THE ORIGIN OF TUNING EFFECTS IN NUCLEAR DATA

S.I. Sukhoruchkin

Petersburg Nuclear Physics Institute, Gatchina, Russia

Abstract

We consider relations in parameters of the Standard Model and come to a conclusion that there exist scaling factors similar to the QED radiative correction ($\alpha/2\pi$) for the electron magnetic moment and introduced earlier empirically from the analysis of neutron resonance data. Together with the QCD effects it allows the intercomparison of mass values of leptons, nucleons, quarks and fundamental bosons and estimate parameters of tuning effects in nuclear data. Long-range correlation in nucleon masses observed as the shift relative to integers of the electron mass m_e is considered.

1 Introduction

The fundamental problem of particle mass origin was discussed by Nambu [1]. He suggested a search for empirical relations in particle masses for further development of the Standard Model – the theory of all interactions, including the QCD – a basic theory of the strong interaction. QCD-based lattice calculations are important for the nuclear theory.

Recent data on particle properties [2] together with the results from unfinished experiments at LEP [3-5] (Fig.1) allowed the intercomparison of particle masses and stable mass/energy intervals in a common Table 1 similar to that in [6-9]. The value at the top of this table is the top quark mass (m_t) which is according to Wilchek "the most reasonable of quark masses" [10]. The recent accurate value m_t=171.2(21) GeV is in integer relation 3:2:1 with values 115 GeV=M_H and 58 GeV=M^{L3} of mass groupings observed at LEP [3-5] (Fig.1, Table 1). This is the first example of empirical relations in particle masses.

The second example is a ratio between the well-known SM-parameters: μ-lepton mass and Z boson mass, namely, 105.66 MeV)/91187 MeV=$1.159\cdot 10^{-3}$. It coincides with the $\alpha/2\pi$=$1.159\cdot 10^{-3}$ known as QED correction. The use of radiative correction of the type g/2π is a well-known method [11,12], the $\alpha/2\pi$ is the Schwinger correction for the magnetic moment of the electron [13] and its inclusion into electron mass m_e was discussed in [14].

The third example is the relation m_e:δm_π:m_μ=1 : 9 : (13×16-1=9×23) [15,16] which takes place between lepton masses and mass splitting of the pion δm_π. It allowed introduction of the parameter δ=16m_e (doubled value of the pion β-decay energy) for presentation of many different particle masses and was noticed by independent authors [16-18]. The recent value of δm_π=4.9536(5) MeV forms with the reduced electron mass m_e^*=$m_e(1-\alpha/2\pi)$ the ratio $\delta m_\pi/m_e^*$=9.00 close to the integer. The lepton ratio m_μ:m_e=206.77 also becomes integer for the reduced electron mass m_μ:m_e^*=207.096=L=13·16-1 [6-9].

As the fourth example we should mention the ratio ($\alpha/2\pi$) between the electron mass and the interval in masses M_q=441 MeV =3ΔM_Δ=(3/2)(m_Δ-m_N)=(3/2)294 MeV introduced by Sternheimer [19] and Kropotkin [20] m_e/M_q=0.511/441=$1.159\cdot 10^{-3}$. The mass parameters M_Z, m_μ, M_q, m_e are shown in top part of Table 1 where values differing by the QED correction factor $\alpha/2\pi$ are situated one under another in different sections labeled by "x" – power of ($\alpha/2\pi$). They have similar integer numbers "m" and "n".

