SYMMETRY - MOTIVATED

TUNING EFFECT IN PARTICLE MASSES

AND NUCLEAR DATA

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INTRODUCTION

- The Standard Model is a general theory of all interactions in which all three vector interactions (strong, weak and electromagnetic) are united in the representation:
- $$SU(3)_{col} \otimes SU(2)_L \otimes U(1)_Y$$
- Particle masses are parameters of the Standard Model. Y. Nambu suggested (1998) that empirical relations in particle masses could be used for the development of the Standard Model.
- The observed ratios are: $(m_\mu + m_e)/2(\delta m_\pi - m_e) = 13.00$. The lepton ratio L=207=13x16 – 1.

neutron mass $m_n + m_e/2(\delta m_\pi - m_e) = 115.007$. Ratio m_n/m_e=1838.6836605(11), shift δm_n = 161.65(6) keV.

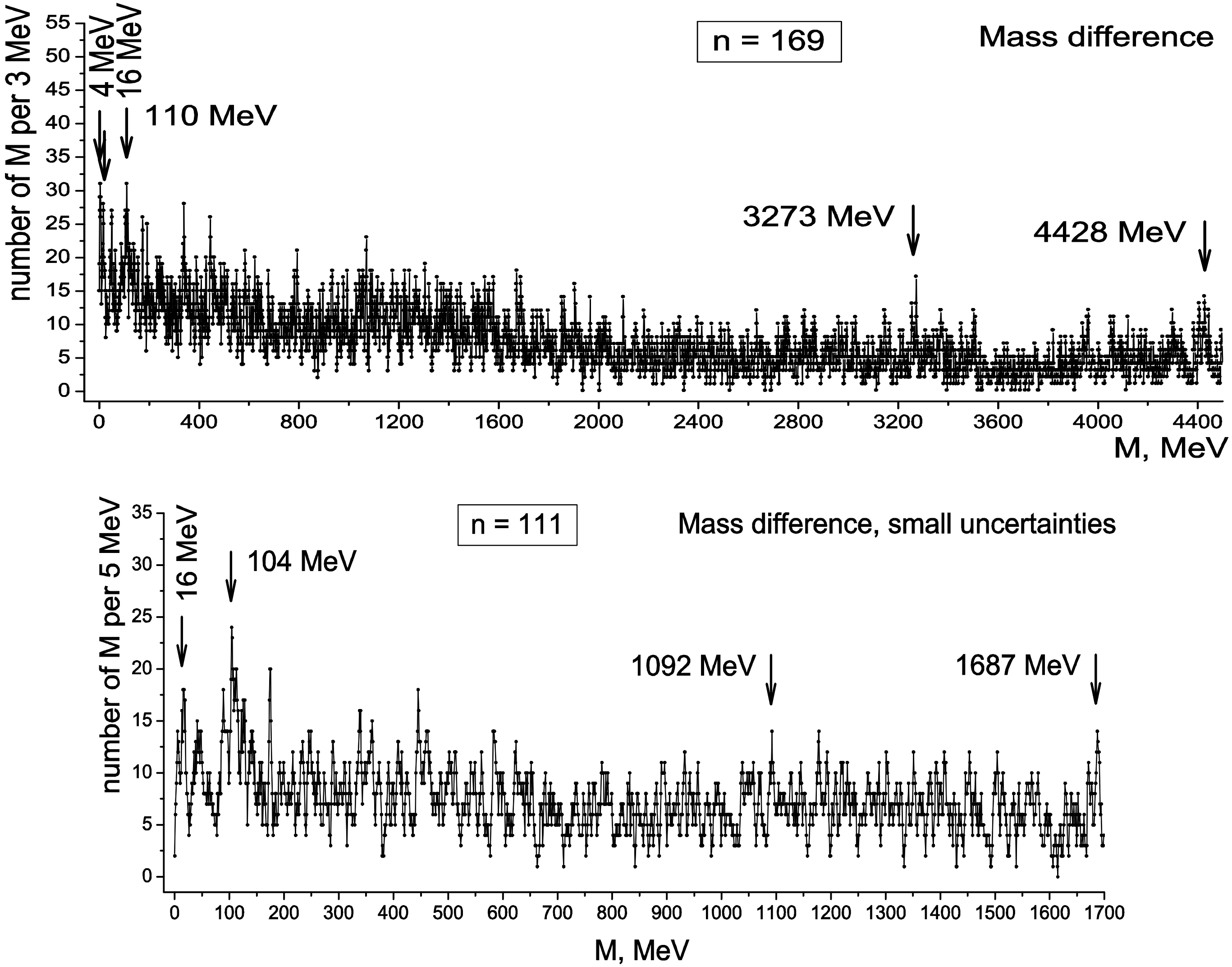
$$\textbf{Ratio } \delta m_N / \delta m_n = 8 \times 1.0001(4).$$

$m_n - m_p = \delta m_N$=1.2933322(4) MeV;

$$m_n = 115x16m_e - m_e - \delta m_N/8; \qquad m_p = 115x16m_e - m_e - 9\delta m_N/8.$$

