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Review Article

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On The Mass Spectrum of Elementary Particles

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Annotation
In the 50s of the last century, M.I. Danysh and J. Pniewski discovered the existence of hypernuclei. In them under the action of cosmic rays, one of nucleons was turned into an excited state. In this paper, it is shown that masses and magnetic moments of such excitations coincide with properties of some elementary particles. Based on this consent, a number of elementary particles should be considered as excited states of different combinations of electrons, positrons, and protons, rather than as composed from quarks with a fractional charge.

Keywords: Hypernucleous, Excited State, Meson, Hyperon, Quark, Mass, Magnetic Moment

Excited States of Particles

The assumption that elementary particles can exist in excited states was first made in the early 50s of the last century [1]. Marian Danysh and Jerzy Pniewski suggested that the new phenomenon they discovered at studying the effect of cosmic rays on nuclei into a photoemulsion, can be explained by the transition of one of the nucleons to an excited state. They showed that the energy in this event is not enough for the birth of a new particle and one can only talk about the excited state of a nucleon. At the same time, the nuclei containing such a nucleon were called Λ-hypernucleuses and ∑-hypernucleuses, depending on the excited state of the nucleon. A year later, Nobel laureate sir Cecil Frank Powell devoted a special review to this burning issue in the journal Nature [2].

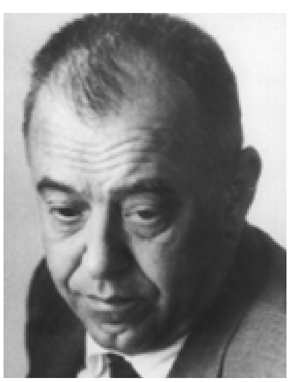

Figure 1: Academician Marian I. Danysz

Figure 2: Professor Jerzy Pniewsky

Figure 3: Nobel laureate sir Cecil Frank Powell

However, about 10 years after, the physical community leaned towards the idea of the quark structure of elementary particles, and about experimentally discovered excited states of particles was almost forgot-ten.

However, fractional quarks, despite the best efforts of experimental physicists, have not been found. And the phenomenon of confinement, which explains their lack of free states, violates the general Gilbert principle, which prohibits unobservable objects from having specific physical properties [3].

At the same time, the quark theory successfully classifies particles by certain hypothetical parameters such as oddity, isotopical spin, and quark composition, but it does not explain the measurable properties of particles, such as their masses and magnetic moments.

Particle Masses

Charged mesons as excited states of electron (positron).

According to modern concepts, μ-mesons, being leptons, do not have a quark structure and do not participate in reactions with strong in- teraction, unlike charged π±-mesons, which consist of quarks and are characterized by strong interaction with other particles.

The characteristic chain of mesons transformations $\pi^\pm \to \mu^\pm \to e^\pm$ provides a fundamentally important fact for understanding of the nature of these particles.

These particles are connected only by the successive emission of several neutrinos. Since, according to the standard theory of electromagnetism, neutrinos should be considered as a specific gamma-quantum, the emission of neutrinos is a process of energy release. I.e., pion and muon are excited states of electron. This circumstance makes it possible to calculate their masses [4-6].

What is the physics of the excited state of particles?

How can we imagine a particle (electron) in an excited state? We can assume that the excitation energy of a charged particle is determined by its kinetic energy when moving along a closed trajectory in a certain small volume of space. It is important during this movement; the particle should not radiate. This movement is carried out by an electron in a stationary orbit in the Bohr atom. Based on this analogy, we assume that a quasi-stable excited state of a particle is created if it rotates along a circle of radius R at such a speed that n de Broglie waves fit on the length of this circle.

