NEW METHOD OF SPACING ANALYSIS OF ALL NUCLEI

S.I. Sukhoruchkin, D.S. Sukhoruchkin

B.P. Konstantinov Petersburg Nuclear Physics Institute 188300 Gatchina

Abstract

Results of an application of Combined Adjacent Interval Method (COMAIM) to all nuclei of Nuclear Chart are considered. Parameters derived from residual interaction of nuclei with valence nucleons are compared with stable intervals in spectra corresponding to phonon-like excitations in some of near-magic nuclei. Common trends in observed values of stable intervals are discussed in connection with tuning effect in nuclear data and particle masses.

1. Introduction

In this work, we continue earlier reported [1,2] analysis of nonstatistical effects (superfine- and fine structures) in highly-excited nuclear states. Despite the fact that nucleons have a very complicated structure and in most of nuclear models nucleon quark structure remains to be ignored, we should take into account that the Standard Model as the theory of all interaction is still in the unfinished stage. The presence of the common empirically observed discreteness in many particle masses named "tuning effect" considered elsewhere [3-6] is presented in Table 1 and Fig.1 where nucleon masses are given in a very simple representation with the common for many particle period δ=16m_e=8176 keV found with the analysis of so-called CODATA relation between masses of nucleons and the electron [7]. Nearly the same value could be obtained from empirical observation by Y. Nambu and A. Autot made in 70-ties [8,9] on masses of the μ and π mesons (m_μ+m_π):(13+17)=8174 keV close to the doubled value of the pion's β-decay energy 2(δm_π-m_e)=8166 keV due to the noticed in [10] closeness of the pion charge splitting δm_π=4.594 keV to 9m_e=4.599 keV=Δ. Integer values of the parameter $\Delta = 9m_e$ were found in nuclear binding energies [11]. There are numbers n=13,16,17,18,50 and 115 of the period $\delta = 16m_e$ for the mentioned particle masses including the pion parameter f_π, nucleon Δ-excitation, the equidistancy between pseudoscalar meson masses (crossed arrows in Fig.1) and constituent quark masses in Nonrelativistic Constituent Quark Model (NRCQM) M_q''=m_ρ/2=388 MeV (n=3·16=48), M_q=m_Ξ/3=441 MeV (n=3·18=54, initial quark mass, three-fold value of the ΔM_Δ=147 MeV). All they are presented in Table 1.

Nucleon mass in nuclear media is represented as 6f_π+ΔM_Δ (Fig.1). Value ΔM_Δ can be compared with stable character of residual interaction of valence nucleons at different nuclear shells 340 keV=ε_{np}, ε_{n2n} [12], Fig.19-22 in [13]. They are in the relation of 340 keV/294 keV=116·10^{-5} close to QED correction $\alpha/2\pi$=116·10^{-5}. It is a continuation of the similar relation between the scalar mass and ΔM_Δ (ratio 147 MeV/125 GeV=118·10^{-5}) and corresponds to a possible important role of the influence of the physical condensate [3] on the properties of the heavy fermions forming nucleons.

Recent confirmation of the common valence nucleon interaction parameters in nuclei around Z,N=20,28,50 [6,14] is in accordance with the described below results obtained with the COMAIM method [1]. Collected in PNPI file of excitations of all nuclei contains 718 isotopes (with number of known energies above one hundred) and 10 stable intervals for each of them were used for a study of the systematic trends in the excitation energies.

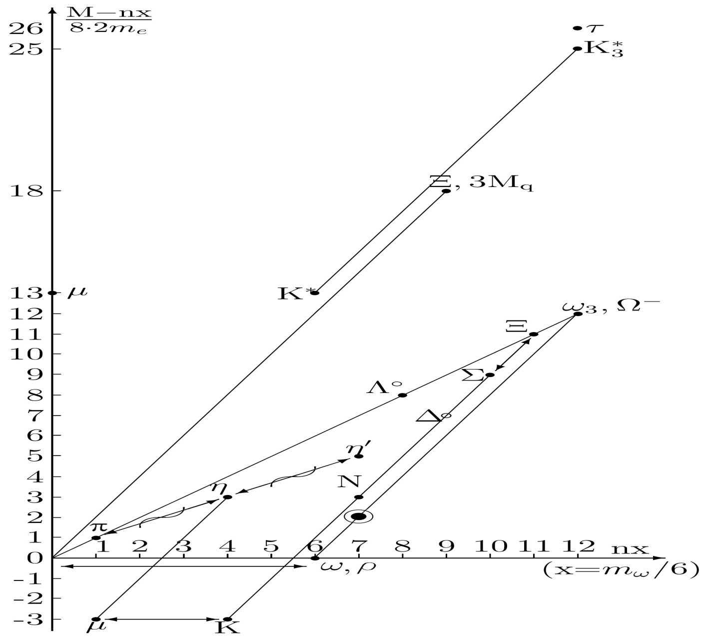

Fig. 1. Evolution of the baryon mass N shown in two-dimensional presentation. Values on the horizontal axis are in units $16 \cdot 16m_e$ = f_π=130.7(4) MeV≈ $m_\rho/6$. The remainder – M_i-k16δ= =M_i-k16 $\cdot$ 16m_e are displayed along vertical axis in units 16m_e. Lines correspond to:
1) main parameter ΔM_Δ=147 MeV of baryon constituent quark masses (m_{Δ°-m_n)/2=18δ;
2) pion mass 140 MeV=f_π+δ, n=17; masses of Λ, Ξ, Ω hyperons are close to 8m_π, 11m_π, 12m_π;
3) stable interval in pseudoscalar mesons $m_{\eta'}$-m_η=m_η-$m_\pi^\pm$ (crossed arrows, n=50);
4) nucleon mass in nuclear medium (circled point) close to sum ΔM_Δ+6f_π (line ω,ρ - Ω^-).

Table 1. Presentation of parameters of tuning effect in particle masses (three top sections) and in nuclear data (bottom, sections marked X=-1, 0, 1 at left) by the common expression n·16m$_e$($\alpha/2\pi$)^{X}M with the parameter of QED radiative correction $\alpha/2\pi$. Values m$_\mu$, m$_\pi$-m$_e$, boson masses and parameters of nonstatistical effects (at left) are boxed.

