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The Dijet Cross Section Measurement in Proton-Proton Collisions at $\sqrt{s} = 500$ GeV

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These proceedings present the dijet cross-section measurement in proton-proton collisions at a $\sqrt{s} = 500$ GeV and a maximum rapidity range $|y|_{max} \leq 0.8$. This analysis is based on 8.7 pb^{-1} of data collected by the STAR detector during the 2009 RHIC run. This result shows agreement with theoretical next-to-leading order pQCD calculations, motivating the use of dijet asymmetries to further constrain the shape of $\Delta g(x)$.

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1. Introduction

The proton is not an elementary particle, but consists of fundamental particles known as quarks and gluons. Collectively referred to as partons, the interactions of these particles are described by Quantum Chromodynamics (QCD). A long-standing effort, both theoretically and experimentally, has been made to understand the origin of the intrinsic spin of the proton, which may be expressed as:

$$\frac{1}{2}\Delta\Sigma + L_q + \Delta G + L_g = \frac{1}{2} \tag{1.1}$$

where $\Delta\Sigma$ and ΔG represents the spin contribution from the quarks and gluons, and $L_{q(g)}$ the spin contribution from the quark (gluon) orbital angular momentum. [1]. Polarized deep inelastic scattering experiments observed that the quarks carry only a fractional portion of the overall proton spin $\sim 30\%$, [2] [3] refuting theories that the majority of the proton spin originates from the quark spin.

In the last decade, experiments at the Relativistic Heavy Ion Collider (RHIC) have focused on the inclusive jet, pion and photon measurements, which are sensitive to the polarized gluon distribution ($\Delta g(x)$). These results placed significant constraints on $\Delta g(x)$ indicating that, like $\Delta\Sigma$, the gluon contribution to the proton spin is not large [3]. These inclusive analyses, made at a center of mass energy ($\sqrt{s}$) of 200 GeV, are primarily sensitive to a limited kinematic range spanning $0.05 < x < 0.2$. In an effort to expand the kinematic coverage and reduce the uncertainty of the extraction of the total integral, these measurements are being extended to $\sqrt{s} = 500$ GeV. In addition, analysis of observed dijet events, a correlation measurement, are being examined. This measurement, unlike the inclusive observables, permits the reconstruction of Bjorken x_1 and x_2 at leading order.

The dijet cross-section measurement is an important test of the perturbative QCD (pQCD) framework which will ultimately be used to extract $\Delta g(x)$ from the dijet asymmetries. Agreement between data and next-to-leading-order (NLO) QCD theory confirms that the jet energy scale is understood and trigger and detector biases are properly corrected. The dijet cross section is defined as:

$$\frac{d^2\sigma}{dMd|y|_{max}} = \frac{1}{\int Ldt} \cdot \frac{1}{\Delta M \Delta |y|_{max}} \cdot J \tag{1.2}$$

where J is the corrected dijet yields, $\int Ldt$ is the integrated luminosity, ΔM is the invariant mass bin size, and $\Delta|y|_{max}$ is the maximum absolute rapidity of the two jets.

In 2009 approximately 8.7 pb^{-1} of RHIC data from proton-proton collisions were analyzed at the Solenoid Tracker at RHIC (STAR) using for the first time, center of mass energies of 500 GeV. The STAR detector's large acceptance in rapidity and full azimuthal coverage allows jet reconstruction using the Time Projection Chamber (TPC), Barrel (BEMC) and Endcap electromagnetic calorimeters (EEMC)[4]. The jets were constructed from the four-momentum of the charged particle tracks detected in the TPC ($-1.3 < \eta < 1.3$) and the electromagnetic energy deposits in the BEMC ($-1.0 < \eta < 1.0$). To prevent an overestimation of the jet energy, a 100% hadronic subtraction scheme was implemented. This approach subtracts the track four-momentum from the four-momentum of the tower it struck. Events were selected that satisfied the jet patch (JP) trigger, which required $\sim$13 GeV of energy to be deposited into a 1.0 x 1.0 region of $\eta - \phi$ space in the

BEMC and/or EEMC. The absolute luminosity was determined using the vernier scan technique [5].

