Nuclear shadowing with Υ photoproduction in PbPb collisions at 5 TeV

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Ultraperipheral collisions (UPCs) of nucleus corresponds to the scenario when the impact parameter is larger than the sum of the radii of colliding ions, so that strong interaction is suppressed and they interact electromagnetically via emission of quasi-real photons. Recent results of exclusive photoproduction of heavy vector mesons at LHC energies by CMS and ALICE [1] in UPC reveals the unique possibility to extract potential information about the parton distribution function (PDF) at small x. In this work, we have investigated the exclusive Υ(1S) photoproduction in PbPb UPC collisions at $\sqrt{s_{NN}} = 5$ TeV, the collision scenario at LHC in Run2. Predictions of rapidity distribution of Υ(1S) photoproduction with different gluon shadowing parametrization of nuclear parton distribution functions (nPDF) are being presented.

The rapidity distribution of vector meson (Υ) production in symmetric nucleus-nucleus UPCs has the following form:

$$\frac{\sigma_{AA\to AA\Upsilon}(y)}{dy} = N_{\gamma/A}(y)\sigma_{\gamma A\to\Upsilon A}(y) + N_{\gamma/A}(-y)\sigma_{\gamma A\to\Upsilon A}(-y) \quad (1)$$

Here $N_{\gamma/A}(y)$ is the photon flux ; $y = \ln(2\omega/M_\Upsilon)$ is the rapidity of Υ where ω is the photon energy and M_Υ is the mass of the Υ. The two term corresponds to the feature of UPCs that, each nucleus can radiate photon and also can serve as a target.

Photon flux from nucleus is estimated with a point like expression for a charge Z passing a target at a minimum impact parameter b_{min}:

$$N_{\gamma/Z}(\omega) = \frac{2Z^2\alpha_{em}}{\pi}\Big[\zeta K_0(\zeta)K_1(\zeta) - \frac{\zeta^2}{2}(K_1^2(\zeta) - K_0^2(\zeta))\Big] \quad (2)$$

where K_0 and K_1 are the modified Bessel functions of the second kind, $\zeta = \omega b_{min}/\gamma_L$, where b_{min} is the minimal admitted distance in the impact parameter space chosen to suppress the strong interaction. Here, b_{min} is taken as $b_{min} = 1.15R_{Pb}$.

The cross section of exclusive elastic photoproduction of Υ on A can be written as

$$\sigma_{\gamma A\to\Upsilon A}(y) = \frac{d\sigma_{\gamma A\to\Upsilon A}}{dt}|_{t=0}\int dt|F_A(t)|^2$$

where $d\sigma_{\gamma A\to\Upsilon A}/dt|_{t=0}$ is the forward scattering amplitude and $F_A(t)$ is the charge form factor of the nucleus. Using leading order (LO) approximation, the scattering amplitude for elastic photoproduction of Υ from a nucleus reads :

$$\frac{d\sigma_{\gamma A\to\Upsilon A}(W_{\gamma p}, t=0)}{dt} = \frac{M_\Upsilon^3\Gamma_{ee}\pi^3}{48\alpha_{e.m.}\mu^8}\,(1+\eta^2)\, R_g^2F^2(Q^2)\,[\alpha_s(Q^2)\frac{xG_A(x,Q^2)}{A}]^2 \quad (3)$$

where Γ_{ee} is the width of Υ electronic decay; α_{em} is the fine structure constant; $\alpha_s(Q^2)$ is the running strong coupling constant; $x = M_\Upsilon^2/W_{\gamma p}^2$, is the fraction of nucleon momentum carried by nucleons, $W_{\gamma p}$ is the γp center of mass energy; $G_A(x, Q^2)$ is the gluon distribution in the nucleus evaluated at momentum transfer $Q^2 = (M_\Upsilon/2)^2$. The factors $(1 + \eta^2)$, R_g^2 and $F^2(Q^2)$ corresponds to correction due to real part, skewness and next-to leading (NLO), respectively.

