Combined H1-ZEUS α_S Fit to Jets in DIS

Thomas Kluge on behalf of the H1 and ZEUS Collaborations

University of Liverpool - Department of Physics
Oliver Lodge Laboratory - United Kingdom

A new value of $\alpha_S(M_Z)$ from HERA data is presented. This determination is performed using inclusive jet cross-section measurements in neutral current deep-inelastic scattering at high Q^2 recently published by the H1 and ZEUS Collaborations. The method used to obtain the HERA combined 2007 $\alpha_S(M_Z)$ is described. The result is $\alpha_S(M_Z) = 0.1198 \pm 0.0019$ (exp.) ± 0.0026 (th.).

1 Introduction

The strong coupling α_S is one of the fundamental parameters of QCD. However, its value is not predicted by the theory and must be determined experimentally. Many precise and consistent determinations of α_S from diverse phenomena, such as from τ decays and from jet rates in e^+e^- annihilation are in excellent agreement with perturbative QCD (pQCD). High precision in the determination of α_S is obtained by identifying the regions of phase space, where both the measurements and the predictions are less affected by uncertainties.

The usual experimental method to determine α_S is to make measurements of observables which are directly sensitive to α_S, and then fit these data using the pQCD predictions with α_S as a free parameter. At HERA, α_S has been determined from many observables which include jet cross sections, jet substructure and structure functions. An overview of jet-related determinations is given in Fig. 1.

The determinations of $\alpha_S(M_Z)$ at HERA, most of which come from measurements which involve jet algorithms, show a level of precision competitive with other recent $\alpha_S(M_Z)$ determinations [2].

2 Fit Procedure

The data sets used in the fit include the inclusive jet double-differential cross sections as a function of the photon virtuality Q^2 and the jet transverse energy E_T from H1 [3] and the inclusive jet single-differential cross section as a function of Q^2 from ZEUS [4]. The fit to extract $\alpha_S(M_Z)$ is done simultaneously to the 30 data points in total: 24 H1 data points for Q^2 between 150 and 15000 GeV^2 and E_T between 7 and 50 GeV and six ZEUS data points for Q^2 between 125 and 100000 GeV^2.

pQCD predictions of these jet cross sections are calculated as a function of $\alpha_S(M_Z)$ with NLOJET++ [5] using the fastNLO package [6]. The factorisation scale μ_f is chosen to be Q and the renormalisation scale μ_r is chosen to be the E_T of each jet. The cross sections are determined using the MRST2001 proton PDFs [7, 8].

The measurements and theory predictions are used to calculate $\chi^2(\alpha_S(M_Z))$ with the Hessian method, where parameters representing systematic shifts of detector related observables are left free in the fit. The sources of systematic uncertainty are treated as correlated for measurements within one experiment, but as uncorrelated between the two experiments; details are given in the publications of the used data set. It was checked that the model

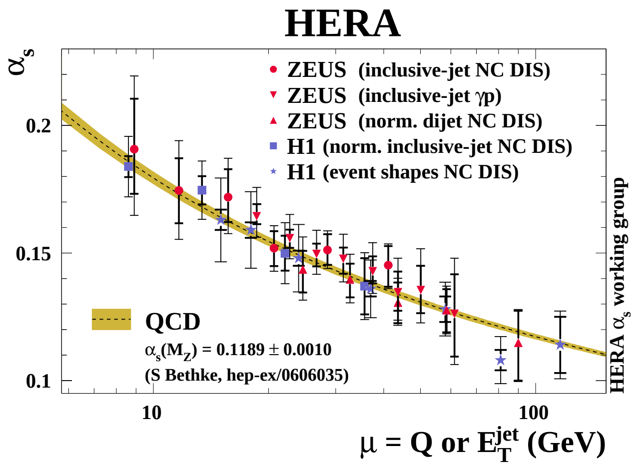

Figure 1: Collection of previous determinations of $\alpha_S(\mu)$ from H1 and ZEUS. The inner (outer) error bar denotes the experimental (total) uncertainty for each fitted value. The dashed line shows the two loop solution of the renormalisation group equation evolving the 2006 world average $\alpha_s(M_Z)$, with the band denoting the total uncertainty.

