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, with a particular focus on spin asymmetries involving jet production.

A major goal of the RHIC spin program is to determine the gluon polarization (*i.e.*, helicity) in the proton over a wide range of *x*. The longitudinal double-spin asymmetry, A_{LL}, for inclusive jet production is an ideal tool in this effort because the cross section is large and dominated by quark-gluon and gluon-gluon scattering processes, both of which have large partonic asymmetries. Texas A&M has played a leading role in STAR gluon polarization measurements for over a decade. During the past year, STAR published "Longitudinal double-spin asymmetry for inclusive jet and dijet production in *pp* collisions at $\sqrt{s}$ = 510 GeV" [1]. This describes the results of our former graduate student (now BNL post-doc) Dr. Zilong Chang's dissertation research, together with the results of former University of Kentucky graduate student Dr. Suvarna Ramachandran.

The paper provides a detailed description of the high-statistics STAR measurement of mid-rapidity jet and di-jet A_{LL} in 510 GeV *pp* collisions, based on data recorded during the 2012 RHIC run. Notably, it describes several substantial improvements in STAR jet asymmetry measurement techniques that were developed by Dr. Chang while he was a TAMU graduate student. These improvements lead to by far the best match that STAR has ever obtained for a wide range of jet properties in data *vs*. simulation, including detailed comparisons of the jet p_T spectra, the longitudinal (z) and transverse (j_T) fragmentation distributions within the jets, and the observed electromagnetic energy fractions. (See [1] for details.) They also lead to much smaller systematic uncertainties than were practical in any previous STAR jet A_{LL} measurement, as illustrated in the left panel of Fig. 1, and they enable completely new observables to be

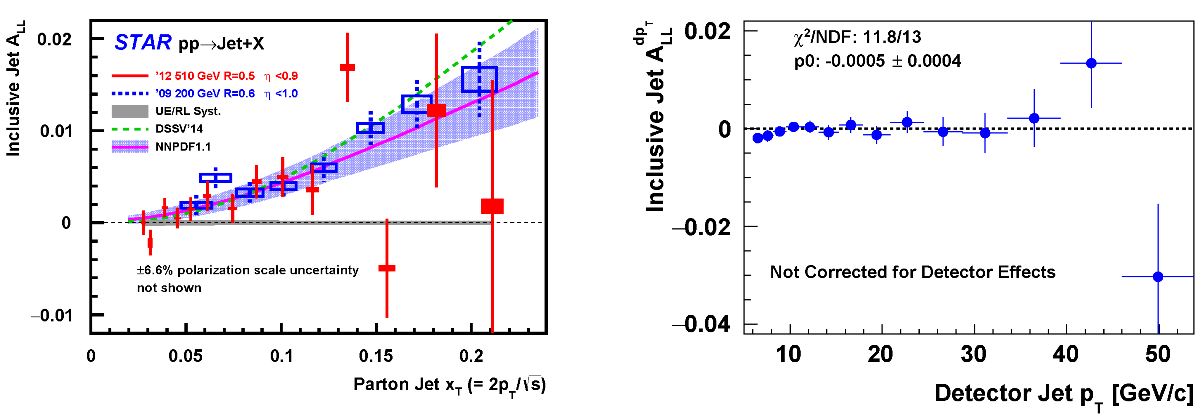

Fig. 1. (Left) The inclusive jet A_{LL} vs. jet p_T from the 510 GeV *pp* collision data that STAR recorded during 2012. (Right) A_{LL} for the underlying event from the same data set. See [1] for details.

investigated, such as the first-ever measurement of A_{LL} for the underlying event that accompanies jet production at RHIC, shown in the right panel of Fig. 1. These inclusive jet results provide important new constraints on the magnitude of the gluon polarization, especially in the range $0.015 < x < 0.1$. The di-jet results, which are separated into four different topology categories depending on the individual jet pseudorapidities, provide important new constraints on the shape of $\Delta g(x)$ over the same x range [1].

In parallel, we have been working on analysis of the azimuthal transverse single-spin asymmetries of identified hadrons within jets to measure the Collins effect, which involves the convolution of the quark transversity in the proton with the Collins fragmentation function. STAR recorded about 52 pb^{-1} of transversely polarized *pp* data at $\sqrt{s} = 200$ GeV during 2015, which is twice the luminosity sampled during 2012. These results will provide the most precise measurement of the Collins effect at this collision energy.

We have developed several new techniques to reduce systematic uncertainties. For the particle identification (PID), we use the particle ionization energy loss (dE/dx) and particle mass measured with the Time Projection Chamber (TPC) and Time of Flight (TOF). A new likelihood method has been developed to calculate the corresponding particle fractions in the sample that makes full use all of the information we can get from the detector. Pure samples of charged pions and protons are identified as the weak decay daughters of Λ and K_S. TOF has a very good ability to select the low momentum charged kaons and electrons. We also use the electromagnetic calorimeter to identify high momentum electrons. With these four types of particles well determined, we are able to constrain the PID with very good precision.

The underlying events are also studied in this analysis using the off-axis cone method [1]. Underlying event subtractions are made for each reconstructed jet. The underlying event subtraction increases the matching fractions between the detector level jets and particle/parton level jets and reduces the differences in $\langle p_T \rangle$ between the different levels. We also set an upper limit on the j_T of hadrons included in the spin asymmetry measurements that substantially reduces the underlying event background while removing only a very small fraction of the true jet fragments. After these, we calculate the underlying event fractions in the sample and correct the measured asymmetries for these underlying event dilutions.

