# An exotic long-living particle “neutroneum”

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**Key words:** neutron, exotic, electroweak, reaction

## Abstract

We demonstrate that exoatom “neutroneum” is the low-laying extremely narrow resonance in the elastic electron-proton scattering. This resonance is caused by the weak interaction and corresponds to the transition of the initial state of the system «electron + proton» into the virtual neutron-neutrino pair. Due to its small width and amplitude, this resonance cannot be registered in the direct experiment on $ep$ - scattering. The third particle at the collision of the electron and the atom of hydrogen results in a three-body effect in the expression for the cross-section of the neutroneum creation – the two-particle propagator of the electron and proton (i.e., excited hydrogen) is under the integral. Therefore the width of the resonance in the cross-section of the creation of the neutroneum at colliding of the electron and the hydrogen is by fourteen orders more than the width of the similar resonance in elastic $ep$ - scattering, and its properties can be investigated experimentally. The estimation of the size, lifetime, threshold and cross-section of the neutroneum creation are carried out. It is shown that the energy of the neutroneum creation threshold is considerably smaller than the threshold energy of the thermonuclear reactions. It means, that neutron-like nuclear-active particles can be create at ultralow energies, and, hence, to be a cause of the nuclear reactions similar to reactions, caused by neutrons, in all cases, when nuclear reactions with the charged particles are forbidden by a high Coulomb barrier.

## 1. Introduction

The hypothesis of exotic neutrinos atoms «neutroneum» and «dineutroneum» existence has been formulated and partially proved in [1-7]. This hypothesis is supported by experimental data on cold fusion which is forbidden by high Coulomb barrier. For example, the penetration factor of the Coulomb barrier for «cold nuclear fusion» at the room temperature is about $P \sim 10^{-2740}$.

The basic criticism of numerous works on «cold fusion» (CF) is based on this estimation and bad reproducibility of the basic experimental data on CF. But a lot of experimental data were received in the best scientific laboratories, which incontestably prove that "forbidden" processes takes place [8]. As was mentioned in [8], the observable nuclear reactions are not thermonuclear. This conclusion concerns, first of all, to helium, because the charge of its nucleus twice more than a proton charge and the Coulomb barrier at the low energies [8] is impenetrable.

Experimental data [8] on nuclear reactions at high-current electric discharge in helium were confirmed by P.L. Kapitsa [9] (two years earlier, than Kurchatov’s [8]). Thus, the results of the best experimentalists of the XX-th century indicates - we must search new, till unknown, mechanisms of "neutralization" of the electric charge of the lightest nuclei at the low energies.

The hypothetical neutrinos exoatoms «neutroneum» and «dineutroneum» [1-7] are the possible particles, which induce CF and low energies nuclear reactions (LENR). According to it, we have to classify the neutrinos exoatoms in the framework of the elementary particles physics.

Hypothetical particle «neutroneum» creates in collision of the free electron and hydrogen atom, and than it decays into proton and electron [1-7]. The existence of the neutrinos exoatoms is possible because the Hamiltonian of the $ep$ - interaction includes not only electromagnetic, but also weak terms (fig. 1).

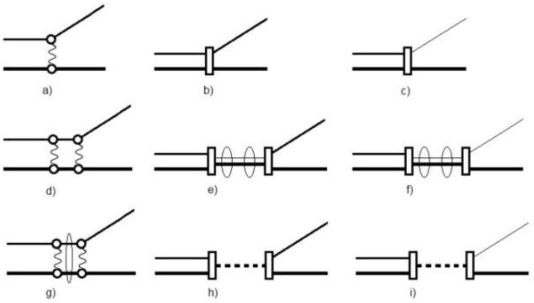
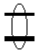
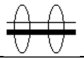


Fig. 1. Electromagnetic and weak interaction amplitudes of elastic scattering and nuclear reactions at $ep$-collisions (see Table 1).

Table 1[1]

Lines and vertexes of the Feynman diagrams

| Symbol | Interpretation of the vertexes and lines | Comments |
|---|---|---|
| ▯ | Weak interaction | UFI, SM |
| ○ | Electromagnetic interaction | QED |
| ● | Strong interaction (vertexes $f_{\pi NN}$, $f_{\pi N\Delta}$, $f_{\rho NN}$ и $f_{\rho N\Delta}$) | RQT |
| ∿∿∿ | Photon | QED |
| - - - - | π- and ρ- meson | RQT |
| ─ | Neutrino | RQT, SM |
| ─ | Electron | QED, RQT, SM |
| ━ | Nucleon | RQT, SM |
| ▬ | Δ- isobar | RQT |
|  | External line - hydrogen wave function<br>Two-partical propagator of the proton and electron | QED, RQT |
|  | Regular part of the two-partical propagator of the neutron and neutrino | RQT, UFI, SM |
| ▬ ▬ ▬ ▬ | External line – neutroneum wave function<br>Singular part of the two-partical propagator of the neutron and neutrino | Hypothesis<br>RQT, UFI, SM |

The two-partical propagator of the «neutrino + neutron» pair (fig. 1), we will represents as a sum of regular and singular terms (fig. 2).

