Analysis of transverse single spin asymmetry for the forward neutron at the RHICf experiment

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In high energy p+p collision, a spin-involved production mechanism of the forward (pseudo-rapidity $\eta > 6$) neutron can be studied by the transverse single spin asymmetry (A_N), which is defined by the left-right cross section asymmetry with respect to the beam polarization. The forward neutron A_N was measured by the PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) at three different collision energies, 62.4, 200, and 500 GeV. Recently, the A_N at 200 GeV was unfolded as functions of longitudinal momentum fraction (x_F) and transverse momentum (p_T).[1)]

The non-zero neutron A_N is explained by an interference between the spin-flip and non-flip amplitudes with non-zero phase shift. The model using the π and a_1 meson exchanges between two protons for the spin-flip and non-flip showed a good agreement with the p_T dependence of the data.[2)]

In June 2017, the RHICf experiment[3)] measured the A_N of the forward neutral particles in polarized $p + p$ collisions at $\sqrt{s} = 510$ GeV. We installed an electromagnetic sampling calorimeter[4)] (RHICf detector) at the zero-degree area which was 18 m away from the interaction point of the STAR experiment at RHIC. We measured the neutrons of $0 < p_T < 1$ GeV/c which was a wider p_T coverage than those of previous measurements at PHENIX. The RHICf data can be compared with them and the validity of the π and a_1 exchange model in the higher p_T range can be also tested. In this article, we report the analysis status of the neutron A_N measurement.

First, the neutron candidate is separated from the electromagnetic event using the difference between their shower developments in the detector. A variable called $L_{\rm 2D}$ which is defined by the correlation between the longitudinal depth of the detector where the accumulated energy deposit reaches 20% and 90% of the total was used for this separation.

RHICf detector has limited interaction length (1.6 λ_I) for the neutron energy measurement. The x_F and p_T distribution is obtained by the Bayesian unfolding[5)] method. Neutron Monte Carlo sample generated by randomizing the energy and direction was used for the input distribution. Figure 1 shows the p_T projections of the input and unfolded distributions of neutrons. The input distribution was made based on the QGSJET-II 04 model.[6)] One can see the unfolded distribution reproduces the input well. If the $\langle p_T \rangle$s of each bin are estimated based on the unfolded distribution, their differences to the original mean values are smaller than 0.02 GeV/c.

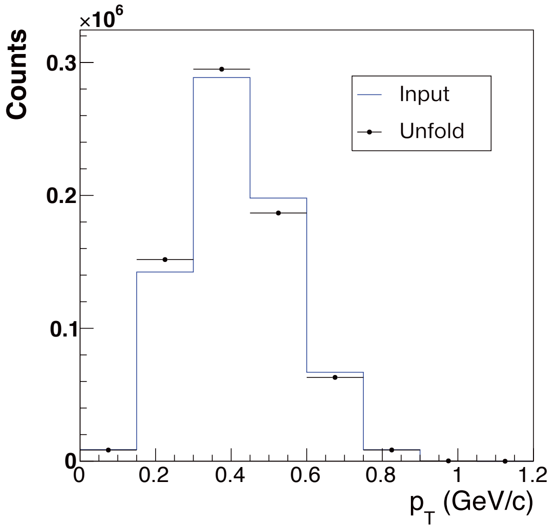

Fig. 1. Input and unfolded p_T distribution of neutron.

After the unfolding, it is necessary to subtract the background A_N because the electromagnetic contamination and the hadronic backgrounds like proton and charged pion are still included in the unfolded distribution. Each background fraction was estimated based on the Monte Carlo samples generated by QGSJET-II 04. The electromagnetic background A_N was calculated by fitting the $L_{\rm 2D}$ distributions of the neutron candidates in the up and down polarizations using the shape of the hadronic and electromagnetic samples studied from the QGSJET-II 04 model. Since the backgrounds hadrons cannot be separated from the true neutron, their A_N was assumed as a value which was bigger than the one of the neutron candidates where they belonged to but smaller than 1 which was the maximum A_N a particle can have.

Currently, we are estimating the systematic uncertainties through the analysis procedures described above. It is expected that the analysis will be complete and the result for the neutron A_N covering the highest p_T range ever will be obtained soon.

References
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