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 - identifies jets and calculates missing transverse momentum and other energy sums
  - Global FEX (gFEX) - identifies large radius jets
  - Jet Trigger Public Results
  - Threshold cuts noise and ranges from 0 to some greater than a dependent threshold
  - The “Local maximum”, seed with the highest ET, is determined by scanning all seeds that exist within a range of 5 x 5 towers and finding the seed with highest ET
  - Small-R jet is defined as a cone of R = 0.4, where R = sqrt((Δη)^2 + (Δφ)^2) and R = 0 if a jet has ΔR = 0 is surrounded by a 0.3 x 0.3 seed that consists of 3 x 3 towers above given threshold
- Electron FEX - identifies electromagnetic FEX (eFEX)

References:
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/L1CaloTriggerPublicResults
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/L1JetTriggerPublicResults
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MissingEtTriggerPublicResultsMarch-2019

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

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

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

JFEX Structure:
- Six jFEX modules
- Each module is an ATCA (Advanced Telecommunication Computing Architecture) board with 4 processor Xilinx UltraScale PIPAs (field programable 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, ET and other energy sum parameters

jFEX ET 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:
- Efficiency of jFEX MET algorithm versus truth MET in a ZH-→bb Monte Carlo simulation
- jFEX MET is calculated as the vector sum of all towers with ET greater than an n dependent threshold
- Threshold cuts noise and ranges from 0 – 5 GeV
- jFEX MET algorithm in ZH-→bb compared to Run 2 MET threshold L1_XELO in Z+enu events
- This plot is shown as a proof of principle and is the same algorithm as Run 2, hence the performance is the same

Run 3 jFEX Jet Trigger Efficiencies

Below: Plots of per jet trigger efficiencies in HH-ribbb Monte Carlo samples for Run 2 L1 jets, Run 3 jFEX jets, and the offline Anti-kt reconstruction algorithm running over R = 0.4 towers
- Run 3 jFEX algorithm and offline Anti-kt reconstruction algorithm apply 2 GeV noise cut to towers
- Thresholds for all three approaches were tuned to have equivalent rates

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