SHORT COMMENT ON THE LEFT- AND RIGHT-HANDED CURRENT IN NEUTRINOLESS DOUBLE BETA DECAY

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Nuclear Matrix Element Calculation for 0νββ Decay of ^{136}Xe in Left-Right Symmetric Model using Nuclear Shell Model

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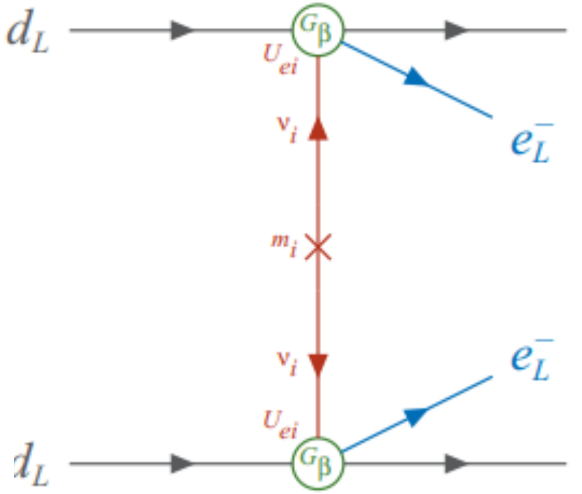
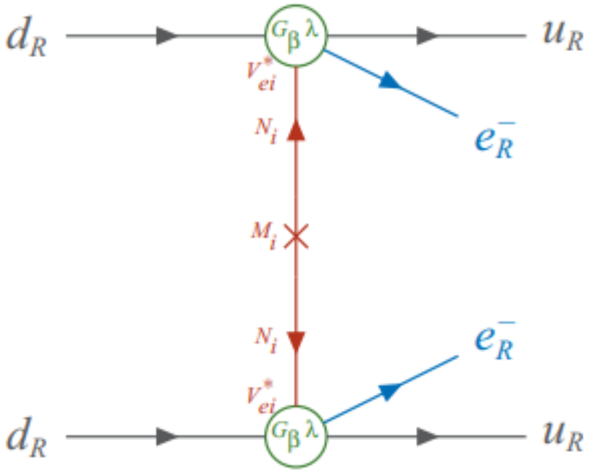
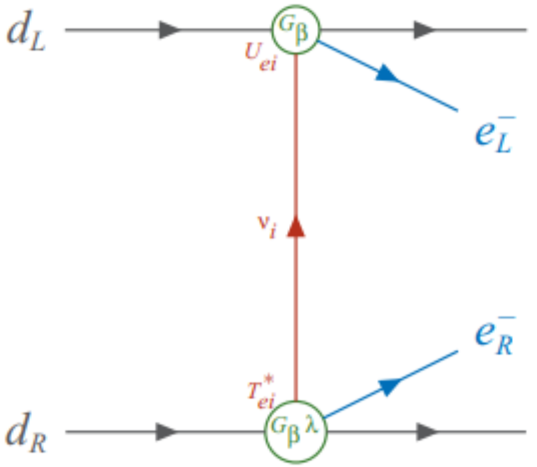


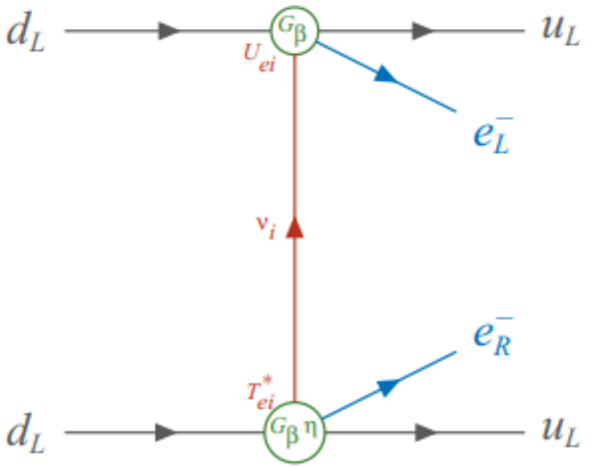
(a) Light neutrino exchange for purely LH currents. Diagram $\propto \eta_m$ arising from $j_L J_L^\dagger j_L J_L^\dagger$ term.



(b) Heavy neutrino exchange for purely RH currents. Diagram $\propto \eta_N$ arising from $j_R J_R^\dagger j_R J_R^\dagger$ term.



(a) λ-diagram due to both LH and RH currents. Diagram $\propto \eta_\lambda$ arising from $j_L J_L^\dagger j_R J_R^\dagger$ term.



(b) η-diagram due to gauge boson mixing. Diagram $\propto \eta_\eta$ arising from $j_L J_L^\dagger j_R J_L^\dagger$ term.

If we consider all the diagrams of $0\nu\beta\beta$ decay in left-right symmetric model, the decay rate can be written as

$$
\begin{aligned}
\left[T_{1/2}^{0\nu}\right]^{-1} = & g_A^4 \left[C_m |\eta_m|^2 + C_N |\eta_N|^2 + C_\lambda |\eta_\lambda|^2 + C_\eta |\eta_\eta|^2 \right. \\
& + C_{mN}|\eta_m||\eta_N|\cos(\phi_m - \phi_N) + C_{m\lambda}|\eta_m||\eta_\lambda|\cos(\phi_m - \phi_\lambda) \\
& + C_{m\eta}|\eta_m||\eta_\eta|\cos(\phi_m - \phi_\eta) + C_{N\lambda}|\eta_N||\eta_\lambda|\cos(\phi_N - \phi_\lambda) \\
& \left. + C_{N\eta}|\eta_N||\eta_\eta|\cos(\phi_N - \phi_\eta) + C_{\lambda\eta}|\eta_\lambda||\eta_\eta|\cos(\phi_\lambda - \phi_\eta) \right]
\end{aligned}
$$

Nuclear Matrix Element (NME) (Our Interest)

$$
C_m = G_{01}\left[\overbrace{M_{GT} - \left(\frac{g_V}{g_A}\right)^2 M_F + M_T}\right]^2,
$$

…Similarly for other terms of decay rate equation

Phase Space Factors which are Calculated Accurately

Nuclear Matrix Elements Calculation of 136Xe 0νββ Decay using Shell Mo

NME of 0νββ decay is written as

$$M_\alpha = \langle f | \tau_{-1}\tau_{-2}\mathcal{O}^{\alpha}_{12} | i \rangle$$

Transition Operators of 0νββ in left-Right Sy

$$\mathcal{O}^{GT,\omega GT,qGT,GTN}_{12} = (\sigma_1.\sigma_2) H_{GT,\omega GT,qGT,GTN}(r, E_k)$$

$$\mathcal{O}^{GTR}_{12} = \vec{\sigma}_1 \cdot \vec{\sigma}_2 H_{GTR}(r, E_k). \qquad \mathcal{O}^{F,\omega F,qF,FN}_{12} = H_{F,\omega F,qF,FN}(r, E_k)$$

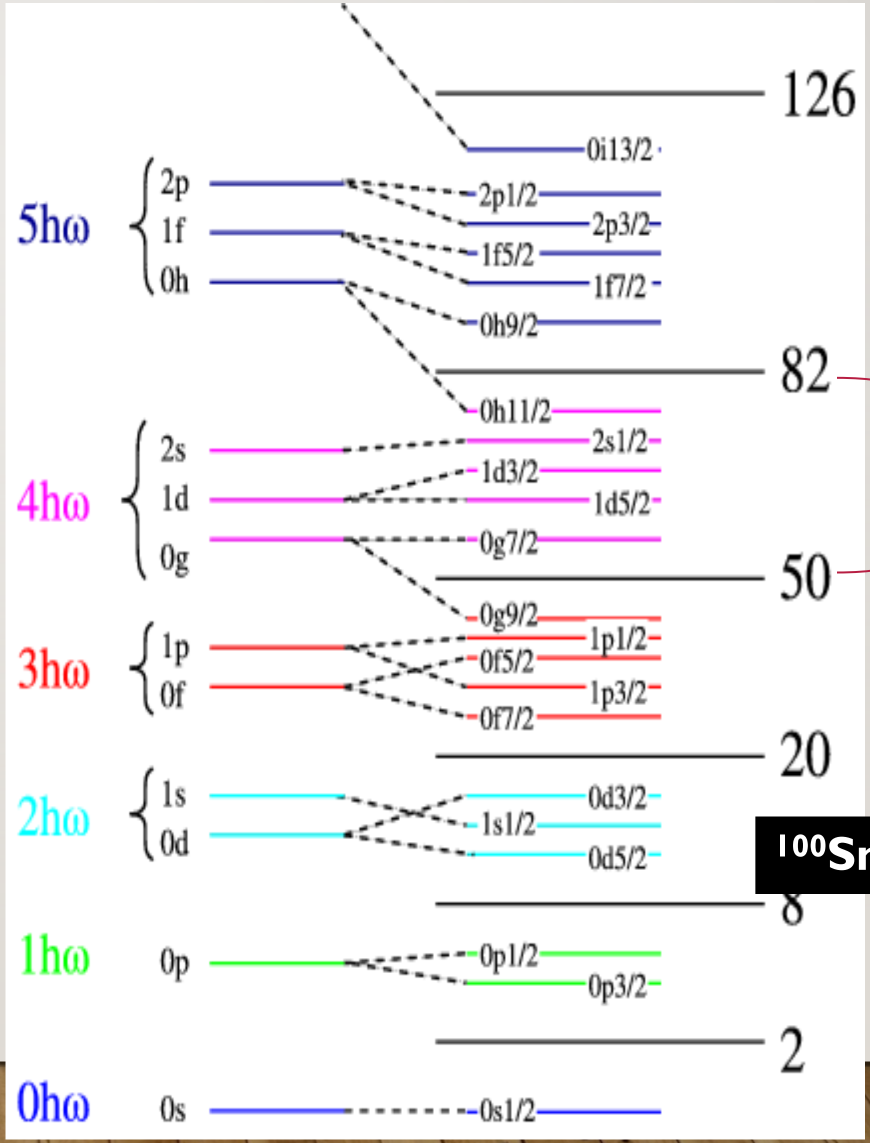
$$\mathcal{O}^{TR}_{12} = S_{12} H_{TR}(r, E_k) \qquad \mathcal{O}^{T,\omega T,qT,TN}_{12} = S_{12} H_{T,\omega T,qT,TN}(r, E_k)$$

$$\mathcal{O}^{P}_{12} = (\vec{\sigma}_1 - \vec{\sigma}_2) H_P(r, E_k),$$

Nuclear Matrix Element are Calculated in Shell N

$$M_\alpha(J_k, J, E_k^*) = \sum_{k_1' k_2' k_1 k_2} \sqrt{(2J_k+1)(2J_k+1)(2J+1)}$$
$$\times (-1)^{j_{k1}+j_{k2}+J} \begin{Bmatrix} j_{k1'} & j_{k1} & J_k \\ j_{k2} & j_{k2'} & J \end{Bmatrix} \mathrm{OBTD}(k, f, k_2', k_2, J_k)$$
$$\times \mathrm{OBTD}(k, i, k_1', k_1, J_k) \langle k_1', k_2' : J || \tau_{-1}\tau_{-2}\mathcal{O}^{\alpha}_{12} || k_1, k_2 : J \rangle,$$

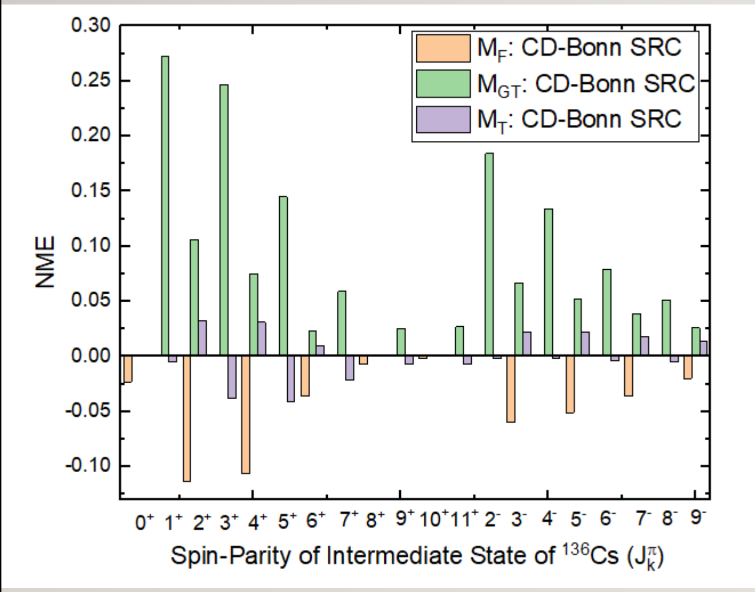
Shell Model Calculation for ^{136}Xe 0νββ Decay

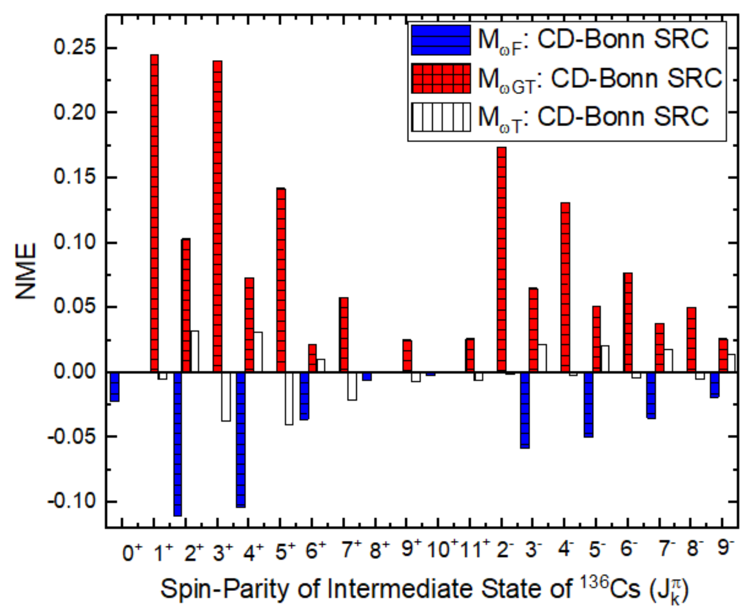


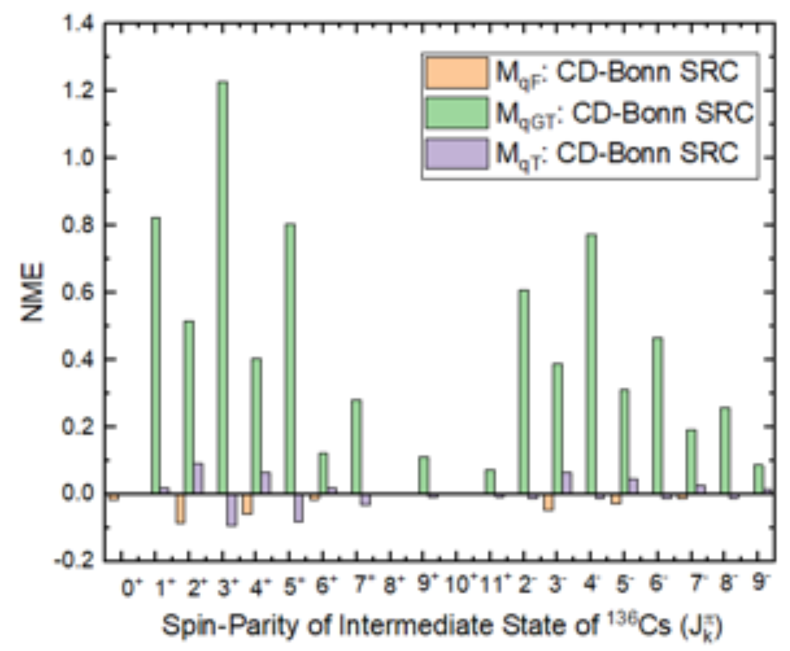
GCN5082 Hamiltonian

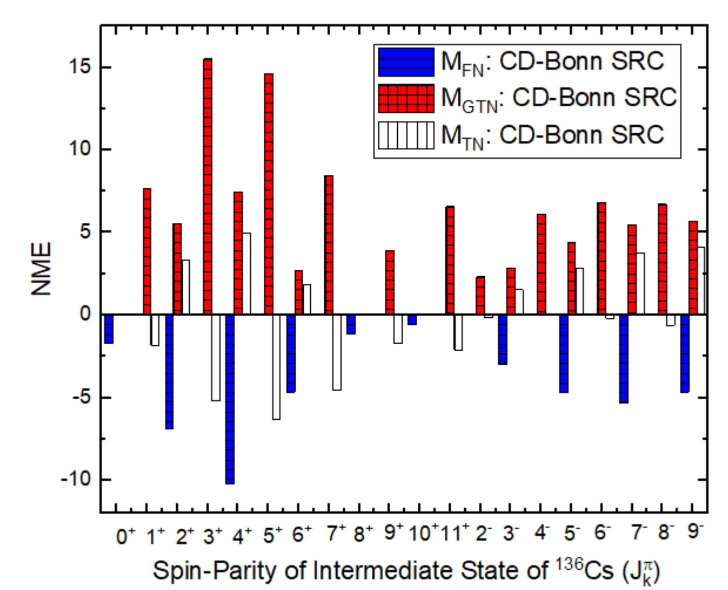
^{100}Sn as inert Core

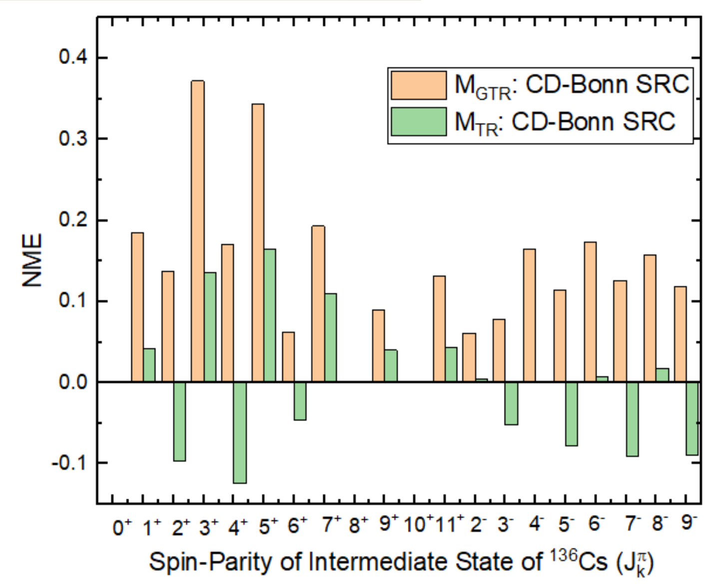
Results: Contribution of different Spin-Parity States of Intermediate Nucleus ^{136}Cs to the Nuclear Matrix Element of ^{136}Xe $0\nu\beta\beta$ in Left-Right











LEFT-RIGHT SYMMETRIC MODEL IN THE LATEST LITERATURE

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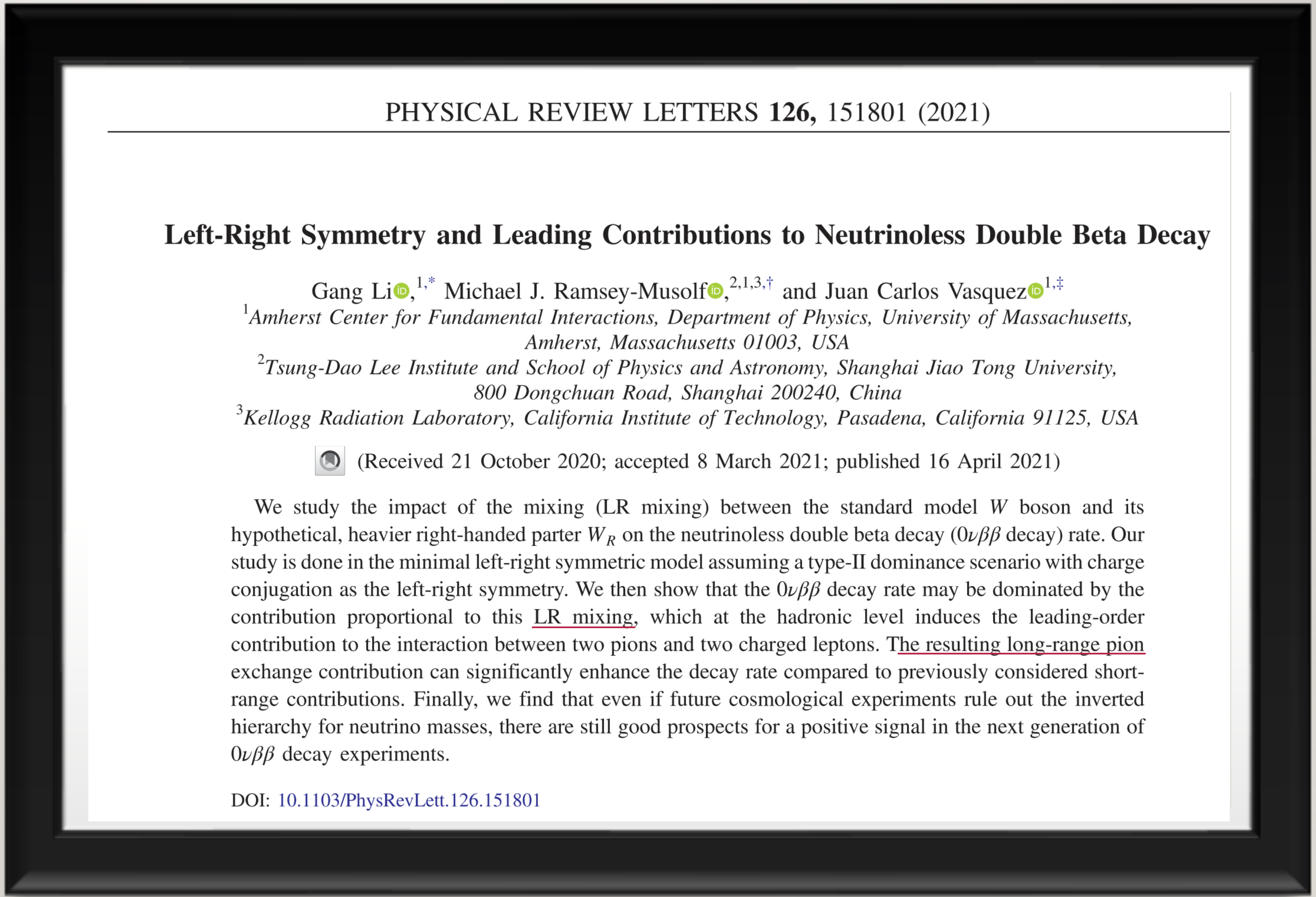
IMPORTANCE OF LONG-RANGE EFFECT (NON-LEADING ORDER)



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Left-Right Symmetry and Leading Contributions to Neutrinoless Double Beta Decay

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We study the impact of the mixing (LR mixing) between the standard model W boson and its hypothetical, heavier right-handed parter W_R on the neutrinoless double beta decay ($0\nu\beta\beta$ decay) rate. Our study is done in the minimal left-right symmetric model assuming a type-II dominance scenario with charge conjugation as the left-right symmetry. We then show that the $0\nu\beta\beta$ decay rate may be dominated by the contribution proportional to this LR mixing, which at the hadronic level induces the leading-order contribution to the interaction between two pions and two charged leptons. The resulting long-range pion exchange contribution can significantly enhance the decay rate compared to previously considered short-range contributions. Finally, we find that even if future cosmological experiments rule out the inverted hierarchy for neutrino masses, there are still good prospects for a positive signal in the next generation of $0\nu\beta\beta$ decay experiments.

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[SUMMARY] DOUBLE BETA DECAY WITH LEFT- AND RIGHT-HANDED WEAK CURRENTS

Without Including Higher Order Current in Neutrino Potential

$$f_{qGT}(q,r) = \frac{1}{(1+\frac{q^2}{\Lambda_A^2})^4} qrj_1(qr).$$

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Including Higher Order Current in Neutrino Potential

$$f_{qGT}(q,r) = \left[\frac{g_A^2(q^2)}{g_A^2}q + 3\frac{g_P^2(q^2)}{g_A^2}\frac{q^5}{4m_N^2} + \frac{g_A(q^2)g_P(q^2)}{g_A^2}\frac{q^3}{m_N}\right] rj_1(q,r),$$

Decay Candidate	qGT Type NME (Without Higher Order Current)	qGT Type NME (With Higher Order Current)(Our Calculation)	SRC Type
^{48}Ca	0.709	3.491	CD-Bonn
^{82}Se	3.034	12.538	CD-Bonn
^{136}Xe	1.440	7.463	CD-Bonn

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PHYSICAL REVIEW C **92**, 055502 (2015)