigger:

Standalone muon reconstruction: $\sigma_p/p \sim 20\%$

Velo Tracks reconstruction and Primary Vertex

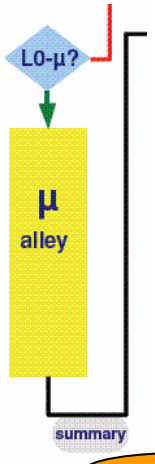
Match velo tracks and muons: $\sigma_p/p \sim 5\%$

Muon Trigger:

T tracking of Velo track candidates: $\sigma_p/p \sim 1\%$

Refine muon ID: match long tracks and muons

Muon Alley: decision and performance



Muon Inclusive streams:

- **Single Muon:**
  - A enhanced b sample: B→ μX
- **Dimuon:**
  - Select a dimuon with no lifetime bias!
  - Use narrow mass to study tracking and alignment, i.e B field effects

~20 kHz

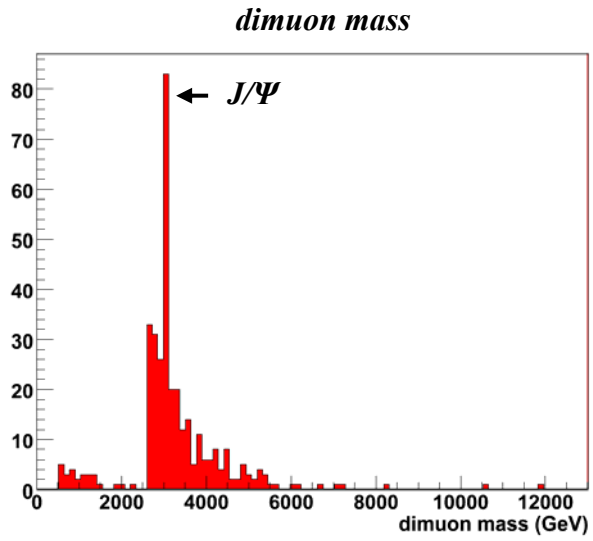
Muon PreTrigger:

- **b->μ 11%**
- **Signal efficiency:** ~88%

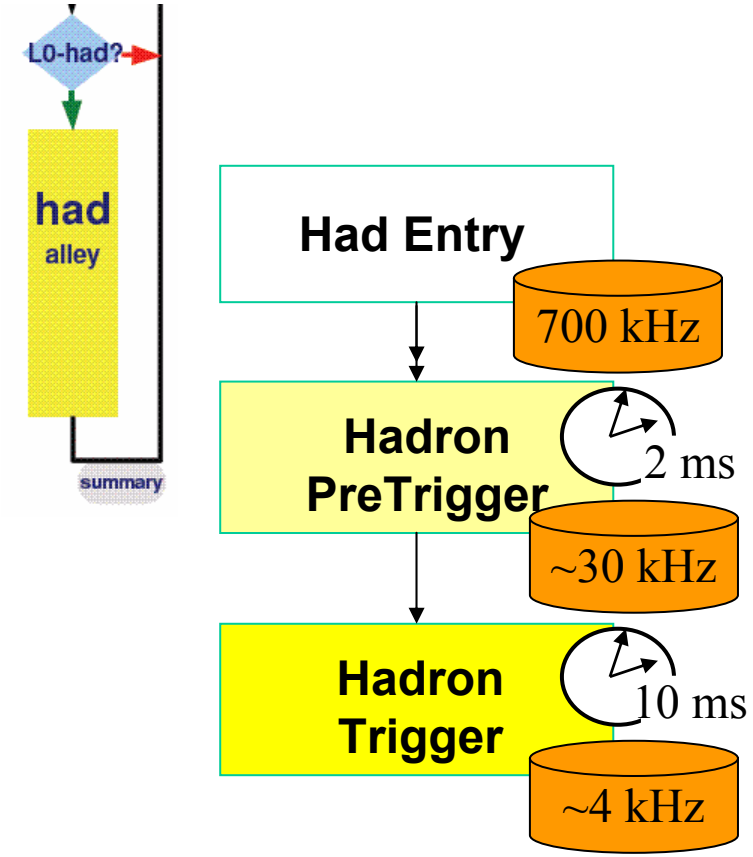
Muon Trigger:

- **Single muon**
  - Pt> 3GeV IPS> 3
  - B→μ content 60%
- **Dimuon**
  - mass >0.5GeV and IP>100μm
  - mass>2.5GeV (no IP cut!)
  - 170Hz of J/ψ
- **Signal efficiency**: ~87%

~1.8 kHz



Hadron Alley: strategy



Hadron PreTrigger:

Reconstruct Velo Tracks and Primary Vertices

Select tracks with IP>150μm

Measure Pt using Trigger Tracker: $\sigma_p/p \sim 20\text{-}40\%$

Hadron Trigger:

Select tracks with |IP|>100μm

Measure Pt using Tracking Stations: $\sigma_p/p \sim 1\%$

Make secondary vertices

Hadron Alley: performance

Hadron PreTrigger:

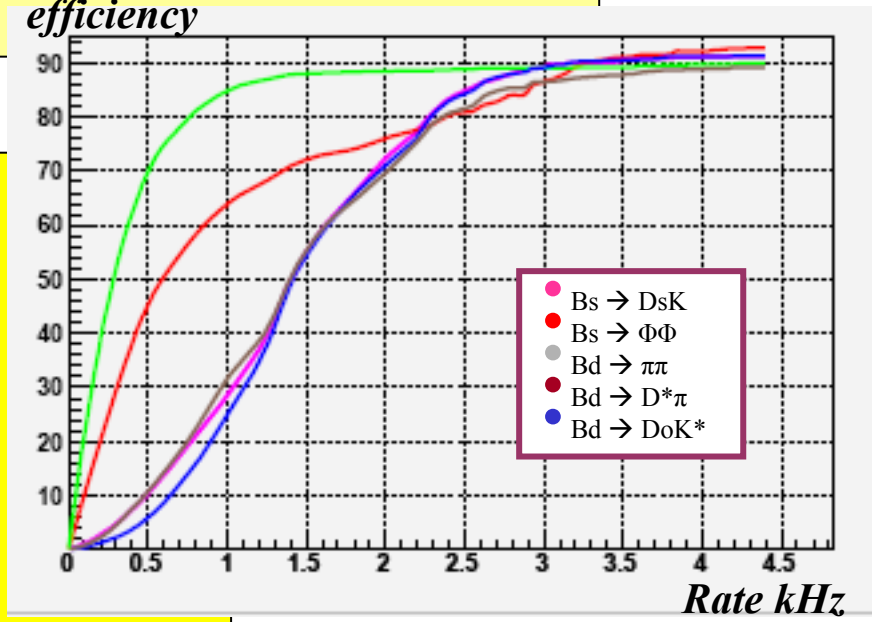
- Single hadron: IP>150μm, Pt>2.5 GeV
- Double hadron :IP>150μm, Pt1>1.1 GeV, Pt2>0.9 GeV
- **14% b content**
- **Signal efficiency:**
  - **~82% B→ππ, Bs->DsK**

~30 kHz

Hadron Trigger:

- |IP|>100 μm, Pt> 1GeV
- Make 2 track vertices:
  - Distance Of Closest Approach (DOCA) < 200 μm
- vertex "pointing" to PV
- ***48% b content, 17% c content***
- ***Signal efficiency: ~90% Bs→DsK, B→ππ***

~4 kHz



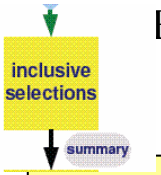
Inclusive streams and Exclusive Selections

Strategy:

Full tracking reconstruction at few kHz

Select Inclusive stream (D*,Ds,Φ,…)

Exclusive selections (Bs→DsK,B→hh,…)



D* inclusive stream:

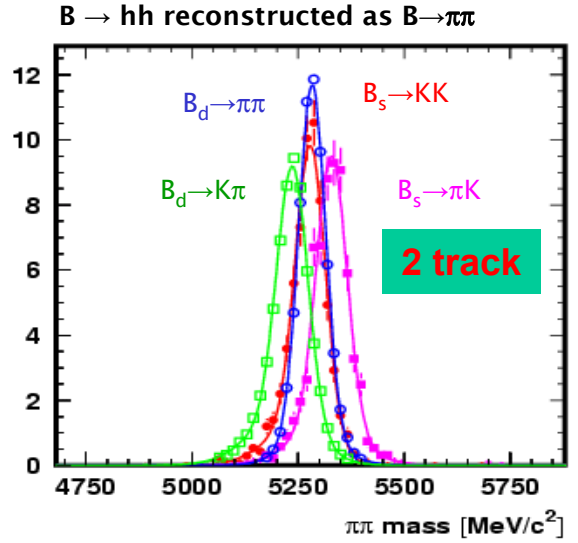
~250 Hz

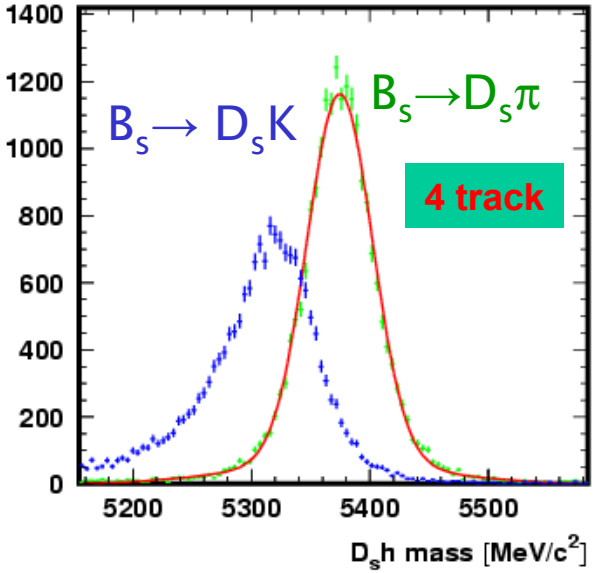
- Clear signal: $D^{*+} \rightarrow D^0(K^-\pi^+)\pi^+$
- To calibrate Particle Identification (PID)

Exclusive selections:

