Can Elementary Particles have Excited States

Abstract

The existence of hypernuclei was discovered in a middle of the last century.

During the formation of these nuclei under the action of cosmic rays, one of the nucleons passes into its excited state and turns into the Λ- or Σ-particle.

In this paper, it is shown that various combinations and excited states of stable elementary particles have masses and magnetic moments, the values of which coincide with the masses and magnetic moments of short-lived particles with satisfactory accuracy.

Based on this agreement, it is assumed that unstable elementary particles can be excited states of various combinations of electrons, positrons and protons, and not quarks with fractional charges, as is usually assumed at present.

1. The excited state of particles

In the early 50s of the last century, an important discovery was made in elementary particle physics [**1**].

Authors of this discovery was M. Danysh and E. Pnievsky. They showed that hypernuclei can form under an action of cosmic rays in targets.

Since in these cases the energy is not enough for the birth of a new particle, and reactions observed by them consist in the formation of excited states of the nucleon of a nucleus.

M. Danysh and E. Pnievsky studied the reaction

$$K^- + {}^0n \rightarrow \Lambda + \pi^- \tag{1}$$

As K-meson and π-meson have the same decay reaction

$$K^- \rightarrow \mu^- + \nu \qquad\qquad \pi^- \rightarrow \mu^- + \nu, \tag{2}$$

it becomes clear that K^--meson is the excited state of π^--meson.

Since there are no other particles in the reaction (1), Λ-meson must be the excited state of neutron ${}^0n$.

The discovery of the possibility of the existence of particles in excited states indicated a further way of studying elementary particles.

The importance of this discovery became obvious to the Nobel laureate sir Cecil Frank Powell. He soon published in ≪Nature≫ his article "Excited Nucleons" [**2**], where he pointed out the importance of this discovery: *"We are entering a new field where basically new concepts remain to be established; but it seems reasonable to conjecture that the nucleon is transformed into an excited nucleon as a result of changes in its internal constitution. If so, we are beginning to make a new penetration into what Maxwell called "the strange strata of the material world", a penetration into the world of the nucleon."*

However, a few years later, M. Gell-Mann proposed a hypothesis about the quark structure of elementary particles, and the physical community leaned towards this idea.

The consideration of elementary particles as excited states was practically forgotten.

However, despite the efforts of experimental physicists in many laboratories around the world, quarks with a fractional electric charge have not been discovered.

In order to explain this, the idea of confinement was put forward, assuming the complete undetectability of quarks in the free state.

At the same time, the authors of the idea of confinement violated the Gilbert-Galileo principle, which imposes a ban on the existence of unobservable objects with specific physical properties [**3**], similar to angels from religious dogmas.

At the same time, despite the unobservability of quarks, it is generally accepted to classify particles based on them.

The main parameters of this classification are hypothetical immeasurable properties: quark composition, isotopic spin, strangeness, etc.

At the same time, it does not bother anyone that the quark theory does not explain the really measurable basic properties of particles - their masses and magnetic moments.

2. Particle masses

2.1. Excited states of particles. Being in a small volume of empty space, a particle can acquire an excitation due to kinetic energy if it moves along a closed trajectory.

At the same time, it is important that the particle carries out this movement without radiation, just as electron moves in a stationary orbit of a Bohr atom.

If we proceed from the analogy with Bohr atom, then a particle will acquire a quasi-stable excited state if it rotates along a circle with a radius of R at a speed at which n de Broglie waves fit along the length of this circle.

So that

$$2\pi R = n \cdot \lambda_{dB}. \tag{3}$$

The de Broglie wavelength is determined by the particle momentum p:

$$\lambda_{dB} = \frac{2\pi\hbar}{p}. \tag{4}$$

Thus, we obtain the condition of the quasi-stable excited state of particle:

$$R \cdot p = n\hbar. \tag{5}$$

If the motion of a charged particle is considered, then this equation includes the generalized momentum of the particle depending on the vector-potential A created by the magnetic field particle:

$$p_e^* = p_e - \frac{e}{c}A. \tag{6}$$

The vector-potential of the circular current is determined by the magnetic moment μ_0 of this current [**4**]:

$$A = \gamma \frac{\mu_0}{R^2\sqrt{1-\beta^2}}, \tag{7}$$

where $\gamma = \frac{1}{\sqrt{1-\beta^2}}$ and $\beta = \frac{v}{c}$ are relativistic factors.

