Studies on transverse spin properties of nucleons at PHENIX

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For understanding the polarized structure of the nucleon, we have performed measurements with polarized proton collisions at RHIC using the PHENIX detector. A 3-D picture including the transverse structure of the nucleon provides a conclusive understanding of the nucleon structure beyond the simple parton picture. It shows many-body correlation of partons and presents the orbital motion inside the nucleon. It is described by extending or generalizing the picture of the 1-D parton distribution, and measured with transversely polarized proton collisions. Experimentally, it is measured as single transverse-spin asymmetry $A_N = (d\sigma\uparrow - d\sigma\downarrow)/(d\sigma\uparrow + d\sigma\downarrow)$, where $d\sigma\uparrow$ ($d\sigma\downarrow$) is the production cross section when the protons are polarized up (down).

A_N has shown unexpected large asymmetry in the forward-rapidity region and required development of many models based on perturbative QCD. There are two theory frameworks. One is the so-called Sivers effect in the initial state. It is described by Sivers distribution function, which represents transverse-momentum dependence of partons inside the transversely-polarized nucleon, or higher-twist distribution function, which shows quark-gluon and multi-gluon correlations. The other is the so-called Collins effect with transversity distribution in the initial state combined with final-state effect. The transversity distribution represents a correlation between the transversely polarized nucleon and the transversely polarized partons inside. The final-state effect is described by Collins fragmentation function or higher-twist fragmentation function.

In 2006, an electromagnetic calorimeter system called Muon Piston Calorimeter (MPC) was installed in a small cylindrical hole in the muon magnet piston. It consists of lead tungstate crystals and covers the forward and backward rapidity region, $3.1 < |\eta| < 3.9$. Measurements of A_N in forward electromagnetic clusters [1)] and π^0 and η mesons[2)] with the MPC showed large forward asymmetry increasing with Feynman x (x_F) as shown in the previous measurements. In front of the MPC, preshower detectors[3)] were installed in 2014. We will measure prompt photon asymmetry, which is sensitive to the Sivers effect, and π^0 correlations with jet-like clusters, which are sensitive to the Collins effect.

We also measured asymmetry of open heavy-flavor production, or charmed meson production. Since heavy-flavor production is dominated by the gluon-fusion process and has no final-state effect, it is sensitive to the gluon inside the nucleon. We have already had a good knowledge on the quark sector where twist-3 quark-gluon correlation functions contribute to the A_N, however the gluon sector where twist-3 tri-gluon correlation functions contribute is largely unknown . Figure 1 shows our preliminary results for A_N measurement of the single-muon from charmed-meson decay in 2012. Much improved results are expected to be obtained in 2015 through the use of the forward silicon vertex detector (FVTX) installed in 2012. The FVTX can identify secondary decay vertex of the charmed meson by measuring the distance of the closest approach of the muon track from the initial collision vertex. A_N of μ^+ and μ^- will be measured at an error level of 1%. In theoretical calculations, they are expected to be different so that charm and anti-charm contributions can be distinguished. Asymmetry of heavy-flavor production has also been measured in J/ψ channel[4)].

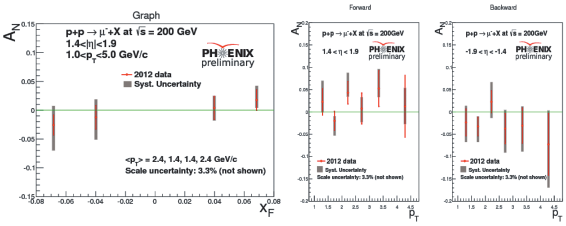

Fig. 1. A_N of the single-muon from charmed-meson decay; (left) x_F dependence, (center) p_T dependence of the forward muon, $x_F > 0$, (right) p_T dependence of the backward muon, $x_F < 0$.

After the 2016 RHIC run, the PHENIX detector will be upgraded by replacing the present central magnet with a solenoid, which will make the forward direction available. We have proposed a forward spectrometer to cover rapidity region $1 < \eta < 4$, with a capability of measuring hadrons, photons, electrons, muons and jets[5)]. The forward upgrades will extend our ability to investigate the Sivers and Collins effects by performing full jet reconstruction; the Sivers effect through the observation of the A_N of the final-state jet itself, and the Collins effect through an azimuthal anisotropy in the distribution of hadrons in the jet.

References

1) A. Adare *et al.* [PHENIX Collaboration], Phys. Rev. D **90**, no. 1, 012006 (2014).
2) A. Adare *et al.* [PHENIX Collaboration], Phys. Rev. D **90**, no. 7, 072008 (2014).
3) S. Campbell *et al.* [PHENIX Collaboration], arXiv:1301.1096 [nucl-ex].
4) X. Wang for the PHENIX Collaboration: in this report.
5) Y. Goto for the PHENIX Collaboration: RIKEN Accel. Prog. Rep., Vol.47 (2014), p.93.

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