Beta Radiation, Gamma Radiation and Electron Neutrino in the Process of Neutron Decay

Daniele Sasso *

Abstract

In this paper let us consider the process of neutron decay whether when neutron is free or when neutron is inside nucleus. Decay produces always one proton, one electron and a third particle, that we identify rather with electron neutrino than with electron antineutrino that is an altogether similar particle to neutrino. Neutrino and antineutrino are here considered energy quantum particles with zero mass, zero electric charge and zero spin and have the spectrum of frequency into the gamma radiation. A new explanation in regard to the continuous spectrum of velocities of beta electrons is then given. Let us deduce at last the value of spin for a few important particles of the microphysical world and define the numeric relation between angular spin and magnetic spin with regard to electron.

1. Introduction

The process of neutron decay inside nucleus, known as β radiation, represented for physicists a motive of great disorientation because a continuous spectrum of speeds and energies for these nuclear electrons was measured while a line spectrum was waited as for orbital electrons round nucleus. This contradiction was solved by Fermi with the introduction of a new particle, called electron neutrino, which had been supposed already previously by Pauli. It proved definitively nuclear electrons aren' t orbital as external electrons revolving round nucleus. Electron neutrino solved apparently the problem concerning the continuous spectrum of β decay but it created many other problems, relating to physical nature of neutrino, to its mass, to its speed and its spin. Also its experimental observation has been very difficult. A large part of these problems are solved today and this article has also the target to make a further contribution to this aim together with the previous article[1] where neutrino is supposed to be an energy quantum with physical structure of electromagnetic nanowave which has zero mass, zero electric charge and zero spin. In the cited article neutrino has muon nature and its frequency spectrum is placed in the frequency band of the delta radiation (δ) which is over the frequency band of the gamma radiation (γ) while the frequency spectrum of electron neutrino is just into the gamma band. Highest frequencies of neutrino and respective smallest wavelengths enable neutrinos the characteristic property to cross in largest part matter without let or hindrance. In the last part of the article we calculate the value of the spin with regard to some particles and to some microphysical systems, starting always from the general relation between electric charge and spin.

* e_mail: dgsasso@alice.it

2. Decay of free neutron and electron neutrino

Neutron is a very interesting nuclear particle because it has a complex structure unlike protons and electrons that have a simple structure at nuclear level and only for protons a complex subnuclear structure is supposed through the quark model. Neutron[2][3] was discovered by J. Chadwick in 1932 and its discovery represented the beginning of theoretical nuclear physics. It is a neutral particle in the electric eyes, with a nuclear mass a bit larger than proton. In fact proton has a resting mass equal to 1,00759 m.p.u. (mass physical unity) equivalent to 938,07 MeV while resting neutron has a mass equal to 1,00898 m.p.u. equivalent to 939,36 MeV. Neutron is tied with protons inside nucleus and can be also free outside atomic nucleus. Proton is a stable particle with a pratically infinite average life (measurable when it is free) and therefore doesn' t decay, for which it is possible to suppose that it has an elementary nuclear structure, i.e. not made by other nuclear particles. Only within physics at very high energies a complex subnuclear structure by quarks has been supposed for protons.
Free neutron, i.e. outside nucleus, is unstable and in a time of about 900 seconds equal to about 15 minutes decays into one proton and one electron

$$\text{neutron} \longrightarrow \text{proton}^{+} + \text{electron}^{-} \qquad (1)$$

At rest masses and intrinsic energies are

$$\begin{aligned} \text{neutron mass} &= 1.00898 \text{ m.p.u.} \longrightarrow 939.36 \text{ MeV} \\ \text{proton mass} &= 1.00759 \text{ m.p.u.} \longrightarrow 938.07 \text{ MeV} \\ \text{electron mass} &= 0.0005487 \text{ m.p.u.} \longrightarrow 0.51 \text{ MeV} \end{aligned}$$

Let us observe that the sum of resting masses of both, proton and electron, is equal to 1.00814 m.p.u. equivalent to 938.58 MeV and so it is lower than resting mass of neutron. Mass difference is 0.000841 m.p.u. equivalent to 0.78 MeV which is about 1.5 mass of resting electron. That difference of both, mass and energy, before decay can be explained with emission by neutron on decaying of an energy particle which represents in the intact neutron the binding energy between proton and electron. The release of energy in the spontaneous decay of free neutron is the proof that proton and electron in free neutron are bound weakly before decay according to the relation that replaces and specifies the (1)

$$\text{neutron} = \text{proton}^{+} + \text{electron}^{-} + \text{weak binding energy} \qquad (2)$$

