A NEW PARAMETER SET FOR THE RELATIVISTIC MEAN FIELD THEORY

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Subtracting the Strutinsky shell corrections from the selfconsistent energies obtained within the Relativistic Mean Field Theory (RMFT) we have got estimates for the macroscopic part of the binding energies of 142 spherical even-even nuclei. By minimizing their root-mean-square deviations from the values obtained with the Lublin-Srasbourg Drop (LSD) model with respect to the nine RMFT parameters we have found the optimal set (NL4). The new parameters reproduce also the radii of these nuclei with an accuracy comparable to that obtained with the NL1 and NL3 sets.

1. RMFT Parameters

The Relativistic Mean Field Theory (RMFT),[1] which is essentially a Hartree-Fock like method based on the Dirac equation for the nucleons and on the Klein-Gordon equation for the ρ, ω, σ mesons reproduces nuclear properties quite well when its parameters (i.e.: masses of nucleon m and mesons m_ρ, m_ω, m_σ and their coupling constants ρ_ρ, ρ_ω, ρ_σ, ρ_2, ρ_3) are fitted to the largest possible amount of nuclear data. Usually the masses and root-mean-square (rms) radii of 8 magic nuclei were used to find the RMFT parameters and several sets were established for various regions of the periodic table to describe quantities such as masses, electric quadrupole moments or radii. We have checked the quality of three parameter sets: NL1,[2] NL2,[3] NL3,[4] by comparing their macroscopic energies, obtained by subtracting the Strutinsky shell correction from the RMFT binding energies, evaluated without pairing forces,[5] with the Lublin-Strasbourg-Drop (LSD) energy.[6] The minimization of the root-mean-square differences between the macroscopic energies allowed to find a new set of RMFT parameters, NL4, which, even if rather close to the NL3 set (see table below), results in a rms deviation that is more than 2 times smaller (3.29 instead of 7.17 MeV).

Set	m	m_ω	m_ρ	m_σ	g_ω	g_ρ	g_σ	ρ_2	ρ_3
NL3	939	782.501	763.0	508.194	12.868	-4.474	10.217	-10.431	-28.885
NL4	938	782.474	763.9	508.194	12.867	-4.360	10.216	-10.432	-28.882

2. Radii

The rms radii of the neutron and charge-density distributions obtained with the new NL4 set are about as good as those of D1S Gogny [7] force but systematically better than those of NL3 [4] (except for the heaviest isotopes in the case of r_{ch}) as can be observed in Fig. 1 for the neutron radii of 13 nuclei and in Fig. 2 for the charge radii of different isotopic and isotonic chains as well as for β stable nuclei.

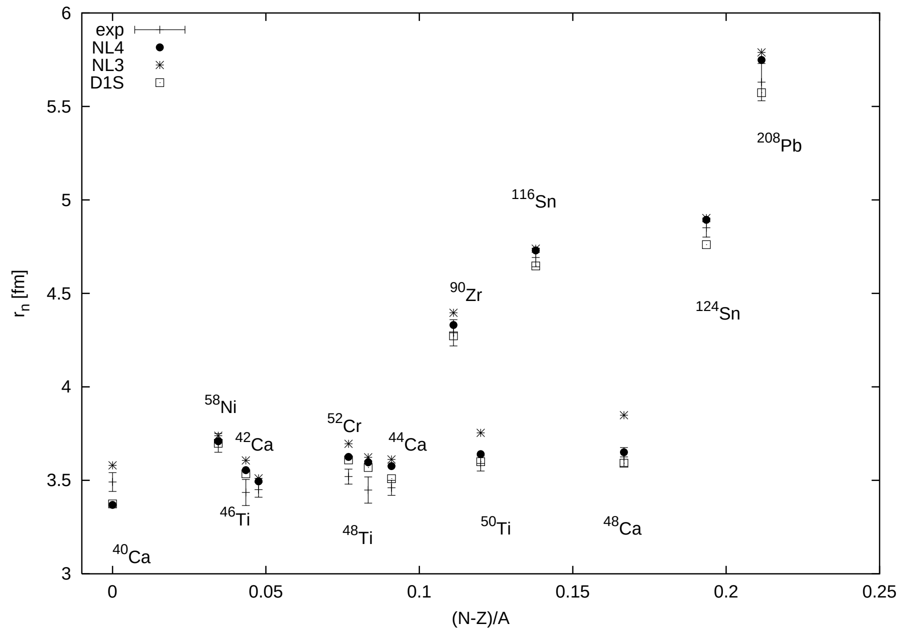

Fig. 1. Neutron density radii of 13 spherical, even-even nuclei evaluated with the NL3[4] and NL4 RMFT parameters sets and the Gogny D1S force,[7] as compared to the experimental data.[8]

We found that the charge, neutron and proton radii as well as the ratio r_p/r_n obtained within the RMFT with the new NL4 parameter set can be very well approximated by the expression

$$r = r_0 \left(1 + \alpha \frac{N-Z}{A} + \frac{\kappa}{A}\right) A^{1/3} \tag{1}$$

with the parameters listed in the table below.