X	M	n = 1	n = 13	n = 16	n = 17	n = 18	Comment
-1	3/2			m$_t$=172.0			Part.
GeV	1	16M_q=δ°	$\boxed{M_Z=91.2}$	M_H=115		$\boxed{M_H=126}$	masses
0	1	16m_e=2m_d-2m_e	$\boxed{m_\mu=106}$	f$_\pi$=130.7	$\boxed{m_\pi\text{-}m_e}$	$\boxed{\Delta M_\Delta=147}$	NRCQM
MeV	3			M"$_q$=m$_\rho$/2		M$_q$=441=ΔE$_B$	param.
1	1	$\boxed{16m_e=\delta=8\varepsilon_\circ}$			$\boxed{k\delta\text{-}m_n\text{-}m_e=}$	$\boxed{170 = m_e/3}$	Part.
keV	8	δm_N=1293.3			$\boxed{=161.651(6)}$		CODATA
1	1	$\boxed{9.5=\delta'=8\varepsilon'}$	123	152	Δ^{TF}=161	170 (Sn)	Nuclear
keV	3				484 (E^*)	512 (Pd)	data
	4		492**	606*	648 (Pd)	682(Co)	
	8		984*	1212	1293 (E^*)	1360 (Te)	
2	1	$\boxed{11=\delta''=8\varepsilon''}$	143	176	749 (Br,Sb)		Neutron
eV	4		570 (Sb)		1500 (Sb,Pd)		reson.

2. Excitations in nuclei around the tin

We study here parameters of the residual interaction and stable phonon-like excitations in nuclei situated at the filled nucleon shells Z=50. For example, in spacing distribution of all 151 energy levels of near-magic ^{121}Sn strong nearly equidistant sharp maxima at 584 keV and 1156 keV (both 3 standard deviations) correspond to stable 2^+ excitations in many tin isotopes (E^*=1210-1290 keV). Stable excitations with values 1255 keV in ^{103}Rh-^{105}Ag found earlier [1] were confirmed here with the similar stable interval 1255 keV in neighbour ^{104}Rh. Intervals 1289 keV-1291 keV in ^{105,107}Ag correspond to D=648 keV-1293 keV=δm_N in ^{97,98}Pd found earlier (see below). Obtained with COMAIM method parameters were used in the analysis. Study of a common trend in residual valence nucleon interaction and stable phonon-like excitations simultaneously in many nuclei provide an information for production of nuclear microscopic models based on the nucleon structure.

Stable character of the first excitations of magic ^{101,103}Sn close to $18\delta'$=170 keV (Table 2) corresponds to the tensor force action. This effect could be common for other nuclei with neutron number N=51 (^{85}Se and ^{98}Ag, Table 2, center). Both low-lying excitations of magic ^{133}Sn (N=83) are close to integer number of the 170 keV (Table 2, left). Phonon-like excitations in nuclei $^{116-118}$Sn (Table 3, left and Fig.2, right) correspond to excitations with values ε_o=1022 keV=$6\cdot 18\delta'$ in nuclei ^{113}In and ^{117}Sn (Table 3, boxed). They are included in the maximum at 1022 =ε_o in the sum E^* distribution (Fig.3, top left).

Table 2. Excitations (in keV) in nuclei with Z=50,34,47 and D in ^{85}Se (Fig.2 in [1]), close to integers of $18\delta'$=170 keV=$m_e/3$=$\varepsilon_o/6$ or Δ^{TF}=$17\delta'$=161 keV=$\delta m_N/8$.

Z	50	50	50		34			34	47			47
N	51	53	83		51			50	51			50
^AZ	^{101}Sn	^{103}Sn	^{133}Sn		^{85}Se			^{84}Se	^{98}Ag			^{97}Ag
E^*	170	168	854	1363	170	339	511	1455	167.8	515	1291	1290
$2J^\pi$	7^+	$(7)^+$	3^-	3^-	D	D	D	2^+	(3^+)	2^+,3^+	1^+-3^+	13^+
$18\delta'$	170	170	851	1362	170	340	511	$(9/8)\delta m_N$	170	511	δm_N	δm_N

Stable interval D=E^*=2049 keV (close to $2\varepsilon_o$=2044 keV) in the spectrum of nucleus ^{113}In (Fig.4, top right) is adjacent with several intervals with values rationally related with it. Distribution of intervals adjacent with D=x=2049 keV is presented in Fig.4 (center) together with the relation D=k$\varepsilon_o/2$ (k=1,3,4,6,7). In Table 3 (right) values of excitation in ^{113}In themselves are compared with integers of the parameter ε_o.

Intervals D=509, 1030 and 2029 keV close to the same sequence were found in neighbour ^{116}Te (also N=64). In the spectrum of this nucleus an initial equidistacy with the interval D=682 keV=$(2/3)\varepsilon_o$ (Table 4, left) changes into the stable character of the interval 510 which is a result of the proximity of the excitation values themselves to E^*=n$\cdot\varepsilon_o$ (right). In spectra of ^{97}Pd and ^{98}Pd (N=51,52) there are stable intervals D=648-965-1293 keV (Fig.4) which correspond to the equidistant excitation ΔJ=2 (Table 5, left) close to δm_N=1293 keV. Stable interval D=512 keV belongs to the fine structure system n×170 keV in other nuclei with N=51 (Table 2) and was found in excitations of ^{55}Co (Fig.5 top left) with configuration of nucleons in the ground state – a hole in magic ^{56}Ni. Spacing distribution in ^{55}Co and D^{AIM} distribution for x=1022 keV=ε_o (Fig.5, right) contains maxima at 511 keV as well as 682 keV=4×($18\delta'$=170 keV) and 324 keV=2×$17\delta'$.

