New Physics in the Standard Model Based on the Electron and its Symmetry

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Preface

This review contains the analysis of empirical correlations in particle masses and nuclear data (excitations and binding energies) for obtaining additional fundamental information about the parameters of the Standard Model.

The relations between the masses of the constituent quarks and the masses of the fundamental fields, as well as the role of nuclear parameters associated with the one-meson exchange dynamics are discussed.

We consider unexpectedly accurate empirical relations between nucleon masses and electron rest mass, obtained on the base of the recommended by the Commitee on Data (CODATA), named here as the CODATA relations.

Integer relations (1:13:16:17:18:54) between the general discreteness parameter $\delta = 16m_e$ =8.176 MeV (introduced empirically earlier as close to the doubled value of the pion β-decay energy, and now being confirmed from the pion parameter f_π=130.7 MeV, equal to 16δ=130.8 MeV), m_π, the muon mass, and the constituent quark mass $M_q = m_\Xi/3$=441 MeV are compared with the fundamental fields and with the number of fermions in the central field.

The unexpected exact empirical relation between the leptons $m_\tau = 2m_\mu + 2m_\omega$, where $m_\omega = 6f_\pi = 6\times16\delta = 6\times16\times16m_e$, is considered together with the the lepton ratio L=207=13×16-1 as an important feature of the particle mass problem.

We show here that the success of the Nonrelativistic Constituent Quark Model (NRCQM) mentioned by R. Feynman according to F. Close's remark in the CERN Courier review, can be associated with the unique role of the electron and the general character of symmetrization, which manifests itself in the exact ratios 1:2, 1:3 and 1:16 between the electron mass and the general discreteness parameter $\delta = 16m_e$, and other particle masses.

The main results of this work were obtained from the global analysis of all particle masses known with the accuracy about 10 MeV, and the further application of the correlation Adjacent Interval Method. These types of analysis have never been used before and allowed us to establish the distinguishing character of the relationships between the masses of leptons and other fundamental particles in the Standard Model.

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CHAPTER 1

Introduction

The Standard Model (SM) is a modern theory of all interactions (except for gravitation), with the representation [1] $SU(3)_{col} \otimes SU(2)_L \otimes U(1)_Y$, where the three components correspond, respectively, to the quantum chromodynamics (QCD), weak interaction and electrodynamics (QED).

The development of the Standard Model has been considered by many authors, including R. Feynman, who noted that the Nonrelativistic Constituent Quark Model (NRCQM) is correct as it explains so much data. It is for theorists to explain why [3]. We describe in this work results obtained and discussed in [4-12], and additionally consider the analysis of most recent data, which allows to make a definite conclusion about the direction of the Standard Model development, and the NRCQM [13,14] is one of components of this new physics. The reality of the constituent quark with the mass of about 1/3 of the baryon mass or 1/2 of the meson mass is in accordace with experimental data for masses of first multiplets of baryons and mesons, namely, $m_\Xi/3$=441 MeV and $m_\omega/2$=391 MeV (the baryon and the meson constituent quark masses, M_q and $M_q{}^\omega$, respectively).

Several empirical observations of unexpected correlations between particle masses have been made since 1952, when Y. Nambu [2] turned attention to the distingushing role of the pion mass. For example, the author has found out that:
1) the pion and muon masses are related as 17:13:1 to the doubled pion β-decay energy, which is very close to $16m_e = f_\pi/16$ (where f_π=130.7 MeV is the pion parameter), named here as the general discreteness parameter $\delta = 16m_e$=8.176 MeV:

$$\delta = 16m_e = f_\pi/16; \tag{1}$$

(the muon mass and the lepton ratio m_μ/m_e=206.768, close to $L = 16 \times 13 - 1$=207, were considered in the literature as very importat parameters);
2) there are the exact relations between the masses of nucleons and the electron mass named here the "CODATA relations":

$$m_n = 115 \cdot 16m_e - m_e - \delta m_N/8; \quad m_p = 115 \cdot 16m_e - m_e - 9\delta m_N/8; \tag{2}$$

from these relations follows that the role of the physical condensate [15,16] and the QED correction (scaling factor) $\alpha/2\pi$, close to 1/(32 $\times$ 27) is important;
3) the recently determined mass of the third lepton m_τ=1776.86(12) MeV [1] concides with the doubled sum of masses of the muon and ω-meson ($m_\omega = 6f_\pi$) 1776.62(24) MeV:

$$m_\tau = 2m_\mu + 2m_\omega. \tag{3}$$

These three important observations provide interconnection between the main SM parameter related to QED (lepton masses, QED correction (scaling factor) $\alpha/2\pi$, the role of fundamental fields) and the main hadronic parameters (meson and baryon masses, constituent quarks, QCD parameters).

The empirical correlations in nuclear data were studied for a long time. The distinguishing character of stable nuclear intervals coinciding with or related to the nucleon mass splitting δm_N=1293 keV and the electron mass m_e=511 keV [4-12] was noted, and this was named the tuning effect. Then, when particle masses were precisely measured, the observation in the particle mass spectrum of the same stable nuclear intervals became the starting point for combined analysis of the particle masses and nuclear data. This recently performed combined analysis has confirmed the main statements of the Standard Model and can be considered as a basis for an empirical approach to its development. An appropriate slogan for this approach is the "data-driven science" [17-21].

An example of empirical correlations is given in Fig. 1, where the distribution of values $\Delta M = m_i - m_j$ between all particle masses [1] (PDG-2020 and 2021 update) is presented as an ideohistogram in the region of 0–4600 MeV with an averaging interval Δ=5 MeV. Maxima at 16 MeV=2$\delta = 2 \cdot 16m_e$, 49 MeV=6$\delta = 6 \cdot 16m_e$, 104 MeV (close to the muon mass m_μ=105.7 MeV)=13$\delta = 13 \cdot 16m_e$, 780 MeV (close to the omega meson mass m_ω=782 MeV)=6 $\cdot\, 16\delta = 6 \cdot 16 \cdot 16m_e = 6f_\pi$, where f_π=130.7 MeV is the pion parameter; 447 MeV$\approx$

M_q=441 MeV, 3504 MeV=8$M_q = \delta^\circ/2$ ($\delta^\circ = \delta \cdot \alpha/2\pi^{-1}$), 3962 MeV and 4427 MeV, close to integers k=1, 8, 9 and 10 of the constitutnt quark mass M_q=441 MeV=m_Ξ/3.

R. Feynman mentioned [15] that there is no theory which explains masses of the particles, and calculation of their values is similar to that for the magnetic moment of the electron.

V. Belokurov and D. Shirkov noted [16] that due to vacuum polarization effects the electron magnetic moment μ, the Bohr magneton $\mu_0 = e\hbar/2mc$, has an additional contribution called the anomalous magnetic moment.

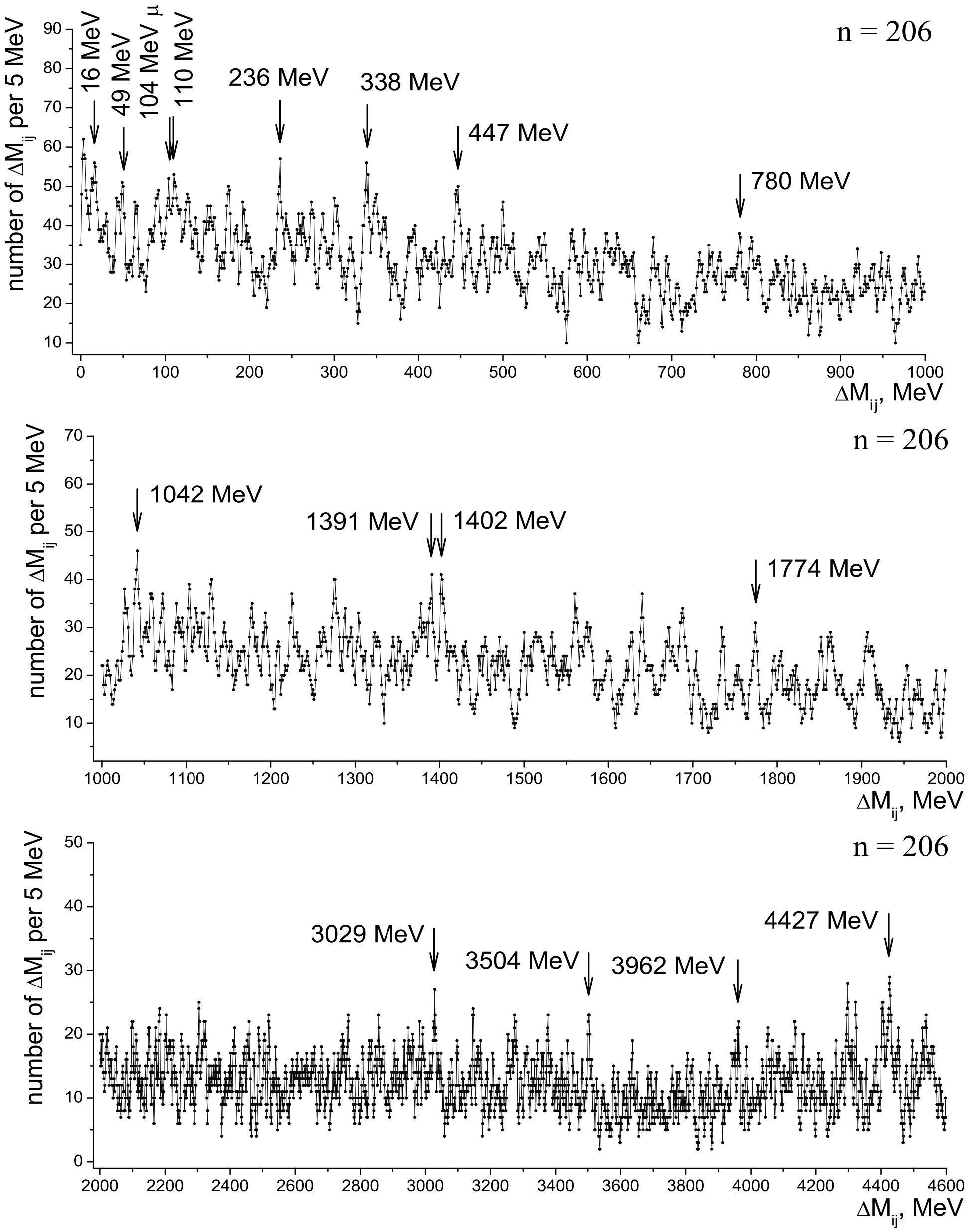

Fig. 1. ΔM distribution of all differences between particle masses from PDG-2020 [1] and 2021 update in the region 0–4600 MeV, averaging interval 5 MeV. Maxima at 16 MeV= 2δ, 49 MeV=6δ, 104 MeV (close to the muon mass m_μ=105.7 MeV)=13δ $= 13 \cdot 16 m_e$, 447 MeV$\approx$ M_q, 780 MeV=m_ω, 1042 MeV=8f_π, 1391-1402 MeV=10m_π and 1774 MeV$\approx$ m_τ. Intervals 3504 MeV$\approx 8M_q = \delta^\circ/2$, 3962 MeV$\approx 9M_q$ and 4427 MeV$\approx 10M_q$ are considered in text.

The correction to μ was calculated in 1948 by J. Schwinger and is $\delta\mu = (\alpha/2\pi)\mu_0 \approx 0.00116\mu_0$. Due to the small value of the electron mass (because of the lack of strong interaction) and R. Feynman's remark about the analogy between the corrections for the magnetic moment and electron mass [15], one can expect that the component close to the QED correction $\alpha/2\pi$ is contained in the electron mass itself.

The electron mass m_e=511 keV, the nucleon mass splitting δm_N, the integer values of m_e and the components $\alpha/2\pi$ in these values are the basic parameters of the tuning effect (presence of integer relations in particle masses and stable mass/energy intervals in nuclear data with the m_e and the general discreteness parameter $\delta = 16m_e$) considered here [4-12,17-20]. In Table 1, the value of this correction to the magnetic moment (top line) is presented together with other empirical ratios with similar values and values mentioned in the literature [21,23,24].

