JET STUDIES AT CDF USING RUN II DATA

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We present measurements of the inclusive jet cross section, jet shape and energy flow in di-jet events in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV.

1 Introduction

Hadronic jets are one of the key signature (and background) of most studies at hadron colliders. An understanding of both their production cross section and their kinematic properties is an essential element of any precision measurement and search for physics beyond Standard Model. Over the last quarter of the century, Quantum Chromodynamics (QCD) has been established as the only viable theory of hard interactions. The QCD coupling constant, α_s, is precisely determined and its running is well established. Currently, the precision of parton distributions needs improvement, especially at large x to accurately predict Standard Model rates and hence the discovery potential of current and future experiments. Jet production probes the shortest distance scale currently accessible, $\sim 10^{-17}$ cm, and provides a unique window to new phenomenon.

Basic processes at hadron colliders can be described as the emission of partons type i_1, i_2 from incoming hadrons carrying momentum fractions x_1^i and x_2^i with probabilities $f_i(x_1)$, $f_i(x_2)$, scattering of partons with a probability proportional to cross section $\hat{\sigma}_{ij}$ and showering and transformation of outgoing partons to hadrons which appear as collimated spray, *jets*, in the detector (Fig. 1). Given accurate QCD predictions, the jet production cross section can be used to determine the parton distribution functions (PDF), $f_i(x)$. The structure within a jet is important to accurately simulate backgrounds to various signatures. It is also a good test of perturbative QCD calculations and

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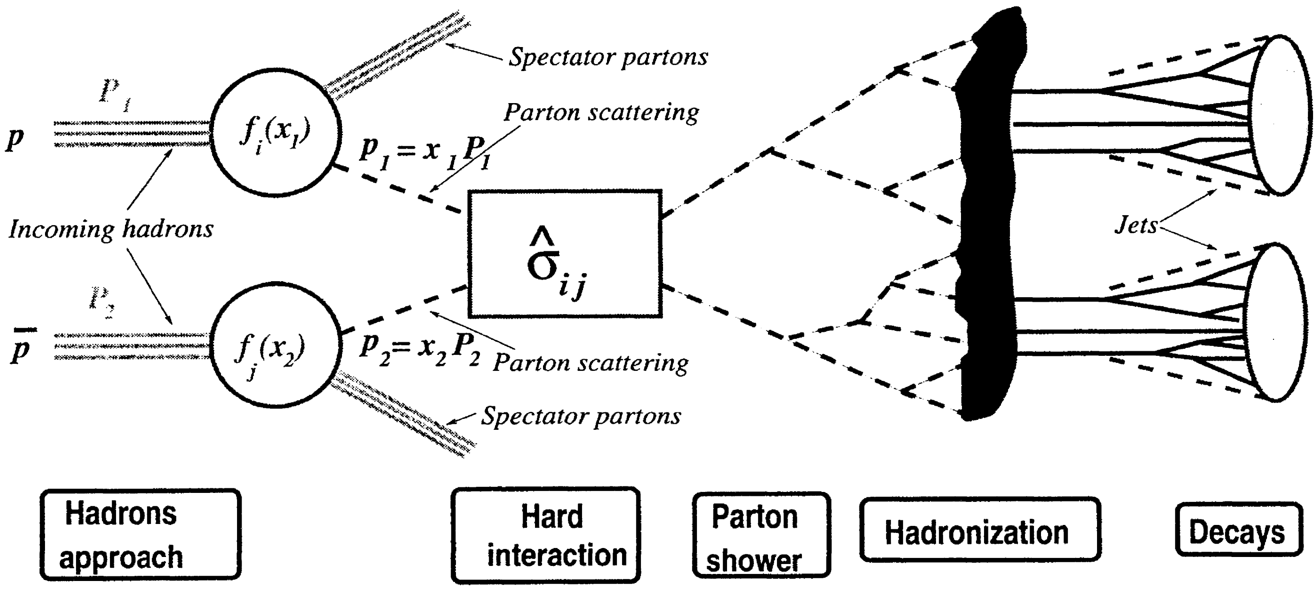

Figure 1: Schematic diagram of jet production at hadron colliders.

fixed-order parton shower MC programs. This article presents the inclusive jet cross section, energy distribution within a jet and energy flow in di-jet events measured using $\sim 90\ pb^{-1}$ data collected from February, 02 to January 03.

The Fermilab Tevatron $p\bar{p}$ collider was upgraded from center of mass energy $\sqrt{s} = 1.8$ to 1.96 TeV. The inclusive jet cross section increases by 20% at low jet transverse energy, E_T, and by $\sim 300\%$ at $E_T = 400$ GeV at $\sqrt{s} = 1.96$ TeV. The CDF detector was upgraded to take full advantage of high luminosity promised for Run II. The central tracking system, plug calorimeter ($1.2 \leq |\eta| \leq 3.6$) and luminosity monitoring system were replaced. New electronics, triggering system and data acquisition hardware and software have increased the quality and quantity of data being recorded. These improvements have already lead to better statistical precision. A large data sample collected specifically to calibrate and monitor the detector will help reduce systematic uncertainties.

