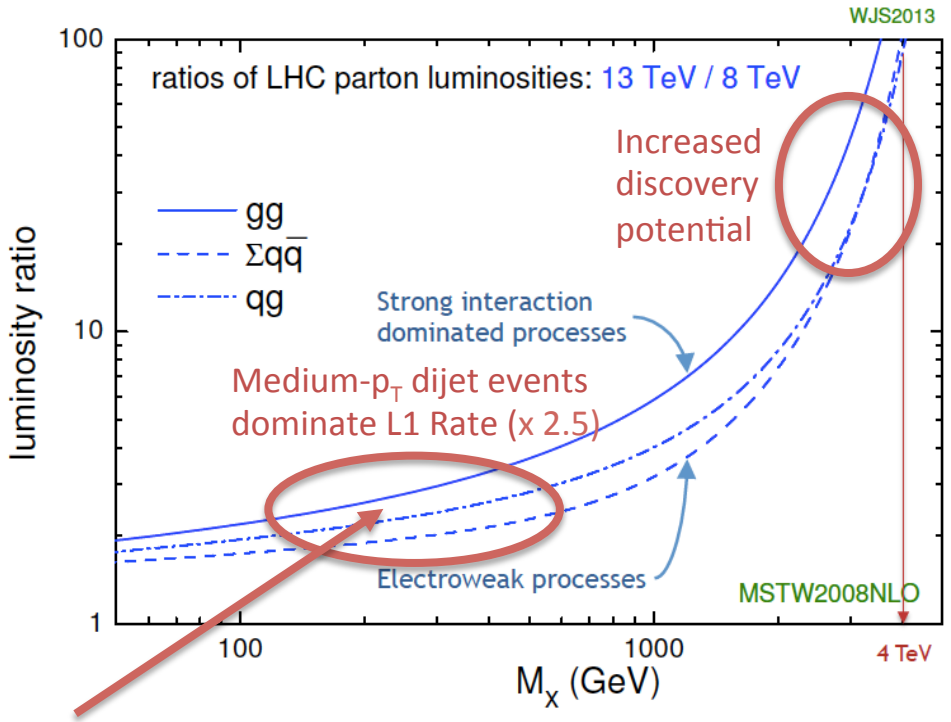
Trigger Challenges for Run2

Joerg Stelzer for the ATLAS collaboration, Rencontres du Vietnam Quy-Nhon, Aug 16th 2014



Rate Challenge

- L1 rate x 2-3, luminosity x 2 → ~ 5 times higher trigger rate, run 1 trigger selection does not scale

Pile-up Challenge

- $\langle\mu\rangle$ ~ 43 @ 1.6×10^{34} cm^{-2}s^{-1} (25ns) ± 20%

Startup Challenge

- 13 TeV: cross section increase for heavy objects (x10 @ 2 TeV)
  - Discoveries possible early on – trigger must be ready on day 1

Rate Challenge

Not new but different from Run 1 …

- L1 Rate the limiting factor in Run 1 (70kHz)
  - Detector readout upgrade → 100kHz in Run 2, still the limiting factor
  - Various L1 Trigger upgrades during LS1
- High level trigger (HLT) performance (resolution) closer to offline
- Major task during LS1 was preparation of comprehensive trigger "menu" (= set of trigger selections) for Run 2
  - Tend towards more complex, dedicated triggers
    - *Can not afford to waste bandwidth on background*
  - All relevant physics covered, all needed supporting triggers included?
  - Dedicated workshop March 2014
- Single lepton trigger – Run 1: 24 GeV e and mu (+isolation)
  - Major workhorses for many analyses, half our bandwidth in Run 1
  - Not sustainable in Run 2 (but needed, e.g. W+b, associated Higgs production) → improvements at L1, raise thresholds, tighter isolation
- New computing model includes 1kHz trigger output

L1 Muon and Calo Upgrade

Better suppression and counter-act effects of pileup and 25 ns running

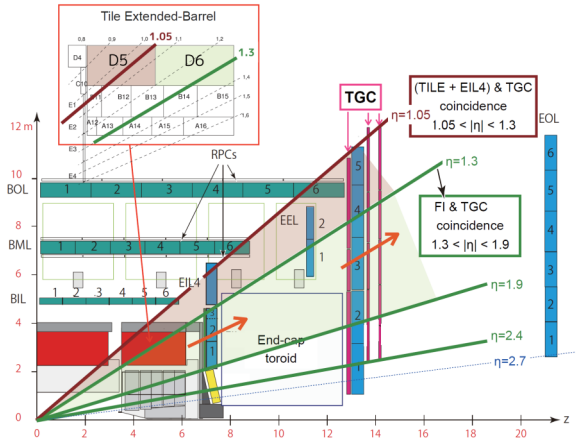
L1 Muon

Run 1: Fake rate dominated by slow particles originating outside the IP hitting the endcap

