Exclusive photoproduction of Υ in pPb collisions at CMS

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Introduction

Exclusive photoproduction of heavy vector mesons at very high photon proton center of mass energies ($W_{\gamma p}$) can be studied in ultraperipheral collisions (UPC). Recently the CMS, ALICE [1] and LHCb [2] presented their measurements of exclusive heavy vector meson photoproduction at the LHC. The process occurs through γp or γPb interaction via the exchange of two-gluons with no net color transfer. Hence, the cross-section of the process is proportional to the square of the gluon density. It provides an unique opportunity to study the gluon distribution of proton (nucleus) at small x, where x is the gluon momentum fraction which is kinematically related to $W_{\gamma p}$ ($x = (M_{\Upsilon}/W_{\gamma p})^2$).

In this paper, we report the first measurement of the exclusive photoproduction of Υ states in dimuon decay channel in ultraperipheral pPb collisions at $\sqrt{s} = 5.02$ TeV using data from 2013 run corresponding to an integrated luminosity of $32.6nb^{-1}$. We report the photoproduction cross-section of Υ as a function of $W_{\gamma p}$ in the range $83 < W_{\gamma p} < 913$ GeV which corresponds to the rapidity of the Υ meson in the range $-2.4 < y < 2.4$ with CMS experiment. The x values probed are of the order $x \sim 1.0 \cdot 10^{-4}$ to $x \sim 1.3 \cdot 10^{-2}$. The experimental results are compared with different theoretical predictions. We also report the measurement of the differential cross-section $d\sigma/dt$, where t is the squared four-momentum transfer at the proton vertex, in the range $|t| < 1.0(GeV/c)^2$. As the dependence of elastic Υ photoproduction on t can be parametrized as $e^{-b|t|}$ at low values of $|t|$, this study estimated the b parameter and compared with the existing results from HERA [3, 4].

Data/MC event selection

The STARLIGHT [5] event generator was used to simulate the Υ states and the QED ($\gamma\gamma \to \mu\mu$) background. The non-exclusive backgrounds from inclusive Υ and Drell-Yan (DY) processes were simulated using PYTHIA 6 for *pp* collisions and properly scaled for *pPb* collisions. The UPC events were selected by applying dedicated UPC trigger. In order to select the exclusive events, two tracks originating from the single vertex were selected and to minimize the uncertainties related to low p_T muon efficiencies, muons with $p_T > 3GeV/c$ were selected. In addition, the events with dimuon p_T between $0.1 < p_T < 1.0$ GeV/c were selected to reduce proton dissociation and inclusive background contribution.

Background estimation

The main background contribution of this analysis is from QED which was estimated by STARLIGHT. The non exclusive background (inclusive Y, DY and proton dissociation) was estimated by data-driven method. To estimate the non-exclusive background, dimuon p_T template with $ntrack > 2$, within p_T 1.5-5 GeV/c was considered. This template was normalized to ntrack = 2 template within p_T 1.5-5 GeV/c. The normalized data template and the QED background from STARLIGHT were then subtracted from the data to extract the signal contribution. The same procedure was followed for the pPb and Pbp data samples separately to extract the signal. The distributions of t and y for pPb ans Pbp samples were unfolded in the kinematic region using the Bayesian method to correct for detector effects and data migration between bins. The unfolded spectra was corrected for acceptance. The systematic uncertainty in the b-slope of the differential cross-section $d\sigma/dt$ and $d\sigma/dy$

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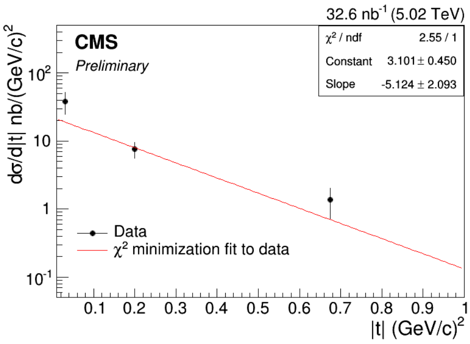

FIG. 1: $d\sigma/dt$ distribution of signal Υ.

