International Journal of Engineering, Science and Mathematics
Vol. 10 Issue 09, September 2021,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

AN OVERVIEW OF EVEN-EVEN NUCLEI

Bhuvan Bhasker Srivastava[1] **Shad Husain** [2]

Email - husainshad4@gmail.com

Abstract

A nucleus having an even number of neutrons and protons is called an even-even (EE) nucleus in atomic physics. Approximately 60% of all stable nuclei are bosons, which mean they have an integer spin. Using covariant density functional theory, the ground-state properties of even–even nuclei from Z=10 to Z=20 are extensively investigated. The influence of triaxiality on nuclear binding energy, including the mean-field part and the rotational correlation energy, is investigated. There is a significant amount of triaxial distortion in 38Si, 46S, and 48S. There is a small but significant effect of the triaxial deformation degree of freedom on the a-field part of the nuclear binding energy in the current nuclei. To make matters even more interesting, we demonstrate that phenomenological collective correction helps to better reflect the evolution trend of the N=20 shell gap by decreasing the root mean square of binding energies for 41 nuclei from Ne to Ar by 2.22MeV to 1.60MeV.

Keyword

Nuclei, CDFT, Even

Introduction

Closed-shell nuclei have differing nuclear structures on both sides of their closed shells based on neutron and atomic numbers as well as the P-factor and energy ratio R4. Different theoretical models and experimental data are used to study nuclear structure.

Even-even nuclei are found to have a wide range of excited states, as follows: Nth excited state usually has spin I2n. There are 66 out of 68 nuclei studied in which the assignment I=2 + (even parity) is compatible with experimental data. There were 26 nuclei studied for n=2, and I=2+ spins were found in around a third of them. Another third had I=4+ spins, and the other third had a variety of spins with even and odd parities. As the number of protons or neutrons in nucleus increases, the energy of the first excited state increases as well. The one-particle hypothesis for odd A nuclei is expected to break down if the first excited state is very low, such as in the rare earths zone and for the heavy metals from thorium up. This may explain why there are no isomers of odd proton nuclei below the 82th magic number. Compared to the cores of the odd neutron nuclei (N82), the initial excited state of the even-

even core in this region has an average energy of about 0.1 Mev.[1] Even-even nuclei's Isomerism is covered in this article. Comparisons with theoretical predictions derived from an extended jj coupling model and the liquid drop model of the nucleus are performed.Nuclei with zero angular momentum (even-even nuclei) are practically the same as nuclei with zero angular momentum (e.g., even-odd and odd-odd nuclei).

The gamma transitions between excited states have an electric quadrupole nature. E2 transitions between the first excited 2+ state and the 0+ ground state have been the subject of several study. New undiscovered nuclear structural effects must be taken into account at higher K-shell internal conversion coefficients of pure E2 transitions. Recent experiments, on the other hand, imply that the earlier big deviations were most likely caused by some experimental factors rather than by any new changes in nuclear structure[2].Nucleide K-shell internal conversion coefficients for E2 transitions, which were shown to differ significantly from theoretical values, are not consistent with the correlation of K(exp)/kK(exp) (theor).

Nuclei distant from stability can now be studied thanks to the radioactive ion beam (RIB) of recent years. Light-mass neutron-rich nuclei are of special interest. These include halo phenomena, neutron skins [3], new magic number [4], and the "core" nucleus's disconnection from the halo's structure [5]. The structure of nuclei in the low-mass range has been studied theoretically using a variety of methodologies. The only microscopic theory that can be used for large-scale nuclear structure calculations throughout the complete table of nuclides is density functional theory (DFT). An effective relativistic Lagrangian-based covariant density functional theory (CDFT) has been able to describe the ground-state properties for all nuclei on the nuclear chart, including both spherical and deformed ones.

Understanding the structure of nuclei, particularly the shape and shape transitions of nuclei, relies heavily on spectroscopic features. Recent years have seen a lot of attention paid to the unusual shapes of nuclear systems, such as rods and pears. An precise and worldwide description of nuclear ground states and excitations is provided by the covariant density functional theory (CDFT).

