

## INCLUSIVE JETS at the TEVATRON

CHRISTINA MESROPIAN

*The Rockefeller University*

*1230 York Avenue*

*New York, NY 10021*

*USA*

for the CDF and D $\emptyset$  Collaborations



Results from CDF and D $\emptyset$  collaborations on the inclusive jet cross sections at 1800 and 630 GeV and strong coupling constant are presented. The statistical uncertainties are significantly reduced relative to the previous results and experimental systematic uncertainties are comparable with the uncertainties in the theoretical predictions. Despite observed discrepancies with theory, which could be accommodated by modifications of parton distribution functions, the inclusive jet cross sections can be described by perturbative Quantum Chromodynamics.

### 1 Introduction

After CDF published the results of the inclusive jet cross section from the 1992-1993 data<sup>1</sup>, which showed discrepancies with NLO QCD predictions, a great deal of effort was made to achieve a better understanding of the theoretical uncertainties of this measurement and the experimental differences between CDF and D $\emptyset$  results. Both CDF and D $\emptyset$  use iterative fixed cone algorithms which incorporate the Snowmass algorithm. Since the experimental clustering algorithms are more efficient at recognizing overlapping jets than NLO calculations, an additional constraint on the parton clustering is applied to the theory which requires two partons to be separated by more than  $\mathcal{R}_{sep} \times R$ , (where  $R$  is the radius of the jet cone) to be considered separate jets.

Since the inclusive jet cross section has been calculated only to NLO, the results of theoretical predictions depend on factorization and renormalization scales ( $\mu_F$ ,  $\mu_R$ ). Fig.1a shows the theoretical uncertainties for the inclusive jet cross section associated with the choice of  $\mathcal{R}_{sep}$ ,  $\mu_F$  and  $\mu_R$ .

Another source of theoretical uncertainty is the choice of parton distribution functions - PDFs. As shown in the Fig.1b this can introduce  $\approx 20\%$  variations in the jet cross sections. For

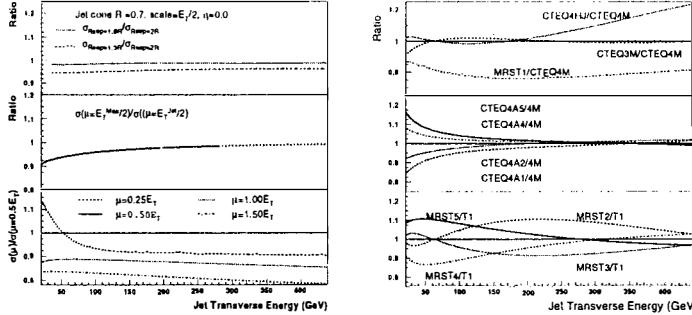


Figure 1: Theoretical predictions for the inclusive jet cross section using (a) different choice of  $R_{sep}$  and  $\mu$ , (b) different PDFs. Each prediction is normalized to NLO EKS calculation with CTEQ4M,  $\mu = E_T^{jet}/2$ ,  $R_{sep} = 1.3$ .

comparing experimental results to theory predictions two programs are used. The EKS<sup>2</sup> program, which is a complete  $\mathcal{O}(\alpha_s^3)$  analytical calculation of the inclusive jet cross section, and JETRAD<sup>3</sup>, a complete  $\mathcal{O}(\alpha_s^3)$  event generator. Both programs require the selection of renormalization and factorization scales, a set of parton distribution functions and a jet clustering algorithm, but give identical results when the same parameters are used.

## 2 Inclusive Jet Cross Section at 1800 GeV

The inclusive jet cross section represents one of the basic tests of QCD at a hadron-hadron collider. The cross section is written as  $\frac{d^2\sigma}{dE_T d\eta} = \frac{N}{\Delta E_T \Delta \eta \mathcal{L}}$ , where  $N$  is the number of jets observed in  $\Delta E_T$  and pseudorapidity  $\Delta\eta$  interval and  $\mathcal{L}$  is the integrated luminosity. The CDF collaboration measures the cross section in the region  $0.1 \leq |\eta| \leq 0.7$ , while DØ performs the analysis in the  $|\eta| \leq 0.5$  region.

