PROCEEDINGS OF SCIENCE

Jet Production at Low Momentum Transfer at HERA

Daniel Britzger* **for the H1 Collaboration**
DESY, Notkestr. 85, 22607 Hamburg, Germany
E-mail: daniel.britzger@desy.de

New results on inclusive jets, dijet and trijet differential cross sections in neutral-current deep-inelastic ep scattering (DIS) using the H1 detector at HERA are presented [1]. The DIS phase space of this measurement is given by the virtuality of the exchanged boson $5 < Q^2 < 100\,\mathrm{GeV}^2$ and the inelasticity of the interaction $0.2 < y < 0.65$. Jets are defined in the Breit frame using the k_T jet-algorithm and are required to be in the pseudorapidity range in the laboratory rest frame of $-1.0 < \eta^\mathrm{jet}_\mathrm{lab} < 2.5$. The transverse momentum of the jets is required to exceed $P^\mathrm{jet}_\mathrm{T} > 5\,\mathrm{GeV}$. Differential cross sections are measured as a function of Q^2 and $P^\mathrm{jet}_\mathrm{T}$ for inclusive jets, and for dijet and trijet events as a function of Q^2 and the average transverse momentum of the two jets with the highest transverse momentum in an event, $\langle P_\mathrm{T}\rangle$. The data are compared to predictions in next-to-leading order perturbative QCD and and overall reasonable agreement within the sizeable uncertainties of the predictions is found. The new data complement a previous H1 measurement at higher momentum transfer $Q^2 > 150\,\mathrm{GeV}^2$.

XXIV International Workshop on Deep-Inelastic Scattering and Related Subjects
11-15 April, 2016
DESY Hamburg, Germany

*Speaker.

PoS(DIS2016)085

1. Introduction

The production of jets in neutral-current deep-inelastic electron-proton scattering (NC DIS) is an important process to study the phenomenology of QCD. The measurements of jet cross sections are performed in the Breit frame, where the incoming parton collides head-on with the exchanged virtual boson. Consequently, if the jets exceed a significant transverse momentum, jet production cross sections are directly sensitive to the fundamental parameter of QCD: the strong coupling constant, α_s. In addition, jet production in DIS is also directly sensitive to the gluon content of the proton and is thus an important ingredient to the extraction of the parton distribution functions (PDFs) of the proton.

Typically jet cross sections are defined as inclusive jet cross section, where every individual jet in an NC DIS event is counted, or more exclusively for instance as inclusive dijet or trijet cross sections, where events are counted which fulfill topological and kinematic criteria on jet quantities.

Jet cross sections are compared to predictions obtained in the framework of perturbative QCD, where the soft contributions to the cross sections are factorized into the PDFs and the hard scattter-ing coefficients are calculated pertubatively. These predictions have to be corrected for hadronisation effects using correction factors obtained from Monte Carlo event generators (MC). Currently, data are compared to predictions in next-to-leading order QCD, while predictions in even next-to-next-to-leading order QCD became available only very recently [2].

The measurement here is based on data collected during the HERA-II running period in the years 2006 and 2007 with an integrated luminosity of $184\,\text{pb}^{-1}$. The measurement is performed in an identical phase space as an earlier H1 measurement using HERA-I data [3] and complements a measurement of jet cross sections by H1 at higher values of Q^2 [4].