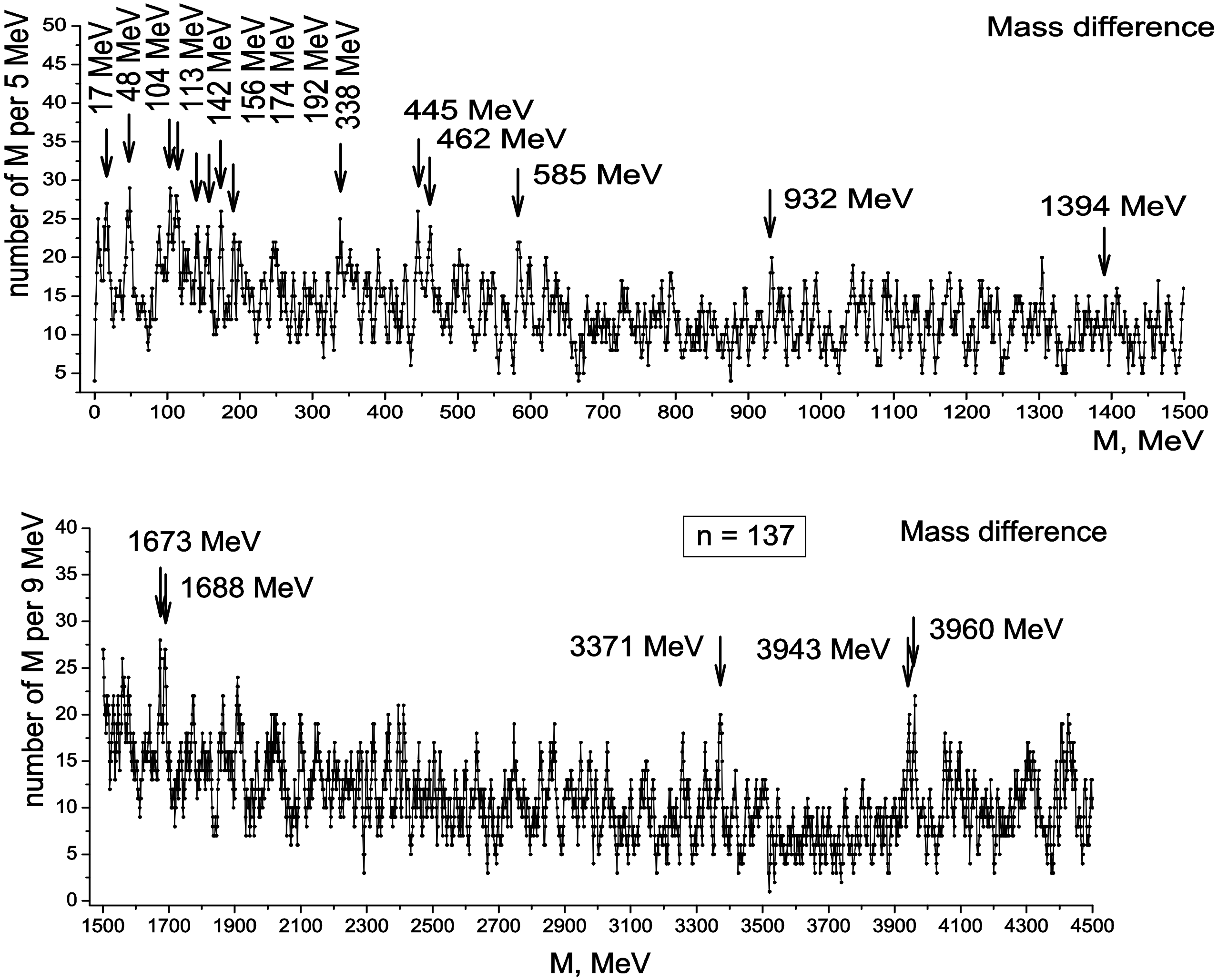
The lepton ratio L=m_μ/m_e=206.77 becomes integer 207=9×23=13×16-1 after a small QED radiative correction applied to m_e (it becomes $m_\mu/m_e(1-\alpha/2\pi)$=207.01). The factor $\alpha/2\pi$ =115.9x10^{-5}, the QED radiative correction to the magnetic moment of the electron (Schwinger term) coincides with the relative value 117(11) 10^{-5} of the deviation of δm_π = 4.5936(5) MeV from $9m_e$ = 4.5990 MeV.

- Ratio of parameters of the Standard Model, masses of the muon and Z-boson: m_μ/m_Z =115.9×10^{-5} .
- Belokurov and Shirkov suggested (1991) that electron mass also contains this factor $\alpha/2\pi$.
- A common approach is based on R. Feynman remarks: “The theories about the rest of physics are very similar to the theory of quantum electrodynamics: they all involve the interaction of spin ½ objects with spin 1 objects. Why are .. the theories of physics so similar in their structure?”.



Distribution of differences between all particle mass values from PDG-2016 (*top)*

and values known relatively accurate (*bottom*).



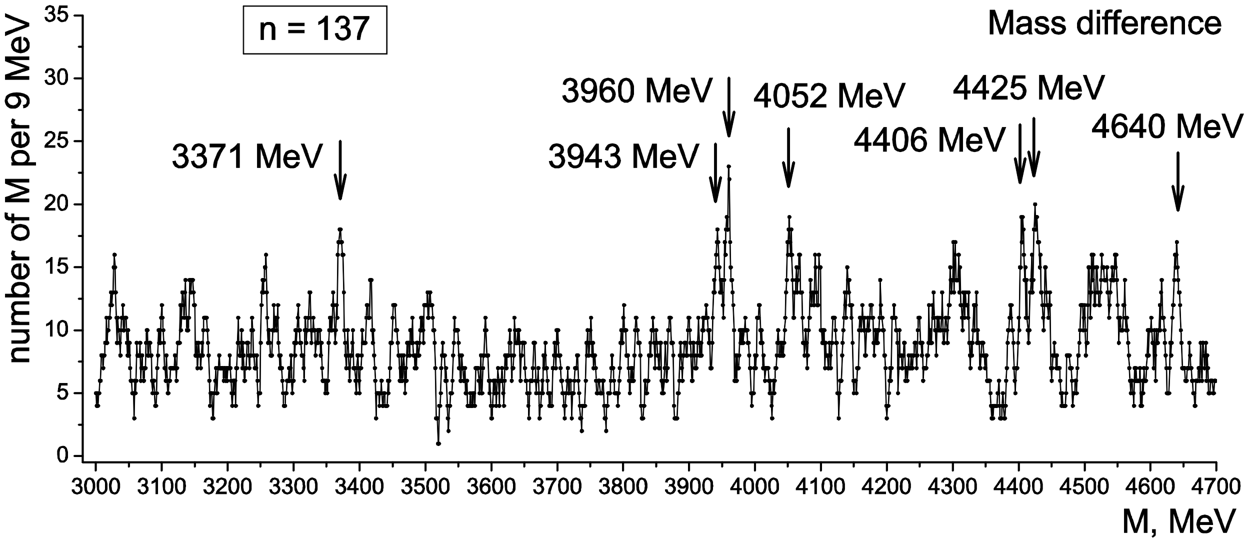
Differences between particle masses Δ M for averaging interval 5 MeV (*top*) and 9 MeV (*bottom*). Stable intervals (marked with arrows) are close to integer numbers of δ=16m_e found in CODATA relations (*top*) and to the b-quark mass estimation 4.2 GeV.