(Where n is an integer or fractional rational number).
So that

(1) $$2\pi R = n \cdot \lambda_{dB}.$$

Given that the de Broglie wavelength of a particle is determined by the magnitude of its momentum p

(2) $$\lambda_{dB} = \frac{2\pi\hbar}{p},$$

we obtain a condition for the existence of a quasi-stable excited state of electron:

(3) $$R \cdot p = n\hbar.$$

Given the fact that we consider the motion of a charged particle, in this equation we need to use the generalized momentum of the particle, which depends on the value of the vector potential A, which is created when it moves:

(4) $$p_e^* = p_e - \frac{e}{c}A.$$

In the case of relativistic circular motion, the vector potential is determined by the magnetic moment μ0 of the circular current

(5) $$A = \frac{\mu_0}{R^2\sqrt{1-\beta^2}}$$

Since for a circular current

(6) $$\mu_0 = \frac{eR\beta}{2}$$

finally, for the case $\beta \to 1$, we obtain an expression for the generalized electron momentum

(7) $$p_e^* = p_e - \gamma\frac{\alpha\hbar}{2R}.$$

Where
$\beta = v/c$, $\gamma = \frac{1}{\sqrt{1-\beta^2}}$ are relativistic factors of electron,
$\alpha = \frac{e^2}{\hbar c}$ is the fine structure constant.

The sign of the moment of the generalized momentum (spin) of the Particle

(8) $$S = [R \times p_e^*]$$

depends on the sign of the particle's momentum, i.e. on the direction of its rotation. Therefore, when writing equality (8) in scalar form

(9) $$S = \pm\hbar\left|n - \frac{\alpha\gamma}{2}\right|$$

it should be taken into account that the quasi-equilibrium excited state of a particle can exist for both signs of spin, i.e. the mass of the particle M = γme (me is the electron mass at the rest) can be determined from
the equality:

(10) $$\alpha\gamma = 2 \cdot n \pm 2S/\hbar$$

By analogy with the model of quarks with a fractional charge, an excited electron (positron) in a quasi-stable state can be called as an integerly charged quark.

If there are Q integerly charged quarks in a closed orbit, then it's mechanical moment will increase by a factor of Q. Since the total charge of such a particle consisting of integerly charged quarks cannot be greater than one in absolute value, the contribution to the total value of the vector-potential made by additional integerly charged quarks must bezero. Therefore, for Q > 1, the equilibrium equation (10) must take into account the presence of several integerly charged quarks:

(11) $$\alpha\gamma = 2nQ \pm 2S/\hbar$$

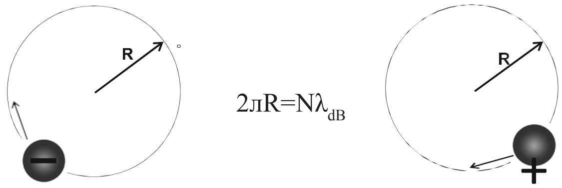

Figure 4: Illustration of a quasi-stable excited states of electron and positron, i.e. an integerly charged quarks.

3.1. Particle mass at Q = 1. Considering the case of Q = 1, S = 0, n = 1, from Eq.(11) we get the mass of a particle close to the mass of a charged $\pi^{\pm}$-meson:

$$\gamma \cdot m_e = \frac{2}{\alpha} m_e = 274.08 m_e \tag{12}$$

If $Q = 1$ and $S = \hbar/2$, then the case with a lower excitation energy is interesting, i.e. the case when n < 1.

If we choose $n = 1/4$ for this case, then by simple calculations we get the particle mass close to the mass of μ± meson:

$$\gamma_{s=\frac{1}{2}, n=\frac{1}{4}} m_e = 205.56 m_e. \tag{13}$$

For clarity, these results are summarized in the Table (1).

Table 1: The results of model calculations of the particle mass with the parameter Q = 1

the particle	possible decay	spin	particle mass Mm	Q	n	±2S/k	$\alpha\gamma$ Eq.(11)	mass γm_e	$\frac{M_m - \gamma m_e}{M_m}$
$\pi^{\pm}$	$\mu^{\pm}$	0	$273.13 m_e$	1	1	0	2	$274.1 m_e$	$-3.5 \bullet 10^{-3}$
$\mu^{\pm}$	$e^{\pm}$	$h/2$	$206.77 m_e$	1	1/4	+1/2	3/2	$205.6 m_e$	$5.8 \bullet 10^{-3}$
$K^{\pm}$	$\mu^{\pm}$	0	$966.11 m_e$	1	3.5	0	7	$959 m_e$	$7.3 \bullet 10^{-3}$

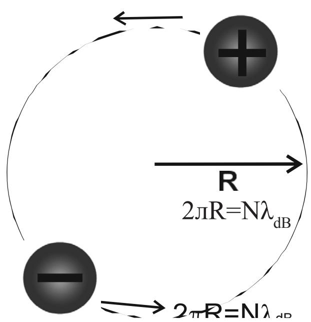

Figure 5: Illustration of the appearance of a quasistable excited state of a particle composed of two in-tegerly charged quarks (Q=2).

