On The Neutrino

微中子諸問題之探討

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Abstract: Experimental and theoretical results of the recent neutrino research are summarized and reviewed in order to exhibit what the neutrino really is. And an effort is made to show a clue to a future comprehensive study of elementary particles.

I. Introduction

In the text we shall try to discuss the so-called neutrino in various aspects……evidenc for the existence, static properties, source,…… of it. Because many experiments on neutrino have been concerned with those found in cosmic radiation, the subjects of cosmic rays and neutrino are interrelatively studied. In doing so, we shall attempt to capture some of the drama of the neutrino story by a suitable arrangement and reveal the experimental difficulties, which still put us in perplexity.

On recent theoretical work such selected items are apt to display the weakness of the various thoeries rather than their positive achievement. The balance of such a review is rather embarrassing. All this may be encouraging for further theoretical study.

A large number of the subjects enumerated here are ones concerning which many investigations are now under way and improved results may soon be obtained. In recognition of this fact and all concerned materials not available here, no attempt has been made to make a complete and comprehensive discussion on the subject. Thus this article is only intended to serve as a guide to research workers entering this field.

II. Evidence for the existence of neutrino

In the phenomenon of Beta-radioactivity energy seemed to disappear and the conservation of angular momentum to be violated. It was first suggested by Pauli in 1933 that actually energy and angular momentum are stolen away in β-decay process by a particle called the neutrino (ν). Recently good experimental data are available on both the birth (production) and the death (interaction with matter) of all fundamental particles except the neutrino. The only pointview accepted by many physicists is that the assumption of the existence of the neutrino should be made subject to the outcome of the following kinds of experiment.

After the K-capture of a β-particle by a β-active nucleus a certain amount of the missing energy may be attributed to the neutrino if these quantities obey the energy-momentum relation in each individual case observed. However it is a very difficult measurement to make because of the small recoil energy. A recent experiment of this kind have been carried out by Allen (1) using a noble gas atom. The reaction employed was

$$A^{37} + \beta_{k}^{-} \longrightarrow Cl^{37} + \nu + Q$$

which Q is the disintegration energy and others are conventional. Since the capture orbital K-electron has negligeable momentum, the momentum of recoil nucleus will be equal to that of the neutrino. Further the emitted neutrinos are monochromatic, having energy equal to the difference in mass available. The observation of such recoil does not prove the actual emission of a neutrino, but it may favor the existence of the neutrino.

If the μ-meson decay into an electron and a nentrino, as was believed for sometime, then according to the conservation laws the energy of the decay electron would be very nearly $\mu c^2/2$. Measurement of this decay energy might give evidence for the existence of the neutrino.

Measurements of Steinberger (2) have shown that the ranges of decay electrons in polystyrene hydro-carbon (paraffin) show too large straggling to be compatible with assumption all decay electrons have the same energy. Measurements of Leighton et al (3) in cloud chamber and measurement of the Bristol group in photo-graphic emulsions have shown that a continuous spectrum of the decay electrons is compatible with the assumption of a three-particle decay into electron and two neutrinos, and not more than three like the decay scheme

$$\mu^{\pm} \longrightarrow e^{\pm} + 2\nu$$

However an intense neutrino flux (4) from a Hamford reactor passes through a very large liquid toluene scintillator in which neutrinos are absorbed by protons in the reaction (inverse reaction to β-decay)

$$\bar{\nu} + {}_{1}p^{1} \longrightarrow {}_{0}n^{1} + {}_{+1}e^{0}$$

$$(\text{or} \quad \bar{\nu} + p^{+} \longrightarrow \beta^{+} + n^{0})$$

and the refinements of these experiments being concluded from Los Alamos (5) confirm this result, it will constitute a possible detection of the free neutrinos.

From the above attempts it is very unsatisfactory to have to assume the occurrence of such a particle which has no observable properties. Therefore Bohr ever suggested that it might be preferable to assume the breakdown of the conservation laws instead of assuming the existence of neutrino (6). Recently Marshak and Sudarshan (7) enumerated that in the weak interaction a neutral muon might replace the neutrino. However, it may be convinced that these attempts have increased the amounts of presumptive evidence for existence of the neutrino although they have not yet succeeded.

