Measuring 2012 ATLAS Photon Trigger Efficiency

David Layden

McGill University, University of Waterloo
dlayden@uwaterloo.ca

August 22, 2013

1 Analysis

The measurement of inclusive photon production cross section requires one to know the efficiencies of the triggers which selected the photons used in the study. Thus, the criteria which define the set of photons considered in this trigger analysis are dictated by the photon production cross section study, which aims to test Standard Model predictions in a new energy regime. This work focuses on the *g20_loose* trigger chain, as the efficiencies of the higher E_T photon triggers, which are also required to measure inclusive photon cross section, are measured with respect to ϵ_{g20_loose}.

This analysis was conducted using ROOT, with scripts written in Python.

1.1 Offline Selection

We began our analysis by excluding events for which the ROOT `TTileTripReader` function returned `True`. For each offline-identified photon in the remaining events, we defined a corrected energy, `ecor`, using the `egRescaler.EnergyRescalerUpgrade()` tool, accounting for whether or not the photon was converted. We then defined photon transverse energy and momentum as `ecor`$/\cosh(\eta)$. Using the ROOT `PhotonIDTool`, we assigned to each photon a Boolean value, `isTight`, indicating whether or not it met offline *tight* requirements, based on the output of `PhotonCutsTight(tTight)`, where `tTight = 2012`. Finally, for each event, we considered only the leading tight photon, meaning the offline photon with `isTight = True` with the highest E_T^γ. If an event contained no tight photons at this stage,s it was skipped altogether.

1.2 Bootstrap Method

One must use minimum bias events to compute the efficiency of *g20_loose*, although the relatively small number of these events makes it impossible to compute the efficiency directly in this manner. To improve our statistics, we chose to decompose the trigger chain efficiency using the bootstrap method.

For outcomes A and B belonging to a sample space Ω, the definition of conditional probability states that $P(A|B) = P(A \cap B)/P(B)$. Alternatively:

$$P(A \cap B) = P(A|B)P(B). \tag{1}$$

A photon passing *g20_loose* is synonymous with it passing *L1_EM12* and the HLT portion of *g20_loose* (comprised of *L2_g20_loose* and *EF_g20_loose*), which I will refer to as *HLT_g20_loose*. This fact allows us to use Eq. (1) to decompose the overall efficiency as

$$\epsilon_{g20\_loose} = \epsilon_{HLT\_g20\_loose\,|L1\_EM12} \times \epsilon_{L1\_EM12}. \tag{2}$$

I am using $\epsilon_{\alpha|\beta}$ to denote the efficiency of a trigger α with respect to events that have already passed the trigger β. Furthermore, to avoid overly cumbersome notation, I will leave the functional dependence of ϵ on E_T^γ implicit.

The advantage of decomposing ϵ_{g20_loose} as in Eq. (2), is that it allowed us to use different samples to calculate each term. To find ϵ_{L1_EM12} we still had to use minimum bias events, although the requirement that an event pass *L1_EM12* is much less restrictive than requiring that it pass the entire *g20_loose* chain, thus greatly improving our statistics. For the efficiency of *HLT_g20_loose* with respect to *L1_EM12*, we no longer needed to use minimum bias events. Instead, we started with the full dataset and considered only events which passed *L1_EM12*, although in doing so we had to be careful not to bias our sample.

Conceptually, to determine the efficiency of the HLT part of a chain with respect to the LVL1 component, we would divide the number of photons in a given energy bin that passed the HLT and LVL1 by the number that passed LVL1. However, due to the very nature of the trigger system, we don't have an accurate idea of the number which passed *only* LVL1. In order to resolve this problem, we limited ourselves to photons that were passed through *HLT_g20_loose*. This gave us an unbiased sample, from which we asked what fraction *would have* passed the HLT based on physics requirements, in a given energy bin.