Nuclear structural physics can now be described using CDFT, a modern theoretical method. Three primary classes of state-of-the-art covariant energy density functional have been used to study different physical features of ground and excited states in atomic nuclei within the CDFT framework. All four CEDFs for even-even nuclei are studied, and the systematic theoretical uncertainties are determined within the set of four CEDFs in known locations of the nuclear chart and their propagation towards the neutron drip line.[6] For even-even nuclei, large-scale axial relativistic Hartree-Bogoliubov (RHB) calculations are done to determine alternative ground-state observations. For the two-neutron drip line predictions, the non-relativistic results are also compared.

The nucleus of an atom is surrounded by electrons that are negatively charged. The term nucleus refers to this positive center. An atom's nucleus is responsible for the majority of its mass, but its overall size is orders of magnitude larger than its nucleus. A nucleus is only a few femtometers (1015 meters) in size, although the length scale associated with an atom is only a few angstroms (1010 meters). Protons and neutrons make up the nucleus; however they are not the only charged particles. It is necessary to overcome Coulomb repulsion because protons, which are positively charged, are present.[7] Because of this, nuclear power must be extremely powerful in nature. Another indication that the nuclear force is short-range in nature comes from the nucleus's small dimensions.

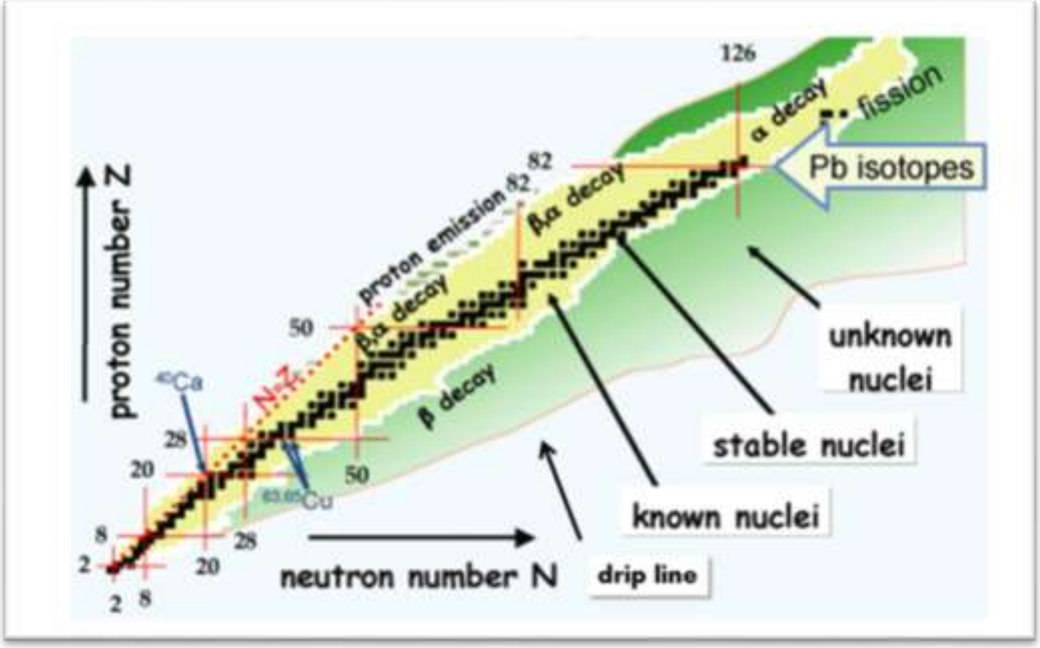

Fig.1 Nuclear chart for ~ 6000 nuclei in the N-Z plane.

Review of Literature

Yukawa (1934) proposed that the attraction between protons and neutrons was due to the existence of a field. The Yukawa particle, which has a mass of 300 times that of an electron, characterizes this field (meson). Because it may take part in weak, strong, and electromagnetic interactions with a net electric charge, the Greek word "meson" (meaning "middle particle") is a fitting name for this particle, which conveys the nuclear force between hadrons. Every single meson has a very short life span, a few hundredths of a microsecond.

Objectives

- Describe the composition and size of an atomic nucleus
- Use a nuclear symbol to express the composition of an atomic nucleus
- Explain why the number of neutrons is greater than protons in heavy nuclei
- Calculate the atomic mass of an element given its isotopes

Research Methodology

In order to learn more about a subject or get new insights, Density functional theory, nuclear map. Techniques and methods that are utilized to gather and analyse data are called research methodologies. A study's validity and reliability can be evaluated critically in the methods section. Explaining the rationale for your research methodology is an important part of the process of conducting research.