As the magnetic moment of circular current

$$\mu_0 = \frac{eR\beta}{2} \tag{8}$$

in the case $\beta \to 1$, we have

$$p_e^* = p_e - \gamma\frac{\alpha\hbar}{2R}. \tag{9}$$

Where $\alpha = \frac{e^2}{\hbar c}$ is the fine structure constant. The sign of the particle generalized momentum (spin)

$$S = [R \times p_e^*] \tag{10}$$

depends on the direction of rotation. Therefore, when writing Eq.(10) in scalar form

$$S = \pm\hbar\left|n - \frac{\alpha\gamma}{2}\right| \tag{11}$$

it should be taken into account that the quasi-equilibrium excited state of a particle can exist at both signs of spin, i.e. the mass of the particle

$M = \gamma m_e$ (m_e is the mass of the electron at rest) can be determined from the equality:

$$\alpha\gamma = 2\hbar \cdot n \pm 2S \tag{12}$$

2.2. Mesons masses. If there are Q leptons in a closed orbit, then, accordingly, its mechanical moment will increase by Q times.

At the same time, it is known from experiments that there are no elementary particles with a charge exceeding one in absolute magnitude. Therefore, the total contribution to the value of the vector potential made by additional leptons should be zero. As a result, for $Q > 1$, the equilibrium equation (12) must take into account the presence of several leptons:

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$$M_{meson} = \frac{2}{\alpha}(nQ \pm S/\hbar)m_e \tag{13}$$

Since the spin of most mesons is zero, then for them we get:

$$M_{S=0} = \frac{2nQ}{\alpha}m_e \tag{14}$$

<u>Mesons at $Q = 1$</u>

From Eq.(14) in this gase at $S = 0$ and $n = 1$ we get the mass of a particle close to the mass of a charged $\pi^{\pm}$-meson:

$$M^{Q=1}_{S=0.n=1} = \frac{2}{\alpha}m_e = 274.08m_e \tag{15}$$

At $S = \hbar/2$, the interesting case with a lower excitation energy, i.e. when $n < 1$.

At $n = 1/4$ we get the particle mass close to the mass of $\mu^{\pm}$meson:

$$M^{Q=1}_{s=\frac{1}{2},n=\frac{1}{4}} m_e = 205.56 m_e. \tag{16}$$

Mesons at $Q = 2$

At $Q = 2$, the spin of all particles is zero and mass is defined by Eq.(14).

Meson at $Q = 3$ The calculated mass of this particle is shown in Table(1).

Mesons at $Q = 4$ Spins of these particles are zero and their masses can be obtained from Eq.(14).

All calculated meson masses in a comparison with the experimental data are shown in Table.(1).

2.3. Mass of neutron and its excited states.

the particle	possible decay	spin	meson mass M_m	Q	n	$\pm 2S/\hbar$	$\alpha\gamma$	calculated mass γm_e	$\frac{M_m-\gamma m_e}{M_m}$ %
$\pi^{\pm}$	$\to \mu^{\pm}$	0	$273.13m_e$	1	1	0	2	$274.1m_e$	-0.35
$\mu^{\pm}$	$\to e^{\pm}$	$\hbar/2$	$206.77m_e$	1	1/4	+1/2	3/2	$205.6m_e$	0.58
$K^{\pm}$	$\to \mu^{\pm}$	0	$966.11m_e$	1	3.5	0	7	$959m_e$	0.73
π^0	$\to e^+e^-$	0	$264.2m_e$	2	1/2	0	2	$274.1m_e$	-1.9
K^0	$\to \pi^+\pi^-$	0	$973.9m_e$	2	2	0	8	$1096m_e$	-7.1
ρ^0	$\to \pi^+\pi^-$	0	$1478.5m_e$	2	3	0	12	$1644m_e$	-11.2
φ^0	$\to K^+K^-$	0	$1995m_e$	2	4	0	16	$2192m_e$	-14.6
ρ^+	$\to \pi^+\pi^0$	$\hbar$	$1497.1m_e$	3	2	-2	10	$1370.4m_e$	8
η^0	$\to \pi^0\pi^0$	0	$1071.9m_e$	4	1	0	8	$1096m_e$	-2.25
ω^0	$\to \pi^-\pi^+\pi^0$	0	$1531.5m_e$	4	3/2	0	12	$1644m_e$	-7.3

TABLE 1. The results of the meson masses calculation.

