10. Composite Particles

In this section we will be calculating the properties of a series of particles, such as the proton, the neutron, the muon etc. which are formed by the different combinations of electrons and quarks.

10.1 Introduction

According to the Standard model of particle physics (SMPP), the electron, the muon and the tau are one-off particles, with the same charge and spin and which basic differences are:

- The electron is stable whereas the other two particles disintegrate.
- The masses are different.

Likewise, the associated neutrinos, are one-off particles, with no charge and the same spin, the only difference is that the mass of each of them is different.

In order to distinguish them, it is necessary to introduce the concept of Leptonic number which is kept in the interactions, for instance the beta decay of the neutron:

$$\begin{aligned} & n \rightarrow p + e^{-} + \overline{\upsilon}_e \\ & L: 0 = \ 0 + 1 \ - \ 1 \end{aligned} \qquad (10.1)$$

According to the SMPP, the neutron turns into a proton because the d quark changes its flavor with no apparent reason and turns into a u quark

On the contrary, in the model developed in this section, we will see that there is a cause that leads to such change. Besides, it is not necessary to introduce the concept of Leptonic number, as the process is undertaken in a simple and natural way.

10.2 Elementary Particles

They are stable particles that lack internal composition and give rise to the rest of the particles, which do not have chain disintegration but turn into other particles, changing their properties, such as the mass, charge, spin etc.

Both the muon and the tau disintegrate resulting in electrons or positrons and neutrinos or antineutrinos, suggesting that they must be formed by a combination of other particles. The same applies to the second and third generation quarks. On the contrary, the up quarks and the down quarks are formed by and only 4D Planck's atom and so they are stable.

The necessary and sufficient condition so that a particle is stable, is that the particle does not have other components internally, and thus, it does not disintegrate, but becomes, taking as an example the collision between electron and positron giving rise to two photons.

We have previously seen how the electron and the up and down quarks are formed by an only 4D Planck's atom in a way that when they spin, they drag the atoms into the space and time. In this line, we can say that these particles are elementary or simple, this is to say, they are not formed by other particles like the atoms, however they have a structure formed by the 4D Planck's atoms.

The simple particles do not disintegrate, they just transform by the collision between two particles. The number of final simple particles must be equal to the initial one. The final total spin is equal to the initial one. If the particle is not at the minimum state of energy (electron), the loss of energy generates new particles, fundamentally photons.

10.3 Formation of up quarks and down quarks by collisions

The up quark (antiquark) , can also be obtained by the collision between a down quark (antiquark) and a positron (electron), producing in this case an electronic antineutrino (neutrino) with negative charge (positive)

$$d + e^{+} \leftrightarrow u + \overline{\upsilon}_e \qquad \overline{d} + e^{-} \leftrightarrow \overline{u} + \upsilon_e \tag{10.2}$$

If we take the spin into account, results in:

$$d(+1/2) + e^{+}(-1/2) \rightarrow u(+1/2) + \overline{\upsilon}_e(-1/2) \tag{10.3}$$

The *d* quark with spin +1/2, collides with a positron (J=-1/2), producing an electronic antineutrino with spin -1/2 plus a *u* quark (J=1/2). In the second transformation, the anti d quark with a spin -1/2, collides with an electron (J=+1/2), producing a *u* antiquark (J=-1/2) plus an electronic neutrino, with a positive charge and a spin +1/2.

The terminology used is:

- The electron (positron) transfers its rotation or charge to the quark, thus, becoming an electronic neutrino (antineutrino) with a positive charge (negative) but keeping its spin.

- The quark with positive charge (negative) becomes a quark with negative charge (positive), keeping the total charge, if we regard the neutrino charge (antineutrino) beneath contempt, with $J=-1/2$ ($J=+1/2$).

Clearly the inverse transformations are also possible but as for the up quark-antiquark, the transformations are:

$$u + e^- \leftrightarrow d + \upsilon_e \qquad \overline{u} + e^+ \leftrightarrow d + \overline{\upsilon}_e \tag{10.4}$$

According to the energy of the collision a photon (antiphoton) can be generated instead of a neutrino (antineutrino)

$$d + e^+ \rightarrow u + \gamma \qquad \overline{d} + e^- \rightarrow \overline{u} + \gamma \tag{10.5}$$

Finally, the collision between a neutrino with an electron can generate the pair down anti-up and the antineutrino with the positron will generate the pair up anti-down.

$$e^- + \upsilon_e \rightarrow d + \overline{u} \qquad e^+ + \overline{\upsilon}_e \rightarrow \overline{d} + u \tag{10.6}$$

10.4 Characteristics of the composite particles

They will be formed by the different combinations of simple and unitary particles, being the majority unstable.

