Discreteness in parameters of the Standard Model

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Introduction I

- **The Standard Model is a general theory of all interactions.**
- **Several well known facts include a vector character of all three interactions (strong, weak and electromagnetic), which are united in the SM with representation**
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- **$SU(3)_{col} \times SU(2)_L \times U(1)_Y$**
- **Quantum chromodynamics (QCD), the first of these three SM components deals with the strong interaction of colored quarks and gluons and is considered as a commonly accepted theoretical base of the nuclear physics.**
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- **R. Feynman wrote :**
- **"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) …. Why are all the theories of physics so similar in their structure?”**

Introduction II

- **Particle masses are parameters of the Standard Model. There is an important suggestion by Y.Nambu (1998) that empirical relations in particle masses could be used for the development of the Standard Model.**
- **Nonstrange pion and ρ-meson are well-known particles composed of light quarks. They are participants of nuclear forces acting between nucleons and form “tuning effect in particle masses” which includes also masses of leptons and scalar/vector bosons.**

Introduction III

- **Nucleon masses are result of the quark-gluon interaction estimated within QCD-lattice calculations. They are parameters of NRCQM -- Constituent Quark Model with meson interaction between quarks (for example, Goldstone-boson interaction). NRCQM is a part of QCD which itself is a part of the Standard Model - theory of all interactions.**
- **Observed universal character of 0+ - 0+ β-transitions in many nuclei means that "the nucleus is one specific case, the coldest and most symmetric one, of hadronic matter" (C. Detraz). The mean binding energy of the nucleon in nuclei is about 8 MeV, mass 940-8=932 MeV.**
- **Important role of the pion exchange and corresponding tensor forces between nucleons is supported with results of the correlation analysis of binding energies and excitations of many nuclei .**
- **Clustering effects in the nuclear structure shows an interconnection between nuclear parameters and parameters of the Standard Mode**

- Recent publications**:**

1. **The QED Corrections in the Standard Model, Discrete'08**, IOP171**,** 012064 .
2. **Fundamental Information from nuclear data, IOP 381,12076 (2012).**
3. **QCD Constituent quark masses as SM parameters,** Nucl. Phys. B(Proc Suppl**.**)

Tuning effect in particle masses

In accordance with the Nambu suggestion it was found that well-known factor alpha/2p=115.9x10-5 , the QED radiative correction to the magnetic moment of the electron (Schwinger term) exactly coincides with ratio of the well-known parameters of the Standard Model, masses of the second lepton and Z-boson

$$m_{\mu}/m_{Z} = 115.9\times10^{-5},\ \alpha/2\pi = 115.9\times10^{-5}$$

It was suggested by Belokurov and Shirkov that the electron mass itself could contain a component proportional to this small factor.

The mass parameters (including pion m_p and muon m_{μ} masses) can be expressed as integers of the doubled value of the pion β-decay energy ($2\delta m_{\pi} - 2m_e$) which is close to $16m_e = \delta$ due to the relation 9:1 between the pion mass difference and the electron mass (it was noticed in 1968). The observed ratios are:

$$(m_{\mu} + m_e)/2(\delta m_{\pi} - m_e) = 13.00$$

$$f_{\pi}=130.7 \text{ MeV (PDG) } /2(\delta m_{\pi} - m_e) = 16.01$$

$$(m_{\pi(+-)} - m_e)/\ 2(\delta m_{\pi} - m_e) = 17.03$$

$$\Delta M_{\Delta}/2(\delta m_{\pi} - m_e) = 18.02$$

$$\text{equidistant interval in pseudoscalar mesons}/2(\delta m_{\pi} - m_e) = 50.1$$

$$\text{neutron mass} + m_e/2(\delta m_{\pi} - m_e) = 115.007$$

Table 1. Comparison of particle masses (PDG 2008) with periods $3m_e$ and $16m_e = \delta = 8175.9825(2)$ (N - number of the period δ), m_e=510.998910(13) keV

