Neutron skin thickness: further constraint to construct an effective RMF model

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The relativistic mean field (RMF) model has been applied to study a variety of nuclear phenomena and has achieved great successes during the last twenty years [1]. However, as an effective model based on Quantum Hadrondynamics, its predictive power can only be checked by comparing its predictions to experiment [2]. To this purpose, we have carried out a systematic study of the ground-state properties of a large number of nuclei throughout the periodic table [3]. (More details can be found in Ref. [4].) Here we would like to mention the special role of neutron skin thickness: why it is important and how it can further constrain the RMF model?

The charge density of finite nuclei has been accurately measured for a long time, which has been used to constrain various theoretical modes, such as RMF and HFB. However, measuring the neutron density or matter density is much harder due to its strong interaction nature, which also inevitably leads to large experimental uncertainties. Therefore in the past, no theoretical models were carefully constrained by this information. However, with the rapid developments of experimental techniques, today we have accumulated a large number of experimental data for this quantity, particularly in the light mass region, which enables us to further constrain our theoretical model. This quantity is also related to the radii of neutron stars [5]. In Fig. 1, we compare the experimental neutron skin thicknesses of ^{208}Pb with those predicted by various theoretical models. It is easily seen that the nonlinear version of the RMF model, TMA and NL3, overestimates this quantity. Recent studies show that this can be cured by adding the following form of interaction terms into the original Lagrangian: $\rho^2\sigma^2$ or $\rho^2\omega^2$ [5]. However, we see that the density dependent version of the RMF model, DD-ME1, predicts a value closer to the experimental ones. It is no surprising since by assuming some form of density dependence for the meson-nucleon couplings the density dependent version can include more interaction terms than the nonlinear version, though implicitly.

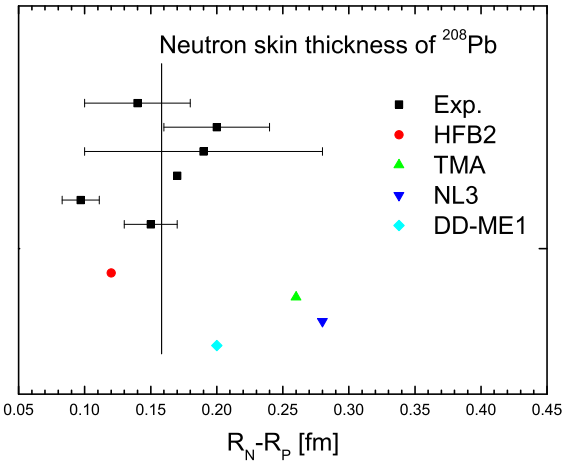

Figure 1: The experimental neutron skin thicknesses of ^{208}Pb in comparison with those predicted by HFB, RMF+BCS/TMA, RMF+BCS/NL3, and RHB/DD-ME1. The vertical line denotes the arithmetic mean of the six experimental measurements.

To conclude, the nonlinear version of the RMF model may not incorporate enough interaction terms permitted by QCD symmetries to better describe the neutron skin thickness. In other words, the neutron skin thickness can be used to further improve the nonlinear version of the RMF model. More detailed analysis can be found in Ref. [4] and further studies are in progress.

References

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