Incompressibility in finite fermionic systems: application to stable and exotic nuclei†

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Recently, it has been inferred that the measurement of isoscalar giant monopole resonances (GMRs) may probe the incompressibility of the nucleus in a range below the saturation density, rather than exactly at the saturation density[1)]. Recent measurements of isotopic chains[2,3)], possibly extended to exotic nuclei[4,5)], are therefore relevant for constraining this more general density-dependent incompressibility. The use of isotopic chains also provided opportunities to study pairing and shell effects on incompressibility. It has been shown that one cannot rule out shell and pairing effects on nuclear incompressibility[6,7)]. We therefore focus on the nuclear incompressibility along isotopic chains and through magicity.

The calculations following fully microscopic approaches based on the energy density functionals (EDFs) to predict the GMR position are usually performed using the constrained Hartree-Fock-Bogoliubov (CHFB) or the quasiparticle random-phase approximation (QRPA) approaches[8)]. In the present study, we calculate the GMR energy for the Skyrme EDF with the CHFB approach. For completeness, results obtained using Skyrme and relativistic functionals are also given using the QRPA approach.

The results obtained using the various methods mentioned above are displayed in Fig. 1 for Sn and Pb isotopic chains. The nuclear incompressibility of a finite nucleus K_A is evaluated using

$$K_A = \frac{2A\langle r^2\rangle^2_{g.s.}}{m_{-1}}, \quad (1)$$

where m_{-1} is the inverse energy-weighted sum rule and $\langle r^2\rangle_{g.s.}$ is the mean-square radius of the ground state. First, it should be noted that the three microscopic methods provide K_A values that do not differ by more than 10%. The nuclear incompressibility K_A is almost constant at 140 MeV around stable nuclei but changes as a function of A in the case of more exotic nuclei.

The incompressibility of fermionic systems has been studied using several approaches. Analytical relations using simple free Fermi gas and spherical Harmonic Oscillator (HO) models allowed us to show the direct link between the incompressibility and the zero-point kinetic energy T_0, implying that incompressibility is rooted in the localization properties of the constituents of the system. The HO model provides $K_A \simeq 5T_0$, showing that 140 MeV is a sound estimation of the nuclear incompressibility in stable nuclei.

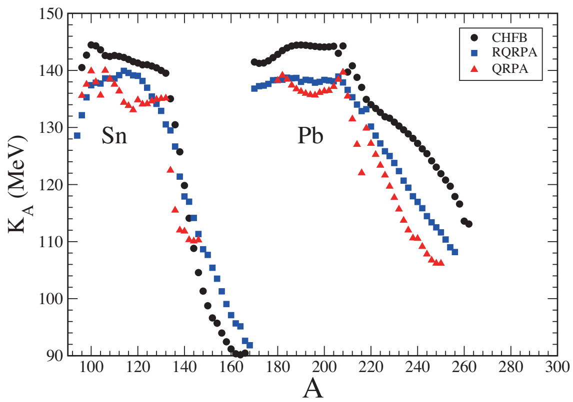

Fig. 1. Nuclear incompressibility in Sn and Pb isotopic chains calculated using the microscopic Skyrme-CHFB method (circles), the Skyrme-QRPA method (triangles) and relativistic QRPA method (squares).

In order to study the evolution of nuclear incompressibility along isotopic chains, several microscopic EDF-based approaches have been used. In the case of exotic nuclei, a decrease in K_A is predicted in all the models because of the emergence of a soft monopole strength. These results confirm the important role of the soft monopole resonance, and attempting to detect it would be useful. More generally, the behavior of the GMR in exotic nuclei and/or beyond magicity should be studied experimentally. Measurements of the GMR around ^{132}Sn and ^{210}Pb would be of interest.

† Condensed from the article in Phys. Rev. C. **87**, 064311(2013)

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References

1) E. Khan, J. Margueron and I. Vidaña, Phys. Rev. Lett. 109, 092501 (2012).
2) T. Li et al., Phys. Rev. C81, 034309 (2010).
3) U. Garg, *COMEX3 conference*, Mackinac Island (2009).
4) C. Monrozeau et al., Phys. Rev. Lett. 100, 042501 (2008).
5) M. Vandebrouck et al., Exp. E456a performed at GANIL (2010).
6) J. Li, G. Colò and J. Meng, Phys. Rev. C78, 064304 (2008).
7) E. Khan, Phys. Rev. C80, 011307(R) (2009)
8) N. Paar, D. Vretenar, E. Khan and G. Colò, Rep. Prog. Phys. 70, 691 (2007)