ATLAS Electron and Photon Trigger Performance in Run 1 and Developments toward Run 2

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Introduction

Electron and photon triggers are essential for signal selection in a wide variety of ATLAS physics analyses to study Standard Model processes and to search for new phenomena. Final states including leptons and photons had, for example, an important role in the discovery and measurement of the Higgs particle. The ATLAS trigger system comprises a hardware-based Level1 (L1) and a software based High Level Trigger (HLT), which is divided into Level2 (L2) and Event-Filter (EF). The increasing luminosity and the more challenging pile-up conditions demanded the optimization of the trigger selections at each level to control rates and keep efficiencies high. During the LHC Run1 proton-proton data-taking period, the L1 rate was kept below 70 kHz, L2 below 6.2 kHz and the EF output rate around 0.57 kHz. The bandwidth allocated to the e/γ triggers was more than 20% of the total EF output rate.

Electron and photon identification in the trigger system

- The L1 system uses reduced granularity to find electromagnetic (EM) energy deposits which then seed the HLT reconstruction.
- Identification relies on shower shape variables to discriminated against the background, and in the case of electrons also on track quality, track-cluster matching variables and electron identification information from the Transition Radiation Tracker.
- For the main physics triggers in Run I, loose and medium requirements were used in the trigger both for electrons and photons.
- The online electron and photon identification criteria at HLT are similar but slightly looser than their offline equivalents.

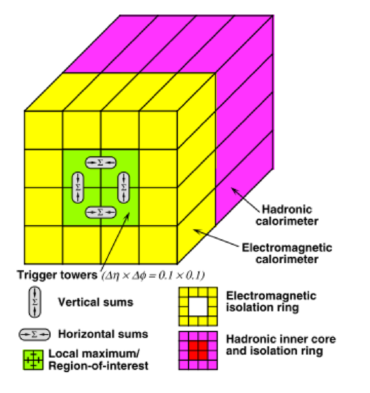

Figure 1: L1 EM clustering.

Trigger menu and rates evolution

As the instantaneous luminosity of the LHC increased during Run I, the trigger menu was adjusted a few times to control the overall rate of e/γ triggers.

L1 optimisation

- for 2011: optimisation of E_T thresholds for different η bins (indicated by "v" in the HLT trigger name) and a veto on hadronic leakage, $H \leq 1$ GeV ("h" in the HLT trigger name) [1];
- for 2012: E_T threshold was increased up to at least 18 GeV depending on η and a veto applied on hadronic leakage. For the dielectron trigger, the L1 E_T threshold was raised close to that of the HLT (indicated by "T" in the trigger name).

HLT optimisation

- for 2011: EF E_T threshold for the single electron trigger was increased from 20 GeV to 22 GeV, and electron identification criteria were re-optimised [1];
- for 2012: EF E_T threshold for the single electron trigger was increased to 24 GeV and a cut on track isolation was introduced: the sum of track p_T in cone of $\Delta R < 0.2$ around the electron track has to be less then 10% of electron E_T (letter 'i' in the name of trigger). Main physics trigger: e24vhi_medium1.

