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QUARK PARTON MODEL WITH LOGARITHMIC SCALING VIOLATION AND HIGH ENERGY NEUTRINO INTERACTIONS

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Модель с логарифмически нарушенным скейлингом и нейтринные взаимодействия при высоких энергиях

В рамках предложенной ранее кварк-партонной модели с логарифмически нарушенным скейлингом рассчитаны сечения глубоконеупругих $\nu(\bar\nu)N$ -взаимодействий. Дана оценка вклада процессов рождения шармованных частиц. При вычислениях учтены кинематические массовые поправки к скейлингу и пороговые эффекты.

Проведено сравнение с экспериментальными данными. Получены оценки угла Вайнберга, а также масс c-кварка и W-бозона.

Работа выполнена в Лаборатории теоретической физики, ОИЯИ.

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Quark Parton Model with Logarithmic Scaling Violation and High Energy Neutrino Interactions

In the framework of the proposed earlier quark parton model with logarithmic scaling violation we calculate cross sections of deep inelastic $\nu(\bar\nu)N$ -interactions, evaluate the contribution of the charmed particle production. The kinematical mass corrections to scaling violations and threshold effects are taken into account.

Joint analysis of the experimental data on deep inelastic ep-, ed-scattering and charged current neutrino interaction are performed by using the unique set of free parameters of the model. Evaluations of the c-quark and W-boson masses are obtained. We analyse neutral current data as well. The analysis is performed with taken into account scaling violation effects. Considering the Weinberg angle θ_W as a fitting parameter we have fitted the relevant data.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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Introduction

Earlier [1-2] we have proposed a quark parton model with logarithmic scaling violation, which well describes the data on deep inelastic $e(\mu)p$, $e(\mu)d$ -electromagnetic scattering. In the present paper we will consider high-energy neutrino-nucleon interactions.

In recent years the neutrino physics theory and experiment have been successfully developed. As a result, an essential progress has been achieved in understanding such fundamental problems as the isotopic and Lorentz structure of weak interactions in investigating properties of new particles. In this connection a possibility arises to distinguish effects of the structure of interacting particles from effects due to the special dynamics of weak interaction, and thresholds of new particle production.

So, deep inelastic $\nu(\bar\nu)N$-interactions become a source of an important information on quark structure of hadrons. Even now the neutrino data being employed together with the data on deep inelastic electromagnetic interactions provide us with a rather strict test of models of the nucleon structure. Here we consider our model.

We have obtained predictions of the model on the case of deep inelastic $\nu(\bar\nu)N$-interactions. The kinematical mass corrections to scaling and threshold effects due to the new particle production have been taken into account. At high energies such effects become particularly important.

The paper is organized as follows:

In Sec. 1 we briefly formulate the main assumptions of the model and write the explicit form for the quark-gluon momentum distributions allowing for the charm suppression in the nucleon. The final expressions contain only two free model parameters.

In Sec. 2 we obtain the correspondence rules between quark distributions and structure functions for the interactions with the hadron V-A current of the general form. The thresholds of new-quark production and kinematical mass corrections to scaling are taken into account. In the framework of the model with the help of these rules there have been calculated cross sections of deep-inelastic $\nu(\bar{\nu})$N-interactions for both charged and neutral currents. Total cross-sections of the charmed particle production have been calculated as well. We used the Weinberg-Salam - GIM/3/ (WS-GIM) model as the basis for the weak interaction dynamics.

Sec. 3 is devoted to the analysis of the experimental data. Estimations of the C -quark, W -boson masses and the Weinberg angle θ_W have been obtained as well as the model parameters from the best fit to the data.

1. Quark-Gluon Distributions

The basis of our model/1-2/ is the analogy between the system of "equivalent" photons in quantum electrodynamics and the quark-gluon "sea" of the nucleon. We also suggest renormalizability and asymptotic freedom of the quark-gluon interaction. As it has been pointed out in/2/ our model does not contradict QCD. We hope that the model can be justified in the framework of QCD in a certain way.

With the mentioned assumptions the "bare" quark and gluon distributions can be obtained. The "bare" distribution (see /2/) is the one which does not reflect the fact that quarks and gluons are constituents of a concrete hadron.

