CENTRAL AND FORWARD INCLUSIVE JETS AT THE TEVATRON

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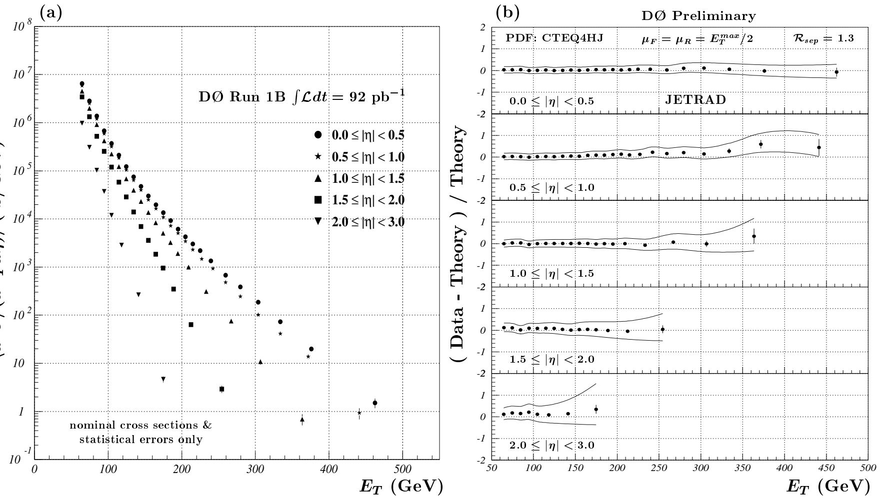
We report on a new measurement of the rapidity dependence of the inclusive jet production cross section in $p\overline{p}$ collisions at $\sqrt{s} = 1.8$ TeV using 92 pb^{-1} of data collected by the DØ detector at the Tevatron collider. The differential cross sections, $\langle d^2\sigma/(dE_T d\eta)\rangle$, are presented as a function of jet transverse energy (E_T) in five pseudorapidity (η) intervals, up to $|\eta| = 3$, significantly extending previous CDF and DØ measurements beyond $|\eta| = 0.7$. The extended range of the measurement should provide greater discrimination among different parton distribution functions. We also discuss previous measurements of the inclusive jet cross sections made by the two collider experiments at central pseudorapidities up to $|\eta| = 0.7$. Finally, we present recent measurements from the CDF and DØ experiments of the ratio of central inclusive cross sections from two center-of-mass energies, 0.63 TeV and 1.8 TeV, as a function of jet x_T. Experimental results are compared to next-to-leading order QCD predictions.

1 Jet Cross Sections — Tests of QCD

In the last decade of the 20th century, high energy physics saw impressive progress made in both theoretical and experimental understanding of collimated streams of particles or "jets" resulting from inelastic hadron collisions. The Fermilab Tevatron $p\overline{p}$ Collider, operated at center-of-mass energies of 0.63 TeV and 1.8 TeV, has been a prominent arena for studying hadronic jets. Theoretically, jet production in $p\overline{p}$ collisions is understood within the framework of quantum chromodynamics (QCD) as a hard scattering of constituents of protons, the quarks and gluons (or partons) that manifest themselves as jets in the final state. Studying various jet cross sections in CDF and DØ, therefore provides stringent tests of QCD.

Perturbative QCD calculations of jet cross sections [1], using new and accurately determined parton distribution functions (PDFs) [2], add particular interest to the corresponding measurements at the Tevatron. These measurements test the short range behavior of QCD, the structure



(c)

$$\chi^2 = \sum_{i,j} (D_i - T_i) \times \left[\mathrm{Cov}^{full}_{i,j}\right]^{-1} \times (D_j - T_j)$$

$$\mathrm{Cov}^{full}_{i,j} = \sum_{\beta}^{errors} \rho^{\beta}_{i,j} \times \sigma^{\beta}_{i} \times \sigma^{\beta}_{j}$$