2. Phase space and mesurement of jet cross sections

The data are corrected for detector effects, like resolution or acceptance effects, using a regularised unfolding procedure as implemented in the TUnfold algorithm [5]. In order to control migrations at the boundaries of the phase space, the NC DIS events are selected in an extended phase space compared to the phase space of the cross sections. The NC DIS events are selected in the kinematic range $3 < Q^2 < 120\,\text{GeV}^2$ and $0.08 < y < 0.65$, and the jet cross sections are then obtained for the NC DIS kinematic range $5 < Q^2 < 100\,\text{GeV}^2$ and $0.2 < y < 0.65$. Jets are constructed using the k_T jet-algorithm in the Breit frame and within the range of pseudorapidity in the laboratory rest frame $-1.5 < \eta^\text{jet}_\text{lab} < 2.75$. Jets must exceed a transverse momentum in the Breit frame of $P^\text{jet}_\text{T} > 3\,\text{GeV}$. The inclusive jet cross sections are then obtained for $-1.0 < \eta^\text{jet}_\text{lab} < 2.5$ and $5 < P^\text{jet}_\text{T} < 45\,\text{GeV}$ and are measured as a function of Q^2 and P^jet_T. The cross sections for dijet (trijet) production are defined by considering events with at least two (three) jets in the pseudorapdity range $-1.0 < \eta^\text{jet}_\text{lab} < 2.5$ and exceeding $P^\text{jet}_\text{T} > 5\,\text{GeV}$. The dijet and trijet phase space is further constrained by requiring the invariant mass of the two jets with the highest transverse momentum in the event to be greater than $M_{12} > 18\,\text{GeV}$, in order to remove infrared sensitive regions of the pQCD calculations. Dijet and trijet cross sections are obtained as a function of Q^2 and the average P^jet_T of the two leading jets $\langle P_\text{T}\rangle = (P^\text{jet1}_\text{T} + P^\text{jet2}_\text{T})/2$ in the range $5 < \langle P_\text{T}\rangle < 45\,\text{GeV}$.

For the determinaton of the migration matrix for the TUnfold algorithm, MC events are generated using the Djangoh [6] and Rapgap [7] MC event generator.

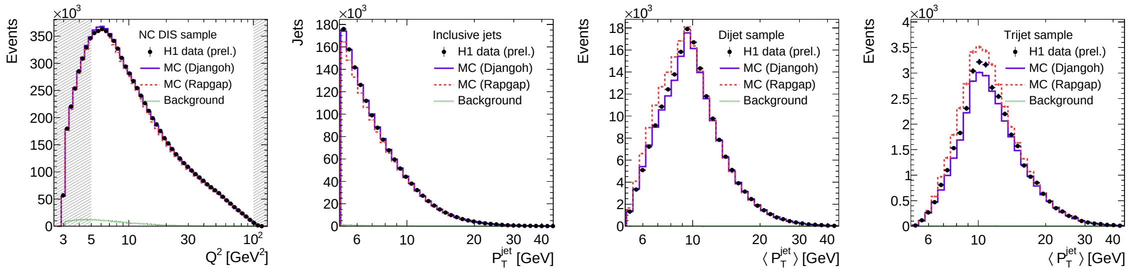

Figure 1: Selected data are compared to predictions on detector level obtained from the Djangoh and Rapgap MC generators. From left to right: distributions of Q^2 and y for the selected neutral current DIS data on detector level, distributions of the transverse momenta $P_T^{\rm jet}$ of the inclusive jet measurement on detector level, and distributions of $\langle P_T \rangle$ of the dijet and trijet data on detector level for the measured phase space. The background is obtained from simulated photoproduction events. The shaded areas indicate kinematic regions which are considered in the extended phase space of the unfolding procedure. The MC events are weighted to achieve a better description of the data.

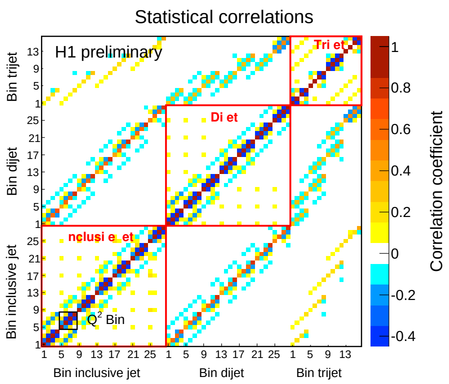

Figure 2: Correlation coefficients of the statistical uncertainty of the three unfolded cross section measurements. The axis labels denote the bin numbers of the respective jet measurement. As example, the black box indicates the four $P_T^{\rm jet}$ bins in one Q^2 bin of the inclusive jet data. The correlations between the measurements are known since they are measured on detector-level and propagated through the unfolding procedure.