The spectrum $f(E_\gamma)$ of "equivalent" photons has the form:

$$f(E_\gamma) \sim \alpha / E_\gamma \,, \tag{1.1}$$

where α is the constant of the electromagnetic interaction; E_γ, the energy of the equivalent photon.

By analogy with (1.1) we shall write the "bare" distributions of quarks φ and gluons ϕ of the nucleon "sea" in the form:

$$\varphi = a'(g)\cdot\frac{1/3}{\sqrt{x^2+\frac{\mu^2}{P^2}}} \,, \quad \phi = a''(g)\cdot\frac{e^{-\beta x}}{\sqrt{x^2+\frac{\mu^2}{P^2}}} \,, \tag{1.2}$$

where g is the constant of the quark-gluon interaction; $\sqrt{x^2+\mu^2/P^2}$, the energy of the quark (gluon) of mass μ, carrying the fraction x of the total nucleon longitudinal momentum P. $a'(g)$ and $a''(g)$ are some unknown functions of g. The nature and the role of the exponential Boltzmann factor in the gluon distribution were discussed in papers /1,4/. The vacuum polarization, appearing in a nucleon because of the quark-gluon interaction results in the change of bare coupling constant g to the effective one $\bar{g}(Q^2)$. In the case of a renormalizable interaction $\bar{g}(Q^2)$ depends logarithmically on Q^2. Thus:

$$\varphi = a'(\bar{g}(\ln Q^2))\frac{1/3}{\sqrt{x^2+\frac{\mu^2}{P^2}}} \,, \quad \phi = a''(\bar{g}(\ln Q^2))\frac{e^{-\beta x}}{\sqrt{x^2+\frac{\mu^2}{P^2}}} \,. \tag{1.3}$$

Here we obtain factorization of the x and Q^2 -dependence of the "bare" distributions.

The strict calculation of the functions $a'(Q^2)$ and $a''(Q^2)$ in the framework of QCD may be a subject for a subsequent paper. Here we still use the phenomenological representation for a' and a'' as in[1,2]:

$$a'(Q^2) = a''(Q^2) = a(Q^2) = a/\bar{g}(Q^2) \, . \tag{1.4}$$

In the case of QCD:

$$\bar{g}^2(Q^2)/4\pi = \frac{12\pi}{25 \ln Q^2/\Lambda^2} \, , \tag{1.5}$$

where Λ = 0.5 GeV/c (conventional value).

Applying the method, described in [4] to the formulae (1.3) we shall obtain the distribution functions of the u, d, s, c quarks, $\bar{u}, \bar{d}, \bar{s}, \bar{c}$ antiquarks and g -gluons inside a proton. Final expressions for exact SU(3)-symmetry have the form:

$$u = 2G_v + G_c \, , \; d = G_v + G_c \, , \; \bar{s} = s = \bar{u} = \bar{d} = G_c \, , \; g = 6 e^{-\beta x} G_c$$

$$G_v(x,Q^2) = x^{-1/2} \frac{(1-x)^{2a(Q^2)}}{B(\frac{1}{2}, 2a(Q^2)+1)} \cdot \frac{\Phi(a(Q^2), 2a(Q^2)+1; -\beta(1-x))}{\Phi(a(Q^2), 2a(Q^2)+3/2; -\beta)} \tag{1.6}$$

$$G_c(x,Q^2) = \frac{a(Q^2)}{6x} \cdot (1-x)^{2a(Q^2)+1/2} \cdot \frac{\Phi(a(Q^2), 2a(Q^2)+\frac{3}{2}; -\beta(1-x))}{\Phi(a(Q^2), 2a(Q^2)+3/2; -\beta)}$$

$\Phi(\alpha, \beta; z)$ is a degenerate hypergeometric function.

For the case of the broken SU(4)-symmetry of the nucleon "sea" (i.e., charm is suppressed) it looks like

$$u = 2G_v + (1-\alpha_c)G_c \, , \; d = G_v + (1-\alpha_c)G_c \, ,$$

$$\bar{u} = \bar{d} = \bar{s} = s = (1-\alpha_c)G_c \, , \; c = \bar{c} = 3\alpha_c G_c \, , \tag{1.6}$$

Here $0 \leq \alpha_c \leq \frac{1}{4}$ is a parameter of the charm suppression in a nucleon. The mechanism of the charm suppression, that we use, is defined by the change from $a'(Q^2)$ to $(1-\alpha_c)a'(Q^2)$ and from $a'(Q^2)$ to $3\alpha_c a'(Q^2)$ in the expressions for the light and for the charmed quark "bare" distributions, respectively.

