Longitudinal Double-Spin Asymmetries for Di-jet Production at Intermediate Pseudorapidity in Polarized Proton Proton Collisions at $\sqrt{s} = 200$ GeV

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Motivation: Constraining $\Delta G$

Deep inelastic scattering measurements have found that the spin of the quarks ($\Delta \Sigma$) account for ~30% of the total spin of the proton, the rest must come from gluon spin ($\Delta G$) or orbital angular momentum ($L$) of the partons.

RHIC data have been added to the DSSV global analysis. Including the STAR 2009 inclusive jet results show, for the first time, a non-zero gluon polarization in our region of sensitivity.

The low $x$ behavior and shape of $\Delta g(x)$ are still poorly constrained. Recent data will extend our reach in $x$ using forward pion and jet results, and also using higher collision energies.
Exploring Gluon Polarization at RHIC

\[
A_{LL} = \frac{\sigma^{++} - \sigma^{-+}}{\sigma^{++} + \sigma^{-+}} = \frac{\sum_{a,b,c} \Delta f_a \otimes \Delta f_b \otimes d\hat{\sigma}_{f_af_b \rightarrow f_cX} \cdot \hat{a}_{f_cX} \otimes D_{f_c}^h}{\sum_{a,b} f_a \otimes f_b \otimes d\hat{\sigma}_{f_af_b \rightarrow f_cX} \otimes D_{f_c}^h}
\]

- For most RHIC kinematics, gg and qg dominate, making \(A_{LL}\) for jets and hadrons sensitive to gluon polarization.

- At the parton level, helicity correlations are very large in leading-order QCD.
Pushing to Lower X: Dijets at Forward Rapidity

\[ x_1 = \frac{1}{\sqrt{s}} \left( p_{T3} e^{\eta_3} + p_{T4} e^{\eta_4} \right) \]

\[ x_2 = \frac{1}{\sqrt{s}} \left( p_{T3} e^{-\eta_3} + p_{T4} e^{-\eta_4} \right) \]

\[ M = \sqrt{x_1 x_2 s} \]

\[ \eta_3 + \eta_4 = \ln \frac{x_1}{x_2} \]

\[ |\cos \theta^*| = \tanh \left| \frac{\eta_3 - \eta_4}{2} \right| \]

- Correlation measurements such as di-jets capture more information from the hard scattering and provide a more direct link to the initial kinematics than inclusive probes.

- Leading order expressions show how different jet configurations are sensitive to different kinematic values.

- Di-jets may place better constraints on the functional form of \( \Delta g(x,Q^2) \).

- More forward jets are indicative of more asymmetric collisions which will contain lower x partons.
Forward Rapidity Di-jet Topology

- Adding the Endcap opens up several new di-jet topologies.
- Forward jets probe lower values of gluon momentum fraction while selecting more asymmetric collisions.
- The large imbalance in momentum fractions, coupled with the unpolarized PDF's, suggests that $x_2$ is dominated by gluons, while $x_1$ are most often valence quarks.
Data-Simulation Comparison

- Simulation events created using PYTHIA which run through a STAR detector response model based on GEANT 3, and then embedded into Zero-Bias data.

- In general, we see good agreement between Run 9 data and simulation for single jet kinematic quantities.
Challenges and Methods

- TPC efficiency decreases in forward region
- Fewer tracks means reconstructed jets will have lower $P_T$ and jet mass on average

Endcap Region

Machine Learning: Multilayer Perceptron (MLP)

Variables: Endcap jet detector level $P_T$, detector eta, neutral fraction; Barrel jet $P_T$

Target: particle level jet $P_T$

• Barrel and Endcap jets are separately corrected in $P_T$ and mass using similar methods
• Di-Jet invariant masses are calculated using the shifted jet transverse momentum and mass from machine learning
Dijet Double Spin Asymmetry

- Di-jet $A_{LL}$ shown for two Barrel-Endcap topologies
- New results are compared to current DSSV14 and NNPDFpol1.1 expectations
- The forward dijet data will more tightly constrain predictions for gluon spin at lower momentum fraction