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DIHADRONIC AND DILEPTONIC RESONANCES

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1 Introduction

It has been shown in our works [1]-[6] that resonances in wave systems arise when the ratio of the size r of a resonance system to the corresponding wavelength λ is determined by the relation

$$r = (n+\gamma)\lambda, \quad n = 1,\ 2,\ 3..., \tag{1}$$

where γ is a number of the order of 1 ($0 \leq \gamma \leq 1$) which depends on boundary conditions for a given degree of freedom and on a dynamic equation for the resonance system. It is worthwhile to note that *two different classes of resonances with boson- and fermion-like features arise in waveguide ring structure depending on their field topology* [8]: the case γ=0 corresponds to boson-type structure and γ=1/2 — to fermion-type structure of resonances.

For hydrogen-like atoms the relation (1) may be written in the form ($\gamma = 0$)

$$r = n\lambda_D \quad or \quad l = rP = n\hbar, \tag{2}$$

where $P = mv$ is the electron momentum, and λ_D is the de Broglie wavelength

$$\lambda_D = \frac{\hbar}{P}. \tag{3}$$

So, the Bohr quantization conditions for hydrogen-like atoms coincide with the conditions of resonances in any wave macrosystems. They are quantization conditions of the Ehrenfest adiabatic invariant — the conservation law of angular momentum l.

Let us consider the collision of two particles a and b with the production of an unstable resonance state R decaying later into two particles c and d:

$$a + b \to R \to c + d. \tag{4}$$

By using the energy-momentum conservation law, the invariant mass may be naturally calculated by the formula ($\hbar = c = 1$)

$$m_R = \sqrt{m_a^2 + P_{ab}^2} + \sqrt{m_b^2 + P_{ab}^2} = \sqrt{m_c^2 + P_{cd}^2} + \sqrt{m_d^2 + P_{cd}^2}, \tag{5}$$

where P_{ab} and P_{cd} are the momenta of particles in their mass center systems.

We can write formula (5) in another form using relations (1) and (3)

$$m_R = \sqrt{m_c^2 + (\frac{n+\gamma}{r})^2} + \sqrt{m_d^2 + (\frac{n+\gamma}{r})^2}. \tag{6}$$

It is obvious that formula (6) derived from energy-momentum and angular momentum conservation laws is analogous to that for eigenfrequencies of resonators, interferometers, organ pipes, etc., having the wave nature. The similitude of analytic forms for eigenfrequencies of cavity resonances, invariant masses of hadronic and leptonic resonances and eigenvalues for hydrogen atoms is not accidental but represents the general law of the resonator principle. The eigenfrequencies of closed and open wave systems result from the geometric quantization of corresponding standing waves.

Here we want to make an important remark. Chew G.F., Gell-Mann M. and Rosenfeld A.H. pointed out in old forgotten paper [9] in 1964 the fact that there is a deep physical analogy between the widely adopted models of open resonators in classical and wave mechanics, in particular, in elementary particle physics. They concluded (see [9], page 85):

To explain how an unstable particle can communicate with several open channels we have found it helpful to draw an analogy between the behavior of unstable particles and the behavior of resonant cavities such as organ pipes and electromagnetic cavities. Cavities of the latter sort (such as the magnetron tube employed in radar) are used in electronics to create intense electromagnetic waves of a desired frequency, which is a resonant frequency of the cavity. Each cavity has a characteristic "lifetime": the time required for the electromagnetic radiation to leak out.

In quantum mechanics, particles and waves are complementary concepts, and the amount of energy associated with a particle, or nuclear state, can be expressed as an equivalent frequency. In other words, energy is proportional to frequency. The fact that the Δ-particle appears when a pion is scattered by a proton at or near a certain energy — the resonance energy — is equivalent to saying that the particle appears at a certain frequency. Thus a resonance energy in particle physics can be compared to the resonance frequency of an acoustic or electromagnetic cavity. What is the "cavity" in particle physics? It is an imaginary structure: one cavity, each with its own special properties, for each set of values of the quantum numbers conserved in strong interactions.

The analogy between unstable particles and the resonant modes of electromagnetic cavities can be carried further. To the electromagnetic cavity one can attach the long pipes known as wave quides, which have the property of efficiently transmitting electromagnetic waves of high frequency but not those of low frequency. When the electromagnetic wavelength is slightly larger than the dimensions of the wave guide, the guide refuses to transmit. In this sense the wave quide acts like a particle channel that is open only above its characteristic threshold energy. If a cavity has attached to it several wave quides of different sizes, high-frequency radiation can flow into the cavity through one guide and flow out through the same or different guides.

By analogy energy can flow into a nuclear interaction through one channel and pass out through one or more open channels. As the energy (frequency) is increased from low values, the channels open up one by one and new nuclear reactions become possible, with energy going out through any of the open channels. Now, as the frequency is increased, suppose it passes through a resonance frequency of the nuclear cavity. At this point it becomes easier for the cavity to absorb and reradiate energy. The resonance appears as a peak in the scattering cross section of a nuclear reaction. In other words, a resonant mode of the cavity corresponds to an unstable particle, such as Δ or $\pi(750)$.

Just as an electromagnetic cavity that is near resonance holds on to electromagnetic energy for a long time, so the unstable particle typically takes somewhat more than the characteristic time of less than 10^{-23} second to decay. If energy is fed into the cavity through one pipe, stays in the cavity for a while because of resonance and comes out again through the original pipe, that corresponds to a scattering collision between two $\pi(137)$ particles that produce the unstable particle $\pi(750)$, which finally decays again into the original particles. Alternatively, the energy can emerge through another pipe, which corresponds to the case in which $\pi(750)$ decays into four $\pi(137)$ particles. These, of course, are only two of many examples.

One can use the wave guide analogy to describe not only unstable particles but also stable ones. A stable particle is merely one that has such a low mass that all the communicating channels are closed. Therefore it is a "bound" state rather than a scattering resonance. For an electromagnetic cavity this condition would correspond to a resonant mode whose frequency is below the threshold frequency of all the wave guide outlets. If radiation could be put into the cavity in such a mode, it could not leak out. Of course, an actual cavity would eventually lose radiation by leakage into and through its walls. Such leakage corresponds to the decay of metastable particles via the weak and electromagnetic reactions. An absolutely stable particle really does live forever.

The reader who is unfamiliar with the phenomenon of resonance in electromagnetic cavities may be wondering if we have simplified his task by introducing the electromagnetic analogy. Would it not be just as easy to explain resonances in particle physics directly? Possibly so. But by drawing attention to similar behavior in two apparently different fields we hope we have illustrated a unity in physics that may make particle behavior seem less esoteric. The more basic value of the analogy, however, is that it has helped theorists to understand some deeper points in particle resonances than we have been able to talk about here.

Open resonators have a real physical surface that divides space into two parts: the interior part of the resonator, where the corresponding eigenstates of the resonator are generated, and the exterior part of the resonator where the waves escape from the resonator. The main feature of all resonators is that the wave functions or their derivatives are equal to zero on the boundary. This condition was used to determine quantized values of the velocities and momenta of the constituents of a decaying resonance.

Relation (6) has been used in works [1]-[5] to analyze the mass distribution of hadronic resonances from the light to heavy ones; its accuracy is surprisingly high and unusual for this branch of physics. The parameter r=0.86 fm was fixed in all calculations.

The method of model- and parameter-independent calculation of hadronic (and also leptonic) resonance masses has been developed by Gareev [7]. The energy-momentum and sectorial velocities conservation laws, and also the correspondence, similitude and dimension principles were used. We will apply the Gareev method to analyze masses of resonances in (pp), (np), $(\pi\pi)$, $(p\pi^+)$, (e^+e^-) - systems, etc.

