JET MEASUREMENTS AND EXTRACTION OF THE STRONG COUPLING CONSTANT AT HERA

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Results on jet measurements in neutral current deep inelastic scattering at HERA are presented. The low-x_{Bj} and low-Q^2 region is explicitly investigated using forward jet production and the azimuthal asymmetry between jets in dijet production. Recent results on the determination of the strong coupling constant, $\alpha_s(M_Z)$, are discussed.

1 Introduction

Precise measurements of jet production in photoproduction (PHP) and deep inelastic scattering (DIS) demonstrate good understanding of underlying physics and great success of the QCD-based theoretical calculations. In PHP, resolved photon process, where the photon fluctuates into a source of partons, one of which takes part in the hard scatter, plays an important role. Such a process in γp scattering should be quite similar to hh collisions. With increasing virtuality of the photon the resolved contribution decreases rapidly. Recent studies in DIS inclusive jet and dijet production [1,2] showed however, that even at moderate Q^2, 10-50 GeV^2, the contribution from resolved photons is still important. Moreover this contribution is essential in the region of low x_{Bj} and low Q^2, where the DGLAP-based calculations are expected to fail and the BFKL dynamics should be more prononced.

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2 Jet production in the low-x_{Bj}, low-Q^2 region

Jet production in the forward, proton direction, pseudorapidity region of $\gamma^* p$ scattering was a long time ago suggested as a good testing ground to study effects of the BFKL dynamics [3]. In this region, the production of high-E_T jets via DGLAP is suppressed because of the k_T ordering in the Q^2 evolution. Such an ordering requires that the highest E_T jet (corresponding to the highest k_T-parton) should come from the hard interaction. In dijet production, the two highest-E_T jets should be always back-to-back, compensated both in the energy and in angles (in the leading order of α_s). It is not necessarily true in the case of BFKL, where high k_T partons can also appear quite close to the proton and will carry a big portion of its longitudinal momentum, thus creating high-E_T jets in the forward direction. A strong azimuthal correlation in dijet production is also not required in the BFKL case.

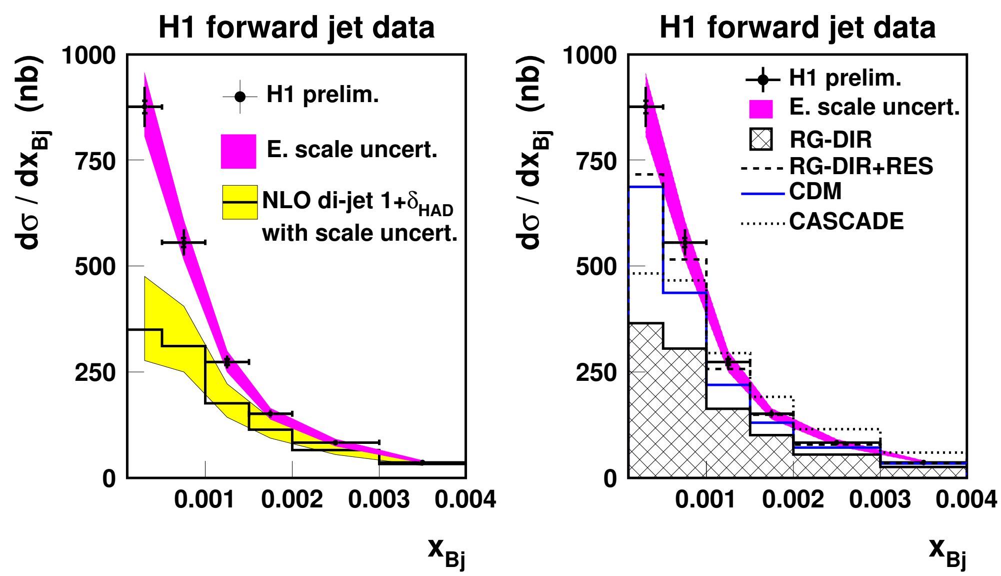

Figure 1: The hadron level cross section for inclusive forward jet production as a function of x_{Bj} compared to predictions of NLO calculations (lhs plot) and different Monte Carlo models (rhs plot)