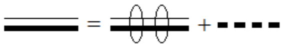


Fig. 2. Two-partical propagator «neutrino + neutron». The first term ($\hat{r}$)- regular, and the second ($\hat{s}$)- singular

If the energy of ingoing electron is overthreshold for $e^- + p \to n + \nu_e$ reaction, than neutron and neutrino are the real particles (fig. 1c).

The channel $e^- + p \to n + \nu_e$ is closed at the low energies, but diagram 1e) is nonzero. Thus, amplitude of the $ep \to n\nu_e$- transition $A_{ep \to n\nu_e} \neq 0$, and time delaying of the inverse transition $n\nu_e \to ep$ can be extremely long due to the high depth of effective $n\nu$- in-

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[1] Abbreviations: QED- quantum electrodynamics; UFI- universal Fermi interaction; RQT- relativistic quantum theory; SM- standard model.

teraction potential (see, for example, [10]). This scenario is possible, if amplitude $A_{ep\leftrightarrow n\nu_e}$ has a pole in the complex energy plane. In this case we deal with the authentic resonance.

The long-living hadron resonances, caused by the strong interaction, traditionally considered as elementary particles. In our case, leptonic number of the resonance, caused by the weak interaction, is nonzero. Therefore we have to consider it as neutrino's exoatom.

The basic argument against the existence of such exoatoms - Compton wavelength of neutrino is much more nucleon radius. But existence of the bound states of the relativistic particles which Compton wavelength $\lambda_C > R_0$ ($R_0$ - interaction radius) is strictly forbidden by Heisenberg uncertainty principle [11-13].

The main counterargument – neutron decaying into proton, electron and electronic antineutrino. There are no lepton satisfies to above mentioned criterion: «uncertainty principle $\Leftrightarrow$ leptons Compton wavelength» in this case. Heisenberg proposed rational solution of this problem [13]. He postulate that relation of "a part and a whole" in microcosm and macrocosm are rather different. From this point of view, neutroneum (hypothetical particle, leptonic number $L_e = 1$) is completely similar to a neutron, because in both cases the only $\beta$ - decay channel is open. Moreover, we can considere neutron as an exotic electroweak resonance. One can create it, for example, by the weak process $e^- + p \to \nu_e + n$ (if electron energy more than the reaction threshold energy). We will prove this statement.

Neutron decay $n \to p + e^- + \tilde{\nu}_e$ indicates its electroweak nature and permits us to establish analogue of hadron resonances [14] and electroweak resonances. To explain this analogy we consider well-known hadron resonance - $\Delta(1232)$ - isobar.

The excitation of this resonance takes place, for example, in $pp$ - collision at the intermediate energies (charge-exchange reaction $p + p \to n + \Delta^{++}$, fig. 3). There are two stable particles (protons) in the initial state and two unstable particles (neutron and $\Delta$ - isobar) in the final state. The neutron is decaying into proton, electron and electronic antineutrino. The $\Delta$ - isobar is decaying into proton and $\pi^+$ - meson. The cause of the neutron decay is the weak interaction. Due to it, the neutron lifetime is immeasurably longer than $\Delta^{++}$ - isobar lifetime. Therefore, in the framework of nuclear physics we can consider neutron as a stable particle.

We can consider $\Delta$ -isobar decay $\Delta^{++} \to p + \pi^+$ as a separate process, because the properties of this resonance do not depend on the way of its excitation. The $\Delta^{++}(1232)$ - isobar, created in a charge-exchange reaction $p(p,n)\Delta^{++}$, and decaying into proton and $\pi^+$ - meson (fig. 4), and $\Delta^{++}(1232)$ - isobar, created in $p\pi$ - elastic scattering ( $\pi^+ + p \to \Delta^{++} \to \pi^+ + p$, fig. 5) are the same resonances.

Invariance of the properties of hadron resonances concerning the excitation mechanism has led physicists to consensus of their status. Since Fermi's discovery of the $\Delta^{++}(1232)$ - isobar, all hadron resonances is considered as elementary particles.

Evident result of comparative analysis of diagrams fig. 3, 4 and 5 is the follows: the line on the corresponding diagram is external, or internal, depends on the conventional products of reactions with the hadron resonance participation.

If we calculate the $\Delta^{++}$ - isobar lifetime than the line ▬ on the diagram fig. 6 is external. If we calculate the shape of $\Delta$ - peak in the cross-section of the elastic $\pi^+ p$ - scattering or pion creation cross-section for $pp$ - collisions at the $\Delta^{++}$ - isobars excitation region, than the same line should be considered as internal. That is the basic idea for the neutroneum identification.

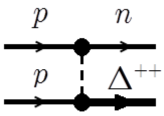


Fig. 3. Resonant charge-exchange reaction at $pp$ - collisions

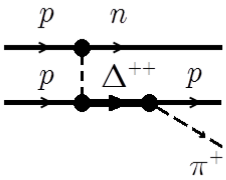


Fig. 4. Resonant pion creation at $pp$ - collisions

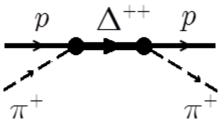


Fig. 5. Elastic $\pi^{+}p$ - scattering with the $\Delta$ - isobar excitation

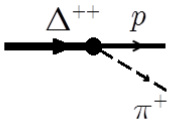


Fig. 6. Decay of the $\Delta^{++}$ - isobar

What is the difference between the perfectly studied neutron and hypothetical neutroneum? For better understanding we shall carry out the comparative analysis of the several diagrams.

