Photoproduction of vector mesons in Xe-Xe ultraperipheral collisions at the LHC and the nuclear form factors of Xe isotopes

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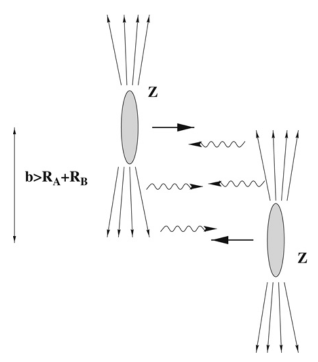
1. Motivation

- Knowledge of the nuclear isoscalar form factor (nuclear structure factor) is essential in searches for weakly interacting massive particles (WIMP) using spin-independent elastic scattering off nuclei with Xenon-based detectors [1].
- The isoscalar form factor is probed in scattering of neutral particles, e.g., in coherent photoproduction of vector mesons $\gamma A \to VA$.
- It can be studied in heavy-ion ultraperipheral collisions (UPCs) at large impact parameters, where the reaction is dominated by emission of quasi-real photons of high intensity and energy (equivalent photon approximation) [2]



- The cross section of coherent and incoherent vector meson V (V=ρ, ϕ, J/ψ) in nucleus-nucleus UPCs:

$$\frac{d\sigma_{AA\to VAA'}(y)}{dy\,dt} = N_{\gamma/A}(y)\frac{\sigma_{\gamma A\to VA'}(y,t)}{dt} + N_{\gamma/A}(-y)\frac{\sigma_{\gamma A\to VA'}(-y,t)}{dt}$$

y = rapidity of V, t = momentum transfer squared, and $N_{\gamma/A}$ = photon flux

2. Vector meson photoproduction on nuclei

- The coherent nuclear cross section is calculated using the Gribov-Glauber model of nuclear shadowing combined with a model for hadronic fluctuations for $\gamma N \to VN$ [3,4]. For ρ, ϕ:

$$\frac{\sigma^{\mathrm{mVMD-GGM}}_{\gamma A\to VA}(W_{\gamma N},t)}{dt} = \frac{d\sigma_{\gamma N\to VN}(W_{\gamma N},t=0)}{dt}\left|2\int d^2\vec{b}\,e^{i\vec{q}_t\cdot\vec{b}}\int\frac{d\sigma}{\langle\sigma\rangle}P(\sigma)\left(1-e^{-\frac{\sigma}{2}T_A(\vec{b})}\right)\right|^2$$

- P(σ)= probability distribution for the photon to interact with target nucleons with cross section σ. Its shape is constrained by data on elastic and diffractive-dissociation photoproduction on the proton;
- $T_A(b)=\int dz\, \rho_A(r)$ = nuclear optical density calculated using the standard spherical Hartree-Fock-SkyrmeIII model.

- For J/ψ, the coherent nuclear cross section can be expressed in terms of two first moments of P(σ) [5]:

$$\begin{aligned}\frac{\sigma^{\mathrm{LTA}}_{\gamma A\to J/\psi A}(W_{\gamma N},t)}{dt} &= \frac{d\sigma_{\gamma N\to J/\psi N}(W_{\gamma N},t=0)}{dt}\left(1-\frac{\sigma_2}{\sigma_3}+\frac{\sigma_2}{\sigma_3}\frac{\sigma_3^A}{A\sigma_3}\right)^2|F_A(t)|^2\\ &= \frac{d\sigma_{\gamma N\to J/\psi N}(W_{\gamma N},t=0)}{dt}\left(\frac{g_A(x,\mu^2)}{Ag_p(x,\mu^2)}\right)^2|F_A(t)|^2\,,\end{aligned}$$

