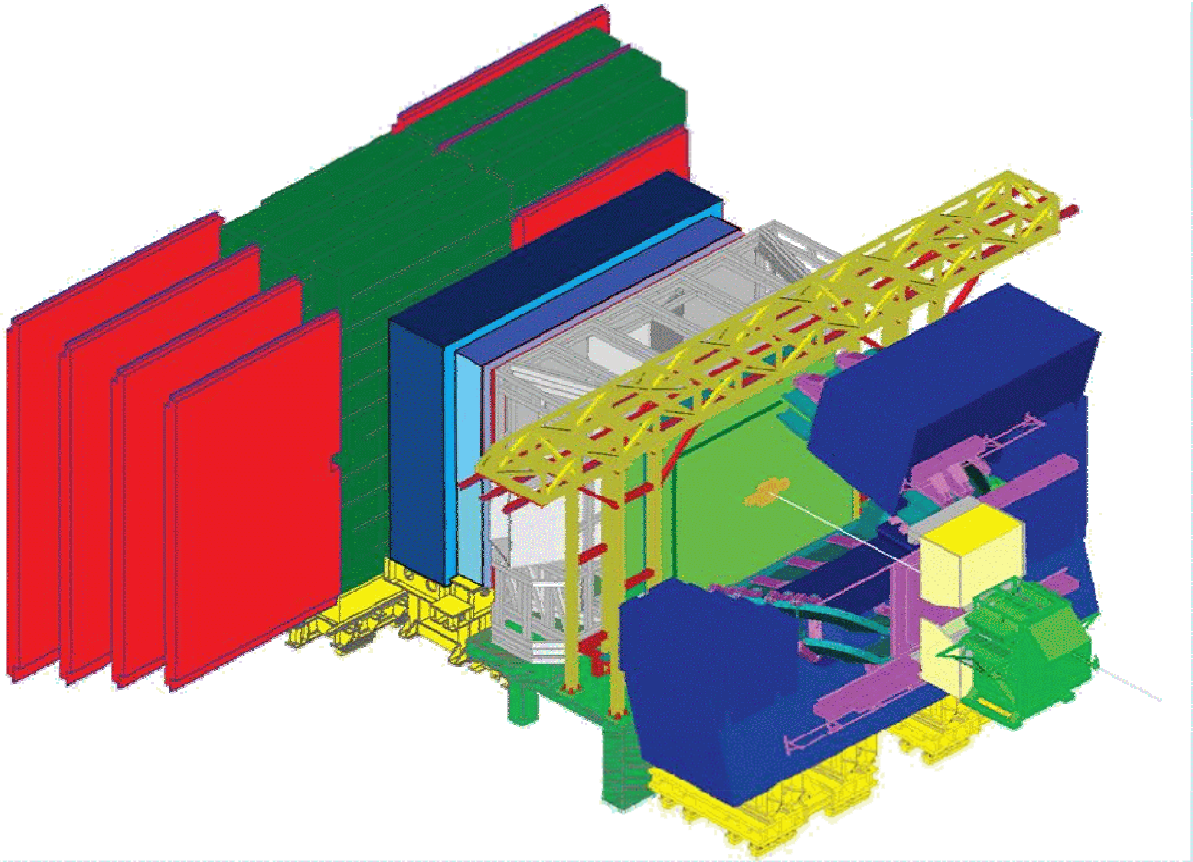
Vertex Reconstruction and Tracking in the Trigger in LHCb



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Outline

- *First*
  - Thanks to H. Dijkstra + trigger team
- Aim to give overview only!
- Detector (key elements)
- Trigger Strategy
- Trigger Instantiation
- Performance
- Future Developments
  - Exciting opportunities (see M. Artuso's talk)

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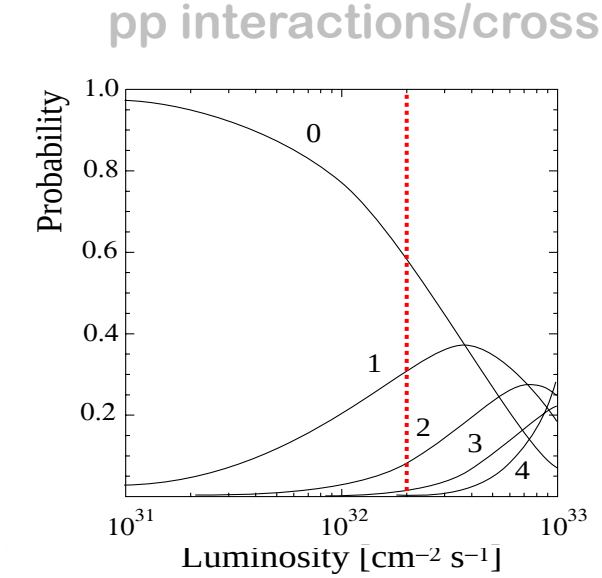
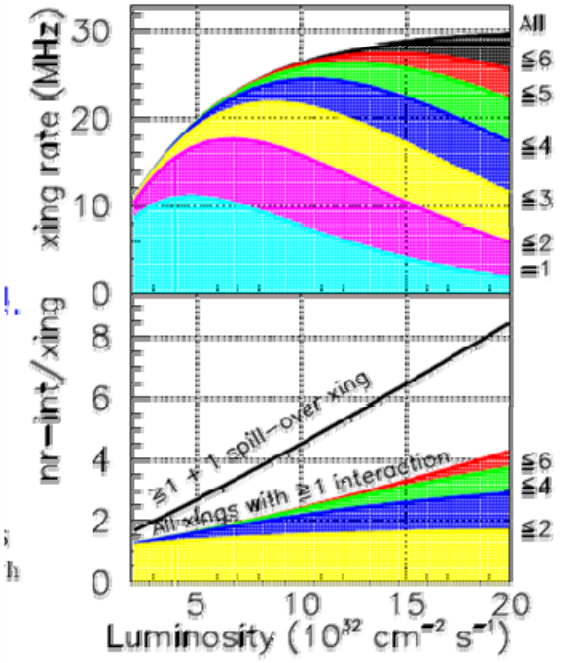
LHC*b* at LHC

- **Luminosity:** $2 \cdot 10^{32}$ cm^{-2} s^{-1}
  - 10 to 50 times lower than ATLAS, CMS
- **LHC*b* rates:**
  (for visible events ≡ at least 2 tracks in acceptance)
  - Total rate (minimum bias): 10 MHz
  - bb: ~100kHz
    - Whole decay of one B in acceptance: 15kHz
  - cc: ~600kHz
  - "Spillover" linear with luminosity
  - O(10^{12}) b's / Year





