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ALICE Highlights at Hard Probes 2015

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Abstract

A review of selected measurements by the ALICE Collaboration discussed at the Hard Probes 2015 conference is given. The production of J/ψ as well as long-range two particle correlations in proton-lead collisions at $\sqrt{s}$ = 5.02 TeV are discussed. The parton energy loss in a quark-gluon plasma created in Pb–Pb collisions at $\sqrt{s}$ = 2.76 TeV is discussed based on the measurements of semi-inclusive charged particle jets correlated with a high-p_{T} hadron, the nuclear modification factor (R_{AA}) for identified hadrons and D-mesons. Moreover, D-meson R_{AA} is compared with the R_{AA} of non-prompt J/ψ measured by the CMS Collaboration showing that the parton energy loss depends on the mass of the parton. In addition, further studies of J/ψ production in peripheral nuclear collisions show an excess of low momenta mesons beyond the expectation for purely hadronic production.

Keywords: heavy-ion collisions, proton-lead, high-energy, LHC, quarkonia, jet quenching

1. J/ψ production

1.1. J/ψ *in proton-lead collisions*

To study the nuclear effects in quarkonia production proton-nucleus (pA) collisions at the LHC provide a qualitatively different environment, as compared to heavy-ion collisions. Several initial/final-state effects related to the presence of the nuclear matter can influence the observed charmonium yields. The ALICE Collaboration measured the inclusive J/ψ production in p-Pb collisions at the nucleon–nucleon center of mass energy $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. The measurement of the $\mu^+\mu^-$ decay mode was performed in the center of mass rapidity domains $2.03 < y_{\mathrm{cms}} < 3.53$ (forward, p-going direction) and $-4.46 < y_{\mathrm{cms}} < -2.96$ (backward, Pb-going direction), down to zero transverse momentum [1]. The measurement in the e^+e^- decay mode was performed in the mid-rapidity region ($-1.37 < y_{\mathrm{cms}} < 0.43$) [2]. While at forward rapidity, a suppression of the J/ψ yield with respect to binary-scaled pp collisions is observed,

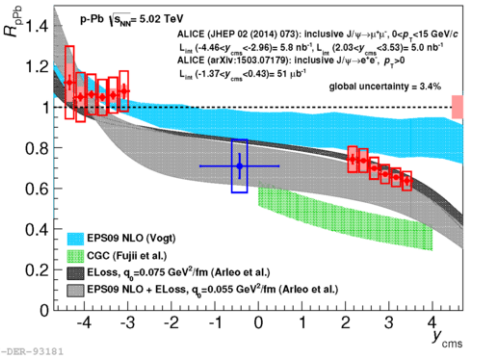

Figure 1: Nuclear modification factor for J/ψ as a function of rapidity in the center of mass reference frame in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV [1, 2].

in the backward region no suppression is present. The ratio of the forward and backward yields is also measured differentially in rapidity and transverse momentum. Theoretical predictions based on nuclear shadowing, as well as on models including, in addition, a contribution from partonic energy loss, are in reasonable agreement with the experimental results [1] (see Fig. 1).

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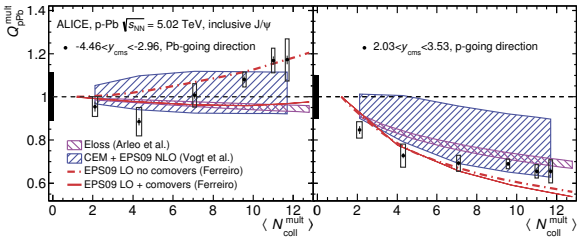

Figure 2: (Colour online) Inclusive J/ψ $Q_{p\mathrm{Pb}}$ as a function of $\langle N_{\mathrm{coll}}^{\mathrm{mult}} \rangle$ at backward (left) and forward (right) rapidity. The boxes centered at $Q_{p\mathrm{Pb}} = 1$ represent the relative uncertainties correlated over centrality. For details see [3].

