ARGON-37 ↔ CHLORUM-37 TRANSFORMATIONS

Antonio PUCCINI

Neurophysiologist of Health Ministry, Naples - Italy

A B S T R A C T

As it is known, unlike Argon-40 (Ar_{18}^{40}) and stable isotopes (Ar_{18}^{38} e Ar_{18}^{36}), Argon-37(Ar_{18}^{37}) is unstable, in fact it is radioactive and decays in 35 days. Thus, in order to regain stability, Ar_{18}^{37} makes one of its protons (*P*) to *capture* an electron (e^-) from its own atom. It follows that, leaving unchanged the value of its *atomic mass* (A = 37), this isotope undergoes the transformation of a *P* into a neutron (*N*), whereby its atomic number (Z) drops by one unit(Z=17). As known, as the *atomic number* of an element varies, its chemical properties vary too, so much so that the Ar_{18}^{37} is transmuted into another element: the Cl_{17}^{37}.

All this due to the *electron capture* occurred in Ar_{18}^{37} and represented as follows:

$$e^- + P \rightarrow N + \nu_e \qquad (1),$$

where with ν_e we mean an electronic neutrino. At this point, however, it would be reasonable to wonder: where did this ν_e come from? It is as if in this equation some intermediate passage was omitted. One of the phenomena that are very often accompanied by *electron capture*, is the so-called *photoannihilation*, characterized by the *materialization* of electro-magnetic radiation (γ), with consequent production of pairs (particle-antiparticle), such as: $\gamma \rightarrow \bar{\upsilon}_e + \nu_e$.

If we consider this phenomenon, Eq. (1) should be integrated as follows:

$$e^- + P + \bar{\upsilon}_e.+ \nu_e \leftrightarrow N + \nu_e \qquad (2).$$

Let's try to read backwards Eq.(2), omitting the ν_e placed in both members of the equation:

$$N \rightarrow e^-, P, \bar{\upsilon}_e \qquad (3).$$

It is surprising: Eq.(3) shows exactly the decay products of *N* or negative β-decay (βd^-).

According to Pauli and Fermi the 3rd particle or $\bar{\upsilon}_e$ added in βd^- (Eq.3), had to have the mass of e^-; instead the $\bar{\upsilon}_e$ weighs ≤0.00001 electronic masses.

If we assumed that the 3rd particle, *indirectly* detected, as with the *Cherenkov Effect*, was an anti-neutral electron (ē°) sufficiently accelerated, it would compensate for the unsolved *mass gap problem* of βd^-, corresponding to 0.511–0.78281 MeV.

1. I NT R O D U C T I O N

The study of the Argon-Chlorum transformations was proposed by Pontecorvo as an attempt to try to detect a highly elusive particle: the neutrino(ν). As it is known, the existence of the ν it was hypothesized by Pauli [1] to try to compensate for a disconcerting *mass gap problem*, that emerged conspicuously in the neutron (*N*) decay, or *negative β-decay* (βd^-):

$$N \rightarrow P + e^- \qquad (1),$$

where *P* is a proton and e^- is an electron with a negative electrical charge. Calculations show immediately a big *mass-energy gap*. In fact, the *N* weighs $1.67492728 \cdot 10^{-24}$[g], while the *P* weighs $1.67262171 \cdot 10^{-24}$[g]; on its turn the e^- weighs $9.1093826 \cdot 10^{-28}$[g]. The mass difference (Δ_M) between *N* and *P* corresponds to: $2.30557 \cdot 10^{-27}$[g]. According to the mass-energy conversion factors, if we consider by Feynman that "1 MeV is about $1.782 \cdot 10^{-27}$[g]"[2], and follow the *cgs metric system*, we have the value of Δ_E :

$$\Delta_E = (2.30557 / 1.782) \cdot 10^{-27}[g] = 1.29381 \text{ MeV}/c^2 \qquad (2).$$

This is the energy value that in the βd^- must be carried away by an e^- (or β radiation), in order to safeguard the energy balance in this process. The energy value expressed in Eq.(2) represents the maximum value of the energy spectrum ($\eta = E_{max}$) of the β radiation emitted with βd. The minimum energy carried away by an e^- corresponds to 0.511MeV, thus the value of Eq.(2) is more than double than the energy of an e^- not particularly accelerated. With the decay of the *N*, instead, the β ray is accelerated to a very high speed, showing a marked *kinetic energy*(E_{Kin}). Nevertheless, only in very limited circumstances, and coincidentally, the total energy carried away by the β radiation is able to compensate for the difference in mass-energy between *N* and *P*.

In short, in the βd^- many Conservation Laws were not respected, among which immediately stood out the violation of the Law of Conservation of Mass and Energy. In fact, when Marie Curie observed for the first time this type of decay, she only associated it to the emission of an e^-: see Eq.(1). Even Bohr thought that it was necessary to accept this deficiency: it seemed to him it was inevitable to resign to the violation of those conservation laws. For some years it was not possible to find a solution, until there was a *master strike*. Pauli, in fact, did not give up. Therefore, after much hesitation, on 04/12/1930 Pauli sent that famous letter to the participants of the Congress of Physics in Tubingen. Pauli wrote: "Dear Radioactive Ladies and Gentlemen, as the bearer of these lines, to whom I graciously ask you to listen, I will explain to you in more detail, because of the "wrong" statistics of the N- and Li-6 nuclei and the continuous β spectrum, I have hit upon a desperate remedy to save the "exchange theorem" of statistics and the law of conservation of energy. Namely, the possibility that in the nuclei there could exist electrically neutral particles, which I will call neutrons, that have spin 1/2 and obey to the exclusion principle and that further differ from light quanta in that they do not travel with the velocity of light. The mass of the neutrons should be of the same order of magnitude as the electron mass and in any event not larger than 0.01 proton mass. The continuous β spectrum would then make sense with the assumption that in β decay, in addition to the electron, a neutron is emitted such that the sum of the energies of neutron and electron is constant. But so far I do not dare to publish anything about this idea, and trustfully turn first to you, dear radioactive people, with the question of how likely it is to find experimental evidence for such a neutron if it would have the same or perhaps a 10 times larger ability to get through [material] than a γ ray. I admit that my remedy may seem almost improbable because one probably would have seen those neutrons, if they exist, for a long time. But nothing ventured, nothing gained. Thus, dear radioactive people, scrutinize and judge. Your humble servant W. Pauli "[1].

Pauli called this new particle *neutron*. The neutron(*N*) as such was discovered by Chadwick only two years later[3], thus *Pauli neutron* was called *neutrino* (ν) as suggested by Amaldi to Fermi.

