Jet Cross-Sections and α_S in DIS at HERA

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Measurements of inclusive-jet and dijet cross-sections in high-Q^2 deep-inelastic scattering are presented together with a short overview of extractions of the strong coupling parameter α_S from jets. The data samples used were collected with the ZEUS detector at HERA-1 and HERA-2. The measured distributions are compared to QCD calculations in next-to-leading order which describe the data very well. The various determinations of α_S give a consistent picture, have competitive uncertainties and clearly demonstrate the running of the coupling predicted by QCD.

1 Introduction

Measurements of jet cross-sections in high-Q^2 deep-inelastic scattering (DIS) have traditionally been used to test the concepts of perturbative QCD (power expansion, factorisation, PDF universality). In addition, jet measurements in DIS allow precise determinations of the strong coupling α_S and are a valuable input to global fits of the PDFs (see for example [2]).

In this article measurements of jet cross-sections in high-Q^2 DIS are reported which are new in two respects: First, the first neutral-current (NC) jet measurement in a combined HERA-1+HERA-2 data sample from the ZEUS experiment is presented, showing single- and double-differential dijet cross-sections. A similar measurement of such dijet cross-sections in HERA-1 data has recently been published by the ZEUS collaboration [3]. Second, HERA-1 data have been used to measure inclusive jet cross-sections with different values of the R parameter in the inclusive k_T jet clustering algorithm [4]. This parameter defines the distance up to which two particles may be joined into a new pseudo-particle in the process of jet clustering. An investigation of the R-dependence of jet cross-sections may prove helpful for heavy flavour physics, for

Figure 1: ZEUS inclusive-jet cross-sections $d\sigma/dQ^2$ for various values of R.

hadronisation studies or for physics studies at the LHC. The inclusive-jet data have in addition been used for a new determination of α_S. For this reason, this article also gives a short overview of α_S measurements from jets at ZEUS.
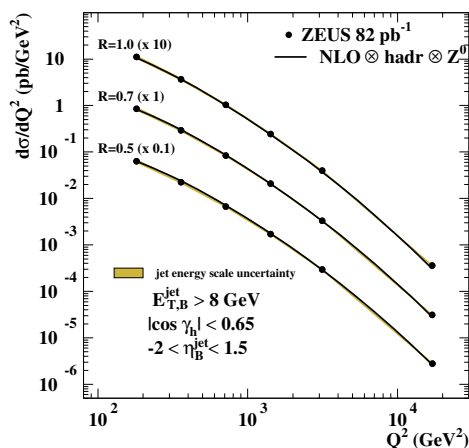
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2 Data samples and selections

The inclusive-jet analysis reported on was carried out in 82 pb^{-1} of data from the years 1998-2000; the dijet analysis used in addition about 127 pb^{-1} from the electron running period in 2004/05. Together with a ZEUS jet measurement in charged-current events [5], this dijet measurement is the first jet measurement in HERA-2 data.
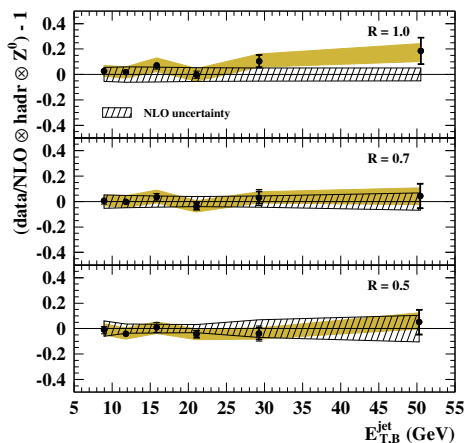

Figure 2: Ratio of data over NLO QCD for the inclusive-jet cross-sections $d\sigma/dE_T^{Breit}$ for various values of R.

