Neutrinoless double beta decay and Physics beyond the Standard Model

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Introduction

The nuclear ββ decay, in which the charge *Z* of an even *Z*-even *N* nucleus is changed by two units while the mass number *A* remains the same, is a rare and spontaneous process of weak interaction in nature. The ββ decay can be categorized in mainly two modes, namely two neutrino double beta $(\beta\beta)_{2\nu}$ decay and neutrinoless double beta $(\beta\beta)_{0\nu}$ decay. The $(\beta\beta)_{2\nu}$ decay establishes the validity of different nuclear models employed for nuclear structure calculations by calculating the nuclear transition matrix elements (NTMEs) $M_{2\nu}$. The $(\beta\beta)_{0\nu}$ decay violates the lepton number conservation by two units and can be studied in any theory in which lepton number conservation is not exact. Hence $(\beta\beta)_{0\nu}$ decay is an excellent process to probe the new physics beyond the standard model (SM) of electroweak unification. Apart from the well studied left-right symmetric model, the $(\beta\beta)_{0\nu}$ decay can also be studied in Majoron models, R-parity violating as well as conserving supersymmetric (SUSY) models. Further, the $(\beta\beta)_{0\nu}$ decay can verify issues like compositeness, leptoquarks, sterile neutrinos and violation of weak equivalence principle. The detailed progress of experimental as well as theoretical studies on ββ decay in general and $(\beta\beta)_{0\nu}$ decay in particular can be found in references [1,2] and references there in.

The PHFB model in conjunction with pairing plus multipole type of two-body effective interaction has been successfully applied to study the $(\beta\beta)_{0\nu}$ decay [3-7]. In present work the same PHFB model has been applied to study the $(\beta\beta)_{0\nu}$ decay in various theories beyond the SM.

Theoretical framework

The details about the model space, single particle energies, *PQQ* type of effective two-body interaction and the procedure to fix its parameters have been given in Refs. [3,4]. The Hamiltonian of the effective two-body interaction used in the present work is given as

$$H = H_{s.p.} + V(P) + V(QQ) + V(HH) \quad (1)$$

where $H_{s.p.}$, $V(P)$, $V(QQ)$ and $V(HH)$ denote the single particle Hamiltonian, pairing, quadrupole-quadrupole and hexadecapole-hexadecapole parts of the effective two-body interaction. We use four different parametrizations of the interaction Hamiltonian, namely *PQQ*1, *PQQ*2, *PQQHH*1 and *PQQHH*2 [5]. Further, we use the Jastrow type of short range correlations with Miller-Spencer, Argonne V18 and CD-Bonn NN potentials [5,8]. The detailed theoretical formalism to study the $(\beta\beta)_{0\nu}$ decay in Majoron and SUSY models are given in refs. [9,10,11]. Further, the theory of compositeness and leptoquark in connection with $(\beta\beta)_{0\nu}$ decay is given in refs. [12,13].

Results and discussions

The NTMEs involved in $(\beta\beta)_{0\nu}$ decay in various theories stated above are calculated within PHFB model using pairing plus multipole type of two-body interaction. 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 $(\beta\beta)_{0\nu}$ decay of ^{94,96}Zr, ^{100}Mo, ^{128,130}Te and ^{150}Nd isotopes for the $0^+\rightarrow0^+$ transition. At present, some results are presented for the case of ^{100}Mo with *PQQ1* parametrization. The detailed results will be presented in the symposium.

Table 1: NTMEs for the Majoron accompanied $(\beta\beta)_{0\nu}$ decay of ^{100}Mo for the *PQQ1* parametrization.

NTME	F	F+S		
		SRC1	SRC2	SRC3
$M^{(\chi)}_{Fm_\nu}$	2.15	1.89	2.15	2.22
$M^{(\chi)}_{GTm_\nu}$	-5.52	-4.72	-5.43	-5.66
$M^{(\chi)}_{Tm_\nu}$	0.05	0.05	0.05	0.05
$M^{(\chi)}_{CR}$	-0.26	-0.23	-0.26	-0.27
$M^{(\chi)}_{F\omega^2} \times 10^3$	1.18	1.14	1.19	1.20
$M^{(\chi)}_{GT\omega^2} \times 10^3$	-5.79	-5.60	-5.86	-5.91

Table 2: NTMEs of $(\beta\beta)_{0\nu}$ decay in SUSY models via exchange of gluinos for ^{100}Mo with in PHFB model using *PQQ1* interaction.

NTME	F	F+S		
		SRC1	SRC2	SRC3
M^N_F	0.716	0.037	0.056	0.067
M^P_F	0.007	0.003	-0.002	0.002
M^N_{GT}	-0.210	-0.108	-0.164	-0.196
M^P_{GT}	-0.023	0.009	0.004	-0.007
$M^{1\pi}_{GT}$	5.422	2.169	3.80	4.831
$M^{2\pi}_{GT}$	2.613	1.856	2.45	2.661
M^P_T	0.001	0.001	0.001	0.001
$M^{1\pi}_T$	0.285	0.285	0.302	0.302
$M^{2\pi}_T$	0.130	0.132	0.134	0.134

Table 3: NTMEs of $(\beta\beta)_{0\nu}$ decay in SUSY models via exchange of squark for ^{100}Mo with in PHFB model using *PQQ1* interaction.

NTME	F	F+S		
		SRC1	SRC2	SRC3
M_F	-258.7	-131.7	-201.4	-241.1
M_{GT-MT}	412.4	207.4	318.8	382.1
M_{GT-AP}	-25.77	-20.00	-24.92	-26.57
$M_{GT-\pi}$	506.4	441.8	511.2	528.9
M_{T-MT}	-10.33	-10.36	-10.85	-10.83
M_{T-AP}	-1.13	-1.14	-1.15	-1.15
$M_{T-\pi}$	17.90	18.06	18.09	18.07

In Table 1, 2 and 3, SRC1, SRC2 and SRC3 denote the Jastrow type of short range correlations (SRC) with Miller-Spencer, Argonne V18 and CD-Bonn NN potentials, respectively.

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