Leading Baryon Production in Deep Inelastic Scattering at HERA

M.Kapichine[a]
For the H1 Collaboration

[a]Joint Institute for Nuclear Research, Joliot Curie 6, RU-141980 Dubna, Russia.
e-mail: kapishin@sunse.jinr.ru

Deep–inelastic scattering events with a leading baryon have been detected by the H1 experiment at HERA using a forward proton spectrometer and a forward neutron calorimeter. Semi–inclusive cross sections have been measured in the kinematic region $2 \leq Q^2 \leq 50$ GeV^2, $6 \cdot 10^{-5} \leq x \leq 6 \cdot 10^{-3}$ and baryon $p_T \leq 200$ MeV. A Regge model of leading baryon production which consists of pion, pomeron and secondary reggeon exchanges gives an acceptable description of both semi–inclusive cross sections in the region $0.1 \leq x_{\mathbb{P}} \leq 0.3$. The leading neutron data are used to estimate the structure function of the pion at small Bjorken–x.

1. Introduction

Diffractive events observed at HERA can be interpreted as being mainly due to interactions of a virtual photon with a pomeron. In addition to virtual photon–pomeron interactions, one also expects meson exchanges to contribute to the total DIS cross section and to the production of leading protons and neutrons with small p_T.

We report the measurement of the semi–inclusive cross sections for leading proton and neutron production in deep–inelastic scattering (DIS) at HERA where 27.5 GeV positrons collided with 820 GeV protons. The data were obtained during 1995 and 1996 using the H1 detector upgraded with a forward proton spectrometer (FPS) and a forward neutron calorimeter (FNC).

The measurements are compared to the results of a Regge model of leading baryon production and are used to test the pion exchange expectation for the ratio of neutron and proton production and to constrain the pion structure function.

2. Semi–Inclusive Structure Functions $\mathrm{F}_2^{\mathrm{LB}(3)}$

Semi–inclusive cross sections have been measured in the kinematic region $2 \leq Q^2 \leq 50$ GeV^2, $6 \cdot 10^{-5} \leq x \leq 6 \cdot 10^{-3}$ and baryon $p_T \leq 200$ MeV for DIS events with a final state proton with $0.7 \leq z \leq 0.9$ or a neutron with $0.2 \leq z \leq 1$, where $z = 1 - x_{\mathbb{P}}$. The total luminosities of the proton and neutron data samples are 1.44 pb^{-1} and 3.38 pb^{-1} respectively.

The differential cross section for leading baryon production defines the semi–inclusive structure function $\mathrm{F}_2^{\mathrm{LB}(3)}$ integrated over the measured t range:

$$\frac{\mathrm{d}^3\sigma(ep \to eNX)}{\mathrm{d}x\,\mathrm{d}Q^2\,\mathrm{d}z} = \frac{4\pi\alpha^2}{x\,Q^4}\left(1 - y + \frac{y^2}{2}\right)\mathrm{F}_2^{\mathrm{LB}(3)}(x, Q^2, z),$$

We assume that the ratio between the absorption cross sections for longitudinally and transversely polarized virtual photons is equal to 0. Measurements of leading proton $\mathrm{F}_2^{\mathrm{LP}(3)}$ and of leading neutron $\mathrm{F}_2^{\mathrm{LN}(3)}$ in the range of $0.7 \leq z \leq 0.9$ are present in Figure 1.

The semi–inclusive cross section for proton production is larger than the cross section for neutron production in any specific (x, Q^2) bin. This result rules out pion exchange as the main production mechanism for leading protons since pion exchange models predict that the ratio of neutron and proton production should be equal to two.

