Measurement of the inclusive isolated prompt photon cross-section in pp collisions at √s = 7 TeV using 35 pb⁻¹ of ATLAS data

The MIT Faculty has made this article openly available. Please share how this access benefits you. Your story matters.

Citation

As Published
http://dx.doi.org/10.1016/j.physletb.2011.11.010

Publisher
Elsevier

Version
Final published version

Citable link
http://hdl.handle.net/1721.1/95931

Terms of Use
Creative Commons Attribution

Detailed Terms
http://creativecommons.org/licenses/by/3.0/
Measurement of the inclusive isolated prompt photon cross-section in \( pp \) collisions at \( \sqrt{s} = 7 \) TeV using 35 \( \text{pb}^{-1} \) of ATLAS data

ATLAS Collaboration

**Abstract**

A measurement of the differential cross-section for the inclusive production of isolated prompt photons in \( pp \) collisions at a center-of-mass energy \( \sqrt{s} = 7 \) TeV is presented. The measurement covers the pseudorapidity ranges \(|\eta| < 1.37 \) and \(1.52 \leq |\eta| < 2.37\) in the transverse energy range \(45 \leq E_T < 400\) GeV. The results are based on an integrated luminosity of 35 \( \text{pb}^{-1} \), collected with the ATLAS detector at the LHC. The yields of the signal photons are measured using a data-driven technique, based on the observed distribution of the hadronic energy in a narrow cone around the photon candidate and the photon selection criteria. The results are compared with next-to-leading order perturbative QCD calculations and found to be in good agreement over four orders of magnitude in cross-section.

The production of prompt photons at hadron colliders provides means for testing perturbative QCD predictions [1], providing a colorless probe of the hard scattering process. The measurement of the inclusive production of prompt photons could be used to constrain the parton distribution functions; in particular it is sensitive to the quark content of the proton [2] through the \(gg \rightarrow q\bar{q}^{\gamma} \) subprocess, which at leading order dominates the inclusive prompt photon cross-section at the LHC.

ATLAS has recently published a measurement of the inclusive photon cross-section in \( pp \) collisions at \( \sqrt{s} = 7 \) TeV using an integrated luminosity of 880 \( \text{nb}^{-1} \) [3]; a similar measurement has been performed by the CMS Collaboration [4] using an integrated luminosity of 2.9 \( \text{pb}^{-1} \). Analogous measurements have been performed in \( pp \) collisions at a lower center of mass at the Tevatron [5,6], and in deep inelastic \( ep \) scattering at HERA [7,8]. This Letter presents the measurement of the differential production cross-section of isolated prompt photons with transverse energies \( E_T \) above 45 GeV using 34.6 \( \pm 1.2 \) \( \text{pb}^{-1} \) of \( pp \) collision data at \( \sqrt{s} = 7 \) TeV collected in 2010. Isolated prompt photons in the pseudorapidity ranges \(|\eta| < 0.6, 0.6 \leq |\eta| < 1.37, 1.52 \leq |\eta| < 1.81\) and \(1.81 \leq |\eta| < 2.37\) are studied.

In the following, all photons produced in \( pp \) collisions and not coming from hadron decays are considered as prompt: they include both direct photons, which originate from the hard subprocess, and fragmentation photons, which are the result of the fragmentation of a colored high-\( p_T \) parton [9,10]. Isolated photons are considered: from a theoretical perspective, photons are isolated if the transverse energy \( E_T^{\text{iso}} \), within a cone of radius \( R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2} = 0.4\) centered around the photon direction in the pseudorapidity \( (\eta) \) and azimuthal angle \( (\phi) \) plane, is smaller than \( E_T^{\text{iso}} \). In JetPHOX [9], used for next-to-leading order (NLO) calculations, \( E_T^{\text{iso}} \) is calculated from all partons. Similarly, a corresponding isolation prescription is applied experimentally on the reconstructed objects, based on the energy reconstructed in an \( R = 0.4 \) cone around the photon candidate, corrected for the effects associated with: the energy of the photon candidate itself, the underlying event and the collision pileup [3]. The main background to these isolated prompt photons is composed of photons from decays of light neutral mesons, such as the \( \pi^0 \) or \( \eta \).

