Performance of the ATLAS Missing Transverse Momentum Triggers for Run 3

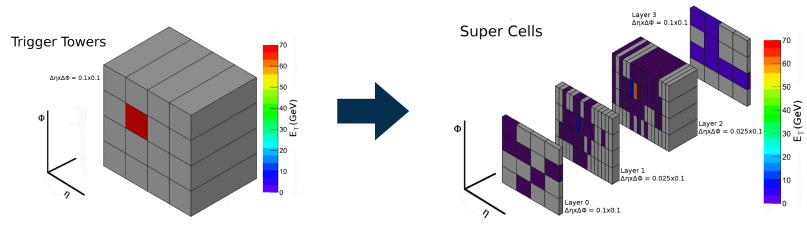
The ATLAS trigger system underwent major upgrades between 2018-2022. In particular, the level-1 calorimeter (L1Calo) hardware E_T^{miss} trigger has been upgraded and tracking introduced in the software-based E_T^{miss} triggers. The new and improved Run 3 algorithms will ensure high signal efficiency for collision events with non-interacting particles passing through the detector. These events provide an interesting probe for new physics interactions beyond the Standard Model, while also providing the basis for precise measurements of Standard Model parameters. The new Run 3 E_T^{miss} L1+HLT Trigger chains are expected to reduce trigger rate by 40% for the same efficiency compared to Run 2.

1. L1Calo Upgrades

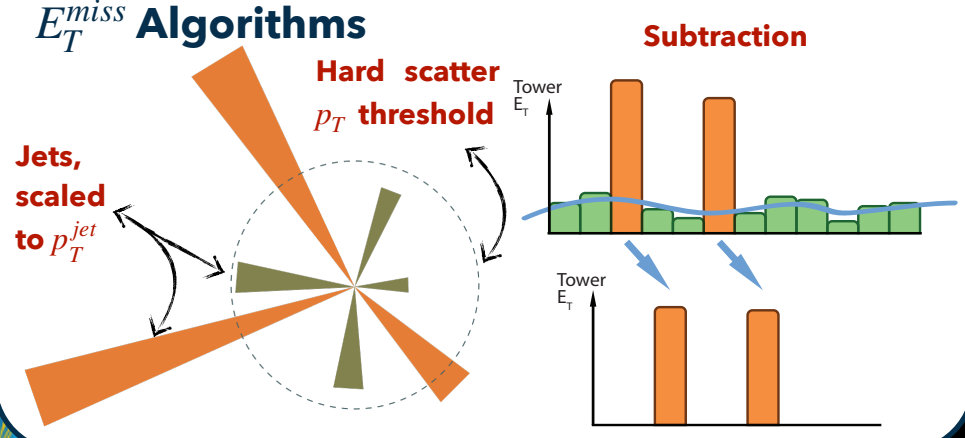
New Global Feature Extractor (gFEX) and Jet Feature Extractor (jFEX) used for L1MET algorithms. Able to execute sophisticated online algorithms to identify E_T^{miss} on both boards.

Drastically improved Liquid Argon (LAr) calorimeter granularity

Run 2 *Run 3*



2. Pile-up Suppression in L1Calo and HLT E_T^{miss} Algorithms



3. L1Calo E_T^{miss} Algorithms and Performance

Noise cut – Computes E_T^{miss} from the vector sum of all towers with E_T above an η-dependent threshold of 1-2 GeV, increasing towards the forward region for larger trigger towers.

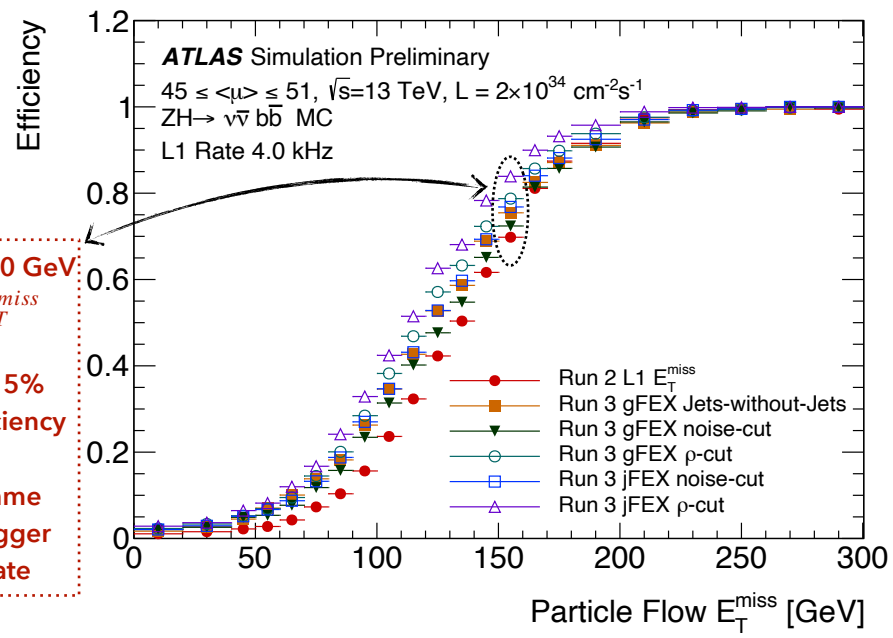
Highest Signal efficiency

ρ-cut – Performs a local per-event pileup density (ρ) subtraction, applies an η-dependent threshold and computes E_T^{miss} from the vector sum of all towers.