Both CDF and DØ put similar requirements on the events and jets selected for calculation of the cross section. Events with large missing  $E_T$  are excluded to avoid background from cosmic rays. Additional corrections should be done to account for detector mismeasurements, finite energy resolution and non-jet energy falling in the jet cone.

CDF applies a so-called “unsmeared” procedure for the simultaneous correction for detector response and energy resolution. The detector response functions are determined from the Monte Carlo simulation tuned to the CDF data. The trial spectrum is smeared using these functions and compared to the raw data. Using an iterative procedure the parameters of trial spectrum are obtained which give the best match between the smeared trial data and raw cross section. The corresponding unsmeared curve referred as a “standard curve” and used to correct measured cross section. The simultaneous correction allows to obtain the result which is independent of  $E_T$  binning while having the same statistical uncertainty. Fig. 2 shows the inclusive jet cross from the CDF 1994-1996 data, corresponding to a total integrated luminosity of  $89 \text{ pb}^{-1}$ . The five-fold increased data sample over 1992-1993 CDF data results in a significantly reduced statistical error. For comparison with NLO predictions, the EKS program is used with  $\mu_R = \mu_F = E_T^{jet}/2$ , CTEQ4M as a PDF choice and  $R_{sep} = 1.3$ . As one can see from Fig. 2b the flexibility in gluon distribution functions (different PDF sets) can accommodate the discrepancy between the data and the theory predictions.

The results from DØ inclusive jet cross section from  $92 \text{ pb}^{-1}$  has been published recently<sup>4</sup>. The cross section DØ measuring is in rapidity region  $|\eta| < 0.5$ , which was chosen because the

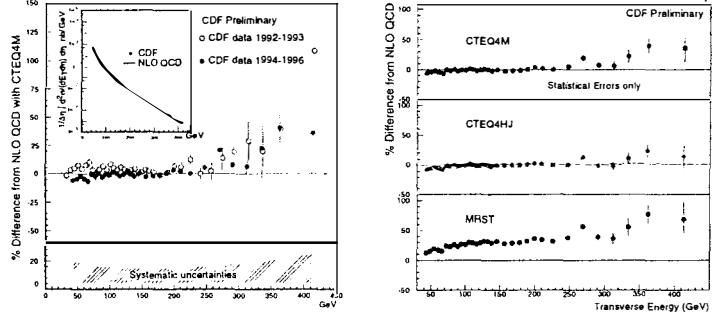


Figure 2: CDF Inclusive jet cross section compared to predictions from EKS program with CTEQ4M, (shaded band represents the quadrature sum of the correlated systematic uncertainties for 1994-1996 data); (b) 1994-1996 data sample compared to EKS NLO predictions for different PDF choices.

detector is uniformly thick and both the jet resolution and calibration are optimal. The analysis differs from CDF in that the spectrum is corrected independently for energy calibration and then for distortion due to jet energy resolution. The Fig. 3a shows comparison of  $D\bar{\Omega}$  - data with theoretical prediction from JETRAD with  $\mu = 0.5 E_T^{max}$ , and  $\mathcal{R}_{sep} = 1.3$ . There is a good agreement over 7 orders of magnitude.

### 2.1 Comparison of CDF and $D\bar{\Omega}$ Results

For comparison of CDF and  $D\bar{\Omega}$  results, the  $D\bar{\Omega}$  analysis was repeated for the CDF pseudorapidity region  $0.1 < |\eta| < 0.7$ . The data also has been corrected for the 2.7% difference in luminosity definition.

