THE STRONG COUPLING AND THE GLUON DENSITY FROM JETS IN DIS

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The extraction of the parameters of perturbative QCD is one of the main tasks for the HERA experiments. Studies on the structure of the hadronic final states with jet algorithms give a direct handle on the parton density functions and the strong coupling strength over a wide kinematic range. In this article, new results of the H1 and ZEUS collaborations for the strong coupling and the gluon density in the proton are presented.

1 Introduction

The observation of the hadronic final state in lepton hadron interactions is an essential tool for tests of QCD. A general feature of the events is the non-isotropic energy flow, i.e. large fractions of the particles created in the interactions are concentrated in small regions in space. Jet algorithms are used to measure the number and properties of the energy clusters.
Theoretical calculations for the cross sections of these processes are done by folding perturbative calculable partonic cross sections with parton density functions that describe the structure of the hadrons as given by the factorization theorem. The universality of the parton density functions and the size of the expansion variable, the strong coupling strength, α_s provide the basic parameters. A comparison of these parameters for different processes and with other experiments provides a basic means in testing QCD.

2 Determination of the strong coupling strength

The ZEUS collaboration has measured the inclusive and the dijet cross section in bins of the virtuality Q^2 using the inclusive k_t algorithm[1] in the data taken in 1996 and 1997.[2] After correcting for detector and hadronization effects, NLO pQCD calculations allow to extract the strong coupling strength α_s from the dijet cross section or the dijet rate. This is shown in figure 1.
A special emphasis was put on estimating the error induced by the parton density functions (**pdf**s) of the proton that are taken from other experiments. Recently, a global fit by M. Botje[3] was published including information on the errors on the pdfs and their full correlation.

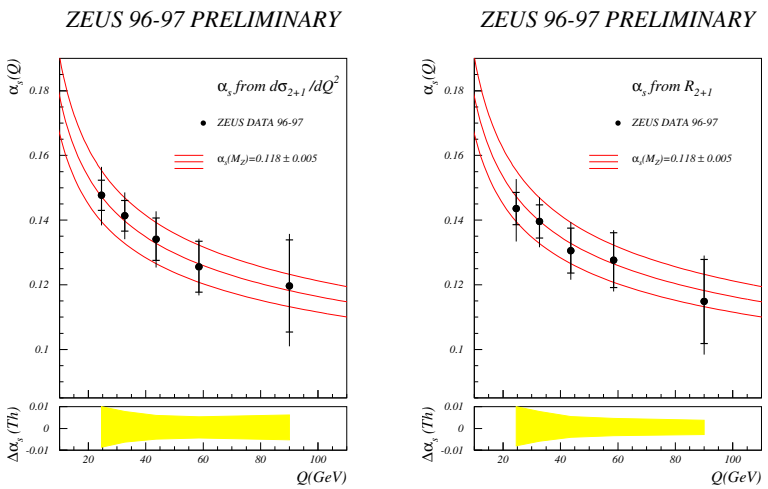

Figure 1: The strong coupling strength α_s as a function of scale as extracted by the ZEUS collaboration from dijet cross section (left) and dijet rate (right). The data points are shown with the statistical error (inner error bars) and the squared sum of the statistical and experimental systematic error (full error bars). Additional correlated theoretical errors shown in the band below the main plot are estimated by varying the renormalization scale and the parton density functions.

A fit of all $\alpha_s(Q^2)$ values is performed and the result for the strong coupling at the mass of the Z boson extracted from the dijet cross section is

$$\alpha_s(M_Z) = 0.1186 \pm 0.0019(\text{stat}) \, {}^{+0.0020}_{-0.0007}(\text{exp}) \, {}^{+0.0035}_{-0.0033}(\text{e.scale}) \\ {}^{+0.0048}_{-0.0038}(\text{ren.scale}) \pm \mathbf{0.0031}(\mathbf{pdf}) \pm 0.0005(\text{hadr})$$

and the one from the dijet rate is

$$\alpha_s(M_Z) = 0.1166 \pm 0.0019(\text{stat}) \, {}^{+0.0023}_{-0.0005}(\text{exp}) \, {}^{+0.0036}_{-0.0034}(\text{e.scale}) \\ {}^{+0.0050}_{-0.0042}(\text{ren.scale}) \, {}^{\mathbf{+0.0012}}_{\mathbf{-0.0011}}(\mathbf{pdf}) \pm 0.0005(\text{hadr})$$

It can be seen that the pdf uncertainties cancel partially for the rate.