Particle mass at Q = 2. The spin of all particles with the parameter Q = 2 is zero. Therefore, the equality (11) in this case is converted to the form

$$\alpha\gamma = 4n \tag{14}$$

The comparison of the masses corresponding to this equality with the experimental data is shown in Table. (3.2).

TABLE 2. Results of model calculations of the particle mass with the parameter Q = 2.

particle	possible decay	spin	mass particles M_m	Q	n	±2S/k	$\alpha\gamma$ Eq.(14)	***mass*** γm_e	$\frac{M_m - \gamma m_e}{M_m}$
π^0	e^+e^-	0	*264.2m_e*	2	1/2	0	2	*274.1m_e*	$-1.9 \bullet 10^{-2}$
K^0	$\pi^+\pi^-$	0	*973.9m_e*	2	2	0	8	*1096m_e*	$-7.1 \bullet 10^{-2}$
ρ^0	$\pi^+\pi^-$	0	*1478.5m_e*	2	3	0	12	*1644m_e*	$-11.2 \bullet 10^{-2}$
ϕ^0	K^+K^-	0	*1995m_e*	2	4	0	16	*2192m_e*	$-14.6 \bullet 10^{-2}$

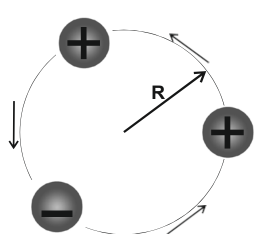

FIGURE 6. Illustration of the appearance of a quasistable excited state of a particle composed of three integerly charged quarks (Q=3).

TABLE 3. Results of model calculations of the particle mass with the parameter Q = 3.

particle	possible decay	spin	mass particles M_m	Q	n	±2S/k	αγ Eq.(11)	*mass* γm_e	$\frac{M_m - \gamma m_e}{M_m}$
ρ^+	$\pi^+\pi^0$	*h*	$1497.1m_e$	3	2	-2	10	$1370.4m_e$	$8 \cdot 10^{-2}$

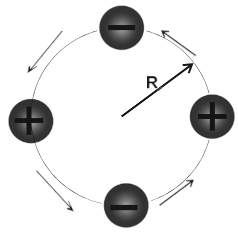

FIGURE 7: Illustration of the appearance of a quasistable excited state of a particle composed of three integerly charged quarks (Q=4).

TABLE 4. Results of model calculations of the particle mass with the parameter Q = 4.

particle	possible decay	spin	mass particles M_m	Q	n	±2S/k	αγ Eq.(14)	*mass* γm_e	$\frac{M_m - \gamma m_e}{M_m}$
η^0	$\pi^0\pi^0$	0	$1071.9m_e$	4	1	0	8	$1096m_e$	$-2.25 \cdot 10^{-2}$
ω^0	$\pi^-\pi^+\pi^0$	0	$1531.5m_e$	4	3/2	0	12	$1644m_e$	$-7.3 \cdot 10-2$

Particle mass at Q = 4. An illustration of the appearance of a quasi-stable excited state of a particle composed of four integerly charged quarks is shown in Figure (3.4). The spins of particles made up of four quarks are zero. Therefore, the masses of these particles can be obtained from Equation (14). The results of these calculations are shown in Table (3.4).

Mass of Neutron and Its Excited States

According to modern concepts, a neutron is an elementary particle, just like a proton. The assumption of this symmetry of nucleons arose at an early stage of studying the atomic nucleus.

