Phenomenological Four-Body Interactions in the NCSM

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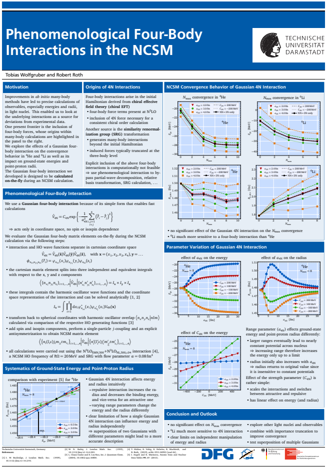

Motivation

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Why look at four-body interactions?

- chiral effective field theory (EFT) at N^3LO gives rise to 4N force terms
- similarity renormalization group (SRG) induces many-body forces

Why use a phenomenological 4N interaction?

- initial or induced 4N forces in general not computationally feasible in many-body calculations
- use phenomenological interaction to bypass expensive calculation steps

$\Rightarrow$ develop a phenomenological four-body interaction that can be computed on-the-fly during a NCSM calculation

Many-Body Toolchain with Phenomenological 4N Interaction

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Initial Hamiltonian	start with two- and three-body interaction derived from chiral EFT
↓ SRG evolution	calculate SRG evolution and truncate induced forces at the 3N level
↓ Add phenomenological 4N interaction	calculate phenomenological 4N matrix elements $$\left\langle \{n_i l_i m_i\}_{i=1,\dots,4} \middle| \hat{V}_{4\mathrm{N}} \middle| \{n_i{}' l_i{}' m_i{}'\}_{i=1,\dots,4} \right\rangle$$
↓ NCSM calculation	run many-body calculation in harmonic oscillator basis

Gaussian Four-Body Interaction

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Why use a Gaussian four-body interaction?

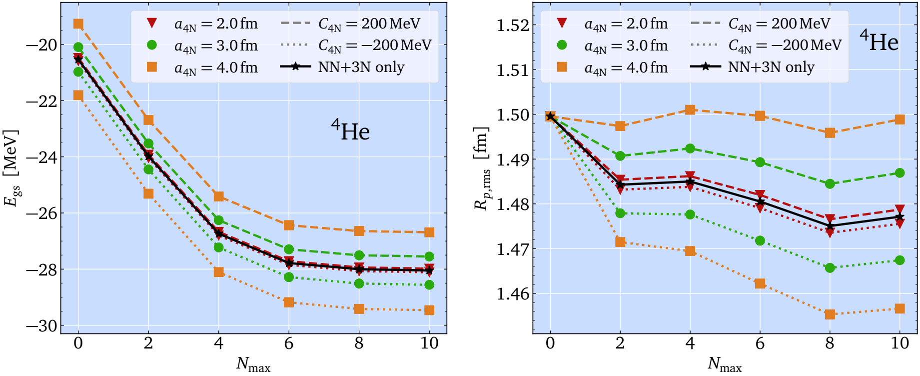
- more flexible than e.g. contact interaction
- comparatively intuitive to understand and simple to calculate
- completely different matrix element calculation without PWD, relative basis, ...

$$\hat{V}_{4\mathrm{N}} = C_{4\mathrm{N}} \exp\left\{ -\frac{1}{a_{4\mathrm{N}}^2} \sum_{\substack{i,j=1 \\ i<j}}^{4} \left(\hat{\vec{r}}_i - \hat{\vec{r}}_j \right)^2 \right\}$$

Interaction has two free parameters

- $C_{4\mathrm{N}}$: strength of the interaction, also determines if attractive/repulsive
- $a_{4\mathrm{N}}$: range of the interaction

N_{max} convergence behavior of Gaussian 4N Interaction



- $\hbar\Omega = 20$ MeV, $N^3LO_{EMN,500} + N^3LO_{NL,500,cD4}$ + Gaussian 4N
- no significant effect on N_{max} convergence
- attractive interaction increases energy and reduces radius, repulsive vice-versa

Outlook

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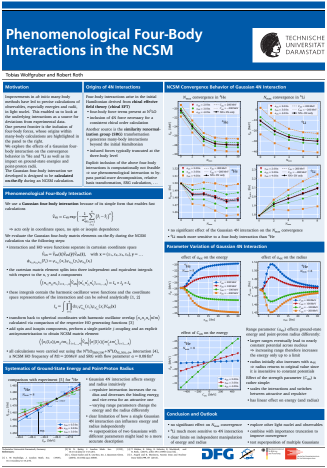
- explore other light nuclei
- combine with importance truncation to improve convergence
- calculate other observables besides ground-state energies and radii
- implement ability to use superposition of two Gaussians
- mittigate SRG induced effects and correct energy/radius



Thank you for your attention!

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computing time:

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