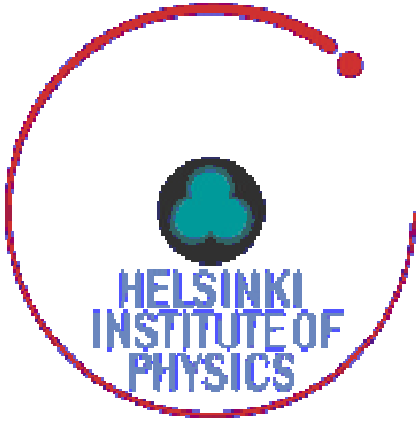
ATLAS T/DAQ system & Exclusive Production Trigger



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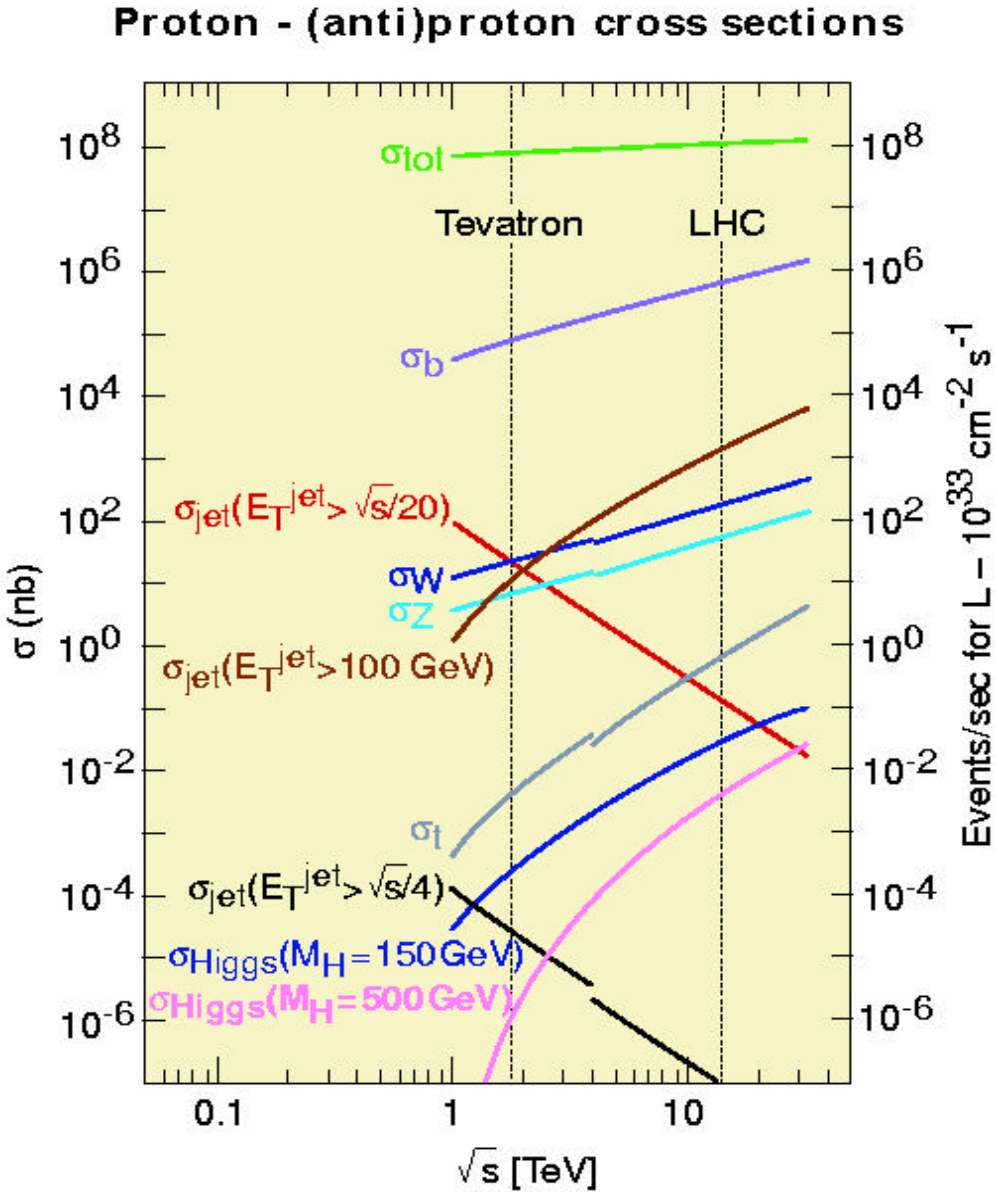
Contents

- LHC cross-sections/rates
- T/DAQ architecture
- LVL1 trigger
  - Latency breakdown
- Trigger studies for exclusive production

