объединенный
институт
ядерных
исследований
дубна

E2-88-915

G.V.Efimov, M.A.Ivanov, V.E.Lyubovitsky*

QUARK-DIQUARK APPROXIMATION OF THE THREE-QUARK STRUCTURE OF A NUCLEON AND THE NN PHASE SHIFTS

Submitted to "Nuclear Physics A"

*Tomsk State University, USSR

1988

I. Introduction

The three-quark structure of baryons seems to be the most available in the unitary classification of hadrons [1,2]. However, the three-body problem is very difficult and can be solved only under some simplifications (for example, in the nonrelativistic quark models with the simplest potential [3,4] and bags [5,6]).

In the original work [1] on the quark model of mesons and baryons Gell-Mann discussed the possibility of existence of free diquarks. Later, the quark-diquark model of baryons was suggested by Ida and Kobayashi [7] and by Lichtenberg and coworkers [8]. In that model, one of the constituent particles of a baryon can be regarded as a quark and the other as a tightly bound state of two quarks, a diquark. The quark is taken to belong to a six-dimensional representation of SU(6) while the diquark to a twenty one-dimensional representation. The members of the baryon octet and decaplet belong to the 56-dimensional representation as usual.

The supersymmetric generalization of the quark-diquark model has been performed in [9,10]. It founded on a suggestion that the chromomagnetic fields between the quarks and diquarks were the same in the excited mesons and baryons.

The diquarks were considered to be the bound constituents of exotic mesons [11] and other more complicated formations of an hadronic matter [12,13].

The use of the quark-diquark model should considerably reduce the mathematical difficulties by converting a three-body problem into a two-body one.

In [12]. the nonrelativistic calculation of P- and D- state baryons has been done in a dynamical quark-diquark model. The magnetic moments and axial form factors of baryons have been obtained in a nonrelativistic approximation by taking into account the quark colour [14]. Masses of ground-state spin - 3/2 baryons were calculated in a relativistic quark-diquark model [15,16] with a potential motivated by the QCD. The parameters of the model were determined by fitting vector-meson masses. The results were in a rather good agreement with experiment.

Diquarks in the deep inelastic structure functions have been used in [17,18].

Thus, the quark-diquark model is quite a suitable approximation of the three-quark structure of baryons. Despite this fact, little has been done in the line of actual quantitative calculations of baryon characteristics in a dynamical quark-diquark model. Mainly, all calculations were directed for getting the static characteristics of baryons: masses, magnetic moments, etc.

More sophisticated chatacteristics of baryons are the electromagnetic form factors and phases of NN-scattering which are defined by their inner structure. One should know the hadronization mechanism and the quark behaviour at large distances for the description of these values.

We have developed [19,20] the quark confinement model (QCM) based on a definite representation about the hadronization and quark confinement. First, hadrons are treated as collective colourless excitations of quark-gluon interactions. Second, the quark confinement is realized as averaging over the vacuum gluon fields for the quark diagrams. Strong, weak and electromagnetic hadron interactions can be described in the QCM from a unique point of view. The preliminary calculations[19-26] of the meson and baryon processes have shown that the model reproduces the quark structure of hadrons quite correctly. The hadron inner structure in the QCM is defined by the quark behaviour at large distances.

We have considered [25,26] a nucleon and Δ -isobar to be composed of three quarks and calculated the electromagnetic and strong meson-baryon form factors. The results were in agreement with experiment and other approaches.

At the same time, the consideration of baryons as three-quark systems encounters some difficulties caused by the nature of two-loop diagrams defining the baryon form factors. These diagrams are the convolution of the entire functions [19,25,26] which leads to the growth of physical matrix elements at high energies. The special assumptions [25,26] were used to avoid this problem. It was remarked that the S-matrix can be constructed without the above-mentioned difficulties when there are only three lines at the vertex of the interaction Lagrangian (for example, meson + quark + antiquark). Therefore, the hypothesis arised to describe a nucleon as quark-diquark system. In this case we have only three lines of the vertex of the interaction Lagrangian (nucleon + quakr + diquark).

In this work we will consider two possibilities of the quark-diquark approximation of the three-quark structure of a nucleon. First, a nucleon will be considered as a three-quark system and a diquark will approximate the interaction of the quark pair at the

level of quark diagrams describing the nucleon form factors. Second, from the begining we will consider a nucleon to be composed of a quark and diquark described by the standard quantum field. In all the cases the diquarks are supposed to be the hard core which does not interact with mesonic fields.

In the framework of these representations we calculate the magnetic moments, the electromagnetic radii and the ratio G_A/G_V. The behaviour of the electromagnetic nucleon form factors in the low-energy region ($0 \leq Q^2 = -q^2 \leq 1\ GeV^2$, where q is transfer momentum) is given. There is a qualitative agreement of our results with experiment for both the variants of quark-diquark approximations. The strong meson-nucleon form factors are calculated and the one-boson exchange potential is constructed. The behaviour of the phases of NN-scattering is obtained by solving the Lippman-Schwinger equation with this potential. Our results obtained in the first variant of the quark-diquark approximation are in a rather good agreement with the experimental data and OBE-model with the Bonn potential [27,28].

Thus, the quark-diquark approximation of the three-quark structure of a nucleon, in which a diquark is considered to be the hard core, correctly reproduces the nucleon inner structure in the low energy and allows one to describe the behaviour of the electromagnetic form factors and NN-phase-shifts.

The paper is organized in the following way. In Sec.2 the basic assumptions of the QCM are given and the interaction Lagrangians of the mesons and nucleons with quarks defining the hadron structure are written.

In Sec.2 we give the quark diquark approximations of the three-quark structure of nucleon. In Sec.3 the choice of the model parameters is discussed. In Sec.4 the results of the calculations of the static nucleon characteristics and electromagnetic form factors are compared with the experimental data and predictions of another approaches.

In Sec.5 the calculated strong meson-nucleon form factors are used to construct the one-boson exchange potential. The NN-phase-shifts are obtained up to $E_{Lab} \leq 300$ MeV by solving the Lippman - Schwinger equations with our potential and compared with experiment and phenomenological approaches.

2. The Quark Structure of Hadrons in QCM

In the QCM the hadron interactions result from the quark exchange. Therefore, the interaction Lagrangians are basic objects for the dynamical description of the low-energy processes. They should be ultimately obtained from QCD. However, due to the mathematical problems raised by the nonperturbative character of QCD in the low-energy region we are still far from answering this question. So we will construct the interaction Lagrangians under the following requirements. The Lagrangians should be invariant under the C,P,T and SU_3 transformations. They will be chosen in the simplest form without the derivatives.

The Lagrangian describing the interactions of hadrons with quarks can be written in the form /19,20/

$$\mathcal{L}_H(x) = H(x) \sum_A g_H^A \, J_H^A(x) \,, \tag{2.1}$$

where $J_H^A(x)$ is the quark current with the quantum numbers of a hadron H.

Let us adduce the Lagrangians $\mathcal{L}_H$ for the mesons as two-quark /19–24/ systems and the nucleons as three-quark ones /25,26/. For simplicity, we restrict ourselves to the SU_2 -symmetry.

