SYMMETRY-MOTIVATED ANALYSIS OF PARTICLE MASS DATA

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Introduction

Standard Model as a modern theory of all interaction except the gravitation consists of three components :

$SU(3)_{col} \otimes SU(2)_L \otimes U(1)_Y$ (1)

Quantum Chromodynamics, QCD - the first of SM-components describes the strong interaction between quarks and gluons within hadrons (mesons and baryons) and is a well-accepted theoretical base of the modern nuclear physics.

Atomic nucleus has a complex structure and in many nuclear models the quark structure of the nucleon does not presents explicitly.

Standard Model and QCD are not in their final form, they do not explain existing mass hierarchy and relation between parameters.

CODATA relation:

$$m_n = 115\cdot 16 m_e - m_e - \delta m_N /8$$

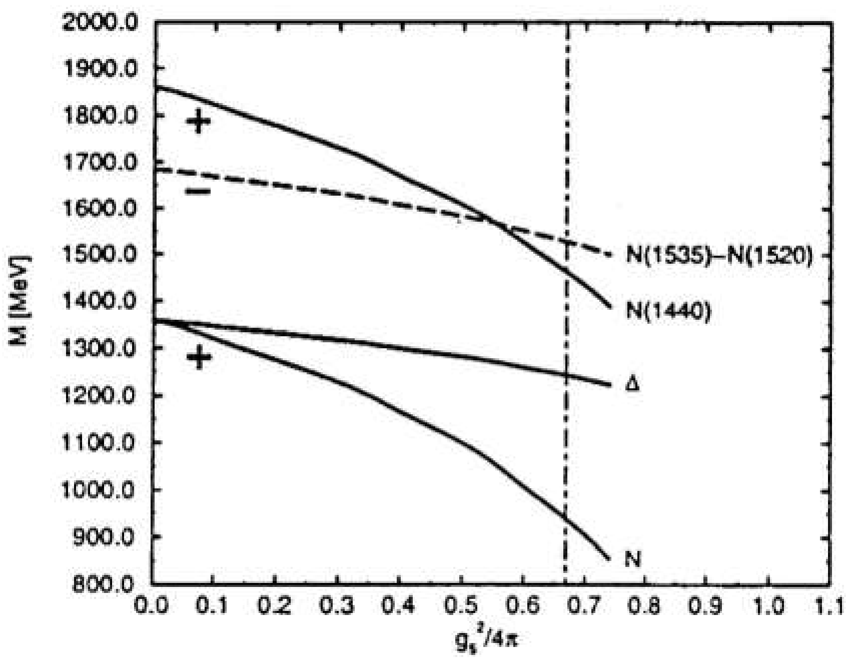
$$m_p = 115\cdot 16 m_e - m_e - 9\delta m_N /8$$

$$m_n - m_p = \delta m_N = 1.2933322(4)\ \mathrm{MeV}$$

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

Left: Calculation of non-strange baryon masses as the function of quark-interaction due to boson Goldstone exchange within NRCQM model.

Right: QCD-based gluon quark-dressing calculated with Dyson-Schwinger equation,initial quark mass m_q=0 (bottom), 30 and 70 MeV; the quark-parton gets moment dependent mass increase, which is two order larger than current masses due to the cloud of gluons around the quark with low momentum.



