Machine-learning techniques to assess the relevance of three-body interactions in the shell model

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Field: nuclear physics (theory)

Prerequisites: quantum mechanics, numerical methods, nuclear physics

Description

In this project the problem of neutrons and/or protons placed in a single-j shell is considered. Realistic shell-model calculations require a larger valence space and, as known from effective-operator theory, the restriction to a single-j shell will induce higher-order interactions among the nucleons. The question addressed in this project is the following: To what extent can the energy spectra of nuclei be described with a shell-model Hamiltonian with up three-body interactions in a single-j shell?

We propose to study this problem for nuclei situated in the $f_{7/2}$ region, that is, with neutron number N and proton number Z between 20 and 28. Energy spectra can be taken from NNDC [1]. The data are randomly divided into a training and test set [2]. The interaction matrix elements are fitted to the former and the fitted values are subsequently used to reproduce the latter. This procedure is executed for a two-body Hamiltonian and for a two-plus-three-body Hamiltonian, respectively, and the relative merits of both approaches are compared.

Outline

- Introduction to the shell model with neutrons and protons in a single-j shell.
- Classification of two- and three-body interactions in a single-j shell in isospin formalism.
- Collection of the energy data from NNDC.
- First application to semi-magic $f_{7/2}$ nuclei with T=1 two-body and T=3/2 three-body matrix elements.
- Application to all $f_{7/2}$ nuclei with T=0,1 two-body and T=1/2,3/2 three-body matrix elements.

[1] National Nuclear Data Center, https://www.nndc.bnl.gov
[2] P. Mehta, M. Bukov, C.K. Fisher and D.J. Schwab, *A high-bias low-variance introduction to Machine Learning for physicists,* arXiv:1803:08823v3.