Figure 1 shows the H1 results [4] on inclusive forward jet production at $5 < Q^2 < 85$ GeV^2 and $0.0001 < x < 0.004$. The jets are defined using the k_T algorithm in its inclusive mode and by requiring in the laboratory frame $p_{T,jet} > 3.5$ GeV, $7° < \Theta_{jet} < 20°$. To suppress the phase space for DGLAP evolution the requirements $0.5 < p^2_{T,jet}/Q^2 < 5$ and $E_{jet}/E_{proton} > 0.035$ were applied. The cross section as a function of x_{Bj} compared to the predictions of the NLO QCD calculation from DISENT shows that the calculation does not describe the data at low x_{Bj}. The rhs plot shows comparison with predictions of the RAPGAP model, where including a resolved photon contribution a reasonable description of the data is observed. The CCFM-model (CASCADE) predicts a somewhat different shape for the x_{Bj} distribution, which results in a comparatively poor description of the data.

It is interesting to compare the resolved photon effects with results of NNLO contribution, however current technics does not allow to perform such a calculation. To check the NNLO effects ZEUS restricted the inclusive forward jet measurement[5] by requiring at least one jet to be in the forward region together with significant hadronic activities in the backward one. Such a requirement suppresses the α_s^0 contributions. The NLO calculation in this case can be generated at next order of α_s compare to the H1 inclusive measurement.

The ZEUS cross section measurement is presented in Fig. 2 for $Q^2 > 25$ GeV^2 and $E_T^{jet} > 6$ GeV. The measurement is performed in the very forward region $2 < \eta^{jet} < 3$. The DGLAP

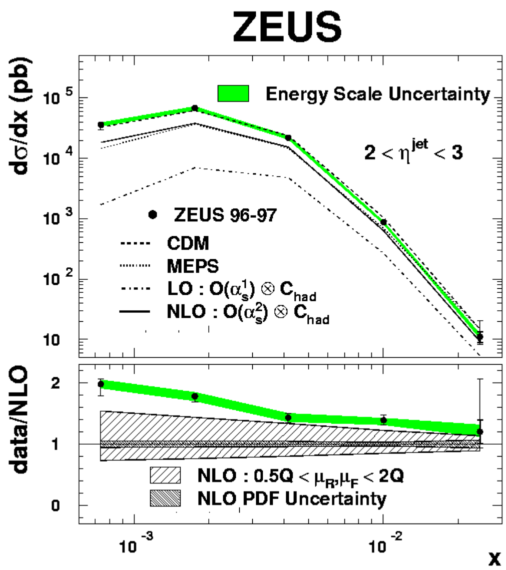

Figure 2: Differential cross section for the forward jets production as a function of x_{Bj} measured by ZEUS [5]. Predictions of different QCD models and calculations explained in the text are shown.