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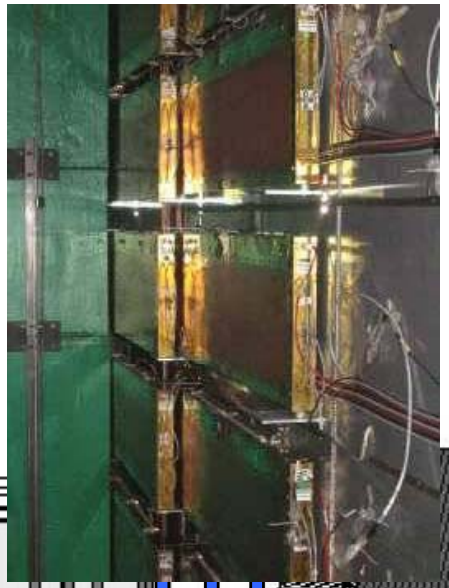
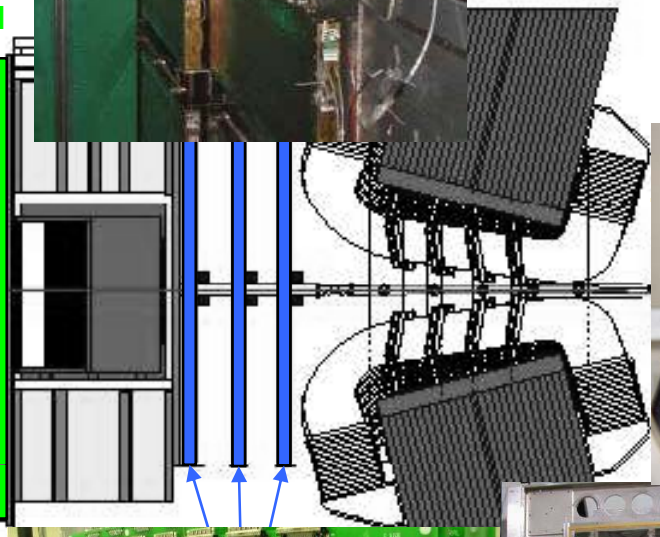
Detector

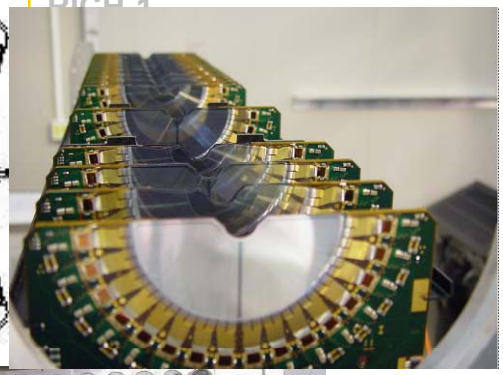


Approx 15m^2 Si

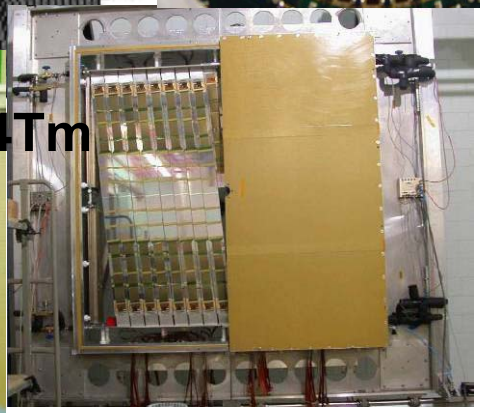
Trigger Tracker

M1





$\int B \sim 4Tm$



3M wire MWPC@2mm

Muon Stations

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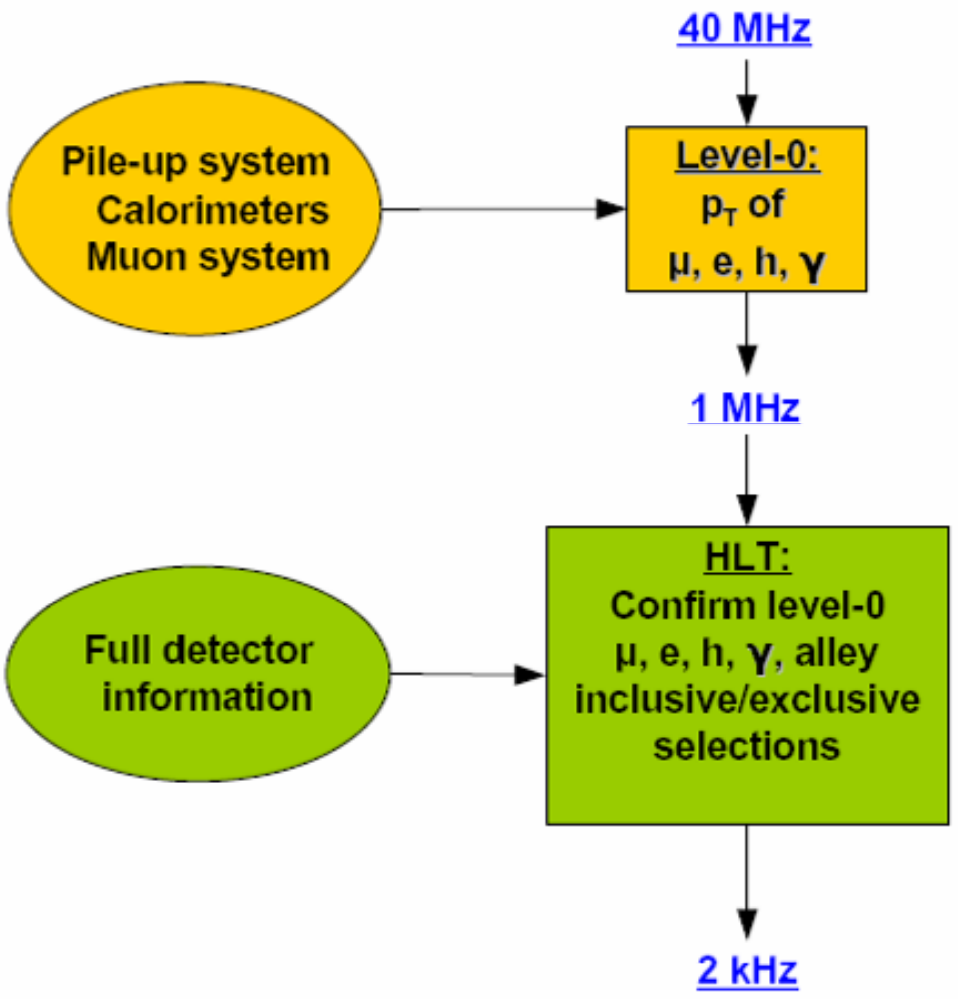
Trigger Strategy



Custom electronics

Pipeline latency of 4 μs. Reject empty or busy events.

