

Jets and α_s measurements in DIS at HERA

Marcos Jimenez

On behalf of the H1 and ZEUS collaborations

Universidad Autonoma de Madrid
Cantoblanco, 28049 Madrid

Abstract

Recent measurements of jet production at HERA provide an excellent testing ground for perturbative QCD (pQCD) and allow improved determinations of the strong coupling, α_s . A review of recent measurements of di-jet and inclusive-jet cross sections in neutral current DIS (NC DIS) at HERA is presented, and the latest determinations of α_s are shown.

1 Introduction

Jet production in ep collisions at HERA at $O(\alpha_s)$ in pQCD proceeds via the Born, boson-gluon fusion, and QCD Compton processes. In the Breit frame, where the virtual boson and the proton collide head on, the Born process does not yield transverse momenta (E_T). Jet production with E_T in the Breit frame is thus directly sensitive to α_s and to the parton distribution functions (PDFs) of the proton, providing an excellent testing ground for pQCD.

In pQCD, a jet cross section is expressed as the convolution of the PDFs with the matrix elements. The PDFs describe the long distance, or soft part of the interaction and are not calculable in pQCD. They can, however, be determined through global QCD fits to a wealth of data. In regions where they are well constrained, the low Q^2 region has the advantage of high statistics, whereas the high Q^2 region has the advantage of smaller theoretical uncertainties. Thus, in the low Q^2 general aspects of pQCD can be tested, such as the impact of missing higher orders.

The high Q^2 region allows precision testing of pQCD and provides a suitable environment on which to study the jet reconstruction algorithm.

In regions where the PDFs are not so well constrained, such as the gluon PDF in the mid-to-high x region, jet cross sections can be incorporated into global QCD fits to help further constrain them. This has been recently demonstrated by the ZEUS collaboration in an NLO QCD fit analysis [1].

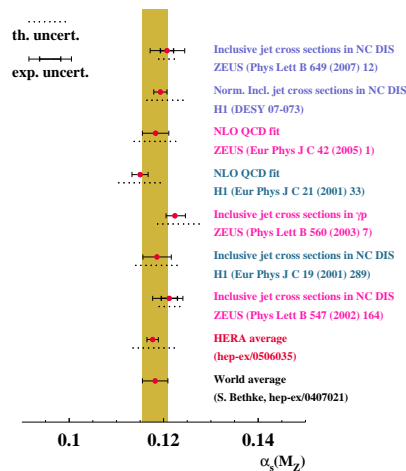


Figure 1: Measurements of $\alpha_s(M_Z)$ at HERA

The strong coupling constant, α_s , is one of the fundamental parameters of QCD. However, its value is not predicted by the theory and must be determined by experiment. Many precise and consistent determinations of α_s from diverse phenomena underlie the success of pQCD. At HERA, α_s

has been determined from many observables, which include jet cross sections and structure functions, by the H1 and ZEUS collaborations. The uncertainty in these determinations is dominated by the theoretical contributions, which amount to 4% for jet cross sections. This contribution presents the latest inclusive jet production studies made by the H1 and ZEUS collaborations and the resulting determinations of α_s , which result in an unprecedented level of precision at HERA [3],[4]. Furthermore, these determinations allow a stringent test of the predicted running of α_s by pQCD.

2 Inclusive jet production in low Q^2

The H1 collaboration recently studied inclusive jet production in the region $5 < Q^2 < 100 \text{ GeV}^2$. The cross sections were measured differentially in Q^2 and E_T of the jets and compared to pQCD at next-to-leading order (NLO). It was found that the NLO prediction described the data well down to values of $Q^2 > 10 \text{ GeV}^2$ and $E_T > 10 \text{ GeV}$. At lower values, the discrepancy between the data and the NLO increased considerably. Here, the dominant uncertainty in the NLO stemmed from the lack of knowledge of the higher order contributions. This prompted the conclusion that higher order contributions become increasingly relevant at low Q^2 and E_T and are necessary for a further study of this region.