The physical community has repeatedly discussed the question of whether the neutron should be considered a fundamental particle in the last century and has made its verdict without relying on measurement data, which at that time at the initial stage of studying the atomic nucleus simply did not exist.

I. E. Tamm was one of the first who proposed to consider the neutron as a composite particle constructed from a proton and an electron [7]. But this attempt was unsuccessful. Now it is clear that it is impossible to construct a neutron from a proton and a non-relativistic electron.

The main problem that the quark model solves by introducing lower - level quarks is to explain the mechanism of neutron-proton conversion. If to develop the approach of I. E. Tamm, then in order to construct a particle from a proton and an electron that has the properties of a neutron, we must consider an association of a proton with a relativistic electron [4].

In this way, it is possible to calculate with quite satisfactory accuracy all the main parameters of a neutron: its mass, spin, magnetic moment and energy of its decay, and the phenomenon of neutron decay itself does not require a complex explanation.

In addition, this model opens up the possibility of explaining the nature of nuclear forces, which is based on standard quantum mechanics. In this case, it becomes possible to exclude gluons, mesons, and the strong interaction (at least for light nuclei) from consideration. Importantly, this model predicts that the neutron must have excited states [8, 9].

The existence of excited states is an important feature of the Bohr atom. The excited states of the electron shell of an atom differ in different degrees of excitation. They are determined by the number of de Broglie waves of the electron that fit on the circumference of the electron orbit. Based on this principle of the formation of excited states, we can show that they exist for neutron too. Let's look at this question in more detail.

Energy of Interaction of a Relativistic Electron with Proton

Let us consider a particle similar to a Bohr atom, but with a relativistic electron. In this composite particle, an electron with a rest mass me and the charge - e (Figure (4.1)) rotates around proton on a circle of radius Re with the velocity $u \to c$.

Since the motion of this electron is relativistic, its mass will be significantly greater than the rest mass:

$$m^*_e = \gamma m_e, \quad (15)$$

where the relativistic factor

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \quad (16)$$

and $\beta = \frac{v}{c}$.

In this case, it is also necessary to take into account the movement of the proton, which will rotate around the common center of mass with the heavy electron.

In this case the movement of these particles can be characterized by a ratio of the mass of the relativistic electron to proton mass:

$$\vartheta = \frac{\gamma m_e}{M_p/\sqrt{1-\beta_p^2}}. \quad (17)$$

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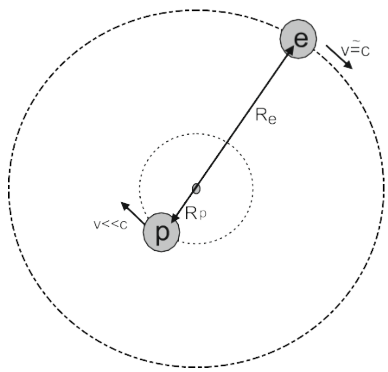

Figure 8: A heavy (relativistic) electron, revolving around a common center of mass whit a proton.

Given the condition of equal momenta, we have $\beta_p = \upsilon$, and therefore radii of electron and proton orbits are determined by equalities:

$$R_e = \frac{R_{ep}}{1+\vartheta}, \qquad R_p = \frac{R_{ep}\vartheta}{1+\vartheta}. \quad (18)$$

Where $R_{ep} = R_e + R_p$

At that the electron relativistic factor is equal to

$$\gamma = \frac{\vartheta}{\sqrt{1-\vartheta^2}} \frac{M_p}{m_e}. \quad (19)$$

A magnetic field applied to proton resulting from its motion along a circle of radius Rp can be defined according to Larimore's theorem. The value of this field is determined by the gyromagnetic ratio of proton. As a result of this field, the proton magnetic moment will be oriented parallel to the axis of rotation.

