INCLUSIVE HADRON PRODUCTION AND DIJETS AT HERA

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This article summarizes a talk given at the International Symposium on Multiparticle Dynamics 1999 in Providence/USA. It provides an overview on the variety of measurements of the hadronic final state in jet production for deep-inelastic scattering and photoproduction at HERA.

1 Introduction

The HERA storage ring provides beams of protons at 820 GeV and positrons at 27.5 GeV energy. Collisions of these are recorded at two general purpose detectors, H1[1] and ZEUS[2]. Measurements of the hadronic final state in deep-inelastic scattering and in photoproduction processes allow precise tests of the validity of perturbative Quantum-Chromo Dynamics (pQCD). In addition the extraction of the strong coupling strength α_s or the parton density functions with high precision becomes possible.

2 Deep-Inelastic Scattering

In deep-inelastic scattering the squared momentum transfer Q^2 from the beam electron to the proton is large. The scattered electron found in the detector at large scattering angles allows a precise determination of the event kinematics. The hadronic final state is resolved into jets e.g. by means of the longitudinal-boost invariant k_t algorithm[3].

Inclusive jet[4], dijet[5,6], and three jet[7] cross sections are measured. Inclusive and dijet distributions are shown in figures 1 and 2. NLO pQCD predictions[8] describe the data well and allow the strong coupling strength α_s to be extracted. H1 obtained from inclusive jet cross sections

$$\alpha_s(M_Z^2) = 0.1181 \pm 0.0030(\mathrm{exp})^{+0.0039}_{-0.0046}\,(\mathrm{theo})^{+0.0036}_{-0.0015}(\mathrm{pdf}) \qquad (1)$$

and ZEUS determined

$$\alpha_s(M_Z^2) = 0.120 \pm 0.003(\mathrm{stat})^{+0.005}_{-0.006}\,(\mathrm{exp})^{+0.003}_{-0.002}(\mathrm{theo}) \qquad (2)$$

from dijet cross sections. Both values are in agreement with the current world average. The uncertainty on α_s is dominated by the variation of the hadronic

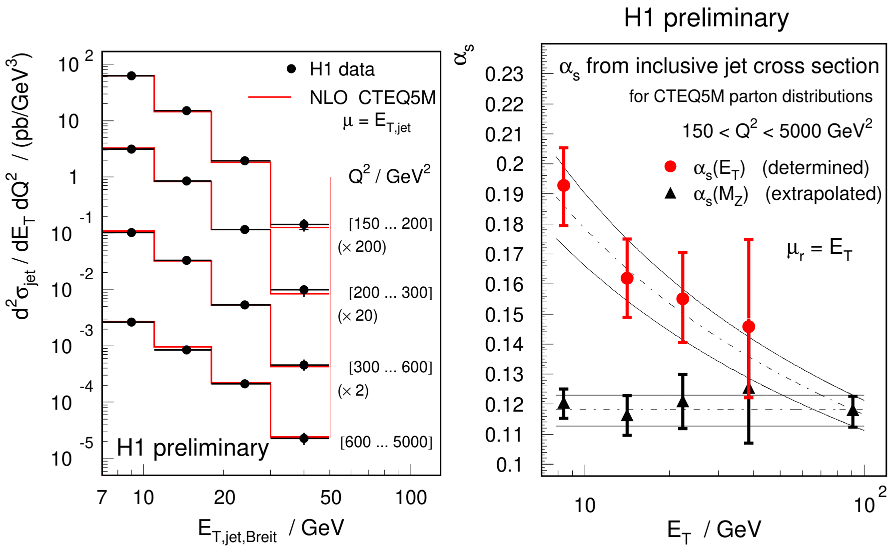

Figure 1. H1 double differential cross sections for inclusive jet production in DIS. The data are compared to NLO predictions. The strong coupling strength α_s, extracted from the inclusive jet distributions, is also shown.

energy scale, the renormalization scale, and the variation of the parton density functions. The gluon density is determined from dijet events by H1 as shown in figure 2. The distribution is in agreement with the extraction from scaling violations and with global fits. Three jet cross sections[7] are as well measured, but for the interpretation only LO pQCD calculations are available.

3 Photoproduction

In photoproduction the squared momentum transfer is small ($Q^2 \approx 0$) and the scattered electron most often leaves the experiment undetected. For jet production the transverse jet energy provides the reference scale. As for DIS, dijet[9,10] and three jet[11] processes are measured.

