

ANTIMATTER AND TACHYONS

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Abstract: The concepts of matter and antimatter require a new interpretation, after having shown that the relativistic mass of quantum particles is of electromagnetic nature, virtual and indeterminate, which can not be accepted by Classical Mechanics, but may be assumed by Quantum Fields Theory thanks to Uncertainty Principle.

By applying this principle in interactive processes of the radiation (photons) with electrons, it may be shown that those particles with negative mass (positrons) are moving at higher velocities than that of light in vacuum, which coincides with the analysis carried out by means of a reformulation of the relativistic equations, avoiding the space-like or negative interval (non-causal); so the particles called Tachyons may be identified with Antiparticles (positrons), based on the peculiar behavior of electrons and photons, in relation to energy and momentum.

Keywords: superluminal particles o taquiones, positrons and electrons, photons.

1. INTRODUCTION

Modern Physics (since early 20th century) has become a kind of confusion ceremonial, mainly for two reasons: 1) establishing a Relativistic Quantum Mechanics, which has assumed the inertial mass, although paradoxically there is no need of mass in Quantum Field Theory; 2) to consider that mass as the essential parameter of electromagnetic, weak and strong interactions, which must even govern the evolution of the whole Universe through Gravitation, so that the so-called “gravitational colapse” is accepted, despite the extreme smallness of the constant G with respect to the other interactions.

On the other hand, the approach to quantum description of physical phenomena has been held from Classical Mechanics, with a mass that demands a different physical meaning, since by introducing it at Relativistic Quantum Mechanics and finally Quantum Field Theory has managed to establish a Standard Model for Elementary Particles, full of fissures and cracks, as it is evidenced by the fact that it had been modified in a very short time, to accomodate Supersymmetry, Superparticles, String Theory, etc.

Therefore, there are enough reasons to carry out a detailed analysis of relativistic theory, that actually leads to a mere mathematical “artifice”, with which it is intended to give physical meaning to the parámetros that are emerging in the thread of its development.

Special Relativity is constructed on the basis of the Interval hypothesis, whose only condition is to be constant and in the case that was negative the corresponding physical event is called “non-causal” according to the Minkowski diagram.

In this situation is found the peculiar or rather singular case of Tachyons, appearing as a result of considering the existence of particles with greater speed than that of light in vacuum, c , and whose existence might be coherent as a result of a reformulation of to the relativistic theory.

2. RELATIVE TIME

As it is well known, the origin of the theory lies in the result of Michelson-Morley’s experiment, which eliminates the existence of ether in vacuum, which implies that the speed of light, c , becomes a constant universal, so that it can not be relativized with respect to the velocity of any body, v , that is, the expression, $c-v$, should not have any physical meaning.

Relativistic equations are hard to understand, that is, they are rather incomprehensible, because from the relations between coordinates (x,t) and (x',t') , attached to the fixed (O) and the moving (O') coordinates systems, where observers are placed, is established the relationship between elapsed times, cdt and cdt' traveled by light from both frames, without realizing that any measurement can only be made from one of them, fixed or moving, since both are interchangeable, on account of the "relative" character of v .

Actually, the moving frame (O') will not make sense, since the coordinates, x' disappear when entering the elapsed times, dt, dt' , to arrive at the well-known formula of time dilation: $dt = dt'/\sqrt{(1-v^2/c^2)}$ (1), but then it arises the four-dimensional space, which seems to claim the existence of that moving frame.

On the other hand, the previous formula is equivalent to $c^2 dt'^2 = c^2 dt^2 - v^2 dt^2$ (2), which indicates the geometry of the problem: the distance vdt is perpendicular to the distance, cdt' , traveled by the light emitted from the point (O'), which it appears as the geometric projection of the distance cdt , considered from the fixed frame (O).

But, there is no experiment that may prove it; this is because the relationship between dt and dt' , must be the same for any velocity, v , so that for a greater value of it, both quantities, dt' and dt are also increasing, although this is hidden when it is introduced the concept of Interval: $ds = cdt' = cdt = \text{const}$; but, *How it could be accepted a fixed elapsed time, $d\tau$?*

In any case, dt' ($d\tau$), and the velocity, v , would be a predetermined data, we might "calculate", dt , but in practice one usually determines the velocity, v , corresponding to a given relation of the times; thus, if we consider that $dt = 2dt'$, when applying (1) or (2), we obtain: $4c^2 - 4v^2 = c^2 \implies v = 0.866c$, a really *amazing result!*, which induces us to question the validity of (1) or (2) as true equations.

