LEADING BARYON PRODUCTION AT HERA

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New results on leading baryon production at HERA are presented for cross sections in photoproduction, in deep inelastic scattering and in the range in between these two kinematic regions. They are interpreted in terms of a Regge parameterization and, for the data with medium to high photon virtuality, in terms of structure functions. Vertex factorization is tested for these leading baryon data, as well as for events with a dijet system or a ρ meson in the final state.

1 Introduction

The study of *ep* scattering events with a leading baryon at HERA has the aim of determining the production mechanisms that lead to the formation of a proton or neutron leaving the interaction region with a high fraction of the incoming beam momentum. Possible production mechanisms are illustrated in fig. 1. Leading baryons can be produced as part of the fragmentation process in inclusive scattering events (components of the system X in the left hand figure). In the middle of fig. 1, the exchange of an object like a π or a Reggeon results in a leading proton (LP) or leading neutron (LN). Finally, in events involving the exchange of a pomeron or other reggeon, the proton can be excited to a low mass resonance, which in turn decays to final states including protons or neutrons. An example, corresponding to proton dissociative ρ production is shown on the right side of fig. 1.

Another issue to be investigated is a possible violation of factorization. The hypothesis of vertex factorization assumes that the cross section dependence on the baryon variables is independent of the particle production

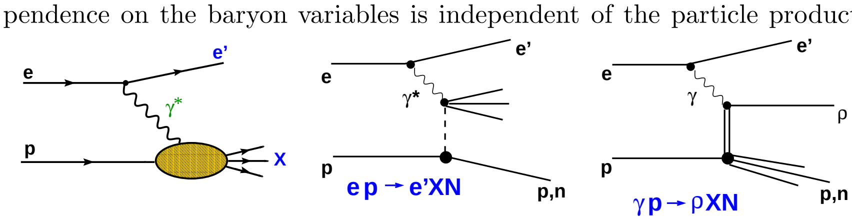

Figure 1. HERA *ep* scattering event (left) with a leading baryon produced by an exchange process (middle) or by fragmentation of the proton remnant (right).

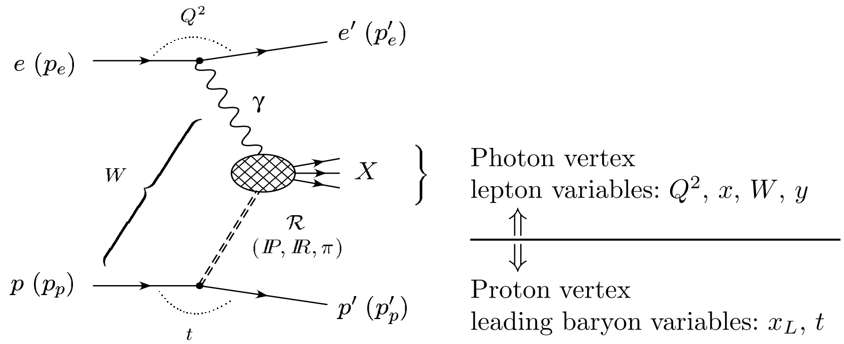

Figure 2. Kinematic variables in *ep* collisions at HERA.

at the photon vertex (see fig. 2 for illustration). The baryon variables are $x_L \equiv z = E_{p'}/E_p$ and $t = (p' - p)^2 = -(p_T^2/x_L) - (m_B^2(1 - x_L)^2/x_L)$.

The experiments H1 and ZEUS have each installed dedicated detectors along the beam line in the direction of the outgoing proton to detect charged leading particles. The ZEUS experiment uses a leading proton spectrometer (LPS) consisting of six stations of Roman Pots. The H1 experiment has a similar system for the forward proton spectrometer (FPS). Both experiments have in addition placed calorimeters in the beam line to measure forward neutrons (FNC). The analysis cuts on the baryon variables applied to the different data taken with the above devices are listed in table 1. The analyses concentrate on three different regions of photon virtuality Q^2, which allows vertex factorization tests.

Table 1. Kinematic regions of the analyzed data.

lepton variables:		
region	Q^2[GeV^2]	W[GeV]
γp	$\lesssim 0.01$	60 – 250
low Q^2	0.1 – 0.74	85 – 258
D I S	3 – 254	45 – 225

leading baryon variables:		
detector	$x_L(\equiv z)$	p_T^2[GeV^2]
H1 FPS	0.66 – 0.9	< 0.04
ZEUS LPS	0.6 – 1.0	< 0.5
H1 FNC	$\gtrsim 0.5$	$< (0.66 x_L)^2$
ZEUS FNC	> 0.2	$< (0.66 x_L)^2$

2 Physics Results

In this contribution, general results for the production of leading protons as well as for leading neutrons are presented. Special results from the leading proton data in the diffractive region of $x_L \gtrsim 0.95$ are discussed elsewhere in these proceedings[1].

