Explaining the complexity of experimental results on the lifetimes of free-neutrons and hyperons and the masses of W-bosons based on the atom-like structure of baryons

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Abstract: The complexities of the precise experimental data on the lifetimes of free neutrons and hyperons and the masses of W bosons have not yet been resolved within the quark model. These three extremely important problems concern the weak interactions. Here we present exact solutions to these problems within the atom-like structure of baryons described in the Scale-Symmetric Theory (SST). The SST solutions show that they are beyond the Standard Model, but in previous articles we have shown how the quark model emerges from the atom-like structure of baryons. The mean lifetimes of free neutrons are very important in nuclear physics, particle physics and cosmology. Within SST we calculated the ground state for mean lifetime of free neutrons that is $878.10\ s$ – it follows from the transition from the nuclear weak interactions to the weak interactions of the electrons in the presence of dark matter. We showed that in a bottle, the central spacetime condensate in the neutron, which is responsible for the β decay, can be in different mass states that leads to two excited states of neutron lifetime, *i.e.* $880.36\ s$ and $882.63\ s$. We showed that in neutron beams, mean lifetime of neutrons depends on neutron velocity because emissions of quanta by the central spacetime condensate with increasing neutron velocity are more and more suppressed. For neutron velocity equal to a threshold velocity $3.356\ km/s$ we obtain a longer mean neutron lifetime equal to $888.89\ s$. For velocity $2.2\ km/s$ we obtain $886.83\ s$. We showed that mass of the W boson depends on the place of creation – the two calculated basic values are 80,360.11 MeV and 80,378.96 MeV which lead to the mean value 80,369.5 MeV that is very close to the world average central value (80,369.2 MeV). We also calculated the exact lifetimes of the hyperons.

Keywords: Scale-Symmetric Theory (SST), Lifetimes of Free Neutrons, W Boson Masses, Lifetimes of Hyperons.

1. Introduction

There is the discrepancy between "bottle" and "beam" methods of measurement of the free-neutron lifetime. There is the long-standing disagreement between ultracold neutrons (UCN) and in-beam neutrons results.

For ultracold neutrons we have [1]

$$\tau_n^{UCN} = 877.75 \pm 0.28\ (stat)^{+0.22}_{-0.16}\ (syst)\ s\ . \tag{1}$$

The Particle Data Group (PDG) average of eight of the best UCN measurements (error scaled by 1.8) is [2]

$$\tau_n^{UCN,PDG} = 878.4 \pm 0.5\ s\ . \tag{2}$$

Here we show that these PDG data are consistent with results obtained within the SST model – such model leads to the ground state for the neutron lifetime and to two excited states.

For in-beam neutrons we have [3]

$$\tau_n^{in-beam} = 887.7 \pm 1.2\ (stat) \pm 1.9\ (syst)\ s\ . \tag{3}$$

From (3) and (1) we obtain the time distance between the central values of lifetimes of the in-beam and UCN neutrons

$$\tau_n^{in-beam} - \tau_n^{UCN,PDG} \approx 10\ s\ . \tag{4}$$

Here we show that the discrepancy between "bottle" and "beam" methods of measurement of the free-neutron lifetime follows from behaviour of the spacetime condensate that is responsible for the weak interactions – its properties are described in the Scale-Symmetric Theory (SST) [4].

In [5], we showed how the transition from the atom-like structure of baryons (described in SST [4]) to the quark model is realized, *i.e.* we described both the transition from the SST structure of baryons to the masses of the up and down quarks and the transition from the elementary electric charges in SST to the fractional electric charges of quarks. In [4] and [5], we calculated masses of all quarks and showed that at low energies there dominates the atom-like structure of baryons whereas at higher energies we must take into account both models, *i.e.* the SST model of baryons and the quark model. It is the reason that by applying only the quark model we cannot calculate the exact masses, spins and magnetic moments of nucleons and the mean lifetime of free neutrons. But emphasize that at higher energies, especially at high-energy collisions, the quark model is very important.

To solve the bottle-beam problem for neutrons (it concerns the β-decays at low energies) and the W boson mass problem and to calculate the exact lifetimes of hyperons we must apply the atom-like structure of baryons.

The Scale-Symmetric Theory is based on the four successive phase transitions of the SST initial inflation field, *i.e.* there are five fundamental levels of Nature. The third phase transition leads to the atom-like structure of baryons [4]. The calculated within SST masses of nucleons are $n = 939.56542\ MeV$ and $p = 938.27208\ MeV$. In the centre of the baryons, there is the spacetime condensate with a mass of $Y = 424.12176\ MeV$ and a radius of $r_{C(p)} = 0.8711018109 \times 10^{-17}\ m$, that is responsible for the nuclear weak interactions – such interactions are defined by the coupling constant $\alpha_{w(p)} = 0.01872289510$. The virtual Y spacetime condensates appear in the $d = 0$ state/orbit with a radius of $A + r_{C(p)} = 0.70615355\ fm$, where $A = 0.69744253\ fm$ is the equatorial radius of the core of baryons. The spin speed in the $d = 0$ state is $v_{d=0} = 0.9938129253\ c$, where $c = 299792458\ m\ s^{-1}$ is the speed of light in "vacuum".

