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Neutron Structure: A New Model

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Abstract: ***In this paper we examine two situations apparently conflicting. On a side the Quantum Mechanics (QM) denies the presence of electrons within the atomic nucleus, so that it was shelved the doublet proton-electron as Neutron model. On the other side, in Nature exist various peculiar situations where many principles ofQM are not applicable. These contexts of extreme physical conditions make possible the process of electron capture ($P+e^-\rightarrow N+\nu_e$) operated by nuclear protons, whereby the electrons remained glued to the protons also for an unlimited time: Neutron Stars testified. The electroncapture (EC) may also leave the nucleus in an excited state, causing the release of γ radiation and then producing pairs of light particles, as couples $\nu_e\bar{\upsilon}_e$. Yet, if the radiation materialization was represented in the EC equation, we could better justify that ν_e appeared ex abrupto in the mentioned equation. Therefore, taking into account also the γ radiation emitted at the time of the EC, and inserting it in EC equation, on the side of the captured electron, we have: $P + e^- + \gamma \rightarrow P + e^- + \bar{\upsilon}_e + \nu_e \rightarrow N + \nu_e$ that is $P + e^- + \bar{\upsilon}_e + \nu_e \leftrightarrow N + \nu_e$ i.e. $N \rightarrow P + e^- + \bar{e}°$ i.e: $P + e^- + \bar{\upsilon}_e \leftrightarrow N$. The latter equation shows both the products of Neutron Decay and the probable. Neutron Structure: that is a multiplet, instead of a doublet. In this way it is safeguarded the Nuclear Spin Statistics. However, as the ν_e mass is considered ≤ 2eV, the latter equation shows a conspicuous mass gap problem, unless one wishes to hypothesize the existence of a neutral anti-electron ($\bar{e}°$). In this case, the latter equation should be rewritten as follows: $N \rightarrow P + e^- + \bar{e}°$***

Keywords: Neutron (*N*) ; Proton (*P*) ; Electron (e^-) ; Neutrino (ν) ; Negative β-Decay (βd^-)

1. Introduction

1.1 Neutron Decay

It is known to all that when Marie Curie observed for the first time the neutron spontaneous disintegration, or Neutron (*N*) *decay*, she only associated it to the emission of a proton (*P*) and an electron (e^-):

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

Let's evaluate the masses of the particles represented in Eq. (1).The neutron weighs $1.67492728 \cdot 10^{-24}$[g], while the proton weighs $1.67262171 \cdot 10^{-24}$[g]; on its turn the electron weighs $9.1093826 \cdot 10^{-28}$[g]. The mass difference (Δ_M) between neutron and proton corresponds to $0.00230557 \cdot 10^{-24}$ [g], that is $\Delta_M = 2.30557 \cdot 10^{-27}$[g]. According to the mass-energy conversion factors, if we consider that "1 MeV is about $1.782 \cdot 10^{-27}$[g]" [1], and follow the *cgs* metric system, we have:

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

This is the mass-energy value that in the *neutron decay*, or *negative β decay* (βd^-), must be carried away by the electron and another hypothetical particle, or the*3rd particle*, in order to safeguard the mass-energy balance in this process. It is well-known that this *3rd particle* was proposed by Pauli.

In fact, in theβd^- many Conservation Laws were not respected, among which immediately stood out the violation of the Law of Conservation of Mass and Energy. For some years it was not possible to find a solution. 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.

Pauli instead did not give up until, with a *master stroke*, he proposed the assumption that the emission of a 3rd particle without electric charge could compensate for this gap. In fact, after much hesitation, on 04/12/1930 Pauli sent his famous letter to the participants of the Congress of Physics in Tubingen. From that letter we can read: "Ihave 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 must be of the same order of magnitude as the electron mass and in any event not larger than 0.01 proton mass"[2]. Pauli called this new particle *neutron*. The neutron as such was discovered by Chadwick only two years later[3], thus *Pauli neutron* was called *neutrino* (ν) as suggested by Amaldi to Fermi.

In this respect, Klein writes: "In order to save the Law of Conservation of Energy, Pauli makes a hypothesis very bold: contrary to appearances, the core does not disintegrate into two bodies (another nucleus that is a proton and an electron), but in three. At the same time a 3rd particle is issued carrying with it the missing energy"[4]. Fermi points up:"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. This, for its enormous penetrating power, escapes any current detection method, and its kinetic energy helps to restore the energy balance in the β disintegrations"[5].

1.2 Weak Interaction Discovery

To this purpose Fermi elaborated one of his masterpieces, the Theory of βDisintegration, according to which whenever in a radioactive nucleus there is the spontaneous disintegration of a neutron, it follows the emission of a

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proton, a βray and a 3rd particle, the *neutrino* (ν), which with its mass, together with its high kinetic energy (Kin $_E$), compensates for the amount of energy and mass that cannot be entirely taken by the β ray[5]. Namely: 1) Proton and Neutron are two different states of the same fundamental object or Nucleon (complying with Heisenberg intuitions [6]). 2) The electron ejected, or βray, does not exist within the nucleus, but it is created, together with this 3rd particle during the process of the neutron transformation into proton (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, now known as Weak Nuclear Force or Weak Interaction (WI): the *Fermi's Interaction*. 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 electron-proton diffusion (provided by Quantum Electro-Dynamics), proposes also for the βd a type of interaction based on the fields 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]. In this case, however, the interaction is punctiform and called '4 fermions interaction'. It constitutes a *contact interaction* between the 4 particles involved: The neutron (which constitutes the initial state) plus the proton, the electron and this 3rd particle, or neutrino (ν).

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 neutron (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. In fact, the WI is the only force capable of changing the *flavour* of a particle that is to transform it into another. Such a *flavour* exchange between Qs involves the transformation of N into a P. The W^- particle immediately decays into an electron (e^-) and an electronic antineutrino ($\bar{\upsilon}_e$):

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

2. Discussion

Therefore, let's consider the value of the*minimum energy* of an electron, i.e. the so-called *Zero Point Energy* (ZPE) [9][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:

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

This value exceeds the 53.192 % the energy of an electron *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 electronis 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 Kin $_E$of β-ray (i.e. the electron), whose energy spectrum, as Fermi had reported [5][11][12], may also coincide with the entire energy value described by Eq. (2).

2.1 Neutron Decay Mass Gap: Still Unsolved Problem

From the analysis of the βd^-, we seem to catch two important results: 1) The total energy of the emitted charged electron 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 0.78281 and 0.511MeV.

Consequently, these are the energy values which must obligatorily be attributed to the 3rd particle emitted with βd^-, represented as $\bar{\upsilon}_e$ in the Eqs. (3) and (4), in order to *balance* and make congruent this equation. Therefore, if the mass of the *neutrino* (ν) corresponded to that assumed by Pauli and Fermi (the same mass of the electron), the mass gap problem of the βd^- would be brilliantly solved.

But reality is different.Regardless the *Standard Model*, according to which the ν was massless, the mass still attributed to ν is well 5 orders of magnitude less than the electron mass!

This limitation, in fact, was inferred from the observations of Supernova 1987A, for which it had been assumed that the mass of the ν_e was <5.8eV[13]. Why this limit? Because the neutrinos 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"[14]. Maiani adds: "The current upper limits of the mass of the neutrinos (m_ν) emitted with the *β-decay* are m_ν<2eV"[15], a value corresponding to <1/250˙000 of the electronic mass.

2.1.1 Pauli-Fermi Requirements on the 3rd PARTICLE of the βd^-

On the contrary, the basic requirements originally requested by Pauli and Fermi for the ν, i.e. for the 3rd particle or missing particle in the βd^-, defined by several authors as a *ghost particle*, are essentially three: 1) it is electrically neutral; 2) it has the same mass of an electron; 3) it has the same spin of the electron[2][5].

Well, why not to think immediately to a neutral electron (e°) ? All requests would be satisfied. It seems the most logical answer, and physically more than adequate to meet the demands of Pauli and Fermi. It could be said that the same results reached by a e° are obtained similarly even with a ν. And then: e° does not exist, this is an invention! The only known electrons are those carrying an electric charge: e^- and e^+. Yet even 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,

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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*, maintaining the symmetry of the *Standard Model* and further simplifying it (according to the *reductionist* approach preferably adopted in Physics[16]).

Yet, one might object: why the e° has never been detected, even accidentally? Electron decay products emerge continuously in the *colliders*! But it is clear: the crucial difference lies in the fact that we are talking about electrons without electricity charge, they do not interact with matter for the same reasons neutrinos do not interfere.

2.1.2 Low Interope of the 3rd Particle of the βd^- with Matter

Let's try to understand why the third particle emitted by the βd does not interact at all with the matter, so it has never been seen directly: 1) Being a leptonic particle, whether it matches the ν, or it is represented by e° or another unknown particle, it follows that it is insensitive to the Strong Interaction (SI). 2) Being neutral particles (one of the primary requirements dictated by Pauli and Fermi), they are insenitive to Electro-Magnetic Interaction too. 3) Its very small mass makes it very weakly subject to Gravity Interaction (GI), although it is sensitive to such interaction. In this regard Feynman reminds us: "The gravitational activation between two objects is extremely weak: the GI between two electrons is less than the electrical strength of a 10^{-40} factor (or maybe 10^{-41}) " [1]. Furthermore, considering that the GI action in itself is extremely weak, and considering that the particle in question travels at very high speed, hence it proves insensitive to the GI. 4) In addition, the 3rd particle emitted with βd^- is right-handed, just as the hypothetical $\bar{\upsilon}$ (or the possible $\bar{e}°$), so it is even more elusive, since it is also insensitive to Weak Interaction (WI).

But even considering the respective particles, which are left-handed, and therefore potentially sensitive to WI, they are essentially unaffected. First of all because the very high acceleration with which the 3rd particle is issued (both in βd_s and in the process of nuclear fusion) makes this particle travel undoubtedly with relativistic speed, reducing in this way the time the WI -and the GI- can exercise their action. Moreover the WI action is notoriously weak, and quite *slow* compared to the GI and SI, thus it is even more difficult that it may prevail on the *kinetic energy* the 3rd particle travels. The WI acts only on a short distance, which restricts even more the possibilities of such a particle to interact since, as it can be seen from our calculations, the maximum distance WI bosons can travel corresponds to $1.543 \cdot 10^{-15}$ [cm] for W^+ and W^- particles, and $1.36 \cdot 10^{-15}$[cm] for Z° particles [17]. So, even e°, despite being sensitive to the WI (since it is left-handed), should be able to cross every *weak field* undisturbed.

