ATLAS Jet Trigger Update for the LHC Run II

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On behalf of the ATLAS Collaboration

LIP - Lisbon
ANIMMA 2015

20-24 April 2015

Introduction: The Large Hadron Collider (LHC) at CERN

- Circular accelerator with 27 km perimeter
- Proton-proton collider
 - ▶ Can also collide heavy ions

	During Run-1	For Run-2
Centre of mass energy	7 TeV to 8 TeV	13 TeV to 14 TeV
Bunch spacing	50 ns	25 ns
Interactions per bunch crossing	20	~ 43
Peak luminosity	$0.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$	$1.6 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$

ATL-DAQ-PROC-2014-032

Introduction: The ATLAS experiment

Multi-purpose experiment designed to probe the Standard Model and search for new physics at very high energies

Muon Spectrometer: $|\eta| < 2.7$

Air-core toroids and gas-based muon chambers
 $\sigma/pT = 2\% @ 50\text{GeV}$ to $10\% @ 1\text{TeV}$ (ID+MS)

EM calorimeter: $|\eta| < 3.2$

Pb-LAr Accordion
 $\sigma/E = 10\%/\sqrt{E} \oplus 0.7\%$

Hadronic calorimeter:

$|\eta| < 1.7$ Fe/scintillator
 $1.3 < |\eta| < 4.9$ Cu/W-Lar
 $\sigma/E_{jet} = 50\%/\sqrt{E} \oplus 3\%$

Inner Tracker: $|\eta| < 2.5$, $B=2T$
Si pixels/strips and straw detector
 $\sigma/pT = 0.05\% pT (\text{GeV}) \oplus 1\%$

$> 10^8$ electronic channels
 $> 1.6 \text{ MB per event (64 TB/s)}$
 $> 3\text{-level trigger reducing } 40 \text{ MHz}$
collision rate to 400 Hz of events to tape

Jet: Spray of collimated particles

- Initiated by quarks or gluons
- Most common high p_T objects produced at the LHC
 - ▶ Important for a wide range of physics analyses
- The energy deposits are aggregated by the reconstruction algorithms and calibrated to provide the jet momentum measurement

The ATLAS Trigger and DAQ systems: Run-1

DOI:10.1140/epjc/s10052-011-1849-1

- Reduce the accepted events by a factor of 10^5

- ▶ Most interesting physics have small cross-section relative to total p-p cross-section
- ▶ Limited bandwidth to disk data storage

Run-1:

- Organized in 3 levels:

- ▶ L1: Hardware based
 - ★ Coarse granularity.
 - ★ Finds high p_T objects positions
 - ★ Provides seeds for next levels
- ▶ L2: Software based
 - ★ Full granularity
 - ★ Regions of interest based
- ▶ EF: Software based
 - ★ Offline like algorithms
 - ★ Can access the full event
- L2 and EF in different farms
 - ▶ Extra data transfer

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The ATLAS Trigger and DAQ systems: Run-2

ATLAS-TDR-023

- Improve the trigger capability for Run-2
 - ▶ Better exploit available computing capacity and output rate from the HLT
 - ▶ New L1 topological processor and fast tracking at HLT:
 - ★ will allow angular and mass jet selection and rejection of pileup jets
 - ▶ Improved data flow architecture
 - ★ L1 output rate raised to 100 kHz (increased energy and luminosity)
 - ★ L2 and EF merged; 250 ms to take a decision for jets
 - ★ Read Out System upgrade; bandwidth increase 10x, memory per channel 5x

Jet trigger: Run-1

- Selects events containing high p_T hadronic jets

Typical chain for single Jet trigger

- L1:

- ▶ Sliding window algorithm
- ▶ Calorimeter towers (trigger towers)

- L2:

- ▶ Readout Regions of Interest
- ▶ Simple cone algorithm
- ▶ Cells as constituents

- EF:

- ▶ Full calorimeter scan
- ▶ Offline algorithms available

Run-1

Run-1 Jet trigger efficiency:

ATL-COM-DAQ-2013-082

- The ATLAS jet trigger demonstrated excellent performance throughout Run-1
- EF turn-on curves considerably steeper than corresponding L1 curves
 - ▶ Improved E_T resolution, compared to the offline reconstructed jets
 - ▶ Monte Carlo simulates the data well

Efficiency turn-on curves for various single inclusive jet triggers

Naming convention: L1_jX and EF_jX, where X is the E_T trigger threshold in GeV

Jet trigger: Run-2

- Selects events containing high p_T hadronic jets

Typical chain for single Jet trigger

- **L1:**

- ▶ Sliding window algorithm
- ▶ Calorimeter towers (trigger towers)

- **HLT** generic jet chain:

- ▶ Prepare detector data (Cell unpacking)
- ▶ Process cell Clustering and Jet maker
- ▶ Evaluate the event (Hypothesis)

Topological Clustering algorithm:

- Iterative 3D calorimeter cell clustering
 - ▶ based on signal/noise
- Applies noise suppression
- Most time-demanding step

Jet reconstruction uses *Anti- $k_\perp$* algorithm [1]

- Fast, collinear and infrared safe and regular shape algorithm

[1] JHEP 0804:063,2008

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Typical chain for single Jet trigger

- L1:
 - ▶ Sliding window algorithm
 - ▶ Calorimeter towers (trigger towers)
- HLT generic jet chain:
 - ▶ Prepare detector data (Cell unpacking)
 - ▶ Process cell Clustering and Jet maker
 - ▶ Evaluate the event (Hypothesis)
- Jet event rate increase by a factor of five
 - ▶ higher energy, luminosity and pileup
- Better exploit available computing capacity
 - ▶ HLT algorithms optimization
 - ▶ Data reduction through the use of a partial calorimeter readout scheme

Algorithm optimization

- The cell unpack and retrieval time was reduced by a factor of 7
 - ▶ More efficient full calorimeter readout
- The cell clustering time was reduced by a factor of 2
 - ▶ Pre-fetching, code inlining and the introduction of more efficient data structures

Data reduction: Partial calorimeter readout scheme

- Reads at once all the cells around the L1 positions, removing any overlap
- Works as a full calorimeter readout with low activity regions suppression
 - ▶ zero-suppressing algorithm
- Increases system flexibility to adapt to different requirements

Partial Scan: Data and processing time reduction

- The Partial Scan reads out 3.5 to 7 % of the calorimeter cells
- The cell clustering in the Partial Scan takes 6 to 10 % of the time required by the complete calorimeter processing

Partial Scan: Comparing partial to full reconstruction

- The full calorimeter readout gets the best resolution
- The E_T of the most central jet differs by less than 0.5% from full scan trigger jets, for jets above 100 GeV

Conclusions:

- The jet trigger has shown excellent performance during the first data taking
- The ATLAS TDAQ introduced important improvements to better exploit Run-2
 - ▶ Significant optimizations were achieved during shut-down:
 - ★ cell unpacking becomes seven times faster
 - ★ cell clustering processing time was reduced by a factor of two
 - ▶ A partial calorimeter readout scheme was developed:
 - ★ zero-suppressing algorithm that filters the low activity regions
 - ★ Speeded up jet reconstruction by a factor of 10 without much loss of physics performance
- The ATLAS jet trigger will collect crucial data to calibrate the detector and allow many unique physics measurements. We are ready to face the challenges of the LHC Run-2!

Thank you!

Acknowledgements

Run: 260272
Event: 5879
2015-04-05 10:46:41 CEST

Backup slide: Topological Cluster