dependence, which in principle could be correlated between experiments, has a negligible effect whether it is treated as correlated or uncorrelated. The experimental uncertainty of the free parameter in the fit, i.e. $\alpha_S(M_Z)$, is defined by that change in $\alpha_S(M_Z)$ which gives an increase in χ^2 by one unit with respect to the minimal value. This experimental error amounts to 0.0019 and $\chi^2/\mathrm{ndf} = 27.4/29$ for the fit.

The theoretical uncertainty is dominated by terms beyond next-to-leading order (NLO) and is estimated by varying the renormalisation scale μ_r by the conventional factors 0.5 and 2 in the calculation. Instead of repeating the fit to the data with these two different renormalisation scales used in the theory calculation, the following procedure is followed. For a single cross section, $\alpha_S(M_Z)$ is varied in the calculation with the central μ_r until the cross section equals the result of the calculation with μ_r scaled by a factor 0.5 or 2 and $\alpha_S(M_Z)$ taken from the fit to the data. The resulting variation in $\alpha_S(M_Z)$ provides the uncertainty of a single measurement. The uncertainties determined this way for each of the measurements are then used to derive the uncertainty on the fitted $\alpha_S(M_Z)$ with the error band method, as described in [9]. This estimation is free from statistical fluctuations of the data as no new fit to the data is performed. The resulting uncertainty from terms beyond NLO on the value of $\alpha_S(M_Z)$ amounts to 0.0021. Further sources of theoretical uncertainty considered include the factorisation scale and the uncertainties coming from the PDFs and the hadronisation models. These terms are added in quadrature, resulting in a total theoretical uncertainty of 0.0026.

3 Result

The new HERA combined 2007 $\alpha_S(M_Z)$ value is

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

with an experimental uncertainty of 1.6% and a theoretical uncertainty of 2.2%.

In addition, to study the running of the strong coupling, fits of $\alpha_S(\mu_R = E_T)$ for several bins of E_T and integrated over Q^2 are performed. The results are shown in Fig. 2 and are compared to the pQCD evolution of $\alpha_S(M_Z)$ from the HERA combined 2007 fit. As can be seen in the figure, the running of the coupling from the HERA jet data is in agreement with the prediction of pQCD.

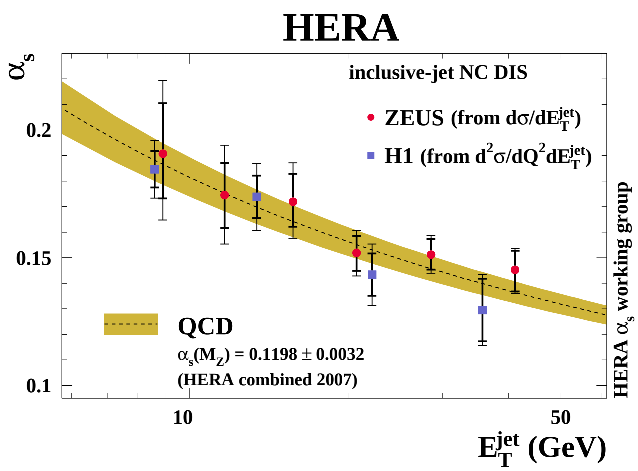

Figure 2: The new results for the fitted values of $\alpha_s(E_T)$ using the inclusive jet cross sections from H1 and ZEUS. The inner (outer) error bar denotes the experimental (total) uncertainty for each fitted value. The dashed line shows the two loop solution of the renormalisation group equation evolving the HERA combined 2007 $\alpha_s(M_Z)$, with the band denoting the total uncertainty

The new HERA combined $\alpha_S(M_Z)$ value is shown in Fig. 3 together with the values obtained by each collaboration separately, the 2004 HERA average [10] and the 2006 world average [2]. The determinations are consistent with each other and with the world average. The 2004 HERA average, which is the average of many determinations of $\alpha_S(M_Z)$ at HERA, has a very small experimental uncertainty (0.9%), but the theoretical uncertainty is large (4%), since in making that average the sources of theoretical uncertainty were conservatively assumed to be fully correlated.

