Nucleon Spin Physics with Hyperons at STAR

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The spin physics program at RHIC [1] studies the internal spin structure of the proton with polarized proton-proton collisions at a center-of-mass energy of $\sqrt{s} = 200\,\mathrm{GeV}$ and in future $\sqrt{s} = 500\,\mathrm{GeV}$. The production of weak bosons in polarized proton collisions at $\sqrt{s} = 500\,\mathrm{GeV}$ will allow the STAR experiment to determine the u, $\bar{u}$, d, and $\bar{d}$ quark polarizations directly and precisely by measuring parity-violating single-spin asymmetries in $ud \to W^+$ and $d\bar{u} \to W^-$ via their leptonic decay, $W \to l\nu$.

We have started to investigate the feasibility of accessing the polarization of the three light quarks at $\sqrt{s} = 200\,\mathrm{GeV}$ via the production of hyperons, in particular the Λ and $\bar{\Lambda}$. Hyperons contain at least one s quark and hyperon polarization can often be measured via the angular distribution in their weak 2-particle decay. A phenomenological study in the framework of perturbative QCD for RHIC conditions leads us to expect that the $\bar{\Lambda}$ polarization becomes increasingly sensitive to $\bar{s}$-quark polarization with increasingly large p_T, more so than to the details of spin transfer in the fragmentation process [2].

The STAR experiment [3] features a large Time Projection Chamber (TPC), which tracks charged particles with pseudo-rapidities up to $\eta \simeq 1.3$ and has capability to identify particles via measurement of specific energy loss [4]. About $0.3\,\mathrm{pb}^{-1}$ of proton collisions at $\sqrt{s} = 200\,\mathrm{GeV}$ were collected during 3-week RHIC machine development periods in the years 2003 and 2004. Beam polarizations up to 45% were reached.

The Λ $\left(\bar{\Lambda}\right)$ was reconstructed via the decay $\Lambda \to p + \pi^-$ $\left(\bar{\Lambda} \to \bar{p} + \pi^+\right)$ with a branching ratio of 64%. Two tracks with opposite curvature were required, as well as a topology that is consistent with the decay. Backgrounds were reduced with additional selections on the specific energy loss of protons and pions in the TPC. After reconstruction and selections $30 \cdot 10^3$ Λ and $27 \cdot 10^3 \bar{\Lambda}$ signals remained. Their mean $|x_F| \simeq 8 \cdot 10^{-3}$ and mean $p_\mathrm{T} \simeq 1.5\,\mathrm{GeV/c}$.

The asymmetry with sensitivity to $\bar{s}$-quark polarization is the longitudinal spin transfer,

$$D_{LL} \equiv \frac{\sigma^{pp_+ \to \bar{\Lambda}_+ X} - \sigma^{pp_- \to \bar{\Lambda}_+ X}}{\sigma^{pp_+ \to \Lambda_+ X} + \sigma^{pp_- \to \Lambda_+ X}}, \qquad (1)$$

in which $\sigma^{pp_{+(-)} \to \bar{\Lambda}_+ X}$ is the differential cross section for the inclusive production of polarized $\bar{\Lambda}$'s with one of the proton beams positively (negatively) polarized. It was extracted according to,

$$D_{LL} = \left[\frac{N^+ - RN^-}{N^+ + RN^-}\right] \frac{1}{\alpha P \langle \cos\theta \rangle}, \qquad (2)$$

c where $N^{+(-)}$ denotes the inclusive Λ or $\bar{\Lambda}$ yield for positive (negative) proton beam helicity, R is the ratio of measured luminosities for positive and negative proton beam helicity, $\alpha = +(-)0.642 \pm 0.013$ [5] is the empirical decay parameter for $\Lambda(\bar{\Lambda})$, P is the measured proton beam polarization, and θ is the angle between the $\Lambda(\bar{\Lambda})$ momentum in the laboratory frame and the (anti-)proton momentum in the $\Lambda(\bar{\Lambda})$ rest frame. In this analysis the detector acceptance is canceled.

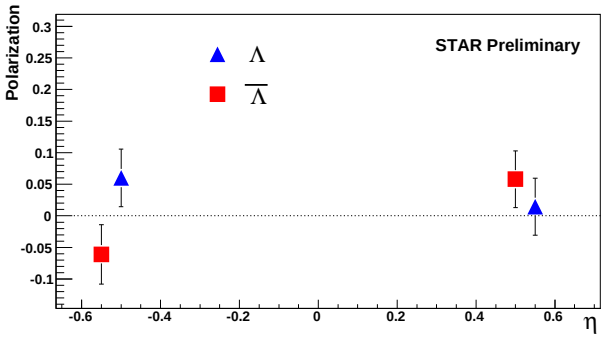

FIG. 1: Preliminary STAR data on the spin transfer D_{LL} in inclusive Λ and $\bar{\Lambda}$ production versus η. Positive η is taken along the direction of the polarized proton beam. The mean $|x_F| \simeq 8 \cdot 10^{-3}$ and mean $p_\mathrm{T} \simeq 1.5\,\mathrm{GeV/c}$. The indicated uncertainties are statistical.

Figure 1 shows preliminary results for D_{LL} versus η with their statistical uncertainties. The systematic uncertainties are estimated to be $\sim$0.01 and $\sim$20% from the beam polarization measurement. No discernable D_{LL} is found, as expected for the modest event sample and limited p_T reach.

STAR has measured the $\Lambda + \bar{\Lambda}$ p_T-spectra [6]. The data are well reproduced by next-to-leading order perturbative QCD evaluation [7] for $p_\mathrm{T} > 2\,\mathrm{GeV/c}$ and a suitable choice for the fragmentation functions. Future high luminosity measurements of D_{LL} for $\bar{\Lambda}$ are thus likely to be interpretable in the perturbative framework, and are expected to be sensitive to $\bar{s}$-quark polarization in the polarized nucleon.

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