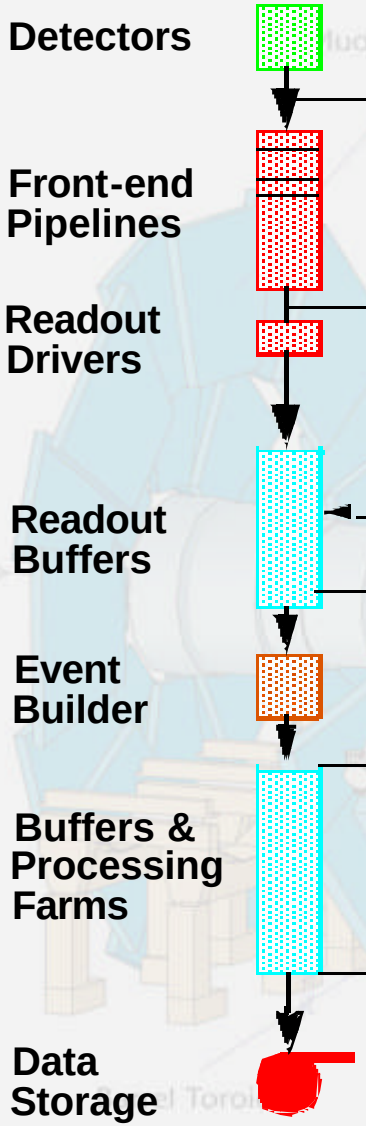
Orsay meeting
September 29th/30th 2003

Cross-sections and rates



- huge range of cross-section values / rates
  - → listed for 10^{34} cm^{-2} s^{-1}
  - → total
    - σ ≈ 100 mb (10^9 Hz)
  - → b production
    - σ ≈ 0.7 mb (7∗10^6 Hz)
  - → W/Z
    - σ ≈ 200/60 nb (2/0.6 kHz)
  - → top
    - σ ≈ 0.8 nb (80 Hz)
  - → Higgs (m_H = 150 GeV)
    - σ ≈ 30 pb (3 Hz)
- With branching ratios included
  - → W → eν 150 Hz
  - → Z → ee 15 Hz
  - → H → γγ 0.003 Hz

The ATLAS Trigger/DAQ System



1 GHz interaction rate / 40 MHz bunch-crossing rate

2ms latency

<75 (100) kHz

O(10) ms latency

O(1) kHz output rate

HLT

~ seconds latency

O(100) Hz output rate

LVL1

- → Hardware based (FPGA and ASIC)
- → Coarse calorimeter granularity
- → Trigger muon detectors

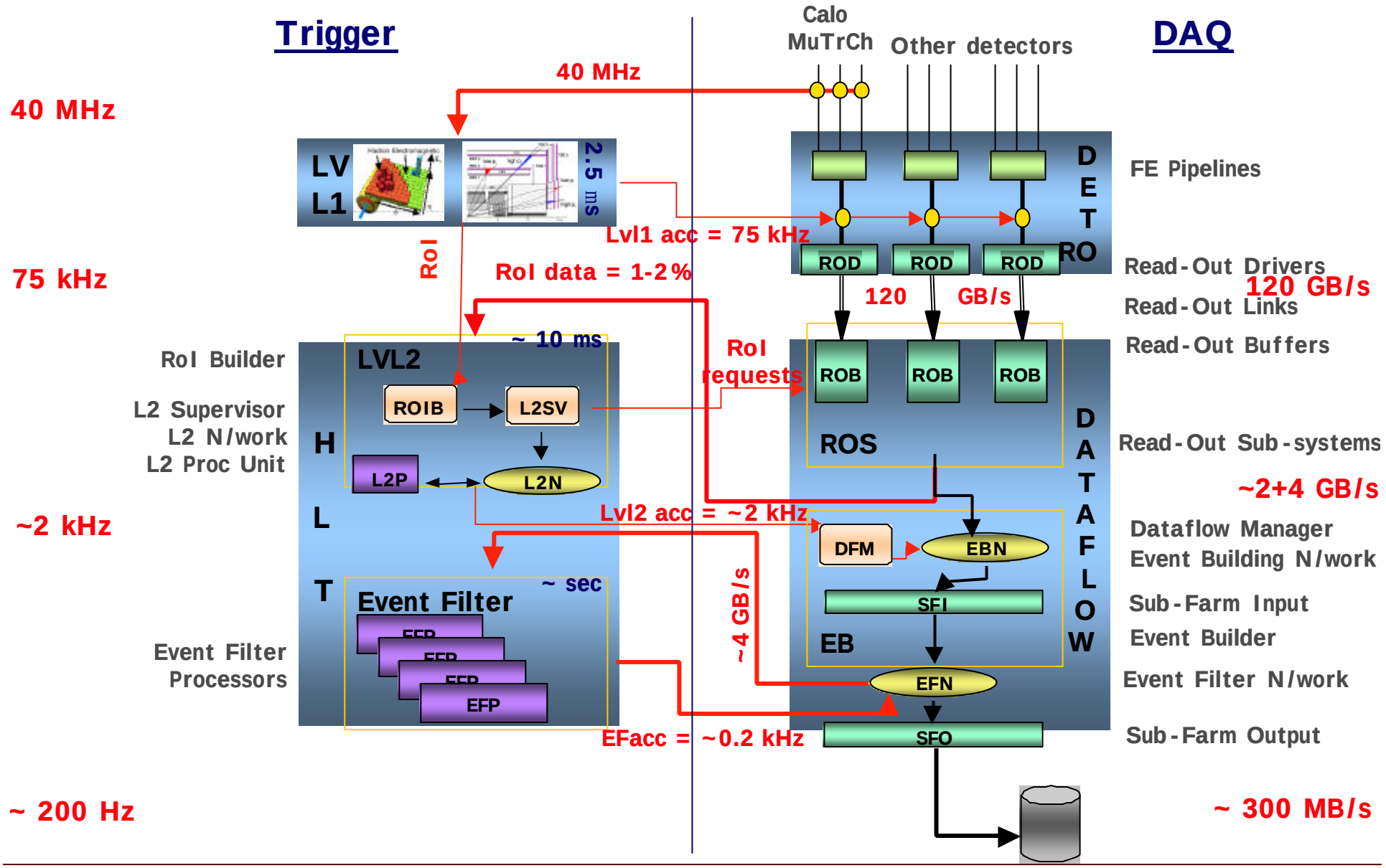
LVL2

- → Region-of-Interest (*RoI*) concept
- → Specialized algorithms
- → Fast selection with early rejection