In this sense, we may add that the only event that takes place is the transmission of the electromagnetic wave, since the velocity, v , is just a given parameter, representing the so-called "boost" in Lorentz's Group, but it disappears in the kinematics approach.

Indeed, from the Four-dimensional space, $dr = (cdt, dr)$, we can get the four-velocity:

$$u = dr/dt' = \{cdt/dt', (dr/dt)(dt/dt')\} = dt/dt'(c, \mathbf{v}) = (c, \mathbf{v})/\sqrt{(1-v^2/c^2)} \quad (3)$$

This four-vector in the tensorial formalism may be expressed by covariant and contravariant components: $u_\mu = \{(c, -\mathbf{v})/\sqrt{(1-v^2/c^2)}\}$, $u^\mu = \{(c, +\mathbf{v})/\sqrt{(1-v^2/c^2)}\}$, so that

$$u^2 = u^\mu u_\mu = (c^2 - v^2)/(1-v^2/c^2) = c^2, \quad \text{where the four-velocity, } u, \text{ is identified with the speed of light, } c, \text{ and the velocity, } v, \text{ (whatever its value) disappear.}$$

But, we can get to the same result by "exchanging" the roles of dt and dt' , so that now the four-velocity will be: $u = (dr/dt)(dt'/dt) = (cdt'/dt, dr/dt) \implies u = (dr/dt')\sqrt{(1-v^2/c^2)} = (c, \mathbf{v})$;

this is a clear demonstration that the formulas (1) and (2) are really identities and not "true equations", since all the quantities, dt, dt' and v are variables ("indeterminate"), so the only certainty is that $dt > dt'$, but no calculation can be made from the formula (1), since the only constant is c ; this is in consonance with the "redundancy" of the observer in the moving frame. -*The "twin paradox" might only be a matter of interest from a philosophical point of view!*

This important result may be interpreted from the physical point of view as it follows:

the mathematically variable value of cdt are quantities relative to cdt' , which represents the "vacuum"; with other words, the interval, dt , is extracted from "vacuum", thanks to the velocity, v , and the absolute value of the speed of light, c .

Actually, it is not possible to measure the elapsed times that the light take to travel the distances, cdt and cdt' , but we can establish the relationship between both quantities through the parameters that define the electromagnetic wave, that is, the frequency, w , and the wave number, k , which are related according to $c = w/k$; in this case, it may be considered the identification of the elapsed times with the wave period, that is, $dt \equiv T$ and $w = 2\pi/dt$, so the time dilation, dt , according to (1), will correspond to a decrease of the frequency, w , which may account for the well-known "red-shift" radiation (Doppler effect): $w = w'\sqrt{(1-v^2/c^2)}$.

Eventually, it should be noted that due to the constancy of c , for a smaller value of wave number, k , at (O), it shall correspond a greater value at (O'), which implies a shorter wavelength: we have the so-called Lorent's "contraction".

3. RELATIVE MASS

3.1 Energy "Equation":

To get the equation of relativistic dynamics, we have only to introduce the mass, m_o in the tensor components of tetra-velocity, so that: $p^\mu = m_o u^\mu = \{m_o c/\sqrt{(1-v^2/c^2)}, +m_o v/\sqrt{(1-v^2/c^2)}\}$ and $p_\mu = m_o u_\mu = [m_o c/\sqrt{(1-v^2/c^2)}, -m_o v/\sqrt{(1-v^2/c^2)}]$, with which the four-momentum:

$$P^2 = (m_o c)^2/(1-v^2/c^2) - (m_o v)^2/(1-v^2/c^2) = [(m_o c)^2 v^2 - (m_o v)^2 c^2]/c^2 - v^2 = (m_o c)^2 \quad (4).$$

The usual four-momentum is $p = cP$, in order that the "time-like" component may be identified with the energy: $E = m_o c^2/\sqrt{(1-v^2/c^2)}$ (5) and the "space-like" with momentum:

$$p = m_o v/\sqrt{(1-v^2/c^2)} \quad (6), \quad p = cP, \quad \text{so that we get the well-known formula of **Energy**:$$

$$E^2 - c^2 p^2 \equiv (m_o c^2)^2 \quad (7)$$

But, $(m_o c^2)^2$ appears as a result of an algebraic calculation, by which the quantities E^2 and $c^2 p^2$, disappear, so the previous formula or its equivalent, $E = \sqrt{[c^2 p^2 + (m_o c^2)^2]}$, is not really an equation but an **identity**, as we have already noted with the sign.

