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Constituent Quarks in the Standard Model

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Abstract

We consider unexpectedly accurate relations between nucleon masses and integer number of the electron rest mass. This side of the tuning effect in particle masses discussed earlier and consisted in integer relations between masses of leptons and hadrons. The role of QED based gluon-quark-dressing effect and relations with constituent quark masses as well as the role of nuclear parameters connected with one-meson exchange dynamics are discussed.

Keywords:
Standard Model, scalar field, QED radiative correction, tuning effect, empirical relations

1. Introduction

According to Y. Nambu [1] empirical relations in particle masses have an important scientific potential which should be used for further development of the Standard Model. which is a theory of all interaction (except gravitation) with a representation:

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

The Quantum Chromodynamics (QCD), the first of these three SM-components [2], deals with the strong interaction of colored quarks and gluons and is a commonly accepted theoretical base of nuclear physics. It introduces masses of constituent quarks forming hadrons, a description of properties of nuclear matter and nucleon interaction. Integer relation in particle masses based on observations in 70-ties in [3-6] can be expressed as numbers n=1,13,16,17,18 of the period δ=16m_e for values m_μ, f_π, m_π and ΔM_Δ=(1/2) of nucleon Δ. The period is determined by the fact that the charge splitting of the pion and the electron mass are in the ratio 9:1 (δm_π=4.594 keV, 4.599 keV=Δ, m_e=511 keV), hence the pion's β-decay energy is close to $\delta/2$=8m_e and the lepton ratio is close to the integer L=13×16-1, namely, $(m_\mu + m_e)/2(\delta m_\pi$ - $m_e)$ =13.00.
Other relations: f_π=130.7 MeV/2(δm_π - m_e) =16.01.
$(m_{\pi^\pm}$ - $m_e)/2(\delta m_\pi$ - $m_e)$ =17.03.
ΔM_Δ=147 MeV/2(δm_π - m_e) =18.02.
$(m'_\eta$ - $m_\eta)$=$(m_\eta$ - $m_\pi)/2(\delta m_\pi$ - $m_e)$ =50.1.
neutron mass $(m_n + m_e)/2(\delta m_\pi$ - $m_e)$ =115.01.

The shift of the neutron mass relative to the value 115δ is equal to δm_n=161.65(6) keV derived from the recent precise ratio between the neutron and the electron masses m_n/m_e=1838.6836605(11) evaluated by CODATA [7]. It accounts the integer ratio with nucleon mass splitting δm_N=1293.3 keV $\delta m_N/\delta m_n$=8(1.0001(1)).

Unexpectedly accurate rational relation by CODATA:

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

$$m_p = 115 \cdot 16m_e - m_e - 9\delta m_N/8 \tag{3}$$

allows several very important conclusion concerning properties of SM-parameters.

First of all it means that the periodicity parameter δ=16m_e reflect common property of many masses including masses of initial constituent quark masses estimated in NRCQM (Nonrelativistic Constituent Quark

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Model). These masses are results of the QCD gluon-quark-dressing effect [8-10]. They are used in NRCQM calculation of baryon/meson masses [11,12].

Values forming CODATA relation, m_e, δm_n=161 keV and δm_N=1293.3 keV are shown in the central part of Table 1 [8] (X=1, M=1 and 8), where integers values (n) of the tuning effect are given at the top and m_μ, m_π and ΔM_Δ – in the 2-nd section together with the standard estimations of the initial constituent quarks in NRCQM: as a half of nonstrange vector meson mass $M''_q=m_\rho/2$=788 MeV or as (1/3) of the initial baryon mass [8,10] coinciding with (1/3) of the mass of Ξ-hyperon M_q=1324 MeV/3=441 MeV where effects from strangeness and quark interaction are compensated.

Boxed values situated one under another differ with factor $\alpha/2\pi=115.96\cdot10^{-5}$. Recently evaluated masses of down and bottom quarks m_d=4.78(9) MeV and m_b=4.180(5) GeV (Fig.1,2) are close to $9m_e$=4.599 MeV and $9M_q$=3.96 GeV. Their ratio $m_d/m_b=114\cdot10^{-5}$ is close to $\alpha/2\pi$ [8]. The ratio between the well-known masses of the second lepton and Z-boson m_μ/M_Z=115.90(4) is also close to $\alpha/2\pi$ [8,10,18]. Boxed values in Table 1 (at left and right) correspond to relation in particle masses.