3 Study of jet radius dependence of inclusive jet cross sections in NC DIS

The k_T cluster algorithm has been extensively used at HERA and has been advocated for usage at the LHC [3]. Although the parameter of the algorithm which plays the role of a jet radius, R , is conventionally set to $R=1$, this choice might not be optimal

for heavy particle searches at the LHC. A study has been carried through by the ZEUS collaboration in which the R parameter has been varied and the effect on the inclusive-jet cross sections and the NLO predictions has been studied. It has been determined that NLO QCD provides predictions with comparable precision in the range $R=0.5-1$. The measurements are shown in Fig. 2. The NLO QCD calculations provide a good description of the measured inclusive-jet differential cross sections $d\sigma/dQ^2$ and $d\sigma/dE_{T,B}^{jet}$ for $R=1, 0.7$, and 0.5 . It is observed that the measured inclusive-jet cross section integrated above $Q_{min}^2 = 125$ and 500 GeV^2 increases linearly with R .

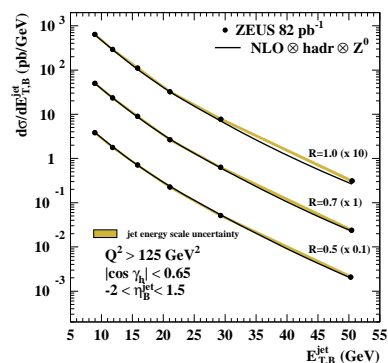


Figure 2: Jet-radius dependence of inclusive-jet cross sections in NC DIS

4 Inclusive jets and dijets in high Q^2 NC DIS

Dijet cross-sections at high values of $Q^2 > 125 \text{ GeV}^2$ have been measured single- and double-differentially in various kinematic and dijet quantities. In addition, inclusive-jet cross-sections were studied

double-differentially in bins of Q^2 as functions of the jet transverse energy.

The very precise data extend former ZEUS measurements of inclusive-jet and dijet cross-sections in high Q^2 DIS. They are well described by the NLO QCD calculations and provide access to the parton distribution functions of the proton, especially the gluon density at high values of the proton momentum fraction. Therefore, the measurements are natural candidates for future use in NLO QCD fits of the parton densities.

5 Determinations of $\alpha_s(M_Z)$

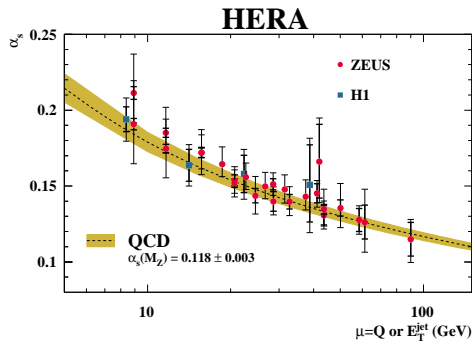


Figure 3: Energy scale dependence of α_s compared to the pQCD NLO prediction

Single and double differential inclusive jet cross sections have been measured as a function of Q^2 and of the transverse energy E_T of the jets in the Breit frame by the H1 and ZEUS collaborations. The measurements are found to be well described by calculations at next-to-leading order in pQCD and present by themselves a stringent test of pQCD. From these measurements, a new set of values of $\alpha_s(M_Z)$ has been determined. The H1

collaboration published the following value of $\alpha_s(M_Z)$:

$$\alpha_s(M_Z) = 0.1193 \pm 0.0014(\text{exp.})_{-0.0030}^{+0.0047}(\text{th.}) \pm 0.0016(\text{pdf})$$

The ZEUS collaboration published the following value of $\alpha_s(M_Z)$:

$$\alpha_s(M_Z) = 0.1207 \pm 0.0014(\text{stat.})_{-0.0033}^{+0.0035}(\text{exp.})_{-0.0023}^{+0.0022}(\text{th.})$$

These values are consistent with each other and have comparable uncertainties. Both represent the highest precision for this type of measurement at HERA, and are also among the most precise in the world. The wide range in E_T available at HERA also allows for the running of α_s to be observed and contrasted to the pQCD prediction. Fig 3 demonstrates the running of α_s and its agreement with the pQCD prediction.

References

- [1] S. Chekanov *et al.* [ZEUS Collaboration], Eur. Phys. J. C **42** (2005) 1 [arXiv:hep-ph/0503274].
- [2] M. Cacciari and G. P. Salam, Phys. Lett. B **641** (2006) 57 [arXiv:hep-ph/0512210].
- [3] S. Chekanov *et al.* [ZEUS Collaboration], arXiv:hep-ex/0701039.
- [4] A. Aktas *et al.* [H1 Collaboration], Phys. Lett. B **653** (2007) 134 [arXiv:0706.3722 [hep-ex]].