MODELLING OF ELEMENTARY PARTICLES' STRUCTURE

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Summary
Based on the previously presented model of space-time, the structural features of elementary particles formation are considered. The paper investigates the model of elementary particles formation composed of such fundamental particles as loveton, electron, neutrino, and their antiparticles. In this paper, a set of basic particles is selected from among the simplest composite elementary particles, followed by a consideration of the ways of their decay, allowing the estimation of the masses and binding energies of fundamental particles. Formulas to calculate the masses of elementary particles have been obtained, and, based on the proposed algorithm and the developed program; mass spectra of both hadrons and leptons have been calculated. Structures of the τ-lepton and proton have been determined, and a possible reason for proton stability has been revealed. The difference between hadrons and leptons, mesons and baryons is explained. Comparison of the calculated data on the masses of elementary particles obtained experimentally showed good agreement with the available empirical data. This fact confirms the validity of the procedure for the formation of composite particles based on the construction of mass formulas for their decay and shows the high efficiency of the proposed approach. Comparison of hadrons and leptons allowed us to propose a hypothesis about the possible nature of the strong interaction by considering electron-positron pairs as electric dipoles.
Key words: lepton, hadron, loveton, fundamental particle, basic particle, compound particle, binding energy, electron-positron pair

INTRODUCTION

The explanation of the mass spectrum of observable particles is one of the burning questions of modern physics. To elucidate the essence of the elementary particles of which material substance is constructed, it is first of all necessary to determine the rules and laws governing their behaviour. To date, there are a significant number of papers devoted to describing the properties and structure of elementary particles [1]. Many researchers [2-5] made a general contribution to the development of constitutive models that applied the model approach to the study of phenomena and processes in the physics of elementary particles. This issue attracts special attention not only because of the definition of the set of fundamental particles, but also because of the need to visualize the particles.

The idea that hadrons are composite particles originated as early as 1949, when Enrico Fermi and Chen-Ning Yang [6] posed the question whether all particles are equally elementary, and pointed out that the main features of Hideki Yukawa's theory can be reproduced if we accept the hypothesis that π-meson is a compound particle composed of a nucleon and an antinucleon. According to their hypothesis the positively charged π^+-meson must consist of a proton and an antineutron, the negatively charged π^--meson of a neutron and an antiproton, and the neutral π^0-meson of a mixture of proton-antiproton and neutron-antineutron pairs. The main requirement was that all quantum numbers of a compound particle must be obtained additively from the quantum numbers of the proton, neutron, and their antiparticles.

The next step in the development of the model of compound particles was the model of Maurice Goldhaber [7], where besides the proton and the neutron the K-mesons (K^+, K^0) and their antiparticles were considered as fundamental particles. In his model the baryons Λ and Σ were bound states of nucleons and antiparticles, and all the other elementary particles could be constructed from these particles. However, in spite of the more extended classification scheme, this approach has not been widely adopted.

In 1956, the model of Seichi Sakata [8] came to the fore. According to this model, there are only three fundamental baryons: the proton, neutron, and Λ-hyperon, as well as their antiparticles, from which all other mesons and baryons are formed. In this case, π-mesons are constructed in the same way as in the Fermi-Young model, and strange particles are constructed using the Λ-hyperon. Each of the mesons, according to the Sakata scheme, consists of one fundamental particle bonded to a fundamental antiparticle. They are bound so strongly that the mass defect is close to the sum of the masses of both mesons. The baryon charge of any of the mesons thus composed is zero, and the other quantum numbers, like isotopic spin and strangeness, are also correct.

Based on the Sakata model, Ken-iti Matumoto [9] proposed formula for the hadron mass in the ground state, according to which the hadron mass m is obtained by subtracting the hadron binding energy from the sum of the masses of its constituent particles and antiparticles, the binding energy is calculated as energy of repulsion of fundamental particles or their antiparticles from each other taken with opposite sign [3]

$$m = (n_N + n_{\bar{N}})m_N + (n_\Lambda + n_{\bar{\Lambda}})m_\Lambda - (n_{N\bar{N}} - n_{NN} - n_{\bar{N}\bar{N}})V(N\bar{N}) - \\ (n_{N\bar{\Lambda}} + n_{\Lambda\bar{N}} - n_{N\Lambda} - n_{\overline{N\Lambda}})V(N\bar{\Lambda}) - (n_{\Lambda\bar{\Lambda}} - n_{\Lambda\Lambda} - n_{\overline{\Lambda\Lambda}})V(\Lambda\bar{\Lambda}), \quad (1)$$

where $n_N, n_{\bar{N}}$ – are the number of nucleons and antinucleons in a compound particle; m_N, m_Λ – are the nucleon and lambda masses of the hyperon; $n_{N\bar{N}}, n_{NN}, n_{\bar{N}\bar{N}}$ – are the number of nucleon-antinucleon combinations and their combinations; $n_{N\bar{\Lambda}}, n_{\Lambda\bar{N}}, n_{\Lambda\bar{\Lambda}}$ – number of nucleon- lambda hyperon combinations and their combinations, including antiparticles; $V(N\bar{\Lambda})$, $V(\Lambda\bar{\Lambda})$, $V(N\bar{N})$ – binding energies of nucleon-lambda hyperon combinations and their combinations, including antiparticles.

The binding energy can be determined using the known mass values of the π-meson, K-meson and Ξ-particle. Here the energy involved in the formation of the material substance is divided into two components. The first component is the total rest energy of the material formations participating in the formation of a new particle, and the second refers to the binding energies between these formations.

In formula (1) the hadron mass is expressed in terms of the number of the fundamental constituent elements that make it up. If the meson is assumed to be a coupled system of strongly interacting particles and antiparticles, like the Fermi-Jang model, one will have difficulty with the multiple formations of particle-antiparticle pairs and the system will have to be treated as complex. From this point of view it seems very strange that Matsumoto formula gives qualitatively correct description of masses, in spite of the hypothesis based on a small fixed number of fundamental components. Understanding of the fact that properties of the hadron as a composite system are determined by the number of fundamental components has been of great importance for the development of further research. In other words, Sakata's model can be regarded not just as one possible classification scheme but as a theory with predictive power. Sakata's model has been improved subsequently by Harry Lipkin [10], who in 1960 has extended the model to include, apart from hadrons, leptons as well.

The next step in classifying hadrons was the model proposed in 1960 by Murray Gell-Mann [11] and independently of him by Yuval Ne'eman [12] – the so-called "octal" way. The octal path was based on two assertions: firstly, the symmetry group of hadrons is group SU(3) and the second - all hadrons are composed of the fundamental eight of baryons. Since in the said eight baryons group there are particles with close properties and close masses, it is possible that there are some stronger and more symmetric interactions. If we leave only these interactions "included", disabling together with weak and electromagnetic, strong interactions as well, then all these eight baryons will not be separate particles, but different states of one and the same particle. Moreover, the symmetry of these interactions will be exactly the one chosen in the Sakata model and, moreover, will be described by the unitary group SU(3). In this approach, the eight baryons: 2N, 3Σ, Λ, 2Ξ, called the fundamental octet, have been chosen as the fundamental particles from which all other elementary particles are composed.

Based on the octal pathway the Gell-Mann-Okubo mass formula [13] was subsequently proposed, providing a sum rule for hadron masses within a given multiplet defined by their isospin I and oddity or, alternatively, hypercharge Y

$$M = a_0 + a_1 Y + a_2 \left[I(I+1) - \frac{1}{4} Y^2 \right], \quad (2)$$

where a_0, a_1 and a_2 are free parameters. The inclusion of electromagnetic interaction leads to the splitting of the masses already inside the isotopic multiplet.