1. Mesons:

$$\mathcal{L}_M = \frac{g_M}{\sqrt{2}} \bar{q} \Gamma_M \hat{M} q \tag{2.2}$$

$$\hat{P} = \vec{\pi}\cdot\vec{\tau} + (\eta' \cos\delta_P - \eta \sin\delta_P)\cdot I \,; \quad \Gamma_P = i\gamma^5 \,;$$

$$\hat{V} = \vec{\rho}\cdot\vec{\tau} + \omega\cdot I \,; \quad \Gamma_V = \gamma^\mu \,;$$

$$\hat{S} = \vec{a}_0\cdot\vec{\tau} + (\varepsilon\cdot\cos\delta_S - f_0\cdot\sin\delta_S)\cdot I \,; \quad \Gamma_S = I - iH_S \hat{\overleftrightarrow{\partial}}/\Lambda_q \,.$$

Here $\delta = \theta - \theta_I$, θ is the octet-singlet mixing angle. We choose $\theta_P = -11^\circ$ ($\delta_P = -46^\circ$) . The choice of parameters characterizing the scalar mesons (δ_S , H_S and m_ε) will be discussed in detail in Sec.3.

2. Nucleons:

$$\mathcal{L}_N = g_N^A \bar{N}_j \, J_j^A + h.c. \tag{2.3}$$

$$J_j^A = R^A_{j j_1 j_2 j_3} \, q^{a_1}_{j_1} q^{a_2}_{j_2} q^{a_3}_{j_3} \cdot \varepsilon^{a_1 a_2 a_3}$$

Here, $j = (\alpha, m)$; α and m are the spinor and isospin indices, respectively. The nucleonic current (2.3) must be symmetric with respect to the permutation of the quark fields. There are two independent matrices R^A (A = V or T) satisfying this requirement /25,26/.

$$R^T_{\{j\}} = 6 g^{\alpha\alpha_1} \delta^{mm_1} \tau_2^{m_2 m_3} (C\gamma^5)^{\alpha_2\alpha_3} + 6(\gamma^5)^{\alpha\alpha_1} \delta^{mm_1} \tau_2^{m_2 m_3} C^{\alpha_2\alpha_3} + (\sigma^{\mu\nu}\gamma^5)^{\alpha\alpha_1} (\vec{\tau})^{mm_1} (\tau_2\vec{\tau})^{m_2 m_3} (C\sigma^{\mu\nu})^{\alpha_2\alpha_3} \,;$$

$$R^V_{\{j\}} = 2 g^{\alpha\alpha_1} \delta^{mm_1} \tau_2^{m_2 m_3} (C\gamma^5)^{\alpha\alpha_3} - 2(\gamma^5)^{\alpha\alpha_1} \delta^{mm_1} \tau_2^{m_2 m_3} C^{\alpha_2\alpha_3} - (\gamma^\mu)^{\alpha\alpha_1} \delta^{mm_1} \tau_2^{m_2 m_3} (C\gamma^\mu\gamma^5)^{\alpha_2\alpha_3} + (\gamma^\mu\gamma^5)^{\alpha\alpha_1} (\vec{\tau})^{mm_1} (\tau_2\vec{\tau})^{m_2 m_3} (C\gamma^\mu)^{\alpha_2\alpha_3} .$$

In terms of the isotopic fields (u- and d -quarks) the nucleonic three-quark currents (2.3) corresponding to a proton and a neutron can be written as

$$J_p^A = Q^A(u, d)$$

$$J_n^A = Q^A(d, u) .$$

where

$$Q^T(u,d) = -6i\sigma^{\mu\nu}\gamma^5 d^{a_1} (u^{a_2} C\sigma^{\mu\nu} u^{a_3}) \varepsilon^{a_1 a_2 a_3}$$

$$Q^V(u,d) = -6i\gamma^\mu\gamma^5 d^{a_1} (u^{a_2} C\gamma^\mu u^{a_3}) \varepsilon^{a_1 a_2 a_3} .$$

These currents were used in the QCD sum rule calculations /30/. Hadron interactions in the QCM are defined by the S-matrix

$$S = \int d\sigma_{vac} \, T \exp\left(i \int dx \, \mathcal{L}_H(x)\right) . \tag{2.4}$$

The time-ordered product in (2.4) is the Wick standard T-product for the hadron and quark fields. The quark propagator has the following form

$$S(x_1, x_2 | B_{vac}) = \langle 0 | T\left(q(x_1)\bar{q}(x_2)\right) | 0 \rangle = \tag{2.5}$$

$$= -\left(\hat{P} + \hat{B}_{vac}\right)^{-1} \delta(x_1 - x_2) .$$

Here, $B_{vac}(x, \sigma_{vac})$ is the vacuum background field which is characterized by the set $\{\sigma_{vac}\}$.

It is suggested that the averaging over vacuum background fields $d\sigma_{vac}$ of the quark diagrams generated by the S-matrix (2.4) have to provide the quark confinement and to lead to ultraviolet finite theory.

The confinement ansatz in the case of one-loop quark diagrams describing the meson-meson interaction consists in the following [19,20]:

$$\int d\sigma_{vac}\, tr\left[M(x_1)S(x_1,x_2|B_{vac})\dots M(x_n)S(x_n,x_1|B_{vac})\right]\to \tag{2.6}$$
$$\to\int d\sigma_v\, tr\left[M(x_1)S_v(x_1-x_2)\dots M(x_n)S_v(x_n-x_1)\right].$$

Here
$$S_v(x_1-x_2)=\int\frac{d^4p}{(2\pi)^4 i}\, e^{-ip(x_1-x_2)}\frac{1}{v\Lambda_q-\hat{p}}.$$

The parameter Λ_q characterizes the confinement range. The measure $d\sigma_v$ is defined as

$$\int d\sigma_v\cdot\frac{1}{v-z}=G(z)=a(-z^2)+z\,b(-z^2). \tag{2.7}$$

The function $G(z)$ called the confinement function is an entire analytical function which decreases faster than any degree of z in an Euclidean direction $z^2\to-\infty$. In the papers [19-24], the following shapes of $a(u)$ and $b(u)$ have been used to describe the effects of the low-energy meson physics:

$$a(u)=2\exp(-u^2-u)$$
$$b(u)=2\exp(-u^2+0.4u). \tag{2.8}$$

The numerical value of the basic parameter

$$\Lambda_q = 460\ \mathrm{MeV} \tag{2.9}$$

is obtained by fitting the main meson decays [19-24].

The structure integral corresponding to the two-loop quark diagram in Fig.1 is written as [25,26]

$$\Lambda^{(3q)}_{MNN}(p,p')=\int\frac{d^4k}{\pi^2 i}\int d\sigma_v\,\Gamma_1 S_v(\hat{k}-\hat{q})\Gamma_M S_v(\hat{k})\Gamma_2\,\Pi^{\Gamma_1\Gamma_2}(p-k), \tag{2.10}$$

where
$$\Pi^{\Gamma_1\Gamma_2}(p-k)=\int\frac{d^4k'}{4\pi^2 i}\, tr\left[\Gamma_1' G(\hat{k}'+\hat{p}-\hat{k})\Gamma_2' G(\hat{k}')\right].$$

Expression (2.10) is to be a convolution of the entire functions that lead to the growth of the matrix element in the physical region of momenta. In the papers [25,26] the special assumptions about the calculation $\Lambda^{(3q)}_{MNN}(p,p')$ have been done to obtain the reasonable results for the nucleon properties.

The hadronization condition used in the QCM [19,20] denotes that the renormalization constant of the wave hadron function is equal to zero

$$Z_H=1+\sum_{AA'} g^A_H g^{A'}_H\left(\tilde{\Pi}^{AA'}_H(m_H)\right)'=0. \tag{2.11}$$

Here, $(\tilde{\Pi}_H)'$ is the derivative of the hadron mass operator defined by the diagrams, Fig.2a, for mesons and, Fig.2b, for nucleons.

