PROCEEDINGS OF SCIENCE

Latest ALICE results on coherent J/ψ photoproduction in ultra-peripheral Pb–Pb collisions at the LHC

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The high flux of photons from lead ions at the LHC allows us to study photon-induced reactions in ultra-peripheral collisions (UPC) of Pb–Pb nuclei in a new kinematic regime. The study of these collisions, where projectiles do not overlap and hence hadronic interactions are suppressed, provides information about the initial state of nuclei. Coherent charmonium photoproduction is of particular interest since it is sensitive to poorly known gluon shadowing effects in target Pb ions.

The newest ALICE results on vector meson photoproduction in UPC Pb–Pb collisions from LHC Run 2 are presented and are compared to current models describing nuclear gluon shadowing.

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1. Proton and nucleus structure

The structure of the proton can be described by parton distribution functions (PDF). At low x the main component is the gluon distribution function which is steeply rising due to gluon splitting. Eventually, the process of gluon recombination will stop this rise and saturation of the gluon PDF will be reached. This has been predicted by perturbative Quantum Chromodynamics (pQCD), but not yet conclusively observed.

It is known that the structure of nuclei is not a simple coherent sum of the structure of its nucleons. It has been measured that at small x, the structure function of lead is smaller than what is expected from the above-mentioned sum. This phenomenon is called shadowing. One of the possible origins of shadowing is saturation.

2. Coherent J/ψ photoproduction in ultra-peripheral collisions

The coherent photonuclear production of a J/ψ is a sensitive probe of shadowing at low x and small scales, where shadowing is poorly known. A diagram of this process is shown in Fig. 1 (left). The lead ions at the LHC are a very intense source of high energy photons where the photon flux intensity is proportional to Z^2 while the maximum energy of the photons is given by the Lorentz boost of the lead ion. Due to the large mass of the produced J/ψ vector meson the measurements can be compared with perturbative calculations, and due to its small decay width and sizeable branching ratio into dileptons the experimental signal is clean. The leading order cross section for this process in collinear pQCD is proportional to the gluon density squared and thus particularly sensitive to potential saturation and shadowing effects.

To measure this process at the LHC, hadronic interactions must be suppressed. This is achieved in ultra-peripheral collisions (UPC) which are interactions at an impact parameter b larger than the sum of the radii of the colliding particles $R_1 + R_2$. This requirement suppresses the short-range strong interaction and leaves a clean sample of events which involve at least one exchanged photon, see Fig. 1 (right). The previous ALICE measurements can be found in Ref. [1]. For a recent review of UPC at the LHC see Ref. [2] and references therein.

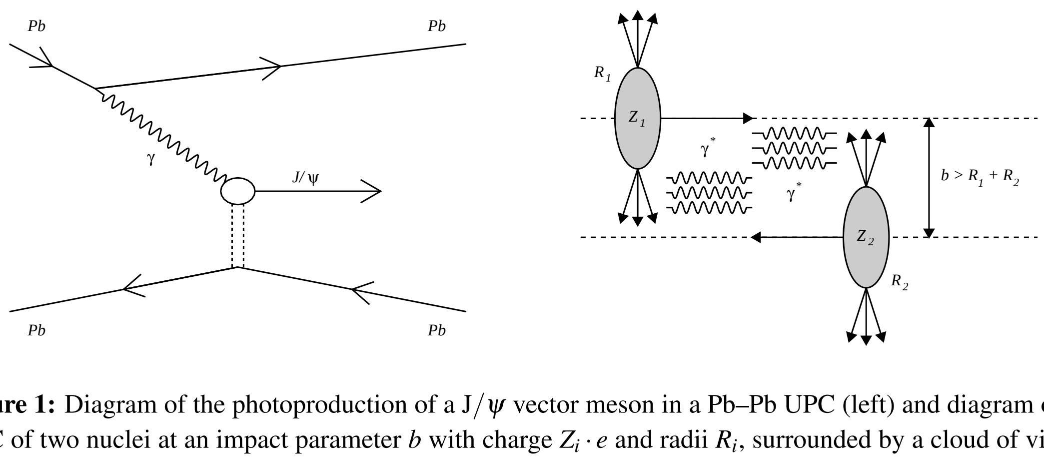

Figure 1: Diagram of the photoproduction of a J/ψ vector meson in a Pb–Pb UPC (left) and diagram of an UPC of two nuclei at an impact parameter b with charge $Z_i \cdot e$ and radii R_i, surrounded by a cloud of virtual photons γ^* (right).