For leptons a similar rule has been discovered by Yoshio Koide [14], who proposed a formula giving the mass ratio of the three leptons: electron, muon and tauon. It has the following form

$$m_e + m_\mu + m_\tau = \frac{2}{3} (\sqrt{m_e} + \sqrt{m_\mu} + \sqrt{m_\tau})^2 \quad (3)$$

This relation, at first sight, cannot have a theoretical explanation and at first it was considered as a mere coincidence. However, the Japanese physicist Yukinari Sumino [15] has developed quite a workable field theory in which he introduces a gauge symmetry giving masses in exact accordance with the Koide formula.

In 1964 Murray Gell-Mann [16] and, independently of him, George Zweig [17] proposed a model of quarks, which drew attention to the fact that it is possible to describe all observed hadrons as a composite construction of some new particles - quarks. In the quark model any baryon is easily constructed as a combination of three quarks and meson as a combination of two quarks. The quark model differs from Sakata's model mainly in the fact that fundamental particles in it are not selected among already known ones, but belongs to a new, deeper level of matter organisation. In other words, the quark model considers all hadrons as composite particles and in this sense is equal to each other. Moreover, the capabilities of the quark model are not limited to the classification of hadrons. The model also gives quite definite predictions about the regularities to be observed in the processes of strong, electromagnetic and weak interactions in hadron decays.

The emergence of the Standard Model [18], which describes the interaction of elementary particles on the basis of quark theory, allowed to order and to classify the acquired knowledge in elementary particle physics. However, in the Standard Model the masses of particles and their ratios are postulated as constants, rather than being derived from general principles and, therefore, it is more of a descriptive theory, the development of which has advanced only in the wake of experiments. It is believed that the so-called Higgs field and its quantum Higgs boson, which determines the presence of mass in elementary particles [19], are responsible for the mechanism of mass formation, and the ratios of these masses differ from each other by many orders of magnitude. The standard model is currently inapplicable to many unsolved problems of modern physics [20]. At the same time, the explanation of the mass spectrum of observable particles may allow, and in the future, to extend and deepen our understanding of the microcosm [21]. In spite of the ongoing searches [22-26], so far the set of characteristics for particles which allow describing the mass spectrum of known elementary particles from the unified position has not been found; the proposed formulas for determination of particle masses have not led to the theoretical construction of the particle mass spectrum.

At the end of the composite particles models' consideration one can conclude that it is not yet completely possible to classify all elementary particles and resonances according to one scheme or one principle. Out of the general system fall first of all the leptons: electron, μ-meson (muon), τ-lepton (tauon), all three types of neutrinos, and their antiparticles. However, there is a rather coherent classification of mesons, baryons, mesons and baryon resonances, i.e. strongly interacting particles. At the present time elementary particle physics is at a turning point in its history, facing a new situation not previously encountered in science. Most importantly, in spite of all efforts, experimenters cannot isolate in pure form the fundamental elements that make up material objects. Attempts to derive the mass spectrum analytically from first principles have also failed. Based on the above, the main purpose of the present work was to identify such general regularities for elementary composite particles, which would allow further development of a general theory consistent with the results of experiments to estimate the mass spectrum of elementary particles.

1. RESEARCH OBJECTIVE

The main task before us is to try and describe the properties of elementary particles on the basis of the previously proposed space-time model [27] without involving any fitting parameters, under conditions of limited information on the properties of elementary particles. Analysis of the decay products of elementary particles shows that their constituent parts are the same set of fundamental particles, united with each other by energy bonds maintaining the integrity of the structure. Since space-time can be considered like a 4-dimensional lattice consisting of bound lovetons and antilovetons, it is logical to assume that the elementary particles we know can be seen as energetically excited states of local regions of this spatial lattice. In this case, the configurations of the particles should not be any, but relatively stable, representing static structures.

While carrying out this research aimed at constructing a model of elementary particles, we will define the following conditions and restrictions:

1. Let's assume that elementary particles are relatively stable configurations formed on the basis of 4-dimensional lattice of space-time loveton - antiloveton, which can be regarded as a perturbation of this space-time lattice.

2. Each elementary particle is constructed from some number of fundamental particles taking into account energies of their interrelations.

3. It is necessary to exclude from consideration dynamic effects, at construction of models of composite elementary particles, at primary stage of the ongoing research, except for the cases when these effects explain a way of formation of the structure of the particle.

4. Number and peculiarities of bonds of fundamental particles together with their masses must determine mass parameters of elementary particles completely.

5. To find the binding energies, responsible for formation of the structure of compound particles, it is necessary to calculate the masses of these particles and indicate the number of each of these bonds inside the compound elementary particle.

6. Decay products are elements of composite particles, as well as number of possible bonds between them. The daughter particles are not created in the process of decay, but are initially present in the particles in question.

7. The real dimensions of the particles are not taken into account, the particles and antiparticles are not identified separately, they are considered without any indication of their belonging to any space and the presence or absence of a charge.

8. All neutrinos are not subdivided into types and only the electron neutrino is considered in the study.

2. *MODELING*

We will model composite elementary particles by analysing the decay products of elementary particles into their constituent parts, each of which has energy bonds maintaining the integrity of the structure represented in a 4-dimensional space-time lattice.

2.1 PRIMARY ELEMENTARY PARTICLES

The most effective method used in dealing with elementary particles will be the approach where the formation of mass formulas is based on the analysis of decay schemes of composite particles. This approach allows dividing the known elementary particles into three groups: fundamental, basic and compound particles.

2.1.1 FUNDAMENTAL PARTICLES

We will consider the fundamental particles to be the true elementary particles, from which all other composite particles can be constructed. These can include such particles as free and bounded lovetons [27], electron, neutrino, as well as their antiparticles. Here, by bound lovetons and antilovetons we will understand such elements, the bonds between which allow to form cells of the space-time lattice. Besides, in the process of formation of elementary particles, we will include into their composition also particles which have been called free lovetons (antilovetons) arising due to breaking of bonds between bounded lovetons and antilovetons. All fundamental particles are united among themselves by boinding energies allowing to describe the whole spectrum of basic and compound elementary particles. The main challenge is to establish how the particles are bound together, by what rules their formation takes place, and in what quantity these bonds are created.

2.1.2 BASIC PARTICLES

All elementary particles not included into the set of fundamental particles, we will consider as composite, represented by sets of fundamental particles in different energetic unions among themselves. At the same time, to determine the binding energies between fundamental particles, we will select a number of particles which masses are measured with pinpoint accuracy. In most cases such particles are rather simple in their composition and should be composed only of fundamental particles. These particles will be called the basic particles. We will refer: proton, neutron, μ-meson, as well as π0- and π±-mesons to the basic particles. All other elementary particles will belong to the group of purely compound particles.

2.2 MASS FORMULAS FOR ELEMENTARY PARTICLES

To construct mass formulas let us consider N elementary particles with masses m_i ($i = 1, 2, . . ., N$), having a composite internal structure and described on the basis of a set of fundamental particles and the constants defining their binding energies.

2.2.1 FORMAL SCHEME OF THE MASS SPECTRUM OF ELEMENTARY PARTICLES

To consider the composite elementary particles it is necessary at first to find out the binding energies between fundamental particles, which form an internal structure of the composite particles. The basis of the current research will be the principle that all masses of basic and other composite particles are combinations of fundamental particles and their binding energies. This approach provides a system of equations representing mass formulas to quantify the bonding energies of fundamental particles. In order to find the binding energies responsible for forming the structure of elementary particles, it is also necessary to specify the number of each of these bonds within a composite particle. For this purpose, for all composite particles, including the basic particles, we will write mass formulas, based on the analysis of products of their decays.