Within SST we showed also that the virtual Y spacetime condensates are created due to the circle → radius transitions of the virtual fundamental gluon loops (FGLs). Mass of FGL at low energy is $m_{FGL} = 67.544413\ MeV$ [4], so the initial mass of the spacetime condensate is $Y^* = 2\pi m_{FGL} = 424.39406\ MeV$.

SST leads to the internal structure of the electron as well – in the center of the electron, there is the spacetime condensate with a mass of $\frac{m_{e,bare}}{2}$, where $m_{e,bare} = 0.5104070514\ MeV$ is the mass of the bare electron, that is responsible for the weak interactions of the electrons in the presence of dark matter (DM) – such interactions are defined by the coupling constant $\alpha'_{w(e),DM} = 1.119446247 \times 10^{-5}$ [4]. For electrons, for regions free from DM, we have $\alpha_{w(e)} = 0.9511181887 \times 10^{-6}$ [4].

The masses of the relativistic pions in the $d = 2$ and $d = 4$ states are $W_{(-),d=2} = 181.70381\ MeV$, $W_{(o),d=4} = 156.66800\ MeV$, $W_{(o),d=2} = 175.70966\ MeV$, $W_{(-),d=4} = 162.01257\ MeV$ [4].

The ratio of the coupling constant for the nuclear weak interactions to the coupling constant for the weak interactions of electrons is $X_{w(p/e)} = \frac{\alpha_{w(p)}}{\alpha_{w(e)}} = 19685.14042$ [4].

Radii of the orbits in baryons are defined by $R = A + dB$, where $B = 0.5018354435\ fm$ and $d = 0,1,2,4$ [4].

Mass of the electric charge in the core of baryons is $X^{\pm} = 318.29555\ MeV$ [4].

Here, by applying the above physical quantities, we calculated the lifetimes of free neutrons in bottles and beams, the basic masses of the W boson, and lifetimes of the hyperons.

2. The Mean Lifetime of Free Neutrons from SST

The Stefan-Boltzmann law states that the total energy radiated per unit surface area per unit time, j, is directly proportional to the fourth power of the black body's temperature. Lifetime, τ, should be inversely proportional to j, so applying the Stefan-Boltzmann law, the Wien's displacement law and the de Broglie and Einstein formulae that lead to $h\frac{c}{\lambda} = Mc^2$, we obtain

$$\frac{1}{\tau} \sim j \sim T_{temp}^4 \sim \frac{1}{\lambda^4} \sim M^4 \ . \qquad (5)$$

From (5) follows that more massive/energetic quanta, *i.e.* higher M or shorter λ, lead to higher j and shorter τ, so the neutron lifetime, τ_n, can be calculated from following formula

$$\tau_n = \tau_1 \left(\frac{M_1}{M_n}\right)^4 , \qquad (6)$$

where M_1 denotes the virtual weak mass that appears in the $d = 0$ state, and M_n denotes the virtual weak mass that leads to the neutron lifetime, *i.e.* denotes the virtual weak mass emitted during the β decay.

The mechanism of the beta/weak decay of neutron is as follows.

The weak interactions via the spacetime condensates are responsible for the β decays of the neutrons, so from (6) follows that a transition from more massive spacetime condensate to less massive spacetime condensate increases lifetime.

The weak mass of the spacetime condensate that appears in the $d = 0$ state, M_1, is the source of the β decay of the neutron, so we have

$$M_1 = \alpha_{w(p)} M_{C,i} \ , \qquad (7)$$

where $M_{C,i}$ is the initial virtual mass of spacetime condensate.

In the β decay, there appears the electron

$$n \to p + e^- + \nu_{e,anti} \ , \qquad (8)$$

$$(n - p) \equiv e^- + \nu_{e,anti} \ , \qquad (9)$$

so there is the transition from the nuclear weak interactions of nucleons to weak interactions of the electron in the presence of dark matter, *i.e.* the involved final virtual weak mass is fixed and is

$$M_n = \alpha'_{w(e),DM} \frac{m_{e,bare}}{2} = 2.856866 \times 10^{-6}\ MeV\ . \quad (10)$$

We can use the period on the $d = 0$ orbit as the mean lifetime of the virtual weak mass M_1 produced by the central spacetime condensate

$$\tau_1 = \frac{2\pi(A + r_{C(p)})}{v_{d=0}} = 1.489202 \times 10^{-23}\ s\ . \quad (11)$$

From (6), (7), (10) and (11) we obtain a very simple formula for the mean lifetime of neutron

$$\boldsymbol{\tau_{n,i} = C_o M_{C,i}^4}\ . \quad (12)$$

where $C_o = 2.747173 \times 10^{-8}\ [s\ MeV^{-4}]$. Formula (12) shows that the different experimental values for lifetime of neutrons must follow from some excited mass states of the spacetime condensate in the center of the neutron.