The event selections of both the inclusive-jet and dijet measurements follow closely that described in [3] and require high values of $Q^2 > 125$ GeV^2 to ensure relatively small theoretical uncertainties. Furthermore, the requirement $-0.65 < \cos\gamma_{had} < 0.65$ was imposed, where in lowest-order (Quark-Parton-Model) events γ_{had} corresponds to the scattering angle of the struck parton. The cut on γ_{had} helps to select phase-space regions with good acceptance and to ensure a good reconstruction of jets in the Breit reference frame.

Jets were reconstructed in the Breit frame using the longitudinally invariant k_T clustering algorithm in the inclusive mode; the Breit-frame pseudorapidities of the jets, η^{Breit}, were restricted to $-2 < \eta^{Breit} < 1.5$, and the Breit-frame transverse energies of the jets, E_T^{Breit}, were restricted to $E_T^{Breit} > 8$ GeV. For the dijet analysis the hardest jet was in addition required to satisfy $E_T^{Breit} > 12$ GeV.

All data distributions were corrected for detector and QED radiation effects using leading-order (LO) Monte Carlo (MC) programs in a bin-to-bin fashion. The data were then compared to next-to-leading order (NLO) QCD calculations that employed either the latest PDF sets from the CTEQ group or the ZEUS-S PDFs. The NLO predictions were corrected for hadronisation effects, and in case of the inclusive-jet measurement, for Z^0 contributions.

3 Experimental and theoretical uncertainties

The experimental uncertainties are dominated by the uncertainty in the jet energy scale which is assumed to be 1-3 %, depending on the jet E_T. Resulting uncertainties on the measured cross-sections are typically 5-10 %. The next-largest uncertainty stems from the model uncertainty in the unfolding of the measured distributions to the hadron level; further sources of uncertainty like the effects of selection cut variations are typically much smaller.

On the theoretical side, the effect of higher orders not considered in the perturbative expansion and the uncertainties on the input PDFs give the largest contributions. The former is typically estimated by variations of the renormalization scale μ_R by an arbitrary, but customary amount; the effects on the cross-sections are typically in the order of 5-10 % for the inclusive jet measurements and slightly larger for the dijet measurements. The effect of the PDFs is somewhat smaller, depending on the region of phase-space considered. The

effects of the uncertainties on α_S, on the hadronization corrections and on the factorization scale are much smaller. It should be noted that in almost all experimental bins the theoretical uncertainty is significantly larger than the experimental one.

4   Inclusive-jet cross-sections

Inclusive-jet cross-sections at high Q^2 were measured as functions of the jet transverse energy in the Breit frame, E_T^{Breit} and of Q^2 for three different values of R: 0.5, 0.7, 1.0 (it turns out that for higher (lower) values of R the uncertainties due to missing higher orders (hadronisation effects) become drastically larger).

The resulting cross-section as a function of Q^2 is shown in Figure 1. The data (points) are compared to the NLO QCD prediction (lines); the description of the data by theory is good. Figure 2 shows the ratio between the measured cross-sections as functions of jet transverse energy E_T and the NLO calculations. The measurement can be seen to be dominated by the (correlated) jet energy-scale and theoretical errors (grey and hashed areas, respectively), except for the highest-E_T (and also highest-Q^2) points for which the statistical uncertainties are large (10 %). Within all errors, the data are well described by the theoretical predictions. The data have also been plotted as a function of the jet radius parameter R, integrated over all E_T and Q^2 values (not shown). A more or less linear increase of the cross-section with R can be observed, which is to be expected since with larger radii the jet algorithm picks up more and more of the jet's energy.
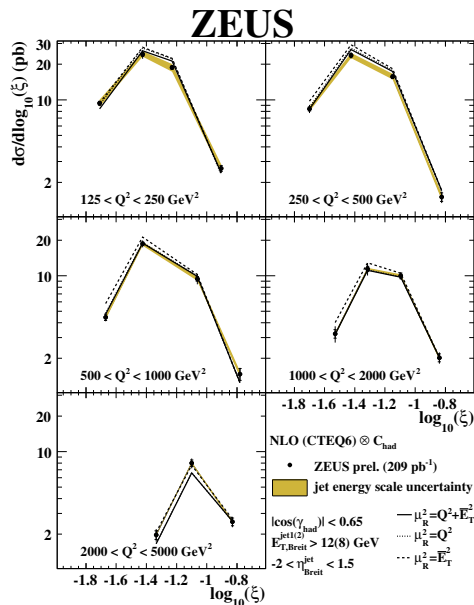

