Evolution and performance of the ATLAS jet trigger

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- General configuration of the ATLAS trigger
- Going from regional to global trigger
- Data taking performance
- The future of the ATLAS trigger after the shutdown
Triggering at LHC Run 1

Bunch-crossing spacing: 50 ns (20 MHz)
Up to around 1000 bunches per beam
Maximal available output rate for physics: few hundred Hz
Rejection factor $O(1 \times 10^5)$, achieved by ATLAS by a 3-level system based on Regions of Interest (ROI): only parts of the detectors seeded by L1 are read out by L2 and EF
Luminosity and pileup evolution

Over three years, LHC luminosity almost reached design value, closely followed by pileup.

In 2012, most of the data was taken with 25-35 interactions/bunch crossing.
Rates still linear with luminosity for 2010 and 2011 (grow by about factor 5 vs factor 4 in luminosity)
Lowest jet trigger switched off in 2012
Saturation effects observed for **MinBias** triggers
Detector occupancy behaviour

Event size also growing linearly with average pileup (i.e. luminosity).

Detector far from being completely saturated

DAQ system needs to cope with growing data volume even for fixed output rate
Trigger rate evolution in a typical run

As luminosity decreases, more triggers are added, to level the output rate profile.
Building Level-1 jets

**Level 1 Calorimeter segmented in Trigger Towers (TT)**

- $\Delta \eta \times \Delta \phi = 0.1 \times 0.1$ minimum size
- Digitizes and associates energy with bunch crossing
- Applies pedestal subtraction and noise suppression ($4 \text{ ADC} \approx 1.2 \text{ GeV}$)
- Applies calibration, in common with $e/\gamma$ and $\tau$; remain at EM scale

Jet Window ($0.8 \times 0.8$)

Jet Element ($0.2 \times 0.2$)

Jet Elements built from $2 \times 2$ TT

Sliding window jet algorithm

Region of Interest (ROI) identified if $E_T$ above threshold $\dagger$

L1 jet local maximum in window

$\dagger$ $E_T$ is an integer at L1 and so it takes $11 \text{ L1-GeV-EM}$ to pass the J10 threshold
Level-1 jet efficiency

100% efficiency points much higher than trigger nominal value because L1 sums electromagnetic and hadronic energy without calibration. Turn-on curves have slow rise at low-pt due to resolution, much worse in trigger towers than for HLT or offline.
Multi-jet rates at L1

Rate increase for multi-jet events is a factor of 10 for a factor of 4 larger luminosity (0.8 to 3.2), much larger than the increase in inclusive jet rate.

Efficiency for multijets never reaches 100% due to geometrical issues:
Problems with the ROI approach

A sliding window has a square size in $(\eta, \phi)$ while offline jets are circular. This creates inefficiencies in busy multijet environments.

Also, due to readout issues, L1 has no eta segmentation for the Forward Calorimeter

The solution:
- require n-1 jets at L1
- pass all L1Calo information to a software that reclusters it using the anti-
kt algorithm, same as offline
- require n anti-kt jets passing the threshold

Additional advantages:
- Use full calorimeter (not just ROI's)
- Same algorithm as offline
- Full FCAL granularity
- Improved resolution
Level-2 jets from full-scan L1 information

Full-scan jet reconstruction from L1Calo towers
- Trigger Towers (TT)
- Jet Elements (JE)
- apply tower-level calibration and pileup suppression
- anti-\(k_T\) jets
- runs inside Level 2 trigger

Read L1Calo not Calo \(\Rightarrow\) increased L2-input rate

Adds flexibility & improved efficiency (multijets, fat jets)

L1 RoIs and offline anti-\(k_T\) jets (EM-scale), energies in GeV

L1.5 A4TT and offline anti-\(k_T\) jets (EM-scale), energies in GeV
Further performance improvements of Level-2 full-scan wrt Level-1

Up to 20% increase of efficiency for nearby jets

Resolution improves by a factor ~2 wrt L1, close to that of offline jets
Eta information allows performance equalisation and sharper turn-on
Event filter rates vs luminosity

- ROI-based level-2 still used for inclusive jets
- Events passing either L2 algorithm are analysed by Event Filter
- All calorimeter cells (same granularity as offline) used: no ROI
- For low-pt chains random events are sent straight to full-scan EF.

Multi-jet rates still growing about a factor of 2 more than their inclusive correspondents
Turn-on curves for a typical L1-L2-EF chain

The thresholds for the three components of the chain have been set to have the same 100% efficiency point (with some safety margin). Subtracting an average calorimeter noise at HLT produces steeper curves.
Due to worse Et resolution and granularity, turn-on in the forward region is much slower, especially for Level-1. Pileup is large in the forward region, so pileup correction is important.
Triggering in the low-Et region

The lowest Level-1 threshold is only efficient for offline jets of ~50 GeV. To trigger below this level, a very prescaled fraction of the random trigger is sent directly to full-scan EF. Performance is good, even if slightly worse than MC predictions.
Higher pt jet triggers

Again, Monte Carlo does not describe well the turn-on curve, but the agreement improves at plateau.
Where does discrepancy come from?

PYTHIA simulation seems to agree better, but data is asymmetric in the endcap.
Here, agreement is not very good in central region, and for all pT points apart from the lowest one
After the current shutdown

- After LS1, L2 and EF will be run on the same node for all ATLAS triggers, as opposite to the current dedicated nodes
- For the jet trigger, L2 and EF will be merged into a single piece of code
- For multi-jets, the full-scan Level-2 will still be run before the final selection based on quasi-offline objects
- Fast tracking will allow assigning jets to pileup vertexes
- Event-by-event pileup subtraction will be available
- Cuts on jet relative angles possible at L1
Conclusions

Jet topologies (especially multijets) were not well-suited for the Roi-based approach of the ATLAS trigger system.

The jet trigger overcame these limitations by providing full-scan jet finding:
- at Level-2 (using L1Calo information)
- at Event Filter (using the full calorimeter information)

This allowed:
- Full efficiency for complex multijet signatures
- Better response in the forward region
- Extending triggering capabilities to very low transverse momenta
- Better response, turn-on sharpening and offline-style pileup corrections

The foreseen integration of Level 2 and Event Filter will produce a smoother system, where HLT jets will be almost identical to the offline.