3. The Ground State and Excited States of the Mean Lifetime of Neutrons in a Bottle

Consider the fundamental mass for the masses $M_{C,i}$. The nuclear weak interactions via the virtual Y spacetime condensates are responsible for the β decays of the neutrons. It emits energy that is the mass distance between the neutron and proton: $m_w = n - p = 1.29334\ MeV$ [4], so we have

$$M_{C,1}^{bottle} = Y - (n - p) = 422.8284\ MeV\ . \quad (13)$$

Notice that the mass $M_{C,1}^{bottle}$ is very close to mass of four muons $4\mu^{\pm} = 422.63\ MeV$, so there is a resonance with very low probability that can slightly decrease the neutron lifetime. In SST, the four-object symmetry (here we have $4\mu^{\pm}$) appears very frequently. The rule of four is observed in inorganic chemistry as well [6], so it suggests that the virtual structure of nucleons leaks to their surroundings – it is the origin of the chaos theory.

From (12) and (13) we obtain the ground state of lifetime of free neutrons

$$\tau_{n,1}^{bottle} = 878.10\ s\ . \quad (14)$$

This SST theoretical result is consistent with the PDG average [2], and is close to the central value in [1] (877.75 s), in [7] (878.3 s), in [8] (878.5 s) and in [9] (877.7 s).

In SST, most of the virtual Y spacetime condensates are created by the real Y spacetime condensate in the center of baryons. But the virtual Y spacetime condensates can be produced also due to the circle → radius transitions of the virtual FGLs, so the initial mass is $Y^* = 2\pi m_{FGL} = 424.39406\ MeV$ [4]. When in formula (13) we use Y^* instead Y then formula (12) leads to the excited state of the mean lifetime of neutrons

$$\tau_{n,2}^{bottle} = 880.36\ s\ . \quad (15)$$

This SST result is close to the experimental central value in [10] (880.2 s) and in [11] (880.7 s).

Notice that we obtain the result $880.36\ s$ also when the Y emits an energy equal to the mass of the bare electron-positron pair

$$M_{C,2}^{bottle} = Y^* - (n - p) = Y - 2m_{e,bare} = 423.101\ MeV\ . \quad (16)$$

Notice that from (12) for $M_{C,3}^{bottle} = Y^* - 2m_{e,bare} = 423.3733\ MeV$ we obtain

$$\tau_{n,3}^{bottle} = 882.63\ s\ . \quad (17)$$

This SST result is close to the experimental central value presented in [12] (882.5 s).
Notice that the arithmetical mean

$$\frac{\tau_{n,2}^{bottle} + \tau_{n,3}^{bottle}}{2} = 881.50\ s \quad (18)$$

overlaps with the experimental central value in [13].
The eight of the best UCN measurements that are taken into account to calculate the PDG average are from [1], [7-13]. We see that the SST results are very close to all the eight experimental central values that appear in the best UCN measurements.

4. The Mean Lifetime of Neutrons in a Neutron Beam

In a neutron beam, emissions of quanta by Y are suppressed so for neutrons with sufficiently high velocities we have $M_{C,1}^{beam} = Y$. From (12) we obtain

$$\tau_n^{beam} = 888.89\ s\ . \quad (19)$$

Our explanation is as follows.
According to SST, the difference in velocity of neutrons in a beam (the order of $10^3\ m/s$) and UCNs in a bottle ($\sim 1\ m/s$) is the reason that leads to the beam-bottle anomaly for the neutron mean lifetime. One of the SST definitions of coupling constants looks as follows [4]

$$\alpha = \frac{v_{spin}}{c}\ , \quad (20)$$

where v_{spin} is the spin speed of emitted loop. We can assume that emissions of such loops by spacetime condensates are impossible when linear velocity of neutrons is higher than v_{spin} because then, after the loop decay, we have $v_n > v_{loop}$. We can calculate a threshold linear velocities of neutrons, $v_{n,threshold}$, above which the spacetime condensates do not emit loops (the mass Y is a composite mass so we have $\alpha_{w(p)} = k\alpha'_{w(e),DM}$, where k is a natural number)

$$v_{n,threshold} = v_{spin} = c\alpha'_{w(e),DM} = 3.356 \times 10^3\ m/s\ . \quad (21)$$

For $v_n \geq v_{n,threshold}$ all the $n - p$ energy is trapped by the Y spacetime condensate.
We can compare this threshold velocity with velocity of neutrons in a beam (the order of $10^3\ m/s$). For example, for neutrons with a velocity $2200\ m/s$ the result of the lifetime measurement is $\tau_n^{in-beam} = 886.8 \pm 1.2\ (stat) \pm 3.2\ (syst)\ s$ [14], *i.e.* not whole the $n - p$ energy is trapped.
From (12) we have $\tau_{n,i} \sim M_{C,i}^4$. On the other hand, from [4] we have $\alpha \sim M^2 \sim v_{spin}$ so for $v_n \leq v_{n,threshold} = 3.356 \times 10^3\ m/s$ we have that the energy $\Delta M = (n - p)\left(\frac{v_n\left[\frac{km}{s}\right]}{3.356}\right)^{\frac{1}{2}}$ from the $n - p$ energy is trapped by the Y spacetime condensate. Such conditions lead to the generalized mean lifetime of neutrons in both a bottle or beam for $v_n \leq 3.356\ \frac{km}{s}$

$$\boldsymbol{\tau_n}\,[s] = \boldsymbol{C_o}\left(\boldsymbol{Y} - (\boldsymbol{n}-\boldsymbol{p})(\boldsymbol{1} - \left(\frac{\boldsymbol{v_n}\left[\frac{km}{s}\right]}{\boldsymbol{3.356}}\right)^{\frac{1}{2}})\right)^{\boldsymbol{4}} . \tag{22}$$

From (22), for the ground state of the mean neutron lifetime, *i.e.* for $v_n = 0$, we obtain $\tau_n = 878.10\, s$.