Part.	m_i, MeV	$m_i/3m_e$	$N\cdot16m_e$	N	$m_i-N\cdot16m_e$	Comments
μ	105.658367(4)	68.92*	106.2878	13	-0.6294	-.0511-0.118
π^o	134.9766(6)	88,05*	138.9917	17	-4,0174	
$\pi^\pm$	139.5702(4)	91.04*		17	+0.5762	+0.511+0.065
η^o	547.853(24)	357.38	547.7908	67	0.06(2)	
ω	782.65(12)	510.54	784.8943	96	-2.24(12)	
φ	1019.46(2)	665.01*	1021.998	125	-2.54(2)	
$K^\pm$	493.677(16)	322.03*	490.5590	60	+3.118(16)	
p	938.2720(1)	612.05*	940.2380(1)	115	-1.9660	$-m_e-9/8\delta m_N$
n	**939.5654(1)**	**612.89***		**115**	**$-m_e$- 161.6(1) keV**	**$-m_e-1/8\delta m_N$**
Σ^o	1192.64(2)	777.98*	1193.693	146	-1.05(2)	-0.51·2=-1.02
Ξ^o	1314.86(20)	857.71*	1316.333	161	-1.47(20)	-0.51·3=-1.53

Fig.1 Tests of the Empirical Mass Rormula m=Nx3me for Leptons and Hadrons, by R.Frosch (in 1967- 1991) Nuovo Cimento v.104A, 6, 913, 1991 Deapest maximum in the mean root deviations corresponds to the period $3m_e$

- The experimental set of 47 masses was replaced by set of 47 random numbers… the probability for random masses to fit the $3m_e$ formula better than the experimental masses is only $2x10^{-4}$ See numbers close to the integers in the 2nd column of the table that follows,