Result and Discussion

The energy density functional for a nuclear system in the point-coupling type of CDFT is as follows:

$$E_{DF} = \int d^3r\ (r)$$

with the energy density

$$(r) = \sum_k v_k^2 \psi_k^\dagger(r)(\alpha \cdot p + \beta m)\psi k(r) + \frac{\alpha s}{2}\rho_s^2 + \frac{\beta s}{3}\rho_s^3 + \frac{\gamma s}{4}\rho_s^4 + \frac{\delta s}{2}\Delta\rho s + \frac{\alpha v}{2}\rho_v^2 + \frac{\gamma v}{4}\rho_v^4$$

$$+ \frac{\delta v}{2}\rho v\Delta\rho v + \frac{\alpha TV}{2}\rho_{TV}^2 + \frac{\delta TV}{2}\rho TV\Delta\rho TV + \frac{1}{2} eAo\rho p$$

Here, m is the nucleon mass, and αS,αV,αTV,βS,γS,γV,δS,δV,andδTV are coupling constants. Moreover, Aμ is the four-vector potential for the electromagnetic field and ρi(i=S,V,TS,TV)represents various local densities. The subscripts S,V,and T indicate the symmetries of the couplings,i.e., S stands for scalar, V for vector, T for isovector, respectively.

The free-nucleon portion, the proton's coupling to the electromagnetic field, and the point coupling interaction terms are all included in the Lagrangian[8]. For nuclei, the D'Alembert operator's derivative term accounts for the leading effects of finite-range interactions.

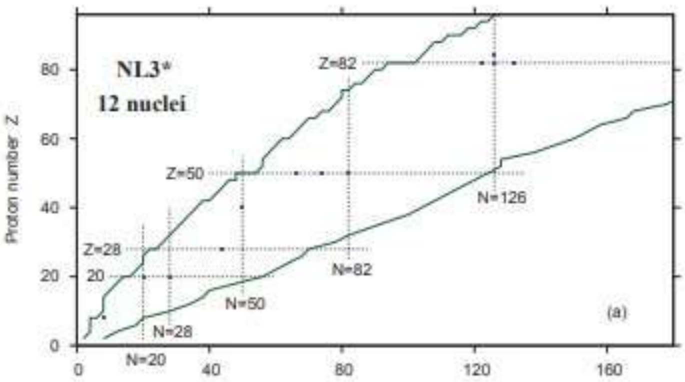

Fig.2 The nuclei shown in the (N, Z) plane, which were used in the fit of indicated CDFT parametrization.

Potential energy surfaces and deformation parameters are discussed here. Even–even 26–56S isotopes are plotted in Fig. 3 as an example of the limited RMF+BCS calculation's potential energy surfaces. From 26S to 56S, the ground-state progression in the –plane is clearly depicted. A spherical 26S nucleus is the most neutron-deficient; 28S is particularly soft along the direction in this region with 0–0.4[9-12]. The nucleus progressively turns spherical as the number of neutrons increases to N=20. The nucleus becomes more quadrupole distorted as the number of neutrons grows. 48S shows a triaxial minimum with 30[15-17]. However, the direction is similarly soft in this triaxial minimum. When the neutron number reaches N=40, the nucleus regains its spherical shape.