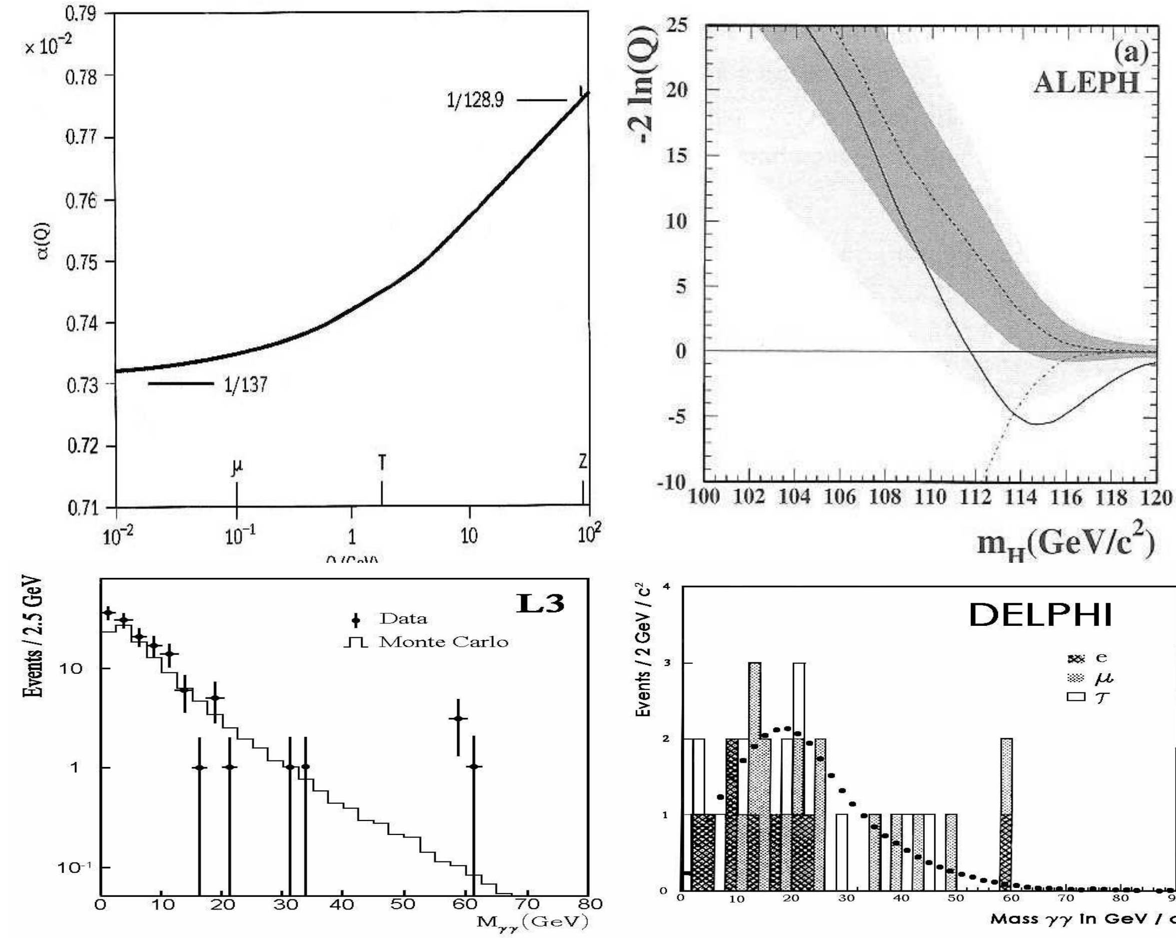


Fig.1. *Top:* Momentum transfer evolution of QED effective electron charge squared. Monotonously rising theoretical curves is confronted with the precise measurements [21] (left). ALEPH results with about 3 standard deviation at mass 115 GeV, observed (solid line) and expected behavior of the test statistic (sharer region) are discussed in [3,4] (right).
Bottom: The measured at LEP two photon invariant mass spectrum from L3 (left) and DELPHI (right) compared with Monte Carlo expectations (channel contributions are indicated) [5].

The fifth example of empirical relations concerns the lepton ratio L. From the relations $m_\mu/M_Z{=}\alpha/2\pi{=}m_e/M_q$ it follows that the ratio M_Z/M_q=206.8 is close to L=207. It is shown later that the Sternheimer/Kropotkin parameter M_q=441 MeV coincides with the estimate of constituent quark mass. Another estimate $M''_q{=}m_\rho/2$=775.5(3) MeV/2= =387.8(2) MeV could be obtained with the ρ-meson mass [2]. With the charged vector boson mass it gives a ratio M_W/M''_q=207.3 also close to L=207 [6-9].

There is observation connected with QED parameter α. In Fig.1 (left) from [21] the dependence of QED parameter α upon the distance is shown (from 1/137 for the large distance to 1/129 for the short distance $1/M_Z$ [22]). Feynman ironically noticed that attempts to compare α with any rational presentations should be called as "super-duper model" [13] if connected with the vector character of all interactions. It is known [7,8] that a ratio about 1/129 exists between the discussed parameter $M_q{=}3\Delta M_\Delta$=441 MeV and $(1/3)m_t{=}M_H/2{=}M^{L3}$. We do not consider it until M_H or M^{L3} will be confirmed.

Another example of empirical relation is connected with a possible fundamental character of nuclear tuning effect. We later show a similarity between correlations in particle

Table 1: Presentation of parameters of tuning effects in particle masses (three upper parts with x=-1,0,1,2) and in nuclear data (separately in binding energies and excitations) by expression $(\mathrm{n}\times 16m_e(\alpha/2\pi)^x)\times m$ with the QED parameter $\alpha = 137^{-1}$. One asterisk marks stable intervals observed earlier in excitations [6] and neutron resonances, two asterisks mark intervals found in [42]; ε_{np} is the parameter of nucleon residual interaction [23,24]; boxed are values related to $(2/3)m_t$=M_H with QED parameter α_Z=129^{-1} (m_π-m_e, $m_e/3$) and the shift in neutron mass nδ-m_n-m_e discussed in text.

