Measurement of transverse single spin asymmetry for J/ψ 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_F 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/ψ 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/ψ production can be sensitive to the J/ψ 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/ψ production have been measured by the PHENIX muon spectrometers at forward and backward rapidities ($1.2 < |\eta| < 2.4$), where two muons enter the same arm. TSSA for the $J/\psi \to \mu^+\mu^-$ decay channel were determined by subtracting a background asymmetry from the inclusive signal as

$$A_N^{J/\psi} = \frac{A_N^{Incl} - r \cdot A_N^{BG}}{1-r}, \quad r = \frac{N_{Incl} - N_{J/\psi}}{N_{Incl}} \tag{1}$$

The first measurement of TSSAs in J/ψ 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 luminositis 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/ψ A_N from 2015 p+p collision is shown in the Fig 1.

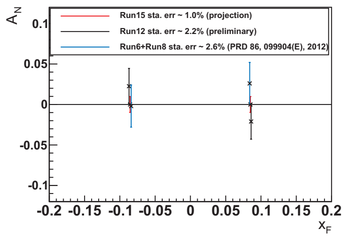

Fig. 1. Projected statistical uncertainty of inclusive J/ψ A_N from the 2015 polarized p + p collisions at 200 GeV.

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 nuclear 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.

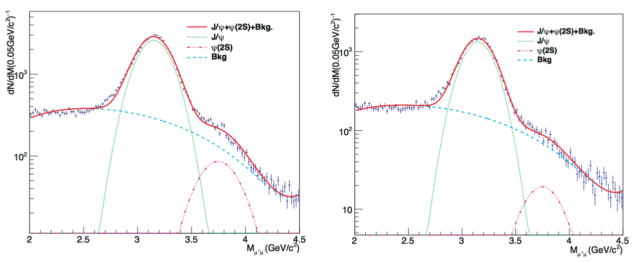

Fig. 2. Invariant mass distribution for p+p and p+Au collisions in 2015 run.

References
1) X.-D. Ji, J.-W. Qiu, W. Vogelsang, Phys. Rev. Lett **97**, 082002 (2006).
2) F. Yuan, Phys. Rev. D**78**, 014024 (2008).
3) PHENIX collaboration: Phys. Rev. D **82**, 112008 (2010), D **86**, 099904 (2012).
4) Y. Kovchegov, M. Sievert, ArXiv: 1201.5890 [hep-ph] (2012).

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