STAR RESULTS ON LONGITUDINAL SPIN DYNAMICS

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We present preliminary results on the double longitudinal spin asymmetries A_{LL} in inclusive jet production and the longitudinal spin transfer asymmetries D_{LL} in inclusive Λ and $\bar{\Lambda}$ hyperon production. The data amount to 0.5 pb^{-1} collected at RHIC in 2003 and 2004 with beam polarizations up to 45%. The jet A_{LL} asymmetries, measured over $5 < p_T < 17$ GeV/c, are consistent with evaluations based on deep-inelastic scattering parametrizations for the gluon polarization in the nucleon, and disfavor large positive values of gluon polarization in the nucleon. The Λ and $\bar{\Lambda}$ D_{LL}, measured at midrapidity and at low average transverse momentum of 1.5 GeV/c, are consistent with zero within their dominant statistical uncertainties.

One of the goals of the STAR (Solenoid Tracker At RHIC) physics program is to study the internal spin structure of the proton in polarized proton-proton collisions at $\sqrt{s} = 200$ and $\sqrt{s} = 500$ GeV. In particular we aim to determine the gluon polarization in the proton and the flavor decomposition of the quark helicity densities in the nucleon sea[1].
In this contribution we report on an exploratory measurement of the double longitudinal spin asymmetry A_{LL} in inclusive jet production, defined as:

$$A_{LL} = \frac{\sigma^{p_+p_+\to\mathrm{jetX}} - \sigma^{p_+p_-\to\mathrm{jetX}}}{\sigma^{p_+p_+\to\mathrm{jetX}} + \sigma^{p_+p_-\to\mathrm{jetX}}} \tag{1}$$

where $\sigma^{p_+p_{+(-)}\to\mathrm{jetX}}$ is the inclusive jet cross sections where the two colliding proton beams have equal(opposite) helicities. A_{LL} is sensitive to the magnitude of the gluon polarization in the proton for momentum fractions $0.03 < x < 0.3$[2]. In addition we present preliminary results on Λ and $\bar{\Lambda}$ hyperon longitudinal spin transfer asymmetries D_{LL}, defined as:

$$D_{LL} = \frac{\sigma^{pp_+\to\Lambda_+X} - \sigma^{pp_-\to\Lambda_+X}}{\sigma^{pp_+\to\Lambda_+X} + \sigma^{pp_-\to\Lambda_+X}} \tag{2}$$

where $pp_{+(-)} \to \Lambda_+X$ is the inclusive Λ cross section where only one proton beam is positively (negatively) polarized. D_{LL} is expected to be sensitive to the polarized Λ fragmentation functions[3] and to the strange (anti-)quark polarization in the nucleon at large transverse momenta[4].

STAR has collected about 0.5 pb^{-1} of data at $\sqrt{s} = 200$ GeV with longitudinally polarized beams during the initial running periods in 2003 and 2004. The average beam polarizations were $30 - 40\%$. The Time Projection Chamber (TPC), providing tracking and particle identification, covered pseudorapidities $|\eta| < 1.3$, and a Barrel Electromagnetic Calorimeter (BEMC) covered $0 < \eta < 1$ [5]. Segmented Beam Beam Counters (BBC) span $3.3 < |\eta| < 5.0$ and measure proton beam luminosity and transverse beam polarization components. Most of the data were collected with a trigger requiring coincident signals from both BBC's and from a BEMC tower ($\Delta\eta\times\Delta\phi=0.05\times0.05$) above a transverse energy threshold of 2.5 GeV.

Jets are reconstructed using a midpoint-cone algorithm[6] with a cone size of 0.4 that clusters charged tracks and electromagnetic energy deposits. Selections include the requirement of a vertex on the beam axis within ±60 cm of the nominal interaction point, a jet axis within a fiducial volume $0.2 < \eta_{\mathrm{jet}} < 0.8$, and a TPC contribution to the reconstructed jet energy to suppress triggers caused by beam background. The sample after selections in this analysis consists of about 3×10^5 jets with transverse momenta of $5 < p_T^{\mathrm{jet}} < 17$ GeV/c.

Experimentally the double longitudinal spin asymmetry is defined as:

$$A_{LL} = \frac{1}{P_1 P_2}\left[\frac{N^{++} - R_1 N^{+-}}{N^{++} + R_1 N^{+-}}\right], \tag{3}$$

where $N_{++(+-)}$ are the inclusive jet yields for equal (opposite) spin orientations of the protons, $R_1 = L^{++}/L^{+-}$ is the ratio of luminosities for equal and opposite proton spin orientations, and $P_{1(2)}$ are the proton beam polarization values.

