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J/ψ production in pPb collisions from CMS

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Abstract. We report on the prompt and nonprompt J/ψ meson production from CMS, using 34.6 nb^{-1} of proton-lead (pPb) data recorded in 2013 at 5.02 TeV. The differential production cross sections are analyzed in the transverse momentum range $2 < p_T < 30$ GeV/c, and the center-of-mass (CM) rapidity region $-2.87 < y_{CM} < 1.93$. The ratio of J/ψ yields at forward (proton-going direction) and backward (Pb-going direction) is studied in several ranges of p_T, rapidity, and the event-activity regions.

1 Introduction

Charmonia represent an important tool for studying the properties of the de-confined medium created in ultra-relativistic heavy-ion collisions, the quark-gluon plasma (QGP). Due to the Debye screening of the heavy-quark potential in QGP, charmonium states are predicted to dissociate sequentially reflecting their binding energies [1]. Given the abundance of charm quarks produced at LHC energies, charmonia can also be produced at the hadronization stage via the recombination of initially uncorrelated charm and anticharm quarks [2]. On the other hand, the measurement of charmonium production in proton-nucleus collisions enables to investigate the so-called "cold nuclear matter" (CNM) effects, which provide new information to examine quantitatively the genuine hot-medium effects in nucleus-nucleus collisions. These effects include modifications of the nuclear parton distribution functions (nPDFs), initial or final state parton energy loss, and nuclear absorption [3]. For example, the depletion of gluon distributions in nuclei from those in a free proton can lead to the suppression of the charmonium yields at small values of x, the momentum fraction carried by a gluon. Such a process is known as "shadowing". The values of x explored in this analysis correspond to $10^{-4} < x < 10^{-2}$. Similar nuclear effects are also expected to affect the open-heavy-flavor production, which can be indirectly examined by the measurement of nonprompt J/ψ mesons coming from b hadron decays.

2 The CMS detector

A detailed description of the CMS detector can be found in Ref. [4]. Its central feature is a superconducting solenoid, providing a magnetic field of 3.8 T. Within the field are the silicon tracker, the lead-tungstate crystal electromagnetic calorimeter, and the brass/scintillator hadronic calorimeter. The

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tracker consists of 66 million pixel and 10 million strip sensor elements to measure charged-particle trajectories in $|\eta| < 2.5$. Muons are measured within $|\eta| < 2.4$ in gas ionization detectors embedded in the steel return yoke, using the detection planes based on three technologies: drift Tubes, cathode strip chambers, and resistive plate chambers. The CMS apparatus also has extensive forward calorimetry, composed of two steel/quartz-fiber Cherenkov hadron forward calorimeters (HF), which cover $2.9 < |\eta| < 5.2$. These detectors are utilized for online event selection and the impact parameter characterization of the events in pPb collisions, where the impact parameter refers to the transverse distance between the two centers of the incoming projectiles.

3 Analysis procedure

The J/ψ mesons were measured via their dimuon decay channel. The invariant mass spectrum of $\mu^+\mu^-$ pairs was modelled by the sum of a Crystal Ball (CB) function and a Gaussian function for the J/ψ signal, and by an exponential function for the underlying continuum background. The prompt and nonprompt J/ψ mesons were separated using the pseudo-proper decay length, $l_{J/\psi} = L_{xy}\, m_{J/\psi}/p_T$, where L_{xy} is the transverse distance between the primary and secondary vertices in the laboratory frame. The invariant-mass spectrum and the $l_{J/\psi}$ distribution of $\mu^+\mu^-$ pairs were fitted sequentially in an extended unbinned maximum-likelihood fit [5].
Prompt and nonprompt J/ψ yields extracted from the fit were corrected for acceptances and efficiencies, which were evaluated from PYTHIA Monte Carlo (MC) simulation. Additional correction factors were applied to minimize the discrepancies between MC simulations and real detector responses, based on a data-driven technique, tag-and-probe [6].

4 Results

4.1 Prompt J/ψ

The rapidity dependence of nuclear effect is quantified using the forward-to-backward production ratio, $R_{FB}(p_T, y > 0) = [d^2\sigma(p_T, +y)/dp_T dy]/[d^2\sigma(p_T, -y)/dp_T dy]$, where the $d^2\sigma/dp_T dy$ is the J/ψ production cross section decayed into muon pairs in a given p_T and y bin, and forward regions $(+y)$ are defined by the proton-going direction.

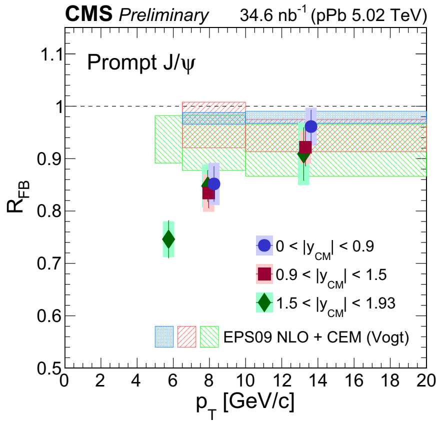

Figure 1. p_T dependence of prompt J/ψ R_{FB} in three rapidity ranges [5]. The shadowing prediction based on the EPS09 (NLO) parameterization is also shown [7]. The error bars show the statistical uncertainties and the shaded boxes represent the systematic uncertainties.

Figure 1 shows the p_T dependence of R_{FB} for prompt J/ψ mesons in three different rapidity ranges. The data points are plotted at the bin-averaged values. The R_{FB} is closer to unity at high p_T, and

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decreases at low p_T. The EPS09 nuclear parton distribution function, with next-to-leading order Color Evaporation Model (CEM) for the J/ψ production, is also shown by bands [7]. Data indicates lower R_{FB} values than the model prediction at $5 < p_T < 6.5$ GeV/c, suggesting hints for other nuclear effects beyond the single nPDF parameterization.