From (22), for neutron velocity $v_n = 2.2 \frac{km}{s}$, we obtain $\tau_n = 886.83\, s$ – this SST value overlaps with the central value in [14]: 886.8 s. We see that the central value for neutron lifetime in [14] is better than in [3] (887.7 s) and [15] (886.6 s).

From (22), for neutron velocity $v_n = 1.0 \frac{km}{s}$, we obtain $\tau_n = 883.98\, s$.

For $v_n \geq 3.356\ \frac{km}{s}$ there should be $\tau_n^{in-beam} = 888.89\, s$.

5. The W Boson Mass Problem

The analyses of the most precise measurements of the W boson mass, $W^{\pm}_{exp}$, use the electron or muon decay modes ($l\nu, l = e, \mu$). The high-precision measurement with the CMS experiment gives [16]

$$W^{\pm}_{exp} = 80{,}360.2 \pm 9.9\ MeV\ . \tag{23}$$

On the other hand, the PDG World Average is [2]

$$W^{\pm}_{PDG,average} = 80{,}369.2 \pm 13.3\ MeV\ . \tag{24}$$

We see that there is a significant difference in the central values but both results are consistent. Notice that the Standard Model (SM) expectation is $W^{\pm}_{SM} = 80{,}356 \pm 6\ MeV$ [2].

For entangled binary systems such as the electron-positron pairs, due to the 4-object symmetry, a state composed of 8 fermions is the ground state [5]. Within SST we already calculated the W boson mass when it is created inside the Schwarzschild surface for the nuclear strong interactions. Assume that due to the four-object symmetry, a spin-0 charge-0 quadrupole of bare electron-positron pairs ($8m_{e,bare}$) transits from the weak interactions of electrons to the nuclear weak interactions (then mass increases $X_{w(p/e)} = \frac{\alpha_{w(p)}}{\alpha_{w(e)}} = 19685.1404$ times) and then such an object emits the spin-1 virtual pair composed of electron (positron) and electron-antineutrino (electron-neutrino) – it looks as a beta decay. The resultant object is the $W^{\pm}$ boson [4]

$$W^{\pm}_{SST,1} = 8m_{e,bare}X_{w(p/e)} - m_{e,bare} = 80{,}378.96\ MeV\ . \tag{25}$$

Electroweak measurements performed with data taken at the electron-positron collider LEP at CERN lead to a combined average W mass equal to $80{,}376 \pm 33\ MeV$ [17] – we see that the central value is very close to the SST result in (25).

Assume that the W boson is created in the ground state above the Schwarzschild surface for the nuclear strong interactions, *i.e.* in the $d = 2$ state. Then instead the emitted bare electron that appears in (25) we have the characteristic electrically charged objects that mean energy is

$$E_{Mean} = \frac{(W_{(-),d=2} - W_{(o),d=4}) + (W_{(o),d=2} - W_{(-),d=4})}{2} = 19.36645\ MeV\ . \tag{26}$$

From (25) and (26) we obtain the SST second basic mass of the W boson

$$W^{\pm}_{SST,2} = 8m_{e,bare}X_{w(p/e)} - E_{Mean} = 80{,}360.11\ MeV\ . \quad (27)$$

From (25) and (27) we obtain the SST mean central value for the W boson mass

$$W^{\pm}_{SST,mean} = \frac{W^{\pm}_{SST,1}+W^{\pm}_{SST,2}}{2} = 80{,}369.5\ MeV\ . \quad (28)$$

This SST result is very close to the PDG central value in (24).

Notice that there is an evidence that particle masses shift inside nuclear matter [18] what makes the SST model credible.

Why the descriptions of the nuclear weak interactions via the Y spacetime condensates that appear in the SST and via the W and Z weak gauge bosons that appear in the Standard Model are similar? It follows from the fact that Y spacetime condensates are the SST black holes (BHs) because of the nuclear weak interactions (the SST weak BHs) [4], so the weak gauge bosons are the composite objects built of the Y spacetime condensates. It looks as a "dark star". In [19], it is shown that the final result of the gravitational collapse is a quantum object, an extremely compact "dark star".

In [4], we showed that the Y^* spacetime condensate is the excited state of Y and that the weak gauge bosons are the associations of the entangled Y spacetime condensates, so by an analogy to (25) we can calculate mass of the excited state of the W boson

$$W^{\pm}_{SST,3} = 8m_{e,bare}X_{w(p/e)}\frac{Y^*}{Y} - m_{e,bare} = 80{,}430.57\ MeV\ . \quad (29)$$

This SST result is very close to the central value in [20]: $80{,}433.5 \pm 9.4\ MeV$ – we do not take this result into account when calculating the average mass within the SST model because the same concerns the PDG average.

