Applying the Green's function (6), it is not difficult to obtain the following formula for the effective cross section of the scattering of an electron in an external field with radiation of n photons having energy in the interval from E_1 to E_2, independent of the number of longitudinal photons radiated in this case:

$$\sigma_n = \sigma_0 \frac{1}{n!}\left\{\frac{2e^2}{\pi}\ln\frac{E_2}{E_1}\right\}^n \quad \text{при} \quad \varepsilon_i \ll E_{\text{эл}},\ \mathbf{p}_i \ll \Delta \mathbf{P}_{\text{эл}}.$$

In conclusion, I express my deep gratitude to Acad. N. N. Bogoliubov for his direction of the work.

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On the Theory of Hyperons

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THE proposed idea consists in attributing to the nucleon an internal structure very suggestive of the structure of the hydrogen atom (see Ref. 1). We shall consider the nucleon as a system of two hypothetical particles ("m-particles"), which interact by means of a certain strong field χ. The essential difference of this model from the hydrogen atom is that the strong field is not Coulombic and is different from potentials considered earlier (the Yukawa potential and others).

In Ref. 2, the author has shown that, within the framework of the basic principles of the existing theory of elementary particles, a consideration of the relativistic field is possible, which gives (for a point source) a potential which falls off very rapidly with distance. The potential can be represented by the approximate formula

$$V(r) = -(\pi a / \sqrt{2} r)\, e^{-r^2/2\lambda^2}, \qquad (1)$$

where r is the distance from the source, a is the χ-charge of the source, λ is some positive constant-the "elementary length" (we limit ourselves to the case $\varkappa = 0$ [2], which presents the greatest interest). The field which leads in the final count to the potential (1) is defined by the equation

$$(\Box - \lambda^{-4}(x^\mu - x_0^\mu)(x^\mu - x_0^\mu))\,\chi = -4\pi a \delta(x - x_0). \qquad (2)$$

It is important, from the physical point of view, to emphasize that 1) for the χ-field, the case of a free field makes no sense, i.e., a field without sources does not exist; further, assuming formally that $a = 0$, we get on the left side of Eq. (2) an isolated point x_0 which corresponds to the position of a "virtual" source; 2) the quantization of Eq. (2) cannot give a state with definite 4-momentum, only states with definite 4-angular momentum. In particular, there does not exist for Eq. (2) a state with definite energy, i.e., there is no stationary state. Therefore, the particles of the χ-field, if they exist in nature, cannot be observed by experiments with counters, Wilson chambers, etc. One can show that, from the experimental viewpoint, these would not be particles, and in this sense, we have come across a possible limit of the applicability of the corpuscular-wave dynamics.

The potential (1) can be understood in dual fashion (limiting ourselves to fields of the Bose type with spin not greater than 1): either as the fourth component of a 4-vector, analogous to the Coulomb potential, or as a scalar or pseudoscalar. The first possibility presents the greater interest, since in this case all the constants of the problem can be determined up to the determination of the mass spectrum (but not by the mass spectrum).

Neglecting the spin of the particles which make up the nucleon by our hypothesis in first approximation, we obtain the wave equation (after separating out the motion of the center-of-mass):

$$\left\{-\left(v - i\hbar\frac{\partial}{\partial t} + aV\right)^2 + c^2\left(-i\hbar\nabla - \frac{a}{c}\mathbf{V}\right)^2 + c^2\left(mc + \frac{\gamma}{c}\Phi\right)^2\right\}\psi = 0, \qquad (3)$$

where (V, $\mathbf{V}$) are the vector, Φ the scalar, potential, a, γ are corresponding binding constants, m is the reduced mass for the v of internal motion. Let us assume that in our system of coordinates $\mathbf{V} = 0$, V is given by Eq. (1) and that Φ is the potential of the scalar meson field. For simplicity we assume that both particles of our system have the same mass m and possess unit χ-charges and meson charges γ, in which $\gamma = g/2$ (g is the meson charge of the nucleon as a whole)*. In view of this,

$$\gamma^2/\hbar c = g^2/4\hbar c \approx (^{25}/_4)\, e^2/\hbar c \approx {}^6/_{137} \ll 1, \qquad (4)$$

which validates the application of perturbation theory to the problem of the interaction with the meson field. We neglect the interaction with the electromagnetic field because of its weakness in comparison with the meson and χ-inter-over intra-nucleonic distances.