Spin	Particle	Antiparticle
1/2		
-1/2		

The particles and the antiparticles are combined among them so as to give rise to particles and antiparticles with the fractional charge (±1/3 ó ±2/3), a neutral element or an integer multiple of the charging unit.

Each particle or antiparticle can have a positive or a negative spin, depending on the orientation of the magnetic field. Positive spin for the particle (antiparticle) oriented towards the direction (contrary) of the reference axis.

10.5 The Muon

The muon, according to the standard model is the second generation of the electron. Furthermore, is an unstable particle just like the neutron and its average life is 2,19703 10^{-6} s se it is calculated by using the Fermi theory, being its mass[38]:

m_μ=105.658369 MEV

The decay process, according to the MEFP is by weak interaction in:

$$\mu^- \rightarrow e^- \overline{\upsilon}_e \upsilon_\mu \tag{10.7}$$

Where the muon neutrino has been introduced ν_μ, different to the electronic neutrino ν_e.

The magnetic moment is

$$\mu_\mu = \alpha_\mu \frac{q\hbar}{2m_\mu} \tag{10.8}$$

The experimentally gyromagnetic factor[38] measured is:

g_μ = 2.002331842

Supposing that the muon is formed by the quark down, its corresponding antiquark plus an electron.

$$\mu^- = d\overline{d}e^-(J = 1/2) \tag{10.9}$$

Mass

We have seen that the mass is on account of the curvature of the space-time fourth dimension, likewise, the electromagnetic fields curve the space-time around them, in a way that the energy of the field at the *r* distance equal to λ_μ, coincides with unitary element energy, this is to say with the electron energy.

In particular results in:

$$E(r) = E(\lambda_\mu) = E_u \tag{10.10}$$

$$K\frac{q_{\overline{e}}q_{\overline{d}}}{r} + K\frac{q_{\overline{e}}q_{\overline{d}}}{r} = 2K\frac{q_{\overline{e}}q_{\overline{d}}}{r} = \frac{2}{3}K\frac{q_{\overline{e}}q_{\overline{e}}}{r} \tag{10.11}$$

Where $q_{\overline{e}}$ is the electron charge and $q_{\overline{d}}$ the quark down charge. For $r = \lambda_\mu$

$$\frac{2}{3}\frac{Kq^2}{\lambda_\mu} = \frac{2}{3}\frac{Kq^2}{\hbar c}m_\mu c^2 = m_e c^2 \tag{10.12}$$

We will have to take into consideration other energies, such as the magnetic, the kinetic and the quarks potential as well as the characteristic mass of the electron. In all of them, the most important one seems to be the electron mass, thus, it results in:

$$m_\mu = \frac{3}{2\alpha}m_e + m_e = \text{ 105,55 MeV} \tag{10.13}$$

If we exchange the down quark for the up quark the combination obtained is:

$$\mu^- = u\overline{u}e^- (J = 1/2) \tag{10.14}$$

The mass will be given by:

$$K\frac{q_e^- q_u^-}{r} + K\frac{q_e^- q_u^-}{r} = 2K\frac{q_e^- q_u^-}{r} = \frac{4}{3}K\frac{q_e^- q_e^-}{2r} \tag{10.15}$$

The two of the denominator is on account of obtaining two up quarks out of three positrons. For $r = \lambda_\mu$, obtenemos para la masa, el mismo valor.

Then, we have two types of muons:

- Type d muon. $\mu_d^- = d\overline{d}e^- (J = 1/2)$
- Type u muon. $\mu_u^- = u\overline{u}e^- (J = 1/2)$

There must be a slight difference between the masses on account of the differences of the constituent elements.

Decays

As for the decays

- The number of final particles is equal to the initial ones.
- The spin is kept

The possible decays are:

a) Collision of particles. The collision between the down quark with the anti-down ($d - \overline{d}$) will give rise to a pair of neutrino-antineutrino or two photons (photon - antiphoton to keep the spin), remaining the electron free.

$$\mu^- \rightarrow e^- + \upsilon_d + \overline{\upsilon}_d \tag{10.16}$$

$$\mu^- \rightarrow e^- + \gamma + \gamma$$

The electron-photon decay is not possible, as the number of final particles varies in comparison with the initial ones.

