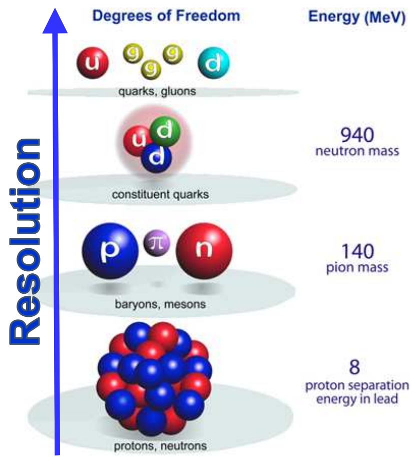

Isospin symmetry reflects a remarkable similarity between the proton-proton, neutron-neutron and neutron-proton strong interaction. The symmetry is widely used in theoretical modeling of atomic nuclei in spite of the fact that it is not a fundamental symmetry of nature. The physics origin of the isospin symmetry breaking (ISB) and its theoretical description depends on basic constituents of the model or, as physicists used to say, on their resolution. At the fundamental level of quantum chromodynamics, the symmetry is broken by different masses and charges of constituent quarks which are the fundamental building blocks of hadronic matter. At lower energies, where the quarks and gluons are no longer visible (not resolvable), the degrees of freedom reduce to point-like barions and mesons. In these effective (field) theories the ISB results from the long-range Coulomb interaction and the short-range ISB strong forces which emerge due to the barion- and meson-mass splittings, one- and two-meson exchanges and meson-photon exchanges.

The primary objective of the project is to investigate the effects of ISB in finite nuclei using the nuclear Density Functional Theory (DFT) and its extensions. The formalism is perfectly tailored to study the ISB effects since it treats Coulomb polarization properly, without involving an inert core, and accounts for an interplay between short- and long-range forces in a self-consistent way. It also allows to include, in a controllable and computationally efficient way, the ISB contact forces. Moreover, after restoring broken symmetries and implementing configuration mixing the formalism can be turned over into a powerful computational scheme complementary to the conventional nuclear shell-model.

The goal is to develop the extended DFT involving long- and short-range ISB forces and apply it to study the nuclear structure and decays. In particular, we aim to investigate the nuclear symmetry energy (NSE) a primary quantity describing a response of the nucleus against the ISB and neutron/proton excess. It influences a broad spectrum of phenomena spanning from a subtle isospin mixing, through stability of neutron-rich nuclei at the drip lines to the structure and masses of neutron stars. We shall focus, however, on the studies of in-medium weak decays. Of particular interest are processes used to search for possible signals of *new physics* beyond the Standard Model like the superallowed $0^+ \rightarrow 0^+$ β-decays. With small, of order of a percent, theoretical corrections accounting for radiative processes and ISB, these semileptonic pure Fermi (vector) decays allow to verify the conserved vector current (CVC) hypothesis with a very high precision and, in turn, they provide the most precise values of the strength of the weak force, $G_{\rm F}$, and of the leading element, $V_{\rm ud}$, of the Cabbibo-Kobayashi-Maskawa (CKM) matrix. In the plans are also extensions that would allow to compute: (*i*) forbidden unique transitions including both the even- and odd-forbidden decays; (*ii*) matrix elements for allowed double beta decay involving two neutrinos ($2\nu\beta\beta$) and, ultimately, (*iii*) matrix elements for neutrinoless double beta decay ($0\nu\beta\beta$). The latter task is of paramount importance for planning future experiments dedicated to $0\nu\beta\beta$ decay. The $0\nu\beta\beta$ decay, if possible at all, is very rare and therefore extremely difficult and expensive to measure. It's discovery, however, would have profound consequences. It would reveal the nature of neutrinos, solve the neutrino-mass hierarchy problem and the matter-antimatter mystery paving a way for particle theorists to work out extensions of the Standard Model.