Neutron Beta Decay and Proton Spin Crisis

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Abstract: Here, using the atom-like structure of baryons described in the Scale-Symmetric Theory (SST), we showed the origin of the A and V variant of the neutron beta decay and the origin of the strong correlation between the spin of proton and the momentum of the electron-antineutrino. The neutron beta decay described within SST solves also the proton spin crisis and leads to the decay of muon consistent with experimental data.

I. Introduction

The successive phase transitions of the inflation field, described within the Scale-Symmetric Theory (SST), lead to the atom-like structure of nucleons [1]. Here, the symbols of particles denote their masses also. There is the spin-1/2 core of nucleons with a mass of H^+ = 727.4401 MeV. It consists of the spin-1/2 electric-charge/torus X^+ = 318.2955 MeV and the spin-0 central condensate Y = 424.1245 MeV both composed of the Einstein-spacetime (Es) components – the Es components are the spin-1 neutrino-antineutrino pairs. The spin-1 large loops m_{LL} = 67.54441 MeV with a radius of $2A/3$ (where A = 0.6974425 fm is the equatorial radius of the electric-charge/torus) are produced inside the electric-charge/torus – the neutral pions are built of two such loops with antiparallel spins. In the $d = 1$ state (it is the S state i.e. the azimuthal quantum number is $l = 0$) there is a relativistic pion – radius of the orbit is $(A + B)$ = 1.199282 fm. Within SST, we calculated mass of proton p = 938.2725 MeV and mass of neutron n = 939.5648 MeV [1].

The large loops are responsible for the internal strong interactions. They cause that nucleons are the modified black holes in respect of the strong interactions with the Schwarzschild radius equal to $2A$ which is bigger than $A + B$. It leads to conclusion that the core-pion system cannot decay due to the strong interactions. But it can decay due to the electromagnetic or weak interactions. So why neutron decays due to the weak interactions, not due to the electromagnetic interactions? Within SST, the answer is very simple – just neutron decays due to the stronger interactions. In SST, value of the coupling constant for the nuclear weak interactions ($\alpha_{w(proton)}$ = 0.01872286) is higher than the fine structure constant (α_{em} = 1 / 137.036 = 0.007297353) [1].

According to SST, in neutron, between the positively charged core and the relativistic neutral pion in the $(A + B)$ state is exchanged the lepton pair composed of electron and electron-antineutrino ($e^- \nu_{e,anti}$) [1].

The phase transitions described within SST lead to internal structure of bare particles such as, for example, neutrinos, electron, muon, tau lepton or nucleons [1]. SST shows that electron-antineutrino has left-handed internal helicity which lead to the right longitudinal polarization (Fig.1 [2] and Table 1 [1]). Neutrinos produce jets in the Higgs field so they move in direction opposite to the half-jet. Jets are produced by all fermions but behaviour of the electron-antineutrino and electron-neutrino dominate because density of neutrino jets is highest. SST shows that directions of motion of the muon neutrinos are forced by the dynamics of decays. Here we will show the origin of such dynamics.

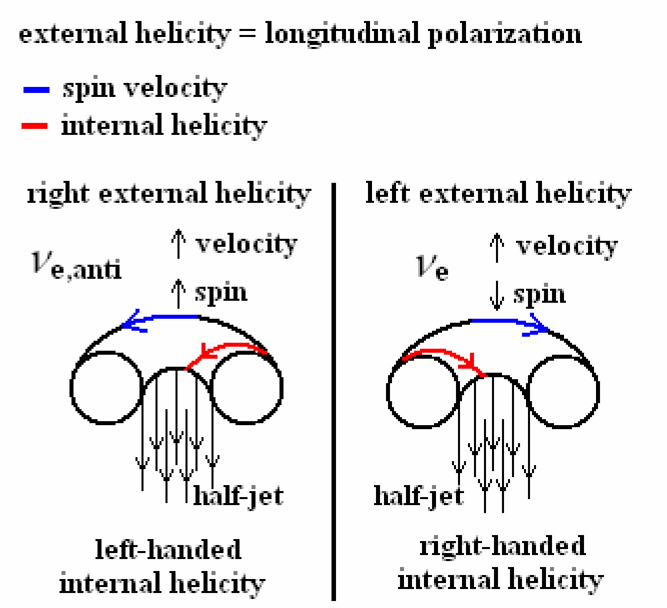

Fig.1
Longitudinal polarization versus internal helicity from SST.