Filter "Farm"

Tracking vertexing Event size ~ 30kb

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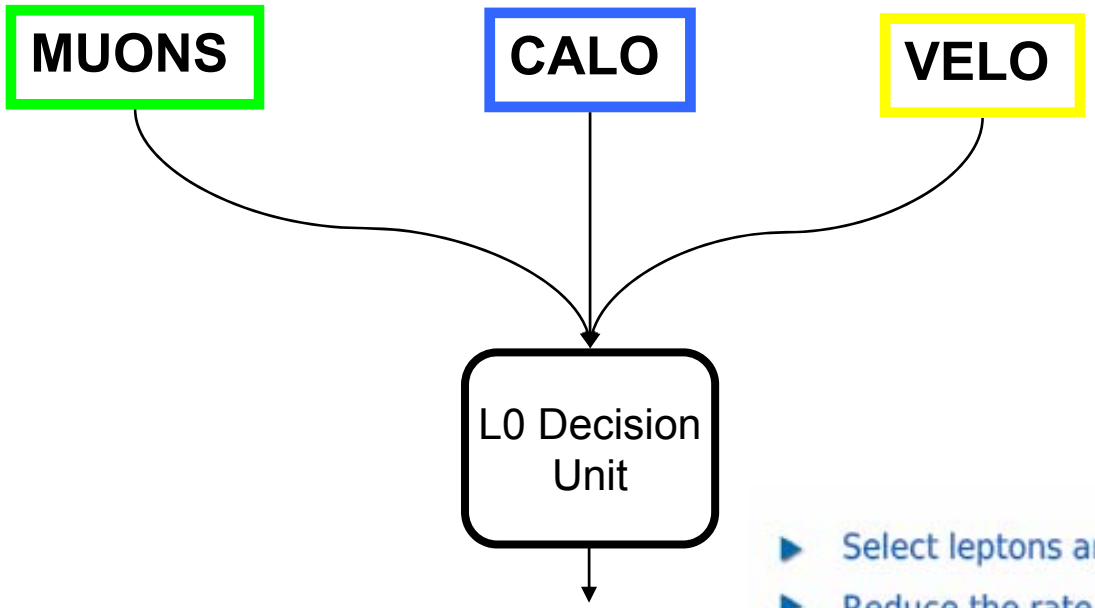
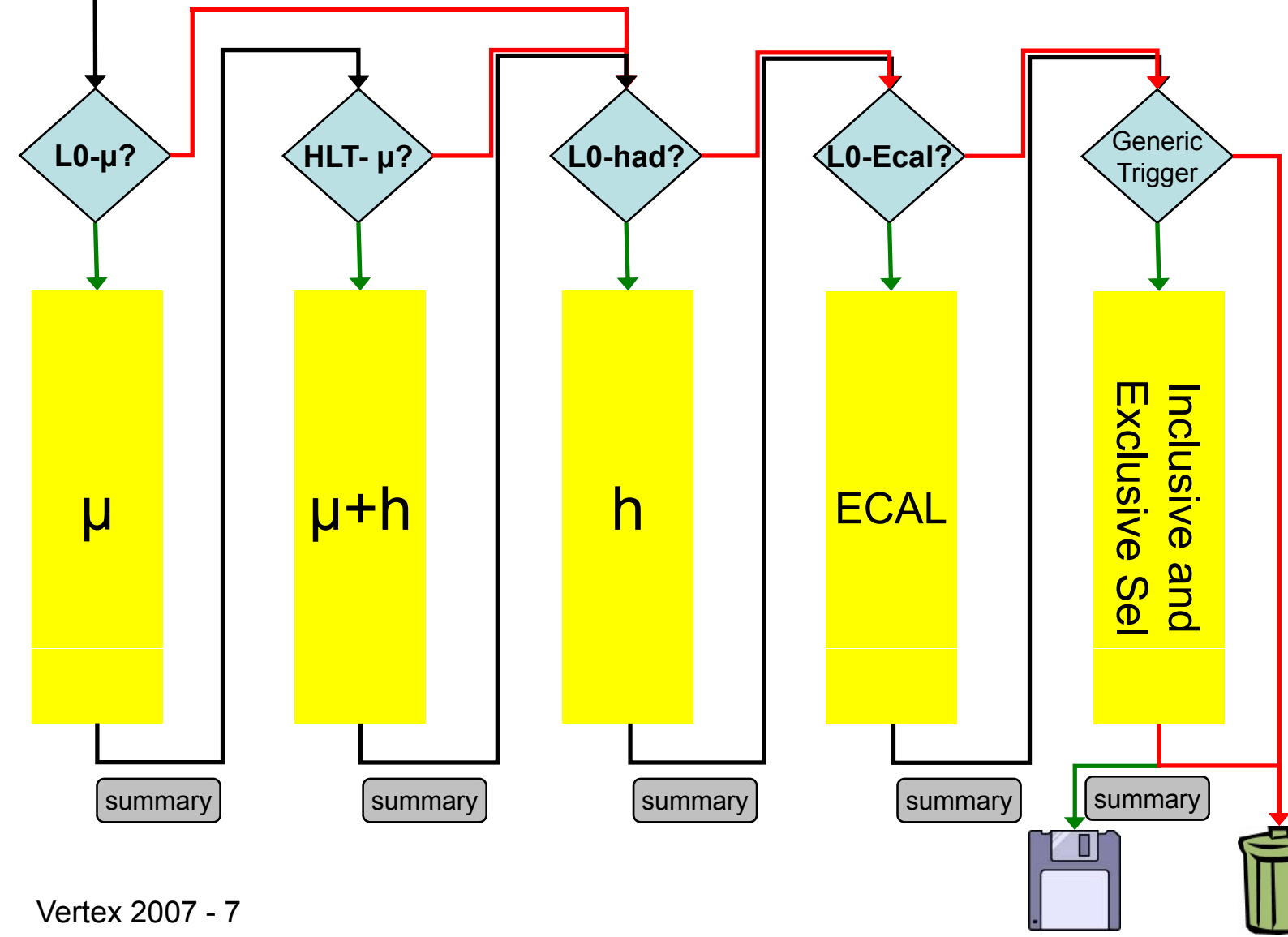
L0 Strategy



- Select leptons and hadrons with high E_T
- Reduce the rate from 40 MHz to 1MHz
- Process all bunches crossing

- 246 boards + spares, 13 types.
- 2 261 optical links at 1.6 Gbps
- Processing time ≤ 1.2 μs

HLT "Alleys"