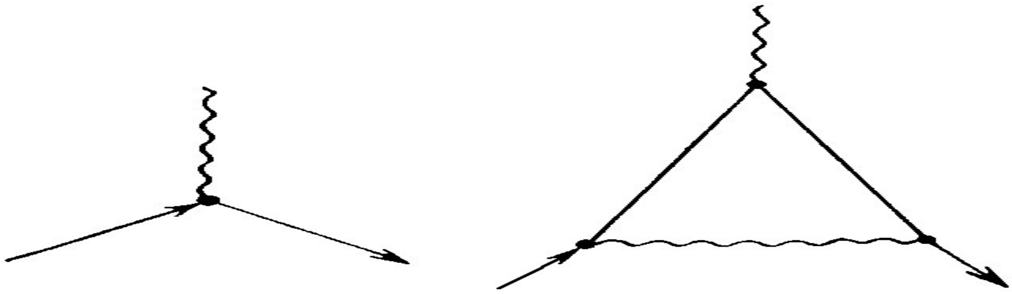

Fig. 2. Feynman diagrams contributing to the electron magnetic moment.
Left: the Bohr magneton.
Right: The one-loop correction by Schwinger $\alpha/2\pi = 116 \cdot 10^{-5}$ [16].

In a "data-driven science" approach to SM development, we begin a discussion of the tuning effect, introduced in [21] on the basis of the above mentioned three observations considered here in more detail. The pion mass splitting δm_π=4593.6(5) keV is close to $9m_e$=4599.0 keV [21] and to the d-quark mass m_d=4.78(9) MeV. Therefore, the doubled value of the pion β-decay energy $2\delta m_\pi - 2m_e$=8165.2(10) keV is close to δ=16m_e (line No. 1 in Table 1). The value $2\delta m_\pi - 2m_e$=8.1652(10) MeV deviates from 16m_e by 10.8(1.0) keV, or by a factor (ratio) 132(12)$\cdot 10^{-5}$ close to $\alpha/2\pi$=116$\cdot 10^{-5}$ [21]. The empirical factor 1/32 $\times$ 27 is given in the bootom line.

The empirical relations found by Y. Nambu ($m_N = m_\mu + 6m_\pi$) and A. Hautot [25,26] (m_π/m_μ = 17/13) allow one to introduce ($m_\pi + m_\mu$)/(17+13)=8174 keV, the same period close to δ=8176 keV [21]. The masses ΔM_Δ=147 MeV=($m_\Delta - m_N$)/2, m_μ, m_π, m_N and f_π=130.7 MeV are close to N$\cdot\delta$ (with N=13, 17, 115, 16 and 18), where N is the number of the genaral discreteness parameter $\delta = 16m_e$. We also take into account relations found by G. Wick, R. Sternhaimer and P. Kropotkin [27-29], where the stable intervals derived as halves of the vector meson masses coincided with the values $m_K - m_\mu = 48\delta = M_q^\omega$=392 MeV and $m_\eta - m_\mu = M_q$=441 MeV, that is, the intervals between the muon and hadrons (see below).

The reasons for the appearance of the second lepton in the particle mass spectrum have been discussed by many authors, see the famous question of I.I. Rabi "Who ordered all of that?" (S.F. King, CERN Courier. 2020. V. 60. No 1. P. 23). We consider the appearance of the second lepton due to the mechanism of formation of a hole in the $1p_{1/2}$ subshell. Symmetry motivated electron-based approach used here explains the appearance of the number 13 in the lepton ratio L, as well as in nuclear data. It was noted in [21] that the deviations of the ratio m_μ/m_e from the integer value $L = 207 = 13 \times 16 - 1$ is close to the QED correction, namely, the difference between the value L$\cdot m_e$=105.7767729 MeV and the muon mass m_μ=105.6583755 MeV [30] is 0.1189014 MeV. This is the ratio $112.5 \cdot 10^{-5}$ with m_μ, which is close to $\alpha/2\pi$ (the 3-rd line in Table 1). The recent value of the accurately known mass of the third lepton m_τ=1776.8(1) MeV coincides (3) with the doubled value of the sum of the muon and ω-meson masses (1777.0 MeV). These relations in lepton masses are the first evidence of the distinguishing role of lepton masses in the particle mass spectrum. We show that lepton masses obey very simple symmetry motivated relations (between themselves, L=$16 \cdot 13 - 1$), which is a continuation of the principal 1:16 relation between m_e and the general discreteness parameter δ, clearly seen in the spacing distribution in the particle masses (Fig. 1). The same 1:16 ratio exists between δ and the pion parameter $f_\pi = 16\delta$=130.7 MeV, which is 1/6 of m_ω (the parameter $m_\omega/2$=391 MeV was used by G. Wick).

Concerning the scaling factor $\alpha/2\pi = 115.9 \cdot 10^{-5}$ it was recently found that the neutron mass shift δm_n=161 keV relative to the integer number of the electron mass [1,22] coincides with the tensor forces parameter Δ^{TF}=161 keV, found in the excitations of nuclei, where the one-meson exchange dynamics dominates [31,32], and the ratio of this shift δm_n=Δ^{TF} to the pion mass $\delta m_n/m_\pi = 115.86 \cdot 10^{-5}$ is close to QED correction (Table 1, 2nd line).

Table 1. Comparison of the parameter $\alpha/2\pi$=116$\cdot10^{-5}$ with the anomalous magnetic moment of the electron $\Delta\mu_e/\mu_e$ (top line), the parameter of parity nonconservation η_{+-}/2 (observation by J. Bernstein [23], second line) and with ratios between the mass/energy values considered in the text (lines No. 1-14, 3 important relations are boxed, see also [24]).

No.	Parameter	Components of the ratio	Value $\times10^5$
	$\Delta\mu_e/\mu_e$	=$\alpha/2\pi$-0.328 α^2/π^2	115.965
	η_{+-}/2	2.232(11)$\times10^{-3}$/2 [22,23]	112(1)
1	$\delta(\delta m_\pi)$/9m_e	(Δ-4593,66(48) keV)/(9m_e=Δ)	116(10)
2	$\delta m_n/m_\pi$	(k$\times m_e$-m_n)/m_π=161.649 keV/m_π	115.86
3	$\delta m_\mu/m_\mu$	(23$\times$9m_e-m_μ)/m_μ	112.1
4	m_μ/M_Z	m_μ/M_Z=91161(31) MeV	115.90(4)
5	$\varepsilon''/\varepsilon'$	1.35(2) eV/1.16(1) keV	116(3)
6	$\varepsilon'/\varepsilon_o$	1.16(1) keV/ε_o=1022 keV	114(1)
7	ε_o/2M_q	ε_o/3(m_Δ-m_N)	116.02
8	D(187 eV)/161 keV	(375 eV/2=187 eV)/161 keV	117
9	(ΔM_Δ=m_s)/M_{H°	147 MeV/125 GeV	118
10	m_d/m_b, [1]	m_d=4.78(9) MeV/ m_b=4.18(3) GeV	114
11	Sb, D(187 eV)/161 keV	(373 eV/2=187 eV)/160 keV,	114
12	Pd, D(1497 eV)/1293 keV		115.7
13	Hf, D(1501 eV)/δm_N	^{172,176}Hf $E^*(0^+)$=1293 keV=δm_N	116.1
14	Os, D(1198 eV)/2m_e	^{178,180}Os $E^*(0^+)$=1023 keV=2m_e	117
15	Pu, D(99 eV)/2$E^*(2^+)$	^{even}Pu $E^*(2^+)$=42.5 keV=$m_e/6$	116.2
16	1/32$\times$27		115.7

So, the proximity of the sum of the masses of the muon and pion to (30=13+17)δ is a systematic effect. The value $\alpha/2\pi = 115.9\cdot10^{-5}$ is close to the empirical ratio $1/27\times32 = 115.7\cdot10^{-5}$.

Discreteness observed in spacing distributions of neutron and proton resonances, namely, the superfine structure with a period ε''=1.35 eV=5.5 eV/4 (Fig. 3) and the fine structure with a period ε'=1.2 keV (Fig. 4) were expressed in [21] as different powers of the QED radiative correction to the constituent quark mass in the NRCQM [28,29] M_q=(3/2)ΔM_Δ=441 MeV, which was introduced empirically by R. Sternheimer and P. Kropotkin from the proximity of several independent intervals in particle masses [21,24,25]. Excitations of some near-magic nuclei (^{10}B, ^{16}O, ^{18}Ne, ^{208,209}Pb) and stable intervals in nuclear binding energies (Fig. 5) multiple of $\varepsilon_\circ = 2m_e$=1022 keV are the base of this discreteness. Ratios close to $\alpha/2\pi$, namely, $\varepsilon''/\varepsilon'$, $\varepsilon'/\varepsilon_\circ$ and $\varepsilon_\circ/2M_q$ are given in Table 1 (lines 5, 6, 7).

The collection and analysis of nuclear data at ITEP and then at PNPI [33] resulted in the establishment of two systems of stable nuclear intervals associated with the nucleon mass splitting δm_N=1293 keV and the electron mass m_e=511 keV with a scaling factor $\alpha/2\pi = 115.95\cdot10^{-5}$, known as the QED correction to the magnetic moment of the electron, which is now indirectly confirmed by the same ratio of the two principal SM parameters $m_\mu/M_Z = 115.87\cdot10^{-5}$.

CHAPTER 2

Historical background

In some papers [21] attention was drawn to the structure in the spacing between neutron levels D_{ij} for some N-odd (compound) heavy nuclei. If single particle or to be more precise few-particle effects play any role in the complex spectra of levels in heavy nuclei they will first of all manifest itself in N-odd compound nuclei. These systems are thought as N-even excited core plus neutron. If the structure in D_{ij} is due to anomalously strong statistical fluctuations then, these data taken together for the large number of nuclei, will give smooth distributions. But it doesn't happen, and distinguishing effect in D_{ij} near 5.5 eV maintains even in cases in levels with relatively broad neutron widths which, as one would expect, correspond to larger contribution of single particle configurations. The first indication of the so-called nonstatistical effects in neutron resonance positions was obtained during the heavy elements neutron cross-section measurements on the time-of-flight neutron spectrometer at the ITEP cyclotron [7,8,21]. The distinguishing effect of the interval 5.5 eV has also been confirmed by the analysis of the summary data on positions (E_o) of neutron resonances (distances from levels to the binding energies of neutron).

A large amount of information on neutron resonances of heavy nuclei with Z=90-96 allows us to perform the analysis of the levels positions and spacings to check the distinguishing character of the superfine structure parameter.

There is a system of stable energy intervals that are multiples of each other. The superfine structure parameter ε''=1.34 eV was found in spacing distribution of neutron resonances of compound nucleus ^{238}Np: maximum at 1.1 eV. This value is close to the position of the first strong resonance at E_n=1.321 eV in this nucleus. The next strong resonance at E_n=5.777 eV is four times larger than the position of the first strong resonance and is close to the parameter 5.5 eV observed in N-even target nuclei of U: 5.98 eV ^{232}U, 5.1570 eV ^{234}U, 5.45 eV ^{236}U. The same situation as in the compound nucleus ^{238}Np is noticed in the compound nucleus ^{234}Pa: 1.341 eV and 5.152 eV. The positions of the first strong resonances in compound nuclei ^{242}Pu and ^{242}Am are 5.813 eV and 5.415 eV, respectively, close to the parameter 5.5 eV$\approx 4\times\varepsilon''$.

The intervals 5.5 eV=4ε'' and ε', as well as intervals that are multiples of them, were found in many heavy nuclei as maxima in positions and spacings distributions of neutron resonances. M. Ohkubo and K. Ideno noticed the intervals 5.5 eV and 11 eV×13=143 eV in Sb and in As in 1971.

Table 2. SM parameters and NRCQM parameters, which are in ratios close to $\alpha/2\pi$ (marked with 1-4 asterisks), and comparison of their values with 9m$_e$ (boxed) and 9m$_{\pi^\pm}$ (double-boxed). The proximity of m$_d$ to 9m$_e$ and m$_c$ to 9m$_{\pi^\pm}$ is discussed in the text.

