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Status of double helicity asymmetries (A_{LL}) in $\pi^{\pm}$ production at mid-rapidity in longitudinally polarized p + p collisions with PHENIX experiment

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The spin of the proton, $\frac{1}{2}\hbar$, is explained by the angular momentum sum rule in terms of quark and gluon components. The result of EMC experiment and others suggested that the spin of the quarks and anti-quarks only contributes about 30% of the proton spin.[1)] This intrigued us to explore how much of the rest of the proton spin originates from the gluons and the orbital angular momenta of quarks and gluons.

The Relativistic Heavy Ion Collider (RHIC) provides polarized proton beams to determine the gluon helicity contribution to the proton spin as one of the main goals of the RHIC spin program.

In perturbative quantum chromodynomics (pQCD), pion and high p_T jet productions are sensitive to the gluon helicity distribution (Δg) in the proton where their production is dominated by gluon-related interactions, for example, q-g and g-g scatterings.

The RHIC double helicity asymmetries (A_{LL}) result in inclusive π^0 production at $\sqrt{s}$ = 510 GeV with the RHIC 2012 and 2013 data sets extending the x range down to x $\sim$ 0.01 and confirming non-zero ΔG.[2)]

For complementary information, the ordering of the asymmetries among three π meson species, π^0 and $\pi^{\pm}$, can directly reveal the sign of the gluon spin contribution to the proton spin.

The A_{LL} in $\pi^{\pm}$ production in longitudinally polarized p+p collisions can access the gluon helicity distribution (Δg) and is defined as

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}, \tag{1}$$

where, $\sigma_{++}(\sigma_{+-})$ denotes the $\pi^{\pm}$ cross section from a collision with the same (opposite) helicity.

At $\sqrt{s}$ = 510 GeV in 2013, PHENIX recorded a total integrated luminosity of 108 pb^{-1} within a 30 cm vertex region and average polarization $P_B(P_Y) = 0.55 \pm 0.02$ (0.56 ± 0.02), where $P_B(P_Y)$ is the polarization of RHIC's blue (yellow) beam.

$\pi^{\pm}$ are reconstructed with the PHENIX tracking detectors, the drift chamber (DC) and pad chambers (PC), covering the pseudo-rapidity range $|\eta| < 0.35$ and the azimuthal angle $\Delta\phi = \pi$, and are separated from backgrounds, electrons, kaons, protons and so on by using a ring-imaging Cherenkov detector (RICH) and electromagnetic calorimeter (EMCal)

Experimentally, A_{LL} can be measured as

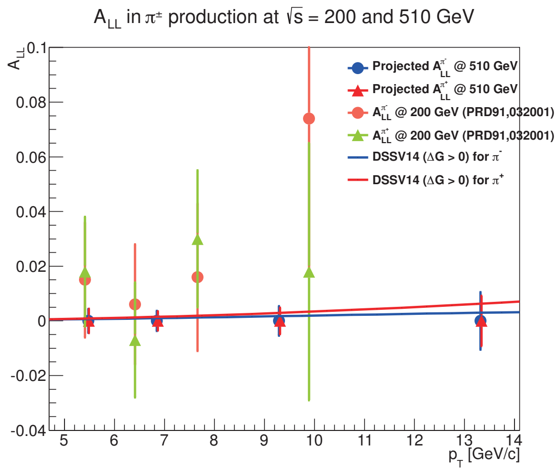

Fig. 1. Projected A_{LL} in $\pi^{\pm}$ production at $\sqrt{s}$ = 510 GeV and published A_{LL} at $\sqrt{s}$ = 200 GeV along with DSSV14 curve.

$$A_{LL} = \frac{1}{P_B P_Y}\frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}, \tag{2}$$

where $N_{++}(N_{+-})$ denotes the yield of $\pi^{\pm}$ candidates from the collisions in the same (opposite) helicity. R is the relative luminosity between colliding bunches with different spin configurations:

$$R = \frac{L_{++}}{L{+-}}. \tag{3}$$

Figure 1 shows the comparison of projected A_{LL} in $\pi^{\pm}$ production at $\sqrt{s}$ = 510 GeV and published A_{LL} at $\sqrt{s}$ = 200 GeV along with the DSSV14 curve with positive gluon polarization. The uncertainty of charged pions at 510 GeV was significantly improved compared to that at 200 GeV. As a complementary probe, charged pions might help in directly inferring the sign of the gluon polarization.

In summary, charged pion analysis as a complementary probe is ongoing with improved statistics and is expected to double-check the sign of the gluon polarization.

References

1) J. Ashman et al. (EMC Collaboration), Nucl. Phys. B**328**, 167 1 (1989).
2) A. Adare et al. (PHENIX Collaboration), Phys. Rev. D**93**, 011501 (2016), 1510.02317.

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