Study of neutrinoless double beta decay in R-parity violating supersymmetric models via exchange of gluinos

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Introduction

The $(\beta^-\beta^-)_{0\nu}$ decay mode is far more interesting since it violates the conservation of lepton number L by two units (ΔL=2). The $(\beta^-\beta^-)_{0\nu}$ decay process requires massive Majorana neutrino and the Majorana mass term requires the breaking of lepton number L. However, the only gauge-anomaly free combination of quantum numbers in general gauge theories is B-L. Therefore, one considers the breaking of B-L symmetry. The B-L conservation is exact in the standard model (SM) of electroweak unification and hence the $(\beta^-\beta^-)_{0\nu}$ decay is not allowed in the SM. However, the B-L violation is expected in the gauge theories beyond the SM. Besides the exchange of a Majorana neutrino, the $(\beta^-\beta^-)_{0\nu}$ decay can also proceed through other mechanisms which involve B-L violation.

Out of such several mechanisms responsible for $(\beta^-\beta^-)_{0\nu}$ decay, we consider here the contribution of R-parity violating Minimal supersymmetric standard model (R_p MSSM). In supersymmetry theories the R-parity (R_p) is a discrete, multiplicative symmetry defined as $R_p=(-1)^{3B+L+2S}$, where S, B and L are the spin, baryon number and lepton number, respectively. The R_p=+1 for ordinary particles and R_p=-1 for their superpartners. The R-parity violating supersymmetric models have been widely reviewed in the literature because of their interesting phenomenological and cosmological implications.

In the R_p-violating MSSM [1,2], the exchange of gluinos, photinos etc. contributes to $(\beta^-\beta^-)_{0\nu}$ decay and leads to a very stringent limit on the first generation Yukawa coupling and combination of the intergeneration Yukawa couplings. Constraint on the Yukawa coupling constant is given as

$$\lambda'_{11i}\lambda'_{1i1} \le \varepsilon'_i\left(\frac{\Lambda_{SUSY}}{100GeV}\right)^3$$

Here, Λ_{SUSY} is effective SUSY breaking scale. The current upper bound for the R_p violating SUSY interaction constant λ_{111}' is $\le 1.2\times10^{-4}$ ($\le 3.8\times10^{-2}$) [3] assuming masses of SUSY particles to be on the scale of 100 GeV (1 TeV) for the case of ^{76}Ge. For the same inputs and using the best fit value of half-life $T_{1/2}^{0\nu}=1.19\times10^{25}$ yr [4], one gets $\lambda_{111}'=1.3\times10^{-4}$ (4.1×10^{-2}) assuming the scale of SUSY particles to be 100 GeV (1 TeV).

In the present work, the relevant nuclear transition matrix elements (NTMEs) necessary to extract SUSY parameters from $(\beta^-\beta^-)_{0\nu}$ decay of nuclei in the mass range 94–150 are calculated using Projected Hartree-Fock Bogoliubov (PHFB) model in conjunction with pairing plus multi pole type of two body interaction. The PHFB model has been successfully applied to study the $(\beta^-\beta^-)_{0\nu}$ decay in left-right symmetric models and majoron models [5]. Finally the constraints on the combination of lepton number violating parameters are derived from the available half-life limits of $(\beta^-\beta^-)_{0\nu}$ decay.

Theoretical framework

The inverse half life of $(\beta^-\beta^-)_{0\nu}$ decay in Rp MSSM is given by [2]

$$T_{1/2}^{-1}(0\nu\beta\beta) = G_{01}\, M_1^{\nu}(m_e R)^{-1}\left(4\overline{\eta}_{(l)} - \overline{\eta}_{(q)} + \eta_{(q)}\right)^2 \quad (1)$$

where the two body nuclear transition matrix elements are

$$M_F^{(i)} = \left\langle 0_f^+ \,\|\, h_+(\mu,\mathbf{r})\tau_n^+\tau_m^+ \,\|\, 0_i^+\right\rangle \quad (2)$$

$$M_{GT}^{(i)} = \left\langle 0_f^+ \,\|\, h_+(\mu,\mathbf{r})\tau_n^+\tau_m^+\boldsymbol{\sigma}_n\,\boldsymbol{\sigma}_m \,\|\, 0_i^+\right\rangle \quad (3)$$

