Fermi National Accelerator Laboratory

FERMILAB-Conf-98/013-E
CDF

Hard Processes and Perturbative QCD Results from CDF

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January 1998

Published Proceedings of the *International Europhysics Conference on High Energy Physics*, Jerusalem, Israel, August 19-26, 1997

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

CDF/PUB/JET/PUBLIC/4449

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Abstract. We present results on the inclusive jet cross section at $\sqrt{s} = 1800$ GeV and 630 GeV, the two-jet cross section, multijet physics and the multijet differential cross section from the CDF experiment at the Fermilab Tevatron Collider.

1 The inclusive jet cross section at 1800 GeV and 630 GeV

The inclusive jet cross-section is obtained by measuring the number of events in a given bin of E_T normalized by the integrated luminosity and acceptance. The published CDF result based on a 19.5 pb^{-1} data sample showed an excess of events at high E_T [1]. The preliminary results from 87 pb^{-1} of data from Run IB are shown in Fig. 1(left) compared to NLO QCD predictions [2] using a renormalization scale $\mu = E_T/2$ and the CTEQ3M parton distribution functions (PDFs). The results are also compared to the previous data using the same PDF and scale. The two datasets are in good agreement. The systematic uncertainties are expected to be about the same size as the published result. Another way to test QCD is to measure the inclusive jet cross-section at two different center-of-mass energies. The scaling hypothesis predicts that if the cross-sections are written in a form that makes them dimensionless then they will be independent of $\sqrt{s}$. QCD predicts that there will be scaling violations due to the evolution of the PDFs with Q^2 and the running of α_s . The CDF experiment has recorded data at $\sqrt{s} = 546$ and 630 GeV in addition to 1800 GeV. In a previous measurement [3] using data at $\sqrt{s} = 546$ GeV, scaling was ruled out at the 95% C.L. but a disagreement with the NLO QCD predictions was observed in the low E_T region at the level of 1.5-2 σ. Fig. 1(right) shows the ratio of the scaled cross-sections plotted as a function of $x_T = 2E_T/\sqrt{s}$. The same disagreement that was observed at 546 GeV is observed in the low x_T region for the data at 630 GeV. The systematic uncertainties for the previous measurement at 546 GeV are shown, these are not expected to change significantly for 630 GeV.

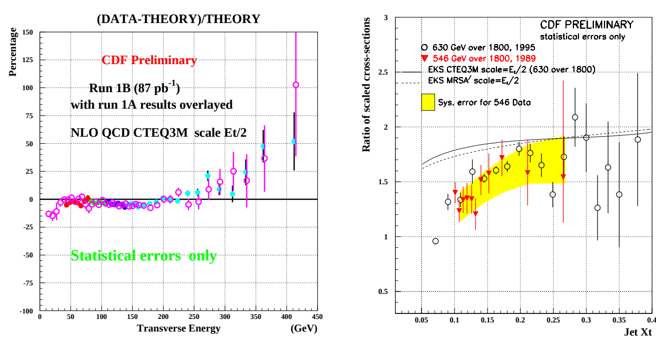

Fig. 1. Left: The preliminary Run 1B inclusive jet measurement is compared to the published CDF result and to NLO QCD predictions using the CTEQ3M PDF. Right: The ratio of scaled cross sections at $\sqrt{s} = 1800$ and 630 GeV.

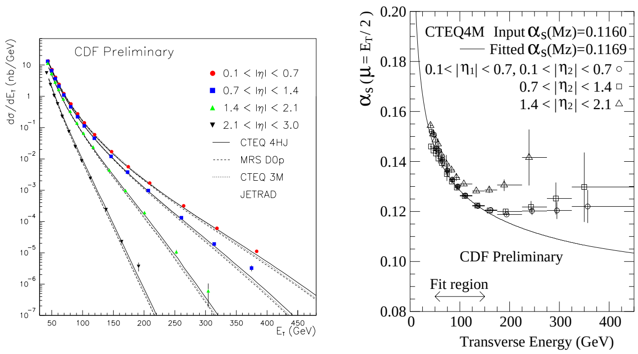

Fig. 2. Left: Comparison of data and NLO cross sections in the different rapidity bins. Right: Extracted α_s values as a function of jet E_T for CTEQ4M.

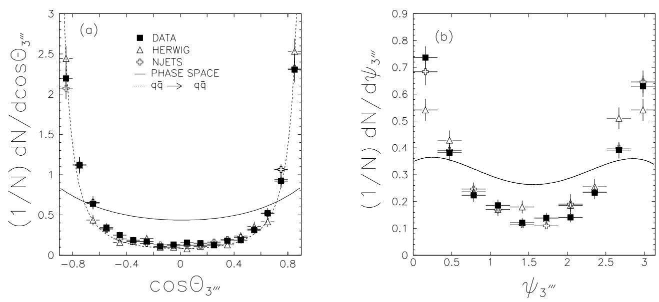

Fig. 3. Distributions of $cos\theta^*$ and ψ for events with ≥ 6 jets compared to theoretical predictions.

