Prompt photon measurements with the ATLAS detector

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An overview of the main prompt photon measurements with the ATLAS detector is presented. The production cross sections for inclusive photons, photon plus jets and diphotons have been measured with 37 pb^{-1} of pp collisions at $\sqrt{s}$=7 TeV collected at the LHC in 2010. Data have been found to be in fair agreement with next-to-leading order perturbative QCD calculations. The overall picture confirms that QCD photons are well understood in ATLAS laying solid foundations for discovery physics involving photons.

1 Introduction

The study of the production of prompt photons at hadron colliders is an important test of perturbative QCD (pQCD) predictions [1], providing a colorless probe of the hard scattering process. Moreover, the measurements of the prompt photon production cross section, inclusive or in association with jets, can be used to constrain the parton density functions [2]. In particular they are sensitive to the gluon content of the proton through the $qg \rightarrow q\gamma$ subprocess, which at leading-order dominates the inclusive prompt photon cross section at the LHC. Finally the diphoton and photon plus jet production represent irreducible and reducible backgrounds respectively for some discovery physics searches, such as the Higgs boson decay into photon pairs [3]. In ATLAS, photons are reconstructed from electromagnetic clusters in the calorimeter and from tracking information provided by the inner detector. Both unconverted and converted photon candidates are considered for this measurement. Photon candidates are required to pass identification criteria based on shower shapes in the calorimeters [4]. In the following "isolated" photons are considered, *i.e.* photons whose transverse energy $E_{\mathrm{T}}^{\mathrm{iso}}$, within a cone of radius $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.4$ centered around the photon direction in the pseudo-rapidity (η) and azimuthal angle (ϕ) plane, is smaller than typically 4 GeV [1]. The background for all these analyses mainly comes from jets containing high energy π^0s faking photons : the isolation requirement is useful to reject the fake photons since they are usually accompanied by hadronic activity around the leading particle direction. For the same reason, the isolation cut also reduces the contribution due to real photons produced in partons fragmentation which is desirable since it cannot be calculated in pQCD. All the results presented here are based on 2010 data collected by the ATLAS experiment at a center-of-mass energy of 7 TeV.

[1]The energy associated to the photon candidate itself is subtracted from the isolation energy.

2 Inclusive photon production cross section

A first measurement of the isolated prompt photon production cross section [4] used 0.88 pb^{-1} of data and covered the kinematic region 15 GeV $\leq E_{\mathrm{T}} <$ 100 GeV in three different pseudorapidity bins: $0.0 \leq |\eta| < 0.6$,$0.6 \leq |\eta| < 1.37$ and $1.52 \leq |\eta| < 1.81$. The most recent measurement [5] explored a higher E_{T} regime, 45 GeV $\leq E_{\mathrm{T}} <$ 400 GeV, and expanded the coverage to include the $1.81 \leq |\eta| < 2.37$ region by using the full 35 pb^{-1} of data from 2010 run. In both analyses, the JETPHOX [6] program was used to compute the NLO cross sections with different sets of parton density functions (PDFs). The measured cross sections are compared in Fig. 1 to the theoretical predictions obtained with the CTEQ6.6 PDF set. The four η bins are included, scaled by an arbitrary factor for the sake of clarity. A very good agreement can be observed, within uncertainties, between the two measurements in the overlapping region. The NLO pQCD predictions agree in all cases with the observed cross sections for transverse energies > 25 GeV, while for transverse energies < 25 GeV the cross sections predicted by JETPHOX are higher than the measured ones. Similar results have been obtained using both MSTW2008 and NNPDF 2.0 PDF sets. The theoretical uncertainty is dominated by the scale uncertainty (10%), which presently limits the discrimination between PDFs. From the experimental side the statistical uncertainty is negligible, the systematic being dominated by the purity and photon efficiency estimations.