x	m	n=1	n=13	n=14	n=16	n=17	n=18
-1	3/2				m_t=171.2		
GeV	1/2				M^{L3}=58		
	1		M_Z=91.2		M_H=115		
0	1	$16m_e$=δ	m_μ=105.7		(f_π=131)	$m_\pi - m_e$	m_Δ-$m_N/2$=147
MeV	3				M''_q=$m_\rho/2$	M'_q=420	M_q=441
					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	1					nδ-m_n-m_e=161.6(1)	170=$m_e/3$
keV	8,3					δm_N=1293.34(1)	m_e=510.99891
1	1	9.5=δ'	(123)	(132)	(152)	(163)	170=$\varepsilon_o/6$, 168*
keV	2	(19)	247**	264*		322**	337*, 340**, ε_{np}
	3		369**			482**	512**, 511*
	4	(39)	492*	532**		648**, 646*	683*, 685*
	6		736**		910*	965*	1024*, 1024**
	8		984*	1060**	1212*	1293**, D_o	1364*
2	1	11=δ''	143*		176*	187*	D in neutron
eV	4-8	44*	570*			749*-1500*	resonances

masses and in nuclear data (in both cases appearance of mass/energy intervals rational to electromagnetic mass splitting m_e, δm_N, δm_π=$9m_e$=Δ [6-9] was named "tuning effect"). Observed stable character of valence nucleon interaction [23,24] seen as discreteness of the nucleon interaction parameters ε_{np} calculated from differences of nucleon separation energies (period 340 keV) was compared with spin-dependent residual interaction between constituent quarks (the nucleon Δ-excitation $2\Delta M_\Delta$=294 MeV). The ratio (340 keV=$\varepsilon_o/3$)/294 MeV=$1.16\cdot 10^{-3}$ is close to $\alpha/2\pi$=$1.159\cdot 10^{-3}$.

Additional empirical observation concerns the factor $1/27\cdot 32$=$1.157\cdot 10^{-3} \approx \alpha/2\pi$ found in 70-ties during the analysis of nuclear and neutron resonance data [25-27] as the ratio between single-particle intervals multiple with ε_o=1.02 MeV, fine-structure intervals (period ε'=1.2 keV) and superfine structure intervals (period 5.5 eV=$4\varepsilon''$=$\delta''/2$) observed independently by Ideno and Ohkubo [28]. Using long-range correlations in fine- and superfine structures [29-42] the ratio $\varepsilon''/\varepsilon'/\varepsilon_o$ was confirmed to be close to $\alpha/2\pi$. Fine structure in nuclear data was first time noticed by Andreev [43] who considered effects connected with the m_e as a manifestation of QED dynamics at different distances.

2 Nucleon structure and constituent quark mass

The Δ-baryon mass corresponding to nearly unbound three-quark state is somewhat less than the initial baryon mass in calculations of baryon masses in the Constituent Quark Model (CQM). It is seen in Fig.2 [44] were CQM calculations with the Goldstone Boson Exchange are presented as a function of the strength of residual quark interaction.