PDF	$0.0 \le \|\eta\| < 0.5$	$0.1 \le \|\eta\| < 0.7$
CTEQ3M	26.1 (35%)	33.2 (10%)
CTEQ4M	20.5 (67%)	27.2 (30%)
CTEQ4HJ	16.6 (86%)	22.3 (56%)
MRSA'	20.8 (65%)	28.8 (23%)
MRST	25.2 (40%)	29.5 (20%)
MRSTg↑	21.5 (61%)	30.1 (18%)
MRSTg↓	47.3 (0.003%)	47.5 (0.003%)

Figure 1: DØ measurement of rapidity dependence of single inclusive jet production cross section presented as a function of jet E_T in five jet η intervals (a), comparisons with α_s^3 QCD predictions calculated by JETRAD with CTEQ4HJ PDF (b). Table (c) shows χ^2 values and corresponding probabilities for 24 degrees of freedom for the previous DØ measurement of the inclusive jet cross section in two central intervals of pseudorapidity.

of the proton in terms of PDFs, and any possible substructure of quarks and gluons. The measurements we report are based on integrated luminosities of 87 and 92 pb^{-1} collected by the CDF and DØ experiments, respectively, during the 1994–95 Tevatron run. In both experiments, jets are reconstructed using an iterative cone algorithm with a fixed cone radius of $\mathcal{R} = 0.7$ in $\eta - \varphi$ space, where the pseudorapidity η is related to the polar angle (from the beam line) θ via $\eta = \ln[\cot\theta/2]$ and φ is the azimuth. Offline data selections eliminate contamination from background caused by electrons, photons, noise, or cosmic rays. This is achieved by applying an acceptance cutoff on the z–coordinate of the interaction vertex, flagging events with large missing transverse energy, and applying jet quality criteria. Details of data selection and corrections due to noise and/or contamination are described elsewhere [3,4]. A correction for jet energy scale accounts for instrumental effects associated with calorimeter response, showering and noise, as well as for contributions from spectator partons, and corrects on average jets from their reconstructed to their "true" E_T. The effect of calorimeter resolution on jet cross section is removed through an unfolding procedure. In DØ, the energy scale and resolution corrections are determined mostly from data, and applied in two separate steps, while the CDF corrections are implemented in a single step by means of a Monte Carlo tuned to their data.

2 Inclusive Jet Cross Sections at $\sqrt{s} = 1.8$ TeV

DØ has recently completed a measurement of the rapidity dependence of the inclusive jet production cross section [4]. The differential cross section, $\langle d^2\sigma/(dE_T d\eta)\rangle$, is determined as a function of jet transverse energy in five intervals of $|\eta|$, up to $|\eta| = 3$, thereby significantly extending previously available measurements from CDF and DØ beyond $|\eta| = 0.7$. The cross section is calculated from the number of jets in each η–E_T bin, scaled by the integrated luminosity, selection efficiencies, and the unfolding correction. The measurement in each of the five $|\eta|$ regions is presented in Fig. 1a. The measurement spans about seven orders of magnitude in E_T, and extends to the highest energies ever reached.

The results are compared to the α_s^3 predictions from JETRAD (Giele, *et al.* [1]), with equal renormalization and factorization scales set to $E_T^{max}/2$, and using the parton clustering parameter $\mathcal{R}_{sep} = 1.3$. Comparisons have been made using all recent PDFs of the CTEQ and MRST