Table 1 *Helicities and charges* [1]

Particle	Internal helicity	Electric charge	Weak charge	Longitudinal polarization
$\nu_{e(anti)}$	L (left)		+	R
ν_μ	L		–	Forced
e^-	R	–		L
p^+	L	+		R
n	L1)		+	R

1) The resultant internal helicity is the same as the internal helicity of the torus having greatest mass.

II. The beta decays of neutron

There are two scenarios for possible beta decays of neutron. They follow from the two possible meta-stable states of the $e^-\nu_{e,anti}$ lepton pair in its bound state i.e. inside nucleons. In a Fermi transition, spins of the emitted leptons couple to total spin $s = 0$ while in a Gamow-Teller transition they couple to total spin $s = 1$. But what phenomena are responsible for the two different transitions? The answer is very simple within SST. Generally, the pair couples to $s = 1$. It results from different internal helicities of the constituents of the pair. Such a pair is most stable when spins of both constituents are parallel and lie on the same straight line. Then the opposite internal helicities of the electron torus and antineutrino torus force their attraction. On the other hand, to conserve the spin-1/2 of the core of nucleons, there must be the Fermi transition inside the core.

The two scenarios for the beta decay of neutron are as follows.

1. By using a magnetic field we polarize neutron in such a way that its spin is “up”.
2. There are two possibilities for orientation of the spin of proton: “down” or “up”.
3. There dominate the jets of the proton and electron-antineutrino because densities of their tori are highest. It means that there should be for both scenarios strong correlation between the spin of proton and the momentum of the electron-antineutrino (the antiparallel orientation).

The first scenario is for the proton orientation “down”(the variant A: see Fig.2):

4. The lepton pair decays outside the core of neutron i.e. there is the Gamow-Teller transition.
5. From Table 1 follows that the internal helicities of proton and electron-antineutrino are the same so their spins must be antiparallel so the spin orientation of the electron-antineutrino is “up”. From Table 1 follows that the longitudinal polarization of the electron-antineutrino is right-handed so it is moving “up”.
6. Total spin of proton, electron and electron-antineutrino must be half-integral and “up” so the orientation of the electron spin is “up”. From Table 1 follows that the longitudinal polarization of the electron is left-handed so it is moving “down”.

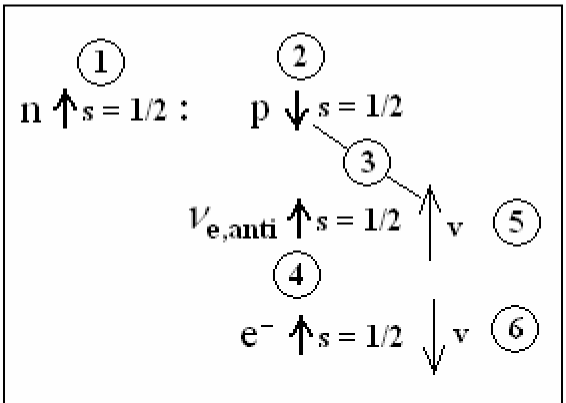

Fig.2
Variant A.

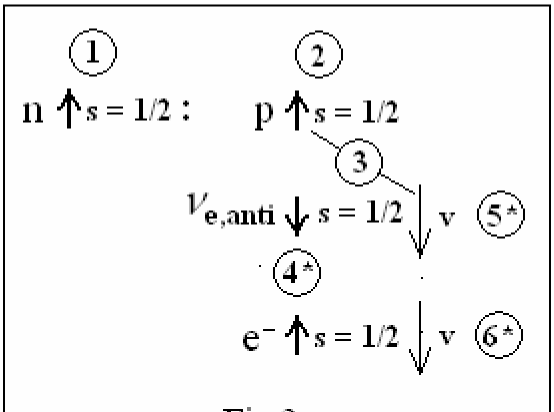

Fig.3
Variant V.

