Exotic modes of excitation and charged-current neutrino-nucleus reactions

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The multipole response of unstable nuclei provides evidence on possible occurrence of new exotic modes of excitation in weakly-bound nuclear systems. Even in stable nuclei various modes of giant collective oscillations had been predicted by theory years before they were observed in experiments, and for that reason it is very important to perform detailed theoretical studies of the evolution of collective modes of excitation in nuclei far from stability. We discuss one of modern theoretical tools that have been developed in recent years for the description of excitation phenomena in weakly-bound nuclei: relativistic quasiparticle random-phase approximation (RQRPA) derived in the small amplitude limit of the time-dependent relativistic Hartree-Bogoliubov (RHB) model[1]. The effective Lagrangian contains explicit density-dependent meson-nucleon couplings. The RQRPA configuration space is based on the RHB canonical single-nucleon basis, including two-quasiparticle pairs formed from the fully or partially occupied states of positive energy in the Fermi sea, and the empty negative-energy states from the Dirac sea. The RHB+RQRPA framework has been employed in studies of the evolution of low-energy dipole modes from stable nuclei to systems near the particle emission threshold, to analyses of various isoscalar modes, those for which data are already available, as well as those that could be observed in future experiments, to a description of charge-exchange modes and their evolution in neutron-rich nuclei[1-4]. In comparison to recent experimental data on low-lying E1 strength from Coulomb dissociation of high-energy radioactive beams of the neutron-rich nuclei ^{130,132}Sn, it is shown that the observed data constrain the model nuclear symmetry energy, and neutron skin thickness can be deduced.

Semileptonic weak interaction rates of spherical open shell nuclei can be studied in a consistent way by using the nuclear ground state and transition matrix elements from the RHB+RQRPA framework. In particular, the inclusive neutrino-nucleus cross sections have been evaluated at low energies[5]. A complete spectrum of charge-changing excitations of various multipolarities and all transition operators arising from the multipole analysis of weak-interaction Hamiltionian are taken into account. Of particular interest are charged-current neutrino reactions with nuclear targets relevant for the nuclear astrophysics and calibration of solar and supernovae neutrino detectors (^{16}O, ^{40}Ar,^{56}Fe, and ^{208}Pb). The model calculations are tested by comparing the neutrino-nucleus cross sections averaged over Michel spectrum with the available experimental data for ^{12}C and ^{56}Fe. Exploratory studies show perspectives of such an approach in systematic and consistent predictions of the neutrino-nucleus cross sections in nuclei away from the valley of stability relevant for neutrino nucleosynthesis.

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