Exclusive photoproduction of Upsilon in pPb collisions at LHC energies

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Introduction

Recent results of exclusive photoproduction of heavy vector mesons at LHC energies by ALICE and LHCb [1] in *pp*, *pPb* and *PbPb* Ultrperipheral collisions (UPC) confirmed the expectations that UPCs are a very promising probe to study the gluon distributions in nucleons and in nuclei at small x [2, 3]. In this work, we have estimated the photoproduction of Υ in pPb collisions at $\sqrt{s}_{NN} = 5.02$ TeV in the framework of perturbative two-gluon exchange formalism employing various parametrization of gluon distributions functions.

The rapidity distribution of Υ production in proton-nucleus UPC interaction with proton from the right and nucleus from the left, is given by the sum of two terms, each term in Weizsacker-Williams (WW) approximation is the product of photon flux and the cross-section of Υ photoproduction:

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

Here $N_{\gamma/p(A)}(y)$ is the photon flux of proton (nucleus); $y = \ln(2\omega/M_\Upsilon)$ is the rapidity of Υ where ω is the photon energy and M_Υ is the mass of Υ. The first term corresponds to photon from nucleus while the second term is due to photon flux from proton. As the photon flux $\propto Z^2$ and have support only small value of ω, dying exponentially at large value of ω, the first term in r.h.s. (γp distribution) dominates and peaks at positive rapidity while the second term (γA distribution) peaks at negative rapidity.

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Photon flux

In case of proton-nucleus UPCs one needs to take into account the suppression of the strong interaction between colliding particles. The photon flux of the proton (nucleus) can be expressed as the convolution over the impact parameter b [2]:

$$N_{\gamma/Z}(\omega) = \int_0^\infty d^2\vec{b}\ \Gamma_{pA}(\vec{b}) N_{\gamma/Z}(\omega,\vec{b}) \quad (2)$$

where $N_{\gamma/Z}(\omega,\vec{b})$ is the photon flux in the transverse distance $\vec{b}$ away from the proton (nucleus) and $\Gamma_{pA}(\vec{b})$ is the probability to suppress the proton-nucleus strong interaction at small impact parameter b as given in [2].

Photoproduction of Υ

The cross-section of exclusive elastic photoproduction of Υ on H ($H \equiv p, A$) can be written as

$$\sigma_{\gamma H\to\Upsilon H}(y) = \frac{d\sigma_{\gamma H\to\Upsilon H}}{dt}|_{t=0} \int dt |F_H(t)|^2 \quad (3)$$

where $d\sigma_{\gamma H\to\Upsilon H}dt|_{t=0}$ is the forward scattering amplitude and $F_H(t)$ is the form factor. Using leading order (LO) approximation, the scattering amplitude for elastic photoproduction of Υ from proton or a nucleus reads [2, 3]:

$$\frac{d\sigma_{\gamma H\to\Upsilon H}(W_{\gamma p}, t=0)}{dt} = \frac{M_\Upsilon^3\Gamma_{ee}\pi^3}{48\alpha_{e.m.}\mu^8}\ (1+\eta^2)\ R_g^2 F^2(Q^2)\ [\alpha_s(Q^2)\frac{xG_H(x,Q^2)}{A}]^2 \quad (4)$$

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; $G_H(x,Q^2)$ is the gluon

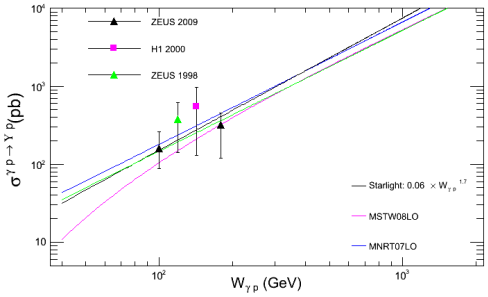

FIG. 1: Photoproduction cross-section of Υ (1S), $\sigma_{\gamma p\to\Upsilon(1S)p}$ with photon-proton center of mass energy $W_{\gamma p}$ compared with the experimental data from HERA [5] and LO result and Starlight prediction.

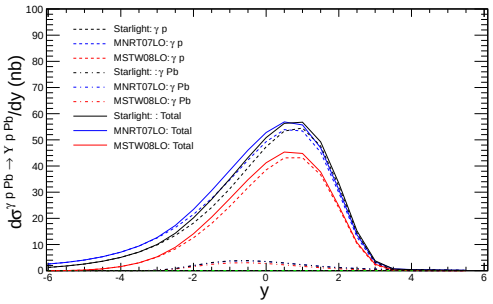

FIG. 2: The rapidity distribution of Υ (1S) photoproduction cross-section for pPb collisions at $\sqrt{s} = 5.02$ TeV.

distribution in the proton (nucleus) evaluated at momentum transfer $Q^2 = (M_\Upsilon/2)^2$. The relevant x region in CMS is $\approx 10^{-2} - 10^{-4}$ at central rapidities ($|y| < 2.5$). 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. For nuclear target, $G_A(x,Q^2) = AG_p(x,Q^2)\times R(x,Q^2)$ is the nuclear gluon density, $R(x,Q^2)$ is the nuclear gluon modification factor. The t-dependence of the cross-section for proton target is generally parametrised with a slope parameter $B(W_{\gamma p})$ and the photoproduction reads, $\sigma_{\gamma p\to\Upsilon p}(W_{\gamma p}) = 1/B(W_{\gamma p})[d\sigma_{\gamma p\to\Upsilon p}/dt|_{t=0}]$. In case of nuclear target, the photoproduction is given by,

$$\sigma_{\gamma A\to\Upsilon A}(W_{\gamma p}) = S_A^2(W_{\gamma p})\frac{d\sigma_{\gamma p\to\Upsilon p}}{dt}|_{t=0} \times\Phi_A(t_{\rm min}) \qquad (5)$$

where $\Phi_A(t_{\rm min}) = \int_{t_{\rm min}}^{\infty} dt|F_A(t)|^2$ and $t_{\rm min} = -M_\Upsilon^4 m_N^2/W_{\gamma p}^4$ is the minimal momentum transfer to the nucleus; $F_A(t)$ is the nuclear form factor; $S_A(W_{\gamma p})$ is the nuclear supprression factor obtained using optical limit of Glauber theory and phenomenological Golec-Beirnat-Wusthoff dipole cross-section [2].

Results

Fig 1. shows the elastic photoproduction of Υ(1S) $\sigma_{\gamma p\to\Upsilon(1S)p}$ with photon-proton center of mass energy $W_{\gamma p}$ with MSTW08 and MNRT07[3] gluon distribution functions and Starlight predictions [4] and also compared with the HERA data [5]. Fig. 2 shows the predicted rapidity distribution of the cross-section of Υ photoproduction in proton-Pb UPC collisions integrated over momentum transfer t at the LHC kinematics estimated by Eq. 1 and with inputs discussed. Estimation is being done using MSTW08 (red), and MNRT07 (blue) gluon distribution functions as well as with Starlight (black) predictions. The solid curves are the total contribution, whereas dashed and dashed-dot curves are for γp and γPb contribution respectively. As one can readily seen that the contribution of photoproduction of Υ on the proton (γp) dominates in the whole rapidity range and MNRT07 and Starlight gives comparable results whereas MSTW08 differs. Our results are comparable with Ref. [6] using color-dipole formalism. The estimation using nuclear PDF with different gluon shadowing parametrisation is under progress.

References

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