Merging IM-SRG and NCSM

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SFB 1245

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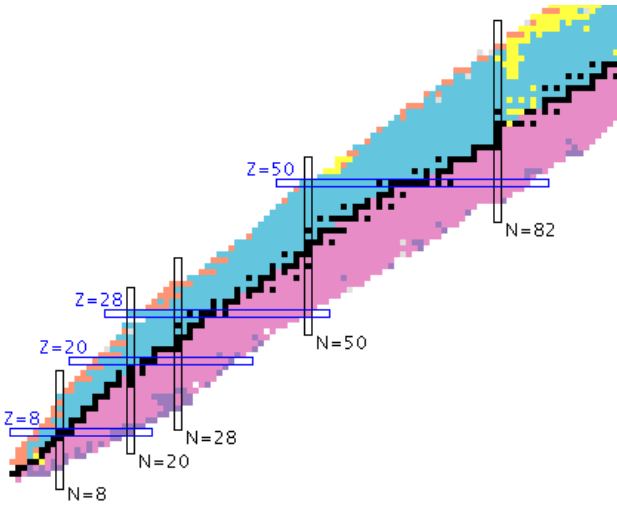
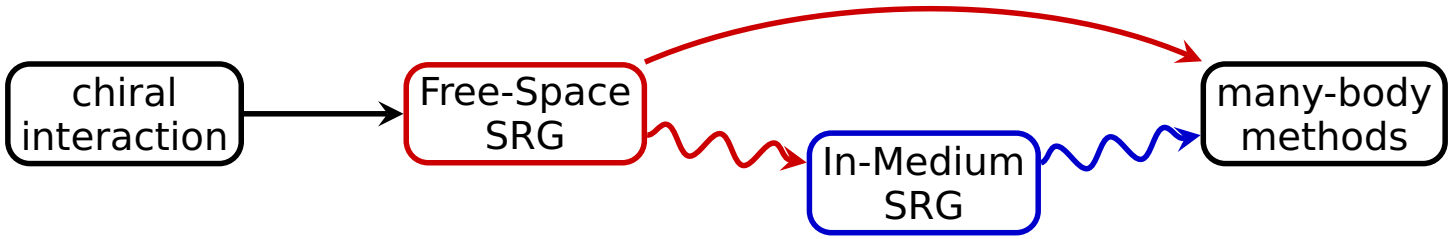
Motivation

- ab initio many-body methods for the description of ground and excited states in open-shell nuclei
- traditionally: shell-model-like approaches
  ⇝ limited by basis dimension, scaling with particle number
- medium-mass methods:
  In-Medium SRG, Coupled Cluster
  ⇝ basic formulations limited to ground states
- idea: use the IM-SRG as an "intermediate" tool for prediagonalization





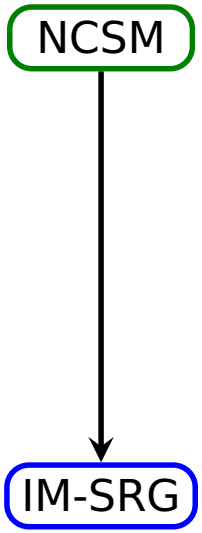
In-Medium No-Core Shell Model

- NCSM calculation in small model space defines reference state

NCSM

$$|\Psi\rangle = \sum_i c_i |\Phi_i\rangle$$

In-Medium No-Core Shell Model



- NCSM calculation in small model space defines reference state

$$|\Psi\rangle = \sum_i c_i |\Phi_i\rangle$$

- perform **multi-reference** IM-SRG aiming at decoupling reference state from generalized ph-excitations $\tilde{a}^{p_1}_{q_1} |\Psi\rangle$, $\tilde{a}^{p_1 p_2}_{q_1 q_2} |\Psi\rangle$, ...

$$\hat{H}(\infty) \; |\Psi\rangle = E(\infty) \; |\Psi\rangle$$

- use normal-ordered operators truncated at normal-ordered two-body level throughout the evolution

$$\hat{H}(s) \equiv E(s) + \sum_{pq} f^p_q(s) \; \{\hat{p}^\dagger \hat{q}\}_{|\Psi\rangle} + \frac{1}{4} \sum_{pqrs} \Gamma^{pq}_{rs}(s) \{\hat{p}^\dagger \hat{q}^\dagger \hat{s} \hat{r}\}_{|\Psi\rangle}$$

