

## **An exotic long-live particle “neutroneum”**

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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 creation of the neutroneum – the two-particle propagator of the electron and proton (excited hydrogen) is under the integral. Therefore the width of the resonance in the cross-section of the neutroneum creation in the electron-hydrogen collision is by eleven orders more than the width of a 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.

## Overview of the electron-proton scattering problem

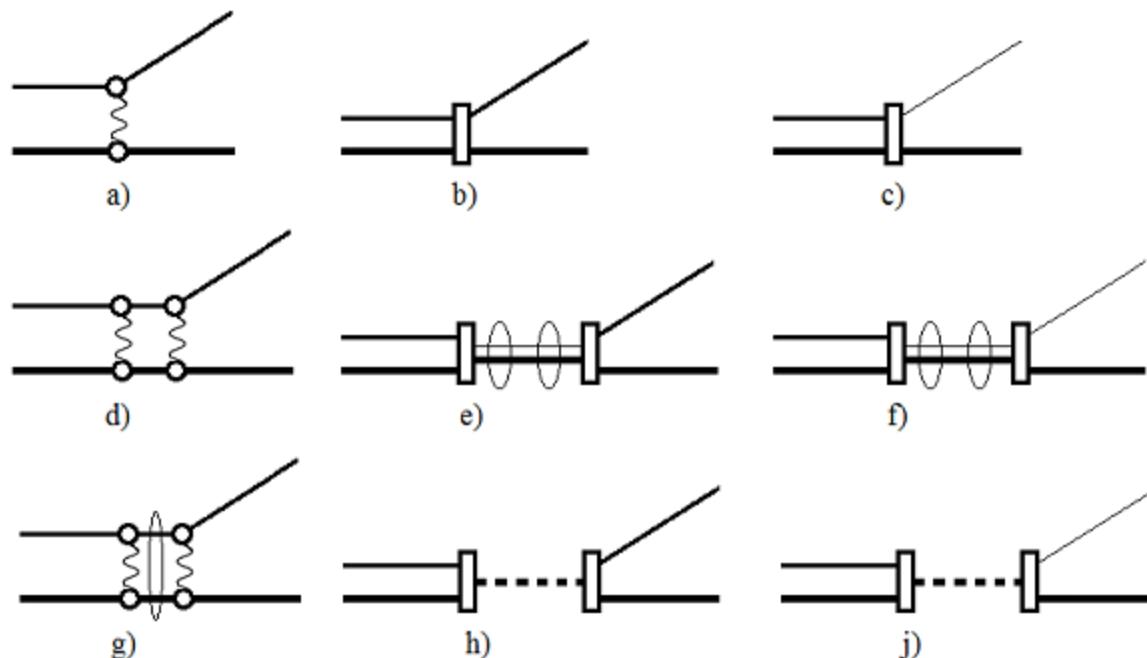
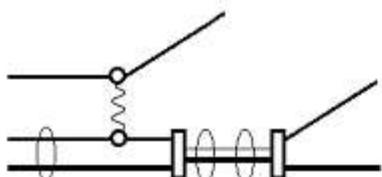
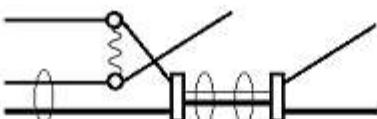


Fig.1. Weak interaction contribution (column 2 and 3).

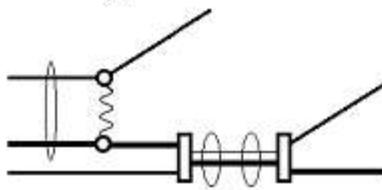
### Three body problem. Weak interaction contribution.



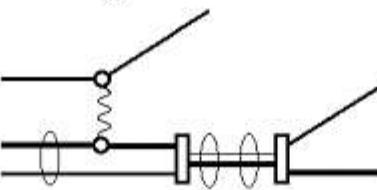
a)



b)

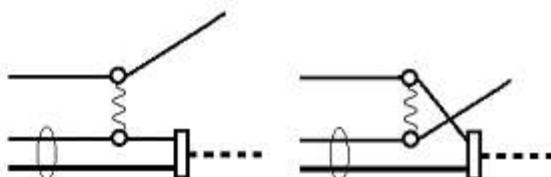


c)

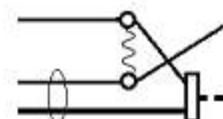


d)

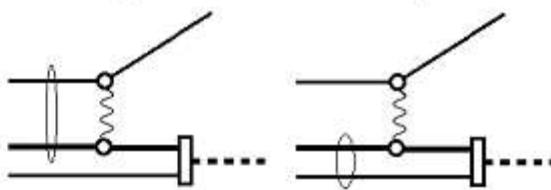
Fig.2. Elastic eH- scattering.



