Discreteness in parameters of the Standard Model

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Abstract.
Tuning effect in particle masses manifests itself in integer relations between lepton masses and parameters of the pion (its mass, the mass splitting and \(f_\pi\)). It involves parameters of constituent quark model and basic values of the Standard Model: masses of vector and scalar bosons, QED parameters and the top quark mass. The role of nuclear data is discussed.

1. Introduction
According to Y. Nambu [1] empirical relations between particle masses can be used for the development of the Standard Model - the theory of all interaction with the representation:

\[ SU(3)_{col} \otimes SU(2)_{L} \otimes U(1)_{Y} \]  

The Quantum Chromodynamics (QCD), the first of these three SM-components [2], deals with the strong interaction of colored quarks and gluons. QCD is a commonly accepted theoretical base of nuclear physics and we use it later in our analysis.

R.Feynman marked: "The theories about the rest of physics are very similar to the theory of quantum electrodynamics: they all involve the interaction of spin 1/2 objects (like electrons and quarks) with spin 1 objects (like photons, gluons, or W's) within a framework of amplitudes by which the probability of an event is the square of the length of an arrow. Why are all the theories of physics so similar in their structure?" [3]. Following Nambu we used [4-8] a general approach to the analysis of SM-parameters, particle masses and nuclear data. Common effects in empirical data are considered together with Feynman’s question about the role of vector fields.

2. Tuning effect in particle masses and SM-parameters
The initial observation of integer relations between particle masses made in 70-ties concerned [9,10] mass splitting of the pion, nucleon and electron. Light quarks and the electron belong to the third (the lightest) SM-family. Masses of light quarks are roughly estimated as few MeV [2] but we use instead exactly known characteristics of the pion (the system of light quark–antiquark). Pion mass splitting \(\delta m_\pi=4.5936\) MeV [2] is close to \(9m_e=\Delta=4.599\) MeV [9,10] and hence the double energy of pion \(\beta\)-decay energy \(2\delta m_\pi-2m_e\) is close to \(16m_e=\delta\). We obtained the following empirical ratios: \((m_\mu+m_e)/(2\delta m_\pi-2m_e)=106.169\) MeV/8.165 MeV=13.00 ; \(m_\pi^\pm-m_e/(2\delta m_\pi-2m_e)=17.03\); for a half of the nucleon \(\Delta\)-excitation \(\Delta M_\Delta/(2\delta m_\pi-2m_e)=18.02\); for a stable interval in pseudoscalar mesons \(m_{\eta'}-m_\eta=m_\eta-m_{\pi^\pm}=409\) MeV/(2\(\delta m_\pi-2m_e=49.97\) and for the neutron mass \((m_n+m_e)/(2\delta m_\pi-2m_e)=115.007\). Pion decay parameter \(f_\pi\) [2] is a part of empirical relation: \((f_\pi=130.7\) MeV)/(2\(\delta m_\pi-2m_e)=16.01\).
The involvement of the electron mass and $\delta m_e \approx 9m_e$ into masses of other particles is the first aspect of the tuning effect. Many authors including Y. Nambu [10,11] noticed a frequent appearance of intervals multiple to pions's mass. G. Wick found the same effect with a half of $\omega$-meson mass $(1/2)m_\omega=391$ MeV $=3f_\pi$ [12,13]. In Fig.1 these relations are shown by two-dimensional presentation with the period $130.4$ MeV $=16\cdot 16m_e=f_\pi \approx (1/6)m_\omega$ along the x-axis. The line connecting the pion with $\Lambda$, $\Xi^-$, $\Omega^-$ hyperons corresponds to $1:8:11:12$ ratio in masses.

The half of nucleon $\Delta$-excitation $147$ MeV $=\Delta M_\Delta$ (a line $N-\Delta$) is close to the value $m_s \approx 150$ MeV [14] seen as intervals between $N$, $\Delta$, $\Sigma$ and $\Xi$-baryons. Such constant slope of lines between other masses ($K-N$, $\eta-\mu$, stable $\Delta I=2$ excitations of vector mesons $K^*-K_3^*$, $\omega-\omega_3$ mesons) and the proximity of the $\Xi^-$ mass to $9\cdot 147$ MeV $=3M_q$ are shown in Fig.1 top. Crossed arrows mark the discussed intervals in pseudoscalars $(50\delta)$ close to the standard estimate of baryon constituent quark mass in NRCQM $M_q^\Delta=410$ MeV $=m_{\Delta++}/3$.