Suppose that formally the mass m_i of an elementary compound particle can be described by the equation

$$m_i = N_L m_L + N_e m_e + N_v m_v + N_{LL} E_{LL} + N_{ee} E_{ee} + N_{Le} E_{Le} + N_{Lv} E_{Lv} + N_{ev} E_{ev}\ , \qquad (4)$$

where N_L, N_e и N_v are the numbers of, respectively, lovetons, electrons, neutrinos or their antiparticles; N_{LL}, N_{ee}, N_{Le}, N_{Lv} and N_{ev} are the numbers of bonds between the corresponding fundamental particles; E_{LL}, E_{ee}, E_{Le}, E_{Lv} and E_{ev} are the binding energies between these particles.

Equation (2) defines the mass of i-th constituent particle. Considering that the binding energies of neutrinos must be several orders of magnitude smaller than the binding energies of the lovetons and electrons, these terms can be combined and included in the term responsible for the neutrino mass. Also, in the future, we will assume that each neutrino has only one bond each with a loveton (antiloveton) and an electron (positron). These statements allow to simplify essentially calculations of binding energies of the other fundamental particles

$$m'_v = m_v + E_{Lv} + E_{ev}\ , \qquad (5)$$

where m'_v is the reduced mass of the neutrino. Substituting expression (5) in equation (2), we get

$$m_i = N_L m_L + N_e m_e + N_v m_v' + N_{LL} E_{LL} + N_{ee} E_{ee} + N_{Le} E_{Le} \ . \tag{6}$$

Equation (6) is a mass formula of a compound particle, containing quantitative relations of the number of bonds and masses, as well as the bonding energies between the fundamental particles composing them.

2.2.2 DETERMINATION THE BINDING ENERGIES OF FUNDAMENTAL PARTICLES

To determine the masses of composite elementary particles let's first find out the values of binding energies between fundamental particles composing their internal structure. The essence of the matter is that the binding energies of fundamental particles included in equation (6), proposed for determination of composite particles masses, have not been determined by anyone up to the present moment. In fact, the binding energies entered in mass formula (1) referred to slightly different set of fundamental particles and, consequently, their numerical values did not reflect real values of binding energies between fundamental particles included in a given elementary particle.

To determine the binding energies and the possible number of each of these bonds within a composite particle, let's apply the method of analysis of basic particles decays. We begin with the analysis of the neutron's decay. This case is interesting because in a rather simple way it allows to estimate the binding energy between the electron and the loveton included through the proton in the neutron composition. As a result of the neutron's decay, we will get a proton, an electron and an electron neutrino as products of this decay. Let's assume that the electron included in the neutron has only one bond with the loveton, hence, the equation to determine the neutron mass will have the form

$$m_n = m_p + m_e + m_v' + E_{Le} \ . \tag{7}$$

Knowing the masses of the basic particles included in expression (5), and considering that the reduced mass of the neutrino must be several orders of magnitude smaller relative to them, the binding energy of the loveton and electron in the neutron can be approximately estimated by the value: $E_{Le} \approx 0.78$ meV.

The terms in formula (6) for the number of bonds between the lovetons N_{LL} and the value of the binding energy itself between these E_{LL} particles are considerably more difficult to estimate. An estimate of these parameters will be made by considering the decay products of π-mesons.

Firstly, let us estimate the binding energies between the electrons E_{ee} and between the bound lovetons E_{LL}. For this purpose we will assume that the binding energies of the electrons between themselves and of the electrons with the lovetons are close in their values, i.e. $E_{ee} \approx E_{Le}$. This conclusion can be taken as plausible when considering the linear size of their contacts with each other. Similarly, let us estimate the value of the binding energy between the lovetons themselves. Taking into account that the dimensions of the loveton and electron differ approximately by a factor of seven [27], we assume the same difference in the binding energies of the lovetons E_{LL} and between the loveton and the electron E_{Le}, which leads to the value: $E_{LL} \approx 5.5$ MeV. Now, from the approximate binding energies obtained, we shall attempt to determine the number of inter loveton contacts for π^0- meson (neutral pion). In other words, let us determine the number of spatial cells of 4-dimensional space-time occupied by this particle.

It is known that π^0-meson can fall into two γ-quantas, and is thus based on a single electron-positron pair which, under annihilation, gives this result. The pion mass, as a major contribution, must contain the binding energies of the lovetons and, based on the mass of π^0-meson, we may assume that the neutral pion occupies at least two spatial cells. The bound lovetons of these cells have twenty bonds between them: $N_{LL} = 20$. The electron-positron pair entering the pion has only one bond: $N_{ee} = 1$. It remains to find out the number of bonds between the loveton and the electron.

A priori let's assume that the electron (positron) from the electron-positron pair is placed at one boundary of this formation and, therefore, has only four bonds with lovetons, and the positron (electron), being inside one of the spatial cells, has eight bonds, i.e. in total we have twelve bonds: N_{Le} = 12 (Fig. 1).

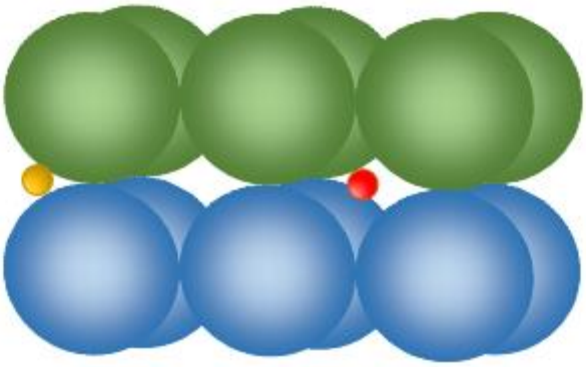

Fig. 1 Schematic structure of π^0-meson:
– bound loveton; – bound antiloveton; – electron; – positron

If one also takes into account the number of neutrinos, which, according to the way π^0-meson decays, reaches the value: N_ν = 4 (note that in the data on decays of particles only the types of neutrinos, and not their number, are specified), in this case the mass formula for π^0-meson will have the following form

$$m_{\pi^0} = 2m_e + 4m'_\nu + 20E_{LL} + E_{ee} + 12E_{Le} \quad (8)$$

As the second base particle for our study we will take π$^\pm$-мезон. Presumably this particle is based on the same π^0-meson. The difference from π^0- meson will then consist only of an additional bond between a free electron and a positron of the electron-positron pair: N_{ee} = 2, and the free electron may also have an additional four bonds with the bound lattice lovetons, allowing us to write down E_{Le} = 16 (fig. 2). The number of neutrinos being a part of π$^\pm$- meson, according to its mode of decay, would in turn increase to five neutrinos.

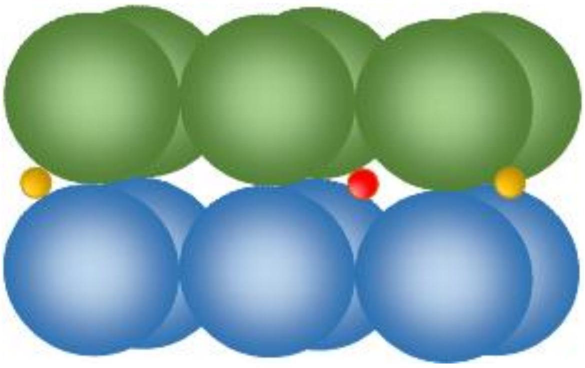

Fig. 2 Schematic structure of π$^\pm$-meson:
– bound loveton; – bound antiloveton; – electron; – positron

Based on the above logical reasoning, in accordance with formula (6), we can form the following mass equation for π$^\pm$-meson

$$m_{\pi^\pm} = 3m_e + 5m'_\nu + 20E_{LL} + 2E_{ee} + 16E_{Le} \quad (9)$$

In the proposed equation (7) we still do not know such parameters as the reduced neutrino mass and the exact values of the coupling energies of the lovetons E_{LL} and electrons E_{ee}. By neglecting the value of the reduced neutrino mass, on the basis of a joint solution of equations (6) and (7), we can approximate values for the coupling energies of the loveton-loveton pair and more precisely, the electron-electron pair: E_{LL} ≈ 6.18 meV; E_{ee} ≈ 0.96 meV.

