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First principles theory for nuclear structure, astrophysics, and new-physics searches

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Answers to some of the most fundamental questions in science, such as the mass and character of the neutrino, the nature of dark matter, or the abundance of matter over antimatter, might very well reside in the physics of the atomic nucleus. As the role of nuclei in unraveling such mysteries continues to deepen, first-principles quantum simulations, beginning from only underlying nuclear/weak forces, are currently undergoing nothing short of a revolution. Long considered a collection of disconnected phenomenological models, breakthroughs in our treatment of nuclear forces rooted in QCD, the strongly interacting many-body problem, and AI/machine learning techniques are transforming modern nuclear theory into a true first-principles discipline.
In this talk I will outline this next-generation "ab initio" philosophy and spotlight several recent milestones for nuclear structure/astrophysics, including statistical predictions of the limits of nuclei, the neutron skin of 208Pb to constrain neutron star properties, and new results informing r-process nucleosynthesis simulations in the N=126 region. I will then focus on our parallel advances driving first ab initio predictions of neutrinoless double-beta decay, WIMP- and neutrino-nucleus scattering, and symmetry-violating moments, with quantifiable uncertainties, for essentially all nuclei relevant in searches for new physics.

Primary author: HOLT, Jason (TRIUMF)

Presenter: HOLT, Jason (TRIUMF)

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