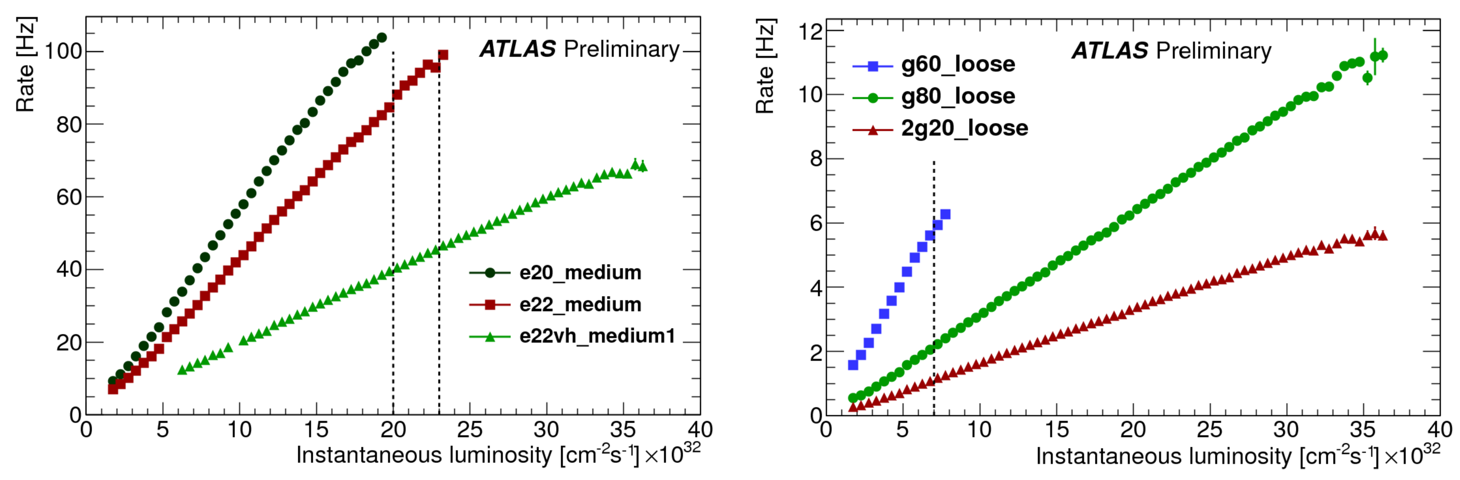

Figure 2: EF output rates in 2011 of the primary (lowest unprescaled) electron (left) and photon (right) triggers as a function of instantaneous luminosity. Vertical dashed lines mark the maximum instantaneous luminosity where a given trigger was used as main physics trigger.

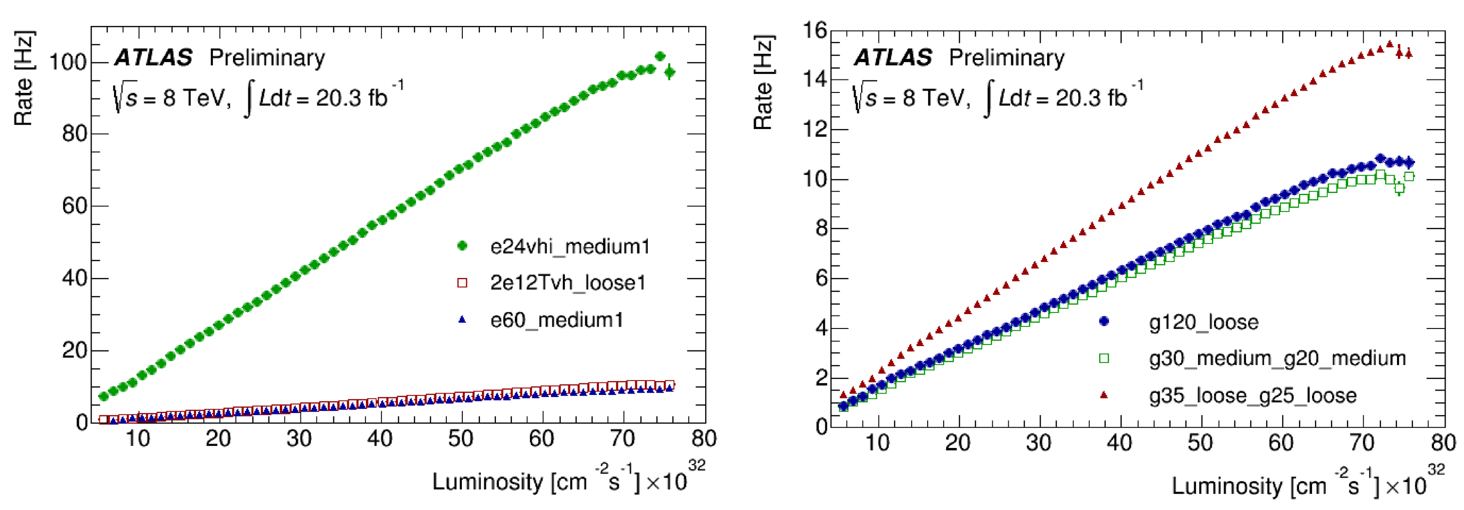

Figure 3: EF output rates in 2012 of the primary (lowest unprescaled) electron (left) and photon (right) triggers as a function of instantaneous luminosity.

The rates show a linear increase as a function of the instantaneous luminosity despite the increased pileup both in 2011 (Fig. 2) [1] and in 2012 (Fig. 3) [5].

