Impact parameter description of the nucleus and the incoherent photoproduction of vector mesons in the color dipole approach

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Abstract

We study the exclusive photoproduction of heavy vector mesons off nuclear targets using the color dipole model within the Glauber-Gribov formalism. We obtained the impact-parameter-dependent cross sections for both coherent and incoherent cases, with spatial correlations among nucleons to account for fluctuations in their positions. This approach aims to provide a more accurate description of the experimental data. Our results are compared to PbPb photoproduction measurements from ALICE, showing good agreement for the coherent case while highlighting the need for additional nuclear effects in the incoherent case.

Cross section

In the Glauber-Gribov formalism, the coherent and incoherent cross sections, respectively, are given by

$$\sigma_{coh} = \int d^2b \left| \int d^2r \int d\alpha \Psi^*_V(\mathbf{r},\alpha)\Psi_\gamma(\mathbf{r},\alpha)\left[1 - e^{-\frac{1}{2}\sigma_{\rm dip}(r,x)AT_A(b)}\right] \right|^2 \quad (1)$$

$$\sigma_{inc} = \frac{AT_A(b)}{16\pi B} \int d^2b \left| \int d^2r \int d\alpha \Psi^*_V(\mathbf{r},\alpha)\Psi_\gamma(\mathbf{r},\alpha) e^{-\frac{1}{2}\sigma_{\rm dip}(r,x)AT_A(b)} \sigma_{\rm dip}(r,x) \right|^2 \quad (2)$$

Deriving the above equations involves certain approximations, such as:

1. Uncorrelated nucleons
2. $\lim_{A\to\infty}\left(1+\frac{x}{A}\right)^A = e^x$
3. $T_A(\mathbf{s}+\mathbf{b}) \approx T_A(b)$
4. $\exp(x) = 1 + x + \ldots$

To assess the impact of these assumptions, we calculated the cross sections without them, modeling the proton in two different ways: as a gaussian and as a heaviside step function.

- Proton as a heaviside

By modeling the proton as a heaviside function, we obtained the following cross section equations:

$$\sigma_{coh} = \int d^2b \left| \sum_{config} \int d^2r \int d\alpha \Psi^*_V(\mathbf{r},\alpha)\Psi_\gamma(\mathbf{r},\alpha) \left[1 - \left(1 - \frac{\sigma_{\rm dip}(r,x)}{4\pi B}\right)^{n(b)}\right] \right|^2 \quad (3)$$

$$\sigma_{inc} = \int d^2b \left[\sum_{config} \left| \int d^2r \int d\alpha \Psi^*_V(\mathbf{r},\alpha)\Psi_\gamma(\mathbf{r},\alpha) \left[1 - \left(1 - \frac{\sigma_{\rm dip}(r,x)}{4\pi B}\right)^{n(b)}\right] \right|^2 - \left| \sum_{config} \int d^2r \int d\alpha \Psi^*_V(\mathbf{r},\alpha)\Psi_\gamma(\mathbf{r},\alpha) \left[1 - \left(1 - \frac{\sigma_{\rm dip}(r,x)}{4\pi B}\right)^{n(b)}\right] \right|^2 \right] \quad (4)$$

Where n(b) is the number of dipole-nucleon interations at a given impact parameter.

- Proton as a gaussian

By modeling the proton as a gaussian function, the expressions for the cross sections are the following:

$$\sigma_{coh} = \int d^2b \left| \sum_{config} \int d^2r \int d\alpha \Psi^*_V(\mathbf{r},\alpha)\Psi_\gamma(\mathbf{r},\alpha) \left[1 - \prod_i^A \left(1 - \frac{\sigma_{\rm dip}(r,x)}{4\pi B} e^{\frac{-(b-s_i)^2}{2B}}\right)\right] \right|^2 \quad (5)$$

$$\sigma_{inc} = \int d^2b \sum_{config} \left| \int d^2r \int d\alpha \Psi^*_V(\mathbf{r},\alpha)\Psi_\gamma(\mathbf{r},\alpha) \left[1 - \prod_i^A \left(1 - \frac{\sigma_{\rm dip}(x,r)}{4\pi B} e^{\frac{-(b-s_i)^2}{2B}}\right)\right] \right|^2 - \int d^2b \left| \sum_{config} \int d^2r \int d\alpha \Psi^*_V(\mathbf{r},\alpha)\Psi_\gamma(\mathbf{r},\alpha) \left[1 - \prod_i^A \left(1 - \frac{\sigma_{\rm dip}(x,r)}{4\pi B} e^{\frac{-(b-s_i)^2}{2B}}\right)\right] \right|^2 \quad (6)$$

Results

Using the presented equations, we numerically calculated the coherent and incoherent cross sections for J/ψ photoproduction, applying all and none of the approximations, with and without shadowing. The correlated configurations were obtained from [3].

