International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Effective theory for low-energy nuclear energy density functionals

J. Dobaczewski[1,2], K. Bennaceur[3], and F. Raimondi[1,4]

[1] *Department of Physics, University of Jyväskylä, P.O. Box 35 (YFL), FI-40014 Jyväskylä, Finland*
[2] *Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, ul. Hoża 69, PL-00681 Warsaw, Poland*
[3] *Université de Lyon, F-69003 Lyon, France; Institut de Physique Nucléaire de Lyon, CNRS/IN2P3, Université Lyon 1, F-69622 Villeurbanne Cedex, France*
[4] *TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia V6T2A3, Canada*

Contact email: *Jacek.Dobaczewski@fuw.edu.pl*

Our work aims at employing the density functional theory in a form of a convergent expansion, and building an order-by-order correctible theory of low-energy nuclear phenomena. In Ref. [1], we used ideas of the effective theory to construct new classes of nuclear density functionals. For a typical scale of low-energy nuclear phenomena, where the pions mediating the long range part of the nuclear interaction are already too fine a probe to be "seen" by the nucleons, the first thing is to cut-off unresolved high-energy effects that cannot be clearly visible in the low-energy regime. The technology to do so is very well known – one has to employ the so-called regularized contact forces. In practice, this means, for example, replacing delta interactions by peaked functions of a given width, whereupon the width "a" provides the resolution scale. Numerous alternative regularization methods have been invented and employed, such as the cut-off of the high-momentum parts of the delta interaction or a dimensional regularization. Although technically they can be very different, they all do the same job. In our work [1]–[3] we used the Gaussian functions. It is easy to understand that their role is to smear away the details of nuclear densities, thus leaving us with only those parts that vary smoothly. Once this is done, one must describe these smooth variations within a controlled expansion of a gradually increasing precision. This, in turn, is done by regularizing the contact pseudopotentials, that is, the contact forces acted upon by series of differential operators. Up to sixth order, the most general functionals of this kind have been derived [2] and their nuclear-matter properties have been studied [3].

We still do not know how this kind of nuclear functionals will perform in describing the experimental data. Our work only provides a promising hint, by showing a perfect convergence of the series to metadata obtained by employing the standard Gogny functional, see Fig. 1. In future studies, we will attempt the full-blown direct adjustments to data. The biggest challenge is to show that by increasing the resolution scale (decreasing the width of Gaussians) one introduces unphysical high-energy phenomena, and, at same point, in accordance with principles of the effective theory, the theory fails.

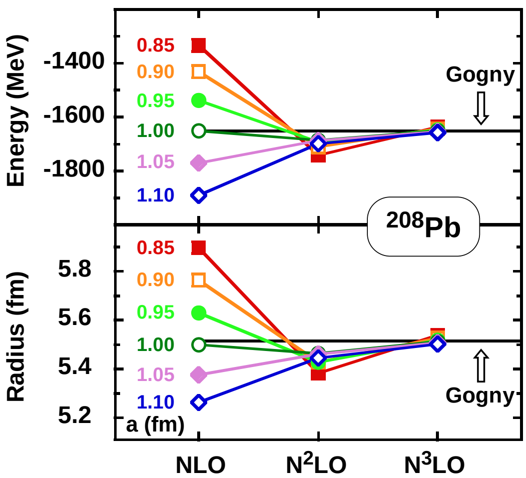

Figure 1: *Convergence of the total energy (upper panel) and proton rms radius (lower panel) in ^{208}Pb.*

[1] J. Dobaczewski, K. Bennaceur, and F. Raimondi, J. Phys. G: Nucl. Part. Phys. 39, 125103 (2012);
[2] F. Raimondi, J. Dobaczewski, and K. Bennaceur, to be published;
[3] K. Bennaceur, J. Dobaczewski, and F. Raimondi, to be published.