HTL tracking performance

- The efficiency of the HLT tracking algorithms (Fig. 4) was measured on data using events selected by HLT tracking monitoring triggers [3] and was found very high, with only a few % loss, for both years.
- The increase of efficiency for 2012 is due to an improved tracking algorithm.

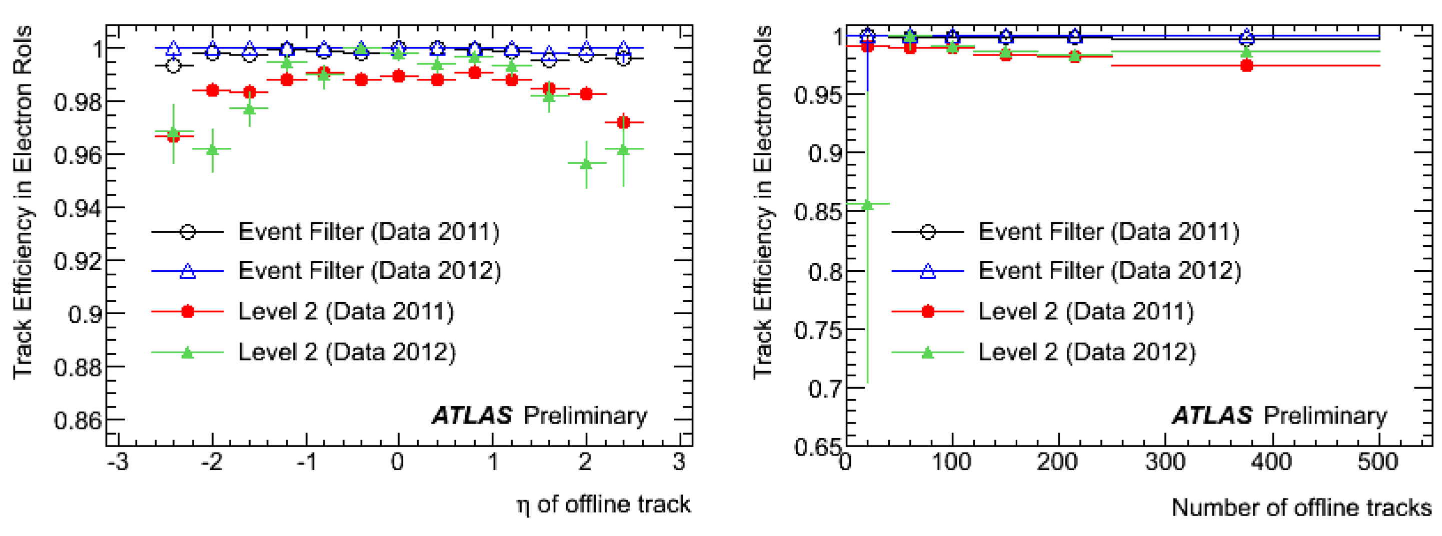

Figure 4: The efficiency of the L2 and EF tracking as a function of the η (left) and the number of offline tracks (right) for offline *medium* electrons.

Electron trigger performance

- The efficiencies of single electron triggers were measured using a *Tag&Probe* method on $Z \to ee$ events.