We can also further decompose our efficiency into LVL2 and EF efficiencies, rather than lumping them together as the HLT. For an additional outcome $C \subseteq \Omega$, Eq. (1) can be generalized as

$$P(A \cap B \cap C) = P(A|B)P(B|C)P(C), \tag{3}$$

which gives us the decomposition

$$\epsilon_{g20\_loose} = \epsilon_{EF\_g20\_loose\,|L2\_g20\_loose} \times \epsilon_{L2\_g20\_loose\,|L1\_EM12} \times \epsilon_{L1\_EM12}. \tag{4}$$

1.3 Trigger Decision Details

We used the `PyTrigDecisionToolD3PD` tool throughout our analysis to extract trigger information from event data. For a given event, one can call the Trigger Decision tool with the name of a trigger (e.g., *L1_EM12*) and a decision type (e.g., `Physics`, `PassedThrough` etc.), for which the tool returns a Boolean value, indicating whether or not an event passed the selected trigger in the specified mode. For example, the tool will return `True` for *L2_g20_loose* and `Physics` if the event in question passed the trigger because it satisfied the right physical requirements. Note that the decision types are not mutually exclusive, in that an event can, for example, return `True` for `Physics` and `passedThrough`, meaning that the event was passed through the trigger, but *would* have satisfied the right physical requirements.

The decision type `L1_TBP` provides the decision of LVL1 triggers *before* prescaling—a particularly convenient option, given that LVL1 triggers are often heavily prescaled. Unfortunately, there is no equivalent decision type for HLT triggers.

1.4 Histogram Criteria

In order to use Eq. (2) to decompose the efficiency, we measured the efficiency of the LVL1 triggers and the HLT (with respect to LVL1) separately. To do so, we made subsamples according to the criteria in Tables (1) and (2), binned the events contained therein by photon transverse energy, and divided the numerator histogram by the denominator.

	Trigger Requirement	Decision Type
Numerator	*EF_rd0_filled_NoAlg*	`Physics`
	L1_EM12	`L1_TBP`
Denominator	*EF_rd0_filled_NoAlg*	`Physics`

Table 1: LVL1 Histogram Criteria

	Trigger Requirement	Decision Type
Numerator	*L1_EM12*	`Physics`
	L2_g20_loose	`passedThrough`
	L2_g20_loose	`Physics`
	EF_g20_loose	`passedThrough`
	EF_g20_loose	`Physics`
Denominator	*L1_EM12*	`Physics`
	L2_g20_loose	`passedThrough`
	EF_g20_loose	`passedThrough`

Table 2: HLT Histogram Criteria

We also further decomposed the *g20_loose* efficiency using Eq. (4), this time defining three subsamples according to Tables (1), (3) and (4). From these subsamples, we calculated the efficiency of each trigger component separately in the manner as described above, and multiplied the three resulting histograms together.

	Trigger Requirement	Decision Type
Numerator	*L1_EM12*	`Physics`
	L2_g20_loose	`passedThrough`
	L2_g20_loose	`Physics`
	EF_g20_loose	`passedThrough`
Denominator	*L1_EM12*	`Physics`
	L2_g20_loose	`passedThrough`
	EF_g20_loose	`passedThrough`

Table 3: LVL2 Histogram Criteria

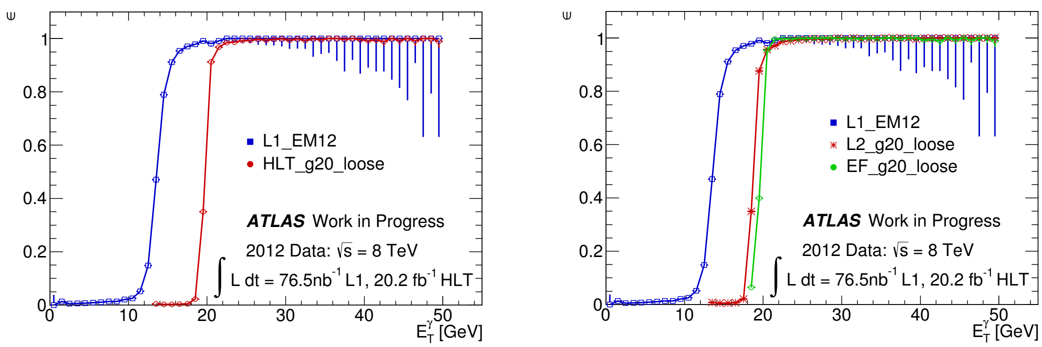
In the early stages of this analysis, we repeatedly measured an HLT efficiency turn-on curve that plateaued at 0.5 instead of at 1. Further examination revealed that the issue was with the EF efficiency, with respect to photons having passed LVL2. We found that by only considering events which were recorded without an EF prescale, we recovered the expected efficiency. This selection didn't have a major impact on the quality of our statistics, so we kept it throughout the rest of the analysis.

