

Commissioning of the Local Polarimeter with forward neutron production in transversely polarized $p^\uparrow + p$ collisions at sPHENIX

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sPHENIX¹⁾ is a state-of-the-art detector system at the Relativistic Heavy Ion Collider (RHIC) that allows us exploring the spin structure of protons in polarized proton collisions. During the 2024 run, sPHENIX recorded the first polarized $p^\uparrow + p$ collision and a summary of these runs is presented here.²⁾

At RHIC, the Yellow and Blue beams collide at interaction points such as sPHENIX. Each beam contains 111 proton bunches, with polarization states alternating in a specific pattern: $p^\uparrow + p^\uparrow$, $p^\uparrow + p^\downarrow$, $p^\downarrow + p^\uparrow$, and $p^\downarrow + p^\downarrow$. This approach effectively averages out the polarization effects of one beam, isolating the contribution from the other beam's polarization direction.

The Shower Maximum Detector (SMD) and ZeroDegree Calorimeter (ZDC) from the PHENIX experiment were repurposed for sPHENIX. Together, the SMD and ZDC are utilized to enhance the purity of neutron samples, with the SMD determining the neutron position and ZDC applying an energy threshold for neutron selection. sPHENIX also leverages methodologies established in the PHENIX experiment³⁾ for the Local Polarimeter.

Two complementary approaches were implemented in the Local Polarimeter: the bunch-by-bunch asymmetry and the raw square root asymmetry. The first method calculates left-right (L-R) and up-down (U-D) asymmetries on a bunch-by-bunch basis to monitor polarization.

Figure 1 shows that the observed bunch-by-bunch L-R asymmetry varies significantly depending on the polarization direction of each bunch. Since the polarization direction is aligned transversely, the expected result is that the difference in U-D asymmetry between the two spin alignment directions is close to zero.

The second method calculates the raw square root asymmetry as a function of the azimuthal angle ϕ , defined as the angle between the particle's direction of motion and the x-axis in the transverse plane, as follows:

$$\epsilon(\phi) = \frac{\sqrt{N_L^\uparrow N_R^\downarrow} - \sqrt{N_L^\downarrow N_R^\uparrow}}{\sqrt{N_L^\uparrow N_R^\downarrow} + \sqrt{N_L^\downarrow N_R^\uparrow}}. \quad (1)$$

This approach accounts for systematic effects, enabling precise polarization measurements.

Figure 2 illustrates azimuthal sine modulations of $\epsilon(\phi)$, revealing forward and backward asymmetries measured by the North ZDC and SMD. Forward asymmetry corresponds to neutrons detected along the

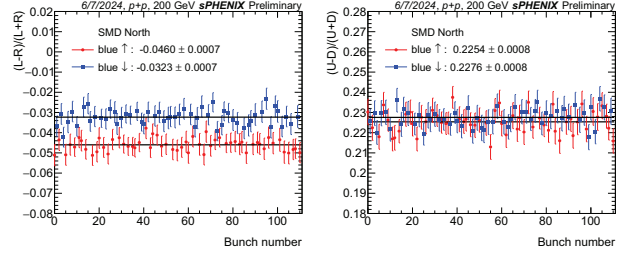


Fig. 1. Bunch-by-bunch L-R (left) and U-D (right) asymmetries for the Blue beam. Here, L and R represent the number of neutron hits in the two leftmost and two rightmost SMD panels, respectively, while U and D correspond to the neutron hits in the two topmost and two bottommost SMD panels.

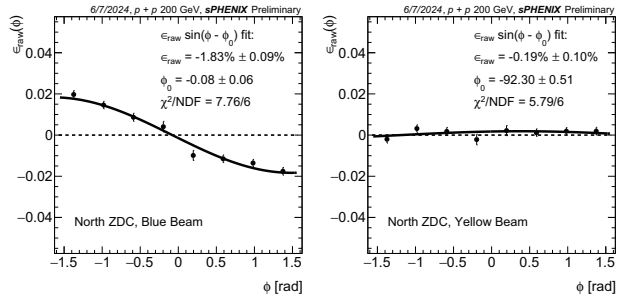


Fig. 2. Azimuthal sine modulation of the raw square root asymmetry for North ZDC and SMD. (Left) Forward asymmetry measured with the North ZDC and SMD for the Blue beam spin direction, and (Right) Backward asymmetry measured with the North ZDC and SMD for the Yellow beam spin direction.

beam propagation direction, while backward asymmetry refers to neutrons detected in the opposite direction. For the North ZDC, the Blue beam (south to north) produces forward neutrons, showing a sine modulation of approximately -1.8% . In contrast, the Yellow beam (north to south) produces backward neutrons, showing no asymmetry consistent with previous PHENIX results.³⁾

References

- 1) sPHENIX collaboration, sPHENIX Beam Use Proposal (2020).
- 2) I. Nakagawa *et al.*, in this report.
- 3) A. Adare *et al.* (PHENIX collaboration), Phys. Rev. D **88**, 032006 (2013).

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