Jets-without-Jets – Computes E_T^{miss} based on a linear combination of the soft and hard contributions to the E_T of all gBlocks (3x3 gTowers) ($\Delta\eta \times \Delta\phi = 0.6 \times 0.6$). Optimised for resolution using ML techniques.

$$H_T^{gTower} = \left| \sum_i^{N_{cells}} E_{T_i} \theta(E_{T_{i,\Delta R}} - E_{T_{cut}}) \right| \qquad E_T^{gTower} = \left| \sum_i^{N_{cells}} E_{T_i} \theta(E_{T_{cut}} - E_{T_{i,\Delta R}}) \right|$$

$$E_{T,jwoj}^{miss} = a \cdot H_x^{gTower}(E_{T_{cut}}, \Delta R) + b \cdot E_x^{gTower}(E_{T_{cut}}, \Delta R)$$



@ 150 GeV E_T^{miss}

+15% Efficiency

Same Trigger rate

4. HLT E_T^{miss} Algorithms and Performance

tcpufit (Run2) – Calorimeter only algorithm using topoclusters (TC's) and a pufit algorithm subtracting pile-up energy deposits after a fit to lower E_T signals.

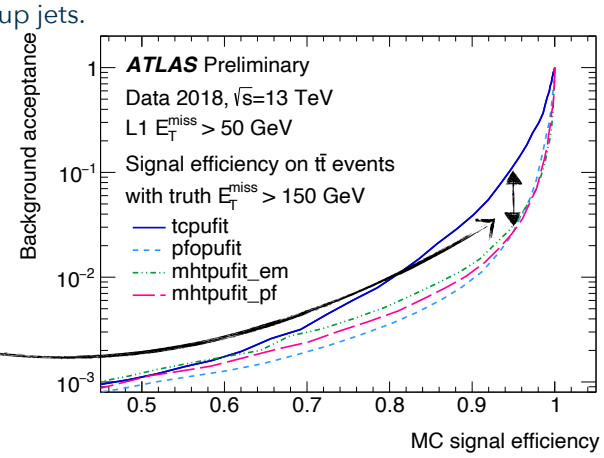
Highest Signal efficiency

pfopufit – replaced Run 2 TC's with Particle Flow Objects (PFO's). Improved hard-scatter vs. pile up categorisation. Made possible due to improved tracking capabilities. Running tracking on a subset of the full events selected online using only calorimeter information.

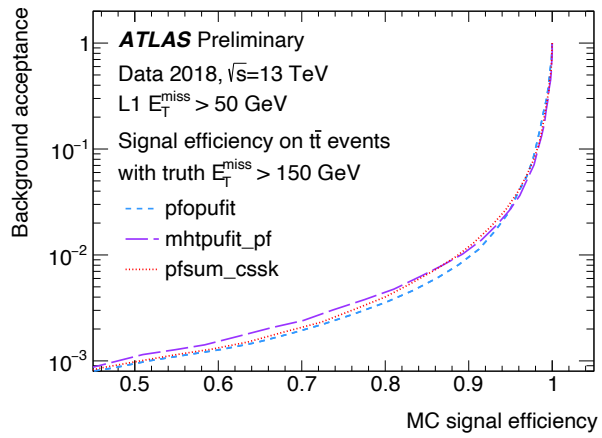
mhtpufit em/pf – Use EM scale/Particle Flow jets passing Jet Vertex Tagger selections to remove pileup jets.

@ 95% Efficiency

~60% less background rate



pfsum cssk – replaced TC's with Particle Flow Objects (PFO's). While also implementing jet energy subtraction. Using the constituent subtraction method to correct for pileup.



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References:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/L1CaloTriggerPublicResults; https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MissingEtTriggerPublicResults; ATLAS Collaboration, Technical Design Report, ATLAS Liquid Argon Calorimeter Phase-I Upgrade, ATLAS-TDR-022; ATLAS Collaboration, Technical Design Report for the Phase-I Upgrade of the ATLAS TDAQ System, ATLAS-TDR-023; ATLAS Collaboration, Performance of the missing transverse momentum triggers for the ATLAS detector during Run-2 data taking, https://arxiv.org/abs/2005.09554