Photons are detected in ATLAS by a lead-liquid Argon sampling electromagnetic calorimeter (ECAL) with an accordion geometry, divided into a barrel section covering the pseudorapidity region \(|\eta| < 1.475\) and two endcap sections covering the pseudorapidity regions \(1.375 < |\eta| < 3.2\). It consists of three longitudinal layers. The first layer has a high granularity along the \( \eta \) direction (between 0.003 and 0.006 depending on \( \eta \), with the exception of the regions \(1.4 < |\eta| < 1.5\) and \(|\eta| > 2.4\)), sufficient to provide an event-by-event discrimination between single photon showers and...
showers coming from a $\pi^0$ decay. The second layer has a granularity of 0.025 × 0.025 in $\eta \times \phi$. A third layer is used to correct for the leakage beyond the electromagnetic calorimeter for high-energy showers, while in front of the accordion calorimeter a thin presampler layer, covering the pseudorapidity interval $|\eta| < 1.8$, is used to correct for the energy absorbed before the calorimeter.

The ECAL energy resolution is parametrized as $\sigma(E)/E = a/E (\text{GeV}) + c$ with the largest contribution coming from the sampling term $a$, corresponding to approximately 10% (20%) in the barrel (endcap) region. For energies above 200 GeV the global constant term $c$, estimated to be $(1.2 \pm 0.6)\% ((1.8 \pm 0.6)\%)$ in the barrel (endcap) for the 2010 data, starts to dominate [11]. In front of the electromagnetic calorimeter the inner detector allows the reconstruction of tracks from the primary vertex presented below. The same trigger condition was used for the generator and the parton shower model, alternative samples are used to correct for the energy absorbed before the calorimeter.

Clusters containing cells overlapping with the conversion products due to meson decays) are rejected. The selection criteria have been determined after correcting the simulated shower shapes for the material. It varies between 1 and 2.5%, depending on $|\eta|$. The uncertainty associated with the imperfect knowledge of the material in front of the ECAL and converted photons separately. This helps to reduce the systematic uncertainties associated with the correction procedure. The

All photon candidates having reconstructed isolation energy $E_T > 3\text{ GeV}$ are considered as experimentally isolated. This definition is similar to applying a 4 GeV cut on the particle-level isolation, defined as the transverse energy of all stable particles in a cone of radius $R = 0.4$ around the photon direction (with the underlying event removed as before). The small difference between the two, caused by noise and other detector effects, is taken into account in the uncertainties associated with the photon reconstruction efficiency $\varepsilon_{\text{reco}}$ discussed below. The particle-level isolation can in turn be related to the parton-level isolation in JETPHOX that is used for the NLO predictions. The efficiency of the isolation criteria is found to be similar (i.e. within a few percent) at both the particle-level and the parton-level for simulated photons passing the selection described below.

As in Ref. [3], the reconstruction and preselection efficiency $\varepsilon_{\text{reco}}$ is computed from simulated prompt photons as a function of the true photon $E_T$. It is defined as the ratio between the number of photons reconstructed in a given $|\eta|$ interval with reconstructed $E_T > 3\text{ GeV}$, and the total number of true prompt photons with true pseudorapidity in the same $|\eta|$ interval, and with particle-level transverse isolation energy $< 4\text{ GeV}$. The estimated $\varepsilon_{\text{reco}}$ for photons with $45 < E_T < 400 \text{ GeV}$ is $\sim 85\%$ (75%) in the barrel (endcap) region. The main inefficiency ($\sim 10\%$) is due to the acceptance loss originating from a few inoperative optical links in the calorimeter readout. A similar reduction is caused by the isolation requirement in the pseudorapidity region $1.52 < |\eta| < 1.81$ where the calorimetric isolation suffers from larger detector effects. The systematic uncertainty on $\varepsilon_{\text{reco}}$ associated with the experimental isolation requirement is evaluated from the prompt photon simulation by varying the value of the isolation criterion by the average difference ($\sim 500 \text{ MeV}$) observed for electrons from $W \rightarrow e\nu$ events in data and simulation. The estimated uncertainty varies between 3 and 4% depending on $\eta$. The uncertainty associated with the imperfect knowledge of the material in front of the ECAL is estimated by comparing the expected efficiencies in a sample simulated with the nominal ATLAS setup, and one with increased material. It varies between 1 and 2.5%, depending on $|\eta|$.