2. Analysis and Results

The anti-k_T algorithm with a radius of 0.6 as implemented in FastJet[6] was used for jet reconstruction and provides an infrared and collinear safe algorithm needed for theoretical calculations. It is also less sensitive to higher order and hadronization corrections than the previously used mid-point cone algorithm [7]. Events with more than one jet were selected as a possible dijet event. The two jets with highest transverse momentum (p_T) were considered and then required to be back-to-back $\Delta\phi > 2.0$ and within the detector's acceptance $|\eta_{det}| < 0.7$. One jet in the pair was required to match the geometric region of the fired JP in the BEMC, ensuring the reconstructed dijet caused the trigger for that event. In an effort to reduce beam background contributions to the jet energy at least one of the jets was required to have a neutral energy fraction requirement < 0.98. Finally, a theoretically motivated asymmetric p_T cut max(p_T) > 13.0 GeV and min(p_T) > 10.0 GeV was applied. The reconstructed jet p_T and η provide access to the initial partonic kinematics at leading order according to the following:

$$x_1 = \frac{1}{\sqrt{s}}\left(p_{T3}e^{\eta_3} + p_{T4}e^{\eta_4}\right) \tag{2.1}$$

$$x_2 = \frac{1}{\sqrt{s}}\left(p_{T3}e^{-\eta_3} + p_{T4}e^{-\eta_4}\right) \tag{2.2}$$

$$\cos(\theta^*) = \tanh\left(\frac{\eta_3+\eta_4}{2}\right) \tag{2.3}$$

where x_1 and x_2 are the initial parton momentum fractions and η_3 and η_4 are the pseudorapidities of the measured jets in the event.

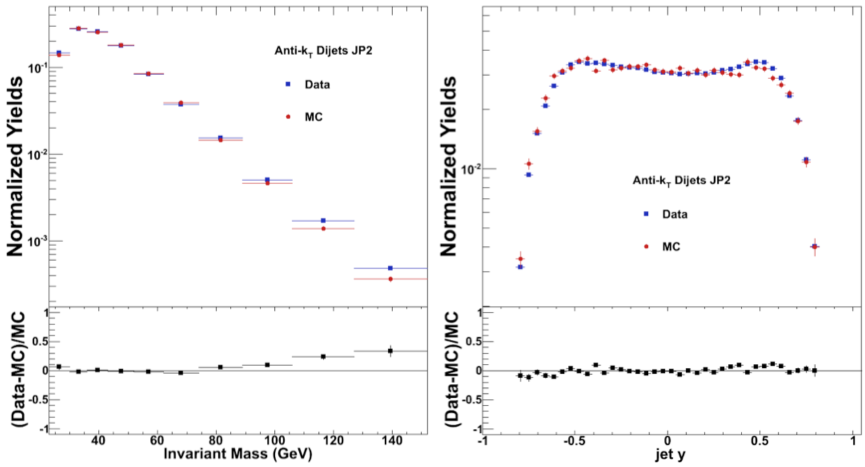

Figure 1: Invariant mass (left) and jet η (right) comparison of the data (blue) and the Monte Carlo embedding (MC) sample (red).

