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Inclusive J/ψ production in pp, p-Pb and Pb-Pb collisions at forward rapidity with ALICE at the LHC

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Abstract. The ALICE Collaboration has measured the inclusive J/ψ production at forward rapidity in pp, p-Pb and Pb-Pb collisions at the LHC. The pp measurements are crucial for a deeper understanding of the physics involving hadroproduction processes and provide the baseline for p-Pb and Pb-Pb measurements. The comparison of the results on the nuclear modification factor in p-Pb collisions as a function of rapidity or transverse momentum with theoretical predictions shows a fair agreement with a shadowing based model and energy loss models with or without a shadowing contribution. The nuclear modification factor in Pb-Pb as a function of collision centrality or transverse momentum shows a weaker suppression than at lower energies and can be described by statistical hadronization or transport models, suggesting a contribution to the J/ψ production due to the (re)combination of charm quarks, especially at low transverse momentum. The extrapolation to Pb-Pb collisions of the cold nuclear matter effects evaluated in p-Pb collisions supports the (re)combination mechanism interpretation.

1. Introduction

ALICE is the LHC experiment dedicated to the study of heavy-ion collisions. The peculiar properties of some of the charmonium states, like their small size ($<$ 1 fm), strong binding energy (several hundred MeV) and large mass of the charm quarks, make them ideal probes of the strongly interacting Quark-Gluon Plasma (QGP) produced in high-energy heavy-ion collisions. It was predicted that for a high temperature medium, the color-screening of the heavy-quark potential would lead to a sequential suppression of the production of quarkonium states with increasing temperature [1] . However, the experimental results in Pb-Pb collisions at LHC energies have revealed that other effects like quarkonium regeneration, in the QGP or at the boundary with the hadronic phase, may contribute to the charmonium production. In order to measure the effects related to cold nuclear matter (CNM), p-Pb collisions have also been studied at the LHC. The study of these effects is important to disentangle hot (QGP related) and cold nuclear matter effects in Pb-Pb collisions.

In this contribution, results on the inclusive J/ψ production at forward rapidity, such as the nuclear modification factor as a function of transverse momentum (p_{T}) in p-Pb collisions at a centre-of-mass energy per nucleon pair $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV, and the nuclear modification factor in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV as a function of centrality or p_{T} are presented and compared to theoretical models. Finally, an estimation of the CNM effects in Pb-Pb, extrapolated from p-Pb measurements, is discussed. The results on the J/ψ production in pp collisions are not presented here but are discussed in [2, 3, 4].

2. ALICE detector and analysed data sample

The main ALICE detectors used for the measurements of muon pairs from the J/ψ decay are the Muon Spectrometer, covering the forward rapidity region ($-4 < \eta < -2.5$); the two VZERO hodoscopes ($2.8 < \eta < 5.1$ and $-3.7 < \eta < -1.7$), used for triggering and centrality determination in Pb-Pb collisions, and the Silicon Pixel Detector (SPD) used for vertex reconstruction.

The energy asymmetry of the LHC beams in p-Pb collisions leads to an asymmetric rapidity coverage for the two different beam configurations: $-4.46 < y_{\rm cms} < -2.96$ at backward rapidity (Muon Spectrometer in the Pb-going direction) and $2.03 < y_{\rm cms} < 3.53$ at forward rapidity (Muon Spectrometer in the p-going direction). The integrated luminosity is 5.8 $\rm nb^{-1}$ (5.0 $\rm nb^{-1}$) for the p-Pb data sample at backward (forward) rapidity and 69 μb^{-1} for the Pb-Pb one.

3. Results

3.1. Nuclear modification factor in p-Pb collisions

The nuclear modification factor in heavy-ion collisions, $R_{\rm AA}$, is an observable that quantifies the nuclear effects and is defined as: $R_{\rm AA} = Y^{J/\psi}/(\langle T_{\rm AA}\rangle \cdot \sigma_{\rm pp}^{J/\psi})$, where $Y^{J/\psi}$ is the J/ψ yield per minimum bias event, $\langle T_{\rm AA}\rangle$ is the nuclear overlap function estimated through the Glauber model and $\sigma_{\rm pp}^{J/\psi}$ is the J/ψ cross section in pp collisions at the same energy[1]. For p-Pb collisions, an equivalent relation is used to define $R_{\rm pPb}$.