2. D I S C U S S I O N

2.1 NEUTRON β DECAY (*βd*⁻)

In that regard Fermi said: "We still have the problem of knowing the laws of forces acting between the particles making up the nucleus. It has indeed, in this regard, in the continuous spectrum of β rays, some clues that, according to Bohr, this would suggest that perhaps in these new unknown laws even the Principle of Conservation of Energy is not valid any more; unless we admit –together with Pauli - the existence of the so-called *neutrino*, that is a hypothetical electrically neutral particle having a mass of the order of magnitude of the electron mass"[4]. To this purpose Fermi elaborated one of his masterpieces, the Theory of β Disintegration, according to which whenever in a radioactive nucleus there is the spontaneous disintegration of a *N*, it follows the emission of a *P*, a β ray and a 3rd particle, the ν, which with its mass, together with its E_{kin} , compensates for the amount of energy and mass that cannot be entirely taken by the β ray[5][6]. Namely: 1) *P* and *N* are two different states of the same fundamental object or Nucleon. 2) The e^- ejected, or β ray, does not exist within the nucleus, but it is created, together with this 3rd particle during the process of the *N* transformation into *P* (in what Fermi deviates from Pauli). 3) The process of radioactive decay of the nucleon is governed by a new Fundamental Force introduced by Fermi: the Weak Nuclear Interaction (WI). In fact, the explanation of the nuclear β decay(*βd*) Fermi gave in 1933 [5] was the prototype of the WI. He, taking as a model the description of the *e⁻ P diffusion*, provided by Quantum Electro-Dynamics, proposes also for the *βd* a type of interaction based on the field theory. Fermi uses the mathematical formalism of the operators of creation and destruction of particles introduced to the Electro-Dynamics by Dirac, Jordan and Klein, called "second quantization" [7][8] [9]. In this case, however, the interaction is punctiform and called '4 fermions interaction'. It constitutes a *contact interaction* between the 4 particles involved: the *N* (which constitutes the initial state) plus the *P*, the e^- and this 3rd particle, or ν. The WI is the only force capable of changing the *flavour* of a particle, that is, to transform it into another. These concepts were represented by Fermi through the mathematical formalism of the βd^-:

$$N \rightarrow P + e^- + \bar{\upsilon} \qquad (3),$$

where $\bar{\upsilon}$ is the anti-neutrino. Now we know that in the spontaneous decay of a nuclear *N*, or βd^- , it is a down quark (dQ) of the *N* to be transformed, by the WI, in an up quark (uQ) through the emission of a W^- boson. Such a *flavour* exchange between Qs involves the transformation of *N* into a *P*. The W^- particle immediately decays into an e^- and an electronic antineutrino ($\bar{\upsilon}_e$):

$$udd(N) \rightarrow udu(P) + W^- \rightarrow udu(P) + e^- + \bar{\upsilon}_e \qquad (4).$$

2.2 *βd*⁻ MASS GAP PROBLEM: STILL UNSOLVED

Thus let's consider the value of the *minimum energy* of an e^-, i.e. the so-called Z*ero Point Energ*y(ZPE)[10]: it is equal to 0.511 MeV. Now, if we subtract this value from the energy value expressed by Eq.(2), we obtain the value of the energy that could be covered by the 3rd particle of the *βd*, denoted by Δ_E:

$$\Delta_E = 0.78281 \text{ MeV} \quad (5).$$

This value exceeds the 53.14 % the energy of an e^- *at rest*. But it is worth pointing out that this is the maximum value the 3rd particle can reach (considering that at the same time the e^- is emitted too). This does not mean that it always has so much energy, rather the contrary. In fact in the value expressed by Eq.(2) we must also consider the E_{Kin} of the β-ray, whose energy spectrum, as Fermi had reported [5][6], may also coincide with the entire energy value described by Eq.(2).

Thus, from the analysis of the *βd*, we seem to catch two important results: 1) the total energy of the emitted charged e^- can fluctuate *randomly* (depending on the intensity of acceleration) in a precise range between 1.29381MeV and 0.511MeV. 2) The energy the 3rd particle can acquire, should fluctuate, still *randomly* distributed between 0.78281MeV and 0.511MeV.

Therefore, these are the energy values which must obligatorily be attributed to the 3rd particle emitted with *βd*⁻, represented as $\bar{\upsilon}_e$ in the Eq.(3), in order to *balance* and make congruent this equation. But reality is different.

The mass still attributed to ν is well 5 orders of magnitude less than the electron mass!

This limitation was inferred from the observations of Supernova 1987A, for which it had been assumed that the mass of the ν_e was <5.8 eV[11]. Why this limit? Because the ν_s of this supernova arrived on Earth a few hours before the visible light; so they "must have traveled at a speed very close to that of light. Since lighter particles travel faster than heavier ones, scientists have concluded that the mass of ν is very small"[12]. Maiani adds: "The current upper limits of the mass of the ν_s emitted with the *β-decay* are m_ν <2eV"[13], a value corresponding to <1/250000 of the electronic mass!

2.3 NEUTRINO DETECTION

In announcing the possible existence of a 3rd particle in the *βd*, both Pauli and Fermi scrupulously specified that it would be very difficult to detect such a particle. In fact, Pauli writes: "This particle would have the same or perhaps a 10 times larger ability to get through [material] than a γ ray"[1]. Fermi adds: "This particle, for its enormous penetrating power, escapes any current detection method, and its E_{Kin} helps to restore the energy balance in the *β* disintegrations"[4]. In fact, questa 3rd particella si rivelò così elusiva e sfuggevole, che vari A.A. la definirono the *ghost particle*.

2.3.1 Cross Section of the 3rd Particle of the *βd*⁻

Bethe and Peierls, i.e., after several calculations, wrote that it would be impossible to detect a ν, since this would pass, without interacting, through a lead wall of over 3500 light years[14]. It must be added that the very small cross section(σ) of such a particle causes it can more easily pass through the matter without interacting with it. In fact, the σ of ν was found to have a value as small as 10^{-44} [cm^2] [14]. This same value was confirmed in 1959 by Reines and Cowan [15], who revealed that the σ of the ν_e was equal to:

$$\sigma = (11 \pm 2.6)10^{-44}[\text{cm}^2] \quad (6).$$

It is really a very small cross section. In comparison, as Fermi tells us "the σ of slow neutrons, is between 10^{-24}[cm^2] and 10^{-21} [cm^2]"[16]. In this respect Rasetti (the founder, together with Fermi of the School of Physics of *via Panisperna*) reminds us: "The ν is the smallest object human beings have ever met. It can cross the matter very easily, that's why it has very little propensity to interact with

matter, not only because it is very small, but also because it travels at very high speeds for which it remains near to atomic nuclei – with which it could possibly interact - for a time which is too short to allow a reaction. In order to have any effect, the ν_s in their movement should fully center the nucleus of an atom, however it is such a rare event that it is estimated that these strange creatures would be able to cross a wall of a few light years thickness without finding any obstacle " [17].
Leafing through the vast literature about it, it is immediately obvious that all the different techniques of detection of the 3rd particle of *βd*, or ν, have always only showed the effects (on the particles involved in the reaction) determined by a particle freed in radioactive decays: to be exact an invisible particle , believed to be the ν (but those detected may well be indirect effects induced by another particle). In fact, It took 25 years to come to a detection, always *indirect*, of the $\bar{\upsilon}$.

