# Measurement of double-helicity asymmetries in inclusive $J/\psi$ production in longitudinally polarized $p + p$ collisions at $\sqrt{s} = 510$ GeV†

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We present a measurement of the double-helicity asymmetry, $A_{LL}^{J/\psi}$, in inclusive $J/\psi$ production in $\sqrt{s}$ = 510 GeV longitudinally polarized $p + p$ collisions at the Relativistic Heavy Ion Collider (RHIC). The data used for the study were collected in the PHENIX experiment during the 2013 run; the sampled integrated luminosity was about 150 pb$^{-1}$ for this analysis. We measured $A_{LL}^{J/\psi}$ by detecting the decay daughter muon pairs $\mu^+\mu^-$ within the PHENIX muon spectrometers in the rapidity range $1.2 < |y| < 2.2$. In $p + p$ collisions at RHIC energies, $J/\psi$ particles are predominantly produced via gluon-gluon scatterings[1]. Due to the large charm quark mass, perturbative QCD is expected to work for calculations of the $J/\psi$ and other charmonia production cross sections in high energy deep inelastic scattering and $p + p$ collisions.

By detecting the $J/\psi$ at forward rapidity, we sample participating gluons from two distinct ranges of Bjorken $x$. The $A_{LL}^{J/\psi}$ can be expressed to be proportional to the product of the gluon polarization distributions at two distinct ranges of $x$. Quantitatively, we used a PYTHIA[2] (PYTHIA 6.4 tuned for RHIC energies) simulation at leading order to estimate the gluon $x$-distribution sampled in $J/\psi$ production within the PHENIX muon arm acceptance. The simulation illustrates that for the $g + g \rightarrow J/\psi + X$ process in the forward rapidity of the PHENIX muon arm acceptance, the two gluons come from two very distinct $x$ regions, with one gluon in the intermediate $x$ region $x \sim 5 \times 10^{-2}$ where recent data of jet[3] and $\pi^0$[4] double helicity spin asymmetries have shown evidence of significant gluon polarization, and the other gluon covering the poorly known small-$x$ region $x \sim 2 \times 10^{-3}$. Thus our new results could be used to further constrain the gluon polarization ($\Delta G$) for $x < 5 \times 10^{-2}$. The $A_{LL}^{J/\psi}$ measurements offer a new way to access $\Delta G$ via heavy-quark production in $p + p$ collisions. They also serve as an important test of the universality of the helicity-dependent parton densities and QCD factorizations.

The final results for $A_{LL}^{J/\psi}$ as a function of transverse momentum $p_T$ and rapidity $|y|$ are summarized in Fig. 1. The average $A_{LL}^{J/\psi}$ measured is 0.012 ± 0.010 (stat) ± 0.003 (syst). The black error bars show the statistical uncertainty. The red boxes show only the uncorrelated point-to-point systematic uncertainties for each $p_T$ or $|y|$ bin. Additionally, there is a $4 \times 10^{-4}$ global systematic uncertainty from the relative luminosity determination and a 6.5% global scaling systematic uncertainty from the polarization magnitude determination for all $p_T$ or $|y|$ bins. To compare our results with the current understanding of the gluon polarization, we have calculated the $A_{LL}^{J/\psi}$ in our kinematic range using a PYTHIA simulation with NNPDFpol1.1[5] as the polarized PDF. To separate the uncertainty from the $J/\psi$ production mechanism, we assumed $\hat{a}_{LL}^{gg\rightarrow J/\psi+X} = 1$, which is the leading order partonic asymmetry for open heavy quarks in the heavy mass limit at RHIC energies[1]. The blue curve with the shaded band is our $A_{LL}^{J/\psi}$ estimation. The solid blue curve is the central value and the blue shaded band is the $\pm 2\sigma$ range.

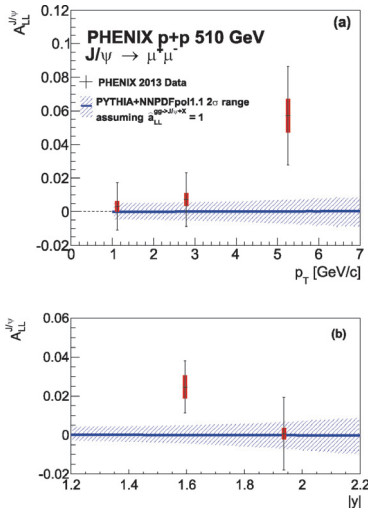


Fig. 1. $A_{LL}^{J/\psi}$ as a function of $p_T$ (top panel) and $|y|$ (bottom panel).

References
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† Condensed from the article in Phys. Rev. D **94**, 112008 (2016)

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