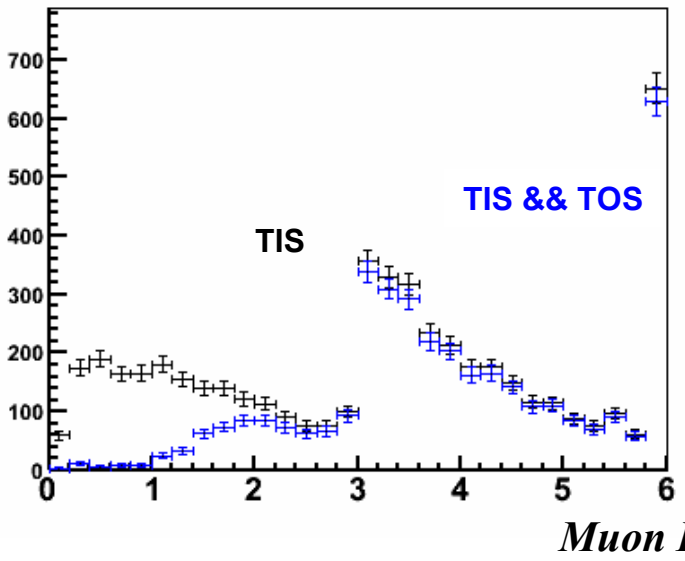
~200 Hz

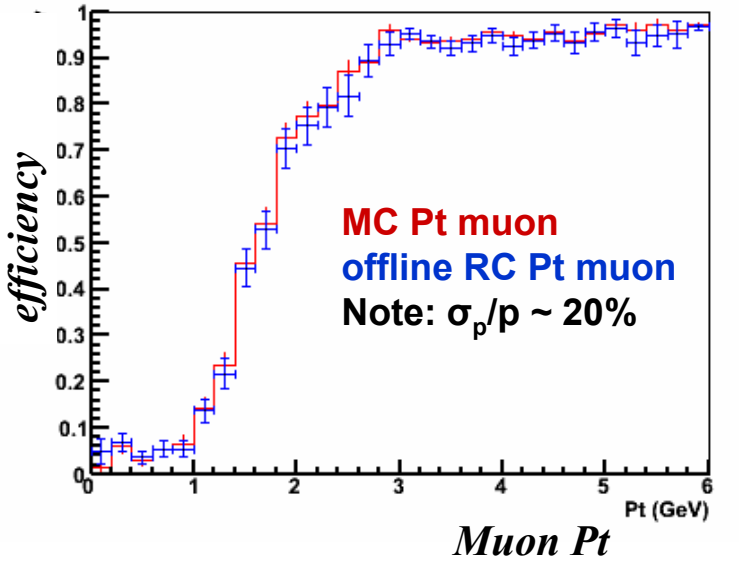
- Via intermediate particles (Φ, D^0,..)
- Wide B mass windows
- Output rate: few Hz
- Efficiency: i.e. 88% B→ππ





Trigger Monitoring





Monitoring: Work in progress…

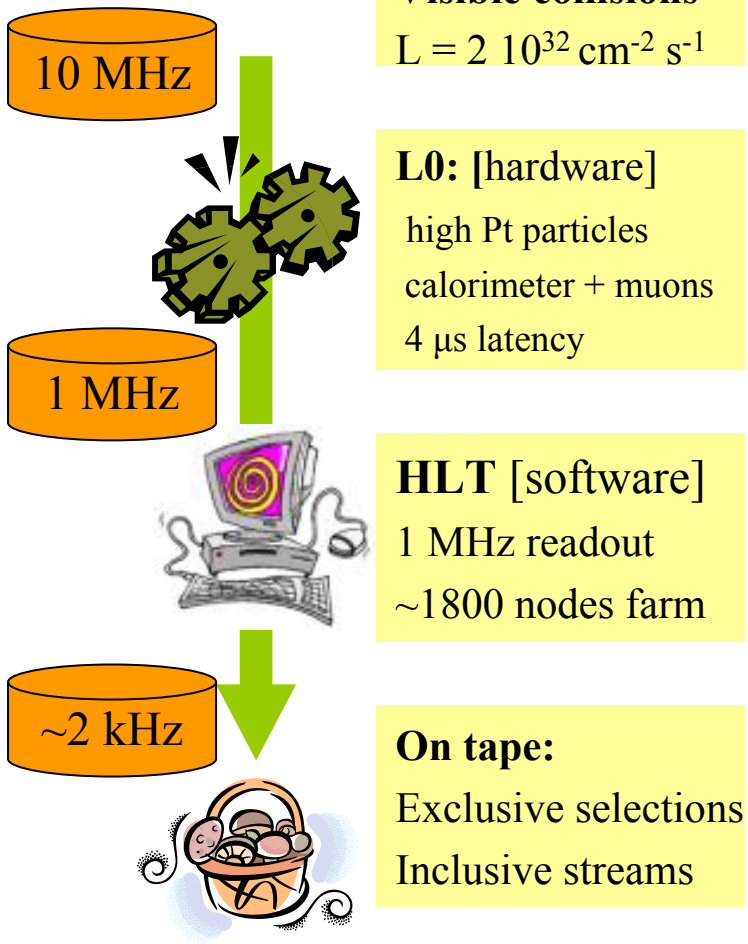
- Internal monitoring: done in the EFF
- External monitoring: done in the Monitoring Farm

Example of external monitoring (L0 muon Pt cut):

- Take triggered event with a muon reconstructed offline
- Take sample where the event was trigger without using that muon (TIS)
- Select subsample where the event was also triggered by that muon (TOS)
  - Compare online quantities (i.e Pt) with offline ones

