Structural evolution from low to high-spin states in ^{130}Xe

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Introduction

Xenon with one of the longest chain of stable isotopes is a promising candidate to study various structural evolutions. The nuclear structure study of Xe isotopes chain has recently acquired substantial momentum to uncover hitherto unexploited coupling schemes of intrinsic and collective nuclear degrees of freedom [1, 2]. The mass A∼130 region is characterized by sharp back-bending phenomenon near $I \sim 10^+$ and γ instability. Eid *et al.* predicted back-bending in ^{130}Xe at $I = 12^+$ using IBA-1 model [3] but Shi Zhu-Yi *et al.* reported using IBM-2 model that ^{130}Xe does not show any prominent change in shape [4]. Moreover, information on high-spin states in ^{130}Xe is lacking both experimentally and theoretically unlike in other Xe isotopes *e.g.* ^{124,126}Xe [5, 6]. These surveys motivated us to look into ^{130}Xe using microscopic shell model at low-spin and pairing independent cranked Nilsson Strutinsky (CNS) calculations at high-spin states. Moreover, a third formalism based on Deformed Hartree-Fock (DHF) theory was used as a bridge between low and high-spin states which might be helpful in determining parameters of interaction Hamiltonian.

Results and Discussions

A. Low-medium spin-states

I. Shell Model calculations and results

In the calculation a valance space consisting of $0g_{7/2}$, $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$ and $0h_{11/2}$ orbitals, for both protons and neutrons, was considered outside an isospin symmetric ^{100}Sn core. The single-particle energies are taken as -9.68, -8.72, -7.24, -7.34 and -6.88 MeV. The starting point of our calculation is the realistic CD-Bonn nucleon-nucleon potential.The interaction was renormalized using the perturbative G-matrix approach, thus taking into account the core-polarization effects [7]. The shell model Hamiltonian was diagonalized by using NuShellX@MSU code [8]. To keep the matrix dimension tractable for SM calculation, proton and neutron excitations from the $0g_{7/2}$ and $1d_{5/2}$ into the $1d_{3/2}$, $2s_{1/2}$ and $0h_{11/2}$ orbitals were restricted to four and six, respectively. The theoretical and experimental spectra for positive parity levels are compared in Fig. 1. Energy levels of the even-spin yrast band are reasonably well reproduced. A sudden decrease of the level spacing is observed for the yrast 10^+ state. This is consistent with the experimental evidence.

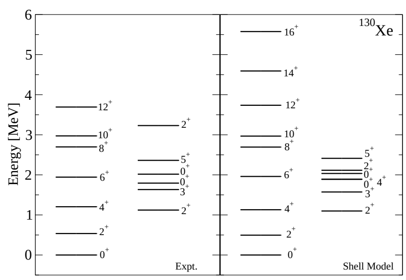

FIG. 1: Comparison of the calculated spectrum of ^{130}Xe with experiment [9]. The calculation is performed in a restricted valence space (as discussed in the text).

II. DHF Model and results

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The deformed Hartree-Fock orbits are calculated with a spherical core of ^{56}Ni, the model space spans the $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$, $0g_{9/2}$, $0d_{5/2}$, $0g_{7/2}$, $0d_{3/2}$, $2s_{1/2}$ and $0h_{11/2}$ orbits both for protons and neutrons with single particle energies 0.0, 0.78, 1.88, 4.44, 8.88, 11.47, 10.73, 12.21 and 13.69 MeV respectively [10]. We used surface delta interaction (with interaction strength ∼0.32 for $p-p$, $p-n$ and $n-n$ interactions) as the residual interaction.

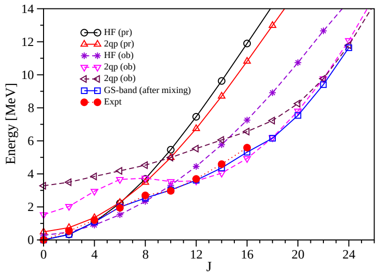

FIG. 2: Comparison of the calculated (DHF) spectrum of ^{130}Xe with experiment [9].

In case of ^{130}Xe, the prolate and oblate HF solutions are degenerate (with energy deference ∼ 600 keV). So for this nucleus, we have performed the shape-mixing calculation by mixing the prolate and oblate configurations. The shape-mixing calculation reasonably reproduces the low lying spectra for ^{130}Xe as can be seen in Fig. 2.

In Table I, we have shown the electromagnetic properties for the ground band calculated using DHF model and comparison is made with available experimental data. For the calculations of B(E2) and quadrupole moments, the effective charges $e_p = 1.6e$ and $e_n = 0.6e$ are used.The g-factors of $g_l = 1.0\mu_N$ and $g_s = 5.586 \times 0.75\mu_N$ for protons and $g_l = 0\mu_N$ and $g_s = -3.826 \times 0.75\mu_N$ for neutrons are used for magnetic moment calculations.

B. High-spin states

Lastly, high-spin bands were probed into and predicted through CNS calculations with parameters derived for A = 130 region [13], which shows that bands based upon two protons excitations from $0g_{9/2}$ orbital coupled

TABLE I: Comparison of calculated and experimentally observed B(E2), static quadrupole moments Q(J) and magnetic dipole moments $\mu(J)$ for ^{130}Xe.

J^π	B(E2;J→ J-2)		$Q_S(J)$ [eb]		$\mu(J)$ [μ_N]	
	Th.	Expt.[11]	Th.	Expt.[12]	Th.	Expt.[12]
2^+	0.113	0.13±0.01	-0.675		+0.611	+0.67±0.02
4^+	0.160		-0.844		+0.925	
6^+	0.174		-0.904		+1.183	
8^+	0.180		-0.920		+1.423	
10^+	0.181		-0.915		+1.664	

with neutrons in (hf) and $0i_{13/2}$ orbitals become energetically favorable at around $I \sim 35$ - $45\hbar$. Details will be presented during the conference.

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