Recent Results from HERA

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Abstract

A brief discussion is presented of some selected areas of ep scattering in which the last two years one has seen a particularly marked advance in our knowledge.

1 Introduction

The ep collider HERA in year 1997 had the most successful running period yet, providing the H1 and ZEUS experiments with a luminosity about 34 pb^{-1}, which is almost equal to the integrated luminosity for the previous five years. This, together with further theoretical development allowed significant progress in understanding of the physics in ep collisions. Some selected areas, where the progress was particularly marked are discussed in the lecture. A cornerstone of the whole discussion is a reaction of deep inelastic scattering. The precise measurement of the inclusive neutral current deep inelastic scattering (DIS) cross section $\sigma(ep \to eX)$ has been one of the prime tasks at HERA as it is required for the understanding of proton substructure and precision tests of QCD.

The double differential DIS cross section is parameterized by the generalized structure functions F_i according to

$$\frac{d^2\sigma^{e^\pm p}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}[Y_+F_2(x,Q^2) - y^2F_L(x,Q^2) \mp Y_-xF_3(x,Q^2)] \quad (1),$$

where $Y_\pm = 1\pm(1-y)^2$, Q^2 is the squared four-momentum transfer between the lepton and the proton and x is the Bjorken variable. The inelasticity is defined as $y = Q^2/(xs)$, where the squared center-of-mass energy $s = 4E_eE_p$ is derived from the electron and proton beam energies E_e and E_p. The generalized structure functions F_2 and F_L contain contributions from both virtual photon (electromagnetic component) and Z^0 exchange. For $Q2 \ll M_Z^2$, where M_Z is the mass of the Z^0 boson, only the virtual photon contribution is relevant. In this case, F_2 and F_L can be approximated by their electromagnetic components, while the parity violating contribution xF_3 becomes negligible. In addition, the contribution of F_L is suppressed in most of the kinematic range explored by the H1 experiment with the exception of the high y region. In the quark parton model, these structure functions are directly related to the quark and antiquark density in the proton $F_2 = x\Sigma e_i^2[q_i(x)+\bar{q}_i(x)]$. In perturbative QCD (pQCD), gluon density is taken into account as well, and the behaviour of the structure functions is described by evolution equations, so-called DGLAP equations (Dokshitzer,1977). The DGLAP equations take into account probabilities for quarks to irradiate a gluon and for a gluon to spit in to quark-antiquark pair or a pair of gluons. These cascade processes account for a change (evolution) of the proton structure with Q^2 and x.

In practice, the DIS cross section is determined by converting the number of events counted in bins of x and Q^2, after background subtraction, into a bin averaged cross section using Monte Carlo acceptance calculations. The 1997 luminosity more than doubles the previously existing luminosity and allowed measurements of F_2 with statistical errors of $1-2\%$ and systematic errors of $3-5\%$ for the measurement of F_2 in a broad Q^2 range. Main contributions to the systematic error of the cross section measurement result from the calorimeter energy calibration and photoproduction background. The precision of the measurement at HERA is now comparable with that reached before in fixed target experiments.

In Figure 1, the preliminary measurement of the F_2 from H1 is shown. One can observe a smooth extrapolation to the fixed target data at low Q^2. The function F_2 shows a steep rise at low x. This effect is referred as a strong scaling violation. In pQCD the strong scaling violation is a consequence of high gluon density in the proton.

Both H1 and ZEUS have performed NLO QCD fits to their F_2 data, using the DGLAP evolution equations. The result of the QCD fit is displayed in the Figure 1. The good agreement between the data and a NLO QCD fit in a very broad kinematical domain covering more than four decades in Q^2 and x is often taken as an impressive proof of applicability of pQCD to describe a structure of elementary hadrons. This dogma is provocatively questioned in the present lecture (see sec. 2 and 6). Sections 3 and 4 are devoted to the searches of rare events beyond Standard Model. Diffractive reactions are discussed in the Section 5. In the section 6 the H1 measurement of a baryon number transfer is discussed. It is a new phenomenon studied recently at HERA.

