Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 2, No. 1, February : 2023

NEUTRINOS; DETECTION, SOURCES AND THEIR FLUXES.

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Abstract— This paper is presenting a brief, about the hypothetical assumptions and the prediction of neutrino generation in various nuclear level phenomena. The investigational picture of various neutrino flavours, during different nuclear-reactions and decays, is also depicted. Detailed information about the multiple sources of neutrino's creation; such as astrophysical neutrinos, geo-neutrinos, cosmological source and man-made sources is also provided. The paper is a trial, to confer a brief theoretical description of the naturally generated neutrinos and the processes involved. Further the necessary information, about the practical investigations, for the man-made facilities operated at elevated energy magnitudes for neutrino's generation; such as accelerators at Brookhaven National Laboratory or CERN and reactors are presented.

Keywords— *Neutrino generation; CERN; astrophysical neutrinos; cosmological source.*

I. INTRODUCTION

The neutrino particle's inceptive proposal was delineated by Pauli in 1930 and it was introduced as an uncharged, feeble in interactivity, spin half particle [1]. The neutrino was hypothetically imagined, as to untangle the indelible issues in regards with the continual energy-spectrum of electrons, during the degradation process of β particles (disobey of energy-momentum conservation) in nuclear physics. Later to the speculations, made about the neutrinos, the nuclear process of Beta degradation was investigated on the basis of theory by Fermi [2, 3, and 4] and Perrin [5]. Fermi suggested the "four fermion current-current type point interaction" having the interactivity magnitude i.e. the coupling constant GF for illustrating the pace & complete profile of beta-degradation process. He contemplated the interactivity-currents being vector and analogically ensuing the quantum electrodynamics (QED).

Investigational outcomes for the shaping of beta-spectrum, via miscellaneous beta degradation nuclear processes revealed about neutrino-mass, that it should be too low comparative to the electronic mass. Bethe and Peierls [6] made the first theoretical investigations, for total scattering-cross-section on ($\underline{\upsilon} + p \rightarrow n + e^{+}$) reaction and interactivity magnitude used as GF governed from nuclear beta-degradations. They established that, the studied cross-section value was excessively small-scale being investigated, except if the neutrino-flux magnitude or the detector's material's mass are raised to high values.

Therefore, the later advancements regarding the investigations of neutrinos were delayed. But Reines & Cowan in 1956 [7, 8] eventually established this hypothesis along with investigational outcomes. From there till now, there is a successful progression in developmental aspects of physics of neutrino-particles.

Further progressive theories and experimentations on neutrinos suggested that

- Neutrinos are supposed to have triple flavours i.e. $\underline{\upsilon_e}(\upsilon_e)$, $\underline{\upsilon_\mu}(\upsilon_\mu)$, $\underline{\upsilon_\tau}(\upsilon_\tau)$ and are too minuscule. There categorization is made as per respective lepton flavor like i.e. Lj (for j = electron, Muon, taon) also consigned lepton number Lj = +1 for neutrino's & (−1) for antineutrino's flavors.
- Every flavor's neutrino and its anti-particle are charge-less, fermion-particles also having ½ and antineutrinos of each flavor are neutral, spin half fermions and accompanied helicity-term whether −1 (+1).
- This neutrino-particle's interactivity with charged leptons & quarks, occurs via the interchange of bulky charged vector-fields Wμ ± with correlative magnitude, between the

neutrino-charged lepton and quark-quark currents for any of the flavor. The above mentioned currents transmute, like V μ − Aμ, also established like the charge-fetching bi-linear covariant which transport linear-momentum & energy (Popularly and phenomenologically recognized as the V − A theory [9, 10, 11].

Phenomenologically the V − A hypothesis, about the feeble-interactivity, is rightly describing these neutrino's interactivity with matter, typically for low- energy magnitudes. But the scattering cross-section, from charged leptonic & and nucleonic particles, for the elevated energies of neutrinos, undergoes divergences (estimated by high-order perturbation theory). Later a consolidated conjecture, for weak as well as e-m leptonic interactivities was contrived by Weinberg [12] and Salam [13]. The integrated theoretical explanation, of electro-weak intractability is perceived by the standard model (SM).