The data are compared to the MC predictions on detector level in figure 1, where contributions from the photoproduction regime $Q^2 < 2\,{\rm GeV}^2$ are subtracted from the data using predictions obtained from the Pythia MC event generator. The MC events are weighted to describe the data on detector level in order to determine a reliable correction of the detector effects. The studied MC event generators provide a reasonable description of the data only after the weighting to the data. Without the weighting, Rapgap has mainly problems describing the normalisation of the data and events with a large number of jets, while Djangoh has problems in describing the P_T-spectra of the jets.

The migration matrix accounts for migrations in up to seven kinematical variables at the same time and is defined such, that the differential inclusive jet, dijet and trijet cross sections are unfolded simultaneously taking all statistical correlations into account. This procedure allows to determine all statistical correlations between the individual cross section points and also between the different observables. These statistical correlation coefficients are displayed in figure 2.

The jet cross sections are defined on non-radiative hadron level, which is obtained by unfolding the detector-level distributions and applying small corrections factors for higher-order QED effects, which are obtained from simulated Djangoh and Rapgap events with these effects switched on or off.

3. Cross sections for jet production in NC DIS

The double-differential cross sections for inclusive jet production in NC DIS are displayed in figure 3 and compared to predictions in NLO pQCD from the program nlojet++ [8] and using the NNPDF3.0 PDF set [9]. The NLO predictions are corrected for hadronisation effects using corrections factors defined as the average of those factors determined with Djangoh and Rapgap. The renormalisation and factorisation scales are chosen as $(Q^2 + P_T^2)/2$. Uncertainties on the NLO predictions are estimated with the so-called 'asymmetric 6-point' scale variation, where the renormalisation and factorisation scales are varied by a factor two in the calculations, while a simultaneous up- or down-variation is not considered, and the largest deviations from the nominal predictions are taken as uncertainty. The NLO predictions provide a reasonable description of the data over the full kinematic range within the experimental and theoretical uncertainties, while there are large uncertainties from scale variations on the theory particularly at lower values of Q^2 or $P_T^{\rm jet}$. In most of the kinematic regions, the data precision overshoots significantly the theory precision, where the dominant systematic uncertainties are the jet energy scale and the model uncertainty.

The inclusive jet cross sections show good agreement with an earlier H1 measurement using HERA-I data [3] as also displayed in figure 3.

The cross sections for dijet and trijet production are compared to NLO predictions in figure 4. The dijet and trijet cross sections are overall well described within the large scale uncertainties of the NLO predictions in the full kinematic range.

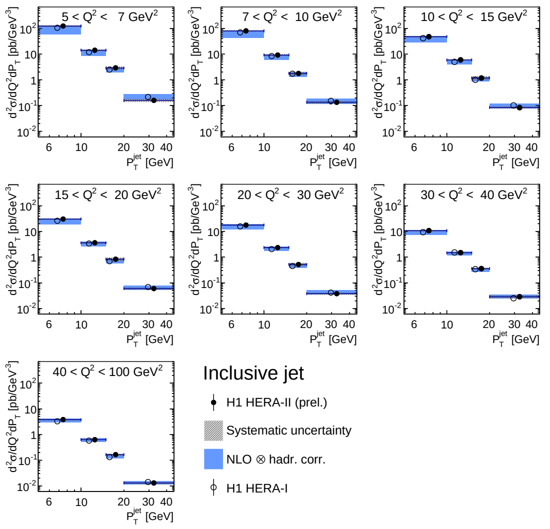

Figure 3: Double-differential cross sections for jet production in NC DIS as a function of Q^2 and $P_T^{\rm jet}$ compared to NLO predictions. The band indicates the uncertainty from scale variations. The shaded areas show the systematic uncertainties. The open circles show the H1 HERA-I measurement in an alomst identical phase space [3].

