

NEUTRINO MASS AND FORBIDDEN BETA DECAYS*

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The possibility to exploiting the first forbidden beta decays to measure the neutrino mass is discussed. It is found that the corresponding Kurie function close to the endpoint behaves like the Kurie function of beta decay of tritium.

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The width of non-unique first forbidden beta decay $\Delta J^\pi = 0^-$ is derived by considering exact Dirac wave functions of emitted leptons and higher order terms of nucleon current. For the spin of initial nucleus $J_i = 0$, the differential decay rate takes the form of

$$\frac{d\Gamma}{dE_e} = G_\beta^2 \frac{2}{\pi^2} p_e E_e p_\nu E_\nu \mathcal{B}_{0-} - \frac{R^2}{9} \left(F_{s_{1/2}}(E_e, R) \left(p_\nu^2 + 9\lambda^2 E_0^2 + 6\lambda E_0 \frac{p_\nu^2}{E_\nu} \right) + p_e^2 F_{p_{1/2}}(E_e, R) + F_{s_{p_{1/2}}}(E_e, R) \left(2 \frac{p_\nu^2}{E_\nu} p_e + 6\lambda E_0 p_e \right) \right). \quad (1)$$

The nuclear matrix element is defined as

$$\mathcal{B}_{0-} = \left| \langle J_f | g_A \sum_n \frac{r_n}{R} \tau_n^+ \{ \sigma_1(n) \otimes Y_1(n) \}_0 | J_i \rangle \right|^2. \quad (2)$$

The squared velocity-dependent nuclear matrix element was replaced with $\lambda E_0 R \mathcal{B}_{0-}$ (see Ref. [1]). The value of parameter λ depends on a given nucleus. The decay rate consists of three contributions associated with emission of electron in $s_{1/2}$ -wave, $p_{1/2}$ -wave and the interference between $s_{1/2}$ - and $p_{1/2}$ -wave, respectively. Fermi functions are given by

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$$\begin{aligned}
F_{s_{1/2}}(E_e, R) &= (g_{-1}^2(E_e, R) + f_{+1}^2(E_e, R)) / j_0^2(p_e R), \\
F_{p_{1/2}}(E_e, R) &= (g_{+1}^2(E_e, R) + f_{-1}^2(E_e, R)) / j_1^2(p_e R), \\
F_{sp_{1/2}}(E_e, R) &= \frac{g_{+1}(E_e, R)f_{+1}(E_e, R) - f_{-1}(E_e, R)g_{-1}(E_e, R)}{j_1(p_e R)j_0(p_e R)}. \quad (3)
\end{aligned}$$

Here, $g_{-\kappa}$ and f_{κ} are radial electron wave functions, which are the solution of Dirac equation with Coulomb potential (see Ref. [2]).

For the non-unique first forbidden beta decay, the Kurie function is defined as [3]:

$$\begin{aligned}
K_{0-}(E_e, m_{\beta}) &\equiv \sqrt{\frac{d\Gamma/dE_e}{p_e E_e (F_{p_{1/2}}(E_e, R)(p_e R/3)^2)}} \\
&= G_{\beta} \sqrt{\frac{2}{\pi^2} \mathcal{B}_{0-}(E_0 - E_e)} \sqrt[4]{1 - \frac{m_{\beta}^2}{(E_0 - E_e)^2}} \sqrt{S_{0-}(E_e)}. \quad (4)
\end{aligned}$$

The shape factor S_{0-} is given by

$$\begin{aligned}
S_{0-}(E_e) &= \left(1 + \frac{F_{s_{1/2}}(E_e, R)}{p_e^2 F_{p_{1/2}}(E_e, R)} \left(p_{\nu}^2 + 9\lambda^2 E_0^2 + 6\lambda E_0 \frac{p_{\nu}^2}{E_{\nu}} \right) \right. \\
&\quad \left. + \frac{F_{sp_{1/2}}(E_e, R)}{p_e F_{p_{1/2}}(E_e, R)} \left(2 \frac{p_{\nu}^2}{E_{\nu}} + 6\lambda E_0 \right) \right). \quad (5)
\end{aligned}$$

Numerical analysis of the shape factor close to the endpoint was performed for a set of even-even isotopes, namely ^{90}Kr , ^{140}Ba , ^{144}Ce , ^{144}Pr , ^{166}Ho , and ^{206}Tl . It was found that calculated shape factors only weakly depend on the electron energy and to a good accuracy could be considered as constant. Thus, the Kurie function (4) coincides up to a factor with the Kurie function of the allowed beta-decay transitions having the same dependence on neutrino mass. This fact opens a possibility to use non-unique first forbidden beta decays to measure neutrino mass.

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