Figure 1. Positions of different particle masses $M_i$ and mass intervals, including an estimate of nucleon mass in nuclear medium (circled) in two-dimensional presentation with x-axis in units $16\cdot 16m_e=f_\pi=130.8$ MeV $=m_\omega/6$ and differences $M_i-k\times 16\cdot 16m_e$ at y-axis in units $16m_e=\delta$ [10].
The second aspect of the tuning effect consists in a role of QED radiative correction. Such correction $g/2\pi$ is used for a comparison of different effects [15]. For example, J.Bernstein compared $\alpha/\pi=2.32\cdot10^{-3}$ with CP-nonconservation parameter in kaon decay $\eta=2.23\cdot10^{-3}$ [16].

Two pairs of exactly known SM-parameters – both lepton masses and masses of Z-boson and Higgs boson ($M_H=126$ GeV) are in empirical ratios very close to the QED radiative correction $\alpha/2\pi=1.59\cdot10^{-3}$ (here $\alpha=1/137$ is the SM-parameter). Coincidence of the ratio $(m_\mu=105.66$ MeV$)/(M_Z=91187$ MeV$)=1.159\cdot10^{-3}$ with $\alpha/2\pi$ was discussed in [13].

The recently measured scalar boson mass 126 GeV [18] and the one third of the electron mass $m_\mu/3=511$ keV/3=170.3 keV form the ratio 170.3 keV/126 GeV=1.35-10^{-6} coinciding with $(\alpha/2\pi)^2=1.343\cdot10^{-6}$ [4,5,17]. It means that $m_\mu/3$ and $M_H$ are parts of two ratios close to $\alpha/2\pi$ between them. The $(1/3)m_\mu$ and $\Delta M_\Delta=147$ MeV (the parameter of $\Delta$-excitation $\pi^-\pi^02\pi^+2\pi^-2\pi^02\pi^+2\pi^02\pi^+2\pi^0$ to the strange quark mass $m_s\approx150$ MeV in NRQCD [14]) are in a ratio $(m_\mu/3)/147$ MeV=$1.159\cdot10^{-3}$. Ratios $m_\mu/M_Z$ and $(m_\mu/3)/\Delta M_\Delta/M_H$ are boxed in Table 1 (left and right, one under another, expressed as different power $X=-1,0,1,2$ (left) of the $\alpha/2\pi$).

Tuning effect in particle masses was found in 70-ties [9,10] when a small relative deviation of the muon mass from the integer number of the electron mass ($L=207=23\times9=13\times16-1$), namely $1.12\cdot10^{-3}$, was found to be close to the QED correction $\alpha/2\pi=1.16\cdot10^{-3}$. The determination by R. Crawford at al. of the pion’s mass difference permitted to find out that relative deviation of this value from $9m_\pi$, namely, $5.4(5)$keV/4593.6keV=1.17(11)×10^{-3} coincides with $\alpha/2\pi$ within 10%.

The ratio $m_\mu/\delta m_\mu=23.001$ is a result of the proximity of similar shifts in both values ($m_\mu$ and $\delta m_\mu$) from $n\cdot m_e$. As a result, the observed lepton ratio $m_\mu/m_e=206.76$ becomes integer $L=207$ after a small correction of the electron mass $m_e^*=m_e(1-\alpha/2\pi)$.

The factor $\alpha/2\pi$ is the Schwinger correction to electron magnetic moment. V.Belokurov and D.Shirkov suggested [19] that similar component is expected to be in the value $m_e$ itself.

Conformation of the factor $\alpha/2\pi$ was obtained earlier during analyses of fine- and superfine-structure effects in nuclear excitations. Introduced [10,17,20] parameters of these two structures $\varepsilon''=(\delta''=11$ keV)/8 and $\varepsilon'=1.2$ keV=($\delta'=9.5$ keV)/9 are given in Table 1 (bottom, see text below). Intervals $4\varepsilon''=5.5$ eV and $\delta'=9.5$ keV were found independently by K.Ideno, M.Ohkubo [21-23].