The J/ψ production in p-Pb collisions was found to be suppressed at forward rapidity while at backward rapidity $R_{\rm pPb}$ is consistent with binary scaling [6]. At forward rapidity (Fig. 1, right) the $R_{\rm pPb}$ increases with $p_{\rm T}$, reaching unity at $p_{\rm T} \geq 7$ GeV/c. At backward rapidity (Fig. 1, left) the increase is less pronounced and $R_{\rm pPb}$ becomes larger than 1 at $p_{\rm T} \geq 7$ GeV/c, although the systematic uncertainty remains large. Model calculations based on the EPS09 nuclear parton distribution functions parameterization (shadowing model) [7] are in fair agreement with data at high $p_{\rm T}$ for both rapidity ranges, but they seem to underestimate the suppression in the lowest $p_{\rm T}$ region covered by the model ($p_{\rm T} \sim 3$ GeV/c) at forward rapidity. Coherent parton energy loss model calculations [8], with or without a shadowing contribution, describe the data at backward rapidity within the uncertainties. At forward rapidity, the calculation with only energy loss is not able to reproduce the $p_{\rm T}$ dependence, but the one including also a shadowing contribution describes the data for most of the $p_{\rm T}$ range, except at low $p_{\rm T}$. Finally, the CGC-based calculation [9] overestimates the suppression at forward rapidity.

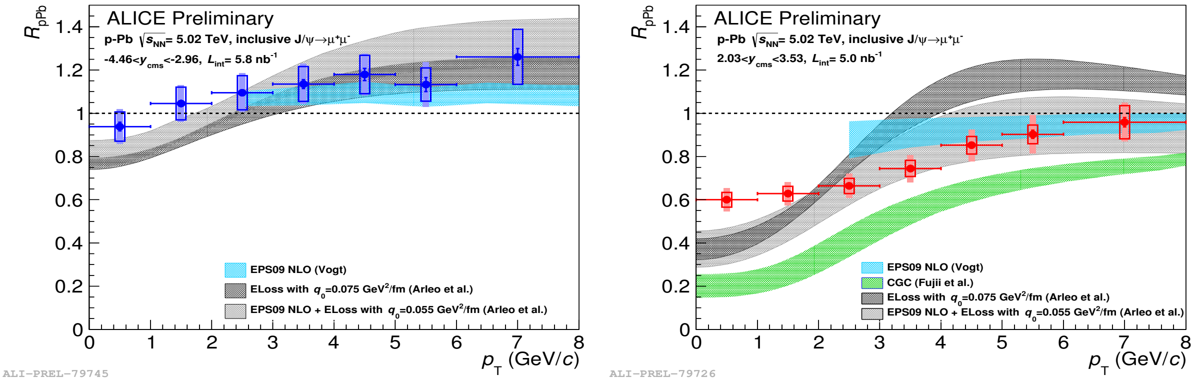

Figure 1. (Color online) J/ψ nuclear modification factor in p-Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV as a function of $p_{\rm T}$, at backward (left) and forward (right) rapidity, compared to theoretical models.

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[1] Extrapolation/interpolation of pp results to $\sqrt{s_{\rm NN}} = 5.02$ TeV is discussed in [5].

3.2. Nuclear modification factor in Pb-Pb collisions

The inclusive J/ψ nuclear modification factor $R_{\rm AA}$ in Pb-Pb collisions as a function of the number of participant nucleons in the collision ($N_{\rm part}$), compared with the PHENIX measurement in Au-Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV, was presented in [10]. The comparison showed less suppression of the J/ψ at $\sqrt{s_{\rm NN}} = 2.76$ TeV, than that at $\sqrt{s_{\rm NN}} = 200$ GeV for large $N_{\rm part}$, suggesting a (re)generation component in the J/ψ production at LHC energies. The ALICE result does not exhibit a significant centrality dependence for $N_{\rm part} \geq 70$. In Fig. 2 (left), it is compared with theoretical models that include a (re)generation component from deconfined charm quarks in the medium. In the Statistical Hadronization model [11], the charmonium production is fully ascribed to the statistical recombination of charm quarks at the phase boundary, since this model assumes the deconfinement and thermal equilibration of the bulk of the charm quarks. The transport models [12, 13], propose a dynamical competition between the suppression in the QGP and the regeneration mechanisms. The latter model includes shadowing, charmonium dissociation by interaction with the co-moving matter and recombination [14]. As can be observed in Fig. 2 (left), models with a full or partial J/ψ production from deconfined charm quarks can reproduce the centrality dependence observed in the experimental data. A precise determination of the amount of shadowing in p-Pb collisions as well as a measurement of the open charm cross section in Pb-Pb collisions are needed in order to reduce the uncertainties on the model calculations.

