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Charmonium and e^+e^- pair photoproduction at mid-rapidity in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV

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Abstract The ALICE Collaboration at the LHC has measured the J/ψ and ψ' photoproduction at mid-rapidity in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV.

The charmonium is identified via its leptonic decay for events where the hadronic activity is required to be minimal. The analysis is based on an event sample corresponding to an integrated luminosity of about 23 μb^{-1}. The cross section for coherent and incoherent J/ψ production in the rapidity interval $-0.9 < y < 0.9$, are $\mathrm{d}\sigma^{\rm coh}_{\rm J/\psi}/\mathrm{d}y = 2.38^{+0.34}_{-0.24}(\mathrm{sta}+\mathrm{sys})$ mb and $\mathrm{d}\sigma^{\rm inc}_{\rm J/\psi}/\mathrm{d}y = 0.98^{+0.19}_{-0.17}(\mathrm{sta}+\mathrm{sys})$ mb, respectively. The results are compared to theoretical models for J/ψ production and the coherent cross section is found to be in good agreement with those models incorporating moderate nuclear gluon shadowing at Bjorken-x around 10^{-3}, such as EPS09 parametrization. In addition the cross section for the process $\gamma\gamma \to e^+e^-$ has been measured and found to be in agreement with models implementing QED at leading order.

1 Introduction

The strong electromagnetic fields generated by heavy ions at the LHC provide an opportunity to study photonuclear interactions in ultra-peripheral collisions (UPC), where the impact parameter may be several tens of femtometres and no hadronic interactions occur. The photon flux is proportional to the square of the nucleus charge, so the photon flux in lead beams is enhanced by nearly four orders of magnitude compared to proton beams. The strong photon flux leads to large cross sections for a variety of photonuclear and two-photon interactions. The physics of ultra-peripheral collisions is described in Refs. [1, 2]. Exclusive vector meson photoproduction, where a vector meson is produced in an event with no other final state particles, is of particular interest, since it provides a measure of the nuclear gluon distribution at low Bjorken-x.

Exclusive production of charmonium in photon–proton interactions at HERA, $\gamma + \mathrm{p} \to \mathrm{J}/\psi(\psi') + \mathrm{p}$, has been successfully modelled in perturbative QCD in terms of the exchange of two gluons with no net-colour transfer [3]. Exclusive vector meson production at mid-rapidity in heavy-ion collisions has previously been studied at RHIC [4, 5]. The exclusive photoproduction can be either coherent, where the photon couples coherently to almost all the nucleons, or incoherent, where the photon couples to a single nucleon. Coherent production is characterized by low transverse momentum of vector mesons ($\langle p_{\rm T}\rangle \approx 60$ MeV/c) where the nucleus normally does not break up by the J/ψ production. However, the exchange of additional photons may lead to the nucleus break-up, estimated by the simulation models at the level of 20–30 % of the events. Incoherent production, corresponding to quasi-elastic scattering off a single nucleon, is characterized by a somewhat higher transverse momentum ($\langle p_{\rm T}\rangle \approx 500$ MeV/c). In this case the nucleus interacting with the photon breaks up, but, apart from single nucleons or nuclear fragments in the very forward region, no other particles are produced.

Recently the ALICE Collaboration published the first results on the photoproduction of J/ψ in ultra-peripheral Pb–Pb collisions at the LHC [6]. This first measurement was performed in the rapidity region $-3.6 < y < -2.6$ and allows us to constrain the nuclear gluon distribution at Bjorken-$x \approx 10^{-2}$. In this paper, results from the ALICE experiment on exclusive photoproduction of J/ψ and ψ' mesons at mid-rapidity in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV are presented. The measurement at mid-rapidity allows the exploration of the region $x = (M_{\rm J/\psi}/\sqrt{s_{\rm NN}})\exp(\pm y) \approx 10^{-3}$, where at present the uncertainty in the nuclear gluon shadowing distribution is rather large [7]. This analysis is focused both on coherently and incoherently produced J/ψ mesons. The measured cross section is compared to model predictions [8–13].

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much shadowing, respectively, to match the data. Our results are about 3 sigma higher than the RSZ-LTA model prediction, although a deviation of just 1.5 sigma is found from the model upper limit. Nevertheless the above predictions may have large uncertainties coming not only from the parametrization of the nuclear gluon distribution but also from the selection of the hard scale, the contributions from the higher-order terms and the treatment of the photon fluctuation to a quark–antiquark pair. The current measurement will contribute to resolve these uncertainties.

None of the three existing models predicts the incoherent photoproduction cross section correctly, but STARLIGHT predicts a correct incoherent-to-coherent ratio.

Finally, the measured two-photon cross section for di-electron production is consistent with the STARLIGHT model. This implies the models predicting a strong contribution of higher-order terms (not included in STARLIGHT) to the cross section are not favored.

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The ALICE Collaboration

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