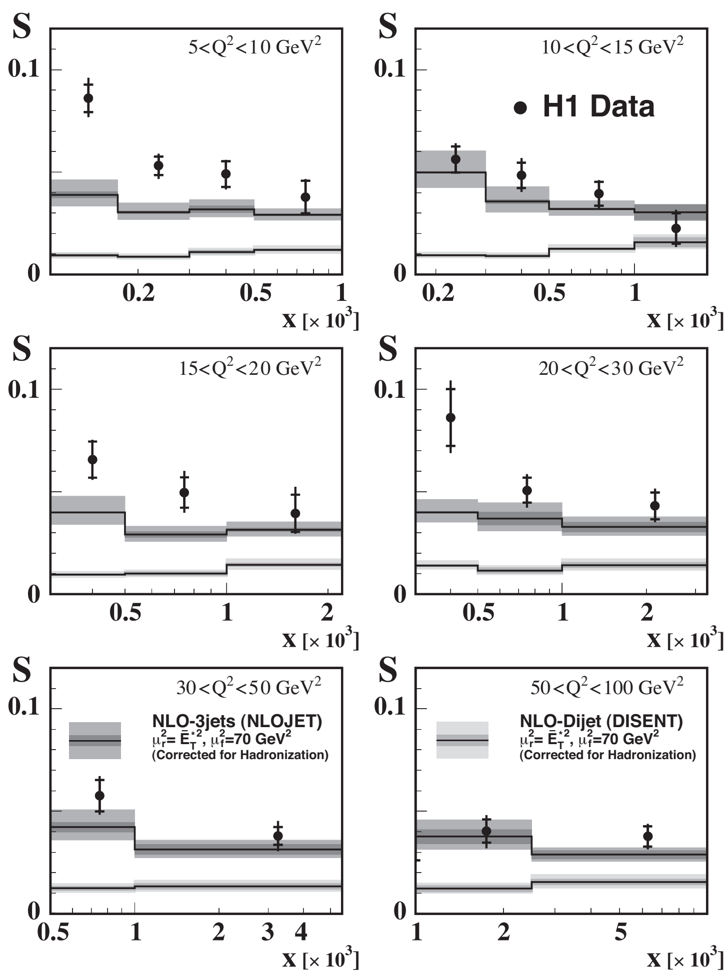

Figure 3: Ratio S of the number of dijet events with a small azimuthal jet separation ($\Delta\phi < 120°$) between the two highest E_T jets with respect to the total number of inclusive dijets events, as a function of x_{Bj} and Q^2

contribution is suppressed by requiring $0.5 < (E_T^{jet})^2/Q^2 < 2$. Single jet production is also suppressed using the total angle of the final hadronic system γ_h. The $cos(\gamma_h)$ had to be less then 0, thus requiring a sufficient backwards activities together with a jet in the forward direction.

The NLO still does not describe the data, although taking in account the size of the theoretical uncertainties the disagreement is not so dramatic. The difference between DGLAP and BFKL dynamics can be also studied using different parton-shower models used in the Monte Carlo programs. The DGLAP-like MEPS (LEPTO) fails to describe the data at low x_{Bj}. The BFKL-like CDM (ARIADNE) describes the data quite well.

Using an inclusive dijet sample, H1 has measured azimuthal correlations between jets [6] in quite restricted phase space: $5 < Q^2 < 100$ GeV^2, $10^{-4} < x < 10^{-2}$. The variable S represents the ratio of number of events with azimuthal difference between two highest E_T jets, $\Delta\phi$, less then 120° to the total number of dijet events; see Fig. 3. The NLO calculation predicts that the S should be very close to 0 in all the bins of the measurement. The NLO QCD calculation for trijet production prediction in more compatible with the data, but still insufficient to describe data at low x_{Bj} and low Q^2.

Comparison of the recent HERA jet data with predictions of QCD-based models demonstrates, that to describe the data in low-x_{Bj}, low-Q^2 region one needs or to include the contribution from the resolved photon process, or to perform calculation extended to next orders of α_s, or to develop a new BFKL-based, QCD calculation.

3 Inclusive jet production and determination of $\alpha_s(M_Z)$

Apart from the above mentioned region of phase space, where DGLAP-based calculations are not expected to work and indeed do not describe the data, the agreement between the data and predictions is good. Results of recent inclusive dijet and trijet measurements by ZEUS[7] are presented in Fig. 4. The NLOJET calculation describes the data well, as shown in the lhs plot, thus making possible an extraction of the $\alpha_s(M_Z)$. The ratio of the dijet to trijet cross sections as a function of Q^2 is shown in the rhs plot together with QCD predictions based on different values of $\alpha_s(M_Z)$. It can be seen that the measurement is very sensitive to the $\alpha_s(M_Z)$ value. Also both the experimental and theoretical uncertainties are reduced in the ratio compared to the cross section measurement, since some of the uncertainties cancel.