In the weak bond between proton and electron inside the free neutron the binding energy is equal, in normal physical conditions, to 0.78 MeV: this weak bond produces instability in the free neutron and so spontaneous decay. The energy released in the decay generates an energy quantum which coincides with the “electron neutrino” and therefore after the decay (fig.1) we have

$$\text{neutron} \longrightarrow \text{proton}^{+} + \text{electron}^{-} + \text{neutrino } (\nu_e) \qquad (3)$$

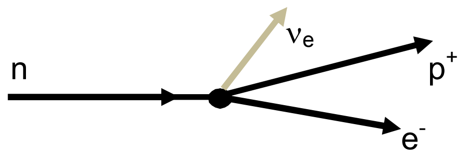

Fig.1 Decay of the free neutron represented by Feynman diagram

We can calculate easily wavelength and frequency of electron neutrino by the Planck relation

$$f = \frac{E}{h} = \frac{0{,}78}{6{,}63 \times 10^{-34}} \frac{MeV}{Js} = 1{,}9 \times 10^{20}\ Hz \qquad (4)$$

$$\lambda = \frac{c}{f} = 1{,}58 \times 10^{-2}\ Angstroms \qquad (5)$$

As per these values of frequency and wavelength the electron neutrino is an energy quantum placed in the frequency spectrum of gamma (γ) rays and so it is from structural viewpoint an electromagnetic nanowave[1].

If the free neutron is moving, its kinetic energy subdivides after the decay between moving proton and moving electron. In order to calculate the division of kinetic energy between proton and electron, the principle of conservation of kinetic energy is valid for which

$$\frac{1}{2} m_n v_n^2 = \frac{1}{2} m_p v_p^2 + \frac{1}{2} m_e v_e^2 \qquad (6)$$

Being $m_p \approx m_n$ and $m_e << m_p$, we have

$$v_p \approx v_n \qquad (7)$$

and so about all the kinetic energy of the free neutron becomes kinetic energy of the proton which assumes a next and slower speed than the neutron.

Also neutron has its own antiparticle, called antineutron[4][5], that has the following complex nuclear structure before the decay

$$\text{antineutron} = \text{antiproton}^- + \text{positron}^+ + \text{weak binding energy} \qquad (8)$$

Antineutron is made up of antiparticles with respect to neutron particles. Also the free antineutron, as the neutron, is characterized inside by an unstable weak bond between antiproton and positron that in a time of about 900 seconds decayes into one antiproton and one positron

$$\text{antineutron} \longrightarrow \text{antiproton}^- + \text{positron}^+ + \text{antineutrino} \qquad (9)$$

The released energy in the spontaneous decay in that case generates an energy particle which we call “electron antineutrino” only for reasons of symmetry but it has the same physical properties of electron neutrino.

3. Decay of nuclear neutron and radiation β

In nature numerous natural and artificial radionuclides emit the β radiation.
It is made up of nuclear electrons and can have two different characteristics:

a. β^- radiation made up of negative nuclear electrons
b. β^+ radiation made up of positive nuclear electrons or positrons

The β^+ radiation is emitted only by artificial radionuclides unlike the β^- radiation which is emitted also by various natural radionuclides.
Negative orbital electrons moving in atom round nucleus have a line spectrum of speeds because orbital electrons can move only on a few stable orbits characterized by discrete values of ray and energy. The β radiation instead generates a continuous spectrum of speeds and in order to explain the continuity of this spectrum we have to examine the mechanism of emission of β rays within electrodynamics of particles[6].
The spontaneous emission of a negative nuclear electron by nucleus happens necessarily because of the spontaneous transformation of one neutron into proton with the ejection of the nuclear electron. The β^- emission is similar to the spontaneous decay of free neutron, with the important difference that now electron emission happens inside nucleus.
Hitting nucleus with particles which have enough energy (α particles, deuterons, γ rays) it is possible to obtain by nucleus the emission of free neutrons that then decay with the mechanism examined in the previous paragraph. It may happen also, in the absence of collisions as in natural radionuclides, that a bound neutron, without breaking the bind with protons of the nucleus, changes into proton with emission of β^- electrons.
It happens in particular when there is an excess of neutrons with respect to protons as for some atoms with high atomic number: in that case a less bound neutron to protons may undergo a process of transformation.
When a neutron is tightly bound to protons the bind between proton and electron inside the neutron is defined by

$$\text{neutron} \longrightarrow \text{proton}^+ + \text{electron}^- + \text{binding energy } (E_L) \qquad (10)$$