With the approximate values of the calculated parameters available, and on the basis of the decay products analysis, we also determine the number of bonds between bound lavtons for a μ-meson (fig. 3), whose mass formula can be given by the following form

$$m_\mu = m_e + 2m'_\nu + N_{LL}E_{LL} + 8E_{Le} \tag{10}$$

Solving equation (8) with respect to the unknown parameter, which is the number of bonds between bounded lovetons, we obtain a value numerically equal to: N_{LL} = 16. The reason for this number of L-L bonds is most likely dynamic effects. Let the μ-meson occupy a single spatial cell. In this case we have 12 bonds between lovetons. Now, let the electron perform shifts arbitrarily in the horizontal plane. Here, a shift of the electron to the right, for example, partially activates in addition the spatial cell to the right of the cell occupied by the μ-meson (as shown in Fig. 3). When moving to the left, forward or backward – in place of the right-hand cell, respectively, other neighboring spatial cells can be partially activated in turn, leading to the addition of 4 more L-L bonds.

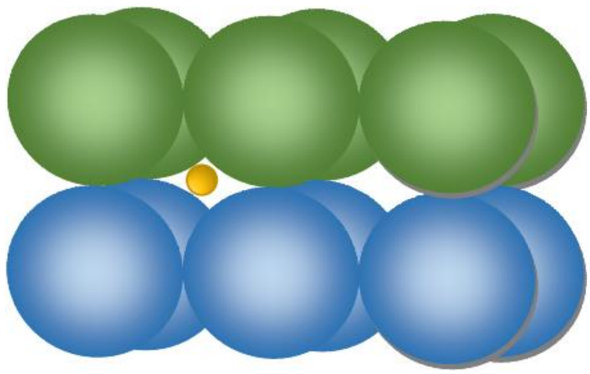

Fig. 3 Schematic structure of μ-meson (in addition to the main spatial particle cell, the figure on the right shows a partially activated cell):
– bound loveton; – bound antiloveton; – electron

Now, knowing the number of bonds between the fundamental particles, let's calculate the exact values of all the bonding energies and the reduced neutrino masses included in the formula (6). To do this we will combine expressions (7-10) in a general system of linear homogeneous equations to determine the parameters of the fundamental particles. Here we do not know the real values of the reduced neutrino mass, as well as the values of the binding energies of the fundamental particles. The solution of the proposed system of equations allows us to obtain the exact values of all these parameters (Table 1).

To conclude this parameters' consideration of the elementary particles, let us define the mass of the loveton as a fundamental particle. During the study of the 4-dimensional space-time structure model [27] from geometrical considerations the value of the mass of the loveton was obtained, which had an approximate value numerically equal to: $m_L \approx$ 892.18 meV. To estimate the real mass of the loveton let us try to form an equation for the proton structure. To do this we will distribute the difference of mass between the proton and the loveton by the number of bonds between the lovetons, as well as possible electron-positron pairs. Taking into account that the proton, being a compound particle, at the same time does not decay into other elementary particles, we will look for the presumable reason for this fact in the absence of such particles as neutrinos in its composition. In this case, the mass formula for the proton may be written in general form

$$m_p = m_L + N_e m_e + N_{LL}E_{LL} + N_{ee}E_{ee} + N_{Le}E_{Le}\ . \tag{11}$$

According to Ockham's methodological principle, which can be summarised as follows:

«entities must not be multiplied beyond necessity", we will assume that only one electron-positron pair should be included in the proton: $N_e = 2$, while we automatically get one electron-positron bond as well: $N_{ee} = 1$. Also, for the same reason, to fix the free loveton we will choose a separate face of the spatial cell. In this case it is possible to determine the number of bonds of bound lovetons equal to four, and the number of bonds of a free loveton with bound lovetons also equal to four. Therefore the total number of bonds between lovetons will be: $N_{LL} = 8$ (Fig. 4a). The number of bonds of the electron (positron) with the lovetons will be estimated considering that each of them can touch only three lovetons (Fig. 4b): $N_{Le} = 6$. Based on the above logical reasoning the mass formula for the proton can be written in the following form

$$m_p = m_L + 2m_e + 8E_{LL} + E_{ee} + 6E_{Le} \,. \quad (12)$$

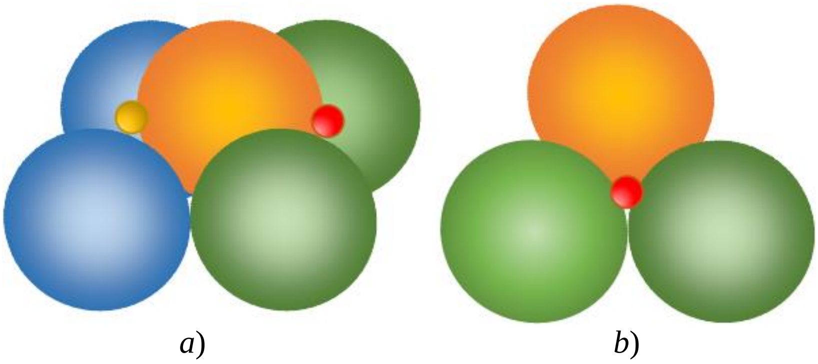

Fig. 4 Schematic structure of proton
a) general view; *b*) side right view:
● – bound loveton; ● – bound antiloveton; ● – free loveton;
● – electron; ● – positron

The obtained value of the mass of the loveton, according to equation (10), will be somewhat less than its geometrical counterpart: m_L = 882.158477726 meV. All calculated values of fundamental particles parameters, including the mass of the loveton, were then summarized together and presented in Table 1.

Table 1.

Estimated data on fundamental particles and their binding energies

Particle	Mass (meV)	Bond type	Binding energy (meV)
Loveton, *L*	882.158477726	*LL*	6.18094291005
Electron, *e*	0.51099895	*Le*	0.78127053419
Neutrino, *ν*	0.00106285981	*ee*	0.95644605733

Note. For neutrinos a value of reduced mass is given. Notations: *LL* – loveton-loveton; *Le* – loveton-electron; *ee* – electron-electron.

Now, having all values of parameters of fundamental particles it is possible to calculate values of masses of basic particles and then to compare them with known experimental data [28]. The results of the calculations are presented in table 2.

Table 2.

Mass spectrum and structural composition of basic particles

Particle	Experiment		*L*	*e*	*ν*	*LL*	*Le*	*ee*	Calculation	
	m_{exp} (meV)	abs. accuracy							m_{calc} (meV)	$\|m_{calc} - m_{exp}\|$
$\mu^{\pm}$	105.6583755	0.0000023	0	1	2	16	8	0	105.6583755	0.00000000
π^0	134.9768000	0.0005000	0	2	4	20	12	1	134.9767999	0.00000001

$\pi^{\pm}$	139.5703900	0.0001800	0	3	5	20	16	2	139.5703899	0.00000001
p	938.27208816	0.00000029	1	2	0	8	6	1	938.2720810	0.00000001
n	939.5654205	0.0000005	1	3	1	8	7	1	939.5654205	0.00000000

Note: *L* is the number of free lovetons.

3. RESULTS AND DISCUSSION

Extensive experimental data are now available for all known elementary particles, both on mass values and on the resulting product compositions after particle decay [28]. This allows the construction of mass formulas of elementary particles on the basis of experimental data on the known channels of their decay.

