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FERMILAB-Conf-99/131-E
CDF and D0

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May 1999

Published Proceedings of the *American Physical Society (APS) Meeting of the Division of Particles and Fields (DPF)*, Los Angeles, California, January 5-9, 1999

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy

CDF/PUB/JET/PUBLIC/4965
April 23, 1999

The Dijet Mass Cross Section at the Tevatron *

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We present recent results on dijet production in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV at the Fermilab Tevatron. Data from both CDF and D0 experiments are shown. Dijet measurements complement prior inclusive jet measurements, which have shown a possible excess above expectations at high transverse energy. The same trend is seen in the dijet mass spectra.

I. INTRODUCTION

At a center of mass energy of 1.8 TeV, high transverse energy jet production from hadron beams probes the small-scale structure of the proton down to 10^{-4} fm. Measurements of the dijet mass spectrum and angular distributions can be used to check consistency with QCD, constrain parton distribution functions, or constrain new physics such as quark compositeness. A previous analysis of the inclusive jet cross section by the CDF collaboration [1] reported an excess of jet production at high E_T, while the corresponding analysis by the D0 collaboration [2] reported no such excess. The dijet mass measurements complement the inclusive jet cross-section measurements because both of the leading jets are included, and the angle between the jets is a part of the mass equation. This talk shows new results from CDF, and recent results from D0 on the dijet mass spectrum. We will show that the CDF and D0 collaborations have done their dijet analyses in ways which allow comparison of the results between the experiments. In addition, the dijet data sample is used by the D0 collaboration to place stringent limits on the energy scale of a possible quark compositeness interaction.

II. CDF DIJET ANALYSIS

The new CDF dijet mass distribution [3] uses a sample of 87 pb^{-1} from Run 1b which was selected online by inclusive jet triggers with E_T thresholds of 50, 70, and 100 GeV. The 50 and 70 GeV jet samples were prescaled. Events were required to contain at least two jets, using cone clustering with a radius of 0.7. The two jets having the highest energies were required to lie within $|\eta| < 2.0$, and the center-of-mass angle between the jets had to satisfy $|cos\theta^*| < 2/3$. Jet energy corrections were applied to correct for calorimeter response variations and underlying event contributions, but not to correct for out-of-cone energy. The resulting "partially corrected" dijet mass is defined using the momentum vectors of each calorimeters cell in the two highest-E_T jets. This mass spectrum is then fit to a function containing four parameters over 5 orders of magnitude in cross-section. The fit yields a $\chi^2 = 17.9$ for 12 degrees of freedom. This mass spectrum is a convolution of the true distribution and the detector resolution. The large number of low-mass events increases the observed cross-section at all masses. A correction of $1.02 - 1.15$ (depending on dijet mass) is well-determined by the steepness of the partially corrected dijet spectrum plus the known detector

*Submitted to the Proceedings of the DPF99 conference at UCLA, January 1999.
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resolution. The partially corrected spectrum is divided by this correction factor to obtain the unsmeared dijet mass spectrum shown on a logarithmic scale over many decades of cross-section in Figure 1.

The uncertainties in the dijet cross-section measurements are dominantly systematic in nature, and are highly correlated between the dijet mass bins. Uncertainties in the absolute energy scale for jets are the largest source of variation: energy scale uncertainties of less than 3% give cross-section variations as large as 30%. The NLO QCD theory curve which is plotted with the data in Figure 1 uses the JETRAD version 2.0 parton level simulation program, using CTEQ4M parton distributions, and a scale $\mu = 0.5 E_T^{max}$. The comparison of data to the QCD predictions is more precisely visible on the linear scale of Figure 2, which shows the range of predictions given by several parton distribution sets, as well as the highly correlated systematic error. The effect of an energy scale shift would be to move all of the points up or down together, and thus it is difficult to fit the shape of the discrepancy within the systematic errors.