3 Determination of the gluon density

Information on the gluon density in the proton can be extracted from two sources: the scaling violations of the inclusive cross section and the contribu-

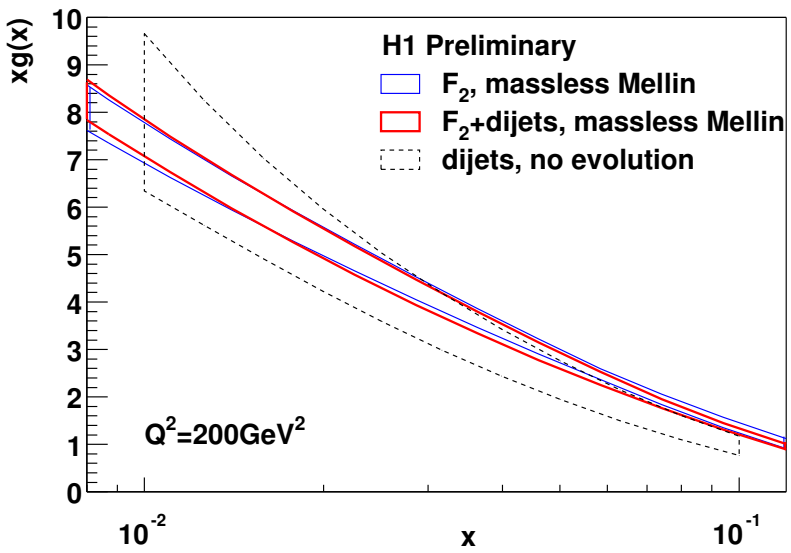

Figure 2: Gluon density at a scale of 200 GeV^2 as a function of the fraction of the parton momentum with respect to the incoming proton momentum as extracted by H1. The thick, full line shows the gluon density of a fit including dijet and inclusive data. For comparison fits with dijet (dashed line) and inclusive data (thin, full line) are plotted.

tion of the boson gluon fusion process to the dijet cross section. The H1 collaboration has measured both cross sections and extracted the gluon density.[4,5] A combined fit of both, the inclusive cross section $\sigma(x, Q^2)$ in the region 20 GeV^2 $\leq Q^2 \leq$ 5000 GeV^2 and the dijet data $\frac{d^2\sigma_2}{dQ^2 dx}$ (200 GeV^2 $\leq Q^2 \leq$ 5000 GeV^2) is performed. While the inclusive data dominate the low x region, the dijet data contribute at medium x ($0.01 \leq x \leq 0.1$) where data from other processes are sparse.

Figure 2 shows the gluon density in the medium x region, evolved in Mellin space to a scale of 200 GeV^2 corresponding to the average scale of the data included. The density extracted using the information coming from the BGF process only has significantly larger errors than the one extracted from scaling violations. In the combined fit, both data sets are well described and the result is consistent with the individual fits. This shows the independence of the pdfs of the processes. However, adding the dijet information mainly influences the fit stability and only a minor reduction in the uncertainty on the gluon density is found.

4 Conclusions

The strong coupling strength has been extracted from dijet cross section and dijet rate at HERA. In this analysis, the parton density functions are taken from other measurements as determined in a global fit. The values extracted from the dijet cross section and the dijet rate are consistent with each other and with the current world average. The determination has a precision that allows to have an impact on the world average. For the first time, the uncertainty of the strong coupling due to the uncertainty in the parton densities is estimated including the full correlation between the different pdfs. It is demonstrated that this uncertainty partially cancels when using the rate instead of the cross section.
The gluon density is extracted for the first time using both, the size of the scaling violations of the inclusive cross section and the direct information from the dijet cross section. Both data sets, taken from measurements of the H1 experiment only, are well described and the resulting gluon density agrees with other extractions using a single source of information only. The inclusion of the direct information from the dijet cross section improves the fit stability compared to an extraction using the inclusive cross section only.
The developments in the understanding of jet cross sections at the HERA collider experiments demonstrate the importance of the lepton proton scattering processes for testing QCD. The accuracy of the results is comparable to those at other colliders and further precision tests can expected for the new and upcoming data taking periods.

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References

1. S. Catani, Yu.L. Dokshitzer, B.R. Webber. Phys. Let. **B** 285:291, 1992.
2. F. Keil. Dijet Events in Charged and Neutral Current Deep-Inelastic Scattering at High Q^2 at HERA. These proceedings.
3. M. Botje. Eur. Phys. J. **C14** (2000) 285, hep-ph/9912439.
4. H1 Collaboration. Eur. Phys. J. **C13** (2000) 609-639, hep-ex/9908059.
5. M. Wobisch. *Conf. Paper 520, 29th Intern. Conf. on High-Energy Physics, Vancouver, Canada* 1998