Charmonium production in pPb and PbPb collisions at 5.02 TeV with CMS

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Abstract. Charmonium states, such as the J/ψ and ψ(2S) mesons, are excellent probes of the deconfined state of matter, the Quark-Gluon Plasma (QGP) created in heavy ion collisions. In addition, the measurements in pPb collisions allow to study the cold nuclear matter effects, being crucial to disentangle these from the QGP-related effects in PbPb collisions. In this talk the new nuclear modification factor R_{AA} of prompt and nonprompt J/ψ in PbPb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV were presented over a wide kinematic range ($3 < p_{\mathrm{T}} < 50$ GeV/c, $|y| < 2.4$), and fine event-centrality intervals. The results were compared to those at 2.76 TeV over a similar kinematic range. In addition, new prompt ψ(2S) R_{AA} results at 5.02 TeV were reported. Finally the final prompt and nonprompt J/ψ results, as well as preliminary ψ(2S) results, in pPb collisions at 5.02 TeV, were discussed.

1 Introduction

Many phenomena, such as dissociation in the QGP and statistical recombination [1–4], on top of cold nuclear matter effects (modifications of nPDFs, initial-state energy loss and nuclear break-up) [5, 6], are required for a complete understanding of charmonium production in PbPb collisions . Therefore measurements in pPb collisions are also crucial for a quantitative determination of the QGP-related effects in PbPb collisions. The recombination mechanism in the QGP is only expected to affect charmonium production at low transverse momentum (p_{T}), while at high p_{T} heavy quarkonium is likely to be produced by parton fragmentation, being sensitive to the parton energy loss in the QGP [7, 8]. In addition, it is interesting to separate the prompt and nonprompt (from b hadron decays) charmonium components, since nonprompt charmonium should reflect medium effects on b hadron production, while the prompt component is affected by dissociation in the QGP and statistical recombination.

In this talk, the prompt and nonprompt J/ψ and prompt ψ(2S) nuclear modification factors (R_{AA}) in PbPb data taken by the LHC CMS experiment at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV were presented [9]. Also, the results of the nuclear modification factor of prompt and nonprompt J/ψ [10], and prompt ψ(2S) [11] in pPb collisions at the same energy were briefly discussed. The integrated luminosities were 28 pb^{-1}, 34.6 nb^{-1} and 0.5 nb^{-1} for pp, pPb and PbPb data samples respectively.

2 The CMS detector and analysis procedure

The central feature of the CMS detector is a superconducting solenoid of 6 m internal diameter, providing a magnetic field of 3.8 T. Within the solenoid volume are a silicon pixel and strip tracker,

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a lead tungstate crystal electromagnetic calorimeter, and a brass and scintillator hadron calorimeter, each composed of a barrel and two endcap sections. Forward hadron calorimeters (HF) extend the coverage to $2.9 < |\eta| < 5.2$. Muons are measured in the pseudorapidity range $|\eta| < 2.4$ in gas-ionisation detectors embedded in the steel flux-return yoke outside the solenoid, with detection planes made using three technologies: drift tubes, cathode strip chambers, and resistive plate chambers. A more detailed description of the CMS detector can be found in Ref. [12].

In the results presented here, charmonia were identified via their dimuon decay. The separation of the prompt and nonprompt components was based on the the pseudo-proper decay length $l_{J/\psi} = L_{xyz} m_{J/\psi}/|p_{\mu^+\mu^-}|$, where L_{xyz} is the distance between the primary and dimuon vertex, $m_{J/\psi}$ is the world average value of the J/ψ meson mass (assumed for all dimuons), and $p_{\mu\mu}$ is the dimuon momentum. The invariant-mass and the $l_{J/\psi}$ distributions of $\mu^+\mu^-$ pairs were fitted in an extended bidimensional unbinned maximum likelihood fit. The invariant mass component in the fits was parameterised with the sum of two Crystal Ball functions for the signal, and with a polynomial function for the underlying background. The $l_{J/\psi}$ component was parameterised in collision data and Monte Carlo simulated events, using templates for the per-event $l_{J/\psi}$ uncertainty distributions, a sum of Gaussian functions to describe the $l_{J/\psi}$ resolution, and an empirical combination of exponential functions for the background.