2.3.2 Detection of the 3rd Particle in cadmium chloride solution

To this purpose, the apparatus designed by Reines and Cowan[18] (complying with Pontecorvo suggestions) was made of a target of about 1000 litres of aqueous solution of cadmium chloride contained in two containers alternating with three other containers filled with a liquid scintillator acting as a detector. Thus, installing this system near nuclear reactors, in which constantly occur countless βd_s, it could happen that the alleged $\bar{\upsilon}$ issued, bombing water *P*s, created a reverse process, i.e. a βd^{+}, transforming the *P* in *N*, moreover the emission of an e^+ and a ν. The e^+, in its turn, annihilating with an e^- of the water, generates a pair of γ photons of a defined frequency, able to produce light in the scintillators placed along the walls surrounding water. Such light, or *Cherenkov light* (*CL*)[19][20], is detected by photomultipliers. The characteristic time is $\sim 10^{-9}$ seconds, and the coincidence between two scintillators represents the time (t_o) of the measure. Therefore, in the same pair of scintillators it occurs a delayed coincidence, compared to t_o. That's all. That is, the strategy of *data taking* by the experimenters essentially consists in recording time, which separate the events sought, and the energy value registered by the photomultipliers.
Thus, this was enough to believe to have found, specifically and unequivocally the effects of the elusive $\bar{\upsilon}$. With good conscience, this statement seems to us a *stretch* in the interpretation of the findings. That statement, in our view, requires a preconceived, a *dogma*: that the 3rd particle emitted with βd^- must be only and unquestionably an $\bar{\upsilon}$, no other type of particle.

2.3.3 Detection of the 3rd particle through SNO and Super Kamiokande

We can still quote two more neutrino detectors: the Subdury Neutrino Observatory (SNO) and the famous Super Kamiokande. They are both made of huge pools of water, whose walls are covered with an infinity of 'light detectors', or photomultipliers. Both experiments use the procedure characterizing the detection of Reines and Cowan, for which the alleged $\bar{\upsilon}$ (or 3rd particle of βd^-) strikes a *P* of a water molecule, triggering a βd^+: the e^-_s freed at relativistic speeds, traveling faster than light (in the same medium), emit the typical *CL* which is captured by photomultipliers. It is believed that it is the ν to trigger the series of reactions leading to the production of the *CL*. Yet, even in these experiments (SNO and Superkamiokande) the ν remains elusive: it is only possible to detect the effects of the invisible particle, the *ghost particle* issued in *βd*.
Nevertheless, in such surveys the production of *CL* is considered as the evidence of the existence of ν and $\bar{\upsilon}$. This interpretation of the experimental data seems to us *forcing*: because, since the precise identikit of the 3rd particle emitted with *βd* is not known, we cannot say with scientific certainty that the effects it produces are attributable specifically and exclusively to a ν.

2.3.4 Radiochemical method proposed by Pontecorvo

Even Pontecorvo was obsessed with the search for ν, until in 1946 he perfected a radio-chemical method based on the Chlorum-Argon transformation, in order to try to capture the ν_s of solar origin. However, the first idea of Pontecorvo to detect free ν_s was to use the *inverse β process* in the Chlorine-35/Sulphur-35 reaction:

$$\nu + Cl_{17}^{35} \rightarrow \beta^+ + S_{16}^{35} \quad (7),$$

where β^+ is a e^+. Pontecorvo says: "The Sulphur-35 (S_{16}^{35}) is a β-active radioelement, decaying to Chlorine-35(Cl_{17}^{35}) with a period of 87.1 days the energy of the β-ray radiation being only 120 KeV. S_{16}^{35} would be produced by absorption of a ν and emission of a e^+ from the original Cl_{17}^{35}" [21]. In the years '45-46 the difference between ν and anti-ν($\bar{\upsilon}$) was not very clear and the Chlorine-35/Sulphur-35 reaction could only be used to detect reactor ν_s (i.e. $\bar{\upsilon}$), while the Chlorine-37/Argon-37 reaction (proposed by Pontecorvo) could be used to look for solar ν_s:

$$\nu + Cl_{17}^{37} \rightarrow e^- + Ar_{18}^{37} \quad (8).$$

Pontecorvo writes: "The problem of the β disintegration has been attacked experimentally in many ways: 1) β spectroscopy, i.e. study of the form of the β spectrum. 2) *N* decay has not yet been detected. The common feature of all these experiments is that the magnitude of the recoil energy of the nucleus having undergone a decay process is examined in the light of the laws of the conservation of energy and *momentum*. It should be noted that experiments of this type, while of fundamental significance in the understanding of the β process, cannot bring decisive direct evidence on the basic assumption of the existence of the ν. Direct proof of the existence of the ν, consequently, must be based on experiments, the interpretation of which does not require the law of conservation of energy, i.e. on experiments in which some characteristic process produced by free ν_s (a process produced by ν_s after they have been emitted in a disintegration) is observed" [22]. In this paper, proposing his method to directly detect "free ν_s", Pontecorvo adds: "It is true that the actual β transition involved, i.e., the actual emission of a β particle in process

$$\nu + Z \rightarrow \beta^-(\beta^+) + Z\pm1 \quad (9)$$

is certainly not detectable in practice"[22](Z is the atomic number and β is an electron: e^-or e^+). The Author precises: "However, the nucleus of charge Z±1, which is produced in the reaction may be (and generally will be) radioactive with a decay period well know. The essential point, in this method, is that radioactive atoms produced by an inverse β-ray process have different chemical properties from the irradiated atoms. Consequently, it may be possible to concentrate the radioactive atoms irradiating with ν_s a large volume of Clorine or Carbon tetra-chloride, for a time of the order of one month, and extracting the radioactive Ar^{37} from such volume by boiling. The radioactive argon would be introduced inside a small counter; the counting efficiency is close to 100%, because of the high Auger electron yield"[22].

