PROCEEDINGS OF SCIENCE

First measurement of isolated-photon plus jet production in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

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The dynamics of isolated-photon plus jet production in pp collisions at $\sqrt{s} = 13$ TeV were studied with the ATLAS detector at the LHC, using a dataset with an integrated luminosity of 3.2 fb^{-1}. The photons were reconstructed for photon transverse energies larger than 125 GeV. The jets were identified using the anti-k_t algorithm with radius parameter R=0.4 and selected in the rapidity range $|y| < 2.37$, for transverse momenta $p_{\mathrm{T}} > 100$ GeV. Measurements of isolated-photon plus jet cross sections are presented as functions of the photon transverse energy, the jet transverse momentum, the azimuthal separation between the selected photon and the jet, the photon-jet invariant mass and the scattering angle in the photon-jet centre-of-mass system. The leading-logarithm parton-shower preditions from SHERPA and PYTHIA as well as the next-to-leading order QCD calculations from *JETPHOX* and multi-leg plus parton shower NLO SHERPA are compared to the measurements.

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1. Introduction

The study of the production of prompt photons in association with hadronic jets provides a test of perturbative QCD and gives informations on the proton parton distribution functions (PDFs). The colorless prompt photon represents a clean probe of the hard partonic interation since the photon is produced in the hard scattering and does not undergo hadronization. The dynamics of the underlying processes, $2 \to 2$ hard collinear scattering, can be investigated using the variable $\cos\theta^* \equiv \tanh(\Delta y/2)$, where Δy is the difference in rapidity of the two-final state particles and is sensitive to the spin of the exchanged particle. The $pp \to \gamma + jet + X$ process proceeds through two different mechanisms [1]:

- Direct photon (mostly quark-gluon Compton scattering, $qg \to q\gamma$, or quark-antiquark annihilation, $q\bar{q} \to \gamma g$), originated during the hard process;
- Fragmentation photon, produced in the fragmentation of a quark with high p_{T}.

2. Data selection and Monte Carlo simulations

The data were collected with the ATLAS detector [2] during the pp collision running period of 2015, at a centre-of-mass energy of $\sqrt{s}$ = 13 TeV. Events were recorded using a single-photon-trigger, with a transverse energy threshold of 120 GeV. The photon candidates are reconstructed from clusters of energy deposited in the ATLAS calorimeter system and classified as unconverted (candidates without a matching track or reconstructed conversion vertex) or converted photons (candidates with a matching reconstructed conversion vertex or a matching track consistent with a photon conversion). The photon identification is based primarily on shower shapes in the calorimeter [3]. An initial selection is derived using the information from the hadronic calorimeter and the lateral shower shape in the second layer of the electromagnetic calorimeter, where most of the photon energy is contained. The final tight selection applies stringent criteria to these variables, separately for converted and unconverted candidates. Events with at least one photon candidate with $E_{\mathrm{T}}^{\gamma} > 125$ GeV and $|\eta^{\gamma}| < 2.37$ are selected. Candidates in the region $1.37 < |\eta^{\gamma}| < 1.56$, which includes the transition region between the barrel and the end-cap calorimeters, are not considered. The isolation transverse energy (E_{T}^{iso}) is computed from topological clusters of calorimeter cells, which contain a significant energy amount above a noise threshold. E_{T}^{iso} is required to be less than $E_{\mathrm{T},cut}^{iso} \equiv 4.2 \cdot 10^{-3} \cdot E_{\mathrm{T}}^{\gamma} + 10$ GeV. Jets are reconstructed using the anti-k_t algorithm with a radius parameter R = 0.4, using topological clusters as input. The jet candidates are required to have p_{T}^{jet} greater than 100 GeV and rapidity $|y^{jet}| < 2.37$. Jets overlapping with the candidate photon are not considered if the jet axis lies within a cone of size $\Delta R = 0.8$ around the photon candidate. These requirements define the fiducial phase-space of the measurement. For the measurements of the cross sections as a function of $m^{\gamma-\mathrm{jet}}$ and $|\cos\theta^*|$, three additional constraints are imposed to remove the bias due to the rapidity and transverse momentum requirements on the photon and the jet: $|\eta^{\gamma} + y^{jet}| < 2.37$, $|\cos\theta^*| < 0.83$ and $m^{\gamma-\mathrm{jet}} > 450$ GeV. The Monte Carlo (MC) programs PYTHIA 8.186 and SHERPA 2.1.1 are used to generate the signal events. The event generator parameters are set according to the tunes A14 and CT10, respectively for PYTHIA and SHERPA.

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3. Background subtraction

A non-negligible background contribution remains in the selected sample, even after imposing the tight identification and isolation requirements on the photon. This background mainly originates from multi-jet processes, in which a jet is misidentified as a photon. A background subtraction data-driven method based on signal suppressed control regions is used. The background contamination in the signal region is estimated using the same two-dimentional sideband technique as in the previous publication [4] and then subtracted to obtain the signal yield.

4. Systematic uncertainties

Several systematic sources that affect the measurements were estimated. In the following the most important systematic sources are listed (the average values, expressed in percent, are shown in parentheses):
Photon and Jet energy scale: Differences between the energy scales in data and simulations lead to systematic uncertainties. (photon energy scale: $\pm$2.8%; jet energy scale $\pm$4.6%);
Photon identification: Estimated from the differences between shower shape variable distributions in data and simulation ($\pm$1.5%).