3.1 COMPOSITE PARTICLE FORMATION

Knowing the masses of the loveton, electron and neutrino, as well as the binding energies between the fundamental particles, we are able to calculate the mass spectrum of all composite elementary particles. We will assume that the main contribution to the mass of a compound particle, besides daughter particles, is given by bound and free lovetons. All listed types of lovetons, together with electrons and their binding energies, including electron-positron pairs, allow to form new elementary particles with increasing complexity.

In the formation of composite elementary particles masses it is necessary to follow a number of empirically selected rules, derived from the analysis of their decay products:

1. A particle may have in its composition, besides products of its decay, for mesons - a number of pions, and for baryons, besides pions, also protons, allowing to form the required mass.

2. The reverse decay process, which is the synthesis of daughter particles, can be performed either along the edges of the space-time cell or along its faces. The first option adds 2 *L*-*L* bonds, while the second option adds 4 *L*-*L* bonds.

3. In the presence of free electrons and positrons, not bound into electron-positron pairs, partial activation of adjacent space-time cells is possible.

4. When studying the ways of formation of composite elementary particles included in hadrons, one can neglect the contribution to the rest-mass of the reduced neutrino mass.

In order to find possible configurations of composite particles, we first determine the admissible combinations realizable for the chosen particle. We require that the calculations of the particle masses reproduce the experimental data with the accuracy within the limits of the absolute errors obtained for each of the particles. In determining the configurations of the complex elementary particles the particles were chosen, which have an absolute error of not more than two electron masses (about 1 MeV). The exception was the particles having a slightly higher instrument error, but playing an important role in the decay processes of other elementary particles. For a number of particles the difference between the experimental and calculated mass values turned out to be, by a rather small value, larger than the experimental error. In this case the experimental value was shifted to one of the limits of the corridor of possible values and the difference of the mass data was re-evaluated. If the difference in mass was within the known instrument error, the value was accepted as true.

The practical selection of possible configurations was carried out according to the following algorithm:

1. Among decay variants the daughter particles having as large mass as possible were determined. Such particles in most cases turn out to be either two, or even one.

2. The missing mass was compared with the values of pion masses, where the latter were chosen taking into account the charge of the mother particle and the presence of pions in the decay products. If the residual mass was found to be less than the pion mass, the number of possible *L*-*L* bonds was additionally determined.

3. The remaining mass was distributed between the electron-positron pairs and the number

of *L-e* and *e-e* bonds. In these cases the following rule was followed: the number of *e-e* bonds for compound particles is always smaller than the total number of electrons and positrons, and the number of *L-e* bonds must be equal or greater than the total number of electrons and positrons.

Here, while the first point of the algorithm was carried out in the manual mode, the next two points were implemented by means of a program, which determined possible combinations of the number of pions, electron-positron pairs, and binding energies of fundamental particles corresponding to a given error of the particle measurement. The resulting set of combinations was analysed and the combination that best matched the required conditions and constraints was chosen.

In addition, in the selection of elementary particles configurations, the direct dependence of the number of loveton-loveton bonds on the total number of pions was actively used. At the same time, in cases of inconsistency in the behavior of these parameters the compositions of the corresponding elementary particles were checked again. Here, and further on, the pions included in the composition of daughter particles included in the decay products were not considered.

3.2 LEPTONS

It is customary to refer to leptons as elementary particles such as electron, muon, tauon and neutrino. The electron, in our study, refers to the fundamental particles and is part of all other leptons. The muon we have considered in the previous section and its composition is already known to us. Recall that a separate consideration of the neutrino can be excluded at this stage, due to its small mass. Here we will focus only on the determination of the composition of the last lepton particle, the tauon.

It should be noted at once that the τ-lepton will be regarded as an excited state of the loveton-antiloveton pair (Fig. 5), with an additional particle in the form of τ-neutrino besides electrons and positrons. Let us pay attention to the dual nature of the loveton-antiloveton pair of the τ-lepton. On the one hand, both loveton and antiloveton form the lattice edge, hence they belong to bound lovetons, but on the other hand, due to their excited state, they also possess mass like free lovetons. On the basis of this notion, the mass of a tauon can be obtained by calculating the following equation (the data on the quantitative composition are obtained by combining the possible combinations of the number of fundamental particles and their binding energies)

$$m_\tau = 2m_L + 5m_e + m'_\nu + E_{LL} + 5E_{Le}\ . \qquad (12)$$

The calculation by formula (12) gives the value of the mass τ-lepton at the limits of its absolute error $|m_{\text{calc}} - m_{\text{exp}}| = 0.10$ ($\Delta_{\text{exp}} = 0.12$): $m_\tau = 1776.9603$. We note that in this case there are no bonds in the electron-positron pairs of the τ-lepton, indicating that the electron-positron pairs in the τ-lepton decay and are represented as separate electrons and positrons.

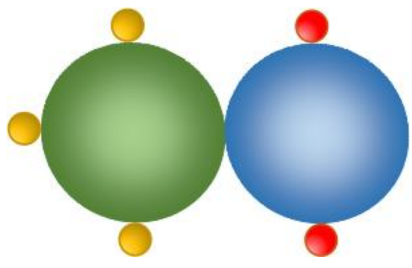

Fig. 5 Schematic structure of τ-lepton:
● – bound loveton; ● – bound antiloveton; ● – electron; ● – positron

An interesting fact is the possibility of representing the τ-lepton also as consisting of the loveton and antiloveton, but having only three electrons, with the presence of the loveton-electron bonds equal to: $E_{Le} = 6$. Such a structure seems to be even more preferable, but a comparison of the calculated and experimental masses of the lepton in this configuration reveals a discrepancy and a slightly increased difference in masses: $|m_{\text{calc}} - m_{\text{exp}}| = 0.14$.

Thus, we conclude that the above analysis, by the example of the τ-lepton structure, shows the correctness of the chosen approach to the possibility of describing the formation of elementary particle masses by choosing a set of fundamental particles and the energies of their interrelation with each other.

3.3 MESONS

The results of the formation of mesons' rest-masses are calculated by the mass formula (6), which in turn are compared with known experimental data [28], are summarized in the approximate table (Table 3). This comparison was carried out for a sufficiently large sample of mesons. The table also shows the difference between the masses of elementary particles obtained by computational and experimental methods (for the true value of the rest mass of the particle was taken the values of masses determined experimentally). At the same time, the calculated values of masses correspond well to the observed values of the meson mass spectrum, and the obtained values of the difference of these masses in their magnitude in most cases did not exceed the absolute error of the experimental values.

Table 3.