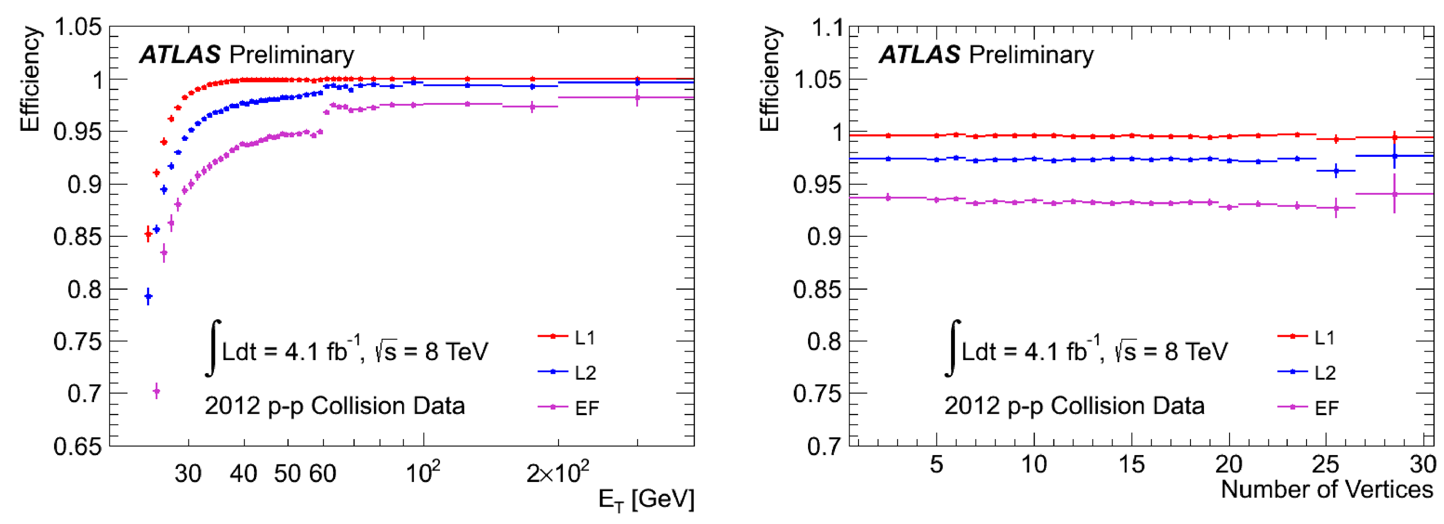

Figure 5: L1, L2 and EF trigger efficiencies as functions of the offline-reconstructed electron E_T (left) and as a function of the number of offline-reconstructed primary vertices (right) for main single electron triggers (e24vhi_medium1 OR e60_medium1) in 2012 with respect to *medium* offline electrons with $E_T > 25$ GeV and $|\eta| < 2.47$, excluding the transition region between the barrel and end cap electromagnetic calorimeters at $1.37 < |\eta| < 1.52$.

- The trigger e24vhi_medium1 requires a trigger electron object with $E_T > 24$ GeV that passes the online *medium* identification requirements and is isolated from other activity in the detector. The hadronic veto requirement at L1 and isolation criteria at EF cause losses for high E_T electrons, thus the trigger is complemented with a higher threshold non-isolated electron trigger, e60_medium1. The resulting gain in the efficiency at $E_T = 60$ GeV is visible on the left of Fig. 5.
- The re-optimised *medium* selection in 2012 was robust against pileup effects (right of Fig. 5).

Photon trigger performance

The efficiencies of the single photon triggers were measured using two approaches: using a bootstrap method with respect to a low-threshold L1 trigger and using a clean sample of radiative Z decays ($Z \to ll\gamma$) (Fig. 6) [5].