The collision $\overline{d} - e^-$, will produce an anti-up quark plus an electronic neutrino with spin +1/2 or antineutrino –1/2.

$$\mu^- \rightarrow \overline{u}d + \upsilon_e = \pi^- + \upsilon_e \tag{10.17}$$

$$\mu^- \rightarrow \overline{u}d + \overline{\upsilon}_e = \rho^- + \overline{\upsilon}_e \tag{10.18}$$

These disintegrations are prohibited by the principle of the conservation of the energy, as the obtained particles have a greater mass than the initial one.

b) Pair production. The pair production occurs because the particles give rise to other particles with less energy when split. The pairs are generated to compensate that energy difference.

The production of a pair electron-positron, will swap the quarks anti-down and down to anti-up and up, respectively, plus an electronic neutrino-antineutrino (equation 10.3).

$$d\bar{d}e^- + e^- + e^+ \rightarrow u\bar{u}\,\upsilon_e + \bar{\upsilon}_e + e^- \rightarrow \upsilon_\mu + \bar{\upsilon}_e + e^- \qquad (10.19)$$

This way formed, the muon neutrino turns out to be a composite particle of:

- Electronic neutrino
- Up quark
- Antiquark up

Which mass will be far many magnitude orders greater than the mass of the electronic neutrino.

If the electronic antineutrino joins the pair $u-\bar{u}$, results in:

$$d\bar{d}e^- + e^- + e^+ \rightarrow u\bar{u}\,\bar{\upsilon}_e + \upsilon_e + e^- \rightarrow \bar{\upsilon}_\mu + \upsilon_e + e^- \qquad (10.20)$$

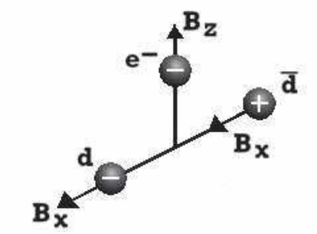

Figure 10.1 Muon’s possible internal structure.

There must be another particle with the same structure, charge –1 and spin 3/2.

$$p^- = d\bar{d}e^-(J = 3/2) \qquad (10.21)$$

If we take into account that the magnetic fields are oriented towards different directions, the internal structure for the combination with spin ½ can be as shown in the figure (10.1).

Magnetic Moment

If we gather that the muon is a composited particle of a quark-antiquark down and an electron. The magnetic moment will be:

$$\mu_\mu = \mu_{e^-} + \mu_{d^-} + \mu_{d^+} \qquad (10.22)$$

Being μ_{e^-} the electron magnetic moment, μ_{d^-} the quark down magnetic moment and μ_{d^+} the antiquark down magnetic moment.

The antiquark down magnetic moment will be:

$$\mu_{d^-} = \frac{q_d vr}{2} = \frac{q_d \omega_d r^2}{2} = \frac{q/3\ 3\omega\ r^2}{2} = \frac{q\omega\ r^2}{2} \qquad (10.23)$$

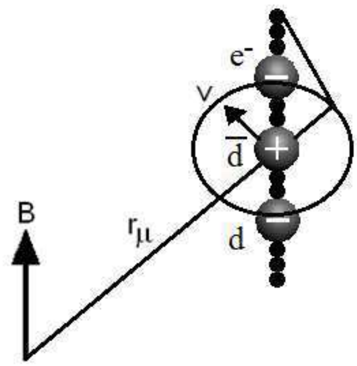

Figure 10.2 Contribution to the d quark and the electron to the muon’s momentum.

Which coincides with the electron. The quarks, just like the electron in freedom state, verify the equation (8.15). The down antiquark spins in the opposite direction to the electron and the down quark.

The contribution to the antiquark momentum will be the same seen in the electron, whereas the contribution to the down quark momentum and the electron will be:

$$\mu_{d^-} = \mu_e = \frac{q\omega\, r^2}{2} = \frac{q\omega\, r^2}{2}\left(\frac{2\alpha\lambda\!\!\!^{-}_{\mu}}{4\pi}\right)^2 \tag{10.24}$$

Then the total moment will be:

$$\mu_\mu = \frac{qv\lambda_\mu}{2}\left(\left(1+\frac{\alpha}{4\pi}\right)^2 + 2\left(\frac{\alpha^2}{4\pi^2}\right)\right) = \alpha_\mu \frac{q\hbar}{2m_\mu} \tag{10.25}$$

Where:

$$\alpha_\mu = \left(1+\frac{\alpha}{4\pi}\right)^2 + \frac{\alpha^2}{2\pi^2} \tag{10.26}$$

And the gyromagnetic factor (equation (8.38)):

$$g_\mu = 2\left(1+\frac{\alpha}{4\pi}\right)^2 + \frac{\alpha^2}{\pi^2} = 2.00232890 \tag{10.27}$$

The gyromagnetic factor coincides with an accuracy of 5 significant numbers with the one experimentally measured.