Summary

- **L0 (hardware trigger):**
  - Finalized!
  - Good performance for muons
  - Acceptable for hadrons
- **HLT (software trigger) at 1 MHz:**
  - 4 alleys: **μ, μ+hadron, hadron, Ecal**
    - Strategy defined
  - Time is "in budget"
  - Performance is good in inclusive selections
  - *Work in progress*:
    - recoding algorithms and tracking
- **Monitoring and calibration**
  - *Work in progress*:
    - developing monitoring methods



Exclusive selections

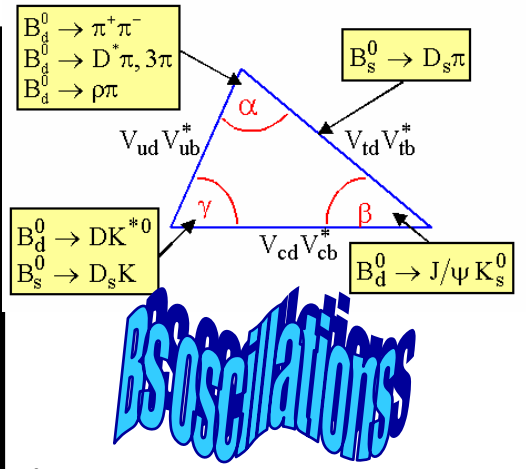
Seed particles:

- Different type of particles of the relevant decays are detected by different subdetectors
  - → different trigger alleys depending in the detector we rely

Muon [muon,tracking]	**Hadron** [tracking, calorimeter]	**ECal (γ,π^0,e)** [calorimeter, tracking]

~200 Hz

$B \to J/\psi K_S$	$B_s \to \Phi\Phi$	
	$B_s \to D_s^- K^+$ $B \to \pi^+\pi^-, B_s \to K^+K^-$ $B \to D^0 K^{*0}, B^- \to D^0 K^-$	
		$B \to \pi^0\pi^-\pi^+$
$B_s \to J/\Psi\Phi$	$B_s \to D_s\pi$	
$B_d \to K^{*0}\mu^+\mu^-$ $B_s \to \mu^+\mu^-$		$B_d \to K^* \gamma$ $B_s \to \Phi \gamma$



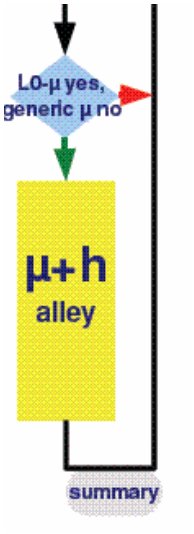
Rare decays

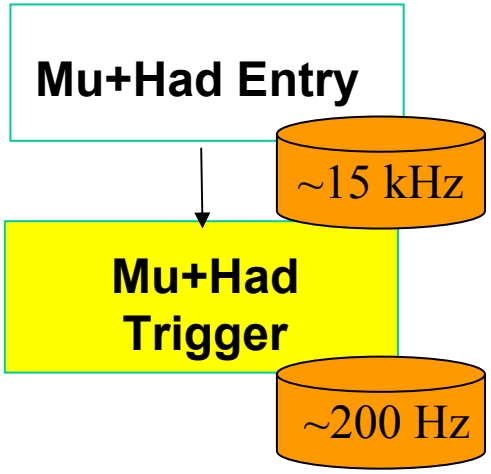
The Inclusive streams

➢ **Inclusive streams:**

- **Single Muon:**
  - Request a displaced high Pt muon:
    - a enhanced b sample: B→ μX
    - a enhanced b-tagging sample
  - Sample triggered independent of the signal → unbiased in the other b
  - Data mining: search for new b decays not considered initially in the trigger
- **Dimuon:**
  - Select a dimuon with no lifetime bias!
  - Use narrow mass to study tracking and alignment, i.e B field effects
  - Use prompt J/Ψ to study error in proper time resolution
- **D*:**
  - Clear signal: $D^{*+} \rightarrow D^0(K^-\pi^+)\pi^+$
  - To calibrate Particle Identification (PID)

