Final results of $A_{LL}^{\pi^0}$ measurement at $\sqrt{s} = 510$ GeV at mid-rapidity through a PHENIX experiment[†]

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One of the important functions of the relativistic heavy ion collider (RHIC) longitudinally polarized proton program is to constrain the gluon-spin component of proton (ΔG) by measuring the double helicity asymmetry (A_{LL}) of π^0 production ($A_{LL}^{\pi^0}$) and jet production (A_{LL}^{Jet}). Based on the results of deep inelastic scattering experiments, the quark-spin component of the proton is only $0.330 \pm 0.011(Theo.) \pm 0.025(Exp.) \pm 0.028(Evol.)$[1]. The remaining spin might be carried by gluons or orbital momentum.

Studies on the measurement of $A_{LL}^{\pi^0}$ and A_{LL}^{Jet} at $\sqrt{s} = 200$ GeV have been successfully published, and they have contributed to constrain ΔG[2,3]. Consequently, a positive $\Delta g(x)$ has been observed in the measured x region[4]. However, the uncertainty of ΔG is still significant owing to the uncertainty at lower the Bjorken x region, which has not been accessed so far[4].

To explore the lower x region, where uncertainty is dominant, longitudinally polarized proton-proton collisions with increased energy, i.e., $\sqrt{s} = 510$ GeV, were successfully carried out in 2012 (Run12) and 2013 (Run13). With the data, $A_{LL}^{\pi^0}$ at $\sqrt{s} = 510$ GeV was measured and published recently. Because of the increased energy, the measurement of $A_{LL}^{\pi^0}$ at $\sqrt{s} = 510$ GeV could reach a lower x range, $0.01 < x$, while the previous measurement of $A_{LL}^{\pi^0}$ and A_{LL}^{Jet} at $\sqrt{s} = 200$ GeV could reach $0.02 < x$ and $0.05 < x$, respectively.

$A_{LL}^{\pi^0}$ can be defined in terms of differences in cross-sections as

$$A_{LL}^{\pi^0} = \frac{d\Delta\sigma^{\pi^0}}{d\sigma^{\pi^0}} = \frac{d\sigma_{++}^{\pi^0} - d\sigma_{+-}^{\pi^0}}{d\sigma_{++}^{\pi^0} + d\sigma_{+-}^{\pi^0}} \quad (1)$$

where $\sigma_{++(+-)}$ denotes the π^0 cross-section for proton collisions with the same(opposite) helicity. The π^0 cross-section can be decomposed into parton distribution functions, partonic reaction cross-sections, and fragmentation functions. Because most of π^0s are from quark-gluon or gluon-gluon scattering at mid-rapidity region, $\Delta g(x)$ is accessible by measuring $A_{LL}^{\pi^0}$. This description is verified by comparing the π^0 cross-section between theoretical and experimental data. Equation 1 can be rewritten in terms of experimental observables as

$$A_{LL} = \frac{1}{P_B P_Y}\frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}, R = \frac{L_{++}}{L_{+-}} \quad (2)$$

where $P_{B(Y)}$ is the polarization of RHIC's "Blue (Yellow)" beam, $N_{++(+-)}$ is the yield of the π^0 candidate from the same (opposite) helicity collisions, and R is the relative luminosity of same and opposite helicity collisions.

π^0s are reconstructed by photon pairs detected by PHENIX mid-rapidity electromagnetic calorimeters. Sophisticated cuts are applied to suppress combinatorial background. The relative luminosity is fully corrected for multiple collisions and detector resolution effects.

Fig. 1 shows the result of $A_{LL}^{\pi^0}$ measurement at $\sqrt{s} = 510$ GeV. The world's first non-zero A_{LL} in hadron production is observed. The results agree with DSSV14 calculation based on a global fit of world A_{LL} data and supports positive ΔG. It thus supports positive ΔG in the previously accessed x region and extends the probed x region down to $x \sim 0.01$. Therefore it provides an additional constraint on ΔG[5,6] This is a crucial step toward world-wide efforts to extract ΔG.

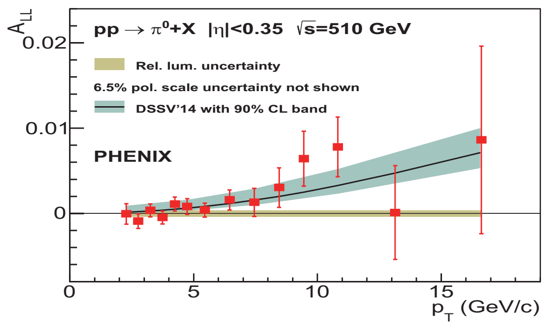

Fig. 1. Result of $A_{LL}^{\pi^0}$ measurement at $\sqrt{s} = 510$ GeV. The red error bars represent combined statistical and point-to-point systematic uncertainties. The yellow box represents systematic uncertainty from the relative luminosity. The theoretical curve with 90% C.L. band is obtained from the DSSV14 calculation[4].

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