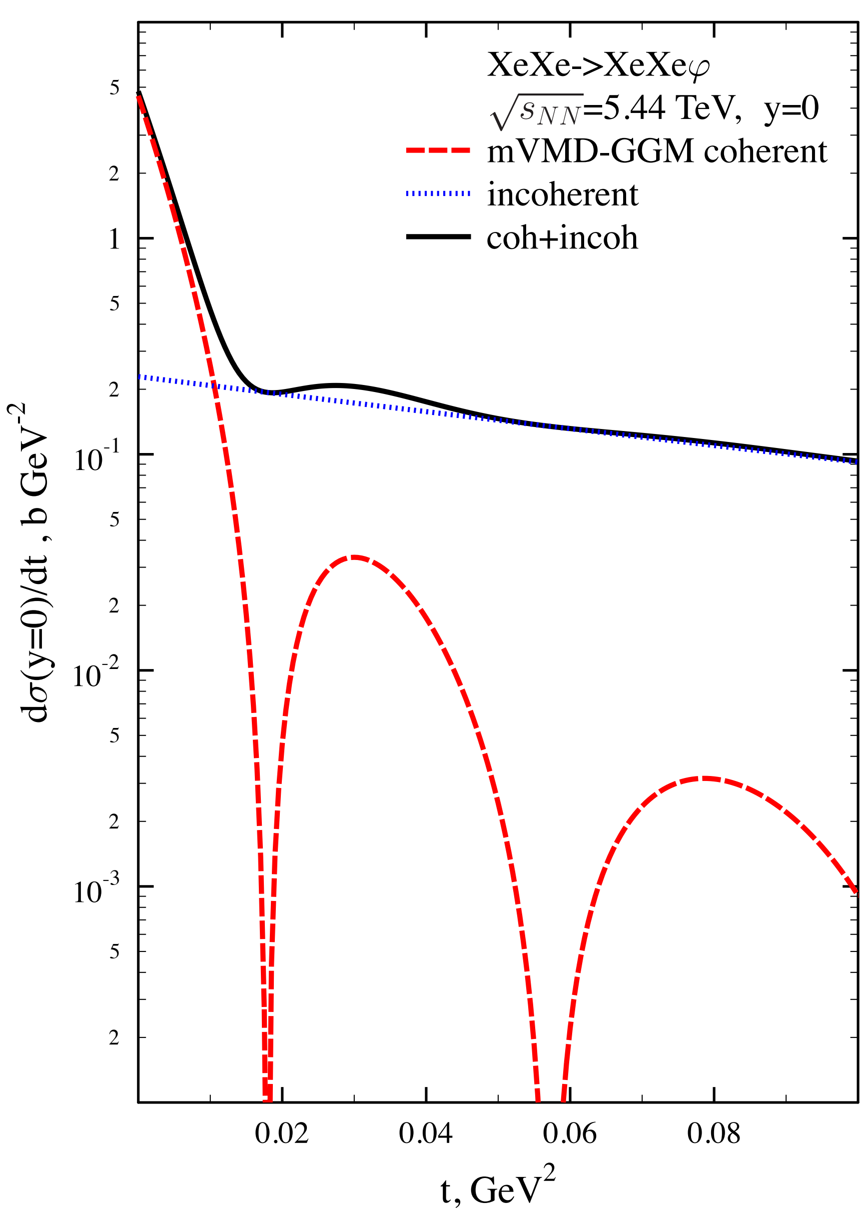
- $\sigma_2=\langle\sigma^2\rangle/\langle\sigma\rangle$, $\sigma_3=\langle\sigma^3\rangle/\langle\sigma^2\rangle$, and $\sigma_3^A=2\int d^2b(1-e^{-\sigma_3 T_A(b)/2})$
- $g_A/[Ag_p]$=ratio of the gluon densities in the nucleus and proton