The compositeness condition (2.11) allows one to define uniquely the coupling constants of the pseudoscalar (π,η,η') and vector (ρ,ω) mesons with quarks in (2.1) as functions of the hadron masses and model parameters in (2.8) and (2.9). There are a few possibilities of describing an interaction of the scalar mesons and nucleons with quarks (see, (2.2) and (2.3)), so that the compositeness condition (2.11) allows one to establish the relation only between the coupling constants g^A_H.

The calculations of the physical matrix elements in the QCM [19,20] are based on the use of the $1/N_c$-expansion. The first approximation completely corresponds to the tree diagrams of the chiral theory. However, the difference is that the hadron-hadron vertices are the structureless points in the chiral theory, which corresponds to the local hadron interactions, while in the QCM they are described by the quark loops defining the hadron structure (form factors, slope parameters, phase shifts, etc.).

3. Quark-Diquark Approximation of the Three-Quark Structure of a Nucleon

As has been mentioned above, in this paper we will consider the two possibilities of the quark-diquark approximation of the three-quark structure of a nucleon. In the first case, from the beginning we consider a nucleon to be composed of a quark and a diquark and use the quark-diquark currents with a nucleon quantum numbers in the Lagrangian (2.1) instead of the three-quark ones. Diquarks are supposed to be the local quantum fields with the standard propagators. In the second case, a nucleon is considered to be the three-quark systems and a diquark is introduced at the level of the quark diagrams as an approximation of the quark pair. The shape of a diquark propagator is chosen by using the Ward identities for the electromagnetic nucleon vertex.

Let us consider the first possibility. The Lagrangian describing an interaction of a nucleon with quark-diquark currents can be written as

$$\mathcal{L}_N^{(qD)} = \sum_{A=1}^{8} g^A_{ND}\, \bar{N}_j\, J_{jD}^A + h.c. \tag{3.1}$$

There are eight quark-diquark currents with quantum numbers corresponding to a nucleon shown in Table I.

Table I

N	Diquarks	$I^G(J^{PC})$	Quark-diquark currents (J_D^A)
1.	S_0	$0^+\ (0^{++})$	$q^a\, S^a$
2.	P_0	$0^+\ (0^{-+})$	$\gamma^5 q^a\, P^a$
3.	V_0	$0^-\ (1^{--})$	$\gamma^\mu\, q^a\, V^a_\mu$
4.	A_0	$0^+\ (1^{++})$	$\gamma^\mu \gamma^5\, q^a\, A^a_\mu$
5.	S_1	$1^-\ (0^{++})$	$\vec{\tau}\, q^a\, \vec{S}^a$
6.	P_1	$1^-\ (0^{-+})$	$\vec{\tau}\gamma^5 q^a\, \vec{P}^a$
7.	V_1	$1^+\ (1^{--})$	$\vec{\tau}\gamma^\mu q^a\, \vec{V}^a_\mu$
8.	A_1	$1^-\ (1^{++})$	$\vec{\tau}\gamma^\mu\gamma^5 q^a\, \vec{A}^a_\mu$

The electromagnetic and weak interactions of the diquarks are introduced as usual in the minimal manner.

The assumption about a quark-diquark approximation of a nucleon formulated in (2.1) leads to the following expression for the meson-nucleon vertex (see Fig.1b):

$$\Lambda^{(qD)}_{MNN}(p,p') = \int \frac{d^4k}{\pi^2 i} \int d\sigma_v\, \Gamma_1\, S_v(\hat{k}-\hat{q})\,\Gamma_M\, S_v(\hat{k})\,\Gamma_2\, D_v^{\Gamma_1\Gamma_2}(p-k). \tag{3.2}$$

Here, $D_v^{\Gamma_1\Gamma_2}(p-k)$ is considered to be a propagator of a diquark in the vacuum background fields. Averaging over the background fields is taken into account by integration over the measure $d\sigma_v$ so that

$$D_v^{\Gamma_1\Gamma_2}(k) = \frac{d^{\Gamma_1\Gamma_2}}{v^2\Lambda_q^2 + \Lambda_d^2 - k^2}. \tag{3.3}$$

The divisors $d^{\Gamma_1\Gamma_2}$ are chosen in accordance with the quantization of the local diquark fields (see, Table I) and the condition of positivity for the proton magnetic moment and the weak axial form factor. It turned out that

$$d^{\Gamma_1\Gamma_2} = \begin{cases} \pm I & \begin{bmatrix} S \\ P \end{bmatrix} - \text{diquarks} \\ \pm g^{\mu\nu} & \begin{bmatrix} V \\ A \end{bmatrix} - \text{diquarks} \end{cases} \tag{3.4}$$

i.e. the P- and V-diquark fields are quantized by means of the indefinite metrics. The additional diagrams, including the electromagnetic and weak interactions, are presented on Fig. 3.

The additional parameter Λ_d characterizes the diquark confinement region.

Let us discuss this scheme of the quark-diquark approximation. As follows from (3.1), there are eight independent quark-diquark currents with the quantum numbers of a nucleon. The compositeness condition (2.11) allows one to cut down the number of parameters up to seven. Therefore, at the first stage we shall consider each quark-diquark currents separately. The final choice of the quark-diquark current will be discussed in detail in Sec.4.

The minimal principle taken for the electroweak interaction of the diquarks leads to, in particular, breaking of the interaction universality of the vector mesons because they can interact only with quarks composing a nucleon. The quark composition of a diquark should be taken into account to restore the vector meson universality. At this stage we shall consider a diquark to be a hard core that does not interact with the mesonic fields.

Another possibility of the quark-diquark approximation of a nucleon three-quark structure comes from the symmetry of the three-quark currents in (2.3) with respect to the permutation of the quark fields. The subdiagrms corresponding to the independent quark loops

$$\Pi^{\Gamma_1\Gamma_2}(p-k) = \int \frac{d^4k'}{4\pi^2 i}\cdot tr\left[\Gamma_1'\, G(\hat{k}'+\hat{p}-\hat{k})\,\Gamma_2'\, G(\hat{k}')\right] \tag{3.5}$$

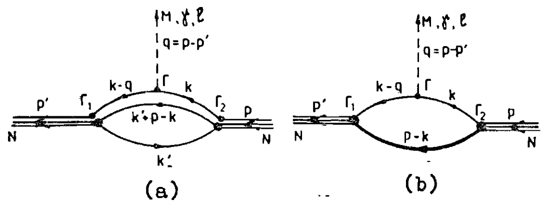


Fig.1

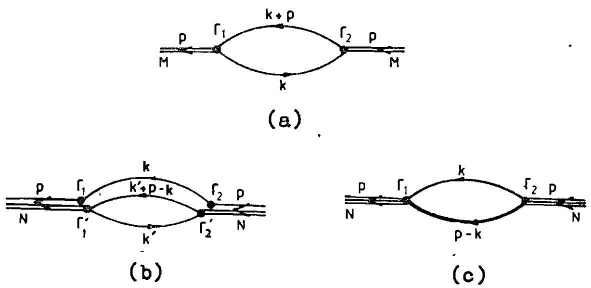


Fig.2

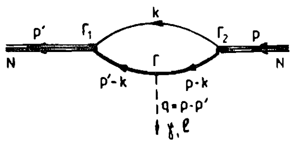


Fig.3

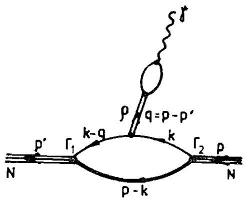


Fig.4

are given off the diagrams, Fig.1a and Fig.2b. The Ward identity for the nucleon electromagnetic vertex and the compositeness condition (2.11) give us the following identity for the nucleon mass operator:

$$g_{NT}^2\, F_{TT}(p) + g_{NV} g_{NT} F_{VT}(p) + g_{NV}^2 F_{VV}(p) \equiv 0 \qquad (3.6)$$

for any momentum p . This means that the following conditions should be performed simultaneously:

$$F_{TT}(p) = \int \frac{d^4k}{\pi^2 i} \cdot \Big\{ 36\, G(\hat{k})\, \Pi^{PP}(p-k) + 36\, \gamma^5 G(\hat{k}) \gamma^5\, \Pi^{SS}(p-k) - 3\, \sigma^{\mu\nu} \gamma^5 G(\hat{k}) \sigma^{\alpha\beta} \gamma^5\, \Pi^{TT}_{\mu\nu,\alpha\beta}(p-k) \Big\} \equiv 0 ,$$

$$\begin{aligned} F_{VT}(p) = \int \frac{d^4k}{\pi^2 i} \cdot \Big\{ & 24\, G(\hat{k})\, \Pi^{PP}(p-k) - 24\, \gamma^5 G(\hat{k}) \gamma^5\, \Pi^{SS}(p-k) + \\ & + 6\, G(\hat{k}) \gamma^\mu\, \Pi^{PA}_{\mu}(p-k) - 6\, \gamma^\mu G(\hat{k})\, \Pi^{AP}_{\mu}(p-k) + \\ & + 3\, \sigma^{\alpha\beta} \gamma^5 G(\hat{k}) \gamma^\mu \gamma^5\, \Pi^{TV}_{\alpha\beta,\mu}(p-k) - 3\, \gamma^\mu \gamma^5 G(\hat{k}) \sigma^{\alpha\beta} \gamma^5\, \Pi^{VT}_{\mu,\alpha\beta}(p-k) \Big\} \equiv 0, \end{aligned} \qquad (3.7)$$

$$\begin{aligned} F_{VV}(p) = \int \frac{d^4k}{\pi^2 i} \cdot \Big\{ & 4\, G(\hat{k})\, \Pi^{PP}(p-k) + 4\, \gamma^5 G(\hat{k}) \gamma^5\, \Pi^{SS}(p-k) - \\ & - \gamma^\mu G(\hat{k}) \gamma^\nu\, \Pi^{AA}_{\mu\nu}(p-k) + 2\, G(\hat{k}) \gamma^\mu\, \Pi^{PA}_{\mu}(p-k) - \\ & - 2\, \gamma^\mu G(\hat{k})\, \Pi^{AP}_{\mu}(p-k) + 3\, \gamma^\mu \gamma^5 G(\hat{k}) \gamma^\nu \gamma^5\, \Pi^{VV}_{\mu\nu}(p-k) \Big\} \equiv 0 . \end{aligned}$$

Our main assumption consists in that the diagrams, Fig.1a and 2b, should be changed by the one-loop quark-diquark diagrams, Fig.1b and 2c, respectively, according to the rule

$$\begin{aligned} & \int \frac{d^4k}{\pi^2 i} \int d\sigma_\nu\, \Gamma_1 S_\nu(\hat{k}) \Gamma_2\, \Pi^{\Gamma_1\Gamma_2}(p-k) \longmapsto \\ & \longmapsto \int \frac{d^4k}{\pi^2 i} \int d\sigma_\nu\, \Gamma_1 S_\nu(\hat{k}) \Gamma_2\, D^{\Gamma_1\Gamma_2}_{\nu}(p-k) \end{aligned} \qquad (3.8)$$

$$\int\frac{d^4k}{\pi^2 i}\int d\sigma_\nu \Gamma_1 S_\nu(\hat{k}-\hat{q})\Gamma_M S_\nu(\hat{k})\Gamma_2 \Pi^{\Gamma_1\Gamma_2}(p-k) \longmapsto$$

$$\longmapsto \int\frac{d^4k}{\pi^2 i}\int d\sigma_\nu \; \Gamma_1 S_\nu(\hat{k}-\hat{q})\Gamma_M S_\nu(\hat{k})\Gamma_2 D_\nu^{\Gamma_1\Gamma_2}(p-k), \qquad (3.9)$$

where

$$D_\nu^{\Gamma_1\Gamma_2}(p)=\frac{d^{\Gamma_1\Gamma_2}}{\nu^2\Lambda_q^2+\Lambda_d^2-p^2}.$$

The divisors $d^{\Gamma_1\Gamma_2}$ are defined by the identities (3.7)-(3.9). It turned out that there are no solutions for the arbitrary g_{NT} and g_{NV} because the identity $F_{VT}(p)=0$ cannot be satisfied by any choice of the values $d^{\Gamma_1\Gamma_2}$. In the particular cases, when either $g_{NT}\neq 0$ and $g_{NV}=0$ or $g_{NT}=0$ and $g_{NV}\neq 0$ the divisors $d^{\Gamma_1\Gamma_2}$ are determined uniquely

$$d^{\Gamma_1\Gamma_2}=\begin{cases} 1, & \Gamma_1=\Gamma_2=S,P \\ g_{\mu\nu}/3, & \Gamma_1=\Gamma_2=V \\ g_{\mu\nu}, & \Gamma_1=\Gamma_2=A \\ 2g_{\mu\lambda}g_{\nu\rho}, & \Gamma_1=\Gamma_2=T \\ 0, & \Gamma_1\neq\Gamma_2 \end{cases} \qquad (3.10)$$

In other words, this quark-diquark approximation of the three-quark structure of a nucleon can be performed independently for each three-quark current. Further, we shall call these two possibilities the T- and V-variant, respectively. Diquarks are supposed to be a hard core not interacting with the external sources (meson, photon and lepton).

It should be remarked that the strong, electromagnetic and weak form factors of a nucleon are described by the only diagram, Fig.1b, in this quark-diquark approximation. Thus, the vector meson universality is valid.

4. Choice of the Model Parameters

In this Section we shall discuss the choice of the model parameters. All model parameters can be divided into two groups. First, the confinement functions in (2.7) and the parameters Λ_q and Λ_d characterizing the confinement region of a quark and a diquark, respectively. Second, the parameters characterizing the ambiguity of choosing the hadron quark current.

The confinement functions $a(u)$ and $b(u)$ and the parameter Λ_q are chosen to be the same as in the meson physics (see (2.8) and (2.9)). The parameter Λ_d characterizing the confinement region of a diquark is defined by fitting the experimental data for the static nucleon properties: the magnetic moments, the ratio G_A/G_V and the strong coupling $G_{\pi NN}(0)$.

Ambiguity of choosing the hadron-quark current takes place for scalar mesons and nucleons.

Scalar mesons have been discussed in detail in /21-23/. It turned out that the simplest choice of the scalar vertex $\Gamma_S=I$ did not allow one to describe the decay $f_0\to\pi\pi$. This problem was avoided by introducing a more complex scalar vertex $\Gamma_S=I-iH_S\overleftrightarrow{\partial}/\Lambda_q$, where H_S and the ε-meson mass m_ε were supposed to be free parameters. The ε-meson mass was determined from the condition of the best agreement of the $\pi\pi$-scattering S-wave lengths with the experiment. It was found that

$$H_S=0.55,\quad \delta_S=17^\circ,\quad m_\varepsilon=600\ \text{MeV}.$$

This set of parameters provided a quite good description of numerous low-energy effects of the meson physics.