According to cross-invariance of the Feynman diagrams, fig. 7 corresponds to a few different processes.

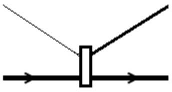


Fig. 7. Weak interaction of lepton and nucleon

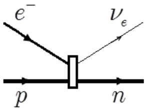


Fig. 8. Neutroneum creation at $ep$ - collision

It is evident, that the same lepton line on the diagram fig. 7 can be interpreted by different ways. For example, if initial state corresponds to the only neutron, than considered diagram should be interpreted, as process of it’s decay. In this case the thin line in the left part of the diagram (fig. 7) describes the process of electronic antineutrino emission: $\xleftarrow{\tilde{\nu}_e}$ and the medium (fat) thickness line in the right part of the diagram corresponds to electron (proton) emission.

If initial state (left part of the diagram, fig. 7) corresponds to a neutron and electronic neutrino (line $\xrightarrow{\nu_e}$), than we deal with $\nu_e + n \to e^{-} + p$ reaction. According to CPT-theorem and cross-invariance of Feynman diagrams, both amplitudes $A_{n\to p+e^{-}+\tilde{\nu}_e}$ and $A_{n+\nu_e\to p+e^{-}}$ has the similar analytical properties [12, 18]. Moreover, if absolute value of momentum for each particle (line) coincides, than $\left|A_{n\to p+e^{-}+\tilde{\nu}_e}\right| = \left|A_{n+\nu_e\to p+e^{-}}\right|$.

Let's consider the weak process $e^{-} + p \to \nu_e + n$. Evidentely, diagram fig. 8 of this process is $T$ - inverse diagram fig. 7, but a neutron creation reaction has a threshold.

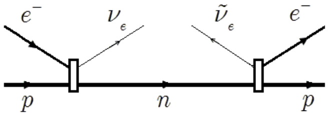


Fig. 9. Prolonged diagram of neutron creation reaction at $ep$ - collisions

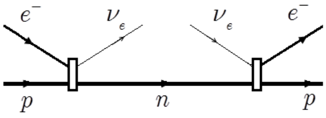


Fig. 10. Reaction $\nu_e + n \to e^{-} + p$, colliding particles are on the mass shell

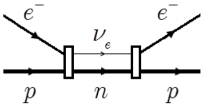


Fig. 11. Elastic $ep$ - scattering, off-shell effects

If ingoing electron energy is overthreshold, than the cross-section of the neutron creation is nonzero ($\sigma_{p+e^{-}\to n+\nu_e} \neq 0$). In this case, we can detect such products of $ep$ - collision, as neutron and neutrino.

The neutron is extremely long-lived particle, but this time is not infinite (mean life $\tau = 888.6 \pm 3.5\ s$ [14]). Therefore, diagram fig. 8 can be continued by the full analogy to the diagram fig. 3. The result of this prolongation is evident (fig. 9).

Direct comparison of fig. 9 and fig. 4 shows, that neutron creation reaction $e^- + p \rightarrow \nu_e + n$ is obvious electroweak analogue of hadron resonances excitation process. From the mathematical point of view, this analogy has a topological nature. Both internal lines (fig.4, fig. 9) must be interpreted as one-partical propagator ($\Delta$ - isobar and neutron, correspondently).

If the energy of incoming electron is overthreshold, than diagram fig. 9 represents $\hat{s}$ - process, i.e. real neutron creation. This neutron, as electroweak resonance, is extremely narrow due to its lifetime. Thus antineutrino emission takes place after the huge delay (neutron’s lifetime). At the underthresold energies region, the neutron is virtual, and this situation corresponds to instant $\nu_e \tilde{\nu}_e$ - pair creation at the quasielastic $ep$ - scattering. In both cases neutron play a role of exotic electroweak resonance.

Let's consider the most prominent aspect of the discussed problem.

According to CP- invariance of the weak interaction, we can replace outgoing antineutrino (fig. 9) by incoming neutrino (fig. 10). Due to the concept of virtual particles, we can "stick together" the broken neutrino line (diagram fig. 10, fig. 11). Therefore, the second-order weak interaction term in the elastic $ep$ - scattering amplitude (diagram fig. 11) one can represents as a sum of the $\hat{s}$ - and $\hat{r}$ - terms (fig. 2). The $\hat{s}$ - term corresponds to the pole in the two-partical neutron-neutrino’s propagator and we named it “neutroneum”.

As it is unequivocally follows from aforesaid, as far as neutron and neutroneum, are the exotic electroweak resonances. The only mathematical difference between neutron and neutroneum is very simple: the pole in the one-particle nucleon propagator corresponds to neutron, while the similar pole in the two-partical neutron-neutrino’s propagator corresponds to neutroneum. The physical difference between this particles rather seriously: neutron is fermion, while neutroneum is boson. Therefore the neutron-induced and neutroneum-induced nuclear reactions are the similar only in one sense: there is no Coulomb’s barrier penetration problem at the super-low energies.

