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POLARIZABILITY OF π-MESONS IN THE QUARK CONFINEMENT MODEL

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I. Introduction

The study of electromagnetic mesonic interactions allows one to obtain further information about the inner structure of hadrons. Electromagnetic properties of pions at low energies are characterised by the finite number of parameters which are determined from the expansion of the pion-photon amplitudes over the γ-quanta frequencies. In particular, the two-photon hadronic interactions are characterised by the coefficients of electric α_π and magnetic β_π polarizabilities[1]. The experimental data on the electric polarizability of a charged π-meson are available [2]:

$$\alpha_\pi = 6.8 \pm 1.4 \pm 1.8 \cdot 10^{-43} \ \mathrm{cm}^3$$

while those on the neutral one are to be measured in future[3].

Theoretical values of α_π and β_π are extracted from the amplitude of $\pi\gamma \to \pi\gamma$. The knowledge of the nature of strong interactions is needed for calculation of the amplitude of this process. However, the theory of strong interactions is not yet available, so one has to recourse to different low-energy approximations and models[1,4-7] for calculation of α_π and β_π. The polarizability of π-mesons has been calculated by means of soft-pion technique and PCAC hypothesis in [4]. The electric polarizability of a neutral π-meson turned out to be equal to zero in this case, while that of a charged pion was connected with the γ-parameter for $\pi \to e\nu\gamma$ decay. Paper [5] is devoted to the investigation of α_π and β_π in the framework of quantum field theory with the chiral-invariant Lagrangians. The contributions from all possible intermediate states to $(\alpha_\pi + \beta_\pi)$ and $(\alpha_\pi - \beta_\pi)$ have been taken into account in the approach based on the dispersion sum rules[6]. The values of α_π and β_π have been extracted from the above sum and difference. Electric α_π and magnetic β_π polarizabilities of pions have been calculated in the superconductivity-type Quark Model [7]. The results of this work indicate that the scalar mesons play an important role in the description of the $\pi\gamma \to \pi\gamma$ process. The values of α_π and β_π obtained is the framework of the approaches mentioned above are listed in Table 1.

The present work is aimed at calculating the electric α_π and magnetic β_π polarizabilities of charged and neutral π -mesons in the Quark Confinement Model (QCM)/8/. The article is organized in the following way:

The main concepts of the QCM are given in section II.

Section III is concerned with the description of the scalar-meson physics. The main parameters characterizing scalars are determined and the width of strong and radiative decays of scalar mesons are calculated.

The amplitude of the $\pi\gamma$-scattering and the relevant α_π and β_π coefficients are calculated in section IV. The contributions from scalar, vector and axial intermediate states to the electric and magnetic polarizabilities of pions are studied. The intermediate $\mathcal{E}(730)$-meson turns out to play the main role in the description of $\pi\gamma \to \pi\gamma$.

II. The main concepts of QCM

The QCM /8/ is based on the definite hypothesis about hadronization and confinement. Hadrons appear as colourless collective variables in the quark-gluon interactions. The confinement is realized by averaging over gluonic vacuum.

The hadronization hypothesis is connected with the development of the QCD beyond a perturbation theory. We use the approach/9/ in which the phenomenological Lagrangians were obtained in a heuristic way from the diagrams analogous to that with one-gluon exchange under some assumptions about the gluonic propagator behaviour in a low energy region. The meson interactions are described by closed quark loops in this approach. It is more convenient to use the following mathematical realization of the mentioned above approach for the calculation of hadron amplitudes. Quark currents with the quantum numbers of hadrons are constructed. For instance, in the case of two-quark mesons

$$J_Q = \bar{q}_a \Gamma_Q \lambda_Q q_a ,$$

where the matrices Γ_Q, λ_Q provide necessary quantum numbers. $\Gamma_Q = i\gamma^5$, γ^μ, $\gamma^\mu\gamma^5$ for pseudoscalar, vector and axial-vector mesons.

Then, one constructs the Lagrangians of a hadron-quark interaction

$$\mathcal{L}_Q^I = \frac{g_Q}{\sqrt{2}} M_Q J_Q , \tag{2.1}$$

Table 1

Approach	$\alpha_{\pi^+} \cdot 10^{-43}$ cm^3	$\alpha_{\pi^0} \cdot 10^{-43}$ cm^3
Experiment /2/	6.8 $\pm$1.4 $\pm$ 1.8	-
Experiment /3/	-	35
Soft pion technique ($\gamma_{\pi e\nu\gamma}$ =0.41) /4/	3.1	0
Chiral Theory /5/	5.3	-0.7
Dispersion sum rules /6/	5.5 $\pm$ 2	0.8 $\pm$ 2
Quark Model of Super-conductor Type /7/	6.81	-1.0
QCM	4.06	-0.18

