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EXCLUSIVE $\gamma\gamma \to l^+l^-$ PRODUCTION AT $\sqrt{s} = 7$ TeV WITH THE ATLAS EXPERIMENT*

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This proceeding reports a measurement of the exclusive $\gamma\gamma \to l^+l^-$ ($l = e, \mu$) cross section in proton–proton collisions at a center-of-mass energy of 7 TeV by the ATLAS experiment at the LHC, based on an integrated luminosity of 4.6 fb^{-1}. The measured cross section is found to be consistent with theory prediction, when proton absorptive effects due to the finite size of the proton are taken into account in the calculation.

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1. Introduction

The Large Hadron Collider (LHC) colliding protons can be used as an effective photon–photon collider thanks to a considerable fraction of interactions mediated by an exchange of photons. Quasi-real photons can be emitted by both the protons, leading to interactions with various final states. In this proceedings, we review a measurement of the elastic production of lepton pairs $pp(\gamma\gamma) \to l^+l^-pp$, referred to as exclusive $\gamma\gamma \to l^+l^-$, measured by the ATLAS detector during 2011 LHC pp run with the center-of-mass energy of $\sqrt{s} = 7$ TeV, using 4.6 fb^{-1} of data [1].

The exclusive two-photon production of lepton pairs can be calculated with the framework of quantum electrodynamics, based on the Equivalent Photon Approximation (EPA) [2], with uncertainties at percent level originating from the proton electromagnetic form factors. However, the calculation requires a significant correction (20%) due to additional interactions between the elastically scattered protons. The absorptive correction is determined with the studied process and compared with the theoretical predictions. Theoretically, it is expected to decrease as a function of mass and rapidity of the produced system. In addition, the fiducial cross section of the exclusive $\gamma\gamma \to l^+l^-$ production is measured.

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2. Selection of exclusive events

The experimental signature of the elastic exclusive process is very clean, and the events can be well separated from the background: apart from the two electrons and muons, there is no additional activity in the central detector, and leptons are back-to-back in the azimuthal angle. Moreover, due to the low virtuality of the exchanged photons, the beam protons are scattered at very small angles. Consequently, the transverse momentum of the lepton pair is very small. The exclusive property of the events is exploited by requiring no additional track in the ATLAS inner detector in addition to the selected lepton pair.

The main sources of background are inclusive Drell–Yan Z/γ^* production (DY), for cases in which not all charged particles are reconstructed as tracks, due to inefficiency of the tracking, single-dissociative (SD) $pp(\gamma\gamma) \to l^+l^-X$ and double-dissociative (DD) $pp(\gamma\gamma) \to l^+l^-XX'$ processes (X, X'' denote additional final state in the event). SD and DD events are characterised by one or two photon exchanges with high photon virtuality and produce activity mainly in the forward rapidity. The kinematic spectra of the signal and backgrounds are modelled using HERWIG Monte Carlo (MC) generator for the elastic exclusive production, LPAIR and PYTHIA8 for the single- and double-dissociations, and POWHEG interfaced to PYTHIA6 for DY (see references in [1]).

The events are required to contain exactly two the same flavour opposite charge leptons, satisfying the following kinematic constraints: $p_{\mathrm{T}}^{l} >$ 12(10) GeV within $|\eta^l| < 2.4$, invariant mass of the pair $m_{l^+l^-} > 24(20)$ GeV for electrons (muons), respectively. The exclusive events are selected by a track veto on charged-track particle activity. The veto requires no addition charged-track particle with $p_{\mathrm{T}} > 400$ MeV be associated with the dilepton vertex, and that no additional tracks or vertices be found within a 3 mm longitudinal distance, $\Delta_{\mathrm{vtx}}^{\mathrm{iso}}$, from the dilepton vertex. These selections remove large portion of the Z/γ^* and multi-jet background, which typically have many tracks.

