Relativistic Hartree-Bogoliubov Description of Deformed Light Nuclei

G.A. Lalazissis [a], D. Vretenar [b], and P. Ring
[a] Aristotle University of Thessaloniki, [b] University of Zagreb

During the last decade a large quantity of data on light nuclei with $4 \leq Z \leq 12$ has become available. In particular, measurements of interaction cross sections by using radioactive nuclear beams at intermediate and relativistic energies, have provided important data on nuclear radii. The nuclear radius is a fundamental quantity which, in principle, provides information on the effective nuclear potential, shell effects and ground-state deformation. For exotic nuclei with extreme values of neutron to proton ratio, particularly important is the isospin dependence of nuclear radii which can signal the onset of new phenomena like, for example, the formation of skin and halo structures. Data on ground-state deformations are also very important for the study of shell effects in exotic nuclei.

In the present work Relativistic Hartree-Bogoliubov (RHB) theory [1] is applied in the analysis of ground-state properties of Be, B, C, N, F, Ne and Na isotopes. Based on the relativistic mean-field theory and on the Hartree-Fock-Bogoliubov framework, the RHB model provides a unified description of mean-field and pairing correlations.

It presents an analysis of ground-state properties of Be, B, C, N, F, Ne and Na isotopes in the framework of the Relativistic Hartree-Bogoliubov (RHB) model. In the last couple of years this model has been very successfully applied in the description of nuclear structure phenomena in medium-heavy and heavy exotic nuclei far from the valley of β- stability and of the physics of the drip lines. The present analysis covers a region which is probably at the low-mass limit of applicability of the mean-field framework. This work is also a continuation of our previous applications of the RHB model of Ref. [2] (spherical RHB calculations of neutron-rich isotopes of N, O, F, Ne, Na and Mg), and of Ref. [3] (deformed RHB calculations of ground-state properties of the $A = 20$ isobaric sequence).

The present calculation has been performed in the configuration space of a deformed harmonic oscillator basis states. The NL3 effective interaction has been used for the mean-field Lagrangian, and pairing correlations have been described by the pairing part of the finite range Gogny interaction D1S. The calculated neutron separation energies, quadrupole deformations, nuclear matter radii, and differences in radii of proton and neutron distributions have been compared with very recent experimental data. For the neutron drip-line nucleus ^{14}Be the RHB calculation predicts a large prolate deformation $\beta_2 = 0.36$ and the ratio of neutron to proton quadrupole moments $Q_n/Q_p = 3.6$. For the neutron-rich Boron isotopes, the calculated matter radii reproduce the recent experimental data [4] for ^{17}B and ^{19}B. This is an important result, since ^{19}B ($T_z = 9/2$) has one of the largest N/Z values known at present in the low-mass region of the nuclear chart.

The RHB model with the NL3+D1S effective interaction predicts the location of the neutron drip-line in Nitrogen and Fluorine in agreement with recent experimental findings [5]: the heaviest particle stable isotopes are ^{23}N and ^{31}F. The calculation, however, does not reproduce the location of the neutron drip line in Oxygen. The calculated matter radii of the neutron-rich Nitrogen and Fluorine isotopes are in agreement with very recent experimental data [6]. The sudden increase of the radii at N=15, which was taken as evidence for the formation of the neutron halo, is not reproduced by the present calculation.

For the neutron-rich Neon isotopes the RHB model predicts pronounced prolate deformations in the region of possible halo structures ($A > 30$). The calculated matter radii are in very good agreement with recent experimental data [7]. For the Na isotopic sequence (see Fig. 1) the calculated radii are in excellent agreement with experimental data on matter radii [8], neutron radii [9], and charge isotope shifts. The calculated ground-state quadrupole deformations are confirmed by the recent experimental data on quadrupole moments of $^{26-29}$Na [10].

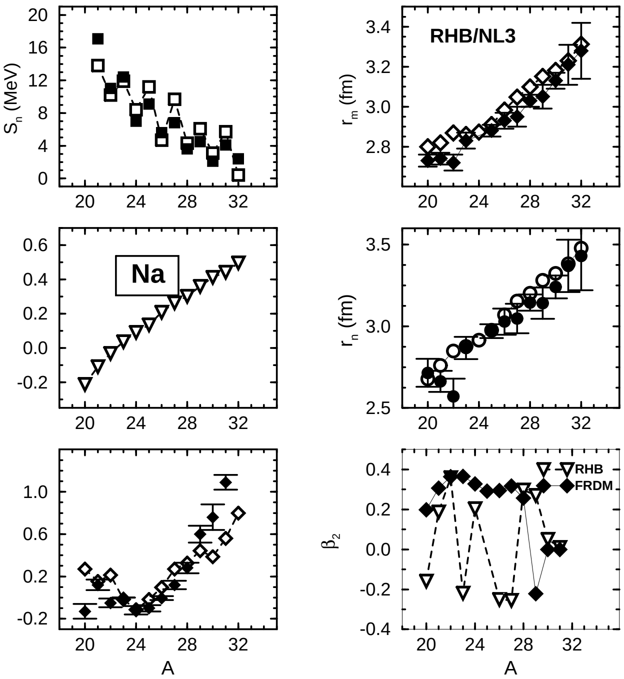

Fig. 1: One-neutron separation energies, radii, charge isotope shifts and ground-state quadrupole deformations of Sodium isotopes. The RHB calculated values are compared with the experimental data and with the β_2 values calculated in the finite-range droplet model.

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