Commissioning of the ATLAS Trigger and Data Acquisition System with Single Beam and Cosmic Rays

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Overview

- Architecture of the ATLAS Trigger/DAQ System
- Experience with Single-beam in 2008
- Detector Commissioning with Cosmic Data
- Functionality and Performance on Monte Carlo Data with $\mathcal{L} = 10^{31}$ Trigger Menu
- Readiness for LHC Collisions

The ATLAS Experiment

Requirements for Trigger and DAQ

- LHC bunch crossing rate: 40 MHz
- At high luminosity (10^{34}): ~23 interactions per crossing
 - $> 10^9$ interactions/sec
- About 10^8 channels to read out.
- Event size: 1.5 Mbyte
 - Larger during special runs: > 15 Mbyte
- Tier0/Reconstruction/Grid/Storage: output limit about 200 Hz/300 MByte/s

- *Inelastic: 10^9 Hz*
- *$W \rightarrow l \nu$: 10^2 Hz*
- *tt production: 10 Hz*
- *Higgs (100 GeV): 0.1 Hz*
- *Higgs (600 GeV): 10^{-2} Hz*

The ATLAS Trigger and DAQ System

First Level Trigger

Provides **Regions of Interest (ROI)** to High Level Trigger: location in eta/phi of objects that triggered the selection.

LVL1 Muon Trigger:
Resistive Plate Chambers (**RPC**) in barrel
Thin Gap Chambers (**TGC**) in end-cap

High Level Trigger and Data Flow

High Level Trigger and Data Flow (2)

- After events are selected by LVL1 trigger they are buffered in the Read Out System (ROS) (up to 75 kHz)
- LVL2 requests data selectively and as needed based on the Region of Interest information given by LVL1
 - Typically: 5 % of total event size, but full granularity compared to LVL1
 - More during commissioning and early running since various full-scan algorithms may request a full sub-detector.
 - Selection is step-wise and the event can be rejected as early as possible.
- Events accepted by LVL2 (1-5 %) are fully built and passed to the event filter farm. (~3 KHz)
 - “Offline” like algorithms working on a full event.
- Events accepted by event filter are written to disk and copied to mass storage (CASTOR) (~200 Hz)

Current Status of DAQ/HLT

- All of the Read Out System (150), control and monitoring machines are installed and commissioned.
- ~35% of the full HLT farm is commissioned
 - 850 machines, 2x4 cores, 16 Gbyte memory, 2.5 GHz
 - 27 racks, one local file server (LFS) each to replicate software from central file server (CFS).
 - Nodes are connected in such a way that they can be used as LVL2 or Event Filter nodes (XPU, where X = L2 or EF).
 - Flexibility to division the system according to needs.
 - Easy partitioning for parallel runs.
- In almost continuous operation: support for detector specific runs, combined cosmics etc.
- Infrastructure (run control, configuration, monitoring) deals regularly with more than 10000 applications.
 - *For Trigger Monitoring see Antonio Sidoti's talk on Tuesday afternoon.*

L2Supervisors, Event Building

Switches

LFS nodes

UPS for CFS

CFS nodes

Online Infrastructure and Monitoring PCs

xPUS

SDX1 | 2nd floor | Rows 3 & 2

Data Logger

Splash Events (Sep 10th 2008)

Pixel detector off.
Muon and SCT at reduced voltage.
All other detectors on.

LVL1 trigger active only.

High level trigger in pass-through mode, but used for routing events to different streams based on LVL1 trigger decision.

L1Calo, MBTS
Beam Pick-up Trigger (BPTX) for single beam

Offline Event Display

L1Calo Trigger

Asymmetries due to one side off by one bunch crossing; corrected due to having these events.

Level-1 Trigger Rates versus Time - RUN 87863

Trigger Rate showing ~40s structure following LHC.

Single Beam

First BC with Fired Trigger

Relative Trigger Timing, 10 September

Relative Trigger Timing, 12 September

Main priority was timing-in different triggers relative to each other.

Quick progress within a few days.

Detector Commissioning with Cosmic Rays

- ➔ After LHC incident, went to commissioning run with special cosmics menu, but physics menu enabled as well.