they are marked by asterisk

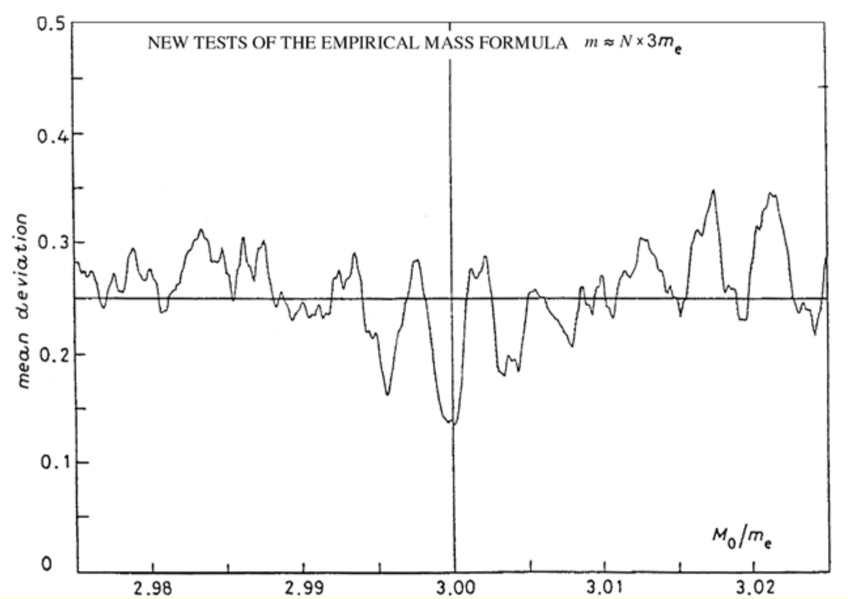


Fig.15 Different estimates of constituent quark masses

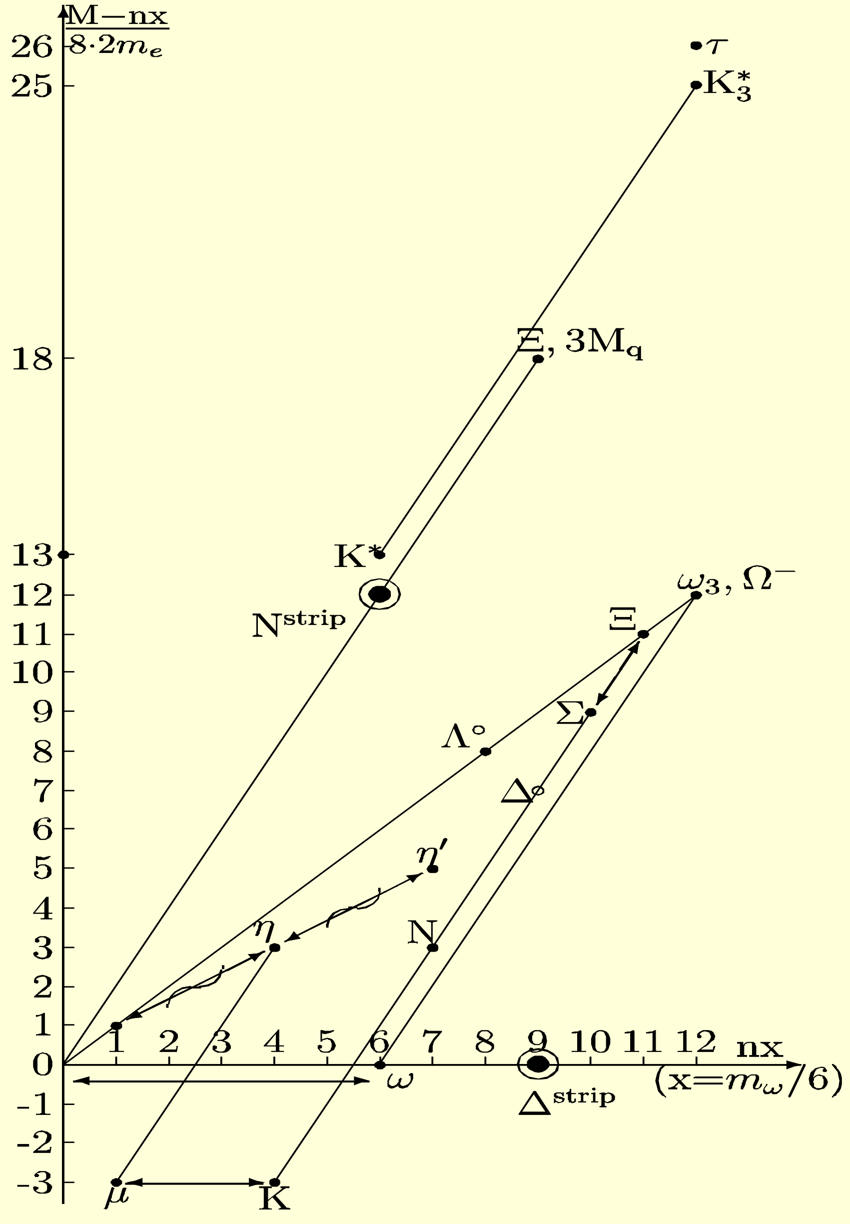


Figure 2 (15) (continued).

Different mass intervals and hadron/lepton masses are shown here by the two-dimensional mass-presentation with the horizontal axis in units δ=16me close to $m_{\omega}/6$. Residuals M_i - n(16×16m_e=16δ) are plotted in the vertical direction (y-axis with units of δ =16m_e). Three values corresponding to different estimates of constituent quark masses are shown as lines with different slopes:

1) horizontal line corresponds to Wick's interval $m_{\omega}/2$=M´´q=48δ;

2) crossed arrows correspond to M^{Δ}_{q}=409 MeV=32+18=50δ and

3) parallel lines with the large slope – to the interval considered by Sternheimer and Kropotkin M_q=441MeV=3x18=54δ. It is corresponding to the initial value of the baryon constituent quark which is equal to three-fold value of nucleon Δ-excitation parameter 147 MeV. Mass of the nucleon in nuclear medium which is less than free nucleon mass (M) by about 8 MeV is located on the straight line from omega-meson mass to the sigma-hyperon mass. This reduced value corresponds to 6x16+18=114δ.

Parameters of the Nonrelativistic Quark Model

<u>Masses of nonstrange vector meson (ρ meson) and Δ-baryon are usally used for estimation of the constituent quark masses.</u>These values are obtained theoretically in lattice-QCD calculations shown in Fig 3.

Baryon masses and hence baryon constituent quark mass estimate can be obtained within NRCQM model where residual quark interactions are taken into account (Fig.4).

The corresponding values for baryon/meson constituent quark masses are

M_q=441 MeV=m_{Ξ^-}/3=(3/2)(m_Δ-m_N), M''_q =m_π/2=775.5(4) MeV/2 =387.8(2) MeV, respectively.

