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J/ψ production measurements in pp and Pb-Pb collisions in the ALICE experiment at the LHC

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ALICE is the experiment dedicated to heavy-ion studies at the LHC: it aims at a comprehensive study of the hot and dense colour-deconfined state of matter called Quark-Gluon Plasma. Quarkonia resonances are considered as powerful probes of the deconfined phase since the heavy quark pairs are produced in the early stages of the collision and their bound states are very sensitive to the coloured medium which they traverse. The reference for heavy-ion studies is given by pp collision measurements, which are also interesting per se for addressing unresolved issues in the description of quarkonia hadroproduction. The ALICE experiment was designed to perform the detection of J/ψ resonances, down to p_t=0, both in the di-electron (at mid-rapidity: $|y| < 0.9$) and di-muon (at forward-rapidity: $2.5 < y < 4$) decay channels and it has collected J/ψ samples with proton beams colliding at $\sqrt{s}$ = 7 and 2.76 TeV and with lead beams colliding at 2.76 TeV per nucleon pair. The results on the differential (p_t and y) cross-sections for inclusive J/ψ production in pp collisions at the two energies will be discussed. For Pb-Pb collisions preliminary results on the nuclear modification factor (R_{AA} and R_{CP}) will be shown and compared with results from previous experiments.

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1. Introduction

The J/ψ meson has long been considered a favoured probe to study the formation of a Quark Gluon Plasma (QGP) in heavy ion collisions and has been extensively studied experimentally at SPS and at RHIC. It is also studied at the LHC at unprecedentedly high collision energies. In presence of a QGP the J/ψ production was originally predicted to be suppressed with respect to pp collisions via colour screening [1] but, at the LHC energies, it could also be enhanced due to the statistical recombination of uncorrelated $c\bar{c}$ pairs from the hot medium [2, 3, 4]. Additionally, even in absence of QGP, several mechanisms can modify the production in heavy ion collisions, such as nuclear shadowing.
Measuring the J/ψ production in pp collisions is mandatory as it serves as a reference for studying its modification in heavy ion collisions. It is also interesting on its own since the J/ψ production mechanism is still largely not understood. Several models make different predictions for the differential cross-sections and polarization of the quarkonia states, so that precise measurements at LHC energies are providing additional constraints to these models.

The ALICE experiment [5] is able to detect heavy quarkonia through their leptonic decay: in the central rapidity region (|y|<0.9) this measurement is performed through the detection of e^+e^- pairs in the Inner Tracking System (ITS) and in the Time Projection Chamber (TPC), while at forward rapidity (2.5<y<4) the $\mu^+\mu^-$ channel is analyzed by means of the Muon Spectrometer.
In 2010 and 2011 the LHC provided pp collisions at $\sqrt{s}$=7 TeV and $\sqrt{s}$=2.76 TeV, as well as Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV. The pp analysis results reported here are based on a fraction (L_{int}=15.6 nb^{-1} for $\mu^+\mu^-$ and $L_{\mathrm{int}} = 5.6$ nb^{-1} for e^+e^-) of the events collected by ALICE at $\sqrt{s}$=7 TeV and on the total amount of events (L_{int}=20.2 nb^{-1} for $\mu^+\mu^-$ and $L_{\mathrm{int}} = 1.1$ nb^{-1} for e^+e^-) at $\sqrt{s}$ = 2.76 TeV. In the case of Pb-Pb collisions a $L_{\mathrm{int}} \sim 2.7$ μb^{-1} (in the centrality range $0-80\%$) was used for the analysis.
The data sample corresponds to events collected with a minimum bias trigger, defined in a different way for pp and Pb-Pb collisions: in the first case it is the logical OR of the ITS pixel layers and of the forward scintillator arrays (VZERO), in the second the AND of the same detector signals. For the muon analysis, the minimum bias trigger is required to be in coincidence with a signal in the muon trigger chambers. The analysis reported refer to inclusive J/ψ production: with higher statistics the separation of prompt and non-prompt components will be possible at central rapidities. For more details on the ALICE strategies for quarkonia detection see [7].

