Revisit of neutron-rich thermally fissile Th and U isotopes

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Introduction

Presently $\sim$ 3000 nuclei are known and another $\sim$ 5000 nuclei with varying lifetime can be predicted by the use of different mass models, which can be synthesized in the laboratory. Most of these nuclei are available on the neutron-rich side of the nuclear chart and possess unusual neutron to proton ratio which is quit different from the normal one in the valley of stability. Therefore, one can observe the new nuclear phenomena involved with these nuclei along with their formation. Since 1940, the fission phenomena has been successfully studied for nuclei which are mainly confined in the valley of stability. Out of the $\sim$ 300 nuclei, in nature only three isotopes (^{233}U, ^{235}U and ^{239}Pu) are thermally fissile on the stability line and have been mainly used in reactors for the power generation [1]. Since these nuclei are very much limited, we mainly investigate whether heavier neutron-rich isotopes of Th and U having thermally fissile properties could exist or not, and if exist then what should their various nuclear properties.

Recently, Satpathy et al. [2] have investigated and reported that the series of Th and U isotopes with N = 154-172 to be thermally fissile on the basis of the fission barrier and neutron separation energy. They have shown that some isotopes in that series are stable against α-decay as well as spontaneous fission. The microscopic study in relativistic mean field (RMF) theory shown that these nuclei undergo exotic decay mode of thermal neutron fission (multi-fragmentation fission) where a number of prompt scission neutrons are expected to be released at a time along with the two heavy fission fragments. Such properties will have important implications in stellar evolution involving r-process nucleosynthesis. Since these type of works are repeated in several publications, because of the importance of the work, we are revisiting the properties with recently available force parameters.

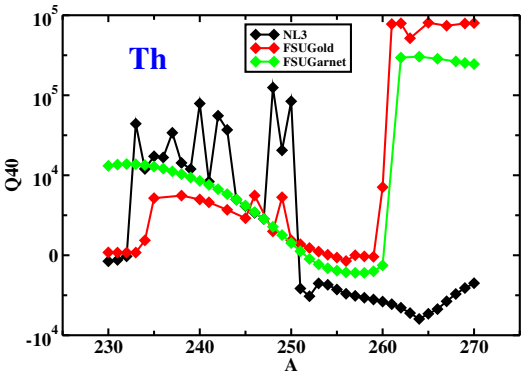

FIG. 1: Hexadecuploe moment ($Q40$) as a function of mass number with NL3, FSUGold, and FSUGarnet parameter sets.

Results and Discussions

We are revisiting the properties of neutron-rich thermally fissile Th (N=140-180) and U (N=138-178) isotopes. We have carried out an extensive study in the recently proposed FSUGold and FSUGarnet parameter sets and compared with the NL3 force. The NL3 interaction has been widely used from last several years in the calculations of various nuclear properties and have been accepted to be very successful.

The ground-state binding energies per nucleon (BE/A), rms charge radius (R_c), and neutron skin thickness ($R_n - R_p$) *etc.* are eval-

TABLE I: The binding energies per nucleon (BE/A) in MeV, rms charge radius (R_c) in fm, and neutron skin thickness ($R_n - R_p$) in fm for some nuclei with NL3, FSUGold, and FSUGarnet parameter sets.

Nucleus	Obs.	NL3	FSUGold	FSUGarnet
^{230}Th	B/A	7.608	7.708	7.674
	R_c	5.784	5.777	5.799
	$R_n - R_p$	0.25	0.224	0.179
^{240}Th	B/A	7.485	7.586	7.567
	R_c	5.855	5.886	5.884
	$R_n - R_p$	0.314	0.285	0.227
^{250}Th	B/A	7.360	7.443	7.415
	R_c	5.920	5.928	5.926
	$R_n - R_p$	0.373	0.349	0.286
^{260}Th	B/A	7.217	7.259	7.249
	R_c	5.972	6.088	5.945
	$R_n - R_p$	0.429	0.404	0.344
^{270}Th	B/A	7.058	7.081	7.040
	R_c	6.002	6.299	6.245
	$R_n - R_p$	0.502	0.443	0.372
^{230}U	B/A	7.626	7.674	7.670
	R_c	5.791	5.885	5.811
	$R_n - R_p$	0.213	0.185	0.148
^{240}U	B/A	7.505	7.611	7.595
	R_c	5.857	5.900	5.894
	$R_n - R_p$	0.291	0.249	0.197
^{250}U	B/A	7.401	7.489	7.465
	R_c	5.967	5.951	5.950
	$R_n - R_p$	0.355	0.310	0.251
^{260}U	B/A	7.264	7.349	7.314
	R_c	5.983	5.974	5.963
	$R_n - R_p$	0.422	0.373	0.308
^{270}U	B/A	7.134	7.161	7.124
	R_c	6.016	6.316	6.255
	$R_n - R_p$	0.496	0.399	0.335

uated in the mass regions A $\approx$ 230 to 270, out of which some results are given in Table I. The range cover the thermally fissile members in the chain of the neutron-rich Th and U isotopes. It is evident from the Table that the calculated BE/A with parameter sets FSUGold and FSUGarnet are well in compared with the existing sucessful NL3 one. In some cases the calculated values are slightly over estimate or under estimate to the results obtained by NL3 set. The hexadecupole moment ($Q40$) and quadrupole deformation parameter (β_2) as a function of mass number for Th and U isotopes with NL3, FSUGold, and FSUGarnet parameter sets are given in figures 1 and 2 respectively.

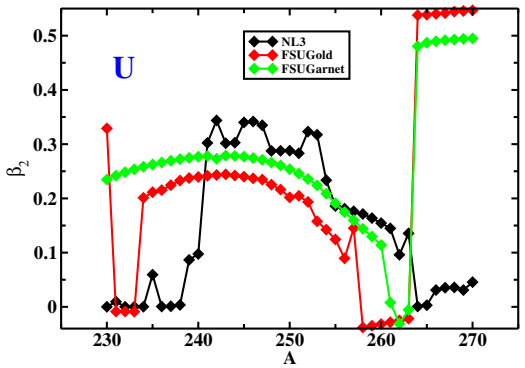

FIG. 2: β_2 deformation parameter as a function of mass number with NL3, FSUGold, and FSUGarnet parameter sets.

Summary and Conclusion

In summary, we have revisited the various nuclear properties of the neutron-rich thermally fissile Th and U isotopes *i.e.* BE/A, R_c and $R_n - R_p$, β_2, and $Q40$ *etc.*, reproduced with the new parameter sets FSUGold and FSUGarnet. Further, we would like to extend our work to study the fission decay properties of these neutron-rich thermally fissile Th and U isotopes with these parameters, taking into account the dynamics of the shape evolution during the fission process.

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