The Origin of the Mass of a Charged Particle and the Mass Prediction of a Fourth-Generation Quark

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I. Electrostatic self-energy has a potential to explain substantial parts of elementary particle mass.

1. Electrostatic self-energy U_{es}

Differential and integral concepts we have acquired and used in mathematics and physics comprise the idea that an object can be considered "a set of some infinitesimals". Since the charge Q is the set of infinitesimal charge dQ, electric force is operated between infinitesimal charges and therefore, electrostatic self-energy exists due to the presence of charge Q itself.

When spherical symmetry and even distribution of charges are assumed, U_{es}, the electrostatic self-energy(or electrostatic binding energy($-U_{es}$)) is as follows:

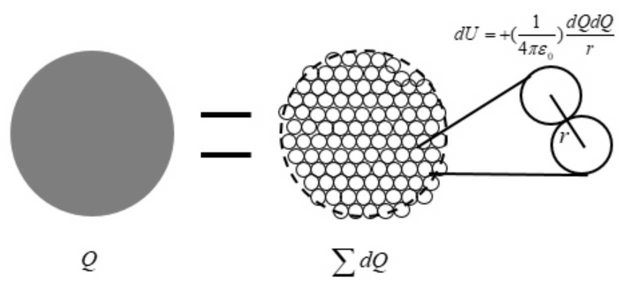

Figure 1: Since all charge Q is a set of infinitesimal charge dQs and each dQ is electromagnetic source, too, there exists electrostatic potential energy among each of dQs.

$$U_{es} = +\frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R_{es}}) \tag{1}$$

However, electrostatic self-energy has positive values for both positive and negative charges.

$$U_{es} = +\frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{{Q_+}^2}{R_{es}}) = +\frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{{Q_-}^2}{R_{es}}) > 0 \tag{2}$$

2. Electrostatic self-energy has a potential to explain substantial parts of elementary particle mass.

Most parts of elementary particles' rest mass are likely to be originated from electrostatic self-energy, due to the presence of charges. Although there are many points to be additionally considered, such a model's suggestions for the magnitude of quark should be currently examined with electrostatic self-energy equivalent to mass energy.

$$E = mc^2 = \frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R_{es}}) \tag{3}$$

$$R_{es} = \frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{mc^2}) \quad (4)$$

For convenience of calculation, it is defined as follows $mc^2 = \alpha(eV)$

$$R_{es} = \frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{mc^2}) = \frac{3}{5}(\frac{1}{4\pi\varepsilon_0})(\frac{k^2e^2}{mc^2}) = \frac{k^2}{\alpha}(8.64 \times 10^{-10})[m] \quad (5)$$

Since mass is $2.4MeV/c^2$ and quantity of electrical charge is (+2/3)e, for up quark,
if k=2/3 and $\alpha = 2.4 \times 10^6$ are substituted,

$$R_{es-U} = \frac{k^2}{\alpha}(8.64 \times 10^{-10})[m] = \frac{(\frac{2}{3})^2}{2.4 \times 10^6}(8.64 \times 10^{-10})[m] = 1.6 \times 10^{-16}m \quad (6)$$

By interpreting this, it can be inferred that the mass of up quark is derived from electrostatic self-energy, if the radius of up quark is approximately $R_{es-U} = 1.6 \times 10^{-16}m$ and here, charges are evenly distributed.

If inferences of other quarks can be acquired,

Down quark's mass: $4.8MeV/c^2$, charge: (-1/3)e

$$R_{es-D} = 2.0 \times 10^{-17}m \quad (7)$$

Strange quark's mass: $95MeV/c^2$, charge: (-1/3)e

$$R_{es-S} = 1.01 \times 10^{-18}m \quad (8)$$

Charm quark's mass: $1.275GeV/c^2$, charge: (2/3)e

$$R_{es-C} = 3.01 \times 10^{-19}m \quad (9)$$

Bottom quark's mass: $4.18GeV/c^2$, charge: (-1/3)e

$$R_{es-B} = 2.29 \times 10^{-20}m \quad (10)$$

Top quark's mass: $172.44GeV/c^2$, charge: (2/3)e

$$R_{es-T} = 2.22 \times 10^{-21}m \quad (11)$$

It is desirable to think that the magnitude of quark from such a simple model is smaller than that of an atomic nucleus.

The above calculation suggests the possibility that electrostatic self-energy due to the presence of charges can explain some parts of elementary particle mass. In order to make a precise model, the model related with kinetic and other energy, relativistic effects and orbital model(in case of electron) related with charge distribution can be also considered

However, this seems to deny the logic of the Higgs mechanism, which gives mass to the elementary particles.

This model claims that most of the mass of a charged particle is from the charge distribution. Electrostatic self-energy comes from the definition of electric force or electrostatic potential energy. And, the electric force or electrostatic potential energy does not come from the Higgs mechanism.

Perhaps, is the Higgs mechanism a mechanism that only applies to weak interaction particles?

II. Hint about structure of quarks and mass prediction of fourth-generation quarks.

1. The fact that the six quark radii vary by roughly 10^1 orders of magnitude, suggests that there is some principle or rule.

In the history of science, there is a case of Titius-Bode' law.

2. We considered only the electrostatic self-energy value. Nonetheless, some rules seem to suggest that the self-energy of the charge may be the most important term.

3. Since R_{es} is a radius, it may be associated with volume (${R_{es}}^3$). A slight error may mean that we have to consider other energy, such as spin energy, kinetic energy, binding energy ...

4. Mass prediction of fourth-generation quarks.

No fourth-generation quarks have been found to date. However, there is no theoretical proof to prohibit existence. If there is a fourth-generation quark, we can estimate the mass of the fourth-generation quark through this reasoning.

