Research Notes

Elementary Particle Mass Sub-structure Power Law

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PACS: 14.60.-z, 14.65.-q, 12.60.Rc

Abstract:

A simple numerical basis for estimates of microquanta of mass and 1/6 charge in elementary particle sub-structures is observed in tables of Standard Model (SM) data. An equation for these relations yields whole particle masses and conserved charges consistent with the SM for the quarks and leptons by a sixth power of the number of such components with systematicly derived departures from a constant coefficient of two thirds of the mass quantum. This observation of a new type of power law basis for systematic regularity in particle structures parallels to a degree some recent theory attempts. The link to proven data for the general class of theoretically hypothesized sub-particles provides a new point of departure for further particle definition, experiments, adaptation of theories, and predictive implications in particle physics.

1. Introduction

The existence of charges of 1/3 in the Standard Model (SM) quarks[1][2], has led numbers of physicists[3] to theorize about preon/parton-like sub-particles of which all atomic particles, including quarks, would be composed. Also, many physicists, such as Manohar and Sachrajda in Particle Data Group (PDG) notes on quarks[1], have tried to define masses and mass ratios for quarks and leptons.[1][3][4] Looking at SM particles which are proven composites of quarks, this research note observes in their data a numerical composite sub-structural equation. These relations can then be logically extended to the SM leptons and quarks. Trials in those groups of conventionally elementary particles yield estimates of component sub-structures with new microquanta of mass and conserved 1/6 fractional charge within whole particle masses matching the SM values. These components would gain mass for the particles in composite interaction in accordance with the generalized equation, first, by a directly interpretable fifth power of the number of the components. Then, after collection of terms with defined limitations, the increased particle masses are resolved by a simplified sixth power law, with systematicly derived departures from a constant coefficient equal to two thirds of the mass microquantum. This power law, only distantly similar to some recent theory[3], provides a new basis for systematic regularity of the quarks and leptons in particle masses and quantal composite sub-structures with conserved charge. The link to proven SM particle data for composites is a phenomenological departure point for reorganizing and retesting such particle aspects as uncertain quark masses[1][2][3], neutrino oscillations[4], etc. in theories and experiments of particle physics. Finally, there are further predictive implications.

2. A sub-structural equation for composite mesons and baryons

Figure l displays current SM data[1] on the larger nuclear particles which are well known (from typical overviews in the literature[2]) to be composites of quarks. The two top curves show the baryon (3 quark) and meson (2 quark) whole particle masses in electron-volts (left scale.) These are plotted against the sums of the known component quark masses. The middle two curves (right scale) show the ratios R of those SM whole particle masses m_p to those sums Σm_c for each particle.

Graphing these SM baryon and meson data in this way reveals that the varying composite numerical relations of the quark sub-structures in these hadrons fit a single derived simple function $R = m_p / \Sigma m_c = N^y$. This equates the ratios to the N number of components (2 or 3 in each case) raised to a positive y power (in an exponential law.) This defines mass gain ratios (from interaction of quark components) which fall toward +1 on the right of figure 1 with the heavier hadrons (listed near the bottom of table 1.) In the lowest two-part curve (right scale) y is plotted for whole number and fractional values from the two upper curves, with small discrepancies from a single regular curve. With the lighter component sums on the left, the value of the exponent y at 4 appears, with little basis, to be asymptoticly approaching the value of 5.

3. Extension of the sub-structure equation relations to elementary quarks and leptons

3.1 General overview of that extension

It was next observed that this apparent limiting value of y = 5 in the composite sub-structure equation can then be extended to the left, as shown in less detail across the lowest part of figure 2, to apply to more nearly elementary SM particles which are not composites of quarks. Specificly, these particles are the well accepted[1][2] quarks themselves and the leptons, including the neutrinos. Steps in the application are outlined in table 1. The resulting computed particle masses from column K of table 1 are graphed to the left in figure 2. (Not all estimate options are included in the figure or table.) The last column (L) of table 1 shows that all but three of the masses derived for SM particles are within the accepted range of the SM data.[1] These three are among the larger particles above 100 Mev in mass. One of the three is within 1% of the SM data, and all are within 2%. No other small integral value of the exponent y than 5 was found to be as suitable over as broad a range of SM particles for this type of particle mass estimate. (There is a special exception in the most extremely light range to be discussed.)

3.2 Logical process of extension of the composite equation into the elementary particles

Those estimated lepton and quark mass values displayed in figure 2 and table 1 resulted from a series of trials with the composite sub-structure equation which identified and added three necessary elements:

3.2.1 Added element 1 The electron's SM mass rounded off to 0.511 Mev was used with the equation (inverted as a power law) to calibrate approximately a uniform mass microquantum for universal components for all the lepton and quark particles. A single mass quantum would be the simplest component base in natural composite structures. No other particle than the electron was found to be as suitable for this calibration of a uniform quantum mass with the equation.

