J/ψ PHOTOPRODUCTION RESULTS FROM ALICE*

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Received 15 August 2022, accepted 7 September 2022, published online 14 December 2022

Diffractive photoproduction of J/ψ vector mesons is studied at the LHC with the ALICE detector in p–Pb and Pb–Pb ultra-peripheral collisions (UPCs), where the Pb ions act as powerful sources of quasi-real photons. In this contribution, the first measurement at the LHC of dissociative photoproduction of J/ψ off protons is presented; this process is sensitive to quantum fluctuations of the structure of the target at the subnucleon level. In addition, cross sections for the exclusive channel and for continuum dimuon production at small masses were obtained in the same kinematic region. This latter process probes our simultaneous understanding, in a new kinematic region, of the photon flux emitted by protons and by lead ions. The transverse momentum dependence of J/ψ photoproduction on lead targets in Pb–Pb collisions at midrapidity, which is sensitive to the gluonic structure of Pb in the impact-parameter plane, is also presented. The measurement of J/ψ photoproduction off hadrons sheds light onto the initial state of QCD targets and provides important constraints on the initial conditions used in hydrodynamical models of heavy-ion collisions.

DOI:10.5506/APhysPolBSupp.16.1-A98

1. Introduction

At low Bjorken-x, the parton composition of nucleons and nuclei is expected to reach the saturation regime [1], where the number of observed partons stops growing. In addition, there is the nuclear shadowing effect, where the ratio of the gluon distribution function extracted from a nucleon and from a nucleus does not scale linearly with the atomic mass number. The saturation scale should depend on the atomic mass number and saturation may be one of the contributions to the observed nuclear shadowing effects.

* Presented at the 29th International Conference on Ultrarelativistic Nucleus–Nucleus Collisions: Quark Matter 2022, Kraków, Poland, 4–10 April, 2022.

Ultra-peripheral collisions (UPCs), with impact parameters larger than the sum of the radii of the colliding particles, allow for the suppression of hadronic interactions and provide photon-induced reactions at the LHC, which are sensitive to the parton distributions of the colliding particles. Vector meson photoproduction can be studied with the ALICE detector in several different collision systems (Pb–Pb, Xe–Xe, p–Pb). It is possible to study the Bjorken-x evolution of the parton distributions, the dependency on the center-of-mass energy of the photon-target system, and the transverse plane distribution of the partons.

2. ALICE detector

Starting from the interaction point the charged particles from collisions at central rapidities are first measured using the Inner Tracking System (ITS), a silicon detector used for event triggering and particle tracking. Further away, the tracks are detected by the Time Projection Chamber (TPC) that is composed of a gaseous drift volume with multiwire proportional chamber end caps. The TPC is used for particle tracking and identification. Finally, the tracks go through the Time-of-Flight (TOF) detector. TOF is a multigap resistive plate chamber detector used for event triggering and particle identification. All of the central rapidity detectors are enclosed in a 0.5 T solenoidal magnet.

To measure particles at forward rapidity, there is the muon spectrometer. It starts with an absorber stopping all particles except muons. These are tracked in five planes of cathode pad chambers with the third plane enclosed in a dipole magnet. Then there is an iron wall protecting two planes of resistive plate chambers used for event triggering.

To enforce the exclusivity condition for the vector meson photoproduction events, two sets of scintillator counters are used, the V0 and AD detectors. The V0 is also used for luminosity determination.

3. Results

Pb–Pb UPC results

The $|t|$ dependence of the coherent J/ψ photoproduction cross section measured by ALICE in Pb–Pb UPCs at $\sqrt{s_{NN}} = 5.02$ TeV [2] via the dimuon decay channel can be seen in Fig. 1. This measurement allows probing of the transverse partonic structure of the nucleus at low x. Comparison to STARlight [3], which is driven by the nuclear form factor, shows a difference in both the shape and magnitude. This demonstrates the presence of $|t|$-dependent QCD dynamical effects. Comparison to the LTA [4] model based on the leading twist approximation of nuclear shadowing data and the b-BK [5] model based on the color dipole approach coupled with the impact-

parameter-dependent Balitsky–Kovchegov equation shows agreement with the data within current uncertainties. Future measurements should differentiate between the two predictions.

