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# HIGH $p_{\mathrm{T}}$ JETS IN DIS AND $\gamma p$ AT HERA*

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Recent results on dijet, inclusive jets, production at high $p_{\mathrm{T}}$ in Deep Inelastic Scattering DIS and photoproduction $\gamma p$ regimes using both the H1 and ZEUS detectors at HERA are presented. Also studies of integrated jet shape and jet radius dependencies in DIS performed by the ZEUS Collaborations are discussed. All the measurements are found to be well described by calculations at the next-to-leading order in perturbative QCD. A combined determination of the value of the strong coupling constant $\alpha_{\mathrm{s}}(M_Z)$ from the H1 and ZEUS Collaborations using inclusive-jet cross-section measurements in neutral current DIS at high $Q^2$ is shown.

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## 1. Introduction

Measurements of jets cross-sections in high-$Q^2$ deep-inelastic scattering (DIS) as well as in photoproduction $\gamma p$ interactions 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 $\alpha_{\mathrm{s}}$ and are a valuable input to global fits of the PDFs (see for example [1]). In this article new results published by the H1 and ZEUS Collaborations will be presented.

## 2. Dijet cross-section

Measurements of cross-sections for high-$E_{\mathrm{T}}$ dijet in photoproduction, when a quasi-real photon, emitted from the incoming electron, collides with a parton from the incoming proton, are presented. The data samples were collected with the ZEUS detector and correspond to an integrated luminosity

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of $\mathcal{L} = 81.8$ pb$^{-1}$ [2]. The measured cross-sections show a sensitivity to the parton distributions in the photon (see Fig. 1 (left)) and in the proton and the QCD effects beyond next-to-leading order. The data are therefore, well-suited to further constrain the proton and photon distribution functions when used in [1] global QCD fits (the same conclusions can be derived by looking at H1 data as in [3] and [4]).

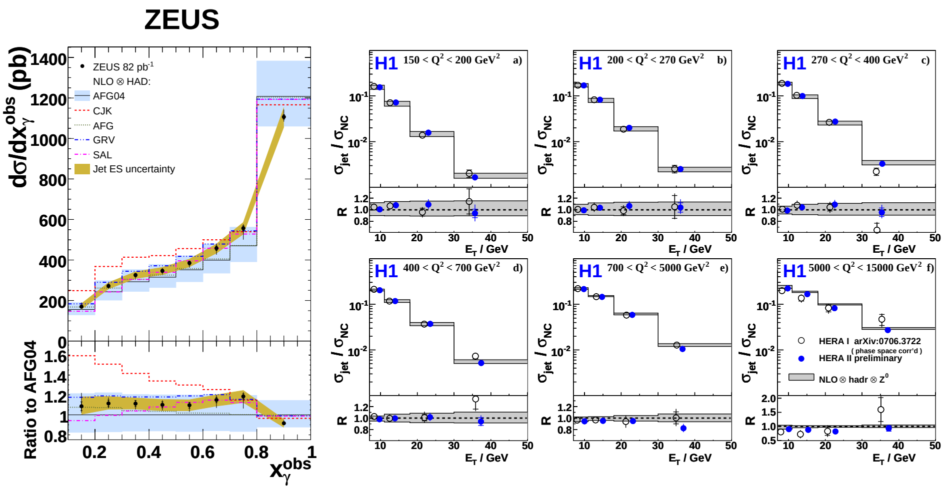


Fig. 1. Left: Dijets cross-section $d\sigma/dx_\gamma{}^{\rm obs}$ by ZEUS. Data are compared with the results of NLO by Frixione–Ridolfi obtained using numerous photon PDFs. Right: Inclusive-jets double-differential cross-section $d^2\sigma/dE_{\rm T,B}^{\rm jet}dQ^2$ by H1. Data are compared with the results of NLOJET++, corrected for hadronisation and $Z^0$ boson exchange.

### 3. Inclusive-jet cross-section

Inclusive-jet cross-section based on the total HERA-II data set equivalent to $\mathcal{L} \simeq 320$ pb$^{-1}$ recorded by the H1 detector have been reported. The inclusive-jet cross-section normalised to the neutral current deep inelastic scattering (NC DIS) cross-section is measured as a function of the hard scale $Q^2$ and $E_{\rm T,B}$, the transverse jet energy in the Breit frame [5], in the phase space defined by $150 < Q^2 < 15\,000\,{\rm GeV}^2$, $0.2 < y < 0.7$, where $y$ quantifies the inelasticity of the interaction, and for $7 < E_{\rm T,B} < 50\,{\rm GeV}$. The measurements are found to be well described by calculations at the NLO in perturbative QCD, pQCD. The present preliminary results are compared to recently published results based on 1999–2000 data recorded by H1 during the HERA-I period with $\mathcal{L} = 65.4$ pb$^{-1}$. As can be seen in Fig. 1 (right) the use of a much larger dataset significantly improves the statistical precision and reduces the total uncertainty of the measurements.

### 4. Jet-radius dependence and integrated jet shape

At sufficiently high $E_{\mathrm{T}}^{\mathrm{jets}}$, where fragmentation effects become negligible, the jet substructure is expected to be calculable by pQCD. Moreover, measurements of jet substructure allow investigations of the differences between quark and gluon initiated jets and the dynamics of the different partonic final states, as well as determinations of $\alpha_{\mathrm{s}}$.