6. Lifetimes of Hyperons

For the lifetimes of the hyperons is responsible the spacetime condensate in the charged pions that is the condensate in the electron/positron with a mass of $\frac{m_{e,bare}}{2} = 0.25520353\ MeV$, so in (12) we have $M_{C,i} = \frac{m_{e,bare}}{2}$. This leads to the normalized lifetime of the 6 hyperons that decay due to the weak interactions

$$\tau_{o,norm} = C_o\left(\frac{m_{e,bare}}{2}\right)^4 = 1.1653 \times 10^{-10}\ s\ . \quad (30)$$

At sufficiently high-energy collisions there are simultaneously created all hyperons so they cannot have the same lifetime because it forces the same state of decay. We need 5 different states because spin of the Ω^- hyperon differs from spins of the other hyperons.

Assume that before the weak decays there can be some changes in states of the spacetime condensate in electron. The quantum state in the denominator is always normalized by the lifetime defined in (30). Then the generalized formula for hyperon lifetime looks as follows

$$\boldsymbol{\tau_{hyperon}} = \frac{\boldsymbol{R_i}}{\boldsymbol{R_j}}\boldsymbol{\tau_{o,norm}} = \boldsymbol{k_n}\boldsymbol{\tau_{o,norm}}\ , \quad (31)$$

where R_i and R_j are quantized: it can be $R_d = A + dB$, where $d = 0,1.2.4$ [4], or it is the diameter of the allowed orbits, *i.e.* $2R_d$, but the R_d weak oscillations are preferred because of the location of the Y spacetime condensate. The factors $k_n = \frac{R_i}{R_j}$, where $n = f, 2,3,4,5,6$, we will call the modes.

From (31) for $R_i = A + 4B$ and $R_j = A + B$ we obtain the lifetime of Λ hyperon

$$\tau_\Lambda = \frac{\mathrm{A+4B}}{\mathrm{A+B}} \tau_{o,norm} = 2.628 \times 10^{-10}\, s\,. \tag{32}$$

The PDG result is $(2.617 \pm 0.010) \times 10^{-10}\, s$ [2].

From (31) for $R_i = A + B$ and $R_j = A + 2B$ we obtain the lifetime of $\Sigma^+$and Ω^- hyperons

$$\tau_{\Sigma^+,\Omega^-} = \frac{\mathrm{A+B}}{\mathrm{A+2B}} \tau_{o,norm} = 0.8215 \times 10^{-10}\, s\,. \tag{33}$$

The PDG result for Σ^+ is $(0.8018 \pm 0.0026) \times 10^{-10}\, s$ whereas for Ω^- is $(0.821 \pm 0.011) \times 10^{-10}\, s$ [2]. The a little lower lifetime of Σ^+than Ω^- can follow from the transition from the nuclear strong interactions (coupling constant at low energies is $\alpha_s = 1$ [4]) of the pion that appears in the weak decay of Σ^+ to the nuclear strong plus electroweak interactions (coupling constant at low energies is $\alpha_{SEW} = \alpha_s + \alpha_{w(p)} + \alpha_{em} = 1.02602$ [4]). Such transition has higher probability for Σ^+ because its electroweak mass/energy is lower. We see also that lifetimes of $\Sigma^+$and Ω^- may vary slightly. We showed that for a loop we have $\alpha \sim v_{spin} \sim \frac{1}{\tau}$, so the lifetime of Σ^+ is

$$\tau_{\Sigma^+}^{corrected} = \tau_{\Sigma^+,\Omega^-} \frac{\alpha_s}{\alpha_{SEW}} = 0.8007 \times 10^{-10}\, s\,. \tag{34}$$

From (31) for $2R_i = 2(A + 2B)$ and $R_j = A + 4B$ we obtain the lifetime of Σ^- hyperon

$$\tau_{\Sigma^-} = \frac{2(A+2B)}{\mathrm{A+4B}} \tau_{o,norm} = 1.466 \times 10^{-10}\, s\,. \tag{35}$$

The PDG result is $(1.479 \pm 0.011) \times 10^{-10}\, s$ [2].

From (31) for $R_i = A + 2B$ and $R_j = A$ we obtain the lifetime of Ξ^o hyperon

$$\tau_{\Xi^o} = \frac{\mathrm{A+2B}}{\mathrm{A}} \tau_{o,norm} = 2.842 \times 10^{-10}\, s\,. \tag{36}$$

The PDG result is $(2.90 \pm 0.09) \times 10^{-10}\, s$ [2].

From (31) for $R_i = A + 2B$ and $R_j = A + B$ we obtain the lifetime of Ξ^- hyperon

$$\tau_{\Xi^-} = \frac{\mathrm{A+2B}}{\mathrm{A+B}} \tau_{o,norm} = 1.653 \times 10^{-10}\, s\,. \tag{37}$$

The PDG result is $(1.639 \pm 0.015) \times 10^{-10}\, s$ [2].

There are some selection rules which clearly define the lifetimes of hyperons.

