RHICf-STAR correlation study to understand the finite transverse single spin asymmetry for very forward neutral pion production

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Transverse Single-Spin Asymmetries (TSSA) offer valuable insights into the particle production mechanism regarding perturbative and non-perturbative QCD. The RHICf experiment was designed to study cosmic-ray and spin physics by measuring particles in the very forward region, pseudo-rapidity (η) > 6 with the RHICf detector.[1] The RHICf detector was installed in front of the STAR Zero-Degree Calorimeter (ZDC), 18 m from the interaction point at the STAR experiment, and collected data in $p + p$ collisions at $\sqrt{s}$ = 510 GeV in along with the STAR detector at Relativistic Heavy Ion Collider (RHIC)[2] in the year 2017. Recent results of TSSA (A_{N}) of neutral pion (π^0) measured by RHICf Collaboration observed a non-zero A_{N} within $p_{\mathrm{T}} < 1$ GeV/c and $\eta > 6$.[3] This measurement range is where the diffractive production process is expected to dominate the particle production mechanism. On the other hand, TSSA for π^0 measured with STAR Forward Meson Spectrometer (FMS) covered different kinematic ranges, $2 < p_{\mathrm{T}} < 4$ GeV/c and $2.6 < \eta < 4.1$ in $\sqrt{s}$ = 200, 500 GeV $p + p$ collisions. Interestingly, the result showed sizeable A_{N} of π^0 similar to the RHICf results, indicating that the diffractive process may also play a significant role in the kinematic range of STAR data in addition to the Collins and Sivers effects. This open question raises the possibility that multiple processes may be involved in the A_{N} of π^0. In this context, we aim to further understand the underlying physics of A_{N} of π^0 with correlations between RHICf and STAR detector data.

In early 2023, the RHICf standalone analysis library made by the RHICf and LHCf collaborations was integrated into the STAR analysis library for the correlation studies. The offline data production, encompassing data from RHICf and STAR detectors simultaneously, was completed using the RHICf-STAR library in 2023. This dataset includes data from the STAR Time Projection Chamber (TPC), Time-Of-Flight (TOF), Electro-Magnetic Calorimeter (EMC), Beam-Beam Counter (BBC), Vertex Position Detector (VPD), Roman Pots (RPS), and FMS, and enables us to conduct a correlation study for A_{N} of π^0 in order to distinguish diffractive or non-diffractive processes. To validate the RHICf-STAR library, we cross-checked and compared the results with the RHICf standalone ones, including two photon invariant mass and energy on an event-by-event basis. Figure. 1 shows the π^0 invariant mass distribution reconstructed with $\pi^0 \to \gamma\gamma$ channel measured by the RHICf detector. The RHICf detector consists of two position-sensitive calorimeters, namely TL (large tower, 40 mm in size) and TS (small tower, 20 mm in size). When two photons from π^0 decay are detected in a different tower or the same tower, we refer to them as type-1 π^0 and type-2 π^0, respectively.

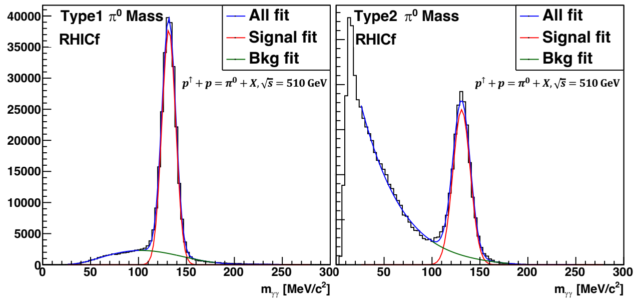

Fig. 1. The invariant mass of two photons from π^0 decays for RHICf Type-1 π^0 (left) and Type-2 π^0 (right) with background and signal fitting.

In $p+p$ collisions, there are three types of diffractive processes: Single Diffractive (SD), Double Diffractive (DD), and Central Diffractive (CD). These diffractive processes are characterized by two main features: the scattered proton and the large rapidity gaps ($\Delta\eta$) between produced particles. In this study, our focus will be on measuring the rapidity gap $\Delta\eta$ using both RHICf and STAR detectors.

We can establish conditions regarding each diffractive process: Single-Diffractive-Like-Event (SDLE), Double-Diffractive-Like-Event (DDLE), Central-Diffractive-Like-Event (CDLE), and Non-Diffractive-Like-Event (NDLE). These conditions are designed based on whether or not there are signals in the STAR detectors, and the acceptance of detectors to find the evidence of distinguished processes through the large rapidity gaps. Recently, we observed that the A_{N} of π^0 potentially depends on these conditions. Specifically, A_{N} appears to be more sensitive to DDLE than to other conditions. we will conduct further studies to more accurately determine these conditions using detector correlations. This will enhance our understanding of the TSSA related to the diffractive processes.

References

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