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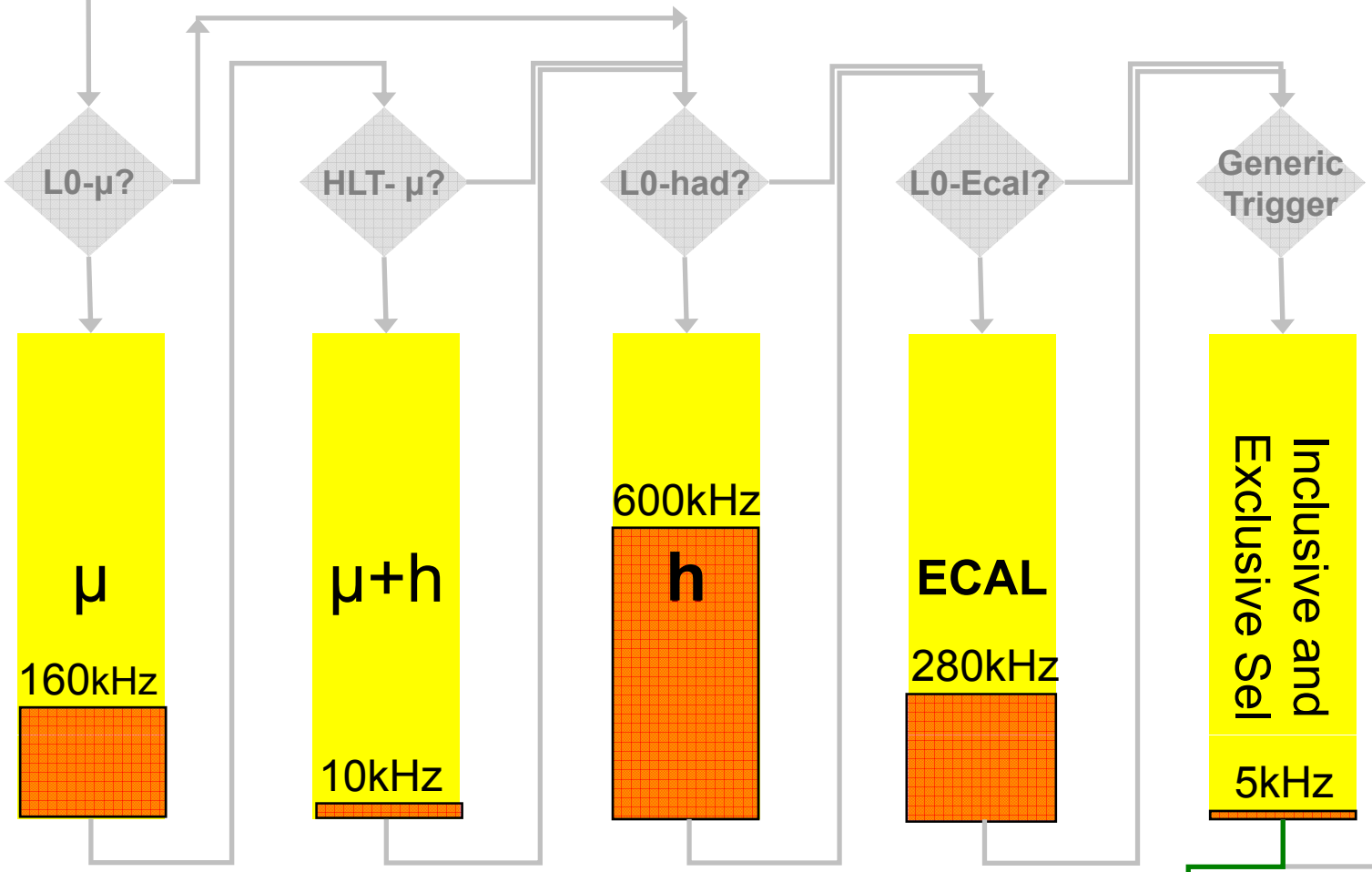
HLT "Alleys"



Output @~2kHz

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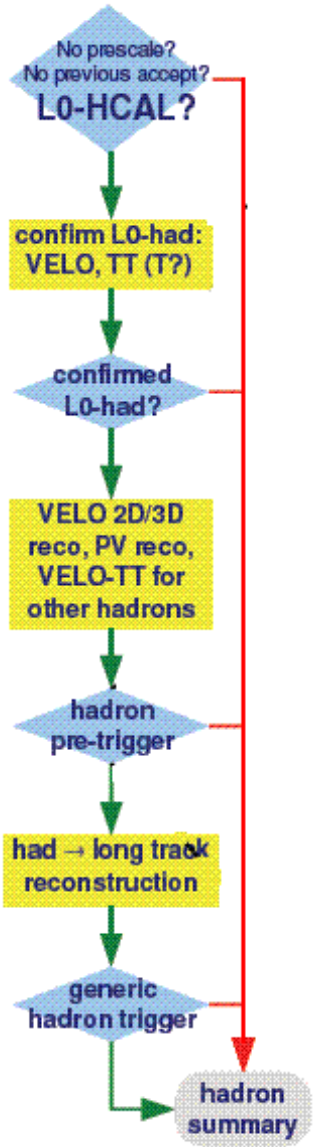
HLT Alleys

Example: Hadron alley

Level-0 confirmation

Pre-trigger (fast rejection)

Reconstruction And Decision



- Each alley consists of 3 major steps
  - Level-0 trigger confirmation
  - Fast rejection using reconstructed e.g.
    - VELO tracks, matching L0 objects
    - Primary Vertex
  - Alley-dependent trigger algorithm e.g.
    - Long tracking (all tracking detectors)
- Keep reconstruction as close to offline as possible

