Measurement of the Triple Differential Jet Cross Section at $\sqrt{s} = 1800$ GeV

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We present a measurement of the triple differential cross section for dijet production in proton-antiproton scattering at a center of mass energy of 1800 GeV. The data were taken with the DØ detector at the Fermilab Tevatron and are compared to next to leading order QCD theoretical predictions with differing parton distribution functions. The data are of sufficient accuracy to rule out or favor parton distribution functions over a wide range in x.

1. INTRODUCTION

The cross section for producing jets of particles in proton-antiproton is directly related to the product of parton distribution functions and a hard parton scattering cross section. If fragmentation effects are small, the cross section for dijet production is

$$\frac{d^3\sigma}{d\eta_1 d\eta_2 dE_T} = \sum_{ij} x_1 x_2 f_i(x_1,\mu^2)\overline{f}_j(x_2,\mu^2) \times \hat{\sigma}(1+2 \to a+b;\mu^2) \quad (1)$$

where η is the pseudo-rapidity of a jet, E_T the transverse energy of a jet, the sum is over parton flavors i, j, f_i and $\overline{f}_j$ are the probabilities of finding partons of type i or j carrying momentum fraction x of the proton or antiproton; $\hat{\sigma}$ is the partonic scattering cross section and μ^2 is the factorization scale in the calculation.

To zeroeth order, only two partons are produced in the final state and the momentum fractions x_1 and x_2 of the initial state partons can be reconstructed from the final state jet parameters:

$$x_1 \simeq \frac{E_T}{\sqrt{s}}e^{\eta_a} + \frac{E_T}{\sqrt{s}}e^{\eta_b} \quad (2)$$

$$x_2 \simeq \frac{E_T}{\sqrt{s}}e^{-\eta_a} + \frac{E_T}{\sqrt{s}}e^{-\eta_b} \quad (3)$$

where s is the proton-antiproton center of mass energy, E_T is the transverse momentum of the jets and $\eta_{a,b}$ are the pseudo-rapidities of the jets.

Measurement of the triple differential cross section over a large range in η and E_T probes the parton distribution functions over a wide range in x. The DØ collaboration has measured [1] the triple differential cross section as a function of E_T over the range $|\eta| \leq 2$ for the special case $\eta_1 = \pm\eta_2$. Events with $\eta_1 \approx \eta_2$ are denoted same-side while those with $\eta_1 \approx -\eta_2$ are opposite-side events. The x range covered in this measurement is approximately $0.005 \leq x \leq 0.7$

The DØ liquid argon calorimeter [2] was the primary detector component used in the measurement. We used a modified Snowmass cone algorithm [4] to find jets within a cone of radius $R = 0.7$ in $\eta\phi$ space, where ϕ is the azimuthal angle about the beam direction. Studies [4] of overlapped jets from separate events have shown that the DØ cone algorithm on average merges jets separated by less than $1.3R$ and resolves them if they are more than $1.3R$ apart. This observed R_{sep} behavior is included in the theoretical estimates of the cross section.

We determined the jet energy scale by first measuring the electromagnetic energy scale with π^0, Υ, Z^0 decays. We then used photons recoiling against jets to transfer the electromagnetic scale to hadronic jets [3]. The energy scale is by far the dominant source of systematic error in the jet cross sections, contributing fractional errors of between 8% and 40%. The second largest source of error, luminosity, is 4.5% and dominated by uncertainties in the value of the total proton-antiproton scattering cross section.

We used E_T balance in dijet events to measure both the energy measurement resolution and the effects of vertex smearing on the measured E_T. The data presented have been corrected for these smearing effects.

Theoretical predictions of the triple differential cross section were generated using the JETRAD next-to-leading-order QCD predictions of Giele, Glover and Kosower [5]. Trial parton distributions from both the CTEQ [6] and MRST [7] sets were used. The renormalization and factorization scales were set to $E/2$ where E is the jet energy. Use of E_T instead of E as the scale does not significantly change the calculation.

