Inclusive-jet photoproduction at HERA and determination of α_s

Ewald Paul[1] on behalf of the ZEUS Collaboration
[1]Physikalisches Institut Bonn, Germany

DOI: `http://dx.doi.org/10.3204/DESY-PROC-2012-02/43`

Differential inclusive-jet cross sections have been measured in photoproduction with the ZEUS detector at HERA at a centre-of-mass energy of 318 GeV using an integrated luminosity of $300\,\mathrm{pb}^{-1}$. Cross sections are presented as functions of the jet pseudorapidity, η^{jet}, and the jet transverse energy, E_T^{jet}. of η^{jet}. The cross sections have the potential to constrain the gluon density in the proton and the photon when included as input to fits to extract the proton parton distribution functions. Next-to-leading order QCD calculations give a good description of the measurements. The value of the strong coupling constant $\alpha_S(M_Z)$ has been extracted from the measurement. The energy-scale dependence of α_S has been determined in the range $17 < E_T^{\mathrm{jet}} < 71\,\mathrm{GeV}$.

1 Introduction

The study of jet production in ep collisions at HERA has been well established as a testing ground of perturbative QCD. Jet cross sections provide precise determinations of the strong coupling constant, α_S, and its scale dependence.

2 Cross sections in comparison to NLO-QCD predictions

Cross sections of inclusive-jet photoproduction were measured as functions of E_T^{jet} and η^{jet} in the kinematic range $Q^2 < 1\,\mathrm{GeV}^2$, $142 < W_{\gamma p} < 293\,\mathrm{GeV}$, $E_T^{\mathrm{jet}} > 17\,\mathrm{GeV}$ and $-1 < \eta^{\mathrm{jet}} < 2.5$. Jets were identified in the laboratory system using the k_T cluster algorithm [4] in the longitudinally invariant inclusive mode [5] with the radius set to unity. Differential cross sections $d\sigma/dE_T^{\mathrm{jet}}$ and $d\sigma/d\eta^{\mathrm{jet}}$ are shown in figs. 1 and 2 respectively. The experimental errors include statistical and systematic errors except the jet-energy uncertainty which is shown separately. The cross sections are compared to NLO QCD predictions based on a program witten by M. Klasen, T. Kleinwort and G. Kramer [1]. In this program, renormalisation and factorisation scale were set to E_T^{jet}. The implemeted parton densities were ZEUS-S for the proton[2] and GRV-HO for the photon [3]. The predictions were calculated on parton level, and corrected to hadron level using Monte Carlo simulations (PYTHIA and HERWIG). In general the data are well described by the predictions. However, some differences are visible at small E_T^{jet} and large η^{jet}. The differences seen for η^{jet} are reduced if the cut on E_T^{jet} is raised to 21 GeV [6].

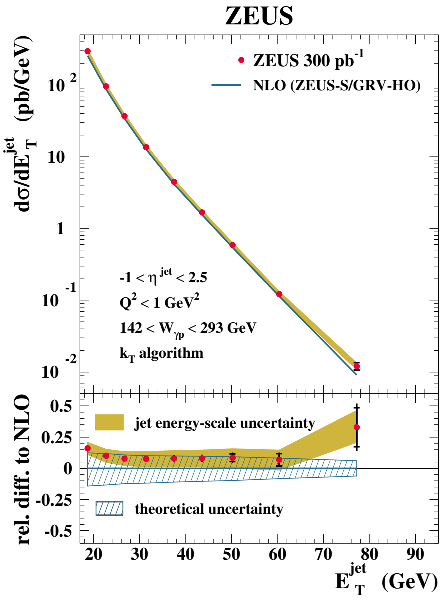

Figure 1: The cross section $d\sigma/dE_T^{\rm jet}$ compared to NLO QCD predictions. Shaded band: energy scale uncertainty of the jets. Hatched band: total theoretical uncertainty.