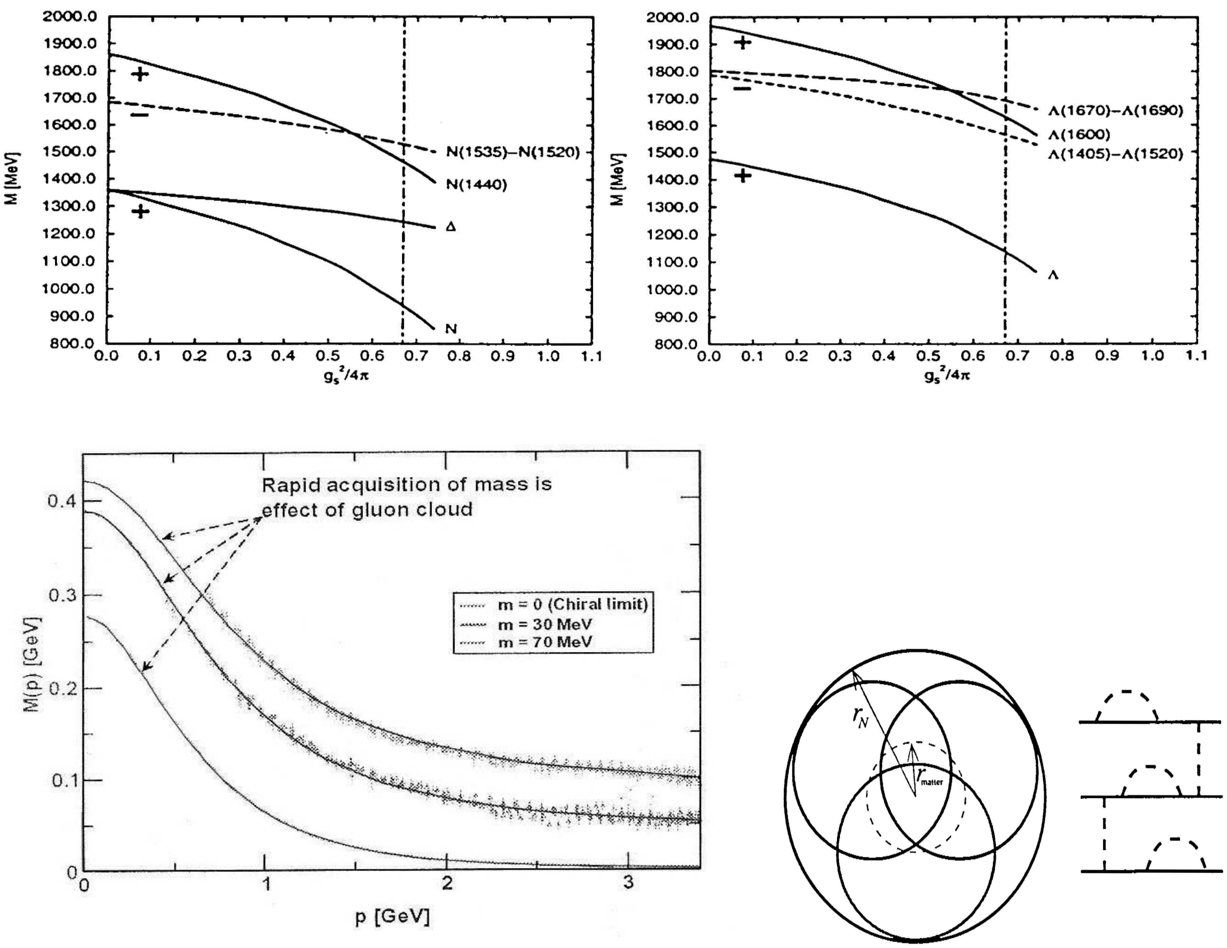


Fig.2. (*Top:*) Calculation of nonstrange baryon and Λ-hyperon masses as a function of interaction strength within Goldstone Boson Exchange Constituent Quark Model; the initial baryon mass 1350 MeV=3×450 MeV=3M_q is marked "+" on the left vertical axis [44].
Bottom: QCD gluon-quark-dressing effect calculated with DSE [46], initial masses m_q=0 (bottom), 30 and 70 MeV (top). The quark-parton acquires a momentum-dependent mass function that at infrared momentum (p=0) is larger by two-orders-of-magnitude than the current-quark mass (several MeV) due to a cloud of gluons that closes a low-momentum quark [46].
Right: Schematic view of nucleon structure used in CQM calculations (*top*), larger radius r_N and smaller r_{matter} correspond to the nucleon size and the space of the baryon matter [44].

The observed nucleon Δ-excitation (294 MeV) is shown as a difference between the observed masses marked "Δ" and "N" on the vertical line in left picture. The initial non-strange baryon mass M_N^{init} ≈1350 MeV in calculations is marked as "+" on left axis.

The value of the quark mass which corresponds to the determined M_N^{init} can be estimated as M_q=(1/3)M_N^{init} ≈450 MeV and is close to 3ΔM_Δ=441 MeV=3×147 MeV and to the interval 441 MeV introduced in [19,20] from the equality of the differences m_Σ-m_N=m_N-m_K=m_η-m_μ=m_{Ξ^-}/3 (a result of the compensation of a mass-increase from strangeness by a mass-decrease due to quark interaction).

Recent progress in lattice-QCD calculations and application of Dyson-Schwinger Equations (DSE) [45,46] results in the understanding of the role of the gluon quark-dressing effect and interconnection between the relatively small values of initial "chiral quark masses" $m_q \approx m_\pi/2$=70 MeV and large values of constituent quark masses $M_q^\Delta \approx M_q$=441 MeV in CQM (for example, M_d=436 MeV in [47]). This quark-dressing effect as the dependence of the dressed-quark mass function M(p) is shown as a top curve in Fig. 3 for initial mass m_q=70 MeV. The mass arises from a cloud of low-momentum gluons attaching themselves to the current-quark; this dynamical chiral symmetry breaking is a non-perturbative effect that generates a quark mass from nothing (even at the limit m_q=0, bottom curve).

3 Long-range correlations in nuclear binding energies

The stable character of differences of binding energies ΔE_B in nuclei differing by α-cluster (noticed by Everling and discussed in [16]) is seen in Fig.4 where ΔE_B-distributions in Z≤26 nuclei differing by 2α- and 4α-configuration are shown. The positions of maxima at 74.6 MeV=16Δ and 147.3 MeV=32Δ are exactly rational (1:2). For the analysis of such groping effects we use here the Adjacent Interval Method (AIM) in which one fixes all stable intervals (x) in the ΔE_B spectrum and plot distributions from the fixed binding energies to all other energies ΔE_B^{AIM}. The AIM method allows an additional study of the nuclear dynamics. The discussed stable intervals in nuclear binding energies are presented in Table 1 together with particle masses and different mass intervals: the nuclear nucleon interactions are result of the spilling out of strong QCD interaction between quarks [48] and we consider all stable mass/energy intervals as the parameters of the QCD dynamics.