The meson quark is close to the threefold value of the pion parameter f_π coinciding with 16x16m_e and deviate from it on Δ=9m_e. Baryon quark mass coincides with the parameter found by R. Sterheimer and P. Kropotkin and corresponds to the slope of lines in Fig.1 between many particles and is very close to 1/3 of the mass of Ξ hyperon.

Both values are in ratios with vector bosons coinciding with the lepton ratio, namely,

M_z/441 MeV=206.8 and M_W/(m_ρ/2)=207.3. The origin of these effects should be considered in the line with observed tunung effects in particle masses and relation between the determined at CERN mass of the scalar fields M_H=126 GeV and the parameter 147MeV=441 MeV/3 and the (1/3)m_e

Presentation of the pion parameter (16x16m_e) and the muon mass (13x16-1) reflect the common stabilyzing effect connected with symmetry properties of QCD components not fully taken into account in the recent theory of quark dressing effect . Parameter M_q play a distinguished role in the discreteness at higher masses, including M_H=18x16M_q and top quark mass 3x8x16M_q in addition to the lepton ratio with Z-boson mass. The role of QED parameters in these relations was discussed elsewhere.

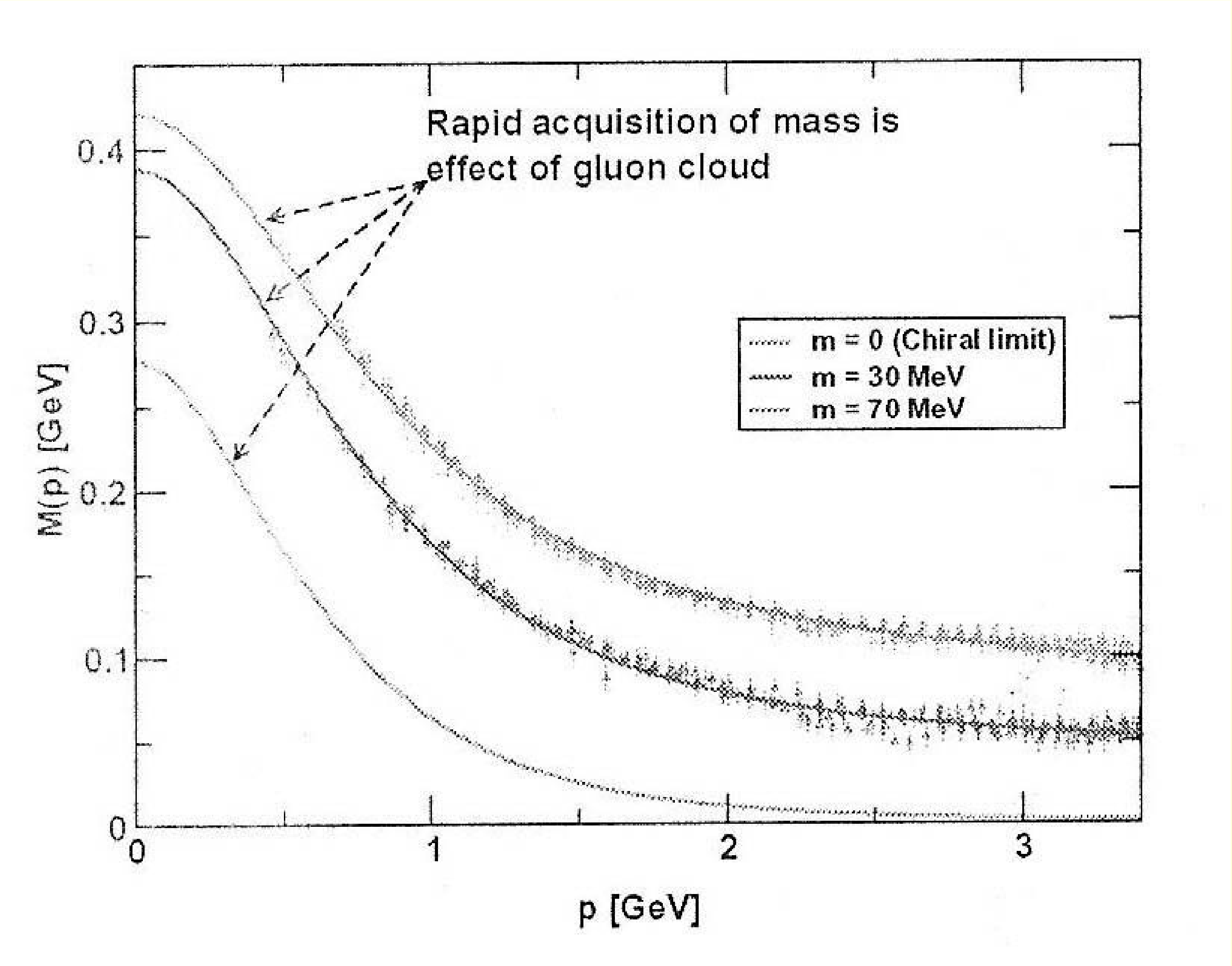
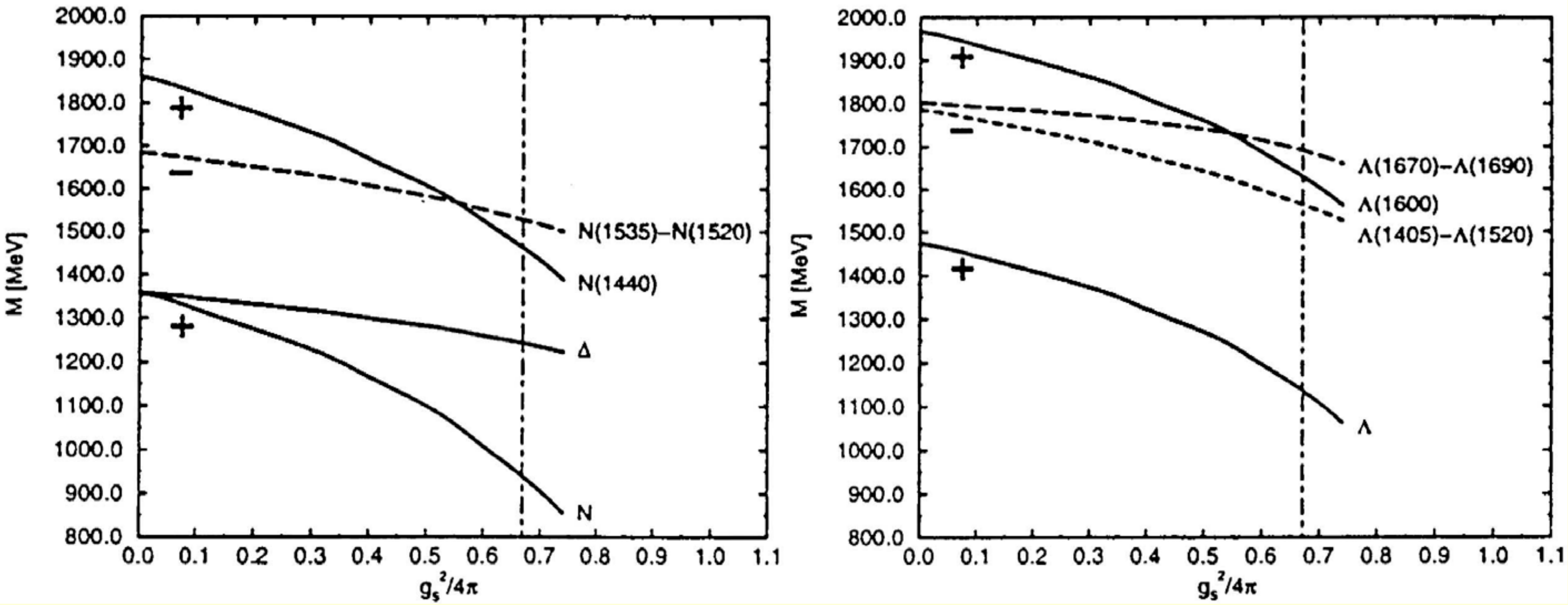


Fig.3 **(Roberts). QCD gluon-quark-dressing effect calculated with Dyson-Schwinger Equation, initial masses m; the constituent quark mass arises from a cloud of low-momentum gluons attaching themselves to the current-quark; this is dynamical chiral symmetry breacking: an**

nonperturbative effect that generates a quark mass from nothing even at chiral limit m=0 (bottom).



