Differential intensities of $2\nu 2\beta$-transitions in ^{100}Mo

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$$(A,Z) \rightarrow (A,Z+2) + 2e^{-} + 2\bar{\nu}$$

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$$\left[T_{1/2}^{0\nu2\beta}\right]^{-1} = G^{(0\nu)} \cdot \left|M^{0\nu2\beta}\right|^{2} \cdot \left(\frac{\langle m_{\nu} \rangle}{m_{e}}\right)^{2}$$

^{76}Ge Heidelberg-Moscow $T_{1/2}^{0\nu2\beta} \geq 1.9 \cdot 10^{25}\, yr$

^{100}Mo NEMO-3 $T_{1/2}^{0\nu2\beta} \geq 1.1 \cdot 10^{24}\, yr$

^{116}Cd KINR, Solotvina $T_{1/2}^{0\nu2\beta} \geq 2.6 \cdot 10^{23}\, yr$

^{136}Xe EXO $T_{1/2}^{2\nu2\beta} = 2.1 \cdot 10^{21}\, yr$

KamLAND-Zen $T_{1/2}^{0\nu2\beta} \geq 5.7 \cdot 10^{24}\, yr$

^{130}Te CUORICINO $T_{1/2}^{0\nu2\beta} \geq 3 \cdot 10^{24}\, yr$

natural tellurium

Baksan Neutrino Observatory

$2\beta^+(0\nu+2\ \nu)$, $EC\beta^+(0\nu+2\ \nu)$, ECEC(0ν)

в ^{78}Kr

$$T_{1/2}(2K,2\nu)=1.4^{+2.3}_{-0.7}\cdot 10^{22}\ \ yr$$

Ю.М. Гаврилюк, А.М. Гангапшев,

Д.А. Жантудуева *et al*, ЯФ, 76, 1123

Phys. Rev. C87, 035501; ЭЧАЯ, 46, 147 (2015);

$$^{100}Mo \rightarrow {}^{100}Ru + 2e^-$$

$$T_{1/2}^{0\nu} = \frac{1}{G^{0\nu} g_A^4 \left| M^{0\nu} \right|^2 \frac{\left| m_{\beta\beta} \right|^2}{m_e^2}}$$

$$T_{1/2}^{0\nu} > 1.1 \cdot 10^{24} \text{ лет}$$

NEMO-3, Phys. Rev. D 92, 072011(2015)

$$^{100}Mo \rightarrow ^{100}Ru + \; 2e^{-} \; + 2\bar{\nu}_e$$

$$T_{1/2}^{2\nu} = [7.1 \pm 0.37(stat) \pm 0.66(syst)] \cdot 10^{18} \quad \text{лет}$$

NEMO-3, J. Phys. G 41, 075204(2014)

$$\left[t_{1/2}^{2\nu 2\beta}\left(0^{+} \rightarrow 0_{f}^{+}\right)\right]^{-1} = \frac{G_{\beta}^{4} g_{A}^{4}}{32\pi^{7} \ln 2} \int_{m_e}^{T+m_e} d\varepsilon_1 \int_{m_e}^{T+2m_e-\varepsilon_1} d\varepsilon_2 \int_{0}^{T+2m_e-\varepsilon_1-\varepsilon_2} d\omega_1 \times$$

$$\times F(Z_f, \varepsilon_1) F(Z_f, \varepsilon_2) p_1 \varepsilon_1 p_2 \varepsilon_2 \omega_1^2 \omega_2^2 A_{0_f^+}$$

$$4\mathrm{A}_{0_f^+} = \left| \sum_N \left\langle 0_f^+ \left\| \hat{\beta}^- \right\| 1_N^+ \right\rangle \left\langle 1_N^+ \left\| \hat{\beta}^- \right\| 0_i^+ \right\rangle (K_N + L_N) \right|^2 + \frac{1}{3} \left| \sum_N \left\langle 0_f^+ \left\| \hat{\beta}^- \right\| 1_N^+ \right\rangle \left\langle 1_N^+ \left\| \hat{\beta}^- \right\| 0_i^+ \right\rangle (K_N - L_N) \right|^2$$

$$K_N = \frac{1}{\mu_N + (\varepsilon_1 + \omega_1 - \varepsilon_2 - \omega_2)/2} + \frac{1}{\mu_N - (\varepsilon_1 + \omega_1 - \varepsilon_2 - \omega_2)/2}$$

