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WEAK NUCLEON FORM FACTORS AND MODIFIED VECTOR DOMINANCE

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The investigation of elastic neutrino reactions in the channels of charged and neutral currents has recently become a subject of growing interest. In contrast to the deep inelastic interactions, probing the nucleon hyperfine structure, this class of interactions provides us with an important information on the static properties of nucleons as a unique object. The most complete information on these properties can be gained by studying nucleon form factors extracted from the measurements of Q^2-dependence of the elastic scattering cross-section. A small probability of elastic neutrino events makes extremely difficult the definition of their kinematic characteristics. As a result, the data available on this problem are, in fact, limited to the measurements of two groups [1,2]. But the new data are expected from the experimental investigations of next years. They will permit the verification of many theoretical models of weak nucleon form factors (NFF). In this paper we propose a simple model based on a possible modification of the conventional vector dominance at short distances.

The dipole behaviour, often supposed though quite well justified experimentally, is theoretically groundless. The vector dominance (VD) is on a distinct statue, as VD has no good agreement with experiment but is grounded theoretically. The latter, however, should be revised. Ref. [3] presents a successful modification of VD for electromagnetic interactions. Now we discuss a possible modification of VD for weak interactions from the view point of the dynamical model of factorized quarks (DMFQ) [4]. The necessity to modify the classical VD can be explained by the quark nucleon structure. Let us assume a simple geometric picture [5] in which the nucleon r.m.s. radius $\langle R^2 \rangle$ comprises the size of the quark confinement region $\langle r_\Lambda^2 \rangle$ defined by the quark bound-state wave function and the size $\langle r_V^2 \rangle$ of the vector-meson cloud of each quark. Thus, approximately

$$\langle R^2 \rangle = \langle r_\Lambda^2 \rangle + \langle r_V^2 \rangle$$

hence it follows that

$$F = F_\Lambda F_{VD} ,$$

where F — is FFN, F_Λ and F_{VD} are the form factors corresponding to the distribution of the "charge" forming the $\langle r_\Lambda^2 \rangle$ and $\langle r_V^2 \rangle$ regions, respectively. We suppose that F_Λ is described by the DMPQ. According to the latter the incident particle $(W^\pm, Z^0, \gamma^*)$ excites in a nucleon the effective potential $V_{eff}(r)$ on which the quasi-independent scattering of the constituent quarks occurs (fig.1).

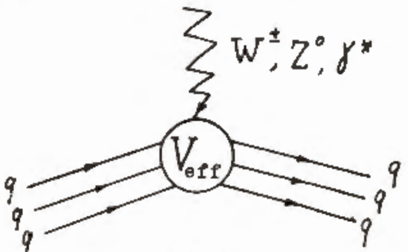

Fig.1

The V_{eff} is given in the relativistic configurational representation (RCR)[6] [1)]. Following refs.[3,4] we take $V_{eff}(r) = \delta(r)/4\pi r^2$ and obtain for the quark scattering amplitude g_i :

$$g_i(Q^2) = \frac{y_i}{\mathrm{sh}\, y_i} , \quad y_i = \mathrm{Arch}\,(1 + Q_i^2/2m^2). \quad (1)$$

[1)] The RCR is related with the momentum space by the Fourier transform that uses, instead of the nonrelativistic plane waves $\exp(i\vec{k}\vec{r})$, the relativistic Shapiro functions $\left(\frac{p_0 - \vec{p}\vec{n}}{m}\right)^{-1-imr}$[7]. The latter realise the unitary irreducible infinite-dimensional representations of the Lorentz group.

Here Q_i is the momentum transferred by one quark of mass m. (For simplicity we assume $m = \frac{M}{3}$, $Q_i^2 = \frac{Q^2}{9}$, M being the mass of a nucleon; Q, the total momentum transfer). According to[4] the FFN is proportional in the case to the product of the amplitudes of quark elastic scattering on V_{eff} . Thus $F_\Lambda(Q^2) = g_i^3(Q^2)$.

Going back to the VD part of the FFN, we restrict ourselves to the contribution of ρ -meson, lightest vector meson, into the vector FFN and of an axial A_1 -meson in the axial FFN. Then, we obtain:

$$F^{(c)}_{V,A}(Q^2) = g_i^3(Q^2)\, \frac{C_{V,A}}{1 + Q^2/m^2_{\rho, A_1}} ,$$

$$m_\rho = 770\ MeV,\ m_{A_1} = \sqrt{2}\, m_\rho . \quad (2)$$

Based on CVC and $G_p^E = G_p^M/\mu_p = G_n^M/\mu_n$ for the electromagnetic form factor, we define the form factor of a nucleon weak magnetism: $F_M^{(c)} = (\mu_p - \mu_n)\, F_V^{(c)}$. μ_p =1,79 and μ_n =-1,91 are anomalous magnetic moments of proton and neutron, respectively. The CVC fixes the vector coupling constant C_V =1. The axial constant C_A =1,23 has been obtained from the nuclear β -decay. Note an important property of quark scattering amplitude: $g_i(Q^2) \xrightarrow[Q\to 0]{} 1$, i.e., the factor $g_i^3(Q^2)$ does not change the form factor normalizations.