The scalar mesons play an essential role for the description of NN-scattering in the one-boson exchange (OBE) model /28/. The light ε-meson (m_ε = 500-700 MeV) has a special place under this consideration. The resonant diagram with the intermediate ε-meson is considered to be the only effective approximation of the 0^{++}- contribution. From this point of view the nature of the scalar mesons can be different for the $\pi\pi$- and NN- scattering. Therefore, we take the ε-meson mass from the meson physics /23/ but suppose the parameters H_S and δ_S to be free. Their values were determined from the condition of the best description of the NN-phase-shifts. It turned out that the NN-phase-shifts could be described quite correctly only in the T-variant of the quark-diquark approximation. The parameters were found to be equal to $H_S=0.27$ and $\delta_S=56.3^\circ$. These numerical values for H_S and δ_S considerably differ from the correspondent ones obtained in the meson physics /23/.

There is a great ambiguity under the choice of the quark- di-quark currents (see Table I). Therefore, we shall act in the following manner. At the first stage, we consider each current separately. It turns out that the current $q^a S^a$ allows one to describe the experimental data with a satisfactory accuracy. But, the parameter $\Lambda_d \simeq 2$ GeV has an unphysical large value. Then, we consider the mixture of this current with others (see, Table I). It appears that the combination $q^a S^a + \gamma^5 q^a P^a$ gives a qualitative description of the experiment. We shall call this choice the $S+P-$ variant.

Finally, we obtain the following values for the model parameters:

1. T-variant: Λ_d = 680 MeV
2. V-variant: Λ_d = 419 MeV
3. S+P-variant: Λ_d = 877 MeV, $Z = g^1_{ND}/g^2_{ND} = 1$.

5. The Static Characteristics and Electromagnetic Form Factors of a Nucleon

The electromagnetic nucleon form factors are defined by the vertex diagrams of Fig.1b, 3,4. The vertex function can be written in the standard form on the mass shell

$$\Lambda^{\mu}_{em}(p,p') = e\left[\gamma^{\mu} F^1_N(q^2) - \frac{i}{2m_N}\sigma^{\mu\nu} q_\nu F^2_N(q^2)\right], \qquad (5.1)$$

where $q = p - p'$ is the photon momentum; $\sigma^{\mu\nu} = \frac{i}{2}\cdot[\gamma^\mu, \gamma^\nu]$.

The compositeness condition (2.11) $Z_N = 0$ and the Ward identity give the following relations $F^1_p(0) = 1$ and $F^1_n(0) = 0$. The magnetic moments are equal to $\mu_p = 1 + F^2_p(0)$, $\mu_n = F^2_n(0)$.

The electromagnetic form factors

$$G^E_N(Q^2) = F^1_N(Q^2) - Q^2/4m^2_N \cdot F^2_N(Q^2),$$
$$G^M_N(Q^2) = F^1_N(Q^2) + F^2_N(Q^2), \quad Q^2 = -q^2 \qquad (5.2)$$

characterize the matter distribution inside a nucleon. The electromagnetic radii are defined in a standard manner

$$\langle r^2_p\rangle^E = -6(G^E_p(0))'/G^E_p(0); \; \langle r^2_n\rangle^M = -6(G^E_n(0))'; \; \langle r^2_N\rangle^M = -6(G^M_N(0))'/G^M_N(0).$$

The calculations of a vertex diagram are performed in Appendix.

At present, G^E_N, G^M_N are measured in a broad range of momenta $Q^2 = -q^2$; $0 \leq Q^2 \leq 30$ GeV^2. The experimental data are described quite accurately by the empirical dipole formula

$$G^E_p(Q^2) \simeq \frac{G^M_p(Q^2)}{\mu_p} \simeq \frac{G^M_n(Q^2)}{\mu_n} \simeq \frac{4m^2_N}{Q^2}\cdot\frac{G^E_n(Q^2)}{\mu_n} \simeq D(Q^2),$$

where

$$D(Q^2) = 1/[1 + Q^2/0.71\,\text{GeV}^2]^2. \qquad (5.3)$$

The weak neutron β -decay $n \to pe\bar\nu$ is defined by the diagrams in Fig.1b and 3. The matrix element is written as

$$M(n \to pe\bar\nu) = \frac{G_F}{\sqrt{2}} l_\mu \bar{p}\left[\gamma^\mu G_V(q^2) - \gamma^\mu\gamma^5 G_A(q^2) - q^\mu G_T(q^2)\right] n, \qquad (5.4)$$

where l_μ is the leptonic current.

The obtained results are shown in Table 2. One can see, there is a qualitative agreement with the experimental data and other approaches.

Table 2. Static nucleon characteristics

Observable value	Experiment	QCM			Other approaches
		T-var.	V-var.	S+P-var.	
μ_p	2.793/29/	3.72	3.50	3.46	3/35/, 2.73/36/ 2.82/37/, 2/14/
μ_n	-1.913/29/	-2.48	-1.81	-1.73	-2/35/, -1.975/36/ -2.06/37/, -1/14/
$\langle r^2_p\rangle^E$, fm^2	0.846±0.055/32/	0.52	0.49	0.45	0.656/38/, 0.674/14/, 0.624/36/
$\langle r^2_p\rangle^M$, fm^2	0.711/33/	0.36	0.35	0.43	0.656/38/
$\langle r^2_n\rangle^E$, fm^2	-0.117±0.002/34/	-0.17	-0.10	-0.24	0/38/, -0.13/36/ -0.121/14/
$\langle r^2_n\rangle^M$, fm^2	0.762/33/	0.36	0.30	0.35	0.656/38/
G_A/G_V	1.254±0.006/29/	5/3	1.91	1	5/3/35/, 1.182/36/ 1.199/14/, 1.540/39/ 1.170/39/, 1.08/5/

Our results for the electromagnetic radii are lower than the experimental ones. This disagreement is caused by using the full renormalized ρ-meson propagator /19/ in the resonant diagram, Fig.4, instead of the free one. One has to remark that the use of the free ρ-meson propagator provides a quite good agreement with experiment.

Let us discuss our results for the values μ_p/μ_n and G_A/G_V. We have

$$\mu_p = \begin{cases} \Phi_0/\Phi_1 & T\text{-variant} \\ 2/3 \cdot \Phi_0/\Phi_1 & S{+}P\text{-variant} \end{cases} \tag{5.5}$$

$$\mu_n = \begin{cases} -2/3 \cdot \Phi_0/\Phi_1 & T\text{-variant} \\ -1/3 \cdot \Phi_0/\Phi_1 & S{+}P\text{-variant} \end{cases} \tag{5.6}$$

$$G_A = \begin{cases} 5/3 \cdot G_V & T\text{-variant} \\ G_V & S{+}P\text{-variant}. \end{cases} \tag{5.7}$$

Here $\Phi_n = \int_0^1 d\alpha \cdot \alpha^n \cdot (1-\alpha) \cdot a\left[\alpha\Lambda_d^2/\Lambda_q^2 - \alpha(1-\alpha)m_N^2/\Lambda_q^2\right]$.