- Fig.4 **(Glozman). Calculation of nonstrange baryon masses (left) and lambda-baryon masses as a function of interaction strength within GBECQM – Goldstone Boson Exchange interaction Constituent Quark Model; initial baryon mass 1350 MeV=3x450 MeV=3Mq is near bottom "+" on left vertical axis.**

The lepton ratio in the Standard Model

Lepton ratio as the distinguished parameter

Earlier, as a realization of Nambu's suggestion to search for empirical mass relations needed for SM-development, it was noticed that the well-known lepton ratio L=m_μ/m_e=206.77 becomes the integer 207=9x23=13x16-1 after a small QED radiative correction applied to m_e (it becomes $m_\mu/m_e(1-\alpha/2\pi)$=207.01)

We see that the same ratio L=207 exists between masses of vector bosons M_Z=91.188(2) GeV and M_W=80.40(3) GeV and two commonly accepted estimates of baryon/meson constituent quark masses M_q=441 MeV=

=$m_{\Xi^-}/3=(3/2)(m_\Delta-m_N)$ and $M''_q=m_\pi/2$=775.5(4) MeV/2 =387.8(2) MeV. These ratios are M_Z/441 MeV=206.8 and $M_W/(m_\rho/2)$=207.3.

In Table 2 both estimates are presented in the central part in columns

Marked n=16 and n=18. Components of both quark masses, namely

f_π=130 MeV and 147 MeV are related to the scalar field masses and top quark mass as it is shown in upper part of the Table 2.

Long-range correlations in the tuning effects

Using exactly known proton/electron mass ratio and observed proximity of the neutron mass m_n=939.5654(1)MeV to the integer number 612.89 of the period $3m_e$ (and simultaneously to $115x16m_e-m_e$) one can determine the deviation of the neutron mass From integer number me. This difference 161.6(1) keV known very accurately coincides with $1/8\delta m_N$ (1/8 of the nucleon mass difference 1293.3 keV) with small uncertainty of 0.1 keV. The ratio of this shift with the pion mass is coincides with QED correction and is shown in Table 2 (boxed).

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The role of nuclear data in a study of the tuning effect in particle masses:

1) Indirect check of QCD effects was performed with the analysis of nuclear data . Figure 6 and Table 3 show result of the correlation analysis of nuclear binding energies starting with the standard determination of nucleon pairs interaction from differences of two valence nucleons separation energies

$\varepsilon_{2n2p}=S_{2p}(N+2)-S_{2p}(N)$ for Z_o=2, 8 and N_o=2, 8 .

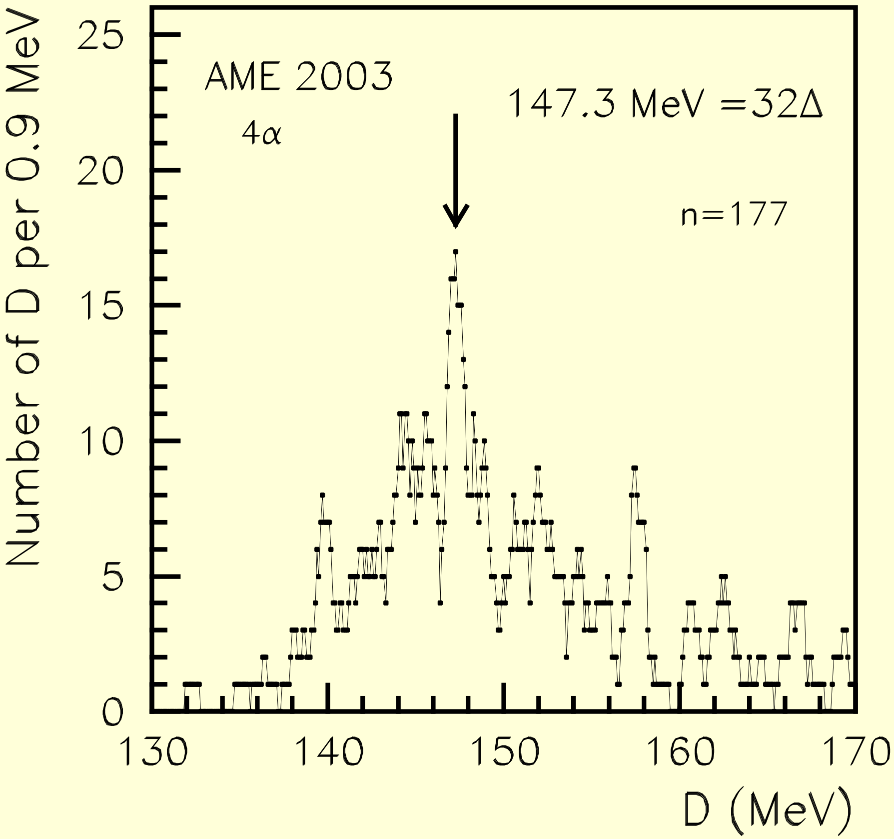
2) Small deviations (about 10 keV) are observed between integer numbers of common period Coinciding with the electron rest mass and experimental differences of binding energies).