Highest rate from RPC trigger ~ 500 Hz

Tracks extrapolated back to surface show structure of ATLAS shafts.

Cosmic Ray Event, no magnetic field.

With solenoid on.

Zoom into Silicon Detector
(SCT)

L1Calo

Offline sum E_T of Liquid Argon calorimeter cells
VS.
L1Calo Trigger Tower E_T

5 GeV trigger threshold

Energy spectrum in hadronic trigger towers.

Very low statistics since only little energy deposited by muons in calorimeter;

but note long tail due to showering:
very useful for debugging the trigger.

All saturated trigger towers
(> 125 GeV) in last bin

LVL2 e/gamma

High level trigger is used to find problems in trigger and/or detectors:

LVL2 e/gamma clusters in η and ϕ

These L1 trigger towers fired because of L1Calo working out of its normal operating range (too low E_T) during cosmics running. Does not affect normal physics running.

Only $< 1\%$ problematic calo cells in more than 200000. Hardware problems were addressed during shutdown.

For τ see Mansoor Shamim's talk on Tau Trigger with Cosmics

LVL2 Muons and Tile

LVL2 Muon algorithms

MDT Cluster vs. number of hits in TGC

- **Cluster finding efficiency: 93%**
 - design goal 99%
 - 4.7% inefficiency due to some MDT chambers off
 - 2% inefficiency due to bad MDT calibration

- **Energy deposition of muons in Tile calorimeter:**

- Expected value of 2.5 GeV from simulations
- Threshold of 300 MeV.

LVL2 Muons in the Tile Calorimeter

Event Filter Muons

Comparison of muon tracks in the muon spectrometer from event filter compared to offline. After fit to Gaussian:

$$\sigma_{\eta}=0.007, \sigma_{\phi}=17\text{mrad}$$

See Roberto Crupi's talk on Muon Reconstruction and Selection in the Event Filter.

LVL2 Tracking

Comparing LVL2 efficiency to offline for various LVL2 tracking algorithms

- TRT only, finds track segments
- IDSCAN: histogramming technique, find z position to IP and search for tracks from there
- SiTrack: Combinatoric search for track seeds in innermost Si layers, extension to outer layers

Collecting Tracks with HLT

After Sep 19th the High Level Trigger was used to collect tracks for commissioning the inner detector and muons for alignment and calibration:
all LVL1 events OR any of the LVL2 tracking algorithms

Various improvements that were implemented with a very short turn-around in the HLT allowed to take a large number of tracks for commissioning.

HLT is working and selecting events !

In Jule/July 2009 this sample was increased another 50% in 2 weeks running.

Cosmic data from August 1 to October 31, 2008

- Calibration stream
- Debug stream
- Physics stream

Events in Debug stream are re-run off-line with HLT to understand the problem.

DAQ/HLT saves the events in multiple streams for easy access

Calibration stream event distribution for Cosmic data from August 1 to October 31, 2008

Physics stream event distribution for Cosmic data from August 1 to October 31, 2008

Performance Measurements on Monte Carlo Data

- Cosmic Runs are just a bit over 500 Hz
 - Not a challenge for the Trigger/DAQ system.
 - For performance tests an *enhanced bias* sample is used (events that would pass LVL1 with a low threshold)
 - Data is pre-loaded into Read Out System and recycled.
- Example: 10^{31} collision menu (~900 trigger chains).
 - A LVL2 input rate of ~90 kHz can be sustained.
 - LVL2 output rate ~ 18 kHz
 - Additional artificial rejection by 5 = 3.8 kHz event building
 - Event Filter output ~200 Hz.
- The Trigger/DAQ system can cope with a rate beyond the immediately needed one.
 - Limit is access to ROS from LVL2 in this trigger menu (designed for 11 kHz LVL1)

Conclusions

- Trigger and DAQ are ready and used almost continuously for data taking.
- The last year has been used to exercise the system with detectors and in combined runs as well as stand-alone tests.
 - Combined data taking before beam has just started...
- Looking forward to beam...

Backup Slides

High Level Trigger and Data Flow (3)