Name	Particle, mass	Particle, mass	Particle, mass
Scalar field	H^0, 125.7(4) GeV****		
Vector field	γ, 0		Z, 91.1876(21) GeV*
NRCQM	ΔM_Δ=147 MeV****		W, 80.385(15) GeV
NRCQM	$M_q = 3\Delta M_\Delta$=441 MeV**		
NRCQM	$M_q^\omega = 3f_\pi$=391 MeV		
Gravitation, J=2	$< 6\times10^{-32}$ eV		
Leptons, Q=0	ν_e $<$2 eV	ν_μ	ν_τ
Leptons, Q=1	e, 0.510999 MeV**	μ, 105.6584 MeV*	τ, 1776.82(16) MeV
Quarks, Q=-1/3	d, 4.78(9) MeV***	s, 95(5) MeV	b, 4.18(3) GeV***
Quarks, Q=+2/3	u, 2.2(5) MeV	c, 1.275(25) GeV	t, 173.21(90) GeV
Comparison with	9m$_e$=4.599 MeV	9m$_\pi$=1255 MeV	9M$_q$=3969 MeV

The parameter $\alpha/2\pi = 115.9\cdot10^{-5}$ is in the relation (4) with the parameters of superfine and fine structures in the positions of neutron resonances ε'' =1.34 eV and ε'=1.2 keV, with M_q, M_Z (91 GeV) and the scalar boson mass M_{H°=125 GeV:

$$\alpha/2\pi = \varepsilon'' : \varepsilon' = \varepsilon' : 2m_e = m_e : M_q = m_\mu : M_Z = M_q : 3M_{H^\circ}. \quad (4)$$

The important role of both parameters NRCQM $M_q = 3 \times 18\delta$ and $M_q^\omega = 3 \times 16\delta$ (presented in the second column of Table 2) is seen from the empirical relations, starting from the proximity to $\alpha/2\pi$ of the ratio of the parameter NRCQM ΔM_Δ=147 MeV to the mass of the scalar field M_{H°=125 GeV (2-nd column in Table 2, line 9 in Table 1). NRCQM provides very accurate (within about 15 MeV) calculations of the baryon masses. Combined with the CODATA relations (2) and the QED radiative correction confirmed by neutron resonance data (Table 1, bottom), this provides a basis for further development of theoretical models.

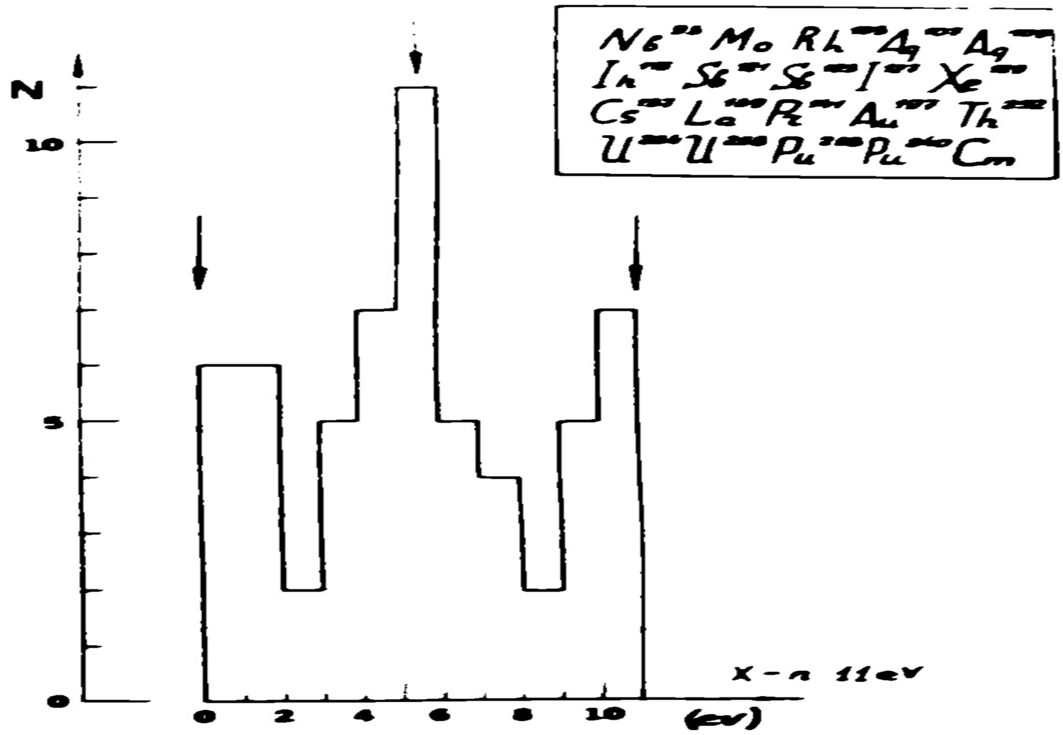

Fig. 3. Distribution of residual values after subtracting an even number of intervals 11 eV from the values of the spacings indicated between the neutron levels of many nondeformed and even-even target nuclei [21].

Discreteness in the positions and spacings of neutron resonances with a period of 5.5 eV, shown in Fig. 3, and a similar discreteness in the proton and neutron resonances of light nuclei with a period of 1.2 keV (Fig. 4), considered as effects of the second and first order from the discreteness in single-particle excitations of light and near-magic nuclei with a period of 1.022 MeV=$\varepsilon_\circ$, found, for example, in levels ^{10}B, ^{12}C, ^{16}O and neon, as well as the discreteness in nuclear binding energies (Fig. 5 [21]), were studied in this work. Dimensionless empirical relations between the above mentioned parameters $\varepsilon_\circ = 2m_e$=1.022 MeV, ε' =1.2 keV (the fine structure) and ε'' =5.5 eV/4 (the superfine structure) were considered in [21] empirically as a sequence of a similar empirical relations between the electron mass m_e and the stable interval $M_q = M_{gammon} = m_\Xi/3$=441 MeV found by R. Sternheimer [27] and P. Kropotkin [28]. Now the value of M_q is known as the mass of the baryon constituent quark in NRCQM [13,14], and the factor $\alpha/2\pi$ has been considered as possible manifestation of physical condensate. Moreover, it is shown below that the parameters NRCQM M_q and M_q^ω have a very general character, manifestating themselves in the masses of leptons and heavy quarks and being responsible for grouping effects in the total spacing distributions (Fig. 1). These parameters are given in Table 1 in lines 5-7 together with some relations found later. In the top part of Table 4, these parameters are presented as powers of the QED radiative correction, which reflects the influence of physical condensate (vacuum) [16]. In the bottom part of Table 1 and Table 4, other examples of comparison of stable nuclear intervals are presented.

Evolution of the nucleon mass from the initial value $3M_q = m_\Xi$ (N=9×18$\delta = 162\delta$, Fig. 6, top) to the deuteron

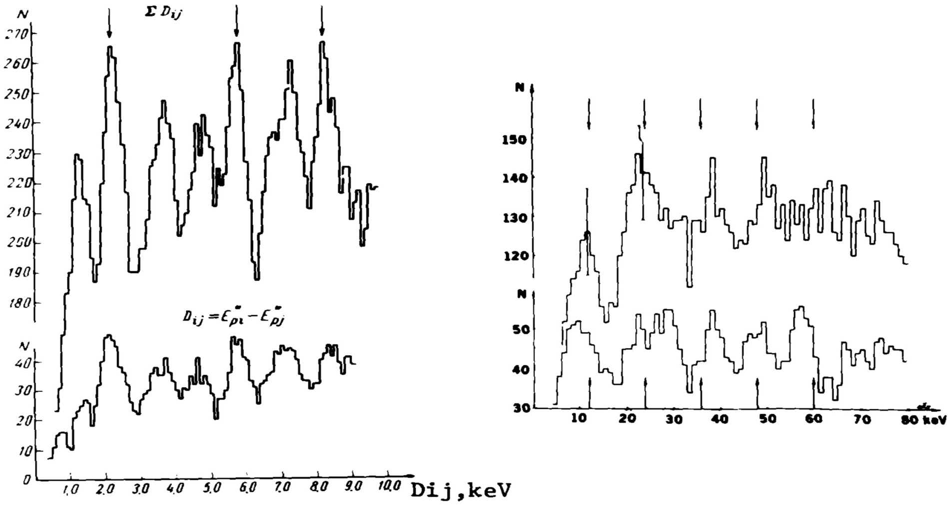

Fig. 4. *Left:* Ideohistogram of integer distribution of D_{ij} – spacing between neutron and proton resonances of light nuclei, arrows indicate the period 1.16 keV. *Right:* Ideohistogram of the distribution of the corresponding energy differences ΔE_γ of radiative transitions, arrows indicate the period 1.16 keV. Below – for ^{104}Rh [21].

mass Δ corresponding to N=151-150 in units of $\delta = 16m_e$ and the constituent quark $M'_q = 50\delta$, directly seen as equidistancy in masses of pseudoscalar mesons (shown in Fig. 6, bottom), means the transition of $\Delta M_\Delta(N = 18)$ in m_π or f_π (N=17, 16). The final stage in the nucleon mass evolution (mass of about 940 MeV-8 MeV=932 MeV) is situated close to $6f_\pi + \Delta M_\Delta$ (circled point in Fig. 6). This corresponds to the important role of the parameters f_π and $3f_\pi = M^\omega_q$ in the particle mass spectrum (N=16·16, in the central column of Table 5).

The two lightest particles, the electron and the muon, correspond to the last SM component (see the expression at the beginning of Introduction). Their masses m_μ/m_e=105.65937 MeV/510.9983 keV=206.77 are in a very accurately known ratio, which deviates slightly (difference=0.232) from the integer value L=207=13×16-1 (the lepton ratio) by a small factor 112.08·10^{-5} (ratio of the difference to L), close to the QED radiative correction $\alpha/2\pi = 115.96 \cdot 10^{-5}$ (line 3 of Table 1). The ratio of the muon mass to the important SM parameter - the vector boson mass $m_\mu/(M_Z$=91.1816(21) GeV)=$115.87 \cdot 10^{-5}$ is very close to $\alpha/2\pi$ (4th line of Table 1). The difference 1566.70 MeV between the mass of a heavy lepton m_τ=1776.82 MeV and two muon masses 210.12 MeV is close to 1569.79=4×48δ=4×392.45 MeV (or to the four constituent quarks $M''_q = m_\rho/2$=388 MeV, and the value 1565.30 - twice the value m_ω=782.65 MeV=2×391.3 MeV). These relations will be considered in the final sections together with the relations between the quark masses m_d and m_b and the proximity of the splitting of the pion mass to $9m_e$ (shown in lines 1 and 10 of Table 1). In the central part of Table 1 (line 9), the recently obtained ratio with the mass of the scalar field SM M_{H° is compared with the ratios (found in [21], lines 5-7) between different structures in nuclear excitations and in particle mass spectrum (superfine structure period ε''=1.35 eV=5.5 eV/4=$\delta''/8$=11 eV/8, fine structure period ε'=1.16 keV=$\delta'/8$=9.5 keV/8, $\varepsilon_o = 2m_e$=1.022 MeV and M_q=441 MeV=3ΔM_Δ). Additional ratios between nuclear intervals considered in this work are presented at the bottom of Table 1, lines 11-14.

Similar correlations are presented in Table 2, where values close to the QED radiative correction are marked with one, two, three and four asterisks. At the bottom of Table 2 proximities of m_d to 9m$_e$ and m$_c$ to 9m$_{\pi^\pm}$ are boxed and double-boxed.

The discreteness with the period δ=16m$_e$ and the parameter $M_q = 54\delta$ has been extended to higher energies. The ratio of the vector boson masses M$_Z$, M$_W$ to the constituent quark masses M$_q$ and M$''_q$=388 MeV=3f_π was found to be equal to the lepton ratio L=m$_\mu$/m$_e$=207. Long-range correlations in the scalar and top quark masses are considered below.

The maxima in Fig. 1 at integer values k of δ: 16 MeV (k=2), 49 MeV (k=6), 104 MeV≈ m_μ (k=13), 447 MeV, close to M$_q$=3ΔM_Δ=441 MeV (k=54), 1774 MeV=m_τ, 3029 MeV≈ $7M_q$, 3504 MeV≈ $8M_q$, 3962 MeV=9M$_q$ and 4427 MeV=10M$_q$ mean the existence of long-range correlations with the parameter M_q (see Table 2).

The position of the nucleon mass in nuclear medium, m_N^{nucl} ≈932 MeV=6$f_\pi + \Delta M_\Delta$ among other stable mass intervals ($m_\mu, f_\pi, m_\pi, \Delta M_\Delta$ under discussion) in Figs. 1 and 6 is part of the evolution of the nucleon mass from $3M_q$=m_Ξ to m_N. This evolution is shown in Fig. 6 in two-dimensional mass representation with a period of 16δ=f_π, close to (1/3)M_q''=(1/6)m_ρ along the horizontal axis and the period δ along the vertical axis. Within the discreteness n(δ), the value of M_q corresponds to N=54, the nucleon mass in free space corresponds to N=115, and the nucleon mass in nuclear media corresponds to N=115-1=114=96+18 (the circled point at 6f_π + ΔM_Δ in Fig. 6).

We see that the tuning effect, found earlier [21] in the lepton masses is confirmed by the analysis of the other particle masses.

