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Discreteness in particle masses and parameters of the Standard Model

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We performed simultaneous analysis of the discreteness in particle mass spectrum and relations in nuclear parameters connected with nuclear tensor force (one-meson exchange dynamics). Analysis of particle masses is in line with the suggestion that empirical relations in masses could be used for the development of the Standard Model. Due to a closeness of the pion mass splitting δm_π=4594 keV to the $9m_e$=4599 keV (m_e is the electron mass) the parameter of the discreteness in particle mass spectrum is close to the doubled value of the pion β-decay energy $16m_e$=$\delta \approx 2\delta m_\pi - 2m_e$ (tuning effect in particle masses). This discreteness was found also in parameters of correlations in nuclear excitations and binding energies. Common tuning effect includes also the nucleon mass splitting δm_N=1293.3 keV which belongs to the fundamental manifestation of the nucleon structure. The value δm_N and its 1/8 part δm_N/8=161 keV were found also in the grouping effect in nuclear excitations and spacing. In the tuning effect in particle masses the value (1/8)δm_N=161 keV accounts the shift of the exactly known neutron mass m_n relative to integer number of the electron rest mass (so-called CODATA relation). We consider these correlations, the possible role of the lepton ratio and the possible hints on the symmetry in the fermion spectra as the new approach to the SM-development.

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1. Introduction

Nucleon interactions within nuclei are commonly considered as a result of one- and many-pion exchange. The role of tensor forces (one-pion exchange) was recently considered by J.Schiffer [1], T.Otsuka [2] and I.Tanihata [3]. They found the regions of nuclear chart where tensor-force effects are important. For example, in heavy antimony isotopes (N=72-82) the valence proton in J^{π}=7/2^{+} state $(\pi, 1g_{7/2})$ strongly interacts with neutrons in the large $\nu, 1h_{11/2}$ subshell. Such deuteron-like situation (spin 1, orbital motion in different directions) with the dominant role of one-pion exchange dynamics in nucleon interaction exists also in light and heavy nuclei. Stable intervals in first excitations of the near-magic ^{116}Sn (E^{*}=1293.6 keV, E_2-E_1=1292.0 kev) correspond to n=8 in this systematics. They are close to the nucleon mass splitting δm_N=1293.3 keV. The system E^{*}, D =nΔ^{TF} was confirmed with stable excitations and spacing in many nearby nuclei [4-8].

The linear trend in excitations E^{*} of ^{odd}Sb isotopes with a slope 161 keV, E^{*}=n(Δ^{TF}=161 keV) is similar to that found in the first excitations of N=21,22 isotopes ^{41}Ca and ^{38,37}S. Here E^{*}=1942.8–1292.0–646.2 keV coincide within 2-3 keV with n=12,8,4 in the system nδ^{TF}. In Z=72,74 isotopes E^{*}=1293–1293–1293–1295 keV (0^{+}, 2^{+} in ^{160}Yb,^{172,176}Hf,^{178}W) correspond to n=8. These E^{*}, D and small intervals at high excitation with D close to $E^{*}(\alpha/2\pi)$ are presented in Table 1 (bottom).

The stable character of excitation about 170 keV in the near-magic ^{101,103}Sn (N=51,53) was confirmed with stable spacing of ^{97,98}Pd (N=51,52). Here stable intervals D=512 keV (close to 3×170 keV, that's n'=3) and D=648 keV and 1293 keV (N=4,8 in the system with Δ^{TM}) was found. The latter interval corresponds to the excitations with ΔJ=2, 1295 keV and 2588 keV). In ^{10}B the interval 1021.72(3) keV (n'=6) is a result of spin-flip effect (0^{+}-1^{+}). Its value is close to 2m_e=1022.0 keV=ε_o. Excitations k·ε_o were noticed in many light nuclei including the magic ^{55}Co. Similar effects with n·161 keV=(1/8)δm_N and n'·170 keV=(1/6)ε_o are considered in [4-9].

Table 1. Presentation of particle masses and parameters from analysis of nuclear data (in lines marked X=-1, 0, 1, 2 at left) by the common expression n·16m$_e$$(\alpha/2\pi)^X$M with the QED radiative correction $\alpha/2\pi$ (α=137^{-1}) [9,10]. Boxed are values M_Z, scalar boson mass M_H, m_μ, m$_\pi$-m$_e$, m$_e$/3, the neutron mass shift N$\delta - m_n - m_e \approx \Delta^{TF}$ and $\Delta M_\Delta \approx m_s$. Stable E*, D_{ij} (at X=1,2) indirectly confirm values at X=1 (center).