Taking into account (4.5)-(4.7), one can obtain

$$\mu_p/\mu_n = \begin{cases} -3/2 & T\text{-variant} \\ -2 & S{+}P\text{-variant} \end{cases} \tag{5.8}$$

$$G_A/G_V = \begin{cases} 5/3 & T\text{-variant} \\ 1 & S{+}P\text{-variant}. \end{cases} \tag{5.9}$$

The results for μ_p/μ_n and G_A/G_V obtained in the T-variant and S+P-variant coincide with the predictions of the nonrelativistic models /35/ and quark-diquark model /14/, respectively.

The electromagnetic form factors obtained in our approach are shown in Fig.5 up to $Q^2 \leq 1$ GeV^2. One can see, there is only a qualitative agreement with the dipole formula (5.3).

6. The Meson-Nucleon Form Factors and NN-Phase-Shifts

In this section we calculate the meson-nucleon form factors which play a fundamental role in the NN-interaction. All experimental NN-scattering data below 300 MeV are described quite accurately by the one- and two-meson exchange model /27,28/. This model treats exchanged mesons as point particles with the standard local propagators. The nucleon internal structure is described by the vertex form factors parametrized as

$$\frac{G^2_{MNN}(q^2)}{4\pi} = \frac{G^2_{MNN}(m_M^2)}{4\pi} \cdot \left[\frac{\Lambda_M^2 - m_M^2}{\Lambda_M^2 - q^2}\right]^2. \tag{6.1}$$

Here m_M and q are the mass and momentum of the meson; Λ_M is the cut-off mass (Λ_M = 1.2-1.5 GeV). The vertex form factors are introduced phenomenologically and are chosen from the best description of the experimental data.

The meson-nucleon form factors in the QCM are defined by the nucleon inner structure which is believed to be described by the quark-diquark approximation of the three-quark structure.

The meson-nucleon vertex is described by the diagram, Fig.1b, and is written on the nucleon mass shell as follows:

1. Pseudoscalar mesons $P(\pi, \eta, \eta')$

$$\Lambda_P(q^2) = T_P \cdot G_{PNN}(q^2) \cdot i\gamma^5 \tag{6.2}$$

$$T_\pi = \vec{\tau}, \quad T_\eta = T_{\eta'} = I$$

2. Scalar mesons $S(a_0, \varepsilon)$

$$\Lambda_S(q^2) = T_S \cdot G_{SNN}(q^2) \tag{6.3}$$

$$T_{a_0} = \vec{\tau}, \quad T_\varepsilon = I$$

3. Vectors mesons $V(\rho, \omega)$

$$\Lambda_V(q^2) = T_V \cdot \left[\gamma^\mu \cdot G_{VNN}(q^2) - \frac{i}{2m_N} \sigma^{\mu\nu} q_\nu F_{VNN}(q^2)\right]$$

$$T_\rho = \vec{\tau}, \quad T_\omega = I. \tag{6.4}$$

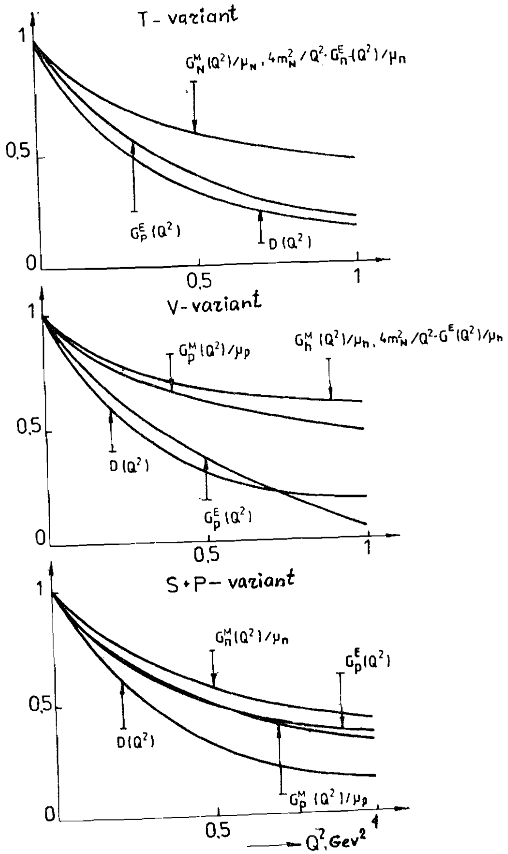


Fig.5

The functions $G_{MNN}(q^2)$ are calculated by analogy with those calculated in Appendix.

The numerical values of $G^2_{MNN}(0)/4\pi$ and $F_{VNN}(0)/G_{VNN}(0)$ are given in Table 3. For comparison, it also shows the results obtained in the Bonn potential[27,28] model and other phenomenological approaches[40-41].

Only the pion-nucleon constant has been used to fit the model parameter, in particular Λ_d. The numerical values of the η, η' and a_0, ε meson – nucleon constants somewhat differ from the phenomenological ones[27,28,42].

Let us consider the calculation of the vector-nucleon constants which are very important for the description of the NN-scattering[28] in the Bonn potential model[28]. It has been established in that the following empirical relations between these constants have to take place for reproducing the experimental data

$$F_{\rho NN}(0)/G_{\rho NN}(0) > 5,$$
$$F_{\omega NN}(0)/G_{\omega NN}(0) \approx 0. \qquad (6.5)$$

Table 3. Numerical values for $G^2_{MNN}(0)/4\pi$

Vertex	$G^2_{MNN}(0)/4\pi$			
	QCM			Other approaches
	T-var.	V-var.	S+P-var.	
πNN	12.44	16.68	13.15	14.08[28]; 14.25[40] 14.28 ± 0.018[41]
ηNN	8.63	0.94	11.74	3.67[42]; 4.27[42]
$\eta' NN$	8.05	0.88	10.95	3.77[42]; 4.23[42]
$a_0 NN$	0.85	0.24	6.91	1.62[28]; 0.82[28]
εNN	3.60	1.02	4.36	4.56[28]; 6.00[27]
ρNN	0.42 (F/G=5.20)	0.42 (F/G=4.31)	0.42 (F/G=4.17)	0.41 (F/G=6.1)[28] 0.55±0.06 (F/G=6.1±0.6)[43]
ωNN	3.78 (F/G=0.24)	3.78 (F/G=0.69)	0.42 (F/G=4.17)	10.6 (F/G=0)[28] 5.7±2.8 (F/G=0)[44]

It the QCM, the vector-nucleon constants are equal to

$$G_{\rho NN}(0) = g_v/\sqrt{2} \qquad \text{T-, V-, S+P-variant} \qquad (6.6)$$
$$F_{\rho NN}(0) = g_v/\sqrt{2}\cdot(\mu_p - \mu_n - 1)$$

$$G_{\omega NN}(0) = \begin{cases} 3g_v/\sqrt{2} & \text{T-, V-variant} \\ g_v/\sqrt{2} & \text{S+P-variant} \end{cases} \qquad (6.7)$$

$$F_{\omega NN}(0) = \begin{cases} 3g_v/\sqrt{2}\cdot(\mu_p + \mu_n - 1) & \text{T-, V-variant} \\ g_v/\sqrt{2} & \text{S+P-variant.} \end{cases} \qquad (6.8)$$

Here, g_v is the coupling of the vector mesons with quarks[19-24]. The numerical values of the magnetic moments μ_p and μ_n obtained in the QCM are shown in Table 2. Making use of (6.6)-(6.8), we have

$$F_{\rho NN}(0)/G_{\rho NN}(0)=\begin{cases}5.20 & \text{T-variant}\\ 4.31 & \text{V-variant}\\ 4.17 & \text{S+P-variant}\end{cases} \qquad (6.9)$$

$$F_{\omega NN}(0)/G_{\omega NN}(0)=\begin{cases}0.24 & \text{T-variant}\\ 0.69 & \text{V-variant}\\ 4.17 & \text{S+P-variant}.\end{cases} \qquad (6.10)$$

One can see, only the T-variant of the quark-diquark approximation satisfies the relations (6.5). Further, we shall fix our attention only to this variant.

