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UNDERSTANDING DEEP INELASTIC SCATTERING DATA

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ABSTRACT

The new experimental results on $\bar{\nu}_p$ deep inelastic scattering show that we possess a good numerical understanding of this important class of phenomena. We argue that among the different descriptions of deep inelastic scattering, the MQM clearly qualifies as the most predictive, economical and realistic approach to this fascinating area of physics.

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Great efforts have been made in the last few years to obtain very detailed information on deep inelastic lepton-nucleon scattering. As is well known, these efforts, initiated more than ten years ago by the pioneering Stanford experiments, have been greatly enhanced by the advent of intense neutrino and muon beams at the larger proton accelerators of NAL and CERN.

The latest piece of information in this fascinating field comes from a very recent experiment carried out at NAL¹⁾ in which, for the first time, one has measured the process

$$\bar{\nu} + p \rightarrow \mu^+ + \text{anything} \quad (1)$$

at large energy and momentum transfer. These new measurements give us the opportunity to try and evaluate what kind of theoretical understanding we possess today about this crucial type of subnuclear processes.

The primary motivation of this letter is thus to compare the generally accepted description of deep inelastic scattering in terms of "asymptotically free" quark-parton models^{2),3)} with the most recently available data and with a more realistic approach to deep inelastic phenomena^{4)*)} which we have already successfully compared with all previously available data⁵⁾.

Now let us briefly describe the data. Reaction (1) has been measured in the x interval ($x = Q^2/2M\nu$) $0.1 \leq x \leq 1$. No analysis of scaling violations has been made due to the limited statistics of the experiment; the mean Q^2 value turns out to be $\langle Q^2 \rangle = 4.5 \text{ GeV}^2$. The absolute normalizations of the structure functions have not been determined with good precision due to uncertainties in the knowledge of $\bar{\nu}$ flux. We have fixed them by imposing that the integral

$$\int_{0.1}^1 x u(x, Q^2) dx = .30$$

for $Q^2 = 4.5 \text{ GeV}^2$, as it follows from our parametrization. Note that in term of conventional structure functions:

$$xu(x, Q^2) = \frac{\bar{F}_2^{\bar{\nu}p}(x, Q^2) + x \bar{F}_3^{\bar{\nu}p}(x, Q^2)}{4} \quad (2)$$

*) In Ref. 5) there are some misprints. The correct value of δ_0 is $\delta_0 = 4.22 \text{ GeV}$ and not $\delta_0 = 2.11 \text{ GeV}$ [see Eq. (4.2) on page 7]. In Table II we must read θ_2/θ_{20} instead of θ_2/θ_0 , θ_1/θ_{10} instead of $\bar{\theta}/\theta_{10}$; and in the charged currents column θ_1/θ_{10} should have the values 2 and 2, instead of 4 and 4.

i) The Buras-Gaemers parametrization

In Ref. 2) Buras and Gaemers introduce for the valence, SU(3) symmetric non-charmed sea, the charmed sea and the gluon structure functions, the following parametrizations:

$$\begin{aligned} x V_i(x, \bar{s}) &= A_i(\bar{s}) x \eta_i^{(i)}(\bar{s}) (1-x)^{\eta_i^{(i)}(\bar{s})} \\ x S(x, \bar{s}) &= A_s(\bar{s}) (1-x)^{\eta_s(\bar{s})} \\ x C(x, \bar{s}) &= A_c(\bar{s}) (1-x)^{\eta_c(\bar{s})} \\ x G(x, \bar{s}) &= A_g(\bar{s}) (1-x)^{\eta_g(\bar{s})} \end{aligned}$$

where

$$\bar{s} = \frac{\log(Q^2/\Lambda^2)}{\log(Q_0^2/\Lambda^2)}.$$

First we remark that this parametrization is totally arbitrary; second, we proceed to count the number of parameters that such a parametrization involves. The complete list of parameters is given in Eq. (2.21) of Ref. 2). Neglecting the charm contribution we count 16 parameters: eight describing $\eta_{1,2}^{(i)}(\bar{s})$; three moments of order two at $Q^2 = Q_0^2$; three moments of order three at $Q^2 = Q_0^2$; Q_0^2 and Λ . These parameters are fixed with some flexibility, which is difficult to evaluate due to their large number, by fits to eN and μ N electroproduction data.

ii) Feynman-Field parametrization

Feynman and Field³⁾ consider quark distributions for $Q^2 \rightarrow \infty$ only, so they provide no description of the scaling violations. They consider $u(x)$, $d(x)$, $\bar{u}(x) \neq \bar{d}(x)$ and $s(x) = \bar{s}(x)$ distributions on which they impose a certain number of constraints. Counting the exact number of parameters in their parametrizations is somewhat difficult, however, without taking into account those parameters which enter into the interpolation procedure between $x = 0$ and $x = 1$ [which involves the use of Chebyshev polynomials, see their Table IV in Ref. 3)] we count at least eight parameters.

