Electron and photon identification in the trigger and offline

Offline identification
- Electron and photon identification is accomplished by a set of $(\eta, p_T)$-dependent cuts on identification variables [4, 5].
- Three operating points defined for electrons (loose, medium, tight) and two for photons (loose, tight) at defined levels of background rejection.
- Re-optimised selection criteria provide three additional operating points (loose $\pm$, medium $\pm$, tight $\pm$) with improved performance over the standard criteria for a higher pileup environment.
- Identification of electrons and photons at the HLT uses similar to offline variables.
- Electron identifications, loose, medium and tight 1 were implemented to trigger on plus-plus electrons.

Event Filter
- The event is tagged by the missing transverse energy $E_{T}^{\text{miss}}$.
- To reflect this change in the L1 seed the letter 'h' is added to the trigger name.

Efficiency $\approx 2\%$.

The A T L A S physics programme relies on the efficient performance of the trigger system to select potentially interesting events from the QCD background processes dominant at the LHC. Events with electrons and photons in the final state are important for many physics studies including Standard Model (SM) precision physics such as top and W cross-sections and searches for new physics.

The A T L A S trigger system [1, 2] comprises a hardware-based Level-1 (L1) trigger and a software-based High Level Trigger (HLT), subdivided into the Level-2 (L2) and Event Filter (EF). During 2011 the L1 output rate was kept below 60 kHz, L1 below 5 kHz and the EF output rate at around 400 Hz averaged over the LHC fills [3]. The bandwidth allocated to the $(\eta, p_T)$ triggers was approximately 30% of the total EF output rate. The full list of signatures that trigger the acquisition of an event is defined in the trigger menu which evolved as the instantaneous luminosity delivered by the LHC increased.

Electron trigger performance
- Single and di-electron triggers are used in a variety of analysis from SM single vector boson to di-boson and Top production studies as well as for searches beyond the Standard model and Higgs.
- Single electron triggers
  - The efficiencies of the HLT electron selection were measured with respect to offline electrons on $Z \rightarrow e e$ events using a Tag&Probe method (Fig 4).
  - Between 25 and 35 GeV the efficiency is slowly increasing before finally reaching the plateau value at about 35 GeV.
  - Inefficiencies of these triggers mainly arise from the resolution of reconstruction and identification variables at the HLT with respect to offline. Due to timing constraints the HLT reconstruction algorithms (especially the L2 tracking) are less refined than the corresponding offline algorithms.

Photon trigger performance
- The g0-loose and g0-loose photons triggers were the lowest upscaled single photon triggers in different periods of 2011 and along with g20-loose are used in many analysis such as SM photon cross section, $W \rightarrow \gamma\gamma$ and searches for physics beyond the SM.
- The efficiencies of the photon triggers were measured on data using a Bootstrap approach.
- In this method efficiency is calculated with respect to an HLT unbiased low-threshold L1 trigger.
- The photon trigger efficiencies show rapid turn-on curves with no significant dependence on the offline photon $\eta$.

Supplementary triggers
- $J/\psi$ and $\psi$ Tag&Probe triggers provide a significant contribution to the 2011 measurements of the offline electron identification efficiencies especially in the low and medium $p_T$ ranges.
- $J/\psi$ triggers
  - Di-electron triggers were developed to record $J/\psi \rightarrow e^+e^-$ events.
  - These triggers require tight identification criteria for one electron (tag) and a very loose selection on the other electron (probe) with an invariant mass cut on the pair between 1 and 6 GeV.
  - In 2011 $J/\psi$ triggers provided $\approx 12,500$ probes in the $p_T$ range 15-20 GeV and $\approx 47,500$ probes in the $p_T$ range 5-15 GeV range.
- W Tag&Probe triggers
  - These triggers are designed to select $W$ candidates decaying to an electron and a neutrino.
  - The event is tagged by the missing transverse energy $E_{T}^{\text{miss}}$ (with cut applied on the $E_{T}^{\text{miss}}$ significance) of the neutrino and the electron probe has the least possible identification bias.
  - In 2011 W Tag&Probe triggers provided $\approx 55000$ probes in the $p_T$ range 15-20 GeV and $\approx 19000$ probes in the $p_T$ range 20-25 GeV.

Supporting triggers for background estimations
- A variety of triggers were developed to collect background-enriched samples for data-driven studies of background contamination in physics analyses or assess and monitor the HLT performance.

References

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As the instantaneous luminosity $(\mathcal{L})$ of the LHC increased, numerous measures were taken to control the overall output rate of the $e/\gamma$ triggers.

L1 optimisation
- September 2011 $(\mathcal{L} > 3 \times 10^{31} \text{cm}^{-2} \text{s}^{-1})$ Optimisation of thresholds and a hadronic leakage requirement were applied on EM10 and EM16 (numbers refer to cluster $E_T$, thresholds) which were subsequently re-named as EM10VH and EM16VH.

L1-HTL threshold separation
- Differences between the HLT and L1 thresholds were reduced for some triggers (to keep the L1 rates within the allowed bandwidth without raising the threshold at HLT).
- To reflect this change in the L1 seed the letter ‘l’ was added to the HLT trigger name (for example, the 2e12 medium was changed to 2e12lT medium).

HLT optimisation
- August 2011 $(\mathcal{L} > 2 \times 10^{31} \text{cm}^{-2} \text{s}^{-1})$: EF threshold for the single electron trigger was raised from 20 GeV to 22 GeV. At L2, the medium and tight electron identification criteria were brought closer to the EF level.
- September 2011 $(\mathcal{L} > 3 \times 10^{31} \text{cm}^{-2} \text{s}^{-1})$: Reoptimisation or electron identification criteria were deployed, moving from the medium to medium1 selections.

With above strategy the single electron trigger rate was kept below 70 Hz during 2011 (Fig 1).

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