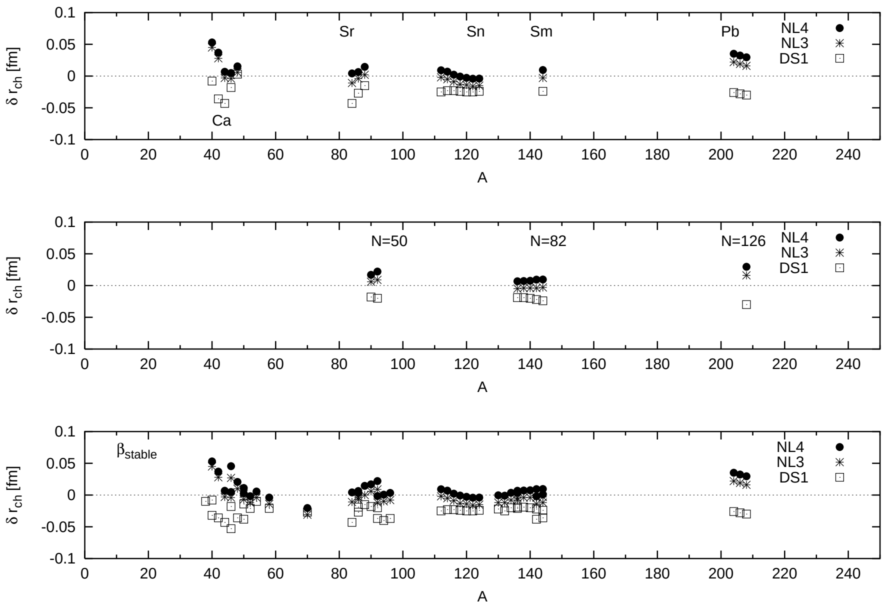

Fig. 2. Rms charge radii of spherical even-even nuclei obtained with the Gogny D1S force[7] and the NL3,[4] and NL4 parameter sets of the RMFT relied to the experimental data,[9] as function of the mass number A for five isotopic chains, (upper part), three isotonic chains (middle part) and the β stable nuclei with $A > 40$ (lower part).

	r_0	α	κ
r_{ch}	1.2328 fm	–0.15	2.1253
r_p	1.2257 fm	–0.152	1.1355
r_n	1.1761 fm	0.2625	3.085
$\frac{r_p}{r_n}$	1.0378	–0.3702	–1.6249

3. Masses

In Fig. 3 the deviation between the experimental and theoretical masses obtained with the RMFT for the NL3 and NL4 parameter sets are compared with the corresponding Gogny D1S [7] Hartree-Fock-Bogolubov (HFB) results. As one can see, the NL4 masses are closer to the experimental data than those obtained with NL3, although they do not reach the high quality obtained with the D1S Gogny force. A part of the discrepancies observed in Fig. 3 for the NL3 and NL4 cases are caused by the approximate treatment of the pairing force. In the RMFT model pairing is added by a BCS procedure with the experimental pairing gaps as an input, while the HFB method includes pairing correlations in the selfconsistent mean field.

4. Conclusions

The following conclusions can be drawn from our calculation. We have shown that the new RMFT parameter set NL4 reproduces the data of spherical, even-even nuclei better

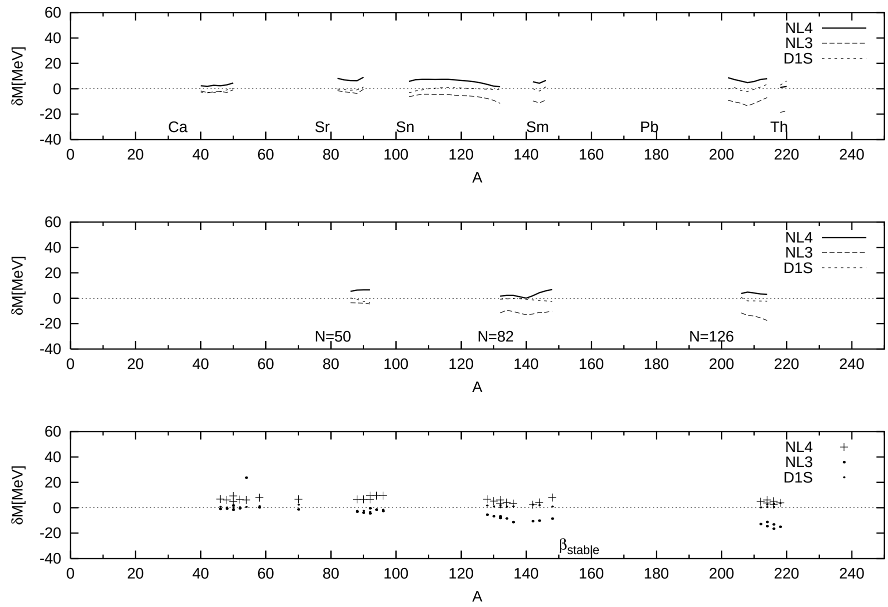

Fig. 3. Masses relative to experimental data [6] for 142 spherical, even-even nuclei evaluated with the Gogny D1S force,[7] and the NL3[4] and NL4 RMFT parameter sets as function of mass number A, for isotopes (upper part), isotones (middle part) and β stable nuclei (lower part).

than previous ones and the quality of its predictive power is comparable to that of the D1S Gogny force. We also find that the NL4 RMFT parameter set allows for a better description of the neutron and charge rms radii than other RMFT parameter sets.

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