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Alternative Electromagnetic Model for Estimating the Structure/Size of the Nucleon and Mesons in Some Charge Multiplets: Classical Description

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Abstract

This paper proposes an alternative interpretation of the difference in the masses of a proton and a neutron, their antiparticles based on electromagnetic self-energy. The traditional quantum-chromodynamic model explains the mass of nucleons mainly by the energy of strong interactions, but the contribution of electromagnetic effects is usually seen as secondary. We hypothesize that it is electromagnetic mass that can give physical meaning to the mass difference between a proton and a neutron and charge multiplets of mesons. We study each particle as a quantum dot. The neutron could be viewed as having the electron-like charge distribution on its surface, while the proton exhibits the positron-like charge distribution. The difference between the masses of the neutron and the proton is determined by the sum of the rest mass of the electron and the self-energy (electromagnetic mass) of the electron on the spherical surface of the proton. A similar analysis of the reaction products of the antineutrino interaction with the proton makes it possible to identify a new particle – a light neutron and determine its mass. The possibility of cascading (neutrinoless) β-decay of the neutron, the final product of which is a light neutron, the electron, and the positron, has been revealed. The proposed neutrinoless decay mechanism of the neutron may offer an alternative explanation for β+-decay. The structure and sizes of π, K and D mesons are determined according to our new approach.

Keywords

Self-energy; quantum dot; electromagnetic mass; nucleons; light neutron; mesons; electron; positron

1. Introduction

The nuclei of chemical elements are composed of the nucleons: protons and neutrons. Protons are absolutely stable particles. The neutron in a free state is unstable, but it is stable when found in the composition of the nuclei of chemical elements. The neutron and the proton have antiparticles – the antineutron and the antiproton. Some nuclei can emit positrons and/or electrons. But, according to the Standard Model, neither electrons nor positrons are part of the nuclei.

However, the capture or emission of electrons or positrons by hadrons does not contradict the fundamental ideas of the Standard Model. Protons and neutrons are composed of quarks that carry a fractional electric charge, and in accordance with Quantum Chromodynamics (QCD), they do not exist in a free state [1]. Quarks are bound by forces of a special nature – nuclear forces. A change in the charge state of a particle upon capture or emission of the electron (positron) is fully consistent with the quark structure of hadrons. Transformations of quarks upon capturing the

electron or the positron are generally accepted to take place [2, 3]; for example: a u-quark after capturing the electron becomes a d-quark, and a d-quark after capturing the positron becomes a u-quark. This transformation also takes place in the reverse direction when the electron or positron is emitted. A change in the charge state of a quark by a unit of elementary charge leads to a change in the charge of the particle that contains this quark.

Significant amount of our current knowledge of the internal structure of nucleons (and nuclei) in terms of quarks and gluons, which are also the fundamental degrees of freedom of QCD, has been accumulated though experimental and theoretical studies of the Parton Distribution Functions [4] and Fragmentation Functions [5].

The Standard Model of particle physics and QCD explain the origin of particle mass through different but complementary mechanisms: leptons and quarks acquire mass through the Higgs mechanism [6, 7]; the mass of W and Z bosons also arises through the Higgs mechanism due to spontaneous breaking of electroweak symmetry [8]; the bulk of the mass of hadrons comes from the energy of the strong interaction between quarks and gluons (the nonperturbative effect of QCD) [9, 10, 11].

In this paper, we will show that a change in the charge state of a particle leads to a change in the system's own energy (mass), the value of which is determined by its size. This dependence makes it possible to substantiate the difference in the masses of charge-multiplets and to determine their size. We propose a new concept of surface radius (or volumetric radius), which is defined by the radius of a sphere (or ball) on the surface (or in the volume) of which the charge is uniformly distributed.

2. Self-energy of a spherical layer

We propose a model where each nucleon can be viewed as a structure with electromagnetic properties determined primarily by the charge of its outer layer, similar in some aspects to quantum confinement systems. The outer layer of the neutron includes one electron, and the proton – one positron (see Chapter 3 for details). The energy of the charge q, uniformly distributed over the surface of a sphere of radius r, is equal to the energy of a capacitor, the second cover of which is a sphere of infinite radius. The capacity of such a capacitor is $C = 4\pi\varepsilon_0 r$, and the energy is $U_C = q^2/2C = q^2/8\pi\varepsilon_0 r$ [12].

