The Exclusive Photoproduction of $\Upsilon(1S, 2S, 3S)$ in pp and pA Collisions at LHC Energies

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We presented the exclusive photoproduction of Upsilon(1S,2S,3S) in pp and pA reactions at the LHC energies for Ultra Peripheral Collisions(UPC). It was calculated in the dipole formalism, with the dipoles models: GBW, CGC and b-CGC. The dipole formalism is characterised by a saturation effect, e.g, the mimic gluon distribution becomes saturated at low-x. This approach has shown a good agreement with the experimental data since HERA and with recent data released by LHCb for processes involving $\Psi(1S, 2S)$, $\Upsilon(1S)$, ρ for UPC in pp.

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1. Introduction

The exclusive photoproduction of vector meson $\Upsilon(1S, 2S, 3S)$ in pp and pA at the LHC energies for Ultra Peripheral Collisions (UPC), is calculated using the dipole formalism for different dipoles models¹: GBW, CGC and b-CGC. It is shown the differential cross section in rapidity and the total cross-section for each model at the centre-of-mass energy of 8.2 TeV (pA) and 14 TeV (pp). In addition, this formalism also includes the corrections associated to the parton saturation phenomenon, which prevents the cross-section to grow indefinitely.

2. Theoretical Framework and Phenomenological Inputs

In proton-proton or proton-nucleus interactions at large impact parameter ($b > R_p + R_p$, with R_p being the radius of the proton) and at ultra-relativistic energies it

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is expected only electromagnetic interactions. In this way, we used the Weizsacker-Williams method to describe this interaction. The rapidity distribution takes into account the equivalent photon flux and the cross section which has the meson wave function and the photon wave function and the dipole cross section. The rapidity distribution is given by ²,

$$\frac{d\sigma [h_1 + h_2 \rightarrow h_1 \otimes \Upsilon \otimes h_2]}{dY} = \left[\omega \frac{dN}{d\omega} \Big|_{h_1} \sigma_{\gamma h_2 \rightarrow \Upsilon \otimes h_2}(\omega) \right]_{\omega_L} + \left[\omega \frac{dN}{d\omega} \Big|_{h_2} \sigma_{\gamma h_1 \rightarrow \Upsilon \otimes h_1}(\omega) \right]_{\omega_R} \quad (1)$$

where $\frac{dN_\gamma(y)}{d\omega}$ is the equivalent photon flux and $y = \ln(2\omega/M_V)$. For more details on dipole models see, e.g.,¹; and for the equivalent photon flux for pp and pA see, e.g.,^{3,4,5}. The scalar part of the $\Upsilon(nS)$ were taken from ⁶.

The parameters for each dipole model were obtained from a parametrization of HERA and ZEUS data. The masses of $\Upsilon(1S, 2S, 3S)$ were taken from ⁷.

GBW Model		
Parameters	OLD ⁸	NEW ⁹
σ_0	29.12 mb	31.85 mb
λ_{GBW}	0.277	0.225
x_0	0.41×10^{-4}	0.0546×10^{-4}

CGC Model		
Parameters	OLD ¹⁰	NEW ¹¹
$\mathcal{N}_0$	0.7	0.7
λ	0.2197	0.2319
x_0	0.1632×10^{-4}	0.6266×10^{-4}
σ_0	27.33 mb	21.85 mb
k	9.9	9.9
γ_s	0.7362	0.762

b-CGC Model		
Parameters	OLD ¹²	NEW ¹¹
$\mathcal{N}_0$	0.558	0.3358
λ	0.119	0.2063
x_0	1.84×10^{-6}	0.00105
B_{CGC}	7.5 GeV^{-2}	5.5 GeV^{-2}
k	9.9	9.9
γ_s	0.46	0.6599

3. Main Results

In figure 1, it can be seen the differential cross section for pp considering the GBW, CGC and b-CGC models for the three Υ states at $\sqrt{s} = 14 \text{ TeV}$. It has shown that the ratio $\Upsilon(2S)$ is 5.83 times smaller than $\Upsilon(1S)$ and $\Upsilon(3S)$ is 11.66 times smaller than $\Upsilon(1S)$, both for the b-CGC-old model at $Y=0$. In figure 2, the ratios are greater than the previous case. The ratio $\Upsilon(2S)$ is 6.25 times smaller than $\Upsilon(1S)$ and $\Upsilon(3S)$ is 12.5 times smaller than $\Upsilon(1S)$, both for the b-CGC-old model at $Y=0$. It is stressed that in pA or AA collisions the differential cross section using the equivalent photon flux will give, in the most of cases, a greater one than pp, since the photon flux is proportional to Z^2 .

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Figure 1. Exclusive $\Upsilon(1S, 2S, 3S)$ photoproduction in pp collisions at $\sqrt{s} = 14$ TeV.

Table 1. Total Cross Sections

process: pp	$\sqrt{s} = 14$ TeV	$2 \leq Y \leq 4.5$	
$\Upsilon(nS)$	GBW[pb]	CGC [pb]	b-CGC [pb]
$\Upsilon(1S) - OLD$	37.15	41.70	46.07
$\Upsilon(2S) - OLD$	6.07	7.12	8.00
$\Upsilon(3S) - OLD$	3.10	3.65	4.07
$\Upsilon(1S) - NEW$	24.40	39.20	38.43
$\Upsilon(2S) - NEW$	3.95	6.70	7.01
$\Upsilon(3S) - NEW$	2.03	3.44	3.65

Table 2. Total Cross Sections

process: pA	$\sqrt{s} = 8.2$ TeV	$2 \leq Y \leq 4.5$	
$\Upsilon(nS)$	GBW[nb]	CGC [nb]	b-CGC [nb]
$\Upsilon(1S) - OLD$	53.00	59.60	65.35
$\Upsilon(2S) - OLD$	8.20	9.74	10.66
$\Upsilon(3S) - OLD$	4.32	4.92	5.30
$\Upsilon(1S) - NEW$	36.70	55.95	55.38
$\Upsilon(2S) - NEW$	5.85	9.20	9.71
$\Upsilon(3S) - NEW$	3.00	4.65	4.98

Figure 2. Exclusive $\Upsilon(1S, 2S, 3S)$ photoproduction in pA collisions at $\sqrt{s} = 8.2$ TeV.

Following the same analysis in the total cross section, it was noticed in the table 1 that the ratio between $\sigma(\Upsilon(1S))/\sigma(\Upsilon(2S))$ and $\sigma(\Upsilon(1S))/\sigma(\Upsilon(3S))$ remain almost the same, e.g, 5.75 and 11.31 respectively. In table 2, it was obtained 6.13 and 12.33 respectively. In these two analysis it was also considered the b-CGC-old model.

4. Summary

The formalism of dipoles has shown a good agreement with the experimental data since HERA and the recent papers ^{3,4,5} have shown that this formalism also agrees with the ALICE, CMS and LHCb experimental data for the exclusive photoproduction of J/Ψ in pPb and PbPb collision and $\Upsilon(1S)$ ¹³ for pp collisions. In pp collisions, it was noticed that each dipole model has a different curve shape and also has parameter dependence as expected. For more details about this paper, see the poster ¹⁴.

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