The extracted values of $\alpha_s(M_Z)$ in each Q^2 bin are also shown in the bottom part of the rhs plot of the Fig. 4. A χ^2-fit to these values gives an average $\alpha_s(M_Z)$ value, that is shown in the Fig. 5 together with the previous $\alpha_s(M_Z)$ determinations from HERA and compared to the world average $\alpha_s(M_Z)$ value.

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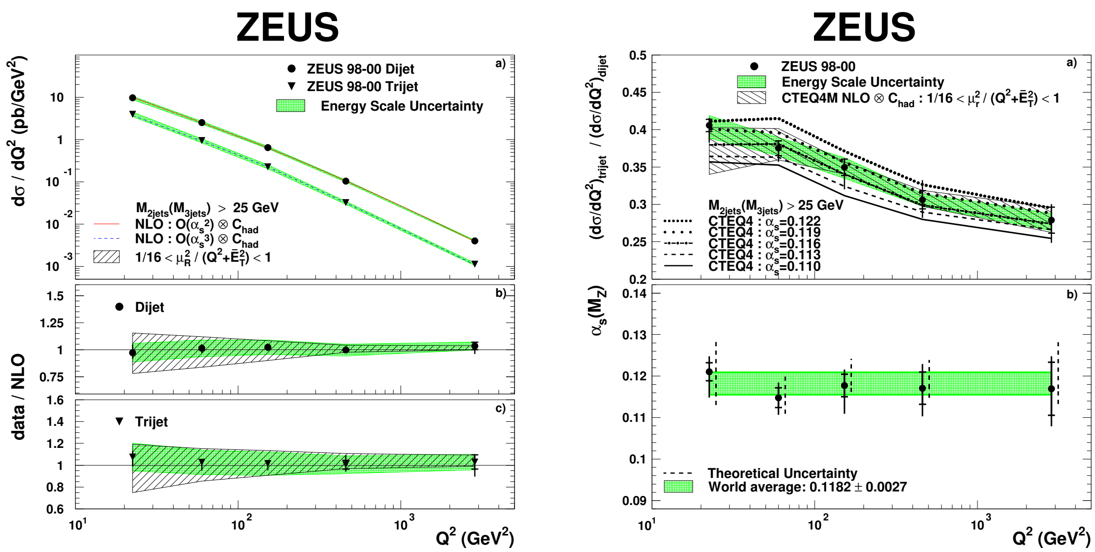

Figure 4: The inclusive dijet and trijet cross sections as a function of Q^2. The predictions of perturbative QCD in next-to-leading order are compared to the data. Rhs plot shows the ratio of inclusive trijet to dijet cross sections and determined $\alpha_s(M_Z)$ values in different regions of Q^2

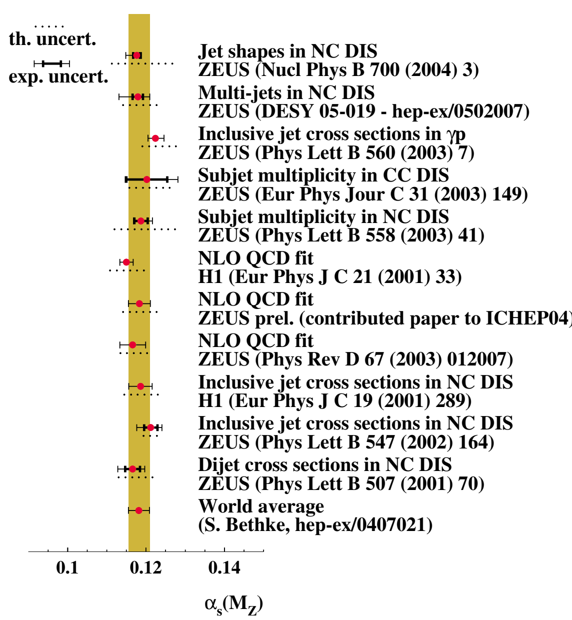

Figure 5: Summary of $\alpha_s(M_Z)$ measurements at HERA