Performance of the ATLAS trigger system

Diego Casadei
on behalf of the ATLAS Collaboration

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Overview

- The ATLAS trigger operated successfully during 2009-2011 LHC running at centre of mass energies between 900 GeV and 7 TeV
  - Here we focus on 2011 performance and prospects for 2012

- 3-level trigger system
  - 40 MHz bunch-crossing rate $\Rightarrow$ ~300 Hz average recording rate
  - L1 uses custom electronics
  - High-Level Trigger = L2 + Event Filter $\Rightarrow$ software-based triggers

- The trigger system selects events by identifying interesting signatures
  - More details in the following pages and in several talks/posters

- ATLAS is currently taking data with proton beams at 4+4 TeV
The ATLAS detector
The trigger and data acquisition system

Region of Interest (RoI) in ($\eta$, $\phi$)

Design numbers 2011 values

- 40 MHz
- 75 (100) kHz
- 50-60 kHz
- ~3 kHz
- 4-5 kHz
- ~200 Hz
- 300-400 Hz

(More details on talks by Andrea Negri)
ATLAS data taking in 2011

- ATLAS data taking efficiency: ~95%
  - 8–17 interactions/bunch crossing
  - High pile-up run with peak of 32.5 int/BC used to study config for 2012
- 3.5 + 3.5 TeV in 2011, 4 + 4 TeV in 2012
Families of trigger signatures

- Calorimeter triggers
  - Standalone:
    - Jets and forward jets; photons
    - Vector and scalar sums of transverse-energies
  - Combined:
    - Electron
    - Tau
    - b-jet

- Muon triggers
  - Standalone, combined, calo
  - B-physics

- Other triggers
  - Zero-bias
  - Minimum-bias
  - Forward
Muon triggers

- Single-muon triggers with constant EF threshold at 18 GeV for entire 2011
  - L1 required $p_T > 10$ GeV and 2-stations coincidence with 75 ns bunch separation, then 3-stations with 50 ns separation

- Di-muon triggers with 10 GeV threshold for entire 2011
  - Logics to solve fake di-muons at chamber boundary activated at L1 and L2

- Isolation not required in 2011 for muon triggers
  - Enabled for 2012 (More details on poster by Alexander Oh)
Electron and photon triggers

- Electron triggers evolved in 2011 to keep high efficiency and low pile-up dependence
  - Higher thresholds for single-electron triggers
    - 14 → 16 GeV at L1, 20 → 22 GeV at EF
  - Tighter selection (less rate with ~ same eff)
    - Hadronic leakage cut at L1 (H)
    - Coarse-granularity L1 dead-material correction (V)
    - More stringent identification at HLT

- Photon triggers in 2011
  - No change for di-gamma trigger (2×20 GeV), whose efficiency remained stable (>98%)
  - Single-photon EF threshold 60 → 80 GeV

- Higher thresholds and tighter selection in 2012

(More details on poster by Liam Duguid)
Jet triggers in 2011 and 2012

- **Trigger towers at L1**
  - Analog sums of cells aligned along the same direction

- **L2 old: cone jets with cells in ROI**

- **L2 new: anti-\(k_T\) jets with trigger towers**
  - Faster (allows full-scan)
  - Can be refined with cells if needed

- **EF: full-scan with anti-\(k_T\) jets using topological clusters**
  - Cluster seed: cell with \(|E| > 4\) noise RMS
  - Add neighbouring cells with \(|E| > 2\) RMS, then all neighbouring cells
Jet trigger performance

- EF-only jet triggers used in heavy-ion run
  - No centrality dependence of the turn-on
  - New L2 tested online (not in active mode)

- High pile-up:
  - Anti-\(k_T\) instead of cone at L2, EF
  - Tighter L1 calorim. noise suppression
Tau triggers

- Tau triggers select hadronically decaying tau leptons
- Several improvements at HLT to be robust against pile-up in 2012
  - Reduced cone size for calo-based variables
  - Tighter track selection (max Dz = 2 mm from leading pT track)
  - New variables combining calorimeter and tracking information

(More details on poster by Patrick Czodrowski)
b-jets triggers

- Two main categories: lifetime and muon+jet (mainly for calib) triggers
- Rely on tracking and vertexing to tag jets at L1 (2011) and HLT (2012)
  - HLT jet triggers required to fire at high luminosity (from Sep 2011)
- Refinements for 2012:
  - Better primary vertexing
  - New L2 jets for inclusive triggers
  - Combined b-jet + MET or lepton

(More details on poster by Viviana Cavaliere)
B physics

- B-physics triggers = low $p_T$ di-muon triggers with additional mass cuts to select specific signatures ($J/\psi$, $\Upsilon$, $B\mu\mu$)
  - L1 lowest threshold re-optimized in Sep to allow it run unprescaled while keeping high efficiency (same EF threshold)
- 2012: EF thr. moves from 4 to 6 GeV for both muons
  - Reduced efficiency: $J/\psi$ (25%), $\Upsilon$ (12%), $B\mu\mu$ (17%)
- 2012: New L1 di-muon triggers requiring at least one muon or both muons in the barrel
  - Keep some eff for low thr (4-6 GeV)

Di-muon invariant mass

The difference between the grey (single muon trigger mu20) and the coloured histograms shows the data collected using the dedicated B-physics triggers.
MET triggers

