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ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

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ELECTRIC AND MAGNETIC POLARIZABILITIES OF THE NUCLEON

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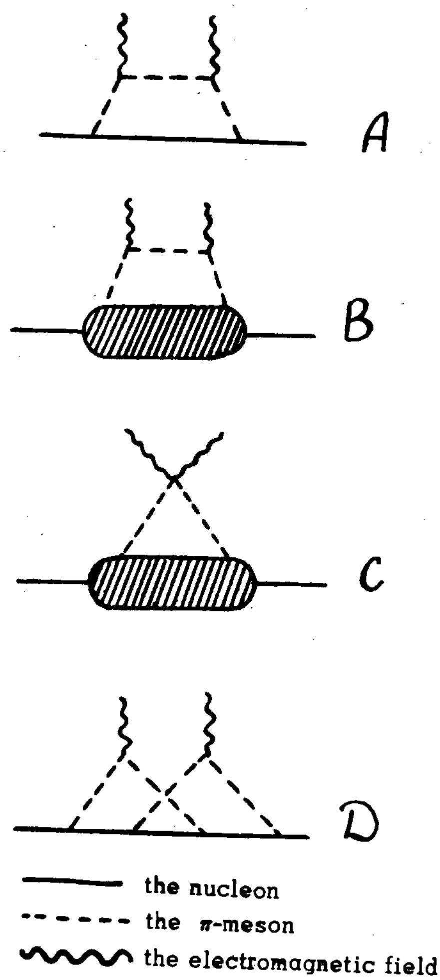
In connection with experimental determinations of the electric polarizability of the nucleon the expectation value of this polarizability $\alpha = (16 \div 18) \cdot 10^{-43}\ cm^3$ has been evaluated theoretically [1]. In the paper cited only one diagram of the type A (see Fig.) has been taken into account, the contribution of the other ones has been approximated by the factor 2. The magnitude of the magnetic polarizability β was not calculated since estimates showed that $\beta << \alpha$ *.



In connection with recently published new experimental data it is interesting to evaluate α and β more precisely .

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* The electric and magnetic polarizabilities of a nucleon are defined by the relation $H = -\frac{1}{2}\alpha E^2 - \frac{1}{2}\beta B^2$ in the static limit, where E and B are constant electric and magnetic fields respectively; H is the e^2 - proportional energy change of the nucleon due to the fields E and H [1,2].

Calculations showed that

$$\alpha = \frac{4e^2}{3\pi} f^2 \int_0^\infty dk\, e^{-k^2/a^2} \frac{k^4}{\omega^8}\left[2k^2 + 10 + \frac{k^2\omega^4}{a^4}\right] -$$

$$- \frac{e^2 a^2}{144\pi^3} \int_0^a dp\, e^{p^2/a^2} \frac{\sigma_+ + \sigma_-}{\omega_p} \int_0^\infty dk \frac{2\omega + \omega_p}{\omega^3(\omega + \omega_p)^2} e^{-k^2/a^2} \qquad (1)$$

$$\left[28 \frac{k^6}{a^6} + \left(22 + \frac{24}{a^2}\right)\frac{k^4}{a^4} - \left(3 - \frac{18}{a^2}\right)\frac{k^2}{a^2} - \frac{27}{a^2}\right]$$

$$\approx 12 \cdot 10^{-43}\ cm^3.$$

Here $\sigma_\pm(p)$ are the total cross sections for the scattering of $\pi^\pm$ - mesons by protons; $\omega_p = \sqrt{1 + p^2}$ being the energy of these mesons ; $\omega \equiv \omega_k$; $f^2 = 0,08$ — the (π N) - coupling constant; $v(k) \equiv exp(-k^2/2a^2)$ — the form factor of the mesic field source; $a = 5,6$. As usual we have set $\hbar = c = \mu_\pi = 1$.