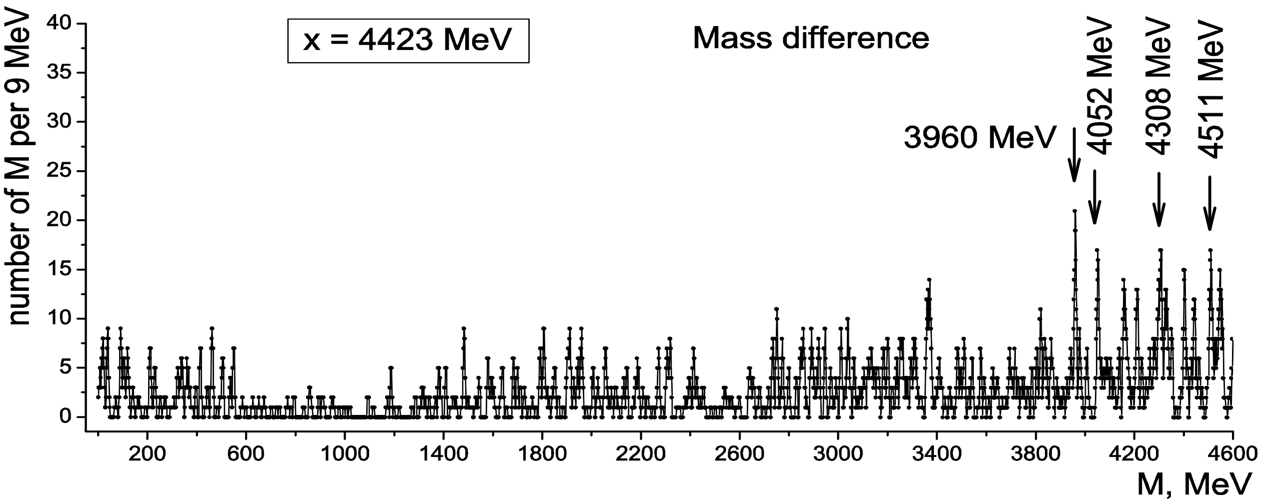
Table. Particle masses (in MeV) known with the uncertainty less than 6-10 MeV.

	Particle		m_i	Δ	17	48	104	142	156	174
1	leptons	electron, ν	0.0				106 (1)	140 (1)		
	μ		105.658				106 (1)			
	τ		1776.82			46 (15)	105 (7,8)			
2	Unflav.	mesons								
	f_π		130.7	0.4	***					
	π°	$1^-(0^-)$	134.977		***					
	$\pi^\pm$	$1^-(0^-)$	139.570					140 (1)		
	η	$0^+(0^{-+})$	547.86							
	$\rho(770)$	$1^+(1^{--})$	775.26							
	$\omega(782)$	$0^-(1^{--})$	782.65						157 (1)	175 (1)
	$\eta'(958)$	$0^+(0^{-+})$	957.78		18 (1)				159 (2)	175 (1)
	$\phi(1020)$	$0^-(1^{--})$	1019.46							173 (3)
	$b_1(1235)$*	$1^+(1^{+-})$	1229.5	3.2		46 (2)			154 (4)	174 (4,5)
	$f_2(1270)$*	$0^+(2^{++})$	1275.5	0.8	19 (2)	46 (2,5)				
	$f_1(1285)$	$0^+(1^{++})$	1282.0	0.5			102 (2)	142 (2,3)		
	$\eta(1295)$**	$0^+(0^{-+})$	1294	4	19 (2)					
	$a_2(1320)$	$1^-(2^{++})$	1318.3	0.5		46 (3)			138 (7)	
	$\eta(1405)$*	$0^+(0^{--})$	1408.8	1.8	18 (4,5)					
	$f_1(1420)$*	$0^+(1^{++})$	1426.4	0.9	18 (5)	47 (8,9)	105 (4,6)	142 (3)	154 (6)	
	$\eta(1475)$**	$0^+(0^{-+})$	1476	4		50 (7,9)		141 (5)	156 (7,8)	
	$f_0(1500)$**	$0^+(0^{++})$	1504	6	16 (6)				158 (9)	
	$f'_2(1525)$**	$0^+(2^{++})$	1525	5		49 (11)		142 (4,7)		
	$\pi_1(1600)$**	$1^-(1^{-+})$	1662	8				142 (6)	158 (9)	
	$\eta_2(1645)$**	$0^+(0^{-+})$	1617	5		50 (12)		141 (5)	156 (12)	
	$\omega_3(1670)$**	$0^-(3^{--})$	1667	4		45 (12)		142 (7)	156 (13)	
	$\pi_2(1670)$*	$1^-(2^{-+})$	1672.2	3.0	17 (7)		105 (7)	140 (8)		
	$\rho_3(1690)$*	$1^+(3^{--})$	1688.8	2.1	17 (7,8)				157 (11)	176 (6)
	$f_0(1710)$**	$0^+(0^{++})$	1723	6		50 (13)		142 (10)		
	$\phi_3(1850)$**	$0^-(3^{--})$	1854	7	16 (9)			142 (11)	156 (14)	
	$a_4(2040)$**	$1^-(4^{++}$	1995	8	15 (10)	50 (17)		142 (11)		172 (7)
3	strange	mesons								
	$K^\pm$	$1/2(0^-)$	493.677							
	$K^*(892)^{*\pm}$	$1/2(1^-)$	891.66			48 (1)				
	$K^*(892)^{*\circ}$	$1/2(1^-)$	895.81		***					
	$K_1(1270)$**	$1/2(1^+)$	1272	7		46 (3,4)			156 (3,5,6)	
	$K_1(1400)$**	$1/2(1^+)$	1403	7	19 (3)					174 (4)
	$K_2^*(1430)^{\pm *}$	$1/2(2^+)$	1425.6	1.5	17 (4)	47 (6,7)	104 (3,5)	142 (2)	154 (5)	
	$K_2^*(1430)^{\circ *}$	$1/2(2^+)$	1432.4	1.3	***					
	$K_2(1770)$**	$1/2(2^-)$	1773	8					156 (12)	
	$K_3^*(1780)$**	$1/2(3^-)$	1776	7		47 (14)				
	$K_4^*(2045)$**	$1/2(4^+)$	2045	9		50 (17)				175 (8)
4	charmed	mesons								
	D°	$1/2(0^-)$	1864.83				103 (9)	142 (10)		176 (6)
	$D^\pm$	$1/2(0^-)$	1869.58		16 (9)	47 (16)		141 (12)	155 (15)	175 (8)
	$D^*(2007)^\circ$	$1/2(1^-)$	2006.85		***					
	$D^*(2010)^\pm$	$1/2(1^-)$	2010.28		15 (10,11)		102 (10)	141 (12)	156 (14)	
	$D_1(2420)^\circ$	$1/2(1^+)$	2420.8	0.5		50 (18,19)	103 (11)		157 (16)	
	$D_2^*(2460)^\circ$	$1/2(2^+)$	2460.57		***					
	$D_2^*(2460)^{\pm *}$	$1/2(2^+)$	2465.4	1.3			104 (12)			