It is important to add, finally, that probably the most significant reason for the scarce interactivity of ν, or the 3rd particle of the neutron decay, with the matter is provided by Maiani, he reminds us that: "The neutrinos (ν_s) produced in the Big Bang do not interact with matter when the temperature (T) of the Universe falls below 1MeV "[18]. Yet it is a very high T, just below $3 \cdot 10^9$ °K [19]. This limit of T is far above most of the common physical reactions. If we then consider that the T that permeates the entire Universe is <3°Kelvin, close to absolute 0, it is better understood ν_s why the never interact, or almost never, neither with matter, nor with other ν_s [20].

2.1.3 Detection of ν or of the 3rd Particle: Never *Directly* Identified

As known, 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. At this regard, 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[21]. 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][21]. It is really a very small cross section. This same value was confirmed in 1959 by Reines and Cowan [22], who revealed that the σ of the electronic neutrino (ν_e) was equal to:

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

It should be noted that it took 25 years to come to a detection, always *indirect*, of the anti-ν ($\bar{\upsilon}$), and then the ν. As it is known, it would have been difficult for most physicists, if not impossible, to be able to trace a ν, as Fermi asserted [12]. Leafing through the vast literature about it, it is immediately obvious that all the different techniques of detection of the 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, as a hypothetical e°, for example.

The apparatus designed by Reines and Cowan[23] 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 protons, created a reverse process, i.e. a βd^+, transforming the proton in neutron, moreover the emission of an e^+ and a ν. Since it was known that the 3rd particle emitted in this process could never be detected, identified directly, Reines and Cowan pointed the research on two the other particles: neutron and positron. The race of the neutron emitted is slowed, "moderated", by the collisions with water (as it had first been shown by Fermi and his *boys of Via Panisperna*) thus, in about 10^{-5} seconds, the neutron is captured by cadmium, with immediate emission of γ rays of a particular frequency and energy (~6MeV). The positron, in its turn, annihilating

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with an electron 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 is detected by photomultipliers. The characteristic time is ~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 [23].

Yet, in order to better analyse with accuracy and without bias the findings from this experiment, we can divide it into two phases: 1) The 1st stage takes into account any βd^- which occurred in the nuclear reactor, resulting in the emission of a 3rd particle, believed to be a $\bar{\upsilon}$. 2) The 2nd stage considers the effects produced by the clash between the 3rd particle (or this $\bar{\upsilon}$) with a proton of the water contained in the tanks: what occurs is a *positive beta-decay* (βd^+) with emission of a ν (which, just as the $\bar{\upsilon}$ will never be disclosed) and with the emission of a positron which, annihilating with an electron of that same water, produces the pair of γ photons detected by the photomultiplier.

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.

In this regard, we read: "The mark that distinguishes events sought is therefore a double coincidence in a pair of scintillators, separated by a time of a few microseconds"[24].

"If instruments had revealed γ rays exactly of two energies provided, separated by suitable intervals, the investigators would have caught the $\bar{\upsilon}$ "[25]. 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.

To this purpose, among the several techniques to detect the ν we can mention two well-known ν detectors: the Subdury Neutrino Observatory (SNO) and the 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 2nd phase of the detection of Reines and Cowan, for which the alleged $\bar{\upsilon}$ (or 3rd particle of βd^-) strikes a proton of a water molecule, triggering a βd^+: the electron freed at relativistic speeds, traveling faster than light (in the same medium), emit the typical *Cherenkov light (CL)* which is captured by photomultipliers (*Cherenkov Effect*) [26].
It is believed that it is the ν to trigger the series of reactions leading to the production of the *CL*: event for us perfectly reasonable even more if it were an e°, since it is just theelectrons to emit the *CL* in our atmosphere. In fact, the electrons of the atmospheric molecules, hit by cosmic rays at high altitude, are accelerated at very high speed so emitting the *CL*[27]. There is no other particle in nature, apart from the electrons and the alleged ν, to be able to produce the *CL*[28].

Yet, even in these experiments (SNO and Super-Kamiokande) 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* and *Cherenkov Effects* (CE_s) are considered as the evidence of the existence of ν and $\bar{\upsilon}$.

This interpretation of the experimental data seems to us forcing for three reasons: 1) 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) we know, with certainty, that the CL is a typical natural phenomenon generated by electrons highly accelerated (which, as we know, are released also in βds) ; 3) the fact that it is known and proven that the CL is produced specifically by extremely accelerated electrons, makes clear, fair, compatible, and even more likely the hypothesis that in βds are emitted e° too (or its antiparticle) instead of ν [29]. No wonder it is still an electron, now without electric charge, to induce the various CEs highlighted during all the surveys carried out.

Yet we are talking about the ν, a particle with a precise and determined requirement: its mass must be equal to the mass of the electron[2]. This is really the minimum value that can be attributed to the 3rd particle (according to Pauli-Fermi requests) [2][5] to balance numbers into the Neutron Disintegration, or βd^-.

2.1.4 An alternative neutron decay model

In short, from the foregoing a clear incongruity comes out: the mass attributed to the ν will never be able to compensate the mass gap problem of the *NeutronDecay*. Never ever: it takes from 100˙000 to 250˙000 to balance the Eq. (3) ! Unless we take into consideration, instead ofν, another particle, probably still unknown, as the 3rd particle of βd^-.

This is certainly a very elusive particle, never directly identified, *de visu*, but always and only for *indirect detection* (through the verification of the *CE*), which is also referred to as *the ghost particle*. It cannot be any particle, but it must satisfy certain requests: 1) In order to preserve the Law of Electric Charge, within the Eq. (3), it must be neutral. 2) In order to comply with the Law of Conservation of the Lepton Number, it must certainly be an anti-lepton. 3) In order to safeguard the Laws of Mass and Energy Conservation, its values must absolutely be between 0.78281MeV and0.511MeV.

Thus, this 3rd particle will first have to correspond to a neutral anti-lepton. At this point, the circle has really tightened: the only known anti-leptons are $\bar{\upsilon}_e$ and e^+. But since it must be a neutral anti-lepton, we must also renounce the e^+. And what's left? Only the $\bar{\upsilon}_e$. But we exclude it,

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because of its very limited mass. (There would be a $\bar{\upsilon}$ more massive than a $\bar{\upsilon}_e$: the *muonic* $\bar{\upsilon}$ ($\bar{\upsilon}_\mu$), however the maximum mass attributed to ν_μ is 170 KeV, so it would necessary at least 3 $\bar{\upsilon}_\mu$ to be introduced in the *βd⁻*. There is still the *tauonic* $\bar{\upsilon}$ ($\bar{\upsilon}_\tau$), but it does not work either: but for the opposite reasons. The $\bar{\upsilon}_\tau$, in fact, is too massive: it weighs ~15 MeV, i.e. much more than the energy needed to compensate the known energy gap that emerges from the N decay. In the end we have to give up, as we have no known particle that can adequately replace the $\bar{\upsilon}_e$as the 3rd particle of *βd⁻*).

Yet it seems to us a conspicuous contradiction to accept the inclusion of a particle in an equation, with the precise aim of filling the *mass gap*, without solving the problem!

It is widely found in the literature that the maximum mass attributed to $\bar{\upsilon}_e$ corresponds to ≈5.8 eV. How could this particle fill an *energy gap* between 511 and 782 KeV ?!

Nevertheless, *βd⁻* continues to be described in this way, i.e. with the $\bar{\upsilon}_e$ as the 3rd particle.Yet it is known that Pauli and Fermi clearly specified [2][5] that this 3rd particle must have the same mass of the electron!

Only in this way the *mass gap* emerging from the *N* decay could be compensated. Obviously in this way the equation of *βd⁻*, Eq. (3), was congruous and perfectly balanced.

However, over the years, the idea that ν had a small mass was diffused, a mass increasingly limited, even zero. With an almost null mass, the *βd⁻* equation became increasingly inadequate, incongruous and *unbalanced*, but it was not remedied. Still, the clues to look for a 3rd alternative particle to the $\bar{\upsilon}_e$ were all there: it had to be an anti-lepton without an electric charge, and with the same mass of the electron. So why not think that there can also be a *neutral electron* (e°) ?

If this particle alternative to ν coincides with an e° (and there would be valid assumptions, in our opinion), then Eq. (3) should be rewritten as follows:

$$N \rightarrow P + e^- + \bar{e}^\circ \qquad (7)$$

Depending on the acceleration suffered at the time of emission, the energy this different 3rd particle can acquire, should fluctuate, still randomly distributed between 0.78281MeV and 0.511MeV.
Also with this solution all the Conservation Laws are safeguarded.

2.2 Neutron Discovery

It is known to all that the discovery of the neutron (*N*) is ultimately due to the experimental research carried out at the Cavendish laboratory in Cambridge, started by Rutherford and completed by his pupil Chadwick in 1932 [3].Rutherford was troubled by the possible structure of the atom and by the concept that the atomic nucleus should also reveal the presence of neutral, massive particles. In his "Bakerian Lecture" (1920), Rutherford hypothesized that, within a nucleus, there could be one or more "very strong electron-proton combinations"[30], while at the same time persisting the possibility of coexistence in the nucleus of a number of protons exactly equivalent to the number of atomic, peripheral electrons, orbiting at enormous distances from the nucleus [30]. On the other hand, the presence of electrons inside the nucleus was not an abstruse concept. Rutherford referred to the experiments of Becquerel, who as early as 1896 had demonstrated, unequivocally, that some atomic nuclei (Uranium salts) emit electrons of high energy, called *β rays* [31]. From that time, therefore, we start thinking of nuclei compound of protons and electrons, i.e. *nuclear electrons* [32]. Rutherford added that, since the atom was hydrogen (H) neutral, considered as a nucleus of single unit charge, a proton (*P*) in this case, having an electron (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 wrote in this respect: "Under some conditions it may be possible for an electron 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"[30]. 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 electrons, subjected in addition to intense forces, may appear deformed, so as to remain tied, *trapped* in the nucleus. The following month, at the British Association Meeting of 25/8/1920, Rutherford called this *neutral doublet* with the term "neutron" [33].

