Transverse single spin asymmetry for forward neutron production in polarized $p + p$ collisions at $\sqrt{s} = 510$ GeV

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Transverse single spin asymmetry (A_{N}) is defined by a left-right cross-section asymmetry with respect to the beam polarization. In high-energy polarized $p+p$ collisions, A_{N} of the forward (pseudorapidity $\eta > 6$) particle is a unique observable for studying the spin-involved diffractive particle production mechanism.

A_{N} for forward neutron production has been explained by the interference between the spin flip (π exchange) and nonflip (a_1 exchange) amplitudes with a nonzero phase shift. This π and a_1 exchange model predicted that the neutron A_{N} would increase in magnitude with the transverse momentum (p_{T}) and explained the PHENIX data, which had been measured with three different collision energies, 62.4, 200, and 500 GeV.[1)] Recent PHENIX results,[2)] which unfolded A_{N} on p_{T} at $\sqrt{s} = 200$ GeV, were also in good agreement with the prediction of the π and a_1 exchange model. However, the π and a_1 exchange model predicted the neutron A_{N} only in the range of $p_{\mathrm{T}} < 0.4$ GeV/c.

In June 2017, the RHICf experiment[3)] measured A_{N} for forward neutron production in polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV by installing an electromagnetic calorimeter,[4)] the RHICf detector, at the zero-degree area of the STAR experiment at the Relativistic Heavy Ion Collider. We measured the neutron A_{N} over a wider range of $0 < p_{\mathrm{T}} < 1$ GeV/c to compare the results with those of PHENIX and to test the π and a_1 exchange model in the higher p_T region. In this article, we report the preliminary results of the neutron A_{N} measured by the RHICf experiment.

Neutrons were separated from the photon background using the difference between their shower developments in the detector. Once the neutron candidates were selected, Bayesian unfolding,[5)] which is available in the RooUnfold library,[6)] was applied to estimate the true longitudinal momentum fraction (x_{F}) and p_{T} distributions. A_{N} could be calculated because unfolding was applied for events from both spin-up and spin-down polarizations. Because finite photon and charged hadron backgrounds were included in the neutron candidates, the A_{N} backgrounds were subtracted by estimating their fractions. Refer to Ref. 7) for a more detailed analysis procedure.

Figure 1 shows the preliminary results for the forward neutron A_{N} as a function of p_{T}. The systematic uncertainties due to unfolding, the beam center calculation, polarization estimation, and background subtraction are included. In the range $p_{\mathrm{T}} < 0.2$ GeV/c, the values of the forward A_{N} measured by RHICf are consistent with those of PHENIX, even though the collision energies are different. In the range $x_{\mathrm{F}} > 0.46$, A_{N} increases in magnitude with p_{T}, even in the p_{T} range beyond where A_{N} was calculated theoretically. Comparing the data points in $x_{\mathrm{F}} < 0.46$ and $x_{\mathrm{F}} > 0.46$, there is a gap, which indicates that the neutron A_{N} is possibly dependent on x_{F}, which has not been predicted.

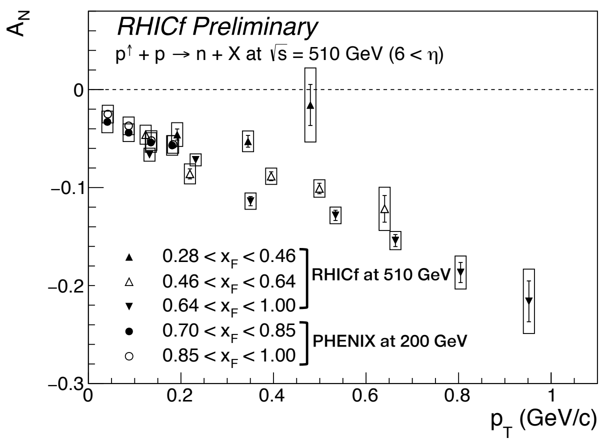

Fig. 1. Forward neutron A_{N} as a function of p_{T} for different x_{F} regions. The triangular and circular data points are the RHICf and PHENIX results, respectively. The error bars indicated by lines and boxes correspond to the statistical and systematic uncertainties, respectively.

In the preliminary results, large systematic uncertainties are assigned to background subtraction because an analysis of the front counter, which had been installed in front of the RHICf detector to suppress the charged hadron background, was not complete. However, the final results will be released soon because the background study has been recently completed.

References
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