ELECTROMAGNETIC STRUCTURE OF THE PROTON AND NEUTRON

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As is well known, the experimental results of the study of the charge and magnetic moment distribution of the nucleon have led to a sharp contradiction with the predictions of meson theory.[1] However, it seems to us that the difficulties are to a large extent caused by an insufficient understanding of the fact that the usual interpretation of the Hofstadter results is neither unique nor exact, but merely possible. The contradiction which supposedly exists between the law of distribution of the meson charge density according to Yukawa's theory $\sim e^{-\alpha r}/r^2$ and the experimentally-obtained law $\sim e^{-\beta r}$ is also without real significance as the range of applicability of these expressions is entirely different.

The total charge and magnetic moment density in the nucleon may be written as $\rho(r) = \rho_\pi(r) + \rho_k(r)$ and $m(r) = m_\pi(r) + m_k(r)$. Here $\rho_\pi(r)$ and $m_\pi(r)$ are the charge and magnetic moment densities of the meson cloud calculated with the Salzman theory [see Eq. (15) of reference 1] taking into account only the one-pion state. By $\rho_k(r)$ and $m_k(r)$ we denote the charge and magnetic moment densities of the core. Since at the present time very little is known about the two-, three-, and higher number pion states we shall consider them as part of the nucleon core.

With the specific form for the cut-off function

$$v(k) \equiv V(\omega) = \exp\{-\beta(\omega - 1)\}, \qquad \omega = \sqrt{k^2 + 1},$$

where $\omega_{max} = 1/\beta$ = cut-off frequency, we transform Salzman's expressions for $\rho_\pi(r)$ and $m_\pi(r)$ to the form

$$\rho_\pi(r) = e\mu^3\tau_3 \frac{2f^2}{\pi^3} e^{2\beta} r^2 \int\limits_{\sqrt{r^2+\beta^2}}^{\infty} \frac{K_2^2(\rho)}{\rho^3\sqrt{\rho^2 - r^2}} d\rho,$$

$$\mathbf{m}_\pi(r) = e\mu^3 c\tau_3 \frac{f^2}{2(2\pi)^3} e^{2\beta}\, \mathbf{r} \times [\sigma \times \mathbf{r}] \left\{ \int\limits_{\sqrt{r^2+\beta^2}}^{\infty} \frac{K_2(\rho)}{\rho\sqrt{\rho^2 - r^2}} d\rho \right\}^2,$$

where $K_2(\rho)$ is a Bessel function.

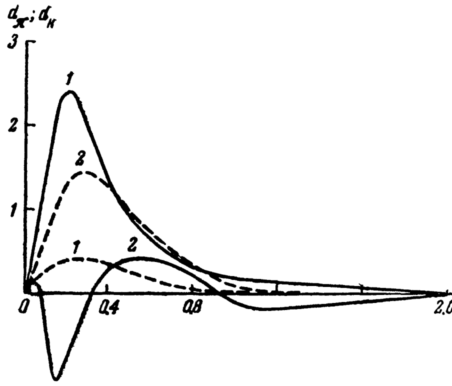
The results of the theory are not sensitive to the specific form of the cut-off. We choose $V(\omega)$ in a manner that gives simplest analytic expressions for $\rho_\pi(r)$ and $m_\pi(r)$, convenient for numerical calculations.

We choose $\beta = \hbar/7\mu_\pi c$ such that the calculated P-wave phase shift for pion-nucleon scattering is in as good agreement as possible with experiment in the low-energy region. Then we obtain for the electric and magnetic radii of the pion cloud $\langle r_e^2 \rangle_\pi = 0.19\,(\hbar/\mu_\pi c)^2$ and $\langle r_m^2 \rangle_\pi = 0.40\,(\hbar/\mu_\pi c)^2$, and for the charge and magnetic moment of the pion cloud $Q_\pi = 0.76\,e$ and $m_\pi = 1.25\,e\hbar/2Mc$.

