DETERMINATION OF α_s FROM (2+1) JET EVENT RATES WITH THE H1 DETECTOR AT HERA

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Using JADE type jet algorithms two analyses are presented, one determining the jet event rate R_{2+1} as a function of momentum transfer Q^2, the other differentially with respect to the resolution parameter of the jet algorithm . The results, corrected for hadronization and detector effects, are compared with next-to-leading order QCD calculations. The determined α_s values are $\alpha_s(M_Z^2) = 0.115 \pm 0.003\,(\text{stat.})^{+0.010}_{-0.011}\,(\text{sys.})$ for the $R_{2+1}(Q^2)$ analysis and $\alpha_s(M_Z^2) = 0.118 \pm 0.002\,(\text{stat.})^{+0.010}_{-0.010}\,(\text{sys.})$ for the differential analysis.

1 Jets and deep inelastic scattering

The basic process of inclusive ep deep inelastic scattering (DIS) is of electroweak nature and only sensitive to the the strong coupling via the parton density in the proton. Direct sensitivity enters by QCD corrections in $\mathcal{O}(\alpha_s)$ which are QCD-Compton scattering ($\gamma q \rightarrow qg$) and Boson-Gluon-Fusion ($\gamma g \rightarrow qq$). The jet signature of these types of events is (2+1) like, where '+1' refers to the proton remnant jet.

The jet definition in the two presented analyses is based on a JADE[1] type cluster algorithm, modified for DIS by including a pseudo particle which takes the not measured part of the proton remnant into account. The distance of any two objects is $d_{ij} = 2E_iE_j(1 - cos\theta_{ij})/W^2$ where $E_{i,j}$, θ_{ij} are the energies of the objects and the angle between them and W is the invariant mass of the hadronic final state. If the minimal distance is below the resolution parameter y_{cut} recombination of the objects is done by simply adding their fourvectors.

The integrated jet event rate R_{2+1} is defined as the number of (2+1) jet events at a given y_{cut} divided by effectively the total number of DIS events. It is measured as a function of the virtuality Q^2 of the exchanged photon. Alternatively in a differential approach with respect to the resolution parameter every event is clustered until (2+1) jets are left. The main observable here is y_2, the minimal distance between each of the jets. The normalized y_2 distribution corresponds to $d\,R_{2+1}/d\,y_{cut}$ if events with (3+1) and higher jet multiplicity can be neglected.

2 Event selection

The analyses are based on HERA e^+p data collected in 1994 and 1995 corresponding to an integrated luminosity of 7 pb^{-1}. A standard selection of DIS event yields an event sample with Q^2 between 40 and 4000 GeV^2 ($R_{2+1}(Q^2)$ analysis) respectively 200 and 10000 GeV^2 (y_2 analysis).

3 Models and calculations

An intrinsic problem of QCD analyses with the calculations based on partons is the question how to compare these to an observable measured in the detector. While the correction for limited detector resolution and acceptance in principle is not a problem, the effects of higher orders and hadronization have to be modeled making certain assumptions. In the two analyses presented here the correction of the data is done using the color-dipole based model ARIADNE[2] and LEPTO[3] which utilizes matrix elements plus parton showers (MEPS). In addition HERWIG[4] was used because of its different hadronization modeling. The next-to-leading order (NLO) predictions were calculated with MEPJET[5] where divergences are treated via the 'phase space slicing' method.

4 Analysis of $R_{2+1}(Q^2)$

Figure 1 (a) below shows the measured R_{2+1} as a function of Q^2 (full circles) with a y_{cut} value of 0.02. The distribution is quite well described by LEPTO 6.5 (full line). Looking at the partons of LEPTO (dashed line) the correction factors turn out to be rather high. The corrected R_{2+1} (triangles) fits well