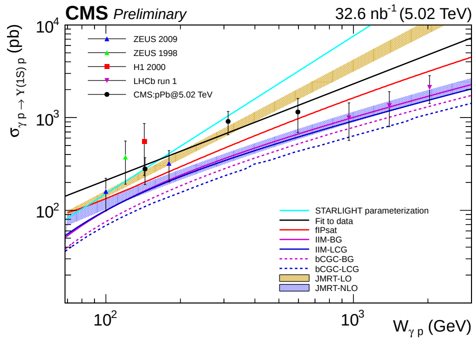

FIG. 2: Photonuclear cross-section of (1S) with photon-proton center of mass energy

was also considered.

Results

A. Determination of b-slope

Fig.1 shows the differential cross-section $d\sigma/dt$ for three $\Upsilon(nS)$ states together, which was calculated by estimating the background subtracted, unfolded and acceptance corrected number of signal events in each $|t|$ bin in the invariant mass range $9.12 < m_{\mu^+\mu^-} < 10.64$ GeV/c^2 and dividing it with integrated luminosity and Δt is the width of $|t|$ bin. It was fitted with an exponential function $N\ e^{-b|t|}$ with χ^2 minimization while using the same binning of the fitted exponential function as of data. A value of $b = 5.12 \pm 2.09$(stat.) $\pm\ 0.27$ (syst.) was extracted for $|t| < 1.0$ GeV^2 from the data. The extracted b slope is compared to the previous measurement $b = 4.3^{+2.0}_{-1.3}$ (stat.) from ZEUS[4] for $60 < W_{\gamma p} < 220$ GeV.

B. Cross section as a function of $W_{\gamma p}$

Fig.2 shows the cross-section of Υ(1S) photoproduction, calculated at each point of rapidity of the dimuon system according to

$$\frac{d\sigma_{\Upsilon(1S)}}{dy} = \frac{f_{\Upsilon(1S)}}{\mathcal{B}(1+f_{FD})}\frac{N^{unfolded}_{sig}}{\mathcal{L}\times\Delta y}, \qquad (1)$$

where $N^{unfolded}_{sig}$ denotes the background subtracted, unfolded and acceptance corrected number of signal events in each rapidity bin in the invariant mass range $9.12 < m_{\mu^+\mu^-} <$ 10.64 GeV/c^2. $f_{\Upsilon(1S)}$ is the fraction of Υ(1S) in $\Upsilon(1S+2S+3S)$ which is $0.68 \pm 0.04(stat.)$, f_{FD} is the feed-down contribution from Υ(2S)$\rightarrow$ $\Upsilon(1S) + X$ ($\pi^+\pi^-$ or $\pi^0\pi^0$) which is 15%, $\mathcal{B}$ is the muonic branching ratio of $\Upsilon(1S)$, (2.48 ± 0.05)%, $\mathcal{L}$ is the integrated luminosity and Δy is the width of y bin.

The γp cross-section for exclusive $\Upsilon(1S)$ production was obtained through the relation

$$\sigma_{\gamma p \to \Upsilon(1S)p} = \frac{1}{\Phi}\frac{d\sigma_{\Upsilon(1S)}}{dy} \qquad (2)$$

where Φ is the photon flux at the mean of the rapidity bin estimated from STARLIGHT. The CMS data are plotted together with the previous measurements from H1 [4], ZEUS[3] and LHCb [2] data in Fig.2 and also compared with different theoretical models. As $\sigma(W_{\gamma p})$ is proportional to the square of the gluon PDF of the proton and the gluon distribution at low Bjorken x is well described by a power law, the cross-section will also follow a power law. Any deviation from such trend would indicate different behaviour of gluon density function. We fit a power law $A \times (W/400)^{\delta}$ with CMS data alone which gives $\delta = 1.04 \pm 0.30$ and $A = 889.42 \pm 196.24$ and is shown by the black solid line. The extracted δ value is comparable to the value $\delta = 1.2 \pm 0.8$, obtained by ZEUS [4].

References

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