Shape variables computed from the lateral and longitudinal energy profiles of the shower in the calorimeters are used to discriminate signal from background [15,18]. As detailed in Ref. [3], selection criteria on these variables, optimized independently for unconverted and converted photons, are applied to reconstructed photon candidates. The requirements on these variables are applied in stages resulting in tight candidates: firstly jets are removed whilst still keeping a high photon efficiency and then secondly wide or closely spaced showers (i.e. those consistent with jets or meson decays) are rejected. The selection criteria have been revised to minimize the systematics on the efficiency extraction, especially in the region $1.81 < |\eta| < 2.37$. The photon identification efficiency $\varepsilon_{\text{ID}}$ is computed from simulation as a function of transverse energy in each pseudorapidity region. It is defined as the efficiency for reconstructed (true) prompt photons, with measured $E_T < 3\text{ GeV}$, to pass the identification criteria mentioned above.

Following the same method as in Ref. [3], the value of $\varepsilon_{\text{ID}}$ is determined after correcting the simulated shower shapes for the observed average differences with respect to data. In the present analysis, however, the corrections are estimated for unconverted and converted photons separately. This helps to reduce the systematic uncertainties associated with the correction procedure. The
Distributions of $E_T^{\gamma}$ for photon candidates with $45 < E_T < 55$ GeV in $|\eta| < 0.6$ passing the tight (solid dots) and non-tight (open triangles) shower-shape-based selection criteria. The non-tight distribution is normalized to the tight distribution for $E_T^{\gamma} > 5$ GeV (non-isolated region), where the signal contamination is fairly small.

As in Ref. [3], a two-dimensional-sideband method is used to estimate the background contribution from data and to measure the prompt photon signal yield. The two dimensions are the transverse isolation energy $E_{\text{iso}}$ and the quality of the photon, defined by whether or not it passes the shower shape identification criteria. On the isolation axis, the signal region contains photon candidates with $E_{\text{iso}} < 3$ GeV, while the sideband region contains non-isolated photon candidates with $E_{\text{iso}} > 5$ GeV. On the other axis, the signal photon candidates are required to pass the tight identification criteria (tight candidates). Those failing the tight isolation criteria but passing a background-enriching subset of these criteria (non-tight candidates) are contained in the sideband. A typical distribution of $E_{\text{iso}}$ for both tight and non-tight data is shown in Fig. 1 for photon candidates with $45 < E_T < 55$ GeV in $|\eta| < 0.6$. The non-tight distribution is normalized to the tight one above 5 GeV where a only small signal contamination is expected.

Corrections for the signal contamination in the background control regions are computed using prompt photon Monte Carlo samples. For the tight isolated signal leaking into the non-isolated region, these are as large as 17% at high $E_T$. Smaller leakages of up to 6% are expected for the other two background control regions. The purity of isolated prompt photons measured with this method increases with $E_T$ from 91% at $E_T = 45$ GeV to close to 100% at $E_T > 200$ GeV.

The measured inclusive isolated prompt photon production cross-sections are shown in Fig. 2. They are presented as a function of the photon transverse energy, for each of the four considered pseudorapidity intervals. They are also presented in tabular form in Appendix A. The error bars on the data points represent the combination of the statistical and systematic uncertainties: systematic uncertainties dominate over the entire kinematic range considered. The contribution from the luminosity uncertainty (3.4%) is shown separately as it represents a possible global change by a common multiplicative factor. The data agree with NLO pQCD calculations, obtained with JetPhox 1.2.2 [9] using the CTEQ 6.6 PDFs [20] and the BFG set II [21] fragmentation functions (FF). These predictions are negligibly affected when using BFG set I instead. The nominal renormalization, factorization and fragmentation scales are set to the $E_T$ of the photon. Theoretical calculations using MSTW 2008 [22] and NNPDF2.0 [23] PDFs show a similarly good agreement to data. The central values obtained with the MSTW 2008 (NNPDF2.0) PDFs are 3 to 5% (1 to 4%) higher than those predicted using the CTEQ 6.6 PDFs. The total systematic uncertainties on the theoretical predictions are represented with a solid band. The scale uncertainty (∼10%) is the leading theoretical systematic uncertainty. It is estimated from the envi-
Fig. 2. Measured (dots) and expected (shaded area) inclusive prompt photon production cross-sections, and their ratio, as a function of the photon $E_T$ and in the range (a) $|\eta| < 0.6$, (b) $0.6 \leq |\eta| < 1.37$, (c) $1.52 \leq |\eta| < 1.81$ and (d) $1.81 \leq |\eta| < 2.37$. The data error bars combine the statistical and systematic uncertainties, with the luminosity uncertainty shown separately (dotted bands).

lope of independent and coherent variations of the three scales, by a factor of two around the central value, with the renormalization scale (coherent variation) dominating this envelope at low (high) $E_T$, while the fragmentation scale produces the smallest variation. The scale error is summed in quadrature with the contributions from the PDF uncertainty (5% at 68% C.L.) and the uncertainty associated with the choice of the parton-level isolation criterion (2%). The same quantities are also shown in the bottom panels after having been normalized to the expected NLO pQCD cross-sections.