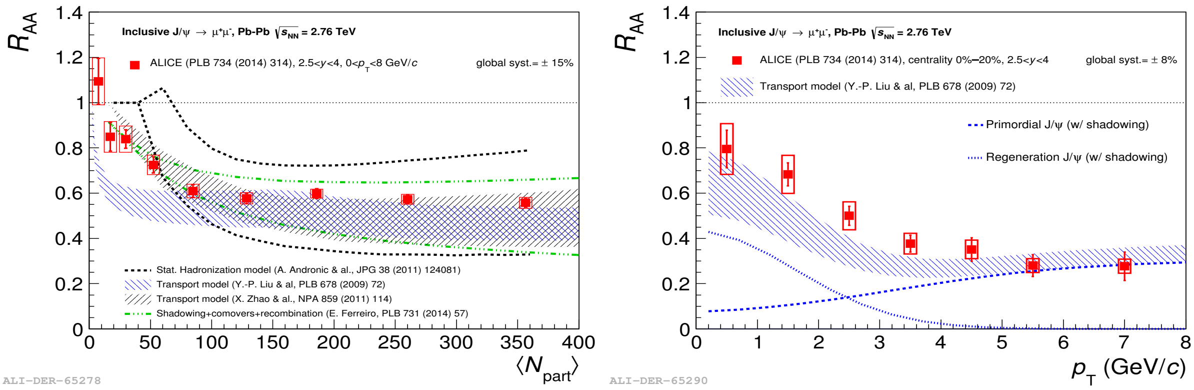

Figure 2. (Color online) Left: J/ψ nuclear modification factor in Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV as a function of $N_{\rm part}$, compared with theoretical models. Right: J/ψ $R_{\rm AA}$ in Pb-Pb collisions as a function of $p_{\rm T}$ compared with a transport model calculation [12].

In [15], the $p_{\rm T}$ dependence of the Pb-Pb $R_{\rm AA}$ was compared with the Au-Au PHENIX measurement. It was observed that the ALICE $R_{\rm AA}$ decreases at high $p_{\rm T}$, indicating a stronger suppression in that kinematic range. Furthermore, the ALICE $R_{\rm AA}$ increases at low $p_{\rm T}$, where it becomes up to a factor four larger than at PHENIX. Since the bulk of the charm quarks is produced at low $p_{\rm T}$, regeneration effects should indeed lead to an increase of $R_{\rm AA}$ at low $p_{\rm T}$, as observed by ALICE. The transport model calculations are in agreement with the ALICE result (Fig. 2, right), and confirm that the recombination component dominates at low $p_{\rm T}$.

The p-Pb results presented in section 3.1 can be used to extrapolate the CNM effects to Pb-Pb measurements under the following assumptions: (i) the J/ψ production mechanism is $g+g \to J/\psi$, which can be shown to lead to a comparable gluon longitudinal momentum fraction in the nucleus in p-Pb and Pb-Pb collisions, despite the different energies and rapidity domains [6], (ii) shadowing is the dominant effect, which allows one to consider CNM effects factorizable in p-Pb and Pb-Pb collisions. Under these assumptions we can evaluate the CNM effects in $R_{\rm AA}$

at forward rapidity as the product $R_{\mathrm{pPb}}(2.03 < y_{\mathrm{cms}} < 3.53) \times R_{\mathrm{Pbp}}(-4.46 < y_{\mathrm{cms}} < -2.96)$, (denoted $R^{forw}_{pPb} \cdot R^{backwd}_{pPb}$). In Fig. 3 (left), we present the comparison of the R_{AA} with the extrapolated CNM effects. For J/ψ p_{T} above 4 GeV/c CNM effects are small, while below they lead to a suppression of the J/ψ production. The CNM effects can be disentangled from the Pb-Pb nuclear modification factor by computing the ratio $S_{J/\psi} = R_{PbPb}/(R^{forw}_{pPb} \cdot R^{backw}_{pPb})$. $S_{J/\psi}$ (Fig. 3 (right)) increases at low p_{T}, further confirming the (re)generation scenario. It then decreases with p_{T} and, for $p_{\mathrm{T}} > 4$ GeV/c, the J/ψ suppression reaches a factor three.

