Measurement of transverse single spin asymmetry for $J/\psi$ production in polarized p+p and p+Au collisions at PHENIX

C. Xu,*1 H. Yu,*1 and X. Wang*1,+2

Large transverse single-spin asymmetries (TSSAs) were first observed in 1976 at large $x_p$ in pion production from transversely polarized proton-proton collisions at $\sqrt{s} = 4.9$ GeV, and they were subsequently observed in hadronic collisions over a range of energies extending up to $\sqrt{s} = 200$ GeV at RHIC energy. In order to describe large TSSAs, two approaches have been developed since the 1990s. One approach requires higher-twist contributions in the collinear factorization scheme and the other approach utilizes parton distribution functions and/or fragmentation functions that are unintegrated in the partonic transverse momentum, $k_T$. These functions are generally known as transverse-momentum-dependent distributions (TMDs). These two approaches have different but overlapping kinematic regimes of applicability, and they have been shown to correspond exactly in their region of overlap$^1$.

Heavy-flavor production mainly come results from gluon-gluon interaction at RHIC energy. $J/\psi$ production has been extensively studied over the last decades, but the details of the production mechanism remain an open question. The measurement of heavy-flavor TSSA can serve to isolate gluon dynamics within the nucleon. It was proposed in 2008 by Yuan$^2$ that within the framework of non-relativistic QCD (NRQCD), the TSSA of $J/\psi$ production can be sensitive to the $J/\psi$ production mechanism. It should be noted that the relationship between the TSSA and the production mechanism is not quite as simple in the collinear higher-twist approach.

The $J/\psi$ production has been measured by the PHENIX muon spectrometers at forward and backward rapidities (1.2 $< |y| < 2.4$), where two muons enter the same arm. The TSSA for the $J/\psi \rightarrow \mu^+\mu^-$ decay channel were determined by subtracting a background asymmetry from the inclusive signal as

$$ A_N^{J/\psi} = \frac{A_{incl}^N - r \cdot A_{BG}^N}{1 - r}, \quad r = \frac{N_{incl} - N_{J/\psi}}{N_{incl}} \quad (1) $$

The first measurement of TSSAs in $J/\psi$ production was published in 2010. The data were taken by the PHENIX during the 2006 and 2008 polarized proton runs at $\sqrt{s} = 200$ GeV; the integrated luminosity are 1.8 pb$^{-1}$ and 4.5 pb$^{-1}$, and the averaged polarizations are 53% and 45% respectively. The $p_T$ and $x_F$ dependencies are studied; for rapidity regions of $-2.2 < y < -1.2$, $|y| < 0.35$, and $1.2 < y < 2.2$, and for $p_T$ up to 6 GeV/$c$,$^3$. The results are statistically limited and they are consistent with zero. During 2015 RHIC run, PHENIX recorded 50 pb$^{-1}$ polarized p+p collisions with a much higher average polarization of 60%. We expect that the statistical errors of the measurement will be improved significantly. The expected statistical uncertainty of inclusive $J/\psi A_N$ from 2015 p+p collision is shown in the Fig 1.

In additional to the polarized p+p collision, RHIC also successfully ran polarized proton beam collisions with large nuclear Au targets. A recent theoretical study proposed that scattering a polarized proton on the saturated nucleus may provide a unique way of probing the gluon and quark TMDs. Measuring the ratio of $A_N$ in polarized p+Au and p+p at 200 GeV might shade a light on the test for saturation physics$^4$. The measurement of $J/\psi A_N$ in these two polarized collision systems are in progress. The invariant mass distributions of dimuons in p+p and p+Au are shown in Fig 2. Invariant mass distributions are fitted using a third-order polynomial and two Gaussian functions.

Fig. 1. Projected statistical uncertainty of inclusive $J/\psi A_N$ from the 2015 polarized p + p collisions at 200 GeV.

Fig. 2. Invariant mass distribution for p+p and p+Au collisions in 2015 run.

References

*1 Department of Physics, New Mexico State University
*2 RIKEN Nishina Center