Let us look that we may arrive at the same result from the definition of relativistic mass,

$m = m_o/\sqrt{(1-v^2/c^2)}$, implicit in the formulas (5) and (6), where we can see that the relation between m and m_o is the same as that of times, $dt, d\tau$, so we can apply the same interpretation respect the redundancy of the moving frame (O'), which we can confirm by the following points:

a) Actually, the **relativistic mass**, m , replaces to m_o , on account of the dilation factor,

$$1/\sqrt{(1-v^2/c^2)}, \text{ so that the previous formula is really the "identity", } m \equiv m_o/\sqrt{(1-v^2/c^2)} \implies$$

$mc^2 \equiv m_o c^2/\sqrt{(1-v^2/c^2)} \implies (mc^2)^2 - c^2(mv)^2 \equiv (m_o c^2)^2$ (8), which is similar to (7); then, both quantities, m and m_o vary with respect to speed, v , and in the case of $v = 0$, the mass m disappears, that is, the relativistic construction does not allows any mass "at rest".

b) We may also add that some authors (Panofski, Möller, etc.) have tried to extract the mechanical properties of mass from the Energy variation: $dE/dt = v.dp/dt = v.F = mc^2 + \text{const}$; but this result has admitted a force, F , which implies an acceleration, a , incompatible with Special Relativity.

3.2 Four-momentum:

The formula (7) becomes the Equation of Four-momentum, p , when it is considered as Interval: $p^2 = E^2 - c^2 p^2 = \text{const}$ (9); then, it turns out a "symmetry" or conservation law, in which case: $E_2^2 - c^2 p_2^2 = E_1^2 - c^2 p_1^2 \implies (m_2 c^2)^2 - c^2(m_2 v_2)^2 = (m_1 c^2)^2 - c^2(m_1 v_1)^2$;

but it is a "fake" equation, since if $v_2 > v_1 \implies m_2 > m_1$ and then, the variation of energy will be greater than that of momentum: $(m_2^2 - m_1^2)c^4 > c^2(m_2^2 v_2^2 - m_1^2 v_1^2) \implies$

$$\implies (m_2 c^2)^2 - c^2(m_2 v_2)^2 > (m_1 c^2)^2 - c^2(m_1 v_1)^2 \implies E_2^2 - c^2 p_2^2 > E_1^2 - c^2 p_1^2; \text{ so, the mass, } m_o, \text{ is variable (not constant), which is a clear demonstration of the "identity" that represents the Energy equation (7).}$$

In this sense, we may consider, m_o , as a quantity associated to "vacuum", from which is produced the relativistic mass, m , which will be the relevant quantity that after including in the **Four-momentum**: $p^2 = (mc^2)^2 - c^2(mv)^2$, will allow to study the characteristics of the Minkowski Diagram:

a) The so-called "light-cone" or Interval null: $E = cp \implies (mc^2)^2 - c^2 m^2 v^2 = 0 \implies$

$m^2 (v^2 - c^2) = 0$, but being $v = c$, the mass, m , may have any value, that is, it is "indeterminate", with what the "infinite" value assumed by the formula (5) maybe avoided; it turns out another test that the said formula is an "identity" (not an equation).

b) If $m^2 c^4 - c^2(mv)^2 > 0 \implies m^2(c^2 - v^2) > 0 \implies v < c$, we have the “timelike” Interval, where the particles will travel at a speed lower than that of light, but both v and m will also be “indeterminate”.

c) When $m_t c - m_t v < 0 \implies v > c$ we are in the “spacelike” Interval, also called non-causal, to which the *tachyons* are adjusted, that is, the particles that travel faster than light, whose mass, m_t will also be variable and as such “indeterminate”, as it occurs in the previous cases.

