Spin physics with STAR at RHIC

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Our group continues to play major roles in STAR investigations of both longitudinal and transverse spin phenomena in polarized *pp* collisions at RHIC. During the past year, we finalized the analysis of STAR data that were recorded during 2009 to determine the longitudinal double-spin asymmetry, A_{LL}, for inclusive jet production at mid-rapidity in 200 GeV *pp* collisions. We also laid the groundwork for the determination of A_{LL} for inclusive jet production at mid-rapidity in 510 GeV *pp* collisions with data that STAR recorded during 2012, and made progress toward a determination of the transverse single-spin asymmetry, A_N, for jet-like events at forward rapidity using data that STAR recorded during 2011.

One of the primary goals of the RHIC spin program is to determine the gluon contribution to the proton spin. At RHIC energies, jet production at mid-rapidity is dominated by *gg* and *qg* scattering. This makes A_{LL} for inclusive jet production a sensitive probe of gluon polarization. Last year, we completed a preliminary analysis of data that STAR recorded in 2009 to determine A_{LL} for inclusive jet production in 200 GeV *pp* collisions [1].

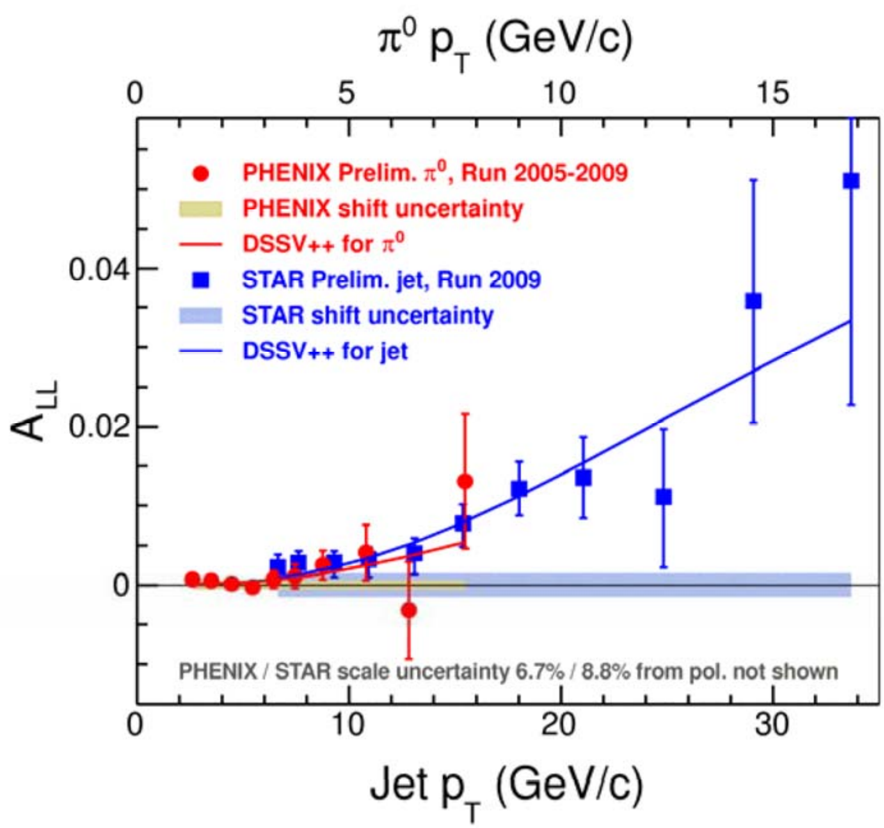

FIG. 1. A_{LL} for inclusive pion and jet production in 200 GeV *pp* collisions from PHENIX and STAR, respectively. The solid curves show the results for the DSSV++ global analysis

The preliminary 2009 STAR inclusive jet A_{LL} results [1] continue to generate a great deal of interest. Recently, the DSSV group [2] performed a preliminary revision of their polarized parton distribution global analysis, DSSV++, which includes the preliminary 2009 inclusive jet A_{LL} results from STAR and preliminary 2009 inclusive π^0 A_{LL} results from PHENIX. The new fit provides an excellent description of the STAR data, as shown in Fig. 1. They find that the integral of $\Delta g(x)$ over the range $0.05 < x < 0.2$, which is well measured with 200 GeV *pp* collisions at RHIC, is $0.10^{+0.06}_{-0.07}$, and conclude that the 2009 results provide the first indication of non-zero gluon polarization within the *x* range that is sampled at RHIC [3]. When they extrapolate the DSSV++ fit over all *x*, they find $\Delta G \sim 0.3$, albeit with very large uncertainties. This is about twice the quark contribution to the proton spin, and would be sufficient to satisfy the spin sum rule.