Table 2

$h_J D_J(0) = -\frac{1}{\Pi'_J(0)}$
$\Pi'_\rho(0) = -\frac{1}{2} m_\rho^2 \left(\int_0^\infty du\, b(u) + \frac{m_\rho^2}{4\Lambda^2} \int_0^1 du\, b\left(-u \frac{m_\rho^2}{4\Lambda^2}\right) \sqrt{1-u} \right.$
$\Pi'_{v\,Tr}(0) = \frac{1}{3} m_v^2 \left(\int_0^\infty du\, b(u) + \frac{m_v^2}{4\Lambda^2} \int_0^1 du\, b\left(-u \frac{m_v^2}{4\Lambda^2}\right) \sqrt{1-u}\,\left(1+\frac{u}{2}\right) \right.$
$\Pi'_A(0) = \frac{1}{3} m_A^2 \left(\int_0^\infty du\, b(u) + \frac{m_A^2}{4\Lambda^2} \int_0^1 du\, b\left(-u \frac{m_A^2}{4\Lambda^2}\right) (1-u)^{3/2} \right.$
$\Pi'_S(0) = -\frac{1}{2} m_S^2 \Big[\int_0^\infty du\, b(u) + \frac{m_S^2}{4\Lambda^2} \int_0^1 du\, b\left(-u \frac{m_S^2}{4\Lambda^2}\right) (1-u)^{3/2} +$ $+ 4H\left(\int_0^\infty du\, a(u) + \frac{m_S^2}{4\Lambda^2} \int_0^1 du\, a\left(-u \frac{m_S^2}{4\Lambda^2}\right) (1-u)^{3/2} \right. -$ $- 4H^2\left(\int_0^\infty du\, u\, b(u) - \left(\frac{m_S^2}{4\Lambda^2}\right)^2 \int_0^1 du\, b\left(-u \frac{m_S^2}{4\Lambda^2}\right) u (1-u)^{3/2} \right) \Big]$

where M_Q is a free meson field describing a meson with quantum numbers Q and mass m_Q. The coupling constant g_Q is defined from the condition that the wave function renormalization constant of a meson is equal to zero[8]:

$$Z_Q = 1 - g_Q^2 \tilde{\Pi}_Q'(m_Q^2) = 0, \tag{2.2}$$

where $\tilde{\Pi}_Q(p^2)$ is the mass operator of the meson M_Q. It is more convenient to use $h = 12(g_Q/4\pi)^2$ instead g_Q in calculations.

The confinement hypothesis means, that the averaging of quark loops, describing hadronic interactions over the gluonic vacuum fields has to provide absence of singularities corresponding to the quark-pair production.

Quark diagrams describing hadronic interactions are generated by the S-matrix in the form

$$S = \int d\sigma_{vac}\, T\exp\{i\int d^4x\, \mathcal{L}_Q^I(x)\}.$$

Here, the time-ordered product is supposed to be the ordinary Vick's T-product of the hadron and quark fields with the quark propagator

$$q_{fQ}(x)\,\bar{q}_{f'Q'}(x') = \delta_{ff'}\,\delta_{QQ'}\,(m_f + \hat{B}_{vac}(x) - i\hat{\partial})^{-1}\delta(x-x') =$$
$$\equiv \delta_{ff'}\,\delta_{QQ'}\,S(x, x'\,|\,B_{vac}).$$

The quark fields must be equal to zero after the normal ordering.

The measure $d\sigma_{vac}$, i.e. the way of averaging of quark diagrams over gluonic vacuum fields is defined as follows[8]:

$$\int d\sigma_{vac}\, Sp[M(x_1)S(x_1,x_2|B_{vac}) \ldots M(x_n)\,S(x_n,x_1|B_{vac})] \to$$

$$\to \int d\sigma_\lambda\, Sp[M(x_1)S_\lambda(x_1-x_2) \ldots M(x_n)S_\lambda(x_n-x_1)],$$

where

$$S_\lambda(x_1-x_2) = \int\frac{d^4p}{(2\pi)^4 i}\,\frac{e^{-ip(x_1-x_2)}}{\lambda\Lambda_f - \hat{p}}.$$

The mass dimensional parameter Λ_f characterises the confinement region of quarks with flavour f.

The measure of integration $d\sigma_\lambda$ is defined by

$$\int d\sigma_\lambda \frac{1}{\lambda - z} = G(z) = a(-z^2) + z\,b(-z^2).$$

where $G(z)$ is called the confinement function.

The explicit form of $G(z)$ is yet unknown, so, one can suppose the functions $a(-z^2)$ and $b(-z^2)$ to be independent. The functions $a(-z^2)$ and $b(-z^2)$ are assumed to be [8] independent of colour and flavour

and to be unique for all quark loops; to be entire, analytical functions in complex z-plane and to decrease rather quickly both in the Euclidean and pseudo-Euclidean directions

$$\lim_{z^2\to\pm\infty}|z^2|^N|a(-z^2)| = \lim_{z^2\to\pm\infty}|z^2|^N|b(-z^2)| = 0 \qquad \forall N>0.$$

In this paper we use the functions $a(u)$ and $b(u)$ of the following form:

$$a(u) = 2\exp(-u^2-u)$$
$$b(u) = 2\exp(-u^2+0.4u). \tag{2.3}$$

The dimensional model parameters Λ_u, Λ_d and Λ_s were fixed by fitting the main constants of the low-energy meson physics and turned out to be equal to [8]:

$\Lambda = \Lambda_u = \Lambda_d = 460$ MeV, $\quad \Lambda_s = 506$ MeV.

III. Physics of scalar mesons

The description of the 0^{++} channel is one of the problems of low-energy physics. On the one hand the introduction of scalar particles turned out to be very convenient for the construction of chiral theories [10]. The phenomenological analysis and model investigations[7,11] of the $\pi\pi$, πN, NN -scattering, $K\to 2\pi$ and $K\to\gamma\gamma$ decays indicate the importance of taking account of intermediate scalar states in the description of these processes. On the other hand, the quark composition of 0^{++} particles is not yet clear. Scalar mesons are treated as two-quark states in [11] while the arguments in favour of their four-quark structure are given in [12]. At last, there is a number of articles, for example[13], where scalar mesons are assumed to be hybrid states or pure glueballs.

