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Semiclassical and Boson Descriptions of the Wobbling Motion in Odd-A Nuclei

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Abstract

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Contents

Chapter 1

Introduction

Ground-state nuclear shapes with spherical symmetry or axial symmetry are predominant across the char of nuclides. Near closed shells, the deformation is indeed sufficient that models based on spherical symmetries can be used to describe nuclear properties (e.g., energies, quadrupole moments, and so on). Besides the spherical and axially-symmetric shapes, the existence of triaxial nuclear deformation was theoretically predicted a long time ago [1]. The rigid triaxiality of nuclei is defined by the asymmetry parameter γ, giving rise to unique quantum phenomena. The quantum mechanical properties of the rigid triaxial shapes drew a lot of attention within the nuclear community, since the description of nuclear properties for the deformed nuclei turns out to be a great challenge.

Chapter 2

Deformed Nuclei

2.1 Nuclear deformation

Most of the nuclei across the nuclide chart are spherical or symmetric in their ground state. Moreover, for the axially symmetric nuclei (i.e, either *oblate* or *prolate*), there is a prolate over oblate dominance.

The spherical shell model only describes nuclei near the closed shells. On the other side, for the nuclei that lie far from closed shells, a deformed potential must be employed.

In the case of even-even nuclei, unique band structures resulting from the vibrations and rotations of the nuclear surface (as proposed by Bohr and Mottelson [1] in the *Geometric Collective Model* - GCM) appear in the energy range 0-2 MeV.

Within the GCM, the nucleus is described as a classical charged liquid drop. For the low-lying energy spectrum, usually the compression of nuclear matter and the nuclear skin thickness are neglected. This results in the final picture of a liquid drop with a constant nuclear density and a sharp surface [2].

2.1.1 Shape parameters

The nuclear surface can be described via an expansion of the spherical harmonic functions with some time-dependent parameters as *expansion coefficients*. The expression of the nuclear shape is shown below [2]:

$$R(\theta, \varphi, t) = R_0 \left(1 + \sum_{\lambda=0}^{\infty} \sum_{-\lambda}^{\lambda} \alpha_{\lambda\mu}(t) Y_{\lambda}^{\nu}(\theta, \varphi) \right) \ . \tag{2.1}$$

In 2.1, R denotes the nuclear radius as a function of the spherical coordinates $\theta, \varphi)$ expressing the direction, and the time t, while R_0 is the radius of the spherical nucleus, when all the expansion coefficients vanish. It is worth mentioning that the expansion coefficients act as *collective coordinates* since the time-dependent amplitudes describe the vibrations of the nuclear surface.

2.1.2 Nuclear radius under rotation

In order to get a grasp at the physical meaning behind the deformation parameters that are used to describe the nuclear surface, it is instructive to see what happens when the system undergoes a rotation transformation.

Bibliography

[1] Aage Niels Bohr and Ben R Mottelson. *Nuclear Structure (In 2 Volumes)*. World Scientific Publishing Company, 1998.

[2] Walter Greiner and Joachim A Maruhn. *Nuclear models*. Springer, 1996.