Figure 3: ZEUS dijet cross-sections $d\sigma/d\log\xi$ in different regions of Q^2.

5   Dijet cross-sections

Figure 3 shows the dijet cross-section for jets above 12 and 8 GeV, respectively, as a function of $\log_{10}\xi$ in different regions of Q^2. In leading order, the observable ξ corresponds to the momentum fraction carried away from the incoming proton by the struck parton. These cross-sections therefore depend on the two variables relevant for the PDFs, the energy scale and the momentum fraction, and thus might be useful for an improvement of the PDF precision.

The data are again compared to NLO QCD predictions, using various squared renormalization scales, namely $\mu_R^2 = Q^2 + \overline{E_T}^2$, $\mu_R^2 = Q^2$ and $\mu_R^2 = \overline{E_T}^2$. The shaded band indicates again the jet energy-scale uncertainty that is assumed to be correlated from bin to bin. Taking into account all uncertainties, the data are well described by the NLO predictions.

However, it should be noted that in different regions of phase-space different scale choices are required to achieve this good agreement: The low-Q^2 data points are better desribed using the squared scale $\mu_R^2 = Q^2 + \overline{E_T}^2$, whereas at high Q^2 $\mu_R^2 = \overline{E_T}^2$ seems more appropriate.

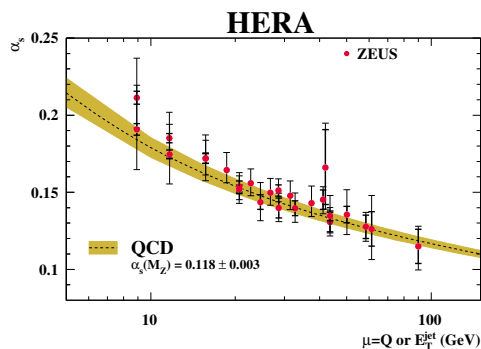# 6 Determining α_S with jets at ZEUS

Figure 4: Comparison of various ZEUS α_S measurements from jets in DIS with the QCD prediction

The strong coupling parameter α_S has been determined from a variety of QCD measurements at ZEUS, the latest result coming from the inclusive-jet measurements described above [4]: $\alpha_S = 0.1207 \pm 0.0014(stat.) \pm^{0.0035}_{0.0033} (exp.) \pm^{0.0022}_{0.0023} (th.)$ The various measurements at different energy scales are well described by the behaviour of the coupling as expected from QCD, see Fig. 4. A combination of ZEUS and H1 α_S measurements has been carried out recently [6] and has led to a value of $\alpha_S = 0.1186 \pm 0.0011(exp.) \pm 0.0050(th.)$. The good agreement of the various measurements with each other and with the world average value indicates the high level of our present understanding of QCD. Nevertheless, it should be pointed out that the α_S measurements from jets in DIS suffer from large theoretical uncertainties which are mostly due to missing higher orders in the perturbative expansion of the presently available QCD predictions.

7 Conclusions

With the advent of HERA-2 analyses and the possibility of combined HERA-1/HERA-2 analyses, QCD studies with jets at HERA enter a new regime. In this contribution, measurements of inclusive-jet and dijet cross-sections have been discussed together with extractions of the strong coupling parameter α_S from jet and other DIS measurements. Although many jet measurements are limited by theoretical uncertainties, the impact of further jet measurements on our knowlegde of PDFs and α_S should be assessed and exploited.

References

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