Table.

	Particle		m_i	Δ	17	48	104	142	156	174
5	charmed	strange	mesons							
	$D_s^{\pm}$	$0^+(0^-)$	1968.27				103 (9)	144 (13)		
	$D_s^{*\pm}$	$0(?^?)$	2112.1	0.4			102 (10)	144 (13,14)		174 (9)
	$D_{so}^*(2317)^{\pm}$	$0(0^+)$	2317.7	0.6			103 (11)	142 (15)		
	$D_{s1}(2460)^{\pm}$	$0(1^+)$	2459.5	0.6				142 (15)		174 (10)
	$D_{s1}(2536)^{\pm}$	$0(1^+)$	2535.10		17 (14)					173 (13)
	$D_{s2}^*(2573)^*$	$0(2^+)$	2569.1	0.8			104 (12)			
	$D_{s1}^*(2700)^{\pm *}$	$0(1^-)$	2708.3	3.4						173 (13,16)
6	bottom	mesons								
	$B^{\pm}$	$1/2(0^-)$	5279.31							
	B°	$1/2(0^-)$	5279.62		***					
	B^*	$1/2(1^-)$	5324.65							
	$B_1(5721)^{+*}$	$1/2(1^+)$	5725.9	2.7			106 (17,18,19)			
	$B_1(5721)^{\circ *}$	$1/2(1^+)$	5726.0	1.3	***					
	$B_2^*(5747)^{+*}$	$1/2(2^+)$	5737.2	0.7			103 (20)			175 (23)
	$B_2^*(5747)^{\circ}$	$1/2(2^+)$	5739.5	0.7	***					
	$B_J(5970)^+$	$1/1(?^?)^{**}$	5964	5	15 (24)					172 (24)
	$B_J(5970)^{\circ}$	$1/1(?^?)^{**}$	5971	5	***					172 (24)
7	bottom	strange	mesons							
	B_s°	$0(0^-)$	5366.82			49 (27)				
	$B_s^{*}*$	$0(1^-)$	5415.4	1.5		49 (27)				
	$B_{s1}(5830)^{\circ}$	$0(1^+)$	5828.63		17 (22)		103 (18,21)			
	$B_{s2}^*(5640)^{\circ}$	$0(2^+)$	5839.84			48 (28)	103 (20)			
8	bottom	charmed	mesons							
	$B_c^{*}*$	$0(0^-)$	6275.1	1.0						
9	$c\bar{c}$	mesons								
	$\eta_c(1S)$	$0^+(0^{-+})$	2983.4	0.5	15 (16)		102 (14)			
	$J/\psi(1S)$	$0^-(1^{--})$	3096.90		17 (17)				158 (18)	
	$\chi_{c0}(1P)$	$0^+(0^{++})$	3414.75					141 (18)		
	$\chi_{c1}(1P)$	$0^+(1^{++})$	3510.66		14 (18)	46 (22)				174 (21)
	$h_c(1P)$	$?^?(0^{+-})$	3525.38		14 (18)					
	$\chi_{c2}(1P)$	$0^+(2^{++})$	3556.20			46 (22)		141 (18)		
	$\eta_c(2S)^*$	$0^+(0^{-+})$	3639.2	1.2		47 (23)				
	$\psi(2S)$	$0^-(1^{--})$	3686.10			47 (23)				173 (21)
	$\psi(3770)$	$0^-(1^{--})$	3773.13			49 (24)			154 (19)	
	$\psi(3823)^*$	$?^?(2^{--})$	3822.2	1.2		49 (24)	105 (15)			
	$X(3872)$	$0^+(1^{++})$	3871.69		15 (19)	49 (25)				
	$X(3900)^*$	$1^+(1^{+-})$	3886.6	2.4	15 (19)					
	$X(3915)^*$	$0^+(?^{++})$	3918.4	1.9		47 (26)	106 (16)			
	$\chi_{c2}(1P)^*$	$0^+(2^{++})$	3927.2	2.6			105 (15)		154 (19)	
	$X(4020)^*$	$1(?^?)$	4024.1	1.9	15 (20)		106 (16)			
	$\psi(4040)^{**}$	$0^-(1^{--})$	4039	1	15 (20)					
	$X(4140)^*$	$0^+(?^{?+})$	4146.9	3.1						
	$\psi(4160)^{**}$	$0^-(1^{--})$	4191	5					156 (20)	
	$X(4260)^{**}$	$?^?(1^{--})$	4251	9						
	$X(4360)^{**}$	$?^?(1^{--})$	4346.9	6					156 (20)	
	$\psi(4415)^{**}$	$0^-(1^{--})$	4421	4						
	$X(4660)^{**}$	$?^?(1^{--})$	4643	9						
10	$b\bar{b}$	mesons								
	$\eta_b(1S)^*$	$0^+(0^{-+})$	9399.0	2.3						
	$\Upsilon(1S)$	$0^-(1^{--})$	9460.30							
	$\chi_{b0}(1P)$	$0^+(0^{++})$	9859.44							
	$\chi_{b1}(1P)$	$0^+(0^{++})$	9892.78		19 (25)					
	$h_b(1P)^*$	$?^?(1^{+-})$	9899.3	0.8						
	$\chi_{b2}(1P)$	$0^+(2^{++})$	9912.21		19 (25)					
	$\Upsilon(2S)$	$0^-(1^{--})$	10023.26					140 (21)		
	$\Upsilon(1D)^*$	$0^-(2^{--})$	10163.7	1.4			105 (23)	140 (21)		
	$\chi_{b0}(2P)$	$0^+(0^{++})$	10232.5	0.4						
	$\chi_{b1}(2P)$	$0^+(1^{++})$	10255.46							
	$\chi_{b2}(2P)$	$0^-(2^{+-})$	10268.65				105 (23)			
	$\Upsilon(3S)$	$0^-(1^{--})$	10355.2	0.5					157 (22)	174 (25)
	$\chi_{b1}(3P)^*$	$0^+(1^{++})$	10512.1	2.3	17 (26)				157 (22)	
	$\Upsilon(4S)^*$	$0^-(1^{--})$	10529.4	1.2	17 (26)					174 (25)
	$X(10610)^{\pm *}$	$1^+(1^+)$	10607.2	2.0						
	$X(10610)^{\circ **}$	$1^+(1^+)$	10609	6						