**Conclusion**: as neutron, as neutroneum are resonances, and they are no stable bound states of its decay products. Thus, we have no restrictions on the Compton wavelength of neutrino, "sliped" in a two-partical neutron-neutrino’s propagator.

In the framework of our approach we will investigate the properties of a hypothetical resonance «neutroneum», designated as $n_\nu$. That is the aim of this work.

## 2. Main formalism

Effective Hamiltonian $h'(\vec{r})$ in the nucleon’s space looks like [2-7]:

$$h'(\vec{r}) = \frac{G}{\sqrt{2} \cdot L^3} \mathrm{e}^{i\vec{k}_e \cdot \vec{r}} \cdot \left[ i\tilde{f}_1 \cdot b_4 - \tilde{g}_1 \ \vec{b} \cdot \vec{\sigma}^N \ \right] \cdot \tau_+ \cdot \delta(\vec{r} - \vec{r}_n) + h.c.. \qquad (1)$$

where $G_\beta = \tilde{f}_1 \cdot G$, $G$ - a constant of the weak interaction, $L^3$ - normalization volume, and $\tilde{f}_1$, $\tilde{g}_1$ - formfactors, $\vec{\sigma}^N$ - is the Pauli matrix in the nucleon space. The hermite conjugated term in Hamiltonian (1) corresponds to well-known electron’s capture reaction. One can show that non-relativistic leptonic matrix elements are equal

$$b_4(\underline{m}_e, \underline{m}_\nu) \approx \delta_{j_\nu\,1/2} \left[ i g_{-1}(r)(4\pi)^{-1/2} \delta_{\underline{m}_e \underline{m}_\nu} + f_1(r) \sum_{m_l} C^{j_\nu \underline{m}_\nu}_{1 m_l\; 1/2 \underline{m}_e} Y_{1 m_l}(\vartheta_\nu, \varphi_\nu) \right]. \tag{2}$$

$$b_k(\underline{m}_e, \underline{m}_\nu) \approx \delta_{j_\nu\,1/2} \sqrt{3} \left[ g_{-1}(r)(4\pi)^{-1/2} C^{1/2\,\underline{m}_e}_{1k\;\, 1/2\,\underline{m}_\nu} - i f_1(r) \sum_{m_l, \sigma} C^{j_\nu \underline{m}_\nu}_{1 m_l\; 1/2 \sigma} C^{1/2\,\underline{m}_e}_{1k\;\, 1/2\,\sigma} Y_{1 m_l}(\vartheta_\nu, \varphi_\nu) \right]. \tag{3}$$

The designations of [2-7, 15-17] are used in this paper.

## 3. Neutroneum decay

Neutroneum’s decay describes by the Feynman diagram [18] (fig. 12).

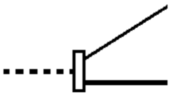


Fig. 12. Neutroneum’s decay

According to the «Fermi's golden rule», decaying probability looks like [17]:

$$dw_{fi} = \frac{2\pi}{\hbar} \cdot \delta(E_f - E_i) \cdot \left| \left\langle f \middle| V \middle| i \right\rangle \right|^2 dn_f. \tag{4}$$

Therefore, the probability of neutroneum decay is equal:

$$w_{n_\nu \to p + e^-} = \frac{2\pi}{\hbar} \int \frac{L^3 d\vec{p}_e}{(2\pi\hbar)^3} \cdot \frac{L^3 d\vec{p}_p}{(2\pi\hbar)^3} \cdot \delta(E_i - E_f) \cdot \left\langle \left| \int \left\langle H^* \middle| h'(\vec{r}') \middle| n_\nu \right\rangle d\vec{r}' \right|^2 \right\rangle. \tag{5}$$

Where the wavefunctions of the initial and the final states are

$$\begin{cases} \left| n_\nu \right\rangle = \left| \left| n \right\rangle \otimes \left| \nu_e \right\rangle \right\rangle_{j_{n_\nu} \underline{m}_{n_\nu}} \equiv \sum\limits_{\underline{m}_n, \underline{m}_\nu} C^{j_{n_\nu} \underline{m}_{n_\nu}}_{1/2\, \underline{m}_n\, 1/2\, \underline{m}_\nu} \left| n \right\rangle \otimes \left| \nu_e \right\rangle \\ \left| H^* \right\rangle \equiv \left| p \right\rangle \otimes \left| e^- \right\rangle \end{cases}. \tag{6}$$

External triangular brackets in (5) means averaging for spin projections $(\underline{m}_{n_\nu}, \underline{m}_p \ldots)$ of all particles in the initial state and summation in the final state. Proton (neutron) wave function is $|p\rangle$ ($|n\rangle$).