III. **The static properties of neutrino**

In the beginning, we may regard the neutrino as a particle which would be characterized by its rest mass, charge, spin, magnetic dipole moments, etc. Now we are going to describe briefly its statical properties selected from the most reliable experimental and theoretical reports in such a way that β-decay can take place without violating any of the conservation laws as follows:

i) Charge——charge is conserved by the disintegration electron in β-decay and none is found in its chargad character till now, hence it is plausible that the neutrino has zero charge.

ii) Spin——by recent differential measurements Blair (8) and Marshak (9) have found that the neutrino has Fermi-Dirac statistics with an intrinsic $\hbar/2$ like the electron, proton and neutron

iii) Magnetic dipole moments——Cowan et al (10) had shown experimentally that if the neutrino has any magnetic dipole moment, it is less than 10^{-7} Bohr electron magnetons. Later he and Reines (11) used a very large scintillation counter near a fission reactor and reported that an upper limit of 10^{-9} Bohr electron magnetons has been placed on the magnetic moment.

iv) Mass — the energy balances (12) give the most reliable estimates of neutrino mass obtained from cyclical systems,

$$B^{11}(p,n)\,C^{11} \quad : \quad C^{11} \longrightarrow B^{11} + e^{+} + \nu$$

and

$$C^{13}(p,n)\,N^{13} \quad : \quad N^{13} \longrightarrow C^{13} + e^{+} + \nu$$

0.001 ± 0.056 and 0.00 ± 0.07 Mev, for the energy equivalent to the mass of the neutrino, respectively. Langer and Moffat (13) had shown that a very careful analysis of Kurie plot of H^3 near the end point energy makes possible an estimates of upper limit of the neutrino mass the most recent value (14) for this upper limit is 0.05% of the electron mass by the momentum balance method. Above all that can be concluded is that the rest mass of neutrino is non-vanishing and is considerably smaller than that of electron, but may be taken to be zero from some theoretical consquences which we shall discuss in the later sections.

v) Cross-section — from the average result of neutrino interaction or closely related experiments (15) the limit $\leq 10^{-31}$ cm² can be made for the neutrino cross-section. The ultimate cross-section (16) that can be detected by the then method is considerably smaller than 2.5×10^{-31} cm². Davis (17) attempted to detect neutrinos by the reaction $Cl^{37}(\bar{\nu}, e^{-})A^{37}$ at Brookhaven National Laboratory and suggested that the theoretically calculated cross-section of 4×10^{-45} cm² per atom would be observed. This is also the conclusion of Davies (18) who found experimentally a much too low (0.9 instead of 2.6×10^{-45} cm²) cross-section for pile neutrinos (from β-decay) on Cl^{37}. Muehlhause and Oleksa (19) determined the antineutrino flux distribution from a measurement of the equilibrium β-ray spectrum from thermal neutron fission U^{235} and found the antineutrino pile cross-section for $\bar{\nu}\,(p,n)\,\beta^{+}$ and $\bar{\nu}\,(d,n)\,\beta^{+}$ as a function of antineutrno energy and their average value to be $\bar{\sigma}_p = 6 \times 10^{-44}$ cm² and $\bar{\sigma}_d = 2 \times 10^{-45}$ cm² respectively. To conclude, the experimental evaluation of the cross-section is hardly compatible with the theoretical one which amounts much approximately with the square of neutrino energy and may say that the interactions of neutrinos with matter are very weak.

For clarity, the recent static physical properties assumed for the neutrino and its close relatives are summarized in an appendex.

IV. Source of the neutrino

Bethe (20) conjectured that the sun may produce a considerable neutrino flux even at distance as far as the earth. The intensity of the neutrino rays coming from the sun is not yet observed for the present. With the observed limit on the cross-section (see III) already most of the neutrinos may escape from the sun, giving a flux at the earth of $3.5\times10^{11}/\mathrm{cm}^2/\mathrm{sec}$, consquently D. Saxon (16) concluded that the sun is the greatest source of neutrino flux which is homogeneously absorbed at the earth and is considered to cause the earth's heat effect.

E. Nahmias (21) discovered that the neutrino and the technetium observed in the spectra of certain stars are formed by the inverse β-reaction

$$Ru^{99} \quad + \quad \bar{\nu} \quad \longrightarrow \quad \beta^{+} \quad + \quad T_c^{99}$$

In his theme F. Pallauf (22) proclaimed that the whole universe must be filled up with neutrino rays because the innumerable suns of the universe are giant atomic pile and during the formation of suddenly shining stars a very considerable amount of energy must be continuously reflected into the form of neutrinos, whereas the neutrinos penetrate the star matter almost unpreventably. Therefore he attempted to explain the gravitational inertial forces as the effect of a penetrating ray which comes on all sides from the universe (see IX).

