## *THE POSSIBLE IDENTIFICATION OF $\overline{\Sigma^-}$ ANTIHYPERONS IN EMULSION*

N. I. PETUKHOVA

Joint Institute for Nuclear Research

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In studies of the interaction of K-mesons with nuclei[1] it was established that $m(\Sigma^-) - m(\Sigma^+) = (15.9 \pm 2.5)\, m_e$. This mass difference may be used to identify the antihyperon $\overline{\Sigma^-}$, which is expected to decay by $\overline{\Sigma^-} \rightarrow \bar{n} + \pi^+$. From the mass difference between $\overline{\Sigma^-}$ and $\Sigma^+$ it follows that the $\pi^+$-mesons in $\overline{\Sigma^-}$ and $\Sigma^+$ decay should have different energy and different range in emulsion (10.1 and 9.1 cm respectively). The $\pi$-meson energies were calculated from the data of Shapiro.[2] The ranges are taken from the curves of Baroni et al.[3]

The ionization straggling of ranges in this energy-region is about 1 per cent. A $\pi$-meson range of 10 cm can be measured to an accuracy of 1.5 per cent. The expected difference in $\pi$-meson ranges is 10 per cent. These numbers show that identification of a $\overline{\Sigma^-}$ antihyperon is possible if the decay occurs at rest and if the $\pi^+$-meson stops in the emulsion. In order to make sure that the decay was at rest, one should look for cases in which the $\pi^+$-meson comes out backward in relation to the direction of the primary.

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[1] Fry, Schneps, Snow, Swami and Wold, Phys. Rev. 104, 270 (1956).
[2] A. M. Shapiro, Revs. Mod. Phys. 28, 164 (1956).
[3] Baroni, Castagnoli, Cortini, Franzinetti and Manfredini, Ric. Scient. 26, 1918 (1956).

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## *STATISTICAL TREATMENT OF ELEMENTARY PARTICLE STRUCTURE*

L. A. KURTENKOV

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In present-day quantum field theory, every charge interacts with a field of elementary particles in its neighborhood. For electric charge the particles are photons or pseudophotons, for nucleonic charge they are mesons, and so on. The problem of elementary particle structure is intimately connected with these fields. The question arises, whether these fields may exhibit some of the properties of ordinary particles, particularly the statistical properties.

We consider an elementary particle as a cloud of virtual particles obeying canonical statistics. The distribution of pseudophotons (with energy $\epsilon = \hbar\omega$) is given by

$$u(\omega)\, d\omega = (\hbar\omega^3(2\pi^2 c^3)\, [\exp(\hbar\omega/\Theta + \alpha) - 1]^{-1}\, d\omega; \tag{1}$$

For black-body radiation $\alpha = 0$, but in general $\alpha \neq 0$. The uncertainty principle connects the energy of a virtual particle with its duration $t$ and its distance $R$ from the center as follows,

$$\varepsilon t \sim \hbar; \;\; R \sim ct; \;\; \varepsilon = \hbar c/pR; \tag{2}$$

Here $c$ is the light-velocity and $p$ is a factor of order unity. In other words, the uncertainty principle protects us from any contradiction with energy-conservation, if we suppose that a virtual particle moving with velocity $\sim c$ and having energy $\epsilon = \hbar\omega$ can be observed at distances ranging from zero to $R \sim \hbar c/\epsilon$.

At a point at a distance $r$ one may find particles with energies from zero to $\hbar c/r$. The total energy-density at distance $r$ is thus

$$W(r)=\int_{0}^{r/c} u(\omega)\,d\omega=-\frac{\hbar c}{2p^4\pi^2}\int_{\infty}^{r}\left[\exp\left(\frac{\hbar c}{p\Theta R}+\alpha\right)-1\right]^{-1}\frac{dR}{R^5}. \tag{3}$$

where we have changed the variable of integration from $\omega$ to $c/R$.

The total energy $E$ of the virtual field is the integral of $W$ over all space. This energy we identify with the rest-energy $m_ec^2$ of the particle, supposing that other virtual fields such as the gravitational field are negligible. The energy-density $W(r)$ is then the energy-density of the Coulomb field. The integrals $W$ and $E$ are everywhere convergent. For large $r$, Eq. (3) gives

$$W(r)=1/8p^4\pi^2(e^\alpha-1)\,r^4,$$

which must be compared with the usual expression $W(r) = e^2/8\pi r^4$ for the energy-density of the electrostatic field of a charge $e$. Hence we have $\hbar c/e^2 = \pi p^4(e^\alpha - 1)$. If $p \sim 1$, $\alpha \sim 1$. On the other hand, the total energy is

$$E=m_ec^2=\frac{2\Theta}{p^3\pi}\int_{0}^{\infty}\frac{dz}{z^4}\int_{0}^{z}\frac{z^3\,dz}{e^{z+\alpha}-1},$$

which gives for $p \sim 1$

$$\Theta_e\sim e^\alpha m_ec^2\sim 10^{-4}. \tag{4}$$

This value of $\Theta$ is comparable to that which appears in the thermodynamical theory of multiple particle production,[1] $\Theta \sim m_\pi c^2 \sim 10^{-4}$. Significant deviations from the Coulomb potential should begin when $\hbar c/p\Theta R_0 \sim 1$, $R_0 \sim \hbar c/\Theta \sim 10^{-13}$ cm. The maximum energy density occurs at $r = 0$ and is given by Eq. (3)

$$W_{\max}\sim\Theta^4/e^\alpha(\hbar c)^3\sim m_e^4c^8/e^6\sim 10^{32}. \tag{5}$$

For the nucleon, the virtual particles are $\pi$-mesons with mass $m_\pi$. Their energy cannot be less than $m_\pi c^2$, and their range of action cannot exceed $R_\pi = \hbar/m_\pi c = 1/k_\pi$. This argument, as is well known,[2] leads to an estimate of the range of nuclear forces. By analogy with Eq. (3), we have

$$W(r)=-\frac{\hbar c}{2p^4\pi^2}\int_{R_\pi}^{r}\left[\exp\left(\frac{\hbar c}{p\Theta R}+\alpha\right)-1\right]^{-1}\frac{dR}{R^5};\quad E=4\pi\int_{0}^{R_\pi}W(r)\,r^2\,dr. \tag{6}$$

Here $\alpha$ and $\Theta$ will in general have new values; $m_n$ is the nucleon mass. The integrals (6) also converge. If we compare Eq. (6) with the Yukawa potential $\varphi = g e^{-k_\pi r}/r$, we find

$$\Theta_n\approx\left[\pi g^2k_\pi^4\hbar^3c/p^3m_n\right]^{1/3}\sim 10^{-4}, \tag{7}$$

which agrees with Eq. (4). This gives us some reason to make the hypothesis, $\Theta_n \sim \Theta_e$. The maximum energy-density at the center is

$$W_{\max}\approx(\Theta^4/\pi^2e^\alpha)(\hbar c)^{-3}\exp(-m_\pi c^2/\Theta)\sim 10^{32},$$

which also agrees with Eq. (5).

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[1] S. Z. Belen'kii and L. D. Landau, Usp. Fiz. Nauk 56, 309 (1955).

[2] E. Fermi, "Nuclear Physics" Lecture notes, (Chicago, 1950).

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