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

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

Introduction

Exclusive photoproduction of Υ(nS) can be studied in Ultraperipheral collisions (UPC) where protons/ions interact at impact parameter much larger than sum of their radii. In such UPCs, the two relativistic nuclei interact electromagnetically through emission of quasi-real photons [1]. The study of exclusive photoproduction of quarkonia offers clean probe of the target hadron structure [2].

In exclusive photoproduction, Upsilon are produced elastically by γp or γPb interactions (Fig.1a), where two colliding hadrons remain intact after the interaction. If the Υ photoproduction is followed by the proton breakup, the process is called "semiexclusive" (Fig. 1b). In UPCs, dimuon can be produced by $\gamma\gamma \to \mu^+\mu^-$ interactions (Fig.1c) which is the dominant QED background. 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.

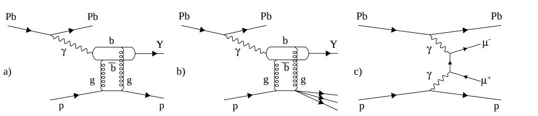

FIG. 1: Diagram representing (a) exclusive Upsilon photoproduction (b) semiexclusive background (c) QED background in pPb collisions.

Exclusivity event selection for HF and CASTOR

The non-exclusive background from $\Upsilon \to \mu^+\mu^-$ originates from semiexclusive (Fig.1b) events and inclusive Υ and Drell-Yan (DY) production, where there can be additional hadronic activity. The exclusivity criteria is applied by selecting only dimuon events with a single vertex and no extra charge particle with $p_T > 0.1$ GeV associated to it. In addition, no energy deposition in HF and CASTOR are applied. The HF and CASTOR energy thresholds are determined from noise distribution study for dedicated runs with single beam (Fig. 2 left) and with UPC dedicated triggers for pPb and Pbp run respectively (Fig. 2 middle and right). Activity observed in only pPb events due to proton dissociation background, as CASTOR detector is situated in the very backward rapidity $-6.6 < \eta < -5.2$ (Fig. 2 middle). The CASTOR and HF leading tower exclusivity threshold taken as 10 GeV and 6 GeV, respectively.

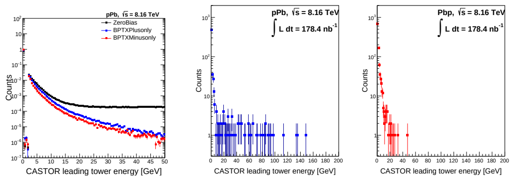

FIG. 2: Noise study of CASTOR: (left) with BPTXPlusonly and BPTXMinusonly data set for pPb run, (middle) with UPC trigger for pPb run and (right) for Pbp run respectively.

*Electronic address: ddutta@barc.gov.in

Background estimation

Inclusive events are generated using PYTHIA and no significant contribution observed after $N_{Tracks} = 2$ exclusivity cut. Semiexclusive background, which falls outside detector acceptance, estimated by data driven template with HF or CASTOR activity above threshold ($E_{HF-lead} > 6$ GeV or $E_{CASTOR-lead} > 10$ GeV). Normalization of semiexclusive template is done by comparing with data after exclusivity cut in the region of dimuon $p_T(\mu^+\mu^-) > 2.0$ GeV (Fig. 3). Estimated semiexclusive (proton dissociative–PD) background is about 12% in signal region.

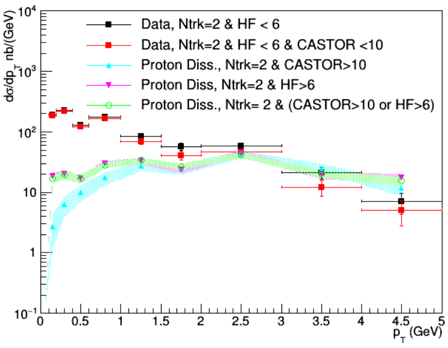

FIG. 3: Semiexclusive background template.

Results

Results are presented for Upsilon photoproduction in pPb collisions at center-of-mass energy $\sqrt{s_{NN}} = 8.16$ TeV, collected by the CMS experiment, corresponding to an integrated luminosity of $L_{int} = 178.4$ nb^{-1}. 100k of generated signal Υ(1S,2S,3S) and 1M of QED background events from STARLIGHT [3] are simulated through GEANT based detector simulation package and reconstructed using generalised muon reconstruction routines in CMS software environment.

The following event selection criteria are applied: (1) $\mu^+\mu^-$ pair with invariant mass between 9.1 GeV $< M_{\mu^+\mu^-} <$ 10.6 GeV, (2) $p_T(\mu^+, \mu^-) > 3.3$ GeV/c with $|\eta| < 2.2$, to minimize the uncertainties related to the low-p_T muon efficiencies, (3) 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, $E_{HF-leadtower} < 6$ GeV, and in CASTOR, $E_{CASTOR-leadtower} < 10$ GeV, to exclude proton-dissociation background. (4) $|y(\mu^+\mu^-)| < 2.2$, (5) $0.1 < p_T(\mu^+\mu^-) < 1.0$ 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.

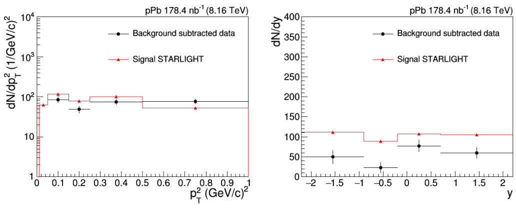

FIG. 4: Dimuon p_T^2 and rapidity distribution of signal Upsilon (1S,2S,3S) after background subtraction compared with MC at $\sqrt{s} = 8.16$ TeV.

Fig. 4a and 4b shows dimuon p_T^2 and rapidity distribution of Υ(nS) after data driven background subtraction without efficiency correction. Data/MC comparison is promising with initial background study. Efficiency correction, unfolding and systematics study under process. With the available good statistics, in pPb collisions at 8.16 TeV, it will be possible to measure the differential cross-section of Υ photoproduction with $W_{\gamma p}$ and with p_T^2 for much larger accuracy. It will give new constraints on gluon distribution in low-x region so far unexplored.

References

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