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CDF

Jet Studies At CDF/D0 Collaborations

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1 INTRODUCTION

Both CDF and D0 collaborations measure inclusive jet cross section, energy flow and observe color coherence effects in $\overline{p}p$ collisions at $\sqrt{s} = 1800$ GeV. The results on new compositeness limit using inclusive jet cross section and energy flow within a jet are described. Data are in good agreement with next to leading order QCD calculations. Color coherence effects are demonstrated by measuring spatial correlations between soft and leading jets in multi jet events

2 Inclusive Jet Cross Section

Measurement of the inclusive jet cross section provides a fundamental test of perturbative QCD. Next to leading order (NLO) calculations of the inclusive jet cross section are available [1, 2], and their uncertainties are small for the standard choices of renormalization scale. At high transverse energy (E_T) deviation from the QCD prediction may indcate the need for higher order corrections, or be an hint for new physics, like quark compositeness. It is possible to fix a limit on the compositeness scale (Λ_C) taking into account the correction of a contact term summed to the leading order QCD terms [3].

For this analysis CDF uses an integrated luminosity of approximatively 21.4 pb^{-1} collected during the 1992-93 run of the Fermilab Tevatron. In the same run D0 collected an integrated luminosity of approximatively 17.0 pb^{-1}.

The inclusive jet cross section is defined to be

$$\frac{1}{\Delta\eta}\int d\eta \frac{d\sigma}{dE_T d\eta} = \frac{1}{\Delta\eta}\frac{1}{\mathcal{L}}\frac{N_{jet}}{\Delta E_T}$$

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where N_{jet} is the number of jets in the E_T range ΔE_T, $\mathcal{L}$ is the luminosity and $\Delta\eta$ is the η range of the data set used. In order to ensure that the energy is well measured, CDF uses only those jets for which $|\eta_D|$ is in the range 0.1–0.7, where η_D is the pseudorapidity of the jet calculated under the assumption that the interaction took place at $z = 0$. The CDF central calorimeter covers $0.0 < |\eta_D| < 1.1$. Thanks to the wider angular acceptance of their detector, D0 has also measured the inclusive jet cross section in the region $2 < |\eta| < 3$.

A standard jet definition used at hadronic collider has been chosen at Snowmass in 1990 [4]. It uses fixed cone algorithms in the η, ϕ space. The jet E_T is defined as the transverse component of the sum of the energy deposited by all the particles in the cone. In this analysis the cone radius is R=0.7.

Figure 1 shows the CDF inclusive jet cross section versus the transverse energy for the pseudorapidity range $0.1 < |\eta| < 0.7$. The next to leading order calculations are superimposed on the fully corrected experimental data. The agreement between the measured cross section and the NLO QCD calculation over 10 orders of magnitudes both in shape and normalization is impressive. The QCD prediction represent data well in the range from 15 GeV to 450 GeV. The compositeness parameter Λ_C is calculated to be larger than 1450 GeV at the 95% confidence level.

3 Jet Shapes

Comparison between perturbative QCD calculations and observations of the energy distribution within a jet [5] is plagued by a lack of knowledge of the fragmentation process. The different leading logarithm QCD based Monte Carlo simulations provides various fragmentation phenomenogical models. ISAJET [6] is based on independent fragmentation; HERWIG [7] is a parton shower Monte Carlo and PYTHIA [8] is based on string fragmentation [9] and includes parton showers for intial and final state partons.

The D0 collaboration has measured the energy flow within a jet using calorimetric information. CDF has done this measurement from 1988-89 data using charged track informations [10].

The investigated variable is $\Psi(r)$ that is the ratio of the energy in sub–cone of radius r to the energy in the cone which define the jet (in this analysis the con radius which define the jet is $R = 1.0$).

Figure 2 show the distribution of the E_T fraction in a cone for the E_T range 95–110 GeV and $|\eta| < 0.2$. The NLO calculations [5] for the renormalization scale E_T and $E_T/4$ are superimposed to D0 data. Predictions from various Monte Carlo are also reported. The different Monte Carlo models describe the shape quite well. Parton level jets, instead, looks broader than data ones.

