Deformed structure in $N = 50$ medium mass nuclei

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Introduction

The study of neutron rich nuclei at the drip-line and around closed shells gained momentum with recent advancements of experimental techniques using radioactive ion beams and fission fragment. Fission from fast particles has become an important tool and it has been the richest source of neutron-rich intermediate-mass nuclei. Fission of Uranium and neighbouring nuclei produce two neutron-rich fragments of unequal A $\sim$ 90 and 140, (besides a few neutrons). As the two fragments proceed to the point of separation they become quite deformed. It is thus essential to study the shapes and microscopic structures of these neutron-rich fragments [1].

Deformed rotational bands have been observed experimently in ^{82}Ge by Hwang et al. [2]. Recently, we have studied theoretically this kind of bands in ^{82}Ge and ^{84}Se by considering deformed configuration obtained by constrained Hartree-Fock calculation [3].

Formalism

The axially deformed states $|\eta m\rangle$ are expanded in the spherical basis states as follows:

$$|\eta m\rangle = \sum_j C_{jm}|jm\rangle \quad (1)$$

where j is the angular momentum of the spherical single particle state and m its projection on symmetry axis. The mixing amplitude C_{jm} are obtained by solving deformed Hartree-Fock equations in an iterative process. The residual interaction is also included self-consistently and it causes the mixing of single-particle orbits of nucleons.

Because of mixing in single particle orbits, the HF configurations $|\phi_K\rangle$ are superposition of states of good angular momentum. The states of good angular momentum can be extracted by means of projection operator

$$P_K^{JM} = \frac{2J+1}{8\pi^2} \int d\Omega\ D^J_{MK}(\Omega)^*\ R(\Omega) \quad (2)$$

Results and Discussions

The deformed HF orbits are calculated with a spherical core of ^{56}Ni; the model space spans the $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$, $0g_{9/2}$, $0d_{5/2}$, $0g_{7/2}$, $2s_{1/2}$, $0d_{3/2}$ and $0h_{11/2}$ orbits both for protons and neutrons with single particle energies 0.0, 0.78, 1.08, 3.44, 7.88, 10.47, 11.73, 12.21 and 13.69 MeV respectively. We use a surface delta interaction (with interaction strength 0.38 MeV for $p-p$, $p-n$ and $n-n$ interactions) as the residual interaction among the active nucleons in these orbits. The shell model space used in this work is large enough and adequate to describe the deformation and other properties of nuclei in this mass region. This model space and surface delta interaction give a good description of spectra of nuclei in the $A = 70$ to $A = 130$ region [4].

In this work, we have investigated the structures and shapes of ^{86}Kr, ^{88}Sr and ^{90}Zr nuclei using angular momentum projected Hartree-Fock (PHF) model [5]. To study the possible structure of the ground band and excited deformed bands for closed shell nuclei, we analyze the potential energy surface in HF calculations for various mass-quadrupole moments, $\langle Q^M_{20}\rangle = \langle Q^p_{20}\rangle + \langle Q^n_{20}\rangle$ (with $\langle Q^p_{20}\rangle$

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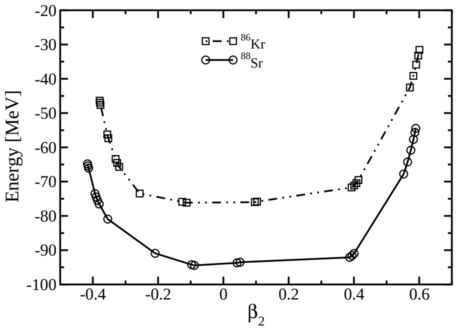

FIG. 1: Hartree-Fock energy of as function of quadrupole deformation parameter ^{86}Kr and ^{88}Sr.

and $\langle Q^n_{20}\rangle$ being quadrupole moments of protons and neutrons, respectively in constrained HF). For constrained HF calculation we use a quadrupole constrained Hamiltonian given by

$$H'(\lambda) = H - \lambda(Q^p_{20} + Q^n_{20}) \tag{3}$$

with λ being constraining parameter. The quadrupole constraint helps to obtain, by self-consistent procedure, the larger deformed solutions; but the Hamiltonian H is used in obtaining energies of various configurations. The energy surface is obtained by plotting $\langle H\rangle$ against deformation parameter β_2. These energy surfaces for ^{86}Kr and ^{88}Sr, is shown in Fig. 1.

In Fig. 2, we have depicted the HF energy surface for ^{90}Zr. We see that the well-know neutron magic nucleus ^{90}Zr exhibits spherical shape with 'zero' quadrupole moment in its ground state. This configuration, as shown in 'red' circle in Fig. 2 is obtained with free HF calculation. The deformed HF configurations (black circles) are obtained by solving quadrupole constrained Hamiltonian equation as mentioned above.

As an example, the band spectra of ^{86}Kr is shown in Fig. 3 in comparison with available experimental results [6]. The first deformed band (denoted by D1 in Fig. 3) built on the constrained HF configuration has rotational structure. The deformed structure as well as electromagnetic properties are obtained for these nuclei and will be presented in details during the conference.

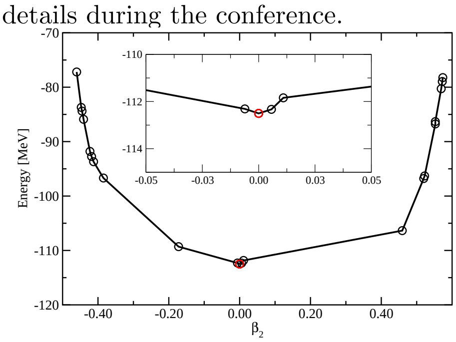

FIG. 2: Hartree-Fock energy of as function of quadrupole deformation parameter for ^{90}Zr.

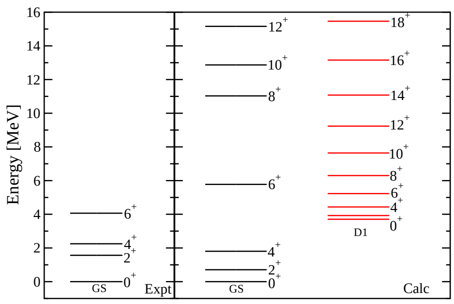

FIG. 3: Band diagram of ^{86}Kr.

Acknowledgments

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References

[1] N. Bohr and J. A. Wheeler, Phys. Rev. 56, 426(1939).

[2] J. K. Hwang, et al., Phys. Rev. C 84, 024305 (2011).

[3] S. K. Ghorui and C. R. Praharaj, Pramana J. Phys 82, 659 (2014).

[4] S. K. Ghorui et.al., arXiv:1111.1174v1 [nucl-th].

[5] C.R. Praharaj, J. Physics G 14, 843(1988); Phys. Lett. B 119, 17(1982).

[6] NNDC [http://www.nndc.bnl.gov]