In the three jet case the event structure can be described by angular distributions. Figure 3 shows the definition and the distribution of $\cos(\theta_3)$ where θ_3 is the angle of the jet with the highest energy with respect to the proton beam direction. The Monte Carlo comparison demonstrates that in addition

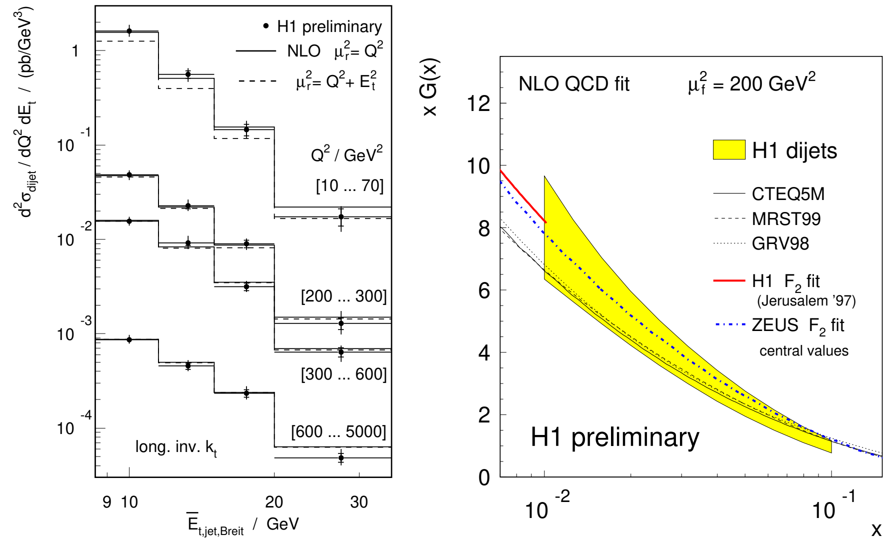

Figure 2. H1 double differential cross sections for dijet production in DIS. The data are compared to NLO predictions. The gluon density, extracted from the dijet distributions, is also shown.

to the direct process where the photon directly interacts with the parton, the resolved process is needed for describing the data. In the resolved case, the photon fluctuates into a partonic state and one of these partons interacts with the parton coming from the proton. pQCD calculations including this process are able to describe the data.

Figure 4 shows the fraction

$$x_\gamma^{\rm obs} = \frac{E_{T,1}^{\rm jet} e^{-\eta_1^{\rm jet}} + E_{T,1}^{\rm jet} e^{-\eta_1^{\rm jet}}}{2yE_e}$$

of the photon momentum observed in dijet processes in the ZEUS data. The strong peak close to $x_\gamma^{\rm obs} = 1$ is attributed to direct processes, but again the resolved component is needed for a description of the data by Monte Carlo models. NLO pQCD calculations in general describe the cross section including the dependence on $x_\gamma^{\rm obs}$ and the rapidity of the jets. However, at large $E_{T,\rm jet}$ a clear disagreement between data and NLO prediction for forward jets is found. Figure 5 shows this more clearly.

The knowledge of the photon structure functions is limited and the pQCD

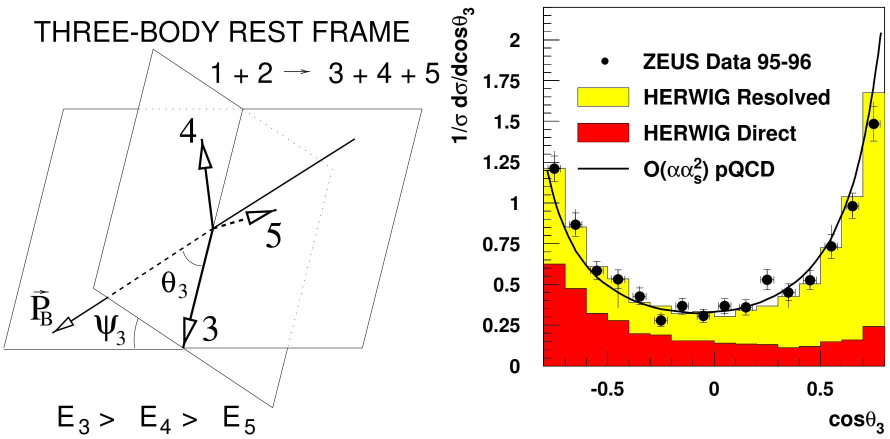

Figure 3. The definition and distribution of $\cos(\theta_3)$ for three jet events in photoproduction measured by ZEUS. In addition to the data, the breakdown of the HERWIG Monte Carlo into direct and resolved component and the theory prediction is shown.

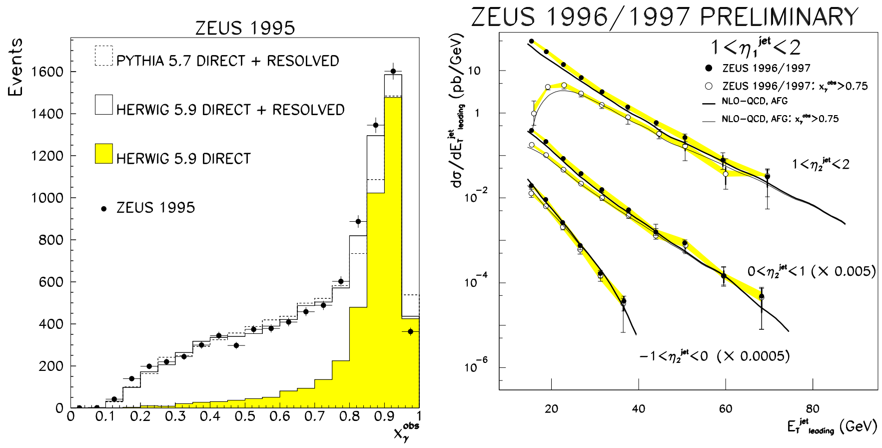

Figure 4. $x_\gamma^{\rm obs}$ spectrum and single differential cross section for dijet events in photoproduction measured at ZEUS compared to Monte Carlo and NLO pQCD predictions. The leading (second) jet is required to have a transverse energy greater than 14(11) GeV.