It is natural to consider the α_c -parameter to depend on x and Q^2 , as there exist obvious intuitive and more strict [5] indications to the strong suppression of the charmed-quark distributions in a nucleon below threshold of charm production. We will not establish the form of $\alpha_c(x,Q^2)$ function and we shall further consider α_c parameter to be some average value of this function in the kinematical range we are interested in.

2. Calculation of Cross Sections

Cross sections of the inclusive reactions:

$$\nu(\bar{\nu}) + N \to \mu^-(\mu^+) + X \tag{a}$$

$$\nu(\bar{\nu}) + N \to \nu(\bar{\nu}) + X \tag{b}$$

are calculated in the lowest order in the weak interaction constant G. In this case the differential cross section has the form

$$\frac{d^2\sigma^\pm}{dx\,dy} = \frac{G^2 M E}{\pi} \left(\frac{M_{ex}^2}{Q^2 + M_{ex}^2} \right)^2 \left[\left(1 - y - \frac{Mxy}{E}\right) F_2^\pm + \frac{xy^2}{2} F_1^\pm \mp \left(y - \frac{y^2}{2}\right) x F_3^\pm \right] , \tag{2.1}$$

where $\mathcal{M}_{ex}=\mathcal{M}_{W^\pm};\mathcal{M}_{Z^0}$; E is energy of the neutrino beam.

In the framework of a parton model one may obtain general correspondence rules /6/ between quark distributions and structure functions $F_i^\pm$ for the interactions with the hadron V-A current of the general form:

$$J_\mu = \sum_{ij} \bar{q}_i \gamma_\mu (C_{ij}^V + C_{ij}^A \gamma_5) q_j \,, \qquad (2.2)$$

q_i is the field of the i-th quark; C_{ij}^V and C_{ij}^A, the vector and axial coupling constants. We obtain these rules taking into account kinematical mass corrections to the scaling violation and threshold effects due to the heavy quarks production. Our consideration is restricted to the conventional parton picture with Q^2 - dependent quark and gluon momentum distributions. It provides us with a natural interpretation for the final results.

Let us write the hadronic tensor $W_{\mu\nu}$ within the parton model:

$$W_{\mu\nu} = \sum_{ij} \int_0^1 \frac{dz}{z} \left(K_{\mu\nu}^{ij}(z)\cdot 2\pi\cdot \delta((p_i+q)^2-m_j^2)\varphi_i^+(z,Q^2) + \tilde{K}_{\mu\nu}^{ji}(z)\cdot 2\pi\cdot \delta((p_j+q)^2-m_i^2)\varphi_j^-(z,Q^2) \right). \qquad (2.3)$$

Here $\varphi_i^+(z,Q^2)$ and $\varphi_i^-(z,Q^2)$ correspond to the momentum distribution functions of the i-th type quarks and antiquarks. $K_{\mu\nu}^{ij}$ and $\tilde{K}_{\mu\nu}^{ij}$ are tensors of the quark transitions

$$K_{\mu\nu}^{ij} = \frac{1}{2}\cdot \sum_{\sigma_i;\sigma_j} \langle p_j\sigma_j | J_\mu(0) | p_i\sigma_i\rangle \langle p_i\sigma_i | J_\nu^+(0) | p_j\sigma_j\rangle$$
$$\tilde{K}_{\mu\nu}^{ji} = K_{\mu\nu}^{ij\,*}. \qquad (2.4)$$

Rewrite (2.3) in the following form

$$W_{\mu\nu} = \frac{\pi}{\mathcal{M}\nu}\cdot \sum_{ij} \int_{-\infty}^{\infty} \frac{dz}{z} \{ \varphi_i^+(z,Q^2)\cdot K_{\mu\nu}^{ij}(z)\,\delta(z-\xi_j) + \varphi_j^-(z,Q^2)\cdot \tilde{K}_{\mu\nu}^{ji}(z)\,\delta(z-\xi_i)\theta(z)\theta(1-z), \qquad (2.5)$$

where an averaging on the initial quark polarization and a summation on the final one have been performed. $\xi_i=\frac{Q^2+m_i^2}{2\mathcal{M}\nu}$ is the reduced ξ -scaling variable, that coincides with the conventional ξ -scaling variable /5/ to the second order in m_i^2/Q^2 .

