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Comparison of symmetric and asymmetric LR model in the context of $0\nu\beta\beta$ decay

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We study the new physics contributions to neutrinoless double beta decay ($0\nu\beta\beta$) in a TeV scale left-right model with spontaneous D-parity breaking mechanism where $g_L \neq g_R$. We compare the predicted numerical values of half life of $0\nu\beta\beta$ decay, effective Majorana mass parameter for three different cases; (i) for manifest left-right symmetric model ($g_L = g_R$), (ii) for left-right model with spontaneous D parity breaking ($g_L \neq g_R$), (iii) for Pati-Salam symmetry with D parity breaking ($g_L \neq g_R$). We show that depending upon the values of the ratio $\frac{g_R}{g_L}$ how different contributions to $0\nu\beta\beta$ decay are suppressed or enhanced.

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1. Introduction

After the discovery of neutrino mass and mixing by oscillation experiments the immediate questions still remain unanswered are : 'Whether neutrinos are Dirac or Majorana particles?'and 'What gives them such a tiny mass?'. The minimal approach to explain non-zero neutrino mass is seesaw mechanism [1] which presumes them as Majorana fermions. If neutrinos are Majorana fermions they can initiate a very rare lepton number violating process in nature called neutrinoless double beta decay ($0\nu\beta\beta$): ${}^{A}_{Z}X \to {}^{A}_{Z+2}Y + 2e^-$.

Other than the standard mechanism, one possible way to have new physics contributions to $0\nu\beta\beta$ decay process is to study the process in Left-Right Symmetric Model (LRSM) [2] since the presence of right-handed neutrino and the possibility of left-right mixing can facilitate new decay channels for the process. In manifest LRSM we usually have the gauge couplings for $SU(2)_L$ and $SU(2)_R$ gauge groups are equal i.e, $g_L = g_R$, known as symmetric case. However a different scenario arises when the D-parity symmetry of a left-right theory breaks at a high scale and the local $SU(2)_R$ symmetry breaks at relatively low scale [3]. As an immediate effect we have $g_L \neq g_R$. This scenario is called asymmetric left-right theory. In this work, our major aim is to elucidate how unequal couplings enhance the rate of $0\nu\beta\beta$ transition in different channels [4]. Also, we show how different contributions to $0\nu\beta\beta$ decay are suppressed or enhanced depending upon the values of the ratio $\frac{g_R}{g_L}$.

2. Results : Effects on $0\nu\beta\beta$ decay in symmetric and asymmetric LRSM

Within the frameworks of symmetric and asymmetric left-right model we present a comparative study of different contributions to $0\nu\beta\beta$ decay process arising due to mediation of either one W_R^- or two W_R^- gauge bosons in terms of half-life and effective mass parameters. In this work we have considered three different cases :

- Case I : $g_L = g_R = 0.632 \;\Rightarrow\; \delta = \frac{g_R}{g_L} = 1$.
- Case II : $g_L = 0.632, g_R = 0.589 \;\Rightarrow\; \delta = 0.93$.
- Case III : $g_L = 0.632, g_R = 0.39 \;\Rightarrow\; \delta = 0.62$.

The occurrence of Pati-Salam symmetry [5] at the highest scale provides large value to Dirac neutrino mass matrix M_D and thus the mixed helicity λ and η diagrams contribute dominantly to the $0\nu\beta\beta$ transition. At the same time, the $W_L - W_L$ mediation due to exchange of heavy sterile neutrinos and $W_R - W_R$ mediated diagrams due to exchange of heavy RH neutrinos also deliver dominant contributions to the process. The suppression factor in effective mass parameters is found to be $\left(\frac{g_R}{g_L}\right)^4 \simeq 0.13$ in the $W_R - W_R$ channel while in the $W_L - W_R$ channel it is found to be $\left(\frac{g_R}{g_L}\right)^2 \simeq 0.36$. Similarly, for the half-life estimation when Pati-Salam symmetry is not included in the symmetry breaking chain, the enhancement factor becomes $\left(\frac{g_L}{g_R}\right)^8 \simeq 1.78$ for $W_R - W_R$ channel while for the $W_L - W_R$ channel the enhancement factor is $\left(\frac{g_L}{g_R}\right)^4 \simeq 1.33$. However when Pati-Salam symmetry appears in the symmetry breaking chain the enhancement factor increases significantly.

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In this case, the enhancement factor is found to be $\left(\frac{g_L}{g_R}\right)^8 \simeq 59.29$ for $W_R - W_R$ channel and for $W_L - W_R$ channel the enhancement factor becomes $\left(\frac{g_L}{g_R}\right)^4 \simeq 7.7$.

In Fig.1 we have shown various contributions to infer how half-life of $0\nu\beta\beta$ decay due to different channels varies with the ratio $\frac{g_R}{g_L}$ i.e. δ. Here the cyan shaded region is sensitive to the current KamLAND-Zen and GERDA bounds. We can see that only the contributions coming from $W_L - W_L$ channel due to light neutrino exchange and from $W_R - W_R$ channel due to heavy neutrino exchange lie within the allowed region. The other dependences of this framework for three different values of δ's are presented in Fig.2.

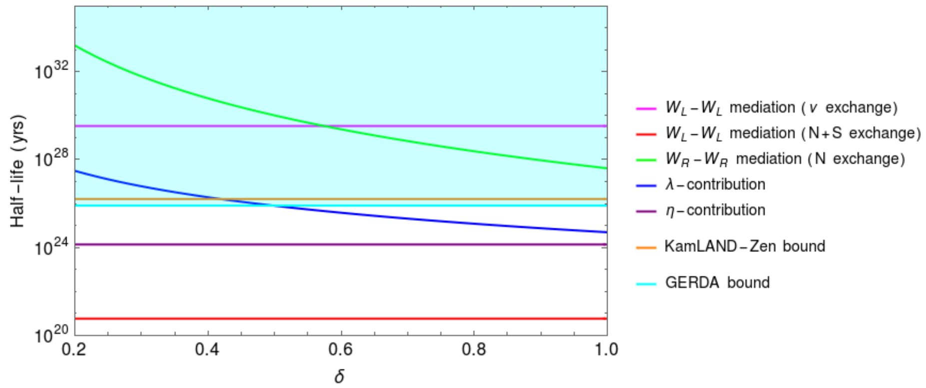

Figure 1: Half life of $0\nu\beta\beta$ process due to all possible channels in the model vs δ $(= \frac{g_R}{g_L})$.

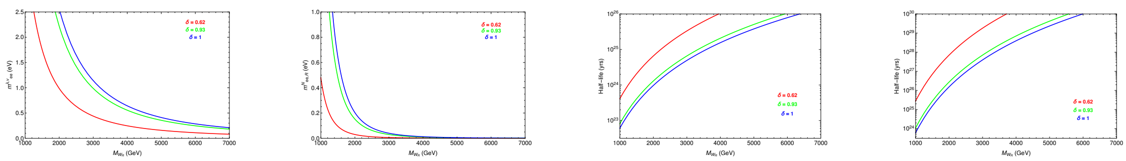

Figure 2: The plot in the left most one shows effective majorana mass parameter due to heavy neutrino N exchange in purely right-handed currents vs W_R mass. Next one shows effective Majorana mass parameter due to $W_L - W_R$ mixing (λ diagram) with ν exchange vs W_R mass. Next, the plot shows half life dependency due to N exchange in $W_R - W_R$ channel vs mass of W_R while the right most panel shows half life due to all λ diagrams (ν, N, S exchange with $W_L - W_R$ mixing) vs mass of W_R. In all the plots three different values of δ are considered: δ=0.63, 0.93, 1.

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