EPJ Web of Conferences will be set by the publisher
DOI: will be set by the publisher

Transverse Single-spin Asymmetries from $p^{\uparrow} + p \rightarrow jet + X$ and $p^{\uparrow} + p \rightarrow jet + \pi^{\pm} + X$ at $\sqrt{s} = 500$ GeV at RHIC

J. L. Drachenberg[1,a], STAR Collaboration

[1] *Valparaiso University*

Abstract. Current extractions of Sivers and transversity functions come from measurements of transverse single-spin asymmetries (SSA) from SIDIS and fragmentation functions from lepton-lepton scattering. The limited kinematic reach leaves sizable uncertainty in model predictions. One way to extend knowledge to higher kinematics is through jet production from high-energy polarized-proton collisions. The STAR detector at RHIC has observed hints of non-zero SSA's for the Collins effect from $p^{\uparrow} + p \rightarrow jet + \pi^{\pm} + X$ at $0 < \eta < 1$ and $\sqrt{s} = 200$ GeV. Extending transverse SSA measurements for the first time to mid-rapidity jet production at 500 GeV allows one to examine the Sivers and Collins effects for a different mix of partonic subprocesses. Moreover, the increased gluon participation allows a more favorable examination of the gluon Collins-like effect. Progress toward these first measurements will be shown.

1 Introduction

One avenue to enrich understanding of nucleon spin structure is through jet production from high-energy polarized-proton collisions [1]. Here, one can measure Sivers, Collins, or linearly polarized gluon effects through different moments of the transverse single-spin asymmetry A_{UT}. The Sivers effect [2, 3] is expected to yield an azimuthal asymmetry in the production of jets, while the Collins effect [4] and "Collins-like" effect from linearly polarized gluons (e.g. Ref. [5]) are expected to yield asymmetries in the azimuthal distribution of hadrons within jets. The STAR detector [6] at RHIC has seen hints of non-zero Collins asymmetries from $p^{\uparrow}+p \rightarrow jet+\pi^{\pm}+X$ at $|\eta| < 1$ and $\sqrt{s} = 200$ GeV [7]. To date, no sizeable asymmetry has been measured in inclusive jet, di-jet, or inclusive pion production at central pseudorapidity [8–12]. Moreover, no experimental measure of the Collins-like asymmetry has been conducted. In 2011 STAR integrated 25 pb^{-1} of luminosity from $p^{\uparrow} + p$ at $\sqrt{s} = 500$ GeV with 48% polarization. This dataset allows the first measure of these asymmetries at $\sqrt{s} = 500$ GeV. Under such conditions, gluonic subprocesses dominate allowing more direct sensitivity to the gluon Sivers function and linearly polarized gluons than is available in collisions at $\sqrt{s} = 200$ GeV. From the previous measurements at 200 GeV, as well as model predictions (e.g. Ref. [13]), it is expected that the contribution from the gluon Sivers effect is small. Additionally, the enhancement of gluonic contributions is expected to suppress the quark-based Collins asymmetries in these data, since transversity for spin-1 particles in spin-1/2 targets vanishes. While no measurements of the "Collins-like" effect exist, model calculations of the maximized "Collins-like" asymmetry (saturated

[a] e-mail: Jim.Drachenberg@valpo.edu

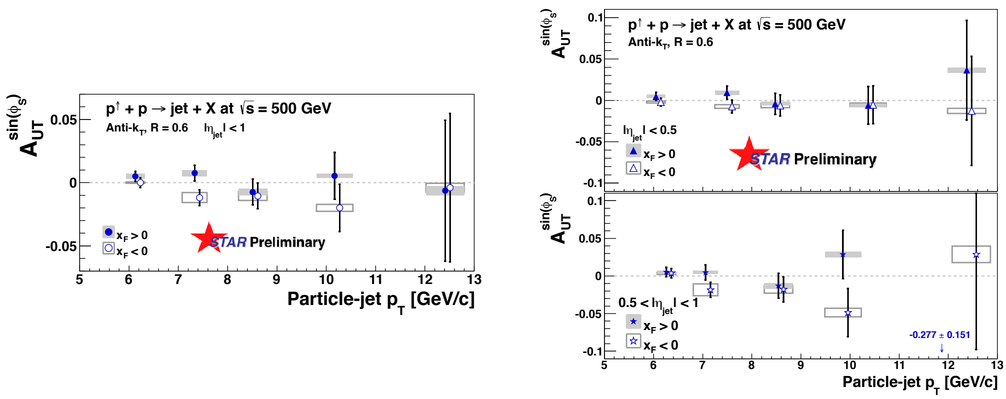

Figure 1. Sivers asymmetries as a function of particle-jet transverse momentum for jet production (left) in the central pseudorapidity region and (right) in bins of pseudorapidity. Statistical uncertainties are shown by error bars and systematic uncertainties by error boxes.

to the positivity bound) show possible asymmetries of ~ 2% [1]. Thus, the 2011 STAR data should provide the first realistic constraints on model predictions.