Performing an integration in the (2.5) and comparing an equal Lorentz structures in left and right hand side, we obtain correspondence rules:

$$F_K^\pm = \sum_{ij} (F_{ji(K)}^\pm + \tilde{F}_{ij(K)}^\pm) \qquad (2.6.)$$

$$F_{ji(1)}^\pm = (C_{ij}^{V^2}+C_{ij}^{A^2})\,\varphi_j^\pm(\xi_i,Q^2)\,\theta(1-\xi_i)$$
$$\tilde{F}_{ij(1)}^\pm = (C_{ij}^{V^2}+C_{ij}^{A^2})\,\varphi_i^\mp(\xi_j,Q^2)\,\theta(1-\xi_j)$$
$$F_{ji(3)}^\pm = \mp 2\, C_{ij}^V C_{ij}^A\, \varphi_j^\pm(\xi_i,Q^2)\,\theta(1-\xi_i)$$
$$\tilde{F}_{ij(3)}^\pm = \pm 2\, C_{ij}^V C_{ij}^A\, \varphi_i^\mp(\xi_j,Q^2)\,\theta(1-\xi_j) \qquad (2.7)$$
$$F_{ji(2)}^\pm = \xi_i F_{ji(1)}^\pm\,, \qquad \tilde{F}_{ij(2)}^\pm = \xi_j \tilde{F}_{ij(1)}^\pm$$

In these expressions $\theta(1-\xi_i)$ -factors correspond to the thresholds of production of quarks with masses m_i . $F_{ij(K)}^\pm$ and $\tilde{F}_{ij(K)}^\pm$ are the partial structure functions of the quark transitions

$$
\left.\begin{array}{ll} F_{ij}^{+}: & q_i \to q_j \\ \tilde{F}_{ij}^{+}: & \bar{q}_i \to \bar{q}_j \end{array}\right\} \quad \text{for } \nu N
$$

$$
\left.\begin{array}{ll} F_{ij}^{-}: & \bar{q}_i \to \bar{q}_j \\ \tilde{F}_{ij}^{-}: & q_i \to q_j \end{array}\right\} \quad \text{for } \bar{\nu} N
$$

The summation in (2.6) is performed over such a set of quark transitions which leads to the final hadronic state of the considered reaction.

Below we display the expressions for structure functions that have been obtained with the help of the (2.6)-(2.7) in the framework of the standard 4-quark model of weak and electromagnetic interactions WS-GIM /3/ in the following three cases:

1. The charged current interactions.

The structure functions in this case are defined by the charged hadronic current:

$$
\begin{aligned}
J_\mu^{c} &= \bar{u}\gamma_\mu(1+\gamma_5)(\cos\theta_c\, d + \sin\theta_c\, s) \\
&+ \bar{c}\gamma_\mu(1+\gamma_5)(\cos\theta_c \cdot s - \sin\theta_c \cdot d)
\end{aligned}
\tag{2.8}
$$

and have the form:

$$
F_{1p}^{\pm} = F_{1p}^{\pm(1)}(x) + F_{1p}^{\pm(2)}(\xi_c)\,\theta(1-\xi_c)
$$

$$
F_{2p}^{\pm} = x\cdot F_{1p}^{\pm(1)}(x) + \xi_c\, F_{1p}^{\pm(2)}(\xi_c)\,\theta(1-\xi_c)
$$

$$
\begin{aligned}
F_{3p}^{+} &= 2(\bar{u}(x) - \cos^2\theta_c \cdot d(x) - \sin^2\theta_c \cdot s(x) + \bar{c}(x)) \\
&- 2(\cos^2\theta_c \cdot s(\xi_c) + \sin^2\theta_c \cdot d(\xi_c))\,\theta(1-\xi_c)
\end{aligned}
$$

