PROCEEDINGS OF SCIENCE

Recent results on ultra-peripheral collisions at the LHC with ALICE

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Ultra-peripheral collisions (UPCs) of relativistic heavy-ion collisions provide a unique opportunity to study photon induced interactions at the LHC in new kinematic regimes. The ALICE experiment has measured the coherent photo-nuclear production of ρ^0 and J/ψ vector mesons in UPCs. The measurement of ρ vector meson is an excellent tool to study nuclear shadowing effects and the approach to the black-disc limit of QCD, while the J/ψ measurement is also a good tool to study nuclear shadowing and saturation effects at low-x. In this contribution, recent results obtained with the data from LHC Run2 will be presented. The first measurement of the cross section of ρ^0 mesons in Xe–Xe at $\sqrt{s_{\rm NN}}$ = 5.44 TeV and Pb–Pb UPCs at $\sqrt{s_{\rm NN}}$ = 5.02 TeV, and the cross section and t-dependence of J/ψ mesons in Pb–Pb UPCs at $\sqrt{s_{\rm NN}}$ = 5.02 TeV will be reported. These results are compared with various model predictions in order to improve our phenomenological understanding of UPCs.

**** Particles and Nuclei International Conference - PANIC2021 ****
**** 5 - 10 September, 2021 ****
**** Online ****

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PoS(PANIC2021)254

1. Introduction

Ultra-peripheral collisions (UPCs) occur when the impact parameter of the colliding nuclei is greater than the sum of their radii. In UPCs, hadronic interactions are highly suppressed and the dominant electromagnetic interactions are mediated by quasi-real photons emitted from the nuclei [1]. The photoproduction of vector mesons is a very sensitive probe of gluonic structure of nuclei. In particular, the gluon density at low Bjorken$-x$ ($x < 10^{-2}$) will be sensitive to nuclear shadowing effects [2]. In this contribution, the results of coherent photoproduction of ρ^0 and J/ψ vector mesons in Pb–Pb and Xe–Xe UPCs measured with the ALICE experiment will be presented.

2. The ALICE experiment

The ALICE detector is built as a general-purpose detector for high-energy heavy-ion experiments [3]. In this study, the tracks of charged particles from vector meson decay ($\rho^0 \to \pi^+\pi^-$ and $J/\psi \to e^+e^-, \mu^+\mu^-, p\bar{p}$) are reconstructed at mid rapidity ($|y| < 0.8$), using the Time Projection Chamber (TPC) and Inner Tracking System (ITS). At forward rapidity ($-4.0 < y < -2.5$), the muon tracks are reconstructed with the forward muon spectrometer. The UPC events are triggered with a dedicated trigger setup. For the measurement at mid rapidity, low activity with back-to-back topology in the ITS and, in the case of J/ψ measurements only, in the Time of Flight (TOF). No activity is required on the forward scintillation detectors V0 (V0A: $2.8 < \eta < 5.1$, V0C: $-3.7 < \eta < -1.7$) and AD ($4.8 < \eta < 6.3$, $-7.0 < \eta < -4.9$). For the measurements at forward rapidity, vector meson photoproduction events are triggered with the muon trigger system by requiring two oppositely charged tracks. Forward neutrons from the nuclear breakup are detected with the Zero Degree Calorimeter (ZDC) to classify the UPC events: no beam rapidity neutron emission (0n0n), at least one neutron on one side only (0nXn+Xn0n), emission on both sides (XnXn).

3. Coherent ρ^0 photoproduction in UPCs

Figures 1 and 2 (left) show the coherent photoproduction cross section of ρ^0 mesons as a function of rapidity in Pb–Pb and Xe–Xe UPCs respectively. The results are compared with several predictions. The individual predictions are described in [4, 5]. In the case of Pb–Pb UPCs, the cross sections are measured by separating the event based on forward neutron emission. The GKZ model, which is based on a vector-dominance model + Gribov-Glauber model of nuclear shadowing, gives a good description for all nuclear breakup classes, although for all models agreement with the measured data appears in most cases satisfactory. The predictions are all scaled from a single calculation based on the modification of the photon flux in each neutron emission class. This result suggests that factorization holds well. The ρ^0 photoproduction cross section in Xe–Xe UPCs shows agreement with all the predictions within 1-2 standard deviations. The measurement of ρ^0 photoproduction might also give us an opportunity to probe the onset of the black disc limit in soft and hard QCD interactions [6]. Fig. 2 (right) shows the γA cross section for the ρ^0 meson coherent photoproduction as a function of the atomic number A. The slope obtained by fitting the data from ALICE and H1 collaborations agrees with the predictions of the Gribov–Glauber approach (GKZ) and the colour dipole model with sub-nucleon degrees of freedom (CCKT). The result is far from the black-disc limit at this energy, $W_{\gamma A}$ = 65 GeV.