We have compared formula (2,3) with the experimental data[1,2]. The results of comparison are represented in fig.2. The same figure presents the results of a dipole formulae. From the point of view of confidence level it is impossible to uniquely distinguish between the two possibilities. New, more accurate experimental data are needed for this purpose. However, it is a current idea that the experimental situation does not favour the dipole formulae. This is especially conspicuous in the $0 \le Q^2 \le 0{,}5\ GeV^2$ region.

Let us consider the weak neutral current FFN $F^{(N)}_{V,M,A}$. We shall make use of results of the Weinberg-Salam model:

$$J_\mu^N = J_\mu^{(3)} - 2\sin^2\Theta_W J_\mu^{em},$$

where $\Theta_W = 0{,}24°$ is the Weinberg angle, $J_\mu^{(3)}$ and J_μ^{em} are isovector and electromagnetic currents.

Using CVC we obtain:

$$F_{V,M}^{(N)}(Q^2) = \frac{1}{2} F_{V,M}^{(c)}(Q^2) - 2\sin^2\Theta_W F_{1,2}^{em}(Q^2),$$

$$F_A^{(N)}(Q^2) = \frac{1}{2} F_A^{(c)}(Q^2). \qquad (3)$$

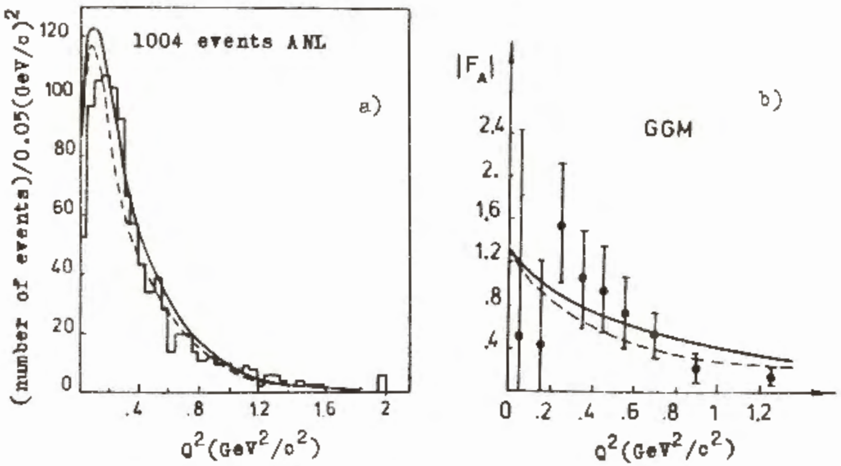

Fig. 2. Experimental data:
a) ANL[2] b) GGM-PS[1]. The solid line is the modified VD predictions, the dashed line is the dipole formula predictions:

$$F_V^{(c)}(Q^2) = \left(1+\frac{Q^2}{m_V^2}\right)^{-2}, \quad F_A^{(c)}(Q^2) = \frac{1{,}23}{\left(1+\frac{Q^2}{m_A^2}\right)^2},$$

$$m_V = 0{,}84\ GeV, \quad m_A = 0{,}98\ GeV.$$

Here $F_{1,2}^{em}(Q^2)$ are electromagnetic form factors of the nucleon.

Knowing $F_{V,M}^{(c)}$ and $F_{1,2}^{em}$ we obtain the predictions of a modified VD for the neutral current form factors.

There are no systematic data on the $\nu N \to \nu N$ at present. Thus, formulae (3) are of a predictive character.

In conclusion we would like to note that at the interpretation of $g_i(Q^2)$ as a quark form factor of the r.m.s. $\langle r_i^2 \rangle \simeq m_i^{-2}$ it is possible to extend the above assumed geometrical picture[5], taking $\langle r_A^2 \rangle = 3\langle r_i^2 \rangle$. Then formula (2) will follow the ratio: $\langle R^2 \rangle = 3\langle r_i^2 \rangle + \langle r_V^2 \rangle$.

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References

1. Rollier M. (Gargamelle Collab.) In: Proc. Paris Colloquium "La Physique du Neutrino Haute Energie", CNRS, Paris, 1 975, p. 349.
2. Derrick M. et al. ANL-HEP-CP-78-31; Barish S. et al. Phys.Rev., 1977, D16, p.3103.
3. Скачков Н.Б., Соловцов И.Л. Письма в ЖЭТФ, 1977, 25, с.334. Биленькая С.И., Скачков Н.Б., Соловцов И.Л. ЯФ, 1977, 26, с.1051.
4. Пашков А.Ф., Скачков Н.Б., Соловцов И.Л. Письма в ЖЭФ, 1977, 25, с.452; ОИЯИ Р2-12003, Дубна, 1979.
5. Скачков Н.Б. ТМФ, 1975, 23, с.313; Sehgal L.M. PITHA 79/22, Aachen, 1979.
6. Kadyshevsky V.G., Mir-Kasimov R.M., Skachkov N.B. Nuovo Cim. 1968, 55A, p. 233.
7. Шапиро И.С. ДАН СССР, 1956, 106, с.647.

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