A. Study of investigational outcomes and properties of neutrinos:

Detection of neutrinos:

Exploratory trials for the findings of neutrino & its anti-particle were explicitly commenced later to the theoretical beta-degradation explanation by scientists like Nahimas [14] in 1935, Rodeback and Allen [15], Leipunski [16], Snell and Pleasonton [17], and others. But the experimental conclusion about the reporting of antineutrinos, was conferred by Reines and Cowan [7, 8] as

$$\underline{\upsilon_e} + p \rightarrow n + e^+ \quad (1)$$

Davis [18, 19] obtained for the reaction ($\underline{\upsilon}$ + 37 Cl → e^- + 37 Ar), the restriction on Cross-section σ^- as to be less than $9.0 \times 10^{-45}\ cm^2$ whereas it was theoretically guessed to be roughly of the order of $\approx 2.6 \times 10^{-45}\ cm^2$. The outcome was greatly significant, to predict the non-production of electrons and referred to υ_e & $\underline{\upsilon_e}$ as to be distinct particles. Thus to handle this phenomenology, a novel quantum number designated as the electron lepton-number: Le and its +1 value is allocated to υ_e & electron also −1 value to $\underline{\upsilon_e}$ & e^+. Scientists Markov [20], Pontecorvo [21], & Schwartz [22] recommended for utilizing the facility like proton-accelerators for generating the neutrino-shaft of elevated energy magnitudes through pion-particle's degradation process:

$$\upsilon + n = \mu^- + p \qquad \upsilon+n=e-+p \quad (2)$$

$$\underline{\upsilon} + n \rightarrow p + \mu^+ \qquad \underline{\upsilon} + n \rightarrow p + e^+ \quad (3)$$

Investigations attempted at the Brookhaven Laboratory & at CERN, suggested the existence of neutrinos via pion degradations occurred with muons, but never with an electron or positron (As mentioned in the equations 2 &3).

Moreover, this established the presence of a distinct neutrino flavour, than that which occurred through beta decaying. Hence a novel lepton-number L_μ is granted to the muon-family and the conservation law was also equally applicable, for the new lepton-numbers respectively. The revelation of τ-lepton was made in 1975 [23] and its feebly-decaying process noticed, the existence of a new flavor of neutrinos υ_τ. Later experimentally manifested during 2000 at the Fermilab & then through the atmospheric neutrino investigations [24, 25].

B. Various neutrino generation sources and their fluxes:

The Standard Model depictures triply-flavoured neutrinos as υ_e, υ_μ & υ_τ along with their anti-partcles. In the early stages, the investigations were executed utilizing the reactor anti-neutrinos, also with the solar neutrinos. Moreover with the developed accelerating equipment, scientists were able to utilize (υ_μ) and $\underline{\upsilon_\mu}$ shafts. The categorization of sources of neutrinos, as well as its anti-particle, is done into dual classes, as the naturally found sources & the man-made one Fig.(1). The naturally generated neutrinos materialize from the sun's interior, the earth's interior & mantle etc. It is invariably whether the origination, collision or the ending of a star outturn into neutrino-production. Explicitly a massive neutrino-flux is discharged, in the time of supernovae eruption. The neutrinos in

Industrial Engineering Journal
ISSN: 0970-2555
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our surroundings exist as an artifact of Big-bang event. Apart from this, multiple sources of astro-physical neutrinos, exist for example the cosmogenic neutrinos, or caused via the viciously colliding energetic protons with bulky nuclei etc. Furthermore several man-made sources are there, such as generation at particle-accelerators, nuclear-reactors, spallation neutron source (SNS) facilities, etc. The entire energy-stretch for the creation of neutrinos & their antiparticles through miscellaneous sources spreads from μeV (10^{-6} eV) to EeV (10^{18} eV) as pictured in Fig. 2 [26].

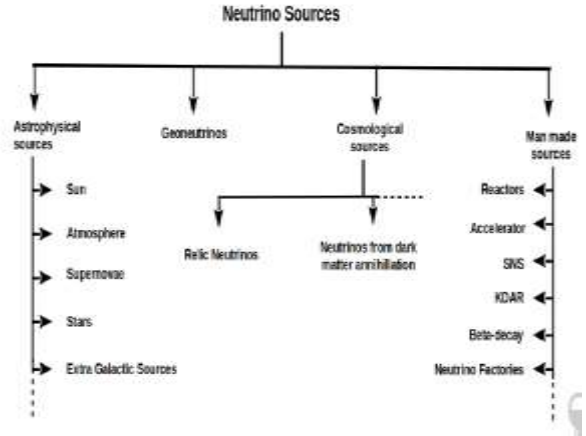

Fig. 1: Multiple sources of creation of neutrinos [26].

Sun's core is responsible for creating the neutrinos, whereas the nuclear reactors as well as earth are interior is accountable for antineutrinos production. Moreover, the all remaining sources involve both, the particle, neutrinos & its anti-particles as outcome. The neutrinos, as the artefact of the Big Bang event, the neutrinos through disseminated supernovae & the elevated energized cosmogenic neutrinos are yet to be encountered experimentally (courtesy C. Spiering) [26].