However, adding a new parameter to the theory (R_{sep}) the agreement between the NLO QCD theory and the CDF data from 1988-89 run improves [5]. Two parton are merged in a single jet if they are less than a distance R_{sep} in η, ϕ space. The default value is $R_{sep} = 2.0 \times R$ but the best value is found to be $R_{sep} = 1.3 \times R$.

4 Color Coherence

We report the first observation of color coherence phenomena at $\overline{p}p$ colliders [11], using the CDF data from the 1988-1989 run. Preliminary results have also been presented recently by the D0 collaboration [12]. The most striking consequence of color coherence in QCD is given by the inhibition of soft radiation [13], due to destructive interference between amplitudes with soft gluons emitted by color connected partons. The lines defining the flow of the color charges involved in the process can be identified as antennas for the emission of additional color radiation. QCD predicts that these antennas behave approximately like standard dipoles.

Color coherence has been observed in $\overline{p}p \rightarrow 3jet + X$ events studying kinematical correlations between the third jet (regarded as the product of "soft" branchings in the Leading Log Approximation) and the second one. We have measured the distance in pseudorapidity, $\Delta\eta = \eta_3 - \eta_2$, and the distance in the azimuthal angle, $\Delta\phi = \phi_3 - \phi_2$. In order to better single out the region of maximum emission, we have introduced a set of "polar" variables: $R = \sqrt{(\Delta\eta^2 + \Delta\phi^2)}$ and $\alpha = sign(\eta_2) \times atan(\Delta\eta/|\Delta\phi|)$. We have compared our data with several shower Monte Carlo calculations that implement, with differing levels of accuracy, the quantum coherence in the gluon radiation process.

The Monte Carlo HERWIG [7] (version 3.2) imposes proper phase space constraints on soft emissions from any kind of color antenna, including those spanned between the initial and final states (initial-final state interference).

The Monte Carlo ISAJET [6] (version 6.25), instead, does not implement angular ordering in the initial or the final state radiation.

The Monte Carlo PYTHIA [8] (version 5.6) imposes proper phase space constraints only on soft emissions of time-like shower evolutions. In particular, this version does not include initial-final state interference. For this reason, we also use a new version of PYTHIA, expressly provided by the author, which implements the phase space constraints for the initial-final state antennas [14] as well. These modifications are now implemented in the latest version of PYTHIA, 5.7.

The coherence effect is observable in Fig. 3 as a change of the slope sign for $\alpha \to \pi/2$. This change is present in the data, HERWIG and PYTHIA+ distributions. The ISAJET and PYTHIA distributions, instead, are monotonically decreasing from $\alpha = -\pi/2$ to $\alpha = \pi/2$. The color coherence is responsible for the differences between the predictions and the agreement with the data improves as higher degrees of color coherence are implemented.

5 Conclusions

We measure the inclusive jet cross section in the E_T range 15–440 GeV. It is in good agreement with NLO QCD predictions. We set a lower limit of 1450 GeV on the compositeness parameter Λ_C. Energy flow is well reproduced by Monte Carlos. However NLO QCD calculation using $R_{sep} = 1.3$ can well describe the jet shape. We observe color coherence effects. The coherence survives the non perturbative phase of adronization.