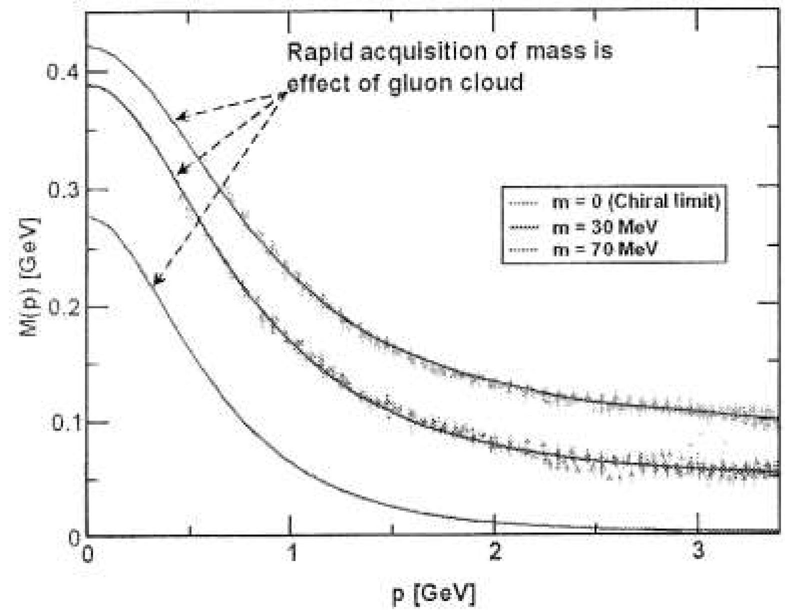


Table. Representation of parameters of tuning effects in particle masses (top) and nuclear data (bottom) with the expression n·16m$_e$($\alpha/2\pi$)^{X}M and different values of the X–power of QED factor $\alpha/2\pi$ and integers M and n=1,13-18. Boxed are five groups of values differing with $\alpha/2\pi$=115.9·10^{-5}.

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= =161.651]	[170 = m_e/3]		Part. mass
keV	8				δm_N=1293			CODATA
1	1	[9.5=δ'=8ε']	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=δ''=8ε'']	143	176	749 (Br,Sb)		[ε'=1188]	Neutron
eV	4,8		570 (Sb)		1500 (Pd,Hf)	X=3	[ε''=1.35]	reson.

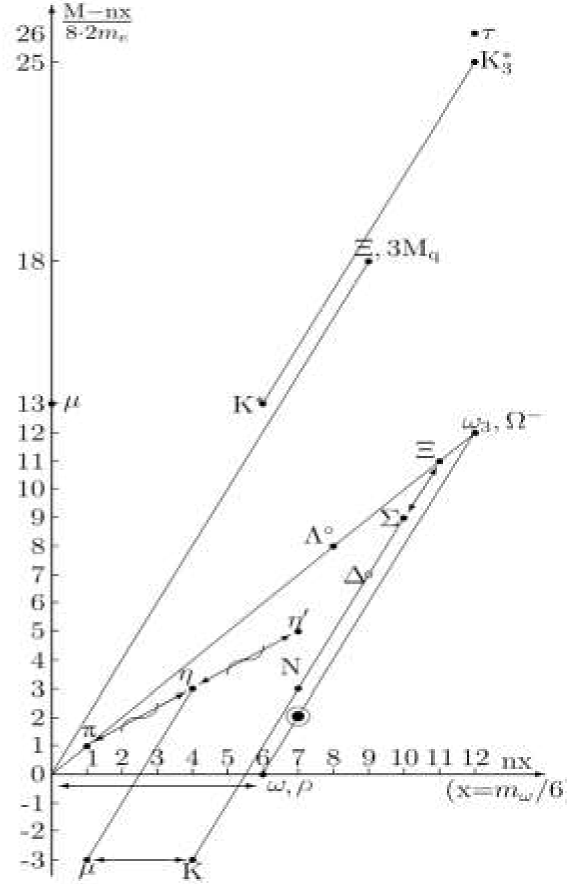


Fig. Two-dimensional representation of particle masses [as the period f_π=16·16m_e=130.4 MeV≈ $m_\omega/6$, somewhat less than pion's mass) along the x-axis and the remainder – in units δ=16m_e. Four different slopes correspond to different mass systematics including noticed by Y.Nambu (line π-Λ-Ξ-Ω) and by T.Takabayashi – equidistance in scalar mesons masses (crossed arrows, π-η-η' intervals, 547.9-139.6=408.3 MeV and 957.8-547.9=409.9 MeV, close to 50δ=408.8 MeV) are seen in the center. Difference between masses of η' meson and the neutron (957.8-939.6=18.2 MeV) is close to 2δ=16.3 MeV Δn = 2 =(117=17+2·50) -115 and boxed in column 17 of Table 1 (at η' and n).
Other intervals are considered in the text and [7-15]. Intervals ω_3-ω (1667(4)-782.7=441 MeV) and K_3^*-K^* (1776(7)-891.7=441 MeV) are close to $2M_q$=2×54δ, with M_q = $m_\Xi/3$=441 MeV=3·18δ being the estimate of the constituent quark mass value in NRCQM (due to gluon quark-dressing effect [16-18]).
Mass of the third τ-lepton is shown at the top (12·16δ+26δ). Distance between this value and close to each other masses of π_2-meson and Ω^--hyperon (1672.2-1673.5 MeV) is close to 104 MeV and m_μ (see boxed values in column 104 in Table 1).
Neutron mass is a member of the sequence K-N-Δ-Σ-Ξ (parallel with the line μ-η) noticed by R.Sternheimer after observation by G.Wick [21] that there are stable intervals close to a half of ω-meson mass (horizontal lines in Fig 3).