Using the AIM-method and x=ΔE_B=147.2 MeV=18δ=32Δ in all Z≤26 nuclei maxima were observed at ΔE_B^{AIM}=73.6 MeV=9δ=16Δ and 130.4 MeV=16δ-ε_o/2. With another x=ΔE_B=73.6 MeV a periodicity with Δ=4.6 MeV (n=6,8,10) was observed. The ΔE_B-distribution for all Z≤26 nuclei has maxima near integers n=16 and 17 of δ, while in nuclei differing by 4α the maximum coincides with 147 MeV=18δ=32Δ. The ΔE_B-distribution in Z=65-81 nuclei contains maxima at 147.1 MeV=32Δ and in all N-even nuclei – at 188.5 MeV=41Δ [49-51], intervals ΔE_B=147 MeV=18δ and 106 MeV=13δ are adjacent to each other. All data used in the described here analysis are from [52]).

Another effective method of a study the nuclear dynamics is the use of a cluster effect: stable ΔE_B=46.0 MeV (n=10 in units Δ, Fig.4 bottom left); ΔE_B=50.6 MeV (n=11), ΔE_B=41.4 MeV (n=9) were found in the independent data for heavy nuclei (correspondingly, N=50-82, N≤50. Z=79-81) differing by ^{6}He-cluster [49]. The important property of observed cluster effects seen as maxima at 147 MeV (4α) and 46 MeV (^{6}He, Fig.4-5) consists in very accurate long-range correlation of ΔE_B in some near-magic nuclei (N=82, ^{39,36}K etc.) with the integer numbers of the common parameter ε_o=2m_e which is observed independently in nuclear excitations and in ΔE_B [53,54].