From our observation, all the above is based more on speculation and contemplation, but less on firm knowledge or bed-rock facts. Moreover according to Pauli's hypothesis the origination of neutrinos is connected with the β-decay. A stream of neutrinos has to come out of the radioactive substance. Therefore we may affirmatively suppose that the strongest continuous working neutrino source of the earth is an uran incendiary because the fission products of the uran are β-rays.

V. Neutrino and Antineutrino

In the Majorana theory (23) all neutrinos are identical, whereas in the Dirac (used by Fermi) theory (24) there are two kinds of neutrinos, corresponding to Particles—neutrinos (ν) and antineutrinos ($\bar{\nu}$). By a precise measurement of the end point of the electron spectrum one would impose a choice between even and odd couplings (25), but could not truly decide between the two above-said possibilities for a neutrino theory.

Cowan and his co-workers (26) sought double β-decay in gram quantities of the separated isotopes Nd^{150} and Sn^{150}, and concluded that Majorana-Furry hypothesis of the identity of neutrino and antineutrino is inapplicable. Later he and Reines (27) alone had shown that the non-identity of the neutrino and antineutrino has again been demonstrated by measurement of the life time of Nd^{150}. A lower limit of 4×10^{18} years was obtained which is to be compared with 1.3×10^{15} years expected if the neutrinos are identical as proposed by Majorana and Furry.

Double decay is the second order process: 2 neutrinos with emission of lepton particles. This can be done according to such scheme

$$2n \longrightarrow 2p^{+} + 2\beta^{-} + 2\nu \tag{1}$$

(Dirac form)

and requires that there are neutrino and antineutrino in nature. It is also enumerated Fermi (28) that the neutrino emitted virtually by the first reaction can be absorbed in the second; no neutrino comes out according to another scheme

$$\begin{array}{ccccccccc} & & n & \longrightarrow & p^{+} & + & \beta^{-} & + & \nu \\ \nu & + & n & \longrightarrow & p^{+} & + & \beta^{-} & & \\ \hline & & 2n & \longrightarrow & 2p^{+} & + & 2\beta^{-} & & \end{array} \tag{2}$$

(Majorana form)

After several years of controversy on the rate of double β-decay Awschalom (29) concluded that there is no double β-decay without neutaino emission as shown in eq. (1).

Landau (30) suggested that the neutrino is completely polarized the direction of its motion whereas the antineutrino is polarized in the opposite direction. On the basis of two component wave function theory (see later) the angular distribution of electron from muon decay is derived, and it is pointed out that the β-decay electrons should have a polarization $\pm(v/c)$ in their direction of motion.

Schopper (31) shew by a circular polarization detector used in a β-coincidence experiments that the antineutrino accompanying β-decay has the opposite screw sense to the neutrino in β^+-decay.

Von Pauli and Lüders (32) shew that neutrino and antineutrino appear formally in the β-decay without consideration of which the conservation of the lepton charge is valid, as well as particle-anti-particle-Pairs come out only in connection with a non-vanishing charge-like quantum nunber. In the physics of elementary particles we have known different charge-like quantum numbers as the electric charge. From the observed stability of nucleons we may conclude that the principle of conservation holds also good for the Baryon number or Baryon charge (33).

According to our observation it were by this time Possible to postulate the following rules about these elementary particles:

(i). Antineutrino and neutrino could co-exist in pairs formation in the nucleus field and break into their own free state of equivalent energy amount.

(ii). They would have exactly equal mass, if having non-vanishing mass, and exact same spin, but opposite electric and magnetic moment.

(iii). A neutrino would be conveyed to the other side of the reaction as an antineutrino, for example

$$n \longrightarrow p^+ + e^- + \nu$$

$$\bar{\nu} + n \longrightarrow p^+ + e^-$$

(iv). Neutrino and antineutrino have opposite screw sense in β-decay.

Furthermore, it would be called to notice that further experiments are required to distinquish them separately.