2 Inclusive Two-jet cross section

In this measurement, the two highest E_T jets are identified and one is required to be in the central (0.1$\leq |\eta| \leq$0.7) region. Because the central region has the smallest energy scale uncertainty, the central jet is used to measure the E_T of the event. The other jet, called the "probe" jet, is required to have $E_T >$10 GeV and to fall in one of the η bins: 0.1$\leq |\eta| \leq$0.7, 0.7$\leq |\eta| \leq$1.4, 1.4$\leq |\eta| \leq$2.1, 2.1$\leq |\eta| \leq$3.0. There are no restrictions on the presence of additional jets. Fig. 2(left) shows the cross section in the individual η bins as a function of the central jet E_T. JETRAD [4] is used for the theoretical predictions with renormalization scale $\mu = E_T^{max}/2$. The data are compared to the predictions using three PDFs, CTEQ4HJ, MRSD0', and CTEQ3M. The statistical uncertainty is shown on the points; the systematic uncertainty is under study. Comparing the data with NLO QCD allows us to extract information about the strong coupling constant α_s [5]. We determine $\alpha_s(\mu)$

for each bin of E_T , η_1, η_2 using $\mu = E_T/2$. The fit region is $50 < E_T < 150$ GeV and $0.1 \leq |\eta_1| \leq 0.7$, $0.1 \leq |\eta_2| \leq 0.7$. The result of the fit for CTEQ4M is shown in Fig. 2(right). The running of α_s with E_T can be clearly seen. Evolving back to $\alpha_s(M_Z)$ yields $\alpha_s(M_Z) = 0.117 \pm 0.009$ (statistical + experimental systematic uncertainties). Note that due to the interplay between the gluon distribution and the value of α_s in the PDF this cannot really be considered a measurement in the same sense as the LEP determinations.

3 Multijet physics

This analysis uses a sample of events taken with a total transverse energy ($\sum E_T^{jet}$) trigger. Inclusive multijet samples are defined after jet energy corrections have been applied and backgrounds removed. The data is compared to predictions from the NJETS LO $2 \rightarrow N$ Monte Carlo[6] and the HERWIG parton shower Monte Carlo[7] as well as with a phase-space model.

In its rest frame an N-Jet system can be defined by $4N - 4$ independent variables [8]. The data contains 3, 4, 5 and 6 jet events, providing 56 variables which can be compared to theoretical predictions [9]. Both HERWIG and NJETS give reasonable descriptions of all 56 variables. Fig. 3 shows the angular distributions $\cos\theta_3$ and Ψ_3 for events with ≥ 6 jets. Good agreement between the data and the QCD predictions is observed while the data is clearly in disagreement with the phase space model.

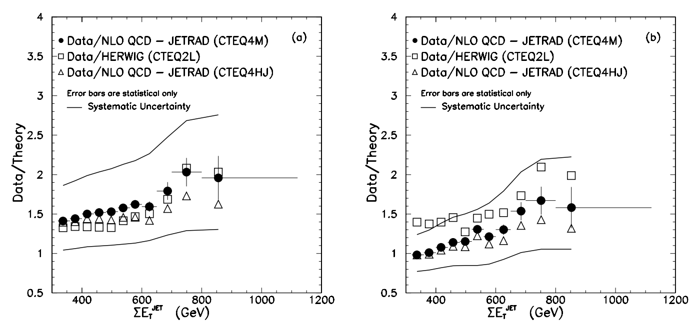

Fig. 4. Multijet differential cross section for (a) $E_T^{min}(20)$ and (b) $E_T^{min}(100)$ compared to theoretical predictions.

3.1 Differential Cross Section for Multijet Events

We measure the cross section for multijet events as a function of the total transverse energy ΣE_T^{jet}, where the sum is over all jets passing a given E_T^{min}

[10]. Two values of E_T^{min} have been used, 20 GeV ($E_T^{min}(20)$) and 100 GeV ($E_T^{min}(100)$). The higher value is chosen to provide a data sample that better approximates the NLO QCD calculation. The data sample consists of events with $\Sigma E_T^{jet} > 320$ GeV. The data have been corrected for the effects of detector resolution. The data are compared to predictions from HERWIG with CTEQ2L PDF's and renormalization scale $Q^2 = stu/2(s^2 + u^2 + t^2)$ and to predictions from JETRAD with CTEQ4M PDF's, and renormalization scale $= 0.5\Sigma E_T^{jet}$. Figure 4 shows the CDF data compared to the predictions. The normalization for $E_T^{min}(20)$ is not well predicted by HERWIG or NLO QCD. For $E_T^{min}(20)$ 31% of the events have >3 jets which suggest that $\mathcal{O}(\alpha_s^4)$ corrections to the NLO $2 \rightarrow 2$ calculation may be important. There is much better agreement with NLO QCD for $E_T^{min}(100)$ but the agreement with HERWIG is still poor. This suggests that the NLO calculation can better describe the data once we are in a region where two-jet events dominate (95% have only two jets passing the threshold). Poor agreement is to be expected for HERWIG, because although it includes a parton shower, the underlying hard scattering cross section is only LO $2 \rightarrow 2$. Sensitivity to renormalization scale is also an indication of the influence of higher order terms. Changing the μ scale from $\Sigma E_T/2$ to $\Sigma E_T/4$ increases the predicted NLO cross section by 26% for $E_T^{min}(20)$ and only 7% for $E_T^{min}(100)$.

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