III. D0 DIJET ANALYSIS AND COMPARISON TO CDF

The D0 dijet mass measurement [4] uses 92 pb^{-1} from Run 1b which was selected online by inclusive jet triggers with E_T thresholds of 30, 50, 85, and 115 GeV. The 30, 50, and 85 GeV jet samples were prescaled. Events were required to contain at least two jets, using cone clustering with a radius of 0.7. The two jets having the highest energies were required to lie within $|\eta| < 1.0$. Jet energy corrections were applied to correct for calorimeter response variations, underlying event and electronics noise contributions, as well as for hadron shower energy leakage outside of the cone radius. The dijet mass is calculated assuming each jet is massless, by using the E_T of each jet and the direction of each jet centroid. As in the CDF analysis, a correction is made to the spectrum to remove the effect of energy smearing. The D0 data with its statistical uncertainty bars and systematic uncertainty range is compared to selected QCD predictions in Figure 3. As for the CDF analysis, the dominant systematic effect is the calorimeter energy scale for jets, contributing $7-30\%$ uncertainty in the cross-section. The systematic errors are highly correlated between mass bins, and the D0 collaboration has produced the bin-to-bin uncertainty correlation matrix shown in Figure 4.

Because of the similarity of analyses, the comparisons of CDF and D0 dijet mass spectra to predictions can be plotted on the same plot. The differences between the analyses are fairly minor: the rapidities of the D0 jets are restricted to $|\eta| < 1.0$ while CDF jets are restricted to $|\eta| < 2.0$, but the additional CDF restriction of $|\cos\theta^*| < 2/3$ makes the jets more central. The event quality cuts do not much affect the kinematics, and the inclusion of internal jet mass contributions by CDF makes a small difference in the dijet mass calculation. The comparisons of CDF and D0 dijet mass spectra to QCD predictions are combined in Figure 5. The trend towards higher cross-sections at large mass is there in both data samples.

IV. D0 QUARK COMPOSITENESS LIMIT

D0 has used the dijet data sample to place improved limits on possible quark compositeness. The technique starts with the assumption of a four-fermion interaction with a particular energy scale. The effect which results is that events become more spherical than QCD alone predicts. Therefore, D0 looks for a signal of the four-fermion interaction in the ratio of the numbers of events in which both jets satisfy $|\eta_{jet}| < 0.5$ to those in which $0.5 < |\eta_{jet}| < 1.0$. This ratio is plotted in Figure 6 as a function of dijet mass. The precise size of the effect also depends on whether the four-fermion interaction interferes constructively or destructively with QCD. Figure 6 also shows predictions of quark compositeness at several energy scales for the case of positive interference. The energy scales for compositeness which are ruled out by this data at 95% C.L. are: $\Lambda^+ > 2.7$ TeV and $\Lambda^- > 2.4$ TeV. This is much higher than the $\Lambda = 1.5 - 1.8$ TeV scale suggested by the excess of high-E_T inclusive jets or the excess of high-mass dijet mass events, and rules out this hypothesis as the source of the discrepancy.

V. CONCLUSIONS

Over many orders of magnitude in cross-section, QCD describes the measured dijet mass spectra at the Tevatron quite well, just as it does for the inclusive jet mass spectra. In detail, however, it is seen that an excess of high dijet mass events is seen above predictions from use of typical parton distribution functions and NLO matrix elements. This excess is qualitatively similar to the excess of high-E_T jets in the inclusive jet spectrum. The CDF and D0 mass spectra agree well, but the groups currently differ on interpretation: CDF believes that the excess in their spectrum is a real effect, while D0 believes the excess can be accomodated within their energy scale and other uncertainties. Finally, D0 has placed stringent limits on the scale of a possible quark compositeness interaction.

This research was supported by a grant (number DE-FG03-91ER40662) from the U.S. Department of Energy.

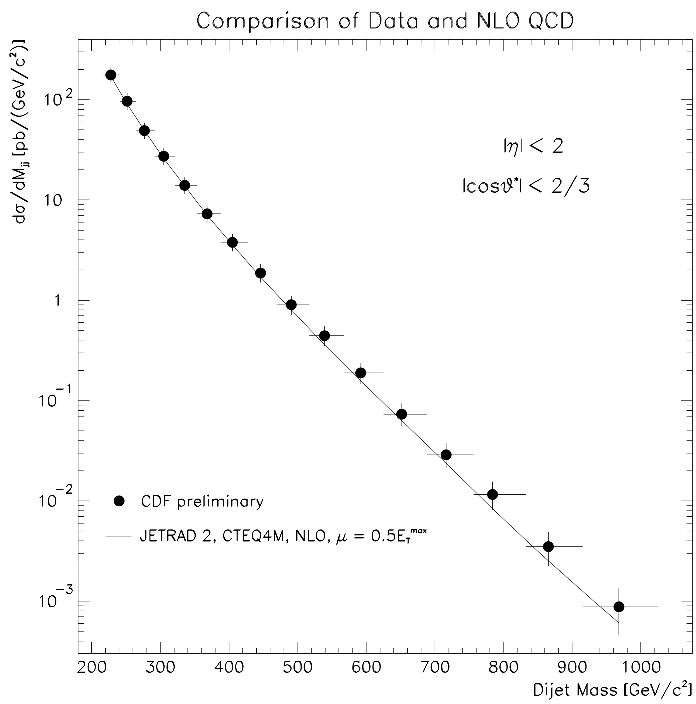

FIG. 1. The CDF dijet mass distribution (data points) shown on a logarithmic scale. Systematic uncertainties were added in quadrature to statistical errors.