Quantization of a stable orbit

We will assume that the condition for forming a stable orbit of a relativistic electron must be the same as in the Bohr hydrogen atom. That is, the stable orbit of a relativistic electron in our case will be if an integer number of de Broglie wavelengths λdB first on the circumference of the electron ring 2πRe, i.e., if

$$\mathbf{2\pi R_e = n\,\lambda_{dB}}. \quad (20)$$

Where n is integer and

$$\lambda_{dB} = \frac{2\pi\hbar}{\gamma m_e c}. \quad (21)$$

In other words, the stability condition of the electron orbit has the form:

$$\frac{r_c}{R_e} = \frac{\vartheta}{n\sqrt{1-\vartheta^2}} \frac{M_p}{m_e} = \frac{\gamma}{n} \quad (22)$$

Where $r_c = \frac{\hbar}{m_e c}$ is the Compton's radius.

Kinetic Energy of the Relativistic Electron + Proton system

The kinetic energy of relativistic electron is determined by the standard equation:

$$\mathcal{E}^e_{kin} = (\gamma - 1)\cdot m_e c^2. \quad (23)$$

Since we assume the electron is ultra-relativistic one (γ »1), we have Approximately

$$\mathcal{E}^e_{kin} \approx \gamma \cdot m_e c^2 \quad (24)$$

The centrifugal force acting on an electron is equal to

$$\mathcal{F}_1 = \gamma m_e[\omega[\omega, R_e]] = \frac{\gamma m_e c^2}{R_e} \quad (25)$$

The kinetic energy of the proton can be written as:

$$\mathcal{E}^p_{kin} = \left(\frac{1}{\sqrt{1-\vartheta^2}} - 1\right)\cdot M_p c^2 \quad (26)$$

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Coulomb Interaction in the Relativistic Electron + Proton System. There is a Coulomb attraction between proton and electron. Taking into account the relativism of the electron, it has the value [10], §24:

$$\mathcal{E}_C = -\gamma\frac{e^2}{R_{ep}} = -\gamma\frac{\alpha r_c}{R_e(1+\vartheta)} m_e c^2. \quad (27)$$

Therefore, the Coulomb force acting between these particles is equal to

$$\mathcal{F}_2 = -\gamma\frac{e^2}{R_{ep}^2} = -\gamma\frac{\alpha}{(1+\vartheta)^2}\frac{r_c}{R_e}\frac{m_e c^2}{R_e}. \quad (28)$$

Magnetic Interaction of a Rotating Relativistic Electron with Proton.

Magnetic energy of the current ring formed by electron. The electron rotation creates an additional contribution to the kinetic energy of the system. This energy of the magnetic field, which occurs due to the electron rotation, tends to break the electron current ring. It depends on the circular current J and the magnetic flux ϕ created by it

$$\mathcal{E}_\Phi = \frac{\Phi J}{2}. \quad (29)$$

As the motion of the electron in the orbit is quantized, the magnetic flux connected with the ring of current must be equal to the quantum of the magnetic flux ϕ0:

$$\Phi = \Phi_0 = \frac{2\pi\hbar c}{e}. \quad (30)$$

The strength of a circular current in the ring J_0 can be expressed through of its magnetic moment and the ring area S_0:

$$J_0 = \frac{\mu_0}{S_0}. \quad (31)$$

As a result, we have

$$\mathcal{E}_{\Phi_e} = \frac{\Phi_0 J_0}{2} = \frac{e^2}{R_e}\frac{1}{2\alpha}\frac{r}{R_e} = \frac{1}{2n}\frac{\vartheta}{\sqrt{1-\vartheta^2}} \cdot M_p c^2. \quad (32)$$

A force arises in the current ring, which tends to break it, with account Equation (19), turns out to be equal to

$$\mathcal{F}_3 = \frac{\gamma}{2n}\frac{m_e c^2}{R_e}. \quad (33)$$

The proton's rotation induces significantly less magnetic energy

$$\mathcal{E}_{\Phi_p} = \frac{\sqrt{2}\cdot\vartheta^2}{\sqrt{1-\vartheta^2}} \cdot M_p c^2. \quad (34)$$

The force induced in this case does not directly affect the equilibrium orbit of electron since it is applied to proton.