The geometric quantization is observed in the hadronic and leptonic decay chains independently of the type of interaction in the considered channels. Geometric quantization is exact because it is a consequence of the exact conservation laws of energy momentum, and angular momentum. Therefore it is responsible for the self-consistency of motion between different channels of a decaying hadron (lepton). As a result, the corresponding wavelengths, momenta, and velocities of the hadronic and leptonic decay products are commensurable. In other words, this conclusion can be reformulated so that constituents of all particles have their own eigenfrequencies as any resonator. And this new formulation of the physical entity of hadronic and leptonic resonances solves the problem of calculation of their masses.

2 Diproton, dipion... resonances

Let us consider the diproton resonances problem. Following [7] we assume that the proton represents an ideal "resonance cavity". It is well known that the proton lives more than 10^{32} years and can decay (but does not decay) via 50 two-particle channels and a much more number of three-particle channels [10] (we will restrict ourselves only to two-particle channels to simplify further discussion).

Table 1. The invariant masses of the pp- and $\bar{p}p$-resonances

mode	P_{cm}	$M(2p)_{th}$	$M(2p)_{exp}$	$M(\bar{p}p)$
$\pi^0 \Rightarrow \mu^\pm e^\mp$	26.13	1877.27	1877.5 ± 0.5[15],1877 ± 0.05[16]	
$\pi^0 \Rightarrow e^+e^-$	67.49	1877.39	1877.5 ± 0.5[15],1877 ± 0.05[16]	
$\pi^\pm \Rightarrow \mu^\pm \nu_\mu$	29.79	1877.49	1877.5 ± 0.5[15],1877 ± 0.05[16]	
$p \Rightarrow e^+ K^{*0}$	41.22	1878.35	1877.5 ± 0.5[15]	
$p \Rightarrow \nu K^{*+}$	45.52	1878.75	1877.5 ± 0.5 [15]	
$\mu^\pm \Rightarrow e^\pm \gamma$	52.83	1879.52		
$\pi^0 \Rightarrow \gamma\gamma$	67.49	1881.39		
$\pi^+ \Rightarrow e^+\nu_e$	69.78	1881.73		
$p \Rightarrow \mu^+\omega$	105.42	1888.35	1886 $\pm$1[12]	
$p \Rightarrow \mu^+\rho^0$	120.63	1891.99	1892 [12]	
$p \Rightarrow e^+\omega$	143.31	1898.31	1898 $\pm$1[12]	
$\rho^+ \Rightarrow \pi^+\eta$	145.94	1899.11	1898 $\pm$1[12]	
$p \Rightarrow e^+\rho^0$	154.41	1901.79	1902[13], 1903 $\pm$1 [17]	
$p \Rightarrow \nu\rho^+$	154.41	1901.79	1902[13],1903 $\pm$1 [17]	
$\rho^0 \Rightarrow \eta\gamma$	189.26	1914.34	1916[13], 1916 $\pm$2[12]	
$\omega \Rightarrow \eta\gamma$	199.33	1918.42	1916 $\pm$2[12],1918$\pm$1[17]	
$K^+ \Rightarrow \pi^+\pi^0$	205.14	1920.87	1918 $\pm$3[20]	1920[10]
$K^0 \Rightarrow \pi^+\pi^-$	206.01	1921.24	1920 $\pm$2[21],1922[12]	
$K^0 \Rightarrow \pi^0\pi^0$	209.05	1922.56	1923.7 ± 4.5[19], 1922 $\pm$1.3[22]	
$K^0 \Rightarrow \mu^+\mu^-$	225.29	1929.88	1930[12]	1930 $\pm$2[10]
$\eta \Rightarrow \pi^+\pi^-$	235.47	1934.74	1932$\pm$3[20]	1935.5 $\pm$1[10]
$K^+ \Rightarrow \mu^+\nu_\mu$	235.53	1934.77	1932$\pm$3[20]	1935.5 $\pm$1[10]
$K^0 \Rightarrow e^\pm\mu^\mp$	237.62	1935.79	1937$\pm$2[12]	1937.3 $^{+1.3}_{-0.7}$[10]
$K^+ \Rightarrow e^+\nu_e$	246.84	1940.40	1940$\pm$0.4[22], 1941[13]	1940 $\pm$1[10]
$K^0 \Rightarrow \gamma\gamma$	248.84	1941.42	1941[13]	1940 $\pm$1[10]
$K^0 \Rightarrow e^+e^-$	248.84	1941.42	1941[13]	1940 $\pm$1[10]
$\eta \Rightarrow \mu^+\mu^-$	252.51	1943.31	1945 [25, 12]	1949 ± 10[10]
$\eta \Rightarrow \gamma\gamma$	273.72	1954.77	1955 $\pm$2[12], 1956 ± 3[24]	
$\eta \Rightarrow e^+e^-$	273.72	1954.77	1955 $\pm$2[12], 1956 ± 3[24]	
$p \Rightarrow \mu^+\eta$	297.15	1968.40	1969[13], 1965 $\pm$2[12]	1968[10]
$p \Rightarrow e^+\eta$	309.43	1975.96	1980 $\pm$2[12]	
$p \Rightarrow \mu^+K^0$	326.43	1986.87	1989 $\pm$1[12, 17]	
$p \Rightarrow e^+K^0$	337.15	1994.02	1999 $\pm$2[12]	
$p \Rightarrow \nu K^+$	339.26	1995.45	1999 $\pm$2[12]	

Table 1. The invariant masses of the pp- and $\bar{p}p$-resonances (continuation)

mode	P_{cm}	$M(2p)_{th}$	$M(2p)_{exp}$	$M(\bar{p}p)$
$\rho^0 \Rightarrow \pi^+\pi^-$	358.01	2008.51	2008 $\pm$3[12],2009$\pm$7[21]	
$\rho^+ \Rightarrow \pi^+\pi^0$	358.89	2009.13	2008 $\pm$3[12].2009$\pm$15[23]	
$\rho^0 \Rightarrow \pi^0\pi^0$	359.76	2009.76	2008 $\pm$3[12],2009$\pm$7[21]	
$\omega \Rightarrow \pi^+\pi^-$	365.21	2013.69	2014 $\pm$2[25],2014 $\pm$2[18]	2011 ± 7[10]
$\rho^0 \Rightarrow \mu^+\mu^-$	369.44	2016.77	2016[13], 2017 $\pm$3[12]	2015 ± 4[26]
$\rho^+ \Rightarrow \pi^+\gamma$	371.58	2018.34	2017$\pm$1.3[22], 2017 $\pm$3[12]	
$\rho^0 \Rightarrow \pi^0\gamma$	372.40	2018.94	2017 $\pm$3[12]	
$\omega \Rightarrow \mu^+\mu^-$	376.42	2021.93	2020 $\pm$3[10]	2020 ± 3, 2022 ± 6[10]
$\omega \Rightarrow \pi^0\gamma$	379.32	2024.09		2023 ± 5[10]
$\rho^0 \Rightarrow e^+e^-$	384.25	2027.81		2026 ± 5[10]
$\omega \Rightarrow e^+e^-$	390.97	2032.94		
$p \Rightarrow \mu^+\pi^0$	453.22	2084.00	2087 $\pm$3[12]	2080 ± 10[10]
$p \Rightarrow \nu\pi^+$	458.76	2088.84	2087[13]. 2087 $\pm$3[12]	
$p \Rightarrow e^+\pi^0$	459.43	2089.43	2087 $\pm$3[12]	2090 ± 20[10]
$p \Rightarrow \mu^+\gamma$	463.19	2092.75		
$p \Rightarrow e^+\gamma$	469.14	2098.04		

In our approach the diproton system is considered as a system of two "resonance cavities". Also we assume that the asymptotic momentum of relative motion of two protons coincides with that of constituents of a proton (the channel asymptotic momentum). In other words, the diproton masses were calculated by the formula $m(2p) = 2\sqrt{m_p^2 + P^2}$ using values of P from

$$m(p) = \sqrt{m_a^2 + P^2} + \sqrt{m_b^2 + P^2}, \tag{7}$$

where m_a and m_b are masses of particles which appear from the proton decay hypothesis in the corresponding channel.