Such long-range correlation is observed in nuclei close to shells Z,N=20 and N=82.

3) Analysis of nuclear excitations resulted in independent determination of the interval of 161 keV in nuclei where one-pion dynamics is expected (ratio 161 keV/139 MeV=$1.16x10^{-3}$ coincides with $\alpha/2\pi$ (Table 2, center).

Table 2. Presentation of parameters of tuning effects in particle masses (three upper parts with x = -1,0,1) and in nuclear data (separately in binding energies x=0 and excitations x = 1,2) by expression $(n\cdot 16m_e(\alpha/2\pi)x)\cdot m$ with QED parameter $\alpha = 137^{-1}$.
Higgs boson and pion masses, the discussed shift in neutron mass $n\delta$-m_n-m_e=161 keV, the parameter of nucleon Δ excitation and $m_e/3$ (which related as $\alpha/2\pi$) are marked.

x	m	n=1	n=13	n=16	n=17	n=18
-1	3/2			m_t=171.2		
GeV	1		M_Z=91.2	M_H=115		**M_H=126**
	1/2			M_{L3}=58		
0	1	$16m_e=\delta$	m_μ=105.7	F_π =130.7.	**m_π-m_e**	**$(m_\Delta$-$m_N)$ /2=147**
MeV	3			$M_q''=m_\rho/2$	M_q'=420	M_q=441
	3			$M_q'''=m_\omega/2$		$3\Delta M_\Delta$=441
0	1	2Δ-ε_o	106=ΔE_B	130=ΔE_B	140=ΔE_B	147.2=ΔE_B
MeV	3					441.5=ΔE_B
1 keV	1 8,	9.5 keV	123 keV		**$n\delta$-m_n-m_e=161.6(1)** δm_N=1293.34(1)	**170=m_e/3** m_e=510.99891
2 eV	1 2	11 eV 22 eV	143 eV		187 eV 375 eV	



- ***Figure 5*** **Observed intervals in nuclear binding energies of light nuclei (Z less 26) differing with 4 α.**

Table 3. Comparison of experimental Δ_{EB} (in keV) and theoretical estimates in magic nuclei (N=82, N=20) with $10\Delta = 45\varepsilon_o$ (^{6}He cluster, left part of the Table) and in light nuclei ^{39}K and ^{36}K differing with 4α (values $32\Delta = 18\delta = 144\varepsilon_o$). Small differences between observed energies and integer numbers of $\varepsilon_o = 2m_e$ (Diff.) correspond to long-range correlations in binding energies.

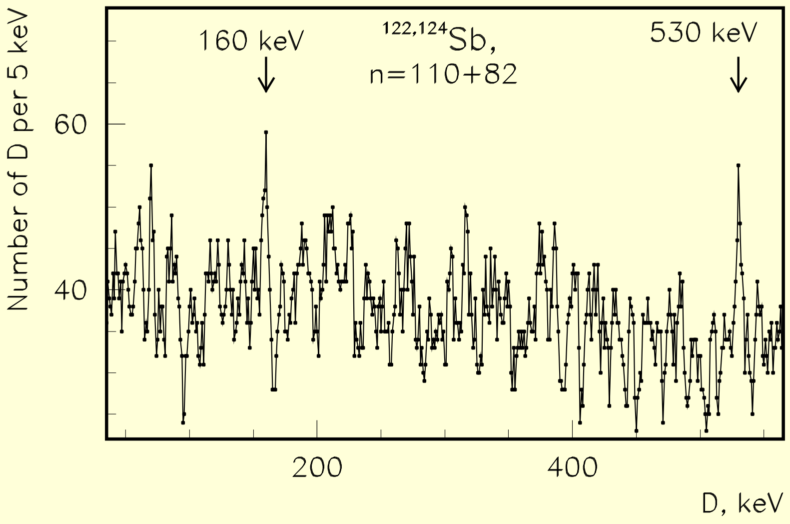
	Z=55	^{137}Cs		Z=57	^{139}La	Z=58	^{138}Ce	^{140}Ce	^{39}K	Z=19
N	80	82	78	80	82	78	80	82	20	17
ΔE_B	45946	45970	46018	45927	46024	46087	45997	45996	147160	147152
$N\cdot\varepsilon_o$		45990			45990			45990	147168	147168
Diff	-44	-20	28	-63	34	97	7	6	- 8(2)	- 16
FRDM	46620	46340	45950	46820	46970	45960	46850	47160	147450	145950
Diff.	630	350	-40	830	980	-30	860	1170	282	1220