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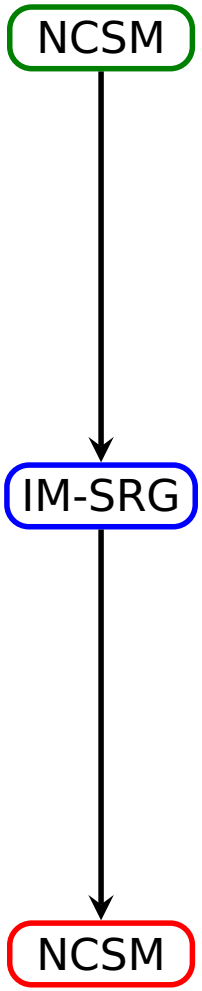

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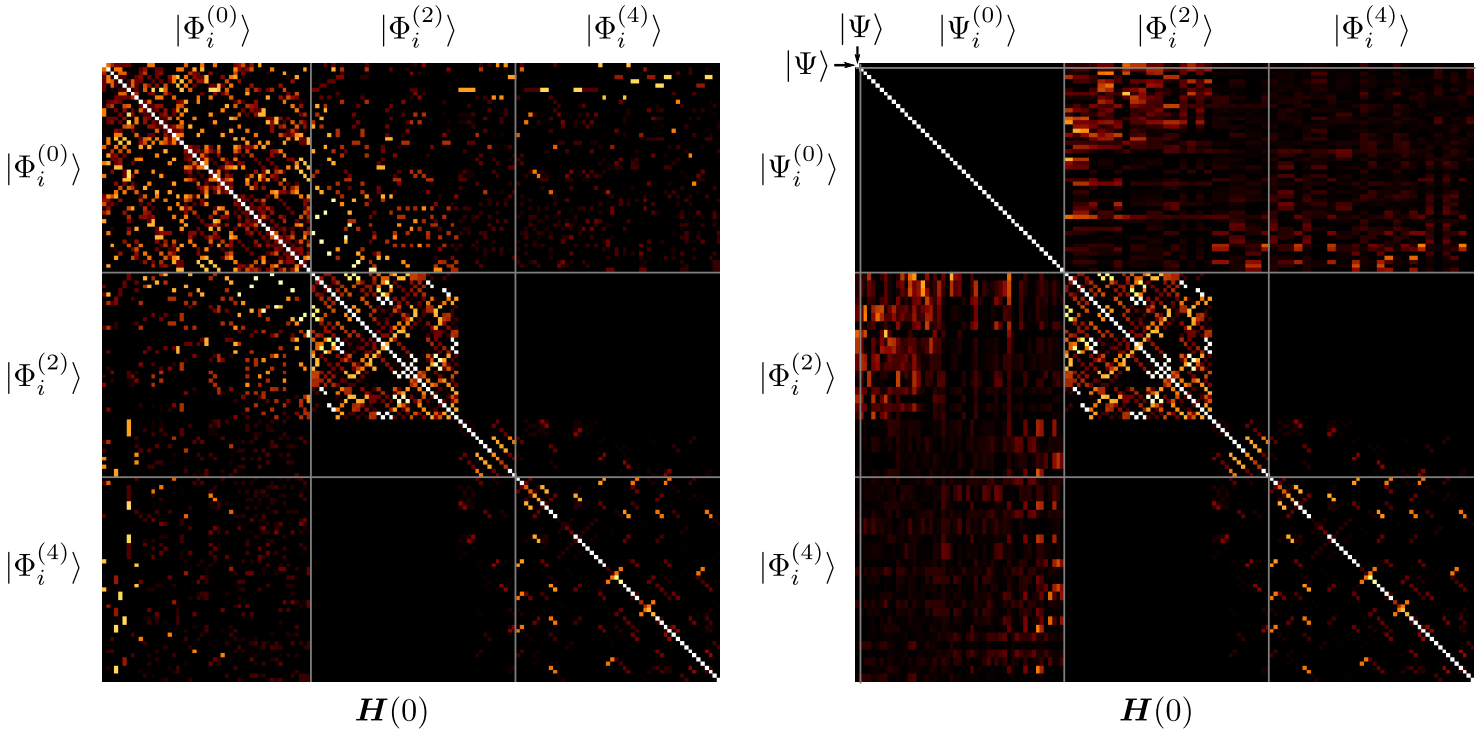
- use IM-SRG-evolved Hamiltonian $\hat{H}(s)$ as input for subsequent NCSM calculation