The behaviour of the strong meson-nucleon form factors normalized to unity is shown in Fig.6 up to 1 GeV^2. For comparison, it also shows the phenomenological results obtained in /28/.

The NN phase-shifts are calculated by making use of the algorithm suggested in /28/. The one-boson exchange potential is constructed in the following way:

$$V(\vec{q},\vec{q}')=\sum_{M=\pi,\eta,a_0,\varepsilon,\rho,\omega}\frac{G^2_{MNN}[(\vec{q}-\vec{q}')^2]/4\pi}{m_M^2+(\vec{q}-\vec{q}')^2} \qquad (6.11)$$

with the meson-nucleon form factors $G^2_{MNN}(\vec{q}^{\,2})$ calculated above. The NN-phase-shifts are determined by solving the Lippmann-Schwinger equation with the potential (6.11). Our results are shown in Fig.7. One can see, there is agreement with the experiment /40,45/ and Bonn potential model /28/.

Thus, the quark-diquark approximation of the three-quark structure of a nucleon, in which a diquark is considered to be a hard core, correctly reproduces the nucleon inner structure in the low-energy and allows one to describe the most nucleon properties.

Further, this picture of a nucleon structure can be effectively used for a unified description of the fundamental processes of the nuclear physics: $\pi\pi\to\pi\pi$, $\pi N\to\pi N$ and $NN\to NN$. Furthermore, it seems to be interesting to calculate the nonleptonic baryon decays in this approach.

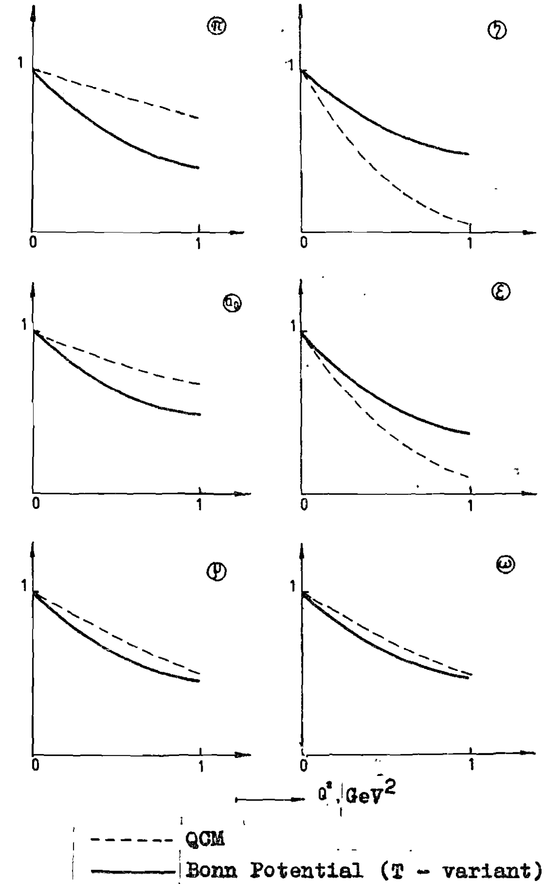


Fig.6.
Nucleon strong form factors obtained in the T-variant.

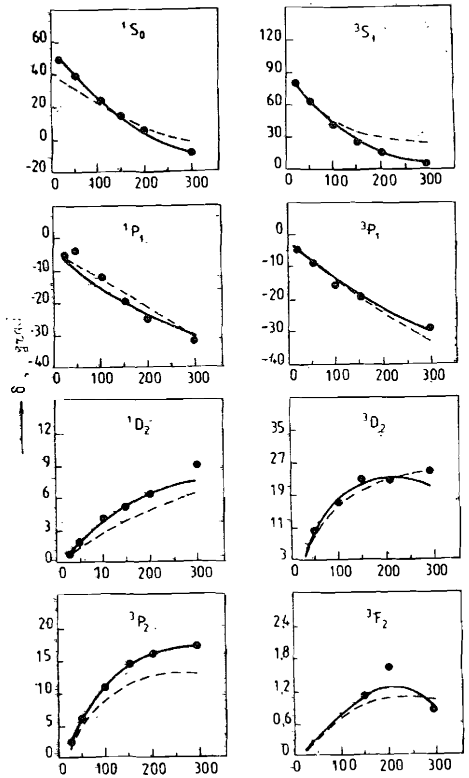
Acknowledgement

The authors would like to thank Chelidze A.D., Machavariani A.I. and Rusetski A.G. for many interesting discussions.

Appendix

The structure integral corresponding to the meson-nucleon vertex (see, Fig.2) in the quark-diquark approximation is written as

$$\Lambda_{MNN}(p,p')=d^{\Gamma_1\Gamma_2}\,\Gamma_1\,T_{\Gamma_M}\left(\frac{p}{\Lambda_q},\frac{p'}{\Lambda_q}\right)\Gamma_2\,,$$



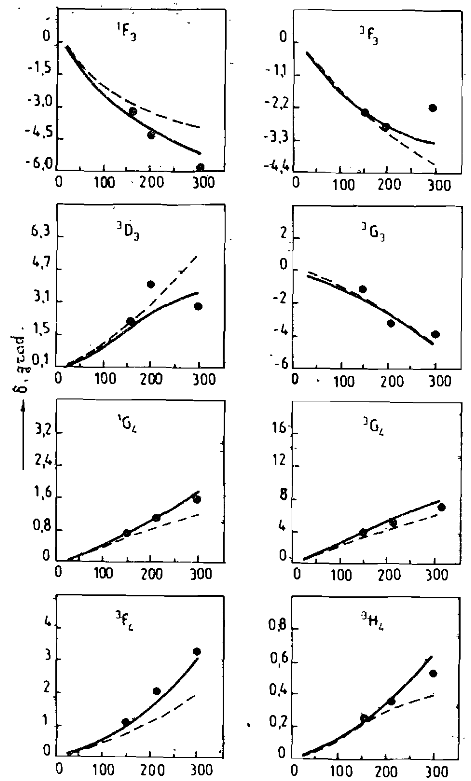
→ E_{lab}, MeV

------ QCM
——— Bonn Potential (T - variant)
●●●●● Experiment

Fig.7 (a). NN-phase-shifts obtained in the T-variant.

$$T_{\Gamma_M}(p,p')=\int\frac{d^4k}{\pi^2 i}\int d\sigma_v\,\frac{1}{v-\hat{k}+\hat{q}}\,\Gamma_M\,\frac{1}{v-\hat{k}}\cdot\frac{1}{v^2+\tau^2-(p-k)^2} \qquad (A.1)$$

$$\tau=\Lambda_d/\Lambda_q$$



→ E_{lab}, MeV

------ QCM
——— Bonn Potential (T - variant)
●●●● Experiment

Fig.7 (b)

