Recent results in high-energy longitudinal polarized proton-proton collisions at √s = 200GeV at RHIC

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We report on recent results of the longitudinal double-spin asymmetry $A_{LL}$ from the STAR and PHENIX experiments. Data were collected in longitudinally polarized proton-proton collisions at a center-of-mass energy of 200 GeV. The results added new constraints to the polarized gluon distribution function $\Delta g(x)$ with the probed $x$ range of $0.02 < x < 0.3$. The results lead to the importance of probing small $x$.

1 Introduction

The STAR and PHENIX experiments at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory are carrying out a spin physics program in polarized proton-proton collisions. One of the goals of the RHIC-Spin program is to constrain the polarized gluon distribution function $\Delta g(x)$.

The longitudinal double-spin asymmetry $A_{LL}$ is defined by

$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}}$$

where $\sigma^{++}(\sigma^{+-})$ is the cross section for the same (opposite) colliding proton helicities. This asymmetry is directly sensitive to $\Delta g(x)$ through gluon-gluon and quark-gluon parton level collisions. This asymmetry has been calculated using NLO perturbative QCD for various parametrizations of $\Delta g(x)$. We measure $A_{LL}$ and test each parametrization by comparing the result with theoretical calculations. In addition, our $A_{LL}$ results contribute to global fits of the polarized parton distributions.

We test the validity of NLO perturbative QCD in the energy range of the experiments using the cross sections for every final state for which we measure $A_{LL}$. We have found good agreement between the cross sections and NLO perturbative QCD calculations $[1,2,3]$. 
Since we observed the first polarized proton-proton collision at RHIC in 2002, we have measured $A_{LL}$ for various final states at a wide range of rapidity at $\sqrt{s} = 62$ and 200 GeV. In this paper, we show the results of $A_{LL}$ measurements for inclusive jet production from the STAR experiment and neutral pion production from the PHENIX experiment at mid-rapidity at $\sqrt{s} = 200$ GeV from data collected during the 2005 and 2006 RHIC runs. We show a quantitative comparison of $A_{LL}$ measurements to theoretical calculations.

2 STAR inclusive jets

The longitudinal double-spin asymmetry, $A_{LL}$, for inclusive jet production was measured with the STAR detector. Jets used in this analysis are reconstructed from tracks and neutral energy deposits and defined by the midpoint-cone algorithm with a cone radius of 0.7. Tracks were reconstructed with the time projection chamber (TPC) in a 0.5T solenoidal magnetic field. The neutral energy deposits were measured with the barrel electromagnetic calorimeter (BEMC), which covers a pseudorapidity range of $|\eta| \leq 1.0$ and full azimuth. The events satisfied the jet patch (JP) trigger. This trigger requires a coincidence between the east and west beam-beam counters and energy deposits in a patch of calorimeter towers ($\Delta \eta \times \Delta \phi = 1 \times 1$) greater than 8.3 GeV. An integrated luminosity of 4.7pb$^{-1}$ was used in this analysis. The measured $p_T$ was corrected to the particle level $p_T$ with a Pythia MC sample.

Figure 1 shows the longitudinal double-spin asymmetry, $A_{LL}$, for inclusive jet production together with NLO calculations based on five different polarized parton distributions: GRSV-max, GRSV-std, GRSV-zero, GRSV-min, and GS-C. GRSV-std and GS-C were obtained from polarized DIS data but have very different functional shapes. These polarized parton distributions have very large uncertainties. GRSV-max, GRSV-zero, and GRSV-min are extreme models. The STAR inclusive jet $A_{LL}$ clearly excludes GRSV-max. A quantitative discussion will be given below.

3 PHENIX neutral pions

Figure 2 shows the longitudinal double-spin asymmetry, $A_{LL}$, for neutral pions from the PHENIX experiment. Neutral pions were reconstructed from two photons using the highly segmented ($\Delta \eta \times \Delta \phi = 0.01 \times 0.01$) electromagnetic calorimeter. An integrated luminosity of 3.5pb$^{-1}$ was used in the Run5 analysis and 7.5pb$^{-1}$ for Run6 analysis. The final scale uncertainty for the Run6 analysis is expected to be around 10% due to polarization uncertainties.
The soft physics contribution was estimated to be around 10% at 2GeV/c and negligible for higher $p_T$. The correction was made for the background $A_{LL}$.

4 Quantitative theory comparison

We quantified the impact of the $A_{LL}$ measurements on constraining the gluon distribution $\Delta g(x)$ within the GRSV framework. In Figure 3 we compared the results with a series of $\Delta g(x)$ assumptions which have the same functional shape as GRSV-std but have different values of the first moment ranging from $\Delta G = -0.9$ to $\Delta G = 0.7$ as well as four GRSV predictions: GRSV-max, GRSV-std, GRSV-zero, GRSV-min. The STAR and PHENIX results are consistent and complementary and disfavor extreme gluon polarization scenarios of the range of $x$ probed by this analysis of $0.02 < x < 0.3$.

5 Discussion

The $A_{LL}$ comparison between data and NLO predictions was made within the GRSV framework. GS-C has $\Delta G = 1.0$ and the $A_{LL}$ for GS-C is consistent with both the STAR and PHENIX results. GS-C has highly polarised gluons in the small $x$, less than the range of $x$ probed by these measurements. To further understand the gluon’s contribution to proton spin, it is essential to measure $A_{LL}$ at small $x$. The measurements with the forward detectors are expected to play important roles for understanding the small $x$ contribution. In addition, the 500 GeV RHIC $A_{LL}$ measurements are expected to probe small $x$.

The STAR and PHENIX experiments will continue to collect data from polarized proton-proton collisions with wider energy range and wider rapidity range in order to measure more precisely the polarized gluon distributions, $\Delta g(x)$, of the proton.

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