VI. Production of neutrino in cosmic radiation

Measurements by Barnóthy and Forró (34) indicate that the ionization is produced principally by a soft radiation. If this is correct, the result can be explained by the assumption that the cosmic rays are carried to a very deep depth (even in 1,000 m depth of water) by a new electrically neutral components as the carrying agent, one can invoke a neutral Yukawa particle or a Pauli neutrino.

Investigating tracks ending in the photographic emulsion exposed to cosmic radiation (35) the types of charged particle called $\pi^{\pm}$ and $\mu^{\pm}$-meson may be identified to exist unstably and disintegrate spantaneously with the scheme (also see Appendix)

$$(1) \qquad \pi^{\pm} \longrightarrow \mu^{\pm} + \nu$$

where there is just one neutrino. From the case (eq.(1)) Oppenheimer (36) mentioned that it is not fully understood and it is not comfortable to understand why the $\pi^{\pm}$-meson does not decay into an electron directly.

The decay of the muon can be represented by the reaction which is a well-known μ-meson decay process

$$(2) \qquad \mu^{\pm} \longrightarrow e^{\pm} + 2\nu$$

where there are two neutrinos. And the production of neutrino by the capture of μ^{-}-mesons has been investigated by Sard and co-workers (37) for the years (1948-53) by allowing cosmic ray μ^{-}-mesons to pass through various materials. It may be probably represented by the reaction

$$(3) \qquad \mu^{-} + p\ (\text{in nucleus}) \longrightarrow n + \nu$$

Several events (38) appear to represent the decay of a charged particle called K-meson (or χ-meson) which was found in the cosmic-ray observation and one is led to the plausible decay in accordance with the schemes

$$(4) \qquad \begin{aligned} K &\longrightarrow e + 2\nu \\ \chi &\longrightarrow e + \nu \end{aligned}$$

Consequently there are good reasons to believe that a large number of neutrino are produced by cosmic rays. No direct experimental evidence for the existence of a neutrino component is available. The difficulties in establishing a neutrino componet are not purely experimental. As no clear theoretical predication have been made as to what processes would be initiated by neutrinos, it is impossible for the present to know for certain what are the best experiments to carry out to prove their prodiction in cosmic radiation.

VII. **Fermi theory of β-decay**

E. Fermi (39) drew an analogy between the emission of electrons and neutrinos from nuclei and emission of photon from excited atoms. A mathematical theory of the interaction between the nucleon and two light particles is based on the quantum theory of fields. The heavy particles are to act as sources and sinks of the light particles and such an interaction is chosen

$$(1) \qquad H_{if} = G \int \left[U_f^0 \varphi_e(r)\ \varphi_\nu(r) \right] O_x U_i \, dv$$

where H_{if} is the so-called matrix elements of the interaction for the initial and final states. $\varphi_e(r)$ and $\varphi_\nu(r)$ are the wave functions of the electron and the neutrino at the position (r) respectively and therefore the integral is over the co-ordinate of the nucleon alone. U_i and U_f describe the nucleus before and after the emission process. The quantity in square brackets represents the entire system after disintegration where U_i represents the entire system before disintegration. The coupling constant G, empirically evaluated from experiments, measures the strength of interaction between the nucleon and the electron-neutron-field with the dimension 10^{-48} to 10^{-49} erg cm^3. 'O_x' is an operator which has one of the five forms identified here only as S, V, T, A and P for meeting all the relativistic and other requirements.

Since the neutrino has little interaction with anything and the charge is small, φ_ν and φ_e with a Coulomb energy effect may be taken as plane waves with momenta P_ν and P_e respectively. The probability of emission will be assumed to depend on the expectation for electron and the neutrino to be at the nucleus, i.e., on the factor $|\varphi_\beta(0)|^2 \ |\varphi_\nu(0)|^2$, then the number of transition processes per unit time at the interval of the electron momental p to p + dp is

$$(2) \qquad P(p)dp = =(2\pi/\hbar)(\Sigma \left| \int U_f O_x U_i dv \right|^2)(|\varphi_\beta(0)||\varphi_\nu(0)|G)^2 dn/dE$$

where dn/dE is energy density of final states and '0' refers to the location of nucleus.