The results of theoretical calculations of diproton resonance masses and experimental data are given in Table 1. Only main "tones" of the proton are used. We can see from Table 1 that wide resonances are a total combination of two-three narrow ones, which, as we state, must be detected with increasing energy accuracy. Theoretical calculations reproduce centroids of experimental data with accuracy of the order of $0.1 - 0.2\%$ in general. This is the strongest argument for our hypothesis.

In the approach presented here, the problem of diproton resonances is strongly correlated with the problem of resonances in the $p\bar{p}$-system: their masses must be almost the same. This has been confirmed by a systematic analysis of the existing data (for details, see [1]).

Our calculations are parameter-free and this leads us to the conclusion that under this unprecedented and accurate reproduction of experimental data there must be simple and beautiful physics.

For the derivation of musical sounds the trumpeter blows his trumpet so that he excites eigen oscillations of the trumpet. And only after it will sound. A simple and common principle of wave resonators consists in the fact that eigen oscillations of any resonator are excited only when frequencies and wavelengths of an external field coincide with those of a resonator to be explored. The physical nature of waves, properties of material used for the construction of resonator, etc. are unimportant. If two protons collide, then resonances in wave systems arise when the corresponding waves (momenta and velocities) of relative motion of two protons and their constituents are commensurable. Hence resonance phenomena in a two-proton system give straightforward information about the internal structure of the proton. It is clear that in a two-proton system additional resonances with "overtones" will be observed. There is a subsystem $\eta \rightarrow \gamma\gamma$ in the proton with momentum $P_{26} = 273.725$ MeV/c, for example. From the commensurable principle we can just expect, out of a proton, the existence of resonances with momenta $P = 2P_{26}, 3P_{26}, 4P_{26}...$ Indeed, the calculated diproton mass is equal to 2172.6 MeV when $P = 2P_{26} = 547.45$ MeV/c and this value coincides with that from experiment 2172 ± 5 MeV [12].

We have specially chosen the proton as a standard of an "ideal resonator" because its energy is known with high accuracy and it is stable. Unlike bound states of nuclei, atoms, etc. the proton, as we have already noted, can decay via 50 two-particle channels and a much more number of three-particle channels with emission of energy. It is related to hadronic resonances with the latter feature and to nuclei and atoms with its stability. Nobody has explained stability of the proton. Therefore, we propound, as a working one, the following hypothesis: the proton is a complex wave system with ideally self-consistent motions according to the resonator principle and spreading of the corresponding waves lies on the geodesic line in four-dimensional space-time.

Thus, we come to the conclusion that, despite the fact of stability of the proton, it has extremely rich structure; the term "planetary-wave" is appropriate here. It is clear from the analysis recited above that the proton is not elementary particle and does not consist of simple "bricks". The habit which appeared in former centuries to explain the structure of complex systems by means of crush into pieces now is so deep-rooted in mentality of contemporary physicists that searches of "elementary bricks" of matter still unsuccessfully continue. Proton is a complex wave system. All the motions of subsystems are commensurable according to the resonator principle. Thus there is observed self-coordination of constituents of matter between each other and also with the whole system irrespective of the type of interaction between constituents. Moreover the constituents of matter (clusters) are similar to each other and to the whole system. Actually the hadrons decay in line in a tree-like manner into lighter ones so as the tree branches are similar to each other and to the whole tree.

The systematic analysis of resonance decay products show that the corresponding motions of the constituents do not exist independently. The motions of constituents in one hadron are self-consistent with motions of constituents in another. Each hadron itself plays three-sided role: has a complex structure, is included into other hadrons, and takes part in the change between components of a substation keeping up the unity of structure. Thus harmonic unity of motions of all hadrons is established. No hadron is able to be more fundamental than others. Therefore we come to the fundamental approach to the elementary particle physics problem that has been suggested by Chew and Frautschi [27]: They assume that "**all hadrons are equally fundamental. Each hadron is assumed to be "made up" of all others so that it is impossible to say which are elementary and which are composite.**" Gell-Mann called this picture nuclear democracy. It is assumed that this model leads to self-consistency conditions and that they are such that the masses of all hadrons and their coupling constants are the unique result of the self-consistency requirement, or bootstrapping according to the geometric quantization conditions $\Leftrightarrow$ to conservation laws of energy momentum and angular momentum independently of a particular type of the interaction. This self-coordination of motions in subsystems of one hadron with those of the others and self-coordination of the motions of hadrons themselves and the participation of subsystems and hadrons in exchange lead to the hierarchy of motions and to the self-organization of matter at the quantum level.

Let us return again to the problem of diproton resonances. The values of masses of diproton resonances, which are conditioned only by the main "tones" of the proton, are represented in Table 1. It is natural to expect that other "tones" will be present too in diproton resonances masses, because of the commensurability principle. Therefore, the situation with diproton resonances has formed such that different experimental groups with the most precise equipment cannot repeat results of each other. It is natural in principle because there are many resonances and they can be excited depending on experimental conditions: some of the de Broglie wavelengths can be commensurable with the geometric size of equipment; a system of two nucleons, if one has a third particle, can manifest other resonance properties in comparison with the free interaction case; the resonance properties of the system depend on the kind of an accompanying third particle.

Let us consider the neutron-proton np-system. A neutron decays through $pe^-\overline{\nu}_e$ channel with 100% probability. Therefore it seems that masses of np- and pp - resonances have to be equal. But they are not equal [12]. The eigenfrequencies of a proton and a neutron display in the np - system and the proton eigenfrequencies display in pp - system. The eigenfrequencies of a proton and a neutron are different. Therefore the masses of np- and pp-resonances may coincide and not coincide.

The masses of np resonances depending only on the "eigentones" of a neutron are presented in Table 2. There are "overtones" in np-resonances masses because of the commensurability principle. Thereby both the cases are similar in spite of the np experimental data being scarce as compared with the pp ones.