"The choice of this elements was done namely: 1) The material irradiated must not be to much expensive, since large volume is needed. 2) The nucleus radioactive produced should have a rather long decay period because of the long time needed for the separation. 3) The separation of the radioactive atoms must be relatively simple. 4) The difference in mass of the elements Z and Z+1 must be small because the *inverse β process* cross section increases with the energy. 5) The background of Z+1 element produced by other causes must be as small as possible"[23].

Pontecorvo asserts: "The ν_s emitted by the sun are not very energetic. The ν source is the pile itself, during operation. In this case ν_s must be utilized beyond the usual pile shield. The advantage of such an arrangement (with respect to use as source of hot uranium metal extracted from a pile) is the possibility of using high energy ν_s emitted by all the very short period fission fragments. Probably this is the most convenient ν source"[22].

As Maiani reminds us "Pontecorvo realizes that a nuclear reactor produces an astronomical quantity of ν_s (from the *decay in flight* of *Ns*) of the order of 10^{20}-10^{23} per second. That is, for events/sec in 1 mt of iron, one would have: $N \approx 10^{20} 10^{17} = 10^3$ events/sec"[24]. To this purpose Pontecorvo proposes to study ν_s, produced by nuclear reactors, observing the reaction: $\nu + Cl_{17}^{37} \rightarrow Ar_{18}^{37} + e^-$, see Eq.(8).

Proposed method: 1) Installation of a large volume container (some m^3) filled with C_2Cl_4 (a liquid generally used as stain remover) at a nuclear reactor. 2) Every 3-4 weeks, boil the liquid, collect the steam (which should contain atoms of Ar_{18}^{37}) in proportional meters. 3) Measure the electronic capture $e^- + Ar_{18}^{37} \rightarrow Cl_{17}^{37} + \nu$ (average life 49 days) by the detection of X rays/ e^-_s emitted by the excited atom of Cl_{17}^{37} when returning to the ground state [25]. That is, in such a transmutation we have that "the isotope 37 of the Argon is radio-active (average life 35 days) for which it returns to the Cl^{37} capturing an e^- of its atom, according to the reaction known as *K capture*:

$$Ar_{18}^{37} + e^- \rightarrow Cl_{17}^{37} + \nu \qquad (10).$$

The Ar^{37} can be extracted from the Cl by passing air, the whole is collected, the Ar is separated from the air, and its quantity of radioactivity is measured. Knowing the probability of reaction, from the number of atoms, produced day by day, we obtain the flow of ν_s "[26].

2.4 RRFLECTIONS ON ARGO-37 ↔ CHLORUM-37 TRANSMUTATIONS

So we have 2 isotopes of different elements: one, the Cl^{37}, is firmly stable, while the other, the Ar^{37}, is unstable (unlike the Ar^{40}, or even the Ar^{38} and Ar^{36}), in fact it is radioactive and decays in 5 weeks. So, probably in order to regain stability, the isotope 37 of the Argon (Ar_{18}^{37}) makes a *P* to capture an e^- from its own atom. It follows that, leaving unchanged the value of its atomic mass (A = 37), this isotope undergoes the transformation of a *P* into *N*, whereby its atomic number (Z = 17) falls by one unit. As is known, as the atomic number of an element varies, its chemical properties also vary, so much so that the Ar_{18}^{37} is transmuted into another element: the Cl_{17}^{37}.

All this due to the *electron capture* occurred in Ar_{18}^{37} and represented as follows:

$$e^- + P \rightarrow N + \nu_e \qquad (11),$$

where with ν_e we mean an electronic ν. At this point, however, it would be licit and scientifically correct to ask: where did it come from and how? How is this presence justified in Eq.(11)?

In short: it is as if in this equation some intermediate passage was omitted.

Furthermore, there is another reflection: Eq.(11) fully respects the Laws of Conservation of the Electric Charge, of the Lepton and Baryon Number, and of the Angular Momentum, but it is clearly and markedly unbalanced with regard to the Laws of Conservation of Mass and Energy. This *balance*, that is, is not in equilibrium, but the right plate *weighs* heavily more, i.e. the second member of Eq. (11), since just *N* weighs between 0.511 and 0.78281 MeV more than the sum of the masses of *P* and e^- (it depends on the acceleration of e^-) [27].

In fact, the e^- represented in Eq.(11) is not provided with a great energy, that is, *it is not relativistic*, as in the *neutronization* phase that occurs in Neutron Stars or with the explosion of a Supernova, where the e^- *captured* by a free P reaches energy values up to ≈200 MeV.

On the contrary, in the case of the Ar_{18}^{37} one of its 18 Ps *captures* an e^- from its atom and, as Majorana specifies, such atomic e^- are not at all relativistic [28] [29].

Moreover, one of the phenomena that are very often accompanied by neutronization, such as electron capture, is the so-called photo-annihilation, characterized by the materialization of electro-magnetic radiation (EMR), with consequent production of pairs (particle-antiparticle):

$$\gamma \rightarrow \bar{\upsilon}_e + \nu_e \qquad (12),$$

where γ indicates a gamma photon , i.e. highly energetic radiation, being of nuclear origin.
Since these processes of *photoannihilation* and of *production of couples* are accompanied by the phenomena of neutronization and electron capture [30], it would be more appropriate to describe them together. For this reason, by entering the Eq (12) in Eq. (11) we obtain:

$$e^{-} + P \rightarrow e^{-} + P + \gamma \rightarrow e^{-} + P + \bar{\upsilon}_e. + \nu_e \rightarrow N + \nu_e \qquad (13),$$

that is: $$e^{-} + P + \bar{\upsilon}_e + \nu_e \leftrightarrow N + \nu_e \qquad (14).$$

In this way, with these two intermediate steps, described with Eq.(13), the previous Eq.(11), describing the *electron capture* carried out by *P*s of the Ar_{18}^{37}, should be more complete and congruous, since the possible steps through which the ν_e is generated are shown, which appeared *ex abrupto* to the 2_{nd} member of Eq.(11).
Yet, from Eq.(14) something new emerges. In fact, leaving aside the ν_e (present on both sides) it is easy to notice that the *N*, present in the 2nd member, corresponds to the 1st member, a compound of 3 particles: $e^{-} + P + \bar{\upsilon}_e$, i.e. a multiplet [$e^{-}$, P, $\bar{\upsilon}_e$].
We would like to point out that the emerged *multiplet* is not a *forcing* at all. It comes from a more complete consideration of the "series of reactions that develop during the collapse of a Neutron Star" [29]: that is considering both "the *neutronization* processes, such as the *electron capture* "[30] described with Eq. (11), and "the Couple Production processes, including *photoannihilation*"[30], described within Eq. (12).
It is precisely the *photoannihilation* which helps us to better understand these peculiar phenomena in all their complexity. In fact, with the photoannihilation we have found the $\bar{\upsilon}_e$ which is missing in the *electron capture* equation(11), where only the ν_e is described, but without the counterpart: which is not justifiable. In fact, as regards the *materialization* processes of the EMR, similarly to what happens with the photoannihilation, a fundamental rule of Physics states that "the particles are always produced in pairs: one made of matter and the other of antimatter "[31]. It is unequivocal. So, where is the $\bar{\upsilon}_e$? The $\bar{\upsilon}_e$ is present in the 1^{st} member of Eq.(14) together with *P* and e^{-}, arranged in sequence, one after the other, to form that *multiplet*, represented by *N*. The latter is placed both at the 2^{nd} member of Eq.(14) itself, and to the 2^{nd} member of Eq.(5), describing the *electron capture*. In this way, also implying the presence of a couple $\nu_e\ \bar{\upsilon}_e$ (generated by photoannihilation), and allocable to the 1^{st} member of (5), this equation becomes more appropriate and physically more valid.
Furthermore, trying to read Eq.(14) in reverse, omitting the ν_e (using the first Principle of Equivalence of the Equations), we have:

$$N \rightarrow e^{-} + P + \bar{\upsilon}_e \qquad (15).$$

It is surprising: Eq.(15) shows exactly the decay products of *N*, in fact this equation corresponds precisely to the famous equation describing the *N decay* or βd^{-} (see Eq.3).
Moreover, if we read this passage according to the verse indicated in Eq.(14), we have:

$$e^{-} + P + \bar{\upsilon}_e \rightarrow N \qquad (16).$$

The reading of Eq.(16) tells us frankly that this *multiplet* gives rise to the *N*!

2.5 CONFLICT between QUANTUM MECHANICS and NUCLEAR ELECTRONS

But it is not possible, it will be said. A *N* incorporating an e^- would imply the presence of e^-_s within the nuclei. But this would conflict with the Quantum Mechanics (QM). In fact, as Maiani reminds us [32], if we bring into play the Heisemberg Uncertainty Principle (HUP) [33] [34] an e^-, located within the radius (*R*) of the atomic nucleus, would have an energy ($\Delta_{\boldsymbol{p}}$) more than 100 times greater than that of *β-rays* (≈1MeV):

$$\Delta_{\boldsymbol{p}} \approx \hbar/R \approx 140 \text{ MeV} \qquad (17),$$

where ħ is Planck's constant, written in the Dirac manner. In fact, according to the QM, simply placing particles in the sphere of radius R implies that these particles have a *momentum* (***p***), as imposed by HUP, of: $\boldsymbol{p} \geqq \hbar/R$ [30].

The so-called *Klein paradox* [35] is based on the same concept, so that, due to its high *momentum*, the e^- immediately runs away from the atomic nucleus. For this reason, after more than a decade Rutherford hypothesis was rejected. He had imagined the *N* as made by the very close union of a *P* with a e^-. In fact, in his "Bakerian Lecture" (1920), Rutherford hypothesized that, within a nucleus, there could be one or more "very strong e^- *P* combinations", while at the same time persisting the possibility of coexistence in the nucleus of a number of *P*s exactly equivalent to the number of atomic, peripheral e^-_s, orbiting at enormous distances from the nucleus [36].

On the other hand, the presence of e^-_s inside the nucleus was not an abstruse concept. Rutherford refered to the experiments of Becquerel, who as early as 1896 had demonstrated, unequivocally, that some atomic nuclei (Uranium salts) emit e^-_s of high energy, called *β rays* [37]. From that time, therefore, we start thinking of nuclei compound of *P*s and e^-_s, i.e. *nuclear electrons* [3]. Rutherford added that, since the atom was hydrogen (H) neutral, considered as a nucleus of single unit charge (a *P*, in this case), having an e^- attached at a certain distance, it was possible that an e^- would combine very much strictly with a hydrogen nucleus, H_1^1 (as to say a *P*), forming a sort of *neutral doublet* 〔*P*, *e*⁻〕. Rutherford stated in this regard:: "Under some conditions it may be possible for an e^- to combine much more closely with the H nucleus, forming a kind of *neutral doublet*. Such an atom would have very novel properties. Its external field would be practically zero, except very close to the nucleus, and in consequence it should be able to move freely through matter"[36]. In this context, under conditions of very high density (as the nuclear matter, equal to 10^{13}g/cm^3), it may turn out that the e^-_s, subjected in addition to intense forces, may appear deformed, so as to remain tied, *trapped* in the nucleus. With such densities even ν_s cannot run away.

The following month, at the British Association Meeting of 25/8/1920, Rutherford called this *neutral doublet* with the term "neutron" [38].

The particular conditions Rutherford referred to, are actually created in Nature, both within an atomic nucleus, as the *P*'s *electron capture* of the Ar_{18}^{37}, just in the conditions related to the *Baryogenesis*, i.e. with the *N Synthesis*: *BB* nucleonic synthesis, *primordial nucleosynthesis*, stellar and explosive nucleosynthesis, *neutronization* and Neutron Stars. All these situations are united by extreme conditions of density, pressure, gravity and Temperature. What happens is that the atoms are crushed each other, each atom is compressed, so, as in in the case of a hydrogen atom (H_1^1), the orbiting e^- is pushed against its nucleus, that is against a *P*, thus creating a different particle, referred to as *N*, which is made, in fact, by a *P* and an e^-: that is a *neutral P*, as Majorana called it[39][40]. What has been described is the well known *Neutron Synthesis*, thanks to an *electron capture* mechanism by a free *P*, as in the stellar *core*, or by a nuclear *P*, as in the case of Argon-37.