Studies of the jet-radius dependency performed with an inclusive-jet sample in DIS with $Q^2 > 125\,\mathrm{GeV}^2$ have shown that there is a linear proportionality of the radius $R$ on the differential cross-section as function of both $Q$ and $E_{\mathrm{T,B}}^{\mathrm{jet}}$ for $0.5 \leq R \leq 1$. [7]. Similarly, an analysis has been performed using DIS events, in the same phase space, collected during the HERA-II period with the ZEUS detector with $\mathcal{L} = 368\,\mathrm{pb}^{-1}$. The data were divided into two samples with one and two jet(s) of transverse energy $E_{\mathrm{T}} > 14\,\mathrm{GeV}$, respectively. As differentiating quantity, the integrated jet shape has been used, defined as

$$\langle \Psi(r) \rangle = \frac{1}{N_{\mathrm{jets}}} \sum_{\mathrm{jets}} \frac{E_{\mathrm{T}}(r)}{E_{\mathrm{T}}^{\mathrm{jets}}}\,,$$

that is the average fraction of the jet's transverse energy that lies inside a circle in the $\eta$–$\phi$ plane of radius $r$ concentric with the jet axis. The results are compatible with the predictions of pQCD that foresee that gluon jets are broader than quark jets $\Psi_{\mathrm{quarks}}(r) > \Psi_{\mathrm{gluons}}(r)$ as can be seen in Fig. 2 (left).

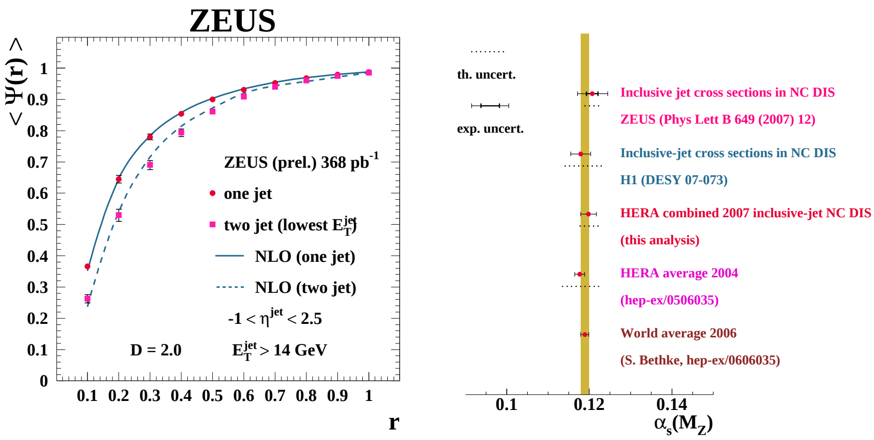


Fig. 2. Left: integrated jet shape, points are ZEUS measurements, curves are NLO calculation with DISENT (1 jet events) and NLOJET++ (2 jets events). Right: $\alpha_{\mathrm{s}}(M_Z)$ determinations from the H1 and ZEUS Collaborations. The HERA combined 2007 $\alpha_{\mathrm{s}}(M_Z)$ and the HERA-2004 and the world-average are also shown.

## 5. Combined $\alpha_s$ determination

The strong coupling constant, $\alpha_s$, is one of the fundamental parameters of QCD. However, its value is not predicted by theory and must be determined experimentally. The success of perturbative QCD is strengthened by precise and consistent determinations of the strong coupling constant from many diverse phenomena [9]. New determinations of the $\alpha_s$ have been recently published by the H1 [10] and ZEUS [11] Collaborations. These determinations have been performed from the measurements of inclusive-jet cross-sections in NC DIS at high-$Q^2$ and have been further used to perform a combined analysis and to obtain a single more precise $\alpha_s$ value [12].

A simultaneous fit to the actual cross-section measurements, instead of combining $\alpha_s$ values as it was done for the HERA-2004 average, was performed. The simultaneous fit was done to 24 H1 data points in the range of $150 < Q^2 < 15000$ GeV$^2$ (see Fig. 1 (right)) and 6 ZEUS data points in the range of $125 < Q^2 < 10\,000\,\mathrm{GeV}^2$. The NLO calculations used were based on the MRST2001 PDF sets. The renormalisation and factorisation scales were set to $E_{\mathrm{T,B}}^{\mathrm{jet}}$ and $Q$, respectively. The experimental uncertainty on the combined $\alpha_s$ value amounts to 0.0019 and was obtained with the Hessian method, which fits the sources of systematic uncertainties as the energy scale, luminosity, model dependence, *etc.* The sources of systematic uncertainty were treated as correlated for measurements within one experiment, but uncorrelated between the two experiments. The theoretical uncertainty coming from terms beyond NLO was estimated using the method of Jones *et al.* [13], and gives the largest contribution. The other sources of theoretical uncertainty considered were: PDF, factorisation scale and hadronisation. Therefore, the HERA combined 2007 $\alpha_s(M_Z)$ value is

$$\alpha_s(M_Z) = 0.1198 \pm 0.0019(\mathrm{exp.}) \pm 0.0026(\mathrm{th.})\,, \quad (\mathrm{HERA\ combined\ 2007})\,.$$

This combined value is shown in Fig. 2 (right) together with the individual values obtained by both collaborations, the HERA-2004 ($0.1186 \pm 0.0011(\mathrm{exp.}) \pm 0.0050(\mathrm{th.})$) and the world-2006 ($0.1189 \pm 0.0010$) averages. The measurements are consistent with each other and with the world average. The HERA 2007 combined $\alpha_s(M_Z)$ has a much smaller theoretical uncertainty due to the combination of the measurements in which the theoretical uncertainties are well under control, at the expense of a slight increase in the experimental uncertainty. This value of $\alpha_s(M_Z)$ is very competitive with the most recent result from LEP [14].

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