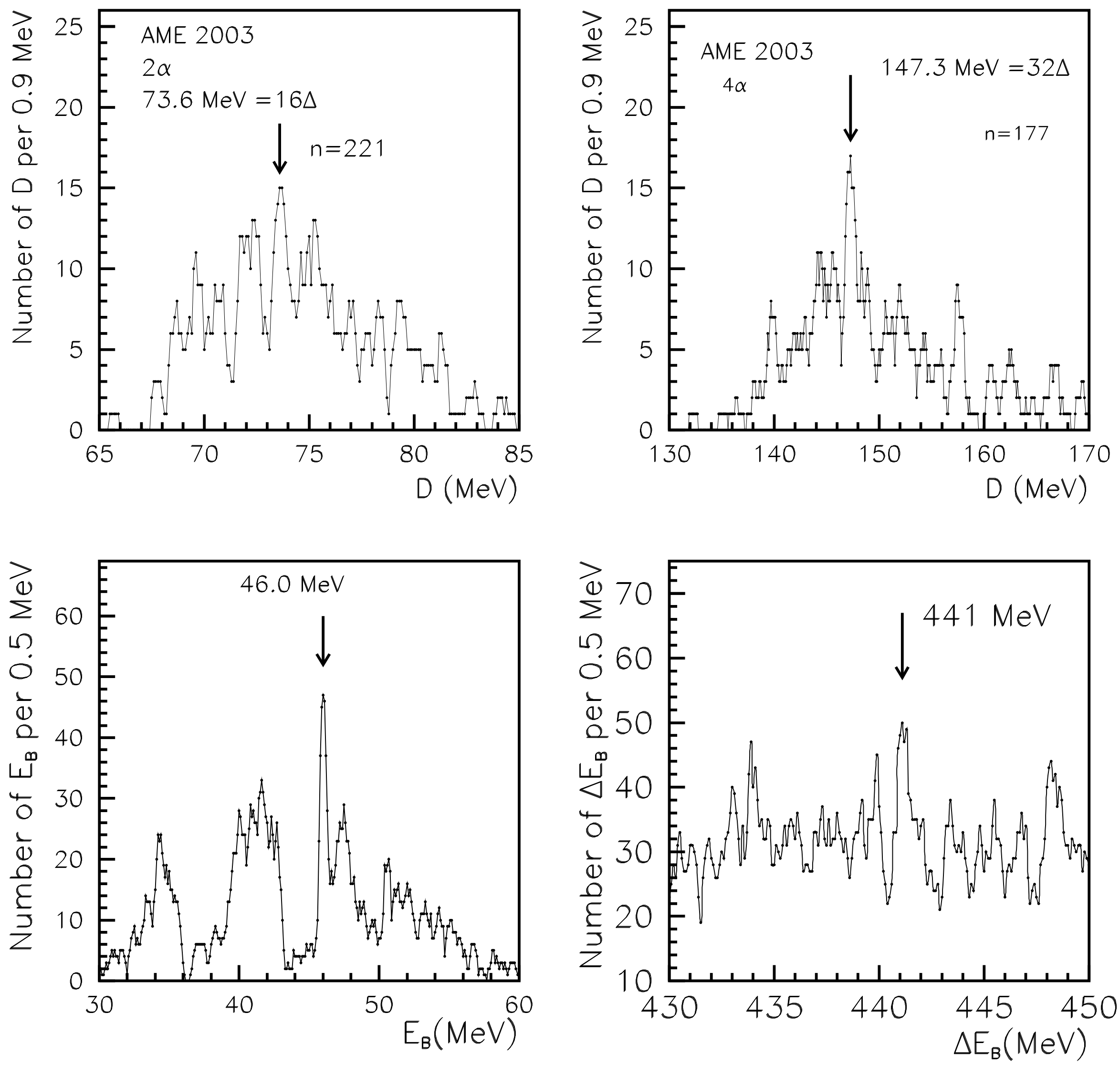


Fig.3. *Top:* ΔE_B-distribution in nuclei Z≤26 differing by two and four α-clusters: marked are ΔE_B=73.6 MeV=16Δ=9δ and 147.2 MeV=32Δ=18δ with Δ=9m_e=4.599 keV and 16m_e=δ. *Bottom:* ΔE_B-distributions in N=even=50-82 nuclei with maximum at 46.0 MeV=10Δ=45ε_o (*left*) and the same for odd-odd nuclei with maximum at 441 MeV3 $\times$ 147 MeV=3$\times$18δ.

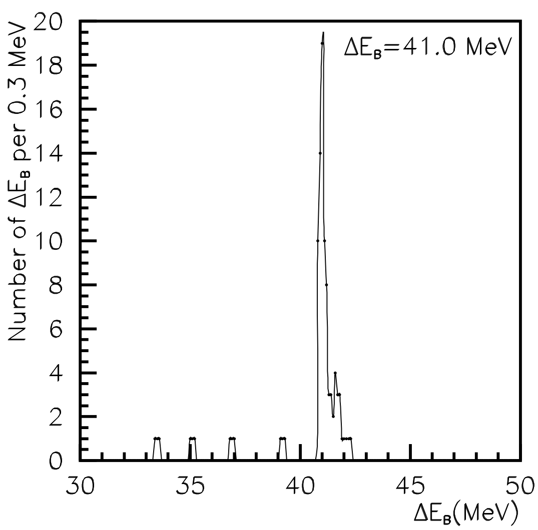
The long-range correlation effect under discussion is absent in calculations of ΔE_B with all existing models (Table 3 for Finite Range Droplet Model). New compilation of experimental and theoretical E_B-values [55] was used also for an additional study of such correlations [54].

Stable intervals ΔE_B=441 MeV and 409 MeV were observed in all odd-odd and even-even nuclei (Fig.4, bottom right). Coinciding values of two stable intervals 147.1-147.2 MeV=32Δ are close to (1/3)$\times$441 MeV. The ratio 2 : (32·27) between ε_o=1.022 keV and 3$\times$147.2 MeV=441.5 MeV in binding energies is similar to the ratio between 2m_e and the Sternheimer/Kropotkin parameter M_q=3ΔM_Δ=441 MeV in particle masses.

Nuclear collective shell effects are based on the saturation properties of nucleon interaction reflected in a nearly constant mean nucleon binding energy ≈8 MeV. The tuning effect in ΔE_B seen as maxima in ΔE_Δ distributions corresponds to the influence of nucleon structure suggested by Devons [56] and additional to smooth dependencies described

Table 2: Comparison of experimental ΔE_B (in keV) and theoretical estimates in magic nuclei (N=82 and N=20) with $10\Delta=45\varepsilon_o$ (^{6}He cluster) and $32\Delta=18\delta=144\varepsilon_o$ (4α in ^{39,36}K).

	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(2)	147152
N$\times\varepsilon_o$		45990			45990			45990	147168	147168
diff.	-44	-20	28	-63	34	97	7	6	-8	-16
FRDM	46620	46340	45950	46820	46970	45960	46850	47160	147450	145950
diff.	630	350	-40	830	980	-30	860	1170	282	1220



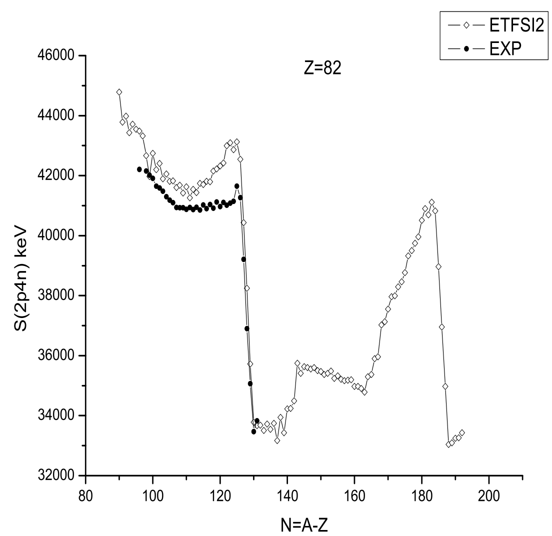


Fig.4. *Top:* ΔE_B-distribution connected with difference ΔZ=2, ΔN = 4 in all lead isotopes with the maximum close to $40\varepsilon_o$=40.9 MeV (*left*); forming of this maximum as the result of the nearly constant value ΔE_B=S_{2p4n} in isotopes with N$\leq$126 (black circle's, stabilizing effect of the known shell N=126); results of the theoretical-model calculations with ETFSI2 model [40] do not show such constancy (open circle's).