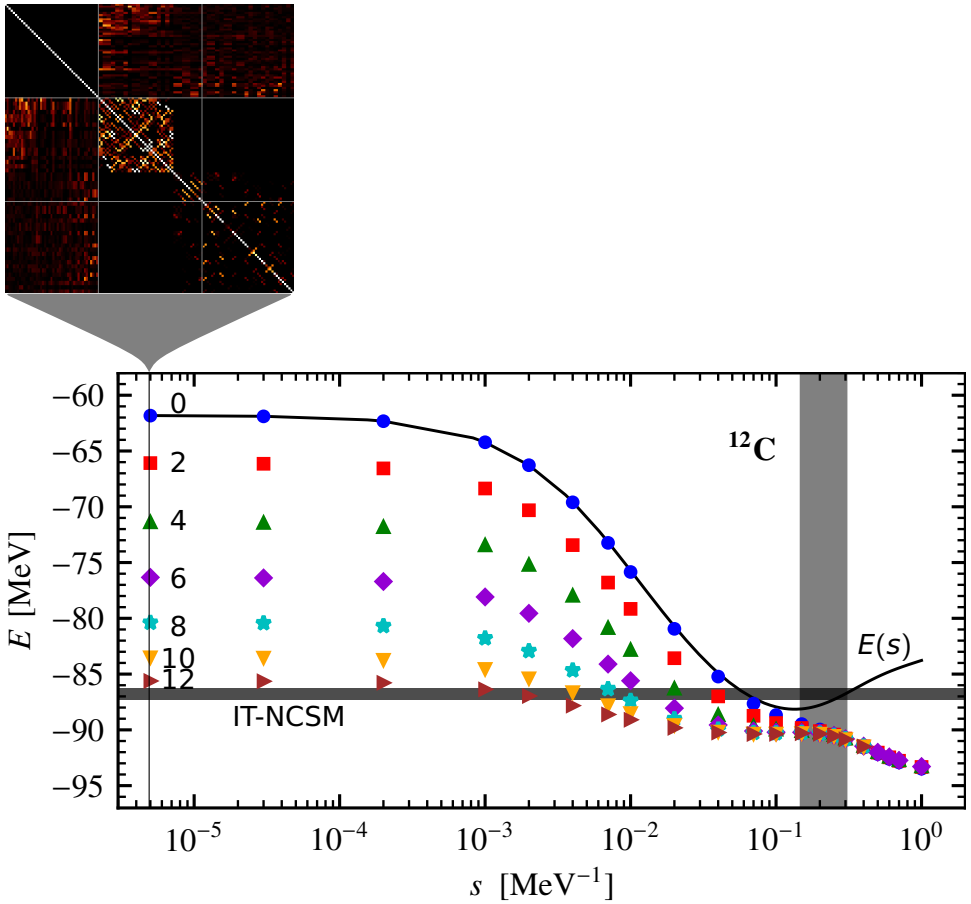
- convergence of NCSM calculation massively improved w.r.t. $N_{\max}$

IM-NCSM: Hamiltonian Representations



- representations of the initial Hamiltonian $\hat{H}(0)$
- $|\Phi_i^{(0,2,4)}\rangle$: Slater determinants from the $N = 0, 2, 4$ space
- $|\Psi_i^{(0)}\rangle$: eigenstates of $\hat{H}(0)$ in the $N = 0$ space with $|\Psi\rangle \equiv |\Psi_0^{(0)}\rangle$

