Spin physics with STAR at RHIC

Z. Chang, P. Djawotho, C. A. Gagliardi, M. M. Mondal, R. E. Tribble,
and the STAR Collaboration

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 made substantial progress toward 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 obtained preliminary results for 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. The 2009 STAR inclusive jet A_{LL} results for 200 GeV *pp* collisions [1] provide the first indication of non-zero gluon polarization in the region $x > 0.05$ [2]. Inclusive jet measurements at mid-rapidity in 510 GeV *pp* collisions provide the opportunity to extend the gluon polarization sensitivity down to $x > 0.02$.

STAR recorded a large inclusive jet data set in 510 GeV *pp* collisions during the 2012 RHIC run. Mr. Z. Chang is using the 2012 STAR data to determine A_{LL} for inclusive jet production 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 uncertainties in the analysis. The two dominant systematics are expected to involve the relative luminosity measurement and trigger and reconstruction bias. Last 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. Since then, Mr. Chang has performed a detailed QA of the 2012 jet data, identifying those runs where the detector response is best understood in order to minimize the trigger and reconstruction bias. Recently, Mr. Chang has identified anomalies in the trigger response associated with energy depositions in a small subset of the calorimeter front-end electronics modules. Once these are resolved, he will be ready to generate the large Monte Carlo simulation that is necessary to estimate the trigger and reconstruction bias systematics. Mr. Chang expects to have preliminary results for inclusive jet A_{LL} at 510 GeV during the coming year.

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 [3,4]. 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.)

We have developed the ability to reconstruct photon and multi-photon jet-like events with the STAR Forward Meson Spectrometer (FMS) in order to gain more insight into the dynamics that lead to the observed large transverse single-spin asymmetries. The FMS provides electromagnetic calorimetry over the full azimuth for the range $2.5 < \eta < 4$. We use the anti-k_T algorithm with resolution parameter R=0.7 to construct jets from the photons observed by the FMS. We then measure A_N for the highest energy jet that satisfies $2.8 < \eta < 4$ and $p_T > 2$ GeV/c. We find that the transverse spin asymmetry depends strongly on the number of photons in the reconstructed jet-like event. Fig. 1 shows the measured

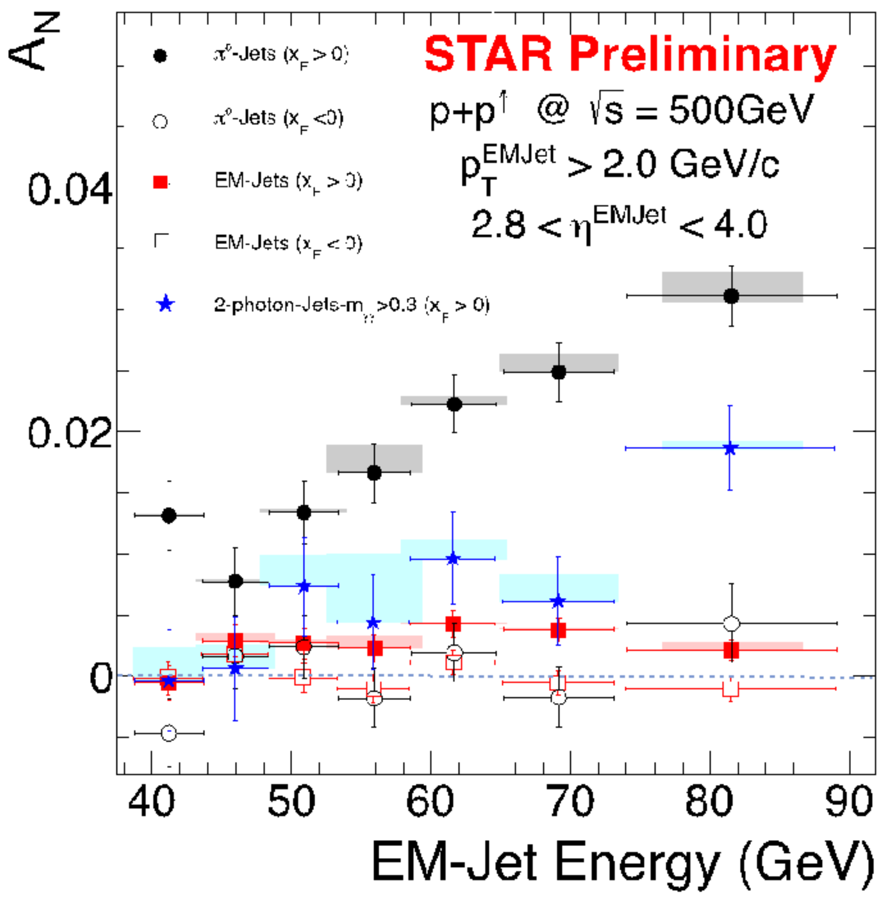

FIG. 1. A_N vs. EM-Jet Energy for three different classes of jet-like events detected with the STAR FMS. See text for a description of the three event classes. The error bars indicate statistical uncertainties, and the shaded bands show the systematic uncertainties.

asymmetry vs. EM-jet energy for three different event classes. Isolated π^0s, or "π^0-jets", represent jets that contain exactly two photons with effective mass $m_{\gamma\gamma} < 0.3$ GeV and energy sharing $|E_1-E_2|/(E_1+E_2) < 0.8$. Their asymmetry is large and increasing with energy. In contrast, EM-jets with three or more photons have a very small asymmetry. The asymmetry for 2-photon EM-jets with mass $m_{\gamma\gamma} > 0.3$ GeV, which arise from the photon combinatorial continuum together with a small contribution from the η meson, falls in between these two limits.

To further explore the dependence of A_N on the event class, we've examined it as a function of EM-jet energy, p_T, and number of photons. The results are shown in Fig. 2. One-photon events, which include a large π^0 contribution in this analysis, are similar to 2-photon events. Three-photon jet-like events have a clear non-zero asymmetry, but it's substantially smaller than that for isolated π^0. A_N then decreases as the event complexity, i.e., the "jettiness", increases. These results indicate that the π^0s that produce the large observed forward transverse spin asymmetry do not arise from the conventional parton fragmentation to jets.

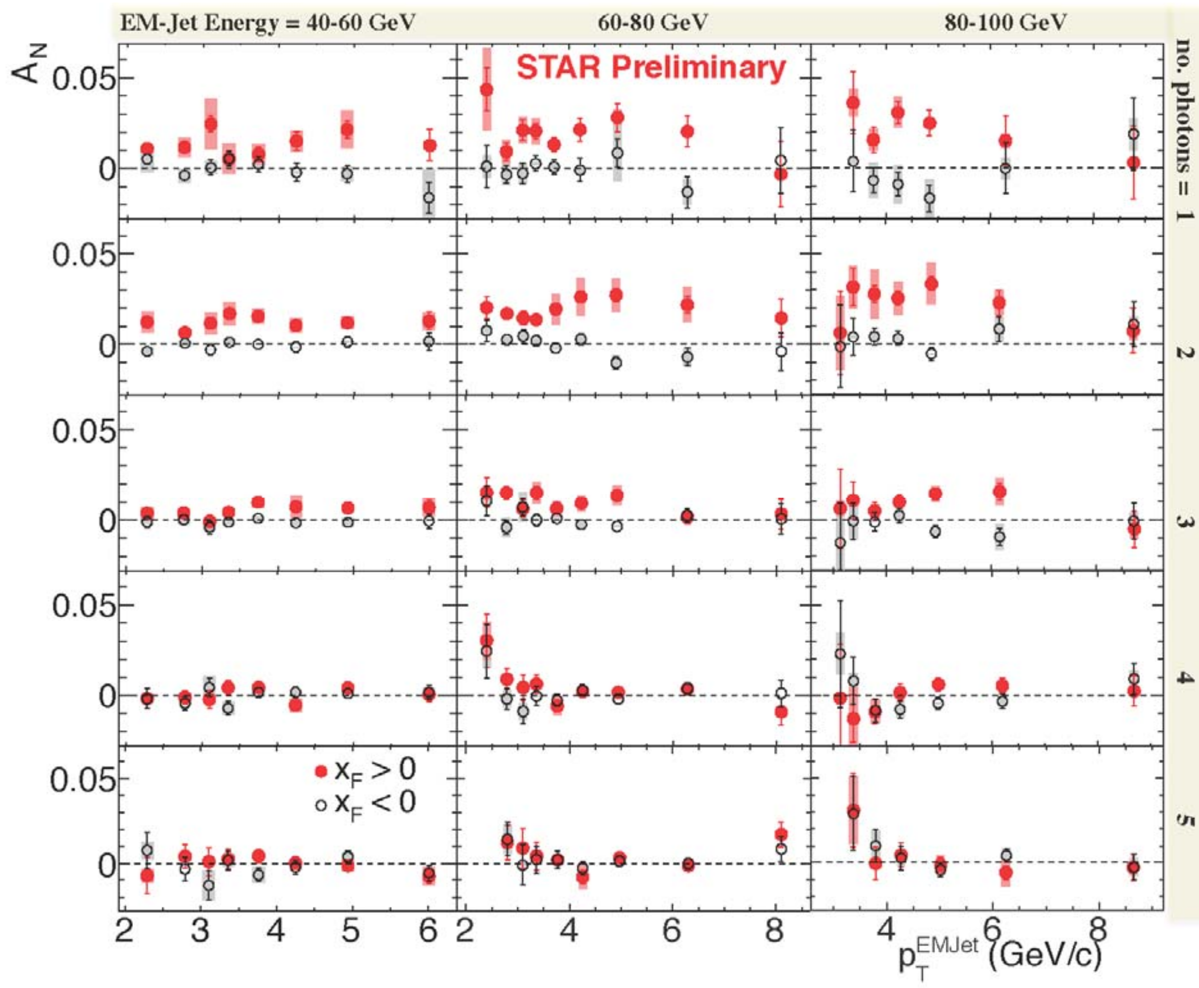

FIG. 2. A_N as a function of EM-jet energy, p_T, and number of photons. We also find that A_N for jet-like events with more than 5 photons (not shown) is similar to that for N_γ=5. The error bars are statistical, and the shaded bands show the systematic uncertainties.

At present, work is underway to explore the sensitivity of the forward transverse asymmetries to the presence or absence of an away-side jet at mid-rapidity.

During the past year, group members served as chair of the god-parent committee for one paper [5], and members of the god-parent committee for two other papers.

[1] P. Djawotho, for the STAR Collaboration, arXiv:1106.5769.
[2] E.C. Aschenauer *et al*. (RHIC Spin Collaboration), arXiv:1304.0079.
[3] B.I. Abelev *et al*. (STAR Collaboration), Phys. Rev. Lett. **101**, 222001 (2008).
[4] L. Adamczyk *et al*. (STAR Collaboration), Phys. Rev. D **86**, 051101(R) (2012).
[5] L. Adamczyk *et al*. (STAR Collaboration), arXiv:1302.6184.