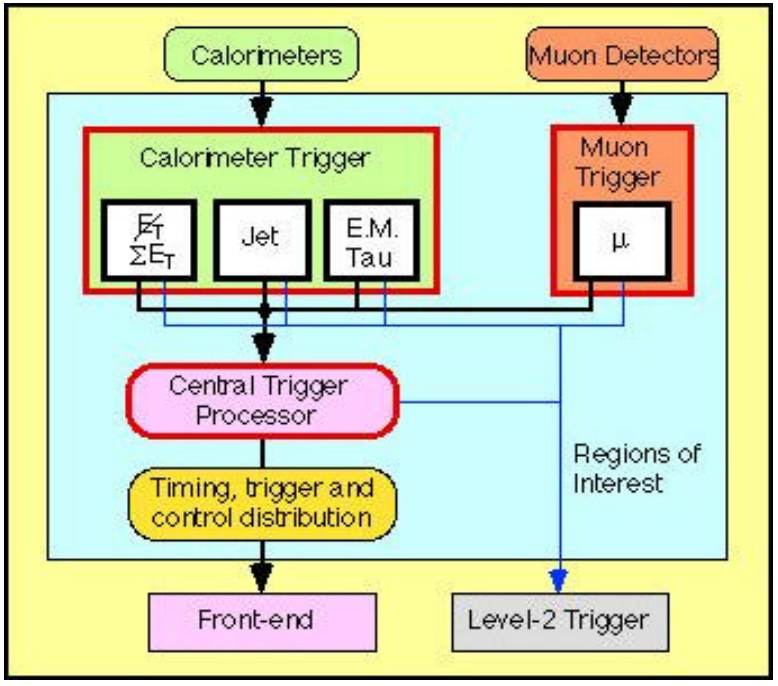
EF

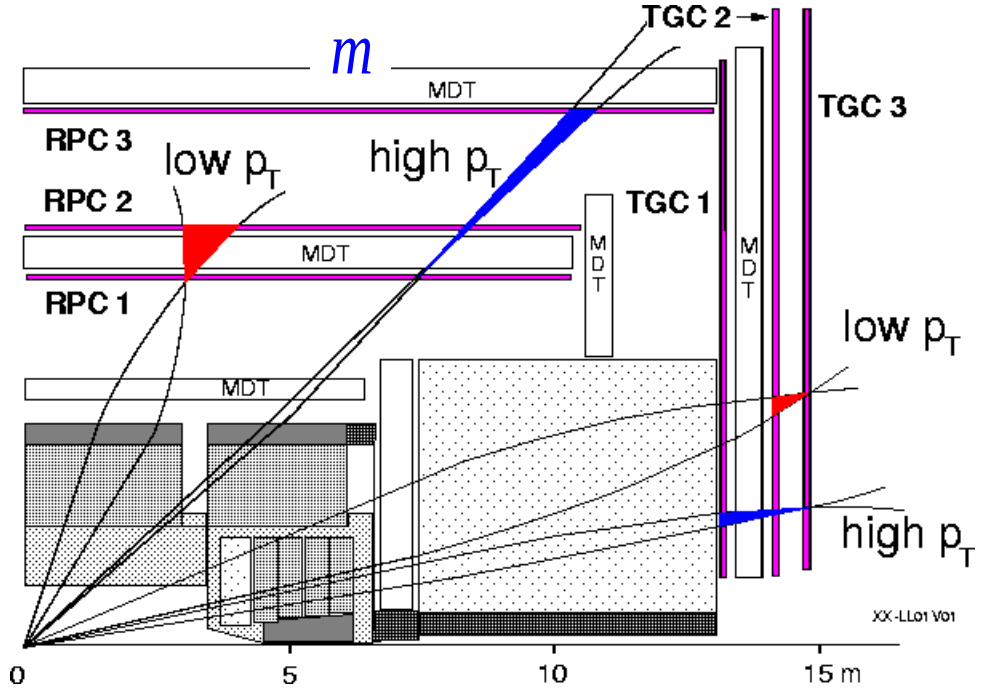
- → Full event available
- → Offline derived algorithms
- → Seeding by LVL2
- → Best calibration / alignment
- → Latency less demanding

