ELECTRON MASS AS THE BASE PARAMETER OF THE STANDARD MODEL

S.I. Sukhoruchkin

Petersburg Nuclear Physics Institute NRC “Kurchatov institute”

188300 Gatchina Russia

Fundamental character of deviation from the statistical model predictions was marked in 1950s by I.V. Kurchatov in connection with grouping effect in neutron resonance positions in heavy nuclei.

Grouping effects in positions and spacings of neutron resonances are considered in the second presentation.

Nuclear physics and Neutron resonance spectroscopy are based on the Standard Model (SM) as a theory of all interactions. We continue presentation the empirical observations of the symmetry motivated and electron-based approach to the Standard Model development.

Four observations were reported in my article “Electron-based Constituent Quark Model” in Nucl. Part. Phys. Proc. 318-323 (2022) 142-147.

1. Empirical relations between masses of nucleons and the electron (named the CODATA relations) are determined now very accurately. The ratio of neutron and electron masses

m_n/m_e = 1838.6836605(11) means that the shift δm_n=161.6491(6) keV from integer m_e n=115×16-1 is exactly 1/8 of the nucleon mass splitting δm_N=1293.3322(4) keV, or $\delta m_N:\delta m_n$=8.00086(3)≈8×1.000(1), that's

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

The shift δm_n = 161.6491(6) keV coincides with the parameter of the tensor forces Δ^{TF} = 161 keV, found in nuclei where one-pion exchange dynamics dominates (^{18}F, ^{55}Co, ^{124}Sb...), and with the radiative correction $\alpha/2\pi$ to the pion mass.
Similar fine structure interval in CODATA relations (namely, 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.

In Fig. 1 and Fig. 2 distributions of excitations of light and heavy nuclei have maxima at 1291 keV and 1294 keV, close to the nucleon mass splitting 1293 keV.

In Fig. 2 maximum at 1024 keV is close to 1022 keV = $2m_e$.

