Constraints on $\Delta G$ through Longitudinal Double Spin Asymmetry Measurements of Inclusive Jet Production in Polarized p+p Collisions at 200 GeV

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Abstract. We report measurements of the longitudinal double spin asymmetry for inclusive jet production using polarized p+p collisions at $\sqrt{s} = 200$ GeV at RHIC. Results from the 2005 and 2006 runs are presented. These results set substantial new constraints on the polarized gluon distribution in the proton over the kinematic range $0.02 < x < 0.3$, when compared to next-to-leading order global analyses of DIS data. The first measurement of the transverse single-spin asymmetry for inclusive jets at mid-rapidity is also presented.

Keywords: gluon polarization, jets, longitudinal double spin asymmetry, STAR

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INTRODUCTION

Polarized p+p collisions at the Relativistic Heavy Ion Collider (RHIC) provide a very suitable environment, rich with strongly interacting probes, to constrain $\Delta G$, the integral of the gluon polarized distribution function, $\Delta g(x, Q^2)$, evaluated at the input scale $Q_0^2 = 0.4$ GeV$^2$, directly and more precisely than previously attained. There are many processes where the gluon participates directly, and the high center of mass energy, $\sqrt{s} = 200$ GeV, and high transverse momentum, $p_T$, make NLO pQCD analysis more reliable. Indeed, several unpolarized p+p cross sections for reactions sensitive to gluons have already been measured at RHIC and are described well by pQCD predictions [1].

The spin program of the Solenoid Tracker at RHIC (STAR) experiment [2] aims, in the short term, to utilize these advantages to constrain $\Delta G$ over the kinematic range $0.02 < x < 0.3$. Coincidence measurements can provide the $x$ dependence of $\Delta G$, but as RHIC was still developing higher luminosity and polarization, the abundant channels for inclusive jet and pion production were exploited. These proceedings report on the inclusive jet production asymmetry, which is an excellent channel to study the gluon polarization due to its large cross section and relative independence from fragmentation functions. The longitudinal double-spin asymmetry, $A_{LL}$, for inclusive jet production is defined as,

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

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where $\sigma^{++} (\sigma^{+-})$ is the inclusive jet cross section when the colliding proton beams have equal (opposite) helicities. The inclusive measurements from RHIC provide significant constraints on $\Delta G$ in the accessible kinematic range.

**EXPERIMENT AND ANALYSIS**

The STAR detector subsystems used in this measurement include the Time Projection Chamber (TPC), the Barrel (BEMC) and EndCap (EEMC) electromagnetic calorimeters and the Beam-Beam Counters (BBC). The TPC with pseudorapidity $|\eta| < 1.3$ and full azimuthal coverage is used to determine the momentum of charged particles. The BEMC and EEMC are lead-scintillator sampling calorimeters and have full azimuthal coverage spanning the pseudorapidities $|\eta| < 1.0$ and $1.08 < \eta < 2.0$, respectively. The calorimeters provide triggering and detection of photons and electrons. In 2005 only the west side of the BEMC, $0.0 < \eta < 1.0$, was active and the EEMC information was not included in the analysis. The BBC is mounted around the beam at longitudinal positions $z = \pm 370$ cm, with full azimuthal coverage and pseudorapidity $3.3 < |\eta| < 5.0$. It was used for triggering, luminosity measurement, and local polarimetry to determine non-longitudinal polarization components.

Jets were reconstructed using the midpoint cone algorithm which clusters TPC charged track momenta and BEMC (and EEMC in 2006) tower energy deposits within a cone radius $R = \sqrt{\Delta \eta^2 + \Delta \phi^2}$. Only reconstructed TPC tracks and BEMC energy deposits above 0.2 GeV were used by the algorithm. The energy seed threshold was 0.5 GeV and jets were merged if more than 50% of their energy was of common origin. A minimum jet $p_T = 5$ GeV/c was also required. The jet axis was required to be within a fiducial range $0.2 < \eta < 0.8$ ($-0.7 < \eta < 0.9$) for 2005 (2006) data combined with a cone radius of $R = 0.4(0.7)$ to reduce the edge effects of the calorimeter acceptance. In addition, the BBC time information was used to select events with a reconstructed vertex on the beam axis within approximately $\pm 60$ cm from the TPC center to ensure a uniform tracking efficiency. Data were collected both with a high tower trigger (HT) that required a minimum energy deposition in a $\Delta \eta \times \Delta \phi = 0.05 \times 0.05$ tower and with a jet patch trigger (JP) that required a minimum energy deposition over a $\Delta \eta \times \Delta \phi = 1 \times 1$ region, in coincidence with the minimum bias trigger condition. JP triggers were dominant in both 2005 and 2006, and in this presentation we show only JP triggers from 2006 data.