In conclusion, the inclusive isolated prompt photon production cross-section in $pp$ collisions at a center-of-mass energy $\sqrt{s} = 7$ TeV has been measured using 35 pb$^{-1}$ of integrated luminosity collected by the ATLAS detector at the LHC. The differential cross-section has been measured as a function of the prompt photon transverse energy between 45 and 400 GeV, in the pseudorapidity ranges $0.0 \leq |\eta| < 0.6$, $0.6 \leq |\eta| < 1.37$, $1.52 \leq |\eta| < 1.81$ and $1.81 \leq |\eta| < 2.37$. In general, good agreement between the data and the NLO pQCD predictions is observed. This measurement improves the precision and significantly extends the kinematic regime explored in the previous measurement [3] and is consistent in the region where the two measurements overlap.

Over most of this extended kinematic range the experimental errors are smaller than the theoretical ones. The large theoretical scale error limits the discrimination between PDFs. Future measurements of this process in finer pseudorapidity binning and those of the photon + jet system should provide more insight into the PDF differences.

Acknowledgements

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently.

We acknowledge the support of ANPCyT, Argentina; YerPhl, Armenia; ARC, Australia; BMWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; ARTEMIS, European
### Table A.1
Measured isolated prompt photon cross-section for $|\eta| < 0.6$ with statistical and systematic uncertainties. The total uncertainty includes both the statistical and all systematic uncertainties (summed in quadrature), except for the uncertainty on the luminosity.

<table>
<thead>
<tr>
<th>$E_{\text{min}}^{\text{iso}}$ [GeV]</th>
<th>$E_{\text{max}}^{\text{iso}}$ [GeV]</th>
<th>$d\sigma / dE_T$ [pb/GeV]</th>
<th>$\delta_{\text{stat}}$ [pb/GeV]</th>
<th>$\delta_{\text{fold}}$ [pb/GeV]</th>
<th>$\delta_{\text{efficiency}}$ [pb/GeV]</th>
<th>$\delta_{\text{corr}}$ [pb/GeV]</th>
<th>$\delta_{\text{folding}}$ [pb/GeV]</th>
<th>$\delta_{\text{tot}}$ [pb/GeV]</th>
<th>$\delta_{\text{umi}}$ [pb/GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 55 83.3 &amp; 5.3 &amp; 0.5 &amp; 4.8 &amp; 3.3 &amp; 3.4 &amp; 2.5 &amp; 7.2 &amp; 2.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 70 32.7 &amp; 0.3 &amp; 0.2 &amp; 1.8 &amp; 1.2 &amp; 1.2 &amp; 1.0 &amp; 2.7 &amp; 1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 85 12.3 &amp; 0.5 &amp; 0.5 &amp; 0.6 &amp; 0.4 &amp; 0.4 &amp; 0.3 &amp; 0.9 &amp; 0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85 100 5.3 &amp; 0.1 &amp; 0.2 &amp; 0.2 &amp; 0.2 &amp; 0.2 &amp; 0.4 &amp; 0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 125 2.2 &amp; 0.05 &amp; 0.09 &amp; 0.08 &amp; 0.07 &amp; 0.07 &amp; 0.02 &amp; 0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125 150 0.80 &amp; 0.03 &amp; 0.03</td>
<td>0.03 &amp; 0.02 &amp; 0.03 &amp; 0.06 &amp; 0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 200 0.26</td>
<td>0.01 &amp; 0.01 &amp; 9.3 &amp; 7.7 &amp; 1 &amp; 0.9 &amp; 0.02 &amp; 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 400 2.8 &amp; 2.10 &amp; 2.10 &amp; 1.1 &amp; 4.1 &amp; 8.4 &amp; 3.3 &amp; 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table A.2
Measured isolated prompt photon cross-section for $0.6 < |\eta| < 1.37$, uncertainties as in Table A.1.