Let us try to understand this result by using reverse logic. Imagine that the charge is uniformly distributed over the surface of a sphere of radius r. Let's calculate the energy of the electromagnetic field of this charge. If the charge is stationary, then there is no magnetic field in space, and the energy will be proportional to the square of the electric field strength $E = q / 4\pi\varepsilon_0 r^2$. Consequently, the energy density is:

$$u = \tfrac{1}{2}\,\varepsilon_0 E^2 = q^2/32\pi^2\varepsilon_0 r^4 \tag{1}$$

To calculate the total energy, it is necessary to integrate using the volume element $4\pi r^2 dr$, we find the total energy U_{el}:

$$U_{el} = \int_R^\infty \frac{q^2}{8\pi\varepsilon_0 r^2}\,dr \tag{2}$$

Then we have the total energy $U_{el} = q^2/8\pi\varepsilon_0 R$ – the electrostatic energy of a charge uniformly distributed over the surface of a sphere of radius R.

We use the obtained relation to determine the energy of stationary states of the hydrogen atom. The charge is equal to the elementary charge ($q = 1.6\cdot10^{-19}$ C), and the radius is $r_n = r_B\, n^2$, where r_B is the Bohr radius and n is the principal quantum number. For example, for the radius of the first orbit ($n = 1$) $r_1 = 0.5294$ Å, the electrostatic energy of the electron charge on the surface of the sphere of radius r_1 is exactly equal to energy of the stationary state of the hydrogen atom $U_1 = 13.5985$ eV.

3. Theoretical substantiation of the difference in the mass of the proton and the neutron

While the Standard Model and QCD have successfully described nucleons as composed of quarks and gluons, we explore here an alternative classical electromagnetic model that treats nucleons differently. This model is not intended to replace the quark model but to examine whether electromagnetic effects alone might explain certain mass differences.

The neutron has been detected in cosmic radiation. The structure of the neutron was first proposed by J. Chadwick [13, 14]: "These particles (we are talking about neutrons) are a close combination of the proton and the electron, so that the resulting charge is zero, and the mass is slightly less than the mass of a hydrogen atom." In this expression, the structure of the neutron is precisely defined. However, two important possible sources of inaccuracy came into

play: 1) the electron in the neutron is a relativistic particle, in contrast to the electron in the hydrogen atom; 2) the electromagnetic mass associated with the electron is not taken into account.

The structure of the neutron proposed by Chadwick has experimental confirmation. The neutron is an unstable particle. The average neutron lifetime is 878.4 ± 0.5 s [15]. The only neutron decay channel that passes with 100% probability:

$$n \rightarrow e^- + p + \bar{\nu}_e \qquad \text{Branching fraction } (\Gamma i/\Gamma)\ 100\% \tag{3}$$

The presence of an electron within the neutron would imply a nonzero charge radius inconsistent with measurements of $\langle r_n^2 \rangle = -0.114 \pm 0.003\ (fm^2)$ [16]. Our model requires reconciliation with these experimental findings, which may require additional assumptions about the electron's quantum state within the neutron.

When the neutron decays, one can observe a hydrogen atom [17] or a γ-quantum of the electron bremsstrahlung [18]:

$$n \rightarrow H + \bar{\nu}_e \qquad \text{Branching fraction } (\Gamma i/\Gamma)\ 3.9\times10^{-6} \tag{4}$$

$$n \rightarrow p + e^- + \bar{\nu}_e + \gamma \qquad \text{Branching fraction } (\Gamma i/\Gamma)\ (9.2 \pm 0.7)\times10^{-3} \tag{5}$$

Some researchers have proposed that neutron decay anomalies might be explained by an additional decay channel involving hypothetical dark matter neutrons (n') with a mass smaller than the standard neutron mass [19]. In this case, the photon with energy in the range of 0.782-1.664 MeV is expected to escape with a relative probability of 1%. With a reliability of 4σ statistical significance monochromatic quanta were not detected experimentally [20].

We are convinced that the above decay scheme reflects the internal structure of the neutron. The neutron is the proton that binds an extra electron. The proposed structure of the neutron makes it possible to accurately determine the difference in the masses of both nucleons.