3.2.2 Element 2 Since neutral, positive, and negative charges, as well as 1/3 steps of charge, are required for various SM particles, the simplest components would be positive and negative 1/6 charge quanta, of the single uniform mass, appearing normally in pairs. Thus any particle can be neutral or of any multiple of 1/3 charge with only two basic kinds of components in the required number of these pairs. (Some of the larger derived particle masses involved in cosmic ray collisions could be more exact matches of the SM masses by allowing a singlet or single triplet option, not a pair. This could sometimes yield a l/6 level of overall charge, which is not permitted in the SM nor observed reliably to date.)

The calibrating electron with its -1 charge would thus have 3 pairs made up of $N = 6$

negative 1/6 quantal components of conserved charge at a rounded 10.9525 electron-volts of mass each. That yields a 6 component Σm_c = 65.715 electron-volts mass. This is multiplied by the 5 th power of 6 for the 0.511 Mev particle mass, listed in table 1. The positron is fully symmetrical with this. No other trial value of such a calibrated universal component mass was found as suitable for deriving SM consistent masses of whole particles (other than quark composites.) Since the electron components are all negative, their universal calibration was not affected by the third element found necessary with neutral particles or pairs.

3.2.3 Element 3 Neutrals required a mass multiplying factor which depends on whether neutral pairs are considered to be: Either, very tightly bound (T in column G of table 1) within, or within and between, quantal pairs in the very smallest particles such as the long-lived[1] solar electron neutrino. Or, bound at a usual level (U) for larger particles which approach or exceed the mass of the muon neutrino. This second U category for mass factor variation in neutrals includes the muon neutrino with all the established quarks and leptons except the electron neutrino.

Even in the U cases the neutral pairs must have a special binding, or interaction, energy mass situation compared to the charged pairs. In its extreme T case, the solar electron neutrino's mass multiplying factor must be 1/9 with a single neutral pair (+1/6,-1/6), with no multiplication of the sum by a power of N (other than y = zero), in order for the computed particle to match the SM mass of <3 electron-volts.[1]

That mass value for the electron neutrino lies beyond a gap of five orders of magnitude below the muon neutrino mass. In this extreme of the lightest mass range of any very tightly coupled T composites, apparently neutral particle mass gains from component interaction would necessarily be reversed. The sum of composite sub-structural masses must then be reduced with an apparent loss of detectable mass due to this level of interaction within the particle.

That kind of interaction loss of detectable mass would not be without precedent at the atomic nuclear level, as pointed out by Treiman near the end of the background chapter of his overview of particle physics.[2] In the nuclei of atoms an interaction loss of mass between neutrons and protons (at a much lower ratio) is as ubiquitously present in the same nuclei as is the mass gain due to the interaction between quarks within the nuclear neutrons (n) and protons (p) as is depicted in the SM data at the lighter left side of figure 1. The general overall trend of natural phenomena in this area then is that the interaction gains, as well as the opposite effect of interaction losses, of detectable mass in composite physical structures are both actually occurring in atoms at steeply increasing ratios, not unlike those of figures 1 and 2, as the component sub-stuctures become lighter or more numerous, or both, whichever is being considered.

Furthermore, from that background of conflicting effects that might be expected to peak in the leptons with their low range of masses[1], there could be an additional significant correlation among well recognized neutrino effects such as the large mass gap between the two lightest neutrinos cited above, the uncertainties about neutrino oscillations discussed in a PDG note by Groom[1], the strong possibility of finding eventually at least a fourth kind of neutrino of uncertain flavor discussed in a PDG note by Kayser[1], and the PDG note by Olive[1] giving the cosmic upper limit of total mass for stable light neutrinos as <24 electron-volts. With those matters in view together with the extreme lightness of the electron neutrino, a systematic variation of the composite structure equation must occur across this gap in the lightest neutrino masses.

On that basis, the composite sub-structure equation was flexibly adapted for T neutral particles and pairs under the above solar neutrino rules, as shown in table 1. This flexible adaptation for such extremely small T neutral particles also included optional charged pairs treated as neutrals and a component equivalent option of singlets or triplets (all of which might in any use need slightly larger factors.) Next, an intermediate adaptation included moderately tightly bound (M) options for any somewhat heavier neutral particles under similar component rules, with a larger factor of 1/3 and y = zero (or more if needed in the gap.)

Finally in element 3, for the usual (U) level of binding in all other classically elementary particles, leptons or quarks, the mass factor of 1/3 systematicly applies only to the fraction of the total component mass contributed by neutral pairs, and the value of y remains at 5. This brings the muon neutrino, with 6 components in 3 neutral pairs, to exactly one third the mass of the electron, as in the SM.