There is a certain probability per unit time for this to happen, corresponding to ascertain mean life for the excited atom. Neglecting the weak force of causing the transition excited on the atom by the electric and magnetic field we can treat the problem quantum-mechanically by perturbation approximate method whose basic result is for the partial disintegration constant for the transition of a system from initial state i and final state f. The expression is finally deduced for P(p) for the allowed transition as follows

$$(3) \qquad P(p) = (G/2\pi^3\hbar^7c^3)\left|M_{if}\right|^2F(E,z)p^2(\hat{E}-E)^2$$

where F(E,z), the Coulomb factor, takes account of the effect of the nuclear electrostatic field on the motion of the electron. It has the value unity for $z = 0$, z is taken negative for negatron emitters and positive for position emitters. The quantity $p^2(\hat{E}-E)$ is just, aside from a multiplying constant, the density of state expression in eq.(2). The quantity P(p) is just what we measure with a β-rays spectrometer.

The probability per unit time that an electron will be emitted with any momentum whatsoever is just the total disintegration constant and is given by

$$(4) \qquad \lambda = \mathrm{In}2/t = \int_0^{\hat{p}} P(p)dp$$

where $\hat{P}$ is the momentum corresponding to E and t is the half life.

Substituting eq.(3) in eq. (4), we have

$$(5) \qquad \lambda = \ln 2/t = \left|M_{if}\right|^2(G^2/2\pi^3\hbar^7c^3)\int_0^{\hat{p}} F(E,z)p^2(\hat{E}-E)^2dp$$

$$= \left|M_{if}\right|^2(m^5G^2c^4/2\pi^3\hbar^7)f(z,\hat{E})$$

where $f(\hat{E},z)$ is a dimensionless function whose value depends only on z and the upper limit of the integral above we can write

$$(6) \qquad ft = \mathrm{constant}/\left|M_{if}\right|^2$$

where ft is called the comparative life of nucleus. It provides a way of comparing the life time of β-active nuclei on the basis of the same atomic number and disintegration energy. It should have the same value for all allowed transitions if the matrix element M_{if} is the same for all such transitions.

The Fermi theory leads to the approximate relationship $\lambda = kE^5{}_{max}$ for β-emitter like Sargent's rule (40). The constant k depends on the change (ΔI) in nuclear angular momentum (spin) accompanying the disintegration and certain symmetry factors (parity). The theory has even correctly predicted the life time for radioactive decay of a free neutron into a proton, electron and neutrino, and also gives an adequate description of the decay of the changed μ-meson into an electron and two neutrino (41-2), nevertheless the agreement of recent observations and the $\lambda \sim kE^5{}_{max}$ relation is not close, as several simplifications are made in obtaining the Fermi theory and some of discrepancies are maybe attributable to uncertainty in experimental information presently available or to the applications which are in fact forbbiden (43-4).

VIII. The two component theory of neutrino

In view of the violation of these invariances in the interactions and the large asymmetry with respect to the spin direction of the oriented nuclei found, Lee and Yang (45) suggested that nature takes advantage of the fact that the neutrino has mass zero and its wave function need only have two components instead of the usual four and a similar theory was independently proposed by Salam (46) and Landau (47).

In this theory, the neutrino can be represented by a spinor function with the need of 3 anticommuting Hermitian matrices and the Dirac equation for the field can be written as ($\hbar = c = 1$)

(1) $$\sigma \cdot p\varphi_\nu = i\partial\varphi_\nu/\partial t$$

where σ_1, σ_2, σ_3 are the usual 2×2 Pauli matrices. For the space rotation through an angle θ round the z-axis, the wave function transformation is in the following way

(2) $$\varphi \longrightarrow \exp(-i\sigma_3\theta/2)\phi$$

the σ-matrices are therefore the spin matrices for the neutrino. For a state with a definite momentum P, the energy and the spin along P are given respectively by

$$H = (6 \cdot p)$$

$$6_p = (6 \cdot p)/|p|$$

They are therefore related by

(3) $$H = |P|\, 6_p$$

In the hole theory of such particles, the spin of a neutrino (defined to be a particle in the positive energy state) is always parallel to its momentum while the spin of an antineutrino (defined to be a hole in the negative energy state) is always antiparallel to its momentum (i.e., the momentum of the antineutrino). The correlation between the spin and the momentum of a neutrino defines automatically the sense of a screw. With the usual (righthanded) convention the spin and the velocity of the neutrino represent the spiral motion of right-handed screw while the spin and the velocity of the antineutrino represent the spiral motion of a left-handed screw. The free neutrino Langrangian is invariant for the substituion $\varphi_\nu \rightarrow \gamma_5\varphi_\nu$, and φ_ν and $\gamma_5\varphi_\nu$ have opposite intrinsic parity. This results is a violation of both parity conservation (P) and charge-conjugation (C) invariance which is in agreement with recent experiments (48)

Furthermore by the Lüders-Pauli theorem (49) the theory can be proved to be invariant under time reversal (T) and the combined inversion (parity and charge conjugation together CP). It follows from this that despite breakdown of parity conservation particles cannot possess electric dipole moments.