iii) The MQM parametrization

From Eqs (3.8) and (3.9) and Table II of Ref. 5) we may write

$$F_2^{\bar{\nu}P} = 2xF_1^{\bar{\nu}P} = \frac{10}{3} \alpha_0 x(1-x)^3 + 12 \theta_{20} \sqrt{x} (1-x)^5 + \quad (4)$$

$$+ 6 \tilde{\theta}_0 (1-x)^9 \frac{Q^2}{Q^2 + m_p^2} + \frac{32}{9} \delta_0 \frac{x^{3/2} (1-x)^{5/2}}{\sqrt{Q^2}} + 2\theta_{10} x^{1/2} (1-x)^7 + 12\lambda_0 \frac{x^{3/2} (1-x)^{13/2}}{\sqrt{Q^2}}$$

$$xF_3^{\bar{\nu}P} = \frac{10}{3} \alpha_0 x(1-x)^3 + 12 \theta_{20} x^{1/2} (1-x)^5 + \frac{32}{9} \delta_0 \frac{x^{3/2} (1-x)^{5/2}}{\sqrt{Q^2}} \quad (5)$$

$$- 2\theta_{10} x^{1/2} (1-x)^7 - 12 \lambda_0 \frac{x^{3/2} (1-x)^{13/2}}{\sqrt{Q^2}}$$

where the parameters have been determined to be

$$\alpha_0 = .85 \quad \theta_{10} = .10 \quad \theta_{20} = .41 \quad \tilde{\theta}_0 = .13 \quad (6)$$

$$\delta_0 = 4.22 \text{ GeV} \quad \lambda_0 = .01 \text{ GeV},$$

from a fit lepto-production data⁵⁾. Thus we have four parameters to describe the scaling part of the structure functions, plus two to account for scaling violations. This number is to be compared with the 16 parameters of Buras and Gaemers and the eight parameters (without scaling violations) of Feynman and Field.

Let us now compare the three previous parametrizations with the experimental results. In Fig. 1 we compare $B(x) = (xF_3^{\bar{\nu}P}(x))/(F_2^{\bar{\nu}P}(x))$ with the experimental data. This quantity, we recall, does not depend on the normalization uncertainties. The solid curve is the MQM prediction for $Q^2 = 4.5 \text{ GeV}^2$, the dashed curve is Buras-Gaemers fit at $Q^2 = 4.5 \text{ GeV}^2$, while the dotted line is the Feynman-Field prediction.

In Fig. 2 the quantity $xu(x) = 1/4 \{F_2^{\bar{\nu}P} + xF_3^{\bar{\nu}P}\}$ is plotted against the data for the three different models. For the integrals we find:

$$\int_{0.1}^1 xu(x) dx \Big|_{BG} = .26$$

$$\int_{0.1}^1 xu(x) dx \Big|_{FF} = .24$$

$$\int_{0.1}^1 xu(x) dx \Big|_{MQM} = .30$$

Experimentally, as we already pointed out, the normalization is uncertain, and it was fixed (arbitrarily) by the authors of Ref. 1) to agree with Buras-Gaemers parametrization. Finally, in Fig. 3 a comparison with $F_2^{\bar{\nu}p}$ (Fig. 3a) and $F_3^{\bar{\nu}p}$ (Fig. 3b) is presented.

As we can see, the quality of the data is not yet at a level where the three different parametrizations can be clearly distinguished. So far the agreement is quite good for all three models; but the differences are such that better data in the future will, one hopes, help us to distinguish among them.

In conclusion, the newly published data¹⁾ show that we do possess a good numerical understanding of deep inelastic scattering structure functions. But the main point we would like to make is that, besides the generally accepted models of Buras and Gaemers, and Feynman and Field, the MQM has again passed, with handsome ease, the experimental test and clearly qualifies itself as the most predictive, economical and realistic description of deep inelastic scattering.

REFERENCES

- 1) E. Fernandez et al., "x Dependence of the Proton Structure Functions from Inelastic Antineutrino-Proton Scattering" PU-79-482, ANL-HEP-PR-79-18, CMU-COO-3066-127 (1979).
- 2) A.J. Buras and K.J.F. Gaemers, Nucl. Phys. B132 (1978) 249.
- 3) R.D. Field and R.P. Feynman, Phys. Rev. D15 (1977) 2590.
- 4) G. Preparata, Phys. Rev. D7 (1973) 2973.
- 5) P. Castorina, G. Nardulli and G. Preparata, CERN preprint TH. 2670 (1979), to be published in Nucl. Phys. B.

FIGURE CAPTIONS

- Fig. 1 : The normalization independent ratio $x\bar{F}_3^{\bar{\nu}p}(x)/\bar{F}_2^{\bar{\nu}p}(x)$.
- Fig. 2 : The structure function $xu(x) = 1/4(\bar{F}_2^{\bar{\nu}p} + \bar{F}_3^{\bar{\nu}p})$, normalized according to the MQM prediction at $Q^2 = 4.5$ GeV.
- Fig. 3 : (a) $\bar{F}_2^{\bar{\nu}p}(x)$ and (b) $\bar{F}_3^{\bar{\nu}p}(x)$, normalized as in Fig. 2.

FIG.1

FIG. 2

FIG. 3