With the new method presented here of using H1 and ZEUS data sets together, no assumption on correlations is made, and a significant reduction of the theoretical uncertainty is achieved by choosing observables for which these uncertainties are well under control. Even though the experimental uncertainty of the HERA combined 2007 value is higher than the HERA average 2004, the total uncertainty of the new combined value, 2.7%, is reduced to almost half due to the significant reduction of the theoretical uncertainty.

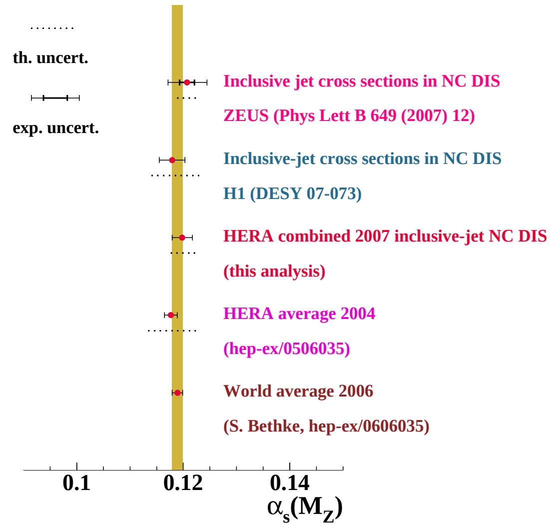

Figure 3: Determinations of $\alpha_S(M_Z)$ from ZEUS and H1 data separately and together with the HERA combined 2007 $\alpha_S(M_Z)$ value. For comparison, the HERA average 2004 and the world average 2006 are also shown. The shaded band represents the uncertainty of the world average.

A comparison to the most recent value of $\alpha_S(M_Z)$ from LEP [11], $\alpha_S(M_Z) = 0.1211 \pm 0.0010$ (exp.) $\pm$ 0.0018 (th.), shows that the central values are compatible within the experimental uncertainty, and that the uncertainty of the HERA combined 2007 value is very competitive with LEP, which includes an average of many precise determinations, such as that coming from τ decays. Furthermore, the enhanced precision of HERA II jet data as presented in [12] allows for further improved $\alpha_S(M_Z)$ fits in the future.

References

[1] Slides: `http://indico.cern.ch/contributionDisplay.py?contribId=212&sessionId=13&confId=24657`

[2] S. Bethke, Prog. Part. Nucl. Phys. **58**, 351 (2007)

[3] H1 Collaboration, A. Aktas et al., Phys. Lett. **B 653**, 134 (2007)

[4] ZEUS Collaboration, S. Chekanov et al., Phys. Lett. **B 649**, 12 (2007)

[5] Z. Nagy and Z. Trocsanyi, Phys. Rev. Lett. **87**, 082001 (2001)

[6] T. Kluge, K. Rabbertz and M. Wobisch, hep-ph/0609285

[7] A.D. Martin et al., Eur. Phys. J. **C 23**, 73 (2002)

[8] A.D. Martin et al., Eur. Phys. J. **C 28**, 455 (2003)

[9] R.W.L. Jones et al., JHEP **0312**, 007 (2003)

[10] C. Glasman, *Proc. of the 13th International Workshop on Deep Inelastic Scattering*, hep-ex/0506035

[11] S. Kluth, *Proc. of EPS HEP2007*, Manchester, England (2007), arXiv:0709.0173.

[12] M. Gouzevitch, these proceedings