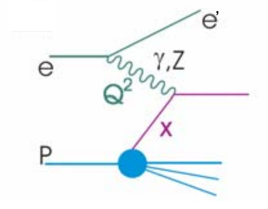
Forward jet azimuthal correlation in DIS at HERA

Lidia Goerlich, Pawel Sopicki, Institute of Nuclear Physics PAN, Cracow
on behalf of the H1 Collaboration

ICHEP2012, Melbourne, Australia

HERA – a precision machine for QCD

The HERA accelerator (1992 – 2007) at DESY in Hamburg/Germany collided 27.5 GeV electrons (or positrons) and 920 GeV protons collecting *ep* data at center-of mass energy of 320 GeV.
The HERA experiments, H1 and ZEUS, measured with high precision deep-inelastic scattering (DIS) events and improved substantially our understanding of the partonic composition of the proton and of Quantum Chromodynamics (QCD), the theory of the strong force.



The scattering of electrons by protons through exchange of a virtual photon or a weak boson.

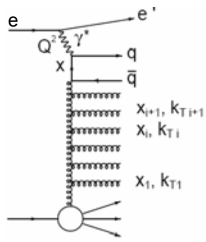
HERA extended the available kinematic range for DIS to regions of the Bjorken scaling variable, x, as small as 10^{-5} at moderate Q^2 of a few GeV^2. This is the region of high parton densities in the proton, dominated by gluons and sea quarks.

DIS kinematics

$$Q^2 = -q^2 = -(e - e')^2$$
$$x = Q^2/(2P\cdot q)$$
$$y = (P\cdot q)/(P\cdot e)$$
$$W^2_{\gamma^* p} \approx Q^2/x$$

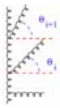
QCD dynamics at low Bjorken-x

At low x a parton from the proton can induce a QCD cascade before an interaction with the virtual photon. In perurbative QCD multiparton emissions are described only with approximations :

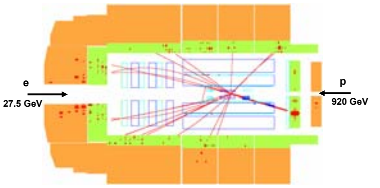


DIS ep scattering at low x. A gluon cascade evolve between the quark box, attached to the virtual photon, and the proton. The gluon longitudinal momentum fractions and transverse momenta are labelled, x_i and k_{Ti}, respectively.

- **DGLAP : Dokshitzer-Gribov-Lipatov-Altarelli-Parisi** evolution
  applicable at large Q^2
  Assumes strong ordering of transverse momentum, k_T, of the emitted partons
  Resums terms ~ $(\alpha_S \ln Q^2)^n$
- **BFKL : Balitsky-Fadin-Kuraev-Lipatov** evolution
  Transition from DGLAP to BFKL scheme expected at low x
  No ordering in k_T, strong ordering in x_i
  Resums terms ~ $(\alpha_S \ln(1/x))^n$
- **CCFM : Ciafaloni-Catani-Fiorani-Marchesini** equation
  applicable at all x and Q^2
  Unification of DGLAP and BFKL approaches
  Emitted partons are ordered in angles



Forward jets in DIS



Measurements of DIS events with energetic jets of high transverse momentum produced close to the proton direction in the laboratory frame (forward region) are considered to be especially sensitive to the QCD dynamics at low x.

The selection of jets with
$p^2_{T,\,fwdjet} \approx Q^2$ suppresses the standard DGLAP evolution.
The phase space for BFKL effects is enhanced by the requirement :
$x_{fwdjet} = E_{fwdjet} / E_p >> x$

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.

Selection of the data

The data used in this analysis were collected with the H1 detector in 2000 and correspond to an integrated luminosity of 38.2 pb^{-1}.

DIS event selection:

$0.1 < y < 0.7$
$5 < Q^2 < 85\ GeV^2$
$0.0001 < x < 0.004$

Forward jet selection:

Jets are identified using the k_T cluster algorithm in the Breit frame and then boosted to the laboratory frame.

$p_{T,\,fwdjet} > 6$ GeV
$1.73 < \eta_{fwdjet} < 2.79$
$x_{fwdjet} > 0.035$
$0.5 < p^2_{T,\,fwdjet} / Q^2 < 6.0$

If more than one jet satisfies these criteria then the jet with the largest pseudorapidity η is chosen.

