Exclusive photoproduction of Upsilon in pp and pPb collisions with CMS Experiment

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Introduction

Photonuclear interactions at unprecedentedly high energies can be studied in ultra-peripheral collisions (UPC) at LHC and provide opportunities in exploring several aspects of particle and nuclear physics [1]. The recent results of exclusive photoproduction of dileptons with CMS [2] in pp collisions, photoproduction of J/ψ in UPC PbPb collisions with ALICE and in pp collisions with LHCb [3], confirmed the expectations [1] that UPCs are a very promising probe to study the gluon distributions in nucleons and in nuclei at small x. In this study we will report the first measurement of exclusive photo production of Upsilon in pp collisions at $\sqrt{s} = 7$ TeV using data taken with CMS in 2011 and in pPb collisions at $\sqrt{s} = 5.02$ TeV using data from 2013 run.

1. Upsilon photoproduction

The exclusive production of vector mesons, where a vector meson but no other particles are produced in the event, occurs by γp or γPb interactions (as shown in Fig.1 (left)) which has been successfully modelled in perturbative QCD in terms of exchange of two gluons with no net colour transfer. Upsilon photoproduction in proton-proton and proton-nucleus UPC interaction 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:

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

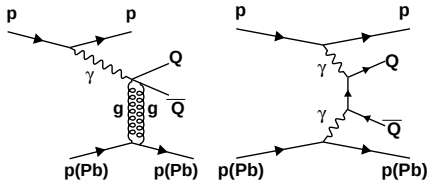

FIG. 1: Diagram representing (left) exclusive Upsilon photoproduction (right) QED background in pp or pPb collisions.

Here A and B stand either for the proton or a nucleus; $N_{\gamma/A(B)}(y)$ is the photon flux; $y = \ln(2\omega/M_\Upsilon)$ is the rapidity of Upslion, where ω is the photon energy, M_Υ is the mass of Υ. Photoproduction is strongly enhanced in heavy ions as the photon flux grows as Z^2. The cross-section $\sigma_{\gamma A(B)\to\Upsilon A(B)}$ is proportional to $[xg_{A(B)}(x,Q^2)]^2$ where x, is the fraction of the nucleon momentum carried by the gluons, and $g_{A(B)}(x,Q^2)$ is the gluon distribution in a proton or nucleus, evaluated in momentum transfer $Q^2 = (M_\Upsilon/2)^2$. The relevant x region in CMS is $\approx 10^{-2} - 10^{-4}$ at central rapidities ($|y| < 2.5$).

2. Simulations

The simulations of the signal events for the $pp \to (\gamma p) \to p\Upsilon(1S, 2S, 3S)p$ in pp collisions at $\sqrt{s} = 7$ TeV, is performed with Starlight event generator [4]. On the other hand, the background $\mu^+\mu^-$ are due to QED $\gamma\gamma \to \mu^+\mu^-$ processes (Fig. 1 (right)) and generated with LPAIR [5], considering both exclusive and single-dissociation processes. Additionally, the parton induced background events from Drell-Yan (DY) production of $\mu^+\mu^-$ pairs are simulated with PYTHIA6 with Tune Z2. The cross-sections for pp collisions at

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TABLE I: Cross-sections for Upsilon photoproduction in pp collisions at $\sqrt{s}$ = 7 TeV from Starlight.

Process	σ (pb)
$pp \to p\Upsilon(1S)p \times \mathrm{BR}[\Upsilon(1S) \to \mu^+\mu^-]$	13.46 pb
$pp \to p\Upsilon(2S)p \times \mathrm{BR}[\Upsilon(2S) \to \mu^+\mu^-]$	4.52 pb
$pp \to p\Upsilon(3S)p \times \mathrm{BR}[\Upsilon(3S) \to \mu^+\mu^-]$	3.56 pb

TABLE II: Cross-sections for Upsilon photoproduction in pPb collisions at $\sqrt{s} = 5.02$ TeV from Starlight.