T/DAQ Architecture



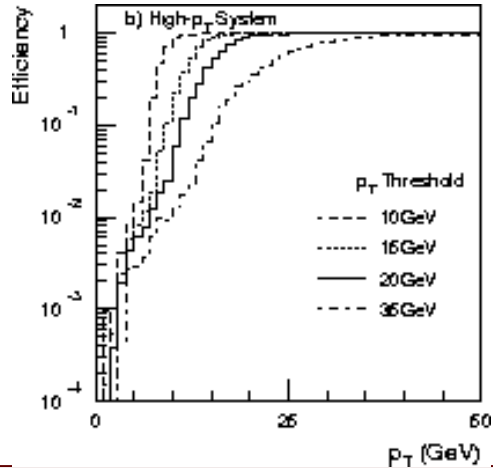
The LVL1 trigger system





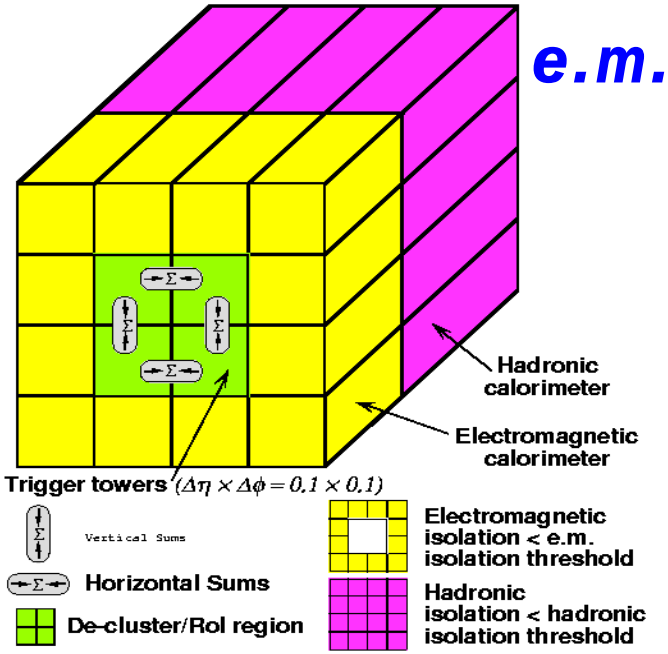
- Identifies **high p_T** objects
  - → muons
  - → e.m. clusters, tau's, jets
  - → missing and summed E_T

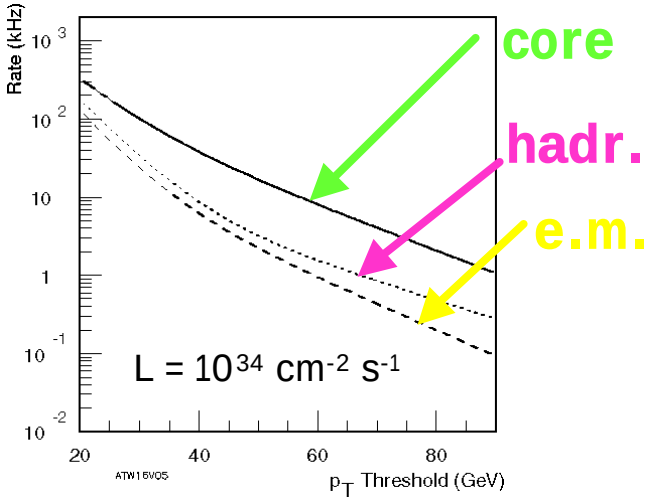
- muon: hits in fast trigger chambers ($|\eta|<2.4$)
  - → RPC (barrel)
  - → TGC (endcap)
    - Together 800k channels



LVL1 trigger system (cont'd)

- Calorimeter trigger
  - → analog cell sums
  - → towers $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
    - 7200 channels
- e.m. clusters ($|\eta|<2.5$)
- tau's ($|\eta|<2.5$)
- jets ($|\eta|<3.2$)
  - → Extension to forward jets under study
    - Flexibility due to FPGA usage
- missing E_T ($|\eta|<4.9$)
- summed E_T ($|\eta|<4.9$)
  - → From cells or from jets





Example: ATLAS LVL1 trigger menu

Selection for $L = 2*10^{33}\ cm^{-2}s^{-1}$	Rate [kHz]
MU20	0.8
2MU6	0.2
EM25I	12.0
2EM15I	4.0
J200	0.2
3J90	0.2
4J65	0.2
J60 + xE60	0.4
TAU25 + xE30	2.0
MU10 + EM15I	0.1
Others (pre-scales, calibration, …)	5.0
Total	~ 25

Jet triggers

LVL1 latency breakdown

- LVL1 latency breakdown
  - Maximum of 2.5 μs
    - ➔ given by depth of front-end pipeline memories
  - → Time from detector to CTP input: 1.4 μs
    - ➔ Calorimeter and muon trigger
  - → CTP decision time: 0.1 μs
  - → Distribution of decision to FE: 0.575 μs
    - ➔ Via TTC system
  - → Contingency: 0.425 μs
    (cable routing, …)
- A leading proton trigger has to arrive within 1.4 μs at the LVL1 CTP
  - → Note that using the contingency (if not needed by main detector) would imply larger dead time!

