UPC: a powerful tool for J/ψ photoproduction analysis in ALICE

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Five facts about UPC

- Ultra-peripheral Collisions (UPC) are mediated by virtual photon exchange between the interacting protons or ions.
- The γ fluctuates to a $q\bar{q}$ pair, and has $J^{PC} = 1^{--}$.
- Large cross section for vector meson photoproduction (J/ψ in this poster), see Fig. 1;
- Protons and nuclei probed at low Bjorken-*x* (order of 10^{-5}).
- The ALICE Collaboration has analysed J/ψ photoproduction in p-Pb and in Pb-Pb events at $\sqrt{s_{NN}} = 5.02$ TeV.

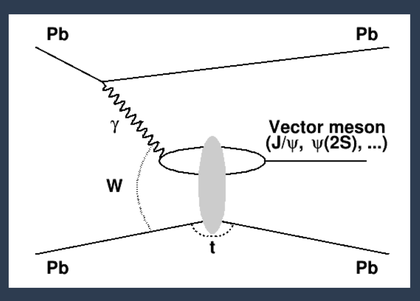
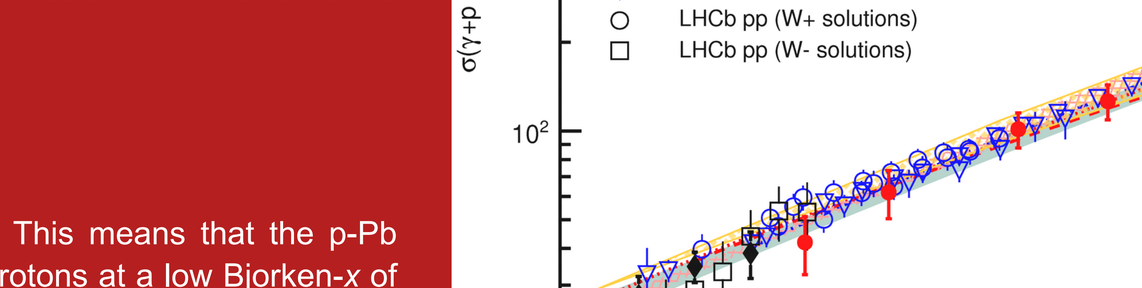


Fig. 1: Feynman diagram for the photoproduction of vector mesons in typical UPC.

The ALICE detector



The ALICE Detector is shown in Fig. 2. It is divided into a central barrel enclosing the Inner Tracking System, the Time Projection Chamber and the Time-Of-Flight System, and a Forward Muon Spectrometer that detects muons in the forward region, i.e. the rapidity region $-4.0 < y < -2.5$. There are also several forward detectors, e.g. the V0 and the AD detectors, which are used as online and offline vetoes to select UPC events.

Fig. 2: The ALICE detector during Run 2.

What p-Pb data can offer us

For coherent J/ψ photoproduction in UPC, the rapidity of the vector meson is related to the Bjorken-*x* as shown in eq. [1]:

$$x = \frac{M_{J/\psi}}{\sqrt{S_{NN}}} \cdot e^{-y}, \qquad [1]$$

where $M_{J/\psi}$ is the mass of the J/ψ, and *y* is its rapidity. This means that the p-Pb dataset has the capability of probing the gluon pdf in the protons at a low Bjorken-*x* of $x \sim 10^{-5}$, due to $\sqrt{s_{NN}} = 5.02$ TeV.

Fig. 3 shows all the p-Pb ALICE measurements for the exclusive photoproduction of J/ψ off protons as a function of $W_{\gamma p}$, the centre-of-mass energy of the photon-proton system. The dataset covers the range from 24 to 706 GeV, corresponding to three orders of magnitude in Bjorken-*x* up to $x \sim 10^{-5}$.

It is important here to study the power-law rise of the cross section of the process. This is interpreted as a steep rise of the gluon distribution, and unitarity would require gluon saturation and hence a slowing of such a rise; this has not yet been observed [1].

Fig. 3: Exclusive photoproduction of J/ψ off protons in p-Pb data.

