Systematics of Exotic Superheavy Nuclei (Z=116, 118, 120 and 122) and their alpha decay half lives

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Introduction

Study of exotic nuclei lying at the extremes of spin, isospin and mass has always been quite fascinating, due to the the richness of knowledge these may provide on the fundamental forces as well as on the allied aspects of nuclear astrophysics. In particular, nuclei lying at the extremes of mass i.e. Superheavy Nuclei (SHN), although not been found to exist naturally, yet the possibility of their existence opens up highly speculated path - to observe number of missing elements as well as the valley of stability in nuclear landscape [1]. Synthesis of SHN in the lab is quite challenging and due to the rigor involved with the present experimental efforts, it is already being discussed if the periodic table has been extended nearly to its limit (where more number of protons can not be held together in the nucleus due to Coulomb repulsion between them), giving rise to the exploration of isotopic chains of already synthesized nuclei.

Modern theories of nuclear structure suggest that in the region of Z = 114 and neutron number N = 184, the ground states of nuclei could be stabilized against fission due to the complete filling of major proton and neutron shells and some of the superheavy nuclei in this mass region may have highly stable nuclei with high half life as the order of the age of the universe, separated from the peninsula of known nuclei by a sea of instability. In the present work, we have explored this mass region and investigated systematics of some exotic even-even SHN with atomic numbers Z = 116, 118, 120 and 122 which may be produced in near future.

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Mathematical Formalism

Relativistic mean field (RMF) model which contain the spin-orbit naturally, has been successfully used to understand and explain many nuclear features of nuclei [2]. This relativistic mean field approach, particularly with the NL3 effective interaction (or with a slightly modified version i.e. NL3* effective interaction), has been widely used in many nuclear structure studies. However, the nonlinear RMF model has certain limitations: It systematically overestimates the value of r_n-r_p [3], and predicts an equation of state for neutron matter which is very different from the standard microscopic many-body neutron equation of state of Friedman and Pandharipande [4]. Also, this approach fails in correctly predicting for the masses that match the standards of nuclear astrophysics. Therefore, The relativistic Hartree-Bogoliubov (RHB) model is extended to explicitly include density dependent meson-nucleon couplings. In this approach, the effective Lagrangian is characterized by a phenomenological density dependence for the σ , ω and ρ meson-nucleon vertex functions, adjusted to properties of nuclear matter and finite nuclei. The Density dependent RHB model (DDRHB) i.e. RHB with density-dependent meson-nucleon couplings represents a significant improvement in the relativistic mean-field description of the nuclear many-body problem and, in particular, for exotic nuclei lying far from β-stability. The improved isovector properties of the effective interaction in the ph-channel on one hand, and the unified description of mean-field and pairing correlations in the Hartree-Bogoliubov framework on the other, offer a unique possibility for accurate studies of nuclei with extreme ground-state isospin values.

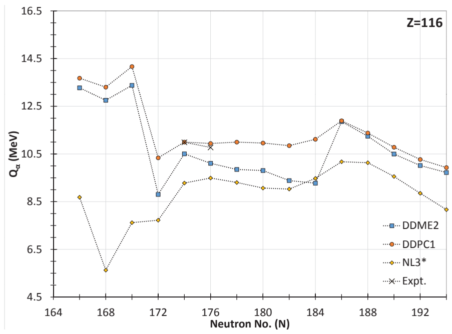

FIG. 1: Comparison of calculated Q_α values (as function of Neutron Number) along with experimental values for Z=116.

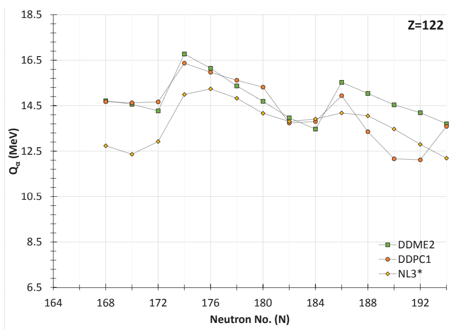

FIG. 2: Same as fig1, but for Z=122.

Results and Discussion

To have a comparable look and analyze the model dependence of the results, we have performed the calculations using both of these relativistic mean field prescriptions (the nonlinear self-coupling of meson fields and the DD meson-nucleon couplings) in the present work. To further check the model prediction reliability of the present calculations, we have also performed calculations for all the observed even-even SHN and compared the same with experimental observations.

In fig. 1, and fig.2, we have shown the results of Q values for alpha decay of Z=116 and Z=122 isotopic chains respectively, for the three different set of calculations performed (experimental observations for Z=116 are also marked). One can see that for the same isotopic chains, the calculated Q_α values vary and can be said to be moderately model dependent. Also, Since the α -decay half-lives are very sensitive to the Q_α values, the variation can give rise to large difference in predicted half-lives. Also one can observe the shell effects in the vicinity of N = 172 and N = 184 for all the cases. The detailed systematics involving ground state properties, (binding energy, rms charge radii, neutron skin), coherently with alpha decay half-lives will be presented in the conference.

Conclusion

In summary, we have studied SHN (BE, quadrupole deformation parameter, rms radii, and neutron skin, shell effect, Q value and -decay half-lives)using two different relativistic mean field approaches for the isotopic chain of Z=116, 118, 120 and 122. As some of these nuclei are being planned to be synthesized, such studies are of considerable importance. Further, it would be worthwhile to study the cluster radioactivity so as to supplement the detection and measurement of potential cases among the abovementioned cases of SHN [5].

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