Hadron + Alley: strategy and preliminary performance



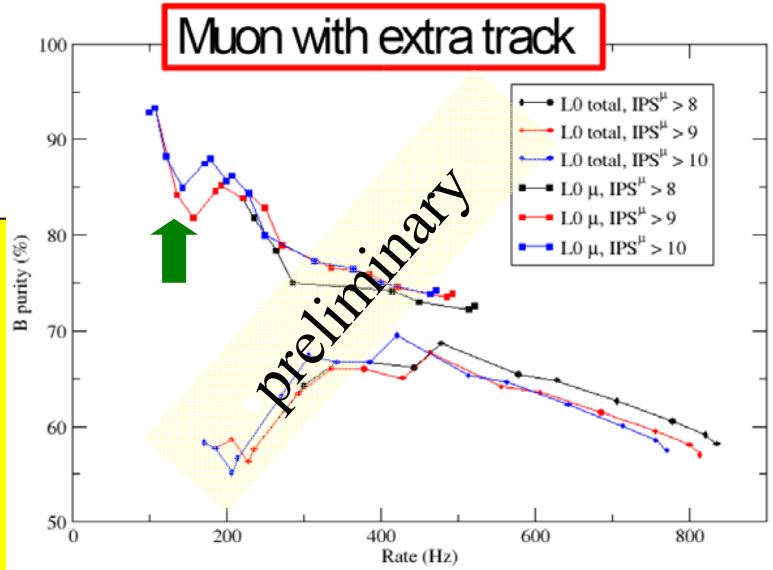


Goal:

very high b content sample

Strategy:

- Select muons and associate a hadron track to them
- Compute IP, Pt of the extra hadron track



Mu+Had Trigger:

Velo reconstruction

Tracks within Distance Of closest Approach, DOCA

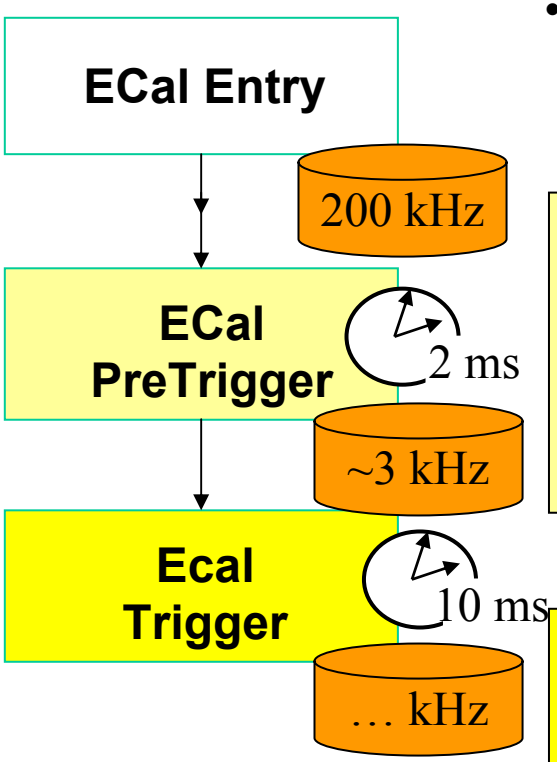
Tracks with IP

Measure Pt using Trigger Tracker: $\sigma_p/p \sim 20\text{-}30\%$

Measure Pt using Tracker Stations: $\sigma_p/p \sim 1\%$

Preliminary: 100 Hz sample with ~90% b purity

ECal Alley: strategy and preliminary performance



Strategy:

- Check that L0 Ecal is an electron or photon
- Require hadron tracks with IP and Pt
  - Redo Hadron line with relax cuts

Ecal PreTrigger:

Velo reconstruction

Tracks IP>150μ

Pt using TT

Ecal PreTrigger:

Pt> 1.3 GeV

Et> 3Gev

B→K*γ efficiency ~70%

Ecal Trigger:

Velo reconstruction

|IP|>100 μm

Pt using T stations: