Right-handed weak currents in neutrinoless double-beta decays and ton scale double-beta detectors part II

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arXiv:2501.0345v1 H. Ejiri, T. Fukuyama, TS

Objective:

- transparent derivation of the effective nuclear transition operators for $0^+ \to 2^+$ DBD
- meson-exchange current of DBD

In this talk:

- revisit sensitivity of η- and λ-terms in $0^+ \to 0^+/2^+$ 0ν DBD

$$[t^{0\nu}_{1/2}]^{-1} = C^J_{\lambda\lambda} < \lambda >^2 + C^J_{\eta\eta} < \eta >^2 + ...$$

$$C^{(0)}_{\eta\eta}/C^{(0)}_{\lambda\lambda} \sim 10^3 - 10^4 \quad C^{(2)}_{\eta\eta}/C^{(2)}_{\lambda\lambda} \sim 10 - 10^2$$

J. Suhonen, O.Civitarese, Phys.Rep. 300(1998)123, D Fang, A. Faessler PRC 107(2023) 015501

$0^+ \to 0^+$ case: $\chi^2_R G_{09} \sim g_A \mu_V C^2_{ss}$

- $N \leftrightarrow \Delta$ DBD (neutrino exchange inside baryon) in $0^+ \to 2^+$ DBD

$N\Delta$ 0ν DBD

sensitivity of η- and λ-terms in $0^+ \to 0^+/2^+$

Interference between L-handed and R-handed terms $\to$ p-wave neutrino propagator

$$P_L(\gamma_0\omega - \boldsymbol{\gamma}\cdot\boldsymbol{k} + m_i)P_R \to \boldsymbol{\gamma}\cdot\boldsymbol{r}$$

possibility to have positive parity nuclear effective operator for $0^+ \to 0^+/2^+$ transition

(1) One of the electrons is p-wave $\to$ Fermi($V-V$) and GT $A-A$

$$0^+ \to 0^+ : (s_{1/2}p_{1/2}) \qquad 0^+ \to 2^+ : (s_{1/2}p_{3/2})$$

(2) Both electrons are s-wave $\to$ $V-A$ interference term

$$0^+ \to 0^+ : (s_{1/2}s_{1/2}) \qquad 0^+ \to 2^+ : X$$

(2) is the source of large sensitivity to η term, which does not exist for $0^+ - 2^+$ transition,

sensitivity of η- and λ-terms in $0^+ \to 0^+/2^+$

Hadron current

$$<\eta> J_L J_L + <\lambda> J_L J_R \to <\eta> (V-A)(V-A) + <\lambda> (V-A)(V+A)$$

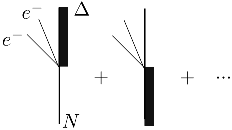
transition amplitude of DBD

$$\mathcal{M}_{fi} \sim \int d\boldsymbol{x} d\boldsymbol{y} \frac{1}{|\boldsymbol{x}-\boldsymbol{y}|} \bar{e}_2(\boldsymbol{y}) \mathcal{O} e_1^c(\boldsymbol{x})$$

$\mathcal{O}$: Difference between η and λ terms.

$$\begin{aligned} & <\eta> [(\not{V}(\boldsymbol{y})(\boldsymbol{r}\cdot\boldsymbol{\gamma})\not{V}(\boldsymbol{x}) + \not{A}(\boldsymbol{y})(\boldsymbol{r}\cdot\boldsymbol{\gamma})\not{A}(\boldsymbol{x})) - (\not{V}(\boldsymbol{y})(\boldsymbol{r}\cdot\boldsymbol{\gamma})\not{A}(\boldsymbol{x}) + \not{A}(\boldsymbol{y})(\boldsymbol{r}\cdot\boldsymbol{\gamma})\not{V}(\boldsymbol{x}))] \\ + \quad & <\lambda> [(\not{V}(\boldsymbol{y})(\boldsymbol{r}\cdot\boldsymbol{\gamma})\not{V}(\boldsymbol{x}) - \not{A}(\boldsymbol{y})(\boldsymbol{r}\cdot\boldsymbol{\gamma})\not{A}(\boldsymbol{x})) - (\not{V}(\boldsymbol{y})(\boldsymbol{r}\cdot\boldsymbol{\gamma})\not{A}(\boldsymbol{x}) - \not{A}(\boldsymbol{y})(\boldsymbol{r}\cdot\boldsymbol{\gamma})\not{V}(\boldsymbol{x}))\gamma_5]. \end{aligned}$$

- $g_A \mu_V$ does not contribute to λ
- s^2, $\boldsymbol{VA} \leftrightarrow sp$, $V_0^2 \boldsymbol{A}^2$: $\quad \dfrac{4.7 \times q_\nu}{2M_N} \leftrightarrow m_e R, V_C R$
- $0^+ - 0^+$ transition is sensitive to η: Right-handed current and $V-A$ structure



- SU(6)/static quark model

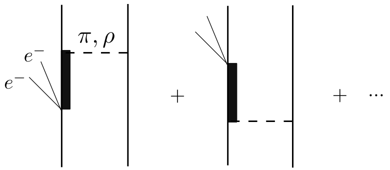
  $\Delta \sim \chi^S \eta^S \quad N \sim (\chi^{MS}\eta^{MS} + \chi^{MA}\eta^{MA})/\sqrt{2}$

- among 2^+ transition operators, spin-spin interaction contributes

$$< \Delta^{++} || \sum_{i,j=1}^{3} \frac{2}{3} [\boldsymbol{\sigma}_i \otimes \boldsymbol{\sigma}_j]^{(2)} h(r_{ij}) \tau_i^+ \tau_j^+ || n >= -\frac{8\sqrt{10}}{3} < \frac{1}{r} >$$

$N\Delta$ transition DBD

Δ component was calculated by π and ρ exchange model (T. Tomoda, NPA484 (1988) 635)



- Meson-exchange current for 0ν DBD
- contributes to $0^+ - 2^+$ transition

$N\Delta$ transition DBD

Possible estimation of MEC: ratio of the matrix elements of IA and MEC

$$\sum_{m,n=1}^{A} \tau_m^+ \tau_n^+ \boldsymbol{\sigma}_m \cdot \boldsymbol{\sigma}_n [\hat{r}_{mn} \otimes \hat{r}_{mn}]^{(2)} h(r_{mn}).$$

$h(r)$: $1/r$ for IA, $Y_2(m_\pi r)$ for MEC

From table of Tomoda(NPA484 635(1988) DBD of ^{76}Ge)

$$\frac{MEC}{IA} \sim 0.1 \propto \frac{f_{\pi N\Delta} f_{\pi NN}}{(m_\Delta - m_N) g_A^2} < \frac{1}{r} >$$

- $0^+ - 0^+$ transition is sensitive to η-term than λ-term due to R-handed current and $V-A/V+A$ structure of weak currents.
- $\sigma \cdot \sigma Y_2$ type operator can be useful measure of MEC.