**Table 1.** Presentation of tuning effects in particle masses by the common expression $n\cdot 16m_e(\alpha/2\pi)^X M$ in lines marked $X=1$, 0, 1, 2 (at left) and QED radiative correction $\alpha/2\pi$ ($X=137^{-1}$). Values $m_n$, $m_{e}$, $m_{\mu}$, $m_{\pi}$, the neutron mass shift $\delta m_n - m_n - m_e$, and scalar boson mass are boxed. Stable intervals in nuclear binding energies [24-27] (X=0, M=1), nuclear excitations ($E^*$, $D_{ij}$, X=1 [28]) and neutron resonances ($X=2$ [23]) are considered as indirect confirmation of relations at X=1 and 0. The unconfirmed mass groupings observed at 116 GeV [29] and 58 GeV in LEP (X=1 [30]) are given in parentheses. Values $\Delta E_B$ in the center (X=0, M=1) and $E^*$, $D$ in two bottom section are nuclear parameters serving for the indirect check of the tuning effect [4-8].

| X | M | n=1 | n=13 | n=16 | n=17 | n=18 |
|---|---|-----|-----|-----|-----|-----|
| GeV | 1 | $2\Delta^\circ - 2M_q$ | $M_2=91.2$ (M$^{13}_{t}=58$) | $M_H=126$ |
| 1/2 | $M_1$=115 |
| 0 | $\delta=16m_e=8.176$ | $m_{\mu}=105.7$, $f_\pi=130.7$, $m_{\pi}-m_n$ | $m_s\approx147=\Delta M_\Delta$ |
| MeV | 3 | $2\Delta - 2m_e$ | $106=\Delta E_B$, $130=\Delta E_B$ | $140=\Delta E_B$, $147.2=\Delta E_B$ |
| | | $M^*_{q}=m_{\mu}/2$ | NRCQM | $M_q=441=\Delta E_B$ |
| 1 | $\delta-m_n-m_e=161.6(1)$ | $170=m_e/3$ |
| 8 | $\delta-
u_e=11=8\varepsilon''$ | $143$, $176$, $186$ (Nd, 373 (Sb)) | $749$ (Br, Sb), $1500$ (Hf, Pd) resonances |
3. Constituent quark masses in the tuning effect

Parameter 147 MeV and its three-fold value $147 \text{ MeV} \times 3 = 441 \text{ MeV} = \mathcal{M}_q$ connected with the scalar field (Table 1, right) play an important role in the tuning effect. The second value is an accurate estimate of baryon constituent quark mass in NRQM $M_d^q = 436 \text{ MeV}$ [14]. The value 440 MeV introduced empirically by R. Sternheimer [12] is close to $1/3$ of the $\Xi$-hyperon mass ($1324 \text{ MeV} / 3 = 441 \text{ MeV}$) as it was noticed by P. Kropotkin [31]. Here is a compensation of the mass increase with strangeness and the decrease due to the quark interaction (see Fig.1 top).

![Figure 2. QCD gluon-quark-dressing effect calculated with Dyson-Schwinger equation, initial masses $m_q = 0, 30$ and 70 MeV (top) [32]. The quark-parton acquires a momentum-dependent mass function that at infrared momentum ($p = 0$) is larger by two-orders-of-magnitude than the current-quark mass (several MeV) due to a cloud of gluons that closes a low-momentum quark; the values at left are constituent quark masses $410 \text{ MeV} = M_{\Delta q} - 441 \text{ MeV} = M_q$.]

The value of constituent quark mass ($M_q \approx 440 \text{ MeV}$) is obtained in calculations with the Dyson-Schwinger Equation (see Fig.2) and in the Quark models [14,33]. The value $M_q = 1/3(M_N^{GBE}) = 450 \text{ MeV}$ for the initial quark mass in the Goldstone Boson Exchange Model [33] is shown in Fig.3 where the ”initial” mass for nucleon and $\Delta$-baryon (before switching on the residual interaction between constituent quarks) is about $M_N^{GBE} \approx 1350 \text{ MeV}$ which is marked “+” on left axis of Fig. 3. The strength of GBE-interaction in this calculation (directed along x-axis, the vertical line) correspond to the real nucleon/$\Delta$-baryon splitting 294 MeV.

Despite the fact that the most part of the real mass in the world can be described as constituent quark mass generation in QCD, there exists a tuning effect. In case of neutral baryons the parameter of the residual constituent quark interaction $2\Delta M_{\Delta} = 1233.8(2) - 939.67 = 293.7(6) \text{ MeV}$ coincides with $36 \delta = 294.3 \text{ MeV}$ ($\delta = 16m_e$, last line of Table 2).

