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, our analysis efforts have focused on the 200 GeV longitudinal spin data that were recorded by STAR during 2009 and 200 GeV transverse spin data that were recorded during 2008. We also led an effort to develop a new trigger logic scheme for the STAR FMS, which is described elsewhere in this report.

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 the double longitudinal-spin asymmetry A_{LL} for inclusive jet production a sensitive probe of gluon polarization. In 2009, STAR sampled ~25 pb^{-1} of longitudinally polarized *pp* collisions, with an average polarization of 58%. Prior to the run, our group initiated a substantial reprogramming of the jet triggers for the Barrel and Endcap Electromagnetic Calorimeters (B/EEMC). This resulted in a 37% increase in jet acceptance compared to the 2006 RHIC run. The STAR DAQ1000 upgrade was also completed prior to the 2009 run. This allowed us to record events at several hundred Hz, with only 5% dead time, compared with 40% dead time at 40 Hz during 2006. We utilized the added flexibility to lower the JP thresholds substantially compared to the 2006 values, thereby significantly increasing the jet trigger efficiency. We also removed the Beam-Beam Counter (BBC) minimum bias coincidence requirement, which had been part of all previous STAR jet triggers. This further increased the efficiency at high jet p_T, and facilitated a direct measurement of the non-collision background at STAR. The increased jet acceptance and trigger efficiency also help to reduce the trigger bias.

Since the run, we have implemented significant improvements in the STAR jet reconstruction procedures. The electromagnetic calorimeters are ~1 hadronic interaction length thick. Many charged hadrons deposit a MIP (minimum-ionizing particle), while others shower and deposit a sizable fraction of their energy while passing through. The strategy adopted in analyses through 2006 was to subtract a MIP from an EMC tower with a charged track passing through. For the 2009 run, we adopted a new procedure. We now subtract up to the full track energy from the struck EMC tower. Detailed PYTHIA+GEANT simulations that we performed demonstrated that this significantly reduces the response to fluctuations from charged hadron showering, and also reduces the average difference between the jet energies at the particle and detector levels. The net benefit comes in the form of an improved overall jet energy resolution of 18%, compared to 23% in the 2006 analysis.

Figure 1 shows the measured inclusive jet A_{LL} versus jet p_T for the 2006 ($-0.7 < \eta < +0.9$) and 2009 ($|\eta| < 1$) data, together with theory predictions from GRSV [1] and DSSV [2]. The yellow triangular region in Fig. 1 shows the χ^2+2% uncertainty region identified in the DSSV analysis. The dominant systematic uncertainties in the 2009 measurement originate from differences between the true and reconstructed jet p_T, the non-uniform trigger sampling of the underlying partonic processes (*gg*, *qg*, and *qq*), and relative luminosities. The 2009 data are more precise than the 2006 data by a factor of four

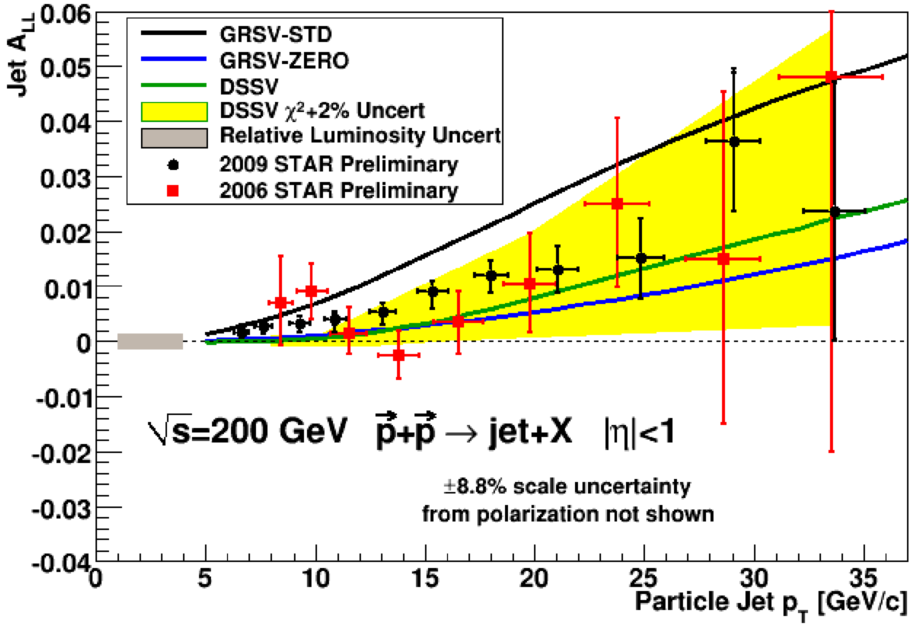

FIG. 1. 2006 (red squares) and 2009 (black circles) STAR measurements of the inclusive jet A_{LL} vs. p_T. The curves show predictions based upon the GRSV [1] and DSSV [2] polarized parton distributions. The yellow band shows the DSSV χ^2+2% uncertainty region [2].

in the low-p_T bins and a factor of three in the high-p_T bins. The data are sufficiently precise to justify separation into two rapidity regions, thereby permitting detailed comparisons with models for collisions that sample different x ranges, subprocess mixtures, and average partonic scattering angles. The separation is shown in Fig. 2. In both Figs. 1 and 2, the STAR 2009 inclusive jet results are seen to fall between the predictions from DSSV and GRSV-STD.

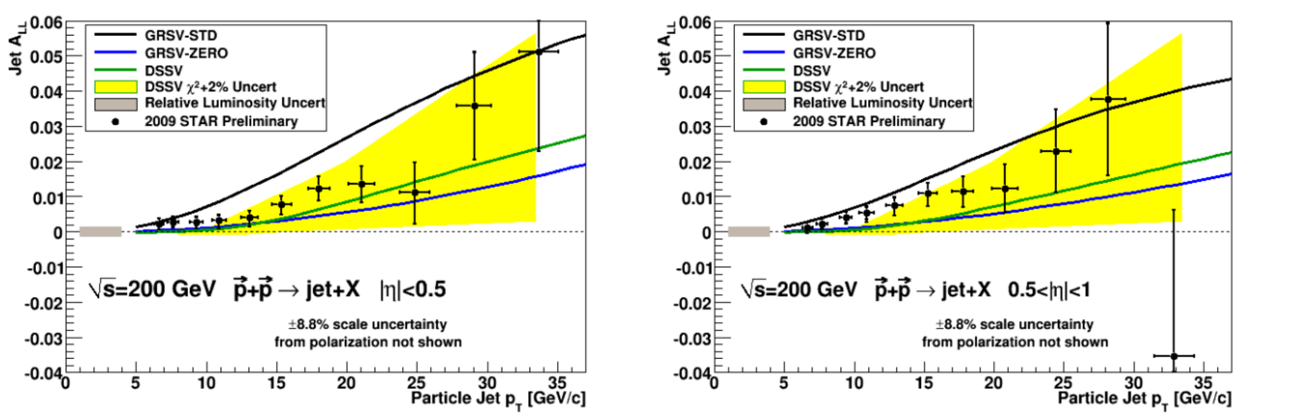

FIG. 2. STAR 2009 inclusive jet A_{LL} vs. p_T for the pseudorapidity regions $|\eta| < 0.5$ (left panel) and $0.5 < |\eta| < 1$ (right panel).

DSSV was the first polarized parton distribution fit that included deep-inelastic scattering, semi-inclusive deep-inelastic scattering, and RHIC data on an equal footing [2]. The STAR 2005 and 2006 inclusive jet A_{LL} measurements played a significant role in constraining $\Delta g(x)$ in DSSV. The STAR 2009 results draw a narrow road through the previous DSSV error band. As such, they are expected to provide a significant reduction in the present large uncertainty of the gluon polarization in the proton once they are included in a new global analysis.

Another major goal of the RHIC spin program is to unravel the origin of the large transverse single-spin asymmetries that have been seen at forward rapidities at RHIC [3]. 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.)

We are investigating two-particle correlations in transversely polarized proton collisions from the 2008 RHIC run. By correlating trigger π^0s from the STAR FMS with charged tracks at similar pseudorapidity measured with the STAR FTPC, we can investigate A_N for two-particle correlations in a kinematic region where we have already measured large A_N for inclusive pions [3]. Our goal is to

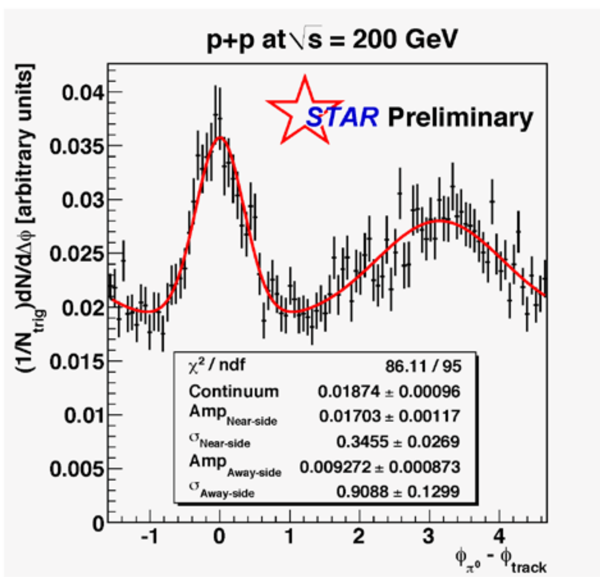

FIG. 3. π^0-charged particle correlations in STAR 2008 transversely polarized *pp* collisions at 200 GeV. π^0s are required to satisfy the trigger condition and have $2 < p_T < 5$ GeV/c. Charged particles are required to satisfy $1 < p_T < 3$ GeV/c. The continuum includes a 12-14% rate-dependent component from pile-up.

measure the interference fragmentation functions (IFF), which are sensitive to quark transversity and closely related to the Collins effect.

Over the past year, we have refined a set of data-driven cuts to optimize the observation of correlations in the 2008 data. We start from a trigger π^0 with $2 < p_T < 5$ GeV/c. We then correlate it with charged tracks with $1 < p_T < 3$ GeV/c measured by the FTPC. The resulting distribution is shown in Fig. 3. Separating the continuum background from the correlation signal is a major task. The FTPC is a "slow detector." The drift time in the FTPC can be up to 50 μs. Thus, it is susceptible to pile-up when tracks from other bunch crossings inadvertently get assigned to a collision vertex. This non-physical background should scale with the collision rate. In contrast, physics quantities, such as Gaussian peak width and height, as well as the true contribution to the continuum, should be independent of the rate. To quantify this effect, we have evaluated the correlations for various coincidence rates measured by the BBC. We then fit the resulting distributions with a double-gaussian signal and a continuum contribution linear in rate. We find is ~86% of the continuum in Fig. 3 is associated with the trigger π^0; the rest arises from pile-up.

It is useful to understand the behavior of the near-side events to characterize the intra-jet correlations. The invariant mass distributions of events with $|\Delta\varphi| < \pi/3$ show the presence of a modest ρ peak on an exponentially falling continuum. This peak is suppressed in π^0-h^- correlations relative to π^0-h^+ correlations. The presence of the peak serves as a good sanity check, and the fact that the spectrum is not overwhelmed by the ρ lends confidence to the idea that we are evaluating jet-like events.

To understand the efficiency of the developed cuts in a more robust fashion, we need to analyze simulated tracks embedded in real data. This embedding procedure will also quantify the momentum resolution and reconstruction efficiency in the FTPC. Quality assessment of a sample embedding set is on-going. To perform the spin measurements, we need to understand the spin patterns of the 2008 data. At present, the STAR spin database is not filled for the 2008 run. Efforts to do so are on-going.

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[2] D. de Florian, R. Sassot, M. Stratmann, and W. Vogelsang, Phys. Rev. Lett. **101**, 072001 (2008).

[3] B.I. Abelev *et al*. (STAR Collaboration), Phys. Rev. Lett. **101**, 222001 (2008).