Microscopic study of octupole-deformations in even-even $^{226\text{-}230}$Th isotopes

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Study of octupole correlations in the actinides has attracted interest because of the predictions that octupole deformation would be present in the Z~88 and N ~ 134 region [1]. These predictions have been explored through a series of experimental studies, which have centred on energy spectra and transition properties [2,3]. The level schemes of even-even positive parity bands of some thorium isotopes have been extended up to higher spin. Azmal et al [4] and Cocks et al [5] have studied the spectroscopy of $^{226\text{-}230}$Th isotopes by using multi-nucleon transfer reactions. They systematically studied the rotational alignment properties of thorium isotopes and revealed the information concerning the role of the octupole phonon and the onset of stable octupole deformation with increasing rotational frequency. A number of theoretical studies are also dedicated over the years to the study of octupole degree of freedom in actinide nuclei [2,6]. Recently, Chen et al [7] predicted the strong non-axial octupole effects in super heavy nuclei. Their results which they have obtained by reflection asymmetric shell model represents the first concrete example of spontaneous breaking of both axial and reflection symmetries in the heavy nuclear systems.

In the present work, the octupole-octupole interaction is incorporated to the pairing plus quadrupole-quadrupole model. The microscopic Cranked Hartree Bogoliubov framework (CHB) [8] is employed with pairing plus quadrupole-quadrupole plus octupole-octupole interaction to study the non-axial nature of $^{226\text{-}230}$Th.

The cranking model for number non-conserving wave functions replaces H by

$$H' = H - \lambda N - \omega J_x ,$$

where the angular frequency ω is adjusted so that

$$\langle J_x \rangle = \sqrt{J(J+1)}$$

and the chemical potential λ is adjusted so that the number operator N has the correct expectation value.

The single particle energies (SPEs) that we have employed are (in MeV) $(2f_{7/2})$=0, $(1h_{9/2})$=0.5, $(1i_{13/2})$=1.9, $(3p_{3/2})$=2.4, $(2f_{5/2})$=2.9, $(3p_{1/2})$=3.9, $(2g_{9/2})$=5.8, $(1i_{11/2})$=7.5, and $(1j_{15/2})$=7.8. This set of input SPEs are taken from Nilsson diagram http://ie.lbl.gov/toipdf/nilsson.pdf.

The strengths of interaction parameters of the like-particle neutron-neutron (χ_{nn}) or proton–proton (χ_{pp}) and the neutron–proton (χ_{np}) has been parametrized by the relations [9]

$$\chi_{nn}(=\chi_{pp}) = -(10-11)\times A^{-1.4}\,\text{MeV}\ \text{a}^{-4}$$

$$\chi_{np} = 1.7\times\chi_{nn}(=\chi_{pp})$$

with G = (18-21)/A.

Here $a(=\sqrt{\hbar/m\omega})$ is the oscillator parameter.

Using the cranking framework, the components of quadrupole moment and octupole moment operators for protons and neutrons for the yrast states in $^{226\text{-}230}$Th up to spin 20^+ are calculated. Besides this, the values of quadrupole deformation, octupole deformation and non-axiality parameters have also been calculated. It turns out from the present calculations that the quadrupole deformation slightly decreases as one goes along the yrast states in all the three isotopes and the value of non-axiality parameter shows that these nuclei posses sizable amount of non-axiality.

In Fig 1, a comparison of the experimental and theoretical yrast states of $^{226\text{-}230}$Th isotopes is displayed. It is observed that reasonably good agreement is obtained for the yrast states.

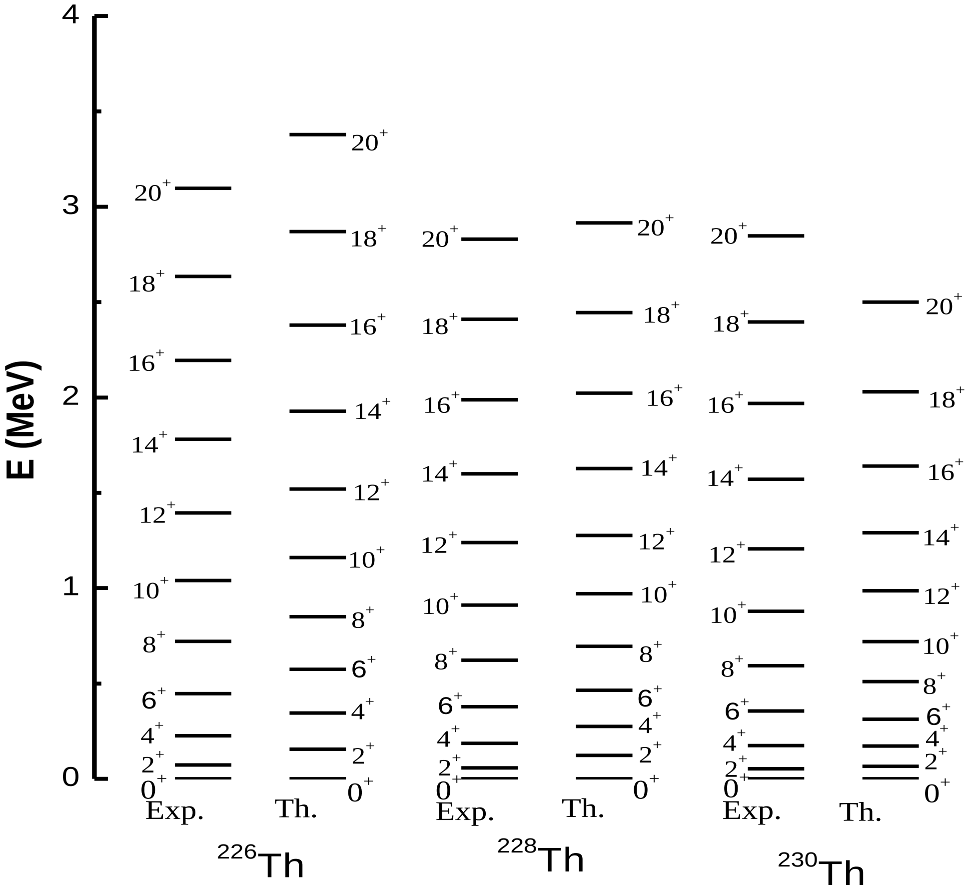

Fig. 1: Comparison of the experimental and theoretical yrast states of $^{226-230}$Th isotopes.

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