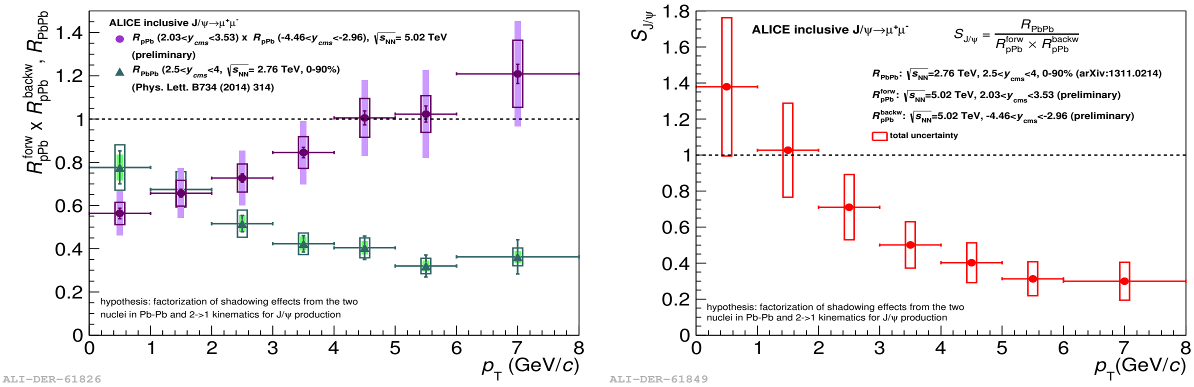

Figure 3. (Color online) Left: J/ψ nuclear modification factor in Pb-Pb collisions as a function of p_{T} and its comparison with the CNM effects extrapolated from the p-Pb measurements. Right: J/ψ nuclear modification factor in Pb-Pb collisions corrected for CNM effects.

4. Conclusions

The inclusive J/ψ production measurements at forward rapidity in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}} =$ 5.02 TeV and Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV have been presented. The nuclear modification factor in p-Pb as a function of p_{T} shows a reasonable agreement with theoretical models based on nuclear shadowing and with models based on coherent parton energy loss. In Pb-Pb collisions the nuclear modification factor as a function of centrality shows less suppression than in lower energy measurements. Theoretical models with a full or partial J/ψ production from deconfined charm quarks describe the data. Less suppression than the one measured at lower energies has been observed at low p_{T}. These observations support the (re)combination scenario in Pb-Pb collisions at LHC energies, which appears to be dominant at low p_{T}.

References

[1] T. Matsui, H. Satz, Phys. Lett. B178 (1986) 416.
[2] B. Abelev et al. (ALICE Collaboration), Phys.Lett. B718 (2012) 295-306.
[3] B. Abelev et al. (ALICE Collaboration), Eur.Phys.J. C74 (2014) 8, 2974.
[4] B. Abelev et al. (ALICE Collaboration), Phys.Rev.Lett. 108 (2012) 082001.
[5] ALICE and LHCb Collaborations, ALICE-PUBLIC-2013-002.
[6] B. Abelev et al. (ALICE Collaboration), JHEP 1402 (2014) 073.
[7] R. Vogt, Int. J. Mod. Phys. E22 (2013) 1330007 and priv. comm.
[8] F. Arleo and S. Peigné , JHEP 1303 (2013) 122.
[9] H. Fujii and K. Watanabe, Nucl. Phys. A915 (2013) 1.
[10] B. Abelev et al. (ALICE Collaboration), Phys. Rev. Lett. 109 (2012) 072301.
[11] A. Andronic et al., J.Phys. G38 (2011) 124081.
[12] Y.-P. Liu et al., Phys.Lett. B678 (2009) 72-76.
[13] X. Zhao et al., Nucl.Phys. A859 (2011) 114-125.
[14] E. G. Ferreiro, Phys.Lett. B731 (2014) 57-63.
[15] B. Abelev et al. (ALICE Collaboration), Phys.Lett. B734 (2014) 314-327.