$$
\begin{aligned}
F_{3p}^{-} &= 2(\cos^2\theta_c \cdot \bar{d}(x) + \sin^2\theta_c \cdot \bar{s}(x) - u(x) - c(x)) \\
&+ 2(\cos^2\theta_c \cdot \bar{s}(\xi_c) + \sin^2\theta_c \cdot \bar{d}(\xi_c))\,\theta(1-\xi_c)
\end{aligned}
$$

$$
\begin{aligned}
F_{1p}^{+(1)}(x) &= 2(\bar{u}(x) + \cos^2\theta_c\, d(x) + \sin^2\theta_c\, s(x) + \bar{c}(x)) \\
F_{1p}^{-(1)}(x) &= 2(u(x) + \cos^2\theta_c \cdot \bar{d}(x) + \sin^2\theta_c \cdot \bar{s}(x) + c(x)) \\
F_{1p}^{+(2)}(\xi_c) &= 2(\cos^2\theta_c \cdot s(\xi_c) + \sin^2\theta_c \cdot d(\xi_c)) \\
F_{1p}^{-(2)}(\xi_c) &= 2(\cos^2\theta_c \cdot \bar{s}(\xi_c) + \sin^2\theta_c \cdot \bar{d}(\xi_c)),
\end{aligned}
\tag{2.9}
$$

where $\xi_c = (Q^2 + m_c^2)/2M\nu$, m_c is the mass of a charmed quark (in the case of light quarks in the final state the variable ξ_i reduces to the usual x).

2. The neutral current interactions.

We derive structure functions for these processes from the neutral hadronic current

$$
J_\mu^{N} = \sum_{i=u,d,s,c} \bar{q}_i \gamma_\mu (C_i^V + C_i^A \gamma_5) q_i
$$

$$
C_u^V = C_c^V = 1/2 - \frac{4}{3}\sin^2\theta_W, \quad C_s^V = C_d^V = -\frac{1}{2} + \frac{2}{3}\sin^2\theta_W
\tag{2.10}
$$

$$
C_s^A = C_d^A = -C_c^A = -C_u^A = 1/2 .
$$

We get the expressions

$$F_1^{\pm(N)} = [(\tfrac{1}{2}-\tfrac{4}{3}\sin^2\theta_W)^2+\tfrac{1}{4}](u(x)+\bar{u}(x)$$
$$+ (c(\xi_c)+\bar{c}(\xi_c))\,\theta(1-\xi_c)) +$$
$$[(\tfrac{1}{2}-\tfrac{2}{3}\sin^2\theta_W)^2+\tfrac{1}{4}](\bar{s}(x)+s(x)+d(x)+\bar{d}(x))$$

$$F_2^{\pm(N)} = [(\tfrac{1}{2}-\tfrac{4}{3}\sin^2\theta_W)^2+\tfrac{1}{4}][(\bar{u}(x)+u(x))x$$
$$+ (c(\xi_c)+\bar{c}(\xi_c))\cdot\xi_c\cdot\theta(1-\xi_c)] +$$
$$[(\tfrac{1}{2}-\tfrac{2}{3}\sin^2\theta_W)^2+\tfrac{1}{4}](\bar{s}(x)+s(x)+d(x)+\bar{d}(x))\cdot x$$

$$F_3^{\pm(N)} = (\tfrac{1}{2}-\tfrac{4}{3}\sin^2\theta_W)(\bar{u}(x)-u(x)+(\bar{c}(\xi_c)-c(\xi_c))\theta(1-\xi_c)) \qquad (2.11)$$
$$+ (\tfrac{1}{2}-\tfrac{2}{3}\sin^2\theta_W)(\bar{s}(x)-s(x)+d(x)-\bar{d}(x)) .$$