The second scenario is for the proton orientation “up” (the variant V: see Fig.3):

4*. The lepton pair decays inside the core of neutron i.e. there is the Fermi transition.

5*. From Table 1 follows that the internal helicities of proton and electron-antineutrino are the same so their spins must be antiparallel so the spin orientation of the electron-antineutrino is “down”. From Table 1 follows that the longitudinal polarization of the electron-antineutrino is right-handed so it is moving “down”.

6*. Total spin of proton, electron and electron-antineutrino must be half-integral and “up” so the orientation of the electron spin is “up”. From Table 1 follows that the longitudinal polarization of the electron is left-handed so it is moving “down”.

Experiments show that Nature realizes the V – A variant i.e. there is strong correlation between the spin of proton and the momentum of the electron-antineutrino i.e. they always should be antiparallel as it is in SST.

III. The proton spin crisis

In a polarized proton target, the spin of the third quark should be polarized in the direction of the spin of proton. But it was found in many experiments that the number of some objects (they can be quarks) with spin in the proton’s spin direction was almost the same as the number of objects whose spin was in the opposite direction. It is the proton spin crisis.

In proton, the $e^{-}\nu_{e,anti}$ lepton pair is exchanged between the spin-$1/2$ positively charged core and the positively charged pion in the $(A + B)$ state. Such a pion has the orbital moment equal to 1 – the direction of circulation is changing very fast so this is the $l = 0$ state. It is possible because in such a pion there is the spin-1 Gamow-Teller $e^{+}\nu_{e}$ lepton pair which flips spin as well in such a way that the total angular momentum is equal to zero. Such a state of charged pion can be only when it is bound because in reality the charged core and relativistic neutral pion create the two spin-1 lepton pairs with opposite spins and charges.

When the spin-1 $e^{-}\nu_{e,anti}$ lepton pair (its spin is antiparallel to the spin-$1/2$ of the charged core) penetrates into the core, it must transform into the Fermi pair ($s = 0$). The total spin of the core and pair ($s_{total} = 1/2$ (core) + (-1) (pair) = $-1/2$), say “down”, must be conserved so we obtain: $s_{total} = -1/2$ (core) + (0) (pair) = $-1/2$. We can see that there is the spin flip of the core. According to SST, the change in the spin direction of the core in proton lasts $0.492 \approx 0.5$ [1] – it solves the proton spin crisis.

IV. The decay of muon (Fig.4)

In muon, the momentum and spin of the electron-antineutrino dominates so in both they are parallel. The weak charges of the neutrinos are opposite so they attract each other. It means that the directions of motion of the neutrinos are the same. The Gamow-Teller transition forces the spin orientation of the electron the same as of the electron-antineutrino. Momentum of electron must be antiparallel to its spin (Table 1). Since total spin must be half-integral and its orientation must be the same as muon so it forces that spin of the muon-neutrino is antiparallel to the spin of muon. We can see that such dynamics forces the left longitudinal polarization of the muon-neutrino. This scenario is consistent with experimental facts.

$$\mu^{-} \uparrow s = 1/2 \; \Big\uparrow v : \quad \nu_{\mathbf{e,anti}} \uparrow s = 1/2 \; \Big\uparrow v \; + \; \nu_{\mu} \downarrow s = 1/2 \; \Big\uparrow v \; + \; e^{-} \uparrow s = 1/2 \; \Big\downarrow v$$

Fig.4 Decay of muon.

References

[1] Sylwester Kornowski (23 February 2018). “Foundations of the Scale-Symmetric Physics (Main Article No 1: Particle Physics)”
http://vixra.org/abs/1511.0188
[2] Sylwester Kornowski (28 December February 2015). “CPT Symmetry and Symmetry-Breaking in the Scale-Symmetric Theory”
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