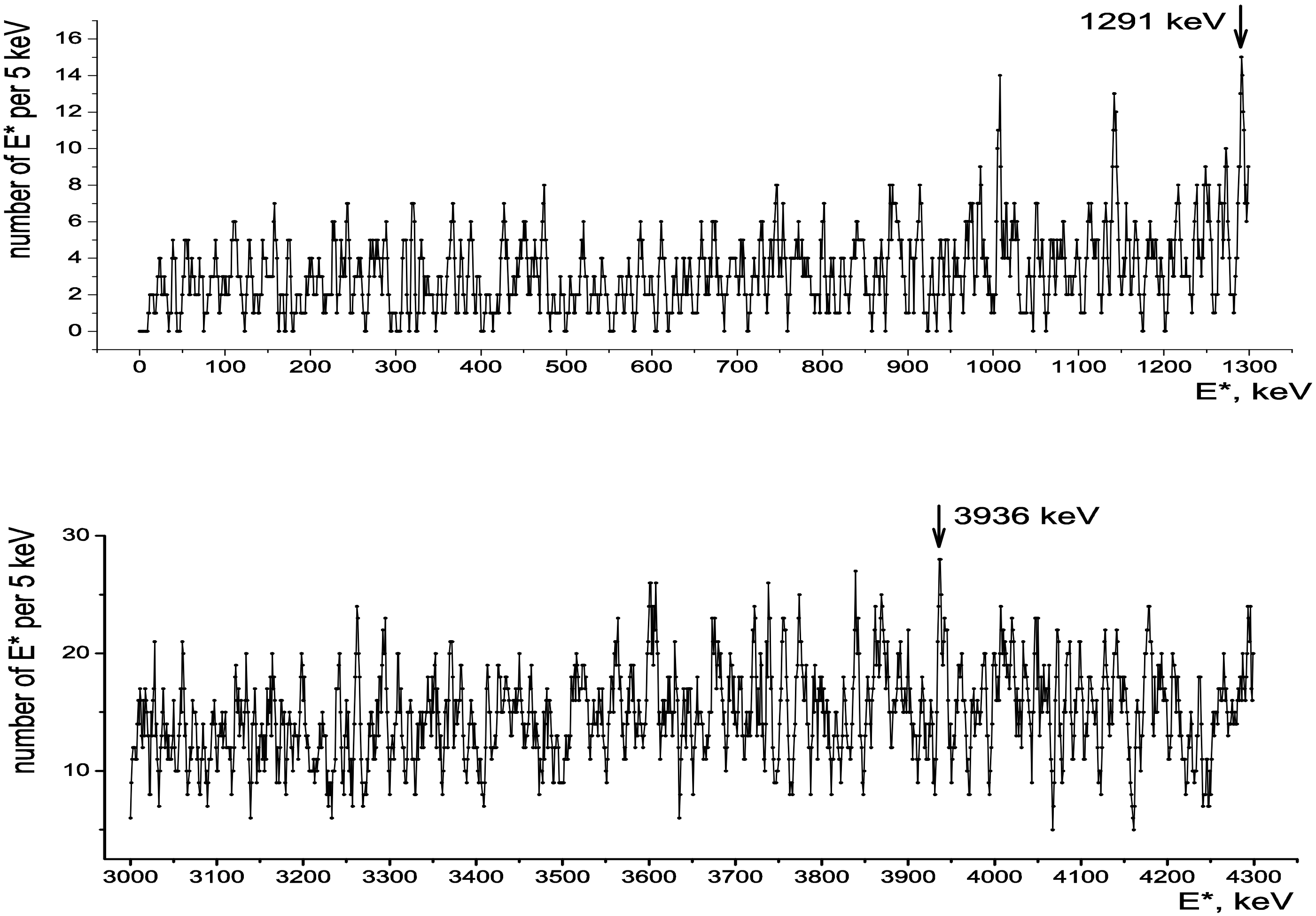

Fig. 1. E* distribution in nuclei Z=4-29 for E*<1300 keV and 3000-4300 keV. Arrows mark δm_N and 4×8×13 δ '=3936 keV.