Table 2. The invariant masses of np-resonances

mode	P_{cm}	$M(np)_{th}$	$M(np)_{exp}$
$\pi^0 \Rightarrow \mu^\pm e^\mp$	26.13	1878.56	
$\pi^\pm \Rightarrow \mu^\pm \nu_\mu$	29.79	1878.78	
$n \Rightarrow \nu K^{*0}$	42.46	1879.76	
$n \Rightarrow e^\pm K^{*\mp}$	46.75	1880.16	
$\mu^\pm \Rightarrow e^\pm \gamma$	52.83	1880.81	
$\pi^0 \Rightarrow \gamma\gamma$	67.49	1882.68	
$\pi^0 \Rightarrow e^+e^-$	67.49	1882.68	
$\pi^\pm \Rightarrow e^\pm \nu_e$	69.78	1883.02	
$n \Rightarrow \mu^\pm \rho^\mp$	122.05	1893.64	
$n \Rightarrow \nu\omega$	144.40	1899.92	1897 ± 1[10]
$\rho^\pm \Rightarrow \pi^\pm \eta$	145.94	1900.39	
$n \Rightarrow e^\pm \rho^\mp$	155.49	1903.41	
$n \Rightarrow \nu\rho^0$	155.49	1903.41	

Table 2. The invariant masses of np-resonances (continuation)

mode	P_{cm}	$M(np)_{th}$	$M(np)_{exp}$
$\rho^0 \Rightarrow \eta\gamma$	189.26	1915.61	
$\omega \Rightarrow \eta\gamma$	199.33	1919.69	1919±3[12, 14]
$K^\pm \Rightarrow \pi^\pm\pi^0$	205.14	1922.13	
$K^0 \Rightarrow \pi^+\pi^-$	206.01	1922.51	
$K^0 \Rightarrow \pi^0\pi^0$	209.05	1923.82	
$K^0 \Rightarrow \mu^+\mu^-$	225.29	1931.14	1932±3[28]
$\eta \Rightarrow \pi^+\pi^-$	235.47	1935.99	1933±3[12, 14]
$K^\pm \Rightarrow \mu^\pm\nu_\mu$	235.53	1936.02	1933±3[12, 14]
$K^0 \Rightarrow \mu^\pm e^\mp$	237.62	1937.04	1933±3[12, 14]
$K^\pm \Rightarrow e^\pm\nu_e$	246.84	1941.65	1942±3[12, 14]
$K^0 \Rightarrow \gamma\gamma$	248.84	1942.67	1942±3[12, 14]
$K^0 \Rightarrow e^+e^-$	248.84	1942.67	1942±3[12, 14]
$\eta \Rightarrow \mu^+\mu^-$	252.51	1944.56	1942±3[12, 14]
$\eta \Rightarrow \gamma\gamma$	273.72	1956.01	1953±2[14]
$\eta \Rightarrow e^+e^-$	273.72	1956.01	1953±2[14]
$n \Rightarrow \nu\eta$	310.29	1977.73	1975±1[28]
$n \Rightarrow \mu^\pm K^\mp$	329.50	1990.12	
$n \Rightarrow \nu K^0$	337.98	1995.79	1998±2[28]
$n \Rightarrow e^\pm K^\mp$	340.09	1997.23	1998±2[28]
$\rho^0 \Rightarrow \pi^+\pi^-$	358.01	2009.71	2007 ± 10[14]
$\rho^\pm \Rightarrow \pi^\pm\pi^0$	358.89	2010.34	
$\rho^0 \Rightarrow \pi^0\pi^0$	359.76	2010.97	
$\omega \Rightarrow \pi^+\pi^-$	365.21	2014.89	
$\rho^0 \Rightarrow \mu^+\mu^-$	369.44	2017.97	
$\rho^\pm \Rightarrow \pi^\pm\gamma$	371.58	2019.54	2021±2[28]
$\rho^0 \Rightarrow \pi^0\gamma$	372.40	2020.15	2021±2[28]
$\omega \Rightarrow \mu^+\mu^-$	376.42	2023.13	2024±3[14]
$\omega \Rightarrow \pi^0\gamma$	379.32	2025.29	2024±3[14]
$\rho^0 \Rightarrow e^+e^-$	384.25	2029.01	
$\omega \Rightarrow e^+e^-$	390.97	2034.13	
$n \Rightarrow \mu^\pm\pi^\mp$	453.20	2085.15	2084±2[28]
$n \Rightarrow e^\pm\pi^\mp$	459.42	2090.58	
$n \Rightarrow \nu\pi^0$	460.09	2091.17	
$n \Rightarrow \nu\gamma$	469.78	2099.78	

On the whole the experimental situation of pp and pn is contradictory. Nevertheless the encouraging facts take place: the same dibaryons have been found in various processes and besides different experiments with high S.D. (up to 9 S.D.). The investigations at the low physical background with a good mass resolution (≤ 1 MeV) and a greater (by 10 - 100 times) statistics are necessary for further progress.

One can say that simple rules following from energy-momentum and angular momentum conservation laws are established, which are responsible for the creation of resonances in a microscopic system (in a macroscopic system too). This gives the possibility of calculation and prediction of mass trajectories of hadronic (and leptonic) resonances. It is

necessary to make use of available information as we acted for calculation of diproton resonances masses.

Let us consider a $p\pi^+$ system and calculate the invariant masses of resonances, using a total combination of channel asymptotic momenta, which "appear in decay of the proton". The results are illustrated below:

$$1080.63,\ 1081.46,\ 1084.71,\ 1086.18,\ 1088.99,\ 1095.73(1094[29]),\ 1096.91.$$
$$1119.09,\ 1130.47,\ 1149.20,\ 1151.49,\ 1159.04,\ 1159.04,\ 1192.33,$$
$$1202.55,\ 1208.55,\ 1209.46,\ 1212.64,\ 1229.96,\ 1241.09,\ 1241.16,$$
$$1253.76,\ 1256,01,\ 1260.17,\ 1284.64. \qquad (8)$$

These results show that in fact the Δ-isobar is a combination of separate resonances in full analogy with giant resonances in atomic nuclei. Conclusion: the hadronic resonances with large widths are sums of separate ones. There should be found separate resonances with narrow widths when energy accuracy will be increased. Experimental examination of the affirmation will be the most serious test for our approach.

Note that in (8) we illustrated only a fragment of the mass spectrum of resonances in the $p\pi^+$ system. Specifically, we used only the main "tones" of the proton in our calculations. But there must be present "overtones" and they also will give contribution to the mass spectrum of hadrons.

The above-mentioned conclusion is justified for the ρ-meson with mass $m = 768.5\pm0.6$ MeV and width $\Gamma = 151.2\pm1.2$ MeV and also for the f_0 - meson with mass $m = 400-1200$ MeV and width $\Gamma = 600 - 1000$ MeV [10]. The results of our calculations of masses of possible resonances in the $\pi^+\pi^-$ or $\pi^-\pi^-$ system are illustrated below:

$$283.99,\ 285.43,\ 291.06,\ 293.61,\ 298.47,\ 310.06,\ 312.09(313\pm3),$$
$$349.82(350\pm10,\ 354),\ 368.96,\ 400.08(397,\ 400),\ 403.87,\ 416.28,$$
$$470.31(470\pm7),\ 486.67,\ 496.23,\ 497.67(K^0_S),\ 502.71,\ 530.04,$$
$$547.45(\eta),\ 547.56,\ 567.13(569),\ 570.61(569),\ 577.03(576\pm4),\ 614.51,$$
$$656.59(652\pm2),\ 678.90,\ 710.02,\ 729.79,\ 733.70(736),\ 768.50(\rho),$$
$$770.14,\ 771.18,\ 781.94(\omega),\ 789.85,\ 793.85,\ 795.38,\ 802.93,\ 808.37,$$
$$817.62(822),\ 830.27,\ 948.45,\ 959.03,\ 960.32,\ 967.52,$$
$$978.91(f_0(980)). \qquad (9)$$

The experimental data from ref. [12, 30, 31] are given in parenthesis.