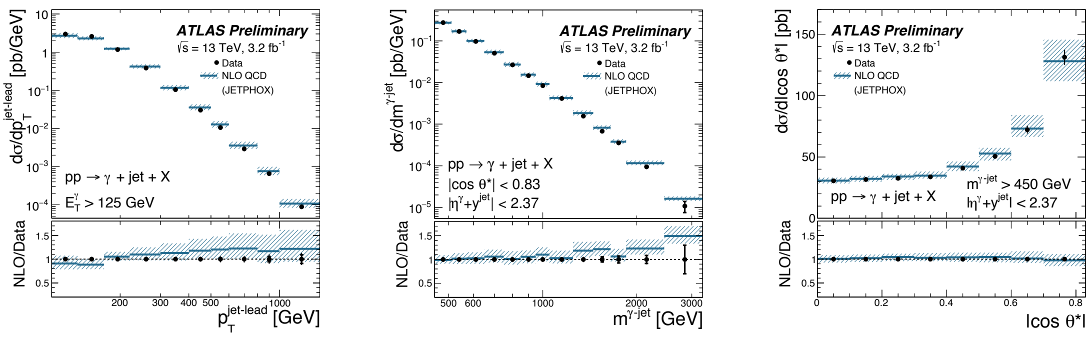

Figure 1: Measured cross sections as functions of $p_{\mathrm{T}}^{\mathrm{jet-lead}}$, $m^{\gamma-\mathrm{jet}}$ and $|\cos\theta^*|$ compared with the NLO QCD predictions of *JETPHOX* [5]. The bottom part of each figure shows the ratios of the predictions to the measured cross section. The error bars represent the experimental uncertainties, while the hatched band displays the theoretical uncertainty.

5. Next-to-leading order QCD calculations

The NLO pQCD predictions used in this analysis are computed using two programs, namely *JETPHOX* 1.3.1_2 [6] and SHERPA 2.2.2 [7]. *JETPHOX* includes a full NLO pQCD calculation of the direct and fragmentation contributions. The number of massless quark flavours is set to five, while the renormalization (μ_R), fragmentation (μ_f) and factorization (μ_F) scales are chosen to be $\mu_R = \mu_f = \mu_F = E_{\mathrm{T}}^{\gamma}$. The calculation are performed using the MMHT2014 parametrization of the proton PDFs and the BFG set II of parton fragmentation functions at NLO. The *JETPHOX* calculations are then corrected for non-perturbative effects. The SHERPA 2.2.2 program combines parton-level calculations of γ + 1,2 jets at NLO and γ + 3,4 jets at LO supplemented with a parton shower. The NNPDF3.0NNLO proton PDFs are used. The following sources of uncertainty in the theoretical predictions were considered: missing higher-order terms, proton's PDFs and the value of α_s. The dominant theoretical uncertainty is that arising from the terms beyond NLO and, in the case of *JETPHOX* (NLO SHERPA) amounts to $\approx$ 10% (10–25 %).

6. Results

The isolated-photon plus jet cross section is measured as a function of E_T^{γ}, $p_T^{\rm jet-lead}$, $\Delta\phi^{\gamma-\rm jet}$, $m^{\gamma-\rm jet}$ and $|\cos\theta^*|$ in the fiducial phase-space region defined by the requirements described in Section 2. The data distributions, after the background subtraction, are then unfolded to the particle level using a bin-by-bin correction procedure. The predictions of the NLO QCD calculations of JETPHOX and NLO SHERPA are compared to the data in Figures 1 and 2. The predictions give an adeguate description of the measured differential cross sections within the theoretical uncertainties. The cross section $d\sigma/|\cos\theta^*|$ increases as $|\cos\theta^*|$ increases, in agreement with the NLO expectations; more results can be found in Ref. [5].

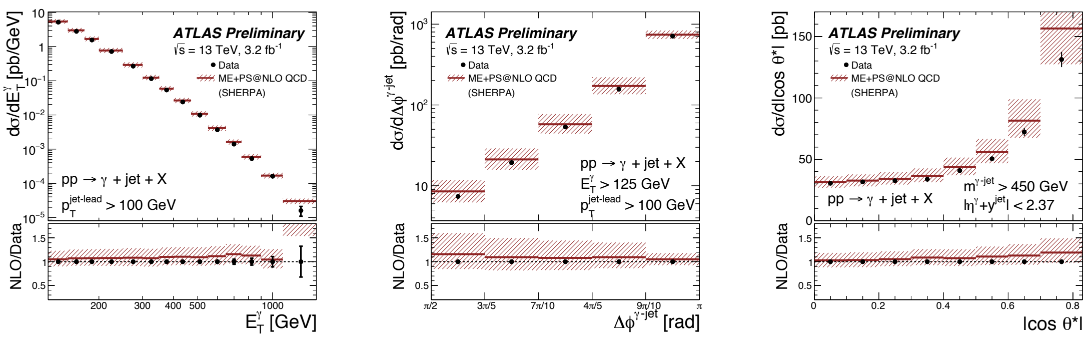

Figure 2: Measured cross sections as functions of E_T^{γ}, $\Delta\phi^{\gamma-\rm jet}$ and $|\cos\theta^*|$ compared with the NLO QCD predictions of NLO SHERPA [5]. The bottom part of each figure shows the ratios of the predictions to the measured cross section. The error bars represent the experimental uncertainties, while the hatched band displays the theoretical uncertainty.

References

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