$$L_N = \frac{1}{\mu_N + (\varepsilon_1 + \omega_2 - \varepsilon_2 - \omega_1)/2} + \frac{1}{\mu_N - (\varepsilon_1 + \omega_2 - \varepsilon_2 - \omega_1)/2}$$

$$\mu_N = E_N - (E_i + E_f)/2,$$

$$M_1^I = \left\langle 1^+_{g.s.} \left\| \widehat{\beta}^- \right\| 0_i \right\rangle = \frac{1}{g_A}\sqrt{\frac{3D}{ft_{EC}}},$$

$$M_1^F = \left\langle 0^+_f \left\| \widehat{\beta}^- \right\| 1^+_{g.s.} \right\rangle = \frac{1}{g_A}\sqrt{\frac{3D}{ft_{\beta^-}}}$$

$$D = \frac{2\pi^3 \ln 2}{G_\beta^2 m_e^5} = 6288.72 \quad c$$

$$f_{\beta^-} = \frac{1}{m_e^5} \int_{m_e}^{\Delta_f} F(Z, E_e) p_e E_e (\Delta_f - E_e)^2 dE_e$$

$$f_{EC} = \frac{\pi \beta_l^2 p_\nu^2}{2m_e^5}$$

SSD mechanism of 2ν2β-transitions

$$t_{1/2}^{(2\nu)}(0^+ \rightarrow 0_f^+) = 2.997 \cdot 10^{14}\, yr \cdot \frac{\cdot 10^{\log ft_{EC} + \log ft_{\beta^-}}}{H(T, J_f^{\pi})}$$

$$H(T,0_f^+) = \int_1^{T+1} d\varepsilon_1 \int_1^{T+2-\varepsilon_1} d\varepsilon_2 \int_0^{T+1-\varepsilon_1-\varepsilon_2} d\omega_1 \times$$

$$\times F(Z_f, \varepsilon_1) F(Z_f, \varepsilon_2) p_1 \varepsilon_1 p_2 \varepsilon_2 \times$$

$$\times \omega_1^2 \omega_2^2 (K^2 + KL + L^2)$$

S.V. Semenov, F. Šimkovic, P. Domin, Письма в ЭЧАЯ, № 6 [109], стр. 26-31 (2001)

$$^{100}Mo \rightarrow {}^{100}Ru + 2e^{-} + 2\bar{\nu}_e$$

$$^{100}Tc \rightarrow {}^{100}Ru + e^{-} + \bar{\nu}_e$$

$$\log ft_{\beta^-} = 4.6 \qquad M_F^I = \left\langle 0_f^+ \left\| \widehat{\beta}^- \right\| 1_{g.s.}^+ \right\rangle = 0.543$$

$$^{100}Tc + e^{-} \rightarrow {}^{100}Mo + \nu_e$$

$$\log ft_{EC} = 4.45^{+0.18}_{-0.30}$$ *PRC 47,2910(1993)*

$$M_1^I = \left\langle 1_{g.s.}^+ \left\| \widehat{\beta}^- \right\| 0_i \right\rangle = 0.641$$

$$T_{1/2}^{2\nu} = 6.8 \cdot 10^{18} \text{ лет}$$

S.V. Semenov, F. Šimkovic, V.V. Khruschev, P. Domin,
Contribution of the lowest 1^+ -intermediate state to the $2\nu\beta\beta$-decay amplitude, ЯФ, Том 63, С. 1271 (2000)

