Study of squark-neutrino mechanism of neutrinoless double beta decay in R-parity violating supersymmetric models

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Introduction

The non-observation of $(\beta^-\beta^-)_{0\nu}$ decay is usually interpreted in terms of an upper limit on the Majorana mass of the neutrino. However, in principle in any kind of extension of the standard model (SM) of electroweak unification, which allows lepton number violation at some level, one can expect contributions to $(\beta^-\beta^-)_{0\nu}$ decay, not necessarily related to the mass of the neutrino. Supersymmetric (SUSY) theories with R-parity violation are the most prominent examples of this class of models. In SUSY models, the new SUSY partner differ from the SM field content in a discrete multiplicative quantum number R-parity (R_p) defined as $R_p=(-1)^{3B+L+2S}$ where B, L and S denote the baryon number, lepton number and spin of a particle leading to $R_p=+1$ for the SM particles and $R_p=-1$ for superpartners.

The quark-level lepton number violating interactions and nuclear structure aspects relevant for the R_p-violating SUSY mechanism have been widely studied in the literature [1]. The two types of R_p-violating SUSY mechanism at quark level are (i) the short range mechanism with the exchange of heavy superpartners [2] and (ii) the long range mechanism involving the exchange of heavy squark and the light neutrino [3] known as squark-neutrino mechanism [4].

Faessler et al. [4] has shown that R_p-violating SUSY contributes to the $(\beta^-\beta^-)_{0\nu}$ decay dominantly via exchange of charged pion between the decaying nucleons by employing QRPA model for the calculation of relevant nuclear transition matrix elements (NTMEs).

In reference [5] and references there in, the PHFB model has been successfully applied to study the $(\beta\beta)_{0\nu}$ decay in left-right symmetric models and majoron models. This motivates us to calculate the relevant NTMEs of $(\beta^-\beta^-)_{0\nu}$ decay of nuclei in the mass range 94–150 within R_p-violating SUSY models involving squark-neutrino mechanism using PHFB model in conjunction with pairing plus multi pole type of two body interaction. Finally the constraints on the lepton number violating SUSY parameters are extracted 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-violating SUSY model is given by [4]

$$T_{1/2}^{-1} = G_{01}\left|M_h^{\bar{q}}\right|^2\left|\eta^{11}_{(q)LR}\right|^2 \tag{1}$$

where G_{01} is phase space factor. The nuclear matrix elements $M_h^{\bar{q}}$ are denoted as $M_{2N}^{\bar{q}}$ and $M_\pi^{\bar{q}}$ for the 2N and pion mode, respectively and expressed as

$$M_{2N}^{\bar{q}} = M_{AP}^{\bar{q}} + M_{MT}^{\bar{q}} + M_{VT}^{\bar{q}} \tag{2}$$

with

$$M_{AP}^{\bar{q}} = \left\langle H_{AP-GT}^{\bar{q}}(r_{12})\sigma_{12} + H_{AP-T}^{\bar{q}}(r_{12})S_{12}\right\rangle \tag{3}$$

$$M_{MT}^{\bar{q}} = \left\langle H_{MT-GT}^{\bar{q}}(r_{12})\sigma_{12} + H_{MT-T}^{\bar{q}}(r_{12})S_{12}\right\rangle \tag{4}$$

$$M_{VT}^{\bar{q}} = \left\langle H_{VT-F}^{\bar{q}}(r_{12})\right\rangle \tag{5}$$

and

$$M_\pi^{\bar{q}} = \left\langle H_{\pi NN-GT}^{\bar{q}}(r_{12})\sigma_{12} + H_{\pi NN-T}^{\bar{q}}(r_{12})S_{12}\right\rangle \tag{6}$$

In PHFB model using closure approximation the NTMEs M_α are calculated as

$$M_\alpha = \sum_{n,m}\left\langle 0_F^+\left\|O_{\alpha,nm}\tau_n^+\tau_m^+\right\|0_I^+\right\rangle \tag{7}$$

Results and discussions

The NTMEs involved in $(\beta^-\beta^-)_{0\nu}$ decay in Rp-violating SUSY model calculated within PHFB model using pairing plus quadrupole-quadrupole (PQQ) interaction are 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 $0^+ \rightarrow 0^+$ transition. At present, the results are presented for the case of ^{100}Mo and ^{150}Nd.

Table 1: The NTMEs M_α of squark-neutrino R_p-violating SUSY mechanism of $(\beta^-\beta^-)_{0\nu}$ decay of ^{100}Mo and ^{150}Nd in the PHFB model using PQQ interaction.

Nuclei	M_α	F+SRC		
		SRC1	SRC2	SRC3
^{100}Mo	$M_{2N}^{\bar{q}}$	44.16	80.48	103.35
	$M_{\pi}^{\bar{q}}$	459.81	529.26	547.01
^{150}Nd	$M_{2N}^{\bar{q}}$	21.02	37.55	47.67
	$M_{\pi}^{\bar{q}}$	219.22	249.90	257.56

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 $0^+ \rightarrow 0^+$ transition within R_p-violating SUSY models involving squark-neutrino mechanism using PHFB model. The lepton number violating parameters of R_p-violating SUSY model using calculated NTMEs and experimental data will be extracted and presented in the symposium.

References

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