Figure 1 shows preliminary results for the double longitudinal spin asymmetry A_{LL} in inclusive jet production in polarized pp collisions at $\sqrt{s} = 200\,\mathrm{GeV}$. The indicated uncertainties are statistical. We have considered systematic uncertainties from relative luminosity R (0.009), trigger bias (< 0.007), the possible contribution from residual non-longitudinal spin asymmetries (< 0.010) and the contamination from beam background (0.003). In addition, there is a scale uncertainty of 25% arising from the beam polarization measurement at RHIC[7]. Analyses with randomized spin patterns and other cross-checks including parity violating single-spin asymmetries show no evidence for beam bunch to bunch or fill to fill systematics. The curves in Fig. 1 show theoretical evaluations of A_{LL} in inclusive jet

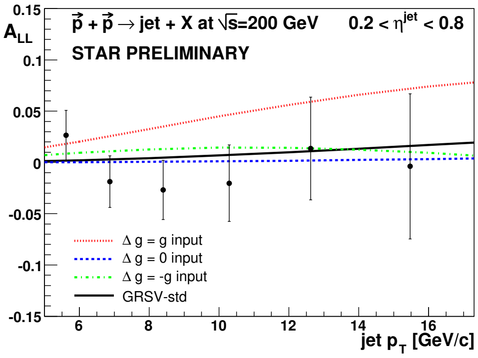

Figure 1. The longitudinal double-spin asymmetry A_{LL} in $\vec{p} + \vec{p} \rightarrow$ jet + X at $\sqrt{s}$ = 200 GeV versus jet p_T. The indicated uncertainties are statistical only. The curves show theoretical evaluations based on deep-inelastic scatetring parametrizations of gluon polarization.

production at $\mu_F = \mu_R = p_T$ for different sets of polarized gluon distribution functions based on fits to deep-inelastic scattering data [2,8,9]. They are based on a best fit to deep-inelastic scattering data (GRSV-std), and otherwise span the range $\Delta g(x, Q_0^2) = \pm g(x, Q_0^2 = 0.4\,\mathrm{GeV}^2)$ [8] as indicated. The data are systematically below the curve based on maximal gluon polarization, and are consistent with the other predictions. Large and positive gluon polarization is thus disfavored. The cross section for inclusive jet production in pp collisions at $\sqrt{s}$ = 200 GeV has been measured for $5 < p_T^{\mathrm{jet}} < 50$ GeV/c [10]. It is well described by the NLO QCD calculations[2].

The $\Lambda(\bar{\Lambda})$ was reconstructed via decay modes $\Lambda \rightarrow p + \pi^-(\bar{\Lambda} \rightarrow \bar{p} + \pi^+)$ with a branching ratio of 64%. Two tracks with opposite curvature and a topology consistent with hyperon decay were required. Additional cuts on the specific energy loss of protons and pions in the TPC reduced background. The transfer asymmetry has been extracted from $\sim 30(27)$K $\Lambda(\bar{\Lambda})$ after selections, using

$$D_{LL} = \frac{1}{P\alpha < \cos\theta >}\left[\frac{N^+ - R_2 N^-}{N^+ + R_2 N^-}\right], \tag{4}$$

where $N_{+(-)}$ are the inclusive $\Lambda(\bar{\Lambda})$ yields for positive (negative) proton helicity $R_2 = L^+/L^-$ is the ratio of luminosities for positive (negative) proton helicity and P is the beam polarization. $\alpha = +(-)0.642 \pm 0.013$ is the empirical decay parameter for $\Lambda(\bar{\Lambda})$[11] and θ is the angle between the (anti-)proton momentum in the $\Lambda(\bar{\Lambda})$ rest frame and the $\Lambda(\bar{\Lambda})$ momentum direction in the laboratory frame. K_s background was suppressed by requiring $\cos\theta < -0.2$.

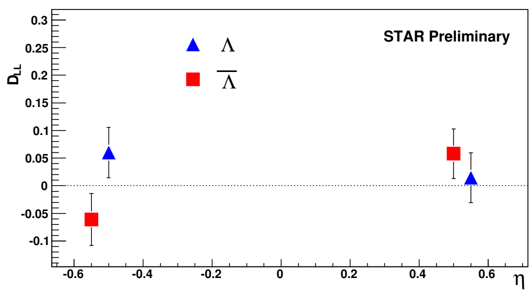

Figure 2. The longitudinal spin transfer asymmetry D_{LL} in $p\vec{p} \to \Lambda(\bar{\Lambda})X$ at $\sqrt{s} = 200$ GeV versus η. The indicated uncertainties are statistical only.

Figure 2 shows D_{LL} versus η for Λ and $\bar{\Lambda}$. Positive η is taken along the polarized beam momentum. Mean $|x_F| \simeq 8 \cdot 10^{-3}$ and $p_T \simeq 1.5$ GeV/c. The indicated uncertainties are statistical. The beam polarization measurement causes 16% systematic uncertainty and the relative luminosity measurement contributes 0.01 uncertainty. Both are well below the statistical precision. The cross section for Λ production in pp collisions at $\sqrt{s} = 200$ GeV [12] is relatively well described by the NLO QCD calculations for $p_T > 1$ GeV/c, which depend strongly on the choice for the parametrizations of the fragmentation functions. Measurements of D_{LL} at large transverse momenta, $p_T > 8$ GeV/c, are expected to be sensitive mostly to the strange sea in the polarized nucleon.

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