Nevertheless, although the reality broadly confirmed that the *N* could be made at least as the *doublet* of Rutherford 〔P, e^-〕, we appealed, *improperly* in our opinion, to the QM, rejecting the hypothesis that the *N* was a *compound particle*, but claiming that the *N* was an *elementary particle*. It means that it was not taken into account that all those physical processes that in Nature produce the *nucleonic synthesis or baryogenesis*, occur exclusively in extreme environmental conditions, where it is widely believed that most of the known physical laws would be less. Weinberg has emphasized widely that, in order to obtain the synthesis of a *P* or a *N*, the Temperature(T) must necessarily be: $T \geq 10^{13}$ °K [41]. In short, it deals with really infernal environmental conditions, that is *singular*, as Einstein and many other authors defined them, pointing out, in fact, that in the presence of a *singularity* the physical laws would no longer be valid, or would not take place as usual.
Furthermore, it must be added that this particle, this *compound*, cannot have an internal space. "The e^-_s are so close to the *P*s that they merge with them and there is not even the smallest space between them" [42]. How could this *complex particle* have its own internal space, and thus its radius, given the likely null distance between e^- and *P*? Just think that in only one cm^2 of the *neutronic flux* (which is the core of a Neutron Star) there are 10^{22} *Ns*!
Likewise "near the *core* of a fission reactor there is a very high *N*s *flow*, in the order of 10^{14} *N*s/cm^2/sec. These extremely high *N*s *flows* are mainly used for the production of radioisotopes with capture reaction"[43], as in the case of the'Argon-37.
It may seem really ridiculous to keep talking about N's radius in these spaces.
Therefore, in Nature the so-called *N* comes from the union of an e^- with a *P*: *Baryogenesis docet*. However, the QM does not allow these conditions to persist, as the e^- would be immediately expelled from the nucleus.
Maybe the mentioned HUP example can be valid for a free *N*, i.e. not firmly bound in an atomic nucleus (nor subject to that enormous pressure), so much so that in the average time of ≈ 885 seconds this *N* decays spontaneously. On the contrary, the *Ns* housed in the nuclei are made stable by the action of the *Strong Nuclear Force* and by the *nuclear binding energy* [44], so they behave differently (they do not decay).
Moreover, in Nature it does not always happen that the e^- is immediately removed (as a result of the HUP) after the *N* is formed: *Neutron Stars testify*, whose *Ns* survive for many millions of years. These stars are a clear example in which the removal of the e^- by the HUP is not carried out: it is reality! That is, in various situations of extreme density, T, gravity and pressure, tending to the *singularities*, the basic principles of the QM, like the HUP, are not applicable. These situations of extreme physical conditions could hide another Physycs (also containing other laws), as well as making possible the coexistence of the so-called *nuclear* e^-_s.
In short, it seems very important to underline that, in these very special circumstances, in our opinion, the considered e^- is not at all located in the nuclear space, as in *Heisemberg's Isospin space* [45] (in this case, it would be expelled by the HUP) but, for a process of *electron capture* operated by *P*, the e^- remained *glued* to the *P*, but without constituting a real self-contained particle, with its internal space and its radius.
Therefore, one could infer that the HUP, and thus the related Eqs.(17), would not be applicable to all those *Ns* (or *neutral complex particles*) created in the various processes that occur spontaneously in Nature, described with the Baryogenesis,
Thus, the extreme conditions of density (10^{14}g/cm^3 nelle Neutron Stars and 10^{13}g/cm^3 in the common nuclear matter) that crushed the e^- against the *P*, thus creating a *neutral compound P*, referred to as

N, make it impossible to look for the radius (R) of this *compound*, given the null distances between e^- and *P*: we are talking about a *degenerate gas* of *N*s, which creates a *neutron flux* where we count a number of *N*s $=10^{22}/cm^2$ per second. How could all these particles ever have their own space and their own *ray*, since there are 10000 billions of billions in one cm^2 ?!
The foregoing explains equally and with the same modalities why, in all those extreme environmental conditions, necessary to allow *baryogenesis*, the QM is not able to expel the e^- and, therefore, to oppose the creation of *N*.
Indeed, it can not be ruled out that, if the HUP had always denied this persistent union between e^- and *P* (basic for the *Neutron Synthesis*), there would not have been a sufficient *baryogenesis* for the formation of matter and our world.
Therefore, those various incompatibility conditions between the *nuclear electrons* and the QM would disappear, since they are not applicable to the *neutral complex particle*, or *neutral P*, indicated as *N*, being the latter extremely condensed (beyond every imaginable measure and probably without analogous situations in Nature) and, therefore, without any internal space and, consequently, without any presumed ray (*R*).
Gamow highlights some problems arising from the Rutherford *N model*, with particular reference to a peculiar concept of the QM: the *nuclear spin statistics*. In Gamow's later articles these difficulties appear in the discussion of angular momenta of radioactive elements [46][47]. Gamow wrote:: "It seems to show that the nuclear electrons do not count in the statistics of the system; either, for some reasons as yet unknown, the nuclear electrons must be described by symmetrical wave-function, or we must give up the idea of assigning space co-ordinates to the electrons inside the nucleus. At present nitrogen is the only element for which this difficulty has arisen, but it seems probable that it is true in general that the statistics of the nucleus depend only on the total number of protons in it. It seems that nuclei with an even number of protons always have an even spin, while those with an odd number of protons have an odd spin. That indicates that the nuclear electrons do not make any contribution to the total angular momentum of nucleus"[48].
Furthermore, analyzing some of the measures taken by Ornstein and van Wijk [49], which were further investigated and confirmed by Kronig [50], it appeared that the spin of the nucleus of nitrogen corresponded to an even number. whereas, according to Rutherford's *N model*, still concerning the nucleus of nitrogen (N_7^{14}), in the nucleus beside the 7 basic *P*s, we have 7 more *P*s closely related to 7 e^-. Thus, within the nucleus appear 21 ½ spin particles. Summing up we have that the nucleus of the nitrogen should have a *half-integer* spin. But this is in open contrast with the experimental data, which show the nitrogen nucleus consisting of 14 nucleons, as its atomic weight (A), so that its spin must express an integer [32]. Shortly thereafter, in U.S. Rasetti carried out a study of the Raman spectra of the nitrogen molecule, pointing out that N_7^{14} nuclei obeyed the Bose-Einstein statistics, as they showed integer spin [51]. Thus, both Kronig experimental data, and Rasetti's, were in open conflict with the *N model* prospected by Rutherford.
Faced with the evidence, Fermi abandons that *N* model, elaborating his mathematical formalism of the *N decay* (see Eq.3), adding the 3rd particle hypothesized by Pauli, specifying: "With the aim of understanding the possibility of emission of *β rays*, we will attempt to construct a theory of the emission of light particles from a nucleus in analogy with the theory of a quantum of light from an excited atom in the usual process of radiation. In the theory of radiation, the total number of the light quanta is not constant; the quanta are created when being emitted from an excited atom and disappear when absorbed"[5].