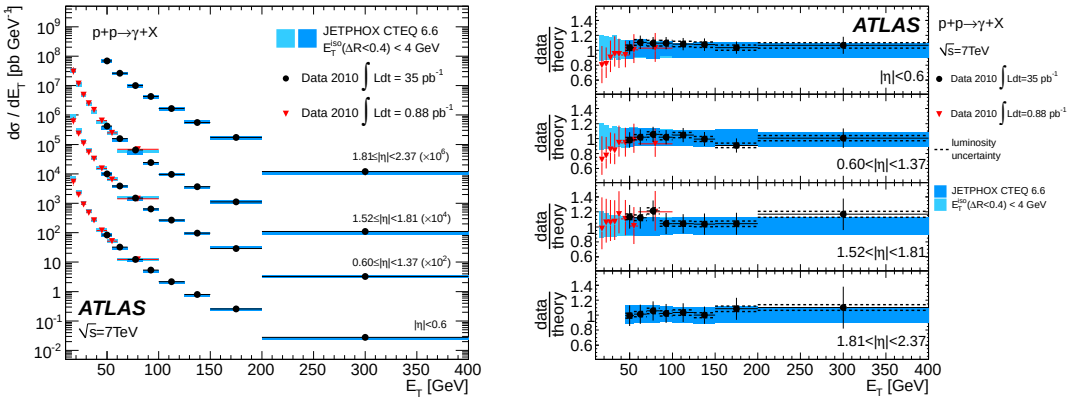

Figure 1: Inclusive photon production cross section [7] compared with NLO predictions obtained using JETPHOX with CTEQ6.6 for the four photon $|\eta|$ ranges described in the text.

3 Photon plus jets production cross section

The differential cross section $d\sigma/dE_{\mathrm{T}}^{\gamma}$, as a function of the photon transverse energy, has been determined [8] for isolated photons in the pseudorapidity range $|\eta^{\gamma}| < 1.37$ and transverse energy $E_{\mathrm{T}}^{\gamma} > 25$ GeV, after integration over the jet transverse momenta for $p_{\mathrm{T}}^{\mathrm{jet}} > 20$ GeV. A minimum separation of $\Delta R > 1.0$ in the $\{\eta, \phi\}$ plane is required between the leading jet and the photon. The cross sections are presented separately for the three jet rapidity intervals $|y^{\mathrm{jet}}| < 1.2$, $1.2 \leq |y^{\mathrm{jet}}| < 2.8$ and $2.8 \leq |y^{\mathrm{jet}}| < 4.4$, distinguishing between the same-sign

($\eta^\gamma y^{\rm jet} \geq 0$) and opposite-sign ($\eta^\gamma y^{\rm jet} < 0$) configurations. This subdivision allows the comparison between data and NLO pQCD predictions in configurations where the relative contribution of the fragmentation component to the cross section and the explored ranges of the incoming parton momentum fraction x are different. As shown in Fig. 2 the NLO pQCD cross sections provided by JETPHOX are in fair agreement with the measured ones considering the typical (10% to 30%) experimental and theoretical systematic uncertainties. In the $E_{\rm T}^\gamma < 45$ GeV region, the NLO QCD calculation consistently overestimates the measured cross section, as in Sec. 2.

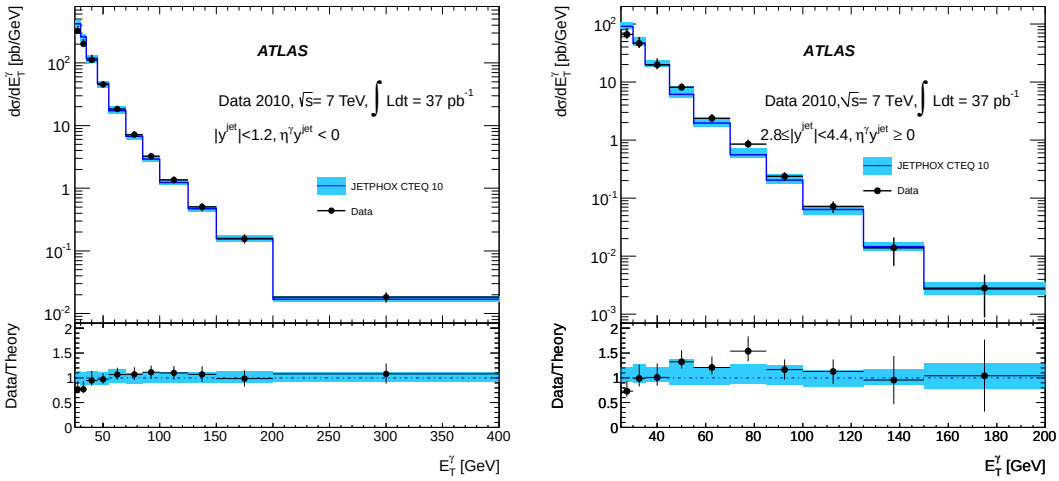

Figure 2: Experimental (black dots) [8] and theoretical (blue line) photon + jet production cross sections, for $|y^{\rm jet}| < 1.2$ same-sign configuration (left) and $2.8 \leq |y^{\rm jet}| < 4.4$ opposite-sign configuration. The black error bars represent the total experimental uncertainty. The blue bands show the total uncertainties on the theoretical predictions obtained with JETPHOX.