3.3 Electromagnetic mass:

The demonstration of the inertial nature of the mass, m_o has been established, based on the serie expansion of the Energy: $E = mc^2 = m_o c^2 / \sqrt{1 - v^2/c^2}$ when $v \ll c$:

$$mc^2 \approx m_o c^2 + 1/2 m_o v^2 \implies mc^2 - m_o c^2 \approx 1/2 m_o v^2 \implies mc^2 - m_o c^2 = E_c$$

But it turns out just a mathematical result, whose physical meaning is not clear, since both sides of the equation must be homogeneous quantities, which implies that c is not a mere constant, but acts as a velocity that no tangible body may assume; with other words, it is “incongruent” to establish the inertial nature for the mass, m_o .

However, it seems that it does not matter when the masses are excluded, as Einstein himself did in his article: *Does the inertia of a body depend upon its energy-content?*, where the previous relationship becomes: $E - E_o = (E_o/c^2)v^2/2$, $\implies m_o = E_o/c^2$, where the mass, m_o , is considered as the inertia of the radiation, for being integrated into the kinetic energy,

$E_o = 1/2 m_o v^2$, that is, the incongruity persists, even though it is explained as “energy-content” of the radiation, which is nothing more than a metaphor that an experimental science should not admit.

Actually, the formula of the kinetic energy is being used to explain the **Photoelectric Effect**: $h\nu - W = 1/2 m_o v^2$, where $E = h\nu$ is the quanta action energy, while W is the binding energy of the electrons in the metal, as a minimum energy (ground state) that it will correspond to maximum a kinetic energy of electrons; for this reason, $1/2 m_o v_{max}^2 \equiv eV$ and $W = \text{const.}$ in which case the previous equation becomes: $eV = h\nu - W \implies V = h\nu/e - \text{const.}$, that may be proved experimentally, in which case the role of kinetic energy leads to consider the inertial nature of the mass, m_o .

But, it has been overlooked that the introduction of $h\nu$ really requires a quantum approach, according to which the energy of the radiation acts on the bound electrons, $m_o c^2 \equiv W$, producing the electrons with energy, $E = mc^2$, so that $h\nu = E - E_o = mc^2 - m_o c^2 \implies$

$h\nu + m_o c^2 = mc^2$; then, it makes sense the introduction of units eV , that is, $mc^2 = eV$; $m_o c^2 = eV_o$, with which we will get the true equation of **Photoelectric Effect**: $V = h\nu/e + V_o = h\nu/e + \text{const.}$ where the constant have the adequate physical meaning, the energy of electrons is due to the relativistic mass, m , and the kinetic energy does not appear, that is, turns out irrelevant (redundant).

For all the above, it seems that the only way to admit this kind of **mass**, m , with physical meaning should be of **electromagnetic** nature and **virtual** (not inertial); this “virtuality” is compatible with a “real” energy, in the same way that happens with the stored images at Internet.

Eventually, Relativity “fails” in its pretension of Unifying Electromagnetism with Classical Mechanics.

4. RELATIVITY AND QUANTUM THEORY

After having shown that Classical Mechanics was rule out, it makes sense that the “Unifying” paradigm of Relativity is reduced to between Electromagnetism and Quantum Theory, in consonance with Quantum Field Theory, where the space-time continuum is not necessary. In this way, the assumption of virtual and electromagnetic mass for the particles involved, will allow a better comprehension of many topics, by avoiding many problems with their physical meanings involved at the mathematical development.

Quantum theory is based on a clear “ambiguity”, since both “particle” and “wave” states overlap; from there arise questions such as uncertainty principle, Hilbert vector space, entanglement, etc.

Likewise, Relativity is also installed on a similar uncertainty, since its formulation leads to an identity instead of an equation, which actually implies that the Energy, $E = mc^2$ and Momentum, $p = mv$ may have any value, that is, both are

“indeterminate” and any physical event may be reduced to interaction between “radiation” (wave) and “particle” (charged), as we will see, among others things, with the Compton effect.

4.1 Photons:

As it is well-known, Quantum Theory makes its appearance by the well-known formula,

$E = hv = \hbar\omega$ (10), where h is Planck’s action quanta; with this it is possible to explain the energy graph of blackbody radiation, introducing the particles called **photons**, which are originated in electromagnetic interaction, acting by means of indefinite exchanges as bosons and being “indistinguishable” from each other as any quantum particle, either boson or fermion.

Could these particles have the same kind of mass required by Classical Mechanics?

As we explained above, we think we have solved this question with the introduction of a virtual and electromagnetic mass, which may be assigned as well to photons, so that we may add to the previous formula, $E = mc^2 = \hbar\omega$, especially after having demonstrated the impossibility of the mass “at rest” for m_0 .

