The study of nuclear structure of even-even Neodymium isotopes using Interacting Boson Model

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Introduction

Neodymium isotopes are the members of the chain of nuclei around mass 140 and they represent an ideal case for studying the influence of the shape transition from spherical to deformed nuclei. The nuclei around mass 140 have many interesting features such as high spin isomers, backbending phenomena and even-odd energy staggering of quasi-γ bands caused by a soft triaxial deformation and features recently referred to as chiral bands [1]. These nuclei belong to a typical transitional region between spherical and deformed shapes. In this paper we determined the most appropriate Hamiltonian that is needed for present calculations of nuclei in the $A \approx 130$ region by the view of projection of IBM-1 parameter. The interacting boson model has been widely used for describing the quadrupole collective states of the medium mass nuclei using the best-fitted values of parameters.

Theoretical Background

In the interacting boson model-1, one assume that low-lying collective quadrupole states can be generated as states of a system of N bosons able to occupy two levels, one with angular momentum J=0, called s, and other with angular momentum J=2, called d-boson. In the second quantized formalism, the most general Hamiltonian containing only one-body and two-body terms can be written as [2]

$$H = \epsilon n_d + a_0 P^\dagger.P + a_1 L.L + a_2 Q.Q + a_3 T_3.T_3 + a_4 T_4.T_4$$

The computer program code PHINT was used for the construction of the IBM Hamiltonian. The input parameters EPS, ELL, QQ, OCT and HEX are related to the coefficients ϵ, a_0, a_1, a_2, a_3, a_4 respectively, where $EPS = \epsilon$, $PAIR = a_0/2$, $ELL = 2a_1$, $QQ = 2a_2$, $OCT = a_3/5$, $HEX = a_4/5$.
Interacting boson model has a very definite group structure, that of the group U(6). Different reductions of U(6) gives three dynamical symmetry limits known as harmonic oscillator, deformed rotor and asymmetric deformed rotor which are labeled by U(5), SU(3) and O(6) respectively.

$$U(6) \supset U(5) \supset O(5) \supset O(3) \supset O(2)$$
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Casten's symmetry triangle (see Fig.1) in its geometric representation describe the three limits. Each vertex represents a geometric limit and the legs represent the region where the structure undergoes a transition from one limit to other.

Result and Discussion

Fig.2 shows the experimental positive parity spectra of the ground state, quasi beta band and quasi gamma band for Nd isotopes. The nucleus ^{142}Nd has N=82, closed neutron shell [3] and nucleus ^{144}Nd shows a nuclear structure of intermediate in the shape transition from the spherical [4] . The energy level spacing in ^{144,146}Nd correspond to a spherical anharmonic vibrator, and those in ^{148}Nd being a transitional nucleus [5].

Gamma softness versus rigidity

Axially asymmetric nuclei in IBM-1 are always γ-soft. These properties of IBM-1 can

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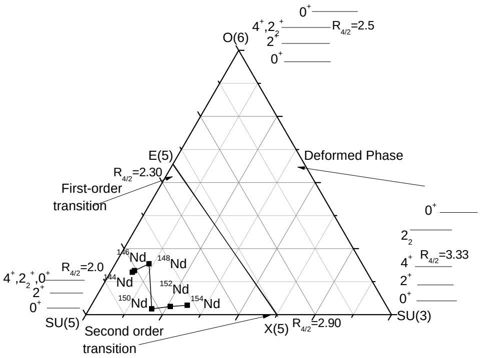

FIG. 1: Casten triangle for the different isotopes of the Nd nuclei.

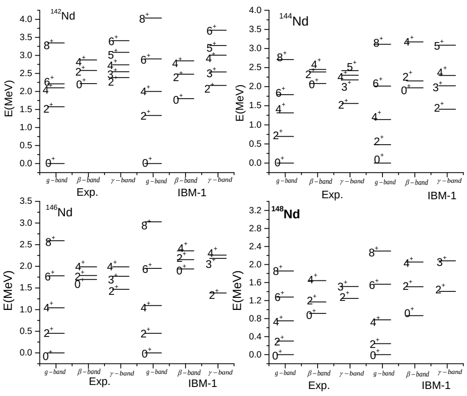

FIG. 2: Comparison of calculated IBM-1 g-band, β-band and γ-band energy with experimental values for $^{142-148}$Nd nuclei.

be tested experimentally by using the energy staggering in the γ-band as a signature of γ-softness or rigidity. In a γ-soft potential, the quasi γ-band levels cluster in energy couplets as $2^+, (3^+, 4^+), (5^+, 6^+), \dots$ whereas in a γ-rigid potential the clustering goes as $(2^+, 3^+), (4^+, 5^+), \dots$. A sensitive signature is therefore the staggering index

$$S(\gamma) = \frac{[E(4_\gamma^+) - E(3_\gamma^+)] - [E(3_\gamma^+) - E(2_\gamma^+)]}{E(2_1^+)}. \quad (1)$$

Negative $S(\gamma)$ values corresponds to axial asymmetry which arises from γ softness in the potential and positive values for γ-rigid, the

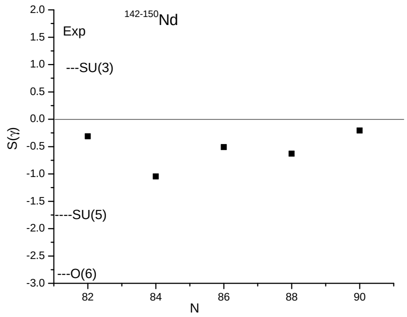

FIG. 3: Empirical values of the staggering index $S(\gamma)$ define in eq.(1) predictions of $S(\gamma)$ are given for the γ-rigid Davydov model as a function of γ.

magnitude of $S(\gamma)$ of course, depends upon the deformed nuclei observed near midshell, $\sim 8^o$. For well-deformed nuclei values of γ_0 are predicated close to the $7^o \sim 10^o$.

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