2 DIS. Low Q^2

The pQCD fails to describe the inclusive DIS cross section at low Q^2, where the data approach a photoproduction limit ($Q^2=0$). In this region it is convenient to present the total photon-proton cross section $\sigma_{\gamma p}$ as function of Q^2 and photon-proton collision energy W ($W=\sqrt{ys}$). For DIS the $\sigma_{\gamma p}$ is directly related to F_2 by

$$\sigma_{\gamma^* p} = (4\pi\alpha/Q^2)F_2(x,Q^2)\,.$$

In Figure 2 the photoproduction data are presented together with the DIS measurements. One can "see" an imaginary dividing line around $Q^2 = Q_0^2 \approx 1GeV^2$. The $\sigma_{\gamma p}(Q^2)$ is almost flat below the Q_0^2 and behaves approximately like $1/Q^2$ above Q_0^2. Physicists used to explain these two distinctive patterns of

$\sigma_{\gamma p}(Q^2)$ behaviour by difference between soft (non-perturbative) and hard (perturbative QCD) regimes. Intuitively, however, we understand that the Nature has only one mechanism for the γp interaction. A striking similarity found between the properties of hadronic final states in photoproduction and DIS (Aid, 1995) strongly supports this universality hypothesis. Thus, it is very important to explore a transition region around Q_0^2. The HERA experiments provide a unique opportunity to do that.

On the other hand, one can look for an alternative phenomenological approach to describe the data, in which a distinction between photoproduction and DIS processes is diminished. Such approach might have a good chance to come closer to an adequate model of the γp interaction. In an attempt to find such model let's to replot the $\sigma_{\gamma p}$ data as function of $Q^2 + Q_0^2$ and fit the data to a simple parameterization

$$\sigma_{\gamma p} = \frac{A}{Q^2 + Q_0^2}\,. \qquad (2)$$

Figure 3 shows the data at two different energies ($W = 200$ GeV and $W = 15$ GeV). The measured total photon-proton cross sections are fitted to the parameterization (2) with only two free parameters: Q_0^2 and an overall normalization (A) for each of the two sets of the data. The results of the fit are also presented in Figure 3 as lines. One can conclude that (2) reproduces all the main features of the data in a wide range of energies and Q^2 (including the photoproduction points). The parameter Q_0^2 is energy dependent. It's value is 1.04 ± 0.04 GeV^2 at $W = 200$ GeV while for $W = 15$ GeV one needs $Q_0^2 = 0.42 \pm 0.01$ GeV^2. It is known that in the small-x region the DGLAP evolution leads to a steep rise of F_2 or to a strong scaling violation. Therefore, at large energies the Q^2 behaviour of the cross section becomes more flat. In our parameterization (2) the same effect of the scaling violation is hidden in the W dependence of Q_0^2 value. The two features of the above parameterization are striking: simplicity and very good quality of data description. Moreover, the expression (2) fits also quite well the data on the nuclear targets. Details about this approach to describe the data can be found in (Engel, 1996). What is a physical meaning of the parameter Q_0^2? We have no answer yet to this question. Whatever it is, a simplicity and universality of the parameterization (2) is very suggestive - a mechanism of gamma-p interaction is indeed universal for all Q^2 and an overall picture of the interaction might be much simpler than the orthodoxal separation of DIS/photoproduction worlds. Further data analyzes at HERA and new theoretical ideas are wanted to shed the new light at this interesting subject.