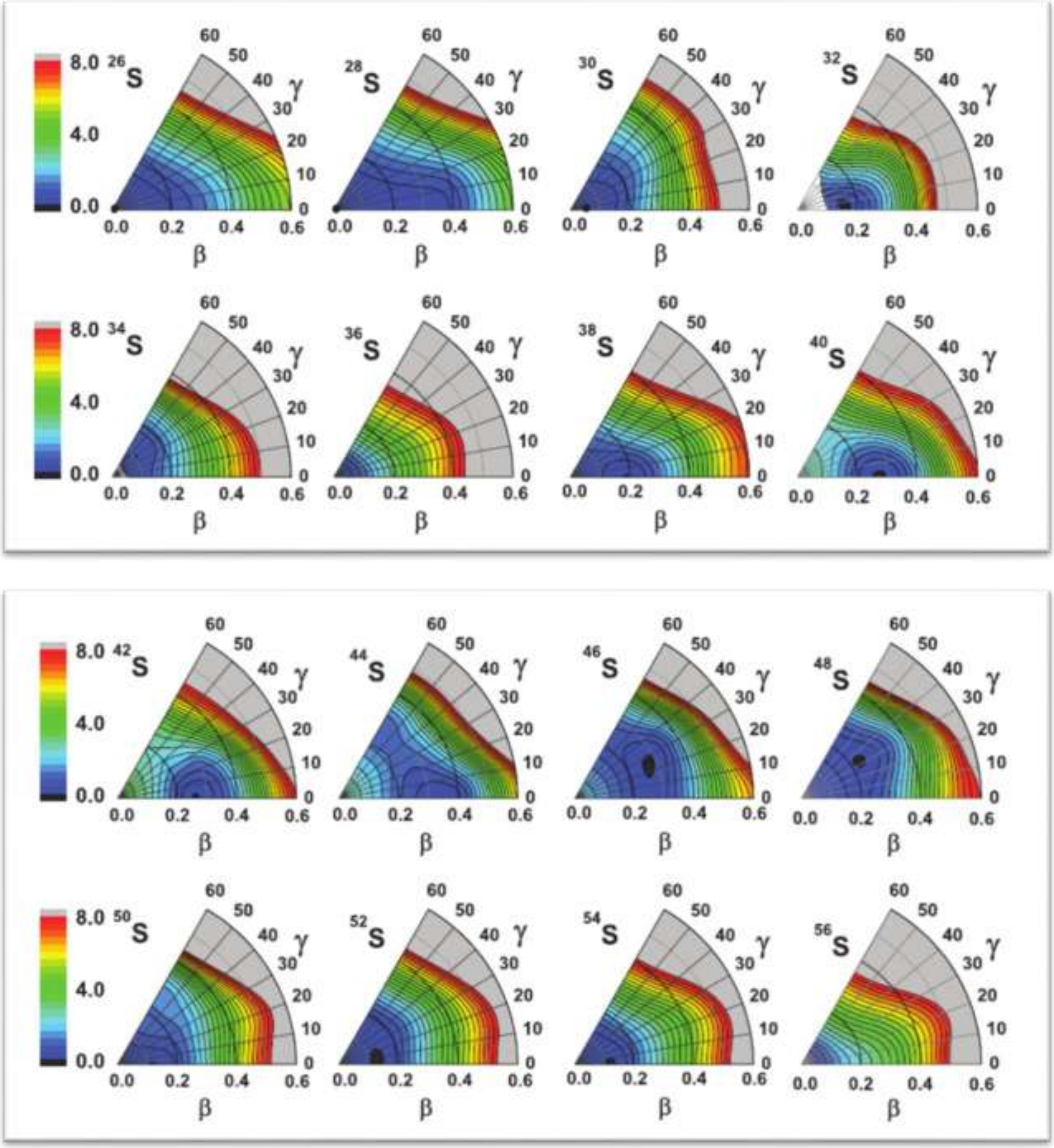

Fig.3 Potential energy surfaces of even–even 26–56S isotopes in the β–γplane from the triaxial RMF cal-culation with the PC-PK1 force. All energies are normalized with respect to the global minimum. The energydifference between neighboring contour lines is 0.4MeV

Conclusion

As a result, we used the point-coupling force PC-PK1 to investigate the ground states in even– even nuclei with 10 Z20 in the context of covariant density functional theory. Triaxial deformation degree of freedom has been studied for its static effects. We have shown that 38Si, 46S, and 48S display significant triaxial deformation, which is consistent with prior investigations on triaxial RMF. However, it is found that the triaxial deformation degree of freedom has a significant impact upon nuclear binding energy in the present nuclei, but the static effect is negligible. Reductions of 2.22 MeV and better reproduction of the N=20 shell gap evolution trend are found when phenomenological collective correction energies are taken into consideration for 41 nuclei ranging from Ne to Ca. In the future, a comprehensive investigation of the beyond-mean-field ground states of light nuclei accomplished with accurate angularmomentum projection will be required to confirm our findings. The influence of triaxiality on medium and heavy nuclei should also be studied.