X	M	n = 1	n = 13	n=14	n = 16	n = 17	n = 18
-1	3/2				m$_t$=171.2		
GeV	1	2Δ°-2M$_q$	M$_Z$=91.2		(M_H=115)		M_H=125.7 [14]
0	1	16m$_e$=δ=8ε_o	m$_\mu$ = 105.7		f$_\pi$=130.7	m$_\pi$-m$_e$	m$_\Delta$-m$_N$/2=147
MeV	3				M"$_q$ = m$_\rho$/2	NRCQM	M$_q$=441
	3		Particle masses		M_q^ω = m$_\omega$/2	Wick – Sternheimer	n$_\Sigma$-m$_N$-m$_K$=441
1	1		Particle masses			Nδ-m$_n$-m$_e$=161.6(1)	170 = m$_e$/3
keV	8,3					δm_N=1293.3 keV	m_e=511.0 keV
1	1	9.5=δ'=8ε'	Nuclear data	132		161=Δ^{TF} (Sb)	170,168 (Sn)
keV	2	19		266		322 (Sb)	339, ε_{n2n}
	3-6	28-56	492 (M.Ohkubo)	533	606	644 - 962 (Sb)	511=ε_o/2 (Co)
2	1	11=δ''=8ε''			176	187 (Nd)	D in neutron
eV	4-8	44	570 (Sb)			749,1500 (Sb,Pd,Rh)	resonances

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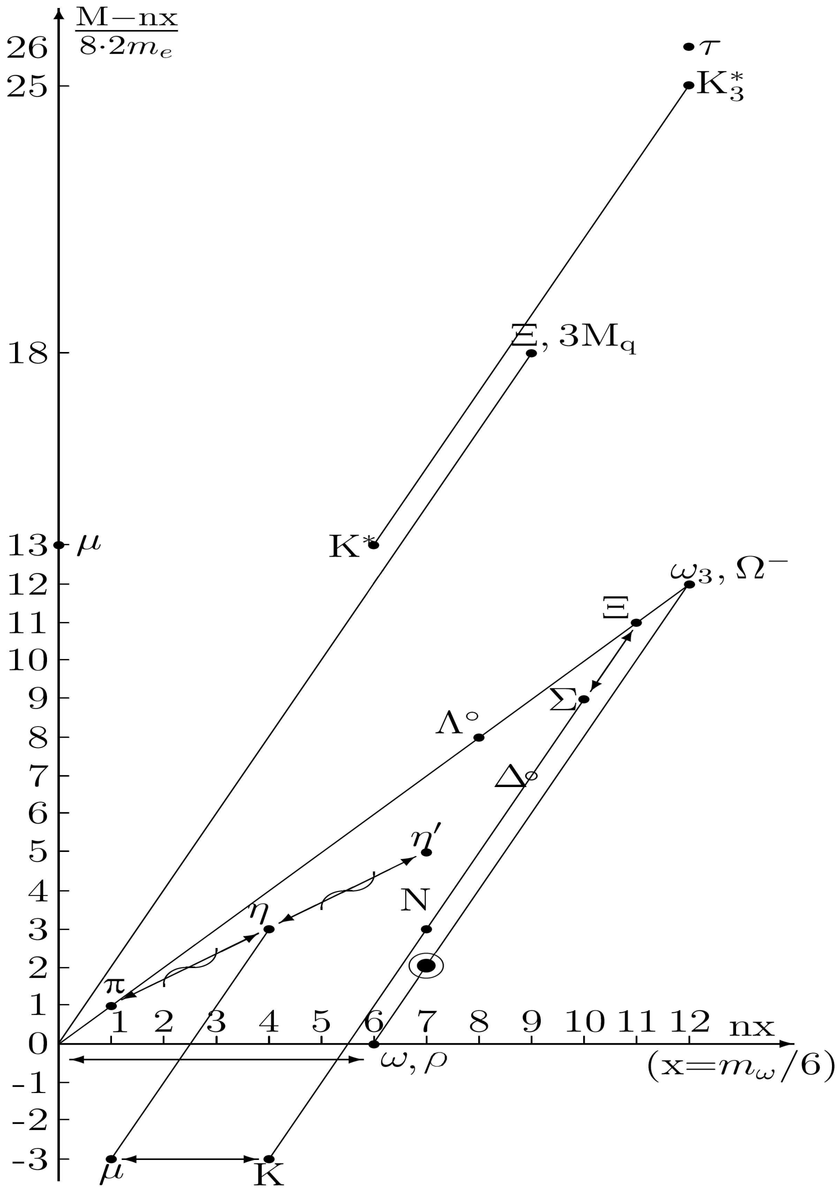