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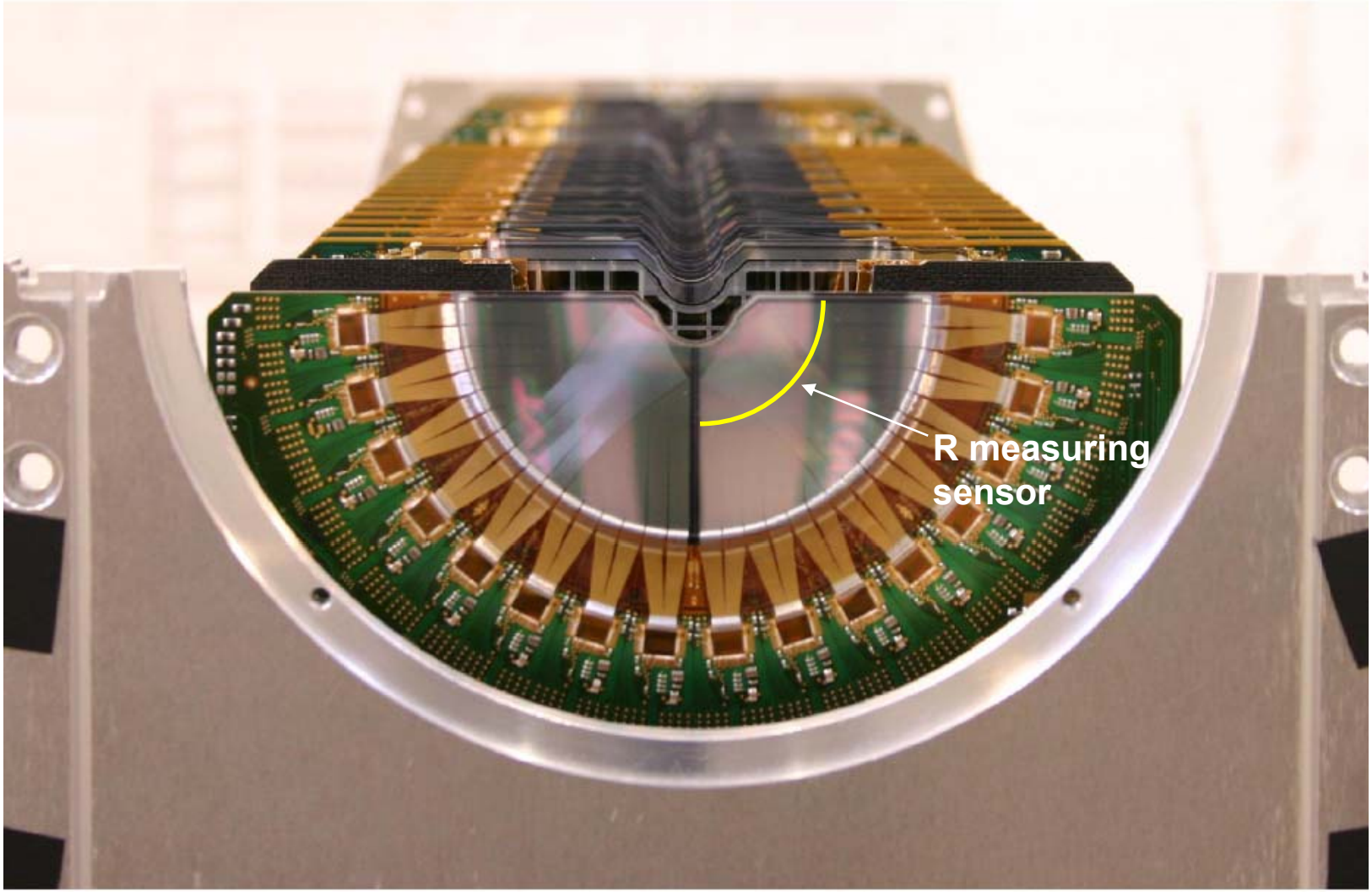
Trigger Instantiation

- L0 – Pile UP VETO
- L0 – Muon
- DAQ
- HLT – Tracking and Vertexing

L0 Pile Up



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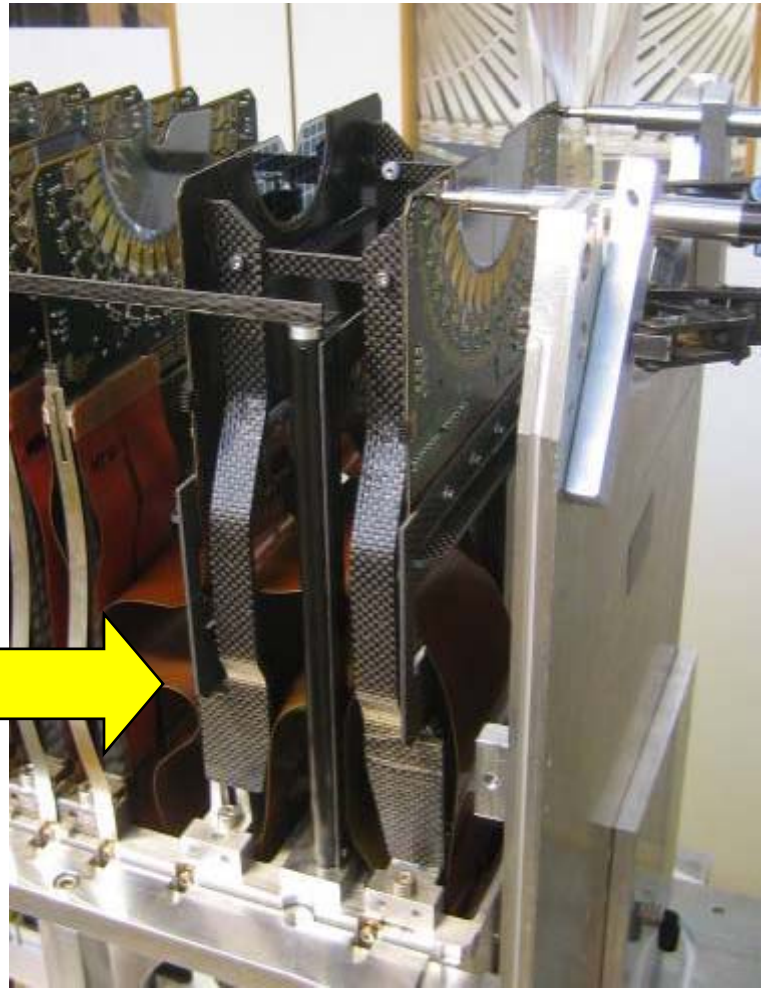
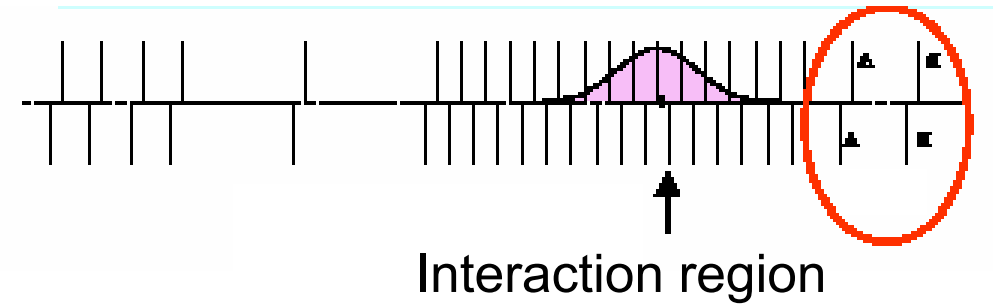
L0 pileup

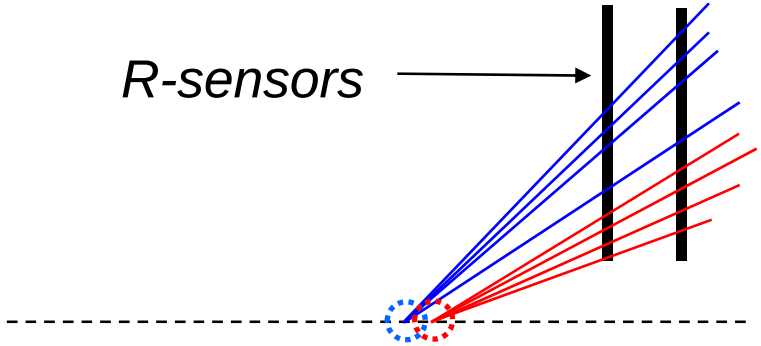


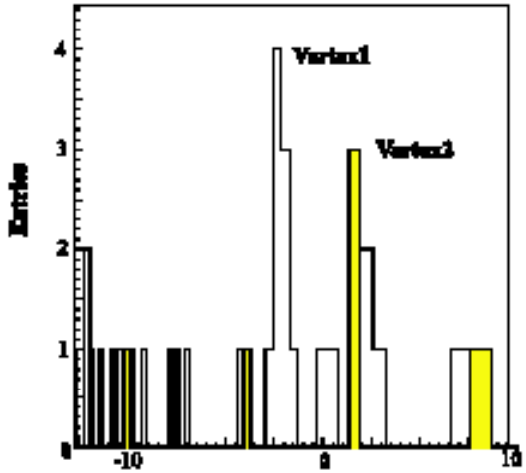
L0 Pile Up

- 2 Si Planes
- Identify multi-PV events
- Special processor used
  - calculate z of vertices
  - Histogram of z
  - Remove hits contribution to that peak
  - find the second highest peak
  - 2-interactions crossings identified with efficiency ~60% and purity ~95%

