RELATIVISTIC ENERGY DENSITY FUNCTIONAL FOR ASTROPHYSICAL APPLICATIONS

Nils Paar, Department of Physics, University of Basel, Switzerland / Department of Physics, Faculty of Science, University of Zagreb, Croatia

Relativistic nuclear energy density functionals (RNEDF) have become a standard framework for nuclear structure studies of ground-state properties and collective excitations over the entire nuclide chart [1]. By employing recent observational constraints on the neutron star mass, a universal RNEDF has been established that simultaneously describes the properties of finite nuclei and neutron star properties. Using the framework that includes the thermodynamic method, the RNEDF, and the quasiparticle random-phase approximation, one can explore the relationships between the properties of collective excitations in finite nuclei and the neutron star phase transition density and pressure at the inner edge separating the liquid core and the solid crust. Recently it has been shown that by employing the calculated and experimental excitation energies of giant resonances, energy weighted pygmy dipole strength, and dipole polarizability, constraints on the neutron star transition density and pressure can be obtained [2].

Weak charged-current neutrino-induced reactions in nuclei and inelastic neutrino-nucleus scattering through the neutral-current play an important role in stellar evolution and nucleosynthesis. Modeling the neutrino-nucleus cross sections provides not only the relevant input for supernova simulations, but it also allows to study a variety of phenomena involving (anti)neutrinos. Recently, a fully self-consistent framework based on the RNEDF has been established to describe neutral- and charged-current neutrino-nucleus reactions [3-5]. Neutrino-nucleus cross sections are calculated using a weak Hamiltonian and the nuclear properties of initial and excited states are obtained within the relativistic Hartree-Bogoliubov model and the relativistic quasiparticle random phase approximation. This framework has been employed in systematic studies of charged-current neutrino reactions with nuclei of relevance for the r-process nucleosynthesis [3] and for the neutrino detectors, including the estimates of the systematic theoretical uncertainties in the calculated cross sections [4]. Inelastic neutral-current neutrino-nucleus cross sections have been described, including their isotopic dependence and respective cross sections averaged over the distribution of supernova neutrinos [5].

Recently a hybrid method has been introduced to explore the feasibility to determine neutrino mass hierarchy by simultaneous measurements of detector responses induced by antineutrino and neutrino fluxes from accretion and cooling phases of type II supernova [6]. By employing the calculated (anti)neutrino-nucleus cross sections for ^{56}Fe and ^{208}Pb, it is shown that simultaneous use of (anti)neutrino detectors with different target material and time dependence of the signal provide useful information to determine the neutrino mass hierarchy from the ratios of neutrino/antineutrino induced emissions.

REFERENCES

[1] T. Nikšić, N. Paar, D. Vretenar, P. Ring, Comp. Phys. Comm. 185, 1808 (2014).
[2] N. Paar, Ch. C. Moustakidis, T. Marketin, D. Vretenar, and G. A. Lalazissis, Phys. Rev. C 90, 011304 (R) (2014).
[3] N. Paar, H. Tutman, T. Marketin, T. Fischer, Phys. Rev. C 87, 025801 (2013).
[4] N. Paar, T. Suzuki, M. Honma, et al., Phys. Rev. C 84, 047305 (2011).
[5] H. Đapo, N. Paar, Phys. Rev. C 86, 035804 (2012).
[6] D. Vale, N. Paar, arXiv:1406.2584 (2015).