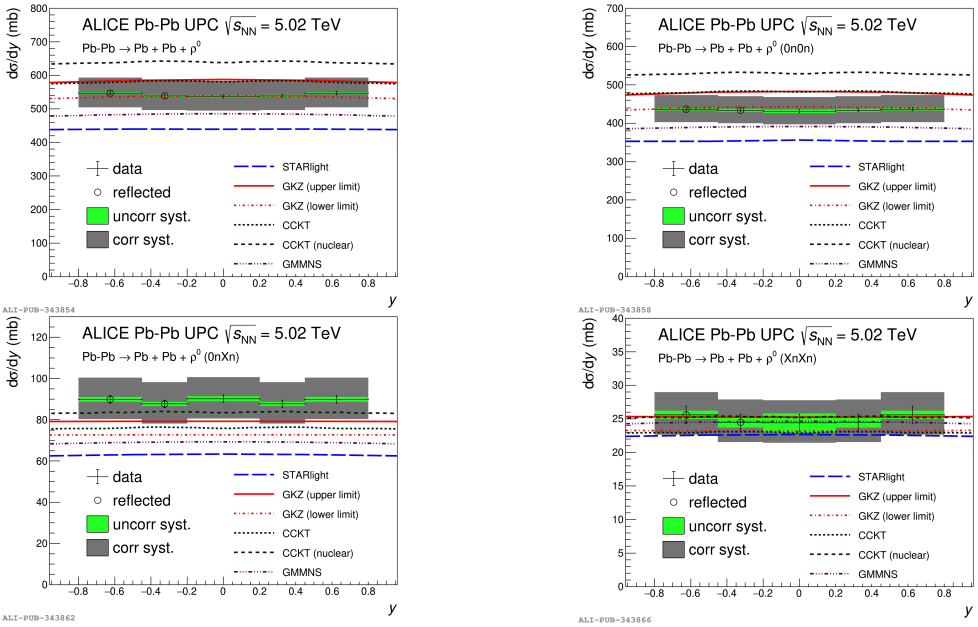

Figure 1: Production cross section of ρ^0 mesons in Pb–Pb UPCs at $\sqrt{s_{\rm NN}}$ = 5.02 TeV as a function of rapidity [4]. The cross sections are measured for different nuclear breakup classes.

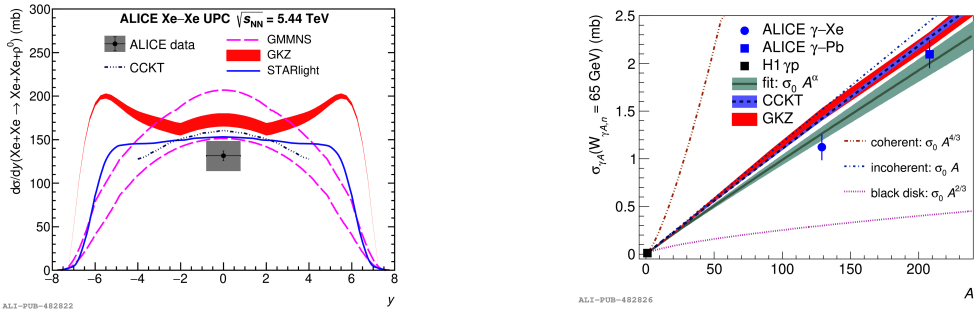

Figure 2: Production cross section of ρ^0 mesons in Xe–Xe UPCs at $\sqrt{s_{\rm NN}}$ = 5.44 TeV as a function of rapidity (left) and A dependence of the γA cross section for ρ^0 meson coherent production (right) [5].