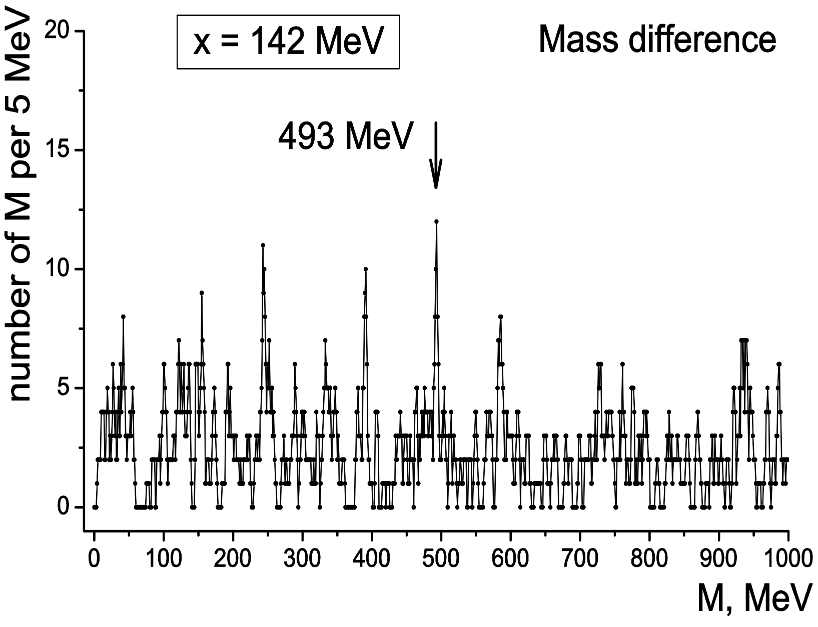


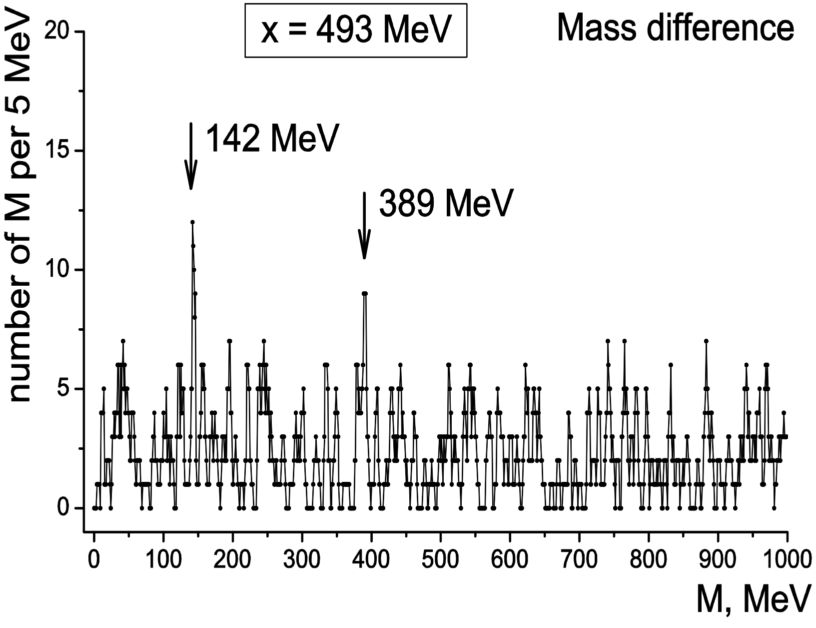


***Top*: Spacing distribution in mass spectrum in high-energy region.**

***Bottom*: Application of AIM Method to x=4423 MeV (AIM upward and downward directions, separately).**

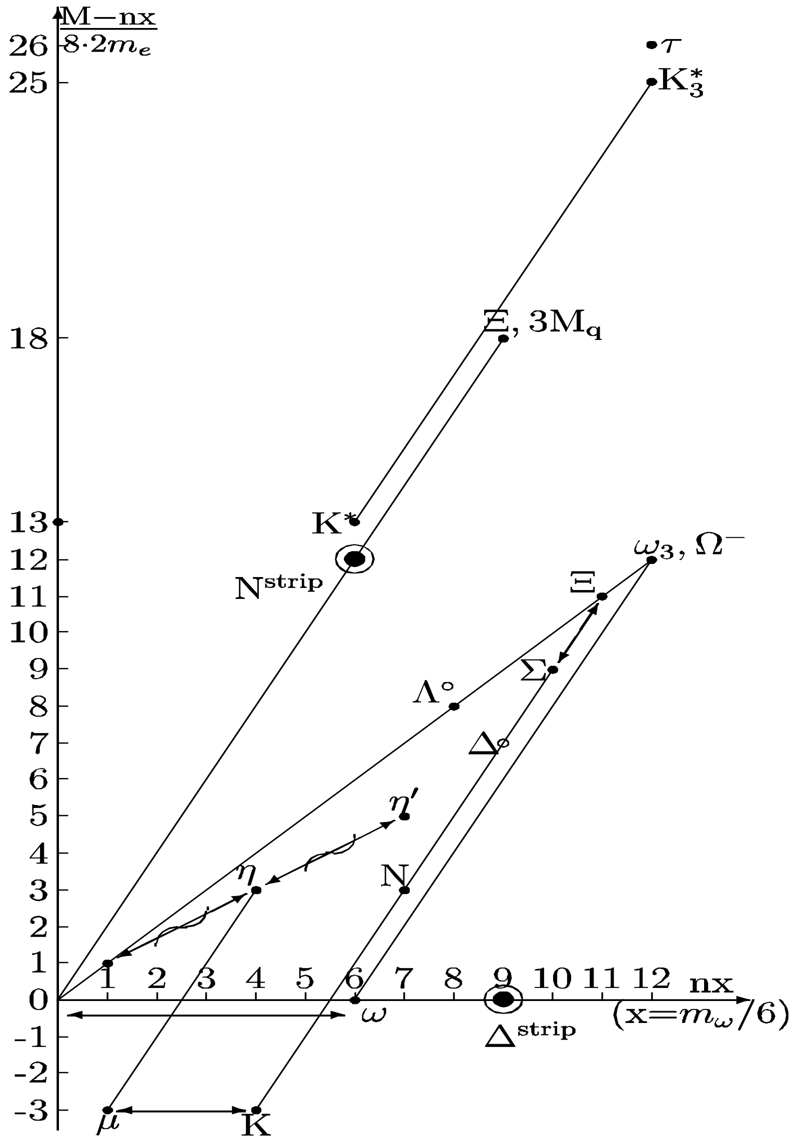
Distribution of intervals adjacent to x=142 MeV (m_π) and x=493 MeV (m_k).





Tuning effect in particle masses.

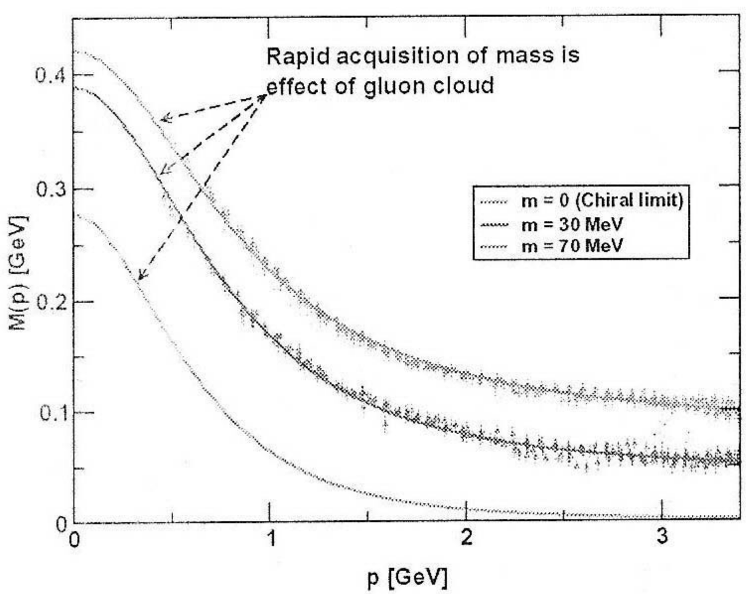
Different estimates of constituent quark masses.



Estimation of the baryon constituent quark mass Mq=441 MeV

Fig. 2a. (C.D. Roberts et al.). QCD gluon-quark-dressing effect calculated with Dyson-Schwinger Equation, initial masses m; constituent quark mass arises from a cloud of low-momentum gluons attaching themselves to the current-quark; this is chiral symmetry breaking: nonperturbative effect that generates a quark mass from nothing even at m=0 (bottom).

Fig.2b. (L.Glozman *et al*.). Calculation of nonstrange baryon (left) and lambda-baryon masses as a function of interaction strength within Goldstone Boson Exchange interaction Constituent Quark Model; initial baryon mass 1350 MeV= =3·450 MeV=3M_q is marked as bottom "+" on left vertical axis.