	Trigger Requirement	Decision Type
Numerator	*L1_EM12*	`Physics`
	L2_g20_loose	`Physics`
	EF_g20_loose	`passedThrough`
	EF_g20_loose	`Physics`
Denominator	*L1_EM12*	`Physics`
	L2_g20_loose	`Physics`
	EF_g20_loose	`passedThrough`

Table 4: EF Histogram Criteria

2 Results

Using the criteria defined in § 1.4, we created numerator and denominator histograms for *L1_EM12* and *HLT_g20_loose* (with respect to *L1_EM12*) and divide them to get the LVL1 and HLT efficiencies of the *g20_loose* trigger chain, shown in Fig. (1a).



(a) $\epsilon_{HLT\_g20\_loose\,|L1\_EM12}$ & ϵ_{L1_EM12} vs. E_T^γ

(b) $\epsilon_{EF\_g20\_loose\,|L2\_g20\_loose}$, $\epsilon_{L2\_g20\_loose\,|L1\_EM12}$ & ϵ_{L1_EM12} vs. E_T^γ

Figure 1: Measured efficiency curves for the various components of the *g20_loose* trigger chain.

We performed a similar procedure using Eq. (4) and considered *L2_g20_loose* and *EF_g20_loose* separately. The efficiencies resulting from this approach are shown in Fig. (1b).

Using either approach, the resulting efficiencies can be multiplied together to yield the full *g20_loose* efficiency, as shown in Fig. (2). Note that both methods gave the same results (including uncertainties), as this fact represents an important crosscheck.

Upon examination of the efficiency turn-on curves in Fig. (2), one finds that ϵ_{g20_loose} reaches a plateau near 100% at $E_T^\gamma = 23$ GeV.

3 Conclusions

Despite our use of the bootstrap method, the lower uncertainties in the high-E_T^γ region remain rather large. The limiting factor here seems to be in the *L1_EM12* efficiency, due to the limited number of minimum bias events, and the falling transverse energy spectrum of leading photons.

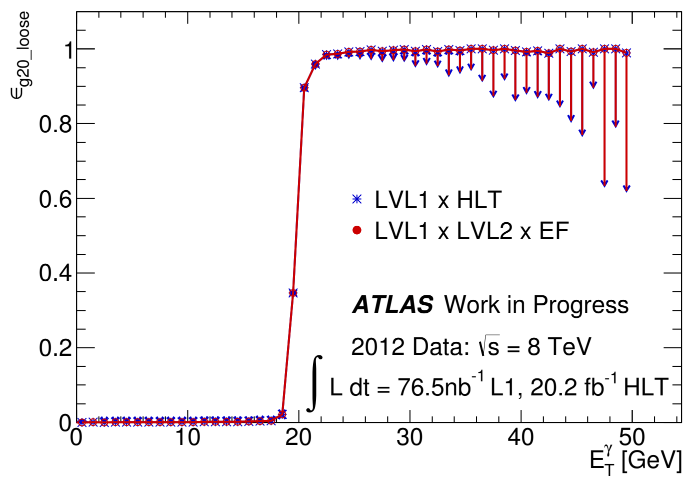


Figure 2: ϵ_{g20_loose} vs. E_T^γ measured in two different ways.

Nevertheless, the measured efficiency of *g20_loose* reaches a plateau above $E_T^\gamma = 23$ GeV, wherein it remains consistent with full efficiency to within $\sim 1\%$. The results do not differ depending on the bootstrap decomposition used (i.e., Eq. (2) or Eq. (4)).

The next step of the inclusive photon cross section analysis involves using a sort of bootstrap method to determine the efficiency of higher E_T-cutoff photon triggers, based on ϵ_{g20_loose}. If the uncertainties in the latter efficiency prove to be a limiting factor, we may complement this study with a radiative Z-decay analysis.

References

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