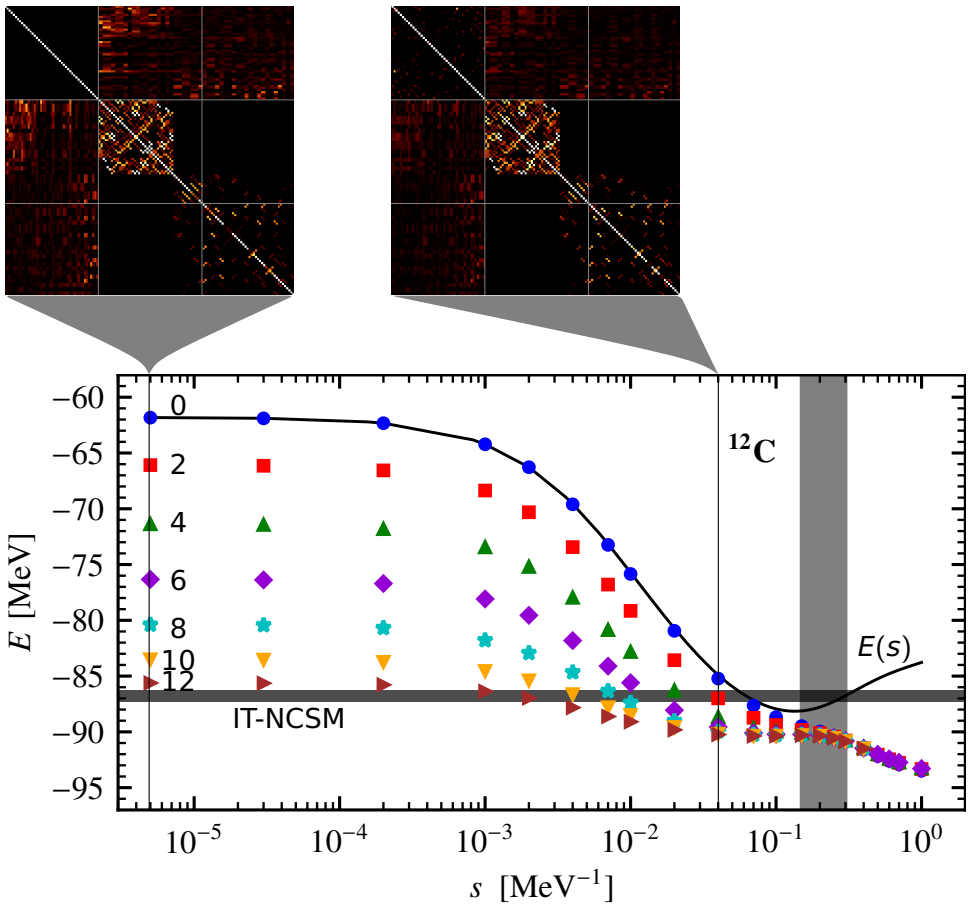
IM-NCSM: Ground State Evolution



$s = 0.00\ \mathrm{MeV}^{-1}$

- $N_{\max} = 0$ space diagonal
- eigenvalue = $E(s)$
- strong couplings of $|\Psi\rangle$ to basis states at higher N
- high $N_{\max}$ necessary for converged results