Table. Excitations (in keV) in nuclei with N=21,22 (top), N=28,27 and the period 161 keV.

(Z-14)/2	3		2	1	1	1	1	0	0
N				Δ N=1	$\Delta N = 2$		$\Delta N = 7$		
^AZ	^{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
^AZ	^{53}Ni $2J_o$=7-			^{58}Ni	^{59}Ni	^{61}Ni	^{53}Co	^{59}Co	
E^*	320(3)	1292*	1456*	1454.2	339.4	1454.8	646.2*	1291.6)	1459
$2J^\pi$	(5^-)	(3^-)	(11^-)	2^+	3^-–5^-	7^-	7^-	3^-	11^-
$n\frac{\delta m_N}{8}$	322	1293	1454	1454	322	1454	647	1293	1454
n	2	8	9	9	2	9	4	8	9

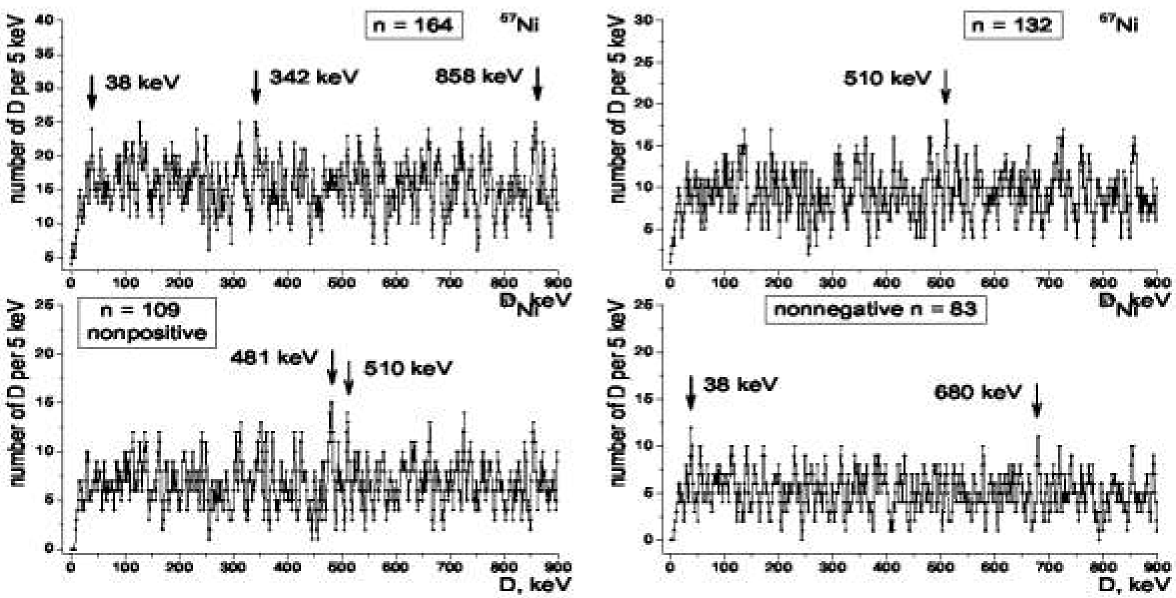


Fig. *Top:* Spacing distribution in all levels of ^{57}Ni (*at left*) and in negative parity levels. *Bottom:* The same for negative parity levels with small spins and for nonnegative parity levels.