![Figure 3. Calculation of nonstrange baryon and $\Lambda$-hyperon masses as a function of interaction strength within Goldstone Boson Exchange Constituent Quark Model; the initial baryon mass $1350 \text{ MeV} = 3 \times 450 \text{ MeV} = 3M_q$ is marked “+” on the left vertical axis. Downward shift of masses of the first baryons (294 MeV between $\Delta$-baryon and N- nucleon) are shown as a function of the GBE strength. Full and dotted lines correspond to states with different parities [33].]
4. Long-range correlations in particle masses and lepton ratio in Standard Model

Discussed empirical relations in particle masses (the first aspect of the tuning effect) are presented in upper/central part of Table 2. Four boxed values at right correspond to the discussed integer presentation of values \( m_\mu + m_e \), \( m_\pi - m_e \) and \( m_n - m_e \) with \( n \times \delta \).

Additional confirmation of the tuning effect is shown in the second column of Table 2 (left) where ratios of particle masses to integer numbers of the common period \( 3m_\pi \approx \delta m_\pi/3 \) are given. This period \( 3m_\pi \) was found by R. Frosch by the computer analysis of the periodicity in all 47 accurately known particle masses [34] (see results in Fig.4). One asterisk marks values which are in accordance with the period \( 16m_\pi \). Boxed in Table 2 are additional values which are in agreement with the correlation while two asterisks correspond to the case of the disagreement.

The shift of neutron mass relative to the integer number of \( \delta=16m_\pi \) (115\( \delta - m_\pi \)) shown in Table 2 (at right, boxed) is determined with the accuracy of 0.1 keV due to a very accurately known proton/electron mass ratio \( m_p/m_e \). This shift accounts 161.6(1) keV which is exactly (1/8) of the nucleon mass splitting \( \delta m_N=1293.3 \) keV, the ratio (1/8)-1.0003(2) with \( \delta m_N \).

The nucleon mass splitting \( \delta m_N \) contains an important information on the quark structure of baryons. The ratio between \( \delta m_N \) and the mass of the \( \Lambda \)-hyperon (the center of the baryon octet), namely, \( \delta m_N/1115.7 \) MeV=1.159\( 10^{-3} \) is close to \( \alpha/2\pi \). Due to Nambu’s relation \( m_\Lambda =8m_\pi \) [11] and the ratio \( 8:1 \) between \( \delta m_N \) and the discussed shift 161 keV all these three values (boxed) are situated in Table 1 one under another. Long-range correlation in particle masses manifested by the equality of the shift 115\( \times \delta - m_\pi - m_n \) to the 1/8 part of \( \delta m_N \) presents an important third aspect of the tuning effect. Similar long-range correlation with \( n\times m_n \) were found in nuclear data.

Manifestations of \( \delta m_N=1293 \) keV in nuclear excitation are given in Table 1 (n=17, M=8): the \( E^* \) grouping in Z-odd nuclei (\( Z \leq 29 \)) and integer relations (n=2,3) in \( E^* \) of \( ^{24} \)Na. The parameter \( \Delta T F .161 \) keV=(1/8)\( \delta m_N \) was found in \( Z=51 \) nuclei (see later discussion of +Table 4).

Deviations of neutral octet baryon masses from integers of \( 16m_\pi \) has a systematic character as it is seen from increasing of the "downwards shift" with the strangeness (from neutron to the \( \Xi^0 \)-hyperon, \( \Delta S=2 \) in Table 2 bottom right), the "shift" accounts about 0.5 MeV per \( \Delta S=1 \).