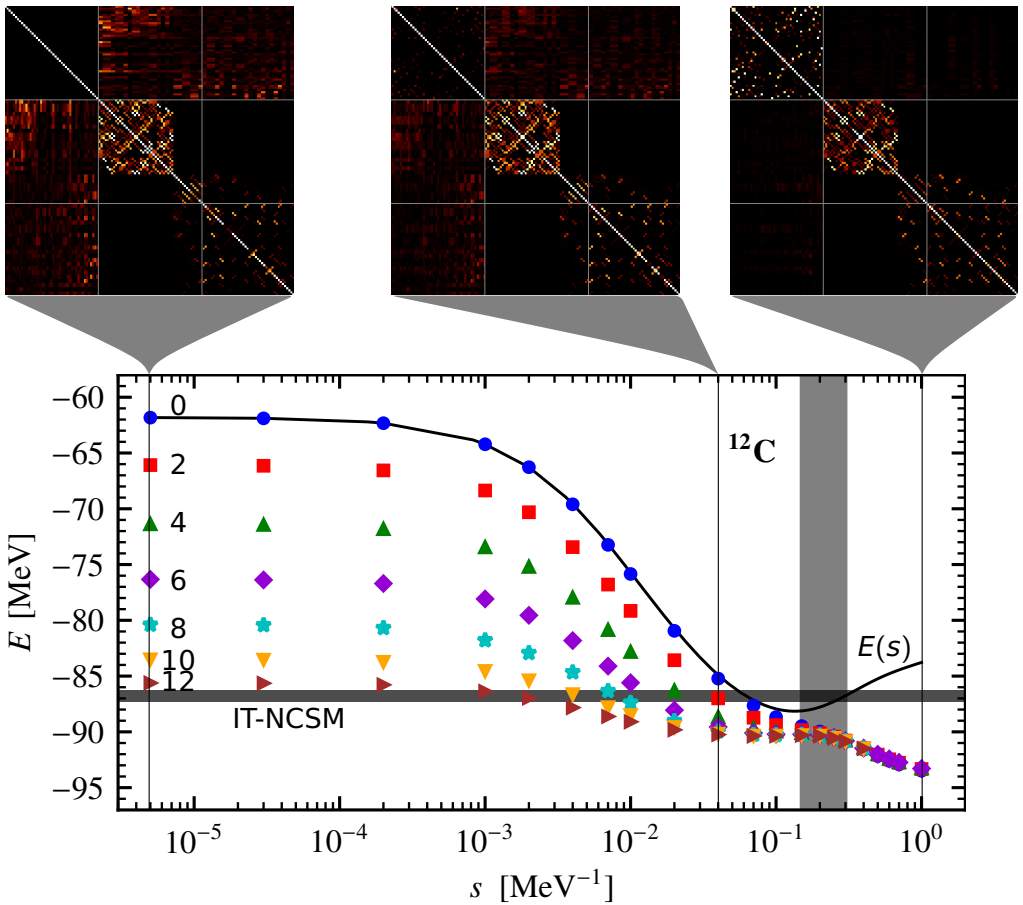
IM-NCSM: Ground State Evolution



$s = 0.07\ \mathrm{MeV}^{-1}$

- matrix elements coupling $N = 0$ and higher N basis states are being suppressed
- NCSM convergence w.r.t. $N_{\max}$ accelerates with increasing IM-SRG flow parameter s

IM-NCSM: Ground State Evolution



$s = 1.00\ \text{MeV}^{-1}$

- $N_{\max} = 0$ space decoupled from all basis states at higher N
- practically converged results at $N_{\max} = 0$.

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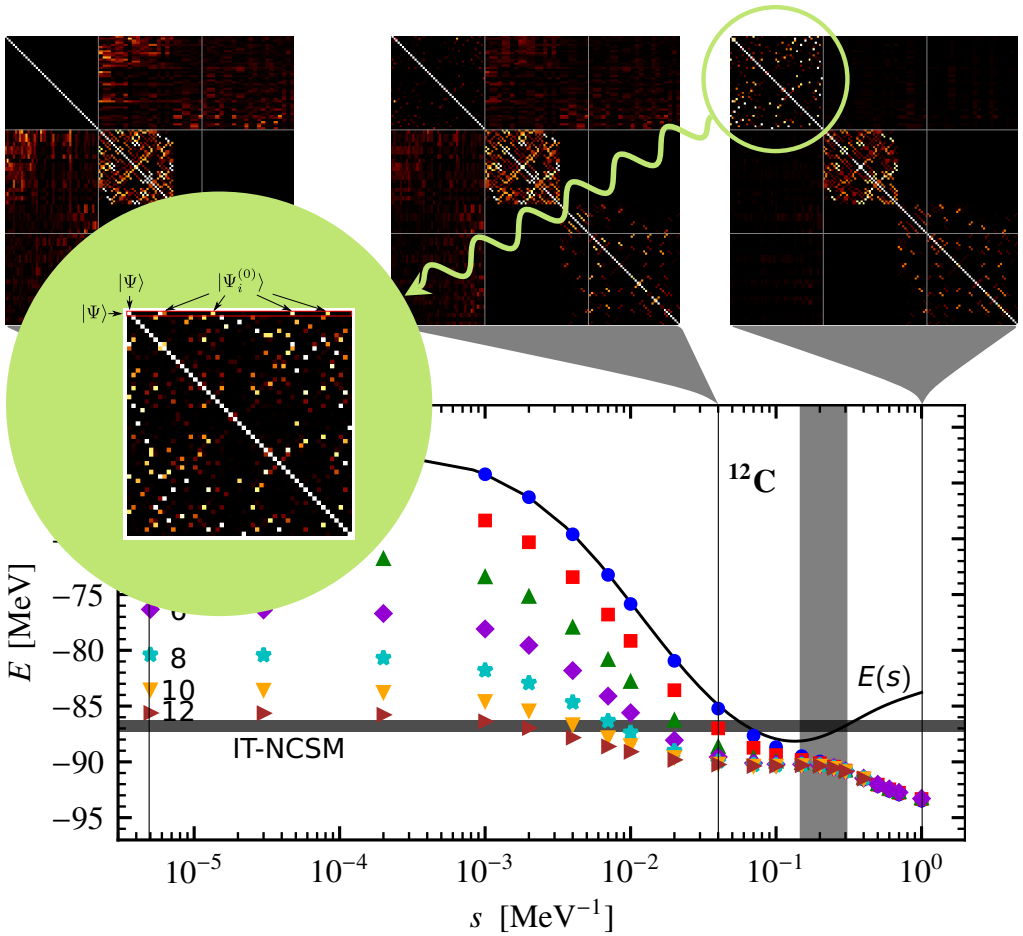