Mass spectrum and structural composition of mesons

Particle	Experiment		Decay products	$\pi^\pm$	π^0	*LL*	*ee*	*e*	*Le*	Calculation	
	Mass, m_{exp} (meV)	Absolute accuracy								Mass, m_{calc} (meV)	$\|m_{calc} - m_{exp}\|$
$K^\pm$	493,677	0,016	–	3	0	12	0	0	1	493,664	0,013
K^0_S	497,611	0,013	–	2	0	34	0	4	8	497,600	0,011
K^0_L	497,611	0,013	–	2	1	12	0	6	8	497,605	0,006
η	547,862	0,017	–	2	1	18	7	8	15	547,877	-0,015
$\rho(770)^\pm$	775,260	0,230	η	1	0	12	3	6	10	775,352	-0,092
$\rho(770)^0$	775,260	0,230	η	0	1	14	1	2	5	775,479	-0,003
$\omega(782)$	782,660	0,130	η	0	1	14	2	4	12	782,689	-0,044
$K^{*+}(892)$	891,670	0,260	$K^\pm$	0	2	20	1	2	3	891,572	0,098
$K^{*0}(892)$	895,550	0,200	K^0	0	2	20	1	2	3	895,506	0,044
$\eta'(958)$	957,780	0,060	η	2	0	20	2	4	4	957,764	0,016
$f(1020)$	1019,461	0,016	η	2	1	8	3	4	4	1019,466	-0,005
$f_2(1270)$	1275,500	0,800	$2K^\pm$	0	1	24	1	2	4	1275,777	-0,277
$f_1(1285)$	1281,900	0,500	$2K^\pm$	0	1	24	3	6	7	1282,078	-0,178
$a_2(1320)$	1318,200	0,600	$2K^\pm$	0	2	8	3	6	7	1318,159	0,041
$f_1(1420)$	1426,300	0,900	$2K^\pm$	2	0	24	3	6	7	1426,242	0,058
D^0	1864,840	0,050	K^0f2(1270)	0	0	14	1	2	4	1864,748	0,092
$D^\pm$	1869,660	0,050	$K^*(892)^+$	5	2	0	2	4	8	1869,683	-0,023
$D^\pm_s$	1968,350	0,070	$K^{*+}K^{*0}$	1	0	4	3	6	14	1968,387	-0,037
$D^{*0}(2007)$	2006,850	0,050	D^0	0	1	0	2	4	4	2006,899	-0,049
$D^{*+}(2010)$	2010,260	0,050	D^0	1	0	0	1	2	5	2010,295	-0,035
$D^{*\pm}_s$	2112,200	0,400	$D^\pm_s$	0	1	0	2	4	6	2111,971	0,229
$D^*_{s0}(2317)^+$	2317,800	0,500	$D^\pm_s$	0	2	12	1	2	4	2317,578	0,222
$D^*_1(2420)^0$	2421,400	0,600	$D^*(2010)^+$	1	1	20	3	6	9	2421,393	0,007
$D_1(2420)^0$	2422,100	0,600	$D^*(2007)^0$	0	2	22	2	4	7	2422,210	-0,110

$D_{s1}(2460)^+$	2459,500	0,600	$D^{\pm}_s$	2	1	10	3	6	12	2459,588	-0,088
$D^*_2(2460)^+$	2461,100	0,700	$D^*(2010)^+$	1	1	28	2	4	4	2461,546	-0,446
$D^*_2(2460)^0$	2462,800	1,000	$D^{*+}(2010)$	1	1	28	1	2	4	2462,977	-0,177
$D_{s1}(2536)^+$	2535,110	0,060	$D^{*+}(2010)$	0	0	2	5	6	9	2535,113	-0,003
$D^*_{s2}(2573)^+$	2569,100	0,800	$D^{*0}(2007)$	0	0	8	3	6	12	2569,219	-0,119
$\eta_c(1S)$	2983,900	0,400	$2f_2(1270)$	0	2	24	3	6	11	2983,826	0,074
$J/\Psi(1S)$	3096,900	0,006	$2\Sigma(1385)^-$	0	1	28	4	8	14	3096,895	0,005
$\chi_{c0}(1P)$	3414,710	0,300	J/Ψ	0	1	28	2	4	8	3415,150	-0,440
$\chi_{c1}(1P)$	3510,670	0,050	J/Ψ	0	2	22	2	4	5	3510,698	-0,028
$h_c(1P)$	3525,380	0,110	J/Ψ	0	2	24	2	4	8	3525,403	-0,023
$\chi_{c2}(1P)$	3556,170	0,070	J/Ψ	2	0	28	2	4	4	3556,189	-0,019
$\psi(2S)$	3686,100	0,060	$J/\Psi(1S)\eta$	0	0	6	1	2	3	3686,170	-0,070
$\psi(3770)$	3773,700	0,400	$2D^+$	0	0	4	2	4	7	3773,470	0,230
$\psi_2(3823)$	3823,700	0,500	$\chi_{c2}(1P)$	0	2	6	1	2	5	3823,594	0,106
$\psi_3(3842)$	3842,710	0,200	$2D^{\pm}$	0	0	16	1	2	3	3842,537	0,173
$\chi_{c1}(3872)$	3871,650	0,060	$2D^0$	0	1	0	2	4	4	3871,739	-0,089
$\chi_{c2}(3930)$	3922,500	1,000	$2D^0$	0	1	6	2	4	8	3921,590	0,910
$\psi(4040)$	4039,000	1,000	$\chi_{c1}(1P)$	2	1	16	3	6	12	4038,993	0,007
$B^{\pm}$	5279,340	0,120	$\psi(2S)K^{*+}$	2	2	22	3	6	14	5279,718	-0,378
B^0	5279,660	0,120	$\psi(2S)K^{*0}$	0	4	24	1	2	10	5279,691	-0,031
B^{*+}	5324,710	0,210	$B^{\pm}$	0	0	6	1	2	8	5324,654	0,056
B^0_s	5366,920	0,100	$2\Lambda(2625)^+_c$	0	0	16	2	4	10	5366,885	0,035
$B^*_2(5747)^+$	5737,200	0,700	B^*	2	0	20	2	4	8	5737,677	-0,477
$B^*_2(5747)^0$	5739,500	0,700	B^*	1	1	20	3	6	13	5738,968	0,532
$B_{s1}(5830)^0$	5828,700	0,200	$B^{*+}K^-$	0	0	0	2	4	8	5828,594	0,106
$B_{s2}(5840)^0$	5839,860	0,120	$B^{*+}K^-$	0	0	2	1	2	9	5839,759	0,101
$B^{\pm}_c$	6274,470	0,320	$J/\Psi D^*(2010)^+K^{*0}(892)$	0	1	20	3	6	9	6274,272	0,198
$B_c(2S)^{\pm}$	6871,470	1,000	$B_c^{\pm}$	2	2	16	1	2	2	6871,790	-0,320
$\Upsilon(1S)$	9460,300	0,260	$2Z_c(4430)$	0	2	36	2	4	10	9460,237	0,063
$\chi_{b0}(1P)$	9859,440	0,310	$\Upsilon(1S)$	0	2	18	3	6	15	9859,165	0,275
$\chi_{b1}(1P)$	9892,780	0,310	$\Upsilon(1S)$	2	0	22	3	6	15	9893,076	-0,296
$\Upsilon(2S)$	10023,260	0,310	$\Upsilon(1S)$	2	1	22	3	6	9	10023,365	-0,105
$\chi_{b0}(2P)$	10232,500	0,400	$\Upsilon(1S)$	0	1	10	3	6	8	10232,232	0,268
$\chi_{b1}(2P)$	10255,460	0,220	$\Upsilon(1S)$	0	1	14	3	6	6	10255,393	0,067
$\chi_{b2}(2P)$	10268,650	0,220	$\Upsilon(1S)$	0	1	16	3	6	7	10268,536	0,114
$\Upsilon(3S)$	10355,200	0,500	$\Upsilon(1S)$	2	0	6	3	6	12	10354,797	0,403

Note. Decay products are daughter particles included in the composition of the considered elementary particle. The table shows the absolute measurement errors of meson masses.

Let us look at the neutral K^0-meson, whose composition differs from the total mass of the particles. The K^0 meson, for example, is a union of two or three pions, and consequently has two configurations, *S* and *L*, which have different lifetimes. The short-lived configuration of the meson is shown in the table (Table 3) to be represented by two $\pi\pm$ mesons, which are united structurally by separate edges that add only two *L-L* bonds to the particle. Electrons and positrons in this configuration (eight particles) may have continuous displacements, additionally partially activating adjacent spatial cells, similar to the formation of the muon. Each of the two pions has four outer edges; hence this allows the addition of 16 *L-L* bonds, making a total of 32 *L-L* bonds. In this case, the total number of bonds for this configuration is a value equal to: $N_{LL} = 34$.