Tuning effect in nuclear excitations

Discussed here empirical relations in nuclear data were represented as the common expression with different powers of the common dimentionless factor to fit a great number of empirically observed stable nuclear intervals (Table 4).

An example of such stable nuclear interval is given in Fig 6 and Table 4 for the found by Schiffer *et al*. **and explained by Otsuka linear trend in valence proton excitations in Sb isotopes. Maximum at 160 keV in spacing distribution in two neighbour Sb-isotopes confirm a stable character of intervals related as QED correction to the pion mass m_{π}=140 MeV. This comparison is supported by the fact that such excitations are observed in nuclei with nucleon configuration which are connected with the pion-exchange dynamics (tensor forces).**

Fig.6 Spacing distribution in Sb-122,124



Appearance of stable intervals in nuclear excitations rational to me and δm_N (named tuning effect) was found in data for many near-magic nuclei.

^{101}Sn	^{103}Sn	^{105}Sn	^{123}Sb	^{125}Sb~
171.7(6)	168.0(1)	199.7(3)	160.3(1)	332.1
$m_e/3$	$m_e/3$		$1/8\delta m_N$	$2/8\delta m_N$
^{125}Sb	^{127}Sb	^{129}Sb	^{131}Sb	^{133}Sb
643.2	491.2	645.2(1)	798.5	962.3(1)
$4/8\delta m_N$	$3/8\delta m_N$	$4/8\delta m_N$	$5/8\delta m_N$	$6/8\delta m_N$

Table 4. : **Nuclear excitations close to $m_{e/}3$ and $n\cdot\delta m_N/8$ in Sn and Sb isotopes**

Parameters of the Standard Model

It was discussed by many authors that radiative correction of the type g/2π could be useful for comparison of different parameters. A possible example of application of this method was given by I. Dyatlov.

The SM-scalar mass permitted to check again the presence of the ratio α/2π with the mass interval similar to the discussed parameters of NRCQM (147 MeV).

Observed in nuclear data long-range correlations with the parameters m_e and $\varepsilon_o=2m_e$ (see Table 3) should be considered as additional argument for a fundamental meaning of earlier found empirical relations in nuclear and neutron resonance data, for example, nonstatistical effects in low-lying and highly excited nuclear states.

Conclusions

- Presence of tuning effects in nuclear excitations and nuclear binding energies is confirmed with new analysis of data from PNPI compilations (Vols. I/19, I/22, I/25 LB Springer) based on the role of pion-exchange.

- Relation between observed stable nuclear intervals and particle masses can be connected with the properties of SM scalars M_H=126 GeV.
- Ratios $m_\mu/M_Z=\alpha/2\pi$ and $(1/3m_e)/M_H=(\alpha/2\pi)^2$ could be a reflection of the fundamental relations between SM-parameters (possible "super-duper" model by R. Feynman).

- Relation $(N\cdot16m_e - m_e - m_n)/\delta m_N = 1/8.000$ could be checked with the new more accurate value of the m_π/m_e ratio (this coincidence is important).

- Observed analogy between tuning effects in particle masses and in nuclear data should be theoretically based on QCD as a part of Standard Model and Nambu suggestion about the role of empirical relation for SM development.
- Scientific potential of nuclear physics can be connected with fundamental role of QED parameters including the electron mass and QED corrections.