2.1 Photoproduction with Leading Protons

The H1 Collaboration recently published final results on the photoproduction cross section with leading protons [2]. A leading proton was found in $1.17 \pm 0.02(\text{stat}) \pm 0.15(\text{syst})$ % of all γp events in the kinematic region of $Q^2 < 0.01$ GeV^2, $60 < W < 260$ GeV and $0.66 < x_L(\equiv z) < 0.9$, $p_T^2 < 0.04$ GeV^2. The differential cross section $d\sigma/dz$ shows no evidence for a x_L, z or W dependence. Due to the relation $M_X^2 = (1-z)W^2$, no M_X dependence was found, contrary to the case for diffraction ($\sim 1/M_X^2$). The data are well described by a Triple Regge model (fig. 3) in which the process is mediated with an effective Regge trajectory of an intercept of $\alpha_i(0) \approx 0.33$. The total cross section with this mixture ($\gamma\alpha_i \to X$) is mainly due to Pomeron exchange $\alpha_k(0) \approx 0.99$.

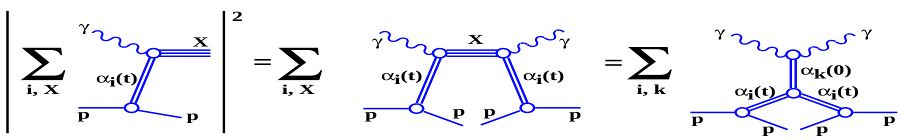

Figure 3. Illustration of the model for the inclusive photon dissociation cross section.

2.2 Cross Section Ratios and Structure Functions for Leading Baryons

The ZEUS Collaboration looked at semi-inclusive cross-section ratios

$$r^{LP(3)}(x_L, x, Q^2) = \frac{N^{LP}(x_L, \Delta p_T^2, x, Q^2)}{N(x, Q^2)} \cdot \frac{1}{\epsilon^{LP}(x_L, p_T^2)} = \frac{F_2^{LP(3)}(x_L, x, Q^2)}{F_2(x, Q^2)} \quad (1)$$

by measuring[3] the number of events with a leading proton, corrected for LPS acceptance (ϵ^{LP}), and dividing by the total number of events with no LPS requirement as a function of the variables x_L, x and Q^2. The results are presented by integrating over the available phase space in p_T^2. The advantage of this ratio method is the near complete cancellation of systematic errors such as, for example, the luminosity measurement. The unfolding of $F_2^{LP(3)}$

is done according to equation (1) by multiplying the measured ratio by a parameterization of F_2. The ratios exhibit little dependence on x_L, x and Q^2 for the DIS and the low Q^2 samples. This implies a similarity between $F_2^{LP(3)}$ and F_2. As a cross check, $F_2^{LP(3)}$ has been unfolded in the restricted p_T^2 range of $p_T^2 < 0.04\text{GeV}^2$ and compared to the previously published results of the H1 Collaboration[4]. Reasonable agreement is obtained.

The similarity of $F_2^{LP(3)}$ and F_2 is demonstrated by a shape comparison of $F_2^{LP(3)}$, unfolded in the full available p_T^2 range of $p_T^2 < 0.5\text{GeV}^2$, with F_2, scaled by the average value of the ratio and the analyzed x_L bin width (fig. 4).

A similarly good description is obtained in the low Q^2 region. Careful

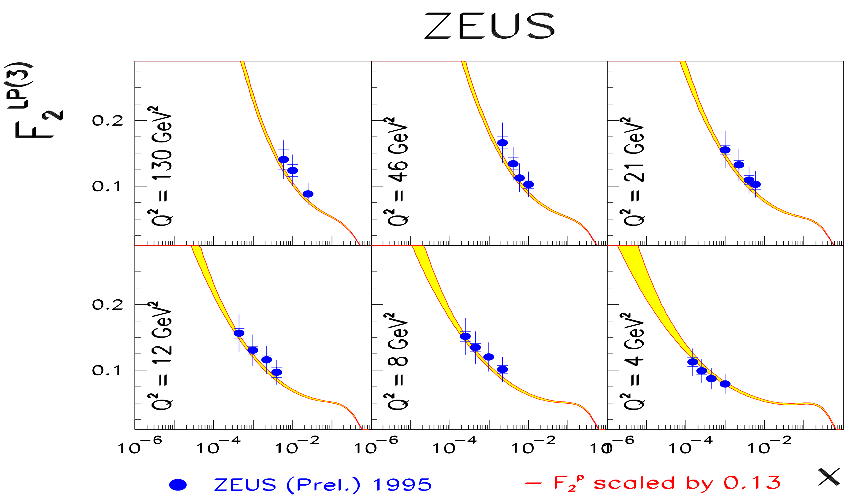

Figure 4. Structure function for leading proton production $F_2^{LP(3)}$ compared to the scaled proton structure function F_2.

