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QCD-based origin of the particle mass discreteness *

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Abstract

We consider the accurate relations in the tuning effect in particle masses which consists in integer relations between masses of leptons and hadrons. The role of the QCD based gluon-quark-dressing effect and relations with the constituent quark masses are discussed. In this work, for the first time a check of these relations was performed by the analysis of particle masses from the Particle Data Group Compilation (PDG-2016). In the distribution of all differences between 137 particles known with the accuracy better than 5–8 MeV the grouping effects in difference of masses in the region of the pion mass (142 MeV), the muon mass (107 MeV), the constituent quark mass (445–460 MeV) and bottom quark mass (3960 MeV) were confirmed. The stability of mass intervals in the region of the constituent quark mass and bottom-quark mass is discussed in the connection with masses of fundamental fields.

Keywords: Standard Model, particle masses, discreteness, nuclear data

1. Introduction

Discreteness in particle masses with the period δ = $16m_e$=8.176 MeV close to the doubled value of the pion's β-decay energy $2(\delta m_\pi - m_e)$=8.168 keV (with δm_π and m_e - electromagnetic mass splittings of the pion and the electron) [1,2] was named "tuning effect" and considered recently in [3-9]. Muon mass (m_μ), pion's parameter f_π=130.7(4) MeV, pion mass ($m_{\pi^\pm}$) and nucleon Δ-excitation ΔM_Δ=147 MeV (per one baryon) are close to integers n=13,16,17,18 of the period δ. In QCD-based calculation of nucleon masses in NRCQM [10] (Fig. 1) the parameter $2\Delta M_\Delta$ = 36δ=294 MeV (the difference between Δ and N in Figure) is used for adjustment of the interaction between quarks (along the horizontal axis) which together with initial baryon mass (marked + on the left axis) allowed description of all baryon masses with good accuracy (of several MeV). Initial baryon mass equal to three initial constituent quark masses $3M_q$ coincides with m_Ξ (Fig. 2 top).

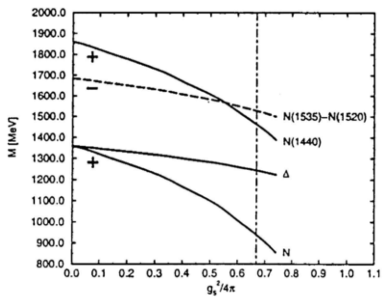

Figure 1: Evaluation of nucleon mass in NRCQM [10], strength of Goldstone Boson exchange interaction is given at horizontal axis, initial baryon mass $3M_q$ is shown with + at left.

Nucleon mass evolution from $3M_q$=m_Ξ to m_N (Fig. 1) is shown in Fig. 2 in two-dimensional mass representation with the period 16δ=f_π close to $(1/3)M''_q$=$(1/6)m_\rho$ (1/3 part of meson constituent quark mass, along horizontal axis) and the period δ along vertical axis). Within the discreteness n(δ) M_q corresponds n=54, n=3·17=51 – for quarks in Δ-baryon, n=151-36=115 corresponds to the nucleon mass in free space (and n=114=96+18 – to the nucleon mass in nuclear media).

The Standard Model - the general theory of all inter-

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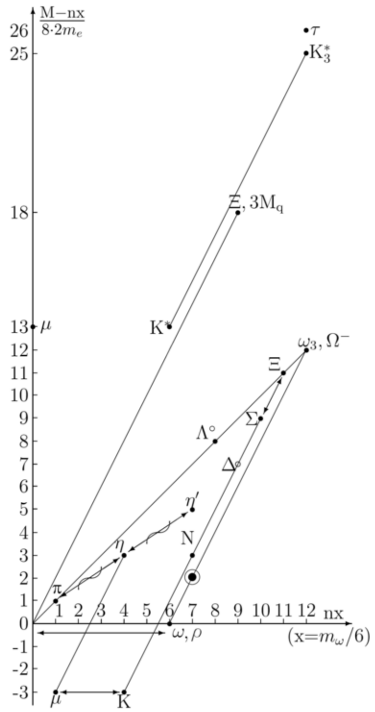

Figure 2: Two-dimensional representation of particle masses as the period f_π=16·16m_e = 130.4 $MeV \approx m_\omega/6$ along the x-axis and the reminder in units δ=16m_e. Four different slopes correspond to different mass systematics including found by Takabayashi equidistance in π, η mesons (crossed arrows). Value m_Ξ=3M_q=3×441 MeV=9ΔM_Δ is used in NRCQM (ΔM_Δ=147 MeV corresponds to the larger slope). The nucleon mass in nuclear medium is shown by the circle around the N (-8 MeV), close to the sum of ΔM_Δ and $6f_\pi \approx m_\rho \approx m_\omega$.

actions except the gravitation has a representation:

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

where the Quantum Chromodynamics (QCD), the first of three SM-components, deals with the interaction of colored quarks and gluons and serves as a theoretical base of the nuclear physics. Constituent quarks forming hadrons are result of the gluon quark-dressing effect considered in [11] (see Fig. 2 in [12], estimate of constituent quark masses $M_q \approx 441$ MeV=m_Ξ/3).