by existing mean-field models. For example, ΔE_B distributions for nuclei N=50-82 with the maximum at 92.0 MeV (for 2^{6}He) in case of data from FRDM has the maximum at 93.0 MeV shifted by about 1 MeV (it corresponds to the mean binding energy of nucleons not the binding of valence nucleons).

The tuning effect in ΔE_Δ can be illustrated with the data for nuclei around the double magic nucleus ^{208}Pb. In Fig.4 (left) a stable character of differences ΔE_B=S_{2p4n} connected with the ^{6}He-cluster configuration is shown for all lead isotopes. A sharp maximum at ΔE_B=41.0 MeV=$40\varepsilon_o$=5δ is the result of a nearly constant value S_{2p4n}=ΔE_B in many isotopes (see the center of Fig.4 right). Such character of S_{2p4n} (black circle's) is not reproduced within existing theoretical models. An example with ETFSI – Effective Thomas-Fermi theory [55] is shown as open circle's in Fig.4 (right).

Arima [57] and A.Bohr [58] suggested a common approach to the theoretical description of nuclear binding energies and nuclear excitations. Really, tuning effects with similar parameters were noticed in both data sets: effects in excitations are considered elsewhere.

4 Long-range correlations in particle masses

Observed similarity in tuning effects in nuclear data and particle masses was considered as a result of the spilling out of QCD interaction from the nucleon bag [48] and QCD-based origin of nucleon mass [10,45-46]. Data on masses of nucleons and Δ-baryons (corresponding to the quark spin-flip effect in nonstrange baryon) continue this similarity in tuning effects: accurately known differences between corresponding masses (Table 3 bottom) are close to the parameter in binding energies ΔM_Δ=147.2(2) MeV=32Δ=18δ.

In nuclear data we observe long-range correlations with the parameter ε_o=2m_e (Table 2). Similar long-range correlations are found independently in new data for particle masses. Earlier a closeness of masses (m_i) to integers of 3m_e was found by Frosch [59] and discussed in [60-63,6-9]. Relation between experimental masses, the period 3m_e and the above discussed parameter δ=16m_e is shown in Table 3. One asterisk marks 5 particles with ratios $m_i/3m_e$ close to integers, their representation with integers of δ and 3m_e was known earlier (both representations are interconnected). Two asterisks mark 4 particles with $m_i/3m_e$ close to integers found independently in [59].

Nucleon masses themselves (m_n, m_p, boxed in Table 3) were found earlier to be shifted downwards from the integer number N=115 of the period δ=16m_e. The number N=115= =6×17+13 is in agreement with the observation by Nambu [84] that m_N=6m_π+m_μ or with the observation by Sternheimer/Wick that m_N=m_μ+M_q+M''_q (N=115=13+54+48). Observed shifts are given as the "remainders" and Comments in Table 3 (at right). In this work two observations considered earlier in [61] were checked:

1). Shifts in masses of three neutral octet baryons (m_n, m_{Σ^o}, m_{Ξ^o}, boxed in Table 3) increase with the strangeness "S" from $\approx -m_e$ up to $\approx -3m_e$ ($\approx m_e$ per ΔS=1).

2). Shifts in nucleon masses were estimated earlier as 162(1) keV and 1455(1) keV [60-63]. They were found to be in the ratio 1:8:9 with D_o=δ_N=1293.3 keV (D_o is corresponding to n=8). To estimate an additional shift of about -m_e in baryonic masses we used a picture of the superposition of constituent quarks of the baryon shown in the central part of Fig.2 (inside the radius of the matter r_{matter}). This region could be responsible for the downwards shift in nonstrange baryon mass (value of m_e per 3×M_q/3) if we use a similarity between both discussed shift-effects which take place in masses of the neutron and both neutral hyperons: each strange constituent quark M_s=m_s+M_q has a value about M_q from QCD gluon quark-dressing effect and the mass of the central part of the baryon is estimated as about M_q (3×M_q/3). Preservation of the total spin of current quarks in constituent quarks and in the nucleon as a whole are important for such consideration.

Value of the shift for the neutron mass based on recent values m_n=939.56536(8) MeV, δ_N=1293.3317(5) keV and m_e=510.998910(13) keV [2] is 161.62(8) keV. The ratio of values D_o and the shift 115×16m_e-m_e-m_n is unexpectedly close to the integer 8 within the accuracy of 4·10^{-4}, namely, we observe the ratio 1293.332/161.62(8)=8.0023(15) or 1293.332/8×161.62(8)=1.0004(2).

