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Article

Mass Model and Calculation Methods for Charged Leptons

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Abstract

It is still an open question that how the masses are formed for charged leptons. The widely accepted Yukawa coupling mechanism generally have quite randomized coupling constants for their masses. In this paper, we tried to build a simple model to calculate the masses of charged leptons. We assumed that the masses are formed by coupling of the plasma characteristic energy from the particle-antiparticle pairs in the background sea, and the electric potential inside the Compton ball. The internal structure of the charged leptons is thought to have three states, i.e. the negative charge, the positive charge and the Planck scale Kerr black hole. For electron and muon, the zitterbewegung is formed by positive charge and negative charge, but for tau, the excited zitterbewegung is formed by negative charge and the Planck scale Kerr black hole. The calculations of this simple model give quite close values for the charged leptons as compared with the lab results. We think we may need pay more attention on the internal structure of a particle.

Keywords: mass; coupling; Compton ball; Planck scale black hole; zitterbewegung

I. Introduction

In standard model of particle physics, fermion masses are thought to be generated via Yukawa coupling. However, the coupling constants seems to be quite randomized, which makes it perplexing in explaining how the masses are formed to have the current observed values, and why there are three flavors observed. It is desirable to have a mechanism that tells us how to make these parameters calculable, and we noticed that physicists even have the goal of removing any mention of mass from the basic equations of physics[1,2].

People once thought that the mass of electron is formed purely by electromagnetic (EM) fields[3]. But this can not explain why there are three flavors for electrons. Now people agree that there are two parts of mass for electrons, i.e., the EM mass and Higgs mass, but it is still unknown what fraction of the electron's mass is due to its interaction with the EM field, and the exact contribution from the Higgs field part is not known too[4,5]. Recently, there are a class of models in which the masses of the third generation of fermions are found from the tree level approximation, while masses for the second and first generations are produced respectively by one-loop and two-loop radiative corrections[6]. But these models seem not realistic[7]. To explain the three flavors of fermions, people have tried to build a three dimensional time model[8]. But it is a problem why there are three dimensions for time, and anyway we think the price paid is too high. In reference [9–11], it is shown that the electron mass could be corrected nonperturbatively by externally applying a strong EM field. This may tell us that EM field is very important for the generation of mass.

In this paper, we tried to give a model to calculate the masses of charged leptons. We found the mass could be well found by coupling the EM field generated by itself and the plasma frequency of the particle-antiparticle pair background sea. The EM field generated by itself is highly correlated

with the Higgs field[12], but generally it is not a simple Yukawa coupling. The concepts of Compton length and the three-dimensional Compton ball are important for describing the mechanism. We studied the internal structure with zitterbewegung(ZBG) for the charged leptons[13–15]. The calculated values are quite close to the experimental results. In section II, we described the mechanism in detail on how to get the EM field generated by itself, and the way to calculate the plasma frequency, and the coupling equation. Calculations are given for all three flavors of electrons. Discussions and conclusions are made in section III.

II. Mass Model and Calculation Methods

We know the internal structure of an electron with mass m is in the ZBG state, in which there are equal contributions from both positive and negative energy states. This picture could be used to describe the interaction between background virtual electron-positron pair too[13–15]. The pair at the beginning is massless and could move at light speed and are separated with a Compton length $\lambda_0 = h/(mc)$. And interaction between the virtual electron and positron gives them an EM mass by an amount equal to[15]:

$$m_z c^2 = -e\phi = mc^2 \alpha / 2\pi \quad (1)$$

The movement of this pair of states includes the motion of its center of mass with EM mass $2m_z$, and relative motion with EM mass $1/2m_z$. For the motion of center of EM mass, it has the energy of $2m_z c^2$. For the relative motion, its Compton length is $\lambda_{zr} = 2h/(m_z c)$. For relative motion, there are potential energy between the positive state and negative state. The potential can be treated as the energy of a particle with $1/2m_z$ moving in a Compton ball with radius equal to λ_{zr} . The Compton ball has a periodic boundary, but for simplicity, here we just treat it as a ball with infinite large potential in the sphere. The ground state energy for this sphere is $E_r = \frac{\pi^2 \hbar^2}{1/2m_z \lambda_{zr}^2}$. So the total energy of this pair of states is:

$E_{zt} = 2m_z c^2 - E_r = 2m_z c^2 - \frac{\pi^2 \hbar^2}{1/2m_z \lambda_{zr}^2}$. (2) Its Compton length is: $\lambda_{zt} = hc/E_{zt} = hc/[2m_z c^2 - \frac{\pi^2 \hbar^2}{m_z \lambda_{zr}^2}]$, which means the charge is uniformly distributed in the Compton ball with radius λ_{zt} . Obviously λ_{zt} is much larger than λ_0 . And at each point inside the Compton ball with radius λ_{zt} , it will have a charge density $n = \frac{1}{4/3\pi \lambda_{zt}^3}$ and mass m , and here the mass is taken to be the mass of $e \pm$ that can be normally generated from the background vacuum with a value of 0.511MeV. This forms a state of matter quite like plasma, and we can get its characteristic energy as:

$$E_{zp} = \hbar \left(\frac{e^2}{4/3\pi \lambda_{zt}^3 \epsilon_0 m} \right)^{1/2} \quad (3)$$

Later, we will show that this background energy E_{zp} contributes one part for calculating the electron mass. Here we will further work on the other part.

In paper [12], we showed that:

$$\square(A^\mu A_\mu^+) = -\alpha_0 \cdot A^\mu A_\mu^+ \ln(\Omega |A^\mu A_\mu^+|^2) + (\square A^\mu) A_\mu^+ + A^\mu (\square A_\mu^+) \quad (4)$$

If neglecting the magnetic term, which is much smaller than the electric potential term, equation (4) could be written as:

$$\square(\phi^2) = -4\alpha_0 \phi^2 \ln(\beta|\phi|) + 2 \frac{\rho}{\epsilon_0} \phi \quad (5)$$

The right hand side of equation (5) gives the potential term for the Lagrangian as:

$$L_V = \frac{4\alpha_0}{3} \phi^3 \left(\ln \beta |\phi| - \frac{1}{3} \right) - \frac{\rho}{\epsilon_0} \phi^2 \quad (6)$$

To make L_V have the minimum value, we divide equation (6) by $2\phi_m$, and choose $\beta|\phi_m| = 1$, then we can get $\frac{4\alpha_0}{9} \phi_m - \frac{\rho}{\epsilon_0} = 0$, and then

$$\phi_m = \frac{9\rho}{4\alpha_0 \epsilon_0} \quad (7)$$

This gives an energy $e\phi_m = \frac{9\rho e}{4\alpha_0 \epsilon_0}$, which we think contributes the other part for calculating the electron mass. Here $4\alpha_0 = 2m_H^2$, and m_H is the mass for Higgs particle. $\rho = \frac{e}{4/3\pi \lambda_{0x}^3}$, with $\lambda_{0e} = h/(1/2m_e c)$, and $\lambda_{0\mu} = h/(1/2m_\mu c)$. m_e is the mass for electron, and m_μ is the mass for muon. We will discuss the Compton radius of tau later. It shall notice that there is a factor of 1/2 in the expression

for the Compton radius, and this means that it is about the motion of the positive and negative states inside the electron, and $e\phi$ is the relative potential between the positive and negative states with relative mass of $1/2m_e$ or $1/2m_\mu$.

The Dirac equation could be written as $(i\gamma_u\partial^u - e\phi - E_{zp})\psi = 0$

Acting on the left with $(-i\gamma_u\partial^u - e\phi - E_{zp})$, we get:

$$(-i\gamma_u\partial^u - e\phi_m - E_{zp})(i\gamma_u\partial^u - e\phi_m - E_{zp})\psi = 0 \quad (8)$$

The mass then can be defined as:

$$m_t = \sqrt{2e\phi_m E_{zp}} \quad (9)$$

We can use the above equations to calculate the mass of electron. From equation (3) (7) and (9), we can get $E_{zp} = 0.492eV$, $e\phi_m = 1.24GeV$. Here $e\phi_m$ is much less than the vacuum expectation value. The total energy could be:

$$e\phi_{me} = e\phi_m + V_H = 1.24GeV + 246GeV = 247.2GeV \quad (10)$$

And the calculated electron mass is $0.497MeV$. The same process can be applied to get the mass of muon, which is $102.5MeV$ with $e\phi_m = 1.05e7GeV$.