The combined analysis of nuclear data and particle masses (see below) not only confirms the empirical connections between leptons (m_e, m_μ) and quarks (m_d, m_c, m_b, m_t), but also demonstrates the distinguishing role of QED radiative correction associated with the properties of physical condensate. The constituent quark masses M_q and M_q^ω, related (as 3:1) to the pion parameters f_π, m_π and ΔM_Δ, take part in the relations between the mass of the scalar field M_{H^0}=125 GeV and the electron mass $m_e = 3{\times}170$ keV.

In Fig. 6 it is shown that the nucleon mass is the result of the evolution of the baryon mass consistent with the discreteness (tuning effect) observed in other particles (m_μ, $m_{\pi^\pm}$, m_c, M_q, M_q'' etc.). The appearance of traces of general discreteness in nuclear data has a natural explanation within the framework of QED–QCD dynamics. The appearance of such a correction indicates the important role of the reaction of a physical condensate on the presence of a particle.

Nucleons and the electron are stable particles that determine the visible mass of the universe. They are in a ratio that is very accurately estimated in the CODATA review as m_n/m_e=1838.6836605(11) [1,22]. The electron-based SM development considered here is derived from the fact that the exactly known shift of the neutron mass from 115·16m_e - m_e is δm_n = 161.6491(6) keV, which is equal to 1/8 of the nucleon mass splitting δm_N=1293.3322(4) keV. The unexpectedly exact ratio δm_N : δm_n = 8.00086(3)≈8×1.0001(1) allows the representation (2).

Y. Nambu noted [2] that in the case of new phenomena first one should collect the data and find some empirical correlations in them. After that, build a model, and then a theory, and the Standard Model is such a theory (however, there are too many input parameters, especially concerning the masses, which are not explained).

Several recent observations are noted. Masses of all particles form correlations in the mass spectrum with a general discreteness parameter 8.176 MeV = δ = 16m_e. The shift δ_n = 161.6491(6) keV coincides with the parameter of the tensor forces ΔTF = 161 keV, found in nuclei where one- pion exchange dynamics dominates (^{18}F, ^{55}Co, ^{124}Sb, Table 3, top, Figs. 7-10), and with radiative correction $\alpha/2\pi$ to m_π. Similar fine structure interval in CODATA relations (170 keV=m_e/3) connected with a shift in nucleon masses equal to the electron mass and corresponding to a shift in the mass of each of constituent quarks that form nucleons, is observed in many near-magic nuclei (Table 1, bottom, Fig. 10).

In Figures 10 and 11, the maxima in sum distribution of nuclear excitations coinciding with the doubled value of nucleon mass splitting 1293 keV δm_N: 2594 keV≈2δm_N=2586 keV (equal to 16 intervals of 161 keV), and the parameter ε_o=1022 keV=2m_e (equal to 6 intervals of 170 keV) are marked with arrows and indicate integers of the fine structure period δ'= 9.5 keV derived from the discreteness parameter 16m_e and QED correction to the electron mass: $\delta \times \alpha/2\pi$=8.176 MeV$\times 115.9 \cdot 10^{-5} = \delta'$.

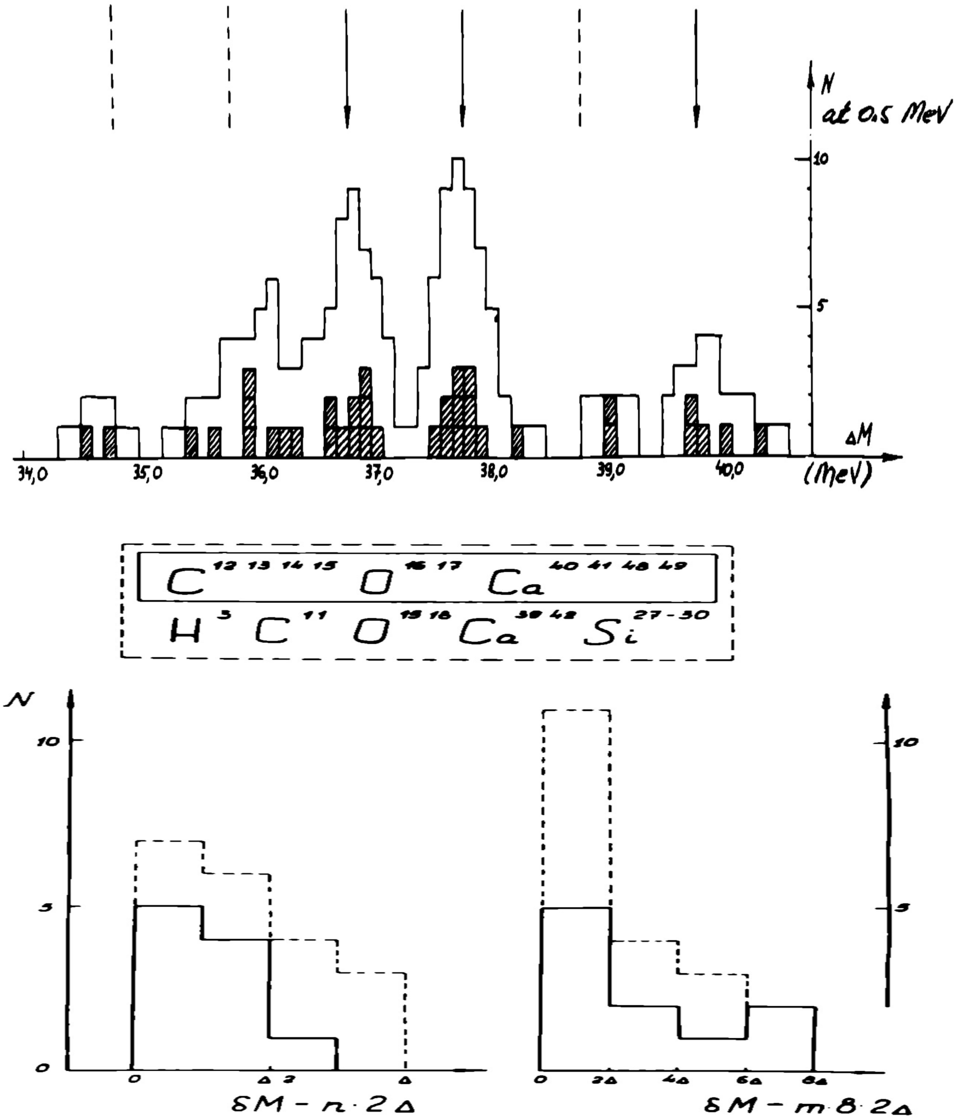

Fig. 5. *Top:* Common distribution of the relative values of the total binding energies of light nuclei and those of $1f_{7/2}$ shell, which differ by α-particle. Dark squares correspond to the values of $\Delta M^A - \Delta M^{A-4}$ themselves, the distribution corresponds to the ideohistogram with the averaging interval ± 0.25 MeV [21]. The arrows indicate the period $\varepsilon_\circ$ =1.02 MeV.
Bottom: Distribution of residuals after subtracting even numbers of the intervals $2m_e$=1022 keV (left) and $8 \times 2m_e$ (right) from the total binding energies of 10 and 20 (dotted line) light nuclei with nearly closed shell.

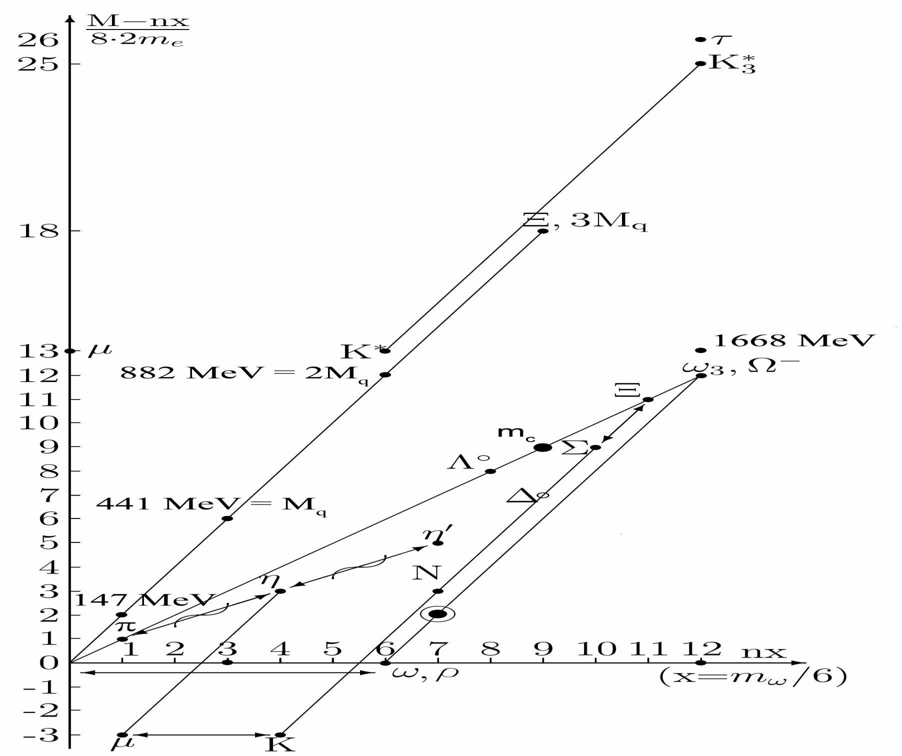

Fig. 6. The evolution of the baryon mass from $3M_q$ to the Δ-baryon and nucleon masses is shown here in a two-dimensional representation: the values on the horizontal axis are given in units of $16{\cdot}16m_e$ = f_π=130.7 MeV, the remainders M_i-n($16{\cdot}16m_e$) are along the vertical axis in $16m_e$. Lines with three different slopes correspond to the three pion parameters $f_\pi = 16\delta$, $m_{\pi^\pm} = 17\delta$ and $\Delta M_\Delta = 18\delta$. The line with m_π=140 MeV=f_π+δ (N=16+1) passes through the masses of Λ-, Ξ-, Ω-hyperons (=8m_π, 11m_π, 12m_π). The stable interval in the pseudoscalar mesons $m_{\eta'}$-m_η=m_η-$m_{\pi^\pm}$ (crossed arrows) is close to M_q^Δ=410 MeV=m$_d$/3=50δ. The nucleon mass in the nuclear medium (m_N^{nucl}, circled point) is close to the sum of ΔM_Δ+6f_π. Values $3M_q = 9\Delta M_\Delta$ and 6f_π+ΔM_Δ are the initial and final stages of the nucleon mass evolution, discussed in the text and in [9,11]. Lines with ω – and K^*-mesons correspond to stable excitations with $\Delta M = 2M_q = 6\Delta M_\Delta$ (and ΔJ=2). The mass of the charmed quark $m_c = 9m_\pi$ is marked on the line between the pion (π) and Ω^-. The mass of the τ lepton is close to $2m_\mu + 2m_\omega$.

Table 3. *Top:* Comparison of excitations (in keV) of near-magic nuclei $^{123-133}$Sb and ^{116}Sn with rational part (n) of nucleon mass splitting δm_N=1293.3 keV.
Bottom: The same for ^{101,103}Sn, ^{10}B, ^{12}C and ^{18}Ne with spin-flip effect in ^{10}B (ε_o=1022 keV=2m$_e$).