The discussed shift in neutron mass nδ-m_n-m_e=161.6(1) is boxed in Table 1 together with three values related to (2/3)m_t with the QED parameter for the short distance α_Z=129^{-1} [6-9]. We see a distinguished role of the pion mass (2m_q) in discussed correlations and it is in line with empirical observations of many authors about the role of the pion mass [16-18,64-66]. Confirmation of Higgs boson mass [3,4,67,68] or mass grouping in L-3 data [5] could change this still uncertain situation in heavy-mass SM-sector.

Table 3: Comparison of particle masses [2] with periods $3m_e$ [6-9,60] and $16m_e$=δ=8175.9825(2) (N – number of the period δ, m_e=510.998910(13) keV).

Part.	m_i, MeV [14]	m$_i/3m_e$	N·$16m_e$	N	m_i-N·$16m_e$	Comments
μ	105.658367(4)	68.92*	106.2878	13	-0.6294	-0.511 -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-(1.455=9/8δm_N)
n	939.5654(1)	612.89*		115	-0.6726(1)	-m_e-(0.162=1/8δm_N)
Σ^o	1192.64(2)	777.98	1193.693	146	-1.05(2)	(-0.511×2=-1.02)
Ξ^o	1314.86(20)	857.71	1316.333	161	-1.47(20)	(-0.511×3=-1.53)
ρ	775.49(34)	505.87	784.8943	96	-9.40(34)	-9.20=-2Δ
τ	1776.84(17)	1159.06	1782.36	218	-5.52(17)	
Δ^o	1233.8(2)	804.83	1234.57	151	-0.8(2)	
Δ^o – n	294.2(2)	191.9	294.3	36		$2\Delta E_B$=294.4 MeV
Δ^+ – p	293.3(5)		294.3	36		

Discussed correlations show distinguished role of both parameters m_e and δm_N=D_o which are observed independently and directly in nuclear data and in accurately known particle masses (in some cases, after QED correction). A role of parameters δ=$16m_e$ and Δ=$9m_e$ in both QCD-based effects (nucleon masses and nuclear intervals) seems to be important. They could be checked by analysis of new nuclear masses and excitations. Masses of fundamental particles are Standard Model parameters which are determined by properties of SM-condensate [69]. Relations between masses and QED parameters (including long-range correlations in masses and nuclear intervals) reflect the role of condensate.

From the relations $(1/3)m_e$=$(2/3)m_t \times (\alpha_Z/2\pi)^2$ in Table 1 we see that masses of fermions with extreme parameters are related by the second power of QED correction for short distance [21,22]. The ratio $M_q/(m_t/3)$=1/129.3(15) is close to 1/129$\approx \alpha_Z$ (with M_q=ΔE_B=441.5(2)MeV, $m_t/3$= 171.2(21)/3=57.1(7)GeV). This numerical relations is the direct result of ratios of other discussed parameters, namely, (1/129)/(1/137)=1.06 and (6π=6.28)/6=1.05. From discussed correlations in particle masses one should conclude that hadronic effects are connected with the important properties of SM-condensate. The interconnection between the observed charge quantization [2] and the observed discreteness of values which are results of QCD interaction (tuning effect in nuclear data) demand new insight into the physics of the short distance of about $1/M_Z$.

Here we started from observation that the ratio between two well known SM-parameters, μ-lepton and Z=boson masses coincides with the QED correction $\alpha/2\pi$ (Scwinger term). Analogy with the lepton relation m_μ:δm_π:m_e=(13·16-1=L):9:1 leads to corresponding intermediate member in relations among large masses (13·16-1=L):9:1=M_Z:m_b:M_q where

m_b about $9M_q$=3.96 GeV is close to mass of bottom quark m_b=4.20+0.17-0.07 GeV [2,1].

The mass of tau-lepton is close to twice the vector K-meson mass which according to Sternheimer [19] can be expressed as $m_{K^*}=m_\omega+m_\mu$. Mass values m_τ=1774.00 and $2m_\omega+2m_\mu$=1774 are very close to each other and to the N×3m_e [59] (Table 3 [1-3,6]).

5 General remarks and conclusions

Suggested by Nambu approach to empirical analysis of particle mass data is illustrated here with the tuning effect with long-range correlations. Involvement of QED corrections into relations between masses of leptons, top-quark and fundamental bosons suggest the fundamental origin of tuning effects in mass/energy data.

The task of this work is to show that observed properties of nuclear tuning effect especially long-range correlations in mass/energy intervals has an analogy to the observed tuning effect in particle masses including nucleon masses. Collection and combined analysis of particle properties and nuclear data is important for further SM-development where a role of electron mass and QED-corrections would be more transparent.

Confirmation of mass grouping observed in LEP could be important for consideration of relations connected with the top quark mass and will allow the search for the way to solve the problem of the unification of different interactions.

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