Also two other authors, in those years, had proposed the existence of nuclear "neutral systems". Van den Broek had hypothesized that the atomic number (Z) was equal to half the atomic mass (A) and that it was equal to the number of electrons orbiting around the nucleus [34]. So Van den Broek proposed the possibility that there might be electrons inside the nucleus (positively charged). Later He suggested that next to the load nucleus there was a group of neutral particles consisting in the combination of a α particle with 2 electrons giving rise to radioactivity [35]. Van den Broek stated that the atomic nucleus could be made of an even number of α particles and of H nuclei, which, together with the electrons (or *β rays*), made "compound systems" [36].

In 1920, in turn, Harkins hypothesized that the combination of 2 H nuclei (like 2 protons) with 2 electrons represented an important constituent of atomic nuclei, especially of the heavier ones. Basically when describing the structure of the nuclei, the US chemist uses different groups of particles: he considers *groups μ* formed by 2 protons and 2 electrons $(\eta_2^+, \beta_2^-)^0$, or the *particle υ* with mass 3, containing 3 protons and 2 electrons $(\eta_3^+, \beta_2^-)^+$ [37]. In the nucleus the so-called *helio group* plays a play maker role: $(\eta_4^+, \beta_2^-)^0$, consisting of a particle α, denoted by η_4^+, that is positively charged, which is electrically neutralized by 2 «*cementing electrons*», indicated by β_2^-[37]. The Author specifies: "It is not improbable that some isotopic atoms are formed by the addition of the group (□□, □□) " [37]. Harkins gives no name to this additional group, which, however, has many

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similarities with the *neutron* (*N*) of which Rutherford will speak a few weeks later [33][38]. Likewise, it is clear the close resemblance of the *Harkins nuclear helio group* (with its *cementing electrons*), if compared with the *neutral satellite*, located within the atomic nucleus, discussed by Rutherford in 1927 [38][39]. Harkins, in essence, proposed a close combination between *P* and e^- within the atomic nuclei, where the *helio group* would play a significant role.

In that period, in short, it was developing the idea that the atomic nucleus was constituted only by protons and electrons [40]. In fact, the conception that the nucleus containedelectrons had been affirmed thanks to the contribution of Marie Curie and Bohr, in relation to the *β* radioactive phenomena. Scientists believed that the electrons expelled had to pre-exist some part, in the atom, or in the nucleus. On the other hand, while it was possible to operate on the orbital electrons, it was not for the electrons issued in the *Neutron decay*, or *negative β-decay* (βd^-) [38].

Rutherford continued through the first 20 years of the last century with his experiments in search of the *N*, involving also the student Chadwick.

In 1930, in Berlin, Bothe and Becker showed a highly penetrating *radiation*, capable of crossing a 20 cm thick lead wall. The theory predicted that, by bombarding a substance with α particles, a photon and a proton, called first Radiation [40] should be formed. Bothe and Becker, on the other hand, found that an unknown radiation was emitted, with a greater energy both of the incident α particles and of the energy of the γ rays emitted. It was a penetrating, highly energetic, and *neutral* radiation, as it was not deflected by electro-magnetic fields. The two authors called it the second radiation: it could make one think of an energetic radiation γ [41].

These experiments were tried again in Cambridge, where in 1932 Webster was surprised to find that the emitted radiation was excessively penetrating, and had considerable energy, which could not be attributed to a γ ray emerging from those experiments [42]. Webster questioned it could be about electro-magnetic radiation (EMR), but of material particles. So, at first Webster suggested it could be *fast corpuscles*: that is, 1 *P* and 1 e^- strictly connected. However, exams and subsequent resultsmade him change his mind [43].

At the same time, in Paris, the Joliot-Curie spouses, reproducing similar experiments, showed that if the mysterious radiation hit paraffin, or other substances containing H, induced the emission of accelerated protons, highly energetic. Photons γ would have never had enough energy to expel protons from matter; therefore they called it "The third Radiation", convinced that they had discovered a new form of *interaction*, operating between radiation and matter [44].Chadwick, on the contrary, considered untenable that the mysterious radiation was made up of photons! In essence Chadwick suspected that both the Parisian couple, both Webster, and Bothe and Becker, without realizing it, had "stumbled" [40] into a neutral and massive particle: the *Neutron* hypothesized by his *master* Rutherford, and Harkins.

The same opinion was also given by Ettore Majorana who, as Amaldi recounts, as soon as he read the Joliot-Curie article and their interpretation, he exclaimed to his colleagues in *Via Panisperna*: "They did not understand anything; probably they are protons of recoil produced by a *heavy neutralparticle* "[45]. Besides Amaldi was also present, among others, Segré, who reports that Majorana "immediately understood that there was what he called a *neutral proton*" [46].

At this point, Chadwick, in collaboration with Dr Feather, reproduced the experiments of the Parisian spouses, that is he bombarded a beryllium disk (Be_4^9) with α particles (He_2^4) emitted by a polonium disk (with a plate of paraffin in between), finding that the acceleration suffered by the protons emitted unequivocally denoted an energy 4 times greater than if they were affected by *γ* photons [40]. Therefore, Chadwick concluded that the protons, emitted in the experiment, had not been hit by an EMR, but by a new corpuscle, the *Neutron* (N_0^1), i.e. a massive and neutral particle, represented by a combination of 1 electron (e^-) with 1 proton (*P*), like a dipole, provided with a mass slightly higher than that of *P*:

$$He_2^4 + Be_4^9 \rightarrow C_6^{12} + N_0^1 \qquad (8)$$

The deductive reasoning followed by Chadwick was extraordinarily linear and logical. Thanks to it, He succeeded in solving the enigma. "*Logically*–so Chadwick reasoned– the protons are made rapidly moving by a particle with a mass similar to theirs. According to an elementary notion of Mechanics, well known, the energy that transfers in a collision is maximum when the colliding particles have the same mass: a typical example is that of two billiard balls"[47].In February 1932, Chadwick sends a letter to the editor of Nature[3] and 3 months later, in describing the neutron, He writes: "We may suppose it to consist of a proton and an electron*in close combination*. We may then proceed to build up nuclei out of α-particles, neutrons and protons, and we are able to avoid the presence of uncombined electrons in a nucleus. This has certain advantages for, as is well known, the electrons in a nucleus have lost some of the properties which they have outside, e.g., their spin and magnetic moment. It has so far been assumed that the neutron is a *complex particle* consisting of a proton and an electron. This is the simplest assumption"[48].

2.3 Majorana's Neutral Proton

The "3rd Radiation" which Joliot-Curies thought they had discovered [44], for Majorana is nothing but a "*neutral proton*" [46], shortly thereafter referred to by Chadwick as "neutron" (*N*) [3][48].

At the time the enigma of how more protons could coexist, and now also neutrons, inside the atomic nucleus, despite the repulsive Coulomb's forces, was still unsolved.

The solution was first proposed by Majorana, "at the beginning of 1932" [49], proposing the existence of "*exchange forces*" between proton (*P*) and *P*, as well as between *P* and *neutral P*, orbetween 2 *neutral protons*, operating in the nucleus.

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As reported both by Fermi and his *Via Panisperna's boys*, Majorana had always been reticent to publish his intuitions: very often he found a solution to a problem, he wrote it on a pack of cigarettes and communicated it to his colleagues, often after exposing it to the blackboard, then he threw away the package (with all equations) [45].

Fermi found very interesting this idea of "*exchange forces*", so he asked his disciple Majorana for permission to publish it, but received a clear denial [45][46]. In fact, "Prior to the official announcement of Chadwick's discovery of the neutron, Majorana is able to explain the structure and stability of atomic nuclei" [49] mediated by the *neutral protons* and *exchange forces*. Majorana also anticipates the pioneering work of Ivanenko [50], but does not want to publish anything, nor does he grant Fermi to speak at the Physics Congress, in Paris, at the beginning of July 1932 [49].

Recamireminds us: "Even before Easter of 1932, Majorana had come to the most important conclusions of his theory: protons and *neutral protons* (as saying *neutrons*) were bound by *quantum forces* originated simply by their *indistinguishability*, i.e. linked by *exchange forces* of the respective spatial positions (and not also by the spins, as Heisemberg will do[6]), so as to obtain the α particle (and not the deuton:H_1^2) as a saturated system with respect to the *binding energy*. It is interesting to point out that these *exchange forces*, precursors of the Strong Nnuclear Force (SNF), treat equally the *P* and the *N* (or *neutral P*), just as if they were the same particle (SNF behaves in the same way too). Only after Heisemberg, Majorana publishes his own article on the same subject. In fact, Fermi manages to persuade Majorana to go to Heisemberg in Leipzig, who finally manages to convince Majorana to publish (even if so late) his results "[49]: "Uber die Kerntheorie"[51]. Soon after, Majorana publishes another article, entitled "On Theory of Nuclei", in which he writes: "The discovery of the neutron (*N*), that is, a heavy elementary particle without electric charge, offered the possibility of building a theory of nuclear structure which, without solving the difficulties associated with the continuous spectrum of *β-rays*, nevertheless makes it possible to widely use the concepts of Quantum Mechanics (QM) in a field that seemed alien to them. According to Heisemberg it is possible for many purposes to consider the nuclei as constituted by protons and neutrons, particles provided with the *intrinsicmechanical momentum* ($1/2 \cdot h/2\pi$) which obey the Fermi Statistics and have approximately the same mass. The average velocity of these particles within the nucleus is presumably quite small compared to light's ($v \sim c/10$) and it can therefore be assumed that the ordinary methods of non-relativistic QM can be applied with great approximation. It still remains to establish the law of interaction between the nuclear constituents. Heisemberg, in the absence of other guiding criteria, was led by the analogy that exists between the common neutral hydrogen atom and the *N* if it is constituted, as generally it is supposed, by a *P* and an e^-. Heisemberg therefore assumes that the interaction between protons and neutrons is qualitatively similar to that which is actually exercised between protons and neutral atoms of hydrogen and depends mainly on a kind of *exchange force*. Likewise, for each pair of neutrons, attractive forces of the Van der Waals type are introduced "[52].