*Both the SST mean lifetime for the weakly decaying hyperons and the PDG average for the central values are $\sim 1.7 \times 10^{-10}\, s$ [2]. This result is close to the lifetime of Ξ^- hyperon. It suggests that for a mean hyperon the $d = 1$ state normalizes the lifetime whereas the pion that appears in the weak decay is emitted via the $d = 2$ state, *i.e.* via the ground state above the Schwarzschild surface for the nuclear strong interactions. From (31) we obtain $k_{mean,exp} =$

$(\frac{R_i}{R_j})_{mean,exp} = 1.4671 \approx k_f = k_1 = \frac{\mathrm{A+2B}}{\mathrm{A+B}} = 1.4184$ (this is for Ξ^-) – this is the fundamental mode of changing the quantized radii along which oscillations occur. Notice that in SST, mass of the strange quark is defined by the $d = 2$ state [5], so the $d = 2$ state should define the basic properties of the hyperons.

*The additional electromagnetic interactions decrease lifetime so lifetimes of charged hyperons should be shorter than the neutral. Lifetimes of the Λ and Ξ^o should be longest.

*When we take into account spin and lifetime (it strongly depends on the atom-like structure of baryons) then each hyperon is in different quantum state. This suggests that the lightest charged hyperons with different spins (*i.e.* $\Sigma^+$and Ω^-) could be in the same lifetime state. But decaying hyperons cannot be in the same lifetime state, so there must be some phenomenon that differentiates the lifetimes of these two hyperons.

*In (31), due to the atom-like structure of baryons, the ratios/modes $k_n = \frac{R_i}{R_j}$ are quantized. Since lifetime states of $\Sigma^+$and Ω^- can be the same, we need 5 different modes for the hyperons decaying due to the weak interactions.

*From (30) follows that for higher mass of spacetime condensate lifetime is longer. Since weak mass of more massive hyperon is higher so its lifetime should be longer. It means that lifetime of Λ should be shorter than Ξ^o. Lifetime of Σ^+should be shortest because it is the lightest charged hyperon. The Σ^- is lighter that Ξ^- so lifetime of Σ^- must be shorter than Ξ^-.

*The second basic mode should be $k_2 = \frac{\mathrm{A+2B}}{\mathrm{A}} = 2.4391$ because it contains both the ground state inside and outside the Schwarzschild surface for the nuclear strong interactions, *i.e.* $d = 0$ and $d = 2$ – this should be for Ξ^o because it is the heaviest neutral hyperon so lifetime should be longest. Value of the third basic mode, k_3, is forced by the fundamental mode so it may be the inverse of the fundamental mode, *i.e.* the normalization radius and the decay radius are swapped: $k_3 = \frac{1}{k_f} = \frac{\mathrm{A+B}}{\mathrm{A+2B}} = 0.7050$ (this is for Ω^-). The arithmetic mean of k_f, k_2, and k_3 is close to k_f, so the three other modes can be close to them. Notice that $k_4 = \frac{2(\mathrm{A+2B})}{\mathrm{A+4B}} = 1.2578$ (this is for Σ^-) is close to k_f (the oscillations along the diameter $2(\mathrm{A} + 2\mathrm{B})$ are forced by the value of k_f), that $k_5 = \frac{A+4B}{\mathrm{A+B}} = 2.2553$ (this is for Λ) is close to k_2, and from (34) we obtain $k_6 = 0.6871$ (this is for Σ^+) that is very close to k_3. The SST theoretical mean of such 6 modes is $k_{mean,th} = 1.4605$ (this leads to $\tau_{mean,SST} = 1.7019 \times 10^{-10}\ s$) and this value is very close to $k_{mean,exp} = 1.4671$ (it is from the experimental average of central values that is $\tau_{mean,exp} = 1.7096 \times 10^{-10}\ s$).

We can also calculate the lifetime of Σ^o hyperon which decays due to the electromagnetic interactions. There is the transition from the nuclear strong interactions via the fundamental gluon loops to the electromagnetic interactions via the $\mathrm{X^+X^-}$ pairs. The characteristic lifetime for the nuclear strong interactions is the period of spinning of the FGL [4]

$$\tau_{strong} = \frac{2\pi\frac{2\mathrm{A}}{3}}{c} = 9.7449 \times 10^{-24}\ s\ . \tag{38}$$

The above remarks and (6) and (38) lead to the lifetime of Σ^o hyperon

$$\tau_{\Sigma^o} = \tau_{strong}\left(\frac{\mathrm{X^+ + X^-}}{m_{FGL}}\right)^4 = 7.69 \times 10^{-20}\ s\ . \tag{39}$$

The PDG result is $(7.4 \pm 0.7) \times 10^{-20}\ s$ [2].

7. Summary

In this paper we derived the very simple formula for neutron mean lifetime $\tau_{n,i} = C_o M_{C,i}^4$ – there is the invariant factor $C_o = 2.747173 \times 10^{-8}$ $[s\ MeV^{-4}]$ which defines the lifetime per 1MeV to the fourth power and there is the initial mass of spacetime condensate $\boldsymbol{M_{C,i}}$ [MeV] that is responsible for the β-decay (weak decay) of neutron.

The SST results for neutron lifetimes are collected in Table 1.

In SST, the bottle-beam problem is solved as follows. The energy-mass distance $n - p$ that appears in the β-decay can be emitted by one part of a few parts of the neutron. Generally, the energy $n - p$ is emitted by Y (or Y^*) because it is responsible for the nuclear weak interactions at low energy [4].

