Transverse single-spin asymmetry for very forward neutral pion production in polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV†

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In high-energy polarized $p+p$ collision, the left-right cross section asymmetry, which is called as transverse single-spin asymmetry (A_N) of very forward ($\eta > 6$) particle production, plays an important role in understanding the spin-involved production mechanism from the view points of perturbative and nonperturbative interactions. The RHICf experiment[1)] measured the A_N of very forward neutral pion in polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV in June, 2017 at the Relativistic Heavy Ion Collider (RHIC).

The nonzero asymmetries of the neutral pion have been measured by many experiments[2,3)] in the forward ($2 < \eta < 4$) kinematic range, and they have been explained only by quarks and gluons' degrees of freedom. However, a possible contribution from the nonperturbative interaction has been recently highlighted because larger asymmetries were observed in more isolated neutral pion events[4,5)] that could be connected to nonperturbative event topology. A straightforward approach to studying the role of nonperturbative interaction is measuring the A_N of the neutral pion in the very forward kinematic area where the nonperturbative interaction is expected to dominate.

We installed an electromagnetic calorimeter (RHICf detector) at the zero-degree area 18 m away from the beam collision point at the STAR experiment. The RHICf detector consists of two sampling calorimeters with lateral dimensions of 20 mm × 20 mm and 40 mm × 40 mm, respectively. Both calorimeters are composed of 17 tungsten absorbers, 16 GSO plates for energy measurement, and 4 layers of GSO bars for position measurement. Since the radiation length of the detector is 44 X_0, the electromagnetic shower stops its development in the middle of the detector. The RHICf detector has an energy resolution of 2.5–3.5% for 100–250 GeV π^0s and the p_T resolution of 3.0–4.5% in $0.0 < p_T < 0.8$ GeV/c.

To the best of our knowledge, we observed large asymmetry in a very forward neutral pion production for the first time, which means a possible contribution from the nonperturbative interaction. Comparison between RHICf and previous forward neutral pion measurements are depicted in Fig. 1. At very low $p_T < 0.07$ GeV/c, the asymmetries are consistent with zero. However, as p_T increases, the asymmetries increase as a function of x_F, approximately showing the same magnitudes and tendency of the forward ones.

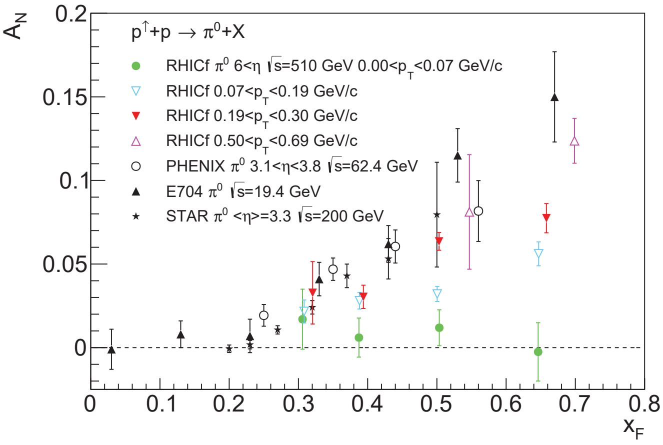

Fig. 1. Forward (black) and very forward (color) neutral pion asymmetries as a function of x_F in different p_T regions.

It may be necessary to consider nonperturbative interaction to understand both forward and very forward neutral pion asymmetries.

However, RHICf data can be affected by perturbative interaction in the low p_T region. The perturbative and nonperturbative interactions may make their own nonzero asymmetries respectively. Since the result of this report is the one analyzed inclusively, more detailed analysis is necessary to reduce the diverse possibilities.

We have started combined analysis with STAR. Signals in the STAR detectors will identify whether the neutral pions of the nonzero asymmetries come from perturbative or nonperturbative interaction. Further, we are preparing a series of follow-up experiments for developing a larger detector. In the near future, further analysis and experiments will provide a powerful input to understand the origin of both forward and very forward neutral pion asymmetries.

References

1) RHICf Collaboration, LOI, arXiv: 1409. 4860v1.
2) A. Adare *et al.* (PHENIX Collaboration), Phys. Rev. D **90**, 012006 (2014).
3) B. I. Abelev *et al.* (STAR Collaboration), Phys. Rev. Lett. **101**, 222001 (2008).
4) S. Heppelmann (STAR Collaboration), Proc. Sci. **191** (DIS2013), 240 (2013).
5) M. M. Mondal (STAR Collaboration), Proc. Sci. **203** (DIS2014), 216 (2014).

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