Study of ground state properties of neutron-rich tellurium isotopes by using Gogny interaction

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Introduction

The recent advancements in the experimental facilities [1-3] has come up with new potentialities of scrutinizing the generation of nuclei far from the line of beta stability. The experimental data on the ground state properties of some neutron rich nuclei is available now [4-6]. The information on the ground state properties of nuclei is crucial not only to understand the nuclear structure but also to weak interactions, super-nova explosion and origin of elements. The deformation of nuclei increases the surface area and leads to a greater surface symmetry energy in a neutron-rich nucleus. The neutron density distribution of nuclei shows the existence of shell structures and neutron halos.

Many theoretical non-relativistic and relativistic approaches have been generally used to investigate the ground state properties of nuclei over the entire nuclear chart [7] with different types of interactions. In this work, the ground state properties and neutron density distributions of neutron-rich tellurium isotopes with neutron number (N)= 82-92 are considered for the present investigation. The radial profiles of neutron densities and ground state properties of neutron-rich Te isotopes have been obtained by solving the Skyrme Hartree Fock Bogoliubov problem by using the axial transformed Harmonic oscillator (THO) basis [8]. The THO basis admits a correct description of deformation effects and pairing correlations in weakly bound nuclei. The calculations are performed by employing the finite range Gogny effective two body interactions with time reversal symmetry and coulomb interaction. The nuclear binding energies, pairing gaps, root mean square radii, skin thickness, charge radius, quadrupole and hexadecapole moments are calculated for neutron rich Te isotopes.

Theoretical Framework

The energy functionals that are employed in HFBTHO calculations are derived from Gogny two-body effective interaction [9]. The finite range contributions to the HFB fields are computed in configuration space. The calculations are performed by taking 50 full spherical oscillator shells with a constant oscillator length of b=2.0 *fm*. In Coulomb interaction both direct and exchange terms are included. The local scale transformation of the single particle basis has been implemented which helps in properly computing the structure of weakly bound nuclei. . The expectation values of axial multipole moments on HFB ground-state are calculated. The charge radii have been obtained by using the following expression

$$r_{ch}=\sqrt{\langle r_p\rangle^2+\langle R_p^2\rangle+\frac{N}{2}\langle R_n^2\rangle+\frac{3}{4M_p^2}}$$

where $\langle r_p\rangle^2$ is the expectation value on the HFB vacuum of the proton radius; $\langle R_p\rangle^2=0.769\,fm^2$ is the proton charge radius; $\langle R_n\rangle^2=-0.1161\,fm^2$ is the neutron charge radius; $3/4M_p^2=0.033\,fm^2$ is the Darwin-Foldy term. The D1, D1S, D1p and D1N parameterizations of Gogny force are used to calculate the ground state properties.

Results and discussion

In order to test the Gogny force with different parametrizations, the calculations are performed with D1, D1S, D1p and D1N parametrizations. From the results of calculations on ground state properties, it is found that out of these four parametrizations, only D1S parameterization of Gogny force reproduces the available experimental data of ground state properties in these nuclei. In Table 1, the results obtained with

Table 1. Ground state properties of $^{134-144}$Te calculated by Gogny D1S interaction.

A	B.E (MeV)		Quadrupole deformation		Skin Thickness (ΔR)	RMS radii (fm)	R_{ch} (fm)		Multipole moments	
	Th.	Exp.	Th.	Exp.			Th.	Exp	Q_2(b)	Q_4(b^2)
134	1137.399	1123.41	0.00	0.0687(13)	0.166	4.796	4.759	4.757	0.000	0.000
136	1144.495	1131.44	0.004	0.0739(55)	0.190	4.824	4.771	4.782	0.150	0.001
138	1143.664	1138.86	0.101		0.213	4.860	4.790		4.149	0.361
140	1150.754	1145.66	0.139		0.232	4.902	4.818		5.886	0.483
142	1156.509		0.159		0.251	4.938	4.840		6.943	0.540
144	1161.553		0.180		0.269	4.974	4.862		8.080	0.608

the Gogny D1S interaction are presented along with the available experimental data [4-6]. From this table , one notices that the values of skin thickness, root mean square radii, charge radii and multipole moments show an increase with mass number. The neutron thickness in these nuclei increases from a value 0f 0.166 for ^{134}Te to 0.269 for ^{144}Te. The last column of the table shows the magnitude of hexadecapole moments in these isotopes. Thus, the present calculations predict the hexadecapole deformation in $^{138-144}$Te.

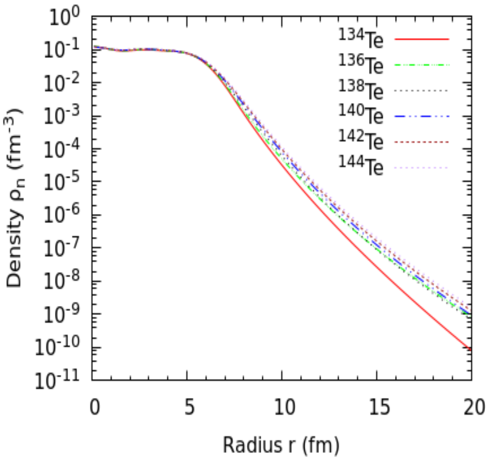

Fig. 1 The neutron density distribution of $^{134-144}$Te obtained with Gogny D1S interaction.

To investigate the evolution of the neutron density distribution in these isotopes, the results obtained from the D1S interaction parameters are plotted in Fig. 1. From this figure, it is noted that the neutron density distributions are extended further with an increase with neutron number. The internal density distribution changes slightly, but the surface and tails of density distributions extend with neutron number. The presence of neutron shell closure at N=82 shows a large change in the tail of neutron density distribution.

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References

[1] A.M. Rodin *et al.*, Nucl. Instrum. Methods, Phys. Res. B **204**, 114 (2003).
[2] M. Thoennessen, Nucl. Phys. A **834**, 688c (2010) .
[3] M. Wang *et al.*, Chin. Phys. C**36**, 1603 (2012).
[4] M. Winker *et al.*, Nucl. Instrum. Methods, Phys. Res. B **266**, 4183 (2008).
[5] I. Angeli and K.P. Marinova, At. Data Nucl. Data Tables **99**, 69 (2013).
[6] B. Pritychenko *et al.*, At. Data Nucl. Data Tables **98**, 798 (2012).
[7] X.W. Xia *et al.*, At. Data Nucl. Data Tables **121-122**, 1 (2018) and references therein.
[8] R. Navarro Perez *et al.*, Comput. Phys. Commun. **184**, 1592 (2013).
[9] J. Decharge and D. Gogny, Phys. Rev. C**21**, 1568 (1980).