Measurement of differential 2-jet rates in DIS at high Q^2

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A measurement of differential 2-jet rates and related 2-jet variables in ep scattereing in the kinematic range of $150 < Q^2 5000\,\mathrm{GeV}^2$ is presented. The data were collected with the H1 detector in the years '95 to '97. The analysis uses two substantially different jet algorithms. The results are compared to the predictions of Monte Carlo models and perturbative QCD calculations in next-to-leading order (NLO).

1. Introduction and definitions

The measurement of differential 2-jet rates has shown up to be a powerful tool for the QCD analysis of the hadronic final state in deep inelastic scattering [1]. 'Differential' means that the hadronic final state of every DIS event is clustered by a jet algorithm with a variable resolution parameter until two jets remain. The main observable then is y_2, the maximal value of the resolution parameter which allows to resolve two jets in the event. Additionally measured 2-jet variables in this analysis are the polar angles of the forward and backward jet in the laboratory system (all angles are measured with respect to the proton direction) and the variables $z_p = \min_{i=1,2}(E_i(1-\cos\theta_i))/\sum_{i=1,2}E_i(1-\cos\theta_i)$ and $x_p = Q^2/(Q^2+m_{12}^2)$ which are related to the cross sections of the leading order processes for 2-jet production in DIS (QCD-Compton: $\gamma q \to qg$, Boson-Gluon-Fusion: $\gamma g \to q q$).

The measurement is done using two different jet algorithms. The first is the factorizable k_t-algorithm [2] applied in the Breit frame with a fixed scale of 100 GeV^2 ($\to y_2 = k_t^2/100\,\mathrm{GeV}^2$ with $k_t^2 = 2\min(E_{1,2}^2)(1-\cos\theta_{1,2})$). A cut $y_2 > 0.8$ is applied to ensure a hard 2-jet structure resulting in a mean transverse energy of the jets in the Breit frame of about 10 GeV. The second algorithm is of a modified JADE type [3] (excluding the scattered positron and including a missing momentum pseudo particle) with a k_t distance measure (named in the following 'modified Durham') which is run in the laboratory frame. The scale used in this algorithm is the invariant mass of the hadronic final state W^2. A cut of $y_2 = k_t^2/W^2 > 0.005$ leads to jets of comparable hardness as for the first algorithm (in addition a medium scenario with a cut $y_2 > 0.001$ has been studied for the purpose of Monte Carlo model tuning [4]). In all cases an acceptance cut on the polar angle of the jets in the laboratory frame is applied: $10^o < \theta_{\mathrm{jet}}^{\mathrm{lab}} < 140^o$. For the modified Durham scenarios in addition hadronic final state objects with $\theta_{\mathrm{obj}} < 7^o$ are neglected. This avoids the inclusion of problematical regions of the detector and improves the resolution.

This choice of algorithms allows the comparison of effects of theoretical versus experimental advantages in the reconstruction of jets.

2. Data sample

The analysis is based on the H1 data collected during the HERA positron running of the years 1995 to 1997. This corresponds to an integrated luminosity of about $35\,\mathrm{pb}^{-1}$. The kinematic cuts applied to the data are on the polar angle of the scattered positron ($\theta < 150^o$), the inelasticity ($0.1 < y < 0.7$) and the momentum transfer ($Q^2 > 150\,\mathrm{GeV}^2$). The resulting sample contains $\sim 60\,000$ events. This allows to measure 2-jet distributions in three different ranges of Q^2 ($150 < Q^2 < 275\,\mathrm{GeV}^2$, $275 < \mathrm{Q}^2 < 575\,\mathrm{GeV}^2$, $575 < \mathrm{Q}^2 < 5000\,\mathrm{GeV}^2$).