LVL1 latency breakdown

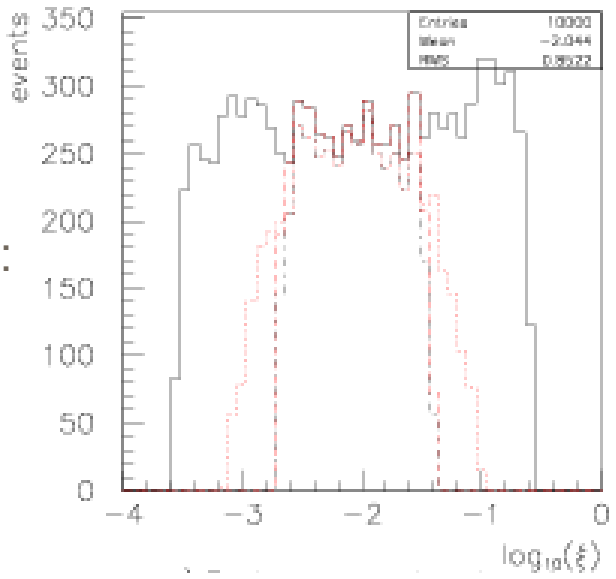
- Leading p trigger has to arrive within 1.4 μs at the LVL1 CTP
  - → Distance from a Roman Pot to the trigger racks in USA15
    Add at least 28 m to the distance of the Pot to the IP
    - Note that this is a simple 2-dimensional estimate
- Latency breakdown for z = 150 (215 / 240) m
  - Proton TOF: 0.5 (0.72 / 0.8) μs
  - Trigger signal: 0.1 μs
  - Signal to CTP: 0.59 (0.81 / 0.89) μs
    - → (assuming 3.3 ns/m – optimistic !!)
  - Conversion(s): 0.1 μs (?)
  - → Total trigger latency of **1.29 (1.73 / 1.87) ms**
- Time for LVL1 decision to reach Roman Pot detector
  - Decision to Pot: 0.89 (1.22 / 1.34) μs (5 ns/m)
  - Subtract proton TOF: -0.5 (-0.72 / -0.8) μs
  - → Total readout latency of **1.68 (2.33 / 2.41) ms**
    - → Can buffer locally with standard ATLAS front-end electronics (2.5 μs)
- Stations at z > 250 m are definitely excluded from the LVL1 trigger
  - → Stations beyond 150 m might increase dead time

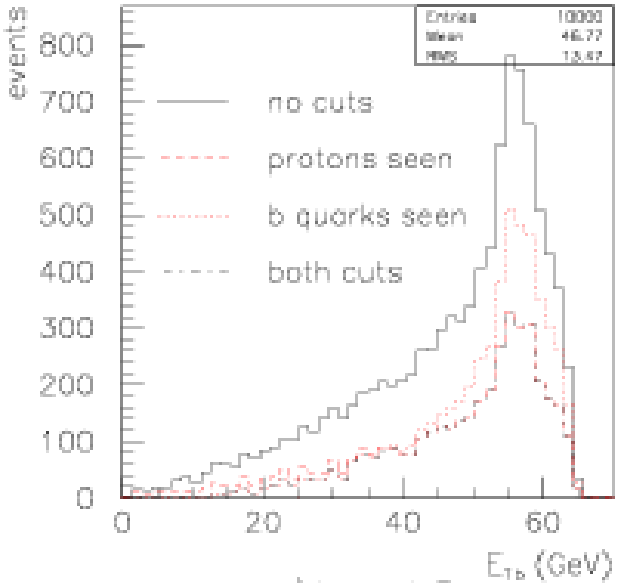
LVL1 trigger for exclusive H

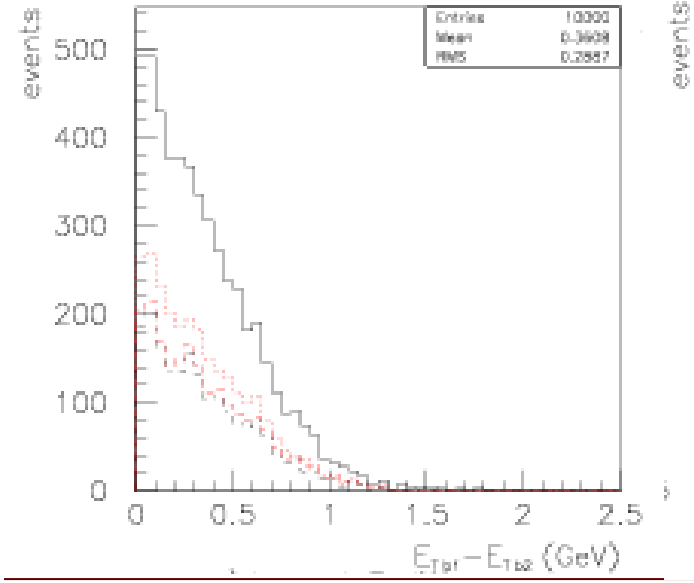
- Master thesis of V. Bergholm
  - Helsinki University of Technology, September 2003
- Question
  - → Trigger at LVL1 on topological criteria
    - Jets from H → bb decay
    - Rapidity gaps
      - → Without using leading proton information
  - → No latency constraints
    - Include leading proton information at HLT
- Approach
  - → Simple generator for kinematics
    - pp → p + H + p, H → bb ($M_H \approx 120$ GeV)
  - → Simplified CMS LVL1 calorimeter trigger simulation
    - Granularity (calo regions)
    - Energy smearing

