Modification of the Reactor Neutrino Model

Sylwester Kornowski

Abstract: The measured prompt spectra in the RENO experiment show an excess of reactor electron-antineutrinos around 5 MeV relative to the prediction from a most commonly used model. This observation suggests that we should modify the current reactor neutrino model. Here, applying the atom-like structure of baryons described within the Scale-Symmetric Theory (SST), we show the origin of the excess of reactor electron-antineutrinos around 5 MeV. We also explain why in the average nuclear fission there is released about 4.5% of energy as the radiation of neutrinos. The calculated within SST excess of the ~ 5 MeV events should constitute about 2.6% of the total observed reactor neutrinos. This result is close to the RENO result ~ 3%.

1. Introduction

The measured prompt spectra in the RENO experiment show an excess of reactor electron-antineutrinos around 5 MeV relative to the prediction from a most commonly used model [1]. This observation suggests that we should modify the current reactor neutrino model.

Here, applying the atom-like structure of baryons described within the Scale-Symmetric Theory (SST) [2], we show the origin of the excess of reactor electron-antineutrinos around 5 MeV. We also explain why in the average nuclear fission there is released about 4.5% of energy as the radiation of neutrinos.

The General Relativity leads to the non-gravitating Higgs field composed of tachyons [2A]. On the other hand, SST shows that the succeeding phase transitions of expanding Higgs field (i.e. of the inflation field) lead to the different scales of sizes/energies [2A]. Due to a few new symmetries, there consequently appear the superluminal binary systems of closed strings (the entanglons) responsible for the quantum entanglement, stable neutrinos and luminal neutrino-antineutrino pairs which are the components of the gravitating luminal Einstein spacetime (it is the Planck scale), cores of baryons, and the cosmic structures that evolution leads to the dark matter, dark energy and expanding universes [2A], [2B]. The non-gravitating tachyons have infinitesimal spin so all listed structures have internal helicity (helicities) which distinguish particles from their antiparticles [2A].

Due to the symmetrical decays of bosons on the equator of the core of baryons, there appears the atom-like structure of baryons described by the Titius-Bode (TB) orbits/tunnels/loops for the nuclear strong-weak interactions [2A].

The SST leads to internal structure of nucleons [2A]. There is the core composed of torus/electric-charge with central condensate both composed of confined or/and entangled neutrino-antineutrino pairs. The core can be charged, H^+, or neutral H^o. In the $d = 1$ TB state there is relativistic charged or neutral pion. The calculated from initial conditions relativistic mass of the charged pion in the $d = 1$ state is $W_{(+,-),d=1} = 215.76$ MeV whereas of the neutral one is $W_{(o),d=1} = 208.65$ MeV. Such model leads to spin and masses of nucleons consistent with experimental data [2A].

According to SST, there are 4 stable neutrinos (the electron-neutrino, muon-neutrino, and their antiparticles) and 2 unstable neutrinos (tau-neutrino and its antineutrino) composed of three different stable neutrinos (there are 4 different states of the unstable tau-neutrinos) [2A]. In reality, the neutrino "oscillations" are the exchanges of the free neutrinos (free neutrinos interact gravitationally only) for neutrinos in the neutrino-antineutrino pairs the Einstein spacetime consists of, or they follow from decays of the unstable neutrinos [2A].

2. Calculations

According to the current reactor neutrino model, antineutrinos are produced in the beta-minus decays in the fission processes

$$^{A}X_{Z} \rightarrow {}^{A}Y_{Z+1} + e^{-} + \nu_{e,anti}\,, \qquad (1)$$

where A denotes the number of nucleons whereas Z and $Z+1$ denote the numbers of protons. In general, the four main isotopes contributing to the antineutrino flux are ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu.

In the nuclear strong interactions there can be produced the pion-antipion ($\pi^+\pi^-$) pairs – there can be created the neutral pions as well [2A].

We know that neutron can transform into proton due to the beta decay. But SST shows that the neutron to proton transition can follow from decay of the negative pion in the $\pi^+\pi^-$ pairs. Inside neutron, in the $d = 1$ state, there can be negative or neutral pion whereas in proton there can be neutral or positive pion [2A]. Consider the $\pi^+\pi^-$ pair creation in the $d = 1$ state in the $H^+W_{(-),d=1}$ mass state of neutron. According to SST, the pion-pion pairs in the strong interactions behave as the electron-electron pairs in the ground state of atoms i.e. the pions cannot be in the same quantum mass state (notice that for the nuclear strong interactions the electric charges are invisible). It means that strong interaction forces decay of one pion in the $\pi^+\pi^-$ pair. Contrary to the Standard Model, SST shows that size of torus/electric-charge of charged particles depends on their mass – for example, size of electric charge of pion or muon is smaller than of electron. It means that due to the repulsive electromagnetic interaction between the relativistic pion $W_{(-),d=1}$ and the π^- in the $\pi^+\pi^-$ pair, the relativistic pion $W_{(-),d=1}$ forces decay of the π^-, not of π^+ (then the binding energy is higher so the system is more stable)

$$\pi^{-} \rightarrow \pi^{o} + e^{-}\nu_{e,anti}\,. \qquad (2)$$

The constituents of the $e^-\nu_{e,anti}$ pair are entangled and the resultant spin of the pair is equal to zero.