10.6 The Pion

In SMPP, a pion is any of three subatomic particles: π^0, π^-, and π^+. Each pion consists of a quark and an antiquark and is therefore a meson.

The π^-, and π^+ mesons have a mass of 139.6 MeV/c^2 and a mean lifetime of 2.6×10^{-8} s. They decay due to the weak interaction[38].

$$\pi^- \to \mu^- + \upsilon_\mu \quad 99.9877\% \tag{10.28}$$

$$\pi^- \to e^- + \overline{\upsilon}_e \quad 0.0123\%$$

Mass

The mass is due to constituent quarks electromagnetic energy, then:

$$E(\lambda\!\!\!^{-}) + \frac{1}{\alpha} E_c = \frac{1}{2}(\frac{m_d - m_e}{2})c^2 \quad (10.29)$$

Since we have two quarks, the electromagnetic energy in the distance $r = \lambda\!\!\!^{-}_\mu$, will be:

$$\frac{K}{r}(9q_d q_d) = \frac{Kq^2}{\lambda\!\!\!^{-}_\mu} = \frac{Kq^2}{\hbar c} m_\pi c^2 = \alpha\ m_\pi c^2 \quad (10.30)$$

We have to take into consideration the kinetic energy, given by:

$$E_c = \frac{1}{2}\left(2m_d \frac{1}{81}\alpha^2\right)c^2 = \frac{1}{9} m_e \alpha^2 c^2 \quad (10.31)$$

$$\alpha\ m_\pi c^2 + \frac{1}{9} m_e \alpha c^2 = 2m_e c^2 \quad (10.32)$$

Thus obtaining for the pion a mass of:

$$m_\pi = \left(\frac{2}{\alpha} - 1\right) m_e = 139{,}54 \text{ MeV/c}^2 \quad (10.33)$$

Decays

a) Collision of particles. The collision $d - \bar{u}$, unlikely because of the electrostatic repulsion, will generate an electron plus an antineutrino.

$$\pi^- = d - \bar{u} \rightarrow e^- + \bar{\upsilon}_e \quad (10.34)$$

b) Pair production. The electrostatic repulsion produces two particles (down quark and up antiquark) with lower energy. Therefore a pair electron-positron is produced to compensate such loss of energy.

The production of an electron-positron pair will turn the anti-up quark into down quark, producing an electronic neutrino, as a consequence of the collision between the positron and the anti-down quark (equation (10.35)).

$$\bar{u} + e^+ \rightarrow \bar{d} + \upsilon_e \quad (10.35)$$

This would lead to:

$$\pi^- + e^+ + e^- = d\bar{d}e^- + \upsilon_e \quad (10.36)$$

The particles formed this way have lower energy than the pion, thus, a second generation of pairs formed by a down quark and an anti-down will be produced.

$$\pi^- + e^- + e^+ + d + \bar{d} = d\bar{d}e^- + d\bar{d}\,\upsilon_e \rightarrow \mu^- + \upsilon_\mu \quad (10.37)$$

Being the muon formed by the combination of the down quark, down anti-quark plus an electron. The muon neutrino will be formed by the combination of the down quark, the down anti-quark plus electronic neutrino.

The combination $u\bar{d}$, can be possible with a spin unit or null.

10.7 The Neutron.

The neutron is a baryon formed by two down quarks and an up quark. Outside the atomic nucleus is unstable, emitting an electron and an antineutrino, turning into a proton, with an average life of τ = 885,7 $\pm$ 0,8 s and a mass of[38]:

$$1.674\ 927\ 211(84) \times 10^{-27} \text{ kg}$$

The combination of three quarks can give rise to two different particles, one with 3/2 spin and another one with a ½ spin, the one which constitutes the neutron. As the spin is ½, it indicates that the down quarks have the magnetic field oriented to the opposite direction (antiparallel spins)

Mass.