inspection reveals a tendency of the data to lie systematically above the scaled F_2 at high Q^2, while for the low Q^2 range (not shown) the data are dominantly below F_2.

In order to look for systematic trends, the cross-section ratios have been studied in the transition from photoproduction to DIS up to high Q^2 values. The ratios show a small, but significant, rise with Q^2 in the H1[2] and the ZEUS data[3]. Possible explanations for this rise include absorptive effects (since in the γp case the photon appears hadron-like while in DIS it is more point-like), a Q^2 dependence of the Reggeon flux, or other violation of factorization.

Studies similar to those described above have been performed for the production of leading neutrons. The results are essentially the same: the x and Q^2 dependence of $F_2^{LN(3)}$ is similar to those of F_2 and again a rise of the cross-section ratio with Q^2 is found[3].

2.3 Dijets with Leading Neutrons

For leading neutron production in the context of fig. 2, only exchanges with non-zero isospin, such as pion exchange, can contribute. The One-Pion-Exchange picture has been tested with leading neutron data by the H1 Collaboration[5] by studying events containing two jets in the final mass system X (see fig. 2). The energy spectrum of the leading neutron is compatible with Monte Carlo simulations of pion exchanges for γp (POMPYT) and DIS (RAPGAP) for neutron energies corresponding to $x_L \gtrsim 0.5$. Using the jet information, the momentum fraction of the scattered parton inside the exchanged pion, x_π, can be calculated. The differential cross-section as a function of x_π has been measured and compared to simulations with different pion structure functions. Data and simulations agree within the systematic errors. Corresponding results have been published by the ZEUS Collaboration[6].

For these dijet data, the ratio of events with a leading neutron to all events has also been analyzed and is shown in fig. 5 as a function of Q^2. Within the experimental uncertainties there is no evidence for factorization breaking.

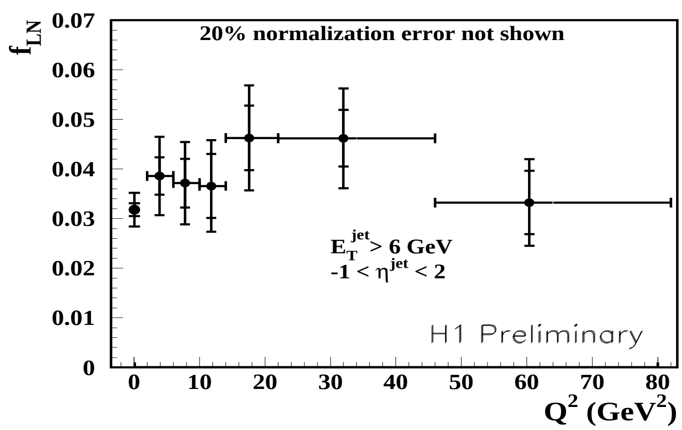

Figure 5. Ratio of leading neutron dijet events to all dijet events as a function of Q^2.

2.4 Proton dissociative ρ photoproduction at large $|t|$

Further vertex factorization tests have been performed by the ZEUS Collaboration[7]. The energy spectra and rates of diffractive photoproduction vector mesons at high $|t|$, where a leading baryon comes from the proton dissociative system (fig. 1 right) are compared to the corresponding spectra and rates of leading baryons observed in DIS (fig. 1 middle). The dependences on p_T^2, x_L and $|t|$ have been examined in the tests:

- the angular distribution of leading protons, as measured by p_T^2, reveals no appreciable difference in the three different x_L intervals analyzed for the two different kinds of event samples;
- the fraction of events containing a leading proton in DIS compared to ρ production shows an x_L dependence which is similar in both the rate and shape. The same result is obtained by analyzing leading neutron events of the two different processes;
- the rate of leading protons and that of leading neutrons has been measured for diffractive photoproduction vector meson events as a function of $|t|$, in this case the four-momentum transfer squared between the incoming photon and the outgoing ρ meson, and displays no significant dependence on $|t|$.

None of these results exhibit any significant violation of vertex factorization within the, sometimes large, experimental uncertainties.

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