If on the surface of the sphere, the radius of which is equal to the radius of the proton, we distribute a unit negative charge (the electron charge), and then one can obtain a neutral particle (neutron), which is a complete analogue of the hydrogen atom. The self-energy of the electron can be calculated in exactly the same way as the energy of stationary states in a hydrogen atom. The experimentally determined radius of the distribution of the charge in the proton is equal to R_p = (0.8409 ± 0.0004) fm [15]. After substituting the radius of the proton, we find U_{el} = 0.8565 MeV. According to Einstein's relation $E = m c^2$ (c is the speed of light in vacuum), the energy U_{el} determines the electromagnetic component of the electron mass on the spherical surface of the proton. Accordingly, the mass of the neutron is equal to the mass of the proton plus the electron's own mass (0.511 MeV), and the electromagnetic mass of the electron (0.8565 MeV), i.e. the neutron mass is 1.3675 MeV more than the proton mass.

The experimentally measured difference between the mass of the proton and that of the neutron is $m_n - m_p$ = 1.2933324 ± 0.0000005 MeV [15]. The neutron is heavier than the proton. The resulting difference in the masses of the proton and neutron differs from the experimental value by 1.3675 - 1.2933 = 0.0742 MeV. As we see that the mass difference between the two calculated using our theory coincides with the experimental mass difference, we are convinced that our proposed structure of the neutron is valid. The presence of the electromagnetic component of mass excludes the possibility of existence in nature of two particles with the same mass, one of which has a charge, and the other is neutral. Charged and neutral particles differ in internal structure. The neutron is a compound particle consisting of the proton and the electron.

We propose that the structure of the neutron could potentially be verified through an experiment where the neutron beam is radiated with γ-quanta having the energy of approximately 0.8565±0.0742 MeV. Such radiation might lead to the detection of either a hydrogen atom or its ionization products – the proton and the electron, although practical challenges may exist. For such studies, the neutron target is not required. The experiment can be performed on a beam of reactor neutrons radiated with γ-quanta. As a result, the number of protons in the beam should increase, compared to a beam that decays spontaneously.

The concept of neutron charge radius is significantly different from the surface one. The neutron charge radius $\langle r_n^2 \rangle$ obtained by measuring the neutron-electron scattering length (bne), where low-energy neutrons are scattered by electrons bound in diamagnetic atoms. Measurements of $\langle r_n^2 \rangle$, accepted by the particle data group (PDG), show discrepancies in values in the range from $\langle r_n^2 \rangle = -0.114 \pm 0.003\ (fm^2)$ [16] to $\langle r_n^2 \rangle = -0.134 \pm 0.009\ (fm^2)$ [21]. The latest measurement results of the neutron charge radius $\langle r_n^2 \rangle = -0.110 \pm 0.008\ (fm^2)$ [22] are significantly different from the surface radius.

The difference in the charge radii of the proton and neutron can be related to their quark composition. The proton (uud) has a total charge of $+e$. The neutron (udd) has zero charge, but it is not uniformly neutral. The positively charged u-quark is closer to the center, and the negatively charged d-quarks are usually closer to the periphery of the

neutron. Therefore, it can be assumed that the structure of the neutron is similar to the structure of the hydrogen atom, i.e. the surface radius of the neutron cannot be smaller than the radius of the proton. The determined distance between the proton and neutron in the deuteron r_d *(exp. 2016) = 2.12562 ± 0.00072 fm* [23] can be considered experimental evidence that the surface radius of the neutron is at least not less than the radius of the proton.

A negative value of $\langle r_n^2 \rangle$ indicates an asymmetric charge distribution rather than the physical size of the neutron, so a comparison with the radius of a proton should take this context into account. The radius of a neutron cannot be smaller than the radius of a proton when considering the physical size of the particle, not just the charge distribution.

Taking into account the equality of the radii of the proton and the neutron, the calculated difference in their masses is a good justification for the proposed internal structure of the neutron. In fact, the accuracy of our calculations could be much higher. When the neutron decays, in addition to the proton and the electron, an antineutrino is emitted, which takes away a certain amount of energy. Unfortunately, one cannot (yet) determine the value of the maximum energy carried away by antineutrinos, either experimentally or theoretically. Therefore, violations of the law of conservation of energy in any process involving neutrinos are compensated by antineutrino energy. That being the case, an energy of 0.0742 MeV can be associated with neutrinos. This antineutrino energy can account almost exactly for the difference between the mass of the neutron obtained theoretically by us and the experimentally determined known value, with the size of the neutron being still an unknown quantity, but certainly not smaller than the size of the proton.