The final expression for the neutroneum decay probability is the follows:

$$w_{n_\nu \to p + e^-} = \frac{G_\beta^2 \cdot \left| \phi(j_{n_\nu}) \right|^2}{2\pi\hbar^4 V_{eff}^{n_\nu}} m_e \sqrt{2 m_e U_{n_\nu}} \cdot F_c(\eta). \tag{7}$$

The spin factor $\phi(j_{n_\nu})$ is equal: $\phi(0) = 1 + 3\lambda = 4.69$, $\phi(1) = 1 - \lambda = -0.23$. «Neutroneum’s effective volume» $V_{eff}^{n_\nu} = 4\pi / g_{-1}^2(0)$ [2-7]. The neutroneum internal energy $U_{n_\nu} > 0$ is

$$U_{n_\nu} = m_{n_\nu} c^2 - m_p c^2 - m_e c^2. \tag{8}$$

Fermi's factor $F_c(\eta)$ (7) takes into account the Coulomb field influence for the outgoing $\beta$-electron. Point-like approximation gives us [15]:

$$F_c(\eta) = \pi\eta \cdot \exp(\pi\eta) \cdot \mathrm{sh}^{-1}(\pi\eta), \tag{9}$$

The numerical results are presented in the Table 2. Neutroneum decay probability $w^0$ was calculated without Fermi-factor. Analogous value $w^c$ includes Fermi-factor. Neutroneum liftime is $\tau^{c}_{n_\nu} = 1/w^{c}_{n_\nu \to d+e^-}$. We use the values: $\lambda = 1.23$, «neutroneum's effective volume» $V^{n_\nu}_{eff} \approx 2.7\, fm^3$, corresponds to the proton's electromagnetic radius $r_0 = 0.86\ fm$ [15]. Denominator $V^{n_\nu}_{eff}$ is the free parameter of the theory. Its value should be corrected on the base of the new experimental data.

Table 2

Decays rates and lifetimes for the singlet ($n^{(s)}_\nu$) and triplet ($n^{(t)}_\nu$) exoatoms neutroneum

| $T_e\,[eV]$ | $w^{0}_{n^{(s)}_\nu \to p+e^-}$ | $w^{c}_{n^{(s)}_\nu \to p+e^-}$ | $\tau^{c}_{n^{(s)}_\nu}$ | $w^{0}_{n^{(t)}_\nu \to p+e^-}$ | $w^{c}_{n^{(t)}_\nu \to p+e^-}$ | $\tau^{c}_{n^{(t)}_\nu}$ |
|---|---|---|---|---|---|---|
| $10^2$ | $8.8 \cdot 10^3$ | $2.2 \cdot 10^4$ | $4.5 \cdot 10^{-5}$ | $2.2 \cdot 10^1$ | $5.4 \cdot 10^1$ | $1.8 \cdot 10^{-2}$ |
| $10^3$ | $2.7 \cdot 10^4$ | $3.8 \cdot 10^4$ | $2.8 \cdot 10^{-5}$ | $6.8 \cdot 10^1$ | $9.5 \cdot 10^1$ | $1.1 \cdot 10^{-2}$ |
| $10^4$ | $8.8 \cdot 10^4$ | $9.6 \cdot 10^4$ | $1.0 \cdot 10^{-5}$ | $2.2 \cdot 10^2$ | $2.4 \cdot 10^2$ | $4.2 \cdot 10^{-3}$ |

Table 2 shows, that neutroneums decay rate at the low energies increases due Coulomb factor in two or three times. At the energy $T_e \sim 1\ keV$ Coulomb's effects are small, and lifetime of the singlet neutroneum $\tau_{n^{(s)}_\nu}$ is of order

$$\tau_{n^{(s)}_\nu} \sim 4 \cdot 10^{-5}\ s. \qquad (10)$$

This time is one order longer, than muon lifetime
$\tau_\mu = (2.197019 \pm 0.000021) \cdot 10^{-6}\ s$ [14].

Experiments on electric explosion of the especially pure material foils in water were carried out [19]. A lot of new chemical elements were found and non-identified "strange" radiation was registered. The capacitors battery voltage, used for electroexplosions, was less, than $5\ kV$ [19]. This experiment supports the estimation (10), and permit us to evaluate the neutroneum creation threshold energy $\varepsilon_{tr} \sim 0.1 - 1\ keV$. Therefore, the neutroneum creation threshold energy is considerably lower, than a threshold of thermonuclear reactions $\sim 10\ keV$ [8, 9, 20].

This conclusion is fundamental. It means, that neutron-like particles can be created at the low energies, and, hence, induces the nuclear reactions, similar to reactions, induced by neutrons, when nuclear reactions with the charged particles are forbidden by the high Coulomb barrier.

## 4. Neutroneum creation

In an accordance of conservation laws and selection rules, hypothetical «neutroneum» can be created in $ep$- collisions, or in $eH$- collisions. Electron capture (i.e., reaction $e^- + p \to n_\nu$) is strictly forbidden by conservation laws.

At the underthreshold energies "neutroneum" is a virtual particle, and contribution of the weak interaction to the amplitude of the elastic $ep$- scattering ($e^- + p \to n_\nu \to e^- + p$) is negligible. This situation partially takes place just for the overthreshold energies. The cross-section $\sigma_{p+e^- \to n_{\nu_e} + X}$ of the inclusive reaction $p + e^- \to n_{\nu_e} + X$ is vanishing due to two important circumstances: 1) diagram 1h) corresponds to extremely narrow resonance ($\Gamma_{n_\nu} \leq 2.5 \cdot 10^{-11}\ eV$), which we cannot measure in the direct experiment on the $ep$ - scattering; 2) if $X = \gamma$, than cross-section $\sigma_{p+e^- \to n_{\nu_e} + \gamma}$ is suppressed by additional small parameter - thin-structure constant $\alpha$. The exception of this common rule – solid state processes, when $X = phonon$, but the analysis of such processes is out of the aim of this paper.