In the QCM we treat scalar mesons $(a_0, f_0, \varepsilon, k)$ as two-quark states described by the Lagrangian

$$\mathcal{L}_S = \frac{g_S}{\sqrt{2}}\,S(x)\,\bar{q}(x)\,\lambda_S\,(I - iH\overleftrightarrow{\partial}/\Lambda)\,q(x), \tag{3.1}$$

where λ_S has the form [14]

$$\lambda_{a_0} = diag(1,-1,0)$$
$$\lambda_{f_0} = diag(-\sin\delta_S, -\sin\delta_S, -\sqrt{2}\cos\delta_S)$$
$$\lambda_\varepsilon = diag(\cos\delta_S, \cos\delta_S, -\sqrt{2}\sin\delta_S).$$

Let us discuss in detail the choice of a matrix $\Gamma_S : I - iH\overleftrightarrow{\partial}/\Lambda$ defining quantum numbers of 0^{++} mesons. For this purpose, let us consider the diagram, fig. 1, describing a strong decay $S \to pp$. The corresponding structure integral calculated for zero masses of final states and normalized to unity at $m_S = 0$ is

$$I_H(m_s) = [I_0(m_s) + 4HI_1(m_s)]/I_H(0)$$

$$I_0(m_s) = \int_0^\infty du\, a(u) - 4\left(\frac{m_s}{2\Lambda}\right)^2 \int_0^1 du\, a\left(-u\frac{m_s^2}{4\Lambda^2}\right)\left[\frac{1}{2}\ln\frac{1+\sqrt{1-u}}{1-\sqrt{1-u}} - \sqrt{1-u}\right]$$

$$I_1(m_s) = \int_0^\infty du\, u\, b(u) + \frac{1}{2}\left(\frac{m_s}{2\Lambda}\right)^4 \int_0^1 du\, u\, b\left(-u\frac{m_s^2}{4\Lambda^2}\right)\left[\frac{1}{2}\ln\frac{1+\sqrt{1-u}}{1-\sqrt{1-u}} - \sqrt{1-u}\right]. \tag{3.2}$$

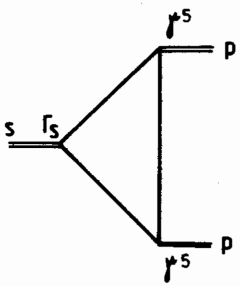


Fig. 1

The $I_H(m_s)$ dependence on m_S with various values of H is plotted in fig. 2. One can see that $I_0(m_s)$ becomes equal to zero at $m_s \approx 1070$ MeV. It leads to that a theoretical value of the $f_0(975) \to \pi\pi$ decay width is to be underestimated ($\Gamma \sim 1$ MeV) in comparison with the experimental one $\Gamma_{exp} = (26 \pm 5)$ MeV. This result, corresponding to the choice of two-quark current with $\Gamma_S = I$ seems to testify in favour of a more complicated structure of scalar mesons. A four-quark component may be essential in scalar mesons. We are going to analyse this possibility in future. In the present work we use an additional two-quark interaction with a derivative in the form (3.1) and consider the parameter H as a free one. Moreover, the ε-meson mass m_ε and the mixing angle δ_S are also considered as free parameters in accordance with the low-energy phenomenology.

As the basis for fitting of the parameters H, δ_S and m_ε we take, first, the Adler condition[10] which means that amplitudes of the $\pi\pi \to \pi\pi$ and $\pi\gamma \to \pi\gamma$ processes are equal to zero when $m_\pi \to 0$ and, second, the experimental value of the $f_0 \to \pi\pi$ width and $\pi\pi$-scat-