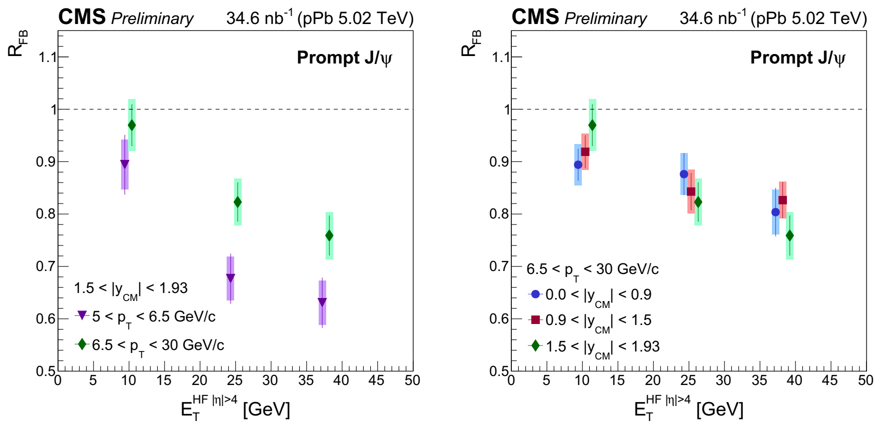

Figure 2. $E_T^{HF|\eta|>4}$ dependence of prompt J/ψ R_{FB} with two different p_T ranges in the most forward region (left), and with the same p_T range in three different rapidity intervals (right) [5]. The error bars show the statistical uncertainties and the shaded boxes represent the quadratic sum of systematic uncertainties.

The R_{FB} is further analyzed in terms of an event activity variable $E_T^{HF|\eta|>4}$, the transverse energy deposited in the hadron forward calorimeter in $4 < |\eta| < 5.2$, as shown in Fig. 2. The clear decreasing tendency of the R_{FB} with increasing $E_T^{HF|\eta|>4}$ has been observed over the whole kinematic interval studied.

4.2 Nonprompt J/ψ

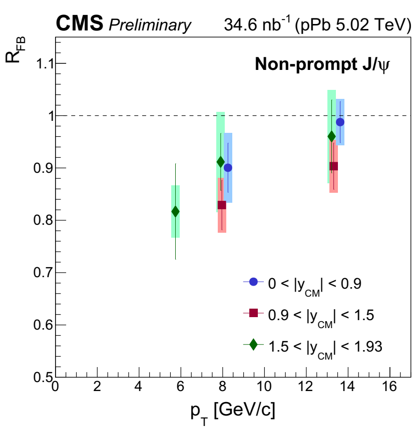

Figure 3. p_T dependence of nonprompt J/ψ R_{FB} in three rapidity ranges [5]. The error bars show the statistical uncertainties and the shaded boxes represent the systematic uncertainties.

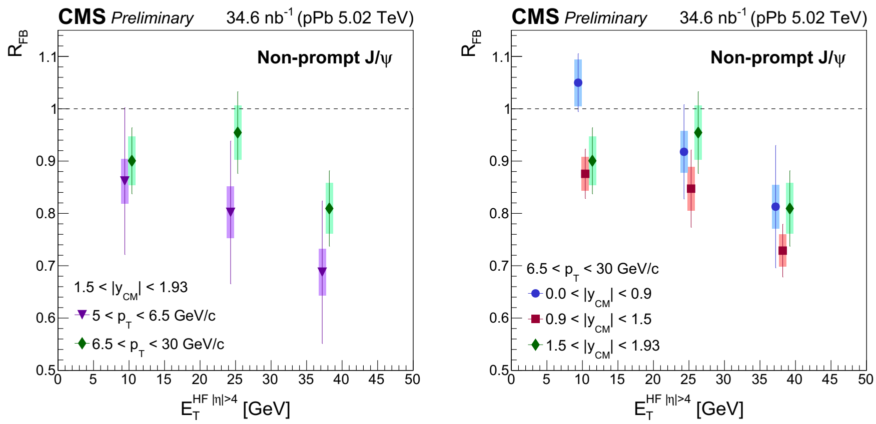

Figure 4. $E_T^{HF|\eta|>4}$ dependence of nonprompt J/ψ R_{FB} with two different p_{T} ranges in the most forward region (left), and with the same p_{T} range in three rapidity intervals (right) [5]. The error bars show the statistical uncertainties and the shaded boxes represent the systematic uncertainties.

The R_{FB} as functions of p_{T} and $E_{\mathrm{T}}^{\mathrm{HF}|\eta|>4}$ for nonprompt J/ψ mesons are also investigated and shown in Figs. 3–4. The nonprompt J/ψ result exhibits similar features as that of prompt J/ψ mesons, while the significance is less within larger uncertainties.

5 Summary

The measurements of prompt and nonprompt J/ψ production in pPb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV are presented. The forward-to-backward production ratio R_{FB} is observed to be smaller than unity at $p_{\mathrm{T}} \lesssim 10\mathrm{GeV}/c$, and compatible with unity for higher p_{T}. The R_{FB} has been studied as a function of the event activity, and found to be more asymmetric with increasing $E_{\mathrm{T}}^{\mathrm{HF}|\eta|>4}$ both for prompt and nonprompt J/ψ mesons. The results hint to nuclear effects present in pPb collisions.

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