3 High Q^2 events

The 1997 data have allowed the H1 and ZEUS collaboration to further study the high Q^2, high x region of the DIS kinematic plane in which an unexpectedly large number of events was found in the data taken in the years 1994 to 1996 (Adloff, 1997a) and (Breitweg, 1977). The H1 collaboration observed $N_{obs} = 12$ events with $Q^2 > Q^2_{min} = 15000 GeV^2$ where only $N_{SM} = 4.71 \pm 0.76$ were expected from Standard Model (SM) calculations. The probability of such a measurement, assuming the SM to be correct, is $P(N \geq N_{obs}) \approx 1\%$. Further, these high Q^2 events tended to be at high y and to be clustered around an electron-quark invariant mass of $M = \sqrt{xs} \approx 200 GeV$, i.e. at x of about 0.4, raising the prospect that the excess of events were due to leptoquark production or R-parity violating SUSY processes. The requirements $187.5 < M < 212.5 GeV$ and $y > 0.4$ were satisfied by 7 events, where only 0.95 ± 0.18 were expected.

The number of NC DIS events with $Q2 > 15000 GeV^2$ observed in 1997 was 10, which is to be compared with an expectation of 8.77 ± 1.26 events. This corresponds to a probability of about 40%. Considering all the 1994-97 data, these numbers become 22 events observed for an expectation of 14.8 ± 2.13, with probability about 6%. The observed excess of high-Q^2 events is visible in Figure 1 as a departure of the data from the QCD fit line at $x = 0.4$. The same events contribute to the excess at high mass M presented in Figure 4 for $y > y_{cut} = 0.4$. It is apparent that the new data have led to a decrease in the significance of the observed excess over SM expectations. Nonetheless, the observed number of NC events at the highest Q^2 values remains larger than expected from the SM. Similar situation was reported from ZEUS collaboration (Grosse-Knetter, 1998). The clarification of this puzzle demands a significant increase in the luminosity available to the H1 and ZEUS experiments, which will become available following the HERA upgrade in the year 2000.

4 Events with high energy isolated leptons

In the frame of the SM, events containing a high energy lepton together with significant missing energy are issued at HERA from the W production and decay in ep collisions. The same final state topology can also provide a signature for the processes beyond the SM like production of excited fermions or supersymmetric particles. Both HERA collaborations have searched for events with high energy isolated leptons and missing transverse momentum (Adloff, 1998a) and (Matsushita, 1998). The charged leptons are directly identified in compact detectors H1 and ZEUS. The presence of non-detected particles can only be deduced from a transverse momentum imbalance.

The H1 analysis is based on the inclusive search for events with the calorimetric transverse momentum (P_T^{calo}) above 25 GeV. This condition ensures high efficiencies and drastically reduces the contributions of neutral current deep inelastic scattering and photoproduction processes. Among the selected sample, 124 events contain also a high energy track with a transverse momentum $P_T > 10\ GeV$. The isolation of those tracks with respect to the calorimetric deposits and to other tracks is quantified using the Cartesian distance in the η, ϕ plane, where η stand for pseudorapidity and ϕ is the azimuth. The isolation of high P_T tracks with respect to the closest track (D_{track}) and to the closest hadronic jet (D_{jet}) is presented in the Figure 5. A majority of high energy tracks has small isolation values corresponding to tracks inside hadronic jets. Six events have isolated high energy tracks ($D_{jet} > 1$ and $D_{track} > 0.5$). At closer look these tracks turned out to be leptons: one event contain an e^- and five events contain muons: 2 negative and 2 positive, and one very energetic μ associated to a stiff track whose sign cannot be determined.

In all events a hadronic shower has been detected in the calorimeters. All events present a significant imbalance in total transverse momentum, reconstructed using calorimetric information for the electron event and using in addition the muon track information for the muon events. The missing transverse momentum points to the presence of an undetected particle. Additional evidence supporting this hypothesis is provided by the acoplanarity ($\Delta\phi$) observed in most events between the high P_T lepton and the hadronic system.

The processes within the SM which may yield events with an isolated high P_T lepton and missing transverse momentum have been investigated by applying the selection procedure explained above. The main SM contribution in both electron and muon channels is the W boson production in ep collisions. The subsequent W leptonic decay provides both an isolated high energy charged lepton and missing transverse momentum associated to the undetected neutrino. The expected number of events corresponding to the integrated luminosity of the data are 1.7 ± 0.5 in the electron channel and 0.5 ± 0.1 in the muon channel. Other SM contributions have been estimated to be small. Summed up all contributions give the expected number of 2.4 ± 0.5 events in the electron channel and 0.8 ± 0.2 in the muon channel.