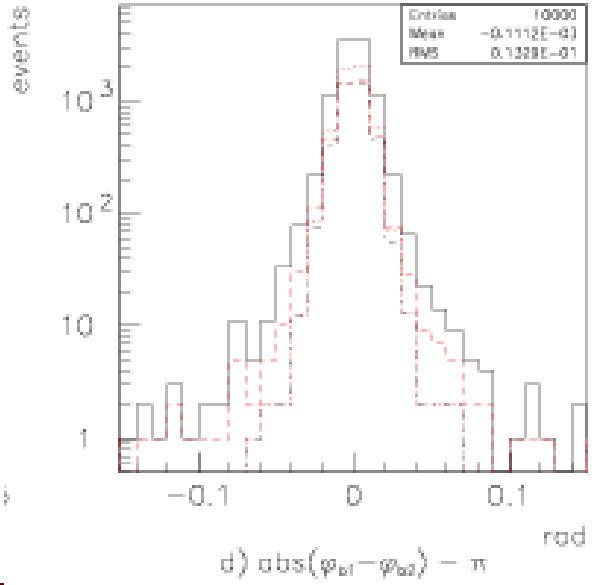
Example: pp → p+H(bb)+p

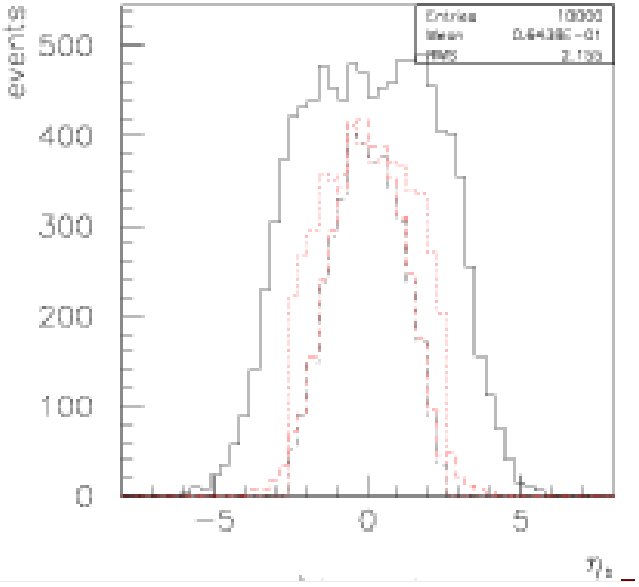
- Kinematical properties of signal process
  - Usefulness cuts:
    - → Protons seen: $\xi > 0.002$
    - → b-quarks seen: $|\eta| < 2.5$



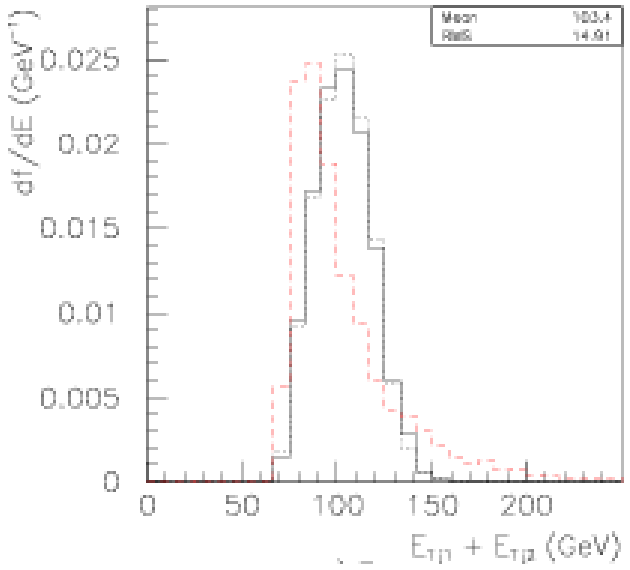


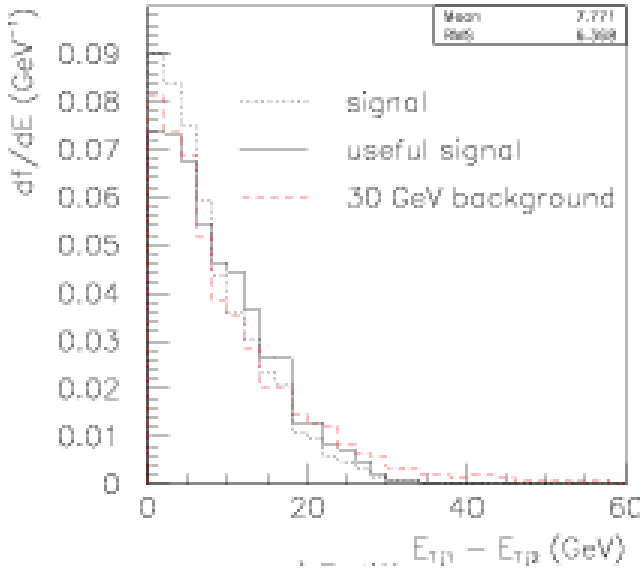


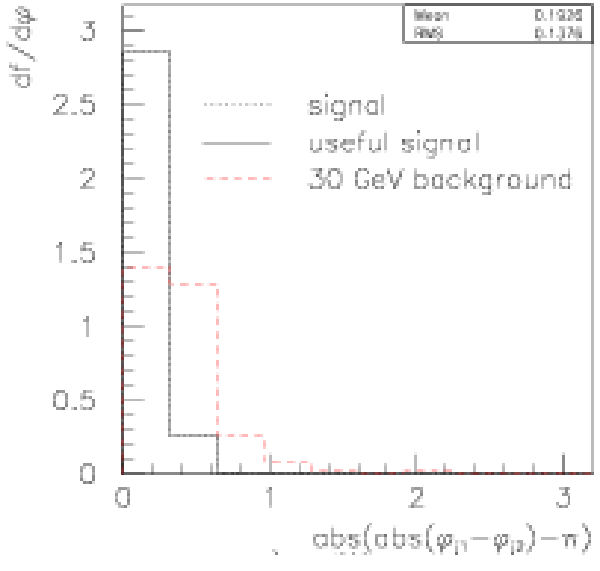




Example: pp → p+H(bb)+p (cont'd)