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- practically converged results at $N_{\max} = 0$.
- couplings of $|\Psi\rangle$ to other basis states $|\Psi_i^{(0)}\rangle$ emerge
- reference state $|\Psi\rangle$ not $N_{\max} = 0$ eigenstate anymore
- eigenvalue $\neq E(s)$
- explicit diagonalization necessary

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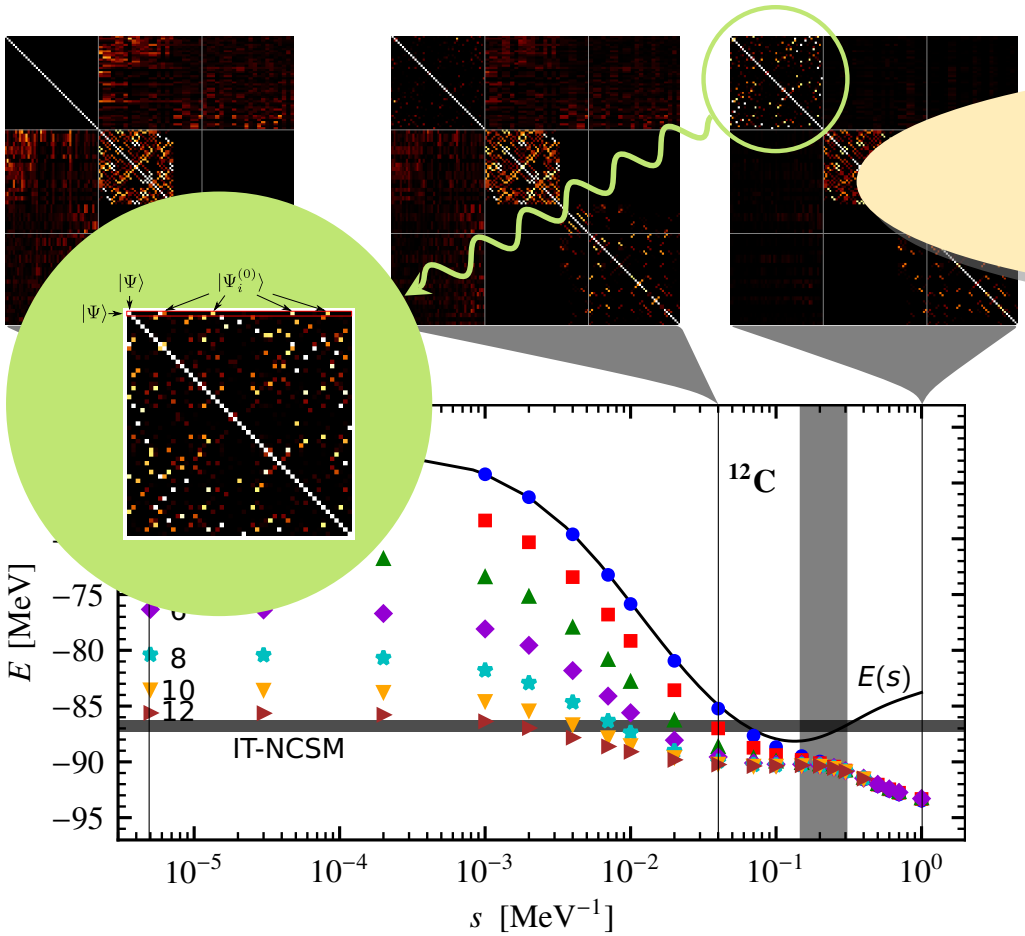