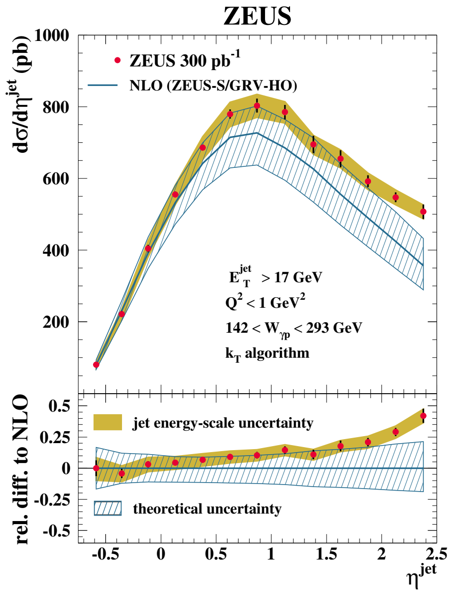

Figure 2: The cross section $d\sigma/d\eta^{\rm jet}$. Other details are the same as in Fig. 1.

3 Dependence on model asumptions

To access the influence of the jet algorithm , cross sections were also studied with the jet algorithms anti-k_T [7] and SIScone [8]. It has been noticed that no significant differences in the comparison between data and predcitions were observed.

Another study was carried out using the Monte-Carlo program PYTHIA-MI for hadronisation corrections. This program includes non-perturbative multi-parton interactions [9]. As can be seen in Fig. 3, the prediction for the $\eta^{\rm jet}$ distribution can be improved by including multi-parton interactions with an appropriate cut on the transverse momentum of the scattered parton. The prediction with $p_{T,\rm min}^{\rm sec} = 1.5\,\rm GeV$ is closest to the data.

4 Dependence on the choice of PDFs

Predictions were caculated using the AFG04[10] and CJK[11] photon PDFs instead of GRV-HO. Figure 4 shows the comparison between the measured cross sections and the predictions based on different photon PDFs. The uncertainty coming from the photon PDFs is largest at low $E_T^{\rm jet}$ and high $\eta^{\rm jet}$ and approximately ofthe order of the theoretical uncertainty. The measured cross sections are, on a similar level, sensitive to proton PDFs[6]. This implies that the measured cross sections have the potential to constrain the gluon density in photon and proton when used as input to a global fit.

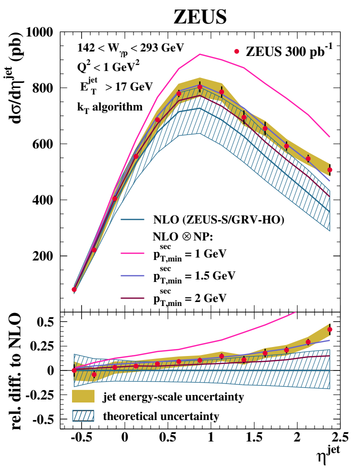

Figure 3: The cross section $d\sigma/d\eta^{\rm jet}$ compared to NLO QCD predictions including multi-parton interactions.

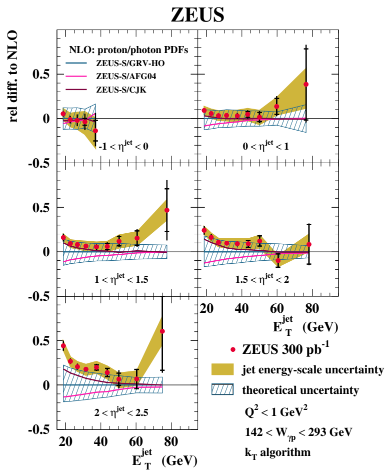

Figure 4: Relative differences between measured and predicted cross sections for several photon PDFs. (Default: GRV-HO).

5 Measurement of $\alpha_S(M_Z)$ and the α_S energy scale dependence

Differential cross sections $d\sigma/dE_T^{\rm jet}$ measured in the range $21 < E_T^{\rm jet} < 71\,{\rm GeV}$ were used to determine values of the strong coupling constant α_S using the method presented previously [12]. The fit was restricted to $E_T^{\rm jet} < 71\,{\rm GeV}$ because of the uncertainty coming from the photon PDFs for higher $E_T^{\rm jet}$ values. The value of $\alpha_S(M_Z)$ was determined by fitting NLO QCD predictions to the $d\sigma/dE_T^{\rm jet}$ distribution [6]. The fit obtained with the k_T algorithm yielded: $\alpha_S(M_Z) = 0.1206^{+0.0023}_{-0.0022}(exp.)^{+0.0042}_{-0.0035}(th.)$. The value is in good agreement with the world and HERA averages and the errors are comparable to those of other recent measurements.