2 Inclusive Jet Cross Section

The jet data were recorded using four triggers requiring a jet above nominal E_T thresholds of 20, 50, 70 and 100 GeV. Detector and cosmic ray backgrounds are removed by requiring the total energy in the calorimeter to be ≤ 1.96 TeV and missing energy significance, $E_T^{miss}/\sqrt{\sum E_T} \leq 6\ \text{GeV}^{1/2}$. E_T^{miss} ($\sum E_T$) is a vector (scalar) sum of the E_T of all towers. Jets are reconstructed from energy

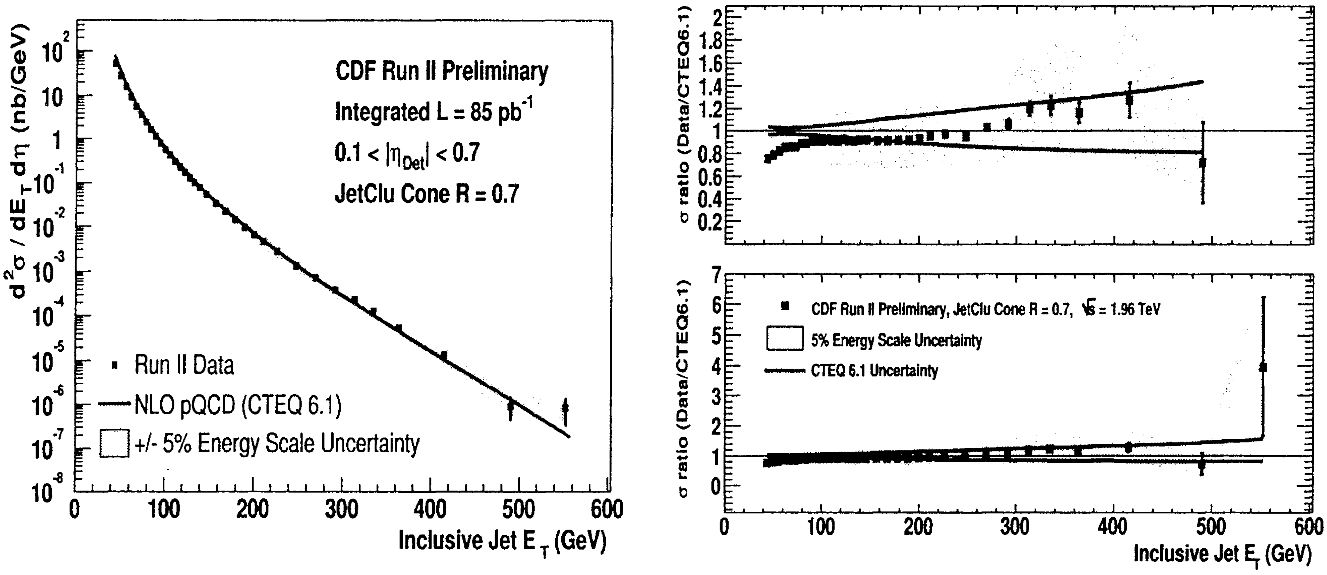

Figure 2: Inclusive Jet Cross Section compared to NLO QCD predictions using CTEQ 6.1 parton distributions.

observed in the calorimeter by CDF's aged-to-perfection iterative fixed cone clustering algorithm developed in 1989/1990 (JetClu)[1]. The calorimeter-level jet cross section determined using modern algorithms, MidPoint and k_T with D=0.7, is very close to the results obtained using JetClu. The energy corrections were derived using a simple di-jet generator, fragmentation functions and a minimum bias generator tuned to CDF data and a fully calibrated CDF detector simulation. The correction procedure[2] corrects for both calorimeter calibration and smearing due to the convolution of the calorimeter energy resolution with a steeply falling spectrum. Jet E_T is corrected to sum of particle E_T's within radius $R=\sqrt{(\Delta\eta)^2+(\Delta\phi)^2}=0.7$ around the jet axis. No correction is made for energy radiated outside the clustering cone from parent parton.

The corrected hadron level jet cross section for jets with psuedorapidity $0.1 \leq |\eta| \leq 0.7$, is compared to parton-level NLO QCD predictions[3], calculated with CTEQ 6.1 PDFs [4]. Hadronization effects are expected to be small. The data extend to $E_T = 550$ GeV, $\sim$ 130 GeV beyond the highest E_T jet observed at $\sqrt{s} = 1.8$ TeV. Many contributions to the systematic uncertainty were studied. It is dominated by a 5% uncertainty in jet energy scale.

