



## Inclusive Diffraction at HERA

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The production of highly energetic forward neutrons has been studied in deep-inelastic positron-proton scattering. The data were taken with the H1 detector at HERA in the years 2006-2007 and correspond to an integrated luminosity of  $122 \text{ pb}^{-1}$ . Semi-inclusive cross sections have been measured in the range of four momentum transfer squared  $6 < Q^2 < 100 \text{ GeV}^2$ , Bjorken scaling variable  $1.5 \cdot 10^{-4} < x < 3 \cdot 10^{-2}$  and the fractional momentum of the neutron  $0.32 < x_L < 0.95$ . Monte Carlo simulation using the one pion exchange model describes the measurements well at low transverse momenta of the neutrons. The data are used to estimate the structure function of the pion.

Measurements are presented of single and double-differential dijet cross sections in diffractive photoproduction based on a data sample with an integrated luminosity of  $47 \text{ pb}^{-1}$ . The events are of the type  $ep \rightarrow eXY$ , where the hadronic system X contains at least two jets and is separated by a large rapidity gap from the system Y, which consists of a leading proton or low-mass proton excitation. The dijet cross sections are compared with QCD calculations at next-to-leading order and with a Monte Carlo model based on leading order matrix elements with parton showers. The measured cross sections are smaller than those obtained from the next-to-leading order calculations by a factor of about 0.6. This suppression factor has no significant dependence on the fraction  $x_\gamma$  of the photon four-momentum entering the hard subprocess. Ratios of the diffractive to the inclusive dijet cross sections are measured for the first time and are compared with Monte Carlo models. The cross section for the diffractive deep-inelastic scattering process  $ep \rightarrow eXp$  is measured, with a leading final state proton with a fractional longitudinal momentum loss  $x_{IP}$  satisfying  $x_{IP} < 0.1$  detected in the H1 Forward Proton Spectrometer. Using a high statistics data sample for which the squared four-momentum transfer at the proton vertex is in the interval  $0.1 < |t| < 0.7 \text{ GeV}^2$  and for photon virtualities in the range  $4 < Q^2 < 700 \text{ GeV}^2$  the cross section is measured differentially in  $t$ ,  $x_{IP}$ ,  $Q^2$  and  $\beta$ ,  $0.001 < \beta = x/x_{IP} < 1$ , where  $x$  is the Bjorken scaling variable. The  $t$  and  $x_{IP}$  dependences are interpreted in terms of an effective pomeron trajectory and a sub-leading exchange. The data are compared with QCD predictions at next-to-leading order based on diffractive parton distribution functions previously extracted from complementary measurements of inclusive diffractive deep-inelastic scattering. The ratio of the diffractive to the inclusive ep cross section is studied as a function of  $Q^2$ ,  $\beta$  and  $x_{IP}$ .

A first measurement of the longitudinal diffractive structure function  $F_L^D$  using the H1 detector at HERA is presented. The structure function is extracted from first measurements of the diffractive cross section at centre of mass energies  $\sqrt{s}$  of 225 and 252 GeV, together with a new measurement at  $\sqrt{s}$  of 319 GeV, using data taken in 2007 at high values of inelasticity  $y$ . The measured  $F_L^D$  is compared to predictions from NLO QCD fits to previous measurements of the inclusive diffractive DIS cross section.

Measurements of the cross section for the diffractive process  $ep \rightarrow eXY$  are presented, where Y is a proton or a low mass proton excitation carrying a fraction  $1-x_{IP} > 0.95$  of the incident proton longitudinal momentum and the squared four-momentum transfer at the proton vertex satisfies  $|t| < 1.0 \text{ GeV}^2$ . Using data taken by the H1 experiment, the cross section is measured for photon virtuality in the range  $3.5 < Q^2 < 90 \text{ GeV}^2$ , triple differentially in  $x_{IP}$ ,  $Q^2$  and  $\beta = x/x_{IP}$ , where  $x$  is the Bjorken scaling variable. These measurements are done after selecting diffractive events showing a large rapidity interval between the hadronic systems X and Y. They cover the periods of data taking 1999-2000 and 2003-2007. Combinations with previous results obtained by H1 with data collected in 1996-1997 are realized to provide a single set of diffractive cross sections using the large rapidity gap selection from the H1 experiment. Comparisons of measurements with predictions from resolved Pomeron and dipole models are shown and discussed.

