On the determination of α_s from differential jet rates at HERA

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Abstract. A measurement of the differential 2+1 jet rate in deep inelastic scattering at HERA in the kinematic range $Q^2 > 200$ GeV^2 is presented. The jets are found using the JADE jet algorithm. Jet distributions measured with the H1 detector are compared to QCD model expectations. The differential 2+1 jet rate is unfolded to remove hadronization and detector effects, and is compared to next–to–leading order QCD calculations. The value of the strong coupling constant α_s is extracted, and contributions to its systematic error are discussed.

INTRODUCTION

The measurement of jets has proven to be a powerful tool to test QCD and to determine α_s in e^+e^- collisions [1]. Clear multi–jet structures are also observed in deep inelastic scattering at HERA. Measurements of the 2+1 jet rate R_{2+1} as a function of the squared four–momentum transfer Q^2 have been performed and have been used to determine α_s at different values of Q^2 [2], thus testing the running of α_s using the data of a single experiment.

Here, an alternative method of determining α_s, using the differential 2+1 jet rate averaged over a large range of Q^2, is presented. Jets are found with the JADE jet finder. After inclusion of a missing–momentum remnant cluster and removal of the scattered electron, the jet algorithm is used to combine pairs of clusters until 2+1 jets are left [2]. Thus all events are considered as 2+1 jet events, and for all events $y_2 \equiv \min m_{ij}^2/W^2$ is calculated [3] which corresponds to the jet rate differential in the resolution parameter y_{cut}.

In the following, the main steps and the dominant systematic effects of this ongoing analysis are discussed.

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2) The '+1' refers to the proton remnant jet.

3) W is the hadronic mass and m_{ij} is the invariant mass of jets i and j.

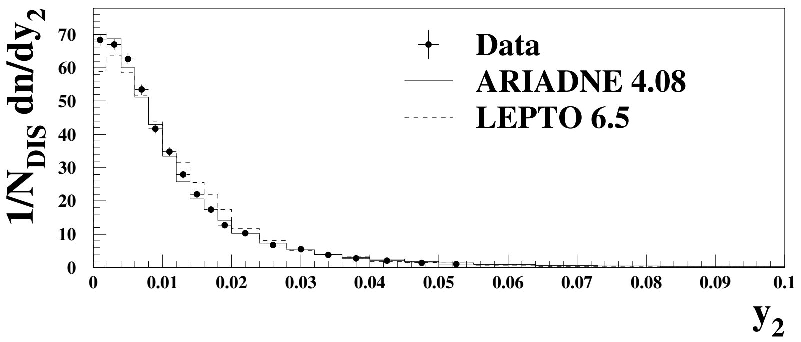

FIGURE 1. Distribution of y_2 for uncorrected data compared to model predictions.

DESCRIPTION OF DATA

In figure 1 the y_2 distribution as measured with the H1 detector is compared to the predictions of the colour–dipole model ARIADNE, version 4.08, and of the parton shower model LEPTO, version 6.5. The most important cuts are $Q^2 > 200$ GeV^2 and $W^2 > 5\,000$ GeV^2. The hadronic energy deposits used are well within the geometrical acceptance of the liquid argon calorimeter. This is ensured by requiring that $\theta_{clus} > 7°$.

We observe an excellent description of the data by ARIADNE. LEPTO provides a less satisfactory description. Similar conclusions are reached from a study of a complementary set of jet variables.

DEFINITION OF JET PHASE SPACE

Before extracting a value of α_s from comparisons of unfolded data and next–to–leading order (NLO) calculations, a region of phase space is selected in which NLO predictions can provide a reasonable description of the data and where effects of initial state multi–gluon radiation are small. We estimate this by comparing the shape of parton distributions from ARIADNE and LEPTO with exact NLO calculations done with the MEPJET program [3].

As an example, the y_2 and the z_p [4] distribution are shown in figure 2. A cut of $y_2 > 0.01$, in addition to the cuts mentioned above, is applied to avoid the

4)
$$z_p = \min_{i=1,2} \left(E_i \, (1 - \cos\theta_i) \right) / \sum_{i=1,2} E_i \, (1 - \cos\theta_i),$$

where E_i and θ_i are the energies and the polar angles of the two non–remnant jets.