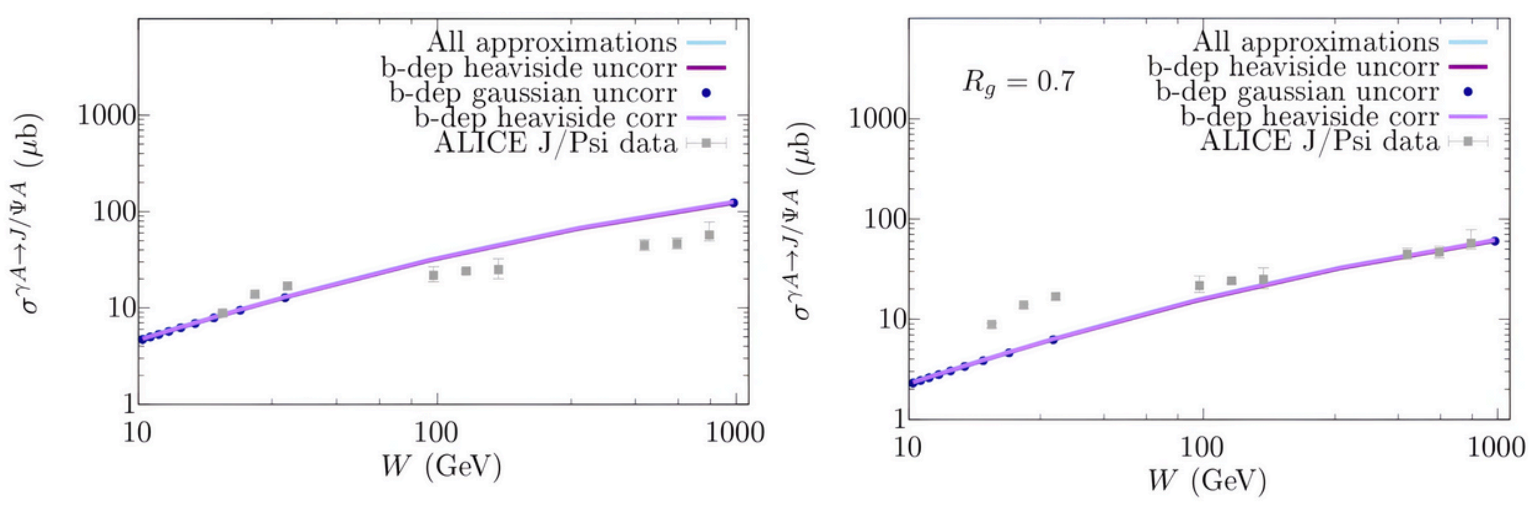

Figure: Coherent cross section with and without shadowing.

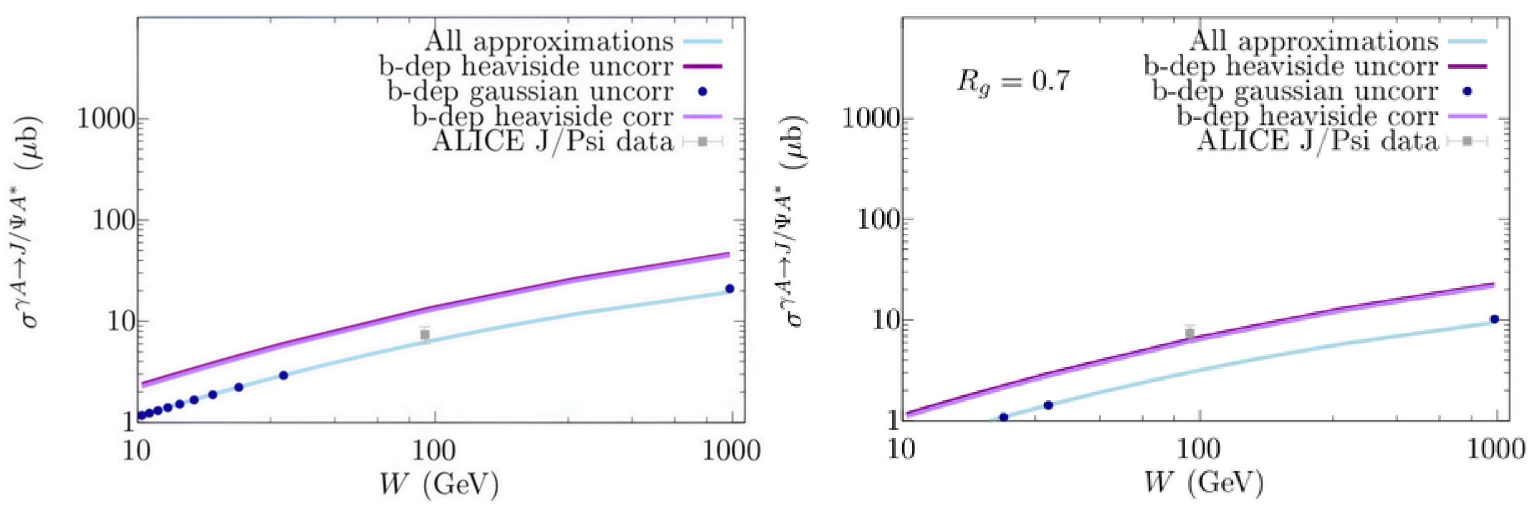

Figure: Incoherent cross section with and without shadowing.

Conclusions

We found that the approximations have little impact, but the incoherent cross section is highly sensitive to the proton shape. Currently, we are focusing our studies on photon-proton collisions to better understand the proton structure and to then apply it to the nuclear case.

References

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