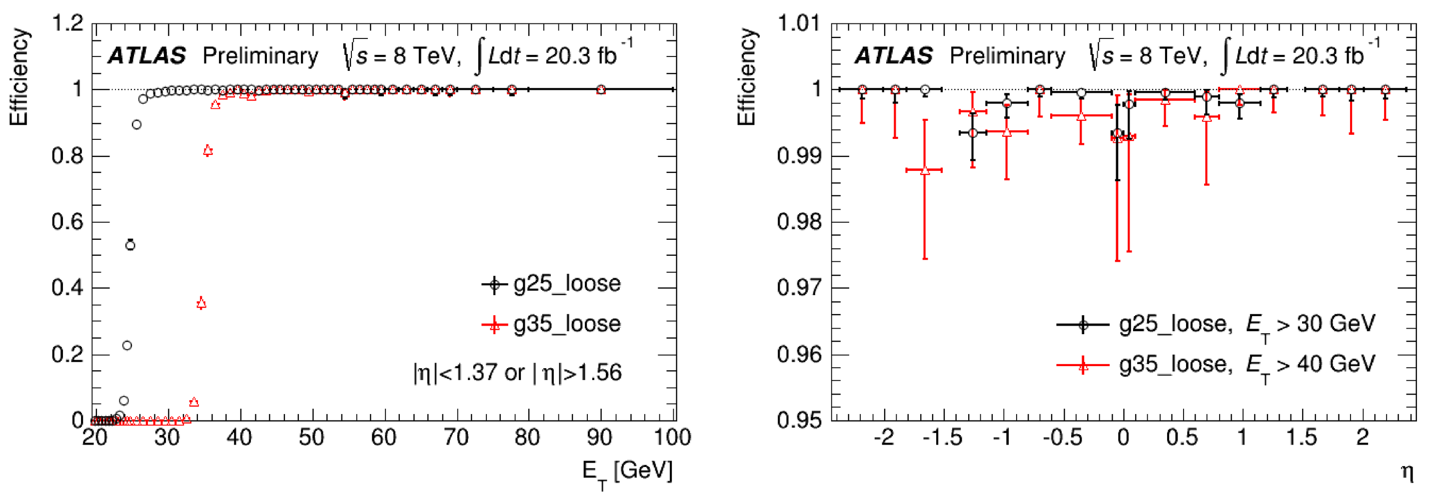

Figure 6: Efficiencies of single photon triggers with respect to offline tight photons as function of offline E_T (left) and η (right), as measured in $Z \to ll\gamma$ events.

Plans for Run II

Changes for Run II at LHC:

- increasing the center-of-mass energy to 13 TeV,
- increasing the instantaneous luminosity to about 1.6×10^{34}cm^{-2}s^{-1},
- resulting in an average number of interactions per bunch-crossing of about 46 (for 25 ns bunch spacing).

ATLAS TDAQ update:

- The ATLAS readout configuration will be changed to allow a L1 accept rate of 100 kHz (70 kHz for Run I).
- The new ATLAS computing model will allow an average EF output rate of 1000 Hz ($\sim$600 Hz for 2012).
- The possibility to define topological triggers already at L1 will be introduced.
- The hardware-based Fast Tracker system (FTK) will provide track information at the input of L2 and allow fast vertex reconstruction.

Changes in trigger menu:

- for L1: applying higher E_T threshold and an EM ring isolation cut. Fig. 7 shows the performance improvements for various EM isolation cuts for different L1 thresholds. Fig. 8 [2] presents the L1 efficiency for an operating point with $E_T > 25$ GeV that is close to planned setup in Run II ($E_T > 24$ GeV, $I \leq 2$ GeV, $H \leq 1$ GeV, with η-dependent E_T threshold).
- for HLT: raising E_T threshold to 28 GeV and tightening online electron identification close to the offline *tight* selection. The track isolation criteria is expected to stay the same as for the end of Run I [6].