To this purpose, as Recami reports [49], from a letter dated 1937, signed by Fermi et al., we read: "In modern nuclear theories the contribution made by Ettore Majorana, with the introduction of the forces called '*Majorana Forces'*, is universally recognized among the most fundamental, as the one that allows to understand theoretically the reasons for the stability of the nucleus. Majorana's workstoday represent the basis for the most important research in this field"[53].

Thus, according to Majorana the 3rd Joliot-Curie Radiation is not at all a form of EMR, but amassive material particle: a *neutral P*, consisting of the *close union* between an e^- with a hydrogen nucleus, i.e. with a *P*. Only in 1934, since He couldn't solve the incompatibilities that emerged between his *neutral P model* with the concepts of the QM (*Nuclear Spin* and *Fermi Statistics*), in order not to violate its laws, Majorana accepted the idea of *N* as an elementary particle.

2.4 Incompatibility between Nuclear Electrons and Quantum Mechanics

Even before Majorana's intuition, it had been tried to formulate a congruous explanation to the coexistenceof particles with equal electric charges, like the protons, in a very narrow space like the nuclear's, without being removed from Coulomb's forces. George Gamov tried to answer this question: "It has often been suggested that non-Coulomb attractive forces play a very important role inside atomic nuclei. We can make many hypothesis concerning the nature of these forces. They can be the attractions between the magnetic moment of the individual constituents of the nucleus or the forces engendered by electric and magnetic polarization. In any case these forces diminish very rapidly with increasing distance from the nucleus and only in the immediate vicinity of the nucleus do they outweigh the Coulomb force"[54]. In this case, however, the picture becomes even more complicated since Rutherford and Harkins'*NeutronModel*, as well as the Majorana's *neutral P*, foresee, together with the protons, the coexistence of electrons inside the nucleus itself. In fact "the behavior of the *nuclearelectrons* remained unexplained, which in combination with half of the *nuclear protons*, allowed to consider both the isotopic mass and the atomic number"[40].

The question was: how is it possible the simultaneous presence of positive and negative charges within the atomic nucleus? Again Gamov, among others, tried to give an answer: "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 coordinates 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"[55].

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As we can see, Gamow highlights some problems arising from the Rutherford-Harkins *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 [56][57].

In such circumstances, in fact, it is more than understandable that the *nuclear exchange forces*, operating on the nucleons (i.e. hadrons), can be insensitive to the e^-, although present within the atomic nucleus. In other words: these forces do not detect the presence of these lepton particles, so it is as if they ignored them. These *nuclear exchange forces*, in fact, also known as *Majorana-Heisemberg forces*, correspond to the Strong Nuclear Force or Strong Interaction (SI): *forces* sensitive to hadrons and insensitive to leptons!

However, what remains unexplained is why the electrons, which are fermions, that is provided with a ½ angular momentum, do not give any contribution to the total spin of the nucleus?

In this regard we read: "It seems as if the e^- in the nucleus lost not only the spin but the right to participate in nuclear statistics too" [58]. It is as saying that the *nuclear electrons* behave as if they were not at all in the nucleus!

On the other hand, analyzing some of the measures taken by Ornstein and van Wijk [59], which were further investigated and confirmed by Kronig [60], it appeared that the spin of the nucleus of nitrogen corresponded to an even number. Whereas, according to Rutherford's *NeutronModel*, still concerning the nucleus of nitrogen (N_7^{14}), in the nucleus beside the 7 basic protons, we have 7 more protons closely related to 7 electrons. 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 mass (A), so that its spin must express an integer [59].

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 [61]. Thus, both Kronig experimental data, and Rasetti's, were in open conflict with the *N model* prospected by Rutherford.

Against this model goes the so-called *Klein paradox* too. Klein was about to study electron scattering trying to cross a potential barrier. Klein's experiment clearly showed that if the value of the potential barrier is of the order of the electron mass, this barrier is nearly transparent [62].

That is, the Klein experiment presented a quantum mechanical objection to the Rutherford *Nmodel*, that an e^- couldn't be confined within a nucleus by any potential wall.

There is still another concept of the QM that is in antithesis with the hypothesis of the presence of electrons within the atomic nucleus. As it is well known, for many years it was considered that the electron (e^-) emitted with the *N decay* came from the nucleus itself. Even Pauli, for the first years, was convinced that both the e^-, and the 3[rd] particle emitted with the *N decay*, or the neutrino (ν), he himself had proposed [2], were in the initial nucleus.

However, as Maiani reminds us [32], if we bring into play the Heisemberg Uncertainty Principle (HUP) [63][64] an e^-, located within theradius (R) of the atomic nucleus, would have an energy (Δ_p) more than 100 times greater than that of *β-rays* (~1MeV):

$$\Delta_p \approx \hbar/R \approx 140 \text{ MeV} \quad (9)$$

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: $\boldsymbol{p} \geqq \hbar/R$ [65].

Therefore, many physicists started to think that, probably, the electrons wasn't really inside the nucleus and that, therefore, the proposed *N model* was wrong. Fermi goes along with this theory, he writes: "In attempting to construct a theory of nuclear electrons and of the *β rays* emission, two well known difficulties are encountered. The first is that the primary *βrays* are emitted by the nuclei with a continuous velocity distribution. If the energy conservation principle is not abandoned, we must therefore admit that a fraction of the energy made available in the *β* decay escapes our present observation possibilities. A second difficulty for the *nuclear electrons theory* arises because the current relativistic theories of light particles (electrons or neutrinos) do not satisfactorily deal with the possibility that such particles could be bound into orbits of nuclear size. As a consequence it seems more appropriate to admit with Heisenberg that all nuclei only consist of heavy particles, protons and neutrons"[11].

In short, as the QM develops, the Rutherford-Harkins *Neutronmodel* begins to falter.

In the end, even Majorana starts to raise some perplexities, abandoning his *Neutral ProtonModel*. So much so that he writes: "If neutron is really made of a proton and an electron, the way their union is realized is however inaccessible to current theories, which would make give to the neutron the Bose-Einstein Statisticsand an entire multiple mechanical moment of $h/2\pi$, contrary to the fundamental hypotheses.

On the other hand, these are directly based on the empirical properties of the nuclei and it is not possible to renounce to them" [52]. And finally, the discoverer of the neutron, Chadwick (until then convinced of his master's model, Rutherford) writes: "It is, of course, possible to suppose that the *N* may be an elementary particle. This view has little to recommend at present" [48].

In short, a *principle* of the QM sent screaming the *Neutron Model* proposed by Rutherford, and shared by the majority of Authors. In fact, after the Rasetti experiment (1932) [61], Fermi no longer shares this *Nmodel* and points out:"During the process of radioactive decay of a neutron, the electron ejected does not exist within the nucleus, but it is created,

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together with a 3rd particle, during the process of the neutron transformation into proton"[5].

Yet, although the *Nuclear Spin Statistics* has every reason to categorically deny the possibility of electrons inside the atomic nucleus, they are and persist in Nature various contexts in which the electrons are, so to speak, *captured* by nuclear protons: it is the so-called *Electron Capture*, also known as the *inverse neutron decay*, or *positive beta-decay* (βd^+). It happens, that is, that the electrons go to merge with protons giving rise to a single particle, a neutron precisely. This process is also known as the *Neutronization*. Thus, the neutronis a *compound* formed by an electron and a proton: $N = P + e^-$, just as the *Rutherford-Harkins Neutron Model*, that is a *neutral doublet*:

$$N = [P, e^-] \tag{10}$$

In short, you have the feeling that something is wrong. On the one hand, the QM denies the presence of electrons in atomic nucleus; on the other hand, there nature itself that allows the union electron-proton giving rise to neutron, just as Rutherford and Harkins had guessed.

To this purpose, we're going to deepen the process of the synthesis of the neutron.

2.5 Neutron Synthesis

Weinberg writes [19] that the *threshold temperature* necessary for the *materialization* of a particle, i.e. for the transformation of energy into matter, must unequivocally be ≧ to the value obtained by dividing the *inertial energy*, or *zero point energy* [ZPE] [10] of the considered particle, for the Boltzmann constant (*k*), equal to 0.00008617eV, for each Kelvin degree (°K). It is thus obtained that while for the e^- (with ZPE = 0.511MeV) the threshold temperature corresponds to 5.93 billion ° K, for the *nucleonic synthesis* (*baryogenesis*) really amazing temperatures are needed, which are obtained under very limited circumstances, sometimes only for short periods of time, equal to fractions of one millionth of a second, as soon after the Big Bang (*BB*). In fact, to obtain the formation of *P* (ZPE = 938.26 MeV) the *threshold temperature* corresponds to 10888 billion °K. Similarly, the creation of *N* (ZPE = 939.55 MeV) requires a *threshold temperature* of 10903 billion K ° [19]. These are very high temperatures that, we could say, in nature are reached only in those situations of *singularities* [66] [67] [68], such as *BB* or Black Holes[69] [70], or *Neutron Stars*: the latter are direct consequences of the collapse of a Supernova.

2.5.1 Big Bangnucleonic Synthesis

As Pacini reminds us, relativistic cosmological models do not limit the initial density of the Proto-Universe. However, based on QM considerations, based on the Uncertainty Principle, such density can never have exceeded 10^{92}g /cm^3, and for no longer than 10^{-44} seconds. In the immediately following period the density and temperature (T), which expresses the average energy of the photons and the Kin $_E$of the particles, are such that the *cosmic fluid* must consist mainly of hadron particles [71]. Indeed, we are in the Age of Hadrons. In this Era the *cosmic fluid* also swarms with pions, as well as with lepton particles such as electrons, neutrinos (in the 3 *families*), with relative anti-particles. Photons are very abundant: they are extremely energetic γ photons. The nucleons, in turn, are distributed in almost equal proportions, both as regards the total number of protons and neutrons in circulation, as well as the relationship between particles and relative antiparticles. In such phase, in such conditions, that is until T ≧ 10^{13} °K, protons and neutrons are continually created, in equal number, together with the respective antiparticles. In this way the new couples (particle-antiparticle) compensate for the annihilating pairs, thus preserving the equilibrium situation. However, the numerical equilibrium protons-neutrons remains such only for an infinitesimal time since, as soon as the T of the Universe descends (it descends in the opposite way to the increase of the dimensions of the universe) [19], this equilibrium ceases together with the baryogenesis itself. In fact, due to the expansion of the universe, the average energy of the particles decreases, and when the average energy of the photons becomes lower than the GeV (value corresponding to the ZPE of the *P* and *N*) the heaviest hadrons in circulation begin to decay, i.e. the nucleons, which however can no longer be created, since now T <10^{13} °K. In addition, the number of nucleons starts to decrease since they collide with the respective antiparticles [71]. At this point, it is important to clarify that, since the primordial nucleosynthesis has not yet begun, neutrons are free, so they spontaneously meet their decay in protons (having the latter a mass just below), so the numerical ratio *P*–*N* will progressively increase in favor of the protons.