3. The charmed-particle production in the charged current interactions.

Summing in (2.6) over the charm-changing-quark transitions only, which corresponds to the charm changing part of the charged current

$$J_\mu^c(|\Delta C|=1) = \bar{c}\,\gamma_\mu(1+\gamma_5)(\cos\theta_c\cdot s-\sin\theta_c\cdot d) \qquad (2.12)$$

we obtain structure functions for this case:

$$F^{\pm}_{1(\Delta C=\pm1)} = F^{\pm(1)} + F^{\pm(2)}; \quad F^{\pm}_{2(\Delta C=\pm1)} = \xi_c F^{\pm(1)} + x F^{\pm(2)}$$

$$F^{\pm}_{3(\Delta C=\pm1)} = \mp(F^{\pm(1)} - F^{\pm(2)})$$

$$F^{\pm(1)} = 2\{\sin^2\theta_c \begin{pmatrix} d(\xi_c) \\ \bar{d}(\xi_c) \end{pmatrix} + \cos^2\theta_c \begin{pmatrix} s(\xi_c) \\ \bar{s}(\xi_c) \end{pmatrix}\}\theta(1-\xi_c)$$

$$F^{\pm(2)} = 2\begin{pmatrix} \bar{c}(x) \\ c(x) \end{pmatrix} . \qquad (2.13)$$

Neutron structure functions can be obtained from (2.9), (2.11), (2.12) by the changes $u \leftrightarrow d$, $\bar{u} \leftrightarrow \bar{d}$. In the case of a composite target containing S neutrons by one proton the structure functions are defined as follows.

$$F^{\pm}_{iT} = (F^{\pm}_{ip} + S F^{\pm}_{in})/(S+1) .$$

Substituting in the above equations the expressions for the quark distribution functions (1.5)-(1.6), we find the cross sections $\sigma^{\pm}$, $d\sigma^{\pm}/dy$, $\sigma^{\pm}(\Delta C=\pm1)$ and the average values of kinematical variables $\langle xy\rangle^{\pm}$, $\langle y\rangle^{\pm}$.

3. <u>The Analysis of the Experimental Data</u>

There exists a considerable set of the experimental data on deep inelastic $\nu(\bar{\nu})N$ -interactions at the neutrino beam energies up to 200 GeV/7-9/. To test the predictions of our model in more detail we have carried out a joint analysis of the neutrino and

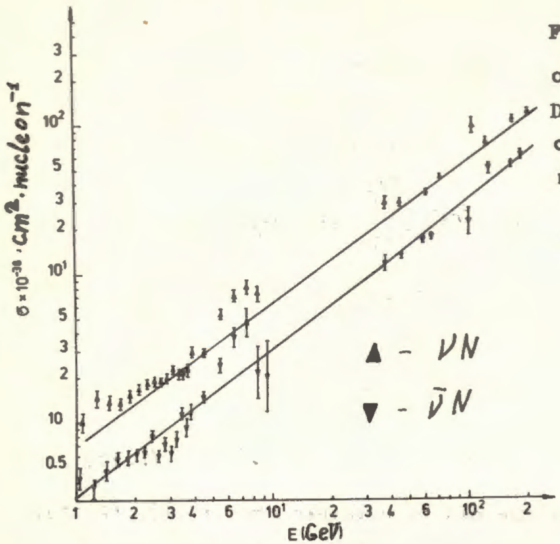

Fig. I. Total cross section of $\nu(\bar{\nu})N$ -scattering. Dots are experiments /9,10/, curves predictions of our model.

deep inelastic ep-, ed-scattering data /7-10/, using the unique set of free parameters of the model. The best agreement of theoretical curves with experimental points (see Figs. I,2) is obtained at the values of free parameters, given in Table 1.

Besides parameters of the model, Table 1 shows the estimations of the C -quark and W -boson masses, defined as values of additional parameters from the best fit to the data. The obtained estimations are in good agreement with the conventional ones. Large errors in their definition are due to the insufficient accuracy of the existing experimental results. From Table 1 one may see to what extent the finiteness of masses of C -quark and W -boson influences the goodness of the description of data.

Figure 3 shows the dependence of the charm production cross section on the neutrino beam energy in the deep inelasic inter- actions with the obtained values of free parameters. Its relative contribution to the total cross section of the reaction is ~8-10 %.

