Gluon polarization measurements with inclusive jets at STAR

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Abstract. At RHIC kinematics, polarized jet hadroproduction is dominated by $gg$ and $qg$ scattering, making the jet double longitudinal spin asymmetry, $A_{LL}$, sensitive to gluon polarization in the nucleon. I will present STAR results of $A_{LL}$ from inclusive jet measurements for the RHIC 2006 run at center-of-mass energy 200 GeV. I will also discuss the current status of the analysis of data from the 2009 run, also at center-of-mass energy 200 GeV. The results are compared with theoretical calculations of $A_{LL}$ based on various models of the gluon density in the nucleon. The STAR data place significant constraints on allowed theoretical models.

Keywords: Gluon polarization, jet production, STAR, RHIC

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INTRODUCTION

The study of the internal spin structure of the proton is an integral part of the Relativistic Heavy Ion Collider (RHIC). The polarized proton collider is especially well suited to measure the polarized gluon contribution to the proton spin. The Solenoidal Tracker at RHIC (STAR) experiment, with its large acceptance, retains an advantage in accessing $\Delta g(x)$ via jet production.

The longitudinal spin sum rule dictates how the proton spin is constructed from the spin and orbital angular momenta of its partonic constituents:

$$\frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta G + L_z,$$

where the quark polarization, $\Delta \Sigma \approx 0.3$, has been measured in deep-inelastic scattering experiments. However, $\Delta G$, the gluon polarization, and $L_z$, the parton orbital angular momentum, are still poorly constrained [1]. RHIC stands to bring significant advances in mapping $\Delta g(x)$.

RHIC collected data at 200 GeV center-of-mass energy in polarized proton-proton collisions with integrated luminosity of 5.4 pb$^{-1}$ in 2006 and 25 pb$^{-1}$ in 2009. The beam polarization was measured with Coulomb-nuclear interference (CNI) proton-carbon polarimeters [2] calibrated with a polarized atomic hydrogen gas-jet target [3]. The average beam polarization was 60% in 2006 and 58% in 2009.

The STAR detector subsystems [4] relevant to jet analysis are the Time Projection Chamber (TPC) immersed in a 0.5 T longitudinal magnetic field and used to reconstruct charged particle tracks with pseudorapidity $|\eta| < 1.3$, the Barrel Electromagnetic Calorimeter (BEMC) with towers at $|\eta| < 1$ and the Endcap Electromagnetic Calorimeter (EEMC) with towers at $1 < \eta < 2$. The Beam-Beam Counters (BBC) with...
3.3 < |\eta| < 5.0 and Zero-Degree Calorimeters (ZDC) located ~18 m downstream of the interaction point were used for monitoring relative luminosities. A timing window imposed on the BBCs was used as part of the minimum bias trigger requirement in 2006. All of these detectors cover full azimuth (\Delta \phi = 2\pi).

**ANALYSIS AND RESULTS**

Jets were reconstructed using a midpoint-cone algorithm [5] with seed transverse energy 0.5 GeV, split-merge fraction 0.5 and cone radius 0.7. Tracks and towers were required to have a minimum transverse momentum of 0.2 GeV/c. The inclusive jet differential cross section was calculated from the data with [6]:

\[
\frac{1}{2\pi} \frac{d^2\sigma}{d\eta dp_T} = \frac{1}{2\pi} \frac{N_{jets}}{\Delta\eta \Delta p_T} \frac{1}{L dt} \frac{1}{c(p_T)},
\]

where \(N_{jets}\) is the number of jets in the bin \((\Delta\eta, \Delta p_T)\) and \(c(p_T)\) is a correction factor determined from simulation with the event generator PYTHIA 6.4 [7] with CDF Tune A settings and GEANT [8] detector response. Figure 1 shows the 2006 measured inclusive jet cross section with theory comparisons [9, 10]. With the inclusion of hadronization and underlying event corrections, the STAR data are well described by theory.
Several important improvements over the 2006 run were realized, both before and after the taking of the 2009 data. Overlapping jet patches were added to the trigger and lower $E_T$ thresholds were adopted for both the BEMC and EEMC. These upgrades helped increase trigger efficiency and reduce trigger bias. They resulted in a 37% increase in jet acceptance over the 2006 run. Upgrades in the data acquisition system, DAQ1000, allowed STAR to record events at several hundred Hz during the 2009 run, with only 5% dead time for the jet data, compared with 40 Hz with 40% dead time during the 2006 run. The enhanced DAQ capability also allowed STAR to remove the BBC coincidence requirement, which helped trigger more efficiently at high jet $p_T$ and perform the first direct measurement of non-collision background at STAR. Improvements in jet reconstruction were also implemented. The electromagnetic calorimeters are $\sim 1$ hadronic interaction length thick. Many charged hadrons deposit a MIP (minimum ionizing particle), while others shower and deposit a sizeable fraction of their energy when passing through. The strategy adopted in analyses through 2006 was to subtract a MIP from an EMC tower with a charged track passing through. In the 2009 run, the total momentum of the charged track is subtracted from the struck EMC tower. This significantly reduces the response to fluctuations from charged hadron showering and reduces the average difference between jet energies at the detector and particle level. The net benefit comes in the form of an improved overall jet energy resolution of 18%, compared to 23% in the 2006 analysis.

Figure 2 shows the measured inclusive jet $A_{LL} = (\sigma^{++} - \sigma^{-+})/(\sigma^{++} + \sigma^{-+})$ versus jet $p_T$ for the 2006 ($-0.7 < \eta < 0.9$) and 2009 ($|\eta| < 1$) data alongside theory predictions of GRSV [11] and DSSV [12]. The STAR data fall between the predictions of the two models. The dominant systematic uncertainties originate from differences between the reconstructed and true jet $p_T$ and the trigger sampling the underlying partonic processes ($qq$, $qg$ and $gg$) differently. The 2009 data are more precise than the 2006 data by a factor of four in low-$p_T$ bins and a factor of three in high-$p_T$ bins. Figure 3 presents the 2009 result in two rapidity ranges, permitting comparisons with models for collisions with different average partonic scattering angles, $x$ ranges, and subprocess mixtures.
CONCLUSION

The STAR experiment measured the inclusive jet differential cross section and longitudinal double-helicity asymmetry $A_{LL}$ in polarized proton-proton collisions at $\sqrt{s} = 200$ GeV. The agreement between NLO pQCD calculations and the measured cross section runs over six orders of magnitude for $p_T \sim 13–57$ GeV/c. The STAR 2005 and 2006 measured inclusive jet $A_{LL}$ were included in the first global analysis [12] to use polarized jets and played a significant role in constraining $\Delta g(x)$ at RHIC kinematics. The markedly increased precision of the 2009 result is expected to vastly reduce the present large uncertainty of the gluon polarization of the proton once included in a global analysis of polarized parton densities. In addition, the complementary STAR measurement of $A_{LL}$ for di-jets for 2009, also presented for the first time at this meeting [13], will reduce the uncertainty in $\Delta g(x)$ associated with extrapolating beyond the x range explored by the inclusive jet measurement.

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