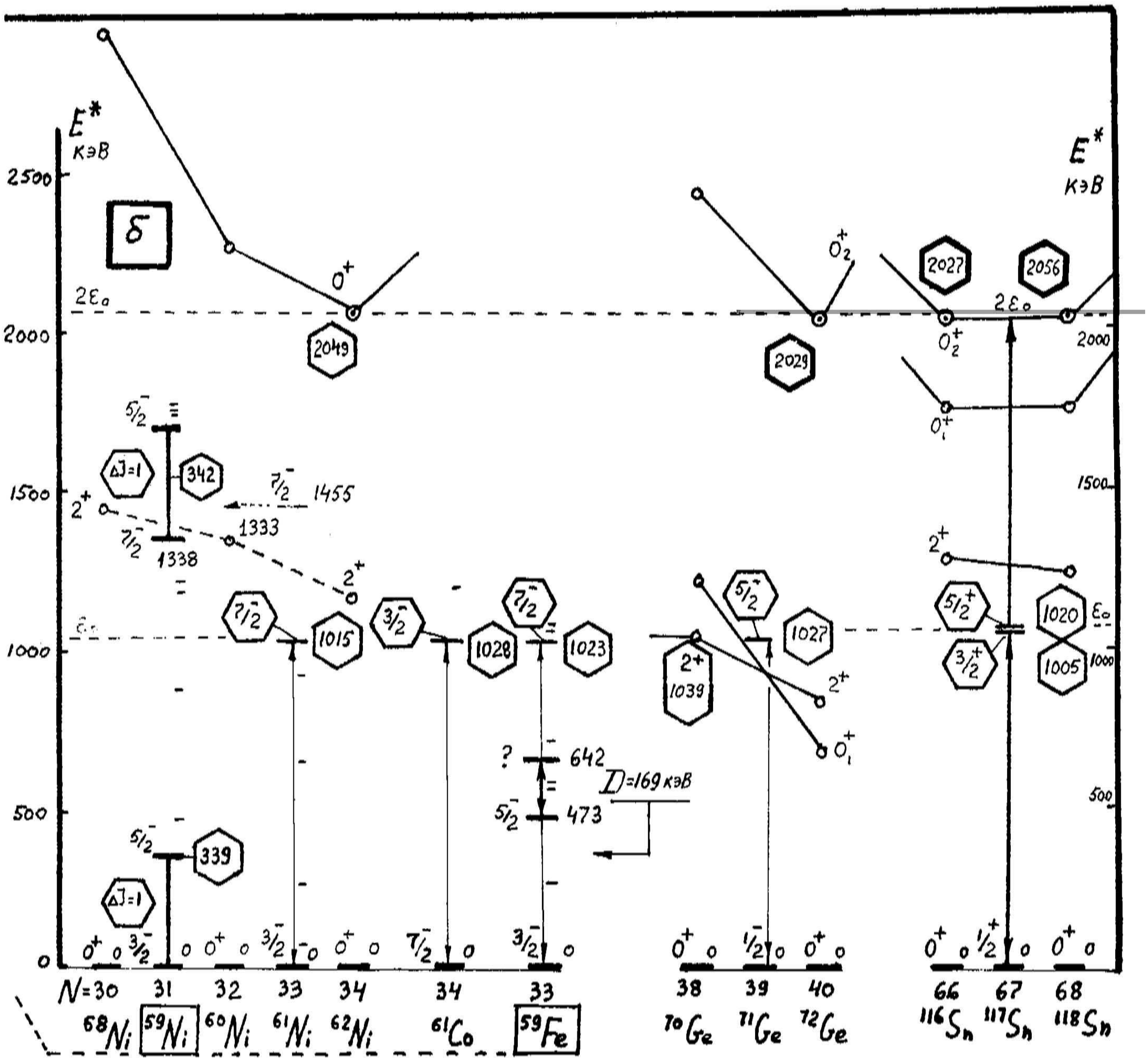

Fig. 2. Energies of 0^+ excitations in nuclei situated at different shells and close to $2\varepsilon_o$. The state in ^{117}Sn (right) with E^* close to the phonon with value ε_o has a structure of the doublet with E^*=1005-1020 keV (boxed). This phonon energy is in agreement with two-phonon 0^+ excitations in the neighbour nuclei (horizontal dotted lines at $2\varepsilon_o$ and ε_o).
Analogous relations were found in the region of Ni-Fe (left) and Ge (center).
In nuclei ^{59,61}Ni and ^{59}Fe (boxed) levels at 1015-1023 keV correspond to 0^+ excitation at 2049 keV in ^{62}Ni (Fig.2, bottom right). Stable character of the ground state splitting 339 keV (due to the residual interaction between three valence neutrons) in ^{59}Ni is seen from the same splitting of this nucleus observed in the region of the level at 1455 keV=$(9/8)\delta m_N$ close to excitations in ^{58,61}Ni (top right part of this figure).

