Polarization mechanism of nucleon magnetic moment development

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The paper considers a polarization mechanism of development of proton and neutron magnetic moments that gives a good agreement with experimental data.

Nucleon magnet moments are estimated, for example, in [1], but there is no sufficiently complete nucleon theory that would allow defining not only moments of nucleons, but their masses as well. This can be done using the polarization theory developed in [2] and revealing the polarization origin of nucleons. Instead of the commonly accepted three-quark nucleon model, a two-structure nucleon model, where a color- and electrically neutral nucleus with a zero spin comprised of quarks and localized in the polarization space exists along with the three-quark shell, is considered [2]. This model gives an agreement with experimental values of neutron and proton mass and magnetic moment to within 0.5%. The paper presents the polarization theory of their magnetic moments produced by the shell.

The quantity of interest to us – magnetic moment $\vec{\mu}_N$ – is found from the polarization condition for the sum of electrical (ε_e) and magnetic (ε_μ) energies of the shell

$$\varepsilon_e + \varepsilon_\mu = 0 \qquad (1)$$

Different types of shell quarks are polarized separately thus forming their polarization spaces. Therefore electric charges of quarks of the same type are added up: in the case of neutron (*udd*), as is known, electric charges q_u=2/3e and q_d=-2/3e are produced, and for proton (*uud*) these will be q_u=4/3e and q_d=-1/3e, respectively. Being located on the surface of the core with radius R_C, they acquire electric energy q^2/R_C. Hence

$$\varepsilon_e = \frac{q_u^2 + q_d^2}{R_C} \qquad (2)$$

The magnetic energy $\varepsilon_\mu = \vec{\mu}\vec{H}(\vec{\mu})$, where $\vec{H}(\vec{\mu})$ is the magnetic field produced by the nucleon magnetic moment:

$$\vec{H}(\vec{\mu}) = \frac{3\vec{n}(\vec{\mu}\vec{n}) - \vec{\mu}}{\vec{r}^{\,3}},$$

with $\vec{n}$ representing a unit radius vector. For quarks, the shells $\vec{r} = \vec{R}_C$, and their radius vector $\vec{R}_C$ is orthogonal with respect to the quark rotation axis along which the magnetic moment is directed. Therefore, for the shell

$$\varepsilon_\mu = -\frac{\mu^2}{R_C^3} \qquad (3)$$

From (1)–(3) there follows the value of the nucleon magnetic moment:

$$\mu = \pm(q_u^2 + q_d^2)^{1/2} R_C \qquad (4)$$

It is known from experience that a proton has a positive magnetic moment, while a neutron has a negative one. The ratio between their magnetic moments equals

$$\frac{\mu_n}{\mu_p} = -\left[\frac{\left(2/3\right)^2 + \left(-2/3\right)^2}{\left(4/3\right)^2 + \left(-1/3\right)^2}\right]^{1/2} = -\sqrt{\frac{8}{17}} = -0,686 \qquad (5)$$

The experimental values are μ_n=–1,913μ_N and μ_p=2,793μ_N, where $\mu_N = \frac{e\hbar}{2m_p c}$ is the nuclear magneton. They give $\frac{\mu_n}{\mu_p} = -0,685$, i.e. the shell approximation proves to be sufficiently accurate, supporting the nucleon model with a non-rotating spherical core and a rotating three-quark shell.

If the value of R_C is taken equal to the Compton wavelength of the core $\lambdabar_{CN} = \frac{\hbar}{m_{CN} c}$, where m_{CN} is the core mass defined as the nucleon mass minus the shell quark mass, we arrive at $\mu_n = -1{,}92\mu_N$, and $\mu_p = 2{,}80\mu_{N.}$. The agreement with experimental values (the difference less than 0.5%) counts in favor of the polarization mechanism of nucleon formation.

The polarization radius of the core is $R_C = \lambda_{CN} = 0{,}21 \cdot 10^{-13}$ cm. According to the above Assumption, it is equal to the nucleon radius in the polarization space, i.e. considerably less than the mean-square proton radius that characterizes distribution of proton electric charge in the 4-dimensional space and, according to [3], is equal to

$$\left\langle r_p^2 \right\rangle^{1/2} = (0,814 \pm 0,015) \cdot 10^{-13}\,\text{cm}. \qquad (6)$$

It should be noted that the experimental value of the limit approach of colliding nucleons correlates with the value of $2R_C$ (see, for example, [1]), i.e. it is defined by the size of nucleonic core that represent inclusions of incompressible structures of the polarization world in the Minkowski space.

We see how simple it is to calculate proton and neutron magnetic moments in the polarization nucleon model.

References

[1] Gottfried K., Weisskopf V.F. Concepts of particle physics. – M.: Mir, 1998.

[2] Chernukha V.V. Polarization theory of the Mega-universe. – M.: Atomenergoizdat, 2008.

[3] Physical Encyclopedia, **4**, 243 (1994). – M.: Sovetskaya Encyclopedia.