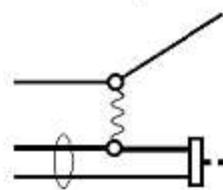
a)



b)



c)



d)

Fig.3. Neutrino creation.

### Standard model of electroweak interaction

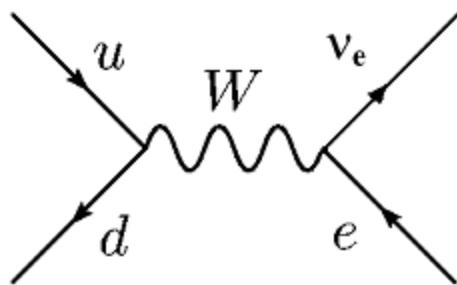


Fig. 4. Neutroneum creation.

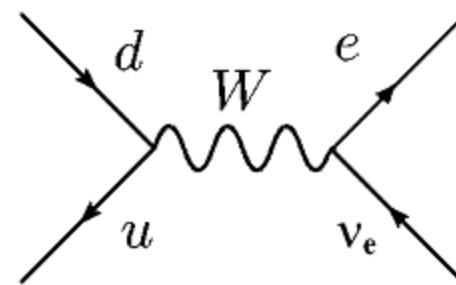


Fig. 5. Neutron and neutroneum decay.

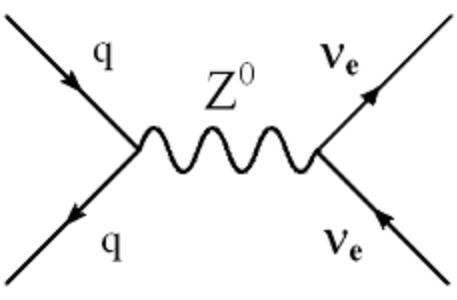


Fig. 6. Quark-neutrino interaction.

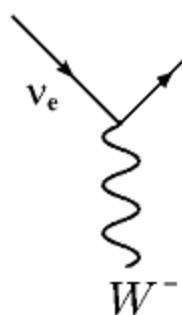


Fig. 7. Neutrino-electron transition.

## Uncertainty principle

$$\delta x \stackrel{\text{def}}{=} \sqrt{(x - \bar{x})^2} \quad \delta p_e \stackrel{\text{def}}{=} \sqrt{(p_e - \bar{p}_e)^2} \quad (5.1)$$

$$0 < \int_{-\infty}^{\infty} \left| \alpha x \psi + \frac{d\psi}{dx} \right|^2 dx < \infty \quad (5.2)$$

$$0 < \int_{-\infty}^{\infty} x^2 |\psi|^2 dx = (\delta x)^2 < \infty \quad (5.3)$$

$$0 < \int_{-\infty}^{\infty} \frac{d\psi^*}{dx} \frac{d\psi}{dx} dx = - \int_{-\infty}^{\infty} \psi^* \frac{d^2\psi}{dx^2} dx = \frac{1}{\hbar^2} \int_{-\infty}^{\infty} \psi^* p_e^2 \psi dx = \frac{1}{\hbar^2} (\delta p_e)^2 < \infty \quad (5.4)$$

$$\alpha^2 (\delta x)^2 - \alpha + \frac{1}{\hbar^2} (\delta p_e)^2 \geq 0 \quad (5.5)$$

$$\delta x \delta p_e \geq \hbar / 2 \quad (5.6)$$

## Relativistic theory [8]:

$$\delta p_e \sim p_e \sim \hbar / \lambda_C, \quad \delta x \delta p_e \geq \hbar / 2 \Rightarrow \delta x \hbar / \lambda_C > \hbar \Rightarrow \delta x > \lambda_C \quad (5.7)$$