$$M_{GT'}^{(i)} = \left\langle 0_f^+ \left\| h_R(\mu,\mathbf{r}) \tau_n^+ \tau_m^+ \boldsymbol{\sigma}_n \, \boldsymbol{\sigma}_m \right\| 0_i^+ \right\rangle \quad (4)$$

$$M_{T'}^{(i)} = \left\langle 0_f^+ \left\| h_{T'}(\mu,\mathbf{r}) \, S_{nm} \, \tau_n^+ \tau_m^+ \right\| 0_i^+ \right\rangle \quad (5)$$

where h_α denotes the neutrino potentials

$$h_+(\mu,\mathbf{r}) = \frac{2}{\pi} \mathrm{R} \int_0^\infty dq \cdot q^2 \frac{j_0(qr) f^2(q^2)}{\omega(\omega + \bar{A})} \quad (6)$$

$$h_R(\mu,\mathbf{r}) = \frac{2}{\pi} \frac{\mathrm{R}^2}{m_P} \int_0^\infty dq \cdot q^4 \frac{j_0(qr) f^2(q^2)}{\omega(\omega + \bar{A})} \quad (7)$$

$$h_{T'}(\mu,\mathbf{r}) = \frac{2}{\pi} \frac{\mathrm{R}^2}{m_P} \int_0^\infty dq \cdot q^4 \frac{j_0(qr) - 3j_1(qr)}{\omega(\omega + \bar{A})} f^2(q^2) \quad (8)$$

Results and discussions

The appropriate NTMEs involved in $(\beta^-\beta^-)_{0\nu}$ decay in Rp MSSM calculated within PHFB model using pairing plus quadrupole-quadrupole (PQQ) interaction is presented in Table 1. Further, the NTMEs have been calculated by considering the finite size of nucleon (F) and Jastrow type of short range correlations (SRC) with Miller-Spencer, Argonne V18 and CD-Bonn NN potentials for the SUSY accompanied $(\beta^-\beta^-)_{0\nu}$ decay of ^{94,96}Zr, ^{98,100}Mo, ^{104}Ru, ^{110}Pd, ^{128,130}Te and ^{150}Nd isotopes for the $0^+\rightarrow0^+$ transition. At present, the results are presented for the case of ^{100}Mo.

Table 1: Calculated NTMEs M_α of SUSY accompanied $(\beta^-\beta^-)_{0\nu}$ decay of ^{100}Mo in the PHFB model using PQQ interaction.

M_α	F+SRC		
	SRC1	SRC2	SRC3
M_{FN}	3.74×10^{-2}	5.64×10^{-2}	6.71×10^{-2}
$M_{F'}$	-3.32×10^{-3}	-1.69×10^{-3}	2.22×10^{-3}
M_{GTN}	-0.108	-0.164	-0.196
$M_{GT'}$	9.14×10^{-3}	4.25×10^{-3}	-7.44×10^{-3}
$M_{GT}^{1\pi}$	2.17	3.80	4.83
$M_{GT}^{2\pi}$	1.86	2.45	2.67
$M_{T'}$	1.24×10^{-3}	1.50×10^{-3}	1.53×10^{-3}
$M_T^{1\pi}$	0.285	0.302	0.302
$M_T^{2\pi}$	0.132	0.134	0.134

In Table 1, SRC1, SRC2 and SRC3 denote the Jastrow type of short range correlations (SRC) with Miller-Spencer, Argonne V18 and CD-Bonn NN potentials, respectively. The calculation of NTMEs for rest of the nuclei stated above along with the extracted limits on SUSY parameters will be presented in the symposium.

Conclusions

To summarize, we study the $(\beta^-\beta^-)_{0\nu}$ decay of ^{94,96}Zr, ^{98,100}Mo, ^{104}Ru, ^{110}Pd, ^{128,130}Te and ^{150}Nd isotopes for the $0^+\rightarrow0^+$ transition in R_p-violating MSSM via exchange of gluinos. The relevant NTMEs are calculated within PHFB model using pairing plus multi pole type of two-body effective interaction. The SUSY parameters of R_p-violating MSSM using calculated NTMEs and experimental data will be extracted and presented in the symposium.

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