2.3.1. *Neutron and neutral hyperons.* According to the generally accepted modern concept, neutron is a basic elementary particle consisting, like proton, of three quarks.

But even earlier I. E. Tamm was considering neutron as a composite corpuscule constructed from proton and electron [**5**].

If to develop the Tamm's idea, we must consider an association of proton with a relativistic electron [**6**].

It gives us a possibility to calculate all main parameters of neutron with quite satisfactory accuracy.

It turns out that the neutron mass is quite a bit higher than the mass of proton.

Ignoring this difference, we can approximately define masses of these barions:

$$M_{b^0} \cong M_{p^+} + \frac{2(n-1)}{\alpha} m_e \tag{17}$$

Where M_{p^+} is the proton mass.

The comparison of these estimates and the data of measurements is given in Table(2).

2.3.2. *Negatively charged baryons.* Similarly, negatively charged baryons can be considered as corpuscles consisting of proton and two electrons.

the particle	possible decay	spin	barion mass M_b	Q	n	calculated mass M^0	$\frac{M_b-M^0}{M_b}$ %
n^0	$\to p^+e^-$	$\hbar/2$	$1838.6m_e$	1	1	$1836.1m_e$	0.14
Λ^0	$\to p\pi^-$	$\hbar/2$	$2183.1m_e$	1	2	$2110.2m_e$	3.3
Σ^0	$\to \Lambda^0$	$\hbar/2$	$2333.6m_e$	1	3	$2384m_e$	-2.2
Ξ^0	$\to \Lambda^0\pi^0$	$\hbar/2$	$2572.8m_e$	1	4	$2658.3m_e$	-3.3

TABLE 2. Comparison of calculation results with measured masses of neutral baryons.

Orbits of each of these electrons are characterized by different parameters n_1 and n_2:

$$M_{b^-} = M_{p^+} + \frac{2(n_1 + n_2)}{\alpha} m_e. \tag{18}$$

The comparison of these estimates and the data of measurements is given in Table(3).

The final calculated distribution of particles by mass in comparison with the measurement data is shown in Fig.(1).

3. Magnetic moments of particles

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 (or positron). 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 [**7**].

Just as in the previous case, when calculating the mass, we will consider neuron (and Λ-hyperon and Σ_0-hyperon) as a corpuscule consisting of proton and relativistic electron.

In neutron, one de Broglie wavelength fits on the electron orbit.

Λ-hyperon and Σ_0-hyperon can be considered as excited states of neutron. In their electronic orbit, two and three de Broglie waves fit, respectively.

the particle	possible decay	spin	particle massM_m	Q	n_1	n_2	M_{calc}	$\frac{M_m - M_{calc}}{M_m}$ %
Σ^-	$\to \pi^-\pi^0$	$\hbar/2$	$2343.1m_e$	2	1	1	$2384.3m_e$	-1.8
Ξ^-	$\to \Lambda^0\pi^-$	$\hbar/2$	$2585.6m_e$	2	1	2	$2658.3m_e$	-2.8
Ω^-	$\to \Xi^-\pi^0$	$3/2 \cdot \hbar$	$3273.0m_e$	2	1	3	$3206.5m_e$	2.0

Table 3. The result of calculation of negatively charged barion masses .