3 The geometric quantization in Ω^--decay chain

The conclusions cited above have been examined for a numerous amount of hadronic resonances. As a vivid example, let us consider the Ω^--decay chain. A successive two-particle decay chain is illustrated below; P_i- are asymptotic channel momenta; i is the number of a channel.

$$\begin{aligned}
&\Omega^- \Rightarrow \Lambda K^-(67.8 \pm 0.7)\%, \quad P_1 = 211.1916,\\
&\Omega^- \Rightarrow \Xi^0\pi^-(23.6 \pm 0.7)\%, \quad P_2 = 293.6753,\\
&\Omega^- \Rightarrow \Xi^-\pi^0(8.6 \pm 0.4)\%, \quad P_3 = 289.8280,\\
&\Omega^- \Rightarrow \Xi(1530)^0\pi^-(4.3 * 10^{-4})\%, \quad P_4 = 16.6495,\\
&\Omega^- \Rightarrow \Xi^-\gamma(< 2.2 * 10^{-3})\%, \quad P_5 = 314.2702,\\
&\Omega^- \Rightarrow \Lambda\pi^-(< 1.9 * 10^{-4})\%, \quad P_6 = 448.7094,\\
&\Lambda \Rightarrow p\pi^-(63.9 \pm 0.5)\%, \quad P_7 = 100.5814,\\
&\Lambda \Rightarrow n\pi^0(35.89 \pm 0.5)\%, \quad P_8 = 103.9785,\\
&\Lambda \Rightarrow n\gamma(1.75 * 10^{-3})\%, \quad P_9 = 162.2176,\\
&\Xi(1530)^0 \Rightarrow \Xi^0\pi^0(100)\%, \quad P_{10} = 157.7000,\\
&\Xi(1530)^0 \Rightarrow \Xi^-\pi^+(100)\%, \quad P_{11} = 146.5503,\\
&\Xi^0 \Rightarrow \Lambda\pi^0(99.54 \pm 0.05)\%, \quad P_{12} = 135.2125,\\
&\Xi^0 \Rightarrow \Lambda\gamma(1.06 * 10^{-3})\%, \quad P_{13} = 184.1247,\\
&\Xi^0 \Rightarrow \Sigma^0\gamma(3.5 * 10^{-3})\%, \quad P_{14} = 116.6577,\\
&\Xi^0 \Rightarrow p\pi(< 4 * 10^{-5})\%, \quad P_{15} = 299.1383,\\
&\Sigma^0 \Rightarrow \Lambda\gamma(100)\%, \quad P_{16} = 74.3888,\\
&\Xi^- \Rightarrow \Lambda\pi^-(\approx 100)\%, \quad P_{17} = 139.0379,\\
&\Xi^- \Rightarrow \Sigma^-\gamma(1.27 * 10^{-4})\%, \quad P_{18} = 118.0745,\\
&\Sigma^- \Rightarrow \pi^- n(< 1.9 * 10^{-5})\%, \quad P_{19} = 193.0738,\\
&K^- \Rightarrow \mu^-\nu_\mu(63.51)\%, \quad P_{20} = 235.5318,\\
&K^- \Rightarrow \pi^-\pi^0(21.16)\%, \quad P_{21} = 205.1382,\\
&\pi^- \Rightarrow \mu^-\nu_\mu(99.9877)\%, \quad P_{22} = 29.7918,\\
&\pi^+ \Rightarrow e^+\overline{\nu}_e(1.23 * 10^{-4})\%, \quad P_{23} = 69.7840,\\
&\pi^0 \Rightarrow \gamma\gamma(98.798)\%, \quad P_{24} = 67.4882,\\
&\pi^0 \Rightarrow \mu^\pm e^\mp(< 3.1 * 10^{-8})\%, \quad P_{25} = 26.1299,\\
&\mu \Rightarrow e^-\gamma(< 4.9 * 10^{-11})\%, \quad P_{26} = 52.82796.
\end{aligned} \tag{10}$$

We can observe the commensurability of all momenta. Let us consider the fragment of the commensurable relations:

$$\begin{aligned}
&\frac{P(20)}{P(23)} = 3.3751 \approx \frac{27}{8}; \frac{P(7)}{P(22)} = 3.3761 \approx \frac{27}{8}; \frac{P(3)}{P(19)} = 1.5011 \approx \frac{3}{2};\\
&\frac{P(6)}{P(15)} = 1.5000 \approx \frac{3}{2}; \frac{P(10)}{P(18)} = 1.3356 \approx \frac{4}{3}; \frac{P(5)}{P(20)} = 1.3343 \approx \frac{4}{3};\\
&\frac{P(16)}{P(22)} = 2.4970 \approx \frac{5}{2}; \frac{P(21)}{P(14)} = 1.7584 \approx \frac{7}{4}; \frac{P(10)}{P(12)} = 1.1663 \approx \frac{7}{6};\\
&\frac{P(10)}{P(24)} = 2.3367 \approx \frac{7}{3}; \frac{P(14)}{P(15)} = 0.3899 \approx \frac{2}{5}; \frac{P(2)}{P(20)} = 1.2468 \approx \frac{5}{4};\\
&\frac{P(10)}{P(11)} = 1.0760 \approx \frac{11}{10}; \frac{P(8)}{P(19)} = 0.5385 \approx \frac{27}{50}; \frac{P(16)}{P(17)} = 0.5350 \approx \frac{27}{50};\\
&\frac{P(12)}{P(15)} = 0.4520 \approx \frac{9}{20}; \frac{P(1)}{P(26)} = 3.9977 \approx 4; \frac{P(7)}{P(26)} = 1.9000 \approx \frac{19}{10}.
\end{aligned} \tag{11}$$

Also we are convinced that the ratios of relativistic velocities $v_j = P_j/E_j$ for different decay chain products are commensurable in the limits of experimental error.

Consideration of the chain of binary decay channels of Σ^- -baryon

$$\begin{aligned}
&\Sigma^- \Rightarrow n\pi^-(\approx 100\%), \quad v(n) = 0.201c, \quad v(\pi^-) = 0.810c,\\
&\pi^- \Rightarrow \mu^-\nu_\mu(\approx 100\%), \quad v(\mu^-) = 0.271c, \quad v(\nu_\mu) = c,\\
&\pi^- \Rightarrow e^-\nu_e(\approx 10^{-4}\%), \quad v_1(e^-) = c, \quad v(\nu_e) = c,\\
&\mu^- \Rightarrow e^-\gamma(\approx 10^{-11}\%), \quad v_2(e^-) = c, \quad v(\gamma) = c
\end{aligned} \tag{12}$$

leads to the following relations for the velocities:

$$\frac{v(\pi^-)}{v(n)} = 4.026 \approx 4\ (0.7\%), \quad \frac{v(\pi^-)}{v(\mu^-)} = 2.986 \approx 3\ (0.5\%),$$

$$\frac{v(\mu^-)}{v(n)} = 1.348 \approx \frac{27}{20}\ (0.1\%). \tag{13}$$

Differences of the assumed commensurabilities from the experimental ones are given in brackets. The relations of $v(\nu_\mu)$, $v_1(e^-)$, $v(\nu_e)$ are equal to one.