The long-lived K^0-meson configuration will already be represented by three pions united by their faces, allowing *4 L-L* bonds to be added. Electrons and positrons in such a configuration have no dynamical shifts leading to partial activation of adjacent spatial cells, so the total number of *L-L* bonds is limited to the value: $N_{LL} = 12$. We also note the number of electron-positron pairs, the number of which is exactly the same as the number of pions, but the reason for the same number of loveton- electron bonds equal to: $N_{Le} = 8$, the authors have not uniquely identified. Note that all *K* mesons have no extra electron-positron pairs (the number of *e-e* bonds is zero) outside of their constituent pions. This fact is unique among composite particles of the meson class.

The second elementary particle that also has the same mass value, not only for the neutral particle, but also for the charged particle, is $\rho(770)$-meson. In accordance with the considered compositions of these particles, we may note that in this case the charged particle includes in its decay products apart from η-meson also the $\pi^{\pm}$-meson, in contrast to the neutral one, which is based on both the η-meson and the π^0-meson.

An overwhelming number of elementary particles contain in their composition electron-positron pairs divided into a number of groups. Thus, a number of particles contain such pairs united in chains. Among the mesons, these include $\pi^{\pm}$, η and φ(1020)-mesons, while the vast majority of mesons have electron-positron pairs in an isolated state. *J/Ψ* particle is also of great interest, its decay giving rise to baryons, and the total number of electron-positron pairs appeared to be the highest of all elementary particles, being of the order of four. Unfortunately for ϒ(1S)-meson no daughter particles of good accuracy were found, so the resulting composition of the particle was determined somewhat arbitrarily, but in accordance with the existing decay version.

4.4 BARYONS

To the class of particles, which are usually called baryons, belong structural elements including in their composition free lovetons. In the approximate table (Table 4) the results of formation of rest masses of baryons, obtained on the basis of calculations by the mass formula (6), are summarized and additionally compared with experimental data [28]. This approach is performed for a large sample of currently reliably determined baryons. The table also shows the error of the measurement of baryon masses by empirical methods and compares the calculated and experimental data.

Table 4.

Mass spectrum and structural composition of baryons

Particle	Experiment		Decay products	$\pi^{\pm}$	π^0	*LL*	*ee*	*e*	*Le*	Calculation	
	Mass, $m_{\exp}$ (meV)	Absolute accuracy								Mass, m_{calc} (meV)	$\lvert m_{calc} - m_{\exp}\rvert$
Λ^0	1115,683	0,006	*p*	1	0	4	7	8	3	1115,687	0,004
Σ^+	1189,370	0,070	*p*	0	1	16	2	4	17	1189,382	0,012
Σ^0	1192,642	0,024	*p*	1	0	18	1	2	2	1192,640	0,002
Σ^-	1197,449	0,030	*p*	1	0	16	3	6	19	1197,487	0,038
D(1232)	1210,000	1,000	*p*	1	0	20	1	2	8	1209,690	0,310
Ξ^0	1314,860	0,200	Λ^0	0	1	8	2	4	14	1315,002	0,142
Ξ^-	1321,710	0,070	Λ^0	1	0	8	3	6	14	1321,644	0,066
$\Sigma(1385)^{*+}$	1382,800	0,350	Λ^0	1	0	20	1	2	2	1382,413	0,387
$\Sigma(1385)^{*0}$	1383,700	1,000	Λ^0	0	1	20	2	4	6	1382,923	0,777
$\Sigma(1385)^{*-}$	1387,200	0,500	Λ^0	1	0	20	2	4	6	1387,517	0,317

$\Lambda(1405)$	1405,100	1,000	Σ^+	1	0	10	3	6	12	1406,060	0,960
$\Lambda(1520)$	1519,000	1,000	Σ^0	0	2	8	2	4	4	1519,125	0,125
$\Xi(1530)^0$	1531,800	0,320	Ξ^0	0	1	12	2	4	5	1531,871	0,071
$\Xi(1530)^-$	1535,000	0,600	Ξ^-	0	1	12	1	2	3	1535,180	0,180
Ω^-	1672,450	0,290	$\Xi(1530)^0$	1	0	0	0	0	1	1672,152	0,298
Λ^+_c	2286,460	0,140	$\Lambda(1520)$	3	1	34	1	2	2	2286,381	0,079
$\Sigma_c(2455)^+$	2452,900	0,400	Λ^+_c	0	1	4	2	4	4	2453,243	0,343
$\Sigma_c(2455)^0$	2453,750	0,140	Λ^+_c	1	0	4	0	0	4	2453,879	0,129
$\Sigma_c(2455)^{++}$	2453,970	0,140	Λ^+_c	1	0	4	0	0	4	2453,879	0,091
Ξ^+_c	2467,710	0,230	$\Omega^- K^+$	1	0	24	3	6	10	2467,788	0,078
Ξ^0_c	2470,440	0,280	$\Omega^- K^+$	0	1	24	3	6	14	2470,254	0,186
$\Sigma_c(2520)^+$	2517,400	0,600	Λ^+_c	0	1	14	2	4	7	2517,396	0,004
$\Sigma_c(2520)^{++}$	2518,410	0,200	Λ^+_c	1	0	14	1	2	5	2518,448	0,038
$\Sigma_c(2520)^0$	2518,480	0,200	Λ^+_c	1	0	14	1	2	5	2518,448	0,032
$\Lambda(2595)^+_c$	2592,250	0,280	Λ^+_c	0	2	4	1	2	12	2592,491	0,241
$\Lambda(2625)^+_c$	2628,110	0,190	Λ^+_c	2	0	10	0	0	1	2628,191	0,081
$\Xi(2645)^+_c$	2645,100	0,300	Ξ^0_c	1	0	4	2	4	8	2644,941	0,159
$\Xi(2645)^0_c$	2646,160	0,250	Ξ^0_c	1	0	4	3	4	8	2645,898	0,262
W^0_c	2695,200	1,700	$\Omega^-\rho^+$	0	1	16	3	6	12	2696,892	1,692
$\Xi(2815)^+_c$	2816,510	0,250	Ξ_c^+	2	0	10	2	4	5	2816,523	0,013
$\Xi(2815)^0_c$	2819,790	0,300	Ξ_c^0	2	0	10	2	4	6	2820,035	0,245
$\Lambda(2880)^+_c$	2881,630	0,240	Λ_c^+	2	0	12	1	2	10	2881,583	0,047
$\Lambda(2940)^+_c$	2939,600	1,500	$\Sigma_c(2455)^{++}$	1	1	32	2	4	12	2939,639	0,039
$\Xi(3080)_c^+$	3077,200	0,400	$\Lambda_c^+\underline{K}^+$	1	0	24	2	4	7	3077,476	0,276
$\Xi(3080)_c^0$	3079,900	1,400	$\Lambda_c^+\underline{K}^-$	0	1	24	3	6	12	3078,767	1,133
Ξ_{cc}^{++}	3621,600	0,400	$\Sigma_c(2455)^{++}\underline{K}^-$	1	2	40	3	6	14	3621,282	0,318
Λ^0_b	5619,600	0,170	$\chi_{c1}(3872)pK^-$	0	1	28	2	4	5	5619,506	0,094
Ξ^0_b	5791,900	0,500	$J/\psi\Xi^0$	0	1	14	1	2	2	5792,407	0,507
Ξ^-_b	5797,000	0,600	$J/\psi\Xi^-$	0	1	14	3	6	6	5796,759	0,241
Σ_b^+	5810,560	0,250	Λ_b^0	1	0	6	3	6	11	5810,785	0,225
Σ_b^-	5815,640	0,270	Λ_b^0	1	0	8	2	4	4	5815,700	0,060
$\Sigma^*{}_b^+$	5830,320	0,270	Λ_b^0	1	0	10	2	4	7	5830,406	0,086
$\Sigma^*{}_b^-$	5834,740	0,300	Λ_b^0	1	0	10	2	4	13	5835,093	0,353
$\Lambda_b(5912)^0$	5912,190	0,170	Λ_b^0	0	2	2	2	4	8	5912,123	0,067
$\Lambda_b(5920)^0$	5920,090	0,170	Λ_b^0	0	2	4	1	2	5	5920,162	0,072
$\Xi'_b(5635)^-$	5935,020	0,050	Ξ_b^0	1	0	0	1	2	2	5935,011	0,009
Ω^-_b	6046,100	1,700	$J/\psi\Omega^- p$	1	1	8	3	6	12	6046,943	0,843
$\Lambda_b(6146)^0$	6146,200	0,400	Λ_b^0	2	1	16	3	6	10	6146,361	0,161
$\Lambda_b(6152)^0$	6152,500	0,400	Λ_b^0	2	1	16	3	6	18	6152,611	0,111

Note. Decay products are daughter particles included in the composition of the considered elementary particle. The table shows the absolute errors in measuring the masses of baryons.

