J/ψ production in p+p at √s = 500 GeV collisions and Au+Au collisions at √s_{NN} = 200 GeV at the STAR experiment

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Abstract. In this paper, we present measurements of J/ψ cross-section and yield dependence on charged-particle multiplicity in p+p collisions at √s = 500 GeV at mid-rapidity in the transverse momentum range of 0-20 GeV/c. Measurements of J/ψ nuclear modification factors in Au+Au collisions at √s_{NN} = 200 GeV up to 14 GeV/c via the di-muon channel with the full data sample taken during RHIC 2014 run is also presented.

1. Introduction
The study of J/ψ meson production has been a long-term interest both in elementary collisions and heavy-ion collisions. In p+p collisions, the study of J/ψ production provides test ground for calculations based on perturbative Quantum Chromodynamics (pQCD) and the evolution of produced c¯c pair. However, none of the existing theoretical models can fully describe J/ψ production. J/ψ measurements at a new beam energy of √s = 500 GeV in p+p collisions will provide additional insights into its production mechanism. On the other hand, the production of J/ψ has also been extensively used to probe the Quark-Gluon Plasma (QGP) created in heavy-ion collisions [1]. The suppression of J/ψ in a deconfined medium due to Debye color screening of the charm quark potential was proposed as a signature of the QGP formation. Interpretation of the J/ψ suppression is, however, still a challenge due to the contributions from the regenerated J/ψ by the coalesced uncorrelated c¯c pairs in the medium and the cold nuclear matter effects. Precise measurements of the nuclear modification factor (R_{AA}) for J/ψ over a broad kinematic range in Au+Au collisions can help better understand the feature of Debye color screening. At STAR, the newly installed Muon Telescope Detector (MTD), which provides both the di-muon trigger and the muon identification capability at mid-rapidity, opens the door to measuring J/ψ via the di-muon decay channel for the first time at STAR. The STAR experiment recorded data corresponding to integrated luminosities of 28.3 pb^{-1} and 22 pb^{-1} for p+p collisions at √s = 500 GeV in the RHIC 2013 and 2011 run, respectively, by using the MTD di-muon trigger and the Barrel Electromagnetic Calorimeter (BEMC) trigger, and 14.2 nb^{-1} for Au+Au collisions at √s_{NN} = 200 GeV in the RHIC 2014 run via the di-muon trigger. In this proceedings, we report 1) the measurements of J/ψ cross-section and yield dependence on event multiplicity in p+p collisions at √s = 500 GeV; and 2) the measurements of J/ψ R_{AA} in Au+Au collisions at √s_{NN} = 200 GeV.

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2. J/ψ measurements in p+p collisions at $\sqrt{s} = 500$ GeV

2.1. J/ψ transverse momentum spectrum and $x_T$ scaling

Figure 1 shows the inclusive cross section of J/ψ in p+p collisions at $\sqrt{s} = 500$ GeV measured via the di-electron and di-muon channels for the transverse momentum ($p_T$) range of $0 < p_T < 20$ GeV/$c$. The measurement via the di-muon decay channel extends $p_T$ reach down to 0. The results in these decay channels are consistent in the overlapping range of $4 < p_T < 9$ GeV/$c$. The experimental results can be well described by CGC+NRQCD calculations at low $p_T$ [3] and NLO NRQCD calculations at high $p_T$ [4]. Figure 2 shows the $x_T = 2p_T/\sqrt{s}$ scaling of J/ψ cross section [5], where the J/ψ cross section in p+p collisions at $\sqrt{s} = 500$ GeV follows a common trend as a function of $x_T$ at high $p_T$. The breaking of the $x_T$ scaling at low $p_T$ can be attributed to soft processes.