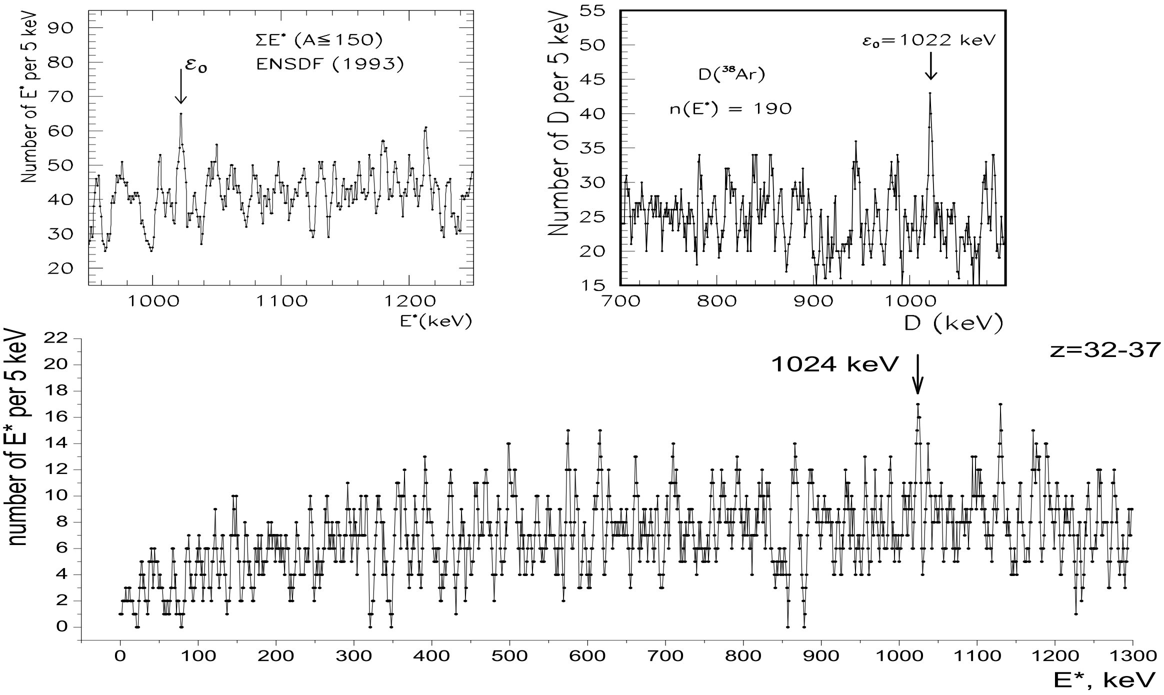

Fig. 3. *Top left:* Excitation energy distribution for all nuclei with A≤150.
Top right: Spacing distribution in level of ^{38}Ar with the maximum at ε_o=1022 keV.
Bottom: Excitation energy distribution in all nuclei with Z=32-35, maximum at 1024 keV contains energies of many nuclei presented in Table 6.

Table 3. Excitations (in keV) of near magic nuclei ^{116,117,118}Sn and ^{113}In (N=64) with values close to integers of the parameter ε_o.

^{Z}A	^{116}Sn	^{117}Sn	^{118}Sn	^{118}Sn	^{113}In	^{113}In							
$2J^{\pi}$	0+	5+	2+	0+	5+	1+,3+		7+,9+	(17-)	19+	21+		
E^*	2027	$\boxed{1020}$	2043	2057	$\boxed{1024}$	D=1030	2040	2049	3068	3071	3072	4089	5115
nε_o	2044	1022	2044	2044	1022	1022	2044	2044	3066	3066	3066	4088	5110
n	2	1	2	2	2	1	2	2	3	3	3	4	5
diff.	16	2	1	12	13	8	4	5	2	6	7	1	5

Table 4. Excitations (in keV) in ^{116}Te, which are close to nε_o.

$2J^{\pi}$	2+	4+	6+	(6+)	10+	12(+)	14+	16+	(16-)	(16-)	(17-)	(18+)	(20-)	(21)
Interval	678.9	680.5					511	507		510	508		510	
E^*	678.9	1359	2002	2565	3575	4585.6	5111	5622	6129	6142	6629	7160	8173	9683
nε_o	682	1363	2044	2555	3577	4599	5110		6132	6132		7154	8176	
n	2/3	4/3	2	5/2	7/2	9/2	5		6	6		7	8	
diff.	3	4	42	10	2	13	1		3	10		4	3	

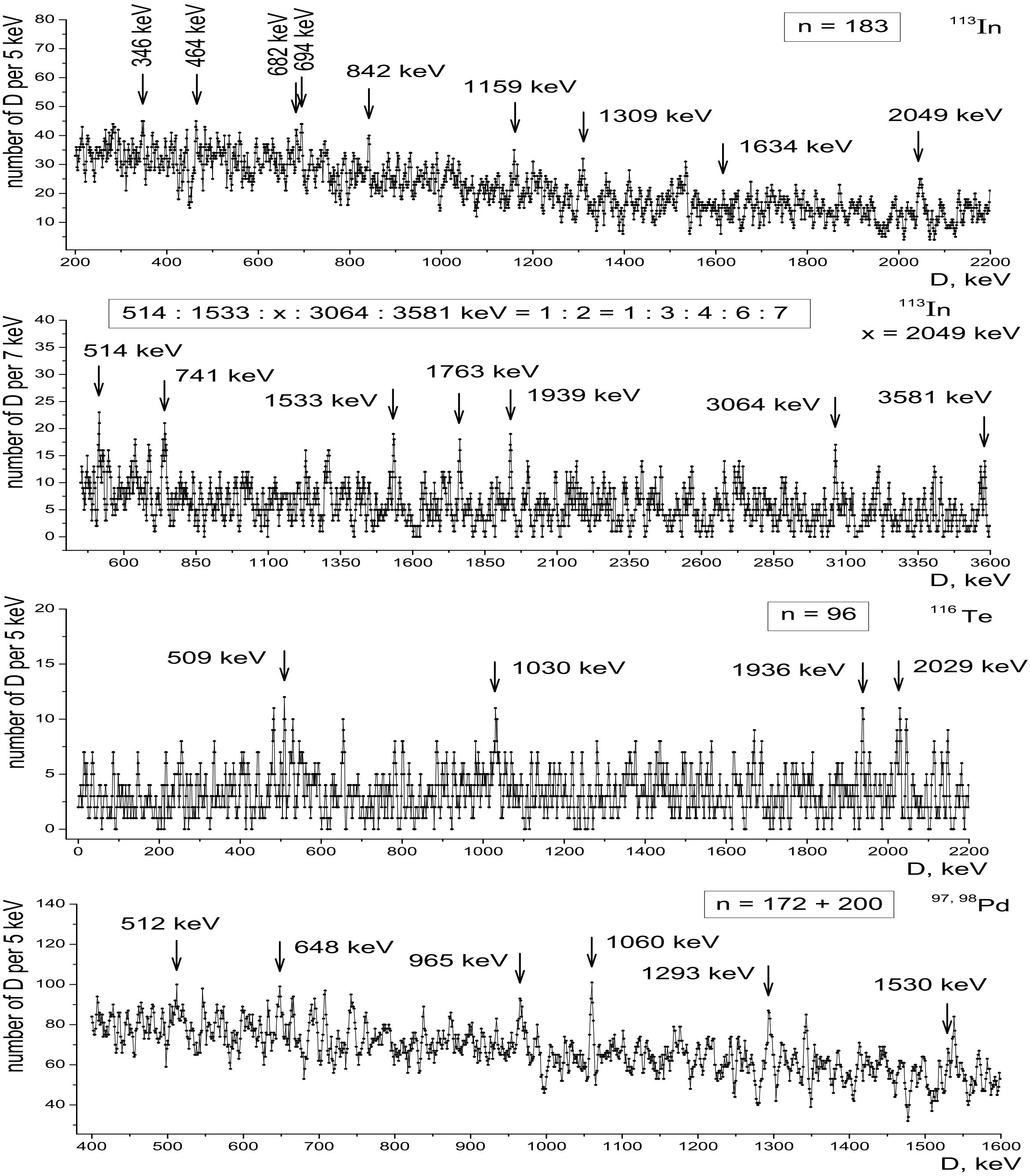

Fig. 4. *Top:* Spacing distribution in levels of ^{113}In with the maximum at D=2049 keV$\approx 2\varepsilon_o = E^*$.

