

Consistent SRG Transformed Chiral Two- plus Three-Body Interactions

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Chiral Effective Field Theory

- based on the fundamental **symmetries of QCD**
- provides NN + 3N interactions **consistently**

best available interaction from χ EFT

- NN at N³LO (Entem & Machleidt, 500 MeV)
- 3N at N²LO (low energy constants c_D & c_E from triton fit)

- initial chiral Hamiltonian causes strong **correlations