Let us consider the obtained results of the analysis of the structural composition of baryons.

A special place should be given to Λ^0- hyperon, which was not accidentally considered as one of the contenders for a place in the row of fundamental particles [8]. Note that in this compound particle, the electron-positron pairs are represented as a chain of particles, and this is the only case among baryons; all other baryons either have sets of independent electron-positron pairs, or these pairs are completely absent (here electron-positron pairs are included in daughter particles are not considered). The latter case occurs in the compositions of four particles: Ω^-, $\Sigma^0{}_c(2455)$, $\Sigma^{++}{}_c(2455)$ and $\Lambda^+{}_c(2625)$.

The results of calculations using mass formulas and the structures of composite particles formed on their basis show their complete agreement with experimental data, taking into account the known errors of estimates of elementary particle masses.

3.5 PRINCIPLES FOR DIVIDING ELEMENTARY PARTICLES INTO CLASSES

When considering elementary particles, it is found that the known classes of particles have a number of fundamental differences (Table 3). The presence of independent electrons and positrons, in other words, the complete absence of electron-positron pairs in the composition of particles, allows us to classify these particles as leptons. This class includes the electron itself. Consequently, leptons can be formed on the basis of two components, such as bound lovetons (antilovetons), included in the composition of spatial cells, and electrons (positrons).

Table 5.

Classification of elementary particles by structural composition

Particle type	Electron (positron)	Bound loveton	Electron-positron pair	Free loveton
Lepton	+	+		
Meson		+	+	
Baryon		+	+	+

Hadrons, in contrast to leptons, necessarily contain electron-positron pairs and bound lovetons. At the same time, hadrons themselves are divided into two classes of mesons and baryons. In the meson subgroup there are no independent electrons (positrons), while mixed mesons may include electrons and positrons in their composition in the presence of one or more positive pions. The composition of baryons can be determined in a similar way. If hadrons, except for bound lovetons and electron-positron pairs, additionally contain free lovetons in their composition, they must be assigned to the class of baryons. In conclusion, let us note that two basic particles can be presented as exceptions to this classification. Thus, a charged pion has in its composition an additional electron (positron) and, therefore, is a fusion of a lepton with a meson. A similar situation is observed for the neutron, which can be regarded as a fusion, in this case, of the lepton with the baryon (proton).

3.6 PHYSICAL NATURE OF THE STRONG INTERACTION

One of the main differences between leptons and hadrons is the absence of bonds between electrons and positrons. This fact indicates that probably it is the presence of electron-positron pairs in hadrons that causes the strong interaction. Let us consider this assumption in more details.

Thus, if the moments p_1 and p_2 of two electron-positron pairs, represented in the form of dipoles situated along one straight line, are equally directed, they are attracted, and the force of attraction F_d is proportional to the product of electric moments of the dipoles: $p_i = el_i$ (e is the electron charge, l is the dipole ratio arm) and inversely proportional to the fourth power of the distance between them [29].

$$F_d = -\frac{6p_1p_2}{4\pi\varepsilon_o r^4}. \tag{13}$$

Given that the arms of both dipoles can change their positions relative to each other, we note the fact that the interaction forces between the dipoles are noncentral, since they depend not only on the distance between them, but also on their mutual orientation. Nuclear forces have a similar property. To compare dipole F_d and coulombian F_q forces let's take their ratio to each other

$$\frac{F_d}{F_q} = \frac{6l^2}{r^2}\,. \qquad (14)$$

We take the value of the dipole arm numerically equal to the proton radius: R_p = 0.84 *fm* [30]. Then the equality of the forces in question will take place at: $r = l\sqrt{6}$, which tentatively gives a distance of the order of *2 fm*. At a further approach of protons the interaction force of electron-positron pairs essentially exceeds the Coulomb repulsion force of free lovetons being fundamental particles for protons. However, already at the onset of contact of free lovetons there is an additional elastic force. Thus, the distance between free lovetons acting as rigid proton cores can be found by considering a single face of a spatial cell consisting of bound lovetons (Fig. 4): $R_L = R_p/(\sqrt{2} + 1)$, which gives the value of the radius of the loveton: R_L = 0.36 *fm*. In this case, the distance between the contacting free lovetons, will have the value of the diameter of the loveton, which is quite close to the distance at which the repulsion of nucleons in the nucleus occurs.

Thus, from both qualitative and quantitative points of view, the attraction forces of electron-positron pairs together with the Coulomb repulsion forces of lovetons allow us to explain the behavior of nuclear forces at small distances. Of course, these estimates are approximate, but the general nature of the interaction between two electron-positron pairs as dipoles allows us to consider the electromagnetic forces as the basis for the strong interaction.

4. CONCLUSION

The presented work overcomes a number of significant shortcomings of previous research related to elementary particle physics. These include the limitation by known particles, i.e. actually a choice of fundamental particles only from the set of known elementary particles. The opposite option, where sets containing only hypothetical particles are considered, is also actively proposed. Here, using the previously proposed model of space-time and matter, a model of the mass spectrum of elementary particles as hadrons and leptons is constructed. In the calculations performed there are no fitting parameters, and the exact correspondence with known experimental data on the masses of elementary particles indicates the correct direction of the research carried out. Qualitatively, and in most important cases, quantitatively, the unity of the method of formation of composite particles is shown.

The following results were obtained as a result of the study:

1. A general model of the mass spectrum of elementary particles obtained on the basis of separation of fundamental particles, as well as by forming mass formulas based on the analysis of the decay products of elementary particles.

2. Partitioning of elementary particles into three groups: fundamental, basic and compound elementary particles was carried out.

3. Using the obtained mass formulas and their solutions the values of bonding energies between fundamental particles were calculated.

4. Structural composition of proton and tau-lepton was determined.

5. The analysis of products of decay of compound particles allowed to determine both the composition of these particles and the number of possible bonds between them.

6. It is shown that the products of decay are initially in the compositions of elementary particles.

7. Leptons and hadrons are different from each other due not only to the presence of strong interaction, but also have differences in their structure. It is found that baryons necessarily have free lovetons in their composition. Free lovetons are absent in mesons and leptons.

8. On the basis of the analysis of mass formulas, taking into account their decay schemes, we calculate the masses of compound particles.

9. The physical nature of nuclear forces determined by the interaction of electron-positron pairs represented in the form of dipoles has been revealed.

Based on the structure of elementary particles the criteria for their partitioning into separate species are defined. It is shown that for the formation of mesons it is sufficient to consider a two-component structure consisting of a set of bound lovetons and electron-positron pairs. Leptons also have a similar two-component structure, but the leptons do not contain electron-positron pairs. In the analysis of mass formulas for baryons, free lovetons are additionally included in the composition of elementary particles to form a three-component structure of elementary particles.

The possibility to determine the structural composition of elementary particles, based on the known masses of fundamental particles and their bonding energies, in the future will allow specifying and extending the methods and approaches used in investigations carried out in atomic nucleus and elementary particle physics.

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