<table>
<thead>
<tr>
<th>$E_{\text{min}}^{\text{iso}}$ [GeV]</th>
<th>$E_{\text{max}}^{\text{iso}}$ [GeV]</th>
<th>$d\sigma / dE_T$ [pb/GeV]</th>
<th>$\delta_{\text{stat}}$ [pb/GeV]</th>
<th>$\delta_{\text{fold}}$ [pb/GeV]</th>
<th>$\delta_{\text{efficiency}}$ [pb/GeV]</th>
<th>$\delta_{\text{corr}}$ [pb/GeV]</th>
<th>$\delta_{\text{folding}}$ [pb/GeV]</th>
<th>$\delta_{\text{tot}}$ [pb/GeV]</th>
<th>$\delta_{\text{umi}}$ [pb/GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 55 99.0 &amp; 0.7 &amp; 8.1 &amp; 4.4 &amp; 3.8 &amp; 3.0 &amp; 10.4 &amp; 3.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 70 38.9 &amp; 0.3 &amp; 3.0 &amp; 1.7 &amp; 1.2 &amp; 1.2 &amp; 3.9 &amp; 1.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 85 14.9 &amp; 0.2 &amp; 1.1 &amp; 0.7 &amp; 0.4 &amp; 0.5 &amp; 1.4 &amp; 0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85 100 6.3 &amp; 0.1 &amp; 0.4 &amp; 0.3 &amp; 0.1 &amp; 0.2 &amp; 0.6 &amp; 0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 125 2.7</td>
<td>0.06 &amp; 0.2 &amp; 0.1 &amp; 0.06 &amp; 0.08 &amp; 0.2 &amp; 0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125 150 1.0</td>
<td>0.03 &amp; 0.06 &amp; 0.04 &amp; 0.02 &amp; 0.03 &amp; 0.1</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 200 0.29</td>
<td>0.01 &amp; 0.02 &amp; 0.01 &amp; 7 &amp; 9</td>
<td>3 &amp; 0.03</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 400 3.2 &amp; 2.10 &amp; 2.10 &amp; 2.1 &amp; 1.1 &amp; 4.1 &amp; 3.3 &amp; 4.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table A.3
Measured isolated prompt photon cross-section for $1.52 < |\eta| < 1.81$, uncertainties as in Table A.1.

<table>
<thead>
<tr>
<th>$E_{\text{min}}^{\text{iso}}$ [GeV]</th>
<th>$E_{\text{max}}^{\text{iso}}$ [GeV]</th>
<th>$d\sigma / dE_T$ [pb/GeV]</th>
<th>$\delta_{\text{stat}}$ [pb/GeV]</th>
<th>$\delta_{\text{fold}}$ [pb/GeV]</th>
<th>$\delta_{\text{efficiency}}$ [pb/GeV]</th>
<th>$\delta_{\text{corr}}$ [pb/GeV]</th>
<th>$\delta_{\text{folding}}$ [pb/GeV]</th>
<th>$\delta_{\text{tot}}$ [pb/GeV]</th>
<th>$\delta_{\text{umi}}$ [pb/GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 55 41.9 &amp; 0.4 &amp; 4.6 &amp; 3.1 &amp; 1.2 &amp; 1.3 &amp; 5.8 &amp; 1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 70 15.7 &amp; 0.2 &amp; 1.6 &amp; 1.0 &amp; 0.4 &amp; 0.5 &amp; 2 &amp; 0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 85 6.4 &amp; 0.2 &amp; 0.5 &amp; 0.2 &amp; 0.2 &amp; 0.7</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85 100 2.4 &amp; 0.08 &amp; 0.2 &amp; 0.2 &amp; 0.05 &amp; 0.08 &amp; 0.3</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 125 1.0</td>
<td>0.04 &amp; 0.07</td>
<td>0.08 &amp; 0.02</td>
<td>0.03</td>
<td>0.1</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125 150 0.36</td>
<td>0.02 &amp; 0.03 &amp; 0.03 &amp; 8 &amp; 10 &amp; 1 &amp; 0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 200 0.11</td>
<td>9 &amp; 10 &amp; 3 &amp; 7 &amp; 10 &amp; 3 &amp; 4 &amp; 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 400 1.1 &amp; 2 &amp; 10 &amp; 3 &amp; 8 &amp; 20 &amp; 4 &amp; 20 &amp; 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table A.4
Measured isolated prompt photon cross-section for $1.81 < |\eta| < 2.37$, uncertainties as in Table A.1.