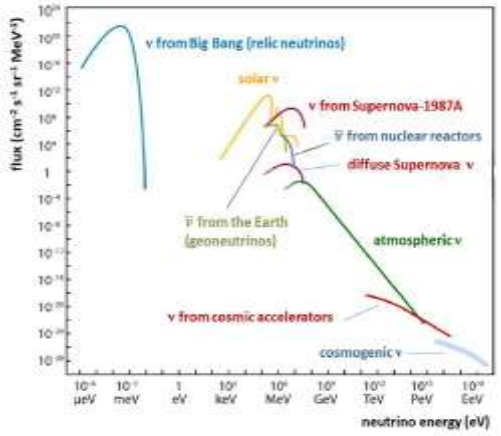

Fig. 2: Neutrinos fluxes on earth via various originations (measured as particles per square cm, sec.,steradian and MeV).[26]

C. Naturally Generated neutrinos

It is well known, that in the entire star's ancestry, even in the sun the energy generation, occurs due to the proceedings of nuclear fusion, which materialize in the star's midst. Mostly the reaction that prevails in sun or smaller stars is the p-p series reaction, whereas in more gigantic ones than sun, the sequence of Carbon-Nitrogen-Oxygen (CNO) reaction is notable. Basically the fusion of hydrogen to helium, eventuates as the progression of chain reactions, which is undertaken to create deuterium-nucleus in addition to release of positron & υ_e. The mentioned activity can be elaborated in terms of an equation as

$4p+2e- \rightarrow 4He+2\upsilon_e+26.7MeV.$ (4)

Out of this nearly 7×10^{10} υ_e/cm^2/sec neutrinos land up to the earth. The degradation of non-primary cosmological particles, such as pion, kaon etc. outturn into atmospheric-neutrino count. They usually generate through the interactivity of preliminary cosmic rays, (chiefly containing protons) with earth's atmosphere. The process can be depicted as:

proton + Aair → neutron + π^+ + X ;

neutron+ Aair →proton + π^-+ X. (5)

Eventually these pions or kaons are accountable, to the upturn of anti-neutrino particles.

$\pi^\pm \rightarrow \mu^\pm \quad \underline{\upsilon_\mu}(\upsilon_\mu)$, (100%)

$\mu^\pm \rightarrow e^\pm \quad \underline{\upsilon_\mu}(\upsilon_\mu)\ \underline{\upsilon_e}(\upsilon_e)$, (100%)

$K^\pm \rightarrow \mu^\pm \quad \underline{\upsilon_\mu}(\upsilon_\mu)$ (63.5%); $\pi^\pm\ \pi^0$ (20.7%); $\pi^\pm\ \pi^+\ \pi^-$ (5.6%)...

These no-primary crests are of the order of giga eV scale and broadened to elevated energy-values. Thus the neutrino-flux declines swiftly, with a surge in energy. Till the magnitude of energy roughly ranges up to one hundred Tera eV, this particle-flux is prevailed by the degradation of pions & kaons.

When a bulky star is in the ending episode, the supernova neutrinos are generated and consequently entirely every flavor's neutrinos & anti-neutrinos fetch an enormous proportion of energy, while blowing up the core collapse-supernovae. Active Galactic Nuclei are supposed to be the originators of highly energized neutrinos and they are able to speed up the proton particles to maximal of $\sim 10^{20}$ eV energy. The AGN's have highly-intensified fields in its vicinity, that are accountable for the interactivity between photo-hadron, that eventually up-thrust neutrino count.

On the other hand the cosmogenic neutrinos are generated through interactivity of cosmic rays, to the cosmic-microwave surrounding radiation, such as the nucleons. Moreover these neutrinos whether are unconfined or in confined state, within having the Lorentz boost factor $\Gamma \geq 10^{10}$. Therefore, they boost up the built of photo-pion, and further these pions degrade to raise to neutrino count:

$N + \gamma \rightarrow N' + \pi^\pm$; N,N′ = proton or neutron. (6)

There is a fact about earth's inner part that it gives-off the heat at a pace of roughly 47 TW and a proportion of this is availed by the process of degradation of radioactive-isotopes in the midst of the earth. This decay is further resulted into the generation of antineutrinos and approximately 10^6 $\underline{\upsilon_e}/cm^2$ antineutrino-counts, thrust-out to the earth's surface. In natural sources of neutrinos and its anti-particle, the earth's inner part as well as the mantle are accountable, due to the presence of few elements such as 40K, 232Th, 238U, etc. These elements undergo a sequential degradation, in addition to occurrence of beta-decay. These decays consequently conclude to the outcomes like

$238\ U \rightarrow 206\ Pb + 8\alpha + 6e- + 6\bar{}ve + 51.7\ MeV.$ (7)

$40\ K \rightarrow 40\ Ca + e- + \underline{\upsilon_e} + 1.311\ MeV$, etc. (8)

These Processes are liable to geo-neutrinos emission. The novel studies now suggest, that the details related to the spatial distribution of such radio-nuclides, are able to provide an estimated dimension of the earth's middle part & mantle as well. The emergence of cosmic microwave background radiation, noticed by Penzias and Wilson [1965], closely resembles the cosmic-neutrino background (CVB) which is famously perceived as the artifact of the Big-Bang event. These CVB neutrinos are those that disengage to matter while the created universe roughly was one sec. Older and theoretical investigations, propound the thermal condition of artifact neutrino as near to 1.95 Kelvin, also the average density roughly to the order of $330/cm^3$.

