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VERIFICATION OF VECTOR DOMINANCE

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Submitted 3 August 1970
ZhETF Pis. Red. 12, No. 6, 329 - 332 (20 September 1970)

When the consequences of the vector-dominance hypothesis are compared with experiment, the question arises of the choice of the coordinate system [1, 2], since the vector meson, unlike the photon, has not only transverse polarization components, but also longitudinal polarization. In addition, there is the question of the validity of the assumption that the hadron amplitudes are independent of the mass of the vector particle. We consider below reactions of the type $0 + 0 \to 0 + 1$, in which, at a constant internal parity ($I_i = I_f$, I_i, and I_f are the internal parities of the initial and final states) the vector particle has only transverse polarization [3 - 5], regardless of the mass value, and in this sense is "photonlike." In reactions of this type it is possible to formulate the consequences of the vector dominance in explicitly covariant fashion, as well as to attempt to resolve the question of whether the hadron amplitude depends on the square of the vector-particle mass or not. The simplest example is afforded by the reactions caused by the isovector photon and the related reactions with $\rho^\pm$ mesons [6]:

$$\gamma + \mathrm{He} \to \mathrm{He} + \pi^0, \quad \pi^\pm + \mathrm{He} \to \rho^\pm + \mathrm{He}, \quad e + \mathrm{He} \to e + \mathrm{He} + \pi^0 .$$

The easiest way to verify the transversality of the polarization of the nonzero-mass vector particle taking part in the reaction $0 + 0 \rightleftarrows 0 + 1$ is with the aid of the selection rule [7]

$$I_i(-1)^{S_i} = I_f(-1)^{S_f},$$

where S_i and S_f are the summary spin projections of the initial and final particles on the normal to the reaction plane. If $I_i = I_f$, $S_i = 0$, and $S_f = s_v$, then the produced vector meson has a spin projection $s_v = 0$, and consequently its vector polarization is directed normal to the reaction plane. Thus, the vector particle is produced in a pure spin state, and its normal density matrix is defined uniquely and does not depend on the dynamics of the collision.

In accordance with the vector-dominance hypothesis, the matrix element of the isovector part of the electromagnetic current j_μ^3 is connected with the matrix element of the current j_μ^ρ responsible for the emission of the neutral ρ meson by the relation

$$(\pi\mathrm{He}\,|j_\mu^3|\,\mathrm{He}) = \frac{e m_\rho^2}{f_\rho}\,\frac{1}{k^2 + m_\rho^2}\,(\pi\mathrm{He}\,|j_\mu^\rho|\,\mathrm{He}), \tag{1}$$

where k is the ρ-meson momentum and equals the momentum of the photon (virtual or real). Since the π meson is pseudoscalar, the matrix element of the current (πHe|j|He) (or of the electromagnetic current $(\pi He|j^3_\mu|He)$) is a pseudovector and is given by

$$(\pi He|\, j^{\rho}_{\mu}\,|\, He) = a(k^2)\, n_{\mu}, \tag{2}$$

where $n_\mu = i\varepsilon_{\mu\nu\rho\sigma} k_\nu p_\rho p'_\sigma = i\varepsilon_{\mu\nu\rho\sigma} q_\nu p_\rho p'_\sigma$ is a unit pseudovector, which can be constructed from the vectors of the problem, namely the initial and final momenta p and p' of the helium and the momentum q of the pion. The amplitude $a(k^2)$, which is free of kinematic singularities [8, 9], is a function of k^2 and of two implicit invariant variables, for example, $s = -(k + p)^2 = -(q + p')^2$ and $t = -(p - p')^2 = -(q - k)^2$.

The π^0-meson photoproduction cross section is given in terms of this notation by

$$\frac{d\sigma(\gamma \to \pi^0)}{dt} = \frac{1}{32\pi(s - M^2)^2}\,\frac{\alpha}{(f_\rho^2/4\pi)}\,|a(0)|^2\,\frac{1}{4}\,\{s\,t\,u - tM^2(M^2 - \mu^2) - M^2\mu^4\}. \tag{3}$$

The cross section for photoproduction by linearly polarized γ quanta is

$$\frac{d\sigma_{tot}}{dt} = \frac{d\sigma}{dt}\,(1 - P_\gamma \cos 2\phi), \tag{4}$$

and yields no new information (F_γ is the degree of linear polarization and ϕ is the angle between the reaction and polarization planes.)