Process	$\sigma(nb)$
$pPb \to (\gamma p) \to p\Upsilon(1S)Pb \times \mathrm{BR}[\mu^+\mu^-]$	5.45 nb
$pPb \to (\gamma p) \to p\Upsilon(2S)Pb \times \mathrm{BR}[\mu^+\mu^-]$	1.87 nb
$pPb \to (\gamma p) \to p\Upsilon(3S)Pb \times \mathrm{BR}[\mu^+\mu^-]$	1.48 nb
$pPb \to (\gamma Pb) \to p\Upsilon(1S)Pb \times \mathrm{BR}[\mu^+\mu^-]$	0.40 nb
$pPb \to (\gamma Pb) \to p\Upsilon(2S)Pb \times \mathrm{BR}[\mu^+\mu^-]$	0.13 nb
$pPb \to (\gamma Pb) \to p\Upsilon(3S)Pb \times \mathrm{BR}[\mu^+\mu^-]$	0.11 nb
$pPb \to (\gamma\gamma) \to p\mu^+\mu^- Pb$, $(8-12)$GeV	0.16 μb

$\sqrt{s} = 7$ TeV from Starlight generator is given in Table I. For pPb collisions the nucleus acts preferentially as the source and the proton as target, leading to γp process as in pp collisions. But there is also non-negligible contribution from γPb process $pPb \to (\gamma Pb) \to p\Upsilon(1S, 2S, 3S)$Pb. The signal Upsilon and two-photon QED background for pPb collisions at $\sqrt{s}$ = 5.02 TeV is generated with Starlight and the cross-sections are given in Table II.

Results

The data set corresponds to the muons collected for pp collisions at $\sqrt{s}$ = 7 TeV with CMS detector with integrated luminosity of 5.24 fb^{-1}. The events which pass the acoplanarity trigger used in the analysis, require both muons to have minimum transverse momentum of 3 GeV/c. The $\mu^+\mu^-$ pair with invariant mass between 8 GeV/c^2 < $M_{\mu^+\mu^-}$ < 12 GeV/c^2 are considered. To select exclusive process, acoplanarity cuts, $[1 - |\Delta\phi(\mu^+\mu^-)/\pi|] < 0.1$ and $\Delta p_T(\mu^+\mu^-) < 1.0$ GeV/c are applied. Finally, events with zero additional tracks associated to the $\mu^+\mu^-$ vertex are considered. The cross-section for Υ (1S), Υ (2S) and Υ (3S) are being estimated which is comparable to the theoretical predictions.

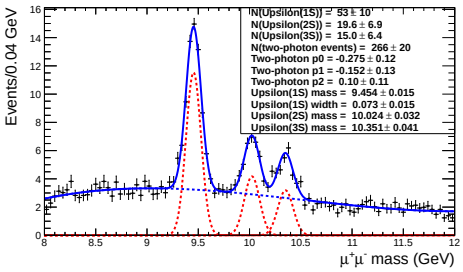

FIG. 2: Dimuon invariant mass distribution of signal Upsilon (1S,2S,3S) and QED background for pPb collisions at $\sqrt{s}$ = 5.02 TeV with Starlight event generator.

The analysis of Upsilon in pPb collision at $\sqrt{s}$ = 5.02 TeV use data taken during 2013 of L_{int} = 30.95 nb^{-1}. The opposite sign dimuon mass within mass range of 8 GeV/c^2 < $M_{\mu^+\mu^-}$ < 12 GeV/c^2 using acoplanarity cut Δp_T < 1.0 GeV/c and $\Delta\phi$ > 2.8 with no extra track in the event are considered. Signal Upsilon (1S, 2S, 3S) and QED background from Starlight, after simulation, reconstruction and applying acoplanarity and exclusivity cuts, is shown in Fig. 2. The signal Upsilon's are fitted with Gaussian function while background is fitted with Chebychev function with 3 parameters which give χ^2/ndf=1.198. No of Upsilon 1S, 2S and 3S are 53, 19 and 15 respectively. The analysis with data, data/MC comparison shows promising results and will be presented.

References

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