predictions for the dijet cross sections using different sets vary by more than 10% as can be seen in figure 5. H1 extracted an effective photon structure

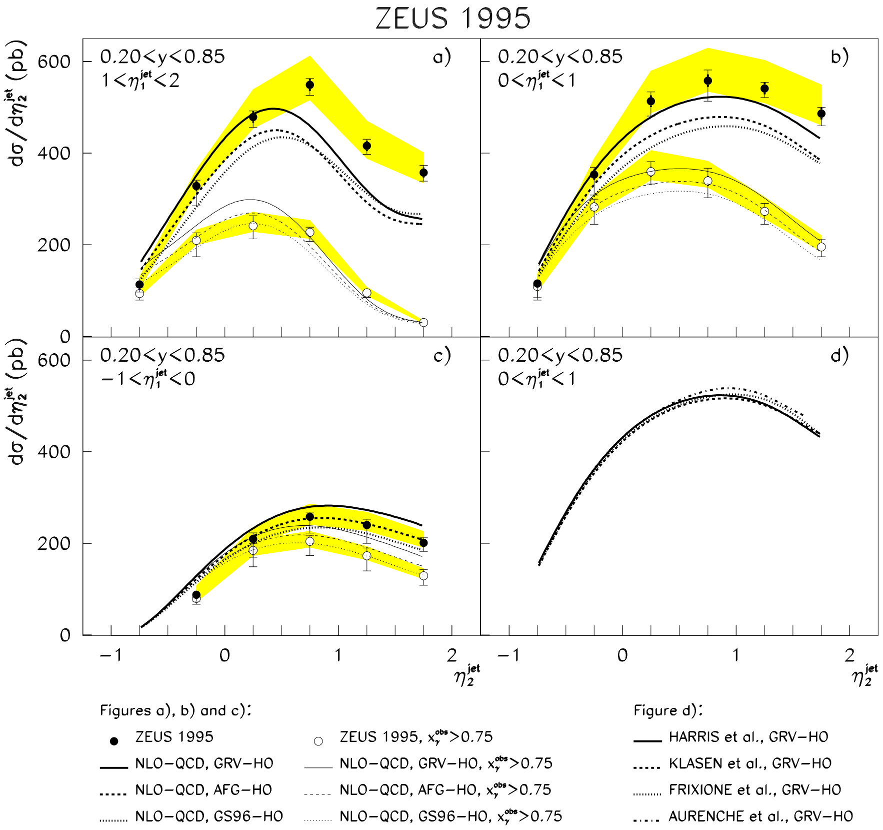

Figure 5. a)-c) Dijet cross section as function of jet rapidity for different $x_\gamma^{\rm obs}$ ranges compared to NLO pQCD predictions using various photon structure functions. The thick band shows the systematic uncertainty; d) Comparison of different NLO pQCD calculations for one choice of photon structure function.

function from photoproduction[12]. As can be seen in figure 6, the existence of a gluonic component in the photon structure is evident.

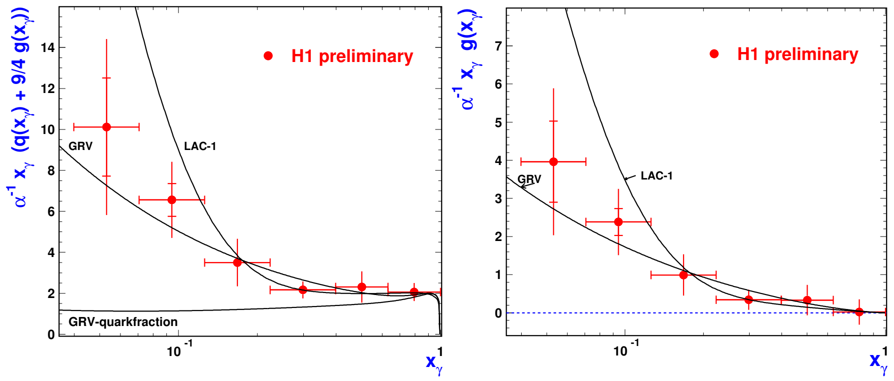

Figure 6. Effective photon structure function (left) and gluon density (right) in the photon as extracted from H1 dijet data for photoproduction. For comparison the LAC-1 and the GRV parameterizations are shown.

4 Summary

This article provides a short overview on the variety of measurements of the hadronic final state in jet production for deep-inelastic scattering and photoproduction at HERA. Perturbative QCD is successful in describing the data and therefore allows to extract parameters such as the strong coupling strength α_s and the parton density functions with a high precision. An additional reduction of the uncertainties needs higher order or resumed calculations for the observables. For photoproduction the importance of the resolved contribution is clearly demonstrated and a significant measurement of an effective photon structure function becomes possible. Higher luminosity will allow to make more precise extractions of the photon structure.

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