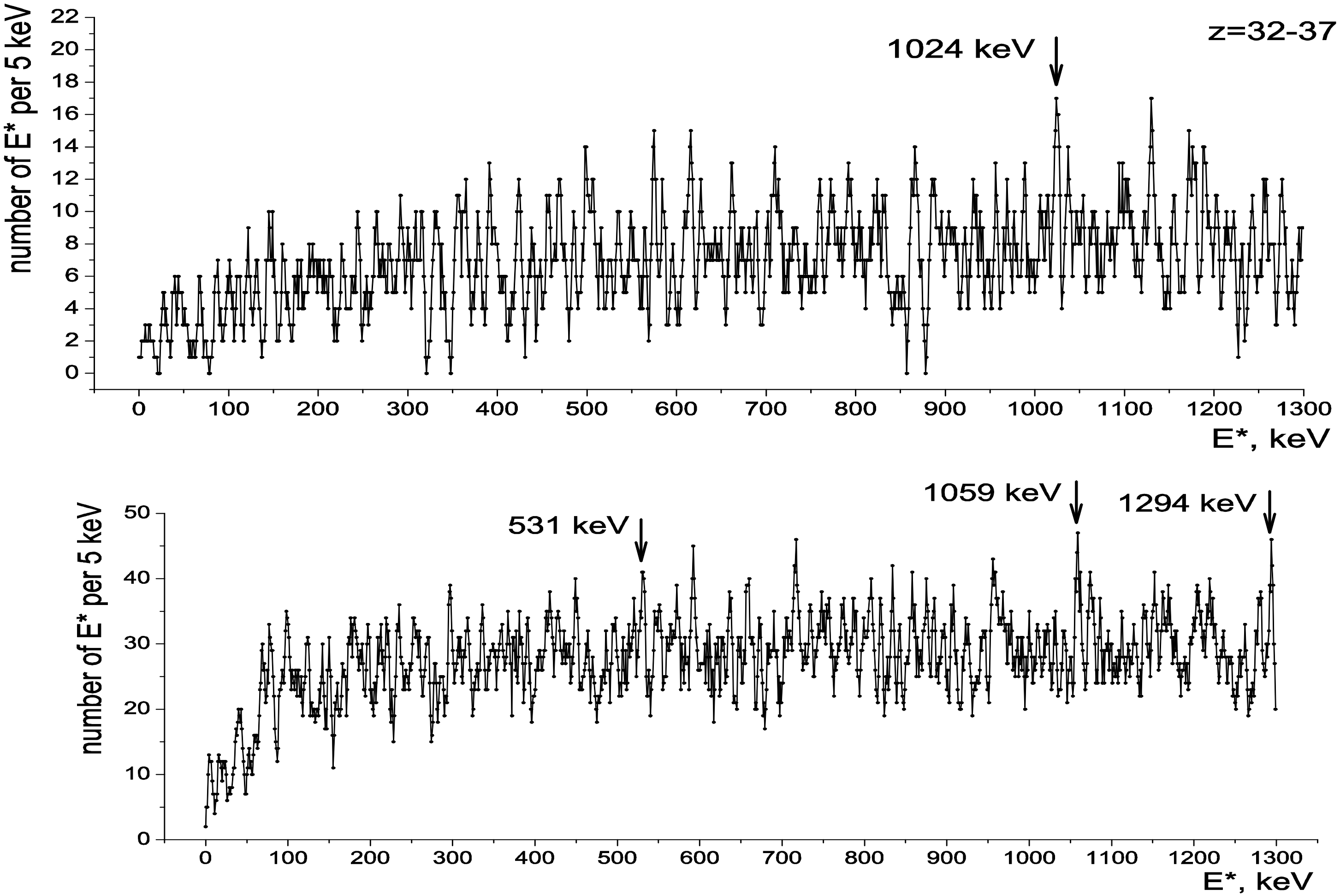

Figure 2. E* distribution in all nuclei with Z=32-35. Maximum 1024 keV=6×18 δ'. The same in nuclei Z=61-73. Maxima at 531 keV=4×7 δ ', 1059 keV=8×7 δ ' and 1294 keV =8×17 δ'= δm_N.

The electron mass, QED radiative correction $\alpha/2\pi$ and their product Mq are the main parameters of Electron-based Constituent Quark Model (ECQM), which contains integer representation of particle masses with a period of $16m_e=\delta$. The muon mass $13\delta - m_e$, pion parameters $f_\pi = 130$ MeV=16δ, $m_\pi = 140$ MeV=$17\delta + m_e$ and $\Delta M_\Delta = 147$ MeV= 18δ, and parameters of the NRCQM (Nonrelativistic Constituent Quark Model) $M_q=3\Delta M_\Delta = 441$ MeV, $M^\omega{}_q=3f_\pi=391$ MeV correspond to the unique common discreteness parameter - the period $16m_e = \delta$ (N=13, 16, 17, 18, 54=3×18, 3×16=48).

Table 1. Presentation of parameters of the tuning effect in particle masses (3 top sections) and nuclear data (bottom) by n·16m_e $(\alpha/2\pi)^X$ M with QED correction $\alpha/2\pi$.

X	M	n = 1	n = 13	n = 16	n = 17	n = 18
-1	3/2			m_t=173.2		
GeV	1	$16M_q=\delta^\circ$	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_μ=106	f_π=130.7	m_π, Λ_{QCD}	ΔM_Δ=147
MeV	2		212	262		296
	3	NRCQM		M_q^ω=391		M_q=441
	6			m_ω=782		$2M_q$=882
	7				974	
	8			1048-1058	1115	
	9				m_c=1270(20)	
	10				1390-1407	
	12				1671-1688	
	24					3504
	27					3962
	30					4427
	60					8849
1	1	$16m_e=\delta=8\varepsilon_\circ$			$k\delta$-m_n-m_e=	170 = $m_e/3$
keV	8,1	CODATA	δm_N=1293.3		=161.651	
1	1	$9.5=\delta'=8\varepsilon'$	123	152	Δ^{TF}=161	170 (Sn)
keV	2		247 (^{91}Zr)		322 (^{33}S)	340 (^{100}Mo)
2	1,4	$11=\delta''=8\varepsilon''$	143 (As)		749 (Br, Sb)	Neutron
eV	4,8		570 (Sb)		1500 (Sb, Pd)	reson.