Eq. (1) contains the contributions of the diagrams of the type B, C and D. The matrix element corresponding to the shaded regions of these diagrams is expressed with the aid of the dispersion relations in terms of f^2 and the cross sections $\sigma_\pm$. (For this it is assumed that the nucleon recoil can be neglected/5/). The α indicated in (1) contains corrections of the order f^4 and higher, which amount to $\Delta\alpha \simeq 2,5 \cdot 10^{-43} cm^3$. Diagrams of the type D do not contribute to α.

For the magnetic polarizability one obtains the value

$$\beta = \frac{2e^2}{3\pi} f^2 \int_0^\infty dk\, e^{-k^2/a^2}\left(2k^2 - 6 - \frac{k^2\omega^4}{a^4}\right)\frac{k^4}{\omega^8} +$$

$$+ \frac{16 \cdot e^2}{27\pi^2} f^4 \int_0^\infty dp \int_0^\infty dk \cdot k^2 p^2 \cdot e^{-(k^2+p^2)/a^2}\left(2 - \frac{k^2}{a^2}\right)\left(2 - \frac{p^2}{a^2}\right)\frac{\omega^2 + \omega_p^2}{\omega^3 \cdot \omega_p^3(\omega + \omega_p)} + \qquad (2)$$

$$+ \frac{e^2}{24\pi^3}\int_0^a dp\, e^{p^2/a^2}\frac{\sigma_+ + \sigma_-}{\omega_p}\int_0^\infty \frac{dk}{\omega(\omega + \omega_p)} e^{-k^2/a^2}\left(-\frac{2}{3}\frac{k^6}{a^6} + 9\frac{k^4}{a^4} - 12\frac{k^2}{a^2} + \frac{1}{2}\right) \simeq$$

$$\simeq -0,2 \cdot 10^{-43}\ cm^3;$$

In calculating β the diagrams of the type B, C, D are likewise taken into account. The contribution of the diagrams of the type D is compensated almost completely by the contribution of the corrections in B and C. The total contribution of all terms proportional to f^4 and to higher powers of f are $\Delta\beta \lesssim 0{,}1 \cdot 10^{-43}\ cm^3$. (More accurate numerical calculations of these corrections are in preparation).

The values α and β are not very dependent on the shape of $v(k)$.

In the papers 2,3 experimental values of α are given, obtained from the Compton effect on the proton. However the coefficient in the formula for the effective cross section which has been named in these papers the electric polarizability of the proton is in fact the sum of the two terms

$$\left[\frac{1}{3} \frac{e^2}{M} < r^2 > + \alpha \right]$$

where M is the mass and $\sqrt{r^2} = (0{,}8 \pm 0{,}04) \cdot 10^{-13} cm$ is the mean square radius of the proton *. The consideration of the term containing $< r^2 >$ changes noticeably the quantity α obtained from /2/,/3/.

The values of α and β (in units of $10^{-43}\ cm^3$) are given in the table with experimental uncertainties indicated .

α	β	obtained from
$\gtrsim 4$	–	photoproduction of mesons on protons [2]
$\gtrsim 4$	–	" [7]
–	~ 0	" [9]
$\lesssim 12$	–	Compton scattering by protons [2]
–	$\approx 7{,}4 - \alpha$ **	consideration of the Compton effect together with the photoproduction of π-mesons on the proton [2]
$5{,}5 \pm 2{,}3$ **	2 ± 2 **	" [3]
$7{,}5 \pm 4{,}2$	–	Compton scattering by protons [3]
$0 < \alpha < 200$	–	scattering of slow neutrons by heavy nuclei at small angles [4]
800 ± 350	–	" [8]

As is seen the theoretical values α and β are close to those of α and β obtained in /2/,/3/ from the direct analysis of the experimental data.

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* We are indebted to A.M.Baldin and V.A.Petrunkin for discussing this problem (For detail see[6]).

** In this case the uncertainties of α and β due to experimental errors in the used values of the photo - production cross sections are not indicated.

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