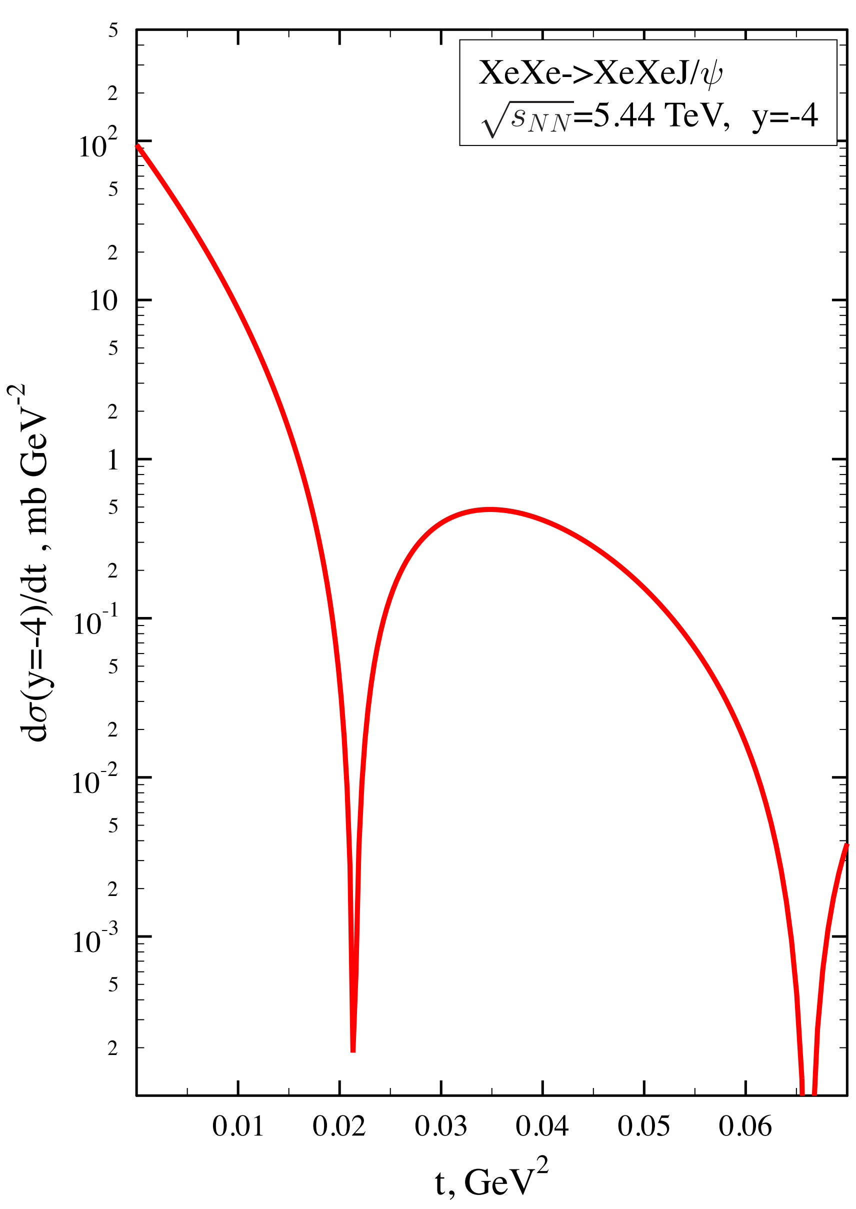
- The incoherent nuclear cross section in the same framework:

$$\frac{d\sigma^{\mathrm{mVMD-GGM}}_{\gamma A\to VA'}(W_{\gamma N},t)}{dt} = \frac{d\sigma_{\gamma N\to VN}(W_{\gamma N},t)}{dt}\int d^2\vec{b}\,T_A(b)\left|\int d\sigma P(\sigma)\frac{\sigma}{\langle\sigma\rangle}e^{-\frac{\sigma_{\mathrm{in}}}{2}T_A(\vec{b})}\right|^2$$

3. Results

- Predictions for t dependence of ϕ and J/ψ photoproduction cross section in Xe-Xe UPCs at 5.44 TeV and y=0 and y=-4





- In the coherent case, the shape of the t dependence (positions of diffractive dips) is sensitive to the isoscalar nuclear form factor.
- However, nuclear shadowing distorts it → to minimize this effect, it is advantageous to study mesons with small cross sections: ϕ, J/ψ
- The incoherent contribution washes out the dips → to suppress it one can study UPCs accompanied by e.m. excitation of colliding ions in the 0n0n channel.
- This analysis also provides useful information on nuclear shadowing in photoproduction, in particular, on the nuclear mass number A and vector meson type dependence.

References:

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