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note effects of neglected many-body contributions beyond normal-ordered two-body level

- from all basis states at higher N
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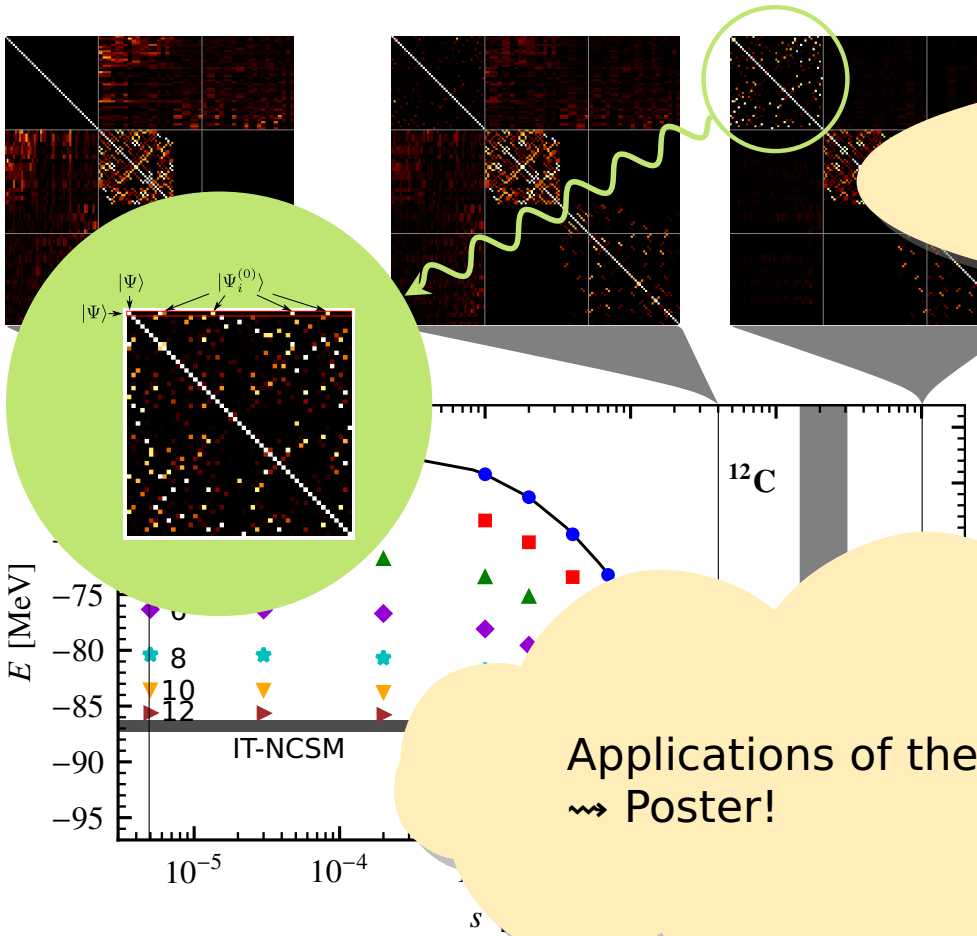

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Applications of the IM-NCSM?
⇝ Poster!

Epilogue

- **Thanks to my group**
  - S. Alexa, **E. Gebrerufael**, T. Hüther, L. Kreher, L. Mertes, R. Roth, S. Schulz, H. Spielvogel, C. Stumpf, A. Tichai, R. Trippel, R. Wirth, T. Dörnfeld

    Institut für Kernphysik, TU Darmstadt

- **Thank you for your attention!**

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