Worse at 25ns: +38%

Run2: require coincidence of muon TGC with its inner station / Tile calorimeter

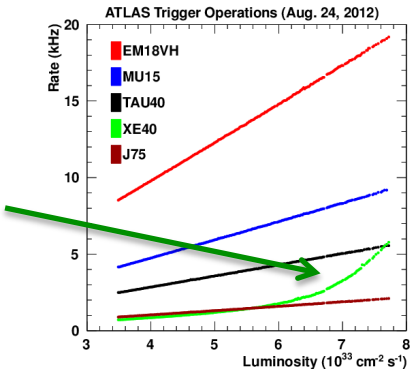
28% rate reduction (1% efficiency loss)



L1 Calo

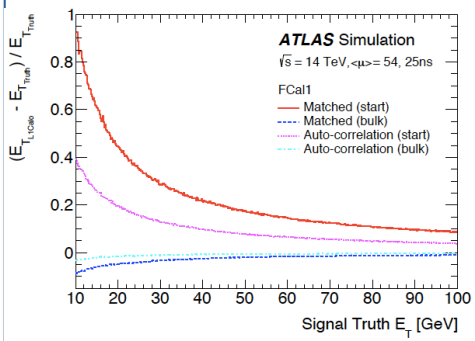
Run 1: Out-of-time pileup degraded

MET at higher pileup

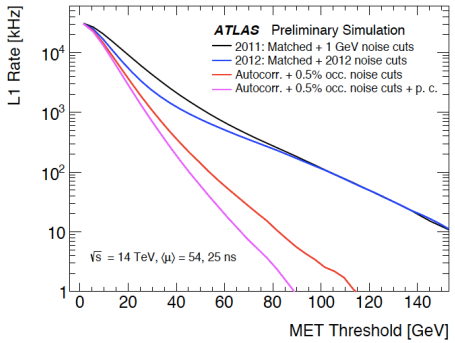


Run 2:

Noise autocorrelation filtering improves energy resolution



Improved Energy resolution

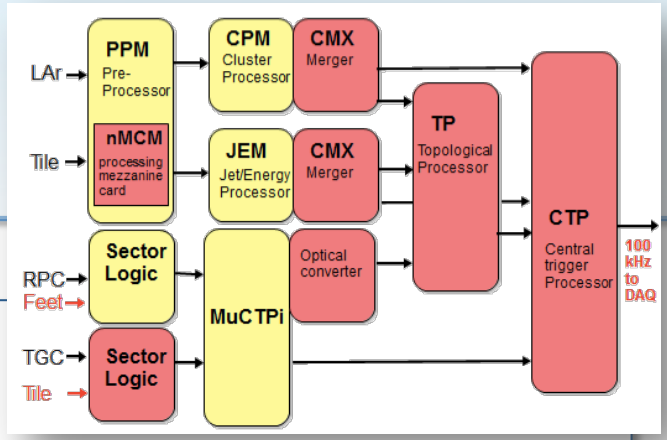


Level-1 rate as a function of the MET threshold f(<μ>=54 / 25 ns)

Dynamic pedestal correction reduces pileup dependence

L1 Topo and Central Trigger

Move complex selection at L1



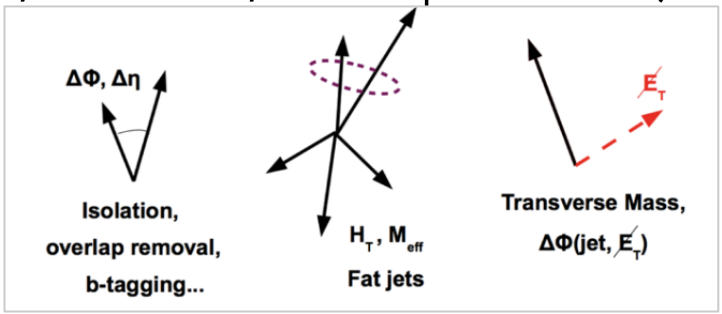
New L1 Topological processor

Trigger objects from calor and muon system

- EM, Tau, Jet, Muon, MET
- 128 L1Topo output channels

Selections based on

- Angular separation (S/B improvement, isolation, overlap removal)
- E_T, ΣE_T, M_{eff}
- ΣE_{Tjet} (improves fat jet efficiency)
- MET correction *f*(L1Jets)



