Υ photoproduction in proton-proton collisions at LHC energies

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Introduction

Photons from high energy charged particles by Weizsacker-Williams approach, opens up the possibility to study photon-hadron interactions at inaccessible energies in the collisions at LHC. Exclusive photoproduction of heavy vector mesons in ultraperipheral collisions (UPC) are of special interest [1, 2]. In this work, we estimate the photoproduction of Υ in the framework of perturbative two-gluon exchange formalism employing various parametrization of gluon distribution functions and predicts the rapidity distributions of exclusive Υ photoproduction in pp UPC at $\sqrt{s_{NN}}$ = 7, 13, 14 TeV, the collision scenario at LHC in Run2, in CMS and LHCb detector accepteance.

The cross-section of Υ production in the proton-proton UPC interaction, is given by the sum of two terms, each term is the product of photon flux emitted by one of the colliding participants and the cross-section of Υ photoproduction on the other:

$$\frac{d\sigma_{pp\to pp\Upsilon}(y)}{dy} = [N_{\gamma/p}(\omega)\sigma_{\gamma p\to\Upsilon p}(\omega)]_{\omega=\omega_l} + [N_{\gamma/p}(\omega)\sigma_{\gamma p\to\Upsilon p}(\omega)]_{\omega=\omega_r}$$

Here, ω_l and ω_r denoting photons from the proton incident from the left and right respectively; $y = \ln(2\omega/M_\Upsilon)$ is the rapidity of Υ, M_Υ is the mass of Υ.

The key ingredient of this study is the estimation of photon flux from proton. For the photon flux, one generally use an approximate expression from Drees and Zeppenfeld referred as DZ here [3]. We have used here the gap survival probability to take into account the probability of soft inelastic interaction between protons estimated using an eikonal model,

$$S^2(\omega) = \frac{\int d^2b|\mathcal{M}(\omega,b)|^2 P(s,b)}{\int d^2b|\mathcal{M}(s,b)|^2}. \quad (1)$$

Here b is the impact parameter, $\mathcal{M}(\omega, b)$ is the diffractive amplitude of the process of interest in the impact parameter space and $P(s, b)$ is the probability for not having strong inelastic proton-proton interaction at impact parameter b and $s = s_{NN}$, the center-of-mass energy, and defined as,

$$P(s,b) = \frac{1}{4(1+\gamma^2)}[(1+\gamma)^3 e^{-(1+\gamma)^2\Omega(s,b)} + (1-\gamma)^3 e^{-(1-\gamma)^2\Omega(s,b)} + 2(1-\gamma^2)e^{(1-.\gamma^2)\Omega(s,b)}] \quad (2)$$

where $\gamma = 0.4$ and $\Omega(s,b) = \alpha\ \sigma_{pp}^{tot}(s)/(4\pi B_P)\ e^{-b^2/(4B_P)}$ is the proton optical density. $\sigma_{pp}^{tot}(s)$ is the total proton-proton cross section and B_P is the slope of the t dependence of the elastic pp amplitude, and parameter α is from normalization requirement. For $\sigma_{pp}^{tot}(s)$, we use the measured value, $\sigma_{pp}^{tot}(s) = 98$ mb at $\sqrt{s_{NN}} = 7$ TeV and predicted values from fit $\sigma_{pp}^{tot}(s) = 111(113)$ mb for $\sqrt{s_{NN}} = 13(14)$ TeV respectively.

In Fig. 1 (upper panel), we compared our estimation of photon flux for pp collision at $\sqrt{s_{NN}} = 7$ TeV with DZ approximation and with STARLIGHT generator. Abs. factor refers to the gap survival probability taken from Ref. [4]. FF, the exact integration without suppression ($S^2(\omega) = 1$); FF + SI, refers flux with the suppression factor estimated by Eq. 1. Fig. 1 (lower panel) shows the photon flux for pp collisions at $\sqrt{s}_{NN} = 13$ TeV.