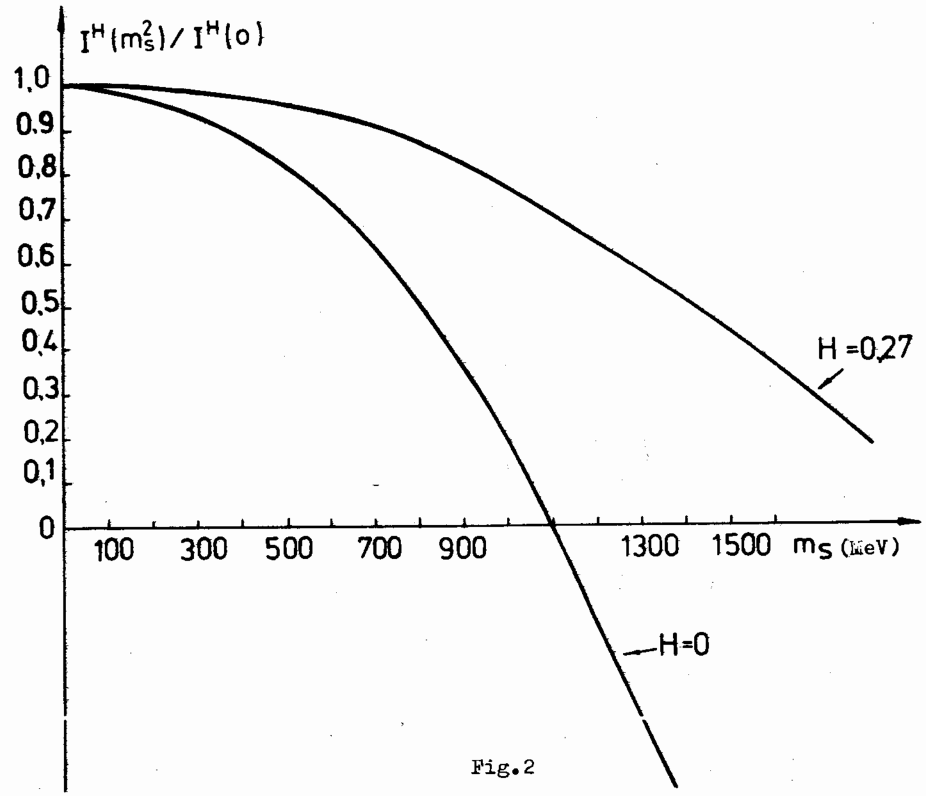


Fig.2

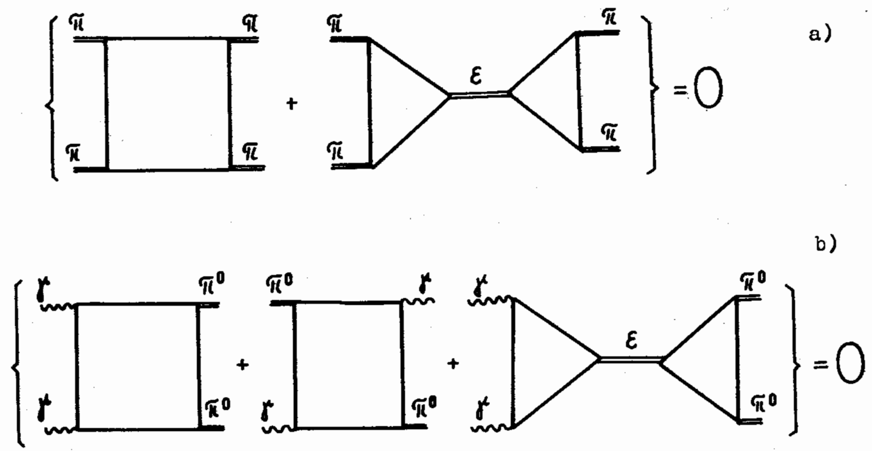


Fig.3

tering S-wave lengths a_0^0 and a_0^2. Graphically, the Adler condition can be presented as in fig. 3. On the QCM it is written in the form

$$G_B^{(0)} = 2\Lambda^2 \cos^2\delta_s \left[G_A^{(0)} + 4HG_B^{(1)} \right]^2 h_\varepsilon D_\varepsilon(0), \qquad (3.3)$$

$$5b(0) = 2\Lambda^2 \cos\delta_s \, (5\cos\delta_s - \sqrt{2}\sin\delta_s)\, a(0) \left[G_A^{(0)} + 4HG_B^{(1)} \right] h_\varepsilon D_\varepsilon(0) \qquad (3.4)$$

The following notation is adopted:

$$G_B^{(n)} = \int_0^\infty du\, u^n b(u)\ ; \quad G_A^{(n)} = \int_0^\infty du\, u^n a(u).$$

$D_\varepsilon(p^2)$ is the full propagator of ε-meson. Due to the compositeness condition (2.2)

$$h_\varepsilon D_\varepsilon(0) = \frac{1}{\tilde{\Pi}_\varepsilon'(0)}.$$

An explicit form of $\tilde{\Pi}_\varepsilon'(0)$ is given in table 2. For fitting H and δ_s it is convenient to use the ratio of equalities (3.4) and (3.3)

$$R = \frac{5\, b(0) \cos\delta_s \left(G_A^{(0)} + 4HG_A^{(1)} \right)}{G_B^{(1)}\, a(0)\, (5\cos\delta_s - \sqrt{2}\sin\delta_s)}$$

which is independent of m_ε. The matrix element of the $S \to PP$ decay can be written in the form:

$$g_{SP_1P_2} = Sp\, \lambda_s \{\lambda_{P_1}, \lambda_{P_2}\} \Lambda \sqrt{h_{P_1} h_{P_2} h_S(H)/6}\, \left[I_0(m_S) + 4H I_1(m_S) \right], \qquad (3.5)$$

where λ_{P_1} and λ_{P_2} are the isotopic matrices corresponding to pseudoscalar mesons P_1 and P_2.

The decay width for $f_0 \to \pi\pi$ is

$$\Gamma(f_0 \to \pi\pi) = \frac{3}{32\pi} \sqrt{1 - \frac{4m_\pi^2}{m_{f_0}^2}}\ \frac{g^2_{f_0\pi\pi}}{m_{f_0}}.$$

The dependences of $R(H, \sin\delta_s)$ and $Q(H, \sin\delta_s) = \dfrac{\Gamma(f_0 \to \pi\pi)}{\Gamma^{exp}(f_0 \to \pi\pi)}$ on H for different values of δ_s are plotted in fig. 4. One can see the values R and Q to be close to unity if H and δ_s are equal

$H = 0.27$, $\sin\delta_s = -0.45$ or $\delta_s = -27°$.

The mass of ε-meson is fixed by the condition of the best coincidence of $\pi\pi$-scattering S-wave lengths a_0^0 and a_0^2 with the experimental data/15,16/. In the QCM the $\pi\pi$-scattering matrix element is defined by the diagrams, given in fig. 5 and is calculated in a standard way. The a_0^0 and a_0^2 dependence on the ε-meson mass is plotted in fig. 6.

