Gluon shadowing and the role of the $c\bar{c}g$ -Fock state in the diffractive photoproduction of J/ψ

Wolfgang Schäfer [1], Agnieszka Łuszczak [2]

[1] Institute of Nuclear Physics, PAN, Kraków
[2] Cracow University of Technology, Kraków

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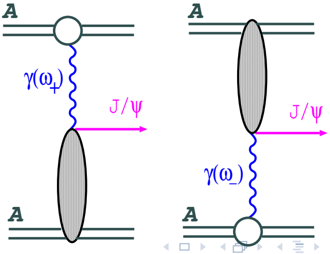
- The exclusive photoproduction of heavy vector mesons in **ultraperipheral heavy ion collisions** yields information on the interaction of small color dipoles with nuclei.
- $\rightarrow$ a probe of the nuclear gluon distribution



Diffractive photoproduction of J/ψ on protons and nuclei

- in the limit of large photon energy ω in the rest frame of the target, the coherence length $l_c = 2\omega/M^2_{J/\psi}$ becomes much larger than the size R of the target $l_c \gg R$
- we can describe photoproduction of the J/ψ as a splitting of the photon into a $c\bar{c}$ pair far upstream the target, and an interaction of a color dipole of size $\boldsymbol{r}$ formed by quark and antiquark. After the interaction with the target, the scattered $c\bar{c}$ pair evolves into the outgoing final state vector meson.

Forward amplitude

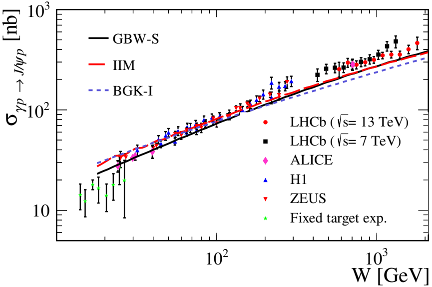
$$\mathcal{A}(\gamma A \to J/\psi A; W, \boldsymbol{q}=0) = 2i \int d^2\boldsymbol{b}\, \langle J/\psi | \Gamma_A(x, \boldsymbol{b}, \boldsymbol{r}) | \gamma \rangle =$$

$$i \int_0^1 dz \int d^2\boldsymbol{r}\, \Psi^*_{J/\psi}(z, \boldsymbol{r}) \Psi_\gamma(z, \boldsymbol{r})\, \sigma(x, \boldsymbol{r})..$$

- the main ingredients are the light-front wave functions of photon and vector meson and the dipole cross section
- **diffractive photoproduction of heavy vector mesons gives us information on the interaction of small color dipoles with protons or cold nuclear matter**

Dipole cross section

- We use dipole cross sections that have been fitted to precise HERA data on the proton structure function $F_2(x, Q^2)$.
- a good agreement with J/ψ diffractive data up to γp-cm energies of a few hundred GeV is obtained.

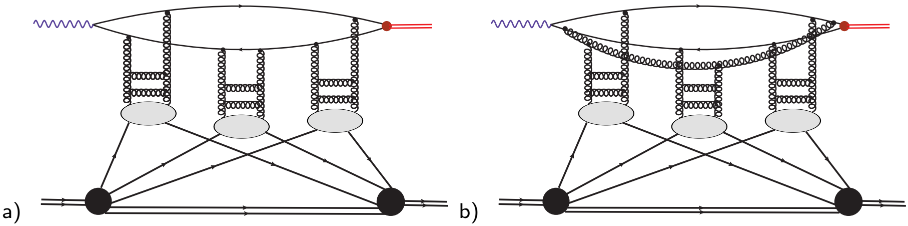


Dipole-cross section $\leftrightarrow$ gluon distribution

$$\sigma(x, \boldsymbol{r}) \quad = \quad \frac{4\pi\alpha_S}{N_c} \int \frac{d^2\boldsymbol{\kappa}}{\boldsymbol{\kappa}^4} \frac{\partial xg(x, \boldsymbol{\kappa}^2)}{\partial \log(\boldsymbol{\kappa}^2)} \left(1 - e^{i\boldsymbol{\kappa}\cdot\boldsymbol{r}}\right) \approx \boldsymbol{r}^2 \, \frac{\pi^2\alpha_S}{N_c} \, xg(x, \frac{1}{\boldsymbol{r}^2})$$

- behaviour at small $\boldsymbol{r}^2$ suggests a proportionality of the diffractive amplitude to the gluon distribution of the target. But: on nuclear targets large higher twists effects from multiple scattering.

Diffractive photoproduction on nuclei



- rescattering of the $c\bar{c}$ dipole only can be obtained by a simple Glauber exponential

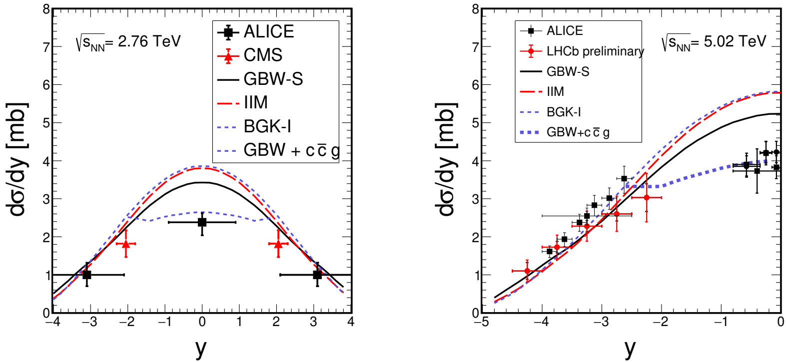
$$\Gamma_A(x, \boldsymbol{b}, \boldsymbol{r}) = 1 - S_A(x, \boldsymbol{b}, \boldsymbol{r})\,, \text{ with } S_A(x, \boldsymbol{b}, \boldsymbol{r}) = \exp\Big[-\frac{1}{2}\sigma(x, \boldsymbol{r}) T_A(\boldsymbol{b}) \Big]\,.$$

- the rescattering of the $c\bar{c}$ pair corresponds to a resummation of higher-twist terms, **not** to a nuclear modification of the nuclear glue! The $c\bar{c}g$ yields a correction:

$$\Gamma_A(x, \boldsymbol{r}, \boldsymbol{b}) = \Gamma_A(x_A, \boldsymbol{r}, \boldsymbol{b}) + \log\Big(\frac{x_A}{x}\Big)\Delta\Gamma_A(x_A, \boldsymbol{r}, \boldsymbol{b})$$

- the **nuclear glue** appears only, once the rescattering of $c\bar{c}g$ states are taken into account. But here the splitting amplitude $q \to qg$ in impact parameter space needs an infrared regularization (**gluon propagation radius** R_c). $x_A \sim 0.01$ also is a parameter of the model.

Ultraperipheral nuclear collisions



- Glauber-Gribov theory including only rescattering of the $c\bar{c}$ dipole works well in the forward region(large rapidities).
- In the central rapidity region inclusion of the $c\bar{c}g$ state introduces additional shadowing which is needed to describe the data. Strong dependence on R_c, a rather small $R_c \sim 0.21$ fm is preferred.
- Shadowing due to the $c\bar{c}g$ state can be (roughly) identified with gluon shadowing of the nuclear pdf. It depends on the infrared regulator. For J/ψ gluon shadowing is not a prediction of perturbation theory (hard scale $Q^2 \sim 2.25\,\mathrm{GeV}^2$). **Moderate gluon shadowing.**