- Pile-up presents difficulties to global quantities like MET and SumET
  - Rates increase faster than linearly with increasing instantaneous luminosity
  - Thresholds have been increased several times in 2011
- Because of the ROI concept, L2 did not allow computing global quantities
  - L1 output rate = EF input rate $\rightarrow$ bottleneck
- New L2 algorithm processing summary info from calorimeters
  - Partial sums over channels connected to each front-end board
  - Active in 2012
- TDAQ upgraded in 2011 to allow accessing all front-end boards
  - Replacement of critical nodes $\rightarrow$ bandwidth increase
- New EF algorithm processing topological clusters in 2012
  - Improved resolution
MET significance triggers

- Event selected by looking at both the vector (MET) and scalar (SumET) sum of transverse energies

- Implemented during 2010 Christmas break, active in 2011 and 2012
  - Recover some efficiency at low MET
  - Rates under control
Summary

- The ATLAS trigger operates since 2009 with very high live time
- The LHC evolution in 2011 implied adjustments in the configuration of most physics triggers
  - New triggers and techniques have also been tested
- 2011 data and initial 2012 data used to tune the configurations for this year
  - Big pile-up increase: 8-10 int/BC (min 2011) ➔ 25-30 int/BC (max 2012)
  - All trigger signatures need to cope with it
  - Most significant changes for jet, b-jets, tau and MET triggers
- A number of talks and posters provides additional details
- THANKS A LOT
Talks and posters about the ATLAS trigger

- Applications of advanced data analysis and expert system technologies in ATLAS Trigger-DAQ Controls framework, Giuseppe Avolio (talk)
- Evolution of the Trigger and Data Acquisition System for the ATLAS experiment, Andrea Negri (talk)
- Triggering on hadronic tau decays in ATLAS: algorithms and performance, Patrick Czodrowski
- b-jet triggering in ATLAS: from algorithm implementation to physics analyses, Viviana Cavaliere (A. Oh)
- A System for Monitoring and Tracking the LHC Beam Spot within the ATLAS High Level Trigger, Rainer Bartoldus (C. Bee)
- Upgrade and integration of the configuration and monitoring tools for the ATLAS Online farm, Sergio Ballestrero (L. Darlea)
- Tools and strategies to monitor the ATLAS online computing farm, Lavinia Darlea
- Centralised configuration tool for a large scale farm of netbooted systems, Liviu Valsan (L. Darlea)
- Resource Utilization by the ATLAS High Level Trigger during 2010 and 2011 LHC running, Doug Schaefer
- Architecture and performance of the ATLAS Inner Detector Trigger software, Pauline Bernat
- Experience with the custom-developed ATLAS trigger monitoring and reprocessing infrastructure, Valeria Bartsch (D.C.)
- The Version Control Service for ATLAS Data Acquisition System Configuration Files, Igor Soloviev
- The Electronic Logbook for the Information Storage of ATLAS Experiment at LHC, Luca Magnoni
- GPU-based algorithms for ATLAS High-Level Trigger, Jacob Howard
- Balancing the resources of the High Level Trigger farm of the ATLAS experiment, Marius Tudor Morar
- Evolution and performance of electron and photon triggers in ATLAS in the year 2011, Liam Duguid
- The ATLAS Muon Trigger at high instantaneous luminosities, Alexander Oh
- Experience with highly-parallel software for the storage system of the ATLAS Experiment at CERN, Wainer Vandelli (M. Tudor Morar)
- Designing the ATLAS trigger menu for high luminosities, Yu Nakahama Higuchi
- High-performance scalable information service for the ATLAS experiment, Sergei Kolos (G. Avolio)
- The ATLAS Level-1 Trigger System, Will Buttinger
- The First Prototype for the FastTracker Processing Unit, Andrea Negri
BACKUP
ATLAS subdetectors

- **Inner Detector: Precision Tracking & Vertexing in \(|\eta| < 2.5\)**
  - Silicon Pixels + Silicon Strips
  - Transition Radiation Tracker
  - 2T Central Solenoid
- **Calorimeters in \(|\eta| < 4.9\)**
  - Electromagnetic: Pb/LAr calo with accordion geometry
  - Hadronic: Fe/Scintillator in barrel, Cu/LAr in end-cap
- **Muon Spectrometer in \(|\eta| < 2.7\)**
  - Resistive Plate Chambers (RPC)
  - Thin Gap Chambers (TGC)
  - Cathode Strip Chambers (CSC)
  - Muon Drift Tube Chambers (MDT) for precision tracking
  - Air Core Toroids
The first-level (L1) trigger system

- Central Trigger Processor (CTP) $\rightarrow$ L1A (“accept”) signal
  - Input from calorimeters, muon spectrometer, additional signals
  - Receives LHC 40 MHz clock and distributes clock and decision to sub-system front-end electronics and to HLT

(More details on poster by Will Buttinger)
Trigger operation

ATLAS Trigger Operations

e20_medium (x0.2)
mu18 (x0.2)
tau100_medium
e100_medium_mu8
j240_a4tc_EFFS
xe60_noMu
2e12_medium

Global trigger rates

ATLAS Trigger Operation

12 trains, 50ns
1332 bunches

no trains
10 bunches

ATLAS Trigger Operations (Oct. 22 & 25, 2011)

Cross section (μb)

L1 rate (kHz) at L = 10^{34} cm^{-2}s^{-1}

<μ> interactions per bunch crossing

EM16VH
MU11
TAU30
J75