## Rectangle potential $U(r)$ .

Table 1

One-dimensional S.e.	Two-dimensional S.e.	Three-dimensional S.e.
$\frac{d^2 u}{dx^2} + \frac{2m}{\hbar^2} (E - U(x)) u = 0$	$\frac{1}{r} \frac{d}{dr} \left( r \frac{d\psi}{dr} \right) + \frac{2m}{\hbar^2} (E - U(r)) \psi = 0$	$\frac{1}{r^2} \frac{d}{dr} \left( r^2 \frac{d\psi}{dr} \right) + \frac{2m}{\hbar^2} (E - U(r)) \psi = 0$
$\begin{cases} u(x) = A \cos Kx &  x  \leq a/2 \\ u(x) = \exp(-\kappa x) &  x  > a/2 \end{cases}$	$\begin{cases} \psi(r) = A J_0(Kr) & r \leq a \\ \psi(r) = H_0^{(1)}(i\kappa r) & r > a \end{cases}$	$\begin{cases} u(r) = A \sin Kr & r \leq a \\ u(r) = \exp(-\kappa r) & r > a \end{cases}; \psi = \frac{u}{r}$
$\kappa = K \cdot \operatorname{tg}(Ka/2)$	$[a \ln(\kappa a)]^{-1} \approx -K^2 a/2$	$K \cdot \operatorname{ctg} Ka = -\kappa$
$E \approx -\frac{ma^2}{2\hbar^2} U_0^2$	$E = -\frac{\hbar^2}{ma^2} \exp\left[-\frac{2\hbar^2}{ma^2 U_0}\right]$	$K_0 a > \frac{\pi}{2} \Rightarrow U_{0\min} = \frac{\pi^2 \hbar^2}{8ma^2}$
$\delta p_z = \hbar K, \delta x_w \delta p_z \ll \hbar, \delta x_w = a$ $\delta x_z \delta p_z \geq \hbar/2, w \equiv \text{wall}, e \equiv \text{exact}$	$\delta p_z = \hbar K, \delta x_w \delta p_z \ll \hbar, \delta x_w = a$ $\delta x_z \delta p_z \geq \hbar/2, w \equiv \text{wall}, e \equiv \text{exact}$	$\delta x_w \delta p_z \geq \pi \hbar/2 > \hbar/2$

S.e. – Schrodinger equation.

$$\kappa^2 = -\frac{2m}{\hbar^2} E, \quad K_0^2 = \frac{2m}{\hbar^2} U_0, \quad K^2 = \frac{2m}{\hbar^2} (E + U_0)$$

## Coupled channels. Optical model. $\text{Re } E > 0$ .

$$\frac{d^2 u}{dr^2} + \frac{2m}{\hbar^2} (E - U(r) - iW(r)) u = 0 \quad (7.1)$$

$$\begin{cases} U(r) = -U_0 & r \leq a \\ U(r) = 0 & r > a \end{cases} \quad \begin{cases} W(r) = -W_0 & r \leq a \\ W(r) = 0 & r > a \end{cases} \quad (7.2)$$

$$E = E_0 - i\Gamma / 2 \quad (7.3)$$

$$\begin{cases} u(r) = A \sin Kr & r \leq a \\ u(r) = \exp(ikr) & r > a \end{cases} \quad (7.4)$$

$$\begin{cases} k^2 = \frac{2m}{\hbar^2} E \\ K^2 = \frac{2m}{\hbar^2} (E + U_0 + iW_0) \end{cases} \quad (7.5)$$

$$\begin{cases} k^2 \equiv (k_1 + ik_2)^2 = \frac{2m}{\hbar^2} (E - i\Gamma / 2) \\ k_1^2 + 2ik_1 k_2 - k_2^2 = \varepsilon - i\gamma \\ k_1 > 0, k_2 < 0, |k_1| > |k_2| \end{cases} \quad (7.6)$$

$$K \cdot \cot \theta = ik \quad (7.7)$$

$$K_0 a \approx \pi / 2, \quad K_0 \equiv \sqrt{\frac{2m}{\hbar^2} U_0}. \quad \text{If } \text{Re } E > 0, \quad \Gamma \approx \frac{2\hbar^2}{mR^2} k_0 a, \quad k_0 \equiv \sqrt{\frac{2m}{\hbar^2} E_0} \quad (7.8)$$