3. 2-jet distributions

The measured 2-jet distributions are corrected for detector effects and the influence of QED radiation of the positron. The main sources of systematic errors on this distributions are the uncertainties in the electromagnetic and the hadronic

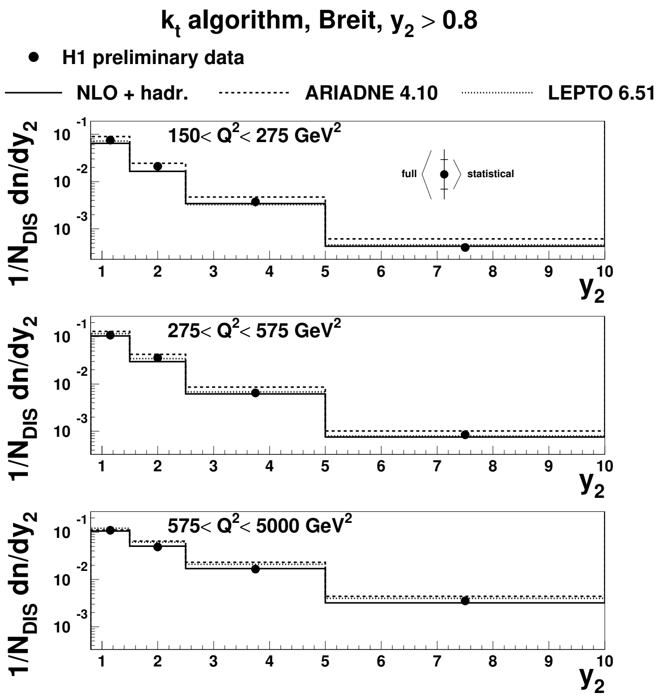

Figure 1. y_2-distribution (factorizable k_t)

energy scale of the H1 liquid argon calorimeter and the differences in the corrections predicted by different Monte Carlo models. In figure 1 the y_2-distribution is shown for the factorizable k_t-algorithm in three different ranges of Q^2. The distributions are less steep as Q^2 rises implying that the 2-jet structure gets harder. The data are compared to the MC models ARIADNE [5] and LEPTO [6] and to a QCD NLO calculation done with the DISENT program [7] (renormalization scale $\mu_R^2 = Q^2$). On top of this calculation an estimate of hadronization corrections has been applied by comparing hadron and parton jets of the MC models. These corrections are in the order of 10-20% for all 2-jet distributions. The models as well as the theoretical calculation describe the data reasonably well.

Also the modified Durham y_2-distribution (fig. 2) is described by the models and the calculation. Again the jet spectrum gets harder with rising Q^2. Besides the numerical values due to the different scales in the jet algorithms the y_2-distributions are very similar.

The quality of the data description by the models and the calculation can for example be seen in the z_p-distribution for the factorizable k_t algorithm (fig. 3). Whereas the shape of the distribution is fairly described by the MC models the predicted 2-jet rate tends to be too high, for ARIADNE in all Q^2 ranges, for LEPTO in the two highest ones. The best description over the whole Q^2 range is given by the QCD NLO calculation. The main theoretical uncertainty for this is the variation of the renormalization scale μ_R which results in effects of $\sim 10\%$ for a variation from $\mu_R = Q^2$ to $1/4\,Q^2$ respectively $4\,Q^2$ for all measured observables.

The same trends in the quality of the data description are visible in the other distributions and they hold for both algorithms as can be seen for example in the x_p-distribution for the modified Durham algorithm (fig. 4).

The data description by the NLO calculation is always best in the highest Q^2 range. This is pointing to an uncertainty in the gluon density (the MRST parton distribution is used here)

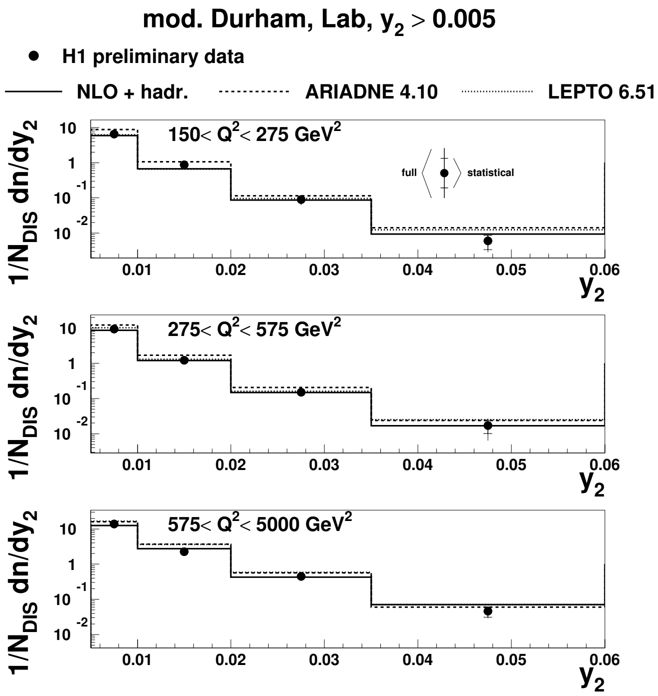

Figure 2. y_2-distribution (modified Durham)