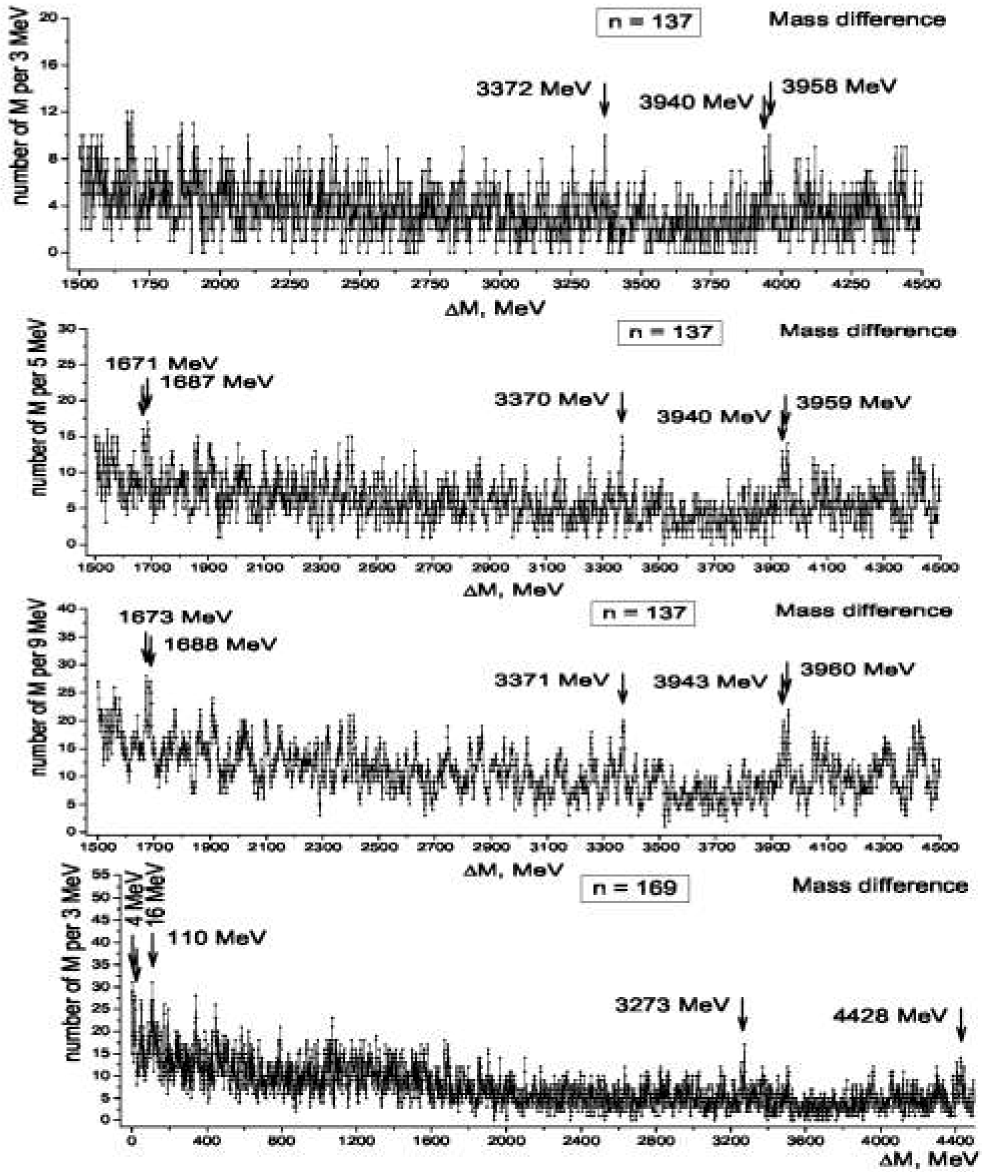


Fig. *Top:* Distribution of differences between particle masses ΔM in the region 1500 -4500 MeV and averaging interval of the histogram 3 MeV. Stable intervals (discussed in the text) are marked with arrows.
Center: The same for averaging intervals 5 MeV and 9 MeV. Intervals 3943 MeV, 3960 MeV are close to bottom quark mass estimation 4.2 GeV [4].
Bottom: Distribution of differences between all particle mass values presented in PDG-16 compilation.