Center: Distribution of intervals D^{AIM} in ^{113}In adjacent to x=2049 keV.

Bottom: Spacing distribution in levels of ^{116}Te with maxima at $\approx$n$\times\varepsilon_o/2$ (n=1,2,3) and 1936 keV$\approx 12 \times 17\delta'$.

Last line: Sum of spacing distributions between levels of ^{97,98}Pd.

Table 5. Stable excitations and stable intervals in levels of ^{97,98}Pd as well as excitations in ^{odd}Sb, close to n$\times\delta m_N$. Stability of excitations of 644 keV at Z=51 correspond to the universal character of tensor interaction. Intervals D=512 keV and D=1060 keV (in the central part of the Table) belong to systems with periods 170 keV=18δ' and 133 keV=14δ'.

^AZ	^{97}Pd	^{97}Pd	^{97,98}Pd					^{113}Sb	^{119}Sb	^{125}Sb	^{132}Sb
$2J^\pi_o$	5^+	9^+	D	D	D	D	D	5^+	5^+	7^+	(4^+)
$2J^\pi$	9^+	13^+						1^+	1^+	$3^+, 5^+$	5^+
E^*	$\boxed{1292}$	$\boxed{1292}$	646	966	1293	512	1060	644.8	644.0	643.0	162.8
$\mathrm{n}\frac{\delta m_N}{8}$	1293	1293	647	966	1293			647	647	647	161
n	8	8	4	6	8	[3]	[8]	4	4	4	1

The conclusion from nuclear data analysis that the nucleon mass difference is the eighth interval in the periodical fine structure with the period close but definitely different than an analogous period connected with the electron rest mass was made only recently based on CODATA evaluation. As it is shown in [6] the ratio 8.00 between nucleon mass difference and the shift of the neutron mass from the integer number of the electron rest mass became known already in 2000 year. But only now the presence of the fine structure in excitations of nuclei around Z,N=20,28,50 and its connection with the nucleon mass difference are firmly established. It allows an interconnection of fine structures in particle masses and in nuclear data based on QCD estimation of the gluon quark dressing effect and NRCQM model. The main result consists in observation that the same value, nucleon mass splitting, takes part in particle mass spectrum and in nuclear excitations.

3. Excitations in nuclei around N=50 and 82

The fine structure effects with parameters (periods) of 161 keV and 170 keV can be seen only with the selection of nuclei and the regions of data analysis. In the broad region of nuclear masses A$\leq$150 (Fig.3, top left) there is a maximum at 1022 keV=ε_o in the sum excitation energy distribution. But such an effect is clearly concentrated at several small regions, for example, in the region of Z=32-37 (Fig.3, bottom, see Table 6). These nuclei are located at the end of the large N=50 shell. The interval 1021 keV itself can be seen in the spectra of low-lying levels of the nucleus ^{38}Ar (Fig.3 top right) located at the end of Z,N=20 shells (Z=18, N=20). In the spectrum of the excited states in ^{80}Br (boxed in the middle of Table 6) there is a ground state doublet with the splitting 1.1 keV, close to the stable interval ε'=1.2 keV observed in spacing of neutron resonances of the same nucleus and in neighbour nuclei. It is an example of the simultaneous appearance of the intervals of the superfine and fine structures in the spectrum of the same near-magic nuclei (spectrum of ^{124}Sb contains another example: superfine intervals D=373 eV - 570 eV and fine structure intervals 322 keV - 492 KeV, ratio 116$\cdot10^{-5}$).

Table 6. Excitation energies of nuclei with Z=33-35 close to the parameter ε_o=1022 keV.

^AZ	^{74}As	^{76}As	^{73}Se	^{75}Se	^{77}Se	^{80}Br	^{80}Br	^{81}Br	^{82}Br	^{83}Br
E^*, in keV	1021.5	1023.2	1021.9	1020.5	1024.1	$\boxed{1021.3}$	$\boxed{1022.4}$	1023.7	1022.5	1021.5

Analysis of stable nuclear excitations performed in 70-ties demonstrated a distinct character of intervals δm_N=1293 keV, m_e and δm_N-m_e=782 keV. Appearance of stable excitations close to δm_N and ε_o in heavy nuclei (Table 7), can be connected with the filling in the large proton subshell $\pi 1h_{11/2}$ analogous to the earlier discussed effect in nuclei with Z=50,51 [12] due to filling in the same neutron subshell. In nuclear regions where nucleon configuration is similar to that in the deuteron (total spin 1, orbital motions in the opposite directions) we expect clear indications on the one-meson exchange dynamics.

Table 7. Excitations (in keV), close to δm_N=1293.3 keV and ε_o=1022 keV in heavy even-even nuclei with Z=68-76 (boxed are values in the N=104 nuclei).

Z	70		72				74			76		
^AZ	^{160}Yb	^{170}Yb	^{162}Hf	^{172}Hf	^{176}Hf	^{178}Hf	^{172}W	^{178}W	^{184}W	^{176}Os	^{178}Os	^{180}Os
E^*	1293	1292	1293	1293	$\boxed{1293}$	1291	1292	$\boxed{1294}$	1295	1026	1023	$\boxed{1023}$
$2J^\pi$	2^+	$(4)^+$		0^+	$\boxed{0^+}$	3^+	(2,3,4)	$\boxed{0^+}$	5^+	4^+	4^+	3^+
N	90	100	90	100	$\boxed{104}$	104	98	$\boxed{104}$	110	100	102	$\boxed{104}$

We continue the analysis of results obtained with the selection of nuclei from the broad regions of the nuclear chart. Sum energy distribution for a broad region A$\leq$70 (Fig.6 left) contains the strongest maximum at 3936 keV=13$\times$303 keV, the same distribution for the region A=100-150 (Fig.6 right) contains the maximum at 1212 keV=4$\times$303 keV. For each of these maxima in distributions one can find some sort of model explanation. For example, there is stable character (equidistancy) of excitations in ^{33}S (1968+1968=3936 keV). Stable intervals 492 keV and 984 keV (close to 1/4 and 1/2 part of D=1968 keV) were observed in fluorine isotopes (Z=9=8+1) and in some other light nuclei.