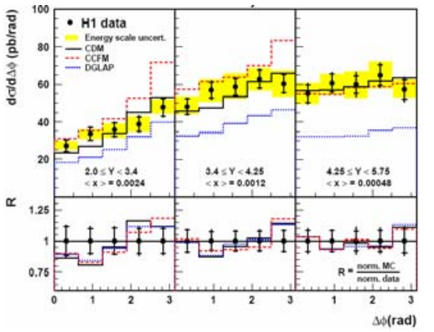
With these requirements 13737 DIS events with forward jets are selected.

A subsample of 8871 events with an additional jet in the central region of the laboratory frame is also studied.

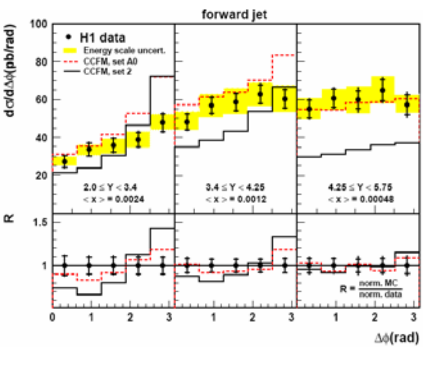
Central jet selection:

$p_{T,\,cenjet} > 4$ GeV
$-1 < \eta_{cenjet} < 1$
$\Delta\eta = \eta_{fwdjet} - \eta_{cenjet} > 2$

Forward jet azimuthal correlation

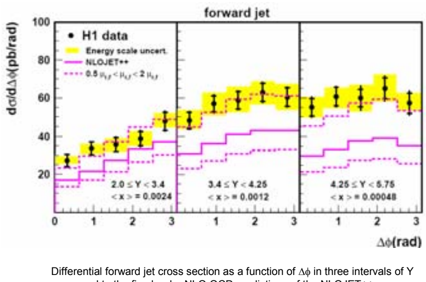


Differential forward jet cross section as a function of the azimuthal angle difference $\Delta\phi$ between the most forward jet and the scattered positron in three intervals of the positron-jet rapidity distance Y, defined as $Y = \ln(x_{fwdjet}/x)$. The predictions of three QCD-based models with different underlying parton dynamics are compared with the data.
At higher values of Y the forward jet is more decorrelated from the scattered positron. The cross sections are well described by the BFKL-like Colour Dipole Model (CDM). Predictions of the DGLAP model fall below the data. The ratio R of different model predictions to the data for normalised cross sections, $1/\sigma \cdot d\sigma/d\Delta\phi$, is also presented. Ratio plots show that the shape of the $\Delta\phi$ distributions does not discriminate between different evolution schemes.



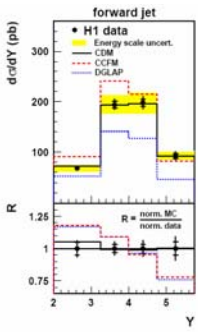
Differential forward jet cross section as a function of $\Delta\phi$ in three intervals of Y compared to the predictions of the CCFM model with two different sets of unintegrated gluon density (uPDF): set A0 with only singular terms of the gluon splitting function and J2003-set 2, marked set 2, including also non-singular terms.

The CCFM model shows sizeable sensitivity to the uPDF. Set A0 provides a reasonable description of the measured cross sections, except the region of large $\Delta\phi$ in the two lowest Y bins. Predictions using J2003-set 2 do not describe the data in normalisation especially at high Y and in shape especially at low Y.

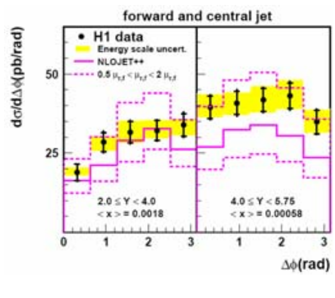


Differential forward jet cross section as a function of $\Delta\phi$ in three intervals of Y compared to the fixed order NLO QCD predictions of the NLOJET++ program used here to calculate dijet production at parton level in DIS at NLO(α_S^2) accuracy. The parton level cross sections are corrected for hadronisation effects using the DGLAP model.

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.



The cross section dσ/dY as a function of the rapidity separation Y between the most forward jet and the scattered positron. 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 with uPDF set A0 are above the data at small Y but describe them at larger Y.



Differential forward and central jet cross section as a function of $\Delta\phi$ compared with with NLO DGLAP predictions. The NLO calculation provides a reasonable description of the data at low Y, at high Y is below the data, but within the large theoretical uncertainty.

Eur. Phys. J. **C 72** (2012) 1910