The search of events with an isolated lepton and missing transverse energy performed by ZEUS collaboration resulted in 3 electron events found (with 3.0 ± 0.7 expected) and no isolated muon event (with 0.8 ± 0.3 expected). An increase of the statistics in the future will help to understand whether the excess of events with isolated muon seen by H1 is a statistical fluctuation or not.

5 Diffractive scattering

About 10 percent of the deep inelastic ep scattering is due to diffractive processes where no quantum numbers are exchanged. Signature for such processes is for example a region of rapidity, which is free of hadron production, a so-called rapidity gap. Events of deep inelastic scattering tagged with rapidity gaps, observed and analyzed by the H1 and ZEUS collaborations have shown the same characteristic pattern exhibited by hadron diffractive dissociation processes in the kinematical region where Pomeron exchange is dominant. The concept of a Pomeron ($I\!\!P$) trajectory, possessing vacuum quantum numbers and mediating diffractive scattering, has proved remarkably successful in formulating a Regge description of high energy hadronic total, elastic and inelastic diffractive cross sections. Further phenomenological development of the Pomeron concept was made by Ingelman and Schlein, who considered the Pomeron as an exchanged particle with its own partonic density. Thus, in the framework of this approach one can calculate hard scattering processes (like DIS, jets and heavy meson production) in the event class with large rapidity gaps. In another words, the partonic structure of the Pomeron is probed in DIS ep reaction at HERA.

A typical diffractive event topology studied at HERA is the following. The virtual photon dissociates into hadronic system X, which is measured in the main detector. Proton stays intact or dissociates into a small mass hadronic system Y, which is strongly boosted down to the proton beam direction and is not observed in the detector. Hadronic systems X and Y are separated by large rapidity interval.

In analogy with DIS inclusive reaction (1) the cross section for diffractive DIS processes can be written down as

$$\frac{d^2\sigma^{e^{\pm}p}_{dif}}{dxdQ^2dx_{I\!\!P}} = \frac{4\pi\alpha^2}{\beta Q^4}(1-y+y^2/2)\times \times F_2^{D(3)}(\beta,Q^2,x_{I\!\!P}), \quad (3)$$

where $x_{I\!\!P}$ is a fraction of proton momentum carried by the Pomeron and β plays a role of x-Bjorken for partons inside Pomeron. Both $x_{I\!\!P}$ and β are measured at HERA experiments:

$$\beta = \frac{Q^2}{Q^2+M_X^2}, \qquad x_{I\!\!P} = \frac{x}{\beta},$$

where M_X^2 is the invariant mass of photon diffractive dissociation system. The HERA data have shown a very clear diffractive pattern, that is the characteristic $x_{I\!\!P}$-dependence observed in diffractive dissociation of hadrons. This feature was observed irrespective of the (β, Q^2) values considered and this was very suggestive that a factorized expression like

$$F_2^{D(3)}(\beta,Q^2,x_{I\!\!P}) = g(x_{I\!\!P})F_2^{I\!\!P}(\beta,Q^2)$$

could apply. Based on this factorization hypothesis, it is usual to interpret $g(x_{I\!\!P})$ as the Pomeron flux factor and $F_2^{I\!\!P}(\beta,Q^2)$ as the Pomeron structure function. For the Pomeron flux factor the Donnachie Landshoff expression (Donnachie, 1987) was assumed.

Figure 6 shows the measurement of the $F_2^{D(3)}$ by the H1 collaboration (Adloff 1997a) together with a QCD fit using DGLAP evolution equations to the $F_2^{D(3)}$ data. As a result of the fit a gluon and quark content of the Pomeron were extracted. More than 80% of the Pomeron momentum is carried by gluons throughout a broad range of β and Q^2. A rich gluonic structure of the Pomeron can already be suggested form a strong scaling violation visible in the Figure 6.

