Nonadiabatic quasiparticle description of proton emission from the odd-odd nucleus ^{130}Eu

Monika Patial[1],* P. Arumugam[1], A. K. Jain[1], E. Maglione[2], and L.S. Ferreira[3]
[1]*Department of Physics, Indian Institute of Technology Roorkee, Uttarakhand 247667, INDIA*
[2]*Dipartimento di Física "G. Galilei", Via Marzolo 8, I-35131 Padova, Italy and Istituto Nazionale di Fisica Nucleare, Padova, Italy and*
[3]*Centro de Fsica das Interacções Fundamentais, and Departmento de Física, Instituto Superior Técnico, Avenida Rovisco Pais, P1049-001 Lisbon, Portugal.*

Introduction

The study of proton emission has aided the understanding of nuclear structure quiet successfully with the precise experimental observations and the exact non-adiabatic calculations. So far this study with the non-adiabatic calculations were performed for odd-even nuclei. We are presenting here the non-adiabatic quasiparticle approach to describe the proton rich odd-odd nuclei near drip line region. It is assumed that decaying proton moves in the single-particle Nilsson level in resonance with the unbound core plus neutron system [1]. Adiabatic approach with zero point energy [2] has already explained some of odd-odd nucleus, and we carry forward this approach one step ahead by taking into account finite moment of inertia, and hence full rotational spectra, which allows considerable Coriolis mixing of quasi-particle states. The emitted proton tunnels through centrifugal and coulomb barrier which results the lifetimes which strongly depends upon the assignment of the configuration of particular states and hence gives valuable information about the angular momentum of decaying state.

Formalism

We have considered a two quasiparticle plus rotor model [4] within the strong coupling limit based on the mean field defined by the deformed Woods-Saxon potential to describe properties of decaying nucleus. The Coriolis calculations are performed with quasiparticle energies, $\tilde{\epsilon}_k = \sqrt{\Delta^2 + (\epsilon_k - \lambda)^2}$, where, ϵ_k are the single-particle energies, Δ is constant pairing gap defined as $\Delta = a_\Delta \times 12/\sqrt{A}$ and λ being the Fermi energy of the nucleus. We introduce the residual np interactions by a suitable constant value for GM splitting and Newby shift along with required proper phase. The partial decay width is obtained by the overlap of wavefunctions of parent nucleus and daughter nucleus coupled to the outgoing proton as shown below:

$$\Gamma^{I,I_d}_{l_p j_p} = \frac{\hbar^2 k}{\mu} \left| \sum_{K_n,K_p} \alpha^{I,M}_{K_T,K_n,K_p} \, \beta^{I_d,M_d}_{K_n} u_{K_p} \times \sqrt{\frac{(2I_d+1)}{(2I+1)}} \langle I_d, K_n, j_p, K_p | I, K_T \rangle N^{K_p}_{l_p j_p} \right|^2 \quad (1)$$

where u_{kp} is the deformation dependent spectroscopic factor of daughter nucleus obtained from the BCS approach. The emitted proton can take range of angular momentum values $|K_T - K_d| \leqslant j_p \leqslant K_T + K_d$ allowed by angular momentum coupling rule. Finally, the total decay width is obtained by summing the partial decay widths over all possible combinations of l_p and j_p values. The other notations are explained in Ref.[5]

Result and discussions

^{130}Eu, a highly deformed ($\beta_2 \sim 0.3$) proton emitter has been assigned [3] a ground state spin parity of 1^+ based on the decay width from adiabatic calculations. Here we explore the non-adiabatic effects in the nucleus along with its interplay with the residual

*Electronic address: monikaphd@gmail.com

TABLE I: Calculated half-lives for different spin parity at predicted deformation $\beta_2 = 0.33$ of ^{130}Eu.

↓Theory	$T_{1/2}$ (ms)			
$I^\pi \rightarrow$	1^+	2^+	2^-	5^-
Adiabatic	1.81	0.67	0.12	0.13
Non-adiabatic	1.81	1.46	0.12	0.14

$T_{1/2}$ (Experiment) $= 0.90^{+49}_{-29}$ ms.

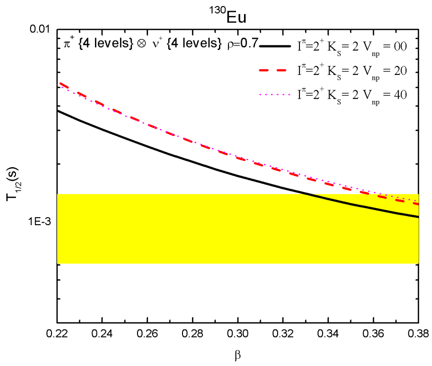

FIG. 1: Half-lives variation with different V_{np} interaction for ^{130}Eu as a function of quadrupole deformation. Experimental half life falls in yellow shaded region.

np interaction. For our calculations we choose few levels near Fermi surface at the deformation $\beta_2 = 0.33$ predicted by Möller and Nix. These levels turn out to be 3/2[411], 5/2[413], 1/2[411] and 9/2[404] for the protons (π) and 1/2[411], 5/2[413], 3/2[411] and 5/2[402] for the neutrons (ν), for the positive parity. The negative parity states are calculated by mixing the above-mentioned positive parity levels of protons and all the negative parity from $h_{11/2}$ sub-shell of neutrons. The variable moment of inertia is obtained by using E^{2+} value of 122 KeV from the neighbouring core ^{130}Sm. The half-lives are calculated with (attenuation coefficient $\rho = 0.7$) and without Coriolis ($\rho = 0.0$) effects, for different spin parity combinations are presented in Table I. Clearly, it can be seen that both $I^\pi = 1^+$ and 2^+ yield half-lives closer to experimental value. However, the $I^\pi = 1^+$ state has to be ground state according to GM rule and and hence could be assigned as the proton emitting state. Our results suggest that the Coriolis mixing is very weak in this case. We study the Coriolis effects and the role of residual neutron-proton interaction (V_{np}) along with the quadrupole deformation on the half-life for decay from the singlet state $I^\pi = 2^+$ of ^{130}Eu. The results for three different strengths of V_{np} are given in Fig 1. We observe that the inclusion of V_{np} could alter the half-life, feebly in a direct way but strongly by modifying the Coriolis interaction.

In conclusion, with our calculations for various possible configurations, we confirm the decaying state to be the $I^\pi = 1^+$ state in ^{130}Eu. We have demonstrated that the residual interaction could influence the effect of Coriolis interaction and such effects could be reflected by the proton emission half-lives, providing us with an opportunity to explore the detailed properties of wave-functions in odd-odd nuclei.

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