Notice that there is satisfied the following relation

$$n - p = (Y^* - Y) + 2m_{e,bare} = 1.293\ MeV \tag{40}$$

so there is a resonance. It means that, for example, the energy equal to $2m_{e,bare}$ is emitted by a spacetime condensate (it changes the neutron lifetime) whereas the energy $Y^* - Y$ is emitted by other parts of neutron (it does not change the neutron lifetime), or vice versa. But the emitted higher energy (here it is $2m_{e,bare}$) by a spacetime condensate leads to shorter lifetime so we assume that the $Y^* - Y$ energy is emitted by other parts of neutron – it leads to the two excited states (see Table 1).

Table 1 *Neutron Lifetimes from Formula (12):* $\tau_{n,i} = C_o M_{C,i}^4$

	$\boldsymbol{M_{C,i}}$ [MeV]	**Lifetime** $\boldsymbol{\tau_{n,i}}$ [s]	**State**	$\boldsymbol{\tau_{n,i}}$ **is close to central value in**
1	$\boldsymbol{Y - (n - p)}$	**878.10**	**Bottle, ground state**	[1], [7-9]
2	$\boldsymbol{Y}$	**888.89**	**Beam, threshold**	[3]
3	$Y^* - (n - p) =$ $= Y - 2m_{e,bare}$	880.36	Bottle, excited	[10-11]
4	$Y^* - 2m_{e,bare}$	882.63	Bottle, excited	[12]
5	Mean of 3 and 4	881.50		[13]

We showed that lifetime of free neutrons depends on their velocity. Emphasize that the origins of the lifetimes of the excited states in Table 1 (it is for the ultracold neutrons) and of lifetimes that follow from (22) are different. We can obtain the value $\tau_n = 880.36\ s$ for ultracold neutrons with a mass of the spacetime condensate equal to $M_{C,i} = Y^* - (n - p) = Y - 2m_{e,bare}$ (see (12)) or for neutrons in a beam moving with velocity equal to $v_n = 0.149\ \frac{km}{s}$ (see (22)). We can obtain the value $\tau_n = 882.63\ s$ for ultracold neutrons with a mass of the spacetime condensate equal to $M_{C,i} = Y^* - 2m_{e,bare}$ (see (12)) or for neutrons in a beam moving with velocity equal to $v_n = 0.595\ \frac{km}{s}$ (see (22)).

We showed that the SST results are very close to all the eight experimental central values that appear in the best UCN measurements.

Notice that the arithmetic mean of the central values that appear in [1] and [7-9]

$$\frac{877.75+878.3+878.5+877.7}{4}\ s = 878.06\ s \tag{41}$$

is very close to the SST value for the ground state in a bottle $\tau_{n,1}^{bottle} = 878.10\ s$.

Notice that the arithmetic mean of the central values that appear in [10-11]

$$\frac{880.2+880.7}{2}\,s = 880.45\,s \qquad (42)$$

is very close to the SST central value $\tau_{n,2}^{bottle} = 880.36\,s$.

Within the Scale-Symmetric Theory we calculated the ground state of the mean lifetime of free neutrons and showed that the mean lifetime of neutrons in a beam is longer because emissions of quanta by the central spacetime condensate Y, when it is moving, are suppressed.

We described some characteristic processes that can change mass of the Y spacetime condensate that appears in the atom-like structure of baryons.

We see that the time distances between the results obtained within the atom-like structure of baryons (described within the Scale-Symmetric Theory) and the experimental central values are very low, so it cannot be a chance. We cannot obtain such consistency of results within the quark model of the baryons but emphasize that within SST we calculated the masses of quarks and showed that they are very important at high energies [4].

From the experiments with UCNs follows that when we effectively eliminate interactions of a neutron with material trap and other neutrons, *i.e.* the excited states are eliminated, then the measured mean lifetime of neutrons is close to the SST ground state that is $878.10\,s$.

It is obvious that applied external fields change/distort experimental results. To obtain the correct result $878.10\,s$, we must correctly interpret influences of external fields on experimental results.

Here, to obtain the correct theoretical result for the mean lifetime of free neutrons, we applied the atom-like structure of baryons and coupling constants for the weak interactions of the baryons and electrons described in SST.

We see that the time distance between the mean lifetime of the neutrons in a beam with the threshold neutron velocity $v_{n,threshold} = 3.356\,\frac{km}{s}$ and in a bottle for $v_n \to 0$ should be $\tau_n^{beam} - \tau_{n,1}^{bottle} \approx 10.8\,s$.

In stable atomic nuclei, the entangled nucleons in proton-neutron pairs exchange the virtual pions – each such exchange in a proton of π^+ for π^o or π^o for π^- [4] resets lifetime of just created neutron. Lifetime of such exchanges ($\sim 10^{-23}\,s$) is about 26 orders of magnitude shorter than the mean lifetime of free neutrons ($\sim$878 s).

Here we showed that mass of the W boson is shifted when it is created inside the Schwarzschild surface for the nuclear strong interactions. For the ground state above such a surface we obtained 80,360.11 MeV whereas for the interior of it we have 80,378.96 MeV. The SST mean value, *i.e.* 80,369.5 MeV, is very close to the PDG average central value 80,369.2 MeV.