Let's consider continuous spectrum electron capture by the hydrogen atom

$$H(e,e')n_\nu \,. \tag{11}$$

According to the main idea, illustrated by fig. 2, we can consider full contribution of the weak interaction into cross-sections of $eH$ - scattering and reactions, as a sum of the $\hat{r}$ - term and $\hat{s}$ - term (fig. 13, 14).

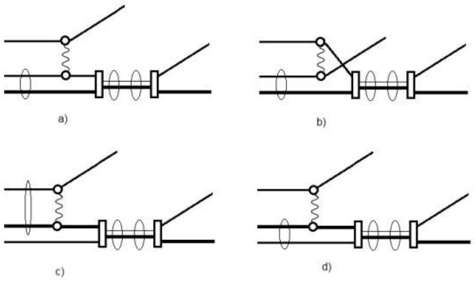


Fig. 13. The regular contribution of weak interaction to ionisation amplitude of the hydrogen atom

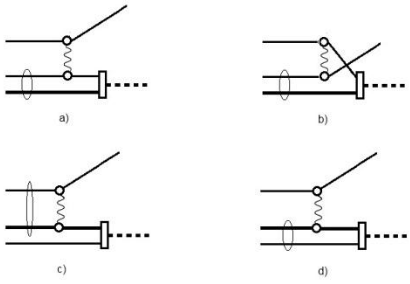
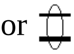


Fig. 14. The contribution of weak interaction to amplitude of reaction of the neutroneum creation

Singularities position of the neutroneum propagator on the complex energies plane is unknown. The nature of this problem - nonperturbative effects in the framework of the Standard Model (SM) at the superlow energies. But according to a very trustfull estimation $\varepsilon_{tr} \sim 0.1 - 1\ keV$, the two-particle neutron-neutrino's has a pole, correspondent to neutroneum mass $m_{n_\nu} = m_p + m_e + U_{n_\nu} c^{-2} < m_n$.

To calculate the cross-section of the electron capture (11) at the neutroneum excitation region, we have to take into account three-body effects. The third particle at the collision of the electron and the hydrogen atom play a role of the catastrophical amplifier of the neutroneum creation cross-section. In the framework of the three-body problem we have to integrate the two-particle propagator  of the electron and proton (i.e., excited hydrogen) over the virtual states. This convolution gives us enormous amplification ($\sim 10^{14}$) not only for the total cross-section, but also for the width of the resonance, and its properties can be investigated experimentally.

According to (8) and evident inequality $m_p \gg m_e$ the neutroneum creation threshold:

$$\varepsilon_{tr} \approx U_{n_\nu} + \varepsilon_H \,. \tag{12}$$

where $\varepsilon_H = 13.6\ eV$ - electron's binding energy for the hydrogen atom.

Neutroneum creation cross-section looks like:

$$\sigma_{H(e,e')n_\nu} = \frac{2\pi L^3}{\hbar v_e} \int dn_f \delta(E_i - E_f) \left\langle \left| \hat{s} \int dn_v \frac{\int d\vec{r}' \left\langle n_\nu \middle| h'(\vec{r}') \middle| H^* \right\rangle \cdot \left\langle e' \otimes H^* \middle| V_c \middle| e \otimes H \right\rangle}{E_i - E_v + i0} \right|^2 \right\rangle . \tag{13}$$

where $v_e$ - ingoing electron's velocity in the proton's rest frame, $dn_f$ ($dn_v$) - final (virtual) states density. Projection operator $\hat{s}$ takes into account only pole contribution into neutroneum creation cross-section $\sigma_{H(e,e')n_\nu}$.

Potential $V_c$ (photon propagator line between two electromagnetic vertexes, fig. 13, fig. 14) is equal to Coulomb potential

$$V_c(\vec{r}_p, \vec{r}_{e_1}, \vec{r}_{e_2}) = \frac{e^2}{\left|\vec{r}_e - \vec{r}_{e'}\right|} - \frac{e^2}{\left|\vec{r}_p - \vec{r}_e\right|}. \qquad (14)$$

Let's consider neutroneum creation at the $eH$ - collision (electron's energy $\sim 10^2 - 10^3\ eV$). The differential and total cross-sections of the $H(e,e')n_\nu$ reaction are equal [2-7]:

$$\frac{d\sigma_{H(e,e')n_\nu}}{d\Omega_{n_\nu}} = \sigma^{(0)}_{H(e,e')n_\nu} \cdot \sqrt{\xi^2_{n_\nu} - \xi^2_{\hat{n}_\nu}} \cdot \sum_{+,-} \left\{ F_c^2(\eta^{(\pm)}) (x^{(\pm)}_{n_\nu})^2 \left|\Phi(x^{(\pm)}_{n_\nu})\right|^2 \right\}, \qquad (15)$$

where

$$\sigma^{(0)}_{H(e,e')n_\nu} = 2\tilde{\phi}^2(j_{n_\nu}) \frac{G_\beta^2 \cdot \varepsilon_e^2}{\pi(\hbar c)^4} \frac{a_B^3}{V_{eff}^{n_\nu}}. \qquad (16)$$