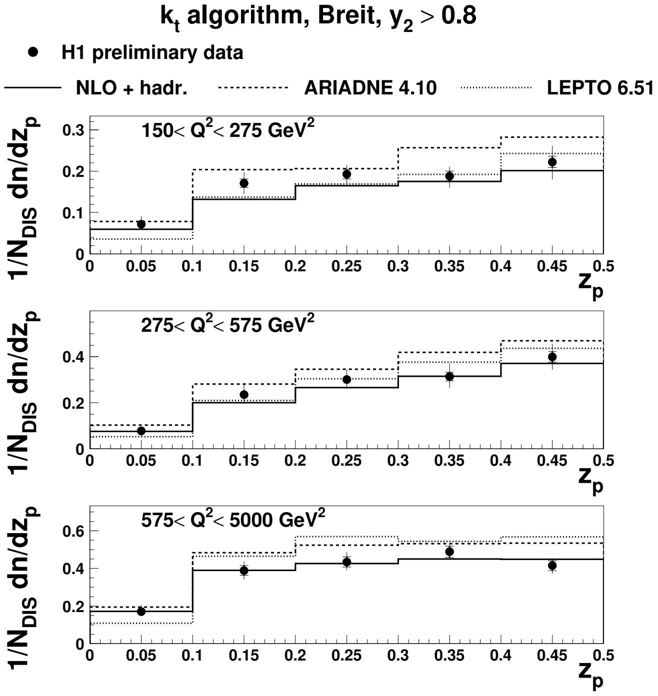

Figure 3. z_p-distribution (factorizable k_t)

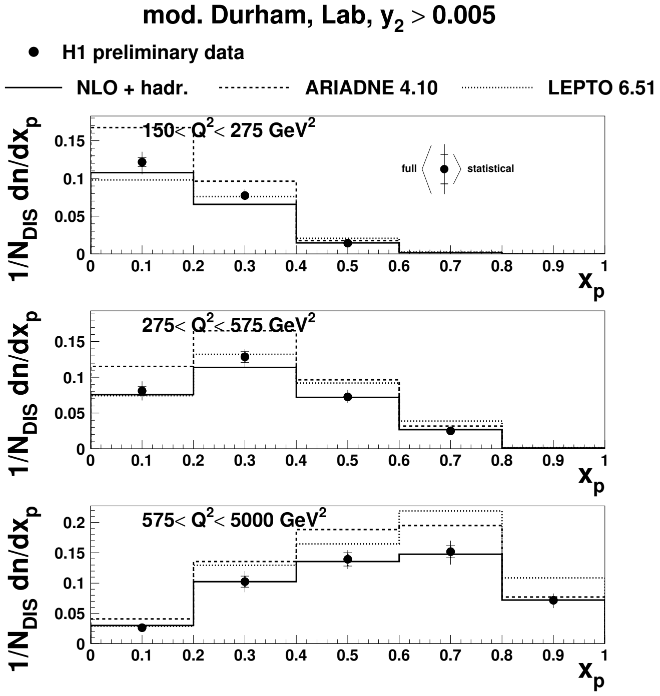

Figure 4. x_p-distribution (modified Durham)

which has most influence in the lowest Q^2 bin. A calculation with an effectively higher gluon density (realized by the MRSH parton distribution together with an $\alpha_s(M_Z^2)$ of 0.118) gives a very good description of the data over the whole Q^2 range. This is consistent with other H1 results on jet cross sections [8].

4. Summary

A measurement of differential 2-jet rates and related observables in DIS at high Q^2 has been presented. The results were obtained with two different and complementary jet algorithms, running in the Breit and in the laboratory frame.

The description of the data by MC models is fair but with significant deviations especially at high Q^2.

NLO QCD calculations are well able to describe all the measured distributions. A slight dependency of the quality of the description on the Q^2 range of the events points to uncertainties in the gluon density of the proton.

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