For the preliminary 2009 inclusive jet results, systematic uncertainties associated with trigger and reconstruction bias are 50-100% of the statistical uncertainties for several low to intermediate-p_T bins. These systematics arise primarily from the subprocess-dependence of our Jet Patch trigger, together with underlying event contributions that cause lower-p_T partons to be reconstructed as higher energy jets. During the past year, we completed a detailed study of the systematic uncertainties as a function of jet algorithm and resolution parameter. We obtained a significant reduction in these systematic effects by switching from the mid-point cone algorithm with a radius R=0.7 to the Anti-k_T algorithm with a resolution parameter R=0.6, at the expense of a 10-15% increase in the statistical uncertainties. We have now completed the final analysis of the 2009 data, and are preparing the paper for publication.

Mr. Z. Chang is using 2012 STAR data to determine A_{LL} for inclusive jet production in 510 GeV *pp* collisions for his dissertation research. A_{LL} values of only 0.001~0.002 are expected for the low-p_T jet bins that provide information regarding gluon polarization at the lowest *x* values. Thus, it's essential to minimize the systematic uncertainty associated with the determination of the relative luminosities of the various spin states at STAR. This past year, Mr. Chang performed a detailed analysis of the scaler data for three different STAR subsystems – the Beam-Beam Counter (BBC), the Vertex Position Detector (VPD), and the Zero-Degree Calorimeter (ZDC). He found that the VPD provides the best measure of the relative luminosities for the 2012 STAR data. The present estimate is that the relative luminosity determination will contribute a systematic uncertainty to A_{LL} of ±0.0004.

Another major goal of the RHIC spin program is to unravel the origin of the large transverse single-spin asymmetries for inclusive π^0 production that have been seen at forward rapidities at RHIC [4]. The asymmetries have been attributed to the Sivers effect, a correlation between the spin of the incident proton and the transverse momentum of the quark or gluon that experiences the hard scattering, the Collins effect, which arises from the spin-dependent fragmentation of polarized scattered quarks, or a combination of the two. The Sivers effect provides a window into parton orbital motion because it requires interference between amplitudes involving partons with different orbital angular momenta. The Collins effect provides a means to explore quark transversity, the third collinear, leading-twist parton distribution function. (The other two are the unpolarized distribution and the helicity distribution, which is explored in longitudinally polarized collisions as discussed above.)

Isolating the origin(s) of the large transverse single-spin asymmetries is going to require π^0 observations over a wider kinematic range, studies of additional hadron species, jets, and photons, as well as coincidence measurements. This past year, STAR published cross section and asymmetry measurements for inclusive π^0 and η meson production at pseudorapidity η=3.68 that span the range $0.4 < x_F < 0.75$ [5]. The cross sections are consistent with perturbative QCD expectations. At $x_F > 0.55$, the results indicate that A_N for the η is larger than that for the π^0; there is only a 3% probability that the two are equal. At present, it is not clear whether such a difference can arise from the Sivers or Collins effects.

Looking forward, we are developing the ability to reconstruct jet-like events with the STAR Forward Meson Spectrometer (FMS). The FMS provides electromagnetic calorimetry over the full azimuth for the range $2.5 < \eta < 4$. The Sivers effect should produce a spin asymmetry for jet-like events, whereas the Collins effect should produce an azimuthal asymmetry in the distribution of fragments about the jet thrust axis. In addition, the large acceptance of the STAR detector provides the opportunity to correlate the jet-like events in the FMS with additional final-state products emitted at other pseudorapidities in order to elucidate the underlying reaction mechanism.

During the past year, group members served as principal authors for two STAR papers [5,6], chair of the god-parent committee for two papers [6,7], and member of the god-parent committee for another paper [8].

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