JETS IN DEEP INELASTIC SCATTERING AT HERA

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Measurements of inclusive jet, two-jet and three-jet production in neutral current deep inelastic scattering at HERA are presented. The measured cross sections are compared with QCD predictions and used to determine the strong coupling α_s.

1 Introduction

Jet production in neutral current (NC) deep inelastic *ep* scattering (DIS) has been studied by ZEUS and H1 using the full 1994-1997 e^+p datasets corresponding to 43 $\text{pb}^{-1}$and 37 pb^{-1}respectively . These luminosities and the high center of mass energy at HERA ($\sqrt{s} = 300\,\text{GeV}$) allow to investigate kinematic regions in the four momentum transfer Q^2 and in jet transverse momenta E_T^{jet} not explored previously in DIS. The high scale values set by these kinematic variables allow sensitive comparisions of the data with higher order perturbative QCD calculations.

2 Inclusive Jet Measurements

Zeus searched [1] in the NC-DIS ($Q^2 > 125$ GeV^2) data for jets in the laboratory frame using the longitudinally invariant k_T-cluster algorithm. The cross section $d\sigma/dE_T^{jet}$ integrated over the pseudorapidity range $-1 < \eta < 2$ is shown in Figure 1 for different Q^2-cuts. The measured $d\sigma/dE_T^{jet}$ distribution exhibits for $Q^2 > 125$ GeV^2 a steep drop over 4 orders of magnitude in the E_T^{jet} range considered. The measurements have been compared with next-to-leading (NLO) order QCD calculations using the program DISENT [2]. The CTEQ4M [3] proton parton distributions (PDF) have been used with the renormalisation and factorisation scales chosen as

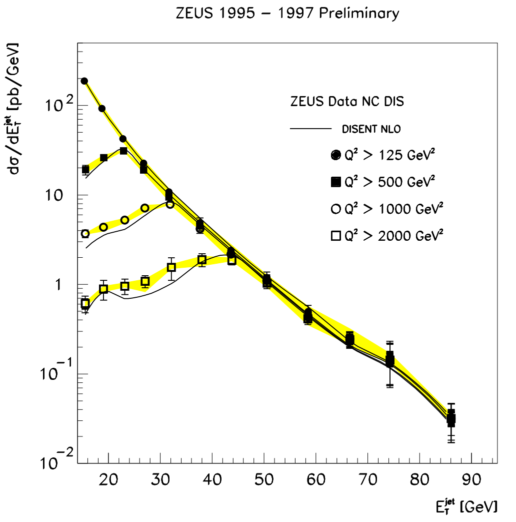

Figure 1: Inclusive jet cross section as a function of E_T^{jet}. NLO QCD calculations are shown for comparision.

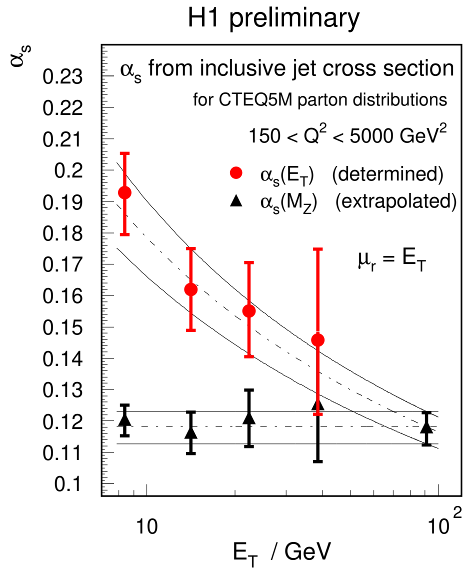

Figure 2: α_s fit results versus jet E_T from inclusive jet measurements.

Q. The NLO QCD calculations refer to jets of partons whereas the measurements refer to jets at the hadron level. An estimate of the effects of hadronisation has been obtained by comparing the cross sections for jets of hadrons and jets of partons with the DJANGO program [4]. The ratio of the cross sections is found to be unity within a spread of ±5%.

The NLO QCD calculations give a good description of the data except for $Q^2 > 1000$ GeV^2, where in the lower E_T^{jet} region the data are above the calculations. This is the region where the NLO corrections are highest (up to 50 %) compared to LO, suggesting that improved QCD calculations may be needed here.