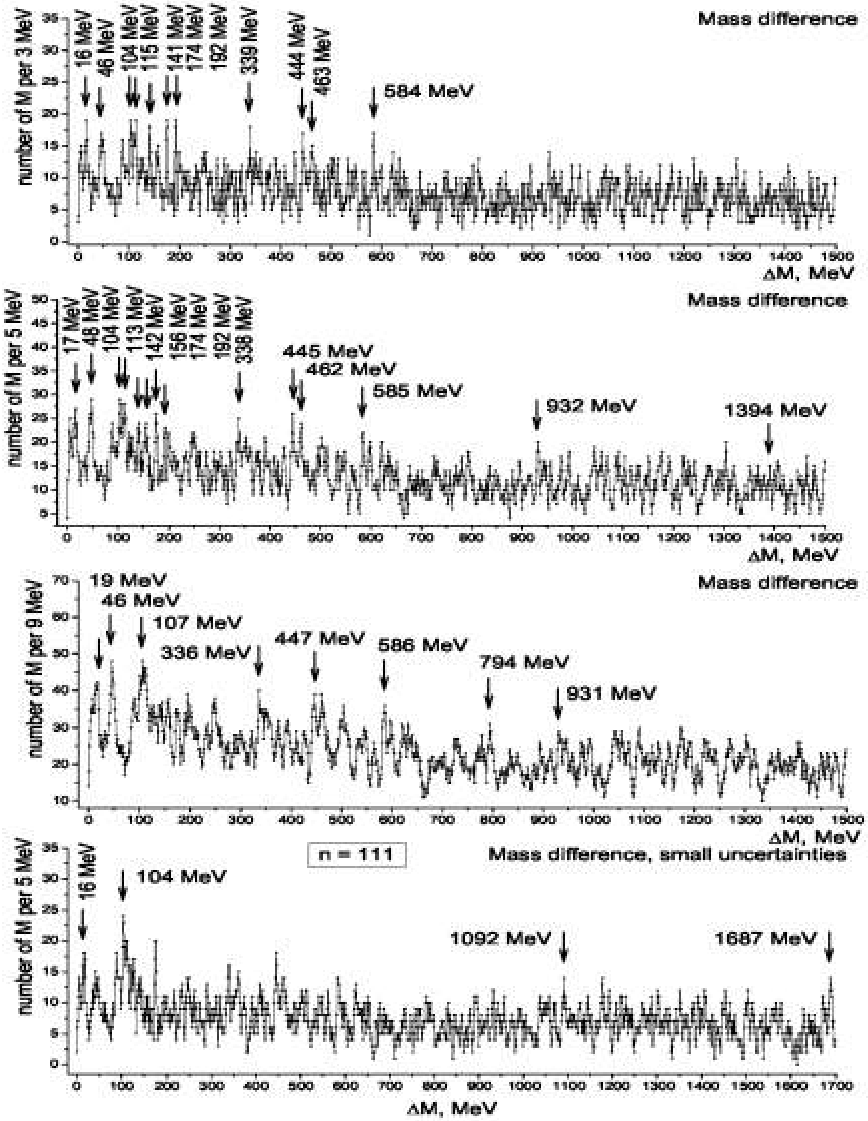


Fig. *Top:* Distribution of differences between particle masses ΔM in the region 0-1500 MeV and averaging interval of the histogram 3 MeV. Stable intervals (discussed in the text) are marked with arrows.

Center: The same for averaging intervals 5 MeV and 9 MeV. Intervals 16 MeV, 48 MeV, 107 MeV$\approx m_\mu$ and 141 MeV$=m_\pi^\pm$ are close to integer numbers of the parameter $\delta = 16m_e$ found in CODATA relations with the masses of nucleons.

Bottom: Distribution of differences between particle masses known relatively accurate (including marked *), averaging interval of the histogram 5 MeV. Stable intervals 104 MeV close to m_μ are discussed in the text and Table 1 (marked with arrow).