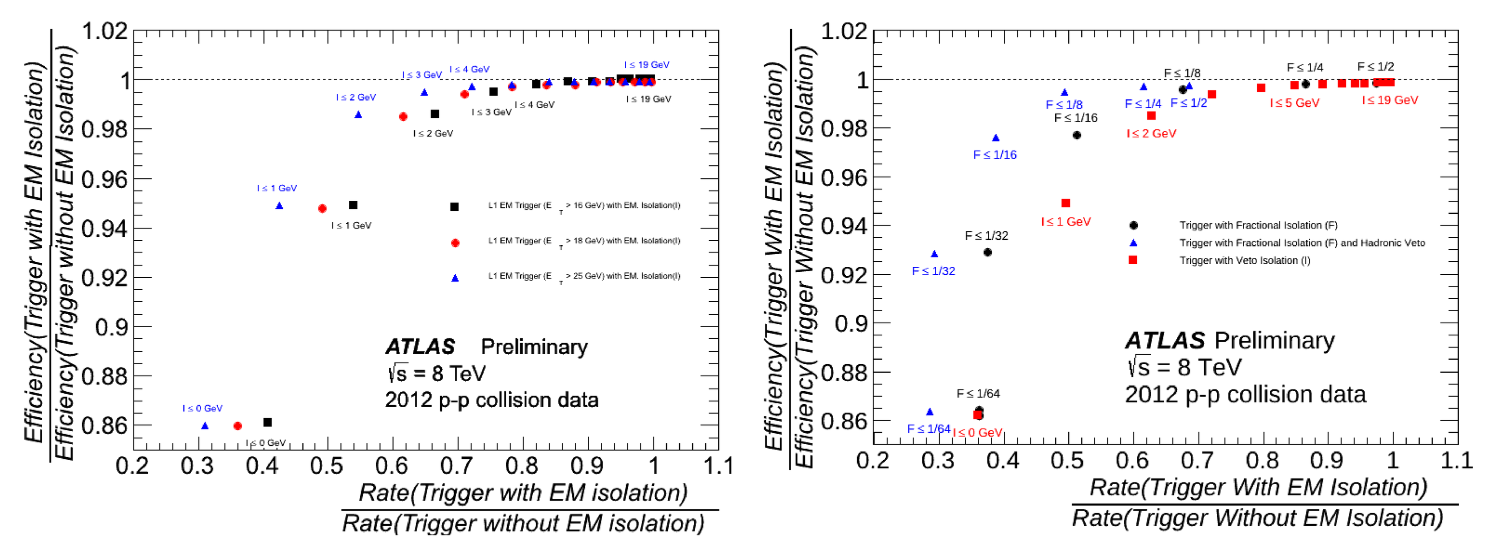

Figure 7: Effect of L1 EM ring isolation criteria on the efficiency and the expected rate for L1 triggers with different E_T thresholds: $E_T > 16$ GeV (both plots), $E_T > 18$ GeV and $E_T > 25$ GeV (left). Both absolute (left) and relative (right) isolation cuts are considered, as well as the effect of the veto on hadronic leakage (right). On the left, the veto on hadronic leakage is always applied.

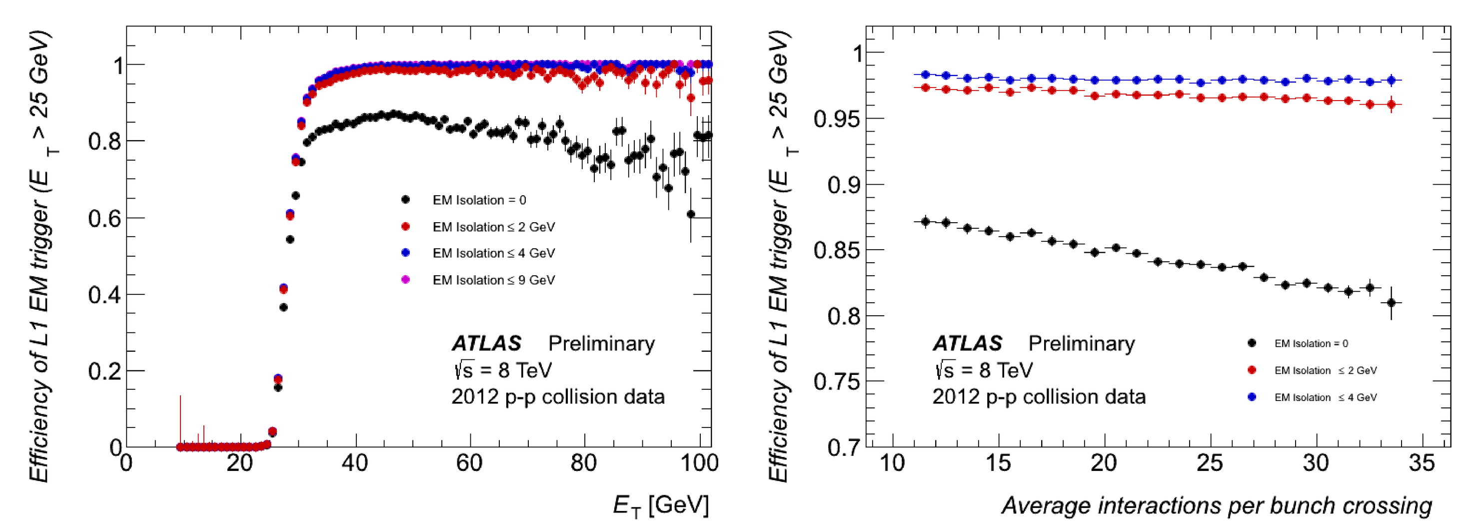

Figure 8: Efficiencies of L1 triggers with $E_T > 25$ GeV with optimisation of threshold depending on η, hadronic leakage and electromagnetic ring isolation requirements as a function of offline electron E_T (left) and average number of interactions per bunch crossing (right).

References

[1] The ATLAS Collaboration, *Performance of the ATLAS Electron and Photon Trigger in p-p Collisions at $\sqrt{s} = 7$ TeV in 2011*, ATLAS-CONF-2012-048 (2012), http://cdsweb.cern.ch/record/1450089.

[2] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/L1CaloTriggerPublicResults

[3] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HLTTrackingPublicResults

[4] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EgammaTriggerPublicResults

[5] https://cds.cern.ch/record/1706278

[6] The ATLAS Collaboration,ATLAS Trigger Menu and Performance in Run I and Prospects for Run II https://cds.cern.ch/record/1621660