Even though the LHC operates at the Tev level, the energy of the splitting particles is lower than the maximum energy of the LHC. In addition, it is not yet possible to completely deny the fourth-generation quark because it is difficult to observe the quark alone.

The charge of the fourth generation quark is $(-1/3)e$ or $(+2/3)e$. Assume that the radius is approximately $\beta \times 10^{-22}m$, $(1 \leq \beta \leq 9)$ and let's get the mass value.

1) If $R = 10^{22}m$, the charge is (-1/3)e

$$R_{4X} = \frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{mc^2}) = \frac{k^2}{\alpha_{4X}}(8.64 \times 10^{-10})[m] = \frac{(-\frac{1}{3})^2}{\alpha_{4X}}(8.64 \times 10^{-10})[m] = \beta \times 10^{-22}m \tag{12}$$

Estimating from the case of six quarks, $1 \leq \beta \leq 9$

$$0.107 \times 10^{12} \leq \alpha_{4X} = (\frac{0.96}{\beta}) \times 10^{12} \leq 0.96 \times 10^{12} \tag{13}$$

The mass X of the fourth generation quark is

$$107(\frac{GeV}{c^2}) \leq X \leq 960(\frac{GeV}{c^2}) \tag{14}$$

When we reduce range from the previous example,
Assuming $1 \leq \beta \leq 3$,

$$320(\frac{GeV}{c^2}) \leq X \leq 960(\frac{GeV}{c^2}) \tag{15}$$

2) If $R = 10^{22}m$, the charge is (2/3)e

$$R_{4Y} = \frac{(\frac{2}{3})^2}{\alpha_{4Y}}(8.64 \times 10^{-10})(m) = \beta \times 10^{-22}m \tag{16}$$

Estimating from the case of six quarks, $1 \leq \beta \leq 9$

$$0.427 \times 10^{12} \leq \alpha_{4Y} \leq 3.84 \times 10^{12} \tag{17}$$

The mass Y of the fourth generation quark is

$$427(\frac{GeV}{c^2}) \leq Y \leq 3840(\frac{GeV}{c^2}) \tag{18}$$

When we reduce range from the previous example,
Assuming $1 \leq \beta \leq 3$,

$$1.28(\frac{TeV}{c^2}) \leq Y \leq 3.84(\frac{TeV}{c^2}) \tag{19}$$

3) If $R = 10^{23}m$, the charge is (-1/3)e

$$R_{4X} = \frac{(-\frac{1}{3})^2}{\alpha_{4X}}(8.64 \times 10^{-10})(m) = \beta \times 10^{-23}m \tag{20}$$

Estimating from the case of six quarks, $1 \leq \beta \leq 9$

$$1.07 \times 10^{12} \leq \alpha_{4X} \leq 9.6 \times 10^{12} \tag{21}$$

The mass X of the fourth generation quark is

$$1.07(\frac{TeV}{c^2}) \leq X \leq 9.60(\frac{TeV}{c^2}) \tag{22}$$

When we reduce range from the previous example,
Assuming $1 \leq \beta \leq 3$,

$$3.20(\frac{TeV}{c^2}) \leq X \leq 9.60(\frac{TeV}{c^2}) \tag{23}$$

4) If $R = 10^{23}m$, the charge is (2/3)e

$$R_{4Y} = \frac{(\frac{2}{3})^2}{\alpha_{4Y}}(8.64 \times 10^{-10})(m) = \beta \times 10^{-23}m \tag{24}$$

Estimating from the case of six quarks, $1 \leq \beta \leq 9$

$$0.427 \times 10^{13} \leq \alpha_{4Y} \leq 3.84 \times 10^{13} \tag{25}$$

The mass Y of the fourth generation quark is

$$4.27(\frac{TeV}{c^2}) \leq Y \leq 38.40(\frac{TeV}{c^2}) \tag{26}$$

When we reduce range from the previous example,
Assuming $1 \leq \beta \leq 3$,

$$12.80(\frac{TeV}{c^2}) \leq Y \leq 38.40(\frac{TeV}{c^2}) \tag{27}$$

If either case 1) or case 2) is selected, one of 3) or 4) is automatically determined due to the charge.

5. This inference is also applicable to more than fourth-generation quarks and elementary particles with charge .

It is necessary to find the underlying principle from the case of six quarks. It is presumed that the movement of quarks is trapped in a space called the nucleus, and the observer effect occurs frequently inside the nucleus.

There are also exceptions such as electron. In the case of electron, it is presumed that the effect of increasing the distribution of the charge like the orbital model should be reflected.

$$R_{es-muon} = \frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{mc^2}) = \frac{(-1)^2}{105.67 \times 10^6}(8.64 \times 10^{-10})(m) = 8.17 \times 10^{-18}m \tag{28}$$

$$R_{es-Tau} = \frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{mc^2}) = \frac{(-1)^2}{1.7768 \times 10^9}(8.64 \times 10^{-10})(m) = 4.86 \times 10^{-19}m \tag{29}$$

$$R_{es-W^{\pm}} = \frac{3}{5}(\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{mc^2}) = \frac{(1)^2}{80.39 \times 10^9}(8.64 \times 10^{-10})(m) = 1.07 \times 10^{-20}m \tag{30}$$

Even in the case of neutral particles, there are cases where there are positive and negative charges inside the particle. In the case of composite particles, the electrostatic self-energy for each charge distribution and the binding energy of two charges must be considered. (ex. meson)

6. Minimum size of charged particles

The equation (3) means that if infinitesimal charges are uniformly distributed within the radius R_{es}, the size of positive-value binding energy becomes equal to that of mass energy. When the particle size or charge distribution is smaller than R_{es}, a situation occurs in which the electrostatic self-energy exceeds the total energy of the particles. Therefore, the radius R_{es} acts as the lower limit of the particle size.