Shape-coexistence study of even-even nuclei

I. Maqbool[1],* P. A. Ganai[1,2], and J. A. Sheikh[1]
[1] *Department of Physics, University of Kashmir, INDIA and*
[2] *Deptartment of Physics, National Institute of Technology Srinagar Kashmir-190006, INDIA*

Introduction

Atomic nuclei exhibit a variety of shapes, varying from spherical to quadrupole and higher-order multipole deformations. Nuclei in-between closed shells generally exhibit a deformation of their ground states. The possible shape that the nucleus may adopt results from a delicate balance between collective and single-particle energies and their dependence on deformation. Prolate ground state shapes are found far more abundantly than oblate deformations. There have been many different attempts to use various theoretical methods, e.g, the shell model self-consistent mean-field models as well as the interacting boson model to determine the nuclear properties. The self-consistent mean-field calculations have used both purely phenomenological and more fundamental treatments of the two-body force and have examined a large class of different questions ranging from the exact charge density to quadrupole moments of deformed nuclei. Many authors discussed the nuclear shape extensively, but imposed axial and reflection symmetries to alleviate the complex numerical problems. In axial symmetric calculations, both prolate and oblate minima with energies very close to each other can coexist in the nuclear deformation energy curve as a function of quadrupole deformation. The phenomenon of nuclear coexistence manifests itself in the presence of close-lying nuclear states with very different intrinsic properties. Spectacular examples of coexistence are super-deformed states, low-lying deformed states in spherical nuclei, high K-isomers and pairing isomers.

The aim of this paper is to report on the calculations of the potential energy surfaces of the doubly even nuclei with Z = N = 10 - 24.

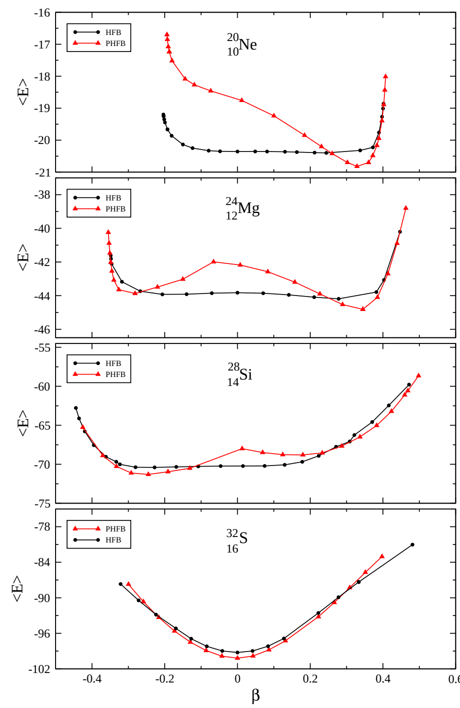

FIG. 1: HFB and PHFB Energy surface calculation for ^{20}Ne, ^{24}Mg, ^{28}Si, ^{32}S.

The Method The starting point of our method is a set of axial HFB wave functions. They are generated by self-consistent mean field calculations, with a constraint on a collective coordinate, the axial quadrupole moment $< Q_{20} >$. In HFB method, such mean-field states incorporate particle-particle correlations through pairing and many-particle many-hole correlations through nuclear deformations. As a result the mean-field states break several symmetries of the exact many-

*Electronic address: `prince_ganai@yahoo.co.uk`

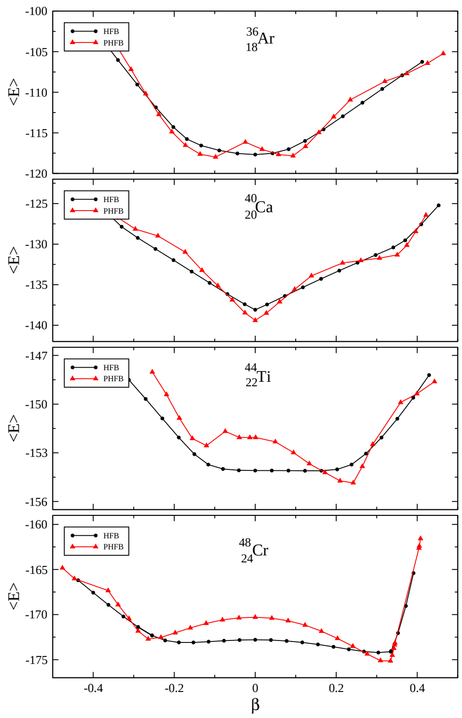

FIG. 2: HFB and PHFB Energy surface calculation for ^{36}Ar, ^{40}Ca, ^{44}Ti, ^{48}Cr.

body states. These symmetry violations make difficult the connection between mean-field results, expressed in the intrinsic frame of reference of the nucleus, and the spectroscopic data, obtained in the laboratory frame of reference. This requires the restoration of broken symmetries associa ted with particle number and rotation.

The two-body interaction used for both particle-particle and particle-hole channels is surface delta interaction. The present study does not involve the definition of a new set of forces. It relies on well-established interaction tested within the mean-field approach over a wide range of nuclei and phenomena covering the nuclear chart. This work is thus part of a program whose aim is to perform an additional evaluation of the Hamiltonian by taking into account the effects of quadrupole correlations. The configuration space used for Z = N = 12 to 24 is $1d_{5/2}, 2s_{1/2}, 1d_{3/2}, 1f_{7/2}, 2p_{3/2}$ with ^{16}O as core .

Results and discussions The mean-field and projected landscapes show that the energies of the nuclei vary very slowly with deformation. Our calculations predict prolate, oblate, and spherical or coexisting prolate-oblate minima in the nuclei studied.

The ^{20}Ne shows mixing of prolate, spherical and oblate shapes. The prolate-oblate coexistence is depicted by the potential energy surface (PES) curve in this case. But the Number Projected Hartree Fock Bogoliubov Theory (PHFB) gives significant prolate ground state of ^{20}Ne.The HFB method gives flat energy surface curve of ^{24}Mg, whereas PHFB study depicts coexistence of prolate-oblate shapes with prolate minimum slightly lower than oblate minimum. In ^{28}Si the HFB energy surface curve is quite flat and PHFB depicts a oblate ground state which is about 1.4 MeV lower than prolate minimum. ^{32}S has spherical shape in both the cases. ^{36}Ar shows some strange behavoir. Its HFB study gives spherical ground state . The spherical N=Z=20 subshell closure is strong enough to stabilize the spherical shape to the N=Z=18 i.e.,^{36}Ar. Its PHFB study shows oblate-prolate shape coexistence. HFB as well as PHFB study shows spherical ground state of ^{40}Ca. In case of ^{44}Ti the HFB study shows strong shape coexistence, the energy surface curve is quite flat. While as PHFB method gives prolate ground state. In case of ^{48}Cr the HFB study shows strong prolate-oblate shape coexistence. There is also coexistence of prolate-oblate shapes with the minimum on prolate side relatively lower than the minimum on the oblate side in PHFB.

References

[1] P. Ring, and P. Schuck, *The Nuclear many-Body Problem* (Springer Verlag, New York, 1980)

[2] J. A. Sheikh, and P. Ring, Nucl. Phys. **A665**, 71 (2000)

[3] M. Bender, P. Bonche, and P.-H. Heenen, Phys. Rev. C **74**, 024312 (2006)