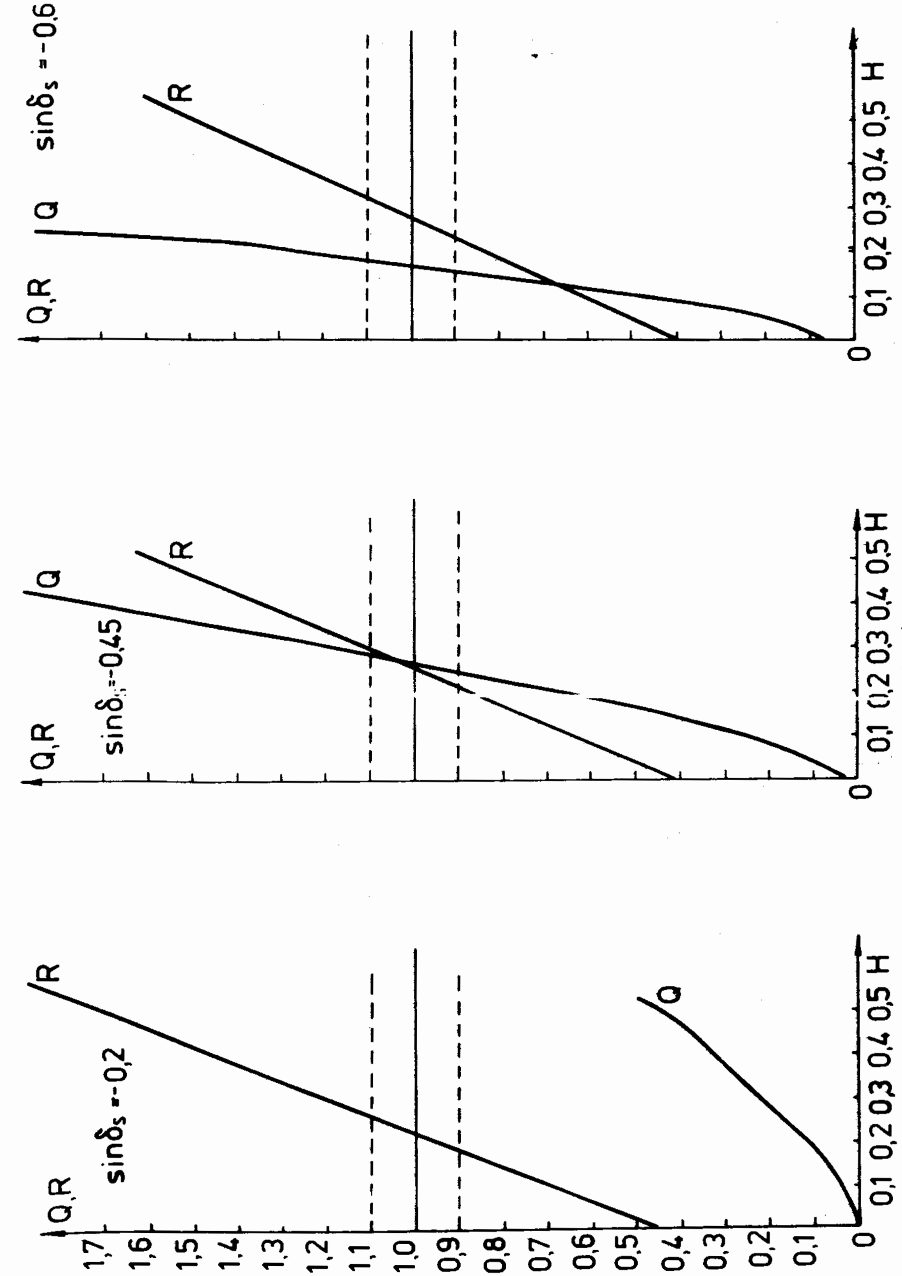


Fig.4

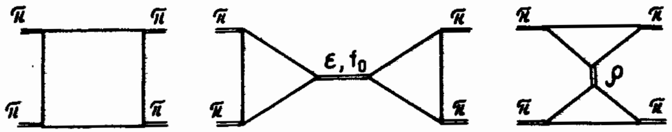


Fig.5

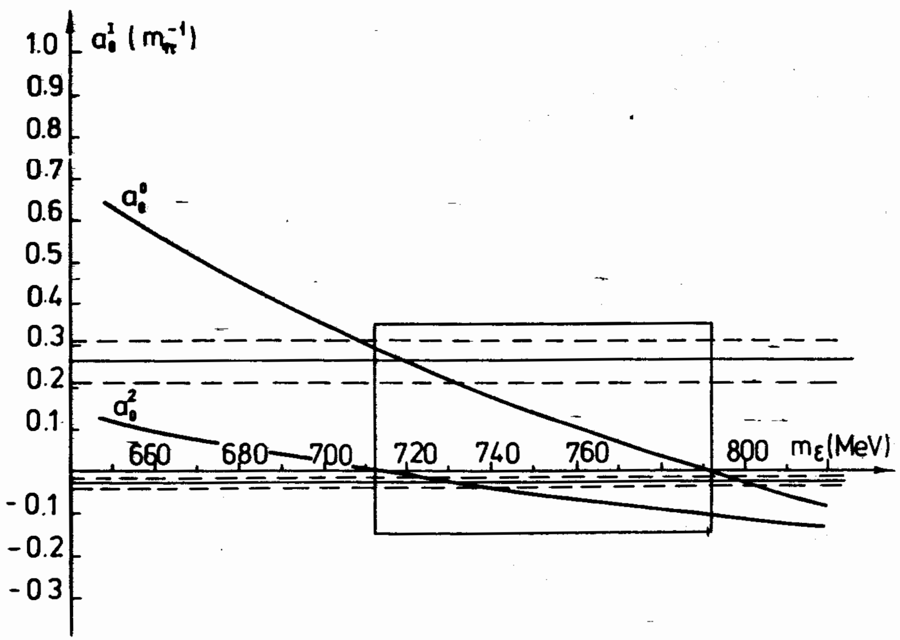


Fig.6

One can see that the best agreement with the experimental data [15] is achieved if

