# Lifetime of the Neutron

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**Abstract:** The Scale-Symmetric Theory (SST) shows that in the bottle experiments, measured mean lifetime of the neutron should be 879.9 s whereas the beam experiments should lead to 888.4 s. The difference is due to the fact that in a bottle, neutrons move in a disorderly way, while in a beam they move in an orderly manner. The ordered motions in the beam force creation of two virtual quadrupoles per decaying neutron (the total spin and charge of quadrupole is equal to zero) instead one quadrupole per neutron in the bottle. Obtained here results are consistent with experimental data.

## 1. Introduction

We can replace the 2005 neutron lifetime result [1] with the improved result [2]. Then the beam and bottle lifetime results included in the 2013 PDG world average [3] lead to [2]

$$\Delta\tau_n = \Delta\tau_n^{beam} - \Delta\tau_n^{bottle} = (888.0 \pm 2.1)\ \mathrm{s} - (879.6 \pm 0.8)\ \mathrm{s} = (8.4 \pm 2.2)\ \mathrm{s} \quad (1)$$

with a discrepancy $3.8\ \sigma$.

Here, applying the Scale-Symmetric Theory (SST) [4], [5], we calculated the two different lifetimes of the neutron and showed the origin of the discrepancy.

The successive phase transitions of the inflation field described within SST lead to the atom-like structure of baryons [5]. Here, the symbols of particles denote their masses also. There is the core with a mass of $H^{+,-} = 727.4401$ MeV. It consists of the electric-charge/torus $X^{+,-} = 318.2955$ MeV and the central condensate $Y = 424.1245$ MeV both composed of the Einstein-spacetime (Es) components – they are the spin-1 neutrino-antineutrino pairs. The 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. 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.

According to SST, outside the nuclear strong fields, the gluon loops (gluons are the rotational energies of the Es components) behave as photon loops [5]. In nucleons, there are three characteristic gluon/photon loops with radii $2A/3$, $A$, and $A + B$. The mean arithmetic radius of them is

$$R_{Mean} = [2A/3 + A + (A + B)] / 3 = 0.7872287 \text{ fm} . \quad (2)$$

Mean range, $L_{Mean}$ , of such loops is

$$L_{Mean} = 2 \pi R_{Mean} = 4.9463039 \text{ fm} . \quad (3)$$

The electron which appears in the beta decay of neutron is free when distance between proton and electron is bigger than $L_{Mean}$. When we neglect the internal interactions (which lead to the decay of neutron) then a relativistic electron becomes free after following mean time

$$T_{Mean} = L_{Mean} / c = 1.649910 \cdot 10^{-23} \text{ s} . \quad (4)$$

But emphasize that the internal interactions extend the lifetime of the neutron.

SST shows that the Es components inside a condensate behave similarly to ionized gas in the stars. The theory of such stars says that the radiation pressure $p$ is directly in proportion to the four powers of absolute temperature $T$

$$p \sim T^4. \quad (5)$$

The analogous relation ties the total energy emitted by a black body with its temperature. Such theory also suggests that the absolute temperature of a star is directly in proportion to its mass. From it follows that total energy emitted by a star is directly proportional to the four powers of its mass. However, because the Heisenberg uncertainty principle results that the lifetime of a particle is inversely proportional to its energy, we obtain that the lifetime of a condensate is inversely in proportion to the mass to the power of four

$$\tau_{Lifetime} \sim 1 / m^4. \quad (6)$$

The Es condensates are responsible for weak interactions so they are responsible also for lifetime of particles decaying due to such interactions [5]. Notice as well that weak mass, $M_w$, of a mass, $M$, is

$$M_w = \alpha_w M , \quad (7)$$

where $\alpha_w$ is the coupling constant for weak interaction.

Applying formulae (4), (6) and (7), we can write following formula for lifetime of a particle decaying because of the weak interactions

$$\tau_{Lifetime,weak} = T_{Mean} (\alpha_{w,1} M_1 / \alpha_{w,2} M_2)^4 . \quad (8)$$

The calculated within SST values of the coupling constants for the weak interactions are as follows [5]:

- for the nuclear weak interactions is $\alpha_{w(proton)} = 0.0187228615$,
- for the weak electron-muon interactions is $\alpha_{w(electron\text{-}muon)} = 0.9511082 \cdot 10^{-6}$.

There are two states of the core of neutrons: the charged state is $H^+$ whereas the neutral state is $H^o = H^+ e^- \nu_{e,anti}$, where $e^-$ denotes the electron and $\nu_{e,anti}$ denotes electron-antineutrino [5]. The electromagnetic binding energy of the electron is [5]

$$E_{em,electron} = e^2 / [(2A/3)\ 10^7]\ [\mathrm{kg}] = 3.096953\ \mathrm{MeV}\ , \quad (9)$$

where $e$ denotes the electric charge of electron. The $E_{em,electron}$ energy leads to the mass of the Higgs boson: 125.0 GeV [5].

