Scaling Behavior of Jet Production at CDF

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SCALING BEHAVIOR OF JET PRODUCTION AT CDF

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ABSTRACT

Inclusive jet cross-sections have been measured in pp collisions at $\sqrt{s} = 546$ and 1800 GeV, using the CDF detector at the Fermilab Tevatron. The ratio of jet cross-sections is compared to predictions from simple scaling and $O(\alpha^2)$ QCD.

1. Introduction

1.1. Theoretical Motivation

The hypothesis of "scaling" predicts that jet production cross-sections, if scaled in a way that makes them dimensionless, will be independent of pp CM energy. By contrast, perturbative QCD calculations of parton hard scattering exhibit non-scaling behavior through the evolution of the proton structure functions and the running of the strong coupling constant, $\alpha_s$.

1.2. Experimental History

Scaling violation in jet production at hadron colliders has been observed previously in data from CERN experiments (AFS and UA2 [1]) and in CERN/Tevatron comparisons (AFS and CDF [2]). For the present measurement it has been possible to conduct the test within a single experiment, using CDF data taken at the widely separated CM energies of 546 and 1800 GeV. This has led to smaller systematic uncertainties, and a more precise investigation into scaling behavior.

2. Cross-section Measurement

2.1. Triggering and Data Samples

Triggering for jet events required one or more clusters of energy within the calorimeter above a set of transverse energy ($E_T$) thresholds. Details of triggering and event selection are given in References [3] and [2]. Jets in the offline analysis were restricted to the central rapidity interval ($0.1 \leq |y| \leq 0.7$). Two inclusive jet data sets were used in this analysis: (1) the full 1988-89 run at $\sqrt{s}=1800$ GeV (integrated luminosity = 4.43 pb$^{-1}$), and (2) a short run at $\sqrt{s}=546$ GeV (8.58 nb$^{-1}$).

2.2. Corrections to the Cross-Sections

Observed inclusive jet $E_T$ spectra were corrected for energy loss and resolution.
tion effects. Corrections were obtained using a tuned Monte Carlo detector simulation described elsewhere [3]. Confirmation of Monte Carlo modeling of jet losses and resolution has come from comparing data and Monte Carlo predictions for momentum balance in photon-jet and di-jet events. Detector effects were de-convoluted from the measured 546 and 1800 GeV cross-sections.

2.3. Systematic Uncertainty on the Cross-Sections

The largest sources of systematic uncertainty on the cross-sections are the knowledge of calorimeter response to hadrons, knowledge of jet resolution, and uncertainty on the non-jet energy correction. Overall systematic uncertainty on the 546 GeV jet cross-section is ±34% in quadrature sum. The 1800 GeV systematic uncertainty is ±18% for that part of the spectrum (91-238 GeV) which overlaps the 546 GeV data in the dimensionless energy variable \( \varepsilon_T \) (\( \equiv 2E_T/\sqrt{s} \)).

We note that our 546 GeV inclusive cross-section agrees well with previous measurements from the UA1 and UA2 experiments at the CERN SpS Collider when similar definitions of corrected \( E_T \) are applied. To compare to CERN, CDF data were reprocessed using set of jet \( E_T \) corrections analogous to CERN's. Figure 1 compares the corrected CDF jet cross-section at 546 GeV (both standard CDF data and "CERN-corrected" CDF data) against UA2 results [1].

3. Scaling Ratio

To test scaling behavior we form the ratio, \( R \), of dimensionless invariant cross-sections \( (E_T^2/E_T^2) \), 546 GeV to 1800 GeV. Ratio data are plotted in Fig. 2. Statistical uncertainties and a band of systematic uncertainty are shown. The total systematic uncertainty is approximately ±15%; thus about half of the systematic error on the individual cross-sections cancels in the ratio.

The deviation of our ratio data from the scaling hypothesis \( (R=1) \) was tested by comparing the average value of \( R \) against unity. The average \( R \) for our data, constructed in a weighted fashion using statistical and systematic errors, is 1.51±0.04±0.21. Comparing the data average to the scaling prediction yields a confidence level of 1.7%. We conclude that scaling in jet production is excluded by our data. We have also compared our \( R \) data against next-to-leading order QCD calculations [5] for a variety of structure functions and choices of renormalization scale \( (Q^2) \). Figure 2 shows two such calculations. Predictions for average \( R \) range from 1.83 to 2.01, and thus lie 1.5-2.4 \( \sigma \) above our data.

4. Conclusions

In summary, the ratio of dimensionless inclusive central jet cross-sections measured in CDF data at 546 and 1800 GeV has provided a test of QCD predictions with greater precision than that of the individual cross-sections; likewise, theoretical uncertainty is reduced by more than a factor of three in the ratio. Using an average ratio test, our ratio data are inconsistent with scaling, and consistent at the 1.5-2.4 \( \sigma \) level with a range of next-to-leading order predictions, although our data favor a
level for the ratio that is lower than that of the predictions tested.

6. References