However, from Eq.(14) emerges that a *multiplet* corresponds to the *N*, as shown also in Eqs.(15) and (16). With the *N multiplet* things change drastically since its components are 3 fermions, no longer 2 as in Rutherford *N doublet*. It follows that the *N* retains its ½ spin value so that this *multiplet* safeguards the Law of Conservation of the Angular Momentum of the *N*.
Now let's look at the Spin Statistics of the Nitrogen Core (N_7^{14}), considering *N* as *multiplet* (rather than *doublet*). This particular changes things.
With the model of the *N multiplet*, we have that in the nucleus of nitrogen to the 7 base *Ps*, as a result of the e*lectron capture* process more 7 *Ps* are added, as well as 7 e^-_s and 7 $\bar{\upsilon}_e$.
So in the nitrogen nucleus we have as many as 28 half-integer spin particles (fermions). Thus, summing up, we have an integer spin, which tells us that the nucleus of nitrogen, along with the Spin-Statistics Theorem, behaves like a boson, in perfect agreement with the Rasetti experiment [51]. And above all, according to reality.
Nonetheless, this *N multiplet*, proposed in this way, does not satisfy us completely, since, observing Eqs.(3) or (15), we notice that something is wrong. In fact, to equalize the mass of the 1st member, i.e. of the *N*, the 3rd particle placed at the 2nd member, i.e. the $\bar{\upsilon}_e$, should weigh between 0.78281MeV and 0.511MeV. But then, as the mass of the ν_e is considered to be small, it takes from ~100000 to 250000 $\bar{\upsilon}_e$ to balance the equation. Therefore, it does not work, it is unthinkable: it must be a different particle to compensate for the mass.
Unless we think, as we have already hypothesized to try to solve the mass gap problem of βd^-, that this 3rd particle is not a $\bar{\upsilon}_e$, but another particle, still unknown. Having to respect, however, also the Law of Conservation of the Lepton Number, this 3rd particle must be obligatorily an antilepton, and of null electric charge. These are 2 of the 3 requests put forward by Pauli and Fermi [1] [5] [52] to characterize the 3rd particle of βd^-.
Their 3rd request is that it had the same mass of e^-. Therefore, a neutral antilepton, with the mass of e^-, immediately made us think of a *neutral electron*: e°, or rather an anti-e° (ē°) [53]. In this case, the *multiplet* corresponding to the *N* would be as follows:

$$N = [\ e^- , P ,\ \bar{e}^\circ\ ] \qquad (18).$$

In order to counterbalance the mass of *N*, the ē°° must have a mass between 0.78281MeV and 0.511MeV, values easily reached with sufficient acceleration.
Also this *multiplet* is completely superimposable to the products of the *N* decay, with the substitution of the $\bar{\upsilon}_e$ with ē°, as proposed with Eq. (18).
It could be said that the same results reached by an e° are obtained similarly even with a ν. And then: e° does not exist, this is an invention! The only known e^-_s are those carrying an electric charge: e^- and e^+. Yet even the ν, when suggested by Pauli, was an invention. Moreover the ν was a particle totally unknown, invented from scratch. Indeed, it was forced to introduce in Physics, *compulsorily*, a new family of particles, with their own characteristics, and with presumed properties quite different from the other elementary particles known at the time. The e°, instead, refers to one of the fundamental particles more widespread in nature, even if only those electrically charged are known. In addition, a not negligible result, with the e° it is not necessary to invent a new category of particles to be added to the Standard Model (SM), maintaining the symmetry of the SM and further simplifying it (according to the *reductionist* approach preferably adopted in Physics[54]).

3. C O N C L U S I O N S

Yet, one may object: even with the *N*, considered as an elementary particle, we are in agreement with the Rasetti experiment. In our opinion, as explained above, the *N multiplet* solves some unsolved problems, as well as making some equations complete and congruous.

First of all, it gives the right role to those processes of *photo-annihilation* and pair production, describing them together with the *electron capture*, we understand the fate of couples like ν_e $\bar{\upsilon}_e$. Though are not shown in Eq.(11), in our opinion they should be added at the first member, thus creating Eq. (14).

As well as we can better understand the presence (otherwise unexplained) of ν_e at the 2^{nd} member of Eq.(11).

Likewise, also in the Argon-37 ↔ Chlorum-37 *Transmutations*, described with the Eq.(10), the effects of *photoannhilation*, of the *materialization* of the EMR and of the *Production of Particle Pairs*, which are accompanied by the *electron capture* process, should be integrated to the latter, which is responsible for this chemical transformation. Moreover, that ν, isolated, present to the 2nd member of Eq.(10) would acquire a better and more congruous context. If we insert Eq.(12) in Eq.(14), we have that the latter should be rewritten as follows:

$$Ar_{18}^{37} + e^- + \bar{\upsilon}_e + \nu_e \rightarrow Cl_{17}^{37} + \nu_e \qquad (19),$$

where *P and N*, described in Eqs.(11) and (14), are included respectively in Ar_{18}^{37} and Cl_{17}^{37}.

Furthermore, it should be noted that the *N multiplet* is completely identical, both structurally and in mass-energy content, to the products of the *N decay*, or βd^-, including the 3^{rd} particle.

Finally, if we considered the possible existence of the e°, with relative antiparticle, instead of *ν*, we would actually and in all respects safeguard the Laws of Conservation of the Mass and Energy , both in the *N decay* and in the *N multiplet*.

Moreover, the ē°, if present in the *N multiplet*, with its neutrality could likewise play a precious *cementing* role, thus contributing to the stability over time of this *multiplet*, i.e. similar to the role of stability played by *Ns* within the atomic nuclei.

Furthermore, the *N multiplet* reflects, in reverse, the three products of the *N* decay in which only one $\bar{\upsilon}_e$ can not compensate for the mass gap problem of βd^-: it would take from 100000 to 250000 of these ν_s to compensate for the gap. On the contrary, a single ē° would be enough to balance the gap mass, so that the *N multiplet* would be more congruous if formulated in this way: *N* = [e⁻, *P*, ē°], i.e. as in Eq.(18).

R E F E R E N C E S

1) Pauli W., Letter to partecipants of the Conference in Tubingien (1930), Septiem Conseil de Physique Solvay, 6th December 1930.
2) Feynman R.P,, "QED", ©1985 by Richard P. Feynman; Adelphi ed.(Milano) 1989,164.
3) Chadwick J., "Possible Existence of a Neutron", Nature, Vol.129, 3252, 312, 27th February 1932.
4) Fermi E., "Le ultime particelle costitutive della materia", 22° Meeting Società Italiana per la Propensione delle Scienze(SIPS),Bari 13/10/1933;Proceedings SIPS ,Roma 1934,Vol.2,pag. 7-14.
5) Fermi E., "Tentativo di una teoria dell'emissione dei raggi β",La Ricerca Scientifica ,4,1933,491-495.
6) Fermi E., "Tentativo di una teoria dei raggi β", Il Nuovo Cimento,1934,11,1-19.