3. Comparison to a Regge Model of Baryon Production

Figure 1 also shows a comparison between the leading baryon structure functions and a Regge model of baryon production. In the model, the contribution of a specific exchange i is determined by the product of its particle flux $f_{i/p}(z)$ integrated over the measured t range and its struc-

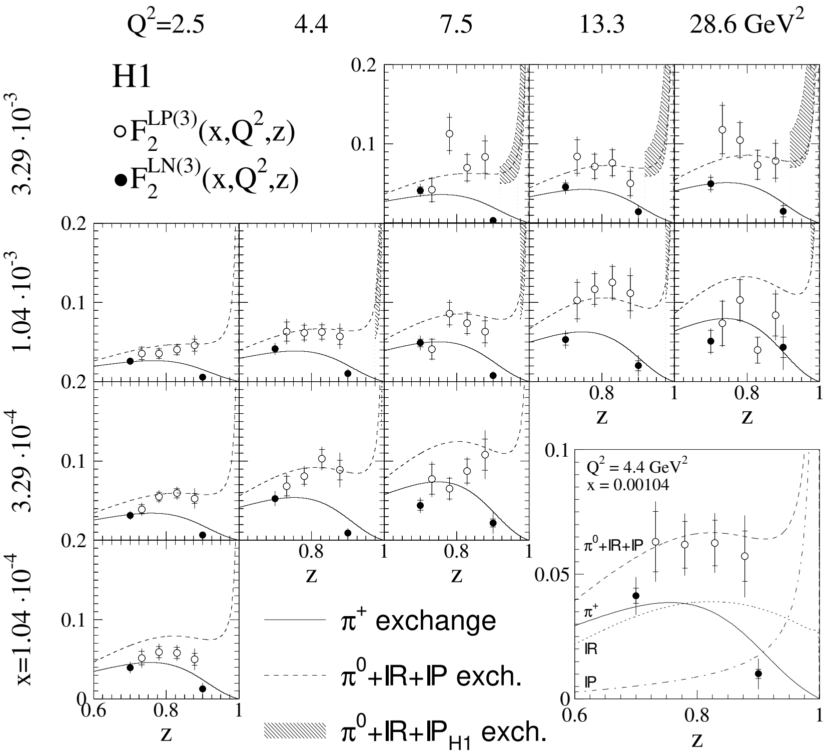

Figure 1. The measured values of $F_2^{LN(3)}$ and $F_2^{LP(3)}$ with $z \geq 0.7$ compared to a Regge model of baryon production. The different contributions are labeled for the figure in the inset.

ture function $F_2^{LB(2)}$ which depends upon β and Q^2. For leading baryon production with $p_T \leq$ 200 MeV we therefore have:

$$F_2^{LB(3)}(\beta, Q^2, z) = \sum_i f_{i/p}(z) \cdot F_2^{i}(\beta, Q^2),$$

where i denotes the pion, the pomeron and secondary reggeons.

In the Regge model, we assume that the neutral pion, the pomeron and the f_2 all contribute to leading proton production. We neglect the contributions due to the other secondary reggeons because there is no sensitivity to them in the data, and because they have been estimated to be much smaller than the contribution due to f_2 exchange [1, 2].

For leading neutrons, we assume that they are produced by charged pion exchange only. In the limited p_T range of the data, leading neutron production due to ρ, a_2 and pomeron exchanges has been estimated to be more than an order of magnitude smaller than the contribution due to pion exchange [3].

We have neglected interference terms and additional backgrounds such as proton and neutron production due to resonance decays because they have been estimated to be small in the measured kinematical range of the data.

The pion, pomeron and reggeon flux factors have been determined using hadron–hadron data [1, 3, 4] with a theoretical uncertainty of $\approx 30\%$ because of absorptive corrections [5].