The charge and magnetic moment distribution of the core will be taken in the form

$$\rho_k(r) = (Q_k / 8\pi a^3)\, e^{-r/a}, \qquad m_k(r) = (m_k / 8\pi a^3)\, e^{-r/a},$$

where Q_k and m_k are the charge and magnetic moment of the core. According to experiment the electric radius of the neutron $\langle r_e^2 \rangle_n \approx 0$. When this is taken into account and when the anomalous magnetic moment of the nucleon is required to be equal to the experimental value $m_N = \tau_3 \times 1.85\,e\hbar/2Mc$ one finds, with $Q_k = (1 + \tau_3)/2 - Q_\pi$, $\langle r_e^2 \rangle_p = \langle r_m^2 \rangle_n = \langle r_m^2 \rangle_p = (0.7\,f)^2$ which is in good agreement with experiment. Here we took $a = \hbar/7\mu_\pi c \approx \hbar/Mc$. In the figure are shown the values



1 – proton structure, 2 – neutron structure; solid curves refer to the charge distribution $d(r) = 4\pi r^2 \rho(r)$ in the proton and neutron, dashed curves to the charge distribution $d_k(r) = 4\pi r^2 \rho_k(r)$ in their cores; r is in units of $\hbar/\mu_\pi c = 1.4 \times 10^{-13}$ cm; d(r) and $d_k(r)$ are in units of $e\mu_\pi c/\hbar$.

of the charge in the proton and neutron and their cores.* Only for $r \gg \hbar/\mu_\pi c$, when

$$\rho(r) \sim e^{-2r} / r^2 \sqrt{r}, \qquad m(r) \sim e^{-2r} / r^2,$$

does the density curve for the proton practically coincide with the curve in Hofstadter's work:[4] the density in the neutron, on the other hand, oscillates, and this explains the small electric radius of the neutron.

Consequently, the main results of Hofstadter can be brought into agreement with meson theory.

At that, the core is characterized by a small size $a \approx \hbar/Mc \ll \hbar/\mu_\pi c$.

*Our values for $\rho_\pi(r)$ are substantially different from those of reference 2; however, as was shown in reference 3, the results in reference 2 are in error.

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RESONANT SCATTERING OF GAMMA RAYS BY Ni^{60}

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WE observed the effect of resonant scattering of gamma rays by Ni^{60} nuclei by a procedure described by us earlier.[1,2] We used a gaseous $CoCl_2$ source. The gamma rays were detected with scintillation counters consisting of organic tolane crystals and FEU-33 photomultipliers. We recorded coincidences between the emitted cascade gamma quanta. The resolution of the coincident circuit was 2×10^{-9} sec.

Nickel and cobalt scatterers were placed alternately in front of one of the detectors. Within the γ-quanta emission-angle interval $180° > \varphi > 126°$ we observed for the nickel specimen an additional absorption of the 133-Mev gamma rays, the absorption being due to resonant scattering. No additional absorption was observed in the cobalt specimen.

We list the experimentally-determined cross sections (in cm^2) of resonant scattering for various angles φ:

φ	180°	150°	90°
$10^{25}\sigma_r =$	3.9 ± 1.2	1.7 ± 1.5	0 ± 1.2

These values agree, within the limits of error, with the σ_r vs. φ curve which we computed theoretically.[3]

The lifetime of the first excited level of Ni^{60} was found to be $\tau = (1.0 \pm 0.3) \times 10^{-13}$ sec (molecular bonds were taken into account in the calculations). This result is in good agreement with that of Metzger,[4] $\tau = (1.1 \pm 0.2) \times 10^{-12}$ sec, and agrees within the limits of error with the result of Alkhazov, Lemberg, et al.[5] obtained by the Coulomb excitation method, $\tau = 5.7 \times 10^{-13}$ sec with a 30% error.

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CERTAIN GAMMA TRANSITIONS IN I^{128} *AND IN NEODYMIUM ISOTOPES*

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USING a single-crystal luminescent spectrometer with NaI(Tl) crystal we investigated the gamma radiation produced in radiative capture of thermal neutrons in iodine and in neodymium isotopes. The measurement procedure was described earlier.[1,2]

I^{128}. The emission spectrum of this nucleus contained, in the energy region from 20 to 400 kev, gamma lines with energies 28 ± 2, 135 ± 3, and 158 ± 4 kev. Their respective intensities (percent per captured neutron) were 23 ± 6, 20 ± 4,