Electrodynamic mass of electron inside the nucleus is null at the critical speed and is negative for greater speeds. The values of mass and energy for the bound neutron are

$$\begin{aligned} \text{neutron} &\longrightarrow 939{,}36 \text{ MeV} \\ \text{proton} &\longrightarrow 938{,}07 \text{ MeV} \\ \text{electron} &\longrightarrow E_e \end{aligned}$$

where E_e is the intrinsic energy of electron that inside the nucleus can be null (at the critical speed v_c=1,41c) or negative (for greater speeds than the critical speed). The binding energy E_L between proton and electron in the free neutron is equal to 0.78 MeV, but in the bound neutron it is greater with a minimum of 1.29 MeV when the electron has the critical speed. In normal physical conditions so the bind between proton and electron inside the nuclear neutron is stronger than in the free neutron, but a weakly bound nuclear neutron may change into proton because its oscillatory own motion due to the thermal energy is able to weaken further the bind of the neutron with protons. In that case the neutron behaves as a free neutron inside the nucleus and therefore decays according to the transformation

$$\text{neutron} \longrightarrow \text{proton}^+ + \text{electron}^- + \text{neutrino } (\nu_e) \qquad (11)$$

Leaving the neutron and the nucleus, the β^- electron decelerates and takes a positive electrodynamic mass. At the same time the neutron emits an energy quantum (neutrino) with frequency and wavelength which for a binding energy equal to 1.29 MeV are

$$f = \frac{E}{h} = \frac{1{,}29}{6{,}63 \times 10^{-34}} \frac{\text{MeV}}{\text{Js}} = 3{,}1 \times 10^{20} \text{ Hz} \qquad (12)$$

$$\lambda = \frac{c}{f} = 10^{-2} \text{ Angstroms} \qquad (13)$$

We observe that the energy quantum has still frequencies and wavelengths which are into the frequency spectrum of the gamma (γ) radiation. The resultant proton remains inside the nucleus and it is ready in order to establish a strong bind with other particles of nucleus.

The continuous spectrum of speeds of β^- electrons is explained considering the value of energy of free electron given by the following relation[6][7]

$$E = mc^2 = m_o c^2 \left(1 - \frac{1}{2}\frac{v^2}{c^2}\right) \qquad (14)$$

in which $E_o = m_o c^2 = 0{,}51\text{MeV}$ is the resting intrinsic energy. It is possible to observe this relation shows a continuous variation of both, electron mass and electron energy, whith respect to the speed and therefore the speed spectrum of the β^- radiation is continuous otherwise than electrons orbiting nucleus that have a line spectrum because they can move only along quantized stable orbits with discrete values of radius, speed and energy.

The graphic trend of the electrodynamic mass and of the intrinsic energy of β^- electrons, when they leave nucleus, is shown in fig.2 .

The β^- electron is emitted with an equal or greater speed than the critical speed and so with a null or negative electrodynamic mass and with a null or negative intrinsic energy. Leaving nucleus the speed of electron outside nucleus decreases significantly with a simultaneous increase of both the electrodynamic mass and intrinsic energy. We can observe from the diagram that electrons outside nucleus may assume any smaller speed than the critical speed and it justifies the continuous spectrum of the β^- radiation (fig.3).

Moreover when the β^- electron leaves the nucleus its speed decreases and passing from the critical speed to the speed of light it emits an energy gamma quantum. A second energy gamma quantum can be emitted at slower speeds.