The shift of neutron mass relative to 115δ-m_e is equal to δm_n=161.65 derived from a ratio m_n/m_e=1838.6836605(11) given by CODATA [13]. It accounts an exact integer ratio with the nucleon mass splitting δm_N=1293.3321(5) keV $\boxed{\delta m_N/\delta m_n\text{=8(1.0001(1))}}$ and resulted in relations:

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

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

In Table 1, CODATA neutron mass shift 161 keV (boxed), NRCQM quark masses based on the gluon quark dressing effect and a value $m_e/3$ corresponding to additional shift in baryon masses $-m_e$ (per each of three quarks, boxed) are presented as a common expression n·16m$_e$($\alpha/2\pi$)^{X}M. Such a method of combined presentation of particle masses and empirically determined mass/energy intervals in nuclear data turned to be useful. For example, in case of the muon mass 105.6584 MeV and Z-boson mass 91.1676 MeV which are in a ratio 115.87·10^{-5} very close to QED-radiative correction to the electron magnetic moment $\alpha/2\pi$ = 115.95 · 10^{-5}, these SM-parameters are boxed and located one under another in the upper left part of Table 1.

R. Feynman, V. Belokurov and D. Shirkov [14,15] noticed that the same factor is involved in calculations of the electron mass itself. In Table 1 (at right) values of the electron mass and scalar boson mass M_H=125 GeV are boxed, because they are interconnected with the same QED correction $\alpha/2\pi$=(m_e/3):ΔM_Δ:M_H [3-9]. They are located one under another due to a proximity of $\alpha/2\pi$ = 115.95 · 10^{-5} to 1/32×27=115.74·10^{-5}. Ratio between the shift of the neutron mass (from n×m_e) and the pion's mass m_π 161.65 keV/139.57 MeV=115.8·10^{-5} is close to $\alpha/2\pi$ as well as the ratio between the parameters given in Table 1 (at left, n=1): δ° = 2(m_b − M_q), δ = 16m_e, δ'=9.5 keV, δ''=11 eV and the ratio 114·10^{-5} between masses of d- and b-quarks (see Fig. 3 in [6], $m_d \approx 9m_e$, $m_b \approx 9M_q$).

An independent confirmation of the fine structure in CODATA relation allows to turn attention to the two other components: the period δ = 16m_e and the shift -m_e/3 (per each of three baryon quarks).

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·16m$_e$($\alpha/2\pi$)^{X}M with QED radiative correction $\alpha/2\pi$ (α=137^{-1}). Values m$_\mu$, m$_\pi$-m$_e$, ΔM_Δ=m_s (in baryons), m$_e$/3 and boson masses are boxed. Unconfirmed mass groupings at M'_H=116 and 58 GeV are given in parentheses (at X=-1, M=1 and 1/2). Stable intervals in nuclear binding energies and excitations (E*, D_{ij} [3-9,12], X=1) coinciding with nucleon mass splitting δm_N and the neutron mass shift δm_n=115δ − m_n − m_e (boxed) are considered as a confirmation of relations in particle masses [3-9].

X	M	n = 1	n = 13	n = 16	n = 17	n = 18
-1	3/2			m$_t$=172.0		
GeV	1	δ°	$\boxed{\text{M}_\text{Z}=91.2}$	(M_H=115)		$\boxed{M_\text{H}=126}$
	1/2	(m_b-M_q)		(M^{L3}=58)		
0	1	16m_e=δ	$\boxed{\text{m}_\mu=106}$	f$_\pi$=130.7	$\boxed{\text{m}_\pi\text{-m}_\text{e}}$	$\boxed{\Delta M_\Delta=147}$
	1		106=ΔE$_B$	130=ΔE$_B$	140=ΔE$_B$	147.2=ΔE$_B$
MeV	3	NRCQM		M”$_q$=m$_\rho$/2		M$_q$=441=ΔE$_B$
1	1				kδ-m$_n$-m$_e$=	
keV	1				$\boxed{=161.651}$	$\boxed{170.3 = \text{m}_\text{e}/3}$
	8				δm_N=1293.3	
1	1	9.5=δ'	123	152	$\boxed{\Delta^{TF}=161}$	$\boxed{\text{170 (Sn)}}$
keV	3	[12]			484 (E^*)	512 (Pd)
	4		492		648 (Pd)	682(Co)
	8		984	1212	1293 (E^*)	1360 (Te)
	17				42?? (^{Ca}Ca)	1360 (Te)
2	1	11=δ''	143	176	749 (Br,Sb)	neutron
eV	4	[12]	570 (Sb)		1500 (Sb,Pd)	reson.