4 Diphoton production cross section

Finally the measurement of the production cross section of isolated diphotons in pp collisions was performed [9]: candidate events were selected requiring two photons, with transverse momenta $p_{\rm T} > 16$ GeV and satisfying experimental identification and isolation requirements. The two candidates were also required to have a separation $\Delta R > 0.4$. In Fig. 3, the differential cross sections as a function of the invariant mass $m_{\gamma\gamma}$ and the azimuthal separation $\Delta\phi_{\gamma\gamma}$ of the photon pair are presented. The experimental results are compared with NLO predictions obtained with the DIPHOX [10] and ResBos [11] generators. More photon pairs are seen in data at low $\Delta\phi_{\gamma\gamma}$ values, while fixed order NLO theoretical predictions favour a larger back-to-back production ($\Delta\phi_{\gamma\gamma} \simeq \pi$). In the $\Delta\phi_{\gamma\gamma} \simeq \pi$ region multiple soft gluon emission is important and fixed-order calculations break down because of infrared divergences. A recent NNLO calculation [12] is expected to improve the agreement in the low $\Delta\phi_{\gamma\gamma}$ region. The distribution of $\mathrm{d}\sigma/\mathrm{d}m_{\gamma\gamma}$ is in good agreement with both the DIPHOX and ResBos predictions, apart from the low mass region which corresponds to the low $\Delta\phi_{\gamma\gamma}$ region discussed previously.

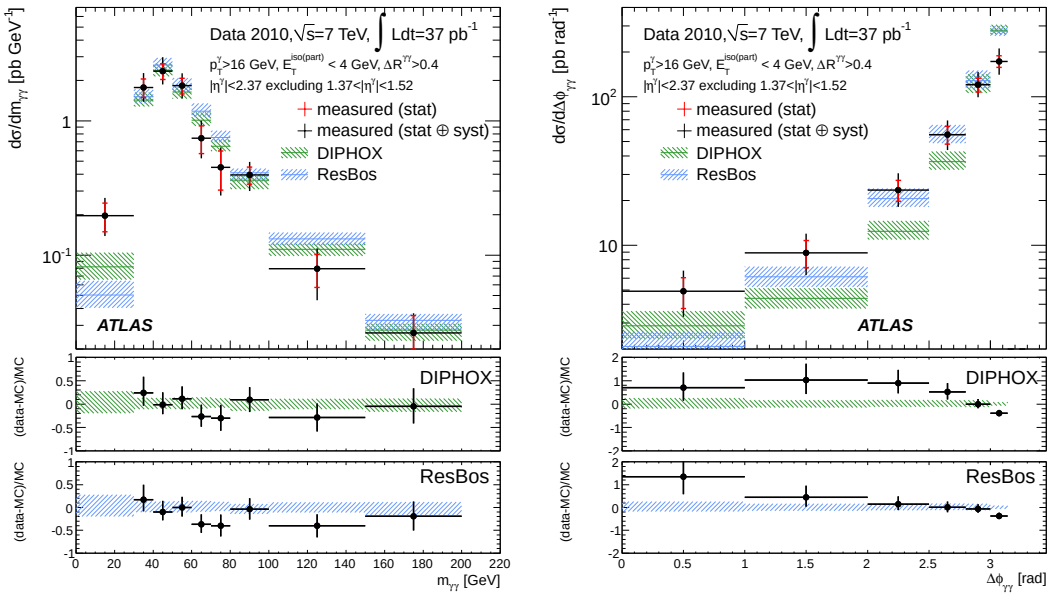

Figure 3: Diphoton production cross section as a function of the invariant mass $m_{\gamma\gamma}$ (left) and the azimuthal separation $\Delta\phi_{\gamma\gamma}$ of the two photons (right). The measurements [9] are compared with DIPHOX and ResBos predictions using the CTEQ6.6 PDF set.

5 Conclusion

The production cross sections for inclusive photons, photons plus jets and diphotons have been measured with 37 pb^{-1} of data collected by the ATLAS detector in 2010 and found to be in fair agreement with NLO predictions. Analyses are ongoing to look into 2011 and 2012 data in order to stress further the reliability of the QCD predictions.

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