Interaction of electron with a proton's magnetic field. In this case, the proton possesses two magnetic moments. It is its own magnetic moment

$$\mu_p = \xi_p \frac{e\hbar}{2M_p c} \quad (35)$$

(where ξ_p = 2:79) and its orbital magnetic moment, which occurs due to the proton rotation in an orbit of radius R_p:

$$\mu_{0p} = \frac{e\vartheta R_p}{2} \quad (36)$$

The own magnetic moment of electron does not manifest itself and it is not necessary to take it into account. As it was shown before, the generalized momentum (spin) of the electron orbit is equal to zero and the magnetic moment of electron is not included in the consideration as there is no direction for the selected orientation of electron spin [8].
The interaction energy of a rotating electron with the magnetic field of proton can be written as:

$$\mathcal{E}_\mu = \pm\frac{\gamma e}{2R_e^2}\left(\mu_{0_p} - \mu_p\right). \quad (37)$$

Given that the system must have minimal energy in a stable state, the magnetic moments μ_p and μ_{0p} must be oriented in the opposite direction and there must be a minus sign in brackets of Equation (37).

But depending on the direction of the proton's magnetic moment and the direction of rotation of electron, the contribution of this interaction to the total energy can be either positive or negative. Therefore, it is necessary to take into account both options with different signs when solving these equations.

The force acting on the rotating electron can be written as:

$$\begin{aligned}\mathcal{F}_4 &= \pm\gamma e\beta\left(\frac{\mu_{0_p}}{R_e^3} - \frac{\mu_p}{R_{ep}^3}\right) = \\ &= \pm\gamma e\left(\frac{\mu_{0_p}}{R_e^3} - \frac{\mu_p}{R_e^3(1+\vartheta)^3}\right) = \\ &= \pm\gamma\frac{m_e c^2}{R_e}\left(\frac{\vartheta^2}{2} - \frac{\xi}{(1+\vartheta)^3}\frac{\vartheta}{2n\sqrt{1-\vartheta^2}}\right)\frac{\vartheta}{2n\sqrt{1-\vartheta^2}}\alpha\frac{M_p}{m_e}.\end{aligned} \quad (38)$$

Where ξ≈2:79 is the magnetic moment of proton, expressed in Bohr magnetons.

The Electron Orbit Equilibrium. The condition of electron orbit equilibrium condition can be expressed in the form:

$$\sum_{i=1}^{4}\mathcal{F}_i = 0. \quad (39)$$

After summing of Equations. (25), (33), (28), (38) and simplifying transformations with taking into account Equation. (22), we get:

$$1 + \frac{1}{2n} - \left(\frac{\vartheta}{n\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{1}{(1+\vartheta)^2} \pm \left(\frac{\vartheta^2}{2} - \frac{\xi}{2n(1+\vartheta)^3}\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right)\right] = 0. \quad (40)$$

State with n=1. When n = 1, the equilibrium equation takes the form:

$$\begin{aligned}&1 + \frac{1}{2} - \left(\frac{\vartheta}{\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{1}{(1+\vartheta)^2}\right] - \\ &- \left(\frac{\vartheta}{\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{\vartheta^2}{2} - \frac{\xi}{2(1+\vartheta)^3}\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right] = 0.\end{aligned} \quad (41)$$

This equation has the solution

$$\vartheta = 0.1991. \quad (42)$$

State with n=2. When n=2, the equilibrium equation takes the form:

$$\begin{aligned}&1 + \frac{1}{2\cdot 2} - \left(\frac{\vartheta}{2\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{1}{(1+\vartheta)^2}\right] + \\ &+ \left(\frac{\vartheta}{2\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{\vartheta^2}{2} - \frac{\xi}{2\cdot 2(1+\vartheta)^3}\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right] = 0.\end{aligned} \quad (43)$$

Solving this equation, we get:

$$\vartheta = 0.263. \quad (44)$$

State with n=3. When n = 3, the equilibrium equation takes the form:

$$\begin{aligned}&1 + \frac{1}{2\cdot 3} - \left(\frac{\vartheta}{3\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{1}{(1+\vartheta)^2}\right] - \\ &- \left(\frac{\vartheta}{3\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{\vartheta^2}{2} - \frac{\xi}{2\cdot 3(1+\vartheta)^3}\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right] = 0.\end{aligned} \quad (45)$$

This equation has the solution:

$$\vartheta = 0.479. \quad (46)$$

Masses of considered particles. The total mass of a composite relativistic particle is determined by the sum of its relativistic kinetic energy and the mass defect, which is determined by the potential energy of their internal interaction. Let's calculate these contributions.