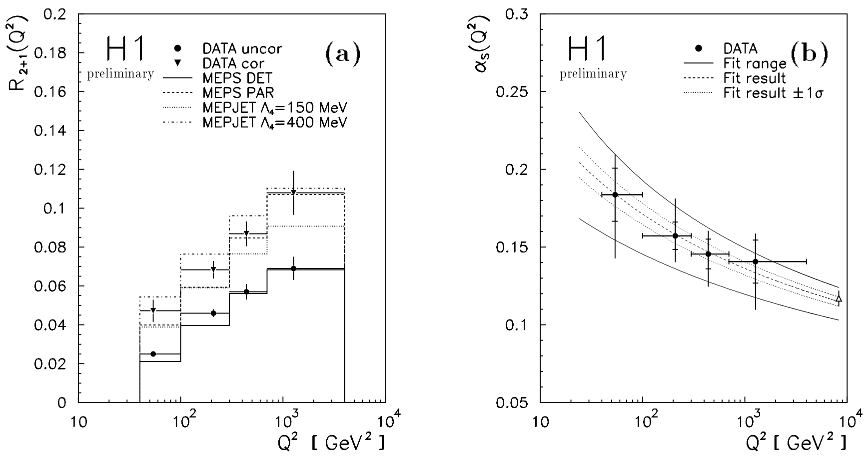

Figure 1: R_{2+1} distribution (a) and extracted α_s (b)

between the NLO predictions for two different $\Lambda^{(4)}_{\overline{MS}}$ (dotted, dashed-dotted line) which correspond to extreme values of α_s.
In figure 1 (b) the extracted α_s for the four Q^2 bins is shown (full circles, inner bars statistical errors only). Taking into account the correlations of the systematic errors, the running of α_s is visible. The dashed and the dotted line give the QCD fit result with 1σ error taking only statistical errors into account. It is in good agreement with the world average of $\alpha_s(M_Z^2)$ (open triangle). The solid lines represent the α_s value extracted in this analysis considering the full systematic error:

$$\alpha_s(M_Z^2) \;=\; 0.115 \pm 0.003\,(\text{stat.})^{+0.010}_{-0.011}\,(\text{sys.}).$$

The main sources of the estimated systematic error are uncertainties of the hadronic energy scale in the H1 detector ($+0.005, -0.003$), the different models used for the correction of detector and hadronization effects ($+0.004, -0.007$) and the variation of the renormalization scale in the NLO calculations from Q^2 to $1/4\,Q^2$ and $4\,Q^2$ ($+0.003, -0.007$).

5 Analysis of the differential jet event rate

Figure 2 shows the corrected y_2 data distribution in the range from 0.01 to 0.1 (full circles, inner error bars statistical, full bars total error).

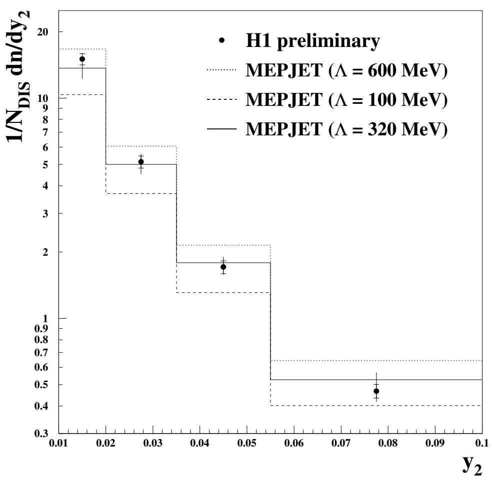

Figure 2: corrected y_2 distribution compared with MEPJET NLO calculations

The dashed and the dotted lines are the results of NLO calculations for extreme values of $\Lambda^{(4)}_{\overline{MS}}$. A minimum χ^2 fit to the corrected y_2 distribution yields $\Lambda^{(4)}_{\overline{MS}} = 320 \pm 33\,\mathrm{MeV}$ (statistical error only). Performing a calculation with this value of Λ a good description of the data is observed (full line).
Converting the extracted Λ to α_s results in

$$\alpha_s(M_Z^2) \;=\; 0.118 \pm 0.002\,(\mathrm{stat.})^{+0.010}_{-0.010}\,(\mathrm{sys.}).$$

Again the main sources of the estimated systematic error are on the experimental side the hadronic scale uncertainty $(+0.003, -0.003)$ and on the phenomenological and theoretical side the model dependence $(+0.004, -0.006)$ and the variation of the renormalization scale $(+0.007, -0.004)$ in the same range as for the integrated analysis.

6 Summary

The strong coupling α_s has been determined by measuring the integrated jet event rate $R_{2+1}(Q^2)$ and using the differential jet event rate y_2. Both analyses are based on a JADE type jet algorithm. Compared with previous published results[6] the data statistics has increased by a factor of ~ 20 and improved Monte Carlo models and NLO calculation programs were used. The results of both analyses are well consistent. The systematic error, originating both from experimental and theoretical uncertainties, is dominating.

References

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