The SST results for W boson mass are collected in Table 2.

Table 2 *W Boson Masses from SST*

	Composition	**Mass** [MeV]	**Mass is close to central value in**
1	$8m_{e,bare}X_{w(p/e)} - m_{e,bare}$	80,378.96	[17]
2	$8m_{e,bare}X_{w(p/e)} - E_{Mean}$	80,360.11	[16]
	Mean of 1 and 2	80,369.5	[2]: World Average
3	$8m_{e,bare}X_{w(p/e)}\frac{Y^*}{Y} - m_{e,bare}$	80,430.57	[20]

The SST results for the lifetimes of hyperons are collected in Table 3.

The main conclusions from this article are as follows.

*The lifetime of a free neutron depends on its velocity and such a dependence results from quantum phenomena – it does not concern the relativistic effects which here can be neglected.
*The lifetime of a free, resting neutron depends also on its excited states, which are the result of its internal dynamics.
*The mass of the W boson depends on the place of its creation in the baryon strong field and on the quantum oscillations of the baryon components.
*The mass of the W boson has two ground states, one ground state is for the interior of the Schwarzschild surface for the nuclear strong interactions and the other is for the ground state outside such a surface – the SST average for such two ground states is 80.3695 GeV.
*Most of the processes that influence the mass and lifetime of particles at low energies are virtual processes which in SST are real processes and virtual particles do not arise from nothing – their creation results from the internal structure and dynamics of the SST spacetime.
*Each central value of a good experimental result, *i.e.* a result with sufficiently low statistical and systematic uncertainties, requires careful analyses because it may lead to additional quantum phenomena inside the object creating the particle under consideration.
*The World Average is not always the ground state. To avoid ambiguity we should always define the ground state of the physical system under consideration.
*We have shown indirectly that the complexities of the good experimental results on the lifetimes of free-neutrons and hyperons and the masses of W bosons strongly depend on the atom-like structure of baryons and cannot be explained within the quark model.

Table 3. *Lifetimes of hyperons*

Hyperon	PDG Lifetime [2]	Lifetime from SST
Λ	$2.617(10) \times 10^{-10}\ s$	$2.628 \times 10^{-10}\ s$
Σ^+	$0.8018(26) \times 10^{-10}\ s$	$0.8007 \times 10^{-10}\ s$
Σ^o	$7.4(7) \times 10^{-20}\ s$	$7.69 \times 10^{-20}\ s$
Σ^-	$1.479(11) \times 10^{-10}\ s$	$1.466 \times 10^{-10}\ s$
Ξ^o	$2.90(9) \times 10^{-10}\ s$	$2.842 \times 10^{-10}\ s$
Ξ^-	$1.639(15) \times 10^{-10}\ s$	$1.653 \times 10^{-10}\ s$
Ω^-	$0.821(11) \times 10^{-10}\ s$	$0.8215 \times 10^{-10}\ s$

In SST, the total width of a particle depends on the masses emitted and absorbed by it and the coupling constant(s). In SST, the total width of the W boson is defined by $\Gamma_{W,weak} = \sqrt{2}\,\alpha_{w(p)} W^{\pm}_{SST,mean} = 2.1280\ GeV$ [4]. We can compare this SST value with the PDG result: $\Gamma_{W,PDG} = 2.14 \pm 0.05\ GeV$ [2], *i.e.* the SST value (~2.13 GeV) is very close to the PDG central value (2.14 GeV) and is fully consistent with the PDG result.

The excellent agreement of the theoretical results obtained in SST with the central values of the experimental results prove indirectly that we can move from the quantum to the classical description without losing any information. Quite the opposite, we see that the description within the SST contains more information. Why is this possible? In SST, the components of the gravitational fields and the carriers of quantum entanglement are the superluminal classical objects (*i.e.* v >> c). Quantum behavior of particles appears at higher levels of complexity. Superluminal quantum entanglement causes a particle to disappear in one place and practically immediately reappear in another place (*i.e.* nonlocal change of position) in the appropriate field, and so on. This leads to wave functions in quantum descriptions (this is the SST superluminal interpretation of quantum mechanics) or statistical images that appear in SST (for example, the atom-like structure of baryons). In SST the set of probabilities of finding a particle in various locations is replaced by a statistical image, which radically simplifies the description of phenomena. Obtaining a statistical image, of course, requires additional boundary conditions that should result from the initial conditions. In such a way is realized a transition from the quantum mechanics via statistical images to the classical descriptions that contain the coupling constants, relativistic effects, quantum numbers, and fundamental physical constants $\hbar$, G and c that are derived in SST from the initial conditions.

Why do descriptions of phenomena using Lagrangian lose some information? The basic reasons are as follows:

*physical objects cannot be treated as mathematical points,

*even structureless objects have viscosity that follows from smoothness of their surfaces so there are interactions without fields – they are the fundamental interactions,

*virtual particles are real and cannot arise from nothing, and

*it is impossible to fully describe phenomena without knowing the exact structure and all interactions of spacetime (only in SST is spacetime described completely and correctly).

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