Running at higher luminosity probably learn to live with multiple PVs!? More in upgrade…

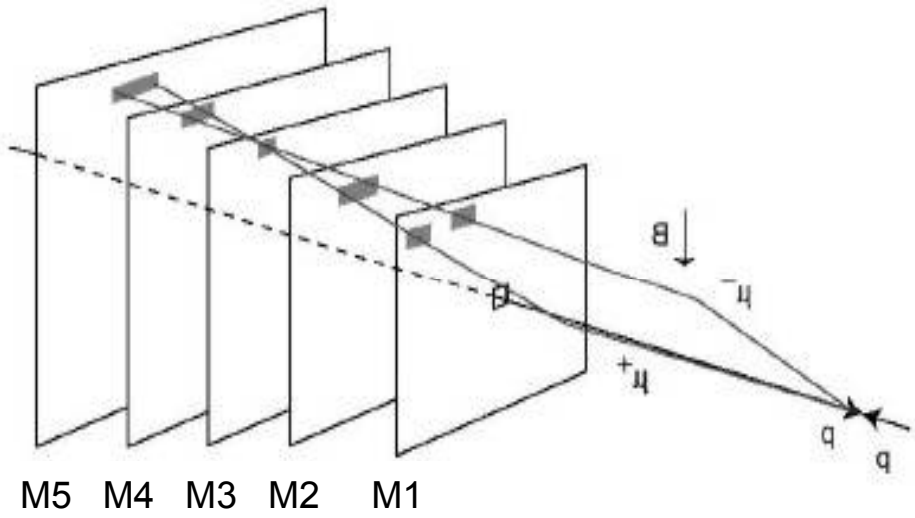






L0 Muon Trigger

- Search for straight lines in M2-M5
- Find matching hits in M1
  - Momentum resolution: ~20% for b-decays
- Information sent to L0DU:
  - 2 highest p_T candidates (per quadrant)
- Performance:
  - $\varepsilon_{B\to J/\Psi(\mu\mu)X}$ = ~ 88 %
  - Latency: ~ 1 μs
- Special Processor