**Quasi-stationary quasi-bound state.  $\text{Re } E < 0$ .**

$$\begin{cases} k^2 \equiv (k_1 + ik_2)^2 = \frac{2m}{\hbar^2} (E - i\Gamma / 2) \\ k_1^2 + 2ik_1k_2 - k_2^2 = \varepsilon - i\gamma \\ k_1 > 0, k_2 < 0, |k_2| > |k_1| \end{cases} \quad (8.1)$$

$$j = \frac{\hbar \text{Re } k}{m} \exp(-2 \text{Im } kr) \quad (8.2)$$

$$\text{Im } k < 0 \quad (8.3)$$

The wavefunction of so state is non-localized in the potential.

$$(n + \nu)_{\text{bound}} \equiv n_\nu \rightarrow p + e^- \quad (8.4)$$

**There are no restriction  $\lambda_c^{(\nu)} < r_0 \approx 0.86 \text{ fm}$ .**

### Quasi-bound neutrino. Central potential.

$$\hat{H}\psi(\vec{r}) = \hbar c \left[ -i\vec{\alpha} \cdot \nabla + \frac{V(r)}{\hbar c} + \beta \frac{m_\nu c}{\hbar} \right] \psi(\vec{r}) = E\psi(\vec{r}). \quad (9.1)$$

$$\begin{cases} \frac{\partial g_k(r)}{\partial r} + \frac{1+k}{r} g_k(r) = \frac{1}{\hbar c} (E - V(r) + m_\nu c^2) f_{-k}(r) \\ \frac{\partial f_{-k}(r)}{\partial r} + \frac{1-k}{r} f_{-k}(r) = -\frac{1}{\hbar c} (E - V(r) - m_\nu c^2) g_k(r) \end{cases} \quad (9.2)$$

$$\int_0^\infty dr r^2 (f^2(r) + g^2(r)) = 1 \quad (9.3)$$

$$\begin{cases} g_{-1}(a) = B_g \\ f_1(a) = B_f \end{cases} \quad (9.4)$$

$$E_n = -V_0 + \sqrt{\hbar^2 c^2 a^{-2} (\delta \pm \pi n)^2 + m_\nu^2 c^4} \quad (9.5)$$

$$E_0 = -V_0 + \sqrt{\hbar^2 c^2 a^{-2} \delta^2 + m_\nu^2 c^4} \quad (9.6)$$

## Theory of the exotic electroweak processes

$$H' = \frac{G}{\sqrt{2}} \int J^{\lambda+}(r) \cdot \hat{G}(\vec{r}, \vec{r}') \cdot J_{\lambda}(\vec{r}') d\vec{r} d\vec{r}' \quad (1)$$

$$w_{n_\nu \rightarrow p + e^-} = \frac{2\pi}{\hbar} \int \frac{L^3 d\vec{p}_e}{(2\pi\hbar)^3} \cdot \frac{L^3 d\vec{p}_p}{(2\pi\hbar)^3} \cdot \delta(E_i - E_f) \cdot \left\langle \left| \int \overline{\langle p | h''(\vec{r}') | n \rangle} d\vec{r}' \right|^2 \right\rangle \quad (2)$$

$$h''(\vec{r}) = \frac{G_\beta}{\sqrt{2} \cdot L^{3/2}} \cdot e^{-i\epsilon r} \cdot \sum_{\mu=+,-} \left[ i\hat{b}_4 - \lambda \cdot (\hat{\vec{b}} \cdot \vec{\sigma}_N) \right]_\mu \cdot \tau_+ \cdot \delta(\vec{r} - \vec{r}_{n_\nu}) + h.c. \quad (3)$$

$$w_{n_\nu \rightarrow p + e^-} = \frac{G_\beta^2 \cdot |\phi(j_{n_\nu})|^2}{2\pi\hbar^4 V_{eff}^{n_\nu}} m_e \sqrt{2m_e U_{n_\nu}} \cdot F(\eta) \quad (4)$$

$$\sigma_{H(e,e')n_\nu}^{tot} (T_e) = \frac{G_\beta^2 |\tilde{\phi}(j_{n_\nu})|^2}{32\pi^2 \hbar^4 v_e V_{eff}^{n_\nu}} \cdot \int \Phi(\vec{p}_e, \vec{p}_{n_\nu}) d\Omega_{n_\nu} \quad (5)$$

## Main processes and numerical results [1-5]

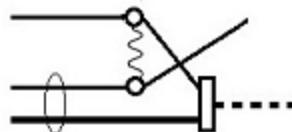
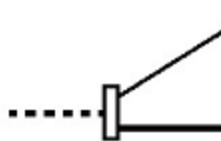


Fig. 8. Neutroneum  $\beta$ -decay. Fig. 9. Neutroneum creation.