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

	Particle		m_l	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)
	$D_{s0}^*(2317)^{\pm}$	$0(0^+)$	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	$0(0^-)$	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)			
	$B_{s2}^*(5840)^{\circ}$	$0(2^+)$	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)	
	$\Upsilon(4S)^*$	$0^-(1^{--})$	10629.4	1.2	17 (26)					174 (25)
	$X(10610)^{\pm *}$	$1^+(1^+)$	10607.2	2.0						
	$X(10610)^{\circ **}$	$1^+(1^+)$	10609	6						

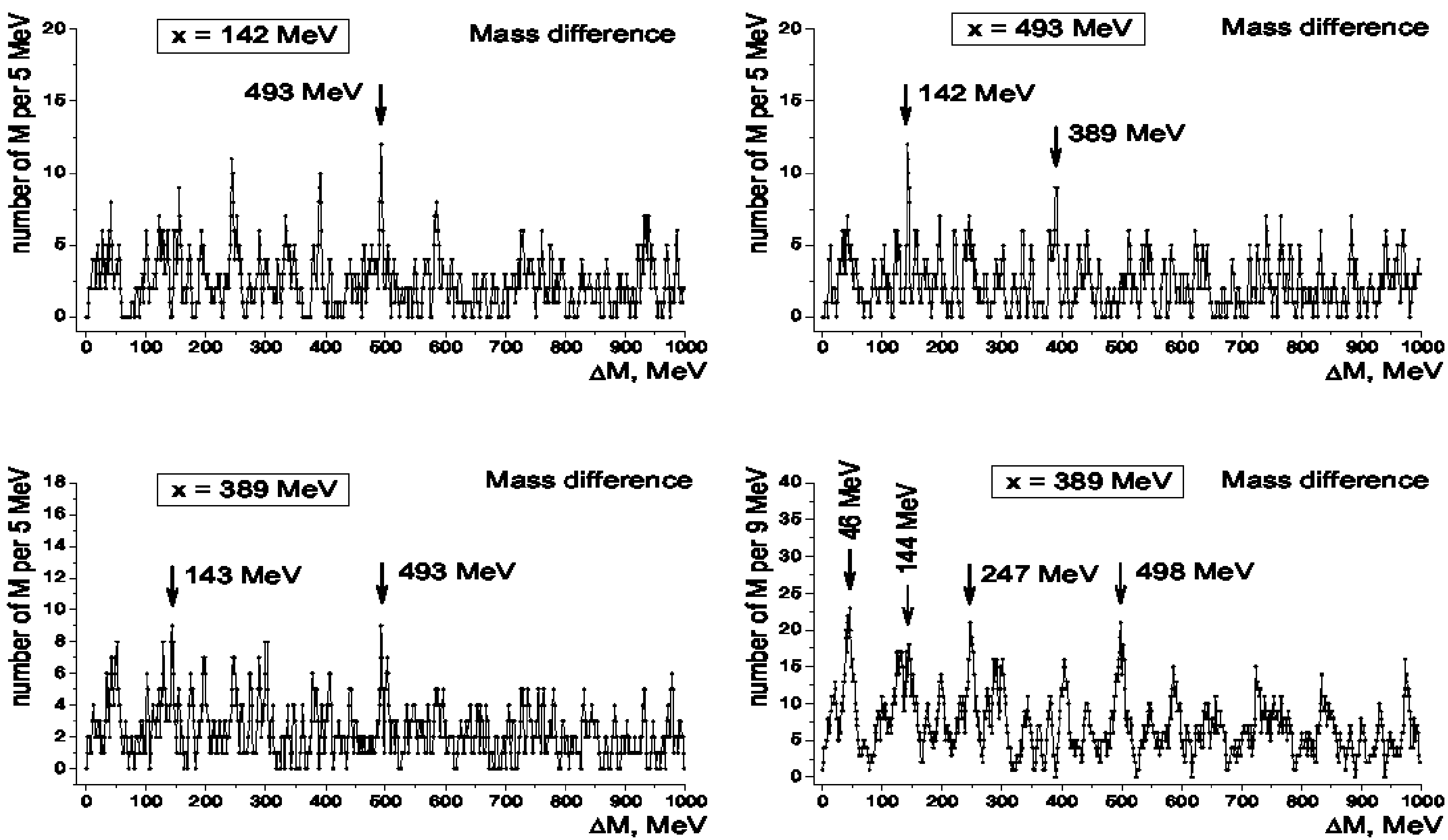


Fig. *Top:* Spacing distribution in all levels of ^{57}Ni (*at left*) and in negative parity levels. *Bottom:* The same for negative parity levels with small spins and for nonnegative parity levels.