H1 measured [5] the single inclusive jet cross section $d^2\sigma/dQ^2dE_T^{jet}$ in four different Q^2 regions within the range $150 < Q^2 < 5000$ GeV^2. Jets are defined in the Breit frame, where the photon collides head on with the proton. Over the whole phase space ranging from 7 to 50 GeV in E_T^{jet} a NLO calculation based on DISENT [2] using the CTEQ5M PDF [6] describes the data well. For each E_T^{jet} and Q^2 bin the strong coupling α_s is adjusted to the cross section measured. In Figure 2 the results are shown as a function of E_T^{jet}, which is used as the renormalisation scale here, after having combined the four Q^2 bins. The fitted values of α_s evolve as predicted by the renormalisation group equation (see Figure 2). The combined value for $\alpha_s(M_Z)$ is :

$$0.1181 \pm 0.0030(exp)^{+0.0039}_{-0.0046}(theo)^{+0.0033}_{-0.0015}(pdf).$$

The largest contribution to the experimental error comes from the uncertainty in the hadronic energy scale. The theoretical error is mainly determined by the uncertainty of the hadronisation corrections and the dependence on the renormalisation scale.

In case the renormalisation scale is taken as Q instead of E_T^{jet} a consistent value of $\alpha_s(M_Z)$ is obtained :

$$0.1221 \pm 0.0034(exp)^{+0.0054}_{-0.0059}(theo)^{+0.0033}_{-0.0016}(pdf).$$

3 Measurements of Dijet Rates

ZEUS [7] has measured dijet cross sections in the phase space $470 < Q^2 < 20000$ GeV^2. The jet search is performed in the Breit-frame using the longitudinally invariant k_T-cluster algorithm. Only events with exactly two jets are selected requesting both jets to have $E_T^{jet} > 5$ GeV with

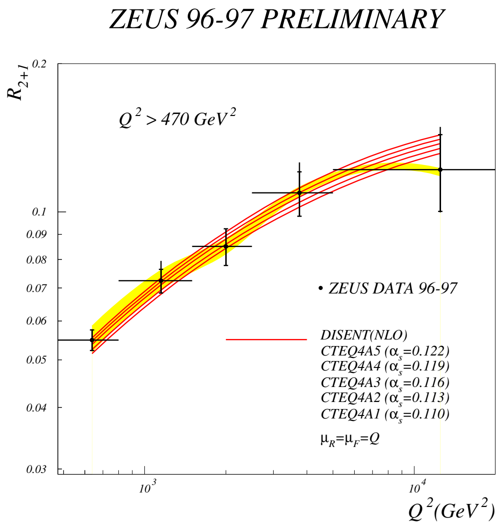

Figure 3: Exclusive dijet rate as function of Q^2 compared to NLO calculations using CTEQ PDF's fitted to different α_s assumptions.

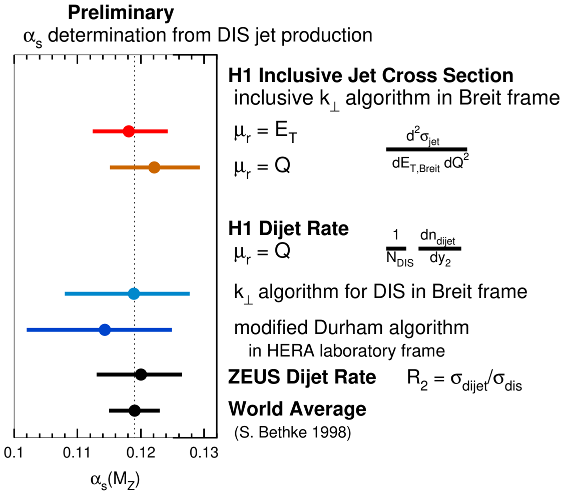

Figure 4: Summary of recent α_s measurements from DIS jets at HERA.

the sum of both exceeding 17 GeV.

The exclusive dijet-cross sections are well described by a NLO calculation using CTEQ4M PDF's [3]. The good description of the data allows an extraction of α_s from the relative dijet rates $R_{2+1} = \sigma_{2+1}/\sigma_{tot}$. The dijet rates, shown as a function of Q^2 in Figure 3, are compared to NLO QCD calculations based on the CTEQ4A PDF [3] series which have been fitted to different α_s assumptions. The value of $\alpha_s(M_Z)$ is obtained from a χ^2 minimisation :

$$0.120 \pm 0.003(stat)^{+0.005}_{-0.006}(exp)^{+0.003}_{-0.002}(theo)$$

Figure 4 summarizes the values of $\alpha_s(M_Z)$ determined in NLO from jet observables in DIS at HERA. The figure contains also the H1 results from differential dijet cross section [5], not described here in detail. The α_s values obtained are in very good agreement with the world average and have a precision only slightly worse than the best single measurements of α_s in other processes.

