JETS IN DEEP-INELASTIC SCATTERING AT HERA AND DETERMINATIONS OF α_S*

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Several methods to extract the strong coupling constant α_s by means of highly energetic jets in Deep-Inelastic Scattering are presented. The results from the various methods agree with one another and with the world average. The errors are competetive to those achieved in α_s determinations in other processes such as proton–anti-proton scattering.

1. Introduction

Measurements of the hadronic final state in deeply inelastic *ep* scattering (DIS) provide precision tests of quantum chromodynamics (QCD). At HERA data are collected over a wide range of the negative four-momentum-transfer Q^2, and the transverse energy E_T of hadronic final state jets. As sketched in Eq. 1 the jet cross section can be expressed as a power series of α_s combined with a convolution of the hard matrix element, $\hat{\sigma}_{jet}$, and appropriate parton distribution functions of the proton.

$$\sigma_{jet} = \sum \alpha_s^n(\mu_r) \sum \hat{\sigma}_{jet}(\mu_r, \mu_f) \otimes \mathrm{pdf}(\mu_f, ...), \quad (1)$$

with μ_r and μ_f being mass scales.

Fig. 1 shows diagrams of the leading order, here $O(\alpha_s)$, processes for dijet-production in DIS.

The accurate measurement of jet production, hence, allows for a precise determination of α_s.

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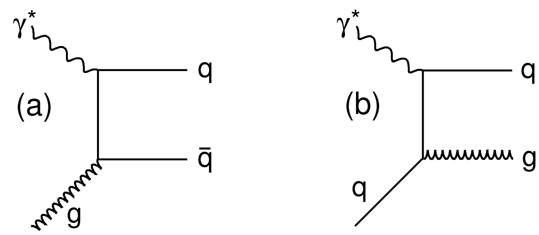

Figure 1. Leading order diagrams for dijet production in ep scattering. (a) photon-gluon fusion and (b) QCD-Compton process.

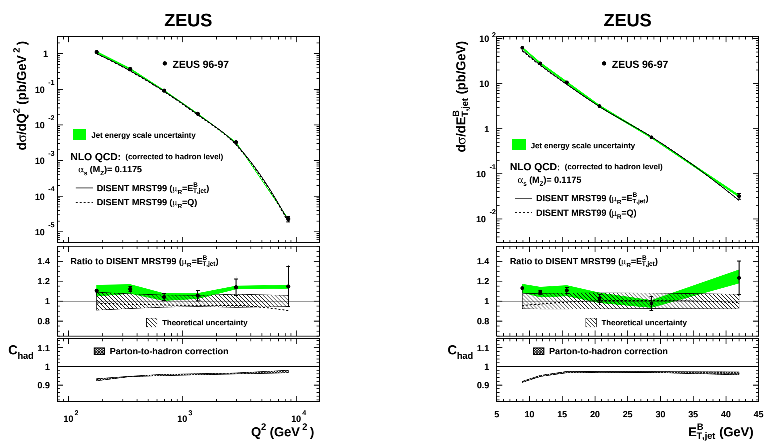

Figure 2. Single inclusive jet cross section as a function of Q^2 (left) and $E^B_{T,\mathrm{jet}}$ (right) compared with NLO QCD predictions.

2. Single Inclusive Jet Cross Section

For this analysis it is required to identify at least one jet above a given transverse energy. Fig. 2 shows the measured single inclusive jet cross section as a function of Q^2 and the transverse energy of the jet as measured in the Breit-Frame compared with NLO-QCD calculations [1].

The data have a typical experimental uncertainty of 7 % and are well reproduced by the theoretical predictions at large values of E_T and Q^2. The NLO-QCD calculations, currently only available at the parton level, are corrected for hadronisation effects using LO models. These corrections are expected to be small at large E_T and Q^2.

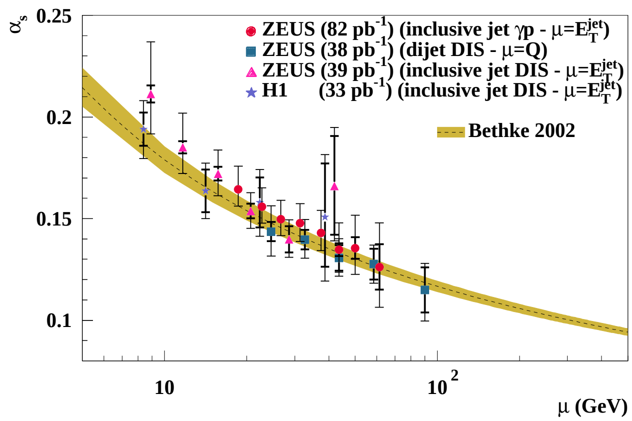

Figure 3. Various results on α_s mesurements in DIS as a function of a mass scale μ compared with results from global fits.

