A relativistic mean field study of even-even superheavy nuclei

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Introduction

The study of superheavy nuclei is an interesting topic for current days research work. The existence and the stability of superheavy nuclei against the large coulomb repulsion because of shell correction added to the liquid drop binding energy [1–3]. The shell closure effect provides the existence of superheavy nuclei and also produces the magic numbers in superheavy mass region. On the basis of magic numbers we predict an island of stability for superheavy mass region which may indicate the existence of doubly spherical magic nucleus heavier than ^{208}Pb. Various magic number have been produced in island of stability using different models as: Z = 114, N = 184, Z = 124 or 126, N = 184 and Z = 120, N = 172 or 184 which is model dependent. It is well known that the neutron to proton ratio N/Z is about 1 for light mass region and this value increases with mass number to neutralise the Coulomb repulsion. Superheavy is class of exotic nuclei with neutron to proton ratio N/Z on range 1.433 - 1.614 as observed experimentally. So the saturation nature of N/Z$\sim$ 1.5 tells the information about the formation of doubly closed shell superheavy nuclei.

Relativistic mean field (RMF) formalism

The relativistic Lagrangian density for a nucleon-meson many body system is expressed as [4],

$$\begin{aligned}\mathcal{L} &= \bar{\psi}_i\{i\gamma^\mu\partial_\mu - M\}\psi_i + \frac{1}{2}\partial^\mu\sigma\partial_\mu\sigma - \frac{1}{2}m_\sigma^2\sigma^2 \\ &- \frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4 - g_s\bar{\psi}_i\psi_i\sigma - \frac{1}{4}\Omega^{\mu\nu}\Omega_{\mu\nu} \\ &+ \frac{1}{2}m_w^2V^\mu V_\mu - g_w\bar{\psi}_i\gamma^\mu\psi_i V_\mu - \frac{1}{4}\vec{B}^{\mu\nu}\vec{B}_{\mu\nu} \\ &+ \frac{1}{2}m_\rho^2\vec{R}^\mu\vec{R}_\mu - \frac{1}{4}F^{\mu\nu}F_{\mu\nu} - g_\rho\bar{\psi}_i\gamma^\mu\vec{\tau}\psi_i\vec{R}^\mu \\ &- e\bar{\psi}_i\gamma^\mu\frac{(1-\tau_{3i})}{2}\psi_i A_\mu.\end{aligned}$$

We use the recently reported well known NL3* parameter set [5]. To take care of the pairing interaction, the standard constant gap BCS - pairing approach is used and the centre of mass energy is also included.

Results and discussion

We have carried out a study of even-even superheavy nuclei from Z=108-118 with neutrons ranging from N=160-190, which means the isotopes include the rmf predicted neutron magic number N=172 and 184. Most of the superheavy nuclei with heavy neutron numbers in RMF have the well defined ground state as a prolate shape while FRDM shows almost spherical ground state. The binding energy in both formalism are quite well satisfactory. The superheavy nuclei for Z=108-118 exhibit the shape co-existence for spherical to prolate configuration. In most of the cases the superheavy nuclei have the prolate configuration on their ground state and low lying excited states with spherical and oblate configuration. Two neutron separation energy S_{2n} are in good agreement with FRDM results. One can also note a kink in Z=116 isotopes for neutron number N=170 and 172 while there is no such behaviour in FRDM.

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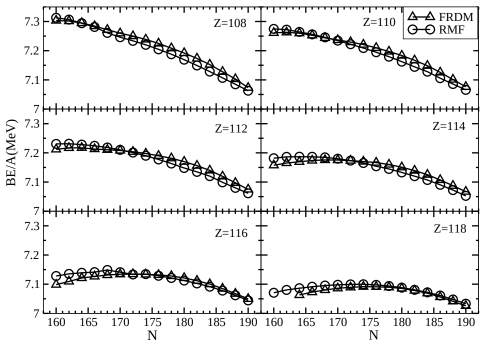

FIG. 1: The comaprison of binding energy calculated by RMF (NL3*) for isotopes of elements Z=108-118 with FRDM results.

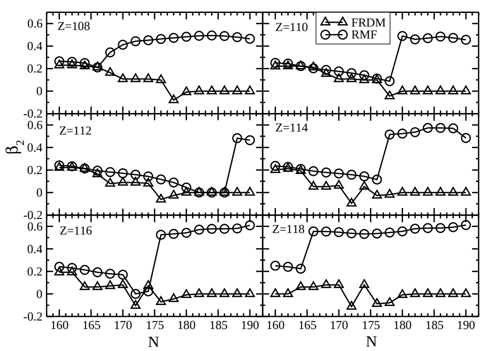

FIG. 2: The β_2 values for isotopes of the elements Z=108-118 obtained with RMF (NL3*). The results with FRDM are shown for comparison.

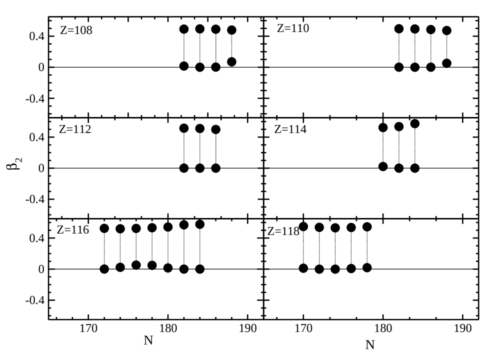

FIG. 3: Isotopes of Z=108-118 exhibit the shape co-existence in RMF formalism.

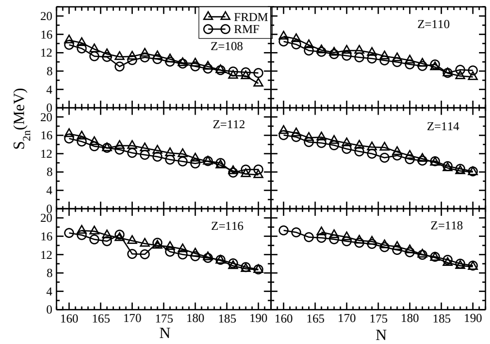

FIG. 4: Two neutron separation energy S_{2n} for even-even superheavy nuclei with neutron numbers ranging from N=160-190 in both formalism.

Conclusion

The RMF with NL3* gives rise to a prolate and spherical solution for most of the nuclei. The magnitude of the prolate deformation increases as the neutron number increases. It is conclude that the superhevy nuclei with heavy neutrons have the superdeformed ground states. Most of the nuclides exhibit the prolate to spherical shape coexistence in which spherical configuration is the first low lying exicted states.

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