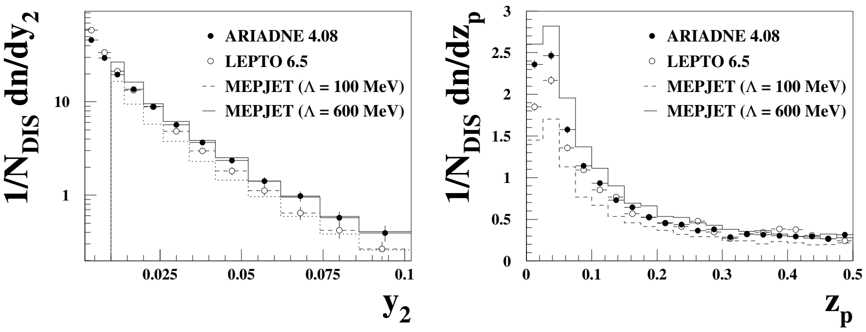

FIGURE 2. MEPJET NLO order predictions for y_2 (left) and z_p (right) for two different values of $\Lambda^{(4)}_{\overline{MS}}$ compared to parton level distributions from ARIADNE and LEPTO.

divergence of the 2+1 jet cross section in NLO. Ignoring the normalization of the distributions, which depends primarily on the value of $\Lambda_{\overline{MS}}$ or correspondingly of $\alpha_s(M_Z)$, we observe a surprising qualitative agreement. Thus we do not apply further jet phase space cuts to obtain our main result, and add or vary cuts to estimate systematic errors only.

SENSITIVITY TO α_S AND SYSTEMATIC ERRORS

Considerable migrations due to detector and hadronization effects are observed in y_2. We correct for this by using a sophisticated unfolding method to obtain the y_2 distribution in four bins shown in figure 3, with the corresponding (correlated) statistical error.

Also shown in figure 3 is the NLO prediction for different values of $\Lambda_{\overline{MS}}$. The same cuts are applied to the unfolded data and in the NLO calculation. In particular, a parton polar angle cut of $\theta_{par} > 7°$ is applied. A strong sensitivity to α_s is observed, and the data and the NLO calculation agree excellently for

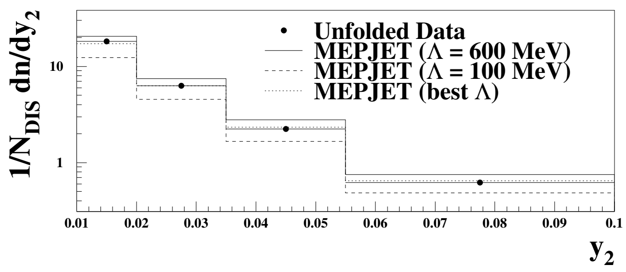

FIGURE 3. Distribution of y_2 for unfolded data compared to NLO predictions for different values of $\Lambda_{\overline{MS}}$.

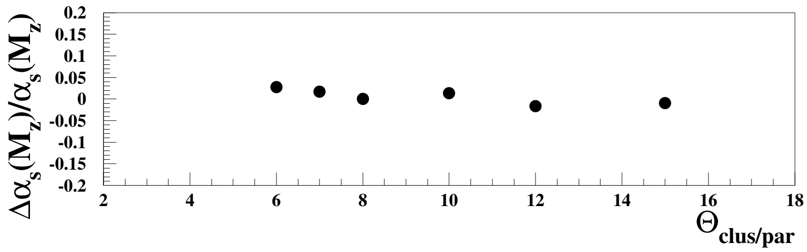

FIGURE 4. Variation of the fitted value of α_s as function of the clusters' and partons' polar angle cut.

the fitted value of α_s.

Various sources of systematic error have been estimated. As a typical example we show the relative change in α_s for different values of the θ_{clus} cut in figure 4. The values of θ_{clus} and θ_{par} are changed simultaneously. No significant change in the measured α_s is seen.

The largest individual systematic error is due to the renormalization scale dependence. By varying the scale from Q^2 to $1/4\,Q^2$ or $4\,Q^2$, or taking the sum of the jets' transverse momenta in the Breit frame as renormalization scale, we obtain a variation in α_s of the order of $\pm 5\%$.

SUMMARY

A measurement of the differential 2+1 jet rate in deep inelastic scattering at HERA in the kinematic range $Q^2 > 200$ GeV^2 is presented. The description of the jet rate and other jet variables by QCD models is generally good. This is particularly true for ARIADNE. The jet rate unfolded for hadronization and detector effects is compared to next–to–leading order QCD calculations. For the fitted value of α_s, an excellent description of the differential jet rate is observed. The largest individual error sources contribute typically $\pm 5\%$ to the uncertainty in $\alpha_s(M_Z)$.

REFERENCES

1. For a review see: P.N. Burrows, hep-ex/9612007.
2. H1 Collaboration, T. Ahmed et *al.*, Phys. Lett. **B346** (1995) 415;
   ZEUS Collaboration, M. Derrick et *al.*, Phys. Lett. **B363** (1995) 201.
3. E. Mirkes and D. Zeppenfeld, hep–ph/9511448.