As another example, we have considered the $K^\pm$-meson decay:

$$\begin{aligned}
&K^\pm \Rightarrow \mu^\pm\nu_\mu, \quad v_1(\mu) = 0.917c, \quad v(\nu_\mu) = c,\\
&K^\pm \Rightarrow \pi^\pm\pi^0, \quad v(\pi^\pm) = 0.827c, \quad v(\pi^0) = 0.835c,\\
&\pi^\pm \Rightarrow \mu^\pm\nu_\mu, \quad v_2(\mu) = 0.271c, \quad v(\nu_\mu) = c,\\
&\pi^\pm \Rightarrow e^\pm\nu_e, \quad v(e) = v(\nu) = c,\\
&\pi^0 \Rightarrow \gamma\gamma, \quad v(\gamma) = c,\\
&\pi^0 \Rightarrow \mu^\pm e^\mp, \quad v_3(\mu) = 0.240c, \quad v(e) = c,\\
&\mu^\pm \Rightarrow e^\pm\gamma, \quad v(e) = v(\gamma) = c.
\end{aligned} \tag{14}$$

The following are observed commensurable relations:

$$\frac{v(\pi^{\pm})}{v_1(\mu)} = 0.906 \approx \frac{9}{10}\ (0.7\%),\ \frac{v(\pi^0)}{v_1(\mu)} = 0.915 \approx \frac{9}{10}\ (1.7\%),$$
$$\frac{v_{\pi^{\pm}}}{v_{\pi_0}} = 0.990 \approx 1\ (1\%), \frac{v_2(\mu)}{v_1(\mu)} = 0.297 \approx \frac{3}{10}\ (1\%),$$
$$\frac{v_3(\mu)}{v_2(\mu)} = 0.885 \approx \frac{9}{10}\ (1.6\%),\ \frac{v_3(\mu)}{v_1(\mu)} = 0.267 \approx \frac{27}{100}\ (1\%). \tag{15}$$

Also the velocities of constituents of $K^{\pm}$-meson decay are commensurable with those of Σ^- -baryon decay. Hence the principle of commensurability of velocities and momenta is universal [7]. It has been considered in detail in the hadron decay chain (Ω^--decay chain).

4 Interpretation of the Darmstadt effect as the resonance in e^+e^- system

Intensive explorations of the Darmstadt effect have begun immediately after the clarification of the narrow positron peaks [32] when heavy ions are scattered. The narrow resonances have been found in the total electron-positron spectrum with energy of peaks equal to 634 ±5, 803 ±6 keV for U+Ta systems, 575 ± 6, 787 ±8 keV for U+Pb systems and 555 ±8, 630 ±8, 815 ±8 keV for U+U systems by ORANGE group. EPOS group has observed the peaks corresponding to 620, 750, 810 keV. The results of the carried out calculations of angular correlations of leptons contradict the hypothesis about decay of the hypothetical axion. Some of e^+e^- peaks affirm the dispersion of the particles at the angle equal to 180° that corresponds to the decay of a free particle moving with mass center velocity of the colliding ions. It was deduced in [33] that the e^+e^- pair cannot be emitted from individually moving nuclei. It is emitted in the presence of the third positive charged partner moving with small transversal velocity ($|\ v_{\pm}\ |<0.02$). Finally, there are evidences that the dependence of the cross section of the process on the energy of incident ions has a resonance character.

So, let us suggest that the entity of the Darmstadt effect deals with the resonance phenomena in an e^+e^--system. The electron is stable. It lives more than 10^{23} years and we do not know any attempts of explanation of this fact. We do not know the internal structure of the electron. Let us take into account the following hypothesis: resonances in the e^+e^--system reflect the internal structure of an electron and a positron as in the situation with a *pp*-system. In other words, we consider the electron and positron as complex and ideal resonators. When the electron and positron collide, there must arise resonances in the e^+e^--system if its frequencies are commensurable with the internal frequencies of the constituents (electron and positron). If the electron (positron) has a complex structure, it must be similar to that of the proton and other hadrons.

We have calculated the masses of e^+e^--resonances basing on the assumption that the velocities of the electron (positron) are equal to those of constituents of all known two-particle decays of hadrons and leptons (commensurable coefficient is equal to 1). For example, a resonance (hadron, lepton) R decays into particles a and b:

$$R \Rightarrow a + b. \tag{16}$$

We can calculate the asymptotic momentum for this decay and velocity of particles a and b:

$$v_{a,b} = \frac{P_{ab}}{\sqrt{m_{a,b}^2 + P_{ab}^2}}. \tag{17}$$

Then

$$P_{e^+e^-} = \frac{m_{e^\pm} v_{a,b}}{\sqrt{1 - v_{a,b}^2}} \tag{18}$$

and the mass of an e^+e^--resonance is equal to

$$m_{e^+e^-} = 2\sqrt{m_{e^\pm}^2 + P_{e^\pm}^2}. \tag{19}$$

Now we will recite a fragment of the results of our calculations. The experimental data are taken from [10, 11, 34] and given in the brackets.

$$\begin{gathered}
1.022059,\ 1.022656,\ 1.023079,\ 1.023329,\ 1.023987,\ 1.024258,\ 1.026876,\\
1.026955,\ 1.027854,\ 1.028237,\ 1.029244,\ 1.029476,\ 1.029904,\ 1.031245,\\
1.034513,\ 1.035822\ 1.037118,\ 1.039020,\ 1.040147,\ 1.041625,\ 1.042424,\\
1.042527,\ 1.043353(1.043[34]),\ 1.046295,\ 1.046712,\ 1.047178,\ 1.050357,\\
1.050508,\ 1.050869,\ 1.051180,\ 1.052787,\ 1.055182,\ 1.055182,\ 1.057687,\\
1.058150,\ 1.061847(1.062[34]),\ 1.063063,\ 1.072682,\ 1.073967(1.077[34]),\\
1.081347,\ 1.087635,\ 1.101556(1.1[10]),\ 1.111588,\ 1.162844,\ 1.173950,\\
1.222222(1.216[11]),\ 1.225956(1.216[11]),\ 1.234439,\ 1.240059,\ 1.259730(1.250[11]),\\
1.290081,\ 1.442571,\ 1.443718,\ 1.446588,\ 1.478648(1.496[11]),\ 1.551127(1.520,\ 1.575),\\
1.681155(1.662,\ 1.68),\ 1.697059(1.7[10]),\ 1.733685(1.726[10],\ 1.730[34]),\\
1.744492(1.742),\ 1.758530(1.782[10]),\ 1.816823(1.8[10],\ 1.82[10]),\ 1.822097(1.827,),\\
1.859311(1.832[34],\ 1.837[10]),\ 1.884107,\ 2.004346,\ 2.380932,\ 2.406907,\\
2.417122,\ 2.420794,\ 2.445545,\ 2.496952,\ 2.515392,\ 2.647650,\ 2.813663,\\
2.819671,\ 2.862870,\ 2.903205,\ 2.906467,\ 2.909418,\ 2.999168,\ 3.048507,\\
3.050526,\ 3.318685,\ 3.440942,\ 3.511252,\ 3.580615,\ 3.625658,\ 3.716721,\\
3.732316,\ 3.781722,\ 3.926994,\ 4.501432,\ 4.595340,\ 4.930220.
\end{gathered} \tag{20}$$

So, we can observe the existence of many resonances in the range of any experimental error. Consequently, the situation is in full analogy with the one described above (*pp*, $p\pi$, $\pi\pi$-resonances).

Later [35] the authors of the paper [36] came to the conclusion that the energy peaks at 1.043 and 1.062 MeV are conditioned by cascade transitions from the high-spin states of the ^{238}U-nucleus. The peak at 1.043 MeV is defined by the coincidence of transitions $32^+ \to 30^+$ and $28^+ \to 26^+$ and the peak at 1.062 MeV - by the coincidence of transitions

$32^+ \to 30^+$ and $30^+ \to 28^+$. The observed peaks are very narrow because of mutual compensation of the Doppler shift energy of the quanta which disperse in opposite directions from the moving nucleus. Of course, we agree with the authors beside one complement. For example, the resonance with 1.062 MeV peak energy has been also observed in the reaction $e^+e^- \to \gamma\gamma$. Therefore we have a double coincidence (double resonance): in the $32^+ \to 30^+$, $28^+ \to 26^+$ transitions and in the $e^+e^- \to \gamma\gamma$ reaction. Actually, this hypothesis can be verified experimentally.