The energy scale dependence of α_S was determined from NLO QCD fits without assumung the running of α_S [6]. The result, shown in fig. 5, demonstrates the running of α_S over a large range in $E_T^{\rm jet}$. The predicted running calculated in two loops [13] is in good agreement with the data.

6 Summary

Inclusive-jet photoproduction was measured with the ZEUS detector at the *ep* collider HERA. Cross sections were calculated as functions of $E_T^{\rm jet}$ and $\eta^{\rm jet}$. In general they are well described by NLO QCD predictions. Three jet algorithms were studied with respect to the comparison of data and predictions showing that the observed differences are small. Studies of multi-parton interactions have shown that their inclusion improves the description of the jet rates at low $E_T^{\rm jet}$ and high $\eta^{\rm jet}$. The measured cross sections have the potential to improve PDFs of photon and proton when included in a global fit. The strong coupling constant α_S was determined at the mass of the Z boson and energy scaling was observed over a wide range of $E_T^{\rm jet}$.

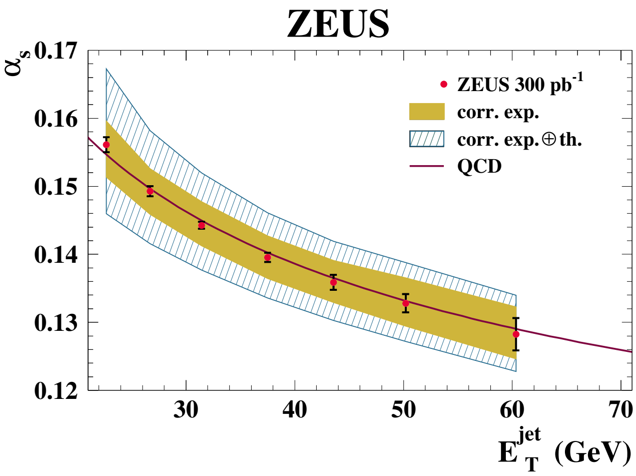

Figure 5: Dependence of α_S on $E_T^{\rm jet}$ as scaling variable. Solid line: normalisation group prediction. Error bars: uncorrelated experimetnal errors. Shaded band: correlated experimental errors. Hatched band: correlated experimental and theoretical errors added in quadrature.

References

[1] M. Klasen *et al.* Eur. Phys. J. Direct **C1** (1998) 1.

[2] ZEUS Collaboration, S. Chekanov *et al.* Phys. Rev. **D67** (2003) 012007.

[3] M. Glück *et al.* Phys. Rev. **D45** (1992) 3986; M. Glück *et al.* Phys. Rev. **D46** (1992) 1973.

[4] S. Catani *et al.* Nucl. Phys. **B406** (1993) 87.

[5] S. D. Ellis and D. E. Soper, Phys. Rev. **D48** (1993) 3160.

[6] ZEUS Collaboration, H. Abramovicz *et al.* DESY 12-045 (March 2012.

[7] M. Cacciari *et al.* JHEP **0804** (2008) 063.

[8] G. P. Salam and G. Soyez, JHEP **0705** (2007) 086.

[9] T. Sjöstrand and M. van Zijl, Phys. Rev. **D36** (1987) 2019.

[10] P. Aurenche *et al.* Eur. Phys. J. **C44** (2005) 395.

[11] F. Cornet *et al.* Phys. Rev. **D70** (2004) 093004.

[12] ZEUS Collaboration, S. Chekanov *et al.* Phys. Lett. **B547** (2002) 164.

[13] D. J. Gross and F. Wilczek, Phys. Rev. Lett. **30** (1973) 1343; H. D. Politzer, Phys. Rev. Lett. **30** (1973) 3633; D. J. Gross and F. Wilczek, Phys. Rev. **D8** (1973) 3633; H. D. Politzer, Phys. Rep. **14** (1974) 129.