Neutrinoless Double Beta Decay in ^{76}Ge and ^{82}Se

Amrendra Kumar[1,2], B.M. Dixit[3], P. K. Raina[4] and P.K. Rath[1]

[1]*Department of Physics, University of Lucknow, Lucknow-226007, U. P.*
[2]*Sri Ramswaroop Memorial College of Engineering & Management, Lucknow – 227105 , U.P.*
[3] *Sri Ramswaroop Memorial University, Lucknow Deva Road, Lucknow -225003, U.P.*
[4]*Department of Physics, Indian Institute of Technology, Ropar, Rupnagar – 140001, Haryana*

Introduction

To ascertain the Dirac or Majoron nature of neutrino and to estimate its mass, neutrinoless double beta (0ν ββ) decay is considered as the most effective naturally occurring phenomenon. Hence, the renewed interest in the study of double beta decay processes of ^{76}Ge and ^{82}Se isotopes is due to the positive experimental results for 2ν ββ decay and measurement of large half lives of the 0ν ββ decay with high confidence level. The present GERDA experiment [1] has deduced half life of 2ν ββ decay $T^{2\nu}_{1/2} = \left(1.84^{+0.09}_{-0.08}\,^{+0.11}_{-0.06}\right) \times 10^{21}$ yr for ^{76}Ge and in the case of 0ν ββ decay, it is $T^{0\nu}_{1/2} > 2.1 \times 10^{25}$ yr. The half-life of 2ν ββ decay $T^{2\nu}_{1/2} = \left(9.6^{+0.1}_{-0.1}\,^{+1.0}_{-1.0}\right) \times 10^{19}$ yr and $T^{0\nu}_{1/2} > 3.2 \times 10^{23}$ yr for ^{82}Se, as measured by NEMO3 collaboration [2].

These exciting developments in the experimental front offer a challenging task of calculating nuclear transition matrix elements with high reliability, which can be obtained only with reliable wave functions. The wave function is nuclear model dependent and hence, it should be versatile enough to reproduce some of the observed nuclear properties of the ^{76}Ge, $^{76, 82}$Se and ^{82}Kr nuclei. The calculated nuclear matrix elements which are involved in the 0ν ββ decay process can be further used to calculate the limit on the mass of neutrino.

Nuclear Structure Aspect

An important observed characteristic feature of nuclei in the Ge region is shape transitions at N=40. The onset of deformation at N=40 necessitates to adopt a calculational framework which permits the interplay of pairing and deformation degrees of freedom simultaneously, and on equal footing [3,4].

PHFB Model

The present calculation is performed employing Projected HFB (PHFB) model in a valance space spanned by the $1p_{1/2}$, $1p_{3/2}$, $0f_{5/2}$ and $0g_{9/2}$ orbits treating the doubly even ^{56}Ni as an inert core with realistic two body effective interaction.
Two different set of wave functions are generated using two distinct effective interactions, namely KUO [5] and JUN45 due to Honma et. al.[6]. The former is a realistic interaction while the latter is an empirical one. The wave functions obtained by using JUN45 and KUO effective two-body interactions are referred to as HFB1 and HFB2, respectively. To ascertain the reliability of the generated wave functions in both the cases, the calculated excitation energy of yrast 2^+ state, occupation numbers, BE2 and g-factor are presented in Table 1 and Table 2 along with the experimentally observed data [7,8,9,10]. Presently, the results for ^{76}Ge and ^{76}Se isotopes are only tabulated due to the want of enough space. It is noticed that the agreement between the calculated spectroscopic properties of ^{76}Ge and ^{76}Se nuclei and the experimentally observed data is reasonably good.

Employing these reliable wave functions, different nuclear transition matrix elements for the study of 0ν ββ decay are calculated. In addition, the two body effective interaction is further decomposed into central, spin-orbit and tensor components and the effect of each component on nine different nuclear matrix elements involved in 0ν ββ decay is studied individually and compositely.

Conclusions

The preliminary results on nuclear matrix elements and extracted limits on the mass of neutrino is quite exciting and we want to present these results in this symposium.

References

[1] B. Majorovits, for the GREDA Collaboration, arXiv:1506.00415v1 [hep-ex], 2015.

[2] M. Bongrand for NEMO3 Collaboration, arXiv:1105.2435v1 [hep-ex], 2011.

[3] A.L. Goodman, Advances in Nuclear Physics, edited by J.W Negele and E. Vogt (Plenum, New York), 11 (1979).

[4] B.M.Dixit, P.K. Rath and P.K. Raina, Phys. Rev. C65, 034311 (2002): Phys. Rev. C67, 059901 (2003).

[5] T.T. S. Kuo (Private Communication).

[6] M. Honma, T. Otsuka, T. Mizusaki and M.Hjorth-Jensen, Phys. Rev. C80, 064323 (2009).

[7]B.P.Kay et.al., Phys. Rev. C79, 2130 (2009).

[8]M.Sakai, At. Data Nucl. Data Tables, 31, 399 (1984).

[9] S. Raman, C. W. Nestor Jr. and P. Tikkanen, At. Data Nucl. Data Tables, 78, 1 (2001).

[10] P. Raghavan, At. Data Nucl. Data Tables, 42, 189 (1989).

Table 1. Occupation numbers for protons and neutrons of ^{76}Ge and ^{76}Se.

		^{76}Ge			^{76}Se		
	l =	HFB1	HFB2	Exp.	HFB1	HFB2	Exp.
Proton	1	1.72	1.6	1.77 ±0.15	2.03	2.54	2.08 ±0.15
	3	2.13	2.3	2.04 ±0.25	3.41	3.2	3.16 ±0.25
	4	0.15	0.1	0.23 ±0.25	0.56	0.26	0.84 ±0.25
Neutron	1	4.9	4.95	4.87 ±0.20	3.91	4.09	4.41 ±0.20
	3	4.88	4.24	4.56 ±0.40	3.95	3.73	3.837 ±0.40
	4	6.21	6.81	6.48 ±0.30	6.14	6.18	5.80 ±0.30

Table2. Comparison of calculated and observed excited energy of yrast 2^+ state, reduced transition probabilities B(E2:$2^+ \rightarrow 0^+$) × 10^{-50} e^2 cm^4 and g-factor of ^{76}Ge and ^{76}Se.

	^{76}Ge			^{76}Se		
	HFB1	HFB2	Exp.	HFB1	HFB2	Exp.
E_{2+}	0.544	0.563	0.563	0.541	0.559	0.559
BE2	5.2	5.48	5.36 ±0.16	8.07	8.13	8.4 ±0.20
g(2^+)	0.386	0.353	0.334 ±0.038	0.327	0.394	0.405 ±0.11