Summary: the discussed energy peaks at 1.043 and 1.062 MeV (and also the others) correspond to relevant resonances in the e^+e^--system. Moreover, the dimensions of these resonances equal $1.9 * 10^{-10}$ and $1.4 * 10^{-10}$ cm.

It is necessary to note that formula (19) is valid when there is free collision of particles. Otherwise, P_{e^+} differs from P_{e^-} and the mass of resonances must be calculated by the formula:

$$m_{e^+e^-} = \sqrt{m_{e^+}^2 + P_{e^+}^2} + \sqrt{m_{e^-}^2 + P_{e^-}^2}, \tag{21}$$

where P_{e^+} and P_{e^-} are the positron and electron momenta.

Hence, the difficult reproduction of measurements of the masses of dilepton resonances by different experimental groups and also of different measurements by the same group has deep physical nature. For example, APEX [38] and EPOS [37] collaborations failed to reproduce their own results observed earlier. It is worthwhile to note that J.J. Griffin [39] came to the conclusion: *This Data provides positive, statistically significant evidence for sharp pairs near 790 keV observed earlier.* There are many resonance-like phenomena in e^-e^+-pairs in the nature and even small changes in the conditions of any experiment can lead to CARDINALLY NEW RESULTS. Therefore new data of APEX and EPOS collaborations have to contain NEW LINES of e^-e^+-pairs different from old ones.

Resonance-like phenomena with narrow widths were observed for "elementary particle" pairs such as: (pp), (pn), $(p\bar{p})$, $\pi\pi$, $(\lambda\lambda)$,... e^-e^+,... -pairs. FOR SOME RESONANCE THERE ARE VERY IMPRESSIVE RESULTS (4, 5, 6 OR EVEN 9 S.D.). Therefore we believe that such a resonance-like phenomenon exists and is generally independent of type of interactions. The lack of acknowledged models and unreproducibility of the resonances mean that it is a new unexpected and mystery phenomenon. Here it is necessary to define the physical entity of such a resonance-like phenomenon — if it exists this will be strong test of modern quantum theory. Further experimental examination of the affirmation will be the most serious test for our parameter free approach.

We accomplish this paragraph with the Nils Bohr statement: *the isolated material particles are abstractions with properties defined and fixed only in the presence of the interaction with other particles* [40] — it seems that this conclusion of Bohr was forgotten completely at the investigation of "elementary particle" pairs resonances.

5 Conclusion

It seems that the rich experimental material on dihadron and dilepton resonances especially narrow nearby the threshold of their appearance is in principle a new one in comparison with nuclear physics data. It cannot be understood without attraction of new notions about the nature of baryons, mesons and leptons. We have recited sufficiently

clear arguments in favor of the fact that the nature of resonances described above has common principles: these resonances are a straightforward manifestation of the complex internal structure of the particles (baryons, mesons, leptons). The generally accepted opinion is based on the fact that these resonances appear when **low energy particles collide and consequently these collisions take place at great distances.** Therefore they do not give the information about the internal structure of colliding particles. Hence there is a standard conclusion: the information about internal structure of the "elementary" particles can be derived from high energy collisions of particles and it becomes more precise with increasing the energy of particles.

Our conclusion is based on the fact that the narrow dihadron and dilepton resonances are conditioned by the complex structure of baryons, mesons and leptons. The material introduced in this work demonstrates, as it seems to us, the equivalence of this affirmation to the physics of processes. Our approach is free of any parameters and it reproduces the centroids of the experimental data of resonance masses discussed above. The accuracy of our calculations depends on the accuracy of the used initial experimental data. Often our calculations give a high accuracy nearby threshold resonances in comparison with existent experimental data, if the initial data have a high accuracy.

We began our researches under the influence of the following conception: varied phenomena in Nature are governed by simple laws common for micro- and macrosystems [7]. The self-coordination and the consistency, ubiquity and unity are the essence of all natural laws. The energy-momentum and the angular momentum conservation laws are universal laws of Nature; they deal with the geometry of four-dimensional space-time. If so, then the geometric quantization (the principle of commensurability) of a micro- and a macrosystems has to be universal because it is the ordinary unification of these laws. Hence, this unification of the universal laws in the geometric quantization rule makes it possible to formulate the resonator principle and the commensurability principle of motions in microsystems in full analogy with those held in macrosystems of the wave nature. In other words, the correspondence principle between micro- and macrosystems established at the dawn of quantum theory development enables us to penetrate into the internal structure of a microsystem. For example, the Kirchhoff rules for calculating complex electromagnetic resonator characteristics consisting of ordinary ones were the starting-point for the formulation of analogous phenomenological rules for calculating dihadronic and dileptonic resonance masses. By the way, it is not necessary to know and to solve appropriate dynamic motion equations, and to introduce any models and parameters in both cases. We have to specially emphasize that the fulfillment of the energy-momentum and angular momentum conservation laws is provided by the macroscopic structure of space-time far from the considered particles where interaction between them disappears. We originated from the principles of commensurability and self-similarity which were discussed in details in [1, 7]. We are convinced in the fact that a positron and an electron have the complex planetary-wave structure similar to that of a proton, neutron, atom, etc. and the clarification of it is the fundamental problem of contemporary science. New and expensive equipment are not needed. One must only increase the accuracy of the existent equipment for low and intermediate energies. The influence of an external field is usually used to establish the eigenfrequencies of the resonators. The resonance phenomena arise when the frequency of the external field coincides with eigenfrequencies of the resonator to be researched. Therefore we suggest the natural method for determination of the eigenfrequencies of "elementary particles" based on collisions of different and the same particles. The resonances will arise when the eigenfrequencies of the relative motions in the resonator will coincide with eigenfrequencies of the colliding particles.

The discovery of the commensurability of velocities and momenta and also of the similarity of "elementary" particle structure is the basic element of the approach described above. The notion of "standing waves" and their remarkable properties are the unified foundation of the approach: the average values of the momentum and angular momentum of the "standing" wave are equal to zero. The stability of majority of systems and also the lifetimes of unstable ones are conditioned namely by these properties of "standing" waves. We have presented a unified parameter- and model-free reproduction of the experimental distribution of pp-, np-, $p\pi$-, $\pi\pi$-, e^+e^--resonance masses. We suggest the existence of identical simple and beautiful physics under this unprecedently precise reproduction of experimental data. We assume the unified theoretical scenario to interpret the observed resonances in the animate and inanimate Nature conditioned by different interactions (electromagnetic, strong, weak, and gravitational [7]). **The geometric quantization $\Leftrightarrow$ the energy-momentum and angular momentum conservation laws are the foundation of the scenario.**

In conclusion, we would like to quote an interesting historical fact. It is known that the sound of two strings of different length is more fine-toned if the ratio of the string lengths is a ratio of small integer numbers [41]. This fact was discovered by Pythagoras. The Pythagoreans believed in the mystic role played by integer numbers in nature. They were convinced that the mystery of the unity of all observed phenòmena should be sought for in various combinations of integer numbers. It is very surprising that there are phenomena in nature that are really described by simple rational relations. We have called that kind of relations the commensurability (geometric quantization) and self - similarity. The existence of commensurability and self - similarity results in the unique unity of the world. The principle of commensurability displays in phenomena in different branches of science [7]. All material objects (micro- and macrosystems) that are described by standing waves know all about each other. Each object is the scaled one of the other and it is not possible to say which is more "fundamental". In this work we considered in detail this statement for elementary particle physics (hadron resonances). Evidently, neither proton nor pion nor electron are elementary objects ("bricks"). The existence of resonances in these systems with any tones indicates the complicated particle structure. Each particle is a combination of subsystems that move in the co-ordination as we said above. Only two fundamental conservation laws of energy and momentum are responsible for this harmonic movement. This leads to commensurability of velocities and momenta or, in other words, to self-similarity.