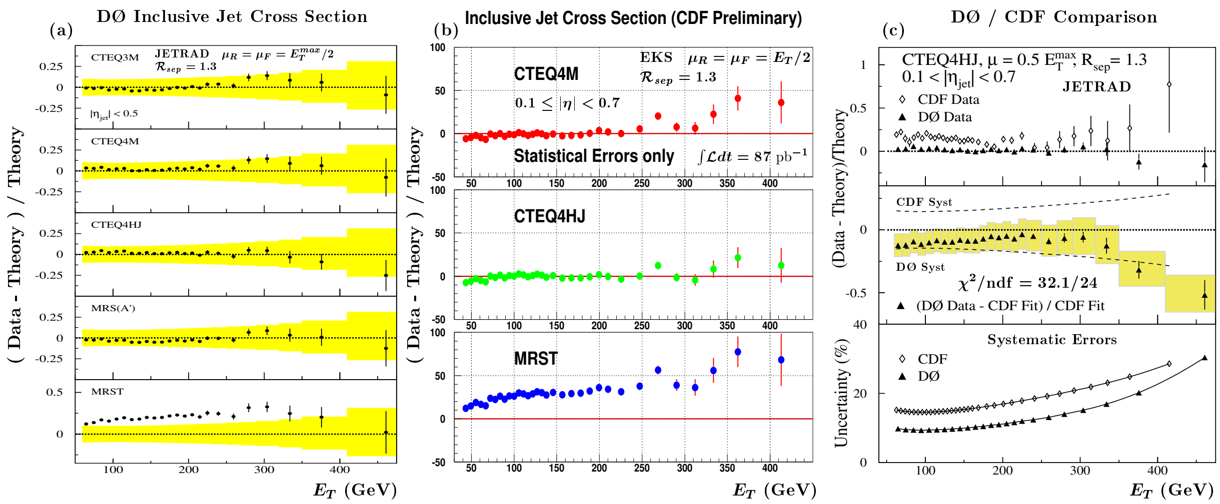


Figure 2: Comparisons of the DØ (a) and the CDF (b) measurements of the central inclusive jet cross section with theoretical predictions. The error bars are statistical, while the error bands indicate systematic uncertainties (the latter not presented in the CDF plot). Different η regions and different calculations (JETRAD and EKS) are used in the two experiments. A comparison of the two experimental results with the *same* theoretical prediction (JETRAD), as well as a direct comparison between the two data sets, is shown in (c).

families. Figure 1b shows the comparisons on a linear scale with the CTEQ4HJ PDF, which appears to best describe the data in all η intervals. The error bars are statistical, while the error bands indicate 1 standard deviation systematic uncertainties. Theoretical uncertainties are on the order of the systematic errors. Work is currently underway to obtain a more quantitative comparison with predictions (such as a χ^2 test), taking into consideration correlations in E_T and in η. The extended range of the measurement promises to provide greater discrimination among different PDFs.

DØ and CDF previously measured inclusive jet cross sections at central η values of $|\eta| < 0.5$ and $0.1 \le |\eta| < 0.7$, respectively. The comparisons on a linear scale between the DØ measurement in the central $|\eta| < 0.5$ region and theoretical predictions with various PDFs are shown in Fig. 2a. Furthermore, the quantitative test of agreement between data and theory has been devised based on a χ^2 statistic using the full covariance matrix of experimental uncertainties, thereby accounting for correlations in E_T among different sources of error. The χ^2 values for the $|\eta| < 0.5$, and various PDFs used in calculations, are presented in the Table in Fig. 1c. For purposes of comparison with the CDF measurement, DØ has also measured the inclusive jet cross section in the $0.1 \le |\eta| < 0.7$ interval, and the corresponding χ^2 values are also summarized in the right hand column of the same Table. Although CTEQ4HJ PDF shows best agreement with the measurement, agreement with most other PDFs is also acceptable.

CDF compares its inclusive cross section in the $0.1 \le |\eta| < 0.7$ interval to predictions from EKS (Ellis, *et al.* [1]), with slightly modified input parameters. These comparisons are presented on a linear scale in Fig. 2b, showing only statistical errors. Good agreement is observed between data and theory when systematic experimental uncertainties are included. Finally, at the top of Fig. 2c is shown a comparison of CDF and DØ central inclusive jet cross sections to the *same* predictions generated using JETRAD with CTEQ4HJ. The direct comparison of the two measurements is shown in the middle plot, while the bottom plot gives the size of the systematic uncertainties in the CDF and DØ results. Adding the fitted CDF systematic errors in quadrature to the DØ covariance matrix, and using this matrix to calculate the χ^2 of agreement between the two data sets, yields $\chi^2 = 32.1$ for the 24 degrees of freedom; This corresponds to about 12% of probability—a reasonable level of agreement, especially given the different experimental techniques employed in the two measurements.