The procedure of extraction of Pomeron partonic densities is well defined mathematically, but whether the whole concept of the Ingelman-Schlein model has a solid physical meaning? To answer this question let's look at diffractive di-jet production at Tevatron. CDF has measured the hadronic jet production in a reaction $p+p \to p+jets+X$. According to the Ingelman-Schlein model, this process occurs as a sequence of two independent steps: first a proton emits a Pomeron, then partons of the Pomeron interact with partons of the other proton producing jets. To calculate the diffractive jet production cross section one needs to know the partonic densities for proton and Pomeron, Pomeron flux and a probability for two colliding partons to produce the high P_T-jets. Now, with the HERA data on the Pomeron structure, all components are available for the calculation. Surprisingly, the result of this calculation turned out to be more than 10 times higher than the measurement (Abe, 1997). The discrepancy between calculation and experiment is even more striking if one considers the jet production in a double Pomeron reaction, where both protons emit Pomerons. For this reaction the calculations overestimate the data by factor more than 100 (Alves, 1999). In addition, the CDF collaboration has measured a partonic density of the Pomeron as function of β using kinematics of di-jet events. As compared with the partonic structure measured at HERA, the partons in "CDF Pomerons" have softer β-spectrum than that in "HERA Pomerons" (Borras, 1998). This discrepancy can't be cured by an introduction of more sophisticated Pomeron flux.

The difficulty to describe both HERA and Tevatron data within the Ingelma-Schlein approach makes the physicists rather sceptic about applicability of this model for diffractive processes.

6 Event shapes in DIS

Deep inelastic scattering data at HERA are used to study event shape variables over a large range of momentum transfer in the Breit frame. The Breit frame provides a clean separation between current(photon) and target(proton) fragmentation. The analysis is done in the current hemisphere. The investigated event shape variables are two variants of thrust, the jet broadening, the C parameter derived from the eigenvalues of the linearized momentum tensor and two jet masses. The data are corrected for detector effects. Details of the analysis can be found in ref. (Martyn, 1998).

The Q dependence of the mean event shape variables $<F>$ measured by H1 collaboration is shown in Figure 7. All variables exhibit a decrease with rising Q, the event shapes become more collimated. The data are compared with NLO pQCD calculations $<F>^{pert}$. As seen from the Figure 7 the perturbative calculations significantly underestimate the data. It is believed, that non-perturbative effects do the rest of the job and summed up with pQCD calculations are able to describe the measurements. Non-perturbative effects are modeled with the following ansatz (Dasgupta 1998):

$$<F>^{pow} = a_F \frac{16\mu_I}{3\pi Q}[\bar{\alpha_0}(\mu_I) -$$

$$-\alpha_s(Q) - b_0\alpha_s^2(Q)] \,. \quad (4)$$

This method is termed power corrections. The power corrections contain calculable coefficients a_F and a free "universal" parameter $\bar{\alpha_0}(\mu_I)$, interpreted as an effective strong coupling below an 'infrared matching' scale μ_I defined by $\Lambda_{QCD} \ll \mu_I \ll Q$. As expected, the non-perturbative contribution decreases with Q. The data are well described by a fit including pQCD and power corrections. The power correction parameter $\bar{\alpha_0}(\mu_I)$ of thrust and jet mass are of the same size and support the concept of approximate universality. For these variables the fit gives value $\bar{\alpha_0}(\mu_I = 2\ GeV) \approx 0.5$. The calculations for the jet broadening and the C-parameter are less reliable yet. A simple hadronisation term of $< F >^{pow} = const/Q$ is not able to describe the data satisfactorily. Thus the power corrections (4) seem to provide an adequate analytical form.

