Study of Yb isotopes in HFB mean field approach

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Introduction

Stable rare-earth nuclei are famous for their large deformation in their ground states. Recently ytterbium, the last of the lanthanide elements, has generated some interest as effects due to a new bosonic carrier beyond the Standard Model of particle physics has been proposed to explain the isotopic shift measurements in Yb isotopes.[1]. Different studies shows that isotopic shift can be explained by taking nuclear deformation into account. In this work our aim is to study the ground state and low lying states of Yb isotopes, in the region $82 < N < 126$, using the Hartree-Fock-Bogoliubov approach with Skyrme energy functional SLY6 for stable nuclei as well as neutron-rich nuclei far away from the stability line.

Theory

The Hartree-Fock-Bogoliubov (HFB) approach is known to be suitable for the study of nuclei far away from the stability where data are scarce. As our interest includes g.s properties as well as the study of very low-lying rotational states in strongly deformed Yb nuclei, where normal Bardeen-Cooper-Schrieffer (BCS) pairing fails, HFB is an approach which is suitable for our calculation. The calculation has been performed using the publicly available code HFODD(ver 2.73) by Schunck et al.[2]. This is a code that solves the HFB equations in a three dimensional Cartesian harmonic oscillator basis.
We do not expect that the pairing strength will be constant throughout the large range of neutron numbers. Therefore, we have used following formula for the neutron and proton pairing strengths (in MeV) which we have obtained by comparing our results for the binding energy and deformation values with experimental measurements.

$$V_P = V_N = 196 + 1.77 * (N - 82) \quad (1)$$

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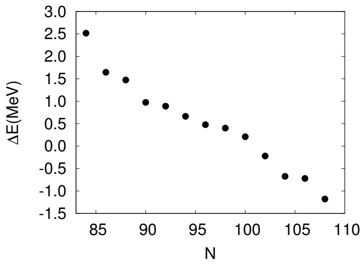

FIG. 1: Difference between theoretical and experimental binding energy values.

Results

Binding Energy: We have calculated the binding energy and deformation of even-even Yb isotopes and compared with experimental values whenever available. From FIG(1) It is seen that binding energy difference between theory and experimental is less than 2 MeV except in the case for N=84. From the FIG(1), one sees that there is a systematic trend in the difference in between theoretical and experimental energy values which points to the fact that a simple pairing interaction is not sufficient to completely explain the ground state binding energy values.
Deformation: In FIG(2) we have plotted the potential energy surface as a function of quadrupole deformation β_2 for some representative nuclei. We have not obtained any pro-

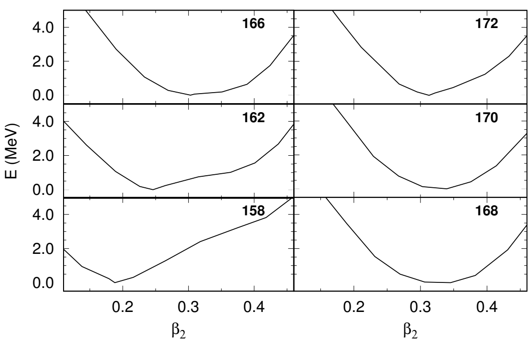

FIG. 2: Potential energy surface of some selected Yb nuclei.

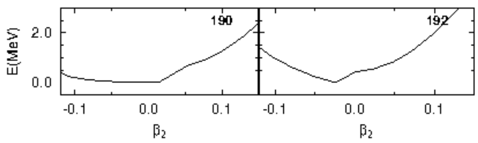

FIG. 3: Potential energy surface in $^{190-192}Yb$.

late to oblate transformation. All the isotopes are reasonably prolate with no γ-deformation.

Potential Energy Surface(PES): Interestingly, in FIG(3) the PES of $^{190,192}Yb$ isotopes become nearly spherical at N=120 which could be due to the presence of a new magic number. To confirm this we have plotted the neutron and proton single particle energy levels in ^{190}Yb. It is confirmed from FIG(4) that there is no deep minima at zero deformation but we get a flat surface which means no new magic number at N=120.

Energy ratio: A number of Yb isotopes near N=100 have deformation values $\beta_2 \geq 0.3$. They are expected to be very good rotors. For a purely rotational excitation, collective model predicts the ratio $R_{42} = E(4^+)/E(2^+)$ to be 3.33. We have calculated it and from TABLE 1 one can see that a number of nuclei come very close to this limit.

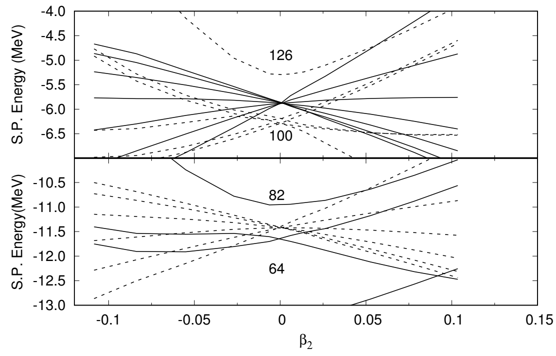

FIG. 4: Single particle levels in ^{190}Yb as a function of deformation.Upper(Lower) panel refer to neutron(proton) single particle levels.

TABLE I: Rotational energy levels in strongly deformed Yb isotopes

Isotopes	$2^+(^a)$	$4^+(^a)$	R_{42}	$2^+(^b)$	$4^+(^b)$
166	102.4	330.5	3.23	71.3	271.0
168	87.7	286.6	3.27	66.6	258.5
170	84.2	277.4	3.29	74.1	277.4
172	78.7	260.3	3.31	69.8	275.0
174	76.5	253.1	3.31	75.8	308.8
176	82.1	271.8	3.31	80.6	322.0
178	84.0	278.0	3.31	86.6	343.3

[a]Experimetal Energy values in (keV)
[b]Theoretical Energy Values in (keV)

Acknowledgments

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References

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