The structure functions for the exchanged particles are basically unknown in the low β region and one has to rely on theoretical models. For the pion structure function F_2^{π} we took the leading order parametrization by Glück, Reya and Vogt [6]. For the reggeon and pomeron structure functions

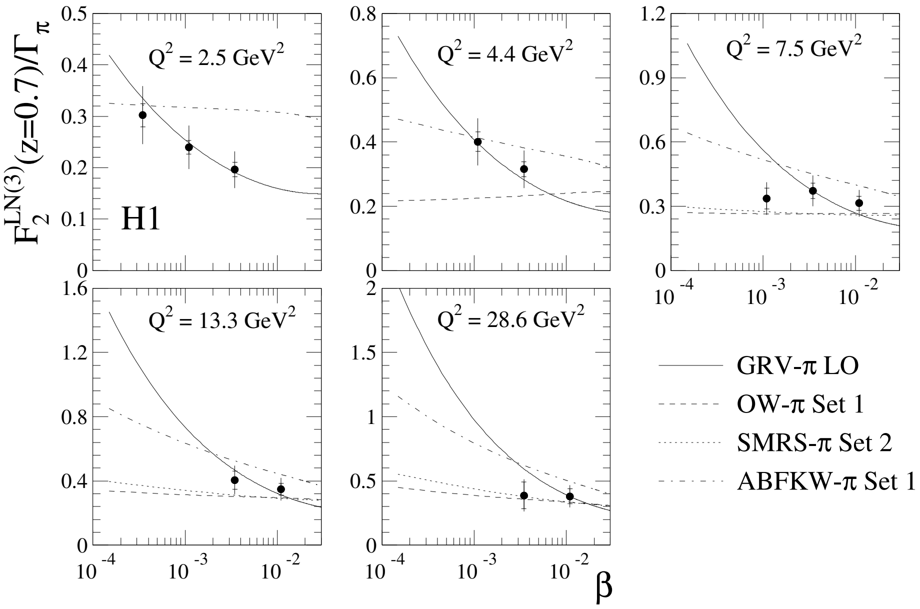

Figure 2. $F_2^{LN(3)}/\Gamma_\pi$ at $z = 0.7$ plotted as a function of β for fixed values of Q^2. The data are compared to different parametrizations of F_2^π.

we assume $F_2^{I\!R} = F_2^\pi$ and $F_2^{I\!P} = (0.026/0.12)F_2^{I\!R}$ following the arguments given in reference [4].

The model gives an acceptable description of the neutron and proton data with $0.7 \leq z \leq 0.9$. The rate of leading neutron production can be described entirely by π^+ exchange. However, proton production requires contributions from both f_2 and π^0 exchange.

4. Pion Structure Function

We use the measurement of $F_2^{LN(3)}$ and the integral of the pion flux factor Γ_π at $z = 0.7$ to estimate the pion structure function at low Bjorken–x. Assuming that the Regge model of leading neutron production is valid, the quantity $F_2^{LN(3)}/\Gamma_\pi$ can be interpreted as being equal to the structure function of the pion.

Figure 2 shows $F_2^{LN(3)}/\Gamma_\pi$ as a function of β for fixed values of Q^2. The data are compared to predictions of several parametrizations of the pion structure function [6–9]. The data are in good agreement with the expectations of the GRV leading order parametrization of the pion structure function.

Our determination using $F_2^{LN(3)}$ is the first result which constrains the pion structure function at values of $x < 0.02$.

REFERENCES

1 K. Golec–Biernat, J. Kwieciński and A. Szczurek, *Phys. Rev.* **D56** (1997) 3955.
2 Yu. M. Kazarinov et al., *Sov. Phys. JETP* **43** (1976) 598.
3 B. Kopeliovich, B. Povh and I. Potashnikova, *Z. Phys.* **C73** (1996) 125.
4 A. Szczurek, N. N. Nikolaev and J. Speth, *Phys. Lett.* **B428** (1998) 383.
5 N.N. Nikolaev, J. Speth and B.G. Zakharov, KFA–IKP–TH–97–17 (1997), hep–ph/9708290.
6 M. Glück, E. Reya and A. Vogt, *Z. Phys.* **C67** (1995) 433; *Z. Phys.* **C53** (1992) 651.
7 J.F. Owens, *Phys. Rev.* **D30** (1984) 943.
8 P. Aurenche et al., *Phys. Lett.* **B233** (1989) 517.
9 P.J. Sutton et al., *Phys. Rev.* **D45** (1992) 2349.