The CTEQ 6.1 PDFs were determined by a fit to world data including Run I jet data from the the DØ and CDF collaborations. At high x, the gluon

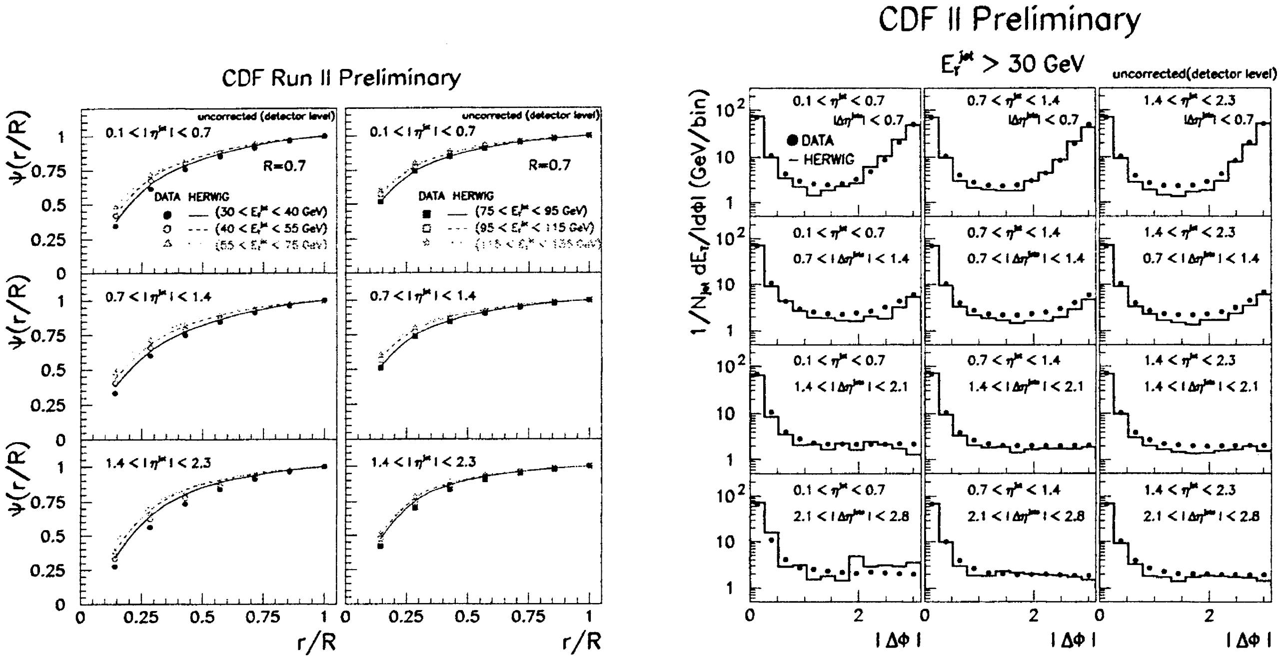

Figure 3: Integral energy distribution as a function of radius r within a jet for jets at different η values (left). (right) Transverse Energy distribution along the azimuthal direction at leading jet η within $\Delta\eta = 1.4$ (right).

distribution, $G(x)$, is mainly determined by the Tevatron jet data. Run II data confirms the conclusion that the most likely explanation of high E_T excess observed in Run I is the under estimation of $G(x)$. The CDF collaboration has also measured the inclusive jet cross section in different η bins. Once final, the low E_T, high η jet data will help constrain $G(x)$ at low Q^2 (E_T) which can be evolved to predict the high E_T, low η jet cross section.

3 Jet Shape and Energy Flow in DiJet Events

The integral jet shape, $\Psi(r)$ is defined as the fraction of the jet transverse energy in a cone of radius r :

$$\Psi(r) = E_T(0,r)/E_T(0,R) \quad (r \leq R).$$

Events containing at least two $E_T \geq 25$ GeV jets with $|\eta| < 2.3$, reconstructed by JetClu, are used. The jet shape $\Psi(r)$ is calculated from calorimeter towers around the jet axis. The data are divided into 6 E_T and 3 η bins and compared to HERWIG MC predictions in Fig. 3. Jets become narrower with increasing E_T. Forward jets are slightly broader than central jets. Herwig gives a good description of central jets for all E_T ranges but at high η, the data jets are broader. Pythia MC predictions are similar. Analysis performed using charged tracks, limited to $|\eta| < 1$ region, shows similar agreement with MC predictions. These distributions, after correcting for hadronization effects, will be compared with α_s^3 parton-level calculation[5] and our previous measurement [6].

The energy deposited in $\Delta\eta\times\Delta\phi = 1.4\times 15^0$ as a function of ϕ-distance from leading jet azimuth position is compared with MC predictions for four intervals of $\Delta\eta_{12} = |\eta_1 - \eta_2|$ separation between two leading jets and three ranges of η of leading jet in Fig. 3. Spectator interaction, initial/final state radiations and multiple jet production contribute to this energy. The peak at $\phi = \pi$ for small $\Delta\eta_{12}$ corresponds to second jet in the event. HERWIG predicts too small E_T around $\pi/2$ from jet, probably be due to too little spectator interactions.

4 Conclusions

We have measured the jet production rate and energy distribution within and close to the jets in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. The data are statistically precise and in near future with much reduced uncertainties, will be used to test perturbative QCD calculations, improve Monte Carlo generators and determine the parton distribution functions, especially $G(x)$, more precisely.

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