In this sense, this mass (like dt') may be considered as a quantity associated to “vacuum”, from where is produced the particle with the mass m , as it is being done in Klein-Gordon equation on “bosons”; although these may have charge, this mechanism will also be adequate for radiation, that is, for photons, because they act in the same way, that is, through an unlimited exchange of particles.

4.2 Electrons:

The importance of the concept of “virtual” mass is consistent with electromagnetic phenomena, whose sources are electric charges, e , as a fundamental parameter, while mass would be derived from that; in this sense, electrons, like all subatomic particles, have mass that are expressed in electron-Volt (eV), which is defined according to $eV = mc^2$, where the electron mass is linked to the quantization program, because the charge of electron, e , is quantified by itself for being considered as unit.

Moreover, by virtue of the wave-corpuscule duality, according to de Broglie formula

$p = \hbar k = h/\lambda$ (11), where the electron behaves as a wave, in which case its dynamic quantities must be in consonance with the space of the phases, $\exp(i\omega t - ikx)$, where $\omega/k = c$, with what one may get: $\hbar\omega = \hbar ck \implies E = cp$, which corresponds to null Interval (“light cone”), where the particle is relativistic and in the context of Quantum Theory, the energy (frequency) and the momentum (wave number) are statistical quantities, that is, they are “indeterminate”.

In this way, the relationships between the energy, E , and momentum, p , must be adjusted to the Uncertainty Principle: $\Delta E \cdot \Delta t \geq \hbar$ and $\Delta p \cdot \Delta x \geq \hbar \implies \Delta E \cdot dt \geq \hbar$; $\Delta p \cdot dx \geq \hbar$ (12), from which it is easy to show that $v < c$.

Indeed, introducing the relations (10) and (12) in the previous expression:

$$\hbar \Delta \omega \cdot dt \geq \hbar \implies \Delta \omega \cdot dt \approx 1; \quad \hbar \Delta k \cdot dx \geq \hbar \implies \Delta k \cdot dx \approx 1, \quad ;$$

$$dt \approx 1/\Delta \omega \implies 1/dt \approx \Delta \omega; \quad dx \approx 1/\Delta k \implies dx/dt \approx \Delta \omega/\Delta k = v \quad (13).$$

It turns out the wave velocity group, lower than the speed of the wave phase: $v < c$.

Why does mass appear more relevant than charge?

This is because it is being used $m_0 = \text{const}$, in the same way of any particle subjected to the laws of Mechanics; but having demonstrated the variability of both m and m_0 the measured value of 9.1×10^{-31} kg, may be assigned to the relativistic mass, m , for a certain velocity, so that when it is expressed in units eV: $mc^2 = 0.5$ MeV, we can only take it as a “reference” value (no minimum), with respect to the mass of proton, that being the compound particle (Hadron) with greater stability can be considered constant and as such subject to Newtonian Dynamics, after applying the Avogadro’s Number.

For that reason, the concepts of “energy_content” and “mass-energy equivalence” are just like metaphors, since the only equivalence is represented by the mass definition unit, $eV = mc^2$, according to which the charge, e , should be the main physical quantity, while the mass, m , reveals its dependence on that charge, as well as the other electromagnetic quantities, like it is also inferred from J.J.Thomson’s experiment.

In this sense, two renowned authors (P. Roman and A. Messiah) referred to Dirac equation of the electron as that of the charge, e , since the physical properties on the mass of electron appears as having some problematic aspects; actually, the discovery of the antielectron or positron was the most marked contribution of this equation, from which was introduced the concept of “antimatter” in Modern Physics.

On the other hand, taking into account the previous formulas, the mass acquires its true meaning when it is integrated in $e\Delta V = \Delta mc^2 = \hbar\omega$ (14) where Δm , appears as a quantity that connects the corpuscular (e) and wave (ω) states and at the same time to establish the energetic conditions that allows the electronic structure of atoms, represented by the quantum numbers (n, l, l_x, s), where the emission or absorption of photons occurs when any electron change its energy level, according to Δmc^2 .