<table>
<thead>
<tr>
<th>$E_{\text{min}}^{\text{iso}}$ [GeV]</th>
<th>$E_{\text{max}}^{\text{iso}}$ [GeV]</th>
<th>$d\sigma / dE_T$ [pb/GeV]</th>
<th>$\delta_{\text{stat}}$ [pb/GeV]</th>
<th>$\delta_{\text{fold}}$ [pb/GeV]</th>
<th>$\delta_{\text{efficiency}}$ [pb/GeV]</th>
<th>$\delta_{\text{corr}}$ [pb/GeV]</th>
<th>$\delta_{\text{folding}}$ [pb/GeV]</th>
<th>$\delta_{\text{tot}}$ [pb/GeV]</th>
<th>$\delta_{\text{umi}}$ [pb/GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 55 68.9 &amp; 6.6 &amp; 7.6 &amp; 3.8</td>
<td>3.9 &amp; 2.1 &amp; 9.6 &amp; 2.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 70 26.4 &amp; 0.2 &amp; 2.7 &amp; 1.3 &amp; 1.3 &amp; 0.8</td>
<td>3.1 &amp; 0.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 85 10.0 &amp; 0.2 &amp; 0.9 &amp; 0.5 &amp; 0.5</td>
<td>0.3 &amp; 1.2 &amp; 0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85 100 4.2 &amp; 0.1 &amp; 0.3 &amp; 0.3 &amp; 0.2</td>
<td>0.1</td>
<td>0.5 &amp; 0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 125 1.7</td>
<td>0.06 &amp; 0.1</td>
<td>0.1 &amp; 0.08 &amp; 0.05 &amp; 0.2</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125 150 0.55</td>
<td>0.03 &amp; 0.03</td>
<td>0.03 &amp; 0.02</td>
<td>0.02</td>
<td>0.06</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 200 0.17</td>
<td>0.01 &amp; 0.01 &amp; 0.01 &amp; 6 &amp; 10 &amp; 3 &amp; 6 &amp; 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 400 1.2</td>
<td>2.10 &amp; 2.10 &amp; 1.1 &amp; 3 &amp; 10 &amp; 3 &amp; 4 &amp; 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix A. Cross-section measurements

Tables A.1–A.4 list the values of the measured isolated prompt photon production cross-sections, for the $0.0 < |\eta| < 0.6$, $0.6 < |\eta| < 1.37$, $1.37 < |\eta| < 1.81$, and $1.81 < |\eta| < 2.37$ regions, respectively. The various systematic uncertainties originating from the purity measurement, the photon selection and identification efficiency and the luminosity are shown. In addition, the correlated uncertainties between the efficiency and the purity determination.
are propagated as such and included separately ($\sigma_{\text{corr}}$). The total uncertainty is the combination of the statistical and systematic uncertainties (summed in quadrature), except for the uncertainty on the luminosity.

Open access

This article is published Open Access at science-direct.com. It is distributed under the terms of the Creative Commons Attribution License 3.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original authors and source are credited.