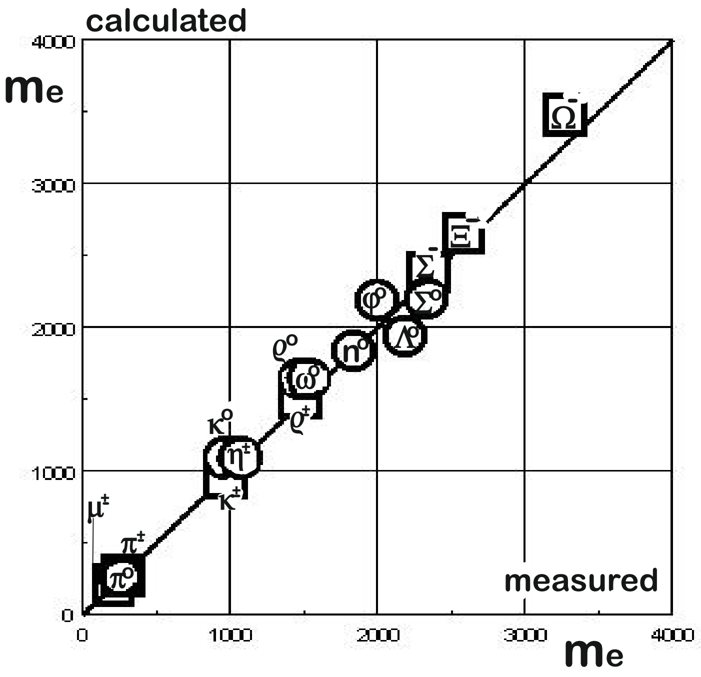

FIGURE 1. Comparison of calculated values of particle masses with measurement data. Circles indicate the values of masses of neutral particles, and squares indicate masses of charged particles.

The difference in the electron rotation speed leads to the fact that the orbital currents will create different magnetic moments for these particles, which are not difficult to calculate.

The particle Σ^+ can be represented as consisting of proton, around which electron and positron rotate in identical orbits.

In this case, the magnetic moments of the electron and positron compensate each other, and the proton's own magnetic moment remains uncompensated, which creates the main contribution to the magnetic moment of Σ^+.

A comparison of these calculated estimates with the measurement data is given in Table(4) and Figure(2).

4. Conclusion

When describing the current state of particle physics, the term "zoo" is often used.

barion	Meas.magn.moment	Calc.magn.moment
n_0	-1.9130427 ± 0.0000005	-1. 9367
Λ	0.613 ± 0.004	-0.6247
Σ_0	1.613 ± 0.08	1.3779
Σ^+	2.458 ± 0.01	≈ 2.79

TABLE 4. Comparison of calculated values of magnetic moments with measurement data

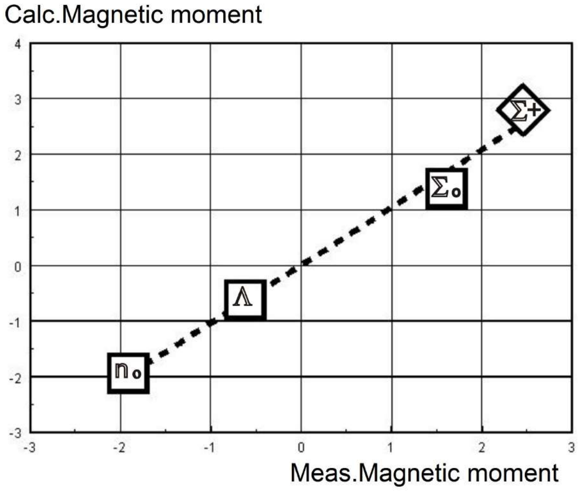

FIGURE 2. Comparison of calculated values of particle magnetic moments with measurement data.

And the point here is not only in the variety of objects of study, but also in the methodology of their research.

Modern physics seeks first of all to find a method of classifying particles by placing them in separate cells in order to distinguish their parameters.

The development of the idea of Danisch-Pniewski-Powell about the existence of excited states of particles radically simplifies this complex problem.

There are only three elementary particles - proton, electron and positron (antiproton belongs to the family of antiparticles, photons and neutrinos are not considered).

All other particles, previously classified as elementary, are considered short-lived complexes composed of three basic particles.

The approach to the description of particles based on the idea of Danysh-Pnevsky-Powell allows us to abandon the quark model and find simple formulas describing the masses and magnetic moments of short-lived complexes of three basic particles.

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 nuclei [**7**].

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