Kinetic Energy of Electron and Proton. After summing Equations. (24), (26), (32), (34) we get

(47)

$$\mathcal{E}(kin) = \frac{\vartheta}{\sqrt{1-\vartheta^2}}\left[1 + \left(\frac{1}{\sqrt{1-\vartheta^2}} - 1\right)\frac{\sqrt{1-\vartheta^2}}{\vartheta} + \left(\frac{1}{2n} + \sqrt{2}\vartheta\right)\right] \cdot M_p c^2$$

Potential Energy of Electron and Proton. After summing Equations. (27) and (37) we have

(48)

$$\mathcal{E}(pot) = \frac{\alpha M_p}{n m_e}\left[\frac{1}{1+\vartheta} - \frac{\vartheta^2}{2}\left(1 - \frac{1}{(1+\vartheta)^3} \cdot \frac{\xi}{n \cdot \vartheta\sqrt{1-\vartheta^2}}\right)\right]\left(\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right)^2 \cdot M_p c^2.$$

The neutron mass and masses of hyperons. The total mass of a proton and an electron, taking into account relativism, is equal to:

(49)

$$\mathcal{E}^{e+p} = m_e + M_p + \frac{\mathcal{E}(kin)}{c^2} - \frac{\mathcal{E}(pot)}{c^2} =$$
$$= m_e + M_p +$$
$$+ \frac{\vartheta}{\sqrt{1-\vartheta^2}}\left[1 + \left(\frac{1}{\sqrt{1-\vartheta^2}} - 1\right)\frac{\sqrt{1-\vartheta^2}}{\vartheta} + \left(\frac{1}{2n} + \sqrt{2}\vartheta\right)\right] \cdot M_p -$$
$$- \frac{\alpha M_p}{n m_e}\left[\frac{1}{1+\vartheta} - \frac{\vartheta^2}{2}\left(1 - \frac{1}{(1+\vartheta)^3} \cdot \frac{\xi}{n \cdot \vartheta\sqrt{1-\vartheta^2}}\right)\right]\left(\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right)^2 \cdot M_p$$

Using this formula, we can calculate the masses of the considered particles depending on the parameter n. The results of these calculations are shown in the Table (5).

When a composite particle decays, an energy equal to the sum of the kinetic and potential energy obtained from these formulas must be released. This estimate for neutron is in qualitative agreement with the measurement data.

The Mass Spectrum of Elementary Particles

The summary image of the calculated masses spectrum of considered particles in comparison with measurement data are shown in Figure (5).

Additionally, there is a large array of data on masses of charged hyperons and other heavy particles. However, it is difficult to obtain theoretical estimates for them, since taking into account their decay

TABLE 5. Values calculated particle mass in comparison with measurement data.

n	$\frac{E_{kin}}{c^2}$	$\frac{E_{pot}}{c^2}$	M_{calc} Eq.(49)	experimental data	$\Delta = \frac{M_{exp} - M_{calc}}{M_{exp}}$
n=1	$702m_e$	$700m_e$	$1839m_e$	$Mn_0 = 1837me$	0.001
n=2	$878m_e$	$605m_e$	$2108m_e$	$M\Lambda_0 = 2183me$	0.03
n=3	$2103m_e$	$1561m_e$	$2378m_e$	$M\Sigma_0 = 2335me$	0.02

patterns, they consist of a proton and several relativistic electrons (and positrons). To solve the problem of their stable state, it is necessary to solve the problem of three (or more) charged bodies that are connected by electric and magnetic forces.

