

Abstract

Nuclear Theory for Double-Beta Decay and Fundamental Symmetries

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The Topical Collaboration on Nuclear Theory for Double Beta Decay and Fundamental Symmetries (the DBD Collaboration), involving nine universities and two national labs, uses theoretical nuclear physics to address questions about fundamental particles and symmetries. The Collaboration pools the expertise and resources of its members in a coordinated attack, leading to progress that would not be possible within the base program, in the absence of this coherent effort.

The atomic nucleus offers unique opportunities to learn about fundamental particles and symmetries: New interactions can be isolated through rare kinds of nuclear decay, and symmetry violation can be enhanced by chance level degeneracies and collective phenomena in which all the nucleons in the nucleus move together. Experimentally the field is vigorous: Next-generation efforts to determine whether neutrinos are their own antiparticles and search for lepton-number violation in double beta decay are under development. Heroic work is underway to precisely measure the electric dipole moments of the neutron and atoms, allowing a search beyond the Standard Model for sources of CP violation that can explain why there is more matter than antimatter in the universe. Other important experiments seek to determine the nature of dark matter and to measure parity violation in neutron-proton reactions. Precision beta-decay experiments remain our best way to search for new generations of quarks.

The DBD Collaboration supports ongoing and planned experiments in this field, generating ideas for new symmetry tests on table tops and at major laboratories, and applying our best methods of nuclear structure and lattice QCD to the important problems of the matrix elements governing double beta decay, superallowed beta decay, nucleon and atomic electric dipole moments, and the interaction of dark matter with nuclei in detectors. The Collaboration is focusing particularly intently on neutrinoless double beta decay, the nuclear matrix elements for which must be calculated accurately if the exciting experimental effort to learn about neutrinos is to reach its potential. Although these matrix elements are notoriously difficult to calculate, recent developments in rigorous nuclear many-body theory, effective field theory, and uncertainty quantification, hold out the promise of greatly improved calculations with reliable error bars. The DBD Collaboration, which brings together experts in all the relevant aspects of nuclear theory for the first time, is uniquely positioned to apply the new methods. These statements are just as true of nucleon and atomic electric dipole moments, to which the Collaboration also devotes substantial effort.