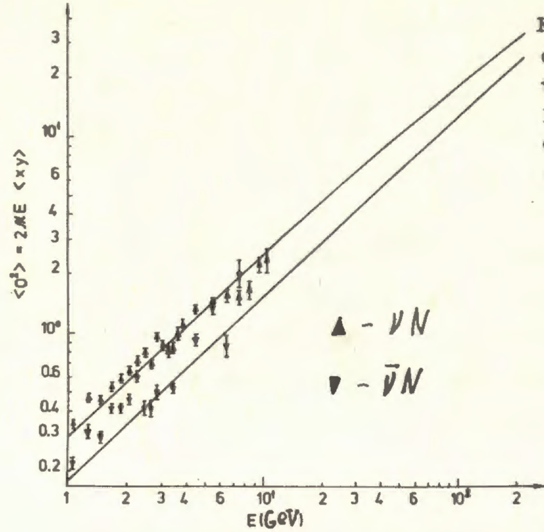

Fig. 2. Averaged value of the four momentum transfer squared. Dots are experiment /10/, curves predictions of our model.

Table 1. Values of parameters in three cases:

a) $m_c = 0$, $M_W = 0$ are fixed parameters;

b) $M_W = 0$ is a fixed parameter, m_c is the free one;

c) M_W and m_c are free parameters.

para-me-ters	a	b	c
α	5.22±0.02	5.2I±0.02	5.30±0.02
β	-2.50±0.09	-2.3I±0.09	-2.40±0.09
d_c	0.25±0.02	0.25±0.02	0.23±0.02
m_c		3.0±I.2(GeV)	3.I±I.2(GeV)
M_W			50.0±I0(GeV)
$\chi^2/\bar{\chi}^2$	330/259	290/259	285/259

The results of $\nu(\bar{\nu})N$-experiments are often represented in the form of the parametrizations

$$\sigma^{\pm} = a^{\pm} E.$$

$$\frac{d\sigma^{\pm}}{dy} = \frac{G^2 M}{\pi} E \cdot A^{\pm}\left(\frac{(1-y)^2}{2}(1 \mp B^{\pm}) + \frac{1}{2}(1 \pm B^{\pm})\right) , \qquad (3.1)$$

where $A^{\pm}$, $B^{\pm}$, $a^{\pm}$ are parameters obtained from the comparison with the experimental data. In our model because of scaling violation these parameters depend on E and y. For a clear presentation of the model predictions in the form (3.1) we shall define averaged values $A^{\pm}(E,y), B^{\pm}(E,y)$ and $a^{\pm}(E)$ in different kinematical ranges. Let us write down then the functional

$$\chi^2 [f] = \int_{E_1}^{E_2} dE \int_0^1 dy \left(f(y,E) - \bar{f}\right)^2 , \qquad (3.2)$$

where $\bar{f}$ corresponds to $\overline{a^{\pm}}$, $\overline{A^{\pm}}$, $\overline{B^{\pm}}$.

Minimizing it

$$\frac{\partial \chi^2 [f]}{\partial \bar{f}} = 0 \qquad (3.3)$$

we shall define the needed parameters by the formulae

$$\bar{f} = \left(\int_{E_1}^{E_2} dE \int_0^1 dy\, f(E,y)\right) / (E_2 - E_1) . \qquad (3.4)$$

The numerical values of $\overline{a^{\pm}}$, $\overline{A^{\pm}}$, $\overline{B^{\pm}}$ predicted by our model versus experimental ones /8/ are given in Table 2.

Now we proceed to the analysis of the neutrino neutral current interaction data. It is well known that the experimental study of this type of interactions is connected with the very complex problems which are more difficult than in the case of charged current ones.

Table 2.

E (GeV)		2-I0	20-60	60-I00	I00-I50	I50-200
σ^{ν}/E	model	0.72±0.04	0.66±0.04	0.57±0.04	0.56±0.04	0.53±0.04
	exp.	0.72±0.05	0.67±0.06	0.56±0.05	0.6I±0.05	0.5I±0.05
$\sigma^{\bar{\nu}}/E$	model	0.29±0.04	0.30±0.04	0.3I±0.04	0.32±0.04	0.33±0.04
	exp.	0.29±0.02	0.26±0.03	0.25±0.03	0.32±0.04	0.32±0.04
$\bar{A}$	model	0.49±0.03	0.46±0.03	0.44±0.03	0.43±0.03	0.42±0.03
	exp.	0.48±0.04	0.45±0.04	0.39±0.04	0.43±0.04	0.43±0.04
$\left(\overline{\int_0^1 dx \cdot x F_3}\right)$	model	0.42±0.03	0.36±0.03	0.3I±0.03	0.26±0.03	0.25±0.03
	exp.	0.4I±0.06	0.39±0.08	0.30±0.08	0.24±0.08	0.24±0.08
$\bar{B}$	model	0.86±0.04	0.85±0.05	0.76±0.05	0.56±0.05	0.50±0.05
	exp.	0.86±0.05	0.86±0.04	0.77±0.II	0.56±0.I2	0.56±0.I2