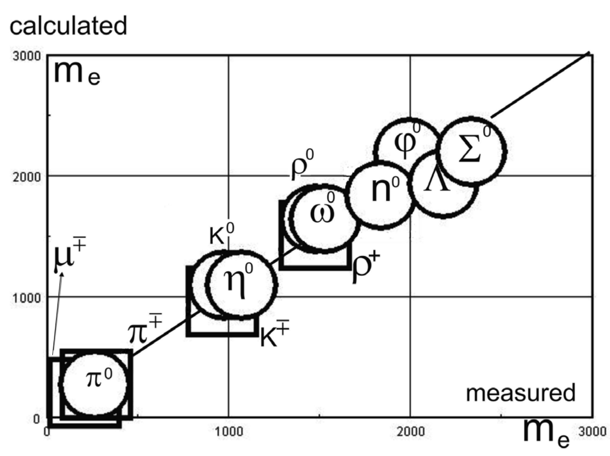

Figure 9: Comparison of calculated values of fundamental particle masses with measurement data. Circles indicate the values of the masses of neutral particles, and squares indicate the masses of charged particles.

Magnetic Moments of Particles

The criterion for the correctness of a theoretical model is its confirmation by all available experimental data. Therefore, it is important to confirm the model under consideration from a di_erent point of view. In addition to calculating the masses of particles, constructed them from integerly charged quarks, we can calculate their magnetic moments and compare their values with measurement data if they exist.

TABLE 6. Comparison of calculated values of magnetic moments with measurement data

n	ϑ	ξ_0 Eq.(51)	ξtotal Eq.(52)	experimental data	Ref.
n=1	*0.1991*	*-4.727*	*-1. 9367*	$\xi n_0 = -1.9130427 \pm 0.0000005$	[11]
n=2	*0.263*	*-3.4147*	*-0.6247*	$\xi\Lambda^0 = -0.613 \pm 0.004$	[11]
n=3	*0.479*	*-1.4121*	*1.3779*	$\xi\Sigma^0 = 1.61 \pm 0.08$	[11]

The magnetic moments of neutron and its excited states are composed of the proton magnetic moment and magnetic moment of orbital current created by electron. The electron's own magnetic moment does not participate in this since the angular momentum (spin) of the circular current created by electron is zero [8-11].

Total magnetic moment generated by circular currents

$$\mu_0 = -\frac{e\beta_e R_e}{2} + \frac{e\beta_p R_p}{2} = \frac{eR_{ep}}{2}\frac{(1-\vartheta^2)}{(1+\vartheta)} = \frac{eR_{ep}}{2}(1-\vartheta). \quad (50)$$

If to express this moment through Bohr magnetons μB, we get

$$\xi_0 = \frac{\mu_0}{\mu_B} = -\frac{(1-\vartheta^2)^{3/2}}{\vartheta}. \quad (51)$$

At summing it with the proton magnetic moment, we get

$$\xi_{total} = \left[-\frac{(1-\vartheta^2)^{3/2}}{\vartheta} + 2.79\right]. \quad (52)$$

With taking into account the values of ϑ, obtained magnetic mofiments are shown in the Table (6).

It should be noted that the magnetic moment of the ∑0-hyperon in the reference table is designated as the transition moment $\mu^0\Sigma\Delta$.

Conclusion

Thus, the development of the Danysh-Pnievsky-Powell idea of the existence of excited states of particles is able today to solve the complex problem of particle physics - to explain their mass spectrum. In cases where simple calculations can be performed, obtained values of particle masses are quite satisfactorily consistent with the measurement data.

In order to find the equilibrium conditions of such particles, for example, as charged hyperons, it is necessary to solve the problem of the motion of three (or more) charged bodies. Solving this problem requires a more complex approach. However, successful calculations of masses of neutral hyperons and other particles, which are carried out above, give hope for the success of more complex calculations of masses and magnetic moments of remaining particles.

Thus, the approach to the description of particles, based on the idea of Danysh-Pnievsky-Powell, allows us to abandon the model of quarks with a fractional charge, which are not observed in nature, and consider those objects that are commonly called elementary particles as short-term bound states of electrons, positrons and protons.

An additional good fortune is that by considering the neutron as the bound state of proton and electron, we can explain the nature of nuclear forces by the well-known quantum mechanical effect and quantitatively predict the binding energy of some (light) nuclei [8].

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