Preliminary result of the transverse single spin asymmetry in very forward $\pi^0$ production in 510 GeV $p^\uparrow + p$ collisions

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The RHICf experiment$^1$ measured the transverse single spin asymmetry, $A_N$, which is defined as the left-right cross section asymmetry of beam polarization, of very forward $\pi^0$ in June, 2017. The spin-related interactions between protons and the production mechanism of a particle can be deeply understood by $A_N$ measurement. To date, the non-zero $A_N$ of forward $\pi^0$ has been measured by many experiments, and the parton-level interaction between protons has generally been considered to be the origin of the $\pi^0$ production. However, recently, larger $A_N$ was observed for more diffractive-like events than the events driven by hard scattering$^2$ therefore, the measurement of $A_N$ in very forward $\pi^0$ production by the RHICf experiment will provide a new input to unveil the origin of the non-zero $A_N$ of $\pi^0$, especially from the viewpoint of diffractive and non-diffractive interactions.

To measure the very forward $\pi^0$, we moved an electromagnetic calorimeter (RHICf detector), which was originally developed for the LHCf experiment$^3$ from CERN to BNL, and installed it at the zero-degree area of the STAR experiment, which was 18 m away from the beam collision point. The RHICf detector consists of two sampling calorimeters; smaller one has a lateral dimension of 20 mm $\times$ 20 mm and the larger one has a lateral dimension of 40 mm $\times$ 40 mm. Each tower is composed of 16 GSO plates for energy measurement and 4 layers of GSO bars for position measurement. $\pi^0$ can be identified and reconstructed by measuring two decayed photons with two towers or even one tower because the position resolution for photons is of the level of a few hundred $\mu$m. We measured very forward $\pi^0$ with a wide transverse momentum ($p_T$) coverage of $0 < p_T < 1$ GeV/c and a longitudinal momentum fraction ($x_F$) range of $0.2 < x_F < 1$. For the correlation study with other STAR detectors, we took the data using the STAR data acquisition system.

Experimentally, $A_N$ is calculated by following equation:

$$ A_N = \frac{1}{P} \frac{1}{D_\phi} \left( \frac{N^{+} - RN^{-}}{N^{+} + RN^{-}} \right), $$

where $N^{\uparrow(\downarrow)}$ is the number of detected $\pi^0$ in $p^{\uparrow(\downarrow)} + p$ collision and $R$ is the luminosity ratio between two collision types of spin up ($\uparrow$) and down ($\downarrow$). $P$ represents the average polarization of the proton beam and $D_\phi$ is a correction factor for $\pi^0$ azimuthal angle distribution because $A_N$ usually depends on the particle’s azimuthal angle by $A_N \propto \sin(\phi - \phi_0)$ where $\phi_0$ is an offset angle. Typical values of $P$ and $D_\phi$ is around 0.6 and 0.96 respectively.

Figure 1 presents our first result for the $A_N$ of very forward inclusive $\pi^0$ production. Surprisingly, non-zero $A_N$ of $\pi^0$ was observed even in very forward $\pi^0$ production. $A_N$ increases as a function of both $x_F$ and $p_T$. Because the non-zero $A_N$ in Fig. 1 was driven by the $\pi^0$ produced in the very forward region where the diffractive process is dominant, the diffraction can be considered to be a possible contributor of this finite $A_N$ as expected by a recent study.$^3$ In order to further study the role of diffraction in the forward $\pi^0$ production, we are now analyzing the correlation between RHICf and STAR detectors. STAR forward detectors and Roman pot$^4$ can identify diffractive events by observing the rapidity gap or a recoil proton. Therefore, we will be able to understand the relation between diffraction and $A_N$ of (very) forward $\pi^0$ with a combined RHICf-STaR analysis.

References

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