3 Results

In Fig. 1, the R_{AA} of prompt (upper) and nonprompt (lower) J/ψ mesons as a function of p_T (left) and centrality (right) are shown in PbPb collisions $\sqrt{s_{NN}} = 5.02$ TeV [9]. The results as a function of p_T are compared to those obtained at 2.76 TeV [14], and found to be in good agreement. No significant p_T trend is observed in the prompt R_{AA} results in the range of 5–20 GeV/c, but a lower suppression is observed at higher p_T for the first time. A similar raise, attributed to parton energy loss, is observed for charged hadrons at the same energy [13]. A lower suppression is also observed at low p_T. In the prompt R_{AA} results in the $1.8 < |y| < 2.4$ range as a function of centrality, we observe that the suppression is stronger for higher p_T in the most central range. A similar observation by the ALICE Collaboration is attributed to a regeneration contribution [4]. The p_T dependence of the nonprompt J/ψ R_{AA} shows hints for a smaller suppression at low p_T. Similarly, a stronger suppression is observed for $1.8 < |y| < 2.4$ and $p_T > 6.5$ GeV/c at all centralities.

The prompt ψ(2S) meson R_{AA} is derived from the product of the double ratio results of the ψ(2S) and J/ψ meson yields in pp and PbPb collisions [15], and the prompt J/ψ R_{AA} computed in the wider bins of Ref. [15]. The results are presented in Fig. 2 as a function of dimuon p_T and centrality, at central rapidity ($|y| < 1.6$). In the bins where the double ratio is not significant, 95% CL intervals on the prompt ψ(2S) R_{AA} are given. The ψ(2S) meson R_{AA} shows no clear dependence with p_T, and hints of an increasing suppression with collision centrality. In the entire measured range, we observe that the ψ(2S) meson production is more suppressed than that of J/ψ mesons, showing that the excited states are more strongly affected by the medium created in PbPb collisions.

In Ref. [10], the prompt and nonprompt J/ψ meson R_{pPb} is measured in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The results show that the prompt J/ψ meson R_{pPb} is slightly above unity without a clear dependence on p_T, except in the most forward bin where suppression at low p_T is observed. The nonprompt J/ψ meson R_{pPb} is consistent with unity for all rapidities, and there is no clear dependence on p_T or rapidity within the uncertainties. The prompt ψ(2S) meson R_{pPb} results in pPb collisions at 5.02 TeV [11], show a stronger suppression than that observed for J/ψ mesons at the same energy, which is unexpected from the current theoretical models including CNM effects, suggesting the presence of final-state effects affecting ψ(2S) meson production. The relatively small modification of the prompt J/ψ and ψ(2S) meson yields in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV indicates that the strong suppression observed in PbPb collisions at the same energy cannot be ascribed to CNM effects alone.