4 Three-Jet Cross sections

Measurements of three-jet cross sections provide tests of perturbative QCD at higher orders than in inclusive jet production.

H1 [5] has measured for the first time the differential cross sections for three-jet production in NC DIS investigating also the pattern of parton radiation by measurements of topological distributions. Jets are defined in the Breit frame. Events with at least three jets are selected with a cut of $M_{3jet} > 25\,$GeV on the three-jet invariant mass. The differential cross section $d\sigma/dQ^2$ for three-jet production measured in the range $5 < Q^2 < 5000$ GeV^2 is shown in Figure 5. It exhibits a steep drop over four orders of magnitude in the measured range. A leading order (LO) QCD calculation, which is $O(\alpha_s^2)$ for three-parton final states, using the program DISENT [2] is compared to the data in Figure 5. Taking into account that hadronisation effects are expected to lower the expected cross section by about 20 - 40 %, the calculation provides a fair description of the data except in the low-Q^2 region.

The topology of three-jet events has been studied in their center-of-mass system measuring the angle Ψ_3 between the three-jet plane and the plane containing the proton-beam direction and the most energetic jet. The distribution of Ψ_3, shown in Figure 5, exhibits clearly the pattern

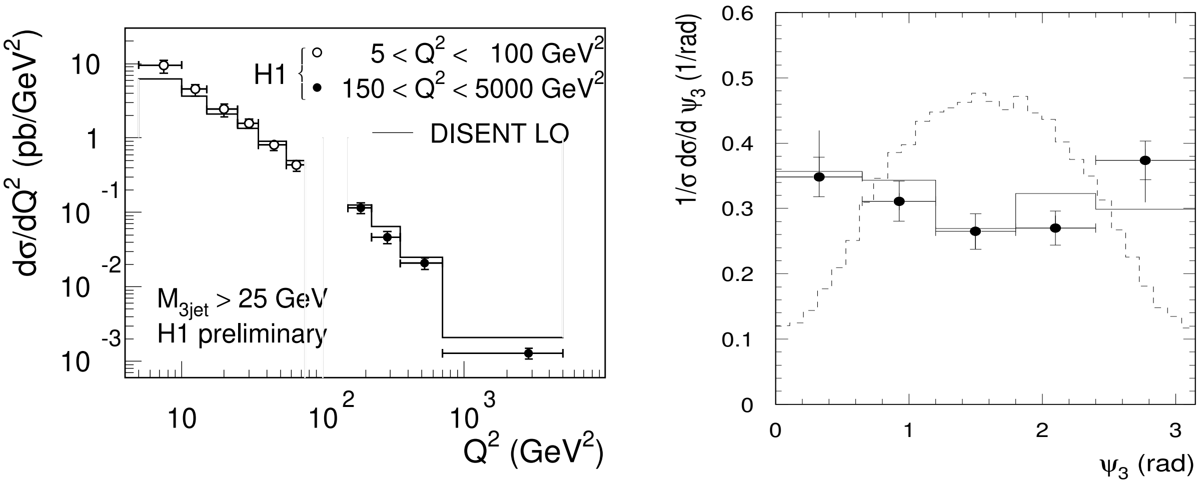

Figure 5: Inclusive three-jet cross section as a function of Q^2 compared to a LO QCD calculation (left). The three-jet topological variable Ψ_3 (see text) compared to LO QCD (solid histograms) and phase-space (dashed histograms) predictions (right).

of parton radiation in QCD : the expectation of phase space would be flat, but is diminished near $\Psi_3 = 0$ and π due to the jet requirements ; however the data behave the opposite way in agreement with QCD, where the initial state radiation pole gives rise to enhanced parton radiation at the extreme Ψ_3 values. This result nicely complements similar investigations of the Ψ_3 distribution in $p\overline{p}$ collisions [8] and γp interactions [9] at HERA.

Acknowledgments

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