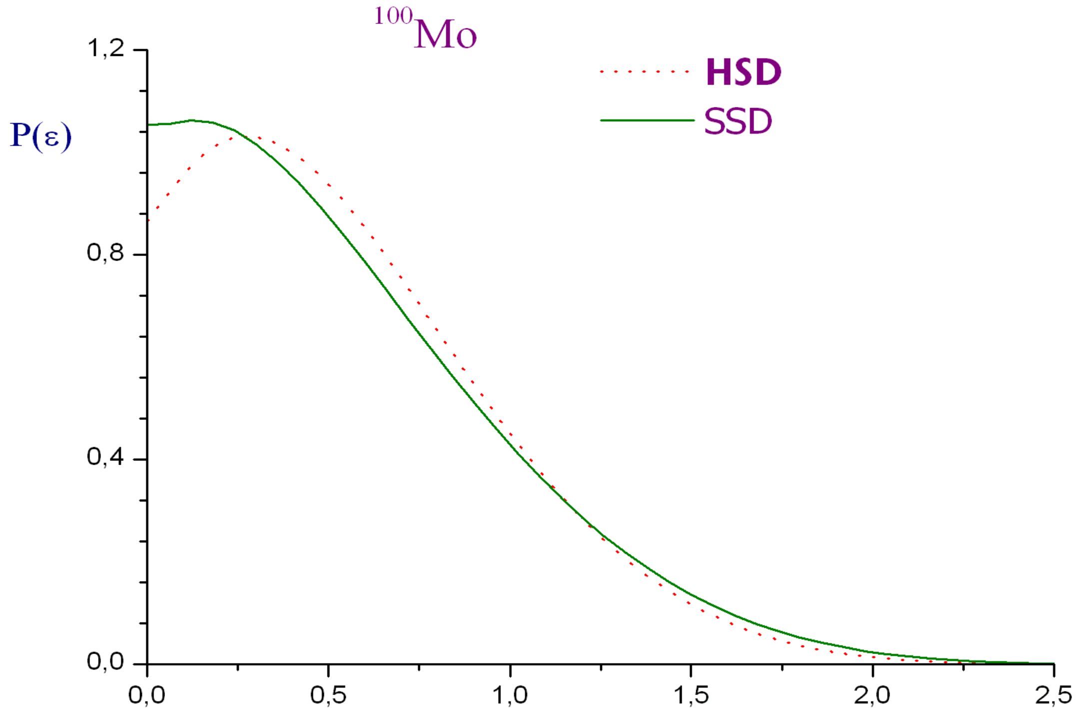


Fig. 1. Electron kinetic energy, MeV

F. Šimkovic, P. Domin, S.V. Semenov, J. Phys G, V.27, 2233 (2001);

Domin P., Kovalenko S., Šimkovic F., Semenov S.V., Neutrino accompanied $\beta^{\pm}\,\beta^{\pm}$, $\beta^{+}.EC$ and *EC/EC* processes within single state dominance hypothesis, Nucl. Phys. A **753**, p. 337-363 (2005).

Shitov Yu.A. Double-Beta-Decay Experiment NEMO-3: Preliminary Results of Phase I (2003-2004), Phys. Atom, Nucl. – 2006. –Vol. 69. – P. 2090-2095.

New more precise measurements

Sjue S.K.L. et al. Electron-capture branch of ^{100}Tc and test of nuclear wave functions for double-β decays // Phys. Rev. C. – 2008.- Vol. 70. – 064317.

$$\log ft_{EC} = 4.29^{+0.08}_{-0.07}$$

$$M_1^I = 0.785$$

$T_{1/2}^{2\nu 2\beta}$ (approximated *K* и *L*)=6.2(9)·10^{18} лет,

$T_{1/2}^{2\nu 2\beta}$ (exact *K* и *L*)=5.0(7) ·10^{18} лет

$T_{1/2}^{2\nu 2\beta}$ experiment NEMO-3 7.1(4)·10^{18} лет

It is necessary to take into account contributions of excited states of technetium-100 to 2ν2β-amplitude ^{100}Mo

NME modules, connecting the initial ^{100}Mo nuclei with ^{100}Tc can be obtained from charge exchange reaction investigations

$^{100}Mo(^{3}He,t)^{100}Tc$.

J. H. Thies, T. Adachi, M. Dozono et al. High-resolution $^{100}Mo(^{3}He,t)^{100}Tc$ charge-exchang experiment and the impact on double-β decays and neutrino charged-current reactions, Phys. Rev. C, Vol. 86, 044309 (2012)

Excited 1^+ - states of ^{100}Tc

E_x, кэВ	B(GT)
355	0.039
838	0.024
1416	0.031
2152	0.01
2318	0.018
2435	0.021
2565	0.011
2611	0.018
2683	0.026

Contributions of excited state of ^{100}Tc should have negative sign

Semenov S.V. Differential intensities of 2ν2β-transition in ^{116}Cd // AIP Conf. Proc. – 2007. – Vol.942.-P. 67—71;

Semenov S.V., Gaponov Yu.V., Šimkovic F., Dvornicky R. Contribution of the excited 1^+ states to the ^{116}Cd 2ν2β-transition amplitude // Proc. of the International Conference. "Current Problems in Nuclear Physics and Atomic Energy" / Ed. by I.M. Vyshnevskiy. - Kyiv, 2007. P.- 473-478;

Semenov S.V., Šimkovic F., Dvornicky R., Bednyakov V.A. Calculation of 2ν2β-transition intensities in ^{48}Ca // Proc. of the 2-nd Int. Conf. "Current Problems in Nuclear Physics and Atomic Energy". Kyiv, 2009. - P. 422 - 424.