3. The analysis procedure

The analysed data sample of Pb–Pb UPC at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV was recorded during the LHC Run 2 with the ALICE detector [3] in the rapidity range $-4.0 < y < -2.5$. The J/ψ is measured in the dimuon decay channel. The key subdetectors used in this analysis are the muon spectrometer for muon track reconstruction and the AD and V0 scintillators, which cover a large rapidity range, used as vetoes to reject background events.

The raw J/ψ yield and the feed-down contribution from ψ' decays were extracted from the invariant mass spectra (Fig. 2 (left)), while the transverse momentum distribution was used to estimate the contribution from the incoherent process (Fig. 2 (right)).

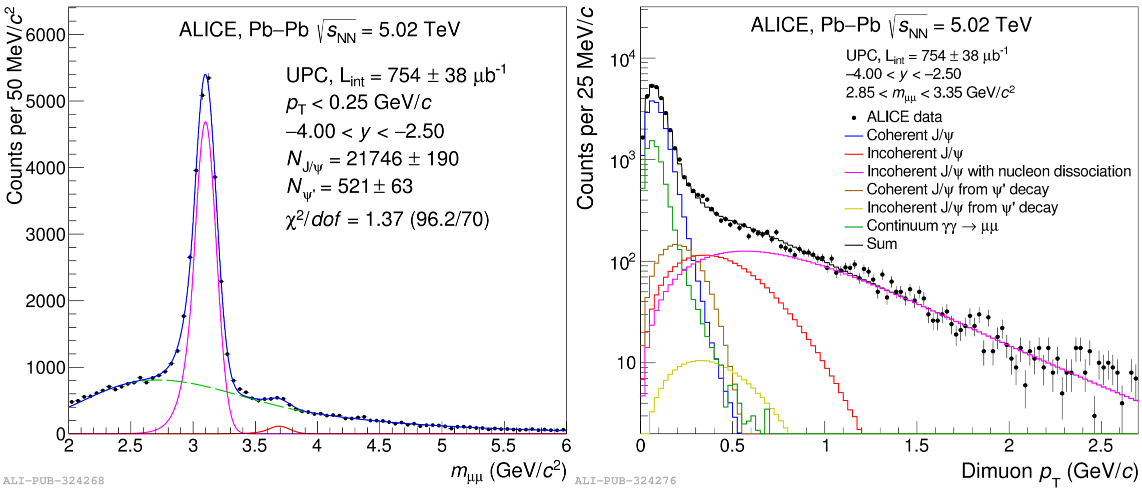

Figure 2: Invariant mass distribution (left) and the transverse momentum distribution (right) of unlike-sign dimuons in the full rapidity range measured with the ALICE detector at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. In the invariant mass plot the magenta line describes the J/ψ peak, the red line describes the ψ' peak, the green line describes the background from $\gamma\gamma \to \mu^+\mu^-$, and the blue line describes the full fit function [4].

4. Results

Figure 3 shows the measured rapidity dependence of the cross section for coherent photoproduction of J/ψ off Pb nuclei. Data is compared with different models for this process. The IPSat (LM) [5] and BGK-I (LS) [6] predictions, based on the colour dipole model, describe best the data. The difference between the Impulse Approximation, which does not consider any nuclear effects, and the measured cross section signals moderate gluon shadowing. The GG-HS (CCK) [7, 8] describes data at forward rapidities and underestimates the measurement at semi-forward rapidities, similar behaviour is observed for EPS09 (GKZ) [9]. Starlight [10], which assumes no gluon shadowing, slightly overshoots data at all rapidities.

Acknowledgments

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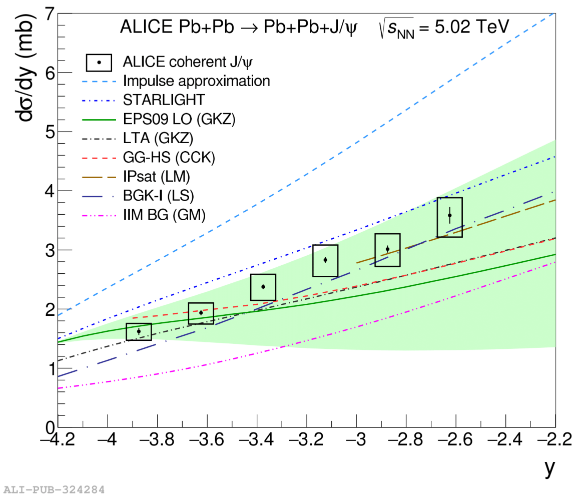

Figure 3: Rapidity dependence of the cross section for coherent photoproduction of J/ψ off Pb nuclei in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. The error bars represent the statistical uncertainties, the boxes around the points the systematic uncertainties. The results are compared with theoretical calculations, see text and Ref. [4] for details.

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