A measurement of inclusive J/ψ production as a function of the centrality of the collision, as estimated from the energy deposited in the Zero Degree Calorimeters was also reported [3]. The nuclear modification factor in selected centrality bins, $Q_{p\mathrm{Pb}}$, is shown in Fig. 2 as function of centrality for the forward and backward rapidity intervals. The $Q_{p\mathrm{Pb}}$ factor is an analogue of $R_{p\mathrm{Pb}}$ obtained with an event multiplicity estimator that is not fully unbiased (for the exact definition see [4]). At forward rapidity, the J/ψ yield scaled by the number of binary collisions is suppressed by up to 40% compared to that in pp interactions. The degree of suppression increases towards central p–Pb collisions at forward rapidity, and with decreasing p_{T} of the J/ψ. At backward rapidity, $Q_{p\mathrm{Pb}}$ is compatible with unity within the total uncertainties, with an increasing trend from peripheral to central p–Pb collisions.

For the most peripheral p–Pb collisions, no modification with respect to pp collisions is observed within the uncertainties of the measurements for both the shape of the p_{T} spectrum of the J/ψ and the $Q_{p\mathrm{Pb}}$ measurements. In contrast, the results in central p–Pb collisions suggest sizeable nuclear effects. At both backward (Pb-going direction) and forward (p-going direction) rapidity data are consistent with a p_{T} broadening which increases monotonically from peripheral to central p–Pb collisions with larger values at forward rapidity. Notably, ALICE measurements show a stronger p_{T} broadening and a steeper increase with increasing centrality at forward rapidity as compared to PHENIX results in d–Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV [5]. We observe a reasonable agreement of the models based on coherent energy loss and multiple scattering with the measured p_{T} broadening. Models based on nPDF and coherent energy loss are in fair agreement with the nuclear modification factor measurements. These results provide an important baseline for understanding and constraining the cold nuclear matter effects in p–Pb collisions as well as their centrality dependence. Such information is essential for a quantitative interpretation of the results obtained in Pb–Pb collisions.

1.2. J/ψ in heavy-ion collisions

The production of J/ψ and ψ' was measured with the ALICE detector in the transverse momentum and rapidity ranges $p_{\mathrm{T}} < 8$ GeV/c and $2.5 < y < 4$ in Pb–Pb collisions at the LHC [6].

The nuclear modification factor, R_{AA}, of inclusive J/ψ was measured as a function of centrality and a constant suppression of about 40% for N_{part} larger than 70 was reported in [7]. Moreover, data shows that above $N_{\mathrm{part}} \sim 150$, the low p_{T} J/ψ R_{AA} clearly differs from the high p_{T} J/ψ R_{AA} and is about three times larger for $N_{\mathrm{part}} > 250$ (a 3.9 σ effect). Complementary to this, an increase of the inclusive J/ψ R_{AA} with decreasing p_{T} is observed below 5 GeV/c in the most central Pb–Pb collisions (0–20%), while no significant p_{T} dependence is seen in the most peripheral collisions (40–90%). As a function of rapidity, the results from [7] show compatible R_{AA} values for $|y| < 0.9$ and $2.5 < y < 3$. For larger rapidity, a decreasing trend is visible. In addition, the r_{AA} defined as the ratio of the J/ψ $\langle p_{\mathrm{T}}^2 \rangle$ measured in Pb–Pb and pp collisions at the same energy was studied. The comparisons of the r_{AA} and the R_{AA} measured in ALICE with lower energy experiments show significant differences. The decreasing trend of r_{AA} observed as a function of centrality is opposite to NA50 and PHENIX measurements. The R_{AA} in the most central collisions is three times larger than the one measured by PHENIX, and the difference reaches a factor four in the low p_{T} region below 1 GeV/c. If the suppression sources observed at lower energies, which were related to color screening in hot nuclear matter on top of cold nuclear matter effects, are still present at the LHC, then other mechanisms compensating the J/ψ suppression are needed to explain the ALICE measurements. This conclusion is further substantiated, in the region $|y| < 3$, by the comparison of the inclusive J/ψ R_{AA} measurements as a function of y to models implementing only CNM effects, which shows a qualitative agreement.

Further analysis of the p_{T} dependence of J/ψ production as a function of collision centrality revealed an excess in the yield of J/ψ at very low transverse momentum ($p_{\mathrm{T}} < 0.3$ GeV/c) in peripheral collisions [8]. A strong increase of the J/ψ R_{AA} is observed in the range $0 \leq p_{\mathrm{T}} < 0.3$ GeV/c for the 70–90% (50–70%) centrality class, where r_{AA} reaches a value of about 7 (2). The excess has been quantified with a significance of 5.4 (3.4) σ assuming a smooth evolution of the J/ψ