In 2004, the H1 Collaboration at HERA installed the Very Forward Proton Spectrometer (VFPS) located at 220m from the interaction point, in the cold section of the proton ring. The spectrometer consists of two Roman Pot stations equipped with scintillating fiber detectors. The device allows the measurement of diffractive proton momentum in the range  $0.009 < x_{pom} < 0.025$ , where  $x_{pom}$  is the energy fraction lost by the proton in the interaction, with a very high acceptance (above 90%). The inclusive diffractive deep inelastic scattering,  $ep \rightarrow e \gamma p$ , has been measured with the H1 detector at HERA using VFPS to measure the scattered proton momentum. The data correspond to an integrated luminosity of  $95 \text{ pb}^{-1}$ .

The cross section has been measured for virtualities of the exchanged boson,  $5 < Q^2 < 100 \text{ GeV}^2$  and in the range  $0.005 < \beta < 0.8$ , where  $\beta = x/x_{pom}$ . The cross section is measured differentially in  $Q^2$ ,  $x_{pom}$  and  $\beta$  and compared to previously measured cross section at HERA. In this measurement, the cross section for inclusive jet production in diffractive deep-inelastic scattering is presented. The leading final state proton is detected in the H1 Forward Proton Spectrometer. The data have been collected during the HERA-2 period. The data cover the range  $x_{IP} < 0.1$  in fractional proton longitudinal momentum loss,  $0.1 < |t| < 0.7 \text{ GeV}^2$  in squared four-momentum transfer at the proton vertex and  $4 < Q^2 < 110 \text{ GeV}^2$  in photon virtuality. The dijet topology is defined by two inclusive jets in the central region, found by the  $k_T$  cluster algorithm in the hadronic centre-of-mass. The data are compared to parton shower and to NLO predictions.

The production of dijets in diffractive deep inelastic scattering,  $ep \rightarrow e \gamma p \rightarrow e p \text{ jet1 jet2 } X$ , has been measured with the H1 detector at HERA using Very Forward Proton Spectrometer to measure the scattered proton momentum. The data correspond to an integrated luminosity of  $95 \text{ pb}^{-1}$ . This process is sensitive to the partonic structure of the diffractive exchange between the proton and the virtual photon. The scattered proton is measured using the VFPS with an acceptance of about 90% in the range  $0.009 < x_{pom} < 0.025$ , where  $x_{pom}$  is the energy fraction lost by the proton in the interaction. The dijet cross section has been measured for virtualities of the exchanged boson,  $5 < Q^2 < 80 \text{ GeV}^2$  and photon-proton centre-of-mass energies,  $100 < W < 250 \text{ GeV}$  and  $|t| < 1 \text{ GeV}^2$ . The jets were identified using the inclusive  $k_T$  algorithm in the  $\gamma p$  frame. The two highest transverse energy jets identified in each event were required to satisfy  $E_{T, \text{jet}} > 5.5$  and  $4 \text{ GeV}$ , respectively in the pseudorapidity range  $-2.0 < \eta_{\text{jet}} < 2$ . The cross sections are compared to the predictions from leading-logarithm parton-shower RapGap Monte Carlo and next-to-leading-order QCD calculations based on recent diffractive parton densities extracted from inclusive diffractive deep inelastic scattering data.