Therefore, after just one microsecond from the *BB*, T falls to <10^{13} °K so it is no longer possible for new neutrons to form under natural conditions, except for those very special and rare situations of *singularities* which are believed to have occurred from several hundred million years after the *BB*.

What are we talking about? Black Holes (BHs) and *neutronization*. In fact, in addition to the *BB*, as Hawking and Penrose remind us [72] [73], the other singularity is represented by the BHs.

2.5.2 Primordial Nucleosynthesis

As known, with the *primordial nucleosyntesis*, which started only 3 minutes and 46 seconds after the *BB* [19], the lightest chemical elements were formed, namely only the first 3: hydrogen (H_1^1), helium (He_2^4) and lithium (Li_3^7), in addition to some isotopes related to these elements, among which deuteron (H_1^2) and helium-3 (He_2^3). This is because, since the "Hadron era" is over, now T is too low (~10^9 °K) for the *N synthesis*, so that those neutrons left free tend to spontaneously decay in protons. So the progressive lack of neutrons does not allow us to move forward in the synthesis of heavier elements. In fact, observing the Mendeleev Table it is noted that there are no stable nuclei with *atomic mass* (A) = 8, so the *primordial nucleosyntesis* stops at ~10^9 °K, ending approximately within a couple of minutes.

Since then, we reaffirm, it will have to go through several hundred million years, until the conditions of gravity, pressure, density and T are sufficient to see again a natural *N synthesis*, that is, a new baryogenesis. This occurs in the star *core*.

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2.5.3 Stellar Nucleo Synthesis

The fundamental process in the evolution of a star is the gravitational contraction of an abundant quantity of gas and dust. Under the influence of gravitational attraction, the mass of gas contracts progressively. Since the contraction releases gravitational energy, the gas that makes up the star is heating up, even for millions of years, until the central temperature has risen to several million degrees [71]. Therefore, the high values of pressure and T reached at the level of the stellar *core* allow the triggering of thermonuclear reactions, with the ignition of the H:

$$4\,H_1^{\,1} \rightarrow He_2^{\,4} + 2e^+ + 2\nu_e + \gamma \qquad (11)$$

where γ indicates gamma photons, highly energetic. Thus the progressive transformation of light elements nuclei into nuclei of heavier elements has begun: the *stellar nucleosynthesis* has begun. In this process of conversion of H into He, part of the stellar mass disappears, having been transformed into energy. Since the amount of energy released is enormous, the T in the star remains high and the pressure of the internal gases is able to counterbalance the gravitational attraction. This phase of equilibrium can last several billion years in stars like the Sun, or last only a few million years in much more massive stars.

When all H of central regions has converted to He, the pace of nuclear reactions slows down due to lack of fuel. Then the star gases cool off, the pressure decreases and, as a consequence, gravity resumes the upper hand, so the star's core contracts. In this regard "In 1930 Chandrasekhar realized that the Pauli Exclusion Principle (PEP) of electrons gas could provide enough pressure (even in the absence of sources of radiation and at T = 0) to counteract the gravitational attraction and to support the star. Why the electrons? Both because they are much lighter than the nucleons, and because they have more extensive quantum effects "[74].

As known, the nuclear fusion is hindered by electrostatic repulsion between the nuclei, which grows progressively and rapidly as the atomic number increases (Z). Then, when the nuclear fuel is over, the outer layer of the star collapses on the central core. Based on Chandrasekhar calculations, if in that phase the collapsed star has a mass ≤1.44 solar masses (☼) (Chandrasekhar *limit mass*), the gravitational collapse is stopped by the counter-pressure exerted by the *degenerate electrons* which make the stellar core, to which a *white dwarf* will remain, over time [75]. The *limit mass of Chandrasekhar* (M_{Ch}) is determined as follows:

$$M_{Ch} \approx 3\sqrt{2\pi}/8\,(\hbar c/G)^{3/2}\,[(Z/A)\cdot 1/_{\mu} m_p]^2 \qquad (12)$$

where ħ is Planck's constant, c is the speed of light in the vacuum, G is the constant of universal gravitation, Z is the atomic number, A is the atomic mass, m_p is the inertial mass of the proton, μ indicates the number of nucleons. With Z/A=0.5, we have M_{Ch}=1.44☼ [76].

As Maiani reminds us "The fusion of complex elements, like carbon (C_6^{12}), oxygen (O_8^{16}) or neon (Ne_{10}^{20}), requires higher and higher ignition temperatures, which are only realized in the stars that start with masses much higher than 1 ☼ "[74]. In fact, it is calculated that to get to the synthesis of iron, stars with mass greater than 8 ☼ are needed [75]. In these circumstances there is a further contraction of the central regions, with a consequent increase in the T: this time up to hundreds of millions of °K, and even beyond. Then the conditions were created to trigger a new type of reaction, in which 3 helium nuclei merge into a carbon nucleus: $3\,He_2^{\,4} \rightarrow C_6^{\,12}$ (3-body reaction). After which since the helium fuel is finished, there is a central contraction, accompanied by a heating. Thus, by successive degrees, increasingly heavier elements will be formed, up to the iron (Fe_{26}^{56}) [71]. For the synthesis of Fe temperatures >10^9 °K are necessary [76]. With Fe the standard *stellar nucleosynthesis* stops.

2.5.4 Explosive Nucleosynthesis

It is well known that Fe has a particularly stable nucleus. In fact, when the nucleus of Fe was formed, the maximum nuclear *binding energy* was reached, and therefore there are no more exo-energetic nuclear reactions that can sustain the star [65]. Now the possible fusion reactions no longer produce energy, thus we loose that heat, which irradiated outwards (exothermic reactions), was returned through the processes of nuclear fusion. On the contrary, with Fe such reactions become endothermic, as they absorb energy from the outside. It follows that the thermonuclear reactions within the stellar core stop, whereby the stellar gases begin to cool, and the star to contract. The nucleus of the star, therefore, no longer supported by nuclear reactions, implodes and surrounding matter falls around [65]. At this point, if the mass is >M_{Ch}, but ~ <3☼, the star will continue to contract ever more rapidly, becoming even brighter till it reaches, finally, in hours or minutes, its inexorable collapse, which takes place in ≈1/4 second. That is, when the nucleus of the star has reached nuclear densities, that is the same density of atomic nuclei (equal to 10^{13}g/cm^3), the fall stops and the matter, which was falling, rebounds on the star core and the star explodes: *collapse supernova*. With the collapse of the star an immense amount of energy is reversed on the outer layers of the star. We have that while the internal parts fall on themselves, the external ones are hit by an immense amount of energy and projected outside, in interstellar space [71]: a *Supernova* is born.

As Maiani reports, while "elements up to Fe are synthesized in the life of the stars (*stellar nucleo-synthesis*), the heaviest elements are synthesized in the *Neutrons flow* of the supernovae final phase and therefore dispersed in the explosion of the supernovae themselves"[74]: *explosive nucleosynthesis*. What happens is that, in the stars with mass >M_{Ch}, once the Fe is formed, the *stellar nucleosynthesis* stops, since the Fe is not meltable. Therefore, once there is no more fuel, hence no more thermonuclear reactions, the gravity takes over: the star begins to contract, with a significant and progressive increase of the T, pressure and density, and the photons acquire energies of the MeV order. Thus, roughly all the nuclei of the natural elements, heavier than the Fe, are generated in the central regions of the star during the collapse and the subsequent explosion, as a consequence of the *neutron capture* process. The strong shock wave produced by the rebound on the star cores of *degenerate neutrons* is such as to trigger explosive reactions of nuclear fusion in the gas falling towards the core itself. These fusion reactions produce a large *flow ofNeutrons* which are absorbed by the nuclei of Fe_{26}^{56}, to form isotopes

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rich in neutrons and therefore unstable [77]. These subsequently decay by fission forming all the heaviest elements of the Fe (that is, with A>56), as well as other stable nuclei of the Fe, such as: Fe_{26}^{54}, $Fe_{26}^{57}$and Fe_{26}^{58}.

It is necessary to bear in mind that when the density reaches the value of 10^{12}g/cm^3, electrons have also acquired a huge amount of energy, they become *relativistic*, so that the minimum energy configuration of protons and neutrons changes, as energetic electron violently struck against the protons of Fe nuclei, they are able to convert them to neutrons through an *electron capture* process (*inverse β process, or β-decay*$^+$):

$$e^- + P \rightarrow N + \nu_e \quad (13)$$

We have that an electron so much energetic (*relativistic*) is able to give to the proton, its own Kin $_E$ to gain that energy gap, corresponding to 0.78281 MeV, transported by the neutron [29].

These electrons, moreover, benefit from an environmental context of very high pressure, such as to overcome the *electric or Coulomb repulsion* between electrons and protons, so that these particles can more easily be pushed against each other to form neutrons. As known, in normal matter it is just this Coulomb *repulsion* to prevent the compression of matter, but if the electric repulsion is missing, or is overwhelmed, the matter can be compressed up to 10^{14} g/cm^3, or more. In short, with the increasing contraction of the star the conditions of a complete *degeneration of the electrons* have been created thus, as the Pauli Exclusion Principle (PEP) imposes, there have not been any *free states* a possible emitted electroncould occupy, which categorically prevents each neutron, as the one created in Eq. (13), to return to being a proton [76].