The neutron's mass is due to the electromagnetic energy of the constituent quarks, then:

$$E(\lambda\!\!\!^{-}) = m_e c^2 \tag{10.38}$$

Since we have three quarks, the electromagnetic energy at an equal distance to its wavelength ($r = \lambda\!\!\!^{-}_n$), will be:

$$\frac{K}{r}\left(\frac{q_u}{q} q_d q_d\right) = \frac{2}{27}\frac{Kq^2}{r} = \frac{2}{27}\frac{Kq^2}{\hbar c} m_n c^2 = \frac{2}{27}\alpha\ m_n c^2 \tag{10.39}$$

We have to take into consideration other energies such as the kinetic and the quarks potential. Let's start by seeing the relationship of the kinetic energy with the electromagnetic one for the electron.

According to the Bohr's atomic model, the system will be stable for the minimum energy state, with an average velocity given by:

$$\frac{mv^2}{\alpha} = \frac{Kq^2}{\lambda\!\!\!^{-}} \tag{10.41}$$

$$v^2 = \frac{Kq^2}{\lambda\!\!\!^{-} mc}\alpha c \tag{10.40}$$

Which indicates that the kinetic energy will have to be divided by α, to be considered as well as the electromagnetic one at a distance equal to the wavelength.

Assuming a circular orbit, the potential energy will be two times the kinetic one, and the system's total energy is:

$$E = E_p - E_c = E_c \tag{10.42}$$

The electrostatic repulsion provides the potential energy, hence, we have to add it, instead, so as to the quarks spin around one another, the system must provide with the kinetic energy.

Likewise, the average velocity of the up quarks is:

$$v_u = \frac{kq_u^2/2}{\hbar c}c = \frac{2}{9}\alpha c \tag{10.43}$$

Two up quarks are obtained from three positrons, hence, we have to divide by 2. The average velocity of the down quarks is:

$$v_d = \frac{kq_d^2}{\hbar c}c = \frac{1}{9}\alpha c \tag{10.44}$$

The kinetic energy is given by:

$$E_c = \frac{1}{2}\left(m_u \frac{4}{81}\alpha^2 + 2m_d \frac{1}{81}\alpha^2\right)c^2 = \frac{1}{2}\left(\frac{9}{2}m_e + 18m_e\right)\frac{6}{81}\alpha^2 c^2 = \frac{45}{54}m_e \alpha^2 c^2 \tag{10.45}$$

And dividing by alpha:

$$\frac{1}{\alpha}E_c = \frac{5}{6}m_e\alpha\ c^2 \tag{10.46}$$

We obtain the kinetic energy and the quarks potential, seen from outside, then, the total energy will be sum of both:

$$E(\lambda\!\!\!^{-}) + \frac{1}{\alpha}E_c = m_e c^2 \tag{10.47}$$

1/α is the part of the energy transferred to the outside. As for the electron and any particular in general it can verified that:

$$\frac{1}{\alpha}\ \frac{Kq^2}{\lambda\!\!\!^{-}_e} = m_e c^2 \tag{10.48}$$

Substituting the equations (10.39) and (10.40) in (10.47) it results in:

$$\frac{2}{27}\alpha\ m_n c^2 + \frac{5}{6}\alpha\ m_e c^2 = m_e c^2 \tag{10.49}$$

From where the value for the neutron’s mass is obtained:

$$m_n = \frac{27}{2}\left(\frac{1}{\alpha} - \frac{5}{6}\right) m_e = 1{,}67497\ 10^{-27}\ \text{Kg} \tag{10.50}$$

The radius will be given by:

$$\frac{Kq^2}{r} = m_n c^2 \tag{10.51}$$

$$r_n = \alpha \hat{\lambda}_n = 1{,}5326\ 10^{-18}\ \text{m} \tag{10.52}$$

Being r_n, the quarks maximum radius separation.

Neutron beta decay

a) Pair production. The neutron decay in a freedom state is :

$$n \rightarrow dud + e^+ + e^- \leftrightarrow udu + \overline{\upsilon}_e + e^- \rightarrow p + W^- \rightarrow p + \overline{\upsilon}_e + e^- \tag{10.53}$$

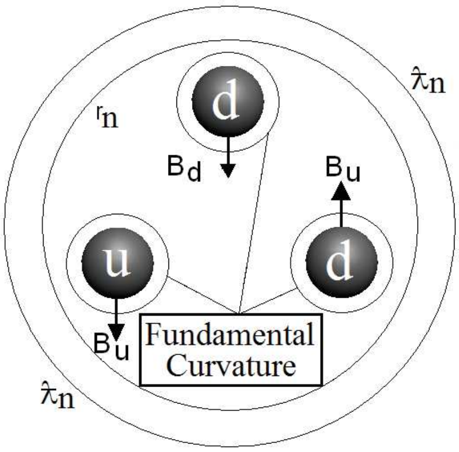

Figure 10.3 Neutron structure.