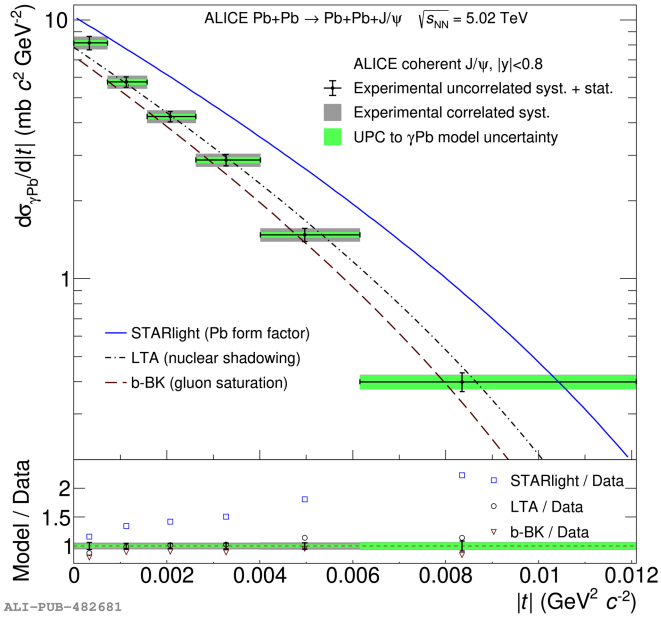

Fig. 1. $|t|$ dependence of the photonuclear cross section for the coherent J/ψ photoproduction compared with model predictions (top panel). Model-to-data ratio for each prediction in each measured point (bottom panel). The uncertainties are split between those originating from the experiment and those originating from the correction to go from the UPC to the photonuclear cross section [2].

p–Pb UPC results

The cross section for the $\gamma\gamma \to \mu\mu$ process in the low invariant mass region was measured in the p–Pb UPCs at $\sqrt{s_{NN}} = 8.16$ TeV. The ALICE results for two rapidity regions in three invariant mass intervals can be seen in Fig. 2 together with predictions from the STARlight [3] model. This model is based on LO QED calculations without final-state radiation effects or other NLO effects. STARlight also does not take into account possible interactions within the radius of the colliding particles which might explain the reason for the slight excess observed in the data. However, the difference is still within 3σ. This result can be utilized to improve current modes which are used to fix background in vector meson or jet photoproduction measurements and improve predictions for light-by-light scattering.

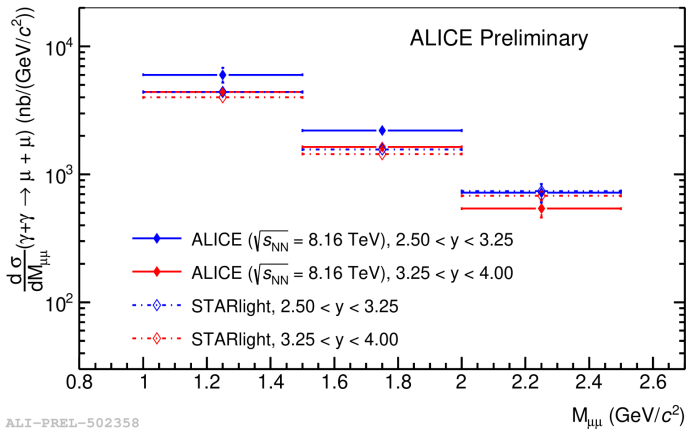

Fig. 2. The differential cross sections for exclusive $\gamma\gamma \to \mu\mu$ production for p–Pb UPCs at $\sqrt{s_{NN}} = 8.16$ TeV as a function of $M_{\mu\mu}$. The vertical error bars represent the statistical and systematic uncertainties summed in quadrature. The results are compared with predictions by STARlight for the same kinematic domain.