The stability of intervals 492 keV (marked with ** in Table 1) was found in the works by M.Ohkubo [15,16], where other nonstatistical effects in neutron resonance spacing distributions and their interpretation were considered. Result of an application of new method of analysis of nuclear spectroscopic data developed by K.Ideno is given in [17].

Considering the maximum at 1212 keV in heavy nuclei we should mentioned that a stability of the first excitation in A-even tin isotopes (1208-1206-1212 keV in ^{106,108,110}Sn) is well known and can be compared with the equidistancy in phonon-like excitations ($\Delta J = 2^+$) in near magic ^{118}Te (excitations 606-1206-1821 keV). Discussed value of stable excitation 606 keV is marked with * in Table 1. Confirmation of the fine structure with common parameter δ' and integers n=13-16-18 shows that there are really additional elements of the fine structure besides the main fine-structure effects with parameters n=17,18 coinciding with observed in nucleon masses as splitting δm_N and m_e (Table 1). One can suspect that the distinguished character of two close to each other fine structure parameters n=17,18 in particle masses are connected with the large influence of short distances and the pions parameters together with the universality of the electric charge.

Stable nuclear intervals multiple with the parameter (period) 133 keV (n=14) were frequently observed in heavy nuclei [2]. In the broad group of nuclei with Z=61-73 there are maxima at 531 keV, 1059 keV and 3182 keV (n=4,8,3$\times$8 of the period 14δ'=133 keV). The interval 132 keV itself was noticed in sum spacing distribution in ^{146,148}Sm (N=84,86). In the same region of nuclear chart stable intervals D=159,161 and 162 keV were found in spacing distribution between levels of ^{169}Ho,^{167}Ho,^{145}Pm (numbers of known levels in these nuclei are 102,110,84, it is sufficient for the further analysis). A list of stable intervals with values close to integer number n of the common parameter δ' for n=13,14,16,17,18 is given in [1,2] for nuclei in the regions Z=3-29,30-47,48-60,61-73,74-100.

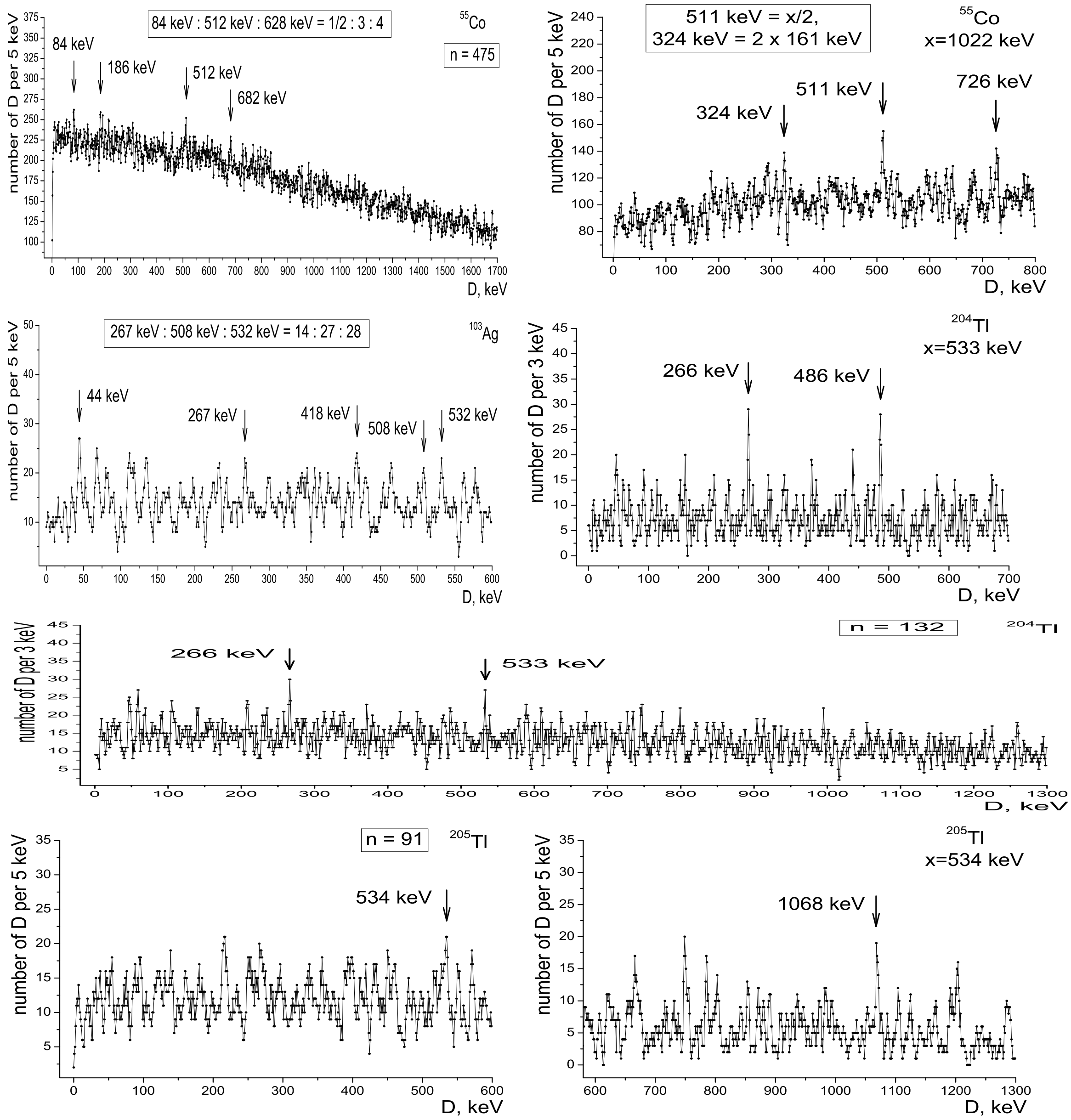

Fig. 5. *Top*: Spacing distribution in levels of ^{55}Co (left) and distribution of ^{AIM}D for x=1022 keV (right).
Maxima at D=324 keV, 512 keV and 682 keV correspond to fine structures with n=17 and 18.
2-nd line left: Spacing distribution in levels of ^{103}Ag (integer relations with the period $2\delta'$).
2-nd line right and bottom: Spacing distributions in levels of ^{104,105}Tl: Maxima at D=266 keV and 533 keV (in ^{104}Tl distribution) correspond to fine structures with two-fold value of the period 133 keV (n=14).
Maxima at D=534 keV and 1068 keV (in ^{105}Tl distribution) correspond to fine structures with four-fold value of the period 133 keV (n=14).
All these maxima correspond to fine structures with the common parameter δ'=9.5 keV derived directly from neutron resonance positions in near-magic nuclei with N=82 [14].