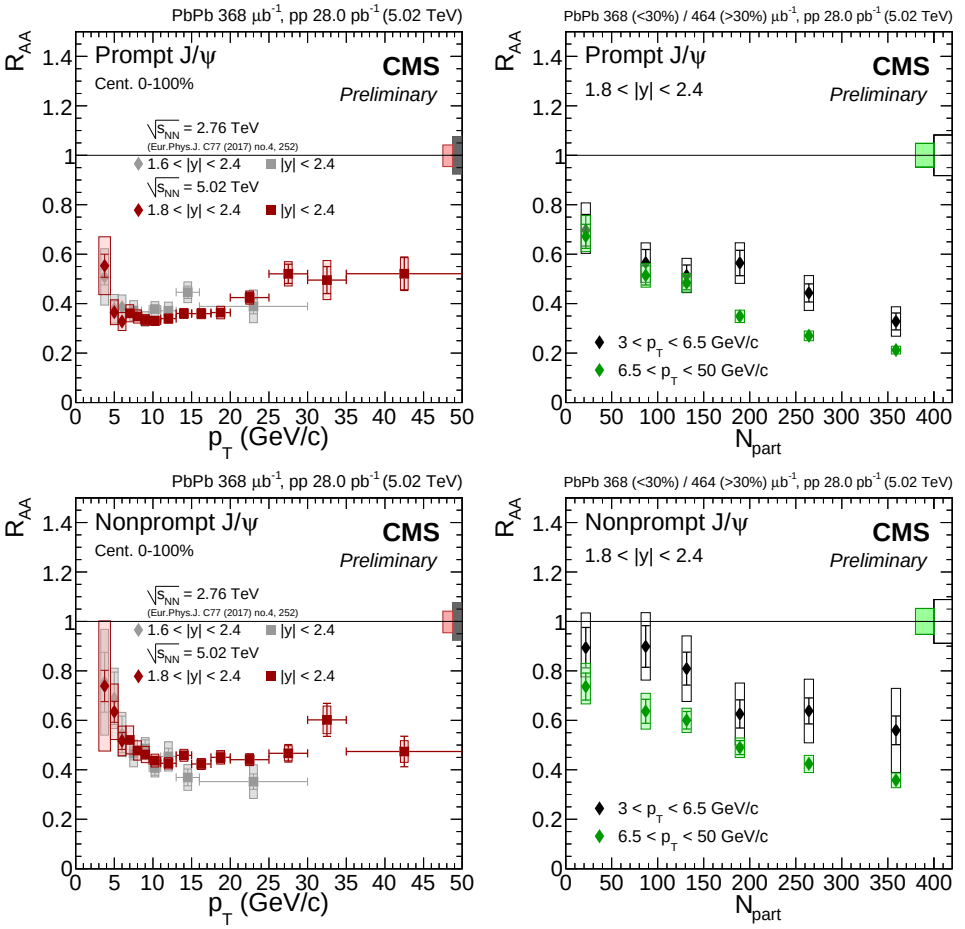

Figure 1. Nuclear modification factor of prompt (upper) and nonprompt (lower) J/ψ mesons as a function of dimuon p_{T} (left) and centrality (right) [9]. The bars (boxes) represent statistical (systematic) point-by-point uncertainties. The boxes plotted at $R_{\mathrm{AA}} = 1$ indicate the size of the global relative uncertainties.

4 Summary

The results of the prompt and nonprompt J/ψ meson R_{AA} have been presented in PbPb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV, as a function of transverse momentum (p_{T}), and collision centrality in different kinematic ranges. The results show a strong centrality dependence, with an increasing suppression towards central events. A smaller suppression at the lowest p_{T} ranges is observed for both prompt and nonprompt J/ψ mesons. The measurements are consistent with previous results at 2.76 TeV. Also a smaller suppression at high p_{T} is observed for prompt J/ψ mesons. The prompt ψ(2S) meson R_{AA} has also been measured in PbPb collisions at 5.02 TeV, as a function of p_{T} and collision centrality. The results show that the ψ(2S) is more suppressed than the J/ψ meson for all the kinematical ranges studied. No p_{T} dependence is observed within the current uncertainties. Hints of an increasing suppression with collision centrality are also observed.

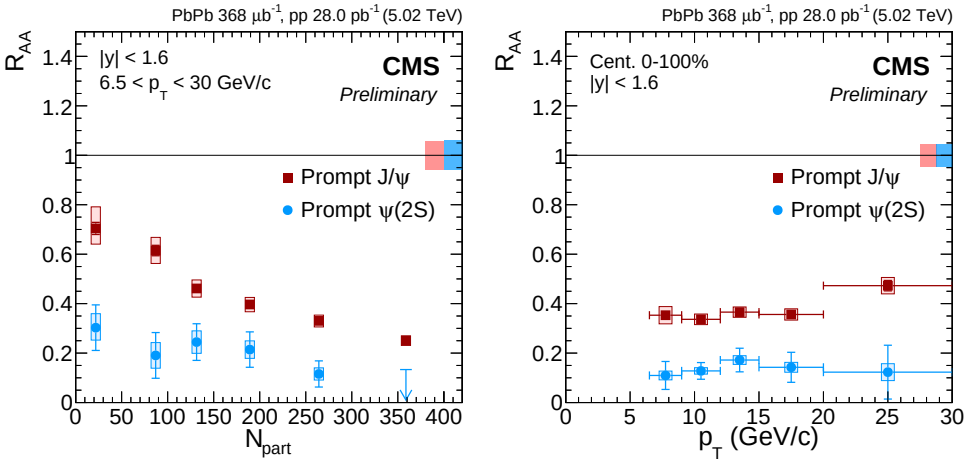

Figure 2. Nuclear modification factor of prompt J/ψ and ψ(2S) mesons as a function of centrality (left) and dimuon p_{T} (right), at central rapidity [9]. The vertical arrows represent 95% confidence intervals in the bins where the double ratio measurement is consistent with 0 (see text). The bars (boxes) represent statistical (systematic) point-by-point uncertainties. The boxes plotted at $R_{\mathrm{AA}} = 1$ indicate the size of the global relative uncertainties.

Finally the prompt and nonprompt J/ψ R_{pPb} results in pPb collisions at 5.02 TeV show small deviations from unity, indicating that the effects observed in PbPb collisions cannot be explained by the presence of CNM effects alone. The prompt ψ(2S) R_{pPb} results show a bigger suppression than for J/ψ mesons, suggesting effects beyond CNM affecting excited states.

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