Investigation of finite transverse single-spin asymmetry for very forward neutral pion and neutron production in diffractive and non diffractive processes

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Transverse single-spin asymmetries (A_{N}) offer valuable insights into the particle production mechanism of perturbative and non-perturbative quantum chromodynamics (QCD) as well as the dynamics of quarks and gluons within a nucleon. Thus far, several experiments have reported non-zero A_{N} for neutral pions (π^0s) in the forward rapidity region.[1)] The most plausible mechanisms underlying the observed non-zero A_{N} are the Sivers and Collins effects. The Sivers effect arises from the correlation between the transverse spin of the initial parton or proton and the intrinsic transverse momentum of partons, which contributes to the hadron's A_{N}. In contrast, the Collins effect describes how the quark's spin influences the transverse spin asymmetry during the fragmentation process.

The RHICf experiment was designed to investigate high-energy cosmic ray physics and spin physics by measuring neutral particles in the very forward region, characterized by a pseudo-rapidity (η) > 6.[2)] The RHICf detector was installed in front of the STAR zero-degree calorimeter, located 18 m from the interaction point at the STAR experiment. Data were collected during transversely polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV in 2017, in conjunction with the STAR detectors at the relativistic heavy-ion collider.[3)]

The RHICf collaboration reported the non-zero A_{N} for π^0s[4)] and neutrons[5)] within $p_{\mathrm{T}} < 1$ GeV/c and $\eta > 6$. These neutral particles measured by the RHICf detector are expected to be predominantly produced through diffractive processes. Although diffractive processes can be the primary source, the contribution of non-diffractive processes to the production of these particles cannot be entirely excluded. We aim to conduct a RHICf + STAR correlation study for investigating the origin of the A_{N} observed for RHICf π^0s and neutrons.

Diffractive processes are characterized by color-singlet (pomeron) exchanges between initial-state protons, which leads to a large rapidity gap ($\Delta\eta$) in the final state or the production of a forward-scattered final-state proton. The color-singlet exchange inherent to diffractive processes is expected to contribute to the large A_{N}. We have classified the single diffractive-like event, double diffractive-like event, and non-diffractive-like event for RHICf π^0 and neutron events using the STAR detectors as the time of flight covered $|\eta| < 1$, and the beam-beam counter covered $2 < |\eta| < 5$.[6)]

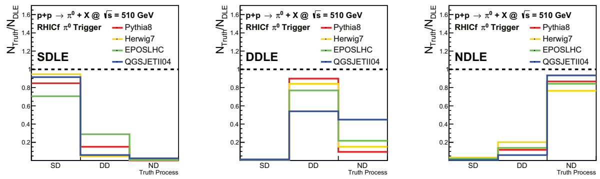

Fig. 1. Contamination ratios of other diffractive-like event processes for single diffractive-like event (left), double diffractive-like event (middle), and non-diffractive-like event (right).

The contamination ratio (R_c) was calculated using the RHICf + STAR simulation with several $p+p$ collision models for soft QCD, including PYTHIA8, HERWIG7, EPOS-LHC, and QGSJETII-04, to evaluate contaminations from the other unintended processes. Figure 1 shows the R_c for these event generator models, with the truth process ratio under each diffractive-like event condition reaching ∼80%. These results show discrepancies between models, which can be attributed to methodological differences in event generations and yet-to-be-defined diffractive processes. Full RHICf + STAR simulations incorporating all models are currently in progress.

The A_{N} for RHICf π^0s and neutrons significantly depends on our DLE condition. To consider the effects of contamination from other processes, we applied a correction to A_{N} as $R^c_{i,j} \cdot A^{corr}_{N,j} = A^{measured}_{N,i}$, where $R^c_{i,j}$ represents the contamination ratio matrix, $A^{measured}_{N,i}$ represents the measured A_N within DLE conditions, $A^{corr}_{N,j}$ represents the corrected A_N, and index i, j represents the DLE condition and truth processes, respectively.

We plan to evaluate the model dependence of the corrected A_{N} and calculate the associated systematic uncertainty. We anticipate that this study will contribute to a deeper understanding of the origin of A_{N}.

References
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DOI:10.34448/RIKEN.APR.58-112