As Werle has shown[3], step by step conversion from Eq. (3) to the nonrelativistic approximation leads to the equation ($V = 0$)

$$i\hbar\, \partial\psi/\partial t = [-(\hbar^2/2m)\nabla^2 + V_v + V_s]\,\psi, \qquad (5)$$

$$V_v = aV - a^2V^2/2mc^2, \quad V_s = \gamma\Phi + \gamma^2\Phi^2/2mc^2. \qquad (6)$$

As can be seen from Eqs. (6) and (1), the m-particles do not fall on one another unless (see, for example, Ref. 4)

$$a^2/c\hbar < 1/2, \text{ т. е } a < \sqrt{c\hbar/2} \approx 3\cdot 10^{-8}\ \text{CGS}. \qquad (7)$$

If we assume that $a \approx 10^{-8}$ cgs units, we can see in Eq. (7) the reason why there is only one type of "(m–χ)-atom" nucleons, since the higher χ-charges contradict the inequality (7). In our problem there are the still undetermined constants λ and m. They are connected with a and $\hbar$ by the relation

$$\lambda a^2 \approx \hbar^2 / m, \qquad (8)$$

which follows from (see Ref. 5)

$$\int_0^\lambda V(r)\, r dr \approx -\frac{2\hbar^2}{M},$$

where M is the mass of the nucleon $\approx 1.6 \times 10^{-24}$ gm. Further, we have the relation[5]

$$2mc^2 - \varepsilon = Mc^2, \quad \hbar\sqrt{2/m\varepsilon} = r_0, \qquad (9)$$

where ϵ is the binding energy of the system, r_0 is the radius of the nucleon $\approx 10^{-13}$ cm. We then find $m \approx 1400\, m_e v$ (m_e = mass of the electron), $\epsilon \approx 450$ mev and then $\lambda = \hbar^2/ma^2 \approx 0.8 \times 10^{-14}$ cm, which is a reasonable order of magnitude for the radius of action of the interaction forces. We see that our assumptions (in contrast to the theory of Markov[1]) lead to the possibility of "dissociation" of nucleons for energies ≥ 450 mev, whereupon one ought to look for the m-particles among the heavy mesons with masses $\sim 1400\, m_e$. The dissociation level is higher than the mass of the hyperon Y_2 (mass $\sim 2570\, m_e$, excitation energy ~ 360 mev[6], the highest of the known exicted states of a nucleon.

Calculation of the excited states of the nucleon for our model is possible only in numerical fashion (for large distances, one needs also to take into account the meson interaction of the m-particles). We note that the only possible bound states with $l = 0$ (l is the orbital quantum number)[5] and equal values of n (principal quantum number) are possible. The number of such states will evidently be small (of the order of 3-4). The selection rules connected with the interaction with the meson field may allow the explanation of the comparatively large lifetimes of the hyperons.

A similar but somewhat more complicated discussion can be carried out for consideration of the spin of m-particles [an equation of the Dirac type in place of Eq. (3)] and for interaction with a pseudoscalar meson field.

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* Evidently it must be assumed that the χ-charges (similar to the electric) have two signs, while the meson charges (like gravitational) have only one sign. It follows from this assumption that the nucleon as a whole does not have a χ-charge, but does have a meson charge g.

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The Problem of the Interaction of Ultrasonic Waves in Liquids

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If a quartz plate is excited as a resonator at two different frequencies, then combination frequencies can easily be observed in the liquid medium. These suggest the possibility of investigating the phenomenon of interaction between the fundamental waves. Below we give some preliminary data on the variation of the intensity of the combination waves with distance.

Let us give briefly the experimental conditions. In order to put two waves into the medium in one