To explain how an unstable particle can communicate with several open channels we have found it helpful to draw an analogy between the behavior of unstable particles and the behavior of resonant cavities such as organ pipes and electromagnetic cavities (see page 85 of old forgotten paper [9]. We suggested that elementary particles do not consist of "bricks" [7]. The wave nature is their fundamental principle. Two different classes of resonances with boson- and fermion-like features arise in waveguide ring structure depending on their field topology [8]. So the origin of $SU(3)$-symmetry becomes clear, and the following working hypothesis has been proposed by us: the superpositions of leptons

form the fundamental representation of $SU(3)$-symmetry. It is known that mesons decay into photons and an even number of leptons. The pre-decay intermediate states contain only an even number of leptons if one assumes that photons arise from annihilation of electron-positron pairs in the intermediate states. Similar considerations of the hypothetical two-particle channels of baryons convince us that these channels contain an odd number of leptons. All the considerations are justified for heavier hadrons. So we come to the conclusion that the Gell-Mann and Zweig notion about quarks as "building elements" of hadrons (combinations of quarks form the observable states, $q\bar{q}$-mesons, and qqq-baryons) is the manifestation of the fundamental fact: mesons decay into an even number of leptons; and baryons, into an odd number. Therefore quarks represent the first main terms in the superposition of "quasiparticles" in our model. Quarks are complicated clusters "quasiparticles" [42]. Hence our model can give the direction to further generalization of quark ideas. Mesons in comparison with leptons are assumed to be a more complex hierarchic structure – their pre-decay intermediate states are a superposition of the Cooper-type pairs of an even number of leptons. Then baryons will be superpositions of an odd number of leptons. The beauty of our approach is evident. The main properties of proton and neutron are still extremely mysterious and inexplicable. The riddle is in the fact that a proton unlike a neutron is stable. The neutron becomes stable only in the environment of other nucleons. Let us make use of the Gareev hypothesis [7] to understand this qualitatively. According to this hypothesis the stability of a proton is due to its being an ideal wave resonator with a good soundness. The constituents of that resonator are leptons, photons, pions, kaons, etc. To confirm this hypothesis we have carried out systematic comparative analyses of the commensurabilities of wavelengths and velocities of proton and neutron subsystems (constituents). Comparing the relations of orbital and sectorial velocities and also Compton and de Broglie wavelengths of proton and neutron constituents, we have come to the conclusion that the motions in the corresponding conjugate channels are commensurable. This means that a proton and a neutron are two conjugate states of the same particle. Nucleons have such a complex structure that they cannot decay without violation of the universal conservation laws of the baryon and lepton numbers. Actually nobody has observed the decay of a proton. However, a neutron decays through the following three-particle channel $n \Rightarrow pe^-\bar{\nu}_e$. The neutron may be considered as a stable particle in comparison with the others because its lifetime is significantly greater than that of the pion, muon, etc. Our model explains the above-mentioned qualitatively: at the decay moment there occurs a preliminary self-consistent reconstruction of the two-particle channels of a neutron so that it gives origin for an intermediate resonance system. Afterwards this system decays through the proton, electron and antineutrino without the violation of conservation laws of baryon, lepton numbers, and strangeness.

The validity of our approach is corroborated by the results of systematic analysis of hadron decay products. The most reliable evidences are a good description of the mass distribution of pn-, pp-, $\pi\pi$- and e^+e^--resonances and predictions of new ones [7] (our calculations are free of any parameters). Information about the inner structure of proton, neutron, $e^\pm$, pions and so on can be obtained from the usual reactions of the type $e^+ + e^- \Rightarrow \gamma\gamma$, $e^\pm + \gamma \Rightarrow e^\pm\gamma$, $p + d \Rightarrow (pp) + n$, $p + d \Rightarrow (pn) + p$, from scattering $e^\pm\mu^\pm$, $e^\pm N$, etc. at low, intermediate, high energies using existing experimental devices.

For example, it is well known that the virtual state exists for the (pn)-system at E^*=70 keV. Therefore we can say from this experimental fact that the new resonances have to be observed with masses m_x^0=931.4 MeV and $m_x^\pm$=930.1 MeV or $m_x^\pm$=469.7 MeV and m_x^0=468.4 MeV (the $(\pi^+\pi^-)$ resonance at $m_{\pi^+\pi^-} = 470 \pm 7$ MeV [28] can be considered as candidate for the new resonance m_x^0=468.4 MeV).

P.S. Professor A.A. Tyapkin (we thank him for very useful discussions) has indicated the paper [43] where authors come to the conclusion:

In summary, we have measured the inclusive jet cross section in the E_T range 15-440 GeV and find it to be in good agreement with NLO QCD predictions for $E_T < 200$ GeV using MRSD0' PDFs. Above 200 GeV, the jet cross section is significantly higher than the NLO predictions. The data over the full E_T range are very precise. They provide powerful constraints on QCD and demand a reevaluation of theoretical predictions and uncertainties within and beyond the standard model.

Recently, the H1 [44] and ZEUS [45] experiments at HERA have reported an excess of large-x, Q^2 deep inelastic scattering events compared to NLO QCD expectations. The H1 data shows a fairly discrete jump in its last x bin which certainly rules out a parton distribution interpretation, since QCD effects at such large Q^2 should be smooth. It has been known it is impossible to modify quark distributions of the conventional type to fit the CDF jets simultaneously with target DIS data [46]. Therefore there are serious experimental indications to modify the structure of the proton (see discussions in [47]).

Finally, we would like to mention that many of ideas presented in this paper were born under the influence of the papers by A.M. Baldin [48].

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Диадронные и дилептонные резонансы

Предложены простые феноменологические правила для вычисления масс дилептонных и диадронных резонансов. Дана общая интерпретация экзотических резонансов в ядерной физике: дармштадтского эффекта, дибарионных, дипионных и т.д. резонансов. Информация о внутренней структуре $e^{\pm}$, протона, нейтрона, пионов и т.д. может быть получена из обычных реакций типа $e^{+}+e^{-} \Rightarrow \gamma\gamma$, $e^{\pm}+\gamma \Rightarrow e^{\pm}\gamma$, $e^{\pm}\mu^{\pm}$, $e^{\pm}N$ ... при низких, промежуточных и высоких энергиях с использованием существующих экспериментальных установок.

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Dihadronic and Dileptonic Resonances

Simple phenomenological rules are suggested for calculation of dihadron and dilepton resonance masses. A general interpretation is given for different exotic resonances in nuclear physics: Darmstadt-effect, dibaryon, dipion and so on resonances. Information about the inner structure of $e^{\pm}$, proton, neutron, pions and so on can be obtained from the usual reactions of the type $e^{+}+e^{-} \Rightarrow \gamma\gamma$, $e^{\pm}+\gamma \Rightarrow e^{\pm}\gamma$, $e^{\pm}\mu^{\pm}$, $e^{\pm}N$ ... at low, intermediate and high energies using existing experimental devices.

The investigation has been performed at the Bogoliubov Laboratory of Theoretical Physics, JINR.

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