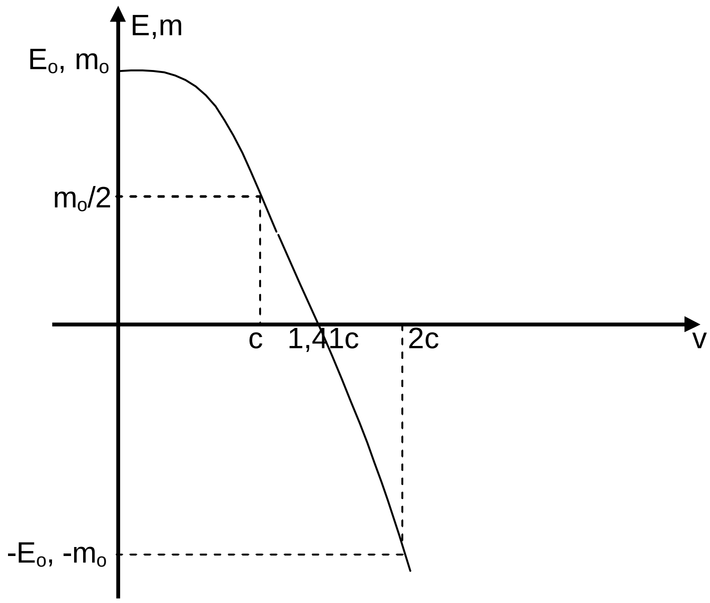

Fig.2 Diagram of energy and of electrodynamic mass of β^- electrons emitted by nucleus.
β^- electrons are emitted with equal or greater speed than the critical speed and leaving nucleus assume positive values of mass and energy while their speed decreases.

Experimental spectra give the spectral density, i.e. the N number of emitted β^- electrons for every value of energy: they show that for every emitting nucleus there is a characteristic energy E_c (generally of the order of 1MeV), which is assumed by the greater part of emitted β^- electrons, in which the diagram has a maximum (fig.3).

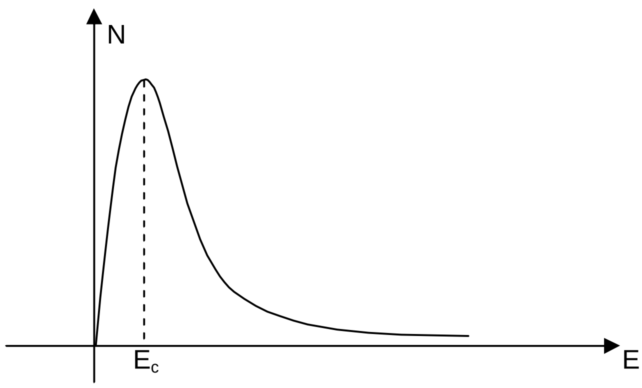

Fig. 3 Continuous spectrum about the intensity of electrons for every value of energy.

Only for artificial radionuclides it is possible to observe the spontaneous transformation of an antineutron with the production of the β^+ radiation composed of positrons (positive electrons)

$$\text{antineutron} \longrightarrow \text{antiproton}^- + \text{positron}^+ + \text{antineutrino} \qquad (15)$$

In that case the nucleus emits one β^+ positive electron which has similar physical characteristics to the β^- negative electron, unless the conventional electric charge. The resultant antiproton remains inside the nucleus and it is available for a new bind with nuclear protons.
The β^+ radiation occurs only in artificial radionuclides which are obtained by forced nuclear reactions that produce antiparticles inside the nucleus. The presence of β^+

radiation only in artificial radionuclides explains because antiparticles are rare in nature. Antineutrino then is a fully similar particle to neutrino and therefore the two particles match.
Because the β emission, whether negative or positive, is always accompanied by γ radiation and because electron neutrinos and electron antineutrinos have a wavelength which is inside the frequency spectrum of γ rays, it is altogether right to suppose that neutrinos and antineutrinos, together with energy quanta emitted later when electrons or positrons leave the nucleus, are just the γ radiation that is observed in the β emission.

4. Angular spin

In a previous paper[8] we calculated the angular spin concerning electron, positron and photon. Let us calculate now the spin also for other fundamental particles starting from relations

$$q_s = \pm \frac{k\hbar}{2} \qquad k= 1, 2,\ldots.. \tag{16}$$

$$Q = \pm n\, e \qquad n= 1, 2, \ldots \tag{17}$$

$$q_s = \frac{k}{n} \frac{\hbar}{2e} Q \tag{18}$$

The ± sign is the same whether for spin or for electric charge, k is the quantum number of energy for electrons when they are bound in electron orbits of atom, n is the quantum number of electric charge for particle. For not bound electron and for all other particles k=1, for neutral electric particles Q=0.

a. Proton.
   Proton has a positive elementary electric charge (n=1, k=1) and therefore its spin is

$$q_p^+ = +\frac{\hbar}{2} \tag{19}$$

b. Antiproton.
   Antiproton has a negative elementary electric charge (n=1, k=1) and a spin

$$q_p^- = -\frac{\hbar}{2} \tag{20}$$

c. Electron neutrino.
   Electron neutrino is an energy quantum which has the same physical nature of photon. Because of its characteristics of frequency and wavelength electron neutrino is inside the frequency spectrum of gamma rays (γ). Electron neutrino has zero electric charge and therefore, as photon, has a zero spin q_{en}=0. The same result is valid for antineutrino which is altogether similar to neutrino.