L0 Decision Unit

Calorimeter

- total E_T in HCAL
- highest- E_T candidates: h, e, γ, 2 π^0's

- Muon system

- Pile-up system
- total multiplicity
- # tracks in second peak

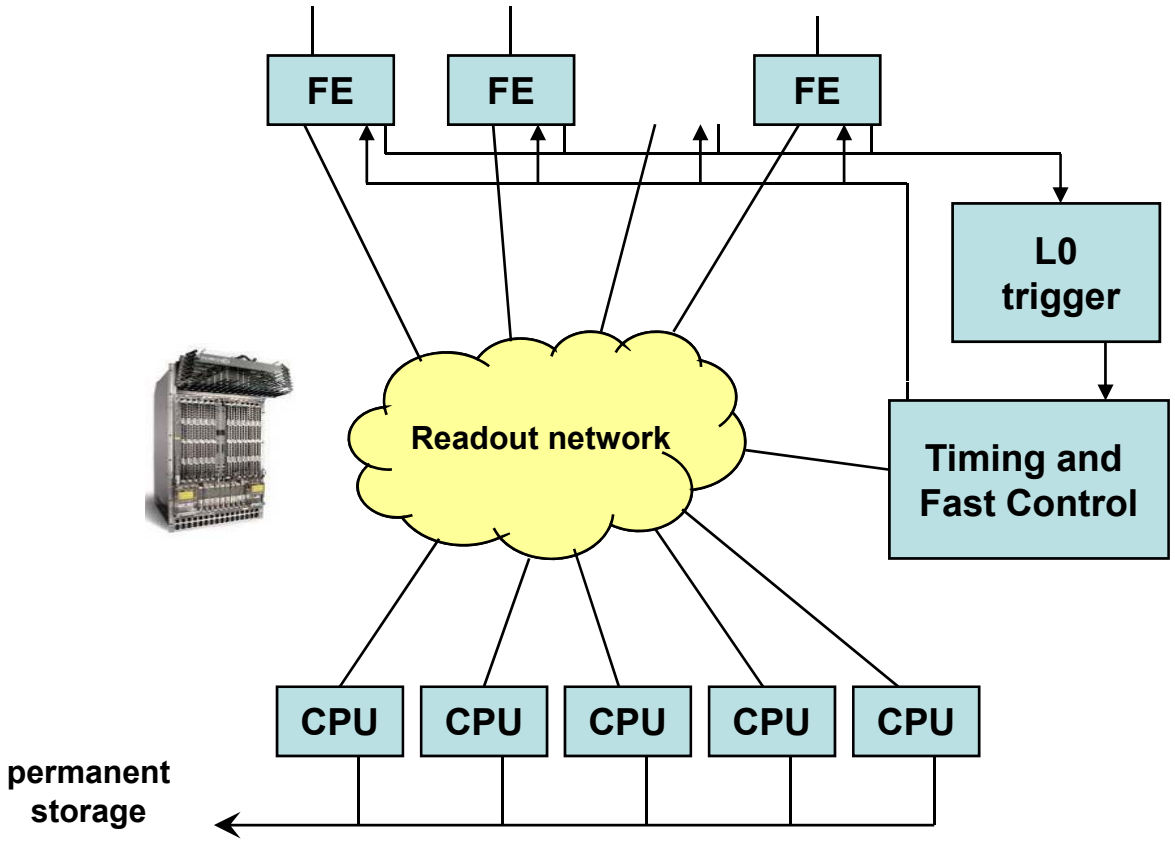
L0 Decision unit

- cuts on global event variables
- thresholds on the E_T candidates

1 MHz

L0DU report

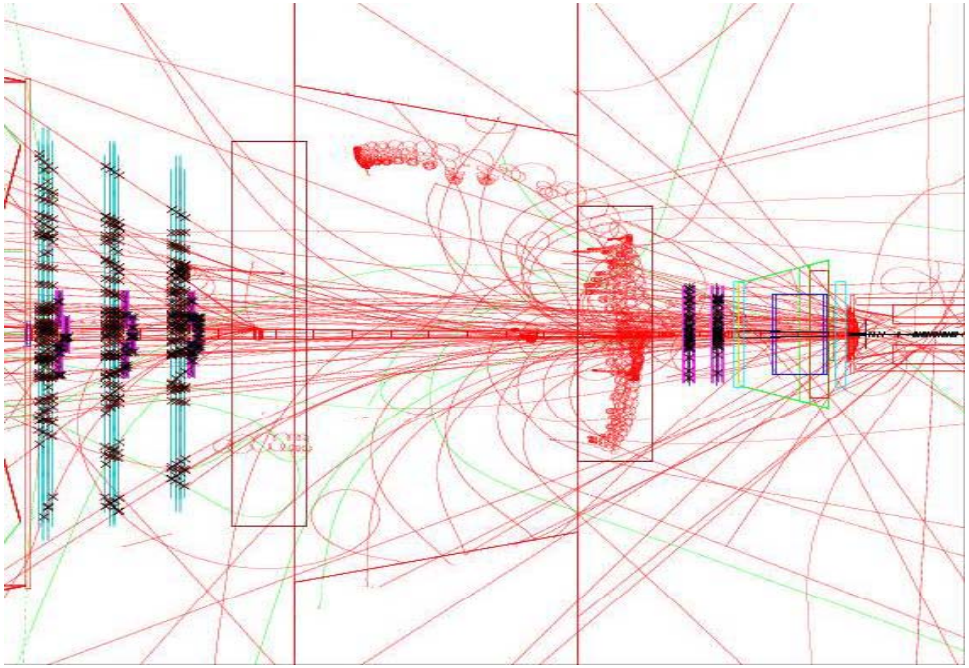
LHCb Trigger-DAQ



See Nico Neufelds's talk….!

HLT

- L0 Confirmation
- Reconstruct Event – full information
  - Offline/online software differences small



HLT – a closer look

- Muons and Hadron Alleys

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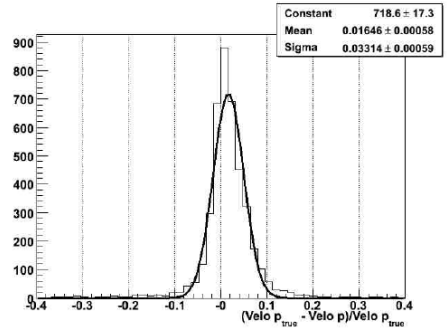
HLT Muon Alley

- Summary
  - Initial L0- μ (20%-30% dp/p) @200kHz
  - Confirmation with tracker
  - Add tracking stations (3% dp/p)
  - If good muon look for others muons
  - Make J/ψ (~80kHz)
  - Make VELO tracks and match (1% dp/p)
    - 2D Matching
  - Cut on muon IP (10kHz)

3D Velo momentum resol



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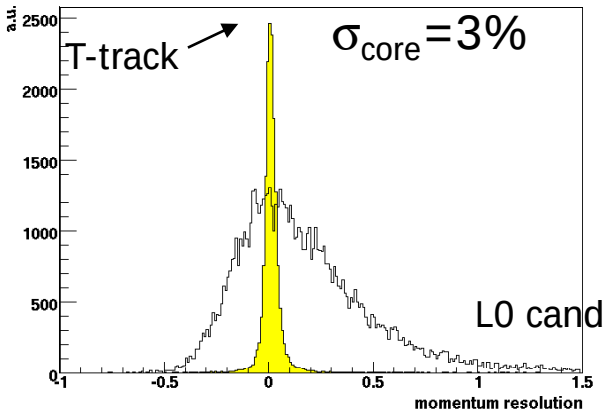
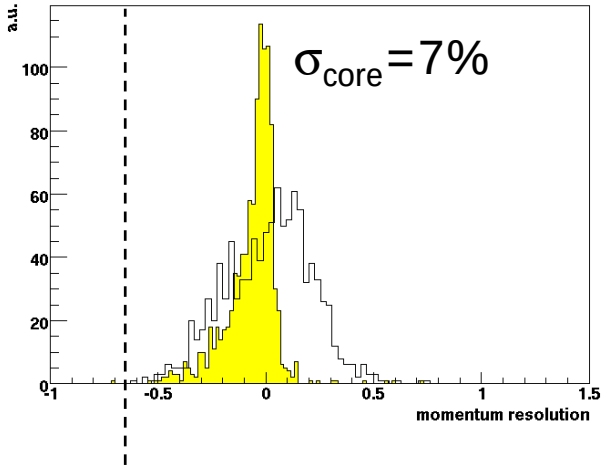
HLT L0 Confirmation/resolution

- Calculate momentum with fast pt-kick (parameterized field parameters)
- Resolution determined with minimum bias events