2 Analysis

The present data were collected utilizing a minimum-bias trigger (VPDMB), requiring a coincidence in STAR's vertex position detector (VPD) [14, 15]. During the 2011 RHIC run, STAR collected additional data by triggering on electromagnetic energy deposited in STAR's barrel (BEMC) and endcap (EEMC) electromagnetic calorimeters [6]. The VPDMB data represent the dominant portion for jets reconstructed with transverse momentum less than 7 GeV/c and provide the best sensitivity to gluonic subprocesses. Jets are reconstructed utilizing the anti-k_T jet-reconstruction algorithm [16] with a radius of 0.6 and utilize energy deposition in the BEMC and EEMC as well as charged-particle tracks from STAR's time projection chamber (TPC) [6].

The asymmetries are calculated utilizing the so-called "cross-ratio" method [17] which removes the effects of luminosity asymmetries as well as instrumental asymmetries. Cross-ratios from the raw yields are binned in terms of the relevant azimuthal angles; and raw asymmetries, ϵ, are extracted by fitting the cross-ratio yields with a function of the form $p_0 + \epsilon \times \sin(\phi)$. The p_0 terms allow an additional check of systematic effects and are found to be consistent with zero. The raw asymmetries are then corrected for beam polarization.

To understand the effects of reconstruction and angular resolution, PYTHIA [18] Monte Carlo events with the "Perugia 0" tune [19] have been embedded into real zero-bias data which provide sensitivity to out-of-time pile-up. GEANT [20, 21] has been used to simulate detector response. The jet-reconstruction is run over the Monte Carlo at the detector, particle-jet, and parton-jet levels. Parton jets remove contributions to the jet energy from underlying event and hadronization effects. Reconstructed jet kinematics at the detector level are corrected to the particle-jet level.

The dominant systematic uncertainties arise from jets reconstructed at the detector level which fail to match to one at the parton-jet level. Additional systematic uncertainties come from the contamination of kaons, protons, and electrons to the charged-pion signal; the "leak-through" of competing

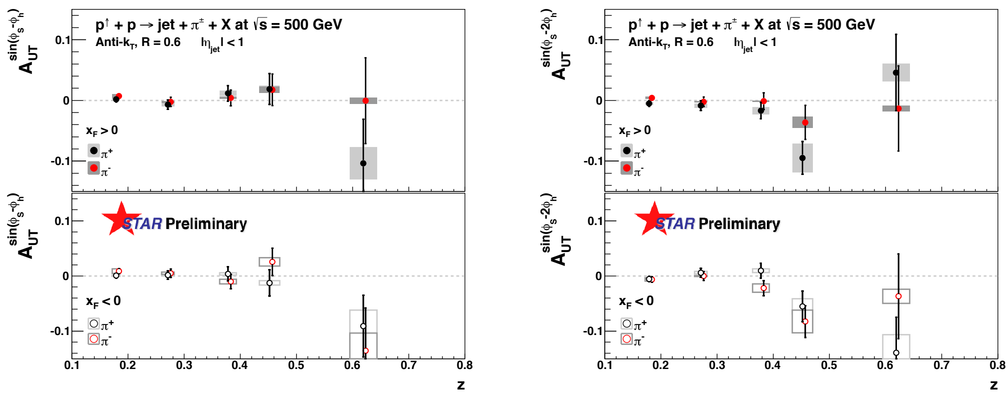

Figure 2. (left) Collins and (right) "Collins-like" asymmetries as a function of pion z. Asymmetries are shown for forward ($x_F > 0$) and backward ($x_F < 0$) scattering.

effects coupling to non-uniform detector acceptance; uncertainties from calorimeter gains, efficiencies, and response to charged hadrons; and tracking efficiency. Measured asymmetries are corrected for smearing due to finite azimuthal-angle resolution.

3 Results

In Fig. 1 the measured asymmetries for the Sivers effect are shown as a function of particle-jet p_T (left) for the full pseudorapidity acceptance and (right) in bins of pseudorapidity. In either case, the measured asymmetries are quite small, consistent with expectation from measurements at $\sqrt{s} = 200$ GeV [8–12] as well as model predictions [13].

The left-hand panel of Fig. 2 shows Collins asymmetries as a function of $z = p_\pi / p_{jet}$ for both forward ($x_F > 0$) and backward ($x_F < 0$) scattering. As expected from the increase in gluonic subprocesses, Collins asymmetries are quite small and statistically consistent with zero. Similarly, Collins asymmetries are small when evaluated as a function of pion j_T (transverse momentum relative to the jet thrust axis) and particle-jet p_T. Analysis of the remaining high-p_T triggers from 2011, as well as STAR's high-statistics dataset at $\sqrt{s} = 200$ GeV taken in 2012, should provide better sensitivity to effects from quark subprocesses [7, 11].