Central Trigger

More refined L1 selection requires more L1 triggers → double L1 central trigger internal capacity and output (512)

Fast TracKer

A hardware track finder

FTK

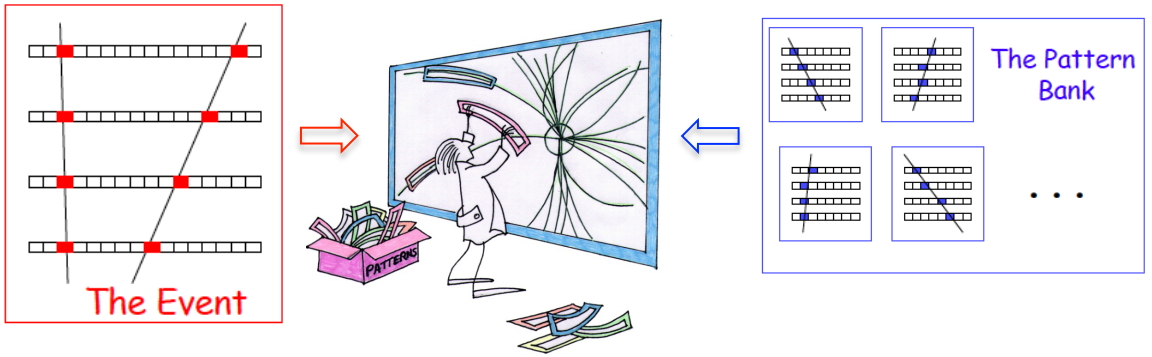
Provides tracks at full L1 rate to the HLT with offline-like resolution in O(100us)

Two steps:

Pattern recognition

Track fitting

- $p_T > 1GeV$
- $|d_0| < 2mm$
- $|z_0| < 100mm$



Particularly useful for implementing b-jets, track based MET, track jets, particle flow → pile-up suppression

Time line: FTK-barrel installation and parasitic usage second half of 2015, use for selection in 2016

High Level Trigger Upgrade

Code speedup, offline selection, …

Two HLT levels in Run 1 merged for Run2: opportunities for code improvements and speedup

- Significant code speedup in tracking, clustering, muon reconstruction

New generation of readout boards allow much more full-scan selections

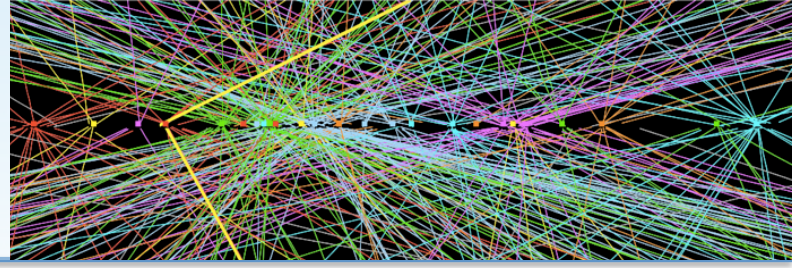
- E.g. jet finding
- CPU resources limited (resource estimation and monitor in place)

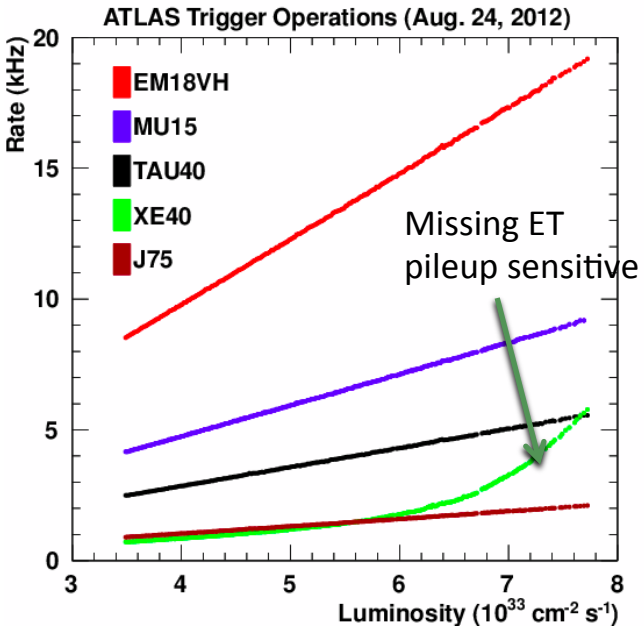
Common theme across all trigger signatures: move to using offline algorithms and (relaxed) offline cuts

