Measurement of the Azimuthal Correlation between the most Forward Jet and the Scattered Positron in Deep-Inelastic Scattering at HERA

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DOI: http://dx.doi.org/10.3204/DESY-PROC-2012-02/59

Deep-inelastic positron-proton scattering events at low Q^2 with a forward jet, produced at small angles with respect to the proton beam, are measured with the H1 detector at HERA. A subsample of events with an additional jet in the central region is also studied. For both samples differential cross sections and normalised distributions are measured as a function of the azimuthal angle difference, $\Delta\phi$, between the forward jet and the scattered positron in bins of the rapidity distance, Y, between them. The data are used to discriminate between QCD models with different parton evolution schemes.

1 Introduction

The HERA ep collider has extended the available kinematic range for deep-inelastic scattering (DIS) to regions of the Bjorken scaling variable, x, as small as 10^{-5} at moderate Q^2 of a few GeV^2. At low x a parton in the proton can induce a QCD cascade before an interaction with the virtual photon. Several perturbative QCD-based approaches are available to describe the dynamics of the parton evolution process. In the standard DGLAP evolution [1] partons emitted in the cascade are strongly ordered in transverse momentum, k_T, measured with respect to the proton direction. At small values of x a transition is expected from DGLAP to BFKL dynamics [2] in which there is no ordering in k_T of the partons along the ladder.

Measurements of DIS events with energetic jets of high transverse momentum produced close to the proton direction in the laboratory frame, referred to as the forward region, are considered to be especially sensitive to the QCD dynamics at low x [3]. The distribution of the azimuthal angle difference, $\Delta\phi$, between the forward jet and the scattered electron may show sensitivity to the underlying physics in the evolution of the parton cascade [4]. In this talk the study of the H1 Collaboration on the azimuthal correlation between the forward jet and the scattered positron in DIS at low x is presented [5].

2 QCD calculations

The measurements presented are compared with predictions of Monte Carlo (MC) generators which implement various QCD models. RAPGAP [6], labeled DGLAP, matches first order QCD matrix elements to DGLAP based leading-log parton showers with k_T ordering. The factorisation and renormalisation scales are set to $\mu_f = \mu_r = \sqrt{Q^2 + p_{\mathrm{T}}^2}$, where p_{T} is the transverse momentum of the two outgoing hard partons in the centre-of-mass of the hard subsystem. DJANGO/ARIADNE is an implementation of the Colour Dipole Model (CDM) [7] in which the parton emissions perform a random walk in k_T such that CDM provides a BFKL-like approach. CASCADE [8] uses off-shell QCD matrix elements, supplemented with gluon emissions based on the CCFM evolution [9] which aims to unify the DGLAP and BFKL approaches. In this analysis two different sets of unintegrated gluon density (uPDF) are used: set A0 with only singular terms of the gluon splitting function and J2003-set 2 including also non-singular terms.

The data are also compared to the fixed order NLO DGLAP predictions of the NLOJET++ program [10] used here to calculate dijet production at parton level in DIS at NLO(α_S^2) accuracy. The parton level cross sections are corrected for hadronisation effects using the RAPGAP model.

3 Results

The data used in this work were collected with the H1 detector in 2000 and correspond to an integrated luminosity of 38.2 pb^{-1}. The analysis phase space is restricted in Q^2, x and inelasticty y: $5 < Q^2 < 85$ GeV^2, $0.0001 < x < 0.004$, $0.1 < y < 0.7$.

Jets are identified using the k_T cluster algorithm in the Breit frame. Events with at least one forward jet satisfying the following cuts in the laboratory frame are selected: $P_{\mathrm{T,fwdjet}} > 6$ GeV, $1.73 < \eta_{\mathrm{fwdjet}} < 2.79$, $x_{\mathrm{fwdjet}} = E_{fwdjet}/E_p > 0.035$ and $0.5 < P^2_{\mathrm{T,fwdjet}}/Q^2 < 6$. Here η_{fwdjet} is the pseudorapidity of the forward jet.

The last two cuts aim to enhance the effects of BFKL dynamics and suppress the standard DGLAP evolution. If more than one jet satisfies these criteria then the jet with the largest pseudorapidity is chosen.