3.3 Resultant more general form of the equation

The equation becomes $m_p = (\Sigma m_c)\, N_c^{\,y}\ F$, where the factor $F = (n_{\pm} / n) + (n_o / a\, n)$,

a=3, $n_{\pm}$ is the number of negative and/or positive charged pairs, n_o is the number of neutral pairs, and as the sum of both kinds of pairs $n = N_c/ 2$. For U cases, y =5 and a=3. For T neutral cases under the T rules, y = 0, a = 3 in denominators, but a changes to 1 if collected into numerators or non-fractions, and also F is divided by an additional departure factor of 3 to provide for the neutral 1/9 factor process of element 3. (This is effectively equivalent to changing a to 9 in T cases.) For M intermediate neutral cases as shown, y = 0 (or more), and a = 3 in fraction denominators, but a again changes to 1 (or up to 3 if needed in the gap) in numerators or non-fractions, without an additional departure divisor. For all leptons and quarks, $\Sigma m_c = N\, m_u$, where m_u = 10.9525 electron-volts for the universal microquantal mass component. For the hadrons of figure 1, F = 1 , y is variable as shown, N = 2 or 3, and the sum term varies with both component quark masses and N.

3.4 Simplifying the 5 th power equation

Computing limited to the lepton and quark masses of table 1 is simpler, though less informative, with substitution and collection of terms in a new constant, *C*. *F* continues its influence. Thus, $m_p = 2n\, m_u\, (2n)^y\, (an_{\pm} + n_o)/an = (2^{\,y+1}/a)\, m_u\, n^y\, (an_{\pm} + n_o) = C\, n^y\, (an_{\pm} + n_o)$, where C_U =233.653..ev $=2^5 C_M = 3\text{x}2^5 C_T$ for U, M, T cases; $C_M = C_U/2^5$; $C_T = C_U/(3\text{x}2^5)$. The particle masses vary with systematic regularity, essentially as a power law with departures from a constant coefficient in accordance with the *F* factor due to neutral pairs and the M/Tcase rules. However, in this form the departures from the 5 th power law are often large enough to equal the root of the power term times a smaller residual factor which varies systematicly with the ratio of neutrals to charged pairs and M/T cases. Also, the constants are large.

3.5 Further simplification to a 6 th power law for usual (U) cases

Since the sum factor always included an additional power of *N*, the equation becomes simpler in terms of *N* where $N_{\pm}$ and N_o are the numbers of components in charged or neutral pairs. Thus $m_p = N\, m_u\, N^y\, \{(N_{\pm}/N) + (N_o/aN)\} = (2m_u/a)\, N^{\,y+1}\{(a\, N_{\pm}/2N) + (N_o/2N)\}$, where the general T, M, and U case rules apply to *a*, *y*, and the special T divisor of 3. (Though applicable, the M/T cases are less intuitive in this format.)

The most significant change is that the power law exponent has become $y + 1 = 6$. A factor 2 has also been moved to the constant factor from the bracketed *F* factor in order to shift its range of departure factors from (+ 1 to +3) to the range (+ 0.5 to +1.5) in the numerous U cases. The constant term then becomes $(2/3)m_u$ for all cases. Before the shift of factor 2, the mean of the departure factor range was 2 and the average over the 27 U mass options matched to the SM was 1.9999148 . After the shift, that mean is 1.0 and the average is 0.9999579. The result is that overall only a negligible average departure from a strict power law would appear. Furthermore, since $N_o = N - N_{\pm}$ the bracketed F term simplifies to $\{ 0.50 + (N_{\pm} /N)\}$ or one half plus the fractional ratio of the charged pair components (or pairs) to all components (or pairs.) Thus, at the SM charge level for a lepton or quark, if no pairs of stated quantal components are charged pairs for a particular U mass value estimate (and in base rule neutral M cases), the factor of departure from a strict 6 th power law is 0.50. If half the pairs in U cases are charged pairs, then the factor is 1.0; there is no departure from an ideally strict sixth power law. If all pairs in the particle are charged, then the factor is 1.50. The decimal fraction is more conveniently used here since this relation is linear for the many other intermediate charged pair fractions for the larger particle estimates.

In result, for quarks and leptons, including U case neutrinos, the simplest final equation is

$$m_p = (2\, m_u/3)\, N^{6} \{0.5 + (n_{\pm} / n)\}$$

(For T or M neutral cases the special rules, exponent 0+1, and special T departure factor of 1/3 also apply.) In all three forms of the equation the derived masses of table 1 are the same if roundings are the same.

3.6 Overall utility of the composite sub-structure power law equation with quarks and leptons

This equation's built-in corrections for departures from a strict sixth power law of quantized particle masses can be of significant size for those standard particles which, under definite SM constraints of particle mass and charge, must be estimated with unequal or unbalanced numbers of neutral and charged pairs of quantal components. This is particularly true for the three most unbalanced particle cases (without alternative sub-structure options under

SM constraints) which define the application of the stated law to the quarks and leptons. These three are the small and very stable[1] electron, the somewhat smaller muon neutrino, and the extremely small electron neutrino.