**Table 2.** Comparison of particle masses with periods \( 3m_\pi \) [34] and \( 16m_\pi \) (n and N - numbers of periods.)

| Part. | \( m_i, \) MeV | \( m_i/3m_\pi \) | N-16m_\pi | Diff., MeV | Comments |
|-------|----------------|-----------------|-------------|-------------|----------|
| \( \mu \) | 105.65839(3) | 68.923* | 106.288 | -0.6294 | -0.511 - 0.118 |
| \( f_\pi \) | 130.7(4) | 130.8 | -0.1 | [2] |
| \( \pi^0 \) | 134.9743(8) | 88.046* | 138.992 | -0.0174 |
| \( \pi^\pm \) | 139.5679(7) | 91.043* | 139.5679(7) | +0.5762 | +0.511 + 0.065 |
| \( \eta^0 \) | 547.45(19) | 357.11 | 547.791 | -0.34(19) |
| \( \omega \) | 781.95(14) | 510.08 | 784.895 | -2.94(14) | -2\times m_e =-3.066 MeV |
| \( \rho \) | 775.49(34) | 505.96 | 778.95 | -9.40 | -2\times m_e =-9.198 MeV |
| \( \varphi \) | 1019.43(8) | 664.98 | 1022.99 | -2.585(8) | -2D_o =2.586 MeV |
| \( K^\pm \) | 493.6469(9) | 322.01 | 490.559 | +3.087(9) | (6\times 0.511 =3.066) |
| \( K^0 \) | 497.671(31) | 324.64** | 498.735 | -1.064(31) | (-1.02) see text |
| \( p \) | 938.2720(1) | 612.051* | 940.2380(1) | -0.6726(1) | \( m_e + 1.4549=9/8D_o \) |
| \( n \) | 939.5654(1) | 612.894* | 940.2380(1) | -0.6726(1) | \( m_e + 0.1616 =1/8D_o \) |
| \( \Sigma^0 \) | 1192.55(10) | 777.920 | 1193.69 | -1.14(10) | (-0.511 \times 2) |
| \( \Xi^0 \) | 1314.9(6) | 857.732 | 1316.33 | -1.40(60) | (-0.511 \times 3) |
| \( \Xi^- \) | 1321.32(13) | 861.92 | 1324.51 | -3.19(13) | (6\times 0.511 =3.066) |
| \( \Omega^- \) | 1672.43(32) | 1090.95 | 1667.90 | +4.53(32) |
| \( \tau \) | 1776.82(16) | 1159.0 | 1782.37 |

**\( \Delta \) n** | 293.7(6) | 294.34 | -0.6(6) |
Figure 4. Check of the formula \( m_i = N \times 3 m_e \) by the minimum of mean-square-root deviation in masses of 47 particles [34]. The most deepest minimum in the whole region of the period \( M_o \) variation is shown; very small occasional probability of this correlation was estimated in [34].

Three-fold values of elements in the relation \( (m_e/3)/\Delta M_\Delta/\hat{M}_H = \alpha/2\pi \), namely, \( m_e/M_q \) together with the ratio \( L = m_\mu/m_e \) (the first aspect of tuning effect) and the exact empirical relation \( m_\mu/M_Z = \alpha/2\pi \) (the second aspect) determines the lepton ratio \( M_Z/M_q = 206.8 \) between vector boson mass and initial baryon constituent quark mass \( M_q = 441 \text{ MeV} \).

The standard way for the estimation of meson constituent quark mass is the use of a half of well-known nonstrange vector meson mass (Table 2). Masses of both vector mesons (\( m_\rho \) are \( m_\omega \)) are somewhat less than \( 6 \times 16 \times 16 m_e = 6 f_\pi = 784.895 \text{ MeV} \) (Table 2 right). The value \( M''_q = m_\rho/2 = 775.49 \text{ MeV} \) (1st aspect of the tuning effect) deviates from \( 3 \times 16 \times 16 m_e = 3 f_\pi \) with 4.7 MeV close to \( 9 \times m_e = \Delta = 4.6 \text{ MeV} \). The mass of the second vector boson \( M_W = 80.399(21) \text{ GeV} \) forms a ratio 207.3 with this NRCQM parameter \( M''_q = 775.49 \text{ MeV} \). This means an empirical indication on the distinguished role of the lepton ratio \( L \). The obtained relations in masses of both vector fields is 4-th aspect of the tuning effect (L-repetition in ratios between different particles). It means that the dynamics of quark-dressing effects (Fig. 2) should include the symmetry properties of interactions to fit this empirical findings. All four aspects of the tuning effect should be considered as the symmetry motivated phenomenon. It is seen also from a common presentation of the muon mass, \( f_\pi = 16 \times 16 m_e \) and \( \Delta M_\Delta \) (1-st aspect of the tuning effect).

