Study of neutrinoless positron double beta decay including induced currents in the nuclear structure calculation within PHFB model

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Introduction

The sixteen rare, experimentally distinguishable, modes of nuclear ββ decay, namely the double-electron emission ($\beta^-\beta^-$), double-positron emission ($\beta^+\beta^+$), electron-positron conversion ($\varepsilon\beta^+$) and double-electron capture (εε) with the emission of two neutrinos, no neutrinos, single Majoron and double Majorons, are semileptonic weak transitions involving strangeness conserving charged currents. The $\beta^+\beta^+$, $\varepsilon\beta^+$ and εε modes are energetically competing and we shall refer to them as $e^+\beta\beta$ decay. In principle, the $\beta^-\beta^-$ decay and $e^+\beta\beta$ decay can provide us with the same but complementary information. The observation of $(e^+\beta\beta)_{2\nu}$ decay modes will be interesting from the nuclear structure point of view, as it is a challenging task to calculate the nuclear transition matrix elements (NTMEs) of these modes along with $(\beta^-\beta^-)_{2\nu}$ mode in the same theoretical framework. Further, the observation of $(e^+\beta\beta)_{0\nu}$ decay modes will be helpful in deciding issues like dominance of mass mechanism or right handed currents [1 hirs94].

In order to study the $e^+\beta\beta$ modes, the calculated model dependent NTMEs should be as accurate as possible. The calculation of accurate NTMEs is quite a challenging task as different NTMEs are obtained by employing distinct nuclear models, for a given transition. Further, for a given model, NTMEs also depend on the model space and effective two-body interaction. The other factors responsible for the uncertainties are the inclusion of pseudoscalar and weak magnetism terms in the Fermi, Gamow-Teller and tensorial NTMEs, finite size as well as short range correlations (SRC), and the use of two effective values of the axial-vector coupling constant g_A.

In case of $(\beta^-\beta^-)_{0\nu}$ decay, it has been reported by Simkovic et al. [2] and Vergados [3] that the contributions of the induced currents, i.e. pseudoscalar and weak magnetism terms of the recoil current in mass mechanism can change NTMEs up to 30%, which has been recently confirmed in the shell model calculation of Strassbourg-Madrid group as well as in IBM. The same effect has also been observed within PHFB model in our earlier work [4]. In the present work we study the effects of pseudoscalar and weak magnetism terms on the Fermi, Gamow-Teller and tensorial NTMEs for the $(e^+\beta\beta)_{0\nu}$ modes within PHFB model.

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. [5-10]. 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 [9]. Further, we use the Jastrow type of short range correlations with Miller-Spencer, Argonne V18 and CD-Bonn NN potentials [10,11]. The theoretical formalism to calculate the half-life of the $(e^+\beta\beta)_{0\nu}$ modes has been given by Doi et al. [12]. Following the Simkovic et al. [1] and Vergados [2], the induced currents can be included to calculate NTMEs of $(e^{+}\beta\beta)_{0\nu}$ modes. The detailed formalism will be presented in the symposium.

Results and discussions

The results of calculated NTMEs $M^{(0\nu)}$ and $M_N^{(0\nu)}$ for light and heavy Majorana neutrino exchange, respectively, for $(e^{+}\beta\beta)_{0\nu}$ modes are presented in Table 1.

Table 1: Calculated NTMEs of ^{106}Cd in the PHFB model for *PQQ*1 parametrization. A and B denotes the NTMEs without and with induces currents.

	$\lvert M^{(0\nu)}\rvert$		$\lvert M_N^{(0\nu)}\rvert$	
	A	B	A	B
F	9.18	8.46	479.32	452.69
F+S1	8.01	7.26	247.19	149.55
F+S2	9.16	8.34	375.02	265.99
F+S3	9.49	8.68	447.58	366.91

The results in Table 1 are calculated within PHFB model using *PQQ*1 parametrization. The F and F+S denote finite size of nucleons with dipole form factor and finite size plus SRC, respectively. Further, the S1, S2 and S3 represent short range correlations with Miller-Spencer, Argonne V18 and CD-Bonn NN potentials, respectively. It can be observed from Table 1 that inclusion of effects due to induced currents reduces the NTMEs up to about 9 % and 40 % for light and heavy neutrino exchange, respectively. Results will be more conclusive when the calculation will be performed over all the positron emitters in the mass range $A = 90 - 156$ using four parametrization within PHFB model. The detailed results will be presented in the symposium.

Conclusions

To summarize, we study the effect of induced currents on the calculation of NTMEs of $(e^{+}\beta\beta)_{0\nu}$ decay using the Jastrow type of SRC with Miller-Spencer, Argonne V18 and CD-Bonn NN potentials employing four sets of wave functions generated through the projected Hartree-Fock Bogoliubov model. It was observed that the inclusion of induced currents in the calculation reduces the NTMEs substantially.

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