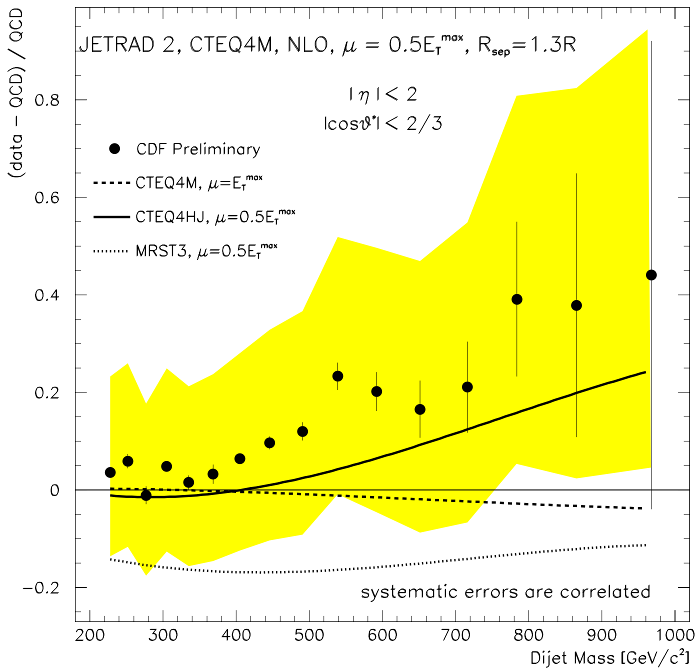

FIG. 2. The deviation of the CDF dijet mass distribution from the prediction of the NLO QCD prediction of JETRAD 2 with CTEQ4M parton distributions at $\mu = 0.5E_T^{max}$. Other parton distribution functions and scale choices are shown for comparison.

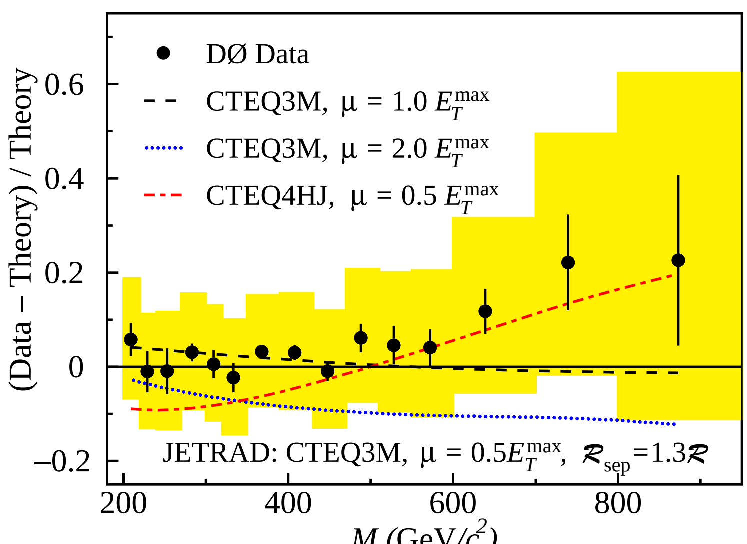

FIG. 3. The deviation of the D0 dijet mass distribution from the prediction of the NLO QCD prediction of JETRAD 2 with CTEQ3M parton distribution functions at $\mu = 0.5E_T^{max}$, and other parton distribution functions and scale choices as labeled.

