The ATLAS Transverse Momentum Trigger Evolution at the LHC towards Run II
Antonia Strübing (Radboud U., Nikhef)
on behalf of the ATLAS collaboration

Introduction
The transverse momentum triggers of the ATLAS experiment at the CERN Large Hadron Collider (LHC) are designed to select collision events with non-interacting particles passing through the detector. Such events provide an interesting probe for new physics interactions beyond the Standard Model, but also provide the basis for precise measurements of Standard Model parameters such as the Higgs couplings. The transverse momentum used in the trigger system is calculated from calorimeter-based global energy sums and supplemented with information from the muon detection system. The trigger operated successfully during the first running period of the LHC. With the start-up in 2015, the LHC is now operating at a higher centre-of-mass energy and increased luminosity, both making it challenging to improve on the Run I performance. A brief summary of the Run I performance studies will be presented, together with the Run II software and hardware-based improvements as well as some of the first results from the Run II data-taking period with √s = 13 TeV.

Emiss trigger algorithms
From the start of data taking in 2011 to the preparation for Run II the missing transverse momentum (MET) trigger underwent several changes.

Trigger structure in 2011:
- calorimeter MET (Level 1) → cell based MET (Event Filter)
- Level 1 MET → firmware MET (Level 2)
- → cell and cluster based MET (Event Filter)

2015: upgraded Level 1 MET
- → High Level Trigger (HLT) merging Level 2 and Event Filter: several cell, cluster and jet based MET

The first level is a hardware based trigger the other levels are software based. The Level 1 output consists of the Regions of Interest (RoIs) which are processed by the Level 2. At the last level, the Event Filter has access to the whole event data.

Calorimeter trigger towers
Calorimeter cells

Level 1 (L1)
Sum over towers in ∆η × ∆Φ = 0.2 × 0.2 for |p_T|>2.5
Energy granularity = 1 GeV
L1 MET decision - Regions of Interest

Level 2 (L2)
Use of firmware to sum over Front-End Boards (FEB) → typically ~128 calorimeter cells, E = 3 o zero suppression
L2 MET decision

Event Filter (EF)
Sum over cells
Full +180K cell granularity, E > 2 o, E > 5 o in 2012
Hadron cluster similar to offline MET reconstruction.
Hadronic cluster (below)
 clustering algorithm similar to offline MET reconstruction.
Seed cells of |E| > 4 o, surrounding cells of |E| > 2 o, add all immediate neighbours, Hadronic calibrations.


Run I performance
Missing Transverse Momentum Significance (XS) trigger algorithms
The XS significance is defined as XS = Emiss/σ. Where σ is the resolution of Emiss. For each bin in ΣE_p, a gaussian fit of the corresponding Emiss is performed. σ is then parameterised as σ = a + b (ΣE_p).

As shown above, XS changes only slowly with p_T while Emiss strongly depends on it. For this reason, XS triggers are useful to keep some low Emiss events with too high Emiss trigger prescales. XS is never fully efficient therefore also accepts events with Emiss over a certain threshold.

Comparison to offline algorithms
Comparisons show that the new and improved online trigger algorithms in 2012 have a better correlation to offline reconstructed Emiss than the algorithms used in 2011.

Developments for Run II and first data in 2015 with √s = 13 TeV
Trigger developments for Run II
The trigger upgrade of Run II comes with increased pile-up conditions. For √s = 13 TeV about 55 - 80 collisions per bunch crossing are expected. This will deteriorate the missing transverse energy resolution and therefore the ATLAS sensitivity to signals with Emiss. To face these challenges there are several developments for the trigger algorithms.

New algorithm at first trigger level
The new Kalman Filter Emiss algorithm (KF-XE) uses offline information to down grade pile-up jets. This ensures that the initial MET is really generated by the hard scattering event. The corrections to the initial Emiss use the initial calorimeter jets and are calculated using the Kalman filter algorithm on a training sample with high pile-up.

The resulting corrections are applied using a binned lookup table depending on the initial jet p_T and n_jets.

Kalman MET

New HLT algorithms

For Run II, the two software based trigger levels, Level 2 and Event Filter, are merged to High Level Trigger (HLT). At HLT level there are three new algorithms which aim at reducing pile-up dependency.

- A cluster algorithm with hadronic calibration which subtracts average n_jets dependent pile-up energy per unit area.
- A cluster algorithm with hadronic calibration that requires at least one jet and performs a fit in which the total pile-up Emiss is constrained to zero.
- A jet energy sum algorithm that uses the reclustered jets n_jets.

Conclusion
The constant improvement throughout Run I led to reliable Emiss triggers for the ATLAS experiment. With the new development of intelligent trigger algorithms which reduce the dependency on pile-up both on Level 1 and HLT level the ATLAS trigger is well prepared to face the challenges of high pile-up conditions.

Contact: antonia.stroubing@cern.ch

LEPTON-PHOTON 2015, 17 - 22 August, Jülich