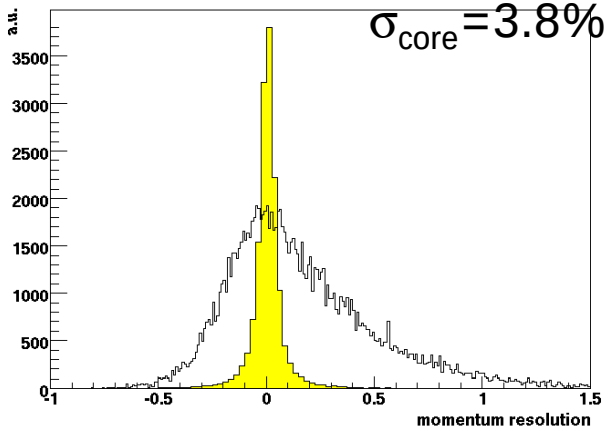
Muon momentum resolution



Electron momentum resolution

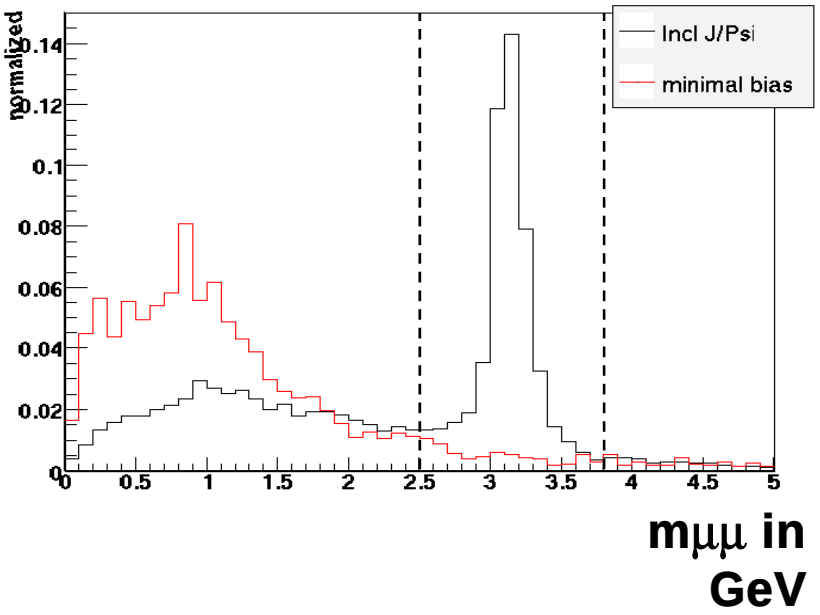


Hadron momentum resolution



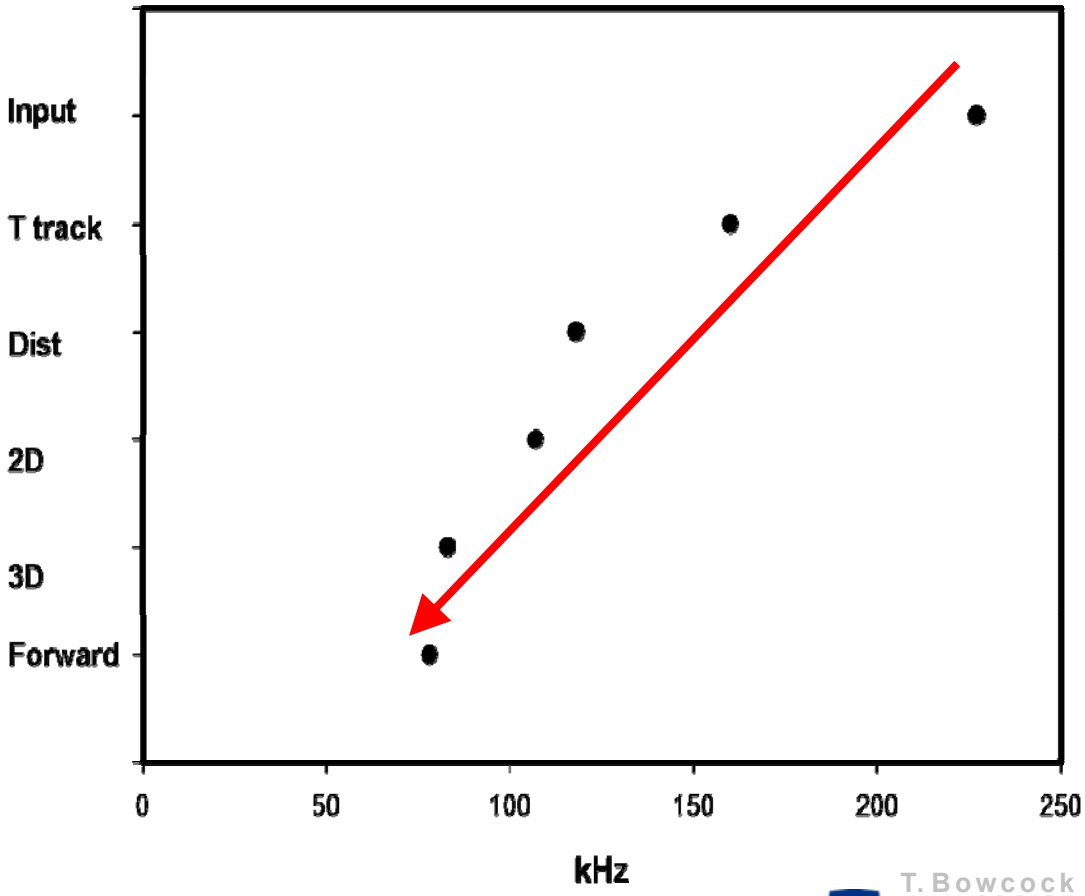
HLT Fast J/ψ

- Within 1ms, we have confirmed muons with σ(p)/p ~3%
- Extrapolate tracks to origin
- Calculate dimuon invariant mass



Muon Alley

	Rate KHz
Input	227
T (track)	160
Dist(T match)	118
2Dmatch VELO	107
3Dmatch VELO	83
HLT forward	78



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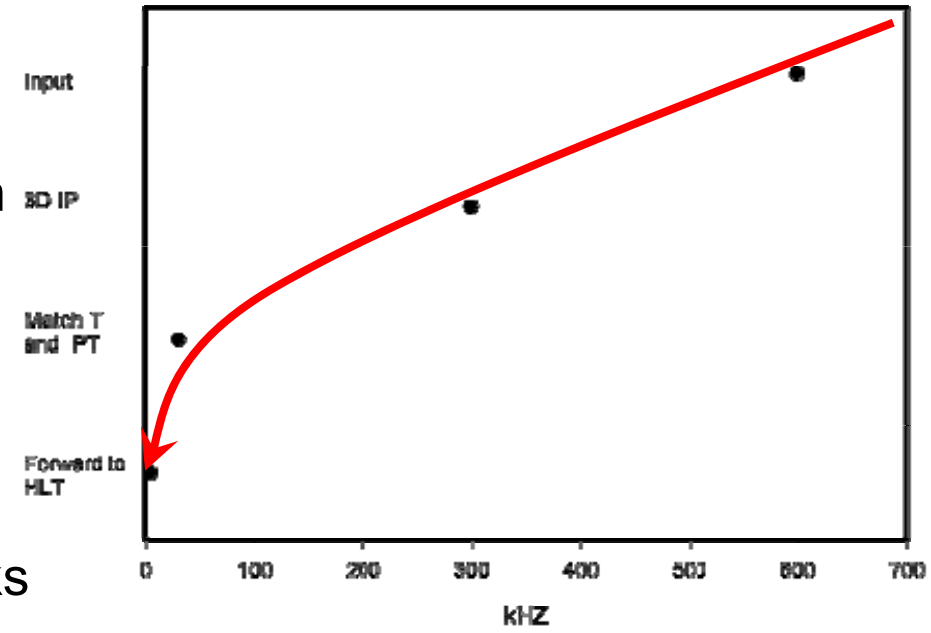
HLT Hadron Alley

- Summary
  - Input ~600kHz
  - VELO 2D (R-Phi geometry)
  - Match to L0-h (~5/event)
  - VELO 3D and confirm Match
  - Cut on IP in 3D as in offline(~300kHz)
  - Match to T and full tracking (dp/p ~1%) and P_T>2.5 GeV (30kHz)
  - Look for primary vertex tracks (5kHz)



Future Developments

- Complete commissioning
- New HLT alleys
  - Refined inclusive and exclusive selections
  - Sophisticated ways of checking trigger performance

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Summary & Comments

- Overview of LHCb trigger
  - Excellent on muon triggers with low (1Gev) P_T requirement. Almost fully efficient
  - Single Hadron trigger with E_T>3.6GeV
  - Strategy involving custom electronics and “standard farm clusters”
- *Even as a B-experiment we do not have a L0 vertex trigger*
  - We need this for the future
  - What happens if luminosity rises by a factor 10 or more
  - New trigger and detector
  - Exciting possibilities….