$D\bar{\Omega}$  performed a  $\chi^2$  comparison between their data and the nominal curve describing the central values of the CDF data (see Fig. 3b). A statistical error only comparison (by assuming

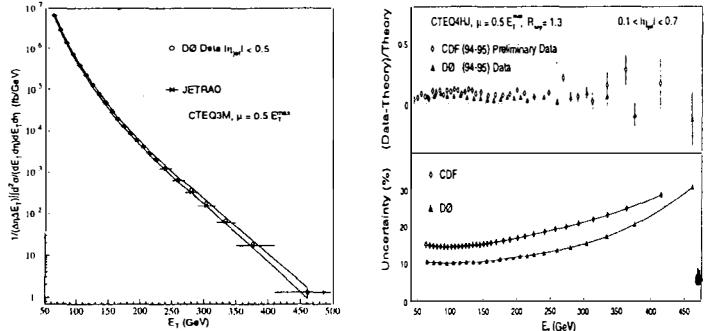


Figure 3: (a) Inclusive jet cross section from  $D\bar{\Omega}$  data; (b) comparison of  $D\bar{\Omega}$  data and CDF nominal curve to JETRAD predictions in the region  $0.1 < |\eta| < 0.7$  (top), and the quadrature sums of the  $D\bar{\Omega}$  and CDF systematic uncertainties (bottom).

the same statistical uncertainty on CDF and  $D\bar{\Omega}$  data and calculating values of CDF curve at  $D\bar{\Omega}$   $E_T$  points)  $\chi^2$  is 35.1 for 24 degrees of freedom. By taking into account systematic uncertainties the  $\chi^2$  equals 13.1 corresponding to the probability of 96%.

## 2.2 Strong Coupling Constant from Inclusive Jet Cross Section

CDF has also used the inclusive jet cross section to extract values of the strong coupling constant. The inclusive jet cross section can be quantitatively described by perturbative QCD in next to leading order (for a given PDF) with the strong coupling constant as a free parameter<sup>5</sup>.  $\alpha_s$  is determined at a scale of  $E_T/2$ , which is directly related to the single jet inclusive transverse energy distribution, and later transformed to the  $\alpha_s(M_Z)$  energy using the renormalization group equations (see Fig. 4a). The cited value  $\alpha_s(M_Z) = 0.1129 \pm 0.0001(\text{stat})^{+0.0078}_{-0.0089}(\text{exp.syst})$  is obtained by calculating a weighted average from 40 – 250 GeV (to avoid bias from high  $E_T$  events of the inclusive jet data set). This method allows an extraction of  $\alpha_s$  from one single experimental data set in a very wide energy range. The disadvantage of this method is the correlation between  $\alpha_s$  values and gluon distributions from PDFs.

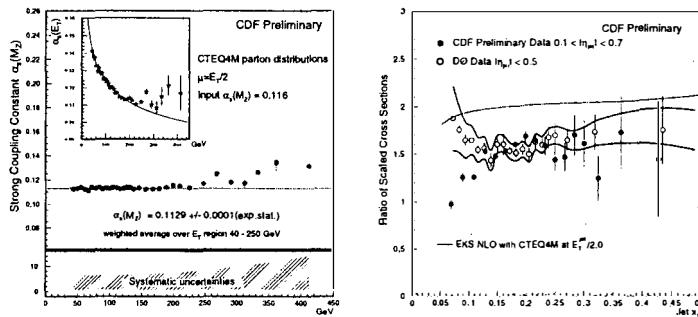


Figure 4: (a) Strong coupling constant extracted from CDF inclusive jet cross section; (b) Ratios of 630 to 1800 GeV inclusive jet cross sections compared to NLO QCD predictions.

## 3 Ratio of jet cross section at two beam energies

The inclusive jet cross section has been measured by both CDF and D0 at  $\sqrt{s} = 630$  GeV. The analysis of the 630 GeV data is analogous to the 1800 GeV analysis. Fig. 4b shows a comparison of CDF and D0 ratios of 630 to 1800 GeV cross sections with their systematic and statistical error compared to CTEQ4M predictions for EKS with  $E_T^{jet}/2$  renormalization scale. The CDF results are in good agreement with previous CDF results<sup>6</sup> and have ruled out the scaling hypothesis. The CDF and D0 results are consistent with each other for  $x_T > 0.1$ , but disagree for  $x_T \leq 0.1$ . The results from both experiments are not in good agreement with NLO QCD predictions. An additional study to understand existing differences is in progress. With a larger data sample these measurements could place constraints on the high  $x_T$  behavior of the PDF while using relatively low  $E_T$  jets.

## References

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