Figure 1: Position of the nucleon mass N among different mass intervals and particle masses in two-dimensional presentation. Values on the horizontal axis are in units $16\cdot 16m_e$ coinciding with the pion parameter f_π=130.7(4) MeV close to $m_\omega/6\approx m_\rho/6$. The remainder – values M_i-kδ=M_i-k$16\cdot 16m_e$ – are displayed along the vertical axis in units $16m_e$. Three lines with different slopes correspond to:
1) the main parameter ΔM_Δ=147 MeV of baryon constituent quark masses from the nucleon Δ-excitation (m_{Δ^o}-m_n)/2=18δ and initial constituent quark mass M_q=3$\times$147 MeV; initial baryon mass 3M_q=m_Ξ (top);
2) the pion mass 140 MeV=f_π+δ (n=16+1), masses of Λ, Ξ and Ω hyperons are close to 8m_π, 11m_π, 12m_π
3) stable interval in pseudoscalar meson $m_{\eta'}$-m_η=m_η-$m^\pm_\pi$ (crossed arrows, n=50 in units δ=16m_e.
Nucleon Δ-excitation and two s-quark masses m_s result in a long line from the kaon (K, n=4·16-3=61) and the neutron mass (N, n=7·16+3=115) to the Ξ^- hyperon mass (Ξ).
Nucleon mass in nuclear medium (m^{nucl}_N, circled large point) is close to the sum of ΔM_Δ=147 MeV and 6f_π=6·16$\cdot$16$m_e\approx m_\omega\approx m_\rho$. It is the last member of the sequence of the baryon mass transformation from the initial mass 3M_q=9ΔM_Δ (at top, n=9·18) to m^{nucl}_N at the bottom.
The mass of τ lepton and 2^+ excitation of vector mesons (shown at top) are considered elsewhere. They are close to integer numbers of the $M_q\approx 3\Delta M_\Delta$=$(\alpha/2\pi)M_H$.

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2. CODATA relation in the tuning effect

Nucleon mass is a result of constituent quark-mass evolution: First, a reduction of each quark mass from M_q (n=3·18) to $\Delta M_\Delta+2f_\pi$ (n=18+2·16 about 50-51). In Fig.1 it corresponds to the shift downwards from $3M_q$ to Δ. At the second step, due to spin-dependent interaction between quarks, nucleon mass looses $2\Delta M_\Delta$ (n=151-36=115). Nucleon mass in the nuclear medium m_N^{nucl} (circled dot in Fig.1, about 8 MeV$\approx\delta$ below m_N) is shifted due to residual quark interaction. The generation of the initial mass and its reduction is explained in QCD and NRCQM [15-17]. The value m_N^{nucl} is the last in a sequence from the initial mass $3M_q$=9ΔM_Δ – to the Δ-baryon mass 1320 MeV=3(2f_π+ΔM_Δ)=3M_q^Δ – to m_N – and finally to 6f_π+ΔM_Δ. So, number n=115 corresponds to the neutron mass.

The shift of the neutron mass relative to the value 115δ equal to $\boxed{\delta m_n\text{=161.65(6) keV}}$ was derived from the recent precise ratio between neutron and electron masses evaluated by CODATA [18] $\boxed{m_n/m_e\text{=1838.6836605(1)}}$. The shift accounts an integer ratio with nucleon mass splitting δm_N=1293.3 keV $\boxed{\delta m_N/\delta m_n\text{=8(1.0001(1))}}$. Such unexpected relation in CODATA results

$$m_n = 115\cdot 16m_e - m_e - \delta m_N/8 \tag{2.1}$$

$$m_p = 115\cdot 16m_e - m_e - 9\delta m_N/8 \tag{2.2}$$

allows conclusions concerning the general properties of the tunung effect in particle masses.

First of all, there are other mass parameters with integer representation of values with the period δ (three top lines in Table 2 [9]). Muon mass with the lepton ratio L=m_μ/m_e=13·16-1=207 has the same combination of nδ – m_e as the neutron mass. Other examples - values f_π and ΔM_Δ.

Secondly, constituent quark masses (M_q and M_q'', Table 2) which are produced with the gluon-quark-dressing effect [15,19] are in the lepton ratios L=207 with the vector boson masses, namely, L^Z=M_Z/M_q=207.4 and L^W=M_W/M_q''=207.5.