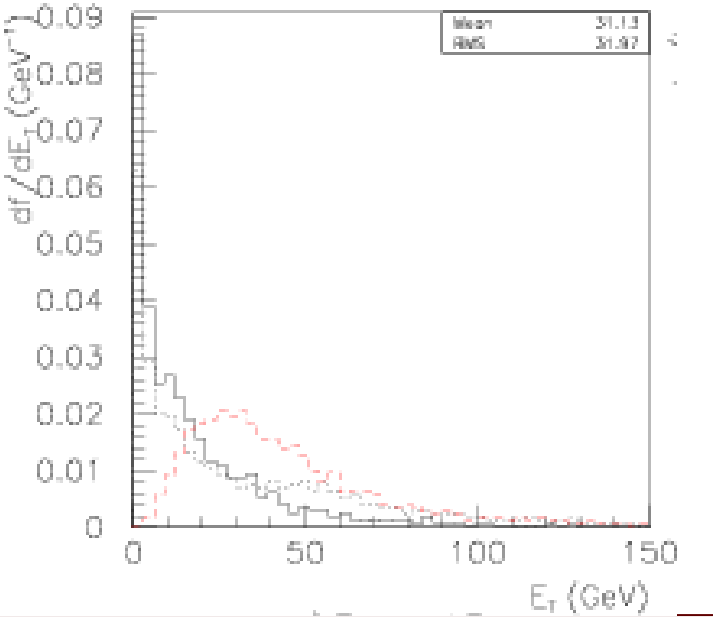






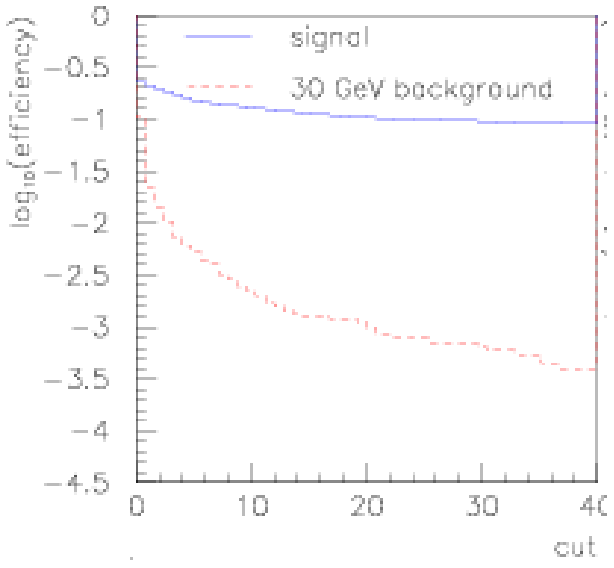
- Comparison of signal and background shapes
  - at low luminosity

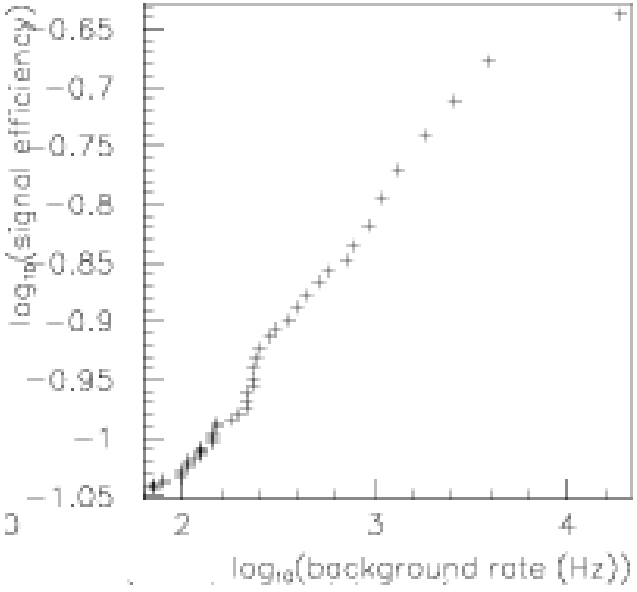
→ Usefulness cut on signal
  - $\xi > 0.002$ and $|\eta| < 2.5$

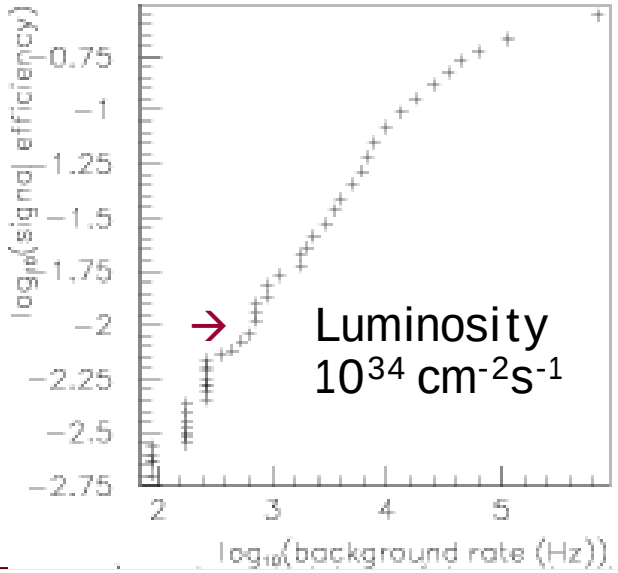


Example: pp → p+H(bb)+p (cont'd)