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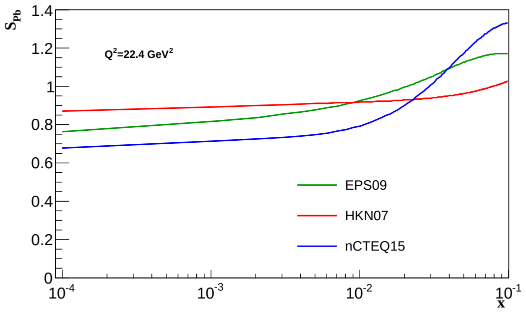

FIG. 1: Suppression factor S_{Pb} for different nuclear gluon shadowing parametrizations.

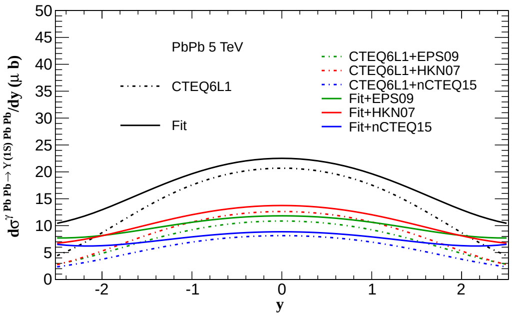

FIG. 2: The rapidity distribution of Υ (1S) photoproduction cross-section for PbPb collisions at $\sqrt{s} = 5$ TeV.

Four recent nucleon and nuclear parton distributions are used for this study. For the proton we use the CTEQ6L1[2] parton distribution and for nucleus three nuclear modification sets are used: (i) EPS09 nuclear PDF at leading order [3] (ii) NLO HKN07 [4] (iii) nCTEQ15 [5]. To evaluate the factors η and R_g, we have fitted the CTEQ6L1 gluon distribution with $1/x^{\lambda}$ and determined the λ from the fit. The suppression factor $F^2(Q^2)$ is phenomenologically determined from normalization while comparing the cross section $\gamma p \rightarrow \Upsilon(1S)p$ with available experimental data from HERA, CMS and LHCb [1].

In case of nuclear target, the photoproduction is given by,

$$\sigma_{\gamma A \rightarrow \Upsilon A}(W_{\gamma p}) = S_A^2 \, \frac{d\sigma_{\gamma p \rightarrow \Upsilon p}}{dt}|_{t=0} \, \Phi_A$$

where $\Phi_A = \int dt |F_A(t)|^2$. S_A is the nuclear suppression factor given by,

$$S_A = R(x, Q^2) \times \kappa_{A/N}. \quad (4)$$

Here, $R(x, Q^2)$ is the nuclear gluon modification factor and the $\kappa_{A/N}$ factor is due to different growth of the nuclear gluon density with x than free proton,

Fig. 1 shows the suppression factor S_{Pb} with x using three different nuclear PDF for $Q^2 = 22.4$ GeV^2 ($Q^2 = M^2_{\Upsilon(1S)}/4$) in the low x region accessible in LHC experiments. We have used $\kappa_{A/N} = 0.87$ neglecting its variation with different gluon distributions. Fig. 2 presents the rapidity distribution of Υ(1S) photoproduction cross section for PbPb UPC collisions at $\sqrt{s_{NN}} = 5$ TeV which is the LHC run 2 scenario, with different nuclear gluon shadowing parametrization. Photoproduction cross section for CMS acceptance ($-2.5 < y < 2.5$) are given in Table 1. We also present the prediction of cross section from power law fit to CMS+HERA data [1] (referred as Fit in Fig. 2 and Table 1). It is observed that, nuclear gluon shadowing affects the cross section of Υ(1S) photoproduction quite substantially.

TABLE I: Υ photoproduction cross-section in CMS acceptance for different nucleon and nuclear PDFs.

Parameterization	cross section (μb)
CTEQ6L1	72
CTEQ6L1+EPS09	39
CTEQ6L1+HKN07	44
CTEQ6L1+nCTEQ15	29
Fit	87
Fit+EPS09	49
Fit+HKN07	54
Fit+nCTEQ15	37

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