The center-of-mass energy dependence of the exclusive J/ψ photoproduction cross section (measured via the dimuon decay channel) can be seen in Fig. 3. A power law fit to the ALICE data gives the exponent value

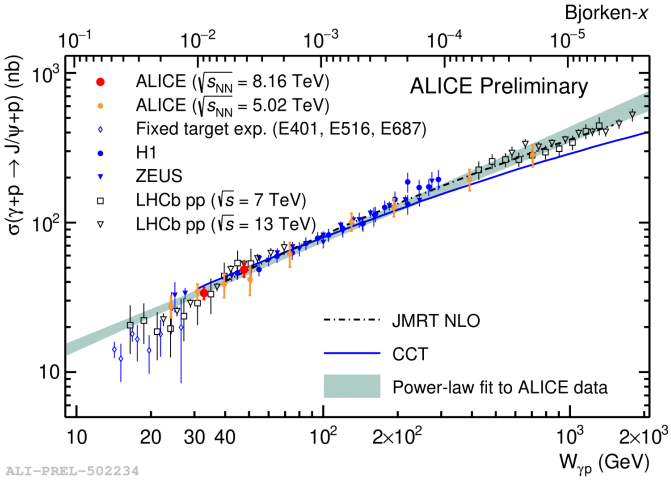

Fig. 3. Exclusive J/ψ photoproduction cross section on proton targets measured by ALICE and compared to previous measurements. Comparisons to the next-to-leading-order JMRT model as well as to the CCT model are shown. The power law fit to the ALICE data is also shown.

$\delta = 0.70 \pm 0.04$. There is no change observed between the results from HERA and the LHC. Also the LHCb and ALICE results are compatible. Two model predictions are also shown, the JMRT NLO [6] model which is based on the DGLAP formalism with main NLO contributions and the CCT [7] model which includes saturation in an energy-dependent hot-spot model. Both models agree with the data.

For the first time the center-of-mass energy dependence of the dissociative J/ψ photoproduction cross section (characterized by a higher average p_{T}) has been measured by ALICE and can be seen in Fig. 4. The data are in agreement with both the H1 results and the CCT [7] model prediction. During the LHC Run 3, ALICE will be able to measure this cross section at the center-of-mass energy where the CCT model predicts a maximum.

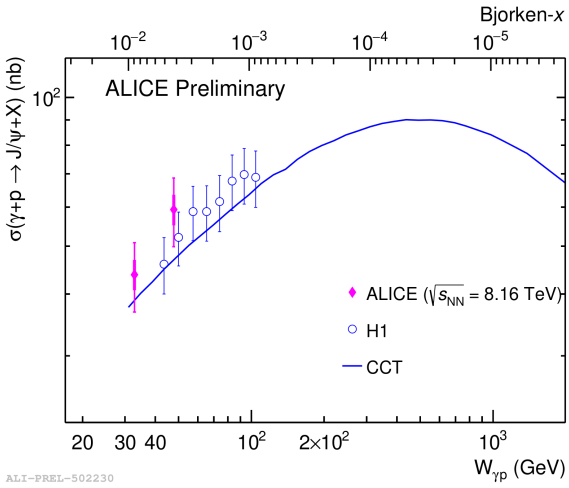

Fig. 4. Dissociative J/ψ photoproduction cross section on proton targets measured by ALICE and compared to H1 data. Comparison to the CCT model is shown. For ALICE points, thick lines represent statistical errors, while the thin line shows statistical and systematic errors summed in quadrature.

4. Conclusion and outlook

In summary, the measurement of the $|t|$ dependence of the coherent J/ψ photoproduction cross section measured in Pb–Pb UPCs shows sensitivity to the parton distribution in the transverse plane. Models with shadowing or saturation describe the data within uncertainties. The cross section for the $\gamma\gamma \to \mu\mu$ process in the low invariant mass region was measured in the p–Pb UPCs and compared to STARlight predictions. The model slightly underestimates the data. The measurement of the exclusive J/ψ photopro-

duction cross section has been found to be in agreement with the previous LHC results as well as the HERA results and theoretical predictions. For the first time, the center-of-mass energy dependence of the dissociative J/ψ photoproduction cross section has been measured at the LHC. The results are in agreement with H1 results and the CCT [7] model.

During LHC Runs 3 and 4, the integrated luminosity will increase by a factor of 13 with respect to Run 2. In addition, ALICE underwent major detector and electronics upgrades during LS2 as well as a transition to a completely new data acquisition system allowing a switch to a continuous data collection policy. These changes will yield much higher data collection efficiency. This will lead to an increase in the precision of all the previous measurements. It will also be possible to make new multi-differential measurements or to study the angular dependencies between dileptons. Completely new observables will also become available, *e.g.* the $\Upsilon(1S)$ production which will allow the probing of a kinematic region with a hard scale ten times larger than that of J/ψ [8].

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