It is very interesting to observe that non-perturbative effects are still important at high values of Q ($Q^2 \gg 100\ GeV^2$). Following the logic of power corrections, one expects also significant non-perturbative corrections to the partonic densities and the structure function F_2 of proton (Dokshitzer, 1999). The calculation of the non-perturbative contributions to the partonic structure of the proton are in progress. If this contribution will be of similar order as for the event shape variables above, we are going to face a conceptual problem with the interpretation of the measured proton structure functions. Basically, the necessity of additional (on top of pQCD) power corrections and the problem of description of $\sigma_{\gamma p}$ at low Q^2 discussed in Section 2 have the same origin. It is interesting to follow up a development in this field.

7 Baryon asymmetry

The existence of the baryons, baryon asymmetry in the universe and the baryon number conservation are phenomena of a fundamental importance in modern picture of the world. The understanding of these phenomena is closely related to the question about the carrier of the baryon identity (the baryon number). In the quark–parton model any quark carries a 1/3 of the baryon number unit. The baryons appear as particles built up from the three constituent quarks. When baryon gets destroyed by inelastic scattering on other particles, the quarks can recombine in another baryon at a new position in the momentum space. How far the baryon number can be transfered in the momentum (or rapidity) space in the inelastic scattering? Within the widely spread approach the baryons act as a diquark–quark system. In the collision of baryons the diquarks take a large part of the projectile momentum and give rise to the leading baryon production in the projectile fragmentation region. In this approach a baryon number transfer over large rapidity intervals is strongly suppressed. The diquark model is very illustrative and describes the bulk of the data on the leading baryon production. However, there are also measurements, which are difficult to explain within the approach, where the carrier of the baryon number is the diquark. Those are: the energy dependence of the $p\bar{p}$ annihilation cross section, the rapidity distributions of the net baryon number $(p-\bar{p})$ at ISR and in high energy heavy ion collisions and reactions with a final state leading baryon having valence quarks different from the quark content of the baryonic projectile. These data indicate that the baryon number can be transported with high probability over a large rapidity gap. To describe these data two new mechanisms of the baryon number transfer have been suggested (Kopeliovich, 1989 and Kopeliovich, 1987): single-quark and gluonic mechanisms. Both mechanisms imply the diquark breaking up. The first one is calculated and well explains the ISR data and the proton stopping in heavy ion collisions. The gluonic mechanism is only roughly estimated as there was no data available to compare with. This mechanism predicts an asymptotic non-vanishing annihilation cross section and no suppression for the baryon number transfer over large rapidity intervals.

The HERA data on high energy photon–proton collisions offer a unique opportunity to study the gluonic mechanism of the baryon number transfer. The asymmetry in the beam energies make it possible to study the baryon production in the photon hemisphere up to 8 unit rapidity distance from the leading baryon production region. At such large rapidity interval the gluonic mechanism gives a dominant contribution to the baryon number transfer. The baryon production asymmetry for protons is defined as

$$A_B = 2 \cdot \frac{N_p - N_{\bar{p}}}{N_p + N_{\bar{p}}},$$

where $N_p, N_{\bar{p}}$ are the numbers of protons and antiprotons produced in a given rapidity interval. The calculations made in (Kopeliovich 1997) give a prediction for the asymmetry A_B in the photon hemisphere at HERA to be as big as about 7%, a non-vanishing number, which is in reach for the presently available statistics collected by experiments at the HERA ep collider.

The proton-antiproton asymmetry in ep collisions at an average center of mass energy $W = 200\ GeV$ has been measured using the H1 detector. The protons(antiprotons) have been identified using dE/dx measurement in the central drift gas chamber within a momentum interval $0.3 < p < 0.6\ GeV/c$ and a pseudorapidity interval $|\eta| < 1.1$, which is about 8 units of rapidity away from the fragmentation region of the leading proton. The Monte Carlo calculation based on the Lund fragmentation model shows no proton asymmetry in this rapidity interval.