2. Masses of all particles , leptons and hadrons form correlations in the mass spectrum with a common period 8.176 MeV = δ = $16m_e$ observed in CODATA relations (shown as 2δ=16 MeV in Figure 3).

Masses of the fundamental fields $M_Z=m_\mu(\alpha/2\pi)^{-1}$ and $M_H{}^o = m_e/3\ (\alpha/2\pi)^{-2}$, and the main parameter of the ECQM and NRCQM models $M_q=m_e(\alpha/2\pi)^{-1}$ are interconnected with symmetry motivated relations and common QED correction (Table.1).

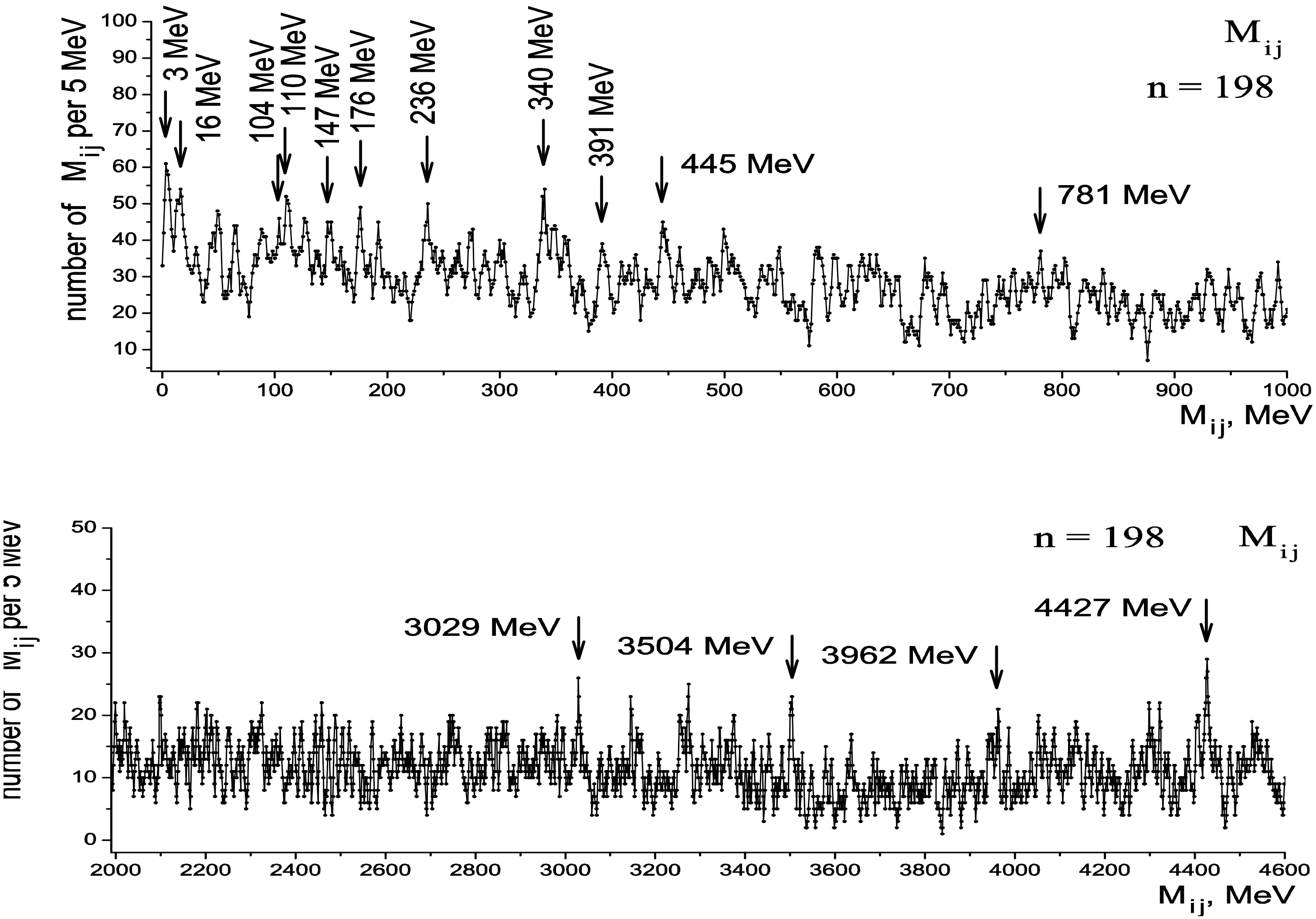

Fig. 3. ΔM distribution of all differences between particle masses from PDG-2020 .