There are two different phenomena responsible for decay of particles. The first type of decay is a result of emission of a radiation mass $M_{radiation,i} = \alpha_i M_i$, where $M_i$ is the mass of some Einstein-spacetime condensate which, sometime, can interact with the simplest spin-1 charged lepton pair composed of the electron and electron-antineutrino. Then lifetime is inversely proportional to the radiation mass: $\tau_i \sim 1 / (\alpha_i M_i)$. Such type of decay is characteristic for the Higgs boson, $W$ or $Z$ bosons – we can see that during such decay, there is not a change of the radiation mass [6]. The second type of decay is a result of a change (of a transition) from one mass, say $m_i$, to another one, say $m_j$, or from interaction defined by coupling constant $\alpha_i$ to interaction defined by $\alpha_j$ – then there are obligatory following relations $\tau_{i\rightarrow j} \sim (m_j / m_i)^4$ and $\tau_{i\rightarrow j} \sim \alpha_j / \alpha_i$ (i.e. $\tau \sim 1 / m^4$ (where $m$ can be $m = \alpha M$) or $\tau \sim 1 / \alpha$). Such type of decay is characteristic for particles which have a rich internal structure such as muon, pions, tau lepton [5] or neutron. The applied models within SST give results which are very close to experimental data – for example, calculated lifetime of muon is $2.1950 \cdot 10^{-6}$ s [5].

According to SST, in each nucleon there is exchanged the lepton pair composed of electron and electron-antineutrino between the circular orbit with a radius of $2A/3$ and the relativistic pion in the $d = 1$ state with a radius of $A + B = 1.199282$ fm [5]. It leads to conclusion that the electron appearing in the beta decay can interact with one of the three photon loops with radii equal to $2A/3$, $A$ and $A + B$. On the other hand, muons are produced in centre of the core of baryons [5] and next they transit in a quantum way to the equator of the core of baryons so they interact only with the photon loop with a radius of $A$. Notice that the exchanges of the lepton pair, which is charged, cause that the mean electric charges of the core and the relativistic pion in the $d = 1$ state are fractional – this phenomenon leads to the incorrect assumption that nucleons are built of three valence quarks carrying the fractional charges equal to $\pm 2/3$ or $\pm 1/3$ of the electron charge [5], [7].

## 2. Calculations

Assume that the scenario of the weak decay of neutron (beta decay) is as follows. There is the transition from the weak mass of the electromagnetic binding energy defined by (9), i.e.

$$\alpha_{w,2} M_2 = \alpha_{w(electron\text{-}muon)} E_{em,electron}\ , \quad (10a)$$

to the weak mass of the $Y$ condensate. The electron inside the core of neutron should produce one virtual electron-positron pair [5]. Such a pair should be created near the condensate $Y$ because there the Einstein spacetime is disturbed. Such a pair has the spin equal to 1. On the other hand, during the weak interaction, the half-integral spin of the core of neutron must be conserved [5]. It leads to conclusion that there instead one electron-positron pair are created two pairs with antiparallel spins (quadrupole). Mass of the Es condensate in centre of electron is $m_{electron,bare}/2$ [5] so

$$\alpha_{w,1} M_1 = \alpha_{w(proton)} (Y + 4\, m_{electron,bare} / 2) , \qquad (10b)$$

where $m_{electron,bare} = 0.5104070$ MeV [5].
Taking into account the above remarks, applying formula (8), we can calculate lifetime of the neutron

$$\tau_{neutron}^{bottle} = T_{Mean} [\alpha_{w(proton)} (Y + 4\, m_{electron,bare} / 2) / (\alpha_{w(electron-muon)} E_{em,electron})]^4 =$$

$$= 879.9 \text{ s} . \qquad (11a)$$

Such results we should obtain in the bottle experiments.

The scenario in a neutron beam is different. In a bottle, neutrons move in a disorderly way, while in a beam they move in an orderly manner. The ordered motions in the beam force creation of two quadrupoles per decaying neutron. It follows from the fact that stability of the neutron beam requires simultaneous creation of two quadrupoles in a plane perpendicular to the beam velocity which should be located symmetrically with respect to each neutron. For neutron beam is

$$\tau_{neutron}^{beam} = T_{Mean} [\alpha_{w(proton)} (Y + 8\, m_{electron,bare} / 2) / (\alpha_{w(electron-muon)} E_{em,electron})]^4 =$$

$$= 888.4 \text{ s} . \qquad (11b)$$

$$\Delta\tau_{neutron,SST} = \Delta\tau_{neutron}^{beam} - \Delta\tau_{neutron}^{bottle} = 888.4 \text{ s} - 879.9 \text{ s} = 8.5 \text{ s} . \qquad (12)$$

Obtained here results are consistent with experimental data [2].

## 3. Summary

Here we present the very detailed description of the beta decay. The Scale-Symmetric Theory shows that in the bottle experiments, measured mean lifetime of the neutron should be 879.9 s whereas the beam experiments should lead to 888.4 s.

The difference in lifetimes is due to the fact that in a bottle, neutrons move in a disorderly way, while in a beam they move in an orderly manner.

## References

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