The dissociation of virtual photons,  $\gamma p \rightarrow X p$ , in events with a large rapidity gap between  $X$  and the outgoing proton, as well as in events in which the leading proton was directly measured, has been studied with the ZEUS detector at HERA. The data cover photon virtualities  $Q^2 > 2 \text{ GeV}^2$  and  $\gamma p$  centre-of-mass energies  $40 < W < 240 \text{ GeV}$ , with  $M_X > 2 \text{ GeV}$ , where  $M_X$  is the mass of the hadronic final state,  $X$ . Leading protons were detected in the ZEUS leading proton spectrometer. The cross section is presented as a function of  $t$ , the squared four-momentum transfer at the proton vertex and  $\Phi$ , the azimuthal angle between the positron scattering plane and the proton scattering plane. It is also shown as a function of  $Q^2$  and  $x_{IP}$ , the fraction of the proton's momentum carried by the diffractive exchange, as well as  $\beta$ , the Bjorken variable defined with respect to the diffractive exchange.

ZEUS inclusive diffractive cross-section measurements have been used in a DGLAP next-to-leading-order QCD analysis to extract the diffractive parton distribution functions. Data on diffractive dijet production in deep inelastic scattering have also been included to constrain the gluon density. Predictions based on the extracted parton densities are compared to diffractive charm and dijet photoproduction data.

The reduced cross section in diffractive deep inelastic scattering events,  $ep \rightarrow e X p$ , was measured with the ZEUS detector at HERA, using three different centre-of-mass energies, 318, 252 and 225 GeV. The diffractive sample was selected by requiring a large rapidity gap between the hadronic system  $X$  and the outgoing proton. The longitudinal component of the diffractive structure function of the proton was extracted.

The semi-inclusive reaction  $e+p \rightarrow e+Xp$  was studied with the ZEUS detector at HERA using an integrated luminosity of  $12.8 \text{ pb}^{-1}$ . The final state proton, which was detected with the ZEUS leading proton spectrometer, carried a large fraction of the incoming proton energy,  $x_L > 0.32$ , and its transverse momentum squared satisfied  $p_{T2} < 0.5 \text{ GeV}^2$ ; the exchanged photon virtuality,  $Q^2$ , was greater than  $3 \text{ GeV}^2$  and the range of the masses of the photon-proton system was  $45 < W < 225 \text{ GeV}$ . The leading-proton production cross section and rates are presented as a function of  $x_L$ ,  $p_{T2}$ ,  $Q^2$  and the Bjorken scaling variable,  $x$ .

Differential cross sections for dijet photoproduction in association with a leading neutron,  $e+ p \rightarrow e+ \text{jet} + \text{jet} + X (+ n)$ , have been measured with the ZEUS detector at HERA using an integrated luminosity of  $40 \text{ pb}^{-1}$ . The fraction of dijet events with a leading neutron was studied as a function of different jet and event variables. Single- and double-differential cross sections are presented as a function of the longitudinal fraction of the proton momentum carried by the leading neutron,  $x_L$ , and of its transverse momentum squared,  $p_{T2}$ . The dijet data are compared to inclusive DIS and photoproduction results; they are all consistent with a simple pion exchange model. The neutron yield as a function of  $x_L$  was found to depend only on the fraction of the

proton beam energy going into the forward region, independent of the hard process. No firm conclusion can be drawn on the presence of rescattering effects.

Diffractive electroproduction of pion pairs at HERA has been studied with the ZEUS detector. The analysis was carried out in the kinematic range of photon virtuality  $2 < Q^2 < 80 \text{ GeV}^2$ ,  $\gamma^*p$  center-of-mass energy  $40 < W < 180 \text{ GeV}$  and two-pion invariant mass  $0.28 < M(\pi\pi) < 2.3 \text{ GeV}$ . The  $\pi^+\pi^-$  invariant-mass distribution was analyzed in terms of three isovector resonances:  $\rho$ ,  $\rho'$  and  $\rho''$ . Masses and widths as well as relative amplitudes were obtained using a fit to the pion electromagnetic form factor. The  $Q^2$  dependence of the pion form factor was studied.

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