Matrix Elements of Next-Generation Chiral Interactions

Project Manager
Thomas Hüther

Principal Investigator
Prof. Dr. Robert Roth

Project Term
2018 - 2019

Project Areas
Particles, Nuclei and Fields

Clusters
Lichtenberg Cluster Darmstadt

Institute
Institut für Kernphysik

University
Technische Universität Darmstadt

Introduction

In recent years interactions from chiral effective field theory (chiral EFT) have been used very successfully in ab-initio nuclear structure calculations of light and medium-mass nuclei. Recently, the Low Energy Nuclear Physics International Collaboration (LENPIC, www.lenpic.org) has started to develop a new generation of chiral interactions that allows for a systematic order-by-order analysis of the convergence of the chiral EFT expansion and a consistent quantification of theory uncertainties for nuclear structure observables [1].

Methods

Using these interactions directly in a many-body calculation is computational expensive, hence, we use the Similarity Renormalization Group (SRG) to ’soften’ these interactions. The SRG improves the convergence properties of many-body calculations, however, the SRG itself involves large-scale numerical calculations with highly specialized and optimized codes that have been developed in our group over the past years. In this project we produced the matrix elements for interactions with the regularization scheme used in the LENPIC collaboration and in addition for a set of different interactions that are based on a nonlocal regularization scheme but allow the same order-by-order analysis. First results were presented on international conferences [2;3]. Chiral EFT also predicts four-nucleon (4N) interactions, which are usually neglected for calculations of finite nuclei. In the last year we have thoroughly investigated the effect of chiral 4N interaction in nuclear structure calculations, using about half of the computing

resources in this project. For the first time we have been able to include partial-wave decomposed chiral 4N interactions in many-body calculations. These novel capabilities have been used to investigate these interactions for varying parameters and different nuclei. Especially calculations of heavier nuclei require the inclusion of all relevant angular momentum channels, which have been constructed during the last year. Overall, we find a very weak effect of the chiral 4N interactions on the ground-state energy.

Results

Additionally, we have investigated a simple phenomenological 4N interaction using the established framework. While it is efficiently possible to include such an interaction in many-body calculations, the chosen interaction was too simple to improve upon the radii and ground-state energies using. However, the results prompt us to further investigate alternative choices for a phenomenological interaction. All investigations employing 4N interactions are discussed in detail in [4]. Furthermore, we studied the influence of various alternative generators for the SRG on the strength of induced many-body forces and convergence behavior due to model-space size in subsequent many-body calculations which lead to a bachelor thesis [5] and we will extend these topic in the next period. In addition development studies for a consistent inclusion of electromagnetic operators were studied in a master project [6].

Reference

[1] Binder, S.; Calci, A.; Epelbaum, E.; Furnstahl, R.J.; Golak, J.; Hebeler, K.; Kamada, H.; Krebs, H.; Langhammer, J.; Liebig, S.; Maris, P.; Meißner, U.G.; Minossi, D.; Potter, H.; Roth, R.; Skibiński, R.; Topolnicki, K.; Vary, J.P.; Witała, H.: "Few-nucleon systems with state-of-the-art chiral nucleon-nucleon forces", Phys. Rev. C 93, 044002 (2016) https://doi.org/10.1103/PhysRevC.98.014002

[2] Hebeler, K.; Hüther, T.; Roth, R.: Explorative calculations with SMS NN+3N interactions, Presentation at The 4th Meeting of the Low Energy Nuclear Physics International Collaboration, Ruhr-Universit¨at Bochum, February 19, (2018)

[3] Hüther, T.; Roth, R.: Light Nuclei with Recent Chiral EFT Interactions, Poster at Progress in Ab Initio Techniques in Nuclear Physics, TRIUMF, Vancouver, CA (Feb 27 - March 02 2018)

[4] Schulz, S.: Four-Nucleon Forces in Ab Initio Nuclear Structure. Dissertation, Physics Departement, The institute of nuclear physics, Technische Univesität Darmstadt (2018) http://tuprints.ulb.tu-darmstadt.de/id/eprint/7384

[5] Dupper, M.: "Similarity Renormalization Group Transformation chiraler Wechselwirkungen", Bachelor Thesis, Technische Universität Darmstadt, (2018)

[6] Mertes, L.: "Precision Calculation of Electromagnetic Observables for Light Nuclei", Master Thesis, Technische Universität Darmstadt, (2017)

Last Update: 2022-04-29 17:28