An electromagnetic and virtual mass is the only way to understand the existence of “orbitals” (not orbit), for the electronic distribution in atoms, as well as for “free” electrons in the processes:

- a) Compton effect: $e_1^- + \gamma_2 \rightarrow e_2^- + \gamma_1$
- b) Pair annihilation: $e^-(\text{electron}) + e^+(\text{positron}) \rightarrow 2\gamma$ (photons)
- c) Pair creation: $2\gamma \rightarrow e^- + e^+$.

They are represented by Feynman diagrams, which are no more than didactic resources, since the conservation of momenta is reduced to the variation of the energy of radiation with respect to the momentum of electrons, according to the Uncertainty Principle, thanks to which we may apply the formula (13), that is, $\hbar\Delta k v = \hbar\Delta\omega$, through which the Compton Effect may be displayed:

$$\hbar k_1 v (\text{electron}) + \hbar\omega_1 (\text{photon}) = \hbar k_2 v + \hbar\omega_2,$$

As we can see, the free electron momentum, $\hbar k_1 v$, will produce a variation of the frequency of the wave with the result of $\hbar\omega_2 > \hbar\omega_1$ and $\hbar k_2 v < \hbar k_1 v$. **4.3 Inertial mass: atomic nuclei:**

Proton turns out to be the most stable of composite particles, called Hadrons and as such can be considered as the starting point to build matter; in other words, it has become the “cornerstone” on which the whole material world is built, whose consistency must be supported in its **real or inertial mass**.

This mass is produced by the **strong interaction**: without going into details, it is known that *quarks* u, u, d , are the components of the proton, p, that supply its charge:

$q_p = 2/3 + 2/3 - 1/2 = +1$, but the mass associated with *quarks* (elementary particles) are “virtual”, so the proton mass, $m_p = 839.2$ MeV is due to the “interactive network”, through the *gluons*, which together with the so-called “confinement” phenomenon does not allow the quarks to go out into exterior space; thus, it is achieved the compactness that any massive body demands, that is, the inertia requires “structure”.

However, it has been established by E. Mach and others, who obsessed for overcoming the absolute concepts of space and time in Newtonian Physics, attributed to centrifugal force of the rotation of the Earth a true existence; it turns out again the issue of “identity” vs “equation”, but in accelerated frame.

The proton becomes the particle that constitutes the turning point between the real or inertial mass subject to Classical Mechanics and the virtual one, required by Quantum Theory, since it may be considered from two points of view:

- a) Given that the measurement of the proton mass is similar to the electron, that is, it is derived from electromagnetic quantities, may be considered as “virtual” when is expressed in eV units and as such, subject to relativistic energy, $E = mc^2$.
- b) To build atomic nuclei, where its value, $m_p = 1.67 \times 10^{-27}$ kg corresponds to the atomic mass unit (*amu*), in which case it should be **real (inertial)** and constant, in consonance with the mass conservation law (Lavoisier) in Chemical reactions and with the requirement of Classical Mechanics; in this case is defined atomic mass unit (*amu*) as 1/12 of the carbon-12 (C^{12}) mass, so that protons and neutrons mass must be equal inside the nucleus. Therefore, the indiscriminate use of *amu* and *eV* units in Nuclear Physics has contributed to the “confusion” in the Standard and Cosmological models.

On the other hand, “baryons” (protons, neutrons) are firmly united in the atomic nucleus through **weak interaction**, which is described by the so-called Gauge “Symmetry”; but this occurs around the “charge” and not the mass, confirming our point of view.

The forces involved are produced by an exchange of “bosons”, called Gauge Particles (W^-, W^+, Z^0), that have high energies (80-90 GeV) originated by potentials and “weak” charges, so the associated masses are electromagnetic and virtual; for this, we have the Fermi equation:

$E = (G_F/\sqrt{2})JJ'$, where $G_F = 1.02 \times 10^{-5}/m_{\text{proton}} = 1.66 \times 10^{-5}$ GeV and J, J' are the currents associated to the “weak” charges, g, g' , so we may get the energies corresponding to the particles, W, W^+ :

$$E^2 = \sqrt{2}g^2/G_F \implies E = 37.3g = 80 \text{ GeV.}$$

The Higgs Mechanism in order to give relevance to the mass “at rest”, m_0 , is unnecessary, since the high energies of the gauge particles correspond to the relativistic mass, m , “virtual”; these particles are bosons with spin zero can not leave the nucleus, that is configured as an “inner” space

Finally, the neutron, $n(u,d,d)$, has a mass higher than that of the proton, because the mass of quark d is greater than that of u , namely, $m_d > m_u$, so that the electromagnetic mass difference between both particles, $m_n - m_p = 939.5 - 938.2 = 1.3$ MeV, explains the spontaneous emission of electrons that take place in beta decay: $n + \nu_e$ (neutrino) $\rightarrow p + e^-$ (β^-), whereas it is necessary an energy contribution to produce the conversion of a quark $u(+2/3)$ into $d(-1/3)$ for the emission of positrons, e^+ : $p + \nu_e^*$ (antineutrino) $\rightarrow n + e^+$ (β^+).