$$m_\varepsilon = 730 \text{ MeV}.$$

In this case

$$a_0^0 = 0.227\, m_\pi^{-1} \qquad\qquad a_0^2 = -0.017\, m_\pi^{-1}.$$

So, we have fixed all the parameters necessary for the description of scalar mesons. It is of interest to calculate widths of strong and radiative decays of 0^{++} mesons. We should like to note that just the radiative decay width $a_0 \to \gamma\gamma$ in the framework of the two-quark scheme is one of an arguments in favour of the four-quark structure of $a_0(975)$-meson [12].

The diagrams describing strong and radiative decays of scalar mesons are presented in figs. 1 and 7. The matrix element of strong

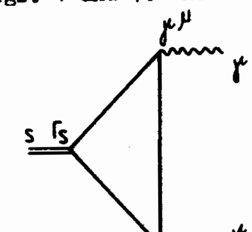


Fig. 7

decays $S \to \rho\rho$ is of the form (3.5) while that for the radiative one $S \to \gamma\gamma$ is

$$M(S \to \gamma\gamma) = [g^{\mu\nu} q_1 q_2 - q_1^\nu q_2^\mu]\, g_{S\gamma\gamma},$$

where

$$g_{S\gamma\gamma} = \alpha \sqrt{6 h_s}\, \frac{1}{\Lambda}\, Sp\, Q^2 \lambda_s \Big[\int_0^1 du\, a\Big(-u \frac{m_s^2}{4\Lambda^2}\Big)(1+u) \ln \frac{1+\sqrt{1-u}}{1-\sqrt{1-u}}$$

$$+ H \frac{m_s^2}{4\Lambda^2} \int_0^1 du\, u\, b\Big(-u \frac{m_s^2}{4\Lambda^2}\Big) \ln \frac{1+\sqrt{1-u}}{1-\sqrt{1-u}} \Big]; \qquad (3.6)$$

with $\alpha = e^2/4\pi^2$ and $Q = 1/3\, diag(2,-1,-1)$ being the charge matrix. The widths of strong and radiative decays are given in Table 3.

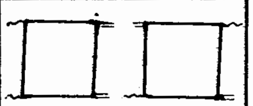
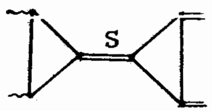
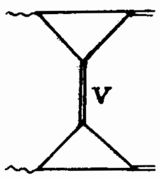
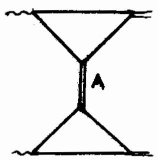
IV. Polarizability of π-meson

Now we pass to calculation of electric and magnetic polarizabilities of π^+ and π^0 mesons. As it has been mentioned in the introduction, these parameters are extracted from the amplitude of Compton scattering on π-meson.

Table 3

Process	QCM	Experiment
$f_0 \to \pi\pi$	26 MeV	26 ± 5 MeV /18/
$a_0 \to \pi\eta$	59 MeV	54 ± 7 MeV /18/
$\varepsilon \to \pi\pi$	300 MeV	-
$f_0 \to \gamma\gamma$	0.03 keV	0.8 keV /18/
$a_0 \to \gamma\gamma$	0.5 keV	$0.19 \pm 0.07^{+0.10}_{-0.07}$ /19/
$\varepsilon \to \gamma\gamma$	0.95 keV	-

Table 4

Diagram	α_{π^+} 10^{-43} cm^3	α_{π^0} 10^{-43} cm^3	β_{π^+} 10^{-43} cm^3	β_{π^0} 10^{-43} cm^3
	-0.615	-6.15	0.615	6.15
	4.51	4.51	-4.51	-4.51
	-	-	+0.26	+1.7
	0.163	1.46	-0.17	-1.42
Result	4.06	-0.18	-3.8	1.92

The matrix element of $\pi\gamma - \pi\gamma$ on the mass-shell of photons in a general case is /17/

$$M_{\mu\nu}(\pi\gamma \to \pi\gamma) = -\sum_{a=1}^{2} T^{a}_{\mu\nu} F_a(\sigma, t). \qquad (4.1)$$

where

$$T^{1}_{\mu\nu} = (q_1 P_1)\, q_{2\mu} P_{2\nu} + (q_2 P_2)\, q_{1\nu} P_{1\mu} - g_{\mu\nu}(P_1 q_1)(P_2 q_2) - P_{1\mu} P_{2\nu}(q_1 q_2)$$

$$T^{2}_{\mu\nu} = g_{\mu\nu}\, q_1 q_2 - q_{1\nu} q_{2\mu},$$

$F_{1,2}(\sigma, t)$ - are the form factors defined by inner structure of π - meson, q_1, q_2 are momenta of initial and final photons, P_1, P_2 are momenta of initial and final π -mesons.

$$\sigma = (P_1 + q_1)^2 = (P_2 + q_2)^2$$

$$t = (P_1 - P_2)^2 = (q_1 - q_2)^2 .$$

Electric and magnetic polarizabilities of π -mesons can be connected with the form factors F by the following relations /17/:

$$\alpha_\pi = -\frac{F_1(m_\pi^2, 0) + F_2(m_\pi^2, 0)}{m_\pi}$$

$$\beta_\pi = \frac{F_2(m_\pi^2, 0)}{m_\pi} . \qquad (4.2)$$

The diagrams defining the $\pi\gamma - \pi\gamma$ amplitudes are presented in table 4. We take into account the diagrams with intermediate scalar, vector and axial-mesons along with the box ones.