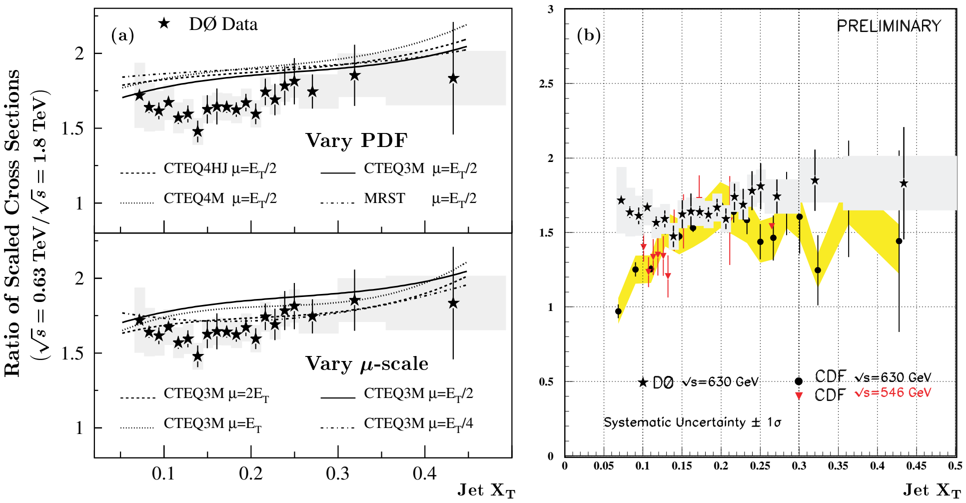


Figure 3: DØ measurement of the ratio of central inclusive jet cross sections from two center-of-mass energies, 0.63 TeV and 1.8 TeV, along with predictions obtained from JETRAD (a). The error bars are statistical, while the error bands indicate systematic uncertainties. CDF measurements of the ratios corresponding to two slightly different low center-of-mass energies overlaid with the DØ measurement (b).

3 The Ratio of Inclusive Jet Cross Sections

DØ and CDF Collaborations have recently measured the dimensionless ratio of inclusive jet cross sections at two center-of-mass energies, $\sqrt{s} = 0.63$ TeV and 1.8 TeV, in the central region of pseudorapidity. The strength of this measurement is that several theoretical uncertainties (notably due the choice of various PDFs) are reduced significantly in the ratio, as are many experimental uncertainties due to their correlated nature at the two energies. Figure 3a presents the DØ measurement of the ratio as a function of jet $x_T = 2E_T/\sqrt{s}$, along with theoretical predictions from JETRAD for different choices of the input parameters. Good agreement between theory and data is observed in the shape, and the normalization appears to be in agreement within 1–2 standard deviations. The measurement of the ratio made by the CDF Collaboration is shown in Fig. 3b with DØ data points overlaid to facilitate visual comparison of the two measurements. The data sets from two experiments are qualitatively consistent at mid and high values of jet x_T. At low x_T, the measurement is more difficult, and there are theoretical issues that could lead to disagreement with data, as well as between experiments. Phenomenological choices can be made that provide better agreement with the data. Work is underway to obtain a quantitative measure of agreement between the measurements and the predictions.

References

1. W.T. Giele, E.W.N. Glover, and D.A. Kosower, Phys. Rev. Lett. **73**, 2019 (1994); S.D. Ellis, Z. Kunszt, and D.E. Soper, Phys. Rev. Lett. **64**, 2121 (1990); F. Aversa *et al.*, Phys. Rev. Lett. **65**, (1990).
2. H.L. Lai *et al.*, (CTEQ Collaboration) Phys. Rev. **D51**, 4763 (1995); A.D. Martin *et al.*, (MRST Collaboration) Eur. Phys. J. **C4**, 463 (1998).
3. F. Abe *et al.*, (CDF Collaboration), Phys. Rev. Lett. **77**, 438 (1996); B. Abbott *et al.*, (DØ Collaboration), Phys. Rev. Lett. **82**, 2451, (1999).
4. L. Babukhadia, "Rapidity dependence of the single inclusive jet cross section in $p\overline{p}$ collisions at $\sqrt{s} = 1.8$ TeV with the DØ detector", Ph.D. Dissertation, University of Arizona, Tucson, Arizona, USA (1999); http://fnalpubs.fnal.gov/archive/1999/thesis/t-babukhadia.ps.