In this theory the neutrino state and the antineutrino state cannot obviously be the same and thus the Majorana theory for such a neutrino is impossible, whereas Mclennan and Serpe (50-1) enumerated that the Lee-Yang equations are equivalent to the Majorana's abbreviated equations and thus are invariant under the full Lorentz group, and made some comments on the particle concept and on the formulation of the β-interaction with the help of the two com-ponent neutrino field. In his paper (52) Lüders also proposed that a wide class of quantized field theories which are invariant under the proper Lorentz group is also invariant with respect to the product of time reversal (T), Charge conjugation (C) and parity conservation (P).

Radicatic and Touschek (53) presented the Serpe--Fiez equivalence theorem for the free neutrino case and proved the interaction of the neutrino description whereas Sokolow (54) shew that there are again four states for rest mass of neutrinos with a definite chirality (handedness).

Watanabe (55) formulated in 1957 four component spinor theory for a particle of spin 1/2 with a definite chirality which has definite mass and the Salam-Lee-Yang-Landau type of neutrino theory can be derived from this formulation for the case m (mass) = 0.

The μ-meson decay (56) was proposed to take place via the emission of an electron, a neutrino and antineutrino, and according to the two component theory this is only possible for the V and A interactions to occur and gives a Michel parameter of $\rho = 3/4$.

Up to now it is generally assumed that the two-component theory of neutrino is such specific than the ordinary theory for the experimental predications, and the possible non-conservation of parity in weak interactions has been beyond doubt verified in the β-decay and π-μ-e-decay. However, many of its consequences are subject to direct experimental confirmation, although evidence availabe so far is strongly in favor of this theory, and more detailed work will be required before a definite conclusion is obtainable about its validity. And the right-handed character of the neutrinos implies that the resulting toroidal system is not symmetric with respect to reflections in its own plane.

IX. **Gravitation and Neutrino**

In Newtonian physics gravity must be either peculiar effect of some peculiar kind of impact which was regarded as the only possible physical cause of motion or the effect of some immaterial cause. There is still not a satisfactory solution of the question: What is the relation between the two apparently disparate causes of motion, impact and gravitation?

So far the neutrino does not respond directly to electric or magnetic fields. Thus in this section we are going to deal with some research works about the relation between the neutrino and the graitational field: the response of neutrinos to gravitational fields or the production of gravitational force by neutrinos.

Previously, the idea that gravitational forces could arise from interchange of neutrinos between any kind of the interacting matter could not be made consistent with a very precise experiment performed by Hungarian physicists Eötvös in 1910. This experiment shew the gravitational weight of any object and its inertial mass are strictly proportional to each other to an accurracy of one part in 100,000,000.

Because of the neutrino experimentally established (5), Pallauf (22) attempted to show that the gravitation may be explained as the result of a neutrino ray of outstanding penetrational force, coming from our universe to milky way system, being equally strong in all directions and hurrying nonresistibly through the vacuum space between the nucleus and the electron in the atom with a velocity of light.

Thus he drawed a programme and derived a formula for bodies without sending neutrino themselves which is identical with Newtonian one such as

$$(1) \qquad K_{I \longrightarrow II} == \left(\frac{3\alpha}{2\pi}\right)\left(\frac{m_1 m_2}{\ell^2}\right)$$

where $K_{I\rightarrow II}$ denotes the force with which the body II (mass = m_2) is acting upon the body I (mass == m_1), ℓ is the distance between the centers of two bodies and α is a constant with dimension of 1.397×10^{-7} cm^3 g sec^2; and another formula for bodies with sending out their own neutrino ray as follows

$$(2) \qquad K_{I \longrightarrow II} = \left(\frac{3\alpha}{2\pi}\right)\left(\frac{m_1 m_2}{\ell^2}\right)-\left(\frac{3\tau}{2\pi}\right)\left(\frac{m_1^2}{\ell^2}\right)$$

where τ is similar to α when the body I sends out neutrino itself and the remainders are the same as the notations in formula (1).

