Shell quenching of even-even Cd isotopes within relativistic mean field theory

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Introduction

The advent and application of nuclear beam facilities allows exploring the nuclear properties of the chart of nuclides from proton-rich nuclei to the neutron drip-line. Recently, Z = 50 mass region is the matter of interest in nuclear structure studies due to the availability of large number of stable isotopes in this region with the occurrence of other important features around Z = 50 like shell closure. The evidence of the quenching of the N = 82 shell closure in ^{130}Cd opened up new possibilities in r-process calculations in this region [1]. However, experimental observations in this area of very neutron-rich waiting point nuclei are still unknown. Although it is evident that the neutron-rich Cd isotopes shows different behavior while approaching N = 82 shell gap but recent observation about excited states of ^{130}Cd does not predict any reduced N = 82 gap in this nucleus [2]. The large measured Q-value and substantially shorter beta-decay half-live also indicates quenching [3] of the N = 82 neutron shell closure for Cd isotopes.

In this contribution, calculations are carried out for the nuclear structure of even-even Cd isotopes within the framework of relativistic mean field (RMF) theory using two recently developed parameter sets FSUGarnet [4] and IOPB-I [5]. Our work includes calculations from the proton rich to neutron rich side for a wide range of neutron numbers. Various physical quantities such as binding energy (BE), two-neutron separation energy (S_{2n}), root mean square (rms) radii, shell quenching at N = 82 for different Cd isotopes are calculated and compared with available experimental data.

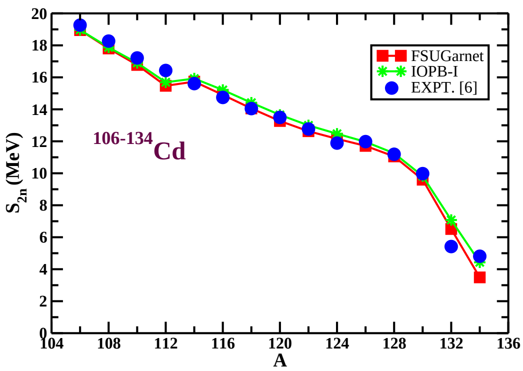

FIG. 1: Two neutron separation (S_{2n}) as a function of mass number with FSUGarnet and IOPB-I force parameters compared with experimental data.

Theoretical formalism

The relativistic mean field formalism (RMF) is a relativistic generalization of non-relativistic effective mean field theory which has an additional advantage in high density region to calculate of nuclear bulk properties like BE, charge radius, neutron skin-thickness *etc.* The fundamental nucleon-meson effective field theory motivated relativistic mean field (E-RMF) Lagrangian density up to 4^{th} order with $\sigma-$, $\omega-$, $\rho-$ mesons and photon A_μ required for our study is taken from Ref. [5]:

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TABLE I: Represents BE in MeV and R_c in fm, for some nuclei with FSUGarnet and IOPB-I parameter sets with available experimental data [6].

Nucl.	Obs.	FSU-Garnet	IOPB-I	EXPT.
^{104}Cd	BE	884.410	886.831	885.872
	R_c	4.525	4.557	
^{112}Cd	BE	953.411	956.261	957.04
	R_c	4.594	4.624	
^{116}Cd	BE	984.045	987.393	987.392
	R_c	4.624	4.651	
^{124}Cd	BE	1036.153	1040.920	1039.616
	R_c	4.680	4.705	
^{128}Cd	BE	1058.918	1064.139	1062.784
	R_c	4.705	4.730	
^{130}Cd	BE	1068.517	1073.962	1072.76
	R_c	4.718	4.743	
^{132}Cd	BE	1075.031	1081.040	1078.176
	R_c	4.733	4.757	
^{134}Cd	BE	1078.519	1085.472	1082.988
	R_c	4.749	4.772	

Results and Discussions

We study the ground state properties of even-even Cd isotopes (N = 56-86). We have carried out an extensive study in the recently proposed FSUGarnet and IOPB-I force parameters and compared with experimental data. It is evident from few results as given in Table I that the calculated BE for FSUGarnet and IOPB-I are well comparable to the data [6] with few exceptions. The two-neutron separation energy (S_{2n}) as a function of mass number for Cd isotopes using above parameter sets are given in figures 1. We notice from the figure that S_{2n} values agree well with experimental data [6] beside few exceptions with noticeable kinks. It is clearly seen that S_{2n} decreases gradually with increase in mass number of Cd isotopes. A sudden drop in S_{2n} is observed for magic number N = 82. Figure 2 suggest no evidence of shell quenching for N = 82 shell gap for both the parameter sets in the Cd isotopic chain.

Summary and Conclusion

In summary, we have studied the various nuclear properties of the even-even Cd isotopes *i.e.* BE, R_c *etc.*, reproduced with the new parameter sets FSUGarnet and IOPB-I. The absence shell quenching for the neutron magic number N = 82 in Cd isotopic chain is studied. Further, we would like to extend our work to study the drip-line, neutron skin thickness, potential energy surface, shell correction energy and some other properties of these isotopes.

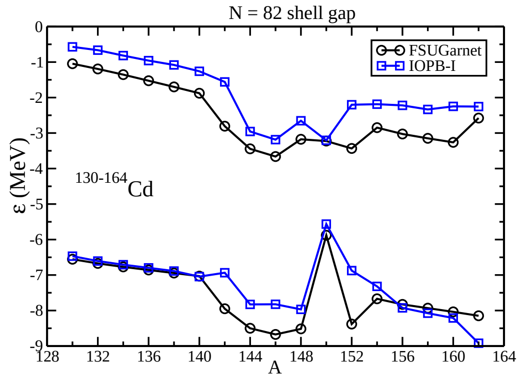

FIG. 2: The single particle energy (ϵ) as a function of mass number A for Cd isotopes with FSUGarnet and IOPB-I force parameters.

Acknowledgments

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