67

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26

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W H E N   D O E S   W E A K   I N T E R A C T I O N   B E C O M E   S T R O N G ?*

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To the Editor.

WHEN DOES WEAK INTERACTION BECOME STRONG ?

The concept of strong interaction [I] was considered in my paper "On Non-Local and Non-Linear Field Theories" which was published in the second issue of "Progress of Physics" for 1957. Strong interaction was understood there as such when during the collisions of the particles their energy is concentrated mainly in the interaction energy but not in their proper kinetic one.

A set of examples was considered on the basis of this criterion and, in particular, the electromagnetic interactions of electrons. But weak interaction of electrons with the participation of μ-mesons and neutrinos was not considered.

It appears that this interaction may become strong in the sense defined above.

The proof of this assertion is given below. This letter therefore, is a contribution to the chapter of my paper, devoted to strong interaction physics.

Let us consider the process of the interaction between neutrino and electron with the electron transformation into μ-meson.

$$\nu + e \to \mu + \nu^1 \tag{1}$$

This is an original "combinational" scattering of neutrinos on an electron.

The energy density by the order of magnitude, in this case is equal to:

$$W = g^* \bar{\Psi}_э \Psi_\mu \bar{\Psi}_\nu \Psi^1_\nu \tag{2}$$

where g^* is Fermi constant, and $\psi_э$, ψ_μ, ψ_ν are the wave functions of electron, μ-meson and neutrino, respectively.

The magnitude g^* may be written in the form:

$$\frac{g^*}{\hbar c} = \Lambda_0^2 \tag{3}$$

where Λ_0 - a certain length of the order of $\cong 16 \quad 10^{-16}$ cm

It was I.S. Shapiro who noticed the possible magnitude of this length in connection with the non-conservation of parity.

For instance, the kinetic energy density for electrons is

$$\varepsilon_э = \bar{\psi}_э \mathcal{D} \psi_э \tag{4}$$

where $\mathcal{D} = \vec{\alpha}\vec{p} + \beta mc^2$ is Dirac Hamiltonian.

Therefore, the order of the magnitude

$$\bar{\psi}_э \psi_э \cong \frac{\varepsilon_э \ell}{\hbar c} \tag{5}$$

where ℓ - the characteristic scale of space region which determines the magnitudes of the gradients so that

$$\frac{1}{c}\frac{\partial}{\partial t}, \ \frac{\partial}{\partial x} \cong 1/\ell$$

Thus, the order of the magnitude W is

$$W = \frac{g^* \ell^2}{\hbar^2 c^2} \varepsilon_э^{1/2} \varepsilon_\mu^{1/2} \varepsilon_\nu \tag{6}$$

Assuming $\varepsilon_э = \alpha\varepsilon$, $\varepsilon_\mu = \beta\varepsilon$, $\varepsilon_\nu = \gamma\varepsilon$,

where ε - the total energy density, we find:

$$\varepsilon \cong \varepsilon(\alpha + \beta + \gamma) + \frac{g^* \ell^2}{\hbar^2 c^2} \varepsilon^2 \alpha^{1/2} \beta^{1/2} \gamma. \tag{7}$$

In accordance with the definition, the interaction will be strong, if $\alpha + \beta + \gamma \ll 1 \quad (\alpha, \beta, \gamma > 0)$ i.e.

$$W = \frac{g^* \ell^2}{\hbar^2 c^2} \varepsilon^2 \alpha^{1/2} \beta^{1/2} \gamma \cong \varepsilon$$

$$\mathcal{E} > \frac{\hbar^2 c^2}{g^* \ell^2} = \frac{\hbar c}{\Lambda_0^2 \ell^2} = \mathcal{E}_{KD}. \tag{8}$$

Now let us consider the neutrino package falling on the electron (in the system of the electron and neutrino centre of gravity), with the characteristic wave length λ and with diametric dimensions $a > \lambda$. In this case the elergy density $\mathcal{E}$ is

$$\mathcal{E} = \frac{\hbar\omega}{\lambda a^2} = \frac{\hbar c}{\lambda^2 a^2}. \tag{9}$$

Further $\ell \approx \lambda$. The condition (8) gives now $a^2 < \Lambda_0^2$ since $a > \lambda$ strong interaction of electron and neutrino occurs if

$$\lambda < \Lambda_0 \tag{10}$$

The direct calculation shows that the cross-section for the considered process $\nu + e \rightarrow \mu + \nu'$ and by the order of the magnitude is equal to:

$$\sigma \cong \Lambda_0^2 \frac{\Lambda_0^2}{\lambda^2} \tag{11}$$

probably becomes greater $\pi\lambda^2$ if $\lambda < \Lambda_0$. In this connection it can be expected that at the wave lengths of the order of Λ_0 some other effects may occur, which will change essentially the electromagnetic interaction of electrons.

Namely at small distances there arises an interaction between electrons which will lead to mutual electron scattering by means of the following process: at first one of the electrons emits a pair of neutrinos (or neutrino and antineutrino) and transforms into μ-meson. The second electron absorbs these neutrinos and also transforms into another μ-meson. Then this meson emits neutrinos, which are absorbed by the first meson. As a result two scattered electrons arise.

These very processes lead to electron charge spreading, i.e., to the arising of electron "form factor".

This "form factor" will essentially change both the Compton effect on the electron at high energies of photons and the electromagnetic interaction of electrons.

The origin of such a spreading can be easily seen from the fact that besides direct absorption and emission of real or virtual photons by an electron it is also possible their absorption and emission by μ-meson arising in the temperary electron dissociation into μ-meson and a pair of neutrinos.

The situation is analogous to the arising of π-meson cloud around the nucleons. This analogy is, however, incomplete as in the case of π-meson cloud its scales are determined by the Compton length of π-meson, and in the case of electron it is the length Λ_0 which is essential but not the Compton length of μ-meson.

The effects mentioned here are also essential at the wave lengths of real or virtual photons, close to Λ_0

In conclusion one more remark about the role of the weak interaction of the mode $p \to n + e^{+} + \nu$ in nucleon collisions. As it was underlined in my paper this interaction fails to become strong at any energies.

At the same time it was assumed that the nucleon energy in the centre of gravity system is distributed in the ellipsoid volume $V \cong \ell_0^3 \sqrt{\frac{Mc^2}{E}}$, where ℓ_0-Compton length of π-mesons $(\hbar/\mu c)$ or, may be that of nucleons $(\hbar/Mc)$; E-nucleon energy in the laboratory coordinate system.

If we assume that the nucleon energy may be concentrated on any small region, then at the lengths of the nucleon waves $\lambda < \Lambda_0$ (in the centre of gravity system) the weak interaction will become essential.

We can show it by the considerations similar to those given above for neutrino and electron. It can be seen also directly from Tamm-Ivanenko theory of pair β-forces [2].

The expression for the potential of these forses states:

$$V = \frac{1}{(2\pi)^3} \frac{g^{*2}}{\hbar c \cdot R^5} = \frac{1}{(2\pi)^3} \left(\frac{\Lambda_0}{R}\right)^5 \frac{\hbar c}{\Lambda_0} \qquad (12)$$

where R - the distance between nucleons.

If $R < \Lambda_0$ then $V = \frac{\hbar c}{\Lambda_0} \gg Mc^2$.

And the nucleon is assumed to be point. Thus the estimation of the magnitudes of weak interactions in nucleon collisions depends essentially on the reliability of the assumption that the proper nucleon energy at rest is distributed in the volume not less than $\left(\frac{\hbar}{Mc}\right)^3$. The theory of meson generation in the energetic nucleon collisions confirms this last assumption [3]

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