In the last part of his theme he enumerated the possibilities for the above supposed theory.

Brille and Wheeler (57) considered the influence of the neutrinos' orbit by force under gravitational fields, i.e., the spinor field of neutrino in a curved metric. In other words it is as much beyond doubt in neutrino physics as it is in electron physics to make a well-defined distinction between negative and positive energy states when general gravitational fields are at work.

And from the geon concept he proposed that geons can be constructed in principle out of neutrinos in much the same way that they can be constructed in principle out of photons.

In order to reconcile in various description of the forces of gravitation, Schiff (58) proposed a theory which is based on study of the neutrino and devised a way to account for the gravity.

In its preliminary form Schiff's theory is not Lorentz invariant. It is being modified in a particular way in order to make it Lorentz invariant and improve agreement with observation.

From the above analysis of interaction between neutrinos and gravitational field we may conclude that the neutrinos are nature's ' Ghost ' particles

X. Concluding Remarks :

Neutrino Physics has an interesting character in and by itself. During the past decades neutrino physics has been developing rapidly, but experi-mental results attained are undoubtedly fragmentary and the techniques used to derive them are far from being fully exploited in the present time one can learn some fraction as mnch about neutrinos as one knows about electrons. In the years ahead the body of experimental knowledge in the field will no doubt grow even more rapidly as new acceleraters siwng into action and as cosmic ray workers take increasing advantage of the latest experimental techniques. In such circumstance it is natural that considerable theoretical attention should be given to the problem of trying to understand the validity of the model from a fundamental point view.

In addition, the authors attempt to have the following suggestions about the neutrino research :

(I) Cartan spinors (59) with other transformation laws on reflection may be used for the neutrino and some conclusions would be analogeous to those drawn from the two component theory.

(2) Nuclear resonance fluorescence may be used to select these γ-rays which are emitted opposite to the neutrino, and an analysis of the circular polarization of the photons would directly helicity of the neutrino under the assumption which the spins of three nuclear states are known.

(3) The spectrum of the photon emitted in the decay of muons

$$(\mu \longrightarrow e + \nu + \bar{\nu} + \gamma)$$

maybe derived in the framework of the the component theory and this effect may be observed with present techniques.

Appendix : Recent static physical properties assumed for the neutrinos and its close relatives

Particle	Symbol	Charge	Rest Mass / electron mass	Spin	Statistics	Intrinsic parity	Lifetime (second)	Strangeness quantum number	Magnetic dipole moment nuclear magnetons	Decay products
Photon	γ	0	$=1.092\times10^{-38}$(60)	1	Bose	even	…………	…………	?	stable
neutrino	ν	0	0.05%	1/2	Fermi	even	…………	…………	$=1.836\times10^{-6}$	stable
antineutino	$\bar{\nu}$	0	0.05%	1/2	Fermi	even	…………	…………	$=1.836\times10^{-6}$	stable
electron	e^-	−1	1	1/2	Fermi	even	…………	…………	−1.836	stable
Positron	e^+	+1	1	1/2	Fermi	even	…………	…………	+1.836	stable
$\mu^{\pm}$-meson	$\mu^{\pm}$	±1	206	1/2	Fermi	?	2.2×10^{-6}	…………	?	$e^{\pm}+2\nu$
Proton	p^+	+1	1836.6	1/2	Fermi	even	…………	0	+2.793	stable
antiproton	p^-	−1	1836.6	1/2	Fermi	even	…………	0	−2.793	stable
neutron	n	0	1839.6	1/2	Fermi	even	770	0	−1.913	$P^+ + e^- + \nu$
antineutron	$\bar{n}$	0	1839.9	1/2	Fermi	even	?	0	?	$P^- + e^+ + \nu$
$\pi^{\pm}$-meson	$\pi^{\pm}$	±1	273	0	Bose	odd	2.5×10^{-8}	0	0	$\mu^{\pm} + \nu$
π^0-meson	π^0	0	265	0	Bose	odd	5×10^{-15}	0	0	2ν or $2e^+ + 2e^-$

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