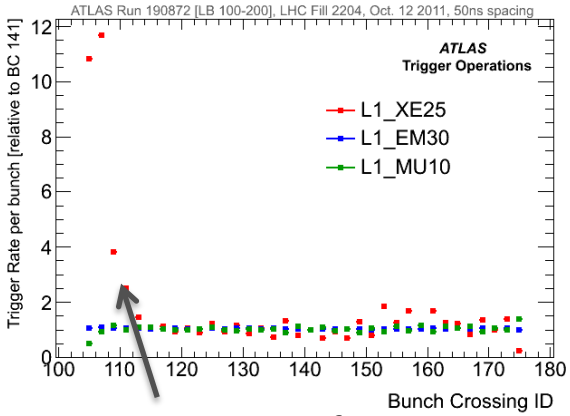
- E.g. offline clustering for jets and taus
- Better resolution, steeper turn on, tighter cuts: lower output rate

More selective triggers, tuned toward particular analyses

Pileup Challenge







High rate at start of bunch train

Run 1: at high luminosity rate increase of triggers sensitive to out-of-time pileup (containing missing E_T)

- Dominated by early bunches in train (pedestal shift)
- Correct for this in Run2 at L1 and HLT

In-time pile-up degrades trigger performance

- Missing E_T
- Jets (more fake "pile-up jets")
- Multi-object triggers (scale badly with pile-up due to random coincidences)

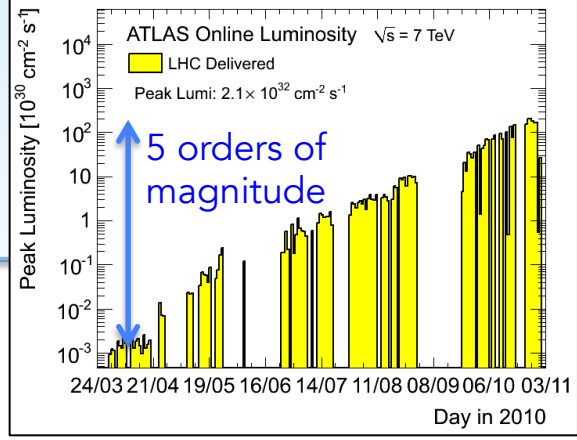
Move to offline clustering (more robust against pile-up)

- With noise cuts tuned for expected pileup

New techniques to suppress pileup are under study. See talk by James Dolen on Monday.

- E.g. usage of tracks: jet-vertex association, track isolation, track MET, particle flow
- Trigger could follow, needs FTK for full scan tracking

Start-up Challenge



Run 1 startup with L1 only

April 2015: intensity ramp-up with 50ns could be very quick ($L=\sim 9\times10^{33}$ cm^{-2}s^{-1},$<\mu>=\sim 40$)

https://lhc-commissioning.web.cern.ch/lhc-commissioning/2015/2015-commissioning-outline.htm

- Little time for commissioning L1 and HLT
  - *Unlike Run 1: first 8 months with simple L1 triggers only*

May 2015 ~1 fb^{-1} of physics data @ 13 TeV with discovery potential

- Mostly covered by simple triggers (jets, leptons)

Flexible trigger menu design to handle uncertainty in maximum LHC luminosity (20%), and maximum L1 rate ATLAS can take

- For many sub-detectors readout rate depends on the occupancy, critical early test of actual maximum L1 rate

→ Trigger prioritization, adaptation strategies

- Menu and signature coordination together with trigger-physics liaisons

Commissioning and calibration triggers ready

Summary

Changes at L1 and HLT to cope with the higher rates are in place
- 100 kHz detector readout, 1kHz average output @ HLT
- More complex selection @ L1 (new L1Topo, wider CTP)
- Reduce fake muon background
- Better energy resolution at L1 and HLT allow tighter selections

Multiple measures taken to reduce pileup dependence
- Dynamic pedestal correction at L1 and HLT
- Offline clustering used in HLT, carefully tuned noise cuts
- FTK in late 2015

Trigger (re-)commissioning
- Much will happen before first Run 2 collision beams
- Final timing-in will require collisions
- Flexible menu strategy for multiple scenarios (lumi, $<\mu>$, L1 rate, 25/50ns)

Still work to do. ATLAS Trigger is well prepared for Run 2 !