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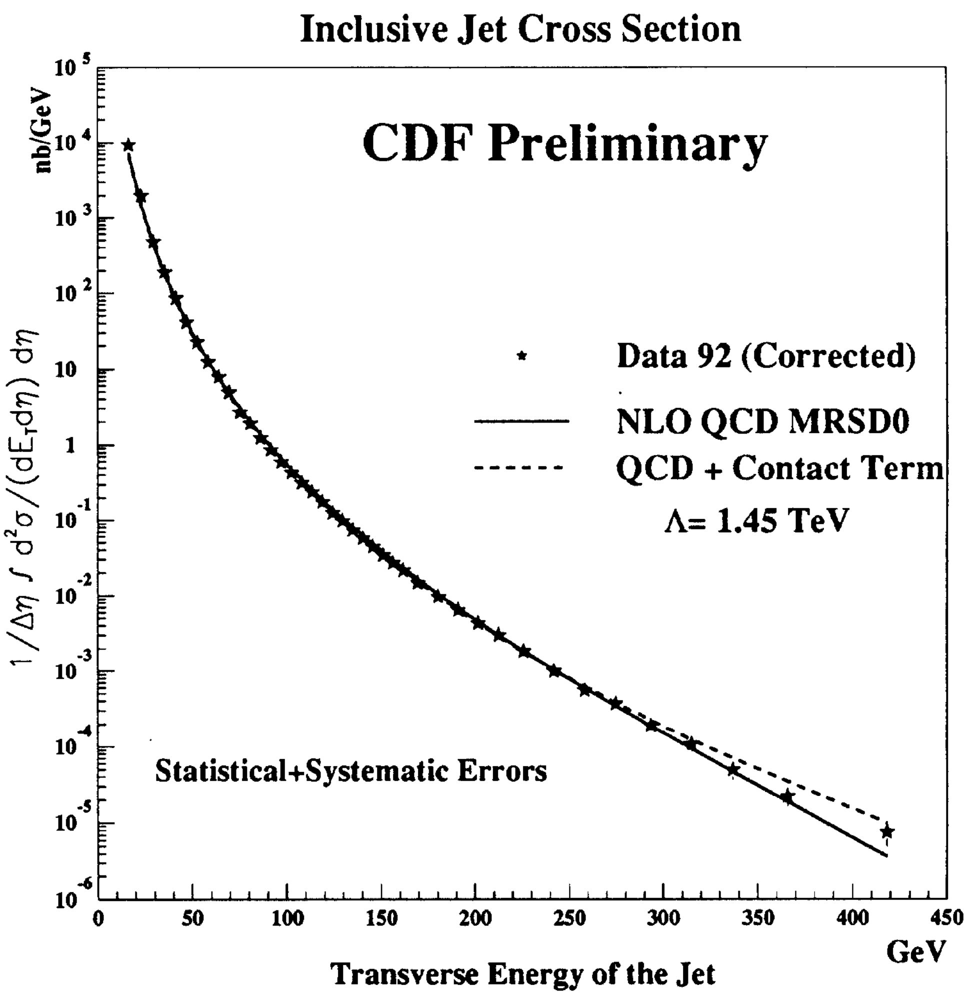

Figure 1: Comparison of CDF Jet Cross Section with NLO QCD calculation.