In this proceedings, distributions only in the muon channel are shown. They are similar for the electron channel. The mass distribution of the pair of the two leptons, $m_{l^+l^-}$, is shown in Fig. 1 (left). The dominant contribution from Z/γ^* is further reduced by excluding events with a dilepton invariant mass 70 GeV $< m_{l^+l^-} <$ 105 GeV. To further suppress mainly the proton dissociative background, the lepton pair is required to have a small total transverse momentum, $p_{\mathrm{T}}^{l^+l^-} < 1.5$ GeV, as can be seen in Fig. 1 (right). After the selection, 869 (2124) dielectron (dimuon) events are observed. The event selection results in an acceptance times efficiency of

19% (32%) for the respective channels. A fraction of the efficiency loss is attributed to the rate of multiple proton–proton collision in one LHC bunch-crossing, which decreases the efficiency of the exclusivity veto.

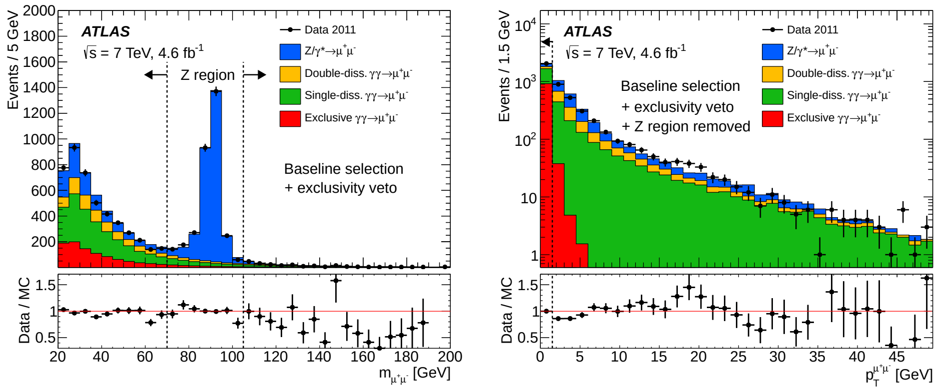

Fig. 1. Mass of the muon pair, $m_{\mu^+\mu^-}$, after the exclusivity veto (left) and the distribution of transverse momentum of the dilepton pair, $p_{\mathrm{T}}^{\mu^+\mu^-}$, after additional suppression excluding the Z peak [1].

3. Signal extraction

After the final selection, a non-negligible contribution is found from DY, single- and double-dissociation in the signal region. Scaling factors for the signal and background processes are obtained by a binned maximum-likelihood fit of the sum of the simulated distributions from the MC templates to the measured dilepton acoplanarity $(1 - |\Delta\phi_{l^+l^-}|/\pi)$ distribution. The result of the fit is shown in Fig. 2 (left). The normalizations of the double-dissociative and DY contributions are fixed to the MC predictions, while those of SD $(R^{\mathrm{s-diss}}_{\gamma\to l^+l^-})$ and elastic exclusive production $(R^{\mathrm{excl}}_{\gamma\gamma\to l^+l^-})$ are obtained from the fit. A good modelling of other kinematic variables of the exclusive $\gamma\gamma \to l^+l^-$ is found, once the normalization of the distribution is scaled by the result of the fit. The modelling of the transverse momentum of the dilepton system can be checked using an alternative exclusive selection $1 - |\Delta\phi_{l^+l^-}|/\pi < 0.008$, and is found to be well-modelled, see Fig. 2 (right).

The fiducial cross section of the exclusive $\gamma\gamma \to l^+l^-$ production is obtained by the product of the measured signal scale factors and the exclusive cross sections predicted by EPA: $\sigma^{\mathrm{excl}}_{\gamma\gamma\to l^+l^-} = R^{\mathrm{excl}}_{\gamma\gamma\to l^+l^-} \times \sigma^{\mathrm{EPA}}_{\gamma\gamma\to l^+l^-}$. For the $\mu^+\mu^-$ channel, the theoretical prediction amounts to $\sigma^{\mathrm{EPA}}_{\gamma\gamma\to\mu^+\mu^-} = 0.794 \pm 0.013(\mathrm{theor.})$ pb, while the rate of exclusive events has been measured to be suppressed by a factor of $R^{\rm excl}_{\gamma\gamma\to\mu^+\mu^-} = 0.791 \pm 0.041\,({\rm stat.}) \pm 0.026\,({\rm syst.}) \pm 0.013\,({\rm theor.})$ with respect to the theoretical prediction, which does not include the absorptive effects. The results are similar in the electron channel.

