# Rotational properties of N=146 isotones

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## Introduction

The actinide nuclei rank among the heaviest elements for which comprehensive spectroscopic data can be obtained. These nuclei exhibit significant deformation, making them some of the most collective nuclei available for both experimental and theoretical investigation. The study of actinide nuclei holds considerable importance for several reasons. One such reason is the alignment of $i_{13/2}$ protons and/or $j_{15/2}$ neutrons under rotational stress. Most yrast bands of even-even actinide nuclei display a smooth increase in alignment with rising rotational frequency, with the strong back-bending phenomenon characteristic of rare-earth nuclei being largely absent. In this regard, Pu isotopes exhibit particularly anomalous behavior. The sharp back-bending observed in heavier Pu isotopes is absent in lighter isotopes, indicating a notable delay in the alignment process [1]. This anomaly is attributed to the presence of octupole deformation [1, 2].

A recent advancement in the particle-number-conserving method within the cranked shell model (PNC-CSM) framework has enabled the study of alternating-parity bands in the isotopes $^{236,238}$U and $^{238,240}$Pu in reflection-asymmetric systems [3].

## The particle number conserving method

In the particle-number conserving (PNC) treatment of cranked shell model (PNC-CSM), particle number is conserved and the Pauli blocking effect is treated consistently. The cranked shell model Hamiltonian with pairing is

$$H_{\mathrm{CSM}} = H_{\mathrm{SP}} - \omega J_x + H_p = H_0 + H_p$$

where $H_0 = \sum_i h_{\mathrm{nilsson}} - \omega j_{x_i}$. The term $H_p$ has monopole and quadrupole pairing correlations $H_p = H_p(0) + H_p(2)$ The $H_{\mathrm{CSM}}$ is diagonalized in a sufficiently large cranked many-particle configuration (CMPC) space to obtain the yrast and low-lying eigenstates. The eigenstate of $H_{\mathrm{CSM}}$ is expressed as:

$$|\psi\rangle = \sum_i C_i |i\rangle$$

here $|i\rangle$ denotes an occupation of particles in the cranked Nilsson orbitals and $C_i$ denotes the corresponding probability amplitude.

## Results and Discussion

In the present manuscript we have applied the the PNC-CSM to study the ground state bands in reflection-symmetric systems of N=146 isotones. In the well-deformed region, variations in the pairing gap, and consequently pairing correlation, may manifest in the systematics of the energy of the $2^+$ state ($E(2^+)$). Previous research has indicated that the pairing correlations are weakened at the deformed shell gap. This reduction leads to a higher moment of inertia and a lower energy of the $E(2^+)$ state at $N = 152$ [4]. Additionally, the absolute value kinematic moment of inertia is closely related to the energy of the $E(2^+)$ state at low spin [5]. The energy of the $2^+$ state, in turn, is influenced by quadrupole deformation and pairing correlations, which decrease in the region of the deformed shell gap. It is well established that a decrease in pairing correlation results in an increased moment of inertia. Figure 1(a) illustrates the systematics

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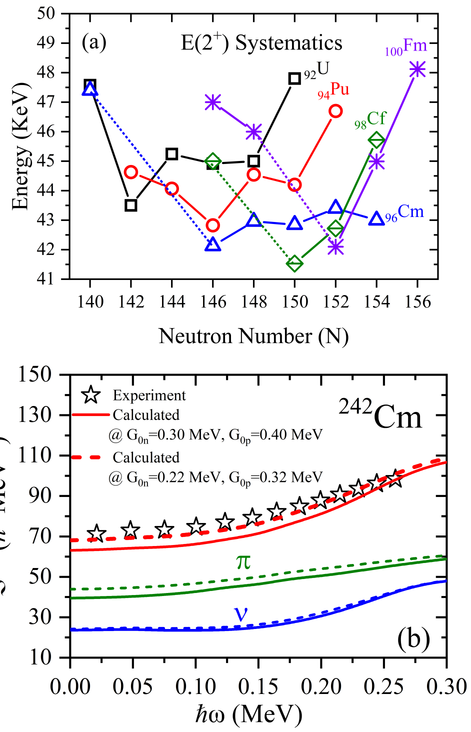


FIG. 1: (a) The systematics of the $2^+$ energies for ground state bands of even-even nuclei with neutron number (N) for actinide. (b) The experimental and calculated kinematic moment of inertia for the GSB bands in $^{242}$Cm. The proton ($\pi$) and neutron ($\nu$) contributions to the moment of inertia is also shown.

of $E(2^+)$ states for even-even actinide nuclei within the ground state bands. The figure1(a) clearly shows that the $E(2^+)$ state at $N = 146$ is lowest for curium (Cm, $Z = 96$) nuclei, followed by plutonium (Pu, $Z = 94$). The $E(2^+)$ states of californium (Cf, $Z = 98$) and uranium (U, $Z = 92$) are nearly identical, while the highest $E(2^+)$ energy is observed in fermium (Fm, $Z = 100$). Experimental data for Pu and Cm isotopes confirm that at $N = 146$, the $E(2^+)$ state is the lowest within their respective isotopic chains.

The Nilsson parameters ($\kappa$ and $\mu$) are taken from Ref. [6]. In this paper, we have adopted the deformation parameters $\epsilon_2$, $\epsilon_4$, $\epsilon_6$ for $^{242}$Cm as 0.248, -0.036, 0.025, respectively. For $^{242}$Cm, the calculated moment of inertia from the PNC-CSM underestimates the experimental value by approximately $8\hbar^2\text{MeV}^{-1}$ in the low-frequency region; however, the overall trend of the calculated moment of inertia matches the experimental curve accurately. Based on systematics of $E(2^+)$ states, we reduced the pairing strengths by 0.08 MeV for $^{242}$Cm. The recalculated results, depicted by dashed lines in figure1(b), now align precisely with the experimental data.

## Conclusion

Analysis of the energy levels of $2^+$ states revealed that among the N=146 isotones, $^{242}$Cm exhibits the lowest $E(2^+)$ state. The PNC-CSM accurately reproduced both the experimental kinematic moments of inertia. For $^{242}$Cm, however, the model underestimated the kinematic moment of inertia at lower rotational frequencies and overestimated the dynamic moment of inertia at higher rotational frequencies. Excellent agreement between the calculations and experimental data for $^{242}$Cm was achieved by reducing the neutron and proton pairing strengths by 0.08 MeV.

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