2. p+p→J/ψ+X : results

The J/ψ yield was extracted by fitting the invariant mass spectrum of $\mu^+\mu^-$ pairs and by counting the events in the background-subtracted invariant mass spectrum of e^+e^-. The inclusive J/ψ production cross section was obtained by dividing the number of J/ψ by the acceptance times efficiency of the detector ($A \times \varepsilon$, estimated through a Monte-Carlo simulation which takes into account the real detecting conditions) and by the integrated luminosity. The final results for $\sqrt{s}$=7 TeV [7] and the preliminaries for $\sqrt{s}$=2.76 TeV [8] are:

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$$\sigma_{J/\psi}\ (2.5<y<4,\ \sqrt{s}=7\ \text{TeV}) = 6.31 \pm 0.25(\text{stat.}) \pm 0.76(\text{syst.})\ ^{+0.95}_{-1.96}(\text{pol.})\ \mu\text{b}$$
$$\sigma_{J/\psi}\ (|y|<0.9,\ \sqrt{s}=7\ \text{TeV}) = 10.7 \pm 1.0(\text{stat.}) \pm 1.6(\text{syst.})\ ^{+1.6}_{-2.3}(\text{pol.})\ \mu\text{b}$$
$$\sigma_{J/\psi}\ (2.5<y<4,\ \sqrt{s}=2.76\ \text{TeV}) = 3.46 \pm 0.13(\text{stat.}) \pm 0.42(\text{syst.})\ ^{+0.55}_{-1.11}(\text{pol.})\ \mu\text{b}$$
$$\sigma_{J/\psi}\ (|y|<0.9,\ \sqrt{s}=2.76\ \text{TeV}) = 6.44 \pm 1.42(\text{stat.}) \pm 1.03(\text{syst.})\ ^{+0.64}_{-1.42}(\text{pol.})\ \mu\text{b}$$

Systematic uncertainties include several sources: signal extraction, trigger and reconstruction efficiencies, p_t and y input distributions used in the $A \times \varepsilon$ evaluation, luminosity. The influence of the unknown degree of J/ψ polarization on the acceptance is quoted separately.

Following the same approach adopted for the evalution of the integrated cross section, also the

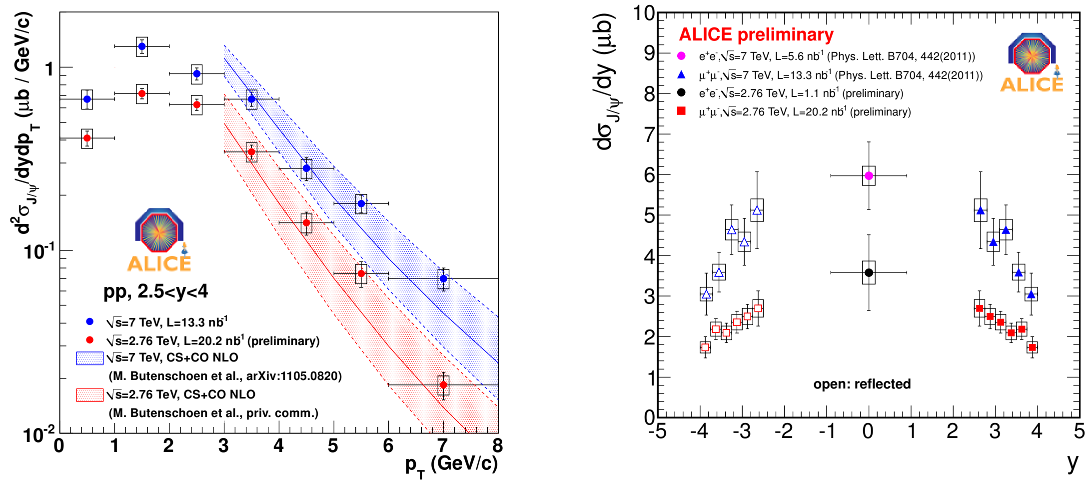

Figure 1: Left: $d^2\sigma_{J/\psi}/dydp_T$ obtained at $\sqrt{s}$=7 TeV and 2.76 TeV, compared with NLO NRQCD calculations [7]. Right: $d\sigma_{J/\psi}/dy$ obtained at $\sqrt{s}$=7 TeV [7] and 2.76 TeV[8].

differential distributions were studied. In Fig.1-left the $d^2\sigma_{J/\psi}/dydp_t$ measured in the muon channel is shown for the two energies together with the theoretical expectations from Non-Relativistic QCD calculations at NLO [6], which well describe the experimental behaviour for p_t>3 GeV/c. In Fig.1-right the $d\sigma_{J/\psi}/dy$ is reported at the two centre-of-mass energies, showing the large rapidity range covered by the ALICE experiment for J/ψ measurement. The comparison of the J/ψ differential cross sections at forward and central rapidity with those obtained by the other LHC experiments at $\sqrt{s}$=7 TeV shows a good agreement (for the comparison see [7], where more details on the enalysis can also be found). The J/ψ production yield at $\sqrt{s}$=7 TeV has also been studied as a function of the charged particle pseudo-rapidity density ($dN_{\text{ch}}/d\eta$) measured in the ITS, both in the dielectron and in the dimuon channels: preliminary results show a similar linear increase [8].

