Streamlining the nuclear force with forces are believed to play a smaller but pivotal role in the description of nuclear structure. In these models, the computationally expensive three-nucleon force needs to be taken into account. However, this force is not the only one that contributes to the nuclear force. For example, the so-called “magic” nuclei, such as neutron-rich and super-heavy nuclei, might be understood with two-nucleon forces alone. The new model requires less computational resources than the previous models.

The derivative-free, nonlinear least squares solver POUNDERS in TAO was used to systematically optimize potentials from the effective field theory of nucleons to next-to-leading order in the phase-shift analysis based solely on two-nucleon forces.

The Hamiltonian matrix evaluation and diagonalization code MFDn (“Many-Body Diagonalization of Nuclear Models”) is a tool developed to study the nuclear problem with the no-core shell model. The Hamiltonian matrix is constructed using a multiwavelet basis with an oct-tree structure. The multiresolution geometry adapts to include only the support with significant wavelet contributions during the diagonalization process.

The description of superfluid Fermi systems with complex topologies and significant spatial extend is necessary to study systems such as fissioning nuclei, weakly-bound nuclei, nuclear matter in the neutron star crust, and ultracold Fermi atoms in elongated traps. MADNESS-HFB solves the self-consistent Hartree-Fock-Bogoliubov problem in large boxes accurately in coordinate space. It uses novel multi-resolution analysis methods to adapt the pseudospectral technique to enable fully parallel 3D calculations of very large systems.

MADNESS is a scalable and adaptive computational tool to describe many-body nuclear and atomic problems involving complex geometries within the superfluid density functional theory.

NUCLEI project members have been awarded allocations at DOE’s Leadership Computing Facilities through the INCITE program since 2008. These computing resources are crucial to scientific discovery in low-energy nuclear physics, both experiment and theory.