Performance studies of the Run 3 jFEX algorithms in the ATLAS calorimeter trigger

Elena Villhauer on behalf of the ATLAS Experiment
University of Edinburgh

Upgrade of ATLAS L1 trigger system from Run 2 to Run 3

- The Run 2 ATLAS trigger system is comprised of two levels: a hardware based Level-1 (L1) and a software Higher Level Trigger (HLT). Between late 2018 and early 2021, the ATLAS trigger system is undergoing upgrades to allow for an increase in luminosity and to improve the performance

Two major sets of upgrades to the ATLAS L1 trigger system:

- The increase in read-out granularity in the Liquid Argon (LAr) detectors ("supercells")
  - 7k towers (Run 2) to 36k supercells (Run 3)
- The addition of new Feature EXtractors (FEXs):
  - Jet FEX (jFEX) - identifies jets and calculates missing transverse momentum and other energy sums
  - Global FEX (gFEX) - identifies large radius jets
  - Electromagnetic FEX (eFEX)

Comparison of Run 2 L1 system to Run 3 L1 system performance

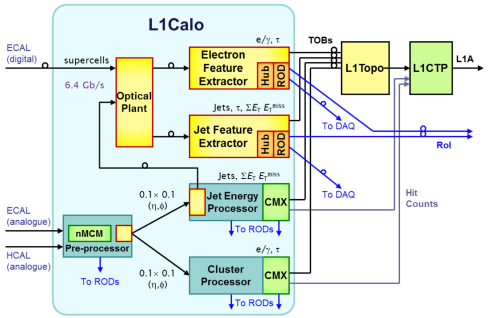


Figure from [1]

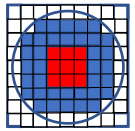
New components for Run 3 are in highlighted in orange and yellow. The gFEX system (not shown) will also be incorporated

jFEX Structure

- Six jFEX modules
- Each jFEX module is an ATCA (Advanced Telecommunication Computing Architecture) board with 4 processor Xilinx **UltraScale+** FPGAs (field-programmable gate array) and can process a total input data rate of ~3.6 Tb/s
- Identifies jets, taus and calculates missing transverse momentum and other energy sums
- The new jFex jets are much finer resolution in η , ϕ than current L1 jets

Formation of a Run 3 jFEX jet

jFEX jet (0.7 x 0.7 rounded-off square), 0.1 x 0.1 tower, 0.3 x 0.3 seed



Small-R jFEX jet:

- Reconstructed using 0.9 x 0.9 sliding window algorithm
- Noise threshold of 2 GeV is required for any jTower
  - ET of jTower is set to 0 if noise cut fails
- Each 0.1 x 0.1 jTower is surrounded by a 0.3 x 0.3 seed that consists of 3 x 3 jTowers
- The "Local maximum", seed with the highest ET, is determined by scanning all seeds that exist within a range of 5 x 5 jTowers and finding the seed with highest ET
- Small-R jet is defined as a cone of Δ R = 0.4, where Δ R = sqrt((Δ η)^2 + (Δ ϕ)^2) and Δ R = 0 is at the center of the local maximum
- Jet ET = sum of ET of each tower

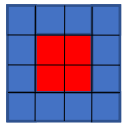
Large-R jFEX jet:

- Uses same algorithm as Small-R jFEX jets, but with an increased cone size of Δ R = 0.8

Formation of a Run 2 L1 jet

Reconstructed using a 0.8 x 0.8 sliding window algorithm with a 0.2 x 0.2 tower and a 0.4 x 0.4 seed

L1 jet ROI (0.8 x 0.8), 0.2 x 0.2 tower, 0.4 x 0.4 seed



On the right: trigger efficiencies for single jet L1 triggers for 2015 and 2016

- L1_JX means single jet trigger that accepts an event if a jet has ET > X GeV
- L1 single jet triggers in 2015 and 2016 become fully efficient at same point

Run 2 L1 Jet Trigger Efficiencies

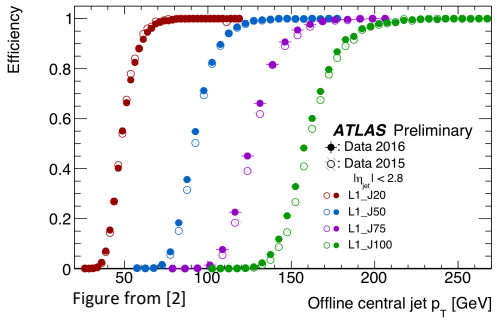


Figure from [2]