It is like saying that electrons and protons*neutronize*, creating a *protostar of Neutrons*.

Initially, the electronic neutrino (ν_e) emitted in Eq. (13), succeed in escaping from the star with quite easily, but subsequently the density in the stellar core increases rapidly to become opaque to these same neutrinos. Moreover, at high temperatures of the stellar core (T≈10^6 °K), the e^- e^+ pairs go to thermal equilibrium with neutrinos (ν_s) and $\bar{\upsilon}_s$ of all *flavors*. Finally, the external parts of the stellar *core* in collapse *rebound* on the central *core* (incompressible) of *degenerate neutrons*, which form the *Neutron Star*. With the rebound a shockwave is created that propagates outwards and sweeps away the outer layers of the star, thus triggering the *supernova explosion* [77]. This wave is pushed by the *thermal* neutrinos, which carry a considerable fraction of the gravitational energy released [75]. Only 1% of the released energy is observable (represented by the Kin $_E$ of the shock wave and by the radiation), while the remaining 99% is taken away by the neutrinos, just formed by the *neutronization* process. Therefore, a shock wave has been created, which sweeps away the outer atmosphere of the star, up to the outside of the star itself. Thus, an intense neutrinos radiation is emitted, announcing the *Supernova*: the light will arrive a few hours later [74].

2.5.5neutronization and Neutron Stars

As we have seen, Eq. (13) shows a typical example of *neutronization*, represented by the creation of a *N*, induced by the coupling of a *P* with an e^-, which, provided with a formidable E_{Kin}, succeeds in overwhelming the electric repulsion which, in general, keeps these two particles apart. Then, with the *neutronization* the electrons, compressed on the protons, join them forming neutrons (and emitting neutrinos) [78]. This is a very peculiar phenomenon, which occurs in very few circumstances such as, for example, in the core of massive shrinking stars, when particular conditions of very high gravity, pressure, T and density are created.

Just when the density reaches a value of 10^7g/cm^3 the process of *neutronization* of matter starts, triggered by the remarkable E_{Kin} acquired by a free *degenerate electron*. Its energy is so high as to compensate and balance the mass gap between *P* and *N*, allowing the reaction illustrated in Eq. (13), and inhibiting the opposite one, which currently occurs under normal conditions, i.e. 'low density', known as *Neutron disintegration* or β-decay$^-$ (*βd*$^-$) [78]:

$$N \rightarrow P + e^- + \bar{\upsilon}_e \quad (14)$$

With the progressive increase of density, in the contracting star the *neutronization* increases dramatically, while the number of protons and electrons decrease. At a density of the order of 10^{14}g/cm^3, i.e. one order of magnitude greater than the density of nuclear matter, 80% of the neutrons, no longer bound within the nuclei, form a *degenerate gas*, so defined for its peculiar behavior [78]. In fact, taking advantage of the insights developed by both Fermi and Dirac, it is inferred that, in an ordinary gas, the pressure decreases parallel to the decrease of T, since the degree of thermal agitation of the atoms decreases. On the contrary, in the case of *degenerate matter*, this does not occur, because of the very high density. In fact, when the particles are extremely close to each other, there are effects of QM that induce a kind of repulsion between the particles. In other words, a form of *counter-pressure* opposes to the gravity, like an anti-gravitational pressure, which in turn is related to two basic principles of QM: the Heisenberg Uncertainty Principle (HUP) and the PEP. According to the QM, the simple fact of confining particles in a sphere of radius (*r*) implies thatthese particles are provided with a *momentum* (***p***):

$$\boldsymbol{p} \geqq \hbar/r \quad (15).$$

At this *momentum* corresponds a *pressure* [65].
In turn, the PEP establishes that 2 identical fermions will never have the same quantum numbers and occupy the same *phase space* cell. Therefore, if each the two fermions with lower energy have a *momentum* (***p***), as described by Eq. (15), the next pair will have: ***p***≧ 2 ħ/*r*, and so on. Thus, the average *momenta*, brought by the particles, are greater than if they were all in the *fundamental state*. This gives rise to a pressure that increases more than linearly with respect to the number of particles [65]. It happens, that is, that even with T=0 there is a pressure, the so-called *Fermi pressure*, whose counter-pressure action is able to support the weight of masses less than about 3 ☼, until the gravitational contraction ceases [71]. In the end, therefore, what remains of the old stellar *core* of the exploded Supernova, is a tiny celestial body, with a diameter of 10-20 Km, on average, of

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which only one cm^3 weighs about 200 million tons: a *Neutron Star* was born.

Whereas, if the mass exceeds the Tolman-Oppenheimer-Volkoff *limit* [79][80], equal to ~ 2.5-3 ☼, the gravity of the *neutron star* can no longer be balanced by the *Neutronsdegeneration pressure* (or *Fermi pressure*). The Tolman-Oppenheimer-Volkoff limit has a certain approximation, especially regarding the lower limit. The uncertainty in the value reflects the fact that the equations of state for the *extremely condensed matter* are not known, that is to say, the equation of state of the *degenerate neutrons* is not yet well defined. Thus, the gravitational contraction proceeds even more quickly and violently, since the greater gravitational mass creates even more marked pressure and density conditions than in the *neutron stars*.
Therefore, it also goes towards the inexorable collapse, with subsequent explosion. Both during the final phase of the contraction and in the explosive phase, the conditions for the nucleosynthesis of all the heaviest elements of the Fe are created, up to uranium: *explosive nucleosynthesis*.

The exploded Supernova, however, this time creates a different astral body: a Black Hole.

Summing up, we have highlighted that *Neutron synthesis* is only performed in particular conditions of gravity, pressure, T and density, as occurs with the *BB*, or during the *primordial nucleosynthesis*, or in the *stellar* and *explosive nucleosynthesis*, as in the processes of *neutronization* and *electron capture*.

2.6 Possible Nuclear Electrons (Safegarding Conservation's Laws)

As it is known, even before being discovered, the *N* had been imagined as composed of a proton (*P*) and an electron (e^-) "forming a kind of *neutral doublet*"[30]: $N =〔P, e^-〕$ as it is represented in Eq. (10). This *neutral doublet*is also superimposable to the interpretation of Marie Curie (see Eq, 1). Also the main authors who deepened the subject, like Van der Broek [35], Harkins[37], Majorana[51][52], Pauli[2], Heisemberg [6], etc… had the same idea. We would like to discuss two topics: the first concerns those real situations in which the electron, *captured* by a proton, is not removed, as the HUP would imply; the second is the so-called *Nuclear Spin Statistics.*

2.6.1 Realsituations in which *Nuclear Electron*is not removed

The particular conditions Rutherford [30] referred to, are actually created in Nature, just in the conditions related to the Baryogenesis, i.e. with the *Neutron Synthesis*: Big Bangnucleonic synthesis, *primordial* nucleosynthesis, stellar and explosive nucleosynthesis, *neutronization* and Neutron Stars.

All these situations are united by extreme conditions of density, pressure, gravity and T. Whathappens is that the atoms are crushed each other, each atom is compressed, so, as in the case of a hydrogen atom (H_1^1), the orbiting electron is pushed against its nucleus, that is against a proton, thus creating a different particle, referred to as neutron (*N*), which is made, in fact, by a proton and an electron: that is a *Neutral Proton*, as Majorana called it. What has been described is the well known *Neutron Synthesis*, thanks to an *electron capture* mechanism by a free proton.

To be honest, therefore, we cannot absolutely define this particle, the neutron, as an elementary particle, but a "*complex particle"* [48], without being able to give it a specific identity, that is as an independent particle. No! Considering how this particle was born, that is from the forced and very close approach, of an electron with a proton, we find it more congruous and consistent to define it as *neutral compound (or complex) particle* or *Neutral Proton*, instead of *Neutron*. Thus, without classifying a new baryon particle at all.

The term "*neutral*" is appropriate since the opposite electrical charges, between e^- and *P*, cancel each other out. It is simply a *neutral complex*, exactly corresponding to *Majorana's Neutral Proton*, like the *NeutronModel* of Rutherford and Harkins. Thus, these authors had not been mistaken in hypothesizing this nuclear particle, the *N*, *made up* of the forced union of an e^- with a *P*, as occurs widely in Nature, through *electron capture*. An example: "in a Neutron Star, with the radius of 10 km, there are 10^{57}neutrons, as many neutrons as there are in the Sun" [65]. And the cosmos is full of Neutron Stars or *yellow dwarfs*.

Nevertheless, although the reality broadly confirmed that the *N* could be made at least as the *doublet* of Rutherford 〔*P*, e^-, it was used *improperly* in our opinion 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 baryogenesys*, 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 T must necessarily be $T \geq 10^{13}$ °K [19].

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 electrons are so close to the protons that they merge with them and there is not even the smallest space between them" [81]. 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}neutrons!

It may seem really ridiculous to keep talking about *Neutron's radius* in these spaces.

Therefore, in Nature the so-called neutron (*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

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electron would be immediately expelled from the nucleus. In fact, when applying the HUP, an electron located within the radius (R) of the atomic nucleus -see Eq. (15) - would have a *mometum* (Δ_p), an energy of more than 2 orders of magnitude greater than that of a common *β ray* (≈1 MeV), because:

$$\Delta_p \approx \hbar/R \approx 140\,\text{MeV} \qquad (16)$$

Maybe the mentioned HUP example can be valid for a free neutron, 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 neutron decays spontaneously. On the contrary, the neutrons housed in the nuclei are made stable by the action of the Strong Nuclear Force (SNF) and by the *nuclear binding energy* [82], so they behave differently (they do not decay).

Moreover, in Nature does not always happen that the electron is immediately removed (as a result of the HUP) after the neutron is formed: *Neutron Stars testify*, whose neutrons survive for hundreds of millions of years, if not forever, even. These stars are a clear example in which the removal of the electron 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 electron*.

In short, it seems very important to underline that, in these very special circumstances, in our opinion, the considered electron is not at all located in the nuclear space, as in *Heisemberg's Isospin space* [6] (in this case, it would be expelled by the HUP) but, for a process of *electron capture* operated by proton, the electron remained *glued* to the proton, 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. (15) or (16), would not be applicable to all those neutrons (or *neutral complex particles*) created in the various processes that occur spontaneously in Nature, described with the Baryogenesis.