Table 1: Presentation of parameters of tuning effects in particle masses (three top sections) and in nuclear data (bottom, sections marked X=-1, 0, 1 at left) by the common expression $n\cdot16m_e(\alpha/2\pi)^X M$ with QED radiative correction $\alpha/2\pi$ ($\alpha=137^{-1}$) [8]. Values m_μ, m_π-m_e, $\Delta M_\Delta=m_s$ (in baryons), $m_e/3$ and boson masses are boxed. Stable intervals in nuclear binding energies and excitations (E^*, D_{ij}, [18-21] X=1) coinciding with nucleon mass splitting δm_N and the neutron mass shift $\delta m_n=115\delta-m_n-m_e$ (boxed) are considered as a confirmation of relations in particle masses [8]. Unconfirmed mass groupings at M'_H=116 and 58 GeV [13,14] are given in brackets (at X=-1, M=1 and 1/2).

X	M	n = 1	n = 13	n = 16	n = 17	n = 18
-1	3/2			m_t=172.0		
GeV	1	δ°	M_Z=91.2	(M_H=115)		M_H=126
	1/2	(m_b-M_q)		(M^{L3}=58)		
0	1	$16m_e=\delta$	m_μ=106	f_π=130.7	m_π-m_e	ΔM_Δ=147
MeV	3			$M''_q=m_\rho/2$	NRCQM - par.	$M_q=441=\Delta E_B$
1	1				$k\delta$-m_n-m_e=	
keV	1				=161.651(6)	170 = m_e/3
	8				δm_N=1293.3	
keV	1	9.5=δ'	123	152	Δ^{TF}=161	170 (Sn)
	3				484 (E^*)	512 (Pd)
	4		492		648 (Pd)	682(Co)
	8		984	1212	1293 (E^*)	1360 (Te)

Contained in the third section parameters from CODATA relation m_e, δm_n=161.65 keV and $\delta m_N=8\delta m_n$ correspond also to particle masses. The last section contains results obtained with nuclear data where QCD-based hadronization could be of the general character.

2. Parameters of the Constituent Quark Model

In Table 2 from [8] the discussed nucleon Δ excitation (the second line, neutral baryons) and three different estimations of constituent quark masses in NRCQM (M_q, $M^\Delta_q=m_\Delta/3$ and M''_q) are given in separate sections. In the central column they are compared with integer values k of the common period $16m_e$, their differences are given at right. Value $\Delta=9m_e$ is close to the discussed m_d.

Table 2: Comparison of particle masses with the period $16m_e=\delta$=8176 keV (comments are given in MeV, constant shift $\Delta=9m_e$ is boxed).

Particle	m_i, MeV	k	m_i-k·16m_e	Comments
f_π	130.7(4) [2]	16		≈0
Δ°-n	294.2(2)	36		2(ΔM_Δ=147.1)
M_q CQM	441	3·18		ΔE_B=441
M_d CQM	436 [11]	3·18-Δ		-5 = -Δ
M_H/18·16	436	3·18-Δ		5 = -Δ
M_Z/L	440.5	3·18		diff. ≈ -2m_e
η'-η, η-$\pi^\pm$	409	50		≈0
M^Δ_q CQM	410	50		ΔE_B=409
ρ	775.49(34)	96	-9.40(34)	-9.20 = -2Δ
M''_q CQM	387.7	48	m_ρ/2 [16]	-4.60 = -Δ
M_W/L	388.4	3·16	3f_π	diff. ≈ -2m_e
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

In this work, we consider some aspects of applications of the discussed CODATA relation to other observed relations for particle masses. We discuss two cases when masses are expressed with the period $\delta=16m_e$ directly. First of all, we see coincidence of the pion decay parameter f_π to $16\delta=6\times16m_e$ (the first line of Table 2).

Secondly, we notice that baryon constituent quark mass introduced empirically by R. Sternheimer as m_η-m_μ [16] and by P. Kropotkin as $m_{\Xi^-}/3$ [17] coincides within a small error with the three-fold value of the well-known parameter of nucleon Δ-excitation. If we take neutral baryon masses, m_n and m_{Δ°, then for the second value, we should estimate the mean value from 5 independent works given in PDG compilation [2]. Result shown in Table 2 depends on estimation of the m_{Δ^o}.

Value obtained from Z-boson mass and the integer L (440.5 MeV=M_Z/L) is about 1 MeV less than