3. Pb+Pb→J/ψ+X : results

The nuclear modification factor (R_{AA}) and the central-to-peripheral nuclear modification factor (R_{CP}) were measured in the $\mu^+\mu^-$ channel, while only an estimate of the R_{CP} was worked out in e^+e^- channel. The centrality of the collision was determined from a Glauber fit to the amplitude of the signal in the VZERO detector: four centrality classes were used for the muon analysis (0-10%, 10-20%, 20-40% and 40-80%), and two for the electron (0-40%, 40-80%). In order to extract the inclusive J/ψ yield, the number of J/ψ in each centrality bin was normalized to the number of Pb-Pb collisions in the corresponding class and corrected for $A \times \varepsilon$ (again estimated with simulation). To measure the R_{AA}, the J/ψ yield was normalized to the inclusive J/ψ cross-section measured in pp collisions in the same rapidity domain at the same energy, while for the R_{CP} the normalization is relative to the 40-80% centrality class.

The inclusive J/ψ R_{AA} (2.5<y<4, p_{t}>0) is shown in Fig.2-left as a function of the average number

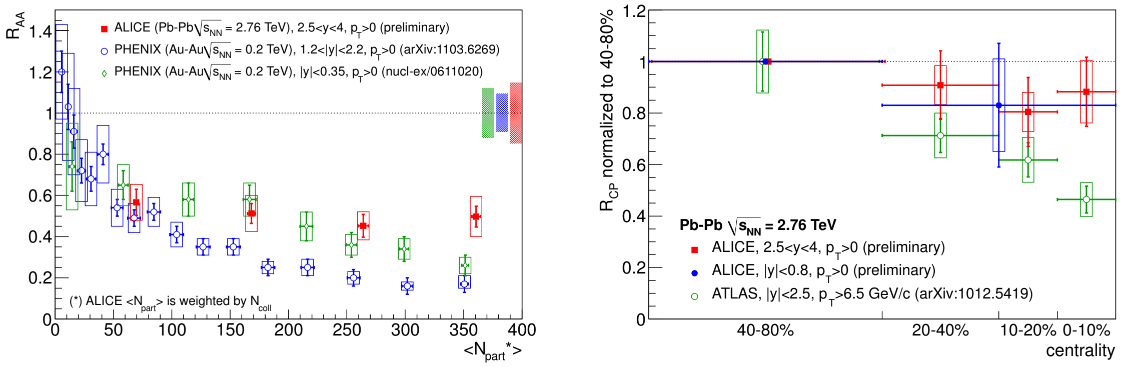

Figure 2: Left: J/ψ R_{AA} for 2.5<y<4 in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV compared with PHENIX results in AuAu at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV. Right: J/ψ R_{CP} for 2.5<y<4 and |y|<0.8 compared with ATLAS results

of nucleons participating to the collision $\langle N_{\mathrm{part}} \rangle$ calculated using the Glauber model and weighted by the number of binary nucleon-nucleon collisions in order to account for the large centrality bins. These results show no significant dependence on centrality, and the centrality integrated value is $R_{\mathrm{AA}}^{0-80\%} = 0.49 \pm 0.03(\mathrm{stat.}) \pm 0.11(\mathrm{syst.})$. The comparison with the PHENIX R_{AA} measurement at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV [9] shows that the inclusive J/ψ R_{AA} found by ALICE at forward rapidity is clearly above the one measured by PHENIX in the region $1.2 < |y| < 2.2$. The comparison of the ALICE R_{CP} result to the ATLAS measurement [10] in the same centrality classes (Fig.2-right) indicates that the J/ψ mesons measured at forward rapidity down to $p_{\mathrm{t}} = 0$ are less suppressed than the high-p_{t} J/ψ mesons at midrapidity (80% of the J/ψ particles measured by ATLAS have a p_{t} larger than 6.5 GeV/c). The same evidence can be observed by comparing the R_{AA} obtained by ALICE and CMS [11] at forward and central rapidities respectively. Our measurement at central rapidity is affected by large statistical uncertainty, which prevents from drawing firm conclusion on this rapidity range. More details on the analysis can be found in [12].

4. Conclusions

J/ψ measurements in pp collisions at $\sqrt{s_{\mathrm{NN}}} = 7$ TeV and at $\sqrt{s} = 2.76$ TeV have been presented. The differential p_{t} distribution is well reproduced by NRQCD NLO predictions. Upcoming results on J/ψ polarization will make the discrimination among the different production models more tight. Results presented for Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV show a significant suppression of the inclusive J/ψ production if compared to pp collisions at the same energy. The comparison of the R_{AA} $\langle N_{\mathrm{part}} \rangle$-dependence with PHENIX results suggests that re-generation mechanisms could play a role in explaining the lower suppression seen in our results. In order to quantify this role, a precise knowledge of the initial state effects at LHC energy is mandatory: this will be possible when p-Pb collisions data will be available.

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