Measuring single-spin asymmetry for forward neutron production in wide p_T range of polarized $p + p$ collisions at $\sqrt{s} = 510$ GeV[†]

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With the first polarized $p + p$ collisions achieved in the relativistic heavy-ion collider (RHIC) at a center-of-mass energy ($\sqrt{s}$) of 200 GeV, non-zero transverse single-spin asymmetry (A_N) for forward neutron production was discovered by an experiment called IP12.[1)] In polarized $p + p$ collisions, A_N is defined by a left-right cross-section asymmetry with respect to the beam polarization. A_N of a forward particle produced at pseudorapidity larger than six is particularly important to study a spin-involved diffractive particle production mechanism.

After the discovery of nonzero neutrons A_N, the PHENIX Collaboration measured them at $\sqrt{s} = 62$ GeV, 200 GeV, and 500 GeV[2)] using a hadronic calorimeter with a high energy resolution. The results were theoretically described well by the interference between the spin flip π and spin nonflip a_1 exchange between two protons.[3)] Recently, one of the PHENIX results at $\sqrt{s} = 200$ GeV was extracted as a function of the longitudinal momentum fraction (x_F) and transverse momentum (p_T) more precisely than earlier by unfolding the kinematic spectra, and the updated results were also consistent with the theoretical calculation. However, the nonzero neutrons A_N were only studied in a narrow kinematic range of $p_T < 0.4$ GeV/c.

The RHICf Collaboration extended the previous measurements up to 1.0 GeV/c to study the kinematic dependence of nonzero neutrons A_N in more detail. In June 2017, we installed an electromagnetic calorimeter (RHICf detector) in the zero-degree area of the STAR detector at the RHIC and measured nonzero neutrons A_N in the kinematic range of $0.2 < x_F < 1.0$ and $0.0 < p_T < 1.0$ GeV/c. The RHICf detector has one order of better position and p_T resolutions than the one used in the previous measurements, thereby enabling more precise measurements of A_N.

Neutron events were separated from the photon background using a variable called L_{2D} that describes how early a particle shower is generated in the detector. We installed a thin scintillator counter in front of the RHICf detector to suppress charged hadrons. The remaining photon and charged hadron backgrounds were removed by performing template fits of the L_{2D} and scintillator counter analog to digital converter distributions by scaling those of the neutron, photon, and charged hadron events in a Monte Carlo sample that described $p + p$ collisions. After the background subtraction, the kinematic values of neutrons, x_F, p_T, and azimuthal angle with respect to the beam axis, were unfolded using Bayesian unfolding[5)] to precisely estimate the A_N values.

Figure 1 shows the neutron A_Ns measured by the RHICf experiment as a function of p_T in three different x_F ranges. The error bars and boxes correspond to the statistical and systematic uncertainties, respectively. The systematic uncertainties mainly originate from the beam center calculation and unfolding processes. In the low-x_F range, A_N reaches a plateau at low p_T. In the high-x_F range, A_N does not reach a plateau, but the absolute value of A_N explicitly increases in magnitude with p_T. A clear x_F dependence is observed for the first time in the RHICf experiment.

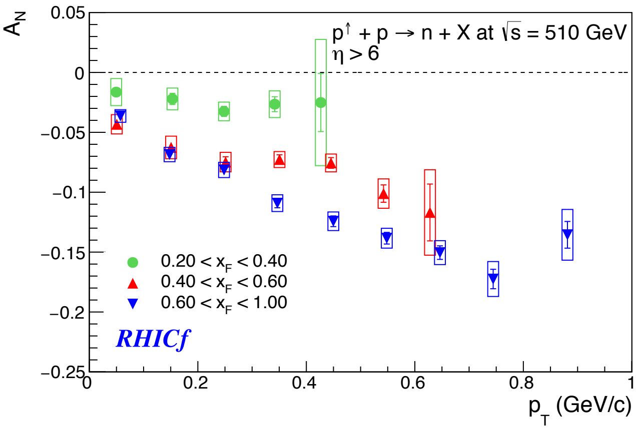

Fig. 1. Forward neutron A_Ns measured by RHICf experiment as function of p_T in different x_F regions.

The π and a_1 exchange model partially reproduces the RHICf data because of the x_F dependence. Because spin effects by the absorptive correction and interference between the ρ and a_2 exchange can also generate finite A_N, more comprehensive theoretical considerations are necessary to describe the present results.

References
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