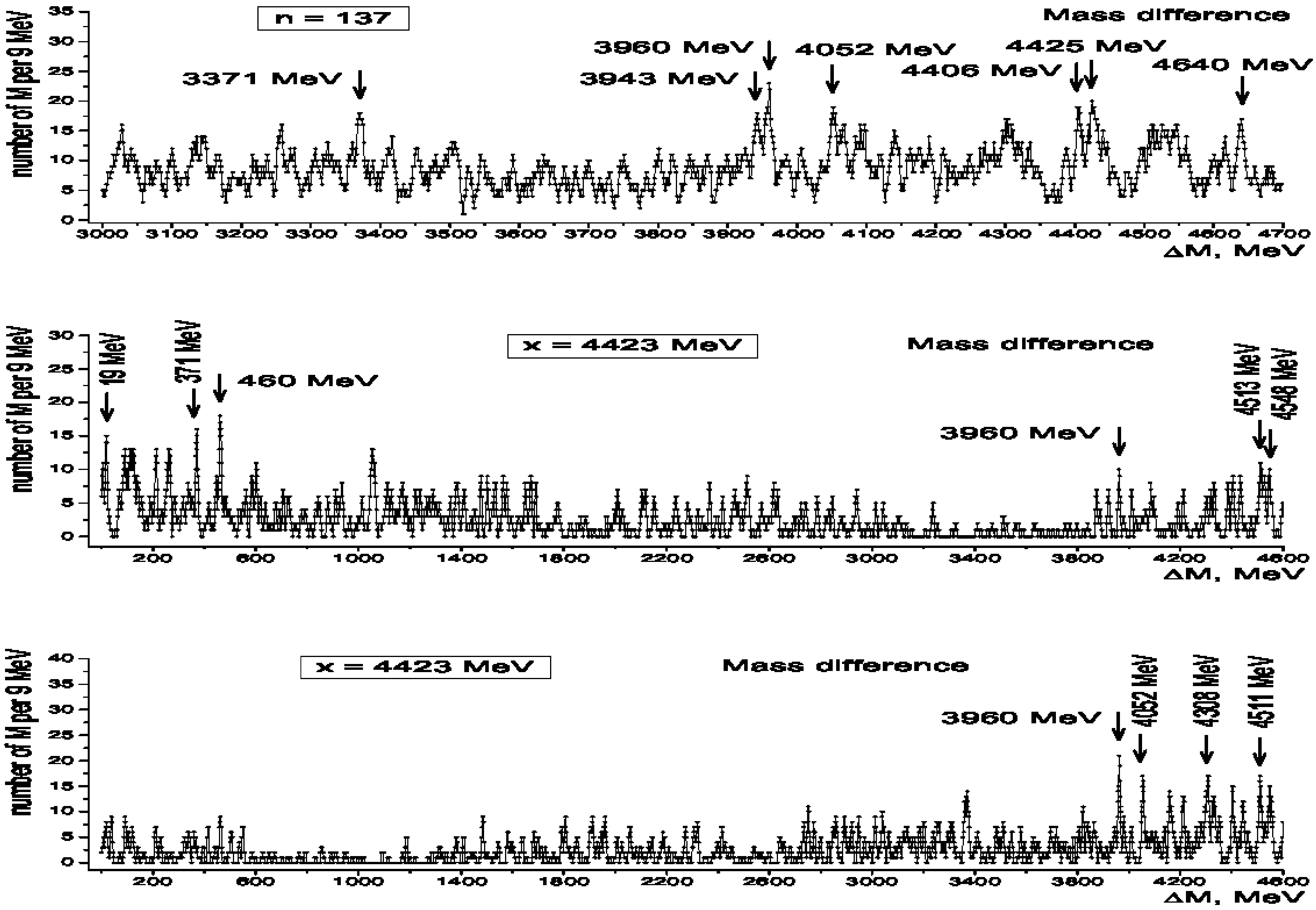


Fig. *Top*: Spacing distribution in mass spectrum in high-energy region). *Bottom*: Application of AIM Method to x=4423 MeV (AIM upward and downward directions, separately).