Figure 3. *Top:*
ΔM distribution of all differences between particle masses from compilation PDG-2020 (interval of the averaging 5 MeV) for the energy region 0—1000 MeV. Maxima at
16 MeV = $2\delta = 2 \times 16 m_e$,
391 MeV = $m_\omega/2$, 445 MeV = M_q, 781 MeV = m_ω.

Bottom:
The same for energy region 2000—4600 MeV.
Maxima at 3504 MeV $\approx 8M_q = \delta^0/2$,
3962 MeV $\approx 9M_q$ and 4427 MeV $\approx 10M_q$.

In the ECQM model a scaling factor ($m_e/M_q= \alpha/2\pi =115.9\cdot10^{-5}$), which is close to the ratio $1/32\times27=115.7\cdot10^{-5}$, corresponds to the influence of vacuum (D. Shirkov).

Observed discreteness in masses of heavy quarks (m_{charm}, m_{bottom}, m_{top}) seen in Fig. 3, right, and masses of the fundamental fields allowed to Introduce the period **$16M_q$ = 7.06 GeV** (Fig. 3).

3. Leptons are considered together with parameters of very successful Nonrelativistic Constituent Quark Model (NRCQM):

the pion parameters $f_\pi = 130$ MeV, $m_\pi = 140$ MeV and constituent quark masses

$M_q = m_\Xi/3 = 441$ MeV, $M^\omega{}_q = m_\omega/2 = 391$ MeV.

Mass of τ-lepton is equal to $2m_\mu + 4\,M^\omega{}_q$ (see Table 2, bottom, Fig. 4, top) .

Table 2. Particle masses (in MeV) of different generations (families).
The relations between the masses are boxed.

Particle	Lepton	Mass	Quark Q=2/3	Mass	Quark Q=-1/3	Mass
1 fam.	e	0.511	u-quark	2.16(49)	d	4.67(48)
		m_e	($3m_e$)	(1.53) [10]	$9m_e$	4.60
2 fam.	μ	105.658	c	1270(20)	s	93(11)
			$9m_\pi$	1256		
3 fam.	τ	1776.86(12)	t	172900	b	4180(30)
$2m_\mu$ $+4M_q^\omega$		1776.62(24)			$9M_q =$	3959
diff.		0.24(24)	m_c-$9m_\pi$=	14(20)		