However, for the lepton and quark masses as a whole, departures from an ideally strict law of the sixth power of component number by the sixth power law here-in noted, are definitively constrained by the stated law in an inherently systematic way which is very simple for all but the electron neutrino. In nearly all cases the derived mass estimate for the whole particle is also within the current SM constraints. The three discrepancies from current SM values[1] in table 1 are low. The left mass curve in figure 2 is so steep on the balanced logarithmic scales that the small vertical departure corrections from a strict sub-structure power law would lie almost along the power law curve and would not alter or move the overall pattern if they were displayed.

The overall close adherence to the SM data, of the masses derived from a single equation and its rules, accounts systematicly for a basic regularity of the seemingly irregular progression of the well accepted[1][2] lepton and quark masses. In this system, other relations would be coincidental or derivative.

4. Further implications

In such a view, the larger SM uncertainties with several options derived here might predict that nature may include mixtures of particle isotopes, similarly to atomic isotopes. Also, the available options here might eventually be found sufficient to match many special interaction characteristics of charm, strangeness, flavor, spin, antiparticles, stability, lifetimes, the nuclear forces, electric field, etc. The options would be especially adaptable within the SM if matched singlet and triplet options are included, in varied structural locations of natural forms due to number of components, in varied charged/neutral pair ratios of varied interaction levels.

The matching application to the established SM top quark implies that the composite sub-structure power law of particle masses might be extended into the general proliferation of less frequently observed heavy particles.[1] In addition, there are within the particle mass range noted here a number of unassigned, but systematicly regular, mass and charge quantal options which might apply to lighter particle proliferations. In general, this would imply the possibility of a very large number of potential rarely observed particles, thus correlating with, and tentatively accounting for, the currently observed[1] proliferation. In figure 2 there is also a large central area crossed with arbitrary connecting lines between the data curves to right and left where a few of such rare particle mass combinations might occur correlatably with this view, but they are otherwise beyond the scope of this research note. It is interesting, however, that the most structurally stable and, probably therefore, the most numerous particles, with the possible exception of the electron neutrino, lie just on opposite sides of this area of figure 2 in a narrow, wedge-shaped band across the area. The band would run from the proton and neutron, about two orders of magnitude above the mass limit slope line on the right, to the electron and the component quarks of the proton and neutron, about four orders above that line on the left.

As a final correlation, the high ratio graph to the left in figure 2 would indicate a very large increase in mass from internal interaction energy with numbers of components under the sixth power law. Thus, in the heaviest quarks most of the component interaction capability would be either engaged well within the assembly of components or shielded, with little of that capability interacting for mass gain externally between quarks in the heavier hadrons, where that ratio approaches 1 in the lower right corner of figure 2. Certainly, the light quarks, with a necessarily higher ratio of external exposure of any sub-structure components from within the smaller component assembly, do make up the light hadrons most capable of the more energetic nuclear strong force interactions. The light electron/positron, with even less internal interaction mass gain (of unresolved nature), could have its six charges on the group surface for a greater ratio of exterior interactions. This implies for all particle interactions a quantized surface to volume ratio effect, as for a sphere, where $S/V = 3/r$. That would imply that such external interactions may be largely geometrically quantized attraction, repulsion, twisting, or combinations of these, between configurations of sub-structural components with more or less surface exposure of many variably polarized fully neutral pairs plus balanced numbers of partially neutralized though oppositely charged pairs, both with very short range net forces, and/or with limited numbers near the particle surface of unneutralized charge pairs with longer range force fields.

5. Summary and conclusion

In conclusion, a simple equation correlates the composite mass relations of the SM particles composed of quark sub-structures. It also applies to more elementary SM quarks and leptons to estimate their masses as composite structures of microquanta of 1/6 fractionally charged sub-particles with informative accuracy. The regularity of particle mass derivations arises here from a sixth power law for the variable number of quantized components. Departures from a strict power law come systematicly from quantally matching both conserved charge and mass of particles. Tying in the top quark extends a regular systematics of mass and charge into the proliferation[1] of particles. This numerical link to the data of experiment-proven SM particles for estimates of sub-structural elements, and for a new power law of masses, provides a departure point for new experiments on the uncertain masses of quarks[1][2][3], on neutrino oscillations[4], etc., and for practical guidelines to further selections between alternative physics theories.[3] There are a number of further implications of potential interest.

Acknowledgements

I thank Fred E. Howard, III, for comments, Katherine M. Douglas and H. Blevins Howard for much assistance with figures, and Cheryl Mack and Christi Buffalino of the US Air Force Armament Laboratory Technical Library for patient assistance with related references.

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