Run 3 jFEX Jet Trigger Efficiencies

Below: Plots of per jet trigger efficiencies in HH->bb(bb) Monte Carlo samples for Run 2 L1 jets, Run 3 jFEX jets, and the offline Anti-kt reconstruction algorithm running over R = 0.4 jTowers

- Run 3 jFEX algorithm and offline Anti-kt reconstruction algorithm apply 2 GeV noise cut to jTowers
- Thresholds for all three approaches were tuned to have equivalent rates

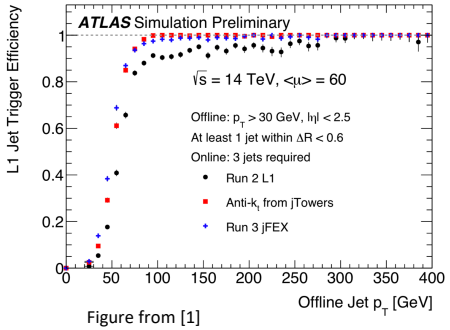


Figure from [1]

- Trigger efficiencies computed as a function of calibrated offline jets where
  - pT > 30 GeV
  - |η| < 2.5
  - At least one jet is > 30 pT and is < Δ R = 0.6 of the probe jet
- 3 online jets required

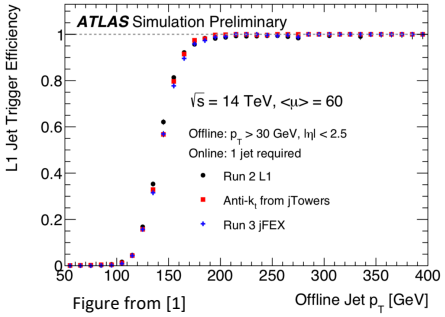


Figure from [1]

- Trigger efficiencies computed as a function of calibrated offline jets where
  - pT > 30 GeV
  - |η| < 2.5
- 1 online jet required

Conclusion

- The new algorithm performs better for nearby jets
- Run 2 L1 jets and the new algorithm perform similarly for 1 online jet events

jFEX MET algorithms

- Designed for better pileup mitigation
- **jFEX MET Algorithm 1: MET calculation - sum over all towers above given threshold**
  - Thresholds are pileup and noise cuts
- **jFEX MET Algorithm 2: rho-subtracted MET calculation**
  - Calculate average energy (from in-time pile-up) event-by-event and subtract energy. from all towers
  - Sum over all towers with positive energy

jFEX MET trigger efficiencies

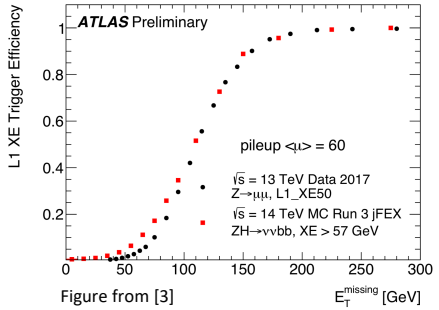


Figure from [3]

- Efficiency of jFEX MET algorithm versus truth MET in a ZH->ννbb Monte Carlo simulation
- jFEX MET is calculated as the vector sum of all towers with ET greater than an η-dependent threshold
- Threshold cuts noise and ranges from 0 – 5 GeV
- jFEX MET algorithm in ZH->ννbb compared to Run 2 MET threshold L1_XE50 in Z->uu events
  - This plot is shown as a proof of principle and is the same algorithm as Run 2, hence the performance is the same

Investigation of L1 jet calibrations

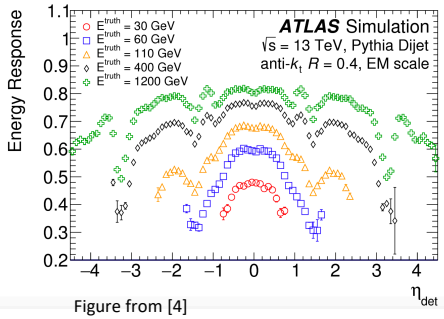


Figure from [4]

- The ATLAS detector is not uniform in eta, so the response to jets is not uniform in eta
- Goal: remove the eta-dependence in energy response to improve the jet resolution

References:

[1]. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/L1CaloTriggerPublicResults
[2]. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetTriggerPublicResults
[3]. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MissingEtTriggerPublicResults#March_2019
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[5]. https://cds.cern.ch/record/1602235/files/ATLAS-TDR-023.pdf
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