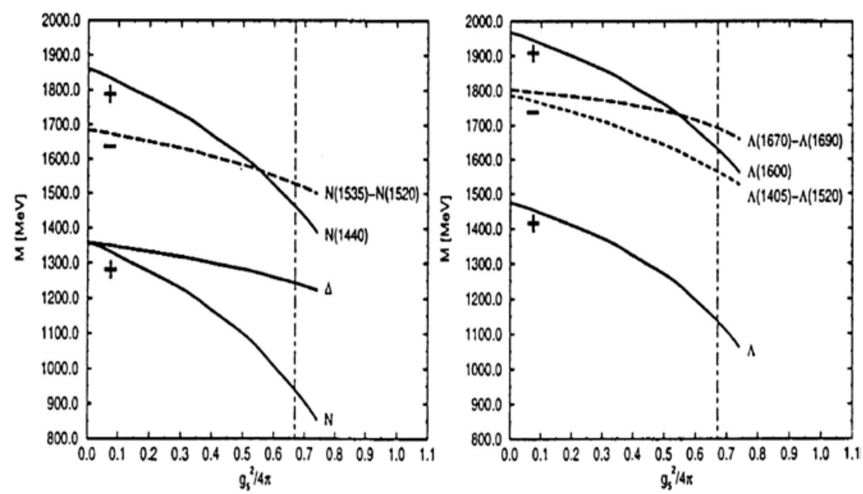
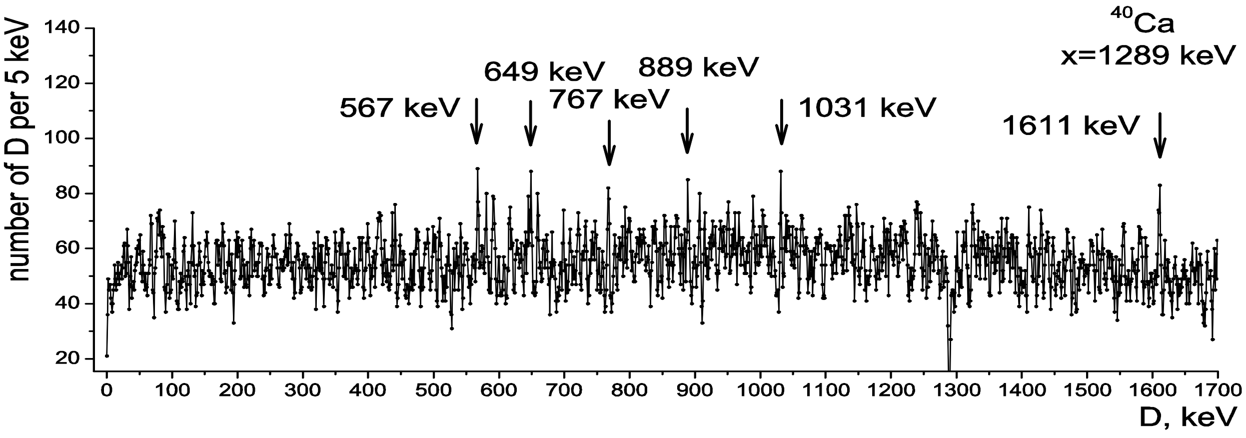
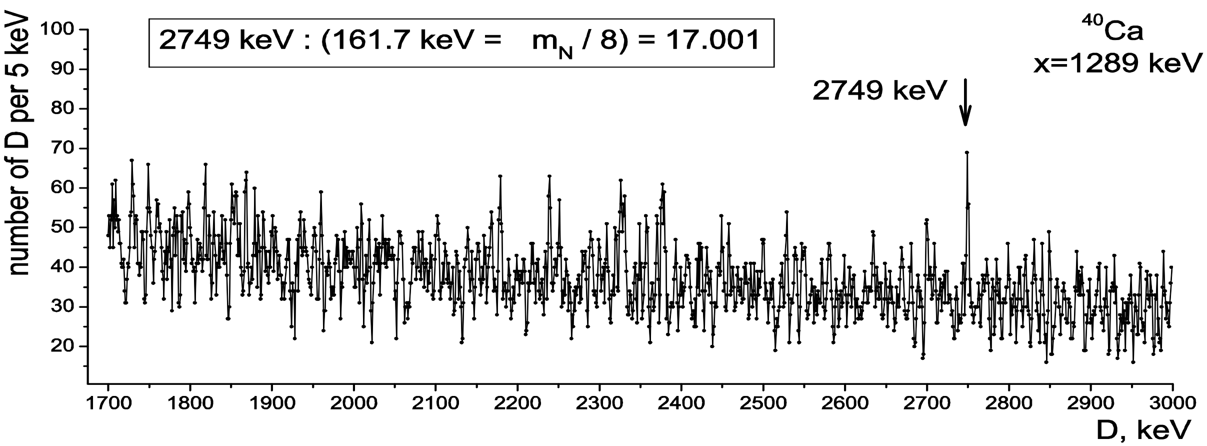


Table B. Linear dependence of excitations in near-magic nuclei (double boxed) upon numbers of protons in Z=14-20 shell (1st line) and numbers of valence neutrons (2nd line, boxed) is compared with the integer numbers of the parameter of 161 keV = Δ^{TF} =δm_N /8 determined in Z=50,51 nuclei (see Proc. QCD14, P.270, Fig.2 and Proc. QCD15, P.214, Table 3, Figs. 3-5).