The electromagnetic and virtual nature of the difference of mass between *neutron* y *proton*, together with the fact that the electron relativistic mass, m , is really “created” in the atomic nucleus (inner space), which may have any value without lower limit, the energy graph can be explained without the help of any other particle, which allows to put neutrino and antineutrino on the left sides of both reactions, that is, in the “inner” space, which shows that these particles do not have to leave it, as we have shown in the article: “*Neutrino: A True Particle?*” (International Journal of Scientific & Technology Research, Volume 5, Issue 12. December 2016).

5. POSITRONS AND TACHYONS

Without going into Dirac equation and his ingenious solution over the existence of **antiparticles**, we may realize that these can be postulated from, $E^2 - c^2p^2 = (m_0c^2)^2$, by admitting the possibility of a negative energy, $E = -mc^2$, that we can transfer to momentum

$\mathbf{p} = -m\mathbf{v}$, in which case the Uncertainty Principle will be now: $\Delta E \cdot dt \geq \hbar$; $\Delta p \cdot dx \leq \hbar$ (15), so $\Delta w \cdot dt \approx 1$; $-\Delta k \cdot dx \approx 1 \implies dx/dt \approx \Delta w/(-\Delta k) = -v < c \implies v > c$, that is, the **velocity** of the **antiparticles** is higher to that of radiation (light)!

Moreover, the formula (14) allows the negative energy of the electron to turn into positive, thanks to the charge of the antiparticle (positron), so that in the process Pair annihilation,

photons (gamma rays) have no charge, but mass (electromagnetic and virtual) that can explain its high energy: $e\Delta V + (-e)\Delta V = 0 \implies \Delta mc^2 = \hbar\omega - (-\hbar\omega) = 2\hbar\omega$.

Also, this process may be explained by $v > c$ for the antiparticle:

$$\hbar k(v-c) + \hbar k(c-v) = 0 \implies \hbar kv \text{ (electron)} + \hbar kv \text{ (positron)} = \hbar kc + \hbar kc = 2\hbar\omega \text{ (fotones)}, \text{ that is, } e^- + e^+ \rightarrow 2\gamma,$$

Likewise, in the reverse process, Pair Creation process: $2\gamma \rightarrow e^- + e^+$. it is possible to demonstrate that photons spin is 1, by CPT Symmetry, which must comply all quantum particles; to that end, we make use of the special interpretation of Feynman on antiparticles, according to which they are moving to the past, namely, the time reversal (T), is in line with the acceptance of the absolute past, which together with the so-called charge conjugation (C), imply that parity (P) should not change, ie, positron spin must be the same as that of electron, $1/2$.

On the other hand, it arises another question that we think has gone unnoticed, referring to the particles so-called **tachyons**, moving at a speed greater than that of light, $v_t > c$, with which the Interval will now be negative: $E_t^2 - c^2p_t^2 < 0$

This situation is called non-causal, since momentum, $c\mathbf{p}_t$ is bigger than energy, E_t but that could be avoided by returning to the starting point of relativistic formulation, that is, to the equation (2), and writing another similar for $v_t > c$, so that the Interval, $cd\tau$, will now fit the expression:

$$v_t^2 dt_t^2 - c^2 dt_t^2 = (v_t^2 - c^2) dt_t^2 = c^2 d\tau_t^2 \implies dt_t = d\tau_t / \sqrt{(v_t^2/c^2 - 1)} \quad (16).$$

So, we have got a relation between the times, dt_t and $d\tau_t$, clearly different from (1), since now it happens a “contraction” instead of “dilation” of time; we can appreciate its peculiar evolution: initially, $dt_t \rightarrow \infty$ for $v_t = c$, but then the elapsed time, dt , decreases when v' increases until reaching the value, $v_t = \sqrt{2}c$, where it will be, $dt_t = d\tau$.