The mass distance between the zero-momentum charged pion and neutral pion, $\Delta\pi$, is $\Delta\pi = 4.5936 \pm 0.0.0005$ MeV [3]. Such distance calculated within SST is $(\Delta\pi)_{SST} = 4.59367$ MeV [2A]. It is as well the energy of the $e^-\nu_{e,anti}$ pair.

The $e^{-}\nu_{e,anti}$ pair can interact with a real positron from the created electron-positron ($e^{+}e^{-}$) pairs and, next, the real $e^{+}e^{-}$ pair in the $e^{+}e^{-}\nu_{e,anti}$ object can transform into virtual one

$$(e^{+}e^{-})_{real}\,\nu_{e,anti} \rightarrow$$

$$\rightarrow (e^{+}e^{-})_{virtual} + \nu_{e,anti}\ \textit{(energy centered at } 5.10\ \text{MeV}\textit{: see formula (4))}. \qquad (3)$$

Then the centered energy of the emitted electron-antineutrino, $E_{e\text{-}antineutrino}$, in the transformation defined by formula (3) is

$$E_{e\text{-}antineutrino} = \Delta\pi + m_{positron} = 5.10\ \text{MeV}. \qquad (4)$$

But the $e^{+}e^{-}$ pairs are created due to the electromagnetic interactions (according to SST, the fine-structure constant is $\alpha_{em} = 1 / 137.036$) or due to the nuclear weak interactions (according to SST, the coupling constant for such interactions is $\alpha_{W(proton)} = 0.0187229$) whereas the $\pi^{+}\pi^{-}$ pairs are created due to the nuclear strong interactions (according to SST, the coupling constant for strong interactions of mesons is $\alpha^{\pi\pi}_{S} = 1$) [2A]. It suggests that the excess of the ~ 5 MeV events should constitute about

$$Excess = 100\% \cdot (\alpha_{em} + \alpha_{W(proton)}) / \alpha^{\pi\pi}_{S} \approx 2.6\% \qquad (5)$$

of the total observed reactor neutrinos. This result is close to the RENO result ~ 3% [1].

According to SST, the $e^{-}\nu_{e,anti}$ pair can interact with the core of baryons – then the mass distance between the charged core and neutral core is 2.663 MeV, or the $e^{-}\nu_{e,anti}$ pair can interact with the relativistic neutral pion in the $d = 1$ state – then the relativistic mass distance between the charged pion and neutral one is 7.117 MeV [2A]. There are the two mass states of neutron ($H^{+}W_{(-)}$ and $H^{o}W_{(o)}$) and two mass states of proton ($H^{+}W_{(o)}$ and $H^{o}W_{(+)}$) [2A]. We can see that the mass distance between the heavier mass state of neutron and the lighter mass state of proton is $E = 2.663 + 7.117 = 9.780$ MeV – this energy represents the upper limit for energy of the emitted electron-antineutrinos. On the other hand, the total emitted energy (thermal plus neutrino energy; energy is emitted from the $d = 1$ state [2B]: see Chapter *Black body spectrum*) is represented by the mass of the charged relativistic pion in the $d = 1$ state i.e. by $W_{(+,-),d=1} = 215.760$ MeV. It leads to conclusion that the upper limit for abundance of energy carried by electron-antineutrinos is

$$A_{upper\text{-}limit} = 100\%\ E / W_{(+,-),d=1} = 100\% \cdot 9.780\ \text{MeV} / 215.760\ \text{MeV} \approx 4.533\%. \qquad (6)$$

This result is consistent with experimental data [4].

3. Summary

An excess of reactor electron-antineutrinos around 5 MeV relative to the prediction from a most commonly used model suggests that we should modify the current reactor neutrino model – here we showed that without the atom-like structure of baryons described within the Scale-Symmetric Theory, we cannot explain the deviations discovered by RENO team.

SST leads to the excess of reactor electron-antineutrinos around 5.10 MeV and shows that the upper limit for abundance of energy carried by electron-antineutrinos emitted in the average nuclear fission should be 4.533% – this result is consistent with experimental data.

The calculated within SST excess of the ~ 5 MeV events should constitute about 2.6% of the total observed reactor neutrinos. This result is close to the RENO result ~ 3%.

References

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