Thus, these neutrons are not at all comparable to an atomic nucleus, with relative radius (R), where it is obvious that we would witness the immediate removal of electrons by the HUP. No! The extreme conditions of density (10^{14}g/cm^3) that crushed the electron against the proton, thus creating a *neutral compound proton*, referred to as *Neutron*, 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 neutrons (Ns), which creates a *neutron flux* where we count a number of Ns=10^{22}/cm^2 per second.

How could all these particles ever have their own space and their own *ray*?!

These observations should also resolve the objection raised by Klein to the notion of an e^- confined within a nucleus (*Klein paradox*) [62]. In fact, analyzing Dirac's equation related to the wave function of the electron [7], Klein pointed out that, for quantum effects, an electron would have acquired a remarkable energy, with consequent impossibility to remain confined within a nucleus.

The idea of Klein is pertinent if applied in a standard context, but it would not be applicable, for example, in a *degenerate gas of neutron*s, for which it could never oppose, in our opinion, the proceeding of a *neutronization*. In a *degenerate gas of neutrons* (constituting the core of the Neutron Stars), not only nucleons, but also electrons acquire relativistic energies. In such circumstances, in fact, the electrons that clash with the protons have an energy ≈200 MeV[65], sufficient to induce the *electron capture*: $e^- + P \rightarrow N + \nu_e$ as already represented with the Eq. (13).

It is easy to infer that the energy acquired by the electron considered by Klein, corresponding to ≤140 MeV, is lower than the energy transported by the *captured electron*, so it would never be able to allow the detachment and removal of the electron from proton.

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 electron and, therefore, to oppose the creation of a neutron.

Indeed, it can not be ruled out that, if the HUP had always denied this persistent union between electron and proton (basic for the *Neutron Synthesis*), there would not have been a sufficient baryogenesis for the formation of matter and our world.

Furthermore, the *degenerate gas* is at the base of the so-called *Fermi pressure*, which represents a further contribution against the *Neutron-decay* (or βd^-) inside the nucleus since, operating on the basis of the PEP, any proton produced by the *N-decay* would not find a free site where to allocate [32]. Indicating with p_d this *degenerate pressure* of the electrons (or *pressure of Fermi*), we have:

$$p_d = 1/5m_e(3/8\pi)^{2/3}h^2\, n^{5/3} \qquad (17)$$

where m_e is the mass of the electrons, n their number, h Planck's constant [83]. In comparison, the ordinary pressure (p_o) is: $p_o = 2nk$T (where k indicates the Boltzmann constant).

In short, in certain particular physical conditions, close to those of *singularity* described by Einstein (and especially deepened by Penrose and Hawking) [68] [73], the known physical laws do not act, or operate in a different way.

The fact is that the electron, *captured* in these extreme conditions by the proton, remains *glued* for hundreds of millions of years, as occurs in the Neutron Stars, despite the HUP or the PEP. "The average density of a Neutron Star is about 10^{14} times higher than that of the Sun. These values are the highest known and are impossible to reproduce experimentally" [76].

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

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Neutral Proton, indicated as *neutron*, 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*).

To recapitulate, to a very dense and very compact *neutral compound*, or *neutral proton*, devoid of an internal space and a ray, QM principles such as HUP would not be applicable. For the same reasons, in these extreme conditions a *Klein Paradox* will never emerge [62], also because the electron is linked to the proton by a very high energy, much higher than that explicable by the HUP to remove the elctron: see Eq. (16).

Still in the presence of these *extreme* environmental conditions, we should mention another, very peculiar phenomenon that prevents the extension of quantum-mechanical effects in such circumstances. That is, when in the core of the Neutron Stars the density reaches $4{\cdot}10^{14}$ Kg/m^3, the minimum energy configuration is that in which some neutrons are outside the nuclei. The appearance of such free neutrons is called the *N*s *dripping* and marks the beginning of a three-component mixture: crystal lattice of neutrons-rich nuclei, non-relativistic free neutrons, and relativistic electrons[76]. The free neutrons fluid has the impressive property of not being viscous. This can be explained by the *coupling of two neutrons degenerates*, due to the short-range attraction component of the nucleon-nucleon force (*Pairing Interaction*). It seems particularly important to underline this point: "The combination of two fermions (like the neutrons, in fact) is a boson, which is not subject to the PEP restrictions" [76]. Therefore, since the degenerate bosons can *all* occupy the lowest energy state, the coupled neutrons fluid can not lose any energy. It is a *superfluid* that flows without friction. Any vortex or turbulence inside the fluid will continue to exist forever, without stopping. As density increases, the number of free neutrons increases, whereas that of electrons decreases. The degeneration pressure of the neutrons exceeds that of the electrons when the density is $\sim 4{\cdot}10^{15} kg/m^3$. Near the center of the star, the nuclei dissolve and the distinction between neutrons internal and external to the nuclei becomes devoid of any meaning: neutrons, protons and electrons are thus free. The protons also mate, forming a *superconductive fluid*with zero electrical resistance. The ratio $N_s{:}P_s{:}e^-_s$ reaches the limit value of 8:1:1, as can be determined by the balance between the *electron capture* process and the *β-decay*, inhibited by the presence of *degenerate electrons* [76].

2.6.2 Nuclear spin Statistics

It is known that the Rasetti experiment [61] unquestionably clarifies that the nucleus of the nitrogen (N_7^{14}) has an even atomic mass, being A=14, so the nitrogen spin is part of the *Bose-Eintein Spin Statistics* (integer spin). As a result, nitrogen behaves like a boson. So, this experiment brings down the whole *Neutron Model* built by Rutherford, Harkins, Van den Broek, Heisemberg, Majorana, etc. Even Wigner shared this model, so much so that he wrote: "The only elementar particle are the proton and the electron" [84], thus excluding the neutron from elementary particles.

Therefore the Rutherford and Harkins *N model* is no more valid since, if we add 7 electrons in the nucleus of the nitrogen, we have 21 fermions (7protons settling + 7 protons linked to the 7 *captured electrons*), i.e. an odd number, from which emerges that nitrogen is a fermion, thus falling within the *Spin Statistics of Fermi-Dirac* (half-integer spin).

But this is in stark contrast to the Rasetti experiment, from which it emerges without doubt that the nitrogen spin is an even number: it is a boson. And so it is.

Faced with the evidence, Fermi abandons that *NeutronModel* and elaborates his mathematical formalism of the *neutron decay* (see Eq.14), also including the 3rd particle hypothesized by Pauli. He says: "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"[11]. Likewise, Iwanenko writes: "The expulsion of an e^- is similar to the birth of a new particle" [50]. At the same time, Perrin states: "The neutrino does not pre-exist in the atomic nucleus, it is created at the time of emission, like the photon"[85].

In analogy with that will try to establish the theory of *β* rayson these assumptions, Fermi adds:

a) The total number of electrons and neutrinosis not necessarily constant
b) Electrons (or neutrinos) can be created or destroyed. Such a possibility does not have any analogy with the possibility of creation or annihilation of an e^- e^+ pair; if, indeed, a e^+ is interpreted as a Dirac ≪hole≫, we can simply view the latter process as a quantum transition of an e^- from a state of negative energy to one with positive energy, with conservation of the total (infinite) number of electrons.
c) Heavy particles, neutron and proton, can be considered, according to Heisenberg, as two different quantum states of a heavy particle. We shall formulate this by introducing an internal coordinate (*p*) for the heavy particle, which can take only two values: $p = +1$, if the particle is a neutron; $p = -1$, if the particle is a proton.
d) The Hamiltonian of the entire system, consisting in heavy and light particles, has to be chosen so that every transition of a proton into a neutron occurs together with the creation of an e^- and a ν. Notice that in this way electric charge conservation is guaranteed"[12].

In short, the novelty lies in the fact that Fermi asserts that, similarly to the processes of Quantum-Electro-Dynamics (QED), both e^- and *ν* do not pre-exist within the atomic nucleus, but are *created* with the *N decay*. Fermi, therefore, is inspired by the photon: a particle created at the emission of light, and destroyed when the light is absorbed [85]. Already in 1927, in fact, Jordan and Klein had shown that the formalism of QED could be applied to the creation and absorption of any particles, e^- included [8]. The formalism of quantized fields proposed by Jordan and Klein naturally

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allowed the translation of the language of the fields into the language of particles, and *vice versa*.

Nothing to add: electrons can not be in the nucleus.

Yet we have the feeling that something is not matching. Let's analyze, for example, the Eq. (13): $e^{-}+P \rightarrow N+\nu_{e}$, which describes the known *electron capture* (*inverse β decay*, βd^{+}), or *neutronization* process. We find that the Eq. (13) is not unbalanced, as the represented electron is highly energetic, amply compensating for the mass gap between *P* and *N*. In fact, "This process is established when the energy of the free *degenerate* electron is so high to balance the defect mass between *P* and *N* in the supernatural material, so to make this reaction more favorable"[78].

We believe, however, that in Eq. (13) there is no description of one or more intermediate steps. In this respect, observing Eq. (13), the isolated ν_e is as if *it is nottelling usits history*.We wonder: where does the electronic neutrino (ν_e) come from, placed at the right member? In fact, it is well known that when a particle is created from scratch, i.e. when a new particle materializes, its antiparticle is simultaneously generated. Likewise, a fundamental rule of Physics states that "matter and antimatter particles are always produced as a couple"[86], it's unequivocal! And so: what happened to the relative antiparticle of ν_e, i.e. the $\bar{\nu}_e$, which not represented in Eq. (13) ? Where is it?

