Study of Upsilon photoproduction in pPb collisions at 8.16 TeV with CMS experiment

Dipanwita Dutta[1],* Kousik Naskar[2], Ruchi Chudasama[1], and Pradeep Sarin[2] for CMS Collaboration
[1]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[2]*Department of Physics, IIT Bombay, Mumbai - 400076, INDIA*

Introduction

Ultraperipheral collisions (UPC) where protons/ions interact at large impact parameter at LHC, provide opportunities in exploring several aspects of particle and nuclear physics [1]. The recent results of exclusive photoproduction of Upsilon with CMS in pPb collisions [2], photoproduction of J/ψ in UPC pPb and PbPb collisions with ALICE and in pp collisions with LHCb [3], reveals importance of these measurements to probe the gluon distributions in nucleons and in nuclei at small x, where x is the fraction of target momentum carried by the gluon. In this work, we will present the study of exclusive photoproduction of Υ(nS) in pPb collisions at $\sqrt{s} = 8.16$ TeV for LHC Run2, data taken during Nov. 2016.

The exclusive photoproduction of vector mesons, where a vector meson but no other particles are produced in the event, occurs by γp or γPb interactions (Fig.1 (left)) which has been successfully modelled in perturbative QCD in terms of exchange of two gluons with no net colour transfer. Photoproduction is strongly enhanced in heavy ions as the photon flux grows as Z^2. As the cross section of photoproduction of Υ(nS) is proportional to the square of gluon density of the target and x is inversely proportional to the beam momentum, at LHC energies it is possible to explore the small x behavior of the gluon density in the proton and nuclei. The relevant x region in CMS is $\approx 10^{-3} - 10^{-5}$ at central rapidities ($|y| < 2.5$) for pPb collisions at 8.16 TeV.

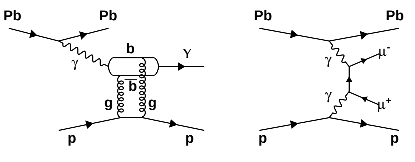

FIG. 1: Diagram representing (left) exclusive Upsilon photoproduction (right) QED background in pPb collisions.

Simulations

The simulations of the signal Υ (nS) for the $pPb \to (\gamma p(Pb)) \to p\Upsilon(1S, 2S, 3S)Pb$ (Fig. 1(left)) and the background $\mu^+\mu^-$ due to QED, $\gamma\gamma \to \mu^+\mu^-$ processes (Fig. 1 (right)) is performed with STARLIGHT event generator [4]. Due to large photon flux ($\propto Z^2$) from Pb ion compared to proton, the γp contribution dominates and peaks at positive rapidity while the γPb contribution peaks at negative rapidity. Table I shows the cross section for different processes from STARLIGHT.

TABLE I: Cross-sections for Upsilon photoproduction in pPb collisions at $\sqrt{s} = 8.16$ TeV for signal, $pPb \to (\gamma p) \to p\Upsilon(nS)Pb$ and $pPb \to (\gamma Pb) \to p\Upsilon(nS)Pb$ and QED background $pPb \to (\gamma\gamma) \to p\mu^+\mu^- Pb$ processes from STARLIGHT.

Process	BR($\mu^+\mu^-$)	$\sigma(nb)$	σ(nb)×BR
Υ(1S) (γp)	2.48%	216	5.354
Υ(1S) (γPb)	2.48%	16	0.389
Υ(2S) (γp)	1.93%	97	1.873
Υ(2S) (γpb)	1.93%	7	0.134
Υ(3S) (γp)	2.18%	70	1.525
Υ(3S) (γPb)	2.18%	5	0.109
QED($8-12$)GeV		235	

*Electronic address: ddutta@barc.gov.in

Results

The scenario corresponds to 178.4 nb^{-1} of pPb collisions recorded by the CMS experiment at LHC, CERN in 2016, with beam energies of 6.5 TeV for the protons and 2.56 TeV per nucleon for the lead nuclei, resulting in a center-of-mass energy of $\sqrt{s_{NN}} = 8.16$ TeV. 100k of generated signal Υ(1S,2S,3S) and QED background events from STARLIGHT are simulated through GEANT based detector simulation package and reconstructed using generalised muon reconstruction routines in CMS software environment. The $\mu^+\mu^-$ pair with invariant mass between 8.5 GeV $< M_{\mu^+\mu^-} <$ 11.54 GeV are considered.

The following event selection criteria are applied: (1) $p_T(\mu^+, \mu^-) > 3.3$ GeV/c with $|\eta| < 2.2$, to minimize the uncertainties related to the low-p_T muon efficiencies, (2) Exclusivity criteria: Events with no additional tracks with $p_T > 0.1$ GeV associated to the $\mu^+\mu^-$ vertex and no energy deposits in HF calorimeters, $E_{HF-leadtower} < 5$ GeV, (3) $|y(\mu^+\mu^-)| < 2.2$, (4) $0.1 < p_T(\mu^+\mu^-) < 1.0$ GeV; $p_T > 0.1$ GeV cut to improve the signal to background ratio, as elastic QED dominates $p_T(\mu^+\mu^-) < 0.1$ GeV and $p_T(\mu^+\mu^-) < 1.0$ GeV cut to reduce the contamination from inclusive Υ and semi-exclusive Υ production.

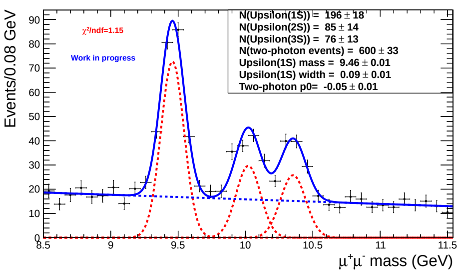

FIG. 2: Dimuon invariant mass distribution of signal Upsilon (1S,2S,3S) and QED background for pPb collisions at $\sqrt{s} = 8.16$ TeV from Starlight event generator.

The invariant mass distribution of $\mu^+\mu^-$ pairs in the range between 8.5 and 11.54 GeV for signal Υ(1S, 2S, 3S) and QED background after simulation, reconstruction and event selection and normalised to the recorded luminosity, is shown in Fig. 2. A fit to the simulated data is performed by using ROOFIT with a linear function to describe the continuum background from the QED process, combined with three Gaussians to describe the signal peaks. The seven free parameters of the fit correspond to the yields of the background and the three signal peaks, as well as the mass and the width of the Υ(1S) resonance and paprameter for linear fit. The Υ(2S)-Υ(1S) and Υ(3S)-Υ(1S) mass differences are set to the PDG values, while the widths of the higher states are expressed by the Υ(1S) width scaled by the ratio of masses.

Number of Upsilon 1S, 2S and 3S and QED background from dimuon invariant mass fit are 196, 85, 76 and 600 respectively. MC simulation results show good reconstruction efficiency with three signal Υ(1S,2S,3S) peaks clearly visible above the QED background. With the available good statistics in pPb collisions at 8.16 TeV, it will be possible to measure the crosssection of each Υ(nS) states with $W_{\gamma p}$, the photon-proton center-of-mass energy. The data/MC comparison shows promising results and will be presented during conference.

References

[1] A. J. Baltz, et al., Phys. Rep. **458**, 1 (2008).
[2] R. Chudasama, Dipanwita Dutta *et al.* (CMS Collaboration) arXiv:1607.00786; https://cds.cern.ch/record/2147428
[3] ALICE Collaboration, Phys. Lett. **B 718**, 1273 (2013); LHCb Collaboration, JHEP **1509**, 084 (2015).
[4] S. R. Klein and J. Nystrand, Comp. Phys. Comm. **212** 258 (2017).