^{A}Z	^{123}Sb	^{125}Sb	^{127}Sb	^{129}Sb	^{131}Sb	^{133}Sb	^{119}Sb	^{116}Sn	^{116}Sn
J^π	5/2$^+$	5/2$^+$	5/2$^+$	5/2$^+$	5/2$^+$	5/2$^+$		N=	66
E^*	160.3(1)	332.1	491.2	645.2(1)	798.5	962.3(1)	644	1294	1292
n(δm_N)	1/8	1/4	3/8	1/2	5/8	3/4			
n$\cdot\delta m_N$	161	323	484	646	808	969	646	1293	1293
Diff.	-1	-9	+7	-1	-9	-7	-2	1	-1
D, eV		373	570						
ratio D/E^*		114$\cdot10^{-5}$	116$\cdot10^{-5}$						
^{A}Z	^{101}Sn	^{103}Sn	^{10}B		^{10}B	^{12}C	^{18}Ne		
J^π	7/2$^+$	7/2$^+$	0$^+$-1$^+$	3$^-$	2$^-$	0$^+$ (T=2)	0^+_1	0^+_2	2^+_3
E^*	171.7(6)	168.0(1)	1021.8(2)	6127.2(7)	5110.3	27595(2)	3576.2	4590(8)	5108(8)
n(ε_o)	1/3	1/3	1	6	5	27	7/2	9/2	10
n$\cdot\varepsilon_o$	170	170	1022	6132	5110	27594	3577	4599	5110
Diff.	2	2	0.2(2)	5	0.3	1(2)	1(2)	9(8)	4(8)

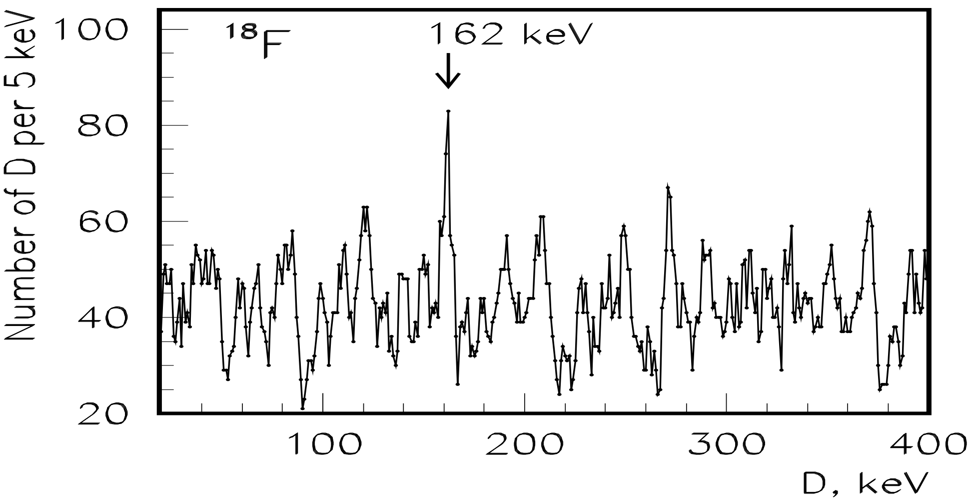

Fig. 7. Spacing distribution in levels of ^{18}F (n=372) in two different regions with maxima at 162 keV=$\delta m_N/8$.

Long before the CODATA relations were observed, the values of the mass shifts of the nucleons relative to integers m_e, namely, δm_n=161 keV and 9$\times\delta m_n$=9$\times$161 keV=(9/8)(1293 keV=δm_N)= 1454 keV together with 1293 keV were independently found.

Below we will show that the members of the system of stable energy intervals rationally connected with the nucleon mass splitting (the value of δm_N itself, the period δm_N/8=161 keV etc.) play an important role in nuclear spectroscopy. The parameter 161 keV coincides with the parameter Δ^{TF}=161 keV found in excitations of nuclei, in which (according to T. Otsuka and I. Tanihata [31,32]) the one-pion exchange dynamics is important (the second line in Table 1).

In the CODATA relations, the shift -m_e = -3$\cdot m_e$/3 can be assigned to each of the three quarks in a nucleon. In the bottom right part of Fig. 12, the scheme of a nucleon consisting of three constituent quarks overlapping within a small central region of radius r$_{matter}$ is presented, together with the radius r$_N$ of the whole nucleon structure. The central region is responsible for the presence of the baryon number (according to this schematic figure [13]).

In QCD-based calculations of nucleon masses in NRCQM [13,14] (Fig. 12, top left), the parameter $2\Delta M_\Delta =$

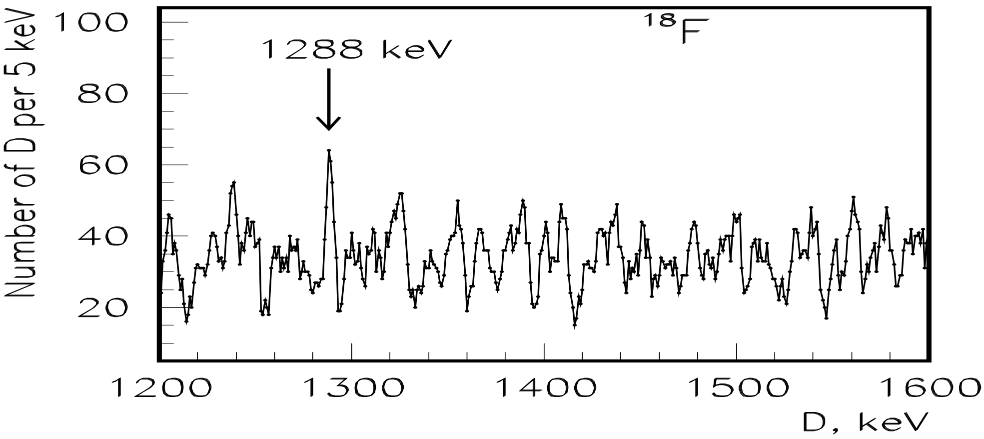

Fig. 8. Spacing distribution in levels of ^{18}F (n=372) in regions with maximum at 1288 keV=8·161 keV.

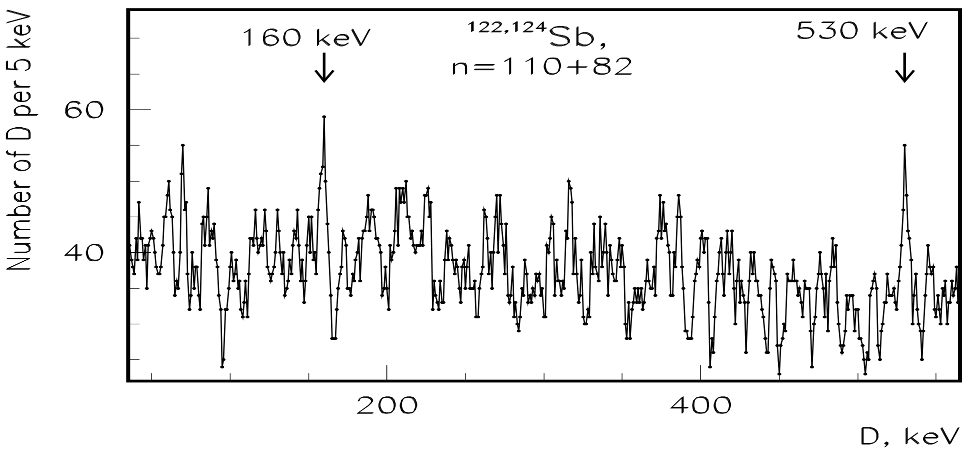

Fig. 9. Maxima in spacing distributions in ^{122,124}Sb levels.

36δ=294 MeV (the difference between Δ and N in Fig. 12, top) is used to adjust the interaction between the baryon constituent quarks (along the horizontal axis in units of $g^2/4\pi$), which, together with the initial baryon mass (marked ”+” on the left axis), allow describing all baryon masses with an accuracy of 10-15 MeV. The initial baryon mass M_N^{init}=3M_q, equal to the three constituent quark masses $3M_q$, coincides with m_Ξ (Fig. 6, top and Fig. 12, marked ”+” on the left axis). Parameters NRCQM ΔM_Δ=147 MeV, M_q=3ΔM_Δ=441 MeV and $M_q'' = m_\rho/2 \approx m_\omega/2 = M_q^\omega = 3f_\pi$=391 MeV (the meson constituent quark) are given in the 2nd section of Table 2.

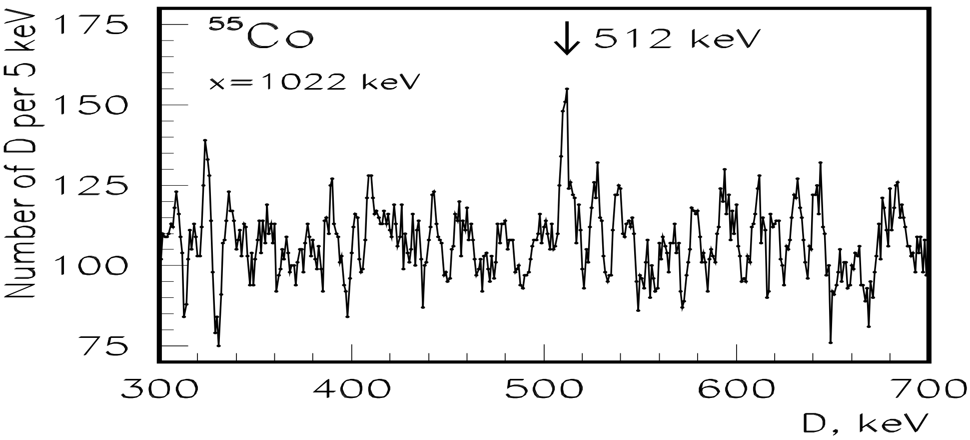

Fig. 10. Distribution in ^{55}Co of intervals in the spectrum adjacent to D=x=1022 keV with a maximum at its half value 512 keV=1002 keV/2=$\varepsilon_o/2 = m_e = 3{\cdot}170$ keV.

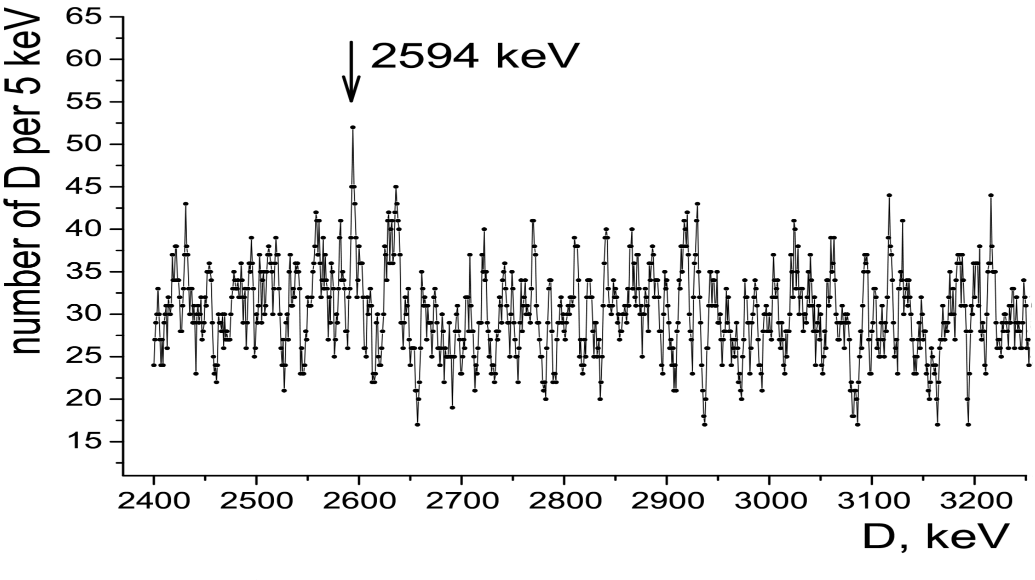

Fig. 11. D-distribution in ^{24}Na, maximum at 2594 keV≈2δm_N=2586 keV.

Table 4. Presentation of the tuning effect parameters in particle masses (3 top sections) and nuclear data (bottom) by expression n·16m$_e$$(\alpha/2\pi)^X$M with QED correction $\alpha/2\pi$ [21]. Values m$_\mu$, M_Z, m$_\pi$, M_{H°, ΔM_Δ=m_s, m$_e$/3, δm_n and parameters $\delta^\circ, \delta, \delta', \delta''$ are boxed. Stable intervals in nuclear binding energies ΔE_B (X=0, M=1) and fine structure in E* and D_{ij} (X=1-2) are considered in the text and [4-12]. Mass groupings M^{L3}=58 GeV and M'_H=115 GeV [34,35] at X=-1, M=1, 1/2 are unconfirmed.