d. Neutron.
Neutron isn' t an elementary particle but it has a complex structure

$$\text{neutron} = \text{proton}^{+} + \text{electron}^{-} + \text{electron neutrino} \qquad (21)$$

The total electric charge of neutron is zero. Because the spin of neutrino is zero the total spin of the neutron is given by

$$q_N = \frac{\hbar}{2} - \frac{\hbar}{2} = 0 \qquad (22)$$

e. Antineutron.
Antineutron is a complex particle with null electric charge

$$\text{antineutron} = \text{antiproton}^{-} + \text{positron}^{+} + \text{antineutrino} \qquad (23)$$

and with null total spin because also the antineutrino (that coincides with the neutrino) has null spin

$$q_{AN} = -\frac{\hbar}{2} + \frac{\hbar}{2} = 0 \qquad (24)$$

f. Hydrogen atom.
Hydrogen atom isn't a particle but a complex microphysical system, different from the neutron, composed by a proton and by an electron orbiting the proton. In that case it is more convenient to consider the q_H total angular momentum than the spin of the hydrogen atom. In order to calculate q_H the total angular momentum[8][9] of electron ($q_{kt}=(\pm k+s)\hbar$) has to be added to the proton spin. Being $s=-k/2$, with regard to the fundamental level for k=1 and according to the ± sign of k we obtain two different values of the total angular momentum of the hydrogen atom

$$q_H^{+} = \frac{\hbar}{2} + \left(1 - \frac{1}{2}\right)\hbar = \hbar \qquad (25)$$

$$q_H^{-} = \frac{\hbar}{2} + \left(-1 - \frac{1}{2}\right)\hbar = -\hbar \qquad (26)$$

g. Deuteron.
The deuteron has electric charge +1 and because it is constituted by a proton-neutron bind it has a spin

$$q_D = \frac{\hbar}{2} + 0 = \frac{\hbar}{2} \qquad (27)$$

5. Angular spin and magnetic spin of electron.

The free electron and the orbital electron bound inside the atom in the energy fundamental quantum state (k=1), have an angular spin

$$q_e^- = -\frac{\hbar}{2} \tag{28}$$

The bound electron, because of its orbital motion round nucleus, has an orbital magnetic momentum expressed by Bohr's magneton[9]

$$M_B = \frac{e\mu_o\hbar}{2m} \tag{29}$$

Moreover the electron, because of its motion round its own axis, has also a magnetic spin due to its electric charge.
The orbital magnetic momentum depends on both, the charge and the mass of electron, for which we can assume that the M_e^- magnetic spin matches the Bohr magneton

$$M_e^- = M_B = \frac{e\mu_o\hbar}{2m} \tag{30}$$

From (28) and (29) we deduce the relation in absolute value between magnetic spin and angular spin of the electron

$$\frac{M_e^-}{q_e^-} = \frac{e\,\mu_o}{m} = 2{,}21\times10^5 \tag{31}$$

$$M_e^- = 2{,}21\times10^5\, q_e^- \tag{32}$$

The numeric value of the magnetic spin is much bigger than the angular spin but both are smallest because their numeric values are about in the order of the Planck constant scale ($h=6.63\times10^{-34}$ Js).

References

[1] D. Sasso, If the Speed of Light is Not an Universal Constant According to the Theory of Reference Frames: on the Physical Nature of Neutrino, viXra.org: 1110.0007, 2011
[2] E. Persico, Atoms and their energy, Zanichelli Editor Bologna, Italy, 1970
[3] P.T. Matthews, The Nuclear Apple, Arnoldo Mondadori Editore, Milano, 1972
[4] K.W. Ford, The World of Elementary Particles, Arnoldo Mondadori Editore, Milano, 1965
[5] Glenn A. Baxter, Anti-Neutron Theory/Model of the Atom, viXra.org, id: 1107.0026, 2011
[6] D. Sasso, Dynamics and Electrodynamics of Moving Real Systems in the Theory of Reference Frames, arXiv.org: 1001.2382, 2010
[7] D. Sasso, Relativity and Quantum Electrodynamics in the Theory of Reference Frames: the Origin of Physical Time, viXra.org, id: 1109.0018, 2011
[8] D. Sasso, On Primary Physical Transformations of Elementary Particles: the Origin of Electric Charge, viXra.org, id:1202.0053, 2012
[9] D. Sasso, Basic Principles of Deterministic Quantum Physics, 2010, viXra.org: 1104.0014