The Υ photoproduction cross-section for

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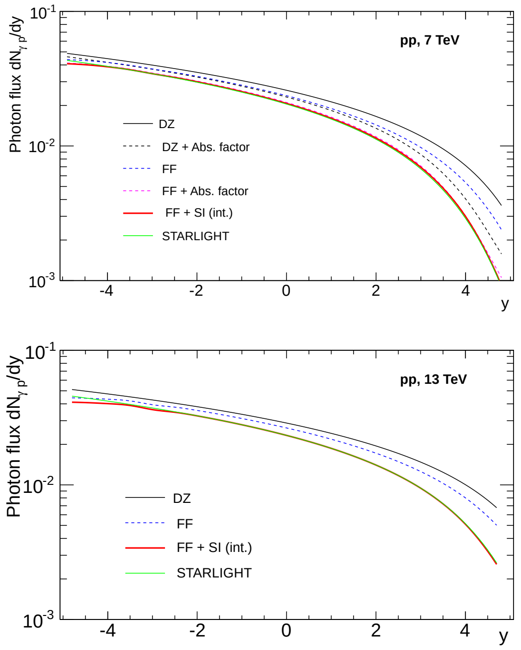

FIG. 1: (Upper panel) The flux of photons from proton $N_{\gamma/p}$ as a function of Υ (1S) rapidity y in proton-proton UPC at $\sqrt{s}$ = 7 TeV. (Lower panel) Photon flux at $\sqrt{s} = 13$ TeV where FF + SI is the exact integration Eq 1.

proton target is given by:

$$\sigma_{\gamma p \to \Upsilon p}(W_{\gamma p}) = \frac{1}{B_\Upsilon(W_{\gamma p})} \frac{d\sigma_{\gamma p \to \Upsilon p}(W_{\gamma p}, t = 0)}{dt}$$

with slope parameter $B_\Upsilon(W_{\gamma p}) = 4.63 + 0.4\alpha' \ln(W_{\gamma p}/90GeV)$ where $\alpha' = 0.06$ [4]. We use different gluon distributions in proton, MSTW08, CTEQ6L, CTEQ6L1, JMRTLO [3, 4] with leading order (LO) approximation of the scattering amplitude for elastic photoproduction of Υ. The $W_{\gamma p}$ dependence of the cross-section $\sigma(\gamma p \to \Upsilon p)$ from CMS [1] and HERA [2] could well described after normalization.

Fig. 2 shows the $d\sigma/dy$ distribution for pp@13 TeV with normalized (scaled) cross sections. In Table I we present the rapidity integrated cross section for proton-proton collisions at 7, 13 and 14 TeV in CMS and LHCb acceptance with and without normalization (scaling). We have given the prediction of cross-section from power law fit with $W_{\gamma p}$ from CMS+HERA data (referred as Fit in the table).

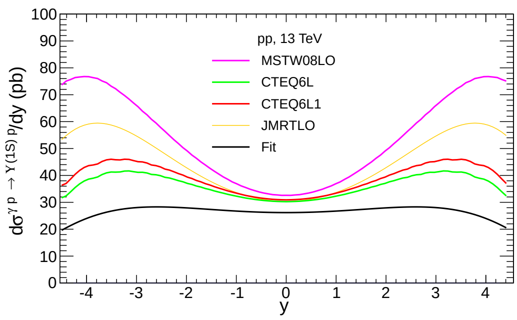

FIG. 2: The rapidity distribution of Υ (1S) photoproduction cross section for pp collisions at $\sqrt{s} = 13$ TeV.

TABLE I: Cross section of photoproduction of Υ(1S) in pp collisions for 7, 13 and 14 TeV in CMS and LHCb acceptance with (w) and without scaling (w/o).

Param.	Acc.	7 TeV σ(pb)		13 TeV σ(pb)		14 TeV σ(pb)	
		w/o	w	w/o	w	w/o	w
MSTW08	CMS	235	99	459	192	496	208
	LHCb	204	64	374	156	414	186
CTEQ6L	CMS	218	87	394	158	422	169
	LHCb	105	42	227	90	247	106
CTEQ6L1	CMS	210	90	386	166	413	178
	LHCb	107	46	235	100	256	118
JMRTLO	CMS	175	93	324	184	348	184
	LHCb	102	55	237	125	261	138
Fit	CMS	78		121		128	
	LHCb	30		55		60	

References

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