References


ATLAS Collaboration

166


121 Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, United States
122 (a) Laboratório de Instrumentação e Física Experimental de Partículas – LIP, Lisboa, Portugal; (b) Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
123 Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic
124 Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic
125 Czech Technical University in Prague, Prague, Czech Republic
126 State Research Center Institute for High Energy Physics, Protvino, Russia
127 Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom
128 Physics Department, University of Regina, Regina, SK, Canada
129 Ritsumeikan University, Kusatsu, Shiga, Japan
130 INFSN Sezione di Roma I; (a) Dipartimento di Fisica, Università La Sapienza, Roma, Italy
131 INFSN Sezione di Roma Tor Vergata; (b) Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy
132 INFSN Sezione di Roma Tre; (b) Dipartimento di Fisica, Università Roma Tre, Roma, Italy
133 Faculty des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Énergies – Université Hassan II, Casablanca; (b) Centre National de l’Energie des Sciences Nucléaires, Rabat; (c) Université Cadi Ayyad, Faculté des Sciences Semlalia, Département de Physique, B.P. 2390, Marrakech 40000; (d) Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda; (e) Faculté des Sciences, Université Mohammed V, Rabat, Morocco
134 DSM/IRFU/Institut de Recherches sur les Lois Fondamentales de l’Univers, CEA Saclay (Commissariat a l’Energie Atomique), Gif-sur-Yvette, France
135 Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, United States
136 Department of Physics, University of Washington, Seattle, WA, United States
137 Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom
138 Department of Physics, Shinshu University, Nagano, Japan
139 Fachbereich Physik, Universität Siegen, Siegen, Germany
140 Department of Physics, Simon Fraser University, Burnaby, BC, Canada
141 SLAC National Accelerator Laboratory, Stanford, CA, United States
142 (a) Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava; (b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
143 Department of Physics, University of Johannesburg, Johannesburg, South Africa
144 SLAC National Accelerator Laboratory, Stanford, CA, USA
145 Department of Physics, University of Maryland, College Park, USA
146 Physics Department, Royal Institute of Technology, Stockholm, Sweden
147 Department of Physics and Astronomy, Stony Brook University, Stony Brook, NY, United States
148 Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom
149 School of Physics, University of Sydney, Sydney, Australia
150 Institute of Physics, Academia Sinica, Taipei, Taiwan
151 Department of Physics, Technion – Israel Inst. of Technology, Haifa, Israel
152 Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
153 International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
154 Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
155 Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
156 Department of Physics, University of Toronto, Toronto, ON, Canada
157 Department of Physics and Astronomy, York University, Toronto, ON, Canada
158 Institute of Pure and Applied Sciences, University of Tsukuba, Ibaraki, Japan
159 Science and Technology Center, Tsinghua University, Beijing, China
160 Department of Physics, University of Illinois, Urbana, IL, United States
161 Department of Physics and Astronomy, University of California Irvine, Irvine, CA, United States
162 INFN Gruppo Collegato di Udine; (a) ICTP, Trieste; (b) Dipartimento di Fisica, Università di Udine, Udine, Italy
163 Department of Physics, University of Illinois, Urbana, IL, United States
164 Department of Physics and Astronomy, University of Upsala, Uppsala, Sweden
165 Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
166 Department of Physics, University of British Columbia, Vancouver, BC, Canada
167 Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava
168 Department of Physics, University of Victoria, Victoria, BC, Canada
169 Waseda University, Tokyo, Japan
170 Department of Physics, The Weizmann Institute of Science, Rehovot, Israel
171 Department of Physics, University of Wisconsin, Madison, WI, United States
172 Fachbereich Physik, Bergische Universität Wuppertal, Wuppertal, Germany
173 Department of Physics, Yeshiva University, New Haven, CT, United States
174 Yerevan Physics Institute, Yerevan, Armenia
175 Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France

a Also at Laboratorio de Instrumentacao e Física Experimental de Partículas – LIP, Lisboa, Portugal.
b Also at Faculdade de Ciencias and CFPUL, Universidade de Lisboa, Lisboa, Portugal.
c Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
d Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
e Also at TRIUMF, Vancouver, BC, Canada.
f Also at Department of Physics, California State University, Fresno, CA, United States.
g Also at Faculty of Physics and Applied Computer Science, AGH – University of Science and Technology, Krakow, Poland.
h Also at Department of Physics, University of Coimbra, Coimbra, Portugal.
i Also at Università di Napoli Parthenope, Napoli, Italy.
j Also at Institute of Particle Physics (IPP), Canada.
k Also at Department of Physics, Middle East Technical University, Ankara, Turkey.
l Also at Louisiana Tech University, Ruston, LA, United States.
m Also at Group of Particle Physics, University of Montreal, Montreal, QC, Canada.
n Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
o Also at Institute for Experimentalphysik, Universität Hamburg, Hamburg, Germany.
p Also at Manhattan College, New York, NY, United States.
Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.
 Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
 Also at High Energy Physics Group, Shandong University, Shandong, China.
 Also at Section de Physique, Université de Genève, Geneva, Switzerland.
 Also at Departamento de Física, Universidade de Minho, Braga, Portugal.
 Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, United States.
 Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
 Also at California Institute of Technology, Pasadena, CA, United States.
 Also at Institute of Physics, Jagiellonian University, Krakow, Poland.
 Also at Department of Physics, Oxford University, Oxford, United Kingdom.
 Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
 Also at Department of Physics, The University of Michigan, Ann Arbor, MI, United States.
 Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l’Univers), CEA Saclay (Commissariat a l’Energie Atomique), Gif-sur-Yvette, France.
 Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
 Also at Department of Physics, Nanjing University, Jiangsu, China.
 Deceased.