- Rate vs. efficiency
  - → Luminosity $10^{33}\,cm^{-2}s^{-1}$
- Ingredients for global efficiency
  - Relative to production cross-section pp → p H p
  - → $|\eta|<2.5,\ \xi>0.002$: 37 %
  - → BR(H → bb): 68 %
  - → b-tagging: (0.77^2) 60 %
  - → combined 15 %
  - → + Trigger efficiency



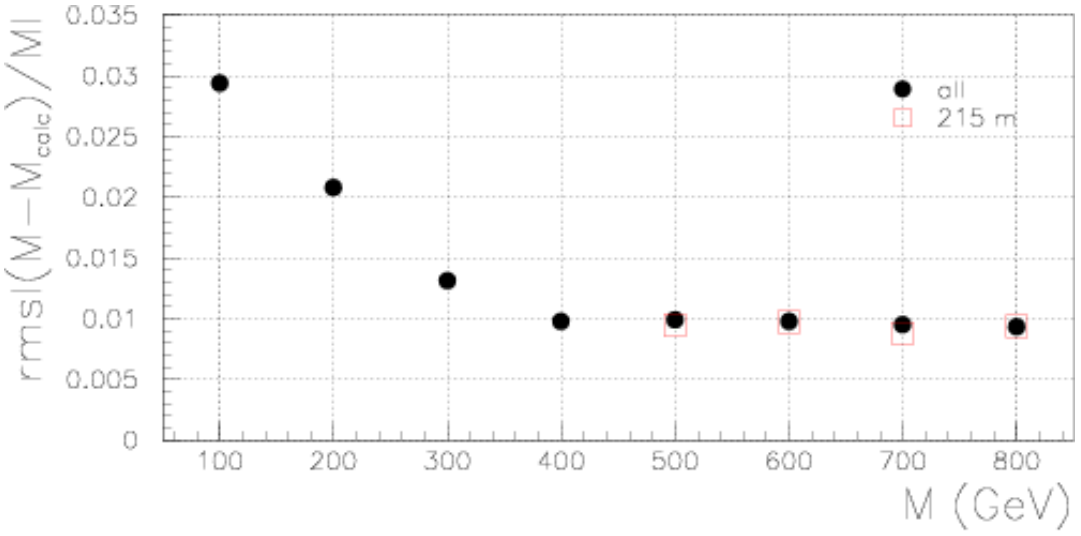


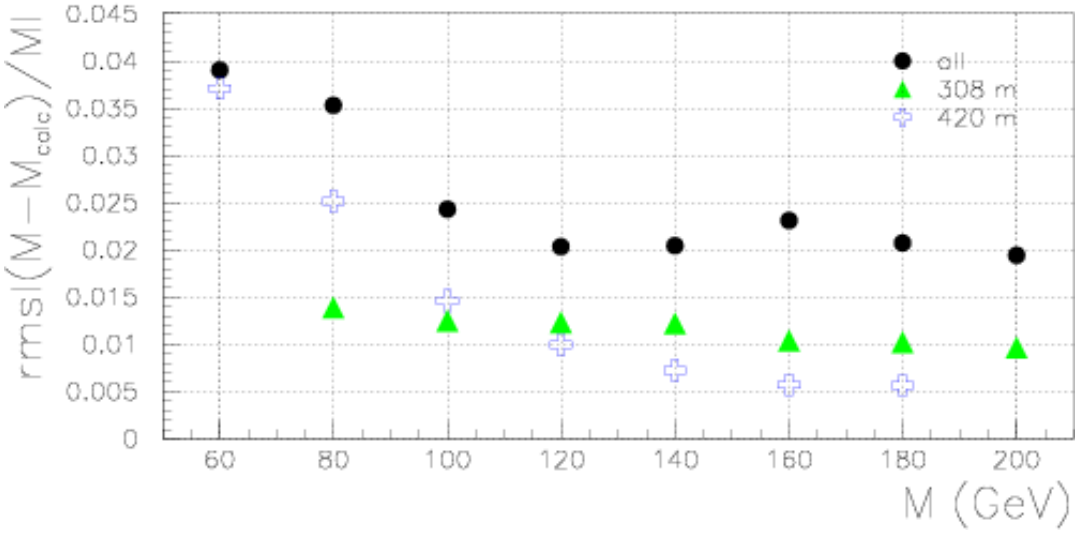


→ Luminosity $10^{34}\,cm^{-2}s^{-1}$

Comment on mass resolution

- Exclusive production, reconstruct M from the two leading protons
  - → Symmetric case $\xi_1 \approx \xi_2$:
    - resolution of ~1% achievable
      - → e.g. '420 m' alone
  - → Asymmetric case $\xi_1 \ll \xi_2$:
    - resolution 'degrades' to 3%
      - → e.g. 'all' –'420m'
      - → Remember resolution on ξ degrades with decreasing ξ





Summary

- ATLAS T/DAQ system
  - → Maximum LVL1 latency: 2.5 μs (FE electronics)
  - → Baseline assumption: leading p signal to arrive @ LVL1 CTP within 1.4 μs (→ about 150 m)
    - Larger distances possible, but increased dead-time
    - Maximum possible distance of ~ 240 m
  - → Trigger on leading protons at LVL1 is a challenge
    - In addition to the instrumentation challenge
- Study on topological trigger criteria at LVL1
    - Master thesis by V. Bergholm (HUT)
  - → Selection via rapidity gap signature most powerful
    - But sensitive to pile-up events (design luminosity)
    - Only applicable for exclusive production