Single transverse spin asymmetry (A_N) in polarized $p + Au$ collisions at $\sqrt{s_{NN}} = 200$ GeV

J. H. Yoo[*1,*2] for the PHENIX collaboration

A proton is basically composed of many sea quarks and gluons in addition to the three valence quarks. According to the early European Muon Collaboration (EMC) data in the 80 s, the contribution of quarks and antiquarks to the entire proton's spin value (1/2) is less than 30%. As a result, the rest should come from the gluon spin and the orbital motions of quarks, antiquarks and gluons. The detailed spin structure of the proton can be revealed by investigating the longitudinal and transverse components. In particular, the transverse spin structure of the proton can provide some insight into the orbital angular momentum component of the partons (quarks and gluons) in the proton.

Transverse single spin asymmetries (A_N) are relevant to the transverse spin structure of the proton. Initially, the A_N of hadrons produced in the transversely polarized $p+p$ collision was expected to be small; however, experiments instead measured large asymmetries of up to $A_N \approx 40\%$ in the forward direction. To better describe the large A_N measurements, the theoretical framework has been extended to include transverse momentum dependent (TMD) distributions and multi-parton dynamics (higher twist effects).[1)] At least two TMD effects have been proposed to explain the observed nonzero asymmetries. The first effect, known as the Sivers effect, correlates the proton spin with the partonic transverse momentum k_T.[1,2)] The second effect, known as the Collins effect, describes the coupling of a transverse quark polarization (transversity) and a transverse spin dependent fragmentation from a struck quark into a hadron.[1,3)] A proton + nucleus ($p + A$) collision gives a parton distribution and transverse momentum distribution in the nucleus by comparing it with the nucleon parton distribution function (PDF). Generally accepted cold nuclear matter (CNM) effects are "nuclear shadowing," "gluon saturation," "radiative energy loss," and the "Cronin effect." Nuclear shadowing implies the modification of the parton distribution functions within a nucleus. The gluon saturation signifies the saturation of the gluon distribution function. The radiative energy loss implies the modification of the momentum fraction of partons due to multiple soft scattering. Finally, the Cronin effect implies broadening of the transverse momentum distribution due to multiple scattering of incident partons. Until recently, the transverse spin structure and CNM had been studied separately. The RHIC Run15 experiment was the first high-energy transversely polarized proton ($p\uparrow$) and nuclear collision in the world. This unique collision experiment allows us to explore the spin degree of freedom in the CNM effects.

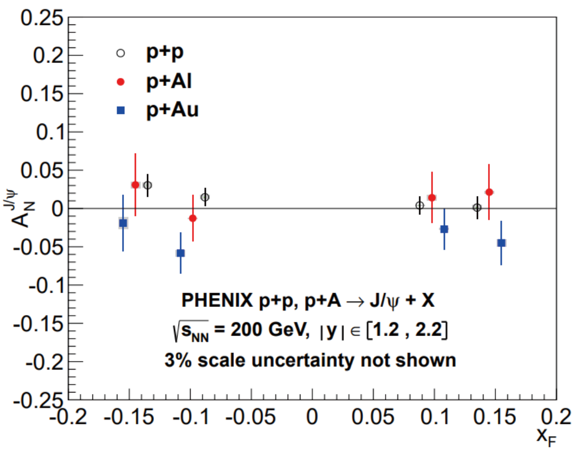

Fig. 1. A_N measured at both forward and backward rapidity in $p + p$, $p + Al$ and $p + Au$ collision for J/Ψ mesons.[1)]

The results for A_N in forward and backward J/Ψ production in $p\uparrow +p$, $p\uparrow +Al$, $p\uparrow +Au$ collisions is shown in in Fig. 1. These results indicate that the nuclear dependence of A_N for J/Ψ production is not small. Compared to the A_N of $p\uparrow +p$ collisions, the observed asymmetry in $p\uparrow +Au$ collisions is larger in absolute value and has opposite sign. Moreover, the A_N of neutral pions and inclusive charged hadrons in $p\uparrow +p$ have previously been measured with the PHENIX midrapidity spectrometer. These asymmetries have been found to be consistent with zero. In addition to a $p\uparrow +p$ collision, the A_N of neutral pions in a $p\uparrow +A$ collision has already been analyzed. The analysis of A_N of charged pions in the midrapidity region in a polarized $p + A$ collision is in progress. A_N measurements with two species of nuclei (Al and Au) will allow us to study the A dependence of A_N and the CNM effects in the system of transversely polarized protons colliding with nuclei.

References
1) PHENIX Collaboration, arXiv:1805.01491v1.
2) D. W. Sivers, Phys. Rev. D **41**, 83 (1990).
3) J. C. Collins, Nucl. Phys. **396**, 161 (1993).

*1 RIKEN Nishina Center
*2 Department of Physics, Korea University