Superdeformation in Pb isotopes

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Introduction

A superdeformed (SD) nucleus is that which is very far from spherical shape and forming an ellipsoid shape with axes in ratios of approximately 2:1:1, normal deformation is approximately 1.3:1:1. The SD shape is thought to be associated with a distinct minimum in the nuclear potential energy, separated from the primary minimum by a high potential barrier. The first discrete-line SD states were found in the A∼150 mass region in ^{152}Dy nucleus [1]. This observation confirmed many years of theoretical prediction [2] of the exotic nuclear shapes with large deformation ($\beta \sim 0.5$) which are stabilized through microscopic shell effects. With this discovery of SD shapes in nuclei and the advent of large γ-ray detectors, various SD bands were explored in several mass regions A∼190, 150, 130 and 80. Using the harmonic oscillator potential and the modified oscillator potential Ragnarsson et al. [3] pointed out the new sets of magic numbers for different prolate, oblate and axially asymmetric shapes. These theoretical findings were confirmed by the empirical analysis of Sharma et al. [4]. In this present work, we have used the Relatvistic Hartree-Bogoliubov (RHB) theory [5] to explore the structure of SD $^{190-212}Pb$ isotopes using the non-linear NL3* and density dependent (DD-ME2, DD-PC1) interactions. We have studied the the excitation energy, the potential depth and the deformation of these Pb isotopes.

Results and Discussions

The constraint calculations has been done to obtain the potential energy surface (PES)

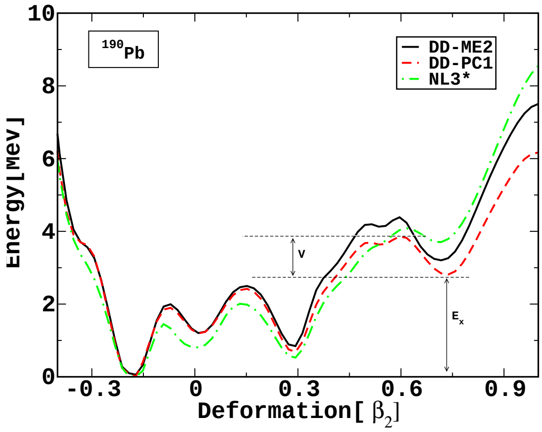

FIG. 1: The potential energy surface of ^{190}Pb.

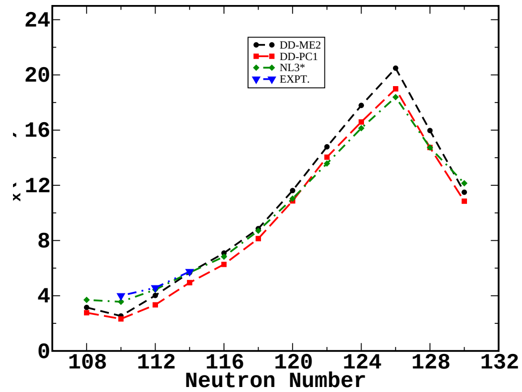

FIG. 2: The SD energies of Pb isotopes E_x as the functions of neutron number obtained by the constrained calculations and experimental data from [6].

as a function of quadrupole deformation for $^{190-212}Pb$ isotopes (example Fig 1 for ^{190}Pb). From the PES, we have calculated the excitation energy E_x and the depth of well of the SD minimum i.e., V as shown in Fig 1. The excitation energy has been plotted as a function

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TABLE I: The depth of the superdeformed minimum V in the superdeformed states of $^{190-212}Pb$.

Nuclei	DD-ME2	DD-PC1	NL3*
^{190}Pb	1.19	1.04	0.3
^{192}Pb	2.4	1.03	0.79
^{194}Pb	2.06	2.21	1.11
^{196}Pb	1.78	2.03	1.18
^{198}Pb	2.07	2.47	1.54
^{200}Pb	3.07	3.49	2.25
^{202}Pb	3.69	4.04	2.83
^{204}Pb	4.1	4.27	3.52
^{206}Pb	4.43	5.63	3.98
^{208}Pb	4.95	5.25	4.5
^{210}Pb	5.48	5.55	4.69
^{212}Pb	6.27	6.13	3.96

of neutron number in Fig. 2, shows the increase in energy with the increase in neutron number upto ^{208}Pb(Z=82,N=126) after which there is the vice-versa trend. Experimental results are available for few nuclei which show the same trend. We have also calculated the depth V as given in Table I which is important for the lifetime of these SD states. The

TABLE II: The quadruple deformation β_2 of the superdeformed states of $^{190-212}Pb$.

Nuclei	DD-ME2	DD-PC1	NL3*
^{190}Pb	0.712	0.73	0.709
^{192}Pb	0.71	0.71	0.71
^{194}Pb	0.654	0.66	0.66
^{196}Pb	0.616	0.616	0.616
^{198}Pb	0.755	0.578	0.575
^{200}Pb	0.59	0.603	0.59
^{202}Pb	0.574	0.584	0.584
^{204}Pb	0.562	0.568	0.584
^{206}Pb	0.593	0.59	0.577
^{208}Pb	0.6	0.597	0.568
^{210}Pb	0.6	0.581	0.552
^{212}Pb	0.633	0.632	0.56

depth of the well increases with the increase in neutron number. The deformation in SD minima lies systemically between 0.5 and 0.75 agrees with the observation of SD nuclei for excited states adopting ellipsoidal shapes with an axis ratio around 2:1 [7]. The two-neutron separation energies in the SD minimum are well reproduced with varying smoothly with the neutron number as can be seen from the Table III.

TABLE III: Two-neutron separation energy in the superdeformation minimum.

Nuclei	DD-ME2	DD-PC1	NL3*	EXPT.
^{192}Pb	18.573	18.549	17.839	-
^{194}Pb	16.2479	16.887	16.528	17.16
^{196}Pb	15.4941	15.719	15.632	16.31
^{198}Pb	14.104	15.539	15.119	-
^{200}Pb	15.682	14.902	14.425	-
^{202}Pb	13.844	13.998	13.645	-
^{204}Pb	13.083	13.132	13.04	-
^{206}Pb	12.776	13.24	12.568	-
^{208}Pb	12.438	12.643	12.106	-
^{210}Pb	11.945	12.144	11.526	-
^{212}Pb	11.037	11.268	10.7267	-

Conclusion

In summary, the superdeformation in $^{190-212}Pb$ is investigated by the microscopic quadrupole constrained within RHB formalism with interactions, i.e., DD-ME2, DD-PC1 and NL3*. The calculations show a clear SD minimum at nearly all the potential energy curves for the Pb isotopes with similar patterns for all the effective interactions. Trend for the change of the excitation energies with neutron number are correctly reproduced.

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