Here: $\tilde{\phi}(j_{n_\nu}) = \sqrt{2j_{n_\nu} + 1} \cdot \phi(j_{n_\nu})$ - spin factor, $a_B$ - Bohr radius, $\varepsilon_e = m_e c^2$ - electron mass, $\xi_{n_\nu}$ - cosine of the neutroneum momentum angle, $\xi_{\hat{n}_\nu}$ - a boundary cosine of the angle of outcoming neutroneum, $\eta^{(\pm)} = (x^{(\pm)}_{n_\nu})^{-1}$ - Coulomb parametre. If $V_{eff}^{n_\nu} \approx 2.7\, fm^3$ than

$$\sigma^{(0)}_{H(e,e')n_\nu} = 2\ \mu barn. \qquad (17)$$

The dimensionless momentum $x^{(\pm)}_{n_\nu}$ depends on the incoming electron energy and the angle of the neutroneum momentum:

$$x^{(\pm)}_{n_\nu} = x_e \cdot \left[\xi_{n_\nu} \pm \sqrt{\xi^2_{n_\nu} - \xi^2_{\hat{n}_\nu}}\right], \qquad (18)$$

where $\vec{x}_e = \vec{k}_e a_B$, $\vec{k}_e$ - wave vector of the incoming electron, and $\Phi(x^{(\pm)}_{n_\nu})$ - formfactor.

The energy dependence of the total cross-section of the neutroneum creation is resonant (see below, fig. 15, fig. 16).

Fig. 15, 16 demonstrate us that the resonance shape essentially differs from Breit-Wigner, and almost $\varepsilon_{tr}$ - independent. The resonance width at semiheight are between $1 \le \Gamma_{H(e,e')n_\nu} \le 6\ keV$, therefore $\Gamma_{H(e,e')n_\nu} / \Gamma_{n_\nu} \sim 10^{14} \gg 1$.

At $\varepsilon_{tr} \sim 0.1\ keV$ the cross-section at the vicinity of the resonance peak is of order

$$\left[\sigma^{tot}_{H(e,e')n_\nu}\right]_{max} \sim 0.1\ \mu barn\ . \qquad (19)$$

Due to increasing the threshold energy up to the $\varepsilon_{tr} \sim 1\ keV$, the maximum value of the cross-section of the neutroneum creation catastrophically decreases under the law, slightly different from the sedate $\left[\sigma^{tot}_{H(e,e')n_\nu}\right]_{max} \sim \varepsilon_{tr}^{-6}$, down to the value $\left[\sigma^{tot}_{H(e,e')n_\nu}\right]_{max} \sim 6 \cdot 10^{-6}\ \mu barn$.

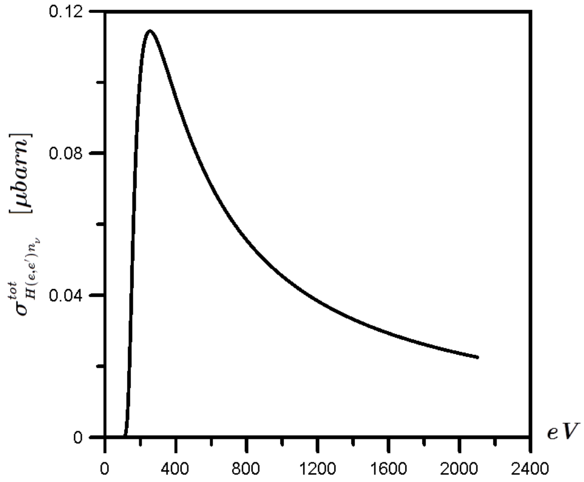


Fig. 15. Energy dependence of the total cross-section of the neutroneum creation. Threshold energy $\varepsilon_{tr} = 100\ eV$

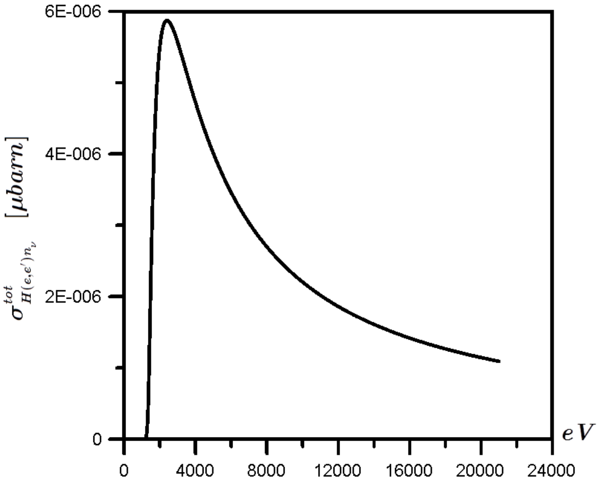


Fig. 16. Energy dependence of the total cross-section of the neutroneum creation. Threshold energy $\varepsilon_{tr} = 1000\ eV$

