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LETTER TO THE EDITOR

A NOTE ON THE SCATTERING OF LIGHT BY A SCALAR PARTICLE

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In a few of recent publications[1,2], devoted to the anomalous redshift phenomenon[3], an idea of de Broglie[4] is revised. This idea consists in the unified treatment of a massive photon and a pseudo-scalar massive particle without charge. The connection with anomalous redshift is realized with the hypoteses in which the observed »tired light« is due to the scattering of light by scalar particles, whose density is to be determined by the agreement with experimental data. In order not to affect Quantum Electrodynamics, and to take into account all observed phenomena, it was argued in[1] that a »model interaction« is subjected to the following constraints. Firstly, one has to exclude $e^+ + e^- \to 2\varphi$ (φ being scalar particle) which suggests the interaction different from the pure electromagnetic one. Further, the model has to account for the strong forward peak for the scattering and finally one has to explain the constant fractional energy loss $\langle \delta_z \rangle_\gamma$ per collision, independent on the incident photon energy in the frequency interval $10^{10}\text{Hz} < \nu < 10^{15}\text{Hz}$ as it is suggested by observations.

To this aim an effective Hamiltonian for $\gamma - \varphi$ scattering has been proposed in[1] build in closed analogy with Hamiltonian for electron-neutrino scattering originally proposed by Bethe[5] and discussed recently by Clark and Pedigo[6]. It reads

$$H_{\text{int}} = \lambda : \overline{\Psi}_\varphi (p') S^{\mu\nu} \Psi_\varphi (p) \Delta_\varphi \Psi_\gamma (k') \beta^\mu q_\nu \Psi_\gamma (k) :, \qquad (1)$$

where λ is the interaction constant, Ψ_φ (Ψ_γ) are 5(10) components of the scalar (photon) field in Duffin-Kemmer formalism, $S^{\mu\nu}$ is the spin operator of the scalar particle and β are matrices of 5(10) order, appearing in the reduction of Klein-Gordon and vector field equations of motion to the first order matrix differential equations[7]. The momentum transfer q reads $q_\nu = k_\nu - k'_\nu$ and Δ_φ is the scalar particle propagator[2].

In this note we shall show that effective Hamiltonian (1) and the conclusions which one deduces by its elaboration can not be obtained neither from the magnetic coupling of the Pauli-type, nor from the scalar or vector coupling *with scalar intermediate particle* in the framework of the Lagrangian field theory.

With respect to the coupling of Pauli-type which reads

$$H_{int} = g : \bar{\Psi}_\varphi (p') S^{\mu\nu} \Psi_\varphi (p) F_{\mu\nu} (k): \tag{2}$$

it is sufficient to notice that one has to look for the Compton-like scattering matrix for the interaction of scalar massive particle with the electromagnetic tensor field $F_{\mu\nu}$. It is straightforward to see that propagators in s and u channels do not give the strong forward enhancement of the amplitude.

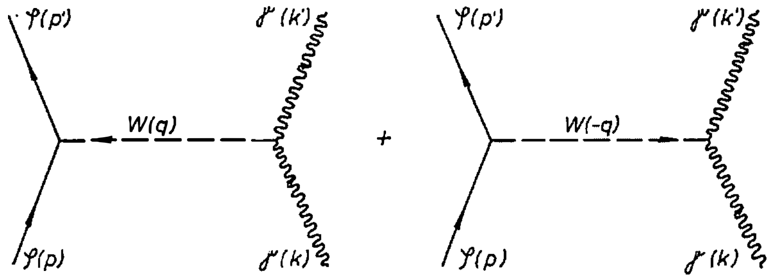

Fig. 1. Feynman diagram for $\gamma - \varphi$ scattering with scalar (4) or vector (5) couplings.

Therefore, let us consider the same process with massive photon in Duffin-Kemmer formalism using the second order perturbation theory.

