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 acceptance.

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:

\[
\frac{d\sigma_{pp-pp\Upsilon}(y)}{dy} = [N_{γ/p}(\omega)σ_{γp-\Upsilon p}(ω)]|_{ω=ω_{L}} + [N_{γ/p}(ω)σ_{γp-\Upsilon p}(ω)]|_{ω=ω_{R}}. 
\]

Here, \( ω_{L} \) and \( ω_{R} \) denoting photons from the proton incident from the left and right respectively; \( y = \ln(2ω/M_{\Upsilon}) \) is the rapidity of \( \Upsilon \), \( M_{\Upsilon} \) is the mass of \( \Upsilon \).

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,

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

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,

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

where \( \gamma = 0.4 \) and \( \Omega(s, b) = \alpha \sigma_{pp}(s)/(4\pi B_{P})e^{-2t/(4B_{P})} \) is the proton optical density. \( \sigma_{pp}(s) \) is the total proton-proton cross section and \( B_{P} \) is the slope of the \( t \) dependence of the elastic pp amplitude, and parameter \( \alpha \) is from normalization requirement. For \( \sigma_{pp}(s) \), we use the measured value, \( \sigma_{pp}(s) = 98 \) mb at \( \sqrt{s_{NN}} = 7 \) TeV and predicted values from fit \( \sigma_{pp}(s) = 111(113) \) 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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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 \(B_\Upsilon(W_{\gamma p}) = 4.63 + 0.4a' \ln(W_{\gamma p}/90\text{GeV})\) where \(a' = 0.06\) [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 \(\Upsilon\). 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. 1: (Upper panel) The flux of photons from proton \(N_{\gamma p}\) as a function of \(\Upsilon\) (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.

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

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

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References