The major experimental challenge of this measurement is a reduction of the background particles: protons coming from collision of beam particles with a residual gas in the vacuum beam pipe and evaporation protons resulted from secondary interactions of hadrons in the material around the beam pipe. A small fraction of protons produced in the material of the outer tracker wall and scattered back in to the sensitive volume of the CJC is reconstructed with an opposite sign of the charge and contribute to the sample of the antiprotons. After suppression of these background particles and correction for the detector effects the proton-antiproton asymmetry was measured to be

$$A_B = (8.0 \pm 1.0 \pm 2.5)\%$$

where the second error reflects a systematic uncertainty. This is a preliminary H1 result reported last year (Adloff, 1998b). At the same time it was checked that charged asymmetry in pions and kaons is compatible with zero.

The available statistics of identified protons and antiprotons allows to study the baryon asymmetry as a function of event properties. The H1 group studied A_B as function of the number of accompanying charged particles N_{ch}^{obs} measured within the same angular interval as the protons. The charged particles are required to originate from the common event vertex. Figure 8(a) shows the results for A_B in bins of N_{ch}^{obs}. The measured baryon asymmetry increases with N_{ch}^{obs} while the charge asymmetry for pions is compatible with zero and doesn't change with N_{ch}^{obs} (Fig. 8b). The error bars in the Figure 8 represent the statistical uncertainties. The systematic uncertainties depend on the baryon properties itself affecting the normalization only and therefore are not shown. It is worthwhile to note that the gluonic mechanisms of the baryon number transfer over large rapidity intervals implies an increased charged particle yield in the the vicinity of the produced baryon. The present measurement opens a new window to explore the dynamics of baryon production.

8 Conclusions

A brief discussion was presented of some selected areas of ep scattering in which the last two years one has seen a particularly marked advance in our knowledge. These include precision measurement of the proton structure, studies of the highest Q^2 events, measurement of diffractive DIS reaction, event shape studies, measurement of the baryon asymmetry. The author believes that further progress in understanding of these results and future significant increase of statistics at HERA are indispensable for the conceptual development in the field.

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Figure Captions

Figure 1. F_2^p results from $Q^2 \approx 1$ to 3000 GeV^2, and for x values between .00002 and 0.65. The NLO DGLAP equations give a good description of the data over the kinematic range considered. The error bars represent the total error of the measurements.

Figure 2. Total γp cross section as function of Q^2 for different values of W.

Figure 3. Total γp cross section as function of $Q^2 + Q_0^2$. The filled circles represent HERA deep inelastic data at $W = 200$ GeV, triangles show the data from E665 experiment at $W = 15$ GeV, the squares represent the photoproduction measurements at corresponding energies. The lines represent fit results explained in the text.

Figure 4. Mass spectra for high-Q^2 events and DIS expectation (histogram).

Figure 5. High energy track isolation with respect to the tracks (D_{track}) versus the isolation with respect to the hadronic jets (D_{jet}) in the events with $P_T^{calo} > 25\ GeV$.

Figure 6. The quantity $x_{\mathbb{P}} F_2^{D(3)}(x_{\mathbb{P}}, \beta, Q^2)$ at $x_{\mathbb{P}} = 0.003$ as a function of Q^2 for different values of β. In both (a) and (b) the solid points show the same data, interpolated to $x_{\mathbb{P}} = 0.003$. In (a) the result of QCD fit in which only quarks contribute to the Pomeron structure at $Q^2 = 3GeV^2$ is superimposed. In (b) the preferred QCD fit in which both quarks and gluons contribute is shown.

Figure 7. Mean event shape variables as function of Q. H1 DIS ep data ($\bullet$) are compared to QCD fits including pover corrections (full curve) and NLO pQCD calculation alone (dotted curve).

Figure 8. The value of asymmetry measured for protons (a) and charged pions (b) as function of the number of accompanying charged particles.

Where to put the figures in the text:

Fig. 1 Preferably at any place within Section 1.

Fig. 2 Preferably at any place within Section 2.

Fig. 3 Preferably at any place within Section 2.

Fig. 4 Preferably at any place within Section 3.

Fig. 5 Preferably at any place within Section 4.

Fig. 6 Preferably at any place within Section 5.

Fig. 7 Preferably at any place within Section 6.

Fig. 8 Preferably at any place within Section 7.