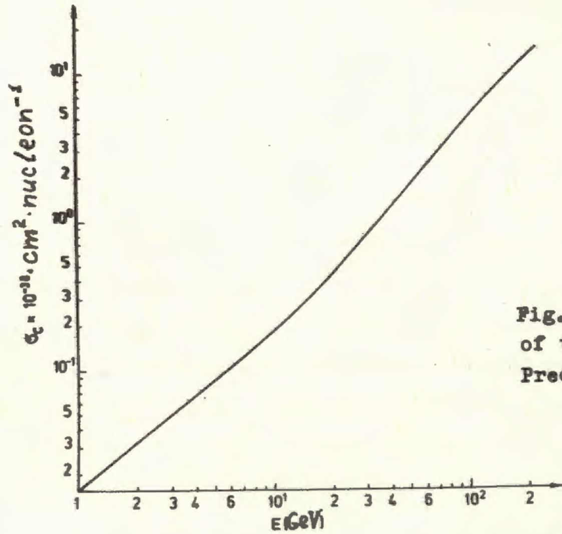

Fig. 3. Cross section of the charm production. Predictions of our model.

There are considerable experimental errors because of difficulties in the registration of neutrinos in final states, in producing of monochromatic neutrino beams, the complexity of background, and so on. However, the present data allow one to obtain real estimations of the very important parameter, Weinberg angle θ_W. For this purpose, the data are analysed usually with the help of the parametrizations for quark distribution functions with exact scaling behaviour. In our opinion, the estimation of the Weinberg angle taking into account scaling violation is a matter of topical interest. To obtain this we shall use quark distributions of our model (1.5)-(1.6). The parameters α, β are defined in Table 1. Inserting (1.5)-(1.6) into (2.11) we get quantities to be measured experimentally:

$$R^{obs} = \frac{\int dE_\nu \Phi(E_\nu) \int_{y_m}^{1} dy \, (d\sigma^{+(N)}/dy)}{\int dE_\nu \Phi(E_\nu) \int_{y_m}^{1} dy \, (d\sigma^{+(C)}/dy)} , \qquad (3.5)$$

$$\bar{R}^{obs} = \frac{\int dE_\nu \Phi(E_\nu) \int_{y_m}^{1} dy \, (d\sigma^{-(N)}/dy)}{\int dE_\nu \Phi(E_\nu) \int_{y_m}^{1} dy \, (d\sigma^{-(C)}/dy)} , \qquad (3.6)$$

where $\Phi(E_\nu)$ is the energy spectrum of the neutrino beam, $y_m = E_h^c/E_h$, $E_h \geqslant E_h^c$; E_h is the energy of final hadronic state. Considering θ_W in (2.11) as a fitting parameter from the best agreement with the experimental data /11/ we obtain the estimation $\sin^2\theta_W = 0.26 \pm 0.04$.

Conclusion

So, one may conclude that the proposed model with two free parameters makes it possible to describe successfully the existing experimental data on ep-, ed-, and $\nu(\bar\nu)N$-deep inelastic scattering.

We have discussed the effects with charm in a nucleon "sea" and in a final hadronic state. The charm suppression in a nucleon has been taken into account. In the kinematical region of the analysed data we have found it to be weak.

With the help of the quark distribution functions predicted by our model we have calculated the cross section of a charm production in the deep inelastic $\nu(\bar\nu)N$-interactions. According to the calculation it is equal to $\sim 8\div10\%$ of the total cross section.

We have analyzed the neutral current data to estimate the value of the Weinberg angle, with the scaling violation, observed in deep inelastic electromagnetic and weak charged current interactions, taken into account.

The obtained estimations of the charmed quark mass $m_c = 3.0 \pm 1.2$ GeV, W-boson mass $M_W = 50 \pm 10$ GeV, and the Weinberg angle $\sin^2\theta_W = 0.26 \pm 0.04$ are within errors in agreement with the generally accepted ones.

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