7) Dirac P.A.M., “The Quantum Theory of the Electron”, Proc. Roy. Soc. A, London,117,610-624,1928.
8) Dirac P.A.M., “The Quantum Theory of the Electron. Part II”, Proc. Roy. Soc. A, London, 118,351-361,1928.
9) Jordan P., Klein O., “Zum Mehrkörperproblem der Quantentheorie”, Zeitshrift fur Phys., 45, 751,1927.
10) Puccini A., “About the Zero Point Energy, Zero Point Mass, Zero Point Temperature and Zero Point Motion in the Subatomic World and Photonics”, Progress In Electromagnetics Research Symposium Proceedings, Suzhou, China, Sept. 12-16, 2011, 1169-1171.
11) Vissani F., “La Domanda di Majorana”, Ithaca: Viaggio nella Scienza,2015,VI, 47-57.
12) Mirizzi A., “Neutrini e Supernovae”, Ithaca: Viaggio nella Scienza,2015,VI, 69-74.
13) Maiani L. “La massa dei neutrini”, Fermi Lectures 23, INFN, Rome, 26th March 2015.
14) Bethe H. and Peierls R., “The Neutrino”, Nature 1934, 133, 532.
15) Reines F., Cowan C.L., “Free Antineutrino Absorption Cross Section”, Phys.Rev.,113,273-279, 1959.
16) Fermi E., “Artificial Radioactivity Produced by Neutron Bombardment”, Nobel Lecture, Stockholm 12th December 1938, in “Les Prix Nobel en 1938”, Stockholm 1939, 1-8.
17) Rasetti F., www.cosediscienza.it/fisica/02_neutrino.htm
18) Reines F. and Cowan C.L., “The Neutrino”, Nature, vol.178, 446-449, September 1,1956.
19) Cherenkov P.A., “Visible emission of clean liquids by action of ϒ radiation”, Doklady Akademii Nauk SSSR, 2,451,1934.
20) Puccini A., “Why Gamma Photons Induce Cherenkov Effect”, Progress in Electromagnetics Research Symposium Proceedings, Moskow, Russia, August 19-23, 2012, 343-347.
21) Pontecorvo B., Chalk River Report, PD-141, Ontario, 25th May 1945.
22) Pontecorvo B., “ Inverse β process”, Nuclear Physics Conference, 4th September 1946, Montreal, National Research Council of Canada, Division of Atomic Energy, Chalk River, Ontario, 20th November 1946, Chalk River Report, PD, 1946, 205.
23) Castaldi R., Brono Pontecorvo a 100 anni dalla sua nascita, INFN Pisa, 19/02/2014.
24) Maiani L. “Entra Pontecorvo…”, Fermi Lectures 7, INFN, Rome, 4th December 2015.
25) Di Lella L., Fisica die neutrini e l’eredità scientifica di Bruno Pontecorvo, Dept. Phys. Univ. Pisa, 9th September 2013.
26) Maiani L. “La reazione dei neutrini con il Cloro 37”, Fermi Lectures 20, INFN, Rome, 19th March 2015.
27) Puccini A., “Majorana Particle is a Neutral Self-Conjugated Electron“, viXra.org, Nuclear and Atomic Physics : 1707.0064
28) Majorana E., “Uber die Kerntheorie”, Zeitschrift fur Physik, 82, 137-145, 1933.
29) Majorana E., “Sulla Teoria dei Nuclei”, La Ricerca Scientifica, Vol.4,1,559-565, 1933.
30) www.Fe.INFN.it/florenti/courses/astrophysics/07/Supernovae
31) http://scienzapertutti.Inf.infn/0407-materia-e-antimateria
32) Maiani L., “Isotopes and nuclear electrons”, Fermi Lectures 4, INFN, Rome, 27th November 2014.
33) Heisemberg W.,“Uber den anscauliken Inhalt der Quantentheoritschen Kinematik und Mechanik“, Zeitschrift fur Physik,Vol.43,172-198,1927.
34) Puccini A., “Uncertainty Principle and Electromagnetic Waves”, Journal of Electromagnetic Waves and Applications, Vol.19, Issue 7, 885-890,2005.
35) Klein O., “Die Reflexion von Elektronen an einem Potentialsprung nach der relativistischen Dynamik von Dirac”, Zeitschrift fur Physik, Vol.53,Issue 3-4,157-165,1929.
36) Sir E. Rutherford, “Bakerian Lecture: Nuclear Constitution of Atoms”, Proceed.Roy.Soc. A, Vol.97, Issue 686,374-400, 1th July 1920.

37) Becquerel H., “Sur les radiations emises par phosphorence”, Comptes Rendus, 122, 420-421, 1896.
38) Sir E. Rutherford, “The Building up the Atoms”, Proceed. of British Association,25/8/1920, “Engineering”, 110,382,1920.
39) Segrè E. in “E. Fermi, Collected Papers”, Chicago, the University of Chicago Press, 1962-65, vol. I, 488, 1962.
40) De Gregorio A., “Il Protone Neutro”, ovvero della laboriosa esclusione degli elettroni dal nucleo, Tesi di Dottorato in Fisica, Univerità di Roma La Sapienza, 2005.
41) Weinberg S., “The First Three Minutes. A Modern View of the Origin of the Universe”,©1977 by S. Weinberg; Mondadori Ed.(Milano),1977, 172-173.
42))http://archive.oapd.INAF.it/Stelle_di_neutroni.html
43) Licata M., “Studio del flusso di neutroni”, Tesi di Laurea in Fisica, Univ. di Bologna, A.A.2013-2014.
44) www.Fe.infn/Reazioni nucleari di interesse astrofisico/03.
45) Heisenberg W.,“Über den Bau der Atomkerne. I”, Zeitschrift für Physik, 77, 1-11, June 7 1932.
46) Gamow G., “Uber den heutigen Stand der Theorie des β-Zerfalls”, Phys. Zeit., 35, 533-542, 1934.
47) Gamow G., “Nuclear Spin of Radioactive Elements”, Proc. Roy. Soc. A, London, 146, 217-222, 1936.
48) Gamow G., “Structure of Atomic Nucleus and Nuclear Tranformations”, Clarendon Press, Oxford, U.K., 1st edition with Preface by Lord Rutherford, Dec. 14 1931.
49) Ornstein L.S., van Wijk W.R., “Untersuchungen über das negative Stickstoffbandenspektrum”, Zeitschrift für Physik, IL,315-322, 1928.
50) Kronig R., “Der Drehimpuls des Stickstoffkerns”, Naturwissenschaften, 16, 335, 1928.
51) Rasetti F, “Alternating Intensities in the Spectrum of Nitrogen”, Nature, CXXIV, 792-793, 1932
52) Fermi E., “An Attempt at a Theory of βRays”, Nuovo Cimento, 11, 1-19, 1934.
53) Puccini A., “Neutral Electron Instead of Neutrino: A New Beta-Decay Model“, viXra.org, Nuclear and Atomic Physics : 1706.0202
54) Randall L., “Knocking on Heaven’s Door”, ©Lisa Randall 2011-2012; il Saggiatore ed. (Milano), 256, 2012.