Table 2. Comparison of particle masses with the period 16m_e=δ=8176 keV (comments – in MeV, constant shift Δ=9m_e is boxed).

Particle	m_i, MeV	k	m_i-k·16m_e	Diff.	Comments (MeV)
μ	105.658367(4)	13	-0.6294	-m_e-0.118	
f_π	130.7(4) [20]	16		≈0	
Δ°-n	294.2(2)	36		≈0	2(ΔM_Δ=147.1), $\Delta E_B = 147.2$ [4]
M_q NRCQM, $m_{Xi^-}/3$	441	3·18			ΔE_B=441 [4]
M_H/18·16	436	3·18-Δ		$\boxed{5 = -\Delta}$	$m_d \approx \Delta$
M_Z/L	440.5	3·18		≈ -2m_e	
η'-η, η-$\pi^\pm$	409	50		≈0	ΔE_B=409 [4]
M_q'' NRCQM, $m_\rho/2$	387.7	48		$\boxed{-4.60 = -\Delta}$	$m_d \approx \Delta$, m_ρ=775.49(34) [14]
M_W/L	388.4	3·16		≈ -2m_e	3f_π
n	939.5654(1)	115	-0.6726(1)		-m_e-(1/8)δm_N
p	938.2720(1)	115	- 1.9666(1)		-m_e-(9/8)δm_N
Σ°	1192.64(2)	146	$\boxed{-1.05(2)}$		-2m_e=-1.022
Ξ°	1314.86(20)	161	$\boxed{-1.47(20)}$		-3m_e=-1.533

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3. Empirical relations in SM-parameters

Exactness of CODATA integer relation could mean the presence of the common general origin of all SM-interactions. It was R.Feynman who draw attention to the common vector character of all interactions [21]. He suggested that in the future "super-duper model" an understanding of the main parameters like α could be achieved. Relations with factor α=1/137 are shown in Table 1 (boxed values related as $\alpha/2\pi$). The proximity of $\alpha/2\pi = 115.9 \cdot 10^{-5}$ to the ratio between the well-know main SM-parameters – masses of the μ-lepton and Z-boson m_μ/M_Z=115.9$\cdot 10^{-5}$ was noticed long ago. Similar relations with QED parameter for a short ($1/M_Z$) distance α_Z=1/129 can be added: the ratio between m_e and the pion mass 170 keV/140 MeV=121$\cdot 10^{-5}$ and between the pion mass and unconfirmed mass M'_H=116 GeV of the possible scalar boson (twice the mass of the groping effect at 58 GeV discussed by S.Ting [22]), namely, 140 MeV/116 GeV=121$\cdot 10^{-5}$, are close to $\alpha_Z/2\pi = 123 \cdot 10^{-5}$. It was suggested by V.Belokurov and D.Shirkov [23] that the small QED factor ($\alpha/2\pi$) could be found in the electron rest mass itself. We briefly consider here four possible connection of the obtained unexpected CODATA relations with other empirical observations.

1) Integer ratios 1 : 16 and 1 ; 9 in CODATA relations (m_e : δ and 161 keV : δm_N) as well as the ratio 1 : 9 in charge splitting (m_e : δm_π) could be considered together with the recent quark masses estimations m_d=4.78(9) MeV close to Δ=9m_e=4.60 MeV and m_b=4.18(1) GeV close to 9M_q=4.0 GeV [9,14] (if values would be confirmed). Observed integer relations in lepton masses m_μ/m_e=L=13$\cdot$16-1 coinciding with the similar ratio between masses of Z-bozon and the constituent quark M_q were considered [9] in connection with the parity nonconsevation as the result of a possible symmetry motivated properties of fermions (currents) composed the mass. It could mean that masses m_e and M_q=$m_e(\alpha/2\pi)^{-1}$ might be considered together with the rational relation 3$\cdot$18$\cdot$16m_e for the large mass. Difference between these two large values accounts about m_e. We need theoretical understanding of the observed tuning effect supplemented with CODATA relation. The general trend in QCD-development based on lattice-calculations should be combined with symmetry properties of common components.