To calculate the mass of tau, we divide charge density $\rho = \frac{e}{4/3\pi\lambda_{0x}^3}$ with a factor:

$$f_p = E_{Planck}/E_{QNM} \quad (11)$$

Here E_{Planck} is the energy of the Planck scale Kerr black hole(PKBH), and E_{QNM} is the energy of the quasi-normal mode of the PKBH. And we also set:

$$\lambda_{0x} = \lambda_{0\tau} = hc/m_\tau. \quad (12)$$

Using equation (7) and (9), we get the mass of tau is $1.82GeV$ with $e\phi_m = 3.36e9GeV$.

We will try to explain why there is a factor f_p and why the Compton radius of $\lambda_{0\tau}$ is different from λ_{0e} and $\lambda_{0\mu}$ by a factor of 2. First $e\phi_m$ is the internal potential energy of the tau between positive energy state with charge -e and negative energy state with charge +e, which forms the zitterbewegung. Our conjecture here is that the zitterbewegung for tau is now between the positive energy state with charge -e and the energy state of PKBH. For this picture, we know:

$$E_{Planck}\Delta t_p = E_{QNM}\Delta t_Q = \hbar \quad (13)$$

For a period of time ΔT , $\Delta T/\Delta t_p$ gives the times for the energy state to be the PKBH, while $\Delta T/\Delta t_Q$ gives the times for the energy state to be -e charge state. Therefore, if we have one energy state of PKBH, then the chance for us to have one -e energy state is just:

$$(\Delta T/\Delta t_Q)/(\Delta T/\Delta t_p) = \Delta t_p/\Delta t_Q = E_{QNM}/E_{Planck} = 1/f_p \quad (14)$$

Therefore, in this way, we can get that the charge density and the $e\phi_m$ shall be divided by the factor of f_p . The mass of the charge then becomes m_τ rather than $1/2m_\tau$ for there is no +e state anymore. It shall note that here the treatment including equation (13) and the factor $1/f_p$ is quite similar to that of the squeeze state and factor in quantum optics[16].

III. Discussion

First, from equation (9), we find the masses of charged leptons are the coupling of two parts: one is the plasma characteristic energy and other is the electric potential inside the Compton ball. We used a self-consistent calculation method to obtain mass. That is, we first assume a particle have mass m , and then this particle will have Compton radius and it will form a Compton ball for the particle with uniform distribution. And then we use equation (4) to calculate the electric potential inside the Compton ball. The plasma characteristic energy for that particle is also based on the EM mass calculations for the particle-antiparticle pairs in the background sea.

We know the concept of ZBG is used to describe the internal structure of the particle. A ZBG for the charged leptons generally means there are two states, i.e. the positive energy state with negative charge and negative state with positive charge inside the charged lepton. This is the case for electron and muon. But for tau, we make a conjecture that its ZBG includes the positive energy state with negative charge and the negative state with a PKBH. That is, for the internal structure of the particle, we generally need to consider three states: the negative charge, the positive charge and the PKBH. For electron and muon, the internal structure is in the ground state, i.e. the ZBG formed by positive

charge and negative charge, but for tau, the internal structure is in the excited state, i.e. the ZBG formed by negative charge and the PKBH.

The masses for charged leptons we calculated are about 3% derivation from those obtained from the experiments. One possible reason is that we only consider the electric potential inside the charged leptons, and it may need to further consider the magnetic field part. And the mass value fixed by quantum field theory may contribute another part. And it needs to point out that the model we built here and calculation methods are quite simple, and some of the details may need further consideration, such as E_r in equation (2) assumed an infinite large potential in the sphere.

IV. Conclusion

In this paper, we built a simple model to calculate the masses of charged leptons. The model assumed that the masses are formed by the coupling of the plasma characteristic energy from the particle-antiparticle pairs in the background sea, and the electric potential inside the Compton ball. The internal structure of the particle needs to consider three states: the negative charge, the positive charge and the PKBH. For electron and muon, the ZBG is formed by positive charge and negative charge, but for tau, the excited ZBG is formed by negative charge and the PKBH. This model and the calculation methods are simple, but give quite close values as compared with the experimental results. In future works, it will be interesting to calculate the masses of quarks based on this simple model.

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