## 5. Theoretical predictions

There are no any bans for such "forbidden" processes as:

1) emulation of DD - fusion in low-energy experiments [21]

$$\begin{cases} D_\nu + d \to t_\nu(1MeV) + p(3MeV); & t_\nu \to t + e^- \\ D_\nu + d \to {}^3_2He_\nu(0.82MeV) + n(2.45MeV); & {}^3_2He_\nu \to {}^3_2He + e^- \end{cases}. \tag{20}$$

2) deuterium creation not only in the known reaction of Bethe $p + p \to d + e^+ + \nu_e$, but also in the chain of reactions, which beginning from creation of exoatom «deutroneum» ($d_\nu$) – bound state of proton and neutroneum. "Deutroneum" is a product of radiative capture reaction: $n_\nu + p \to d_\nu + \gamma$, $\varepsilon_\gamma \sim 300 - 400 keV$ (see [8]). The energy of $\gamma$ - quanta is commensurable with $\varepsilon_e = m_e c^2$, therefore «deutroneum» mass more than the deuteron mass, but less than a sum of masses of two protons and electron. Therefore only decay channel $d_\nu \to d + \nu_e$ is opened, but the decay channel $d_\nu \to 2p + e^-$ is closed. Unlike of Bethe cycle, this reaction is not accompanied by positron creation, and neutroneum creation cross-section at least of 8 orders more than cross-section of Bethe reaction.

3) tritium creation without neutrons emission

$$D_\nu + p \to t + \nu_e. \tag{21}$$

Therefore the abnormal ratio tritium/neutrons $(t / n \gg 1)$ at tritium creation at the electrolisys should be observed [22].

4) helium creation without $\gamma$ - quanta emission [23]:

$$D_\nu + d \to \alpha + e^-. \tag{22}$$

5) short-lived isotopes creation at ultralow energies [24]:

$$D_\nu + {}^{108}_{46}Pd \to n_\nu + {}^{109}_{46}Pd; \qquad n_\nu \to p + e^-. \tag{23}$$

6) high-energy $\alpha$ - particles emission by deuterated metalls under the electron beam or X- ray beam bombarding [25]. For example

$$D_\nu + {}^6_3Li \rightarrow {}^4_2He_\nu + {}^4_2He + 23.802\ MeV; \quad E_\alpha \approx 11.9\ MeV. \tag{24}$$

7) nonexponential law of the radioactive decay for nuclei of the heavy hydrogen-like ions which are decaying due to the orbital electron capture [26].

The theory of exotic electroweak processes based on the well-known physical lows explains all available experimental data on CF and LENR. Thus to verify this theory we have to reproduce at least one of the experiments [21-26]. Independent groups of highly qualified researchers have to carry out this "experimentum crucis" in the best nuclear centers. The aim of this experiment will be precision measurements of the free parameters: threshold $\varepsilon_{tr}$ and «neutroneum effective volume» $V_{eff}^{n_\nu}$.

### Summary

We can summarize the aforesaid as follows.

1. It is proved that as neutron, as neutroneum are the exotic electroweak resonances.
2. Neutroneum exists due to CPT- theorem and Feynman's diagrams crossing-symmetry and we can consider this resonance as quasi-bound (not bound) state of neutron and neutrino in an accordance to Zahariev's theorem [7, 27].
3. The hypothetical elementary particle «neutroneum» is neutral.
4. Neutroneum is boson. Its spin is $s_{n_\nu} = 0$ (may be, $s_{n_\nu} = 1$).
5. Neutroneum isospin $T_{n_\nu} = 1/2, \quad (T_{n_\nu})_z = -1/2$.
6. Barion and lepton quantum numbers of the neutroneum are unity ($B = L_e = 1$).
7. The neutroneum lifetime is of order $\tau_{n_\nu} \sim 4 \cdot 10^{-5}\, s$.
8. The neutroneum mass is $m_{n_\nu} c^2 = m_p c^2 + m_e c^2 + U_{n_\nu} \lesssim 938.788\ MeV$.
9. The neutroneum width is $\Gamma_{n_\nu} \lesssim 2.5 \cdot 10^{-11}\ eV$ (we suppose $V_{eff}^{n_\nu} \approx 2.7\, fm^3$).
10. The upper limit of the cross-section of the neutroneum creation is $\sigma^{max}_{H(e,e')n_\nu} \sim 0.1\ \mu barn$.
11. The threshold of the neutroneum creation reaction is about $\varepsilon_{tr} \sim 0.1 - 1\ keV$. Thus the energy of the neutroneum creation threshold is considerably smaller than the threshold energy of the thermonuclear reactions. It means that neutron-like nuclear-active particles can be created at the ultralow energies, and, hence, to be a cause of the nuclear reactions similar to reactions, caused by neutrons, in all cases, when nuclear reactions with the charged particles are forbidden by a high Coulomb barrier.
12. Weak interaction can be a cause of the long-time (in compare to a nuclear time) neutralisation of a charge of a proton, and, thus, to play a role of the «neutrinous catalyst» of the nuclear reactions at ultralow energies.
13. The qualitative explanation of the results of the Kurchatov's experiments is offered.
14. A lot of "experimentum crucis" are proposed.

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