4. Coherent J/ψ photoproduction in UPCs

Figure 3 (left) shows the coherent photoproduction cross section of J/ψ meson as a function of rapidity with several theoretical predictions. More details for the individual predictions can be found in [7, 8]. The central value of a calculation based on the EPS09 LO of the nuclear shadowing data gives a good description. The predictions based on color dipole + colored glass condensate models reproduce the cross section at $-4 < y < -2.5$ well, but they overestimate at $|y| < 0.8$. Fig. 3 (right) shows the J/ψ meson cross section as a function of t, the square of the momentum transferred between the incoming and outgoing target nucleus, which is sensitive to the transverse gluonic structure at low Bjorken-x. The result is described well by both the models with which it is compared, which include leading twist shadowing and saturation.

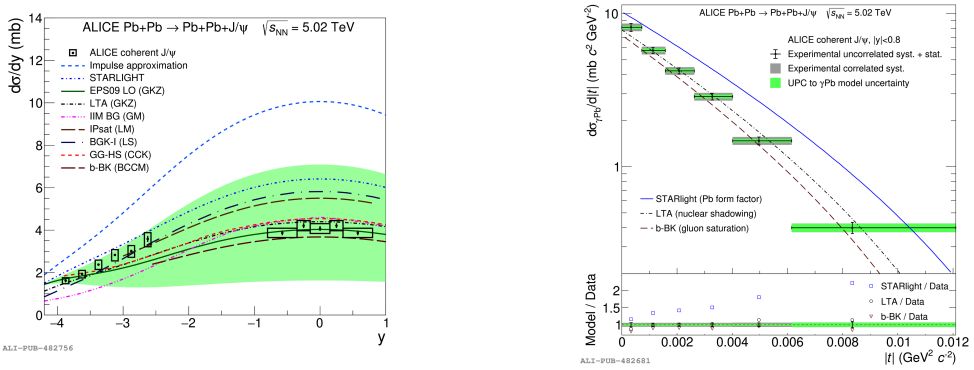

Figure 3: Production cross section of J/ψ mesons as a function of rapidity (left) and of $|t|$ (right) in Pb–Pb UPCs at $\sqrt{s_{\rm NN}}$ = 5.02 TeV [7, 8].

5. Summary and outlook

The ALICE experiment has measured the coherent photoproduction of ρ^0 vector mesons in Pb–Pb UPCs at $\sqrt{s_{\rm NN}}$ = 5.02 TeV and Xe–Xe UPCs at $\sqrt{s_{\rm NN}}$ = 5.44 TeV, and of J/ψ vector mesons in Pb–Pb UPCs at $\sqrt{s_{\rm NN}}$ = 5.02 TeV. A comparison with the predictions suggests shadowing has an important effect. Measurements with the larger data sample expected in LHC Run 3 would give a more strict constraint on the model predictions.

References

[1] A. J. Baltz *et. al.*, "The Physics of Ultraperipheral Collisions at the LHC", Phys. Rept. **458**, 1, 2008

[2] V. Guzey, E. Kryshen, and M. Zhalov, "Coherent photoproduction of vector mesons in heavy ion ultraperipheral collisions: Update for run 2 at the CERN Large Hadron Collider", Phys. Rev. C **93**, 055206 , 2016

[3] ALICE Collaboration, "The ALICE experiment at the CERN LHC", JINST **3**, S08002, 2008

[4] ALICE Collaboration, "Coherent photoproduction of ρ^0 vector mesons in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV", JHEP **06**, 35, 2020

[5] ALICE Collaboration, "First measurement of coherent ρ^0 photoproduction in ultra-peripheral Xe–Xe collisions at $\sqrt{s_{\rm NN}}$ = 5.44 TeV", Phys. Lett. B **820**, 136481, 2021

[6] L. Frankfurt, M. Strikman, and M. Zhalov, "Signals for black body limit in coherent ultraperipheral heavy ion collisions", Phys. Lett. B **537**, 51, 2002

[7] ALICE Collaboration, "Coherent J/ψ and ψ' photoproduction at midrapidity in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV", Eur. Phys. J. C **81**, 712, 2021

[8] ALICE Collaboration, "First measurement of the $|t|$-dependence of coherent J/ψ photonuclear production", Phys. Lett. B **817**, 136280, 2021