What is the sign of the first excited state of ^{100}Tc contribution?

The answer can give experimental distribution on single electron energy, observed by NEMO-3 setup

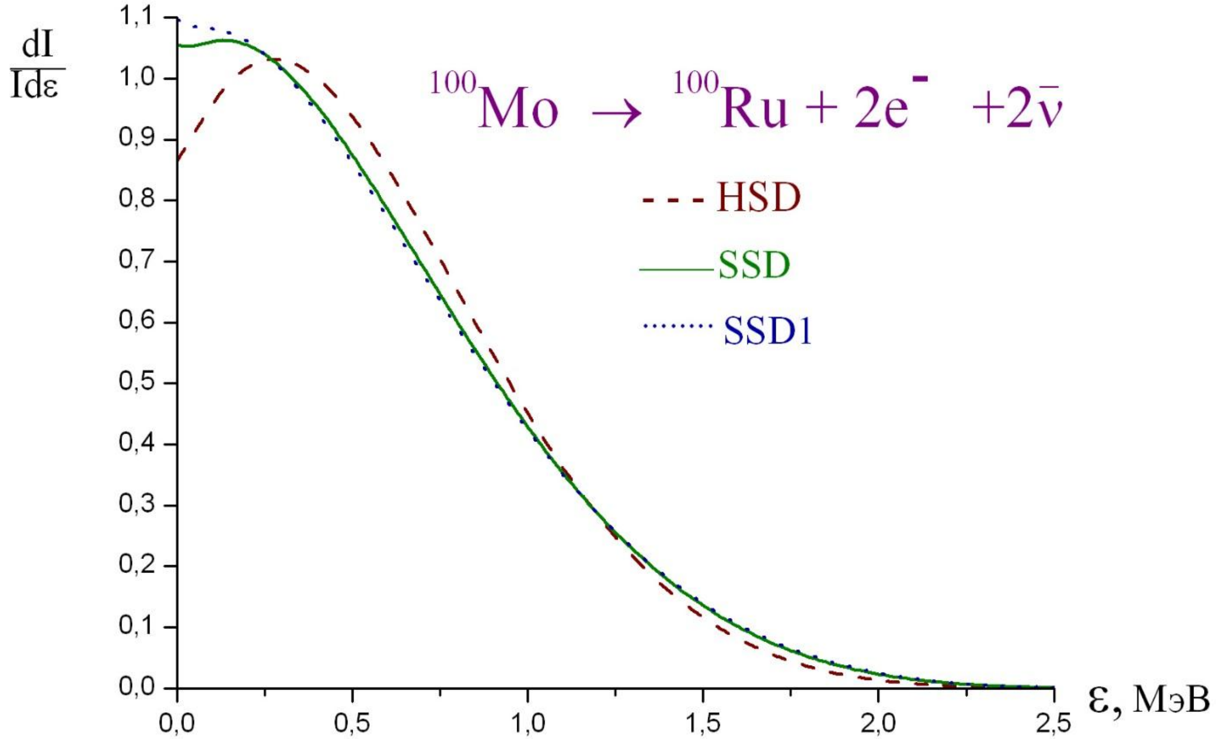
The problem of determination of matrix elements for transitions from intermediate to final nucleus $\left\langle 0_F^+ \middle\| \hat{\beta}^- \middle\| 1_N^+ \right\rangle$

Charge-exchange reaction

$^{100}Ru(d,^{2}He)^{100}Tc$? ^{100}Ru 12.5%

Electrochimpribor, г. Лесной , Lesnoy

Electromagnetic separation , World price ^{150}Nd 20$/mg



Распределение по энергии одного электрона, рождающегося при двойном двухнейтринном бета-распаде ядра ^{100}Mo для трех моделей ядерного механизма перехода (HSD, SSD, SSD1)

It is very interesting to compare the obtained theoretical distribution with NEMO-3 high statistic data.

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Thank you!