Even before looking for the $\bar{\nu}_e$, we must try to understand how it was produced. Since the electron *captured* by proton is highly energetic, it should be highly probable that, violently clashing against proton, this electron has been lightened of a significant amount of energy, freed in the form of electromagnetic radiation (EMR), which can be represented by γ photons. This EMR, therefore, can materialize in *a couple* $\nu_e\ \bar{\nu}_e$ or $e^{-}e^{+}$. It is known, in fact, that when a star is in the gravitational compression phase, the *matterneutronization* can start, which starts when the density reaches 10^7g/cm^3 and the temperature (T) exceeds the *threshold values* necessary for the materialization of electrons and nucleons. In such circumstances, therefore, the EMR consists of highly energetic γ photons which, according to Weinberg's calculations [19], should carry an energy of at least between 1 and 10 MeV, which is enough to generate a couple of electrons or neutrinos (a particle-antiparticle pair). In fact, one of the phenomena that are very often accompanied by *neutronization* is the so-called *photoannihilation*, characterized by *materialzzation* of EMR, resulting in a *Production of Couples (*particle-antiparticle) [65], as:

$$\gamma \rightarrow \bar{\nu}_e + \nu_e \qquad (18)$$

The latter equation is described in the main Astrophysics Treaties and as *photoannihilation* represents one of the most widespread and frequent physical processes of 'Production of Couples' (in this case the couple $\nu_e\ \bar{\nu}_e$).

As these physical processes of *photoannihilation* and *Production of Couples* are frequently accompanied by *neutronization* processes [65], it may be more appropriate to describe them together. For this reason, entering Eq. (18) in Eq. (13) we obtain:

$$e^{-}+P \rightarrow e^{-}+P+\gamma \rightarrow e^{-}+P+\bar{\nu}_e+\nu_e \rightarrow N+\nu_e \qquad (19),$$

$$e^{-}+P+\bar{\nu}_e+\nu_e \leftrightarrow N+\nu_e \qquad (20).$$

In this way, with these intermediate steps, the previous Eq. (13), describing the *electron capture*, should be, in our opinion, more complete and congruous, since the possible steps through which the ν_e is generated are shown in Eq. (18). Furtermore, considering just the *photoannihilation*, which occurs continuously during the *Neutronization* process, something new emerges.

In this regard, omitting the ν_e (present on both sides of Eq.20), according to the first EquivalencePrinciple (of Equations) we obtain an equivalent equation:

$$e^{-}+P+\bar{\nu}_e \leftrightarrow N \qquad (21),$$

where it is easy to notice that the *N* corresponds a compound of 3 particles: $e^{-}+P+\bar{\nu}_e$, i.e. a multiplet [e^{-}, P, $\bar{\nu}_e$]. The *N*, that is, no longer results as an elementary particle, or a doublet, but a miltiplet:

$$N = [\, e^{-}, P, \bar{\nu}_e \,] \qquad (22)$$

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" [65]: that is considering both "the *Neutronization* processes, such as the *electron capture* "[65] described with Eq. (13), and "the *Couple Production* processes, including *photoannihilation*"[65], described within Eq. (18).

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 $\bar{\nu}_e$ which is missing in the *electron capture* equation, where only the ν_e is described, but without the counterpart.

And where is the $\bar{\nu}_e$? The $\bar{\nu}_e$ is present in the left hand-side of Eq. (20) together with *P* and e^{-}, arranged in sequence, one after the other, to form that *multiplet*, represented by *N*. In this way, also implying the presence of a couple $\nu_e\ \bar{\nu}_e$ (generated by *photoannihilation*), and allocable to the 1st member of Eq. (13), this equation becomes more appropriate and physically more valid (see Eq.20).

It is interesting to note that the components of the *multiplet* corresponding to *N*, as shown in Eq. (21) and (22), are exactly the same products hypothesized by Pauli and Fermi for the decay of *N (*see Eq.3), providing an authoritative evidence of path with which Eq. (21) was reached.

Moreover, the presence of $\bar{\nu}_e$ in Eq. (20) should not appear *misplaced*, since the $\bar{\nu}_e$ was created together with its relative particle, the ν_e, just as imposed by the most basic rules of Physics [85] and as occurs, precisely, with *photoannihilation* (shown in equation 18).

But, then, one could object: with the Rasetti experiment [61] it has been clearly demonstrated that the nucleus of nitrogen

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has even spin, so it must have even *atomic mass*. Hence, the *Nuclear SpinStatistics* categorically excludes the presence of *nuclear electrons* and also imposes the *N* as an elementary particle (if we do not consider the quarks). Thus, the hypothesis of the *Neutron multiplet* (*N multiplet*), containing nuclear electrons can not stand: it is wrong!

And yet, if we observe with attention we notice that the *N multiplet*, shown with Eq. (22), is different from Rutherford's *Neutron model*, represented by the *doublet*described in Eq. (10).

With the *N multiplet*, things change drastically because its components are 3 fermions, not 2 as in *doublet*. It follows that *N* keeps its spin ½ value, so that this *multiplet* safeguards the Law of Conservation of the Angular Momentum of the neutron.
As is known, the *neutronization* process takes place in the core of massive stars, creating a truly amazing concentration of neutrons: $10^{22}/cm^2$. All these neutrons, which will constitute all the heavy elements, have been formed by *electron capture*, that is, by the very close union of an e^- with a *P*, as shown in Eq. (13).
As previously discussed and shown with Eq. (20), insertingthe *Production of Couples* process within Eq. (13), related to *electron capture*, we provide a congruous and, probably, more complete explanation both of the presence of ν_e (in Eq.13) and of the presence of the $\bar{\upsilon}_e$ in the *multiplet* describing the *N*. In this case, we reiterate, the $\bar{\upsilon}_e$ is *captured*, together with e^-, by the *P* (as illustrated to the 1^{st} member of Eq.20), forming the *multiplet* shown with the Eq. (21).

One could still object: why $\bar{\upsilon}_e$ is always *captured*, whereas ν_e (also hypothesized present at the 1^{st} member of Eq. (20) is always let go? Why we sometimes do not have the opposite? It is simple: it is imposed by the Law of Conservation of the Lepton Number (L). Given that the *P*, being a baryon has L=0, this value will have to remain constant, throughout the whole course of the *electron capture* process. This process allows the *P* to *hook* tightly an e^-, the latter having L=1. It is easy to see that if the *electron capture* process stopped with the *capture* of only e^-, as shown inEq. (13), the result of this union (e^- with *P*), should give L=1.But it is impossible: the equation mustalways be L=0. Hence, where is the mistake? In leaving the equation related to *electron capture* as it has been described. Whereas, if we consider that a 3^{rd} particle is also *captured*, things could adjust, provided that this particle has L = –1. But only an anti-lepton has L = –1. This is why the ν_e is let go, while the $\bar{\upsilon}_e$ is *captured*!

Furthermore, this 3^{rd} particle is exactly the same Pauli proposed in βd^- [2], which is just the inverse process of *electron capture*, called namely *inverseβd* (or βd^+).

In addition, if composed of 3 particles, the neutron returns to be a fermion.

Now let's look at the Spin Statistics of the Nitrogen nucleus (N_7^{14}), considering the neutron as *multiplet* (rather than *doublet*). This particular changes things.

With the model of the *Neutron multiplet*, we have that in the nucleus of nitrogen to the 7 base protons, as a result of the *electron capture* process more 7 protons are added, as well as 7 electrons and 7 electronic anti-neutrinos ($\bar{\upsilon}_e$).

So in the nitrogen nucleus we have as many as 28 half-integer spin particles (fermions). Thus, summing up, we have an even spin, which tells us that the nucleus of nitrogen behaves like a boson, in perfect agreement with the perplexities raised by Heitler-Herzberg [58] and by Ornstein and van Vijk [59], with Kronig's intuitions [60] and with the Rasetti experiment [61]. And above all, according to reality.

Nonetheless, this *N multiplet*, proposed in this way, does not satisfy us completely, since, observing Eq. (22), we notice that something is wrong. In fact, to equalize the mass of the 1^{st} member, i.e. of the *N*, the 3^{rd} particle placed at the 2^{nd} 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 ~100˙000 to 250˙000 $\bar{\upsilon}_e$ 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 3^{rd} 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 [2] [11] [12] to characterize the 3rd particle of βd^-.

Their 3^{rd} request is that it must have the same mass of e^-[2][5]. Therefore, a neutral antilepton, with the mass of e^-, immediately made us think of a *neutral electron*: e°, or rather an anti-e° (ē°).

In this case, the *multiplet* corresponding to the neutron (*N*) would be as follows:

$$N = [\, e^-, P,\ \bar{e}^\circ \,] \tag{23}$$

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. (7).

3. Conclusions

Somebody may say: even with the *N*, considered as an elementary particle, we are in agreement with the Rasetti experiment, thus there is no need to puzzled about building the model of the *Neutron multiplet.* 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 the *photoannihilation* reactions, describing them together with the *electron capture*, we understand the fate of couples like $\nu_e\bar{\upsilon}_e$, an *implicit* couple, in our opinion, the 1^{st} member of Eq. (13),

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however not shown. As well as we can better understand the presence (otherwise unexplained) of ν_e at the 2nd member of the same equation.

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 3rd particle.

Finally, if we considered the possible existence of the e°, with relative antiparticle, instead of ν, we would actually and in all respects, in a more appropriate and elegant manner, safeguard the Law of Mass and Energy Conservation, 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 neutrons within the atomic nuclei.

Harkins suggested the existence, in the nucleus, of "two *cementing* electrons" [37].

Nor should the novelty emerging from our model be omitted, since neutron (*N*) would no longer exist as an autonomous elementary particle, with its own individual identity. In our opinion, rather than *N*, it would be appropriate to define it, mentioning Majorana, *neutral P* or *complex particle*. That is, with the *multiplet* we would not have a *N*, but 3 different particles, tightly joined together: $[e^-, P, \bar{\nu}_e]$.

Moreover, the *multiplet* reflects, in reverse, the three products of the *N* decay in which only one $\bar{\nu}_e$ can not compensate for the mass gap problem of βd^-: it would take from 100˙000 to 250˙000 of these neutrinos to compensate for the gap.

On the contrary, a single e° would be enough to balance the gap mass, so that the *Nmultiplet* would be more congruous if formulated in this way:

$$N = [e^-, P, \bar{e}°] \quad (24)$$

This would take to a considerable simplification of the *Standard Model*, since there would be a single type of particle between the baryons (that is, among the hadrons of the 1st family), i.e. the *P*, and a single type of particles between the leptons of the 1st family, represented precisely by the electron in its forms: e^-, e^+, e° and ē°.

In conclusion: the 1st Family of the Hadrons would be represented only by the proton, whereas the 1st Family of Leptons would be represented only by the electron.

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