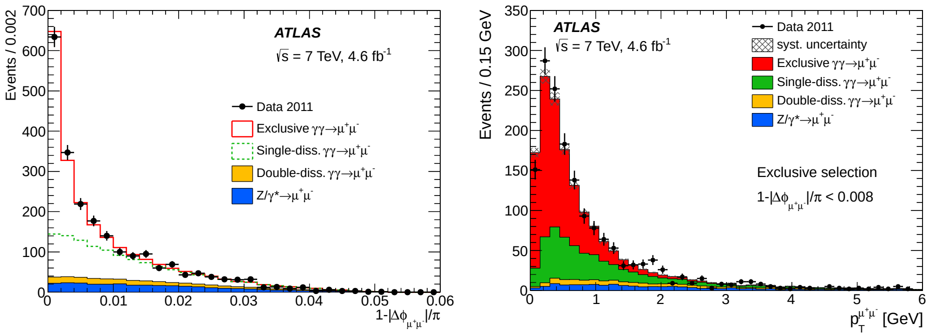

Fig. 2. Result of the fit of Monte Carlo templates of the acoplanarity distribution to data (left) and transverse momentum of the dilepton system using an alternative exclusive selection $1 - |\Delta\phi_{l^+l^-}|/\pi < 0.008$ (right) [1].

4. Results

The measured fiducial cross section of the exclusive $\gamma\gamma \to l^+l^-$ production in the muon channel is $\sigma^{\rm excl}_{\gamma\gamma\to l^+l^-} = 0.628 \pm 0.032\,({\rm stat.}) \pm 0.021\,({\rm syst.})$ pb, with similar result for electrons.

The measurement of the cross section is limited by a statistical uncertainty, which is about twice the size of the total systematic uncertainty. The dominant experimental uncertainty in the muon channel is due to modelling of the charged-particle activity and the cross section of the background (2%), luminosity measurement (1.8%), uncertainties related to the modelling of multiple proton–proton collisions in the MC simulation (1%) and the shape of the fitted MC templates (0.9%), all contributing to the total uncertainty of 3.3%. The experimental uncertainty in the electron channel is slightly larger (4.3%).

The measurement of the absorptive correction is consistent in both lepton channels, showing an approximate suppression of 20% with respect to the predictions of Equivalent Photon Approximation as shown in Fig. 3. It shows the ratios of measured and predicted cross sections to the EPA calculations. Results for the muon and electron channels are also compared with a similar CMS measurement [3]. The figure also shows predictions of an improved EPA calculation including absorptive corrections to account for the finite size of the proton [4].

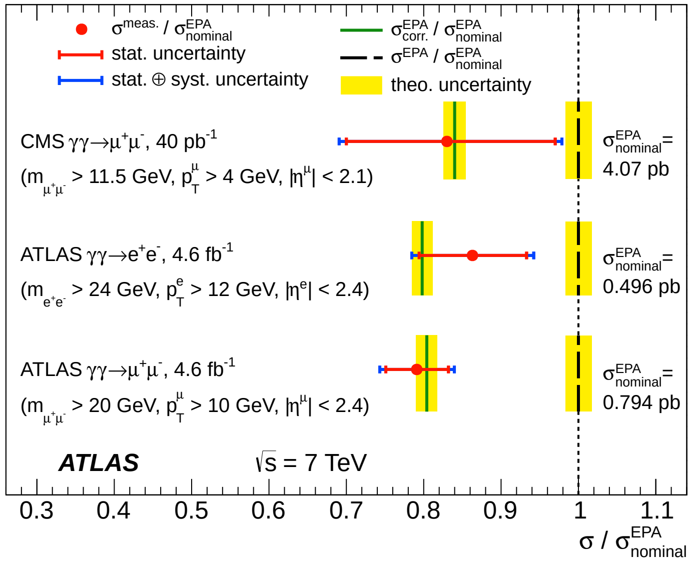

Fig. 3. (Colour on-line) Comparison of the ratios of measured (red points) and predicted (vertical solid/green lines) cross sections to the EPA calculations (dashed/black line) [1]. Results for the muon and electron channels are also compared with a similar CMS measurement [3]. The inner/red error bar represents the statistical error, and the outer/blue bar represents the total error on each measurement. The grey/yellow band represents the theoretical uncertainty of 1.8% (1.7%) on the predicted cross sections, while the vertical solid/green line indicates calculation using an improved EPA [4].

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