2.1. *Determination of* α_s

The dependency of a generic jet cross section on $\alpha_s(M_Z)$ is parameterized in the corresponding analysis bins with the help of suitable NLO-QCD predictions featuring slightly different values of $\alpha_s(M_Z)$. By comparison of the parameterized cross section with the measured cross section the values for α_s are obtained. The resulting $\alpha_s(M_Z)$ from *e.g.* the single inclusive jet cross section for $Q^2 > 500$ GeV is found in the ZEUS analysis to be

$$\alpha_s(M_Z) = 0.1212 \pm 0.0017(\text{stat.})^{+0.0023}_{-0.0031}(\text{exp.})^{+0.0028}_{-0.0027}(\text{theor.}).$$

The experimental error (exp.) is dominated by the uncertainty on the energy scale for the jet measurement. The largest contribution to the theoretical uncertainty (theor.) is given by a residual dependency on the renormalization scale μ_r which corresponds to uncertainties due to the contributions of terms beyond next-to-leading order.

In Figure 3 the result is displayed as a function of a mass scale μ together with other values of α_s extracted from DIS-jet data [2].

The expected running of α_s as a function of μ is clearly visible. In addition the figure demonstrates the compatibility of the resulting α_s values with those obtained in global fits [3].

3. Jet Substructure and Determination of α_s

Jets appear as a collimated spray of particles which are combined to by dedicated algorithms. These particles are the end point of a cascade of succssive particle emissions from the hard interaction to the hadronic final state. The development of the cascade is governed by the strong coupling constant α_s. An attempt is made to resolve subjets using dedicated algorithms within the identified jets [4]. The amount of subjets is expected to depend on α_s. Fig. 4 shows the number of subjets as a function of the jet-E_T measured in the laboratory frame. The number of subjets decreases as the transverse energy of the jet increases. The transverse energy of the jet sets the scale for α_s. Thus, the probablity to radiate partons is small at large transverse energies. The data are well described by NLO-QCD calculations employing different parton pdfs featuring slightly different values of $\alpha_s(M_Z)$. For E_T larger than 30 GeV the hadronization corrections become small allowing for a QCD analysis to determine α_s from subjet multiplicites. The resulting value is found by ZEUS to be

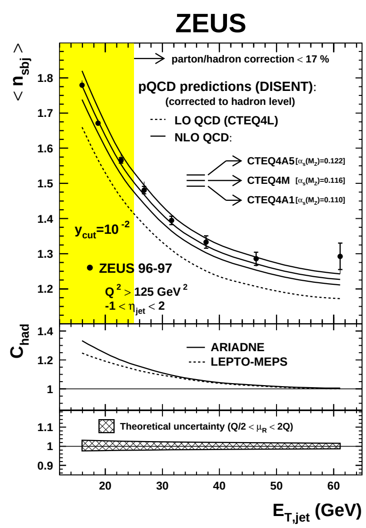

Figure 4. Subjet multiplicites for different transverse energies of jets. Jets were identified in the labaratory frame.

$$\alpha_s(M_Z) = 0.1187 \pm 0.0017(\text{stat.})^{+0.0024}_{-0.0009}(\text{exp.})^{+0.0093}_{-0.0076}(\text{theor.}).$$

4. 3-jet Cross Sections

3-jet cross sections are well suited for an extraction of α_s because the lowest order contribution to this event class is proportional to α_s^2. The sensitivity to uncertainties due to proton pdf's can be reduced by building the ratio $R_{3/2}$, *i.e.* the ratio of 3-jet to dijet cross sections. A measurement of this observable is shown in Fig. 5. While a minor sensitivity to variations of the pdf's is observed the ratio is very sensitive to small variations of α_s which underlines the potential of this observable for future determinations of α_s.

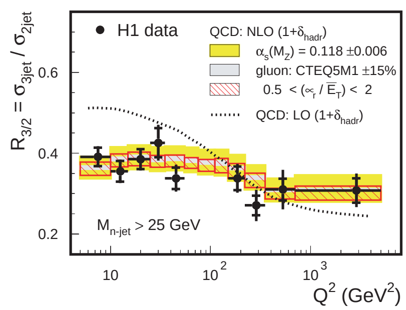

Figure 5. The observable $R_{3/2}$ as a function of Q^2 compared with NLO-QCD predictions.

5. Conclusion and Outlook

The analysis of jet events in DIS allows for precise measurements of the strong coupling constant α_s. A compilation of results is given in Fig. 6. They have a major impact on the current world average value of α_s. Ongoing analysis of HERA I [6] data as well as new data expected from HERA II open the possibility for α_s determinations including 3-jet cross sections.

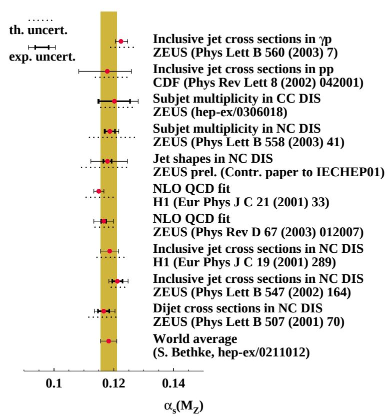

Figure 6. $\alpha_s(M_Z)$ values obtained in DIS together with results from $p\bar{p}$-collisions and the world average.

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