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ELEMENTARY PARTICLES AND FIELDS

Cubic Interaction and Triaxiality in $^{236-246}$Pu Nuclei

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Abstract—In the present study, we investigate even–even $^{236-246}$Pu isotopes with triaxial interacting boson model. Calculations for the energy levels and $E2$ transition probability were performed using the cubic terms. The study of the influence of cubic $[d \times d \times d]$ and quadrupole $[Q \times Q \times Q]$ interactions on the structure of these nuclei is undertaken. The potential energy surfaces as functions of the deformation parameters were calculated. It has been demonstrated how the cubic term $L = 3$ gives rise to a number of the observed properties of the Pu-nuclei. The comparison between the model results and available experimental data have shown that the structure of these nuclei can be investigated by an $SU(3)$ Hamiltonian.

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1. INTRODUCTION

The nuclei with the mass number $A > 200$ have been the subject of various theoretical and experimental studies due to their unique structure and properties. This was a decisive factor in a revival of interest in it so may provide rich references of data for researchers. We cite several experimental [1–13]. Theoretically, there has been wide investigation in an attempt to study their structures, stability, and other properties [14–18]. In the earlier version of Interacting Boson Model IBM-1, the collective states can be reduced to a system of N_B identical bosons. These bosons are the s-boson, with angular momentum $L = 0$, and the d-boson with angular-momentum $L = 2$ state [19–22]. The study by Wilets and Jean [23] confirmed that the degrees of freedom of the deformation parameter play an important role in determining the geometric shape of nuclei in which quadrupole deformities occur. To give the geometric image of the nucleus in its excited collective states, Bohr and Mottelson explained through their geometric model that the shape of the nucleus deviates from the axial symmetry [24].

The Interaction Boson Model (IBM) Hamiltonian has been solved in the Hartree–Fock approximation and that can be seen as a link between the IBM and the geometric model [25–28]. In terms of the quadrupole shape variable, a pictorial representation of the IBM Hamiltonian can be produced through the energy surface derived by taking the expectation value of the IBM Hamiltonian in the intrinsic state. This can give us an idea of the equilibrium and stability of the nucleus [29]. Anther investigation about so-called classical limit by Isacker and Chen [30] including derived a Hamiltonian for each $U5$, $SU(3)$ and $O(6)$ dynamic symmetry. The issue of high-order interaction of d-boson state then has been considered. As well as proved that the stable shapes are shown by the classical limit of IBM Hamiltonian not to be stable triaxial shapes. Heyde et al. [31] show that by incorporating cubic terms in the Hamiltonian of the IBM, one may obtain a stable triaxially shaped nucleus and study the influence of such terms on the energy spectrum in each of the three dynamic symmetries. These analyses were completely restricted to the IBM-1. In contrast Dieperink and Bijker [32, 28] confirmed that triaxiality also occurs in particular dynamic symmetries of the IBM-2 that does distinguish between protons and neutrons.

A three-body interaction between the d-bosons has been included to the Hamiltonian of several nuclei, heavy $_{76}$Os and $_{78}$Pt isotopes were studied. The signature splitting of the γ-vibration band and $B(E2)$ transition were analyzed. It was shown that in none of the nuclei evidence for a stable, triaxial ground-state shape is found [33]. The interacting boson model of Arima and Iachello has been foundational to the description of rotational band in two ^{156}Gd and ^{234}U isotopes. Moreover, the Hamiltonian for 2 and 4-body interaction had been discussed [34].

In the present work of $^{236-246}$Pu investigating, the structure of band levels, electric quadrupole transition rates $B(E2)$, and Potential Energy Surfaces (PES) are purposed. However, the main goal is to determine the effect of three-body boson interactions. Furthermore, we also calculate the PES and the role of three-body interaction in existing of stable triaxial shape within the specified quadrupole deformation

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