5. Additional analysis of the tuning effects in nuclear data

C. Detraz noticed [35] that the universal character of \( 0^+ - 0^+ \) nuclear \( \beta \)-transitions means that "the nucleus is one specific case, the coldest and most symmetric one, of hadronic matter". To check discussed aspects of tuning effects in particle masses we use data from another hadronic effects – nuclear excitations and binding energies. We start with data for light nuclei (Table 3).

Table 3. Comparison of \( E^* \) and \( \Delta E_B \) (keV) in some near-magic nuclei with multiples of \( \varepsilon_o = 2m_e \)

| \( A \) | \( Z \) | \( ^{10}_B \) | \( ^{10}_B \) | \( ^{12}_C \) | \( ^{16}_O \) | \( ^{18}_Ne \) | \( ^{18}_Ne \) | \( ^{20}_Be \) | \( ^{20}_Ne \) | \( ^{138}_Ce \) | \( ^{140}_Ce \) | \( ^{36}_K \) | \( ^{39}_K \) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| \( J^\pi \) | \( ^{+1}_0 \) | 2 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 |
| \( E^* \) | \( ^{1021.8}_E \) | 5110 | 6127 | 27595 | 6130 | 3576 | 4590 | 7151 | 4076 | 4597 | 45996 | 147160 | 147152 |
| \( n(\varepsilon_o) \) | | 1 | 5 | 6 | 27 | 6 | 7/2 | 9/2 | 7 | 4 | 45 | 45 | 8\times16 | 8\times16 |
| \( n(\varepsilon_o) \) | | 1022.0 | 5110 | 6132 | 27594 | 6132 | 3577 | 4599 | 7154 | 4088 | 45990 | 147168 |
| Diff. | | 0.2(2) | 0.3 | 3 | 1(2) | 2 | 1(2) | 9(8) | -3 | -12 | 7 | 8 | -8(2) | -16 |
In the nucleus $^{10}$B with two-holes configuration in the $^{12}$C core the splitting between $0^+, T = 1$ and $1^+, T = 0$ states exactly equal to $2m_e = \varepsilon_o = 1022.0$ keV corresponds to the nucleon spin-flip effect while the first negative parity excitation $E^\ast = 5110.3(6)$ keV corresponds to nucleon transition between the shells. It is shown in Table 3 that these values are exactly rational $1:5.001:27.000$ between themselves and the excitation $0^+_2$ in the above mentioned $^{12}$C core. Similar relations with $\varepsilon_o = 2m_e$ were found in excitations of O and Ne isotopes (Table 3 center). For example, the first cluster excitation in $^{19}$O at $E^\ast = 3067$ keV is close to $3\varepsilon_o$. Standard parameters of the residual interaction of valence nucleon pairs derived from the binding energies of nuclei with $Z, N > 2.8$ $(\varepsilon_{2n2p}/4, \text{Table 3, center})$ are also close to $7\varepsilon_o$ and $4\varepsilon_o$.

Cluster effects in nuclear binding energies $E_B$ considered in [25-27] show long-range correlations in $\Delta E_B$ with $\varepsilon_o = 2m_e$. It is seen in Table 3 right were differences $\Delta E_B$ in light nuclei differing with $4\alpha$ configuration and $\Delta E_B$ in middle-weight N-even nuclei ($N \leq 82$) are partly presented ($\Delta E_B = 128\varepsilon_o$ and $45\varepsilon_o$, small differences $\Delta E_B - n\varepsilon_o$ in table 3 right). Confirmation of tuning effect in particle masses: values $147$ MeV $= 18\varepsilon_o = 32\Delta$ in light and heavy nuclei, $3 \times 147$ MeV $= 441$ MeV and $409$ MeV $= 50\delta$ in all odd-odd and even-even nuclei were observed.

The role of one-pion exchange in nuclear properties was considered by T. Otsuka [28, 36]. The expected stability of excitation due to nuclear tensor force action (one-pion exchange dynamics) can be seen as a linear trend in excitations of Sb isotopes shown in Table 4 [17, 28]. Similar effects were found in other nuclei. Integer ratios between excitations in series of nuclei with the valence proton and sequence $n = 1 - 6$ of pairs of neutrons in $\nu 1h_{11/2}$ subshell ($E^\ast = n \times 161$ keV) permitted determination of tensor-force parameter $\Delta^{TF} = 161$ keV found also in many surrounding nuclei and in nuclei with other nuclear shells [17, 28]. In case of nearby $^{124}$Sb (valence proton and three neutrons in $1h_{11/2}$ subshell) stable intervals 160 keV in low-lying excitation were found together with super-fine effect in highly excited states seen as neutron resonances, namely, intervals 373-750 eV and 570 eV. These superfine intervals are in the ratio $1.16^{-10^{-3}}$ close to $\alpha/2\pi$ with the system of excitation in nearby odd-Sb isotopes (Table 4). Similar effects observed in different nuclei [17, 28] indirectly confirm relations between the pion mass, the shift in neutron mass $161$ keV $= (1/8)\delta m_N$ (coinciding with $\Delta^{TF}$) and stable intervals in neutron resonances.