4. Summary

The production of jets is studied in neutral current deep-inelastic scattering for photon negative four-momentum-transfer squared $5 < Q^2 < 100$ GeV^2 and inelasticity $0.2 < y < 0.65$, using HERA data taken by the H1. The data are corrected for migration and acceptance effects using a

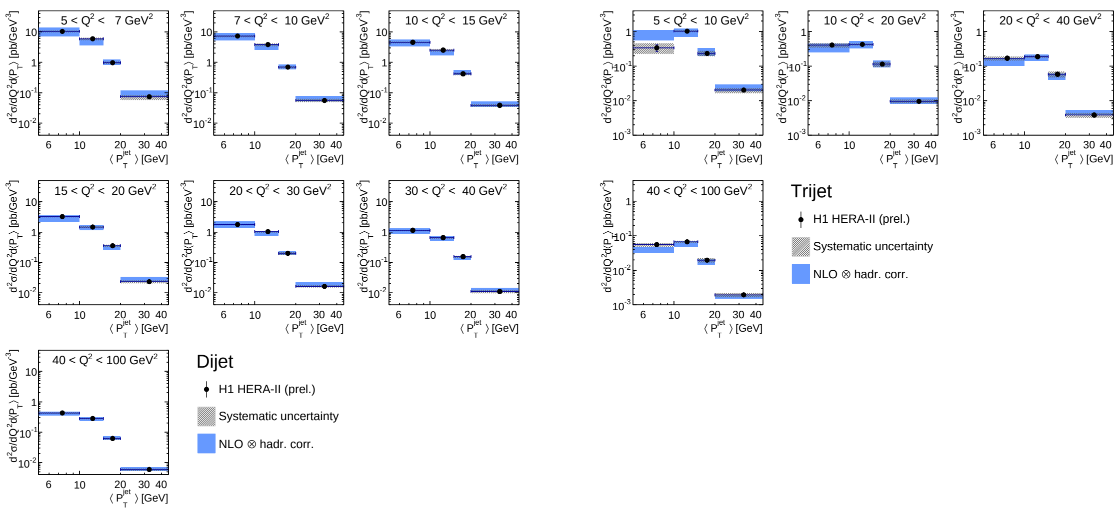

Figure 4: Double-differential cross sections for dijet (left) and trijet (right) production in DIS as a function of Q^2 and $\langle P_{\mathrm{T}} \rangle$.

regularised unfolding procedure and are further corrected for QED radiative effects. Differential ross sections are measured for inclusive jet production, dijet and trijet production and compared to prediction in next-to-leading order in perturbative QCD. An overall reasonable agreement of the predictions and the data is found, where the precision of the data overshoots the precision of the NLO predictions in most of the kinematic range.

The new jet cross sections will be an important input for PDF fits and for a precision determination of the strong coupling constant, in particular together with the predictions in next-to-next-to-leading order QCD for inclusive jet and dijet cross sections [2], which became available on very recently.

References

[1] H1 Collaboration, H1 preliminary report, H1prelim-16-061

[2] J. Currie, T. Gehrmann and J. Niehues, Phys. Rev. Lett. 117 (2016) 042001 [arXiv:1606.03991].

[3] F.D. Aaron *et al.* [H1 Collaboration], Eur. Phys. J. C **67** (2010) 1, [arxiv:0911.5678].

[4] V. Andreev *et al.* [H1 Collaboration], Eur. Phys. J. C **75** (2015) 2, [arXiv:1406.4709].

[5] S. Schmitt, JINST 7 (2012) T10003, [arXiv:1205.6201]

[6] K. Charchula, G. A. Schuler, and H. Spiesberger, *Comput. Phys. Commun.* **81** (1994) 381, DJANGOH V1.4.

[7] H. Jung, *Comp. Phys. Commun.* **86** (1995) 147, RAPGAP V3.1.

[8] Z. Nagy and Z. Trocsanyi, Phys. Rev. Lett. 87 (2001) 082001, [hep-ph/0104315].

[9] R.D. Ball *et al.* [NNPDF Collaboration], JHEP 1504 (2015) 040, [arXiv:1410.8849].