References

1. D. Vretenar, A. Afanasjev, G. Lalazissis, and P. Ring, Phys. Rep. 409, 101 (2005).
2. J. Meng, H. Toki, S. Zhou, S. Zhang, W. Long, and L. Geng, Prog. Part. Nucl. Phys. 57, 470 (2006).
3. T. Nikˇsi, D. Vretenar, and P. Ring, Prog. Part. Nucl. Phys. 66, 519 (2011).
4. Z. Ren, Z. Zhu, Y. Cai, and G. Xu, Phys. Lett. B 380, 241 (1996).[15] D. Hirata, K. Sumiyoshi, I. Tanihata, Y. Sugahara, T. Tachibana, and H. Toki, Nucl. Phys. A 616, 438(1997).
5. G. Lalazissis, A. Farhan, and M. Sharma, Nucl. Phys. A 628, 221 (1998).
6. G. Lalazissis, S. Raman, and P. Ring, At. Data Nucl. Data Tables 71, 1 (1999).
7. P. Möller, R. Bengtsson, B. G. Carlsson, P. Olivius, and T. Ichikawa, Phys. Rev. Lett. 97, 162502 (2006).
8. S. Cwiok, P.-H. Heenen, and W. Nazarewicz, Nature 433, 705 (2005).
9. W. Koepf and P. Ring, Nucl. Phys. A 493, 61 (1989).
10. D. Hirata, K. Sumiyoshi, B. Carlson, H. Toki, and I. Tanihata, Nucl. Phys. A 609, 131 (1996).
11. S. Sugimoto, K. Sumiyoshi, D. Hirata, B. Carlson, I. Tanihata, and H. Toki, [arXiv:9911025 [nucl-th]][Search inSPIRE See text for details
12. J. Carlson, Alpha particle structure, Phys. Rev. C 38 (1988) 1879–1885. doi:10.1103/PhysRevC.38.1879.
13. A.Ramos, A. Polls, W. Dickhoff, Single-particle properties and short-range correlations in nuclear matter, Nucl. Phys. A 503 (1989) 1–52.doi:10.1016/0375-9474(89)90252-2.

14. D. C. Zheng, B. R. Barrett, L. Jaqua, J. P. Vary, R. J. McCarthy, Microscopic calculations of the spectra of light nuclei, Phys. Rev. C 48 (1993)1083–1091. doi:10.1103/PhysRevC.48.1083.
15. M. Honma, T. Mizusaki, T. Otsuka, Nuclear shell model by the quantum montecarlodiagonalization method, Phys. Rev. Lett. 77 (1996) 3315–3318. doi:10.1103/PhysRevLett.77.3315.
16. H. M. M ¨uller, S. E. Koonin, R. Seki, U. van Kolck, Nuclear matter on a lattice, Phys. Rev. C 61 (2000) 044320.doi:10.1103/PhysRevC.61.044320.
17. K. Tsukiyama, S. K. Bogner, A. Schwenk, In-medium similarity renormalization group for nuclei, Phys. Rev. Lett. 106 (2011) 22502.doi:10.1103/PhysRevLett.106.222502.
18. J. Carlson, S. Gandolfi, F. Pederiva, S. C. Pieper, R. Schiavilla, K. E. Schmidt, R. B. Wiringa, Quantum Monte Carlo methods for nuclear physics,Rev. Mod. Phys. 87 (2015) 1067–1118. doi:10.1103/RevModPhys.87.1067.
19. G. Hagen, T. Papenbrock, M. Hjorth-Jensen, D. J. Dean, Coupled-cluster computations of atomic nuclei, Rep. Prog. Phys. 77 (2014) 096302.doi:10.1088/0034-4885/77/9/096302
20. M. Samyn, S. Goriely, M. Bender, and J. M. Pearson, Phys. Rev. C 70, 044309 (2004).
21. S. Goriely, M. Samyn, J. M. Pearson, and M. Onsi, Nucl. Phys. A 750, 425 (2005).
22. N. Chamel, S. Goriely, and J. M. Pearson, Nucl. Phys. A 812, 72 (2008).
23. J. Libert, M. Girod, and J. P. Delaroche, Phys. Rev. C 60, 054301 (1999).
24. Y. Fu, H. Mei, J. Xiang, Z. P. Li, J. M. Yao, and J. Meng, Phys. Rev. C 87, 054305 (2013).
25. M. Bender, G. F. Bertsch, and P.-H. Heenen, Phys. Rev. C 73, 034322 (2006).
26. M. Bender, G. F. Bertsch, and P.-H. Heenen, Phys. Rev. C 78, 054312 (2008).
27. J. M. Yao, J. Meng, P. Ring, and D. Vretenar, Phys. Rev. C 81, 044311 (2010).12/12