About 8M Pythia simulation events have been generated to correct for detector effects on the measured quantities and evaluate various systematic uncertainties. We found systematic deviations of the reconstructed *vs*. true jet pseudorapidity at the ends of the detector. This arises because the systematic missing jet energy at larger pseudorapidity biases the reconstruction of the thrust axis. We estimated the associated bias and make the corresponding corrections to the reconstructed jets. The systematic uncertainties due to the detector's non-uniform acceptance effect are significantly reduced after this correction.

Fig. 2 shows the preliminary results for the Collins asymmetries for identified $\pi^{\pm}$ as a function of the particle level jet p_T. These results are presented for jets that scatter both forward (top panel) and backward (bottom panel) relative to the polarized beam. The asymmetries are large and opposite in sign for π^+ and π^- with similar magnitude for jets coming from the polarized beam. These new asymmetries agree with previous reported results, and have 30% smaller uncertainties. In addition to Fig. 2, we have also obtained Collins asymmetries for charged pions *vs*. hadron z and j_T, Collins asymmetries for charged kaons *vs*. jet p_T, "Collins-like" asymmetries for charged pions, which are sensitive to the linear polarization of gluons in a transversely polarized proton convoluted with the gluon analog of the Collins fragmentation function, and various inclusive jet asymmetries. We are beginning to write the paper that will describe these various results.

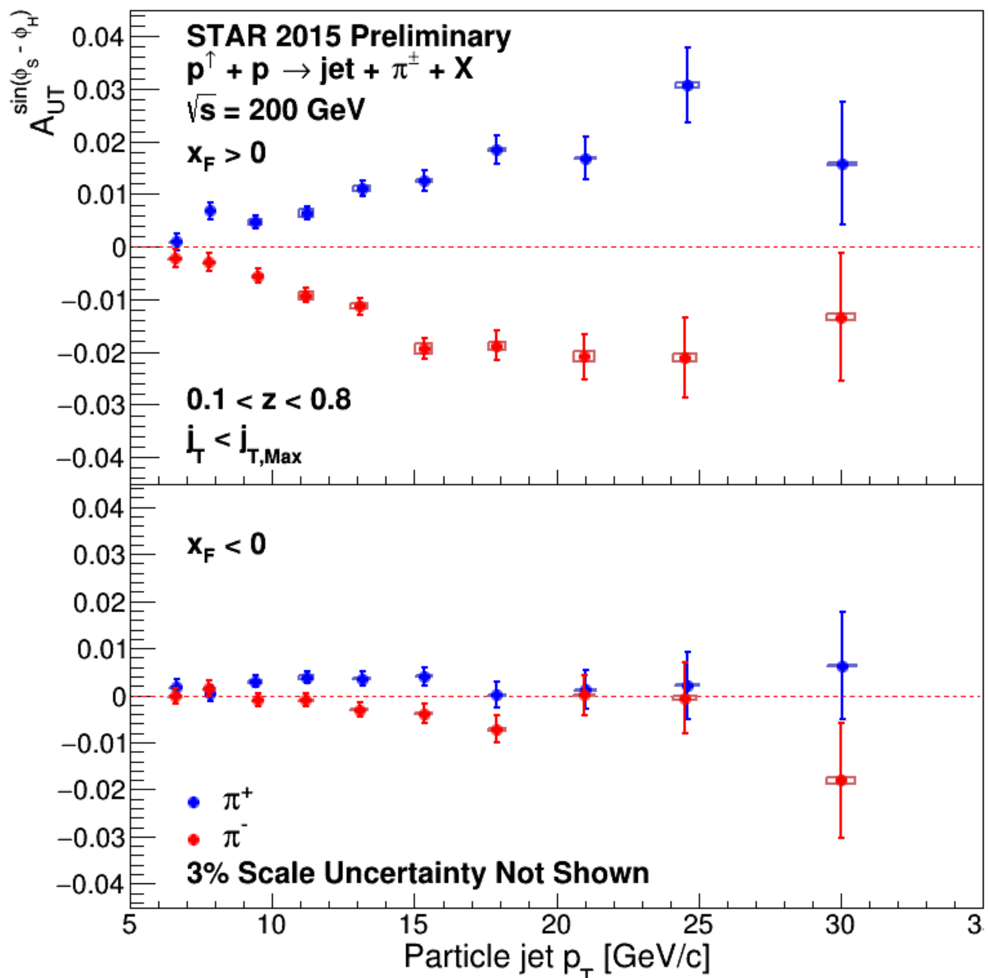

Fig. 2. Preliminary STAR Collins asymmetries in $\sqrt{s}$ = 200 GeV *pp* collisions for π^+ (blue) and π^- (red) as a function of particle-jet p_T.

Finally, we continue to carry various administrative responsibilities for STAR. Dr. Gagliardi is one of the two conveners of the STAR Cold QCD and Spin Physics Working Group. He is also serving on the god-parent committee for a STAR paper that describes measurements of weak boson cross sections and cross-section ratios in *pp* collisions at $\sqrt{s}$ = 510 GeV. Dr. Lin is serving as the software coordinator for the EEMC. He also served as STAR Period Coordinator for three weeks during the current RHIC run.

[1] J. Adam *et al*. (STAR Collaboration), Phys. Rev. D **100**, 052005 (2019).