(Z-14)/2	3		2	1	1	1	1	0	0
N				Δ N=1	$\Delta N = 2$		$\Delta N = 7$		
^{A}Z	^{41}Ca		^{39}Ar	^{37}S	^{38}S	^{33}S	^{43}S	^{32}Si	^{35}Si
E^*	0.0	1943	1267	646.2	1292	322	320.7	1942	973.9
$2J^\pi$	7^-	3^-	3^-	3^-	2^+	D	7^-	2^+	(3^+)
n$\frac{\delta m_N}{8}$	0.0	1941	1293	646	1293	322	322	1941	971
n		12		4	8	2	2	8	6
^{A}Z	^{33}Mg		^{41}K		^{47}Sc	^{47}V	^{50}V	^{51}V	^{55}V
E^*	159	484	980.4	1293.6	807.9	1294.9	320.2	320.1	323.3
$2J^\pi_o$	3^-		3^+		2^+	3^-	6^+	7^-	(7^-)
$2J^\pi$	(7^-)	(3^-)	4^+	7^-	3^-	11^-	4^+	5^-	(5^-)
n$\frac{\delta m_N}{8}$	161	483	971	1293	808	1293	322	322	322
n	1	3	6	8	5	8	2	2	2





D^{AIM} - distribution in ^{40}Ca levels for x=1289 keV close to 8×17δ'= δm_N=1293.3 keV in two energy regions (in upwards direction, Δ = 3 keV) with the maximum at 2749 keV ≈ (17/8) ×1293.3 keV = 2748 keV.

Table C. New data (*) on ^{53}Ni and ^{53}Co excitations with the configuration of nucleon as three holes in ^{56}Ni core. Parameters of the residual interaction of valence nucleons and holes (double boxed) are compared with the same parameters in Z-50,51- and Z,N - nuclei. Boxed are excitations corresponding to maxima in sum distributions shown in Figs.6-8 in Proc. QCD-15.

^{A}Z	^{53}Ni $2J_o$=7-			^{58}Ni	^{59}Ni	^{61}Ni	^{63}Ni		
E^*	320(3)	1292*	1456*	1454.2	339.4	1454.8	87.1	1289.1	1451
$2J^\pi$	(5^-)	(3^-)	(11^-)	2^+	3^-–5^-	7^-	1^-–5^-	9^+	(5,7,9)
$n\frac{\delta m_N}{8}$	322	1293	1454	1454	322	1454		1293	1454
n	2	8	9	9	2	9		8	9
^{A}Z	^{53}Mn					^{55}Mn			
E^*	378	1289.9)	1441.3	2563.1	2573.1	1289.1	1292.1	1293.0	2582
$2J^\pi$	5^-	3^-	(11^-)	13^-	7^-	5^-–11^+	11^-	(1^-)	
$n\frac{\delta m_N}{8}$	322	1293	1454	2586	2586	1293	1283	1293	2586
n	2	8	9	16	16	8	8	8	16
^{A}Z	^{53}Co	^{59}Co				^{69}Cu	^{71}Cu		^{73}Cu
E^*	646.2*	1291.6)	1459	2581.7	2585.8	1297.9	1453.3	2576(3)	1298.0
$2J^\pi$	7^-	3^-	11^-	3^--7^-	7^-	3^-–$1,3^-$	3^-–9^-	(13^-)	$(3^-,7^-)$
$n\frac{\delta m_N}{8}$	647	1293	1454	2586	2586	1293	1454	2586	1293
n	4	8	9	16	16	8	9	16	8

Table. Representation of parameters of tuning effects in particle masses (top) and nuclear data (bottom) with the expression n·16m$_e$($\alpha/2\pi$)^{X}M and different values of the X–power of QED factor $\alpha/2\pi$ and integers M and n=1,13-18. Boxed are five groups of values differing with $\alpha/2\pi$=115.9·10^{-5}.

X	M	n = 1	n = 13	n = 16	n = 17	n = 18	n = 18·6	Comments
-1	3/2			m_t=172.0				
GeV	1	$16M_q=\delta^\circ$	M_Z=91.2	M_H=115		M_H=126		δ°=7.06
	1/2	$(m_b$-$M_q)$		M^{L3}=58				
0	1	$2m_d$-$2m_e$	m_μ=106	f_π=130.7	m_π-m_e	ΔM_Δ=147	$2M_q$	
MeV	3			M"$_q$=$m_\rho/2$		M_q=441=ΔE_B		NRCQM
1	1	$16m_e=\delta=8\varepsilon_\circ$	118		kδ-m_n-m_e=	170 = $m_e/3$		Part.
					=161.651			mass
keV	8				δm_N=1293			CODATA
1	1	$9.5=\delta'=8\varepsilon'$	123	152	Δ^{TF}=161	170 (Sn)	$\varepsilon_o=2m_e$	
keV	3				484 (E^*)	512 (Pd)		
	4		492		648 (Pd)	682(Co)		Nuclear
	8		984	1212	1293 (E^*)	1360 (Te)		data
2	1,4	$11=\delta''=8\varepsilon''$	143	176	749 (Br,Sb)		ε'=1188	Neutron
eV	4,8		570 (Sb)		1500 (Pd,Hf)	X=3	ε''=1.35	reson.

Conclusions

Here we used data on scalar mass M=125.0 GeV and CODATA ratio m_n/m_e to find out an explanation of the systematic appearance of nuclear mass/energy intervals close to mass differences of the nucleon, leptons and the pion. The relation $(n\cdot 16m_e - m_e - m_n)/\delta m_N = 1/8.001(2)$ and the similar long-range correlations in particle masses could be checked with the new data.

- Relation between observed stable nuclear intervals and particle masses can be considered in connection with recently obtained mass of the scalar field, the ratios $m_\mu/M_Z=\alpha/2\pi$ and $(1/3m_e)/M_H=(\alpha/2\pi)^2$. There is a possibility that they are reflections of the fundamental relations between SM-parameters (which were mentioned as a future “super-duper” model by R. Feynman).

- Observed analogy between tuning effects in particle masses and in nuclear data should be theoretically based on QCD as a part of Standard Model. It is in line with Y. Nambu suggestion about the role of empirical relations in particle masses for the SM development.

- Scientific potential of nuclear physics can be connected with a fundamental role of QCD in the Standard Model and with the role of QED parameters.

Thank you for your attention