2.2. J/ψ yield versus event activity

At STAR, we use the number of tracks matched to the Time-of-Flight (TOF) detector in the pseudorapidity interval $|\eta| < 1$ to characterize event activity. The relative yields of J/ψ as a function of event activity from both the di-electron and di-muon channels are presented in Fig. 3. The high-$p_T$ J/ψ results ($p_T > 4$ GeV/$c$) are from the di-electron channel using BEMC-triggered data. The low-$p_T$ J/ψ results ($p_T > 0$ GeV/$c$) are from the di-muon channel using MTD-triggered data. A similar stronger-than-linear trend is observed both at LHC [6] and RHIC. Comparisons of STAR measurements to different model calculations are shown in Fig. 4 for different kinematic ranges. PYHTIA8 with a default setting, including the Multiple-Parton Interaction (MPI) contributions to particle production, can describe the rising trend and $p_T$ dependence in data. Percolation model [7] also qualitatively reproduces the trend in data.

3. J/ψ measurement in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

Figure 5 shows the J/ψ invariant yield as a function of $p_T$ for different centralities in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV within $|y| < 0.5$. The measurements from the di-muon channel are consistent with the published di-electron results [8, 9] at the same collision energy within...
Figure 3. Relative $J/\psi$ yield as a function of event activity in the di-muon decay channel (blue star) and in the di-electron decay channel (red star). Measurements for open (hidden) charm mesons from LHC are shown as open (filled) circles.

Figure 4. Relative $J/\psi$ yield as a function of event activity. Different model calculations are presented: PYTHIA8 and the percolation model. The dash shaded bands represent the statistical errors of the PYTHIA calculations.

Figure 5. $J/\psi$ invariant yield as a function of $p_T$ for different centralities in di-muon channel (closed) and di-electron channel (open).

Figure 6. $J/\psi$ $R_{AA}$ as a function of $p_T$ for different centralities in di-muon channel (closed) and di-electron channel (open). Transport Model predictions are shown as solid and dashed lines.

$|y| < 1$. Figure 6 shows the $J/\psi$ $R_{AA}$ in different centrality bins for Au+Au collisions. A strong suppression at low $p_T$ range in all centrality bins is observed. This suppression could be due to the effects of dissociation and cold nuclear matter (CNM). The rising trend as a function of $p_T$ can be a result of formation-time effects and more feed-down contribution from B hadrons at high $p_T$. Figures 7 and 8 show the centrality dependence of $J/\psi$ $R_{AA}$ at low-$p_T$ and high-$p_T$ ranges, separately. The smaller suppression at the LHC [10, 11] in central collisions at low $p_T$ indicates larger regeneration contribution due to higher charm cross section, while the larger suppression of $J/\psi$ at LHC at high $p_T$ indicates larger dissociation rate due to higher temperature of the medium or shadowing effects. Transport models from Tsinghua [12, 13] and Texas A&amp;M University [14, 15], which include both dissociation and regeneration effects, are also shown. At low-$p_T$ range, both models can describe the centrality dependence at RHIC, but
tends to underestimate $R_{AA}$ at LHC. At high-$p_T$ range, there is tension between models and data.

Figure 7. $J/\psi$ $R_{AA}$ as a function of $N_{\text{part}}$ for $p_T > 0$ in di-muon channel (red star). Measurements from PHINEX and ALICE are shown as open circles and blue squares. Transport Models predictions are shown as lines and bands for RHIC and LHC energies.

Figure 8. $J/\psi$ $R_{AA}$ as a function of $N_{\text{part}}$ for $p_T > 5 \text{ GeV/c}$ in di-muon channel (red star). Measurements from CMS are shown as blue squares. Transport Model predictions are show as solid and dashed lines.

4. Summary

We present $J/\psi$ production in p+p collisions at $\sqrt{s} = 500 \text{ GeV}$ and Au+Au collisions at $\sqrt{s_{NN}} = 200 \text{ GeV}$ at RHIC. In p+p collisions, the inclusive $J/\psi$ spectrum is measured down to $p_T = 0$ and the spectra can be well described by CGC + NRQCD and NLO NRQCD calculations. The relative $J/\psi$ yield grows rapidly as the charged-particle multiplicity increases and a stronger-than-linear rise at higher multiplicities for $p_T > 4 \text{ GeV/c}$ is observed. PYTHIA8 and the percolation model can qualitatively describe the observed trend in data. In Au+Au collisions, we observe clear $J/\psi$ suppression at $p_T < 5 \text{ GeV/c}$ at all centralities and $J/\psi$ $R_{AA}$ can be qualitatively described by transport models including dissociation and regeneration effects.

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