**RESULTS AND SUMMARY**

In 2005 we had an order of magnitude increase in the figure of merit over our previous measurements with coverage in jet $p_T$ up to 30 GeV/c. This allowed us to perform a quantitative comparison of our measured results to global fits of polarized deep-inelastic scattering (DIS) data within the GRSV framework for various fixed values of $\Delta G$. These comparisons showed that the global fits that predict very large $\Delta G$ values and large $A_{LL}$ are excluded. However, some fits like GS-C which has a large positive gluon polarization at low $x$, a node near $x \sim 0.1$, and a negative gluon polarization at large $x$ are still consistent with the data.
In 2006, we performed the first measurements of the transverse single-spin asymmetry, $A_N$, for inclusive jet production at mid-rapidity. Figure 1 shows $A_N$ for four different pseudorapidity ranges covering the calorimeter acceptance. $A_N$ is consistent with zero within the statistical uncertainties.

The left panel of Figure 2 shows preliminary 2006 $A_{LL}$ versus jet $p_T$ corrected for detector response. The points with error bars are the data with statistical uncertainties. As for the gray bands, the height indicates the systematic uncertainties on $A_{LL}$ while the width indicates the systematic uncertainties on $p_T$. The left panel of Figure 2 also shows NLO pQCD calculations which incorporate different scenarios for $\Delta g(x)$, including the best global fit to the inclusive DIS data (std) [5]. The other three curves span the full physically allowed region from maximally positive gluon polarization ($\Delta g(x) = g(x)$) at the input scale to maximally negative gluon polarization ($\Delta g(x) = -g(x)$) and passing through zero gluon polarization ($\Delta g(x) = 0$). In addition, it includes a prediction derived from GS-C which has a node near $x \sim 0.1$ as described earlier. The statistical uncertainties in the 2006 $A_{LL}$ measurements at high $p_T$ are a factor of 3 to 4 smaller than they were in the 2005 data [4], which leads to significantly more stringent constraints on gluon polarization models as illustrated in the right panel of Figure 2. It shows the
FIGURE 2. Left panel: Preliminary 2006 $A_{LL}$ for inclusive jet production at $\sqrt{s} = 200$ GeV versus jet $p_T$, where the error bars are statistical and the gray bands indicate the systematic uncertainties. Right panel: Confidence level calculations of various predictions in the GRSV framework representing the $A_{LL}$ results from 2005 and 2006.

These inclusive jet asymmetries were included in a recent “global” NLO analysis, DSSV [8], which is the first analysis to include inclusive DIS, semi-inclusive DIS, and RHIC pp collision data together. The result of this analysis showed that $\Delta g(x,Q^2)$ is small in the accessible range of momentum fraction, with a possible node in the distribution near $x \sim 0.1$, basically evolving away at higher scales with the opposite phase from GS-C. A study of the DSSV $\chi^2$ profile and the partial contributions $\Delta \chi^2$ of the individual data sets shows that these STAR data provide the strongest limits on negative gluon polarization over the range $0.05 < x < 0.2$ and also contribute significantly to the limits on positive gluon polarization over the same range.

In summary, we reported on $A_{LL}$ measurements from inclusive jet data from 2005 and 2006. These results provide significant constraints on the gluon spin contribution to the proton spin when compared to NLO pQCD calculations. They play a significant role in the first global NLO analysis to consider DIS, SIDIS and RHIC data together. In addition, we reported a preliminary $A_N$ measurement for inclusive jets at mid-rapidity. It is statistically consistent with zero.

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