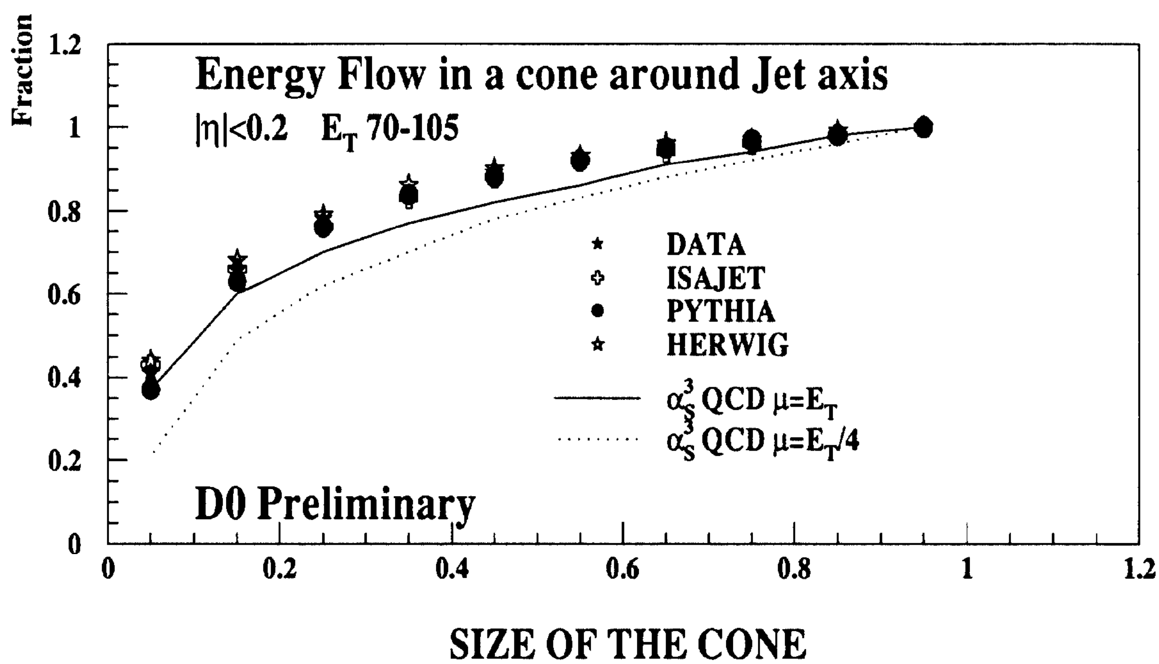

Figure 2: The integral energy flow in a cone around the jet axis compared with various predictions

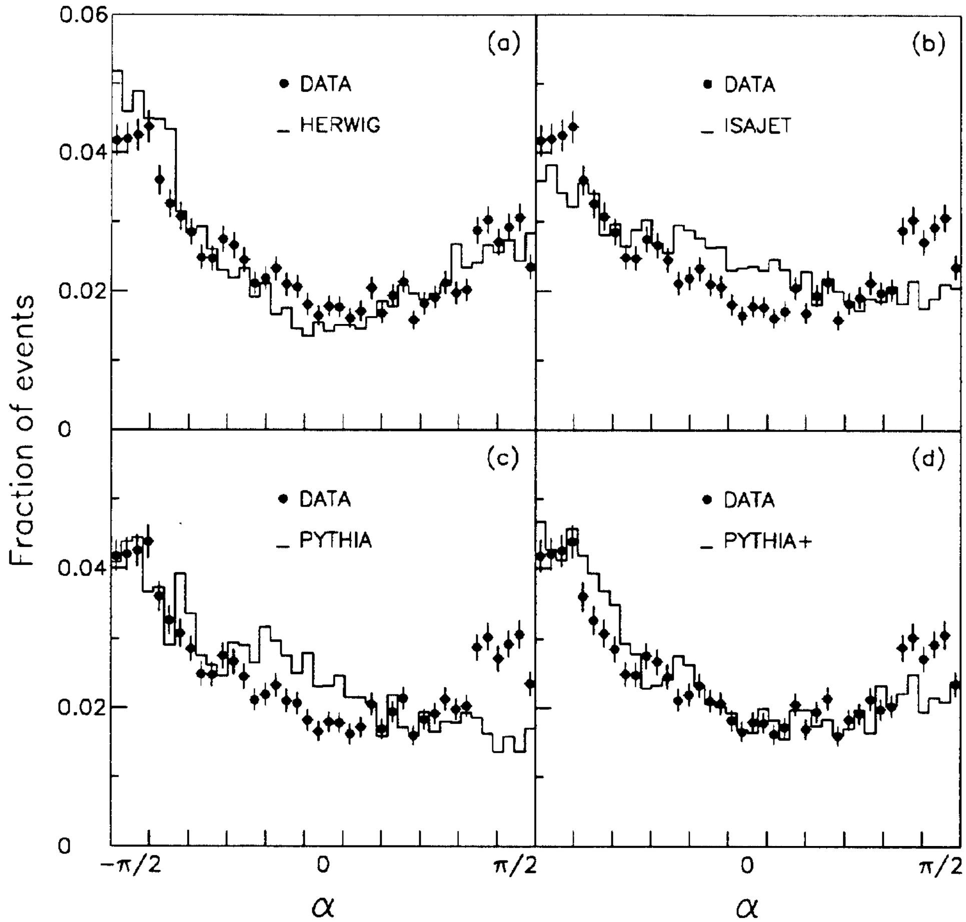

Figure 3: Observed α distribution compared to the predictions of: (a) HERWIG; (b) ISAJET; (c) PYTHIA; (d) PYTHIA+.