When the above approach is transferred to energy and momentum, these should be

$$E_t = m_o c^2 / \sqrt{(v_t^2/c^2 - 1)}, \quad \mathbf{p}_t = m_o v_t / \sqrt{(v_t^2/c^2 - 1)} \quad \text{and then, we may get the “identity” equivalent to (8):}$$

$$c^2 \mathbf{p}_t^2 - E_t^2 = c^2 (m_o v_t)^2 / (v_t^2/c^2 - 1) - (m_o c^2)^2 / (v_t^2/c^2 - 1) \equiv (m_o c^2)^2 \quad (17).$$

The evolution of energy is curious: although initially has a very high value (near infinity), it will decrease until the condition: $v_t = \sqrt{2}c$.

But the surprise is coming when we perform the sum of tachyon four-momentum with that of electron:

$$(c^2 \mathbf{p}_t^2 - E_t^2)_{\text{tachyon}} + (E^2 - c^2 \mathbf{p}^2)_{\text{electron}} = \\ = c^2 (m_o v_t)^2 / (v_t^2/c^2 - 1) - (m_o c^2)^2 / (v_t^2/c^2 - 1) + (m_o c^2)^2 / (1 - v^2/c^2) - c^2 m_o^2 v^2 / (1 - v^2/c^2) \equiv 2(m_o c^2)^2.$$

The equivalence with Pair annihilation process: $e^+ + e^- \rightarrow \gamma$, appears as something evident, when obtaining twice the energy, $m_o c^2$, that in (7) and (16), which implies the equality of the mass of tachyons and electrons:

$$m_t c^2 + m_e c^2 = 2m c^2 \implies m_{\text{tachyon}} = m_{\text{electron}}.$$

Moreover, we may demonstrate that the “charge” of tachyons is opposite to that of electrons by mean of CPT symmetry: from the parity conservation, P, that is, the equality of the spin of tachyons and electrons, time reversal (T) is implicit in the change made from the negative Interval to the positive one: $-cd\tau \rightarrow +cd\tau$, which induces the charge conjugation (C), $-q_e \rightarrow +q_t$

The equality of the masses of positrons and electrons obtained according to the process:

Pair creation: $\gamma \rightarrow e^+ + e^-$, will correspond the same mass, m , and consequently energy, E , for tachyons and electrons:

$$m_{\text{tachyon}} = m_{\text{electron}} \implies m_o c^2 / \sqrt{(v_t^2/c^2 - 1)} = m_o c^2 / \sqrt{(1 - v^2/c^2)} \implies v_t^2 + v_e^2 = 2c^2.$$

This is the condition for the production of positrons and electrons, which besides requiring a high energy, it may be appreciated that the energy variation for tachyons (positrons) respect to v' is of much more limited sequence than the corresponding to v , so it will be more difficult for positrons (tachyons) to appear at the exterior space and therefore the existence of antiparticles is just occasional.

In brief, tachyons are behaving as positrons; with other words:

tachyons and antiparticles are the same particles.

6. CONCLUSION

It has been carried out a detailed analysis of Relativity and although having demonstrated the impossibility of the Unification of this Theory with Classical Mechanics, it allow its insertion in Quantum Field Theory, thanks to the concept of electromagnetica and virtual mass, which is consistent and suitable for the behaviour of particles and radiation, subjecto to this teory, quite different from the real or inertial mass that comply with the laws of Chemistry, Calssical Mechanics and Gravitation.

In this line, we have performed a significant study of the conjunction of real or inertial and electromagnetica or virtual mass adscribed to baryons or nucleons (protons, neutrons) as compound particles, whereas the mass of electrons, positrons and photons in its condition of being elementary particles (without structure) are only electromagnetic or virtual.

After introducing the tachyons by the previous arguments and submitting them to a special behaviour from the relativistic point of view, we have found the unexpected: these particles may be identified with antiparticles, in which case it may explain the high energies necessary for its appearance.

Moreover, we can overcome something that our mind refuses to admit: the existence of negative energy and consequently of antimatter in a real Universe; it also becomes clear that antiparticles should not follow the same evolution as the particles, otherwise, they should appear with the same frequency as these.

Finally, it must be pointed out that by assuming positrons the properties of tachyons, it would be possible to fit the question of "superluminal" electrons_ ie. $v > c$, appearing in some recent studies.

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