The distinguished character of intervals $\Delta M_A = 147$ MeV and $m_\pi$ (as well as $170$ keV-$161$ keV $= \delta m_N/8$) in nuclear data could be connected with presentation of nucleon mass in nuclear media (circled in Fig.1) as six $f_\pi$ and additional $\Delta M_A$ (more data are needed).

**Table 4.** Comparison of $E^\ast$ in $Z = 51$ nuclei with $n \times 161$ keV; stable $E^\ast = 170$ keV in $^{101, 103}$Sn [17, 28].

| $^{133}$Sn | $^{131}$Sn | $^{129}$Sn | $^{127}$Sn | $^{125}$Sn | $^{123}$Sn | $^{125}$Sn | $^{119}$Sn | $^{101}$Sn | $^{103}$Sn |
|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| $2J^\pi \rightarrow J^\pi$ | $5^+$ | $5^+$ | $5^+$ | $5^+$ | $5^+$ | $5^+$ | $5^+$ | $5^+$ | $5^+$ |
| $E^\ast$, keV | 962.0 | 798.4 | 645.2 | 491.2 | 332.1 | 160.3 | 644 | 644.0 | 171 | 168 |
| $n_{E^\ast}/\Delta E_B$ | 969 | 808 | 646 | 484 | 323 | 161 | 646 | 646 |
| n = $(N - 70)/Z$ | 6, 82 | 5, 80 | 4, 78 | 3, 76 | 2, 74 | 1, 72 | 4 | 4 | [1] | [1] |
| $D(Sb) \times 10^3$ keV | $[570]$ | $[570]$ | 373 |

6. Relations in Standard Model parameters

It was suggested by F. Wilezcek that the top quark mass has a very representative status: its mass is the largest [37]. One can notice the relation $3:2:1$ between top quark mass and two unconfirmed mass grouping effects at 116 GeV and 58 GeV (see top lines of Table 1). The value 116 GeV was reported in [29] as a possible Higgs boson mass while the effect at $M_{H^0} = 58$ GeV was considered by S. Ting [30]. The third unconfirmed mass-groping effect at 4 GeV $= \Delta^\nu$ was reported in [38]. $Z$-boson ($M_Z$), the top quark ($m_t$) and the scalar field ($M_H$) together with the unconfirmed effects are put in upper section of Table 1. It corresponds to a suggestion that tuning effect in
masses of particles from the second/third SM-families could be connected with the discreteness in the larger mass values. Such discreteness has a parameter $M_q = 3\Delta M_{\Delta} = 3(\alpha/2\pi) M_H$ which manifests itself in NRCQM as the initial quark mass and takes part in the lepton ratio with the Z-boson mass. Scalar mass $M_H$ and $(2/3)m_t = 116$ GeV = $2M_L^3$ are expressed as $18 \times 16 M_q$ and $16 \times 16 M_q$ with $18M_q = 2\Delta^0$ ($\Delta^0$ is close to bottom quark mass). The electron mass itself and the shift in baryon masses with $m_e = 3(m_e/3)$ are connected with the scalar masses.

7. Conclusions
We considered here 4 empirical properties of particle mass spectrum (4 aspects of tuning effect):
1. Electron, muon, pion, neutron masses and parameters $f_\pi, \Delta M_{\Delta}$ are interconnection;
2. QED radiative correction $\alpha/2\pi$ (with $\alpha = 1/137$ or $\alpha_Z \approx 1/129$ [6]) play an important role;
3. Long-range correlation with electromagnetic mass differences has analog in nuclear data;
4. Lepton ratio repetition reflects symmetry properties of Standard Model. Its understanding could be helpful for the explanation of the vector fields universality mentioned by R.Feynman. The confirmation of the ratio 3:2:1 between the top quark mass and mass-grouping effects could clarify the traces of "super-duper" model [3] in which the vector universality and a proximity of the ratio $M_q/(m_t/3) = 1/128$ to $\alpha_Z \approx 1/129$ marked in [6] could be more transparent.