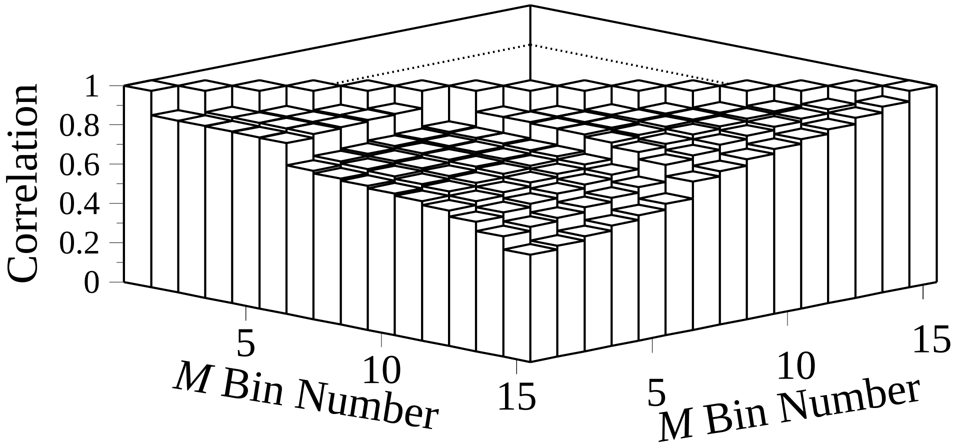

FIG. 4. D0 systematic uncertainty: matrix of correlations between mass bins.

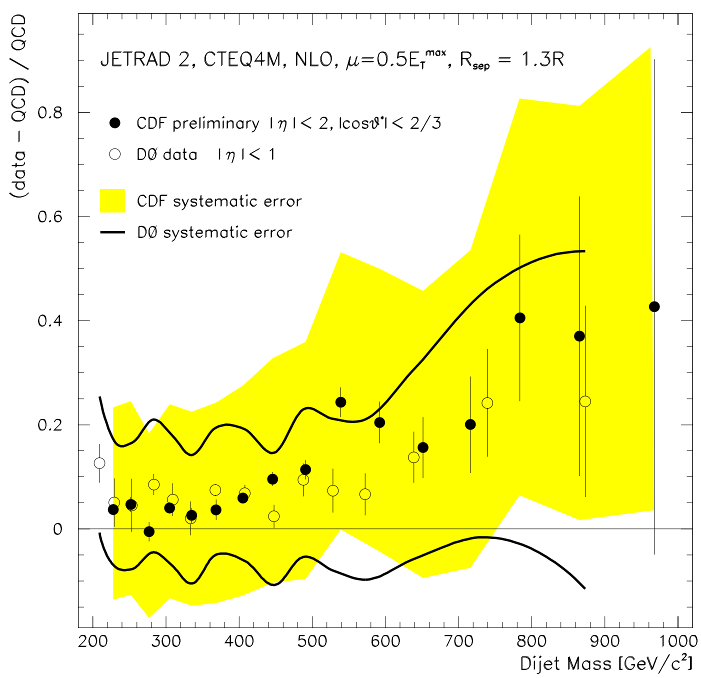

FIG. 5. Comparison of the deviations from prediction of QCD for both CDF and D0 dijet mass distributions. The common prediction is from the NLO QCD calculation plus JETRAD 2, and CTEQ4M parton distributions.

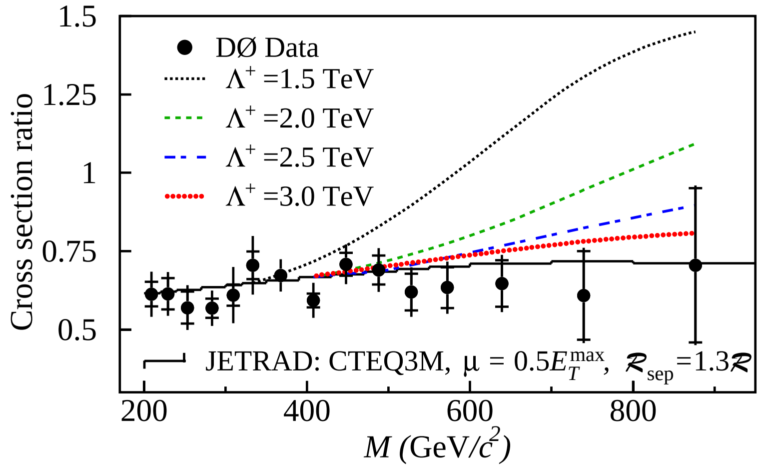

FIG. 6. The ratio of low-rapidity to high-rapidity events as measured by D0.

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[4] B. Abbott, *et al.*, hep-ex/9807014, submitted to Phys. Rev. Lett.