Let the total Lagrangian of the system be

$$\mathcal{L} = \mathcal{L}_\gamma + \mathcal{L}_\varphi + \mathcal{L}_w + \mathcal{L}_{int} \tag{3}$$

where $\mathcal{L}_\gamma$, $\mathcal{L}_\varphi$, $\mathcal{L}_w$, are free particles Lagrangians ($\mathcal{L}_w$ being that of the intermediate scalar particle and hereafter the subscript w will denote this particle) and L_{int} can be specified for the scalar and vector coupling respectively in the following way

$$\mathcal{L}^s_{int} = - : [g_0 (\bar{\Psi} \Psi)_\varphi + g_1 (\bar{\Psi} \Psi)_\gamma] [(\bar{U} \Psi)_w + (\bar{\Psi} U)_w] :, \tag{4}$$

$$\mathcal{L}^v_{int} = - : [g_0 (\bar{\Psi} \beta^\mu \Psi)_\varphi + g_1 (\bar{\Psi} \beta^\mu \Psi)_\gamma] [\bar{U} \beta_\mu \Psi)_w + (\bar{\Psi} \beta_\mu U)_w] :. \tag{5}$$

The »spinor« U which appears in (4) and (5) is defined[8] as $U = u(q = 0)$, where $U(q)$ is the »spinor« in the Fourier decomposition of the free Duffin-Kemmer field. The Feynman diagram together with kinematical variables is represented in Fig. 1.

The S-matrix element for diagrams of Fig. 1. reads

$$S^{(2)} = - \frac{g_0 g_1}{(2\pi)^2} \left(\frac{m_\gamma^2 m_\varphi^2}{p_0 p_0' k_0 k_0'} \right)^{1/2} A \, \delta (k + p - k' - p'), \tag{6}$$

where the matrix element A is equal for the scalar coupling (4) to

$$A = \bar{u} (p') \, u (p) \frac{i \, m_w}{q^2 - m_w^2} \, \bar{u} (k'; s') \, u (k; s) \tag{7}$$

and for the vector coupling (5) we have

$$A = \bar{u} (p') \, \beta^\mu u (p) \frac{i \, q_\mu \, q_\nu - i \, g_{\mu\nu} (q^2 - m_w^2)}{m_w (q^2 - m_w^2)} \, \bar{u} (k'; s') \, \beta^\nu u (k; s), \tag{8}$$

where $s \, (s')$ denotes initial (final) photon polarisation.

By using the Mandelstam variables $s = (p + k)^2$, $t = (p' - p)^2$, $u = (k' - - p)^2$ one obtains the following differential cross-sections

$$\mathrm{d} \sigma = - \frac{g_0^2 \, g_1^2}{64 \cdot 16 \pi \, m_\varphi^2 m_\gamma^2 \, I^2} (4 \, m_\varphi^2 - t)^2 \frac{m_w^2}{(t - m_w^2)^2} (4 \, m_\gamma^2 - t)^2 \, \mathrm{d} t, \tag{9}$$

$$\mathrm{d} \sigma = - \frac{g_0^2 \, g_1^2}{12 \cdot 16 \pi \, m_\omega^2 \, m_\gamma^2 \, I^2} \{ (s - u)^2 \, m_\gamma^2 + \frac{1}{2} (4 \, m_\gamma^2 - t) \, [(s - u)^2 + + (4 \, m_\varphi^2 - t) \, t] \} \, \mathrm{d} t \tag{10}$$

for the scalar and vector coupling respectively, where we denoted

$$I^2 = \frac{1}{4} [s - (m_\varphi - m_\gamma)^2] \, [s - (m_\varphi + m_\gamma)^2].$$

Instead of variable t, it is useful to introduce the energy loss of the photon during the collision, i. e. the variable $T = E_\gamma - E_\gamma'$. Then in the laboratory system, in which the scalar particle is at rest ($\vec{p}_\varphi = 0$), and in the limit of small masses compared to the terms with E_γ and T, for the scalar coupling one obtains

$$d \sigma = c' \, \frac{T^2}{E_\gamma^2} \, \mathrm{d} \, T \tag{11}$$

and for the vector coupling one has

$$\mathrm{d} \sigma = c'' \, \frac{T \, (E_\gamma - T)}{E_\gamma} \, \mathrm{d} T. \tag{12}$$

It is seen from (11) and (12) that the desired form

$$\mathrm{d}\,\sigma = c\,\frac{E_\gamma - T}{E_\gamma\, T}\,\mathrm{d}T$$

obtained in[1] from (1) does not follow from the couplings with intermediate scalar boson in the second order perturbation theory. Therefore, in order to explain this very interesting phenomenon in the framework of the Lagrangian field theory, it is desirable to look for a more sophisticated model.

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