X	M	n = 1	n = 13	n = 16	n = 17	n = 18
-1	3/2			m$_t$=173.2		
GeV	1	16M$_q$=δ°	M$_Z$=91.2	M'_H=115		M_{H°=125
	1/2	(m_b-M_q)		M^{L3}=58		
0	1	16m_e=2m_d-2m_e	m$_\mu$=106	f$_\pi$=130.7	m$_\pi$-m$_e$, Λ_{QCD}	ΔM_Δ=147
MeV	1		106=ΔE$_B$		140=ΔE$_B$	147.2=ΔE$_B$
	3	NRCQM		M"$_q$=m$_\rho$/2		M$_q$=441=ΔE$_B$
1	1	16m_e=δ=8$\varepsilon_\circ$			$k\delta$-m$_n$-m$_e$=	170 = m$_e$/3
		CODATA			=161.651(6)	
keV	8				δm_N=1293.3	
1	1	9.5=δ'=8ε'	123	152	Δ^{TF}=161	170 (Sn)
keV	2		247 (^{91}Zr)		322 (^{33}S)	340 (^{100}Mo)
	3				484 (E^*)	512 (Pd, ^{42}Ca, Co, ^{89}Y)
	4		492	606 (Te)	648 (Pd)	682 (Co)
	6		736 (^{42}Ca)			1022 (E^*, ^{38}Ar, ^{89}Y)
	8		984	1212 (Sn)	1293 (E^*, Pd)	1360 (Te)
	12		1475 (^{38}Ar)			
2	1	11=δ''=8ε''	143 (As)	176	749 (Br, Sb)	Neutron
eV	4		570 (Sb)		1500 (Sb, Pd)	resonances

The pion mass, the fine structure interval 161 keV (interconnected with $\alpha/2\pi$, Table 4, n=17, boxed) and other pairs of parameters discussed here are located one under another due to the proximity values $\alpha/2\pi = 115.9 \cdot 10^{-5}$ and 1/(27×32)=115.7·10^{-5} (X=0 and 1, other similar ratios are considered in the text).

The well-known SM parameters, namely the masses of the muon and Z-boson (boxed), are in the above mentioned ratio: m_μ/M_Z=106 MeV/91.2 GeV=115.90·10^{-5}. The proximity of $\alpha/2\pi$ to the ratio of the electron mass to the parameter NRCQM 3ΔM_Δ=M$_q$=m$_\Xi$/3 (introduced empirically by R. Sternheimer [27] and P. Kropotkin [28]), was connected [21] with the possibility of representing stable intervals of fine and superfine structures (ε'=1.2 keV and ε''=1.35 eV), observed in the analysis of spacing distributions, as the results of the first and second order effects from discreteness in single-particle energies (with a period of ε_o=2$M_q(\alpha/2\pi)$, lines 5-7 in Table 1). In the region around Z=51 (where the one-pion exchange dynamics dominates), the simultaneous appearance of stable intervals of superfine and fine structures, multiples of the periods 187 eV=17×11 eV and 161 keV, is shown in Table 1.

Progress in lattice QCD calculations and the application of the Dyson-Schwinger Equations (DSE) [36] make it possible to understand the role of the quark-gluon dressing effect and the interconnection between small values of the initial "chiral quark masses" $m_q \approx m_\pi$/2=70 MeV and large values of the constituent quark masses M_q=441 MeV in NRCQM (for example, M_d=436 MeV [14]). The quark dressing effect as a dependence of the quark mass function M(p) is shown in Fig. 12 (bottom) for the initial mass m_q=70 MeV. Mass arises from a cloud of low-momentum gluons attaching themselves to the current-quark; this dynamic chiral symmetry breaking is a non-perturbative effect that generates a quark mass from nothing (limit m_q=0, bottom curve).

The CODATA relations (2), the discreteness parameter $\delta = 16m_e$ and the exact fine structure δm_n associated with the pion mass ($(\alpha/2\pi) \times m_\pi$=161 keV) correspond to simple general aspects of the evolution of the nucleon quark structure and Λ-hyperon shown in Fig. 12. The Δ-baryon mass corresponding to the three-quark state is somewhat smaller (N$\approx$ 3×50 and 3×54) than the initial baryon mass calculations in the NRCQM. The nucleon Δ-excitation (294 MeV) is the difference between the observed masses marked "Δ" and "N" on the vertical line in the top left part of Fig. 12. The initial non-strange baryon mass M_N^{init} $\approx$1350 MeV in the calcula-

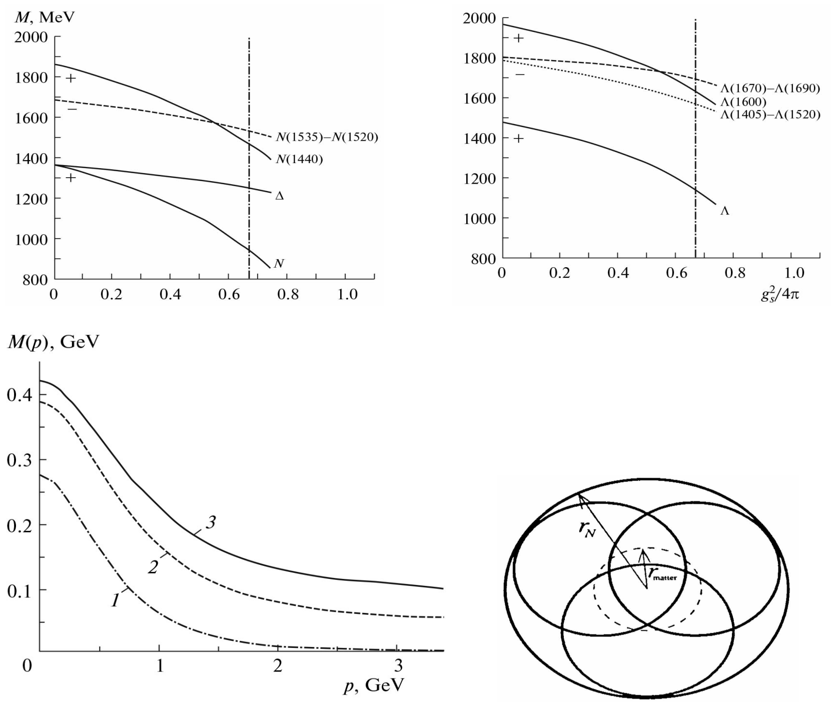

Fig. 12. *Top:* Calculation of nonstrange baryon and Λ-hyperon masses as a function of interaction strength within Goldstone Boson Exchange NRCQM Model; the initial baryon mass 1350 MeV=3×450 MeV=3M_q is marked "+" on the left vertical axis [7-9].

Bottom: QCD quark-gluon dressing effect calculated with DSE [7-9], initial masses m_q=0, 30 and 70 MeV (top). The quark-parton acquires a momentum-dependent mass function that at infrared momentum (p=0) is more by two orders of magnitude than the current quark mass (several MeV) due to the cloud of gluons that closes a low-momentum quark. *Right:* A schematic view of the nucleon structure used in NRCQM: a larger radius r_N and a smaller r_{matter} correspond to the nucleon size and the space of baryonic matter [7-9].

tions is marked with a "+" sign on the left axis. The quark mass value corresponding to a certain value of M_N^{init} can be estimated as M_q=(1/3)M_N^{init} ≈450 MeV. It is close to 3ΔM_Δ=441 MeV=3×147 MeV and to the interval 441 MeV, introduced empirically by R. Sternheimer and P. Kropotkin [27-29] from the equality of the differences m_Σ-m_N=m_N-m_K=m_η-m_μ=m_{Ξ^-}/3 (the result of compensation for the increase in mass due to strangeness by a decrease in mass due to the quark interaction).

The importance of the CODATA relations (2) consists in the empirical evidence of the exact integer ratios between the hadronic masses of nucleons and the electron mass, and in the clear separation of the two fine structure systems, each of which is associated to the QED radiative correction: the first with the interval 170 keV=m_e/3, extending to the parameter of discreteness δ=16m$_e$=2(9m$_e$-m$_e$)≈ $2(m_d - m_e)$, and the second one with the interval 161 keV=δm_N/8. These fine structures are connected by the factor $\alpha/2\pi$ with three pion parameters f_π=130.7(4) MeV [37], m$_\pi$ and ΔM_Δ, corresponding to N=16, 17 and 18 of $\delta = 16m_e$ (the muon mass corresponds to N=13).

The exact integer CODATA relations (2) considered here are based on data from a recent evaluation [30]. Only the high accuracy of the m$_n$/m$_e$ ratio allows us to make definite conclusions. After obtaining independent confirmations of the reality of long-range correlations with the value of m_e, the discreteness parameter $\delta = 16m_e$ and the period δm_N, we can expect that by using the principle of "data-driven science" the particle mass problem can be properly considered in connection with the observed integer relations in the particle masses, the fermionic nature of the electron as the main SM parameter, and the influence of physical condensate in which we live [38].

The distinguishing stability of the intervals ΔM with N=13 (m_μ) and N=18 (m_τ) in Fig. 1 is an extension of discreteness with a stable splitting 16 MeV=2δ, 49 MeV=6δ and 104 MeV=13δ. We consider here the analogy

Table 5. Comparison of the number of fermions in the central field (top line, N^{ferm}) and values $N \times m_e$ with the masses of constituent quarks (all in MeV) and the masses of particles and parameters (lines 3-6). Ratios between masses m_e/M_q, m_μ/M_Z, f_π/((2/3)$m_t = M'_H = 2M^{L3}$), where m_t, M'_H and M^{L3} - masses of the top quark and unconfirmed groupings [1,34,35] and $\Delta M_\Delta/M_{H^0}$, which are close to the QED parameter $\alpha/2\pi$, are given in lines 7-8. The mass grouping at 58 GeV=$m_t/3$ was reported by S. Ting [34]. Boxed in the bottom line are the hole configuration in $1p$ shell (configuration $1s^4_{1/2}$, $1p^8_{3/2}$, $1p_{1/2}$) and the valence fermion configuration as a fermion with the new principal quantum number over the filled shells (configuration $1s^4_{1/2}$, $1p^8_{3/2}$, $1p^4_{1/2}$).

N^{ferm}	1	16	16·13-1=L	16·16	16·17+1	16·18
N		1	13	16	17	18
1 $N^{ferm} \times m_e$		$16m_e$	$L \times m_e$	16δ	$17\delta + m_e$	18δ
2 Value		8.176	106	130	140	147
3 Const. quark				$M^\omega_q = 3f_\pi$		$M_q = 3\Delta M_\Delta$
4 Value				391		441
5 Part. mass	m_e	δ	m$_\mu$	f_π	$m_{\pi^\pm}$	ΔM_Δ
6 Value	0.511	8.176	106	130.7	140	147
7 Part./param.	m_e/M_q		m$_\mu/M_Z$	$f_\pi/2m_t$/3		$\Delta M_\Delta/M_{H^0}$
8 Ratio	115.96·10^{-5}		115.87·10^{-5}	114·10^{-5}		117·10^{-5}
9 Comments			hole in $1p$	filled shell	valence	

between the lepton ratio $L = 207 \approx (m_\mu/m_e)$ and the number of fermions in the central field N^{ferm} (boxed in the 1st line of Table 5). The lepton ratio L=m_μ/m_e=207=16×13-1 is close to the ratios of the vector boson masses to the constituent quark masses: M_Z/M_q=206.8 and M_W/M''_q=207.3 (where $M''_q = m_\rho/2$).

The particle masses (m_e, m_μ, m_π etc., in the second line of Table 5) are compared here with the configuration of fermions in the central field (in the last line). Boxed are the configuration of the hole in the 1p shell and the valence fermion configuration over filled shells 1s1p. The distinguishing character of the values N=16 can be assigned to all three parameters of the pion considered here (f_π, m_π and ΔM_Δ).

The systematic appearance of the parameter of discreteness $\delta = 16m_e$ (k=2 and 6) in Fig. 1 should be explained. For this explanation, the particle-hole plus the single particle configurations can be important.

The symmetry motivated electron-based approach to the Standard Model development considered here is illustrated mainly by the representation of well-known particles and parameters with integers N=13, 16–18 of the parameter of discreteness $\delta = 16m_e$ and m_e, namely, $m_\mu = 13 \times 16 - 1$, $f_\pi = 16 \times 16$, $m_\pi = 17 \times 16 + 1$, $\Delta M_\Delta = 18 \times 16$ (Table 5).

We draw attention to the role of empirical CODATA relations (2) in the development of the Standard Model in accordance with Y. Nambu's proposal on the use of mass/energy data. The unexpectedly accurate CODATA relations (2) with the downward shift of 170 keV=m_e/3, forming -m$_e$, and the 1:8 ratio between δm_n and δm_N: δm_n=161 keV=$\delta m_N/8 = (\alpha/2\pi)m_\pi$, indicate a fine structure with the intervals 161 keV=δm_N/8 and 170 keV=m$_e$/3. It was empirically observed that the parameter 161 keV can be considered together with the pion mass.

Grouping effects in the mass differences at the masses of the muon (N=13) and the pion, as well as the period close to the pion (N=17), have been noticed by many authors [25-29,39,40]. The empirical relations discussed here reflect the stability of the intervals connected with the pion: the pion parameters f_π, m_π and ΔM_Δ (N=16, 17 and 18). The pion parameter f_π=130.7(4) MeV is equal to the value $16\delta = 16 \times 16m_e$=130.8 MeV. We see that the pion parameter corresponding to strong interactions coincides with integer of the electron rest mass, the lepton parameter, associated with electromagnetic interactions. This means that both parts of the SM are interconnected.