Note that F_1 receives contribution only from the diagrams with intermediate vectors and axials.

The form factors $F_{1,2}(m_\pi^2, 0)$ can be written in the form

$$F_1(m_\pi^2, 0) = F^V(m_\pi^2, 0) + F_1^A(m_\pi^2, 0)$$

$$F_2(m_\pi^2, 0) = F^{Box}(m_\pi^2, 0) + F^S(m_\pi^2, 0) + F_2^A(m_\pi^2, 0) - F^V(m_\pi^2, 0) . \qquad (4.3)$$

Disregarding the π -meson mass ($m_\pi^2/4\Lambda^2$ =0.02), contributions from different diagrams can be written as

$$F_{\pi^+}^{Box}(0,0) = -\alpha \cdot 4\pi\, h_\pi \;\; 1/9 \;\; \beta(0)/6\Lambda^2$$

$$F_{\pi^0}^{Box}(0,0) = -\alpha \cdot 4\pi\, h_\pi \cdot 10/9 \;\; \beta(0)/6\Lambda^2 \qquad (4.4)$$

$$F_{\pi^+}^{S}(0,0) = F_{\pi^0}^{S}(0,0) = \sum_{S=f_0,\varepsilon} g_{SPP}(0)\, g_{S\gamma\gamma}(0)\, D_S(0)$$

$$F_{1\,\pi^+}^{A}(0,0) = -\alpha\cdot 4\pi\, h_\pi\, m_\pi^2\, 1/27\, (a(0)/\Lambda)^2\, h_{a_1} D_{a_1}(0)$$
$$F_{2\,\pi^+}^{A}(0,0) = \alpha\cdot 4\pi\, h_\pi\, 2/9\, a(0)\, G^{(0)}\, h_{a_1} D_{a_1}(0)$$
$$F_{1\,\pi^0}^{A}(0,0) = -\alpha\cdot 4\pi\, h_\pi\, m_\pi^2\cdot 1/9\, (a(0)/\Lambda)^2\, h_{f_1} D_{f_1}(0)$$
$$F_{2\,\pi^0}^{A}(0,0) = \alpha\cdot 4\pi\, h_\pi\, 2/3\cdot a(0)\, G^{(0)}\, h_{f_1} D_{f_1}(0)$$
$$F_{\pi^+}^{V}(0,0) = -\alpha\cdot 4\pi\, h_\pi\, m_\pi^2\, 2/3\, (a(0)/\Lambda)^2\, h_\rho D_\rho(0)$$
$$F_{\pi^0}^{V}(0,0) = -\alpha\cdot 4\pi\, h_\pi\, m_\pi^2\cdot 2\, (a(0)/\Lambda)^2\, h_\omega D_\omega(0).$$

Here $D_X(p^2)$ is a full propagator of meson X. The explicit form of $h_X D_X(0)$ for S,V,A -mesons is given in Table 2. The constants $g_{SPP}(0)$ and $g_{S\gamma\gamma}(0)$ are defined by formulae (3.5) and (3.6) with $m_S=0$. The values of H and δ_S fixed in the previous section are used in the g_{SPP} and $g_{S\gamma\gamma}$ calculations.

Substituting (4.3) and (4.4) into (4.2), one gets the values for the electric and magnetic polarizabilities of π^+ and π^0 -mesons. One can see from (4.4) that α_π and β_π depend on the $\mathcal{E}$ -meson mass. This dependence is plotted in fig. 8.

The contributions to electric and magnetic polarizabilities of π^+ and π^0 mesons from different diagrams and the final value for these parameters with $m_{\mathcal{E}} = 730$ MeV are presented in table 4. One can see (Table 4) that diagrams with intermediate scalar mesons give the main contribution to the π^+ meson polarizability. The small value of the π^0-meson electric polarizability is explained by mutual concellation of the contributions from the box diagram and the diagrams with intermediate scalar mesons in accordance with the Adler condition (3.4). The full concellation does not take place because of the inclusion of the $f_0(980)$-meson along with the $\mathcal{E}(730)$-one. The vector and axial intermediate mesons were considered apart from the scalar ones. Intermediate $\omega(780)$, $f_1(1285)$-mesons are seen from table 4 to play a rather important role in the description of π^0-polarizability.

One can see from table 4 that the obtained value for α_{π^+} is close to that from /4/. The quantity $(\alpha_{\pi^+}+\beta_{\pi^+}) = 0.24\cdot 10^{-43}$ cm^3 is small and positive, which is in agreement with the results of the approach based on the dispersion sum rules /6/. Deviation of this value from zero is caused by the vector and axial vector contributions.