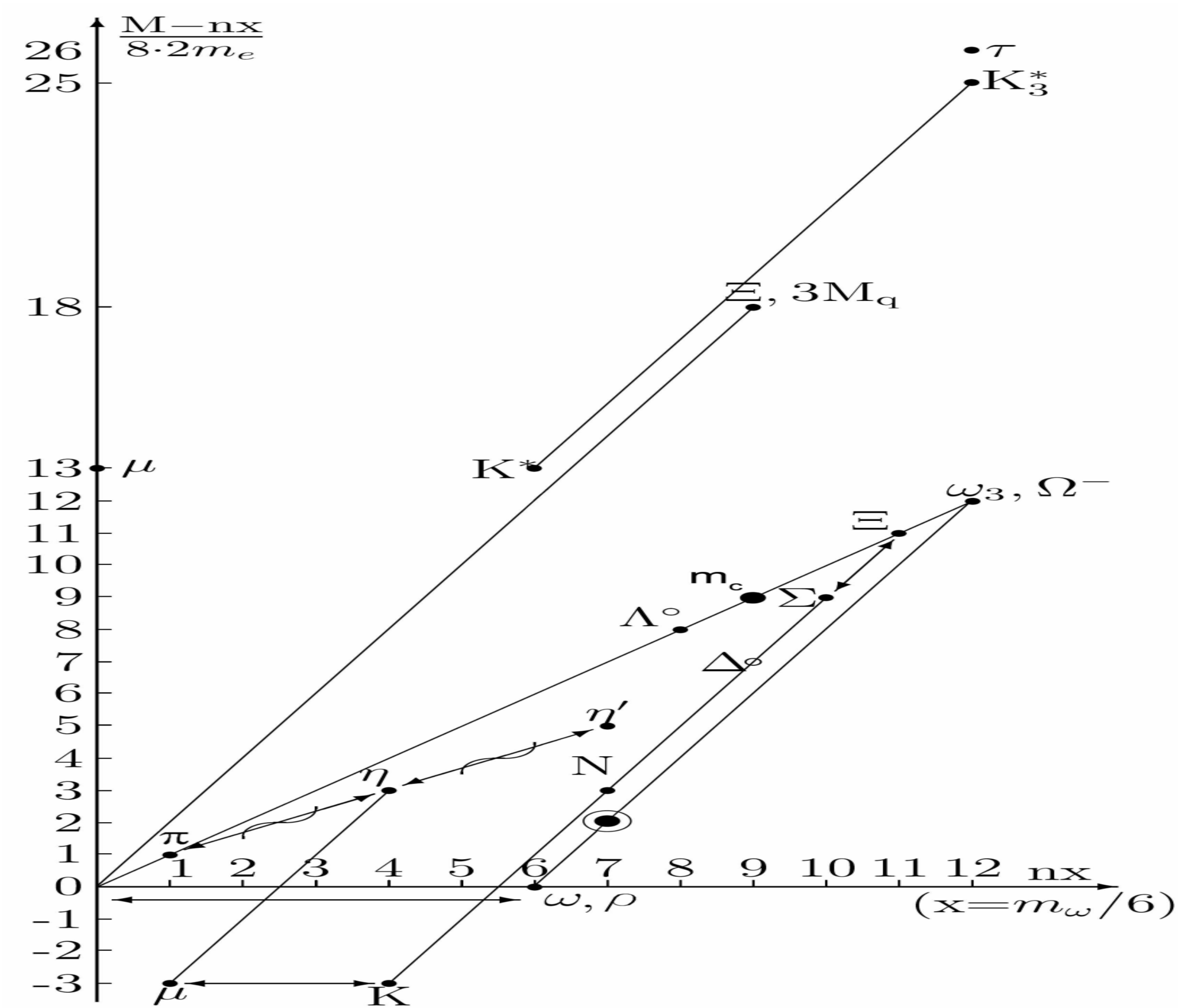

Fig. 4. The evolution of the baryon mass from $3M_q$ to Δ-baryon and nucleon masses.

Fig. 4. The evolution of the baryon mass from $3M_q$ to Δ-baryon and nucleon masses is shown here in a two-dimensional representation: the values on the horizontal axis are given in units $16 \cdot 16m_e = f_\pi$=130.7 MeV, remainders M_i-n($16 \cdot 16m_e$) are along the vertical axis in units $16m_e$. 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=$f_\pi+\delta$ (N=16+1) passes through the masses of Λ-, Ξ-, Ω-hyperons (=$8m_\pi$, $11m_\pi$, $12m_\pi$).

The stable interval in the pseudoscalar mesons $m_{\eta'} - m_{\eta} = m_{\eta} - m_{\pi^{\pm}}$ (crossed arrows) is close to $M^{\Delta q}$=410 MeV=m_d/3=50 δ. The nucleon mass in the nuclear medium (m_{nucl}, circled point) is close to the sum of $\Delta M_{\Delta} + 6f_{\pi}$, which corresponds to the important role of the pion parameters f_{π} and ΔM_{Δ}. The values $3M_q = 9\,\Delta M_{\Delta}$ and $6f_{\pi} + \Delta M_{\Delta}$ are the initial and final stages of the nucleon mass evolution.

The mass of the charmed quark $m_c = 9m_{\pi}$ is marked on the line between the pion (π) and Ω^-.