Making use of the Feynman α -parameterization, one can obtain

$$T_{\Gamma_M}(p,p')=\int d\mu_\alpha\int_0^\infty du\cdot u\cdot\int d\sigma_v\,\frac{F(\alpha,u,p,p')}{[v^2+u+\Delta(\alpha)]^3}\,; \qquad (A.2)$$

$$d\mu_\alpha=2\,d^3\alpha\cdot\delta(1-\alpha_1-\alpha_2-\alpha_3)$$

where

$$F(\alpha,u,p,p')=\Gamma_M\cdot v^2-\frac{1}{4}\gamma^\alpha\Gamma_M\gamma^\alpha u+v(\hat{\tau}_1\Gamma_M+\Gamma_M\hat{\tau}_2)+\hat{\tau}_1\Gamma_M\hat{\tau}_2\,;$$

$$\hat{\tau}_1=\hat{p}'(1-\alpha_2)-\hat{p}\alpha_3\,;$$

$$\hat{\tau}_2=\hat{p}(1-\alpha_3)-\hat{p}'\alpha_2\,;$$

$$\Delta(\alpha)=\alpha_1\tau^2-\alpha_1\alpha_2 p'^2-\alpha_1\alpha_3 p^2-\alpha_2\alpha_3 q^2.$$

Recalling the definition of the confinement function (2.7), we have

$$\int_0^\infty du\cdot u\int d\sigma_v\,\frac{v^2}{[v^2+u+\Delta(\alpha)]^3}=-\frac{\Delta(\alpha)}{2}\cdot\ell[\Delta(\alpha)]\,,$$

$$\int_0^\infty du\cdot u^2 \int d\sigma_v \frac{1}{[v^2+u+\Delta(\alpha)]^3} = \int_0^\infty du\cdot b[u+\Delta(\alpha)],$$

$$\int_0^\infty du\cdot u \int d\sigma_v \frac{1}{[v^2+u+\Delta(\alpha)]^3} = \frac{1}{2}\cdot b[\Delta(\alpha)], \qquad \text{(A.3)}$$

$$\int_0^\infty du\cdot u \int d\sigma_v \frac{v}{[v^2+u+\Delta(\alpha)]^3} = \frac{1}{2}\cdot a[\Delta(\alpha)].$$

The final result is written as

$$\begin{aligned} T_{\Gamma_M}(p,p') = -\Big\{ \int_0^\infty du\cdot b(u) - \int d\mu_\alpha \int_0^{\Delta(\alpha)} du\cdot b(u)\Big\}\cdot\frac{1}{4}\cdot\gamma^\alpha\Gamma_M\gamma^\alpha \\ +\frac{1}{2}\int d\mu_\alpha\cdot b[\Delta(\alpha)]\cdot[-\Delta(\alpha)\cdot\Gamma_M+\hat{z}_1\Gamma_M\hat{z}_2]+ \\ +\frac{1}{2}\int d\mu_\alpha\cdot a[\Delta(\alpha)]\cdot[\hat{z}_1\Gamma_M+\Gamma_M\hat{z}_2]. \end{aligned} \qquad \text{(A.4)}$$

The other integrals corresponding to any quark-diquark diagrams can be calculated in an analogous way.

References

1. Gell-Mann M.: Phys.Lett., 8, 214 (1964).
2. Zweig G.: CERN Preprint NH-401, Geneva, 1964.
3. Isgur N., Karl G.: Phys.Rev.D, 20, 1191 (1979).
4. Eichten E. et al.: Phys.Rev.D, 21, 203 (1980).
5. De Grand T. et al.: Phys.Rev.D, 12, 2060 (1975).
6. Bogolubov P.N., Dorokhov A.E.: Particles and Nuclei, 18, 917 (1987).
7. Ida M., Kobayashi R.: Prog.Theor.Phys., 36, 846 (1966).
8. Lichtenberg D.B.: Phys.Rev., 178, 2197 (1969).
9. Catto S., Gursey F.: Preprint Yalle University YTP 87-36, 1987.
10. Catto S., Gursey F.: Nuovo Cimento A, 86, 201 (1985).
11. Hedry A.W., Hinchliffe I.: Phys.Rev.D, 18, 3453 (1978).
12. Goldstein G.R., Maharana J.: Nuovo Cimento A, 59, 393 (1980).
13. Koca M., Baha Balatekin A.: Nuovo Cimento A, 52, 500 (1979).
14. Golowich E., Hagg E.: Phys.Rev.D, 24, 2495 (1981).
15. Lichtenberg D.B. et al.: Phys.Rev.Lett., 48, 1653 (1982).
16. Lichtenberg D.B. et al.: Z.Phys.C. 17, 57 (1983).
17. Close F.E., Roberts R.G.: Z.Phys.C, 8, 57 (1981).
18. Fredriksson S., Jandel M., Larsson T.: Z.Phys.C, 14, 35 (1982).
19. Efimov G.V., Ivanov M.A.: Preprint JINR, E2-88-37, Dubna, 1988.
20. Efimov G.V., Ivanov M.A.: Proceedings of the Conference Hadron Structure' 87, Smolenice, Czechoslovakia, 14, 201, 1987.
21. Avakyan E.Z. et al.: Yad.Fiz., 46, 576 (1987).
22. Avakyan E.Z. et al.: Preprint JINR, E2-87-630, Dubna, 1987.
23. Avakyan E.Z. et al.: Preprint JINR, E2-88-519, Dubna, 1988.
24. Efimov G.V., Ivanov M.A., Mashnik S.G.: Preprint JINR, P2-88-253, Dubna, 1988.
25. Efimov G.V., Ivanov M.A., Lyubovitsky V.E.: Yad.Fiz., 44, 460 (1986).
26. Efimov G.V., Ivanov M.A., Lyubovitsky V.E.: Preprint JINR, P2-87-776, Dubna, 1987.
27. Brown G.E., Jackson A.D.: The Nucleon-Nucleon Interaction (North-Holland Publishing Company, 1976).
28. Machleidt R., Holinde K., Elster Ch.: Phys.Rep., 149, 1 (1987).
29. Particle Properties Data: Phys.Lett.B, 170, 1 (1986).
30. Ioffe B.L. :Z.Phys.C, 18, 67 (1983).
31. De Alfaro V., Fubini S., Furlan G., Rosseti C.: Currents in Hadron Physics. (North-Holland Publishing Company, 1973).
32. Borkowski F. et al: Nucl.Phys.A, 222, 269 (1974).
33. Hohler G. et al.: Nucl.Phys.V, 114, 505 (1976).
34. Dziembowski Z. et al.: Z.Phys.C, 10, 231 (1981).
35. Greenberg O.W.: Ann.Rev.Nucl.Part.Sci. 28, 327 (1978).
36. Barik N., Dash B.K.: Phys.Rev.D, 34, 2092 (1986).
37. Musakhanov M.M.: Yad.Fiz. 34, 1123 (1981).
38. Halzen F., Martin A.D. Quarks and Leptons: An Introductory Course in Modern Physics (John Wiley and Sons, Singapore, 1984).

39. Dyakonov D., Petrov V.: Preprint 1162, LNPI, Leningrad, 1986.
40. Dubois R. et al.: Nucl. Phys.A, 377, 554 (1982).
41. Koch R., Pietarinen E.: Nucl.Phys. A, 336, 331 (1980).
42. Dumbrajs O. et al.: Nucl.Phys.B, 216, 277 (1983).
43. Hohler G., Pietarinen E.: Nucl.Phys.B, 95, 210 (1975).
44. Hamilton J., Oades G.C.: Nucl.Phys.A, 424, 447 (1984).
45. Arndt R.A. et al.: Phys.Rev.D, 28, 97 (1983).

Received by Publishing Department
on December 29, 1988.