The forward jet cross section $d\sigma/d\Delta\phi$ as a function of the azimuthal angle difference $\Delta\phi$ between the most forward jet and the scattered positron is shown in Figure 1 for three intervals of the positron-jet rapidity distance Y, defined as $Y = \ln(x_{\mathrm{fwdjet}}/x)$. At higher values of Y the forward jet is more decorrelated from the scattered positron. The predictions of three QCD-based models with different underlying parton dynamics are compared with the data. The cross sections are well described in shape and normalisation by CDM which has a BFKL-like approach. Predictions of RAPGAP, which implements DGLAP

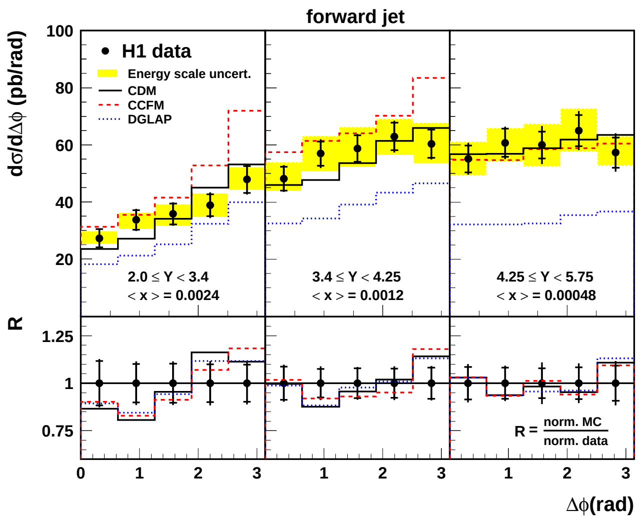

Figure 1: Differential forward jet cross section as a function of $\Delta\phi$ in three intervals of Y compared with the predictions of different QCD-based models. The systematic error due to the uncertainty of the hadronic energy scale is shown as a bound around the data points.

evolution, fall below the data, particularly at large Y. Calculations in the CCFM scheme as implemented in CASCADE using the uPDF set A0 overestimate the measured cross section for large $\Delta\phi$ values in the two lowest Y intervals. However, this model provides as good a description as CDM of the data in the highest Y interval.

In the lower part of Figure 1 the shape of the $\Delta\phi$ distributions, $1/\sigma \cdot d\sigma/d\Delta\phi$, is compared to the different MC predictions. The ratio R of MC to data for normalised cross sections is shown. The ratio plots show that in the analysed phase space region the shape of the $\Delta\phi$ distributions is well described by all MC models and this observable alone cannot discriminate between different QCD dynamics.

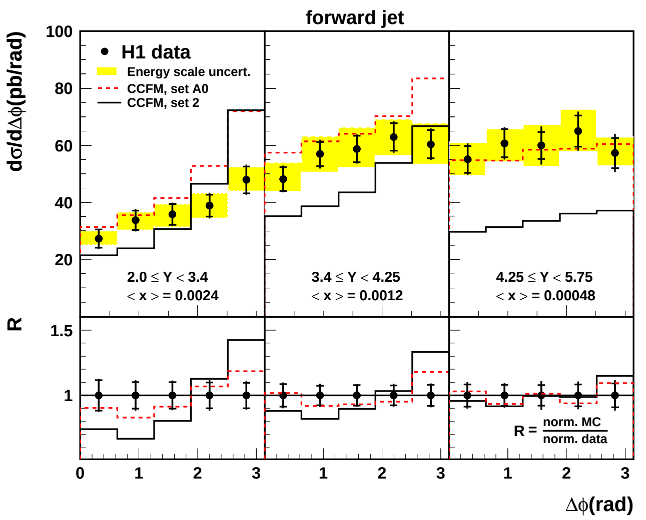

Figure 2: Differential forward jet cross section as a function of $\Delta\phi$ in three intervals of Y compared to the predictions of CASCADE(CCFM) with two different uPDF.

Predictions of the CCFM model presented in Figure 2 indicate a significant sensitivity to the choice of the uPDF. The set A0 is the same as in the previous figure. Predictions using J2003-set 2, marked set 2, do not describe the data in normalisation especially at high Y and in shape especially at low Y.

Comparison of the measured $\Delta\phi$ distributions with NLO DGLAP predictions is shown in Figure 3.

Large theoretical uncertainties of up to 50% from the variation of factorisation and renormalisation scales are observed indicating that in this phase space region higher order contributions are expected to be important.

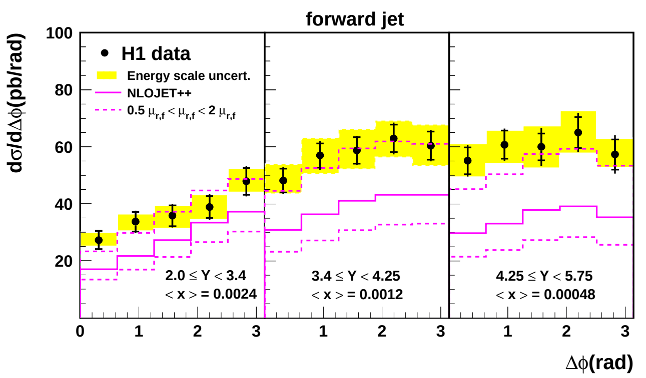

Figure 3: Differential forward jet cross section as a function of $\Delta\phi$ compared to NLO QCD predictions.