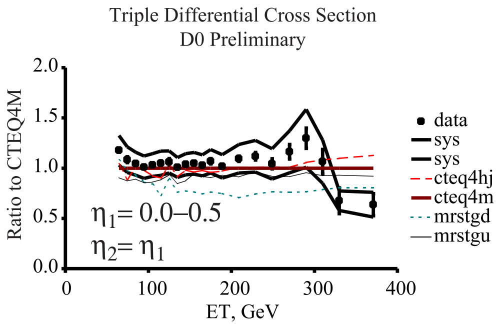

Figure 1. The triple differential cross section compared to various theoretical predictions as a function of E_T for same-side jets in the central η region $0.0 < |\eta| < 0.5$. All cross sections are normalized to the CTEQ4M prediction.

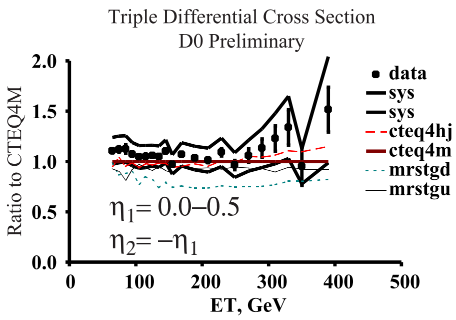

Figure 2. This figure shows the same normalized cross sections as Fig. 1 for opposite-side jets.

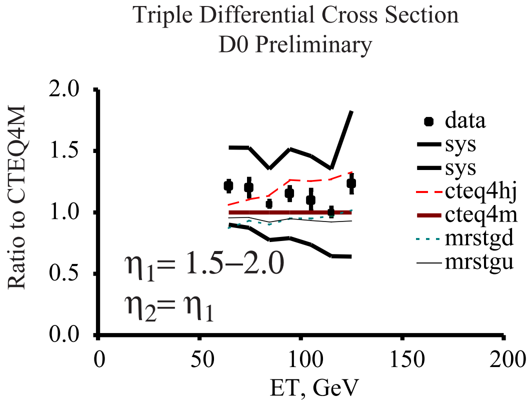

Figure 3. The triple differential cross section compared to various theoretical predictions as a function of E_T for same-side jets in the extreme η region $1.5 < |\eta| < 2.0$. All cross sections are normalized to the CTEQ4M prediction.

Figs. 1-4 show a comparison of the data with the theoretical predictions for the most and least central of the eight η bins studied. Each event appears twice in the plots. For each event, the η bin is determined from the direction of the two leading jets and entries are made at the E_T values of both leading jets. The data points are shown with statistical errors. The dark lines show the estimated systematic error and the lighter curves show the theoretical predictions for various models.

We conclude that the data are sensitive to the choice of parton distribution function and capable of distinguishing between them. Strong correlations between the systematic errors from bin to bin make quantitative statements difficult but the MRSTU and CTEQ4M sets appears to agree best with the DØ data.

REFERENCES

1. G. Di Loreto, "The Triple Differential Di-Jet Cross Section at sqrt(s) = 1.8 TeV", Doctoral thesis, Michigan State University, 1998.
2. S. Abachi *et al.*, Nucl. Instr. Meth. Phys. Res. **A338** (1994) 185.

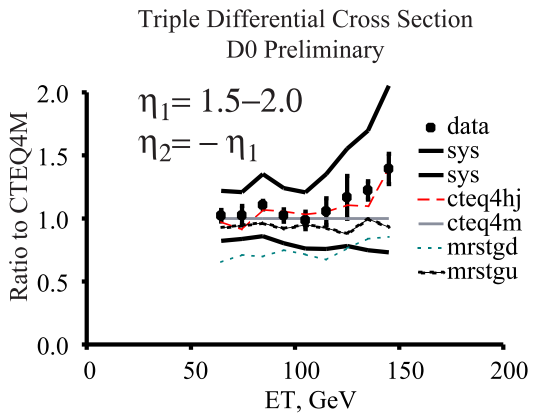

Figure 4. This figure shows the same normalized cross sections as Fig. 3 for opposite-side jets.

3. B. Abbott *et al.*, Nucl. Inst. Meth. Phys. Res. **A424** 352 (1999) 352.
4. B. Abbott *et al.*, Fermilab-Pub-97/242-E (1997).
5. W.T. Giele, E.W.N. Glover, and D.A. Kosower, Phys. Rev. **D52** (1995) 1486.
6. R. Huston *et al.*, Phys. Rev. **D58** (1998) 114034.
7. A.D. Martin *et al.*, Eur. Phys. J. **C4** 463 (1998) 463.