There are four arguments for expanding the tuning effect based on the fine structure intervals 170 keV, 161 keV and NRCQM parameters (line X=0 and X=1 in Table 4) to higher energies, where the boson fields masses (M_{H^0}, M_Z, M_W) and heavy quarks (m_b, m_t) are located (lines with X=-1 in Table 4):

1) It was noted [17-20] that recent estimates of the down and bottom quarks masses [1] are in the ratio m_d :

m_b=4.7(5) MeV : 4.18(4) GeV = 114·10^{-5} close to $\alpha/2\pi = 115.9 \cdot 10^{-5}$ (line 10 in Table 1). The tuning effect includes exact relations with the general discreteness parameter δ=16m_e, and the analogue of this period in the high energy region is the value of $\delta^\circ = 2m_b - 2M_q$=16$M_q$=7.056 GeV. This allows us to represent both main SM parameters, namely: $M_{H^0} = 18\delta^\circ$ and $M_Z = 13\delta^\circ - M_q$ as integers M_q (columns n=1, 13, 18 with X= –1 in Table 4). The discreteness with the parameter M_q can also be noticed in the presence of maxima at 8M_q, 9M_q and 10M_q in the new results of ΔM-analysis of particle masses from PDG-2021 (see Fig. 1). The presence of the grouping effect at values that are multiples of M_q=3ΔM_Δ (k=8, 9, 10 with the period M_q) is connected with the b-quark value (m$_b \approx 9M_q$, the maximum at 3962 MeV in Fig. 1).

2) There is a 3:2:1 ratio between the masses of the top quark (m_t=173.2 GeV) and the masses of unconfirmed mass groupings observed in the L3 and ALEPH experiments at CERN (M'_H=115 GeV, M^{L3}=58 GeV) [34,35]: they correspond to the parameters in the ratio 3/2:1:1/2 in the top section of Table 4, left (n=16). The period m$_t$/3=173.2(10) GeV/3=57.8 GeV [22] is close to 8δ°=56.4 GeV. The masses of scalar and vector fields M_{H^0}=125.0 GeV, (2/3)m_t=115 GeV=M'_H (unconfirmed), M_Z and M_W are related to the NRCQM parameters M''_q=3×16δ=388 MeV close to $3f_\pi$ and M_q=3×18δ=441 MeV close to 3ΔM_Δ (Table 4, X=0, center, n=16 and 18).

3) Symmetry motivated arguments for the connection of the lepton ratio with the property of the fermionic system (Table 5) and the appearance of numbers 8–9–16 in the relations between the particle masses (and, in particular, the appearance of stable intervals/periods $\delta = 16m_e$ (the discreteness parameter) and $\delta^\circ = 16M_q$ can be considered as a reflection of the fermionic symmetries inside the QCD–based dynamics of the origin of the constituent quark masses. From the exact value of the Z-boson mass and the lepton ratio L=13·16-1, the value M^*_q=91.2 GeV/L=440.5(6) MeV can be estimated (Table 5). It is shifted from the value 3·18δ=441.5 MeV=M_q by the value 1.05 MeV, close to 2m_e=1.022 MeV.

In Table 4, integers N=1, 13, 16, 17 and 18, derived from the fine structure discreteness with the period δ'=9.5 keV and the general discreteness parameter δ=16m$_e$ used for description of the muon mass and pion parameters f$_\pi$, m$_\pi$, ΔM$_\Delta$ (n=13, 16-18) were also assigned to δ°, M$_Z$, M$'_H$=115 GeV and M$_{H^0}$=125 GeV. These relations are based on the electron mass m$_e$=δ/16.

4) The unique role of vector interactions (mentioned by R. Feynman [15]) can be considered in connection with the QED factor α_Z=1/129=1/(8×16+1) (shown in Fig. 13, Q=91 GeV [41]). For the same short distance, the QCD parameter α_s=0.1181(11) [42] coincides with 2/17=2δ/m_π=0.1176. The theoretical consideration of α_s, shown in the right part of Fig. 13 is given in [16]. The mentioned empirical ratios can be used for possible interpretation of the SM parameters discussed above.

The QED radiative correction for a short distance $\alpha_Z/2\pi = 123.4 \cdot 10^{-5}$ (Q=91 GeV, Fig. 13) was compared in [8] with $\alpha/2\pi = 115.9 \cdot 10^{-5}$ for a long distance (Q=0, the corresponding parameters α_Z=1/129 and α=1/137). For the scalar masses M$'_H$=115 GeV and M$_{H^0}$=125 GeV the first and the second order corrections were found to be 142 MeV–145 MeV (close to m$_\pi$=140 MeV and ΔM_Δ=147 MeV, respectively) and 175 keV–168 keV (close to m$_e$/3=170 keV). The universal role of the QED correction to the masses of both scalars (M$_{H^0}$ and M$'_H$), connected with the top quark mass and resonance at M^{L3}=58 GeV, is an empirical observation, as well as the expression:

$$m_e/3 = (\alpha/2\pi)(\Delta M_\Delta = M_q/3) = (\alpha/2\pi)^2 M_{H^0}\,. \qquad (5)$$

In the Standard Model, particle masses are connected with a scalar field. Here we see the interconnection between the electron mass and the scalar field with the QED correction, which corresponds to the last part of the SM presentation [1]:

$$SU(3)_{col} \otimes SU(2)_L \otimes U(1)_Y\,. \qquad (6)$$

The relations between m_e and both scalar masses are in accordance with the remark of J. Gasser and H. Leutwyler [38] that the electron mass is the result of the influence of a physical condensate.

F. Wilczek [43] turned attention to the specific value of the top quark mass as the highest value among all particles (173 GeV≈3/2M$'_H$ ≈3M^{L3}, Table 2). This is in agreement with the distinguishing character of the

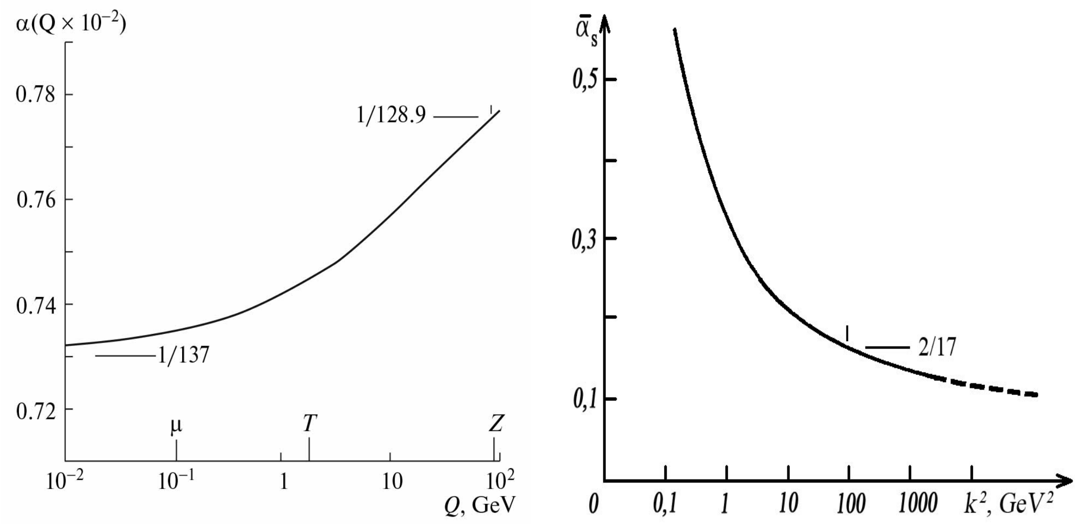

Fig. 13. *Left*: Momentum transfer evolution of QED effective electron charge squared. The monotonically rising theoretical curve is compared with precise measurements (by D. Shirkov [16,41]). *Right*: Behaviour of the effective coupling α_s in QCD as a function of the squared momentum transfer [16].

relation between the scalar field mass and the electron mass m_e. The value $M^{L3} \approx 1/3m_t = M'_H/2$ is close to the expected position of the preon relative to the scalar mass (M'_H).

The discreteness parameter $\delta = 16m_e$ is common for many different particles including leptons and hadrons; this parameter is confirmed by the analysis of data from PDG reviews. The fine structure with the values of shifts 161 keV and 8×161 keV, coinciding with the nucleon mass splitting, was observed earlier in nuclear excitations. Only recently this splitting was estimated theoretically (with a very large uncertainty), but its appearance in nuclear data was noticed long ago [21]. A similar situation exists with the interval 170 keV=m_e/3, frequently seen as an analog of the above mentioned fine structure interval 161 keV. The possibility to study this common fine structure is a unique property of nuclear and neutron resonance spectroscopy that should not be ignored. It is also necessary to take into account the analysis of the neutron resonance positions, which are differences between nuclear excitations and binding energies.

New nuclear data were considered in [4]. The relations between particle masses given in Tables 4 and 5 are based on the role of QED as an important part of the Standard Model and on the universal character of the electric charge.

The universality of vector interactions was mentioned by R. Feynman [15]. He noted that all the theories of physics are similar in their structure: they all involve the interaction of spin 1/2 objects (like electrons and quarks) with spin 1 objects (like photons, gluons, or W's).

The values of M_Z, M_W and other particle masses (Table 6) are considered together with Feynman's question about the role of vector fields.

We now will consider additional data on the fine structure in nuclear excitations discussed in [4-12]. A similar analysis of the fine structure in the nuclear binding energies was presented in [17-20]. The fine structure of scale 170 keV was considered earlier by V. Andreev [44], who drew attention to the role of a short distance (Fig. 13) in the particle mass problem. This analysis was based on a general understanding of the role of QCD as a general theory of strong interactions. In a separate section, we will show the global analysis of the particle mass spectrum from PDG-2016. The values of the initial quark masses from the PDG-2018 are given in Table 2. Stable intervals in nuclear binding energies close to the pion parameters f_π=130 MeV, m_π=140 MeV, ΔM_Δ=147 MeV and 4.6 MeV=$\Delta = 9m_e = \delta m_\pi$ indirectly confirm the tuning effect in particle masses.

Table 6. Comparison of particle masses with the general discreteness parameter (period) 16m_e=δ=8176 keV, number of periods k, comments in MeV. The constant shift Δ=9m_e, close to m_d, is boxed.

Particle	m_i, MeV	k	m_i-k·16m_e	Comments in MeV	Notation
M_W/L	388.4	3·16	$3f_\pi$	diff. ≈ -2m_e	
M_q'' NRCQM	387.7	48	m_ρ/2	-4.60 = -Δ	
ΔM	389	48			
ω	782.65(12)	96	-2.3(1)	diff ≈ -2m_e	
M_Z/L	440.5	3·18	441.5	diff. ≈ -2m_e	M_q^*
M_q NRCQM	441	3·18		ΔE_B	
M_d NRCQM	436	3·18-Δ		-5 = -Δ	
M_H/18·16	436	3·18-Δ		-5 = -Δ	
54δ	441.5	3·18			M_q
54$\delta(1-\alpha/2\pi)$	440.0	3·18			$M_q(1-\alpha/2\pi)$
p	938.2720(1)	115	-1.96660	-m_e-(9/8)δm_N	
n	939.5654(1)	115	-0.6726(1)	-m_e-(1/8)δm_N	
Σ°	1192.64(2)	146	-1.05(2)	-0.51·2=-1.02	
Ξ°	1314.86(20)	161	-1.47(20)	-0.51·3=-1.53	
Δ^o	1233.8(2)	151	-0.8(2)		

CHAPTER 3

Confirmation of the tuning effect in nuclear data

3.1. Analysis of nuclear excited states

Nucleon interactions (Fig. 14) have a long-distance part determined by the one-pion exchange dynamics, tensor forces considered in [9,31,32]).

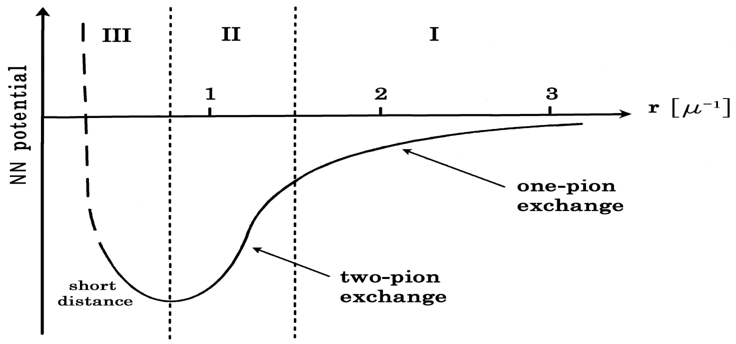

Fig. 14. Hierarchy of scales governing the NN interaction: the distance r is given in units of the pion Compton wavelength, μ^{-1} $\simeq$1.4 fm. I, II and III - different energy regions.

