

Skyrme-type energy density functional with surface-peaked effective mass

D. Yu. Smoliannikov^{1,2*}, N. N. Arsenyev¹, A. P. Severyukhin¹, I. T. Usman²

¹Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russia

²Lomonosov Moscow State University, Moscow, Russia

*e-mail: dsmoliannikov@theor.jinr.ru

The Skyrme energy density functional (EDF) employing the Hartree-Fock (HF) approximation is a highly effective method for investigating the ground-state properties of nuclei throughout the whole periodic table [1]. The Skyrme-HF calculations face a fundamental problem in describing the density of single-particle (s.p.) states near the Fermi surface (see discussions in Refs. [2], [3]). The inclusion of terms proportional to $\tau(\nabla\rho)^2$ and $\rho^2(\nabla\rho)^2$, which influence the radial dependence of the nucleon effective mass at the nuclear surface, results in an increase in the single-particle level density close to the Fermi surface. It should be noted that enhancing this radial dependence negatively affects the accuracy of binding energy descriptions. The contributions of various terms to the nucleon effective mass on the global nuclear properties (binding energies, s.p. spectrum, charge radii, and especially differences of radii) of magic nuclei ^{16}O , ^{40}Ca , ^{48}Ca , ^{56}Ni , ^{100}Sn , ^{132}Sn , and ^{208}Pb has been considered [4]. Based on the analysis performed, two parameter sets (SLy4* and SLy4**) have been proposed for a Skyrme-type EDF including terms proportional to $\tau(\nabla\rho)^2$ and $\rho^2(\nabla\rho)^2$. A comparison of the calculation results with available experimental data demonstrates improved description of the s.p. level density near the Fermi surface, while maintaining the reliability of the description of ground-state properties of nuclei and infinite nuclear matter. We discuss the effect of the radial dependence of the nucleon effective mass at the nuclear surface on energies and transition probabilities for the low-lying quadrupole and octupole states in the neutron-rich Sn isotopes.

The research was supported within the framework of the scientific program of the National Center for Physics and Mathematics, topic No. 6 «Nuclear and Radiation Physics» (stage 2023–2025).

References

1. P. F. Bortignon, A. Bracco, R. A. Broglia, Giant Resonances: Nuclear Structure at Finite Temperature / Harwood Academic, Amsterdam, 1998.
2. J. Carter [et al.], Phys. Lett. B **833**, 137374 (2022).
3. I. T. Usman [et al.], Phys. Rev. C **94**, 024308 (2016).
4. A. Bahini [et al.], Phys. Rev. C **109**, 014325 (2024); Nucl. Phys. A **1059**, 123078 (2025).
5. N. N. Arsenyev, A. P. Severyukhin, R. G. Nazmitdinov, JETP Lett. **118**, 718 (2023).
6. Z. Z. Li, Y. F. Niu, G. Coló, Phys. Rev. Lett. **131**, 082501 (2023).
7. A. P. Severyukhin, S. Åberg, N. N. Arsenyev, R. G. Nazmitdinov, Phys. Rev. C **95**, 061305 (2017).
8. N. N. Arsenyev, I. T. Usman, A. P. Severyukhin, Bahini, Int. J. Mod. Phys. E **36**, 2641012 (2026).