Thus, the electric and magnetic polarizabilities of π^+ and π^0 mesons have been calculated in the Quark Confinement Model. The matrix element of $\pi\gamma \to \pi\gamma$ was calculated taking account of the diagrams with intermediate scalar, vector and axial states. Diagrams with intermediate $\mathcal{E}(730)$-meson turned out to play the main role in the cal-

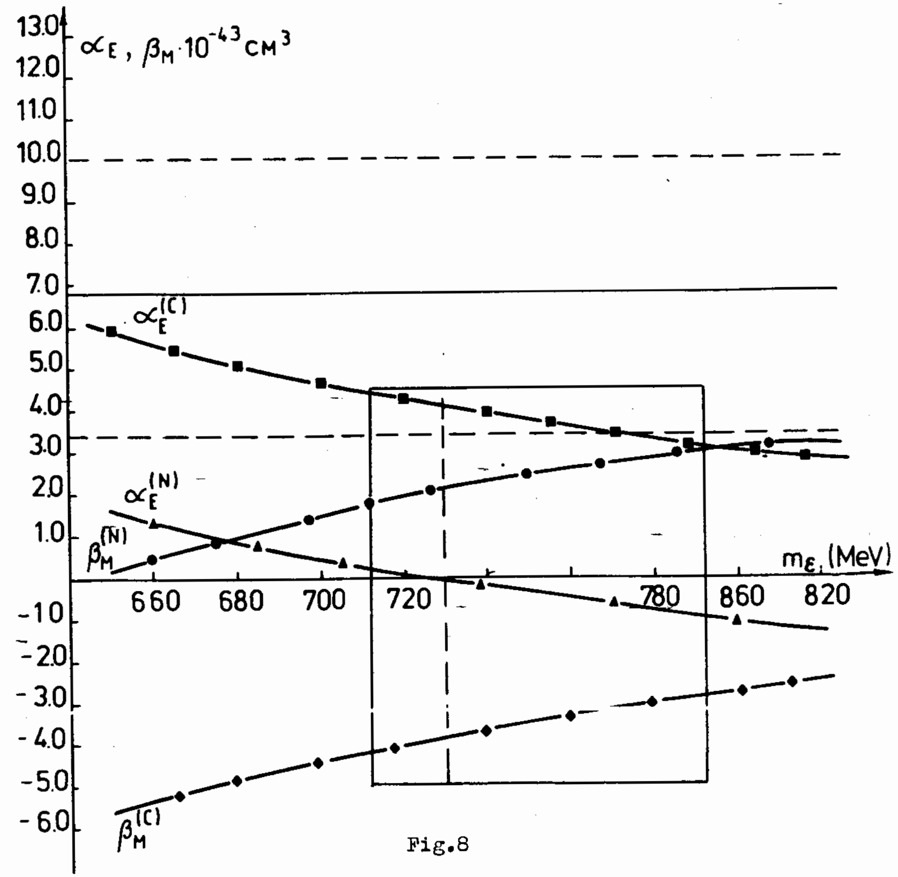


Fig.8

culation of α_π and β_π. The obtained results are in satisfactory agreement with experimental data and are not in contradiction with the results of other approaches.

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Поляризуемость π-мезонов в модели конфайнмированных кварков

Электрические α_π и магнитные β_π поляризуемости $\pi^\pm$ и π^0-мезонов вычислены в модели конфайнмированных кварков. Учтены диаграммы с промежуточными векторными, аксиально-векторными и скалярными мезонами. Оказалось, что промежуточные скалярные состояния вносят существенный вклад в электрическую магнитную поляризуемости пионов. Получены следующие значения для α_π и β_π:

$\alpha_{\pi^\pm} = 4.06\cdot10^{-43}$ см^3 $\quad\beta_{\pi^\pm} = -3,84\cdot10^{-43}$ см^3

$\alpha_{\pi^0} = -0,18\cdot10^{-43}$ см^3 $\quad\beta_{\pi^0} = 1,92\cdot10^{-43}$ см^3.

Вычислены ширины сильных ($a_0(980)\to\pi\eta$, $f_0(975)\to\pi\pi$, $\epsilon(730)\to\pi\pi$) и радиационных ($a_0(980)$, $f_0(975)$, $\epsilon(730)\to\gamma\gamma$) распадов скалярных мезонов. Полученные результаты удовлетворительно согласуются с экспериментальными данными.

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Avakyan E.Z. et al. E2-88-519

Polarizability of π-Mesons in the Quark Confinement Model

The electric α_π and magnetic β_π polarizabilities are calculated in the Quark Confimenet Model (QCM). The diagrams with vector, scalar and axial intermediate states are taken into account. It is found that intermediate scalar mesons give an essential contribution to electric and magnetic polarizabilities of pions. The following values for α_π and β_π are obtained:

$\alpha_{\pi^\pm} = 4.06\cdot10^{-43}$ cm^3 $\quad\beta_{\pi^\pm} = -3.84\cdot10^{-43}$ cm^3

$\alpha_{\pi^0} = -0.18\cdot10^{-43}$ cm^3 $\quad\beta_{\pi^0} = 1.92\cdot10^{-43}$ cm^3.

The widths of strong ($a_0(980)\to\pi\eta$, $f_0(975)\to\pi\pi$, $\epsilon(730)\to\pi\pi$) and radiative ($a_0(980)$, $f_0(980)$, $\epsilon(730)\to\gamma\gamma$) decays are calculated. The results are obtained to be in satisfactory agreement with experimental data.

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

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