In Fig. 15, the manifestation of the fine structure interval 161 keV is shown as a linear dependence of the excitation energies of A-odd Sb isotopes Z=51, N=70–82, where the large neutron shell $1h_{11/2}$ is filled. The same stable interval is observed as a maximum in the sum spacing distribution of odd-odd ^{122,124}Sb nuclei (Fig. 9, 160 keV=17$\times\delta'$, 530 keV=4$\times$14δ', where δ'=9.5 keV).

In Table 3, the stable superfine structure intervals in neutron resonances of the target nuclei ^{121,123}Sb are given (D in eV, from the sum of spacing distributions in ^{125,127}Sb). The D/E^* ratios are close to $\alpha/2\pi$=116$\cdot10^{-5}$, see Table 3, central line.

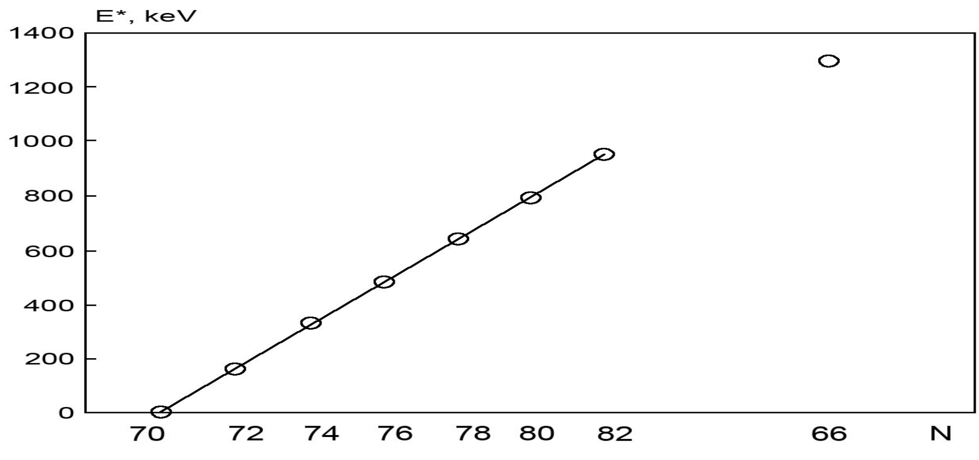

Fig. 15. Linear trend of E^* in ^{odd}Sb with a slope Δ^{TF}=161 keV=δm_N/8 (Table 3). The dot on the right (N=66) corresponds to stable E^* in ^{116}Sn (equidistant E^*, J^π=0$^+$, 2$^+$, 1$^+$, see Table 3, right, boxed).

Both fine structure parameters 161 keV=17δ' and 170 keV=18δ', observed in excitations of nuclei with valence nucleons, are represented by integers (N=17 and 18) of the period δ'=9.5 keV in Tables 3 and 7.

The results of the data analysis presented here for isotopes sequences from the different regions Z, N are arranged from lighter to heavier nuclei with increasing in the number of protons. In Figs. 16 and 17, the sum distributions of E^* of levels in all nuclei with Z$\leq$29 and in Z-odd nuclei are presented. The triplet of maxima at

Table 7. *Top*: Excitations (in keV) in Z=50, 34, 47 nuclei close to integers of $18\delta'$=m_e/3. Integers of $18\delta'$=170 keV and D in ^{85}Se and ^{98}Ag are compared in the center.
Bottom: Excitation energies of nuclei with Z=33-35, close to the parameter ε_o=1022 keV.

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
^AZ	^{74}As	^{76}As	^{73}Se	^{75}Se	^{77}Se	^{80}Br	^{80}Br	^{81}Br	^{82}Br	^{83}Br	Z=32-35	A≤150
E^*	1021	1023	1022	1020	1024	[1021.3]	[1022.4]	1024	1022	1021	1024	1022
D						1.1 keV						
Ratio						$108\cdot10^{-5}$						

1008–1142–1291 keV corresponds to the nucleon mass splitting 1293 keV=δm_N=8×161 keV, which takes part in the CODATA relations. Almost equidistant maxima correspond to the difference (134+149)/2=142 keV between the two parameters: 3×161 keV=483 keV and 2×170 keV=341 keV. For confirmation of the triplet of maxima under consideration, all recent data on the excitations of all nuclei with Z≤29 were used. It is important that the formation of a real phonon from two and three microphonons (d- and s-bosons) is a well-known dynamics.

We continue to study the fine structure effects in nuclei located in different regions of the nuclear chart to confirm (indirectly) the tuning effect in nuclear data. In Table 8, excitations corresponding to the strongest maximum in light nuclei (Fig. 16, bottom) at E^*=3936 keV=32×13δ' are presented. The exact equidistancy of the ^{33}S levels (left) is boxed in Table 8 (left). Similar sum distributions for other broad regions of the nuclear chart are shown in Fig. 18.

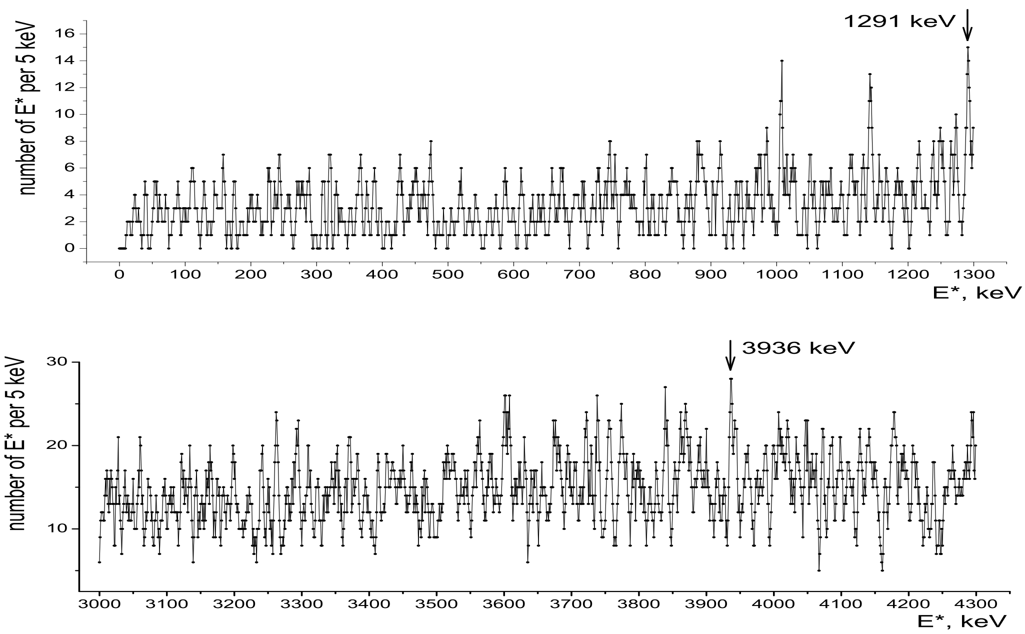

Fig. 16. E^*-distribution in nuclei with Z=4-29 for E^*<1300 keV and 3000-4300 keV. Arrows mark δm_N and 4×8×13δ'=3936 keV. Schematic diagram of the nuclear level system is shown in Fig. 19. The equidistant maxima at E^*=1008 keV=2×17δ'+4×18δ', 1142 keV=5×17δ' + 2×18δ' and 1291 keV=8×17δ' are explained in the text.

We give here additional examples of fine structure in nuclear excitations of near-magic nuclei, where the observed stable energy intervals can be directly compared with the parameters δm_N/8=161 keV and m_e/3=170 keV. The exact integer relations and strong maxima with a width of several keV agree with the accuracy of the CODATA

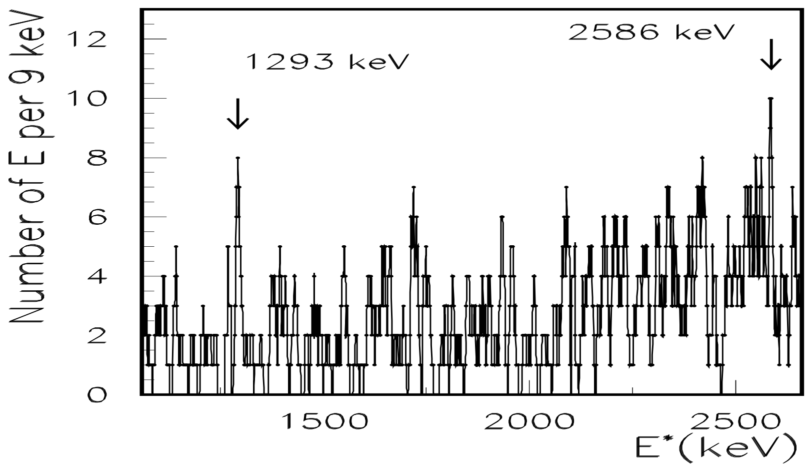

Fig. 17. Total distribution of E^* in Z-odd nuclei with Z≤29. The arrows mark the positions of the maxima at δm_N=1293 keV and 2δm_N=2586 keV.

Table 8. Excitations in light nuclei (in keV) at 3936 keV=32×13δ' from ^{33}S to ^{39}Ca. *Right*: Positions of maxima in D-distributions of ^{18}F and ^{20}F (Fig. 20).

$2J^\pi$	^{33}S	^{38}Cl	^{39}K	^{37}Ar	^{38}Ar	^{39}Ca	D_{ij}(^{18}F)	D_{ij}(^{20}F)
3^+	0.0	E^*_{exp}	E^*_{exp}	E^*_{exp}	E^*_{exp}	E^*_{exp}	493 keV	490 keV
5^+	1967	1982	2523	1410	2167	2469		984 keV=
3^+	3935	3938	3939	3937	3937	3936	3936/8	3936 keV/4

relations and with the properties of future nuclear chemistry considered by F. Wilczek [45]. The proximity of the energy characteristics observed in nucleon masses to those observed in nuclear excitations and binding energies is due to their common QCD-based origin of nucleon hadronic masses and nucleon interactions: QCD is a general theory of all branches of nuclear physics.

Neutron resonance data as part of nuclear physics are widely used in nuclear files. For example, E^* ^{28}Al and ^{32}P are determined mainly from the positions of the resonances measured on the GELINA spectrometer. The study of the superfine structure in neutron resonance spacings as an indirect method for confirming the tuning effect is considered in separate chapters. The origin of the QCD-based tuning effect, as well as the presence of common parameters $M_q = 3\Delta M_\Delta$ in the Constituent Quark Model (NRCQM, Fig. 12) and in the observed groupings of particle mass differences at ΔM=445 MeV, ΔM=3962 MeV=9M_q (in Fig. 1), are important empirical facts useful for a general comparison of the results of the analysis of different hadronic data, started in the 1970s [21] (lines 5-6-7 in Table 1).

The general character of the hadronization process in particle physics and nuclear physics allows to justify the comparison between the parameters of nuclear systematic (nonstatistical) effects and the parameters in the particle mass spectrum.

The demonstration of the general origin of QCD-based constituent quark masses forming a nucleon (see Fig. 12) and derived directly by the standard estimate within the NRCQM model (in the form of 1/3 and 1/2 of hadrons) is important for nuclear physics. Understanding the origin of the coincidence of the electromagnetic mass differences of the nucleon (δm_N=1293.3 keV=8×161 keV) and the electron mass m_e, on the one hand, with the nuclear tuning effects parameters due to tensor forces (Δ^{TF}=161 keV=δm_N/8 and ε_o/6=170 keV=m_e/3 found earlier), on the other hand, require confirmation. Here we distinguish the parameters of interaction of valence nucleons from more complicated cases of collective dynamics of complex nuclei located far from closed shells. The results of the spectra analysis for all nuclei with Z=9-22 are presented elsewhere. T. Otsuka, J. Schiffer and I. Tanihata [31,32] demonstrated the prominent role of the one-meson exchange dynamics (nuclear tensor forces) within the spectroscopy of light and middle-weight nuclei (immediately after ^{16}O and around ^{40}Ca), as well as around