The $\rho^\pm$ meson production cross section, if one uses the isotopic invariance and the invariance under time reversal, can be written in the following manner:

$$\frac{d\sigma(\pi \to \rho)}{dt} = \frac{1}{16\pi}\,\frac{|a(-m_\rho^2)|}{s^2 - 2s(M^2 + \mu^2) + (M^2 - \mu^2)^2} \times$$
$$\times \frac{1}{4}\,\{s\,t\,u - t(M^2 - m_\rho^2)(M^2 - \mu^2) - M^2(m_\rho^2 - \mu^2)^2\}. \tag{5}$$

It is obvious that the cross sections (3) and (5) vanish in the case of production at zero angle.

Since the polarization vector of the produced ρ meson is normal to the reaction plane, the angular distributions of the decay pions is uniquely determined and is given by

$$I(\theta) = \frac{3}{4\pi}\cos^2\theta,$$

where θ is the angle of emission of the pion relative to the normal. This fact may contribute to the separation of the pions of the $\rho \to \pi\pi$ decay from the background pions.

Finally, for the cross section for the production of π^0 mesons in the one-photon approximation, neglecting the electron mass, we have

$$\frac{d^3\sigma(e \to e + \pi)}{ds\,dt\,dk^2} = \frac{1}{16}\left(\frac{\alpha}{2\pi}\right)^2\left[\frac{f_\rho^2}{4\pi}\right]^{-1}\frac{1}{(s_0 - M^2)^2}\,\frac{m_\rho^4}{k^2(k^2 + m_\rho^2)^2}\,\times$$

$$\times\frac{[1 + \epsilon(1-\epsilon)^{-1}]\,|a(k^2)|^2}{[s^2 - 2s(M^2 - k^2) + (M^2 + k^2)^2]^{1/2}}\,\frac{1}{4}\,\{stu - t(M^2 + k^2)(M^2 - \mu^2) - M^2(k^2 + \mu^2)^2\}. \qquad (6)$$

Here $\varepsilon(1 - \varepsilon)^{-1} = 2[(s_0 - s)(s_0 - M^2) - s_0k^2][s^2 - 2s(M^2 - k^2) + (M^2 + k^2)^2]^{-1}$, ε is the usual degree of transverse linear polarization of the virtual photon [1], $s_0 = -(k_i + p)^2$, $k^2 = (k_i - k_f)^2$, $s + t + u = 2M^2 + \mu^2 - k^2$, and k_i and k_f are the momenta of the initial and final electrons.

The fact that the indicated processes are described by a single amplitude $a(k^2)$, and a study of reactions with linearly polarized photons yields no new information, detracts somewhat from the possibility of verifying the hypothesis of vector dominance under the assumption that the amplitude is independent of k^2. The value of the constant $f_\rho^2/4\pi$ obtained as a result of measuring the cross sections (3) and (5) can be only compared with the value extracted from data, and can be used to predict the cross section (6). On the other hand, if we forego the independence of the amplitude of k^2, then an attempt can be made to reconcile the values of the cross sections (3), (5), and (6) by approximating $a(k^2)$ by some very simple dependence, say $a(k^2) = a_0 + a_1k^2$. Alternately, by measuring $|a(k^2)|^2$ for spatially similar k^2 and $k^2 = 0$ it is possible, given adequate statistics, to attempt to extrapolate these data to the point $k^2 = -m_\rho^2$, in analogy with the procedure used to determine the $\pi\pi$-scattering cross section. Finally, the question remains of whether $a(k^2)$ is to be regarded as a function of the variables s and t or of the variables $\nu = kp/M$ and t) besides being a function of k^2 (the changeover from s to ν introduces an additional dependence on k^2, since $s = M^2 - k^2 - 2M\nu$).

The author thanks A.I. Azimov, A.M. Baldin, V.B. Berestetskii, A. Bialas, O.B. Gerasimov, V.N. Gribov, V.I. Ogievetskii, L.B. Okun', and Ya. Smorodinskii for useful discussions.

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ONE-DIMENSIONAL PROBLEM FOR S = 1 WITH MODIFIED ANTIFERROMAGNETIC HAMILTONIAN

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Submitted 4 August 1970
ZhETF Pis. Red. 12, No. 6, 332 - 335 (20 September 1970)

In [1] there was considered the Hubbard model with large Coulomb repulsion for one atom, and account was taken of the orbital angular momentum of the