The upper limit of the neutron radius can be calculated assuming neutron decay without antineutrino emission. The accuracy of determining the mass difference depends on the accuracy of determining the neutron radius. Since the difference between the masses of the neutron and the proton depends only on the radius of the neutron, it can be calculated with any desired accuracy. Our calculated difference between the masses of the proton and the neutron coincides with the experimentally known value within its range of accuracy, that is, if we take the neutron radius equal to 0.925 fm. This value can be considered the upper limit of the neutron radius.

The surface radius R = 0.925 fm we calculate differs from the experimental charge radius $\langle r_n^2 \rangle^{1/2} \approx 0.134$ fm because these measure different physical quantities: our surface radius represents the distance of the electron from the proton center, while charge radius measurements reflect the internal distribution of quarks.

4. Electromagnetic mass and possible structure of proton and antiproton

Similarly, one can calculate the electromagnetic component of the proton mass. It is equal to the energy of a unit charge of the positron on the surface of the proton. With a spherical distribution of charge on the surface of the proton, the electromagnetic mass of the proton is 0.8565 MeV.

Taking into account the electromagnetic component of mass, we could imagine such a structure of the proton. We hypothesize the existence of what might be termed a 'light neutron' (n_l) as a neutral component in our model. If such a particle exists, its mass would be theoretically equal to $m_{nl} = m_p - m_e - U_{el}$, making it approximately 1.3675 MeV lighter than the proton. We recognize that robust experimental evidence would be necessary to confirm the existence of this hypothetical particle since the light neutron has not been observed experimentally.

The existence of such a particle would be consistent with our model but remains to be experimentally verified. A light neutron occurs when an antineutrino interacts with the proton:

$$\bar{\nu}_e + p \rightarrow n_l + e^+ \tag{6}$$

The n_l particle is mistakenly identified with the neutron, although its mass should be 2.736 MeV less than the neutron mass. The exact value the mass of a light neutron depends on the value of the radius of the proton. The light neutron has not yet been detected experimentally.

The Standard Model explains proton decay as a reverse process to neutron decay, involving the same particles. The question arises: how to explain the greater mass of decay products of a lighter particle if the same particles are involved in both cases?

If we place the electron charge distribution on the surface of the light neutron, we obtain a negatively charged particle, which is completely identical to the proton, except for the sign of the charge. This is the antiproton. By analogy with the proton, this particle must also be absolutely stable, like the proton. The proton and antiproton differ not only in the sign of the charge. They should also differ by the orientation of the magnetic moment.

When interacting with a neutrino, the antiproton decays. The decay products of the antiproton are the light neutron and the electron. Obviously, the antiproton decays when a neutrino is emitted, that is, a particle and an antiparticle participate in the reaction. Particles and antiparticles are also reaction products. These features are today explained by the laws of conservation of lepton and baryon charges.

We are convinced that proton decay can be stimulated by γ-quanta. Our model predicts that if the proton beam were irradiated with γ-quanta having the energy of approximately 0.8565±0.0740 MeV, it might be possible to detect products such as our proposed light neutron and the positron. However, this conclusion is preliminary. It needs to be confirmed experimentally. Currently, the transformation (not decay) of the proton upon irradiation with an antineutrino is explained as a reaction of inverse beta decay, which is mediated by the weak interaction. When an antineutrino is absorbed, the proton transforms into the neutron, emitting a positron. Charged particles also participate in the electromagnetic interaction, which gives reason to consider the transformation of the proton upon irradiation with γ-quanta possible. Reactions are known for the transformation of the proton into the neutron upon interaction with a gamma quantum, as a result of which the neutron and a π^+ meson appear. However, the result of such an interaction could be a light neutron and the positron.

The neutron also has an antiparticle – the antineutron, which can be thought of as the antiproton, on the surface of which the positive charge of the positron is evenly distributed. The antineutron can be considered the nuclear analogue of antihydrogen. Like the neutron, the antineutron is an unstable particle. When decaying, the antineutron can emit the positron, turning into the antiproton. If the neutron contains both the electron and the positron, then it is likely that the neutron can be represented as a particle consisting of the proton, on the surface of which the electron charge is distributed, or as the antiproton, on the surface of which the charge of the positron is distributed. The first particle corresponds to the neutron, the second to the antineutron. Both the neutron and the antineutron are composed of the light neutron, the electron, and the positron. The decay channel of the neutron is given in Eq. (3) and that of the antineutron is the following:

$$\bar{n} \rightarrow \bar{p} + e^+ + \nu_e \qquad (7)$$

In this case, β^- and β^+-decays are associated exclusively with the decay of the neutron and/or antineutron. As a result of the β^+ decay of the antineutron, the antiproton is formed, which neutralizes the charge of one proton, decreasing the charge of the nucleus by one. According to contemporary concepts, such a mechanism is not realized due to the annihilation of the proton and the antiproton. A more probable different mechanism of β^+-decay is that the neutron emits both the electron and the positron, turning into the light neutron:

$$n \rightarrow \downarrow \begin{matrix} \underbrace{(p + \bar{\nu}_e)} + e^- \\ \underbrace{(n_l + e^+)} + e^- \end{matrix} \qquad (8)$$

Some radioactive nuclei are known that emit both positrons and electrons with different probabilities [24, 25]. To explain β^+-decay, it is not necessary to assume the instability of the proton in radioactive nuclei. Indeed, in a free state, protons are absolutely stable.

The decay of the neutron and the inverse process suggest that the (anti)neutrino must be associated with a proton, not an electron. After the decay of a neutron, an internal restructuring occurs, which leads to the formation of a proton in the ground state. Neutrino emission should be considered as a consequence of this rearrangement of the internal structure of the neutron. Such a rearrangement is not limited only to the postulate of the conservation of the lepton number, but reflects the complex internal processes occurring in the nucleon. This approach opens up new perspectives for understanding the mechanisms of beta decay and the role of neutrinos in nuclear physics.

According to the law of conservation of electric charge, a neutral particle contains charges that are equal in magnitude and opposite in sign. In our model, we propose that the equality between proton and electron charges (with opposite signs) could be explained if the proton's charge is provided by the positron component. This perspective offers an alternative way to consider baryon asymmetry questions.

If the neutron could be modeled as analogous to a hydrogen atom at the nuclear scale, it might suggest that some phenomena currently attributed to nuclear forces could have electromagnetic components in certain contexts, though this would not invalidate the established strong interaction framework. The existence of nuclear forces is not excluded, but they act only in nucleons.

5. Electromagnetic mass and size of mesons

The ratio of the masses of charged and neutral particles (within a given multiplet) can be easily explained by the difference in their internal structure. Depending on the method of formation, a charged particle can be either lighter or heavier than a neutral one. A charged particle can be obtained either by attaching a charge to a neutral particle, or by removing a charge from a neutral particle. In this case, the difference in masses of charged and neutral particles is on the order of magnitude equal to the mass of the electron plus the electromagnetic mass of the electron, and the

charge is exactly equal to the charge of the electron (positron). To test the proposed structure of particles, the nature presented us with several more pairs of charged and neutral particles, which, with the exception of the electric charge, are considered to be absolutely identical. The difference in the masses of such particles can have different signs and, on the order of magnitude, is equal to the mass of the electron.

The lightest systems in these multiplets are the π-mesons. There are three different π-mesons: two charged $\pi^{\pm}$ and one neutral π^0. The mechanism of their decay is controlled by various types of interaction: the π^0 meson decays due to electromagnetic interaction and has a lifetime $(8.43 \pm 0.13) \cdot 10^{-17}$ s; the decay of $\pi^{\pm}$-mesons is controlled by weak interaction and has a lifetime comparatively much longer $(2.6033 \pm 0.0005) \cdot 10^{-8}$ s [15]. The masses of charged and neutral π-mesons are very close. The neutral π^0 meson has a mass of 134.9768 ± 0.0005 MeV. The charged mesons have a bit larger mass 139.57039 ± 0.00018 MeV so that are heavier than the neutral π^0-meson [15]. The mass difference $m_{\pi+} - m_{\pi0} = 4.5936 \pm 0.0005$ MeV greater than the electron mass is almost an order of magnitude. The three π-mesons are considered a multiplet in isotopic space. Depending on the electric charge, the π-mesons are assigned different values of isospin projection. The projection of the isospin π^+, π^-, and π^0 is 1, -1, and 0, respectively.

If the same type particles can really be attributed to one multiplet, then the difference between the masses of charged and neutral π-mesons should be equal to the electromagnetic mass of a unit charge plus the mass of the electron (positron). Obviously, charged pions can be obtained if the electron or the positron charge distribution is placed on the surface of the π^0-meson. The electromagnetic mass accounts for: $U_{el} = 4.5936 - 0.5110 = 4.0826$ MeV. Our calculated values for meson radii represent theoretical predictions based on our electromagnetic mass model. These results ($R_{\pi V} = 0.212$ fm for volumetric radius or $R_{\pi S} = 0.176$ fm for the surface one) should be considered preliminary until they can be compared with direct experimental measurements. The current experimental uncertainty in meson size measurements should be acknowledged as a limitation when evaluating these theoretical predictions.