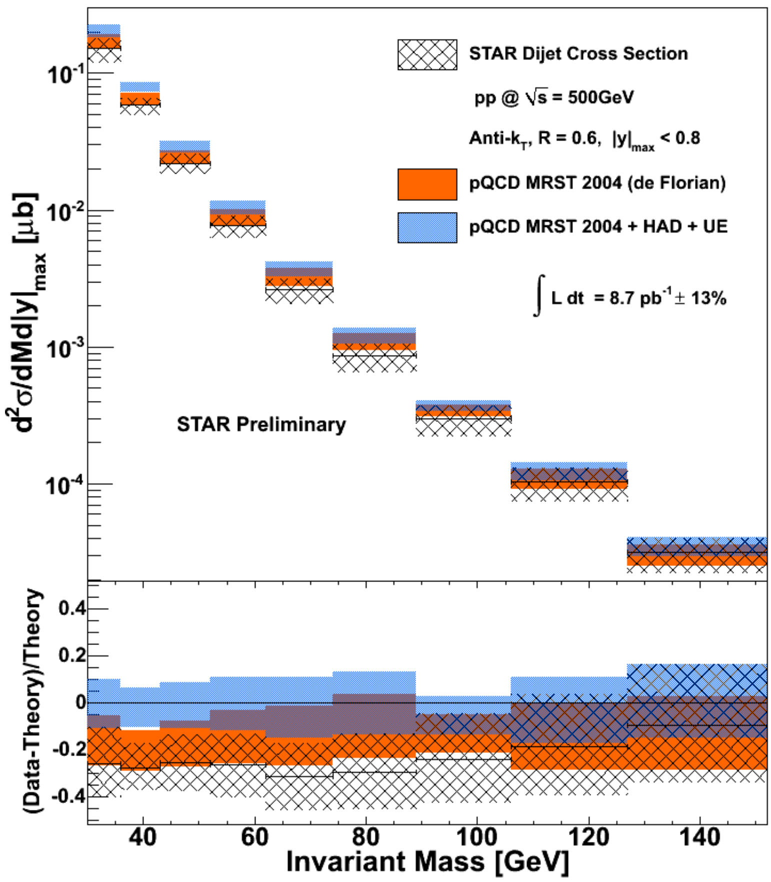

Figure 2: The 2009 dijet cross section measurement for proton-proton collisions at $\sqrt{s} = 500$ GeV shown in the top panel. The bottom panel plots the ratio of the data (hashed) and the pQCD theory (orange) divided by the pQCD theory with the hadroniztation and underlying event corrections applied.

Invariant mass bin migrations, caused by detector resolution and inefficiencies, were corrected using an embedded simulation sample of 83M events. The embedding sample takes zero-bias data, events randomly selected throughout the run, and embeds simulated events generated using PYTHIA version 6.4 [8] with Tune 320 (Perugia 0) [9]. The STAR detector response was simulated using GEANT 3 package[10]. This procedure incorporates features of the STAR event, such as pile-up tracks and background, that cannot be easily simulated. This unique simulation sample also implemented two filters: a dijet pythia level filter and a trigger reconstruction filter. These filters improve signal extraction and reduce CPU time by removing events that would likely fail dijet reconstruction and detector level trigger criteria. These filters were optimized to ensure negligible bias on the final samples. Comparisons of the data and detector level simulation kinematics, as shown in Fig 1, agreed extremely well.

The Singular Value Decomposition (SVD) method [11] implemented in the RooUnfold package [12] was used to unfold the raw dijet yields from the detector level to the particle or parton level. This method takes into account the proper error of the unfolding matrix. This allows for a proper comparison of the data to the theoretically calculated NLO pQCD dijet cross-section, which incorporated the MRST2004 parton distribution functions [13] [14]. The underlying event (UE) and hadronization (HAD) corrections are determined by extracting the cross-section at the parton level, which is then subtracted from the particle level. This difference is then added to the theoretical calculation. Fig 2 shows the dijet cross-section of the theoretical calculation with (without) the underlying event and hadronization effects considered in cyan (orange) as a function of the invariant mass. The cross-hatched boxes show the distribution of the data. There are four major systematics examined: the overall luminosity($\pm 13\%$), the track efficiency ($\pm 7\%$), track momentum resolution ($\pm 1\%$), and the tower energy resolution ($\pm 5\%$). The width of the distribution represents the size of the systematic errors added in quadrature but does not include the luminosity uncertainty.

3. Conclusions

STAR has measured the proton-proton dijet cross section at $\sqrt{s}$ =500 GeV using the anti-k_T algorithm with $R = 0.6$. The experimental measurement is systematically lower than theoretical predictions, but show good agreement within systematic errors. This measurement sets the stage for future dijet asymmetry measurements for data with improved polarizations, which will allow access to the shape of $\Delta g(x)$ at lower momentum fraction, x, where the gluons dominate the structure of the proton.

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