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Abstract

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ON THE APPROXIMATE γ_5-INVARIANCE OF THE THEORY OF STRONG INTERACTIONS

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Recently, questions concerning the appearance of symmetry properties at high energies have been intensively discussed. Thus, for example, in Gell-Mann' s work ([1]) symmetry properties are considered that follow from the invariance of the interaction with respect to a three-dimensional unimodular group. On the other hand, a number of authors (([2], [3]) and others) have raised the question of the existence of vector bosons that carry out strong interactions in the form

$$\mathcal{L}_{\text{int}} = \sum_{\alpha=1}^{4} I_\alpha(x) B_\alpha(x), \tag{1}$$

where B_α is a vector boson field; I_α is the vector current of the strong interaction, equal to $I_\alpha(x) = \sum g_i^2 \bar{\psi}_i \gamma_\alpha \psi_i$. It should be noted that the interaction Lagrangians for weak, electromagnetic, and strong processes in the form (1) possess one common property: they are invariant with respect to γ_5-transformations of spinor particles:

$$\psi_i \to \gamma_5 \psi_i, \qquad \bar{\psi}_i \to \bar{\psi}_i \gamma_5, \qquad \gamma_5^2 = -1. \tag{2}$$

In the present note we discuss the hypothesis that at high energies and momentum transfers $s, t \gg m^2$ the matrix elements of all physical processes are invariant with respect to γ_5-transformations of spinor particles.

The more precise meaning of γ_5-invariance will be illustrated below for a number of physical processes. Let us note that in the case of a γ_5-invariant interaction, γ_5-noninvariant terms in the scattering amplitude arise because of the presence of mass terms of spinor particles in the free Lagrangian.*

On the basis of an analysis of the lowest terms of perturbation theory, one may assume that at high energies and momentum transfers the mass terms play no role and, consequently, a γ_5-invariant interaction will lead to γ_5-invariant matrix elements.

Let us turn to concrete examples.

Starting from Lorentz invariance and the gradient transformation, the most general expression for the electromagnetic vertex of the nucleon is found in the form

$$F_\mu(q^2) = F_1(q^2)\gamma_\mu + i\sigma_{\mu\nu}q_\nu F_2(q^2). \tag{3}$$

From the requirement of γ_5-invariance it follows that

$$\lim_{q^2\to\infty} |q|\, F_2(q^2) = 0, \tag{4}$$

i.e., the magnetic form factor of the nucleon decreases at sufficiently large momentum transfers.

* Here we deliberately assume the absence of renormalization in the theory, since the latter, as was shown in ([4]), may lead to the appearance of γ_5-invariant terms.

Let us clarify the consequences to which the requirement of γ_5-invariance of the amplitude leads for scattering processes of the type

$$0 + \frac{1}{2} \to 0 + \frac{1}{2}; \tag{5}$$

0, $\frac{1}{2}$ are the spins of the particles participating in the reaction.

The scattering amplitude of any of these processes, if the relative parity of the particles at the beginning and at the end of the reaction does not change, may be written in the form

$$M = \bar{u}_2(p_2)\left[A(s,t) + \frac{\hat{q}_1 + \hat{q}_2}{2}\, B(s,t)\right] u_1(p_1), \tag{6}$$

where q_1 and q_2 are the momenta of the bosons, p_1 and p_2 are the momenta of the fermions,

$$s = (p_1 + q_1)^2, \qquad t = (p_1 - p_2)^2.$$

From the requirement of γ_5-invariance it follows that

$$\lim_{s,t\to\infty} A(s,t) = 0. \tag{7}$$

Hence it is easy to establish that, if the initial fermion was longitudinally polarized, then the final fermion will also be longitudinally polarized. In the case where the initial state is unpolarized, the final state will also be unpolarized.

It follows from this, for example, that the polarization of Λ- and Σ^--particles in the scattering processes

$$\pi^- + p \to \Lambda + K^0, \qquad \pi^- + p \to \Sigma^- + K^+$$

at high energies and momentum transfers must decrease.

For nucleon–nucleon scattering the amplitude may be written in the form

$$\begin{aligned} M(s,t) = \bar{u}(p_2)\bar{u}(k_2)\,[G_1 - G_2(\gamma^{(1)}P + \gamma^{(2)}K) \\ + G_3(\gamma^{(1)}P)(\gamma^{(2)}K) - G_4\gamma_5^{(1)}\gamma^{(1)}P\gamma_5^{(2)}\gamma^{(2)}K - G_5\gamma_5^{(1)}\gamma_5^{(2)}]\,u(p_1)u(k_1), \end{aligned} \tag{8}$$

where

$$K = \frac{k_1 + k_2}{2}, \qquad P = \frac{p_1 + p_2}{2}, \qquad Q = k_1 - k_2. \tag{9}$$

The requirement of γ_5-invariance leads to the result that, in the region of large s and t, the expression for the amplitude is substantially simplified and has the form

$$M(s,t) = \bar{u}(p_2)\bar{u}(k_2)\,[G_3\gamma^{(1)}P\gamma^{(2)}K - G_4\gamma_5^{(1)}\gamma^{(1)}P\gamma_5^{(2)}\gamma^{(2)}K]\,u(p_1)u(k_1). \tag{10}$$

Hence it is easy to establish that, if the initial state is unpolarized, then the final state will also remain unpolarized.

It is not difficult to see that for other scattering processes as well, γ_5-invariance substantially simplifies the expression for the scattering amplitude and makes it possible to draw the conclusion that the helicity of the particles is conserved.

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Note: Figure translations are in progress. See original paper for figures.