The cross section $d\sigma/dY$ as a function of the rapidity separation Y is shown on Figure 4. The data are best described by the BFKL-like CDM model. The DGLAP predictions fall below the data, but approach them at small Y. The predictions of the CCFM model are above the data at small Y but describe them well at larger Y.

A subsample of events with an additional jet in the central region of the laboratory frame is also studied. The central jet is

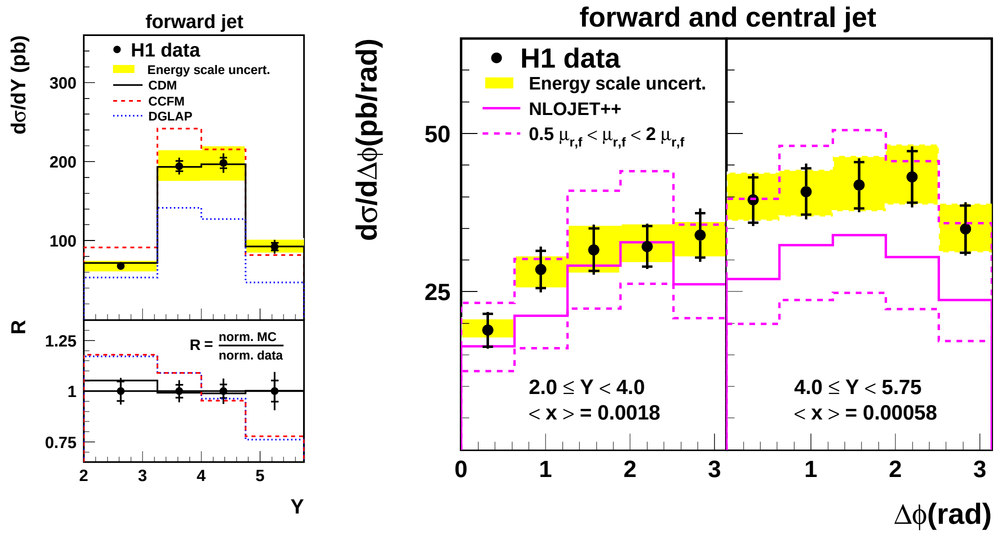

Figure 4: Differential forward jet cross section as a function of Y (left plot) and differential forward and central jet cross section as a function of $\Delta\phi$ in two intervals of Y (right plot).

selected with $P_{\mathrm{T,cenjet}} > 4$ GeV, in the region $-1 < \eta_{\mathrm{cenjet}} < 1$ and with a large rapidity separation from the most forward jet $\Delta\eta = (\eta_{\mathrm{fwdjet}} - \eta_{\mathrm{cenjet}}) > 2$. The measured $\Delta\phi$ distributions are compared with NLO DGLAP predictions on the right side of Figure 4. The NLO calculation provides a reasonable description of the data at low Y, at high Y it is below the data, but within the large theoretical uncertainty.

In summary, measurements of the cross sections as a function of $\Delta\phi$ and Y are best described by the BFKL-like CDM model, while the DGLAP model is substantially below the data. The CCFM model provides a reasonable description of the data but shows sizeable sensitivity to the unintegrated gluon density. The shape of the $\Delta\phi$ distributions does not discriminate further between different evolution schemes. The fixed order NLO DGLAP predictions are in general below the data, but still in agreement within the large theoretical uncertainties.

References

[1] G. Altarelli and G. Parisi. Nucl. Phys. **B126** (1977) 298.

[2] E. Kuraev, L. Lipatov and V. Fadin. Sov. Phys. JETP **45** (1977) 199.

[3] A. H. Mueller. Nucl. Phys. B, Proc. Suppl. **18C** (1990) 125.

[4] J. Bartels *et al.* Phys. Lett. **B384** (1996) 300.

[5] H1 Collab., F. D. Aaron *et al.*, Eur. Phys. J. **C72** (2012) 1910.

[6] H. Jung. Comput. Phys. Commun. **86** (1995) 147.

[7] L. Lönnblad. Comput. Phys. Commun. **71** (1992) 15.

[8] H. Jung. Comput. Phys. Commun. **143** (2002) 100.

[9] S. Catani, F. Fiorani and G. Marchesisni. Nucl. Phys. **B336** (1990) 18.

[10] Z. Nagy and Z. Trocsanyi. Phys. Lett. **87** (2001) 82001.