What Pb-Pb has given us

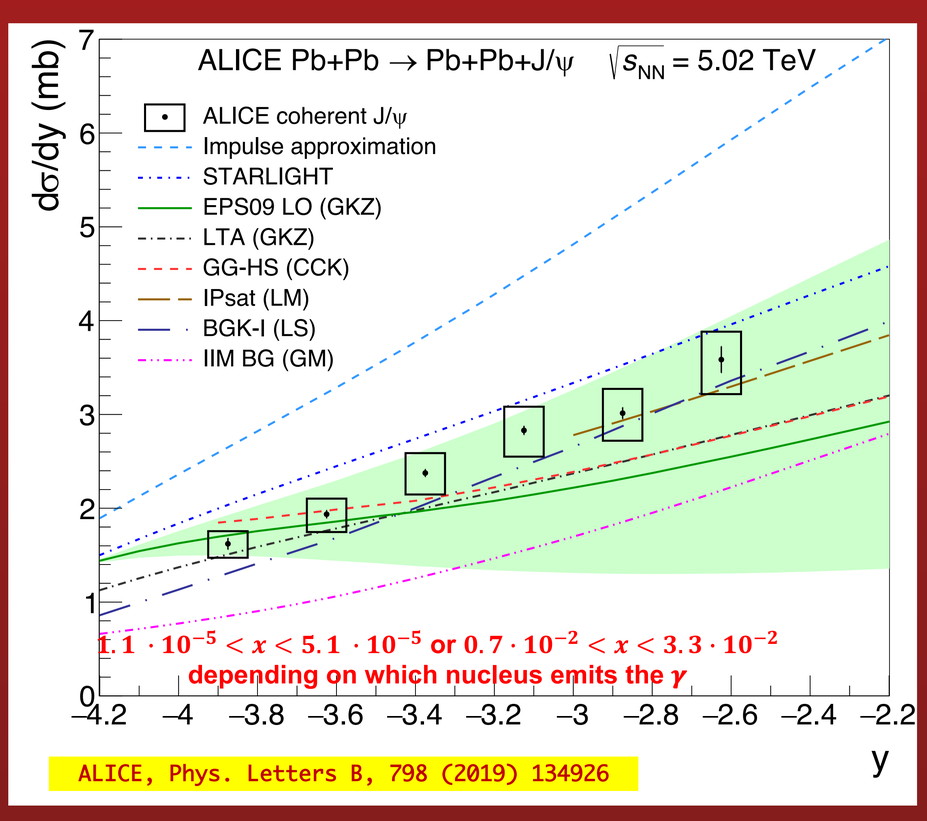


Fig. 4: J/ψ photoproduction cross section in UPC as measured by the ALICE Collaboration. The cross section is shown as a function of rapidity.

Pb-Pb data can be used to investigate nuclear shadowing, which is the decrease of the coherent photoproduction cross section on the whole nucleus compared to treating the nucleus as an incoherent sum of nucleons, $\sigma_A < A \cdot \sigma_N$.

Fig. 4 shows the cross section of the coherent J/ψ photoproduction as a function of rapidity [2]. The impulse approximation model does not include nuclear shadowing. The data favour models including a moderate amount of gluon shadowing. However, in Pb-Pb it is not possible to ascertain which Pb nucleus is the photon source, so the dataset is a mixture of low and high Bjorken-*x* processes.

Conclusion

p-Pb data allow us to search for indications of saturation effects at higher $W_{\gamma p}$ values. The cross sections shown in Fig. 3 cannot grow indefinitely, a basic prediction of the unitarity principle for gluon parton distribution functions. The Bjorken-*x* that ALICE data could probe with the dataset shown here extends down to values of around $\sim 10^{-5}$.

Nuclear shadowing effects are instead the main investigation topic with Pb-Pb data. ALICE data has undisputedly proven that nuclear shadowing models are favoured by the current data, whereas models without any shadowing involvement e.g. impulse approximation, are disfavoured by the current results.

References

[1] ALICE Collaboration. "Energy dependence of exclusive J/ψ photoproduction off protons in ultra-peripheral p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV." *Eur. Phys. J. C* **79,** 402 (2019).
[2] ALICE Collaboration. "Coherent J/ψ photoproduction at forward rapidity in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV." *Phys. Letter B, 798* (2019).

Acknowledgements

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