The production of a electron-positron pair produces the collision between the down quark and the positron, given rise to the transformation of the down quark into up quark and the positron into antineutrino, which as long as stays under the electron attraction (lowest velocity than the escape velocity) will form the W^-. In this way, the number of particles, energy and spin are kept.

One likely structure, is shown below, where the quarks are not within the neutron, but they are the ones which delimit the space curvature and constitute what we observe as neutron.

Being the two magnetic fields probably oriented to the directions x and z or any other similar combination.

10.8 The Proton

According to the SMPP protons are made up of two up quarks and one down quark, which are also united by the strong nuclear force subtended by gluons. The proton average life is: $\tau > 2{,}1\ 10^{29}$ years and its mass is[38]:

1.672 621 637(83) x 10^{-27} kg.

The proton's mass (or neutron's) has been calculated [39] using only the net QCD as described by Andreas S. Kronfeld [40]. La masa calculada es de 936 ± 25 MeV/c^2 The calculated mass is 939 MeV/c^2. In order to calculate the mass the net QCD has been used (where the space time is substituted by a net of interconnected points) and so many teraflops are required.

Mass

The same as for the neutron, the proton mass is due to the electromagnetic energy of the constituent quarks, then:

$$\frac{K}{r}\left(\frac{q_u q_u}{2q} q_d\right) = \frac{2}{27}\frac{Kq^2}{r} = \frac{2}{27}\frac{Kq^2}{\hbar c} m_n c^2 = \frac{2}{27}\alpha\ m_p c^2 \tag{10.54}$$

We have to bear in mind that we need three positrons to obtain two up quarks, thus, the electromagnetic energy will have to be divided by two. The kinetic energy will be:

$$E_c = \frac{1}{2}\left(2m_u \frac{4}{81}\alpha^2 + m_d \frac{1}{81}\alpha^2\right)c^2 = \frac{1}{2}(9m_e + 9m_e)\frac{9}{81}\alpha^2 c^2 = m_e \alpha^2 c^2 \tag{10.55}$$

From where:

$$\frac{2}{27}\alpha\ m_p c^2 + \alpha\ m_e c^2 = m_e c^2 \tag{10.56}$$

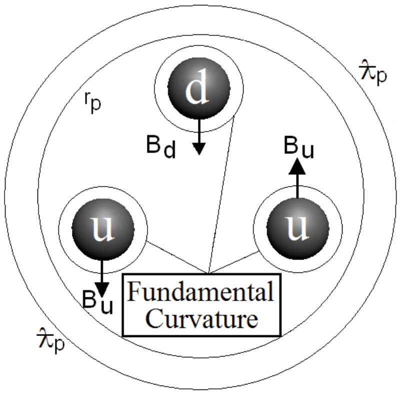

Figure 10.3 Protron structure.

Obtaining for the proton mass:

$$m_p = \frac{27}{2}\left(\frac{1}{\alpha} - 1\right) m_e = 1{,}67292\ \ 10^{-27}\, Kg. \tag{10.57}$$

One possible structure is shown below, where the quarks are not within the proton, but they delimit the space curvature and constitute what we observe as proton.

Being the magnetic fields probably oriented to the directions x, y, z or any other similar combination.

The proton radius is:

$$r_p = \alpha \lambda\!\!\!^{-}_p = 1{,}5347\ 10^{-18}\ \text{m} \tag{10.58}$$

10.9 Conclusion

According to the standard model, both the muon and the Higgs boson are simple particles and therefore the lack structure. Nevertheless, the combination of particles (quarks and electrons) and antiparticles, give rise to composite particles with all the identic characteristics of the ones predicted by the Standard Model. Are they the Standard Model particles? Or are they other different?

From the electromagnetic field energy produced by the combination of particles and antiparticles it is possible to calculate the mass of any particle by using simply paper and pencil with no need for complex programs that require big computers with a great calculus power.

Likewise, the decays are extremely simple with elementary rules.