2) Indirect confirmation of the tuning effect in particle masses was obtained from analysis of excitations of nuclei where tensor phrases connected with one-meson exchange play the dominant role. Development of nuclear model where nucleon structure would be directly included should take into account existing results from analysis of nuclear binding energies. Here in cluster effects with systems like ^{4}He and ^{6}He parameters of the grouping of difference of binding energies ΔE_B clearly demonstrate the distinguished role of intervals connected with integer values of the electron mass m_e (for example, Δ=9m_e etc.). In Table 2 values ΔE_B=147.2 MeV=32Δ coinciding with ΔM_Δ, ΔE_B=441 MeV close to 3ΔM_Δ, 409 MeV close to M_q^Δ are given in comments.

3) Observed additional shift in masses of strange hyperons Σ° and Ξ° (possibly correlated with the strangeness, boxed in two bottom lines of Table 2) could be connected with transformations into the mass of the constituent quark. This effect could be important for understanding of the origin of the dark matter and possible estimation of the gravitation intercity considered in [24]).

4) Rational relations with the masses of heavy fermions (M_q, M''_q) were extended to the scalar boon masses [9,11] (see the fifth line in Table 2). We expect theoretical interpretation of observed empirical effects. Some relations in masses of heavy bosons and quarks were discussed in [9,11].

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4. Conclusions

Combined analysis of particle mass spectrum and nuclear data, considered both as results of quark-structure hadronization process, shows a distinguished role of values of charge mass splitting of the nucleon, the pion and leptons. Rational relations in particle masses including the lepton ratio could be considered as the manifestation of symmetry properties of the common fundamental components directly connected with the electron rest mass and properties of the physical condensate. Presence of CODATA relation, if confirmed, demands drastic modification of property of SM-condensate. Frank Wilczek named the electron rest mass "theoretical puzzle". If the empirical CODATA relation will be confirmed and commonly accepted, it will demonstrate an important role of the electron mass and the QED in the SM-development.

References

[1] J.P. Schiffer et al., Phys. Rev. Lett. 92 (2004) 162501, and private communication.

[2] T. Otsuka, T. Suzuki, Y. Utsuno, Y., Nucl. Phys. A **805** (2008) 127c.

[3] I. Tanihata, Mod. Phys. Lett. A **25** (2010) 1886, and private communication.

[4] S.I. Sukhoruchkin *et al.*, Proc. ISINN–19. JINR E3-2012-30, pp. 284, 296, 308.

[5] S.I. Sukhoruchkin *et al.*, Proc. ISINN–20, JINR E3-2013-22, p. 254.

[6] S.I. Sukhoruchkin *et al.*, Proc. ISINN–21. JINR E3-2014-13, p. 255.

[7] S.I. Sukhoruchkin *et al.*, Proc. ISINN–22. JINR E3-2015-30, pp. 265, 277, 289, 301.

[8] L-B New Series Vols. I/25A,E,H. Springer, 2012, 2013, 2015; H.Schopper (Ed.).

[9] S.I. Sukhoruchkin, Nucl. Part. Phys. Proc. (submit.).

[10] S.I. Sukhoruchkin, *Stat. Properties of Nuclei*. G.Garg (Ed.), p. 215. (Pl. Press, 1972).

[11] S.I. Sukhoruchkin, Nucl. Part. Phys. Proc. **258-259** (2015) 268.

[12] S.I. Sukhoruchkin, Nucl. Phys. B (Proc. Suppl.) **234** (2013) 241.

[13] S.I. Sukhoruchkin, J. Phys.: Conf. Ser. **447** (2013) 012056

[14] K.A.Olive et al. (Partice Data Group), Chin.Phys. C.2014, 38(9),090001.

[15] H.L.L. Roberts *et al*, Phys. Rev. C **83** (2011) 065206.

[16] L. Glozman, *Nucl. Phys.* A **629** (1998) 121c.

[17] C. Itoh *et. al.*, Phys. Rev. D **40** (1989) 3660.

[18] P. Mohr *et al.*, Rev. Mod. Phys. **84** (2012) 1527.

[19] L-B New Series Vol. I/22AB, Springer, 2009. H. Schopper (Ed.).

[20] M. Suzuki, J. Phys. G: Part. Nucl. Phys. **33** (2006) 535.

[21] R. Feynman, QED-Strange Theory of Light and Maatter, Princ. Univ. Press. 1986.

[22] S. Ting, CERN-PPE/93-34, 1993.

[23] V.V. Belokurov, D.V. Shirkov, The Theory of Particle Interactions. AIP, N.-Y., 1991.

[24] S.I. Sukhoruchkin, Program and Thesis, Proc. 40th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Leningrad, 1990, p. 147.

[25] S.I. Sukhoruchkin, Proc. XVI Workshop on High Energy Spin Phys., Dubna, 2015 (submit.).

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