[1] Nambu Y 1998 Nucl. Phys. A 629 3c
[2] Particle Data group 2006 J. Phys. G 33 p.535, M.Suzuki; PDG 2010, Review of Particle Physics
[3] Feynman R 1986 QED-Strange Theory of Light and Matter. (Princ. Univ. Press).
[4] Sukhoruchkin S I 2013 Nucl. Phys. B: Conf. Ser. (in press).
[5] Sukhoruchkin S I 2012 J. Phys.: Conf. Ser. 381 012076; doi:10.1088/1742-6596/381/1/012076.
[6] Sukhoruchkin S I 2009 J. Phys.: Conf. Ser. 171 012064
[7] Sukhoruchkin S I 2011 Proc. Hadron2011 Muenich, 2011, eConf C110613
[8] Sukhoruchkin S I 2007 Nucl. Phys. A 782 37c
[9] Sukhoruchkin S I 1998 Proc. 2nd Conf. Neutr. Cross Section, Washington DC Vol.2 923
[10] Sukhoruchkin S I 1972 Stat. Properties of Nuclei ed. Garg G (Plenum Press) 215
[11] Nambu Y 1952 Progr. Theor. Phys., 7, 595
[12] Sternheimer R 1964 Phys. Rev. 136 1364; Sternheimer R 1964 Phys. Rev. 170 1267.
[13] Sukhoruchkin S I 2000 Symmetries in Subatomic Physics, 3-rd Int. Symp. Adelaide, AIP539, 142.
[14] Itoh C et. al. 1989 Phys. Rev. D 40 3660.
[15] Dyatlov I T 1992 Phys. Rev. D 45 1636.
[16] Bernstein J 1968 Elementary Particles and Currents (Stevenson Inc, publ. Freeman).
[17] Sukhoruchkin S I, Soroko Z N 2013 Proc. ISINN-20 (JINR publ.)
[18] ATLAS collab. 2012 Phys. Lett. B 710 49.
[19] Belokurov V V, Shirkov D V 1991 The Theory of Particle Interactions AIP, New York
[20] Sukhoruchkin S I 1970 Sov. Journ. Nucl. Phys. 444, 285.
[21] Ideno K 1997 Proc. Int. Conf. Neutrons in Research and Industry Creta SPIE Proc Ser 2867 USA 398.
[22] Ohkubo M, Mizumoto M, Nakajima Y 1993 Rept. JAERI-M-93-012.
[23] Landoldt-Boernstein New Series 2009 vol. I/24 ed. Schopper H (Springer)
[24] Sukhoruchkin S I et al., 2012 Proc. Sem. ISINN-19 Dubna 2011, E3-2012-30, pp.284, 296, 308.
[25] Sukhoruchkin S I, Sukhoruchlin D S 2011 Int. J. Mod. Phys. E 20 906
[26] Landoldt-Boernstein New Series 2009 vol. I/22A ed. Schopper H (Springer).
[27] Sukhoruchkin S I 2008 Int. Rev. Phys. (IREPHY) 2 239
[28] Landoldt-Boernstein New Series 2012 vol. I/25A, I/25E ed. Schopper H (Springer)
[29] ALEPH Collaboration, Heister A et al. 2002 Phys. Lett. B 526 191
[30] Ting S 1993 Preprint CERN-PPE/93-34.
[31] Kropotkin P 1971 Field and Matter, 106. (in rus. Moscow University).
[32] Bhagwat M S et al. 2007 Phys. Rev. C 76 045203; Roberts H L L et al 2011 Phys. Rev. C 83 065206
[33] Glozman L 1990 Nucl. Phys. A 629 121c
[34] Frosh R 1991 Nuovo Cim. 104 913
[35] Detraz C 1995 Nucl. Phys. A 583 3.
[36] Otsuka T, Suzuku T, Utsino Y 2008 Nucl. Phys. A 805 127c
[37] Wilczek F 2003 Nucl. Phys. Proc. Suppl. B117 410.
[38] Abazov V M et al., 2009 Phys. Rev. Lett. 103, 061801.