As the right-hand panel of Fig. 2 shows, "Collins-like" asymmetries fall well below the 2% upper-limit from model calculations, in particular at lower values of z, where models expect the largest effects [1]. In Fig. 3 "Collins-like" asymmetries are shown as a function of (left) pion j_T and (right) particle-jet p_T. These measurements cover the full range of pseudorapidity, combine forward and backward scattering, and are shown for four ranges of pion z. No large effects are observed, and the available precision should allow for the first model-prediction constraints beyond the positivity bounds.

References

[1] U. D'Alesio, F. Murgia, C. Pisano, Phys. Rev. D **83**, 034021 (2011)

[2] D. Sivers, Phys. Rev. D **41**, 83 (1990)

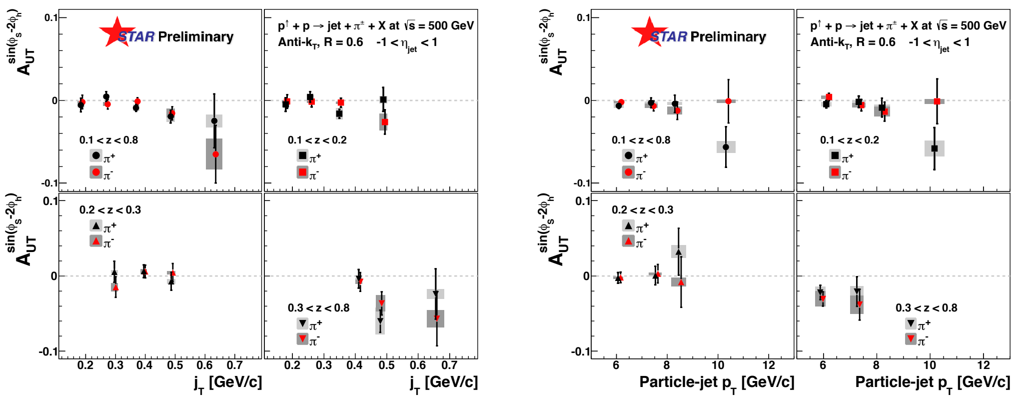

Figure 3. "Collins-like" asymmetries as a function of (left) pion j_T and (right) particle-jet p_T for four ranges of pion z. Asymmetries are integrated over the full acceptance and include forward and backward scattering.

[3] D. Sivers, Phys. Rev. D **43**, 261 (1991)

[4] J. Collins, Nucl. Phys. **B396**, 161 (1993)

[5] M. Anselmino, M. Boglione, U. D'Alesio, E. Leader, S. Melis, F. Murgia, Phys. Rev. D **73**, 014020 (2006)

[6] K. Ackermann et al. (STAR Collaboration), Nucl. Inst. & Meth. **A499**, 624 (2003), and references therein

[7] R. Fatemi (STAR Collaboration), AIP Conf. Proc. **1441**, 233 (2012), proceedings of the XIX Particles and Nuclei International Conference (PANIC11)

[8] S. Adler et al. (PHENIX Collaboration), Phys. Rev. Lett. **95**, 202001 (2005)

[9] B. Abelev et al. (STAR Collaboration), Phys. Rev. Lett. **99**, 142003 (2007)

[10] L. Adamczyk et al. (STAR Collaboration), Phys. Rev. D **86**, 032006 (2012)

[11] E. Aschenauer et al. (RHIC Spin Collaboration), *The RHIC SPIN Program: Achievements and Future Opportunities*, arXiv:1304.0079

[12] A. Adare et al. (PHENIX Collaboration), arXiv:1312.1995

[13] K. Kanazawa, Y. Koike, Phys. Lett. B **720**, 161 (2013)

[14] W. Llope et al., Nucl. Inst. & Meth. **A522**, 252 (2004)

[15] J. Zhou, Master's thesis, Rice University, Houston, Texas (2006)

[16] M. Cacciari, G.P. Salam, G. Soyez, J. High Energy Phys. **04**, 063 (2008)

[17] G.G. Ohlsen, P.W. Keaton, Nucl. Inst. & Meth. **109**, 41 (1973)

[18] T. Sjöstrand, S. Mrenna, P. Skands, J. High Energy Phys. **05**, 026 (2006)

[19] P.Z. Skands, Phys. Rev. D **82**, 074018 (2010)

[20] R. Brun et al., *GEANT3* (1987), CERN-DD-EE-84-1

[21] R. Brun, F. Carminati, S. Giani, *GEANT Detector Description and Simulation Tool* (1994), CERN-W5013, CERN-W-5013