We conclude that the number of observed fine structure systems is larger than that noticed in particle masses (n=13,14,16,17,18 as compared with n=17,18). The presence of many different structures observed in 90-ties did not allow a comparison in that time with existed CODATA-like estimations. Now CODATA relations and analysis of new data for light and near-magic nuclei resulted in the confirmation of fine structures with the same parameters 161 keV and 170 keV as in nucleon masses. Values of splitting from the residual interaction of the valence nucleons 322 keV and 340 keV in ^{53,61}Ni and ^{43}S [14] are in accordance with the direct influence of nucleon structure. Fine structure contained parameters/periods $m_e/3$=170 keV and $\delta m_N/8$=161 keV (n=18 and n=17 in units of δ'=9.5 keV) which determine relations between masses with very high accuracy. We use neutron resonance positions - differences between excitation energies and nuclear binding energies - to control long-range correlations in nuclear binding energies and indirectly control unexpected properties of relations between masses based on CODATA results.

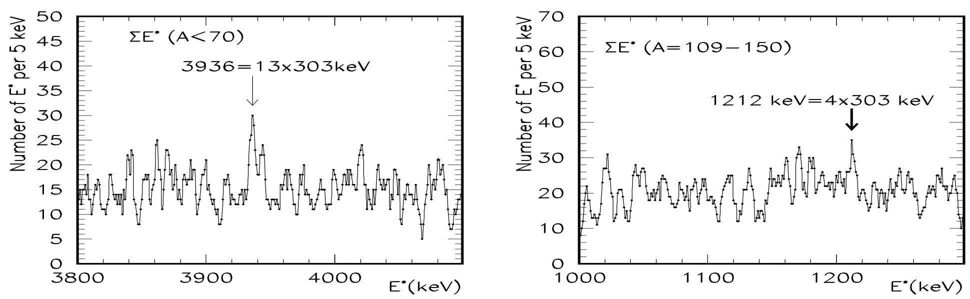

Fig. 6. *Left:* Distribution of excitations in all nuclei with A≤70.
Right: The same for A=100-150; maximum at 1212 keV contains E*(^{110}Sn).

We use an empirical observation on coincidence between particle mass slitting and parameters of fine-structure in nuclear excitations for study dynamics of nucleon interaction inside the nuclear matter. We use the estimations of fine structure intervals (parameters 161 keV=$\delta m_N/8$ and 170 keV=$m_e/3$) according to the relation m_e=$M_q(\alpha/2\pi)^{-1}$ and its interpretation as the result of cumulative effect of small QED-correction in currents inside the constituent quarks. The total amount of this correction to the $3\Delta M_\Delta$ is close to the mass of the real lepton (difference between the electron and the neutrino). Masses of both light particles, m_μ and m_π and pions parameters f_π=130.7 MeV and ΔM_Δ=147,2 MeV (Table 2) are close to integers of δ. This exact discreteness manifested in CODATA relation should be explained with symmetry-motivated estimations [1] including the lepton ratio, the mass of the third lepton (2-nd line in Table 8), discreteness in masses of fermions of all SM-families and in precisely known mass of fundamental vector field M_Z (the 3-rd line in Table 8). An important role of nuclear data is the result of the universal character of the tuning effect demonstrated with CODATA relation and the lepton ratio.

We used for confirmation of the tuning effect in nuclei with Z,N=50 and 82 neutron resonance data and new COMAIM method. It resulted in the confirmation of the parameter δ'=9.5 keV introduced initially by M.Ohkubo from neutron resonance data for ^{140}Ce [13,14] and interacted by QED-factor $\alpha/2\pi$ (shown in bottom left part of Table 1) with the parameter δ''=11 eV confirmed by K.Ideno with neutron resonance data for ^{124}Sb [13,17].

4. Conclusions

Confirmation of the fine structure in CODATA relations allowed to turn attention on exact presentation of newly estimated mass of Z-boson [18] of integer number of m_e, namely, M_Z=($L = 207 = 13 \times 16 - 1$)(440.49 MeV=$54\delta - 1.01(5)$MeV (the shift of M_Z/L=440.49 MeV relative to 54·16m_e=441.50 MeV is 1.01(5) MeV coinciding with 2m_e=1.022 MeV). In Table 8 a part of particle masses (from PDG 2016 [18]) is compared with k - number of the period 16m_e (double boxed is mentioned correlation between M_Z and m_e).
Value $M_H/18 \cdot 16$=125.09(24)/18·16=434.3 MeV deviates from 54δ with 7.2(9) MeV close to Δ=4.60 keV (boxed in Table 8 center).

Table 8. Comparison of particle masses with the period (k) of the 16m_e=δ=2($\Delta-m_e$)=8176 keV.