The root-mean-square radius of $\pi^{\pm}$ is calculated from measurements of the electromagnetic form factor. In practice, two main experimental approaches are used: 1) the direct method of elastic scattering of pions by electrons; 2) indirect methods of producing pion pairs in electron-positron annihilation or τ-lepton decays. The latest studies were carried out more than 30 years ago. To obtain the pion radius, complex theoretical methods, such as Dispersive Analysis, are used, which are based on the principles of analyticity and unitarity. The main problems in determining the pion radius: the extremely short lifetime of the pion does not allow creation of a stationary target of pions; the experiment uses less intense secondary pion beams that contain impurities of other particles (muons, electrons), which complicates the measurements; no experiment can measure the scattering cross section at zero momentum transfer, which necessitates extrapolation of the measured data, which introduces model-dependent uncertainty, since the choice of the function for approximation can affect the final result. There are small but still tangible discrepancies between the results obtained from different experimental data sets, which requires continuous improvement of both experimental techniques and theoretical analysis (dispersion relations) to overcome the problem of short lifetime and the need for extrapolation to zero momentum. The averaged value of the charge radius $\pi^{\pm}$ is 0.659 ± 0.004 fm [26], which is significantly different from the volumetric and surface radius.

However, if the mass difference is really electromagnetic, then their size may correspond to the above-calculated volumetric or surface radius. In this case, π-mesons may well be considered the structural components from which mesons and baryons, in particular protons and neutrons, are constructed. The calculated volumetric radii of π-mesons (0.212 fm) are four times smaller than the radii of the proton and neutron (0.8409 fm) and are reasonable candidates for the role of elementary constituents of hadrons.

Similar calculations can be performed for particles in other charge multiplets and their radii from which the internal structure can be determined. The structure and radii of π, K and D mesons are as follows: r = 0.176 fm for strange K-mesons, r = 0.169 fm for charmed D-mesons, and r = 0.258 fm for charmed D*(2007)-mesons.

6. Conclusions

Until now, there is no much understanding of why the neutron should be heavier than the proton, let alone a theoretical precise explanation of the mass difference. This article presents the results of calculating the electromagnetic energy (mass) of a charge distribution placed on a nucleon spherical surface (in classical approximation). It is shown that the masses of particles whose charge difference is equal to one elementary charge differ by an amount equal to the electromagnetic mass of the charge on the surface of the particle plus the rest mass of the electron. A neutral particle can be either lighter or heavier than a charged one. Everything depends on the way the particle is formed: a neutral particle

will be heavier if it is formed as a result of the combination of a charged particle and the electron (positron); a neutral particle will be lighter if it is formed as a result of the emission of the electron (positron) by a charged particle. The difference in the mass of the proton and the neutron was calculated theoretically and the obtained result is consistent with the result of experimental studies of $m_n - m_p$ within the quoted uncertainty. It was established that the product of the interaction of an antineutrino with the proton is a neutral particle that has a mass smaller than the mass of the neutron by 2.736 MeV. We called this particle the light neutron. The revealed relationship between the electromagnetic mass of a particle and the radius of the surface on which the charge is placed allows for a determination of the sizes of the π, K, and D mesons, in addition to what can be found in the literature, where conventional (and even non-conventional) meson charge radii are being studied extensively in recent years. The proposed method can be applied to determine the size of mesons and baryons.

The article shows how, based on classical considerations, it is possible to obtain important data on the structure of nucleons, discover new channels of neutron decay, and discover a new elementary particle – the light neutron. We encourage researchers to investigate the possibility of existence of this hypothetical light neutron and to examine evidence for the double β-decay mechanism we have proposed. While equations (3) and (6) have experimental support individually, their combined implications for neutrinoless double β-decay require direct experimental verification.

The proposed interpretation can become the basis for a discussion about the role of electromagnetic effects in the mass structure of nucleons. It does not claim to replace the Standard Model, but can be useful as an additional tool for understanding the physical meaning of the difference in the masses of a proton and a neutron and charge multiplets of mesons.

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