**Table 2. Energy dependence of the neutroneum lifetime**

$T_e [eV]$	$w^0_{n_\nu \rightarrow p + e^-}$	$w^e_{n_\nu \rightarrow p + e^-}$	$\tau^e_{n_\nu}$
$10^2$	$8.8 \cdot 10^3$	$2.2 \cdot 10^4$	$4.5 \cdot 10^{-5}$
$10^3$	$2.7 \cdot 10^4$	$3.8 \cdot 10^4$	$2.8 \cdot 10^{-5}$
$10^4$	$8.8 \cdot 10^4$	$9.6 \cdot 10^4$	$1.0 \cdot 10^{-5}$

### Neutroneum creation cross-section at the maximum of the resonance

$$\sigma_{H(e,e')n_\nu}^{max} \sim 0.1 - 0.7 \text{ } \mu\text{barn}, \quad T_e^{thresh} \sim 0.5 - 5 \text{ keV}, \quad 3 \leq \Gamma_{H(e,e')n_\nu} \leq 6 \text{ eV}$$

## Nuclear reactions

$$\tau_s \ll \tau_{em} \ll \tau_w \Rightarrow n_\nu + {}_Z^A X \rightarrow \left( \frac{{}^A_1 X_1}{Z_1} \right)_\nu + \frac{{}^A_2 X_2}{Z_2} \quad (12.1)$$

*Conclusion. There are no neutrons.*

## EXPERIMENT

### 1. dd- fusion

$$\begin{cases} D_\nu + d \rightarrow t_\nu (1 \text{ MeV}) + p (3 \text{ MeV}); & t_\nu \rightarrow t + e^- \\ D_\nu + d \rightarrow {}_2^3 He_\nu (0.82 \text{ MeV}) + n (2.45 \text{ MeV}); & {}_2^3 He_\nu \rightarrow {}_2^3 He + e^- \end{cases} \quad (12.2)$$

### 2. Tritium production

$$D_\nu + p \rightarrow t + \nu_e, \quad t / n \gg 1 \quad (12.3)$$

### 3. Anomalous helium production

$$D_\nu + d \rightarrow \alpha + e^- \quad (12.4)$$

### 4. Unstable isotopes of heavy elements production at extremely low energies

$$D_\nu + {}_{46}^{108} Pd \rightarrow n_\nu + {}_{46}^{109} Pd; \quad n_\nu \rightarrow p + e^- \quad (12.5)$$

All of these reactions were observed in the experiments [13-18].

## Conclusions

1. The existence of the neutroneum is not forbidden by known physical laws.
2. Neutroneum charge is equal zero.
3. Neutroneum is boson ( $s_{n_\nu} = 0$ ).
4. Neutroneum has a half-integer isospin  $T_{n_\nu} = 1/2$ ,  $(T_{n_\nu})_z = -1/2$ .
5. Barion and lepton quantum numbers of the neutroneum are non-zero ( $B = L_e = 1$ ).
6. Neutroneum lifetime  $\tau_{n_\nu} \sim 10^{-5} s$ .
7. Neutroneum mass  $m_{n_\nu} c^2 = m_p c^2 + m_e c^2 + U_{n_\nu} \lesssim 938.788 \text{ MeV}$ .
8. Neutroneum width  $\Gamma_{n_\nu} \lesssim 2.5 \cdot 10^{-11} \text{ eV}$ .
9. At the maximum of the resonance  $\sigma_{H(e,e')n_\nu}^{max} \sim 0.1 - 0.7 \text{ } \mu\text{barn}$ .
10. The threshold of the neutroneum creation  $\varepsilon_{tr} \sim (0.5 \div 5) \cdot 10^3 \text{ eV}$ .
11. Resonance energy of the  $H(e, e')n_\nu$  reaction  $3 - 6 \text{ eV}$  above  $\varepsilon_{tr}$ .
12. Three-body resonance width of the  $H(e, e')n_\nu$  reaction is  $3 \leq \Gamma_{H(s,s')n_\nu} \leq 6 \text{ eV}$ .

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Thank You for attention.