Particle	m_i, MeV	k	m_i-k·16m_e	Comments (in MeV), differences
$\boxed{\mu}$	105.65837	13	-0.6294	-m_e-0.118
τ	1776.82(16)	$4 \cdot 48 \cdot + 2 \cdot 13$		$\boxed{\text{-5.56(16)= -2}m_e\text{-(4.6 =}\Delta)}$
M_Z/L	440.49(5)	3·18	=441.50	$\boxed{\boxed{-1.01(5) = -2m_e}}$
f_π	130.7(4)	16		≈0
$\pi^\pm$	139.5702(4)	17	+0.57624	+m_e+0.065
$\boxed{\pi^\pm\text{-}\pi^\circ}$	4.5936(5)			Δ=9m_e=4.600
Δ°-n	294.2(2)	36		2(ΔM_Δ=147.1); ΔE_B=147.3
M_q NRCQM	441	3·18		ΔE_B=441
M_H/18·16	434.3(9)	3·18-Δ		diff. $\boxed{-7.2(9) \approx -5 = \Delta}$
t-quark	173210(1000)	24x16x54		169540 =24δ°
η'-η-$\pi^\pm$	409	50		≈0
η	547.862(16)	67		
η'	957.78(6)	117		
M_q^Δ NRCQM	410	50		ΔE_B=409
ρ	775.26(25)	96	-9.40(34)	-9.20 = -2Δ
ω	782.65(12)	96	-2.3(1)	diff. ≈ -2m_e
M_q'' NRCQM	387.63(12)	48	$m_\rho/2$	$\boxed{-4.82(12) \approx -4.60 = -\Delta}$
M_W/L	388.33	3·16	48δ=392.45	$M_W/L - M_q''$=0.70(12) ≈ m_e
$\boxed{\text{p}}$	938.2720(1)	115	-1.96660	-m_e-(9/8)δm_N
$\boxed{\text{n}}$	939.5654(1)	115	-0.6726(1)	-m_e-(1/8)δm_N

The real NRCQM parameter $M_q'' = m_\rho/2$ deviates from 48δ with 4.82 MeV (close to Δ=4.60 MeV) and deviates from M_W/L (boxed in Table 8 bottom) with 0.7(12) MeV. The mass of the 3-rd lepton presented in Fig.1 (top) as $12 \cdot 16\delta + 2 \cdot 13\delta$=$12f_\pi + 2m_\mu$ has the shift (from integer number of δ) which is coinciding with $2m_e + \Delta$ (2-nd line).

The most important result obtained from the application of integer values of CODATA parameter $\delta = 16m_e$ we find in the precisely known mass of the vector boson M_Z=91187.6(21) MeV (the second line in Table 8). Observed shift (double boxed) coincides with 2m_e. More precise masses of all three fundamental fields and the heaviest quark could be very useful for confirmation of observed results of application of CODATA period δ and m_e itself as universal parameters of the tuning effect.

We show here (and in [1,14]) the unique character of CODATA relation between masses of the nucleons and the electron:

$$m_n{=}115\times16m_e - m_e - (1/8)\delta m_N \qquad m_p{=}115\times16m_e - m_e - (9/8)\delta m_N$$

in which appear values $\delta m_N/8$ and δm_N itself. These two values are found to be the parameters of fine structure in nuclear excitations (marked with * in Table 7 in [14]). Parameter $\delta m_N/8$=161.65 keV is close but not coinciding with the parameter 160.9 keV which could be derived as $(17/18)m_e/3$ from the main parameters $\delta = 16m_e$ and m_e itself of CODATA relation. Exactness of particle mass presentation (masses of the muon, the pions as well as f_π and ΔM_Δ) demonstrate that the parameter $m_e/3$=170.3 keV derived independently from particle masses and from nuclear data is a unique value. Its relation with the scalar field mass M_H through QED correction $m_e{=}(\alpha/2\pi)\Delta M_\Delta = (\alpha/2\pi)^2 M_H$ (right part of Table 1, n=18) and simultaneously with the top quark mass m_t through the relation with QED correction for a short distance (with α_Z=1/129), namely, $m_e{=}m_\pi(\alpha_Z/2\pi){=}(2/3)m_t(\alpha_Z/2\pi)^2$ [13,14] corresponds to the unique character of the m_e related to properties of the physical condensate in which we live [19].

The role of nuclear data is connected with the presentation of nucleon mass evolution fully described with NRCQM model as transition from $9\Delta M_\Delta$ to $8f_\pi{+}\Delta M_\Delta$ (between the baryon and meson constituent quark masses, $M_q{=}3\Delta M_\Delta$ and $M''_q{=}3f_\pi$). Masses M_q, M''_q are taking part in rational relations with masses of fundamental fields and the top quark. The interconnection between the particle masses and nuclear data was checked also during the analysis of nuclear binding energies and particle mass spectrum [14].

5. References

1. S.I. Sukhoruchkin, Proc. ISINN-23, JINR E3-2016-13, pp. 287 and 251,263,275.
2. H. Scopper (Ed.), Landolt-Boernstein NS, vols. I/25 A-E. Springer, 2012-2013.
3. S.I. Sukhoruchkin, Proc. ICHEP-16, POS(ICHEP2016)1198.
4. S.I. Sukhoruchkin, Proc. EPS-HEP2015, Wien, POS(EPS-HEP2015)527 (2016).
5. S.I. Sukhoruchkin, Proc. DSPIN2015, Dubna, J. Phys. Conf. Ser. **678** (2016) 012052.
6. S.I. Sukhoruchkin, Proc. QCD-16, Nucl. Part. Phys. Proc. (in press).
7. P. Mohr, B. Naylor, D.B. Neeell, CODATA, Rev. Mod. Phys. **84** (2012) 1527.
8. Y. Nambu, Progr. Theor. Phys. **7** (1952) 595.
9. A. Hautot, *Atti Fond. G. Ronchi* **30** No 4 (1975) 477.
10. S.I. Sukhoruchkin, *Stat. Prop. Nuclei*, Ed. G. Garg. Pl. Press, N.-Y., 1972, p. 215.
11. S.I. Sukhoruchkin *et al.*, Proc. ISINN-22, JINR E3-2016-13, p. 277.
12. S.I. Sukhoruchkin *et al.*, Proc. ISINN-19, JINR E3-2016-13, pp. 284, 296, 308.
13. S.I. Sukhoruchkin, Proc. 50-th Ann. PNPI Winter School, 2016.
14. S.I. Sukhoruchkin *et al.*, these Proceedings.
15. M. Ohkubo, Phys. Rev. C **80** (2009) 024607.
16. M. Ohkubo, Phys. Rev. C **87** (2013) 014608.
17. K. Ideno, EPJ Web conf. **122** (2016) 13002.
18. C. Patrignani *et al.* (Particle Data Group), Chinese Physics C **40** (2016) 100001.
19. J. Gasser and H. Leutwyler, Phys. Rep. **87** (1982) 77.