D. Man-made sources: Accelerator and Reactor (anti) neutrinos

It is critical to interpret the nature & properties of neutrinos, which are generated through the accelerators & reactors. Scientists Markov [20], Pontecorvo [21], and Schwartz [22], brought the proposal to execute the investigations on neutrinos, by the use of accelerators and later they

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 2, No. 1, February : 2023

initiated a probability of experimentations to generate neutrino beam, through pion's degradation at the proton-accelerators. More experimentation with highly energized neutrinos also came in picture when improved synchrotron accelerators became available [in 1960]. Also the AGS at Brookhaven & the PS at CERN are set-off to elevated energy magnitudes of the order of Giga eV and higher, which has allowed us to examine neutrino interactivity. During 1962 the neutrinos were generated with the run of accelerators at Brookhaven and CERN, exhibiting the distinctness of νe & νμ. In the experimentations the accelerators were used to provide highly energized protons and later they encountered a target (some material which can tolerate excessive thermal conditions).

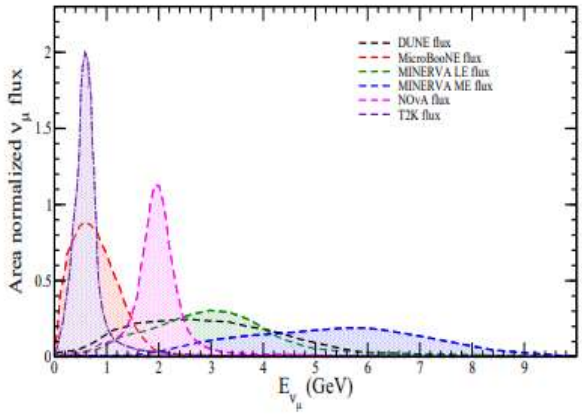

Fig.3: Various neutrino-spectra with dependability on neutrino energy for the accelerator neutrons.[29]

Under such an environment, a proton accelerates to comparative velocity of light, smashes the target and proton's energy leads to generate the hadronic jets. In the jet, various particle-creation takes place, though majorly are the pions & kaons. Such charge-carrying pions-particles do not show stability and thus degrade further to generate muons as well as neutrinos. The charged meson may easily be collimated & directed with the electro-magnets. With the use of these magnetic-horns, pions as well as kaons, are positioned towards the detector, for acquiring the neutrino-jet into a defined direction. Therefore, an appropriately devised electro-magnetic horn set-up, is helpful for intensifying the neutrino flux. In order to gauge the flux of neutrino-particles with precision, meson's momentum as well as the angular-spectra should be quantified closely. During 1965, one technique for deducing the neutrino's flux (in terms of function of proton count encountering the target) had been imposed at Brookhaven lab and further this was employed for experiments at CERN (in 1967). Therefore during seventies, various accelerators started performing at different energies for the neutrino-experiments, such as proton accelerator at Fermilab (three hundred to four hundred giga eV) the proton accelerator (seventy giga eV) at Serpukhov also the SPS (three hundred giga eV) at CERN [27, 28].

CONCLUSION

The neutrinos are fermion particles incorporated in the Standard Model of Particle physics and have interactivity through weak interaction & gravitation. They are under-sized, carry zero charge and too diminutive. Hence one cannot estimate it's mass. As the scale of weak-force is too minuscule, the interactivity in gravity is immensely feeble. Thus neutrinos don't get involved in the strongly interacting fields and therefore the neutrinos usually traverse through matter unhindered and may not be detected.

These neutrinos can be generated via multiple radioactive-degradation processes, such as nuclei or hadronic beta-decay, the naturally occurring reactions happen at the star's inner part. The other ways to create such neutrinos is via unnatural-man made sources like the reactions at nuclear reactors, particle accelerators. They also come into the picture during an event of supernovae and in the

collision process between highly energized particle shafts with bulky atoms. In the field of particle physics, functional testing and explorations are going on neutrinos and few are to investigate and anticipate behavioral aspects of neutrino behavior. Some other work is related to unrevealed properties which are not yet known.

As because of too diminutive weight and neutral charge mean they interact exceedingly weakly with other particles and fields. As a result of that, this peculiarity of neutrinos may be utilized for probing the environs for exploration as different radiations (electro-magnetic or radio) could not. These neutrino-particles have been much advantageous to examine the astro-physical origins, outside the range of our Solar System, since neutrinos do not get diminished considerably, while traversing via the interstellar medium.

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