4. We consider additional empirical observation of the particle mass spectrum and nuclear data, including the role of neutron resonance data in confirming the QED correction that are used for the further SM development. We show that the masses of the fundamental fields $M_Z = m_\mu (\alpha/2\pi)^{-1}$ and $M_H{}^0 = m_e/3(\alpha/2\pi)^{-2}$ and the main parameter of ECQM and NRCQM models, $M_q = m_e (\alpha/2\pi)^{-1}$ are interconnected by symmetry motivated relations and the common QED correction, which can be investigated within neutron spectroscopy.

Table 3. Comparison of the parameter $\alpha/2\pi$ =116·10^{-5} with the anomalous magnetic moment of the electron $\Delta\mu_e/\mu_e$ (top line), the parameter of parity nonconservation $\eta_{+-}/2$ (observation by J. Bernstein, second line) and with ratios between mass/energy values (lines No 1-11, 3 important relations are boxed).

No.	Параметер	Компоненты отношения	Value $\times 10^5$
	$\Delta\mu_e/\mu_e$	$=\alpha/2\pi$-0.328 α^2/π^2	115.965
	$\eta_{+-}/2$ [54]	$2.232(11)\times 10^{-3}/2$	112(1)
	$2\delta m_\pi - 2m_e$	(81652(10) keV)/($16m_e$=δ)	132(12)
1	$\delta m_\mu/m_\mu$	$(23\times 9m_e\text{-}m_\mu)/m_\mu$	112.1
2	m_μ/M_Z	m_μ/M_Z=91182(2) MeV	115.87(1)
3	$\delta m_n/m_\pi$	$(\mathrm{k}\times m_e\text{-}m_n)/m_\pi$=161.649 keV$/m_\pi$	115.86
4	$\varepsilon''/\varepsilon'$	1.35(2) eV/1.16(1) keV	116(3)
5	$\varepsilon'/\varepsilon_o$	1.16(1) keV/ε_o=1022 keV	114(1)
6	$(\varepsilon_o/6)/\Delta M\Delta$		116.02
7	$(\Delta M_\Delta=M_q/3)/M_{H^\circ}$	147 MeV/125 GeV	118
	δ/δ°	$\delta^\circ = 16M_Z/(L=207)$=7.048 GeV	116.0
8	m_d/m_b, [1]	m_d=4.78(9) MeV/ m_b=4.18(3) GeV	114
	m_u/m_c, [1]	m_u=2.2(5) MeV/ m_c=1275(25) MeV	173(40)
9	Sb, D(187 eV)/161 keV	(373 eV/2=187 eV)/160 keV, Table 4 [12]	114
10	Pd, D(1497 eV)/1293 keV	Рис.14, внизу	115.7
11	Hf, D(1501 eV)/δm_N	^{172,176}Hf $E^*(0^+)$=1293 keV=δm_N	116.1
12	Os, D(1198 eV)/$2m_e$	^{178,180}Os $E^*(0^+)$=1023 keV=$2m_e$	117
13	Pd,Cd D(1501 eV)/δm_N	^{97}Pd $E^*(2^+)$=1293 keV	
	[67] D(1585 eV)/$8m_e/3$	^{even}Sn $E^*(0^+)$=$4m_e$	
14	Cd-XeD(1437 eV)	^{even}Cd $E^*(0^+)$ 1222 кэВ	
	[67,68] D(1723 eV)	^{even}Cd $E^*(0^+)$ 1473 кэВ	
	[67,68] D(2007 eV)	^{even}Cd $E^*(0^+)$ 1721 кэВ	
15	Te D(2375 eV)/$4m_e$	^{even}Te $E^*(0^+)$=$4m_e$	
16	N=90 D(793 eV)/$4m_e/3$	$E^*(0^+)$=682 keV=$(4/3)m_e$, .12	
17	Z=94	E*=42.5 keV D=99(2) eV	117

CONCLUSIONS

The interconnection between the most important SM parameters starts with the electron mass and the empirical relation $M_H{}^0 = \Delta M_\Delta \times (\alpha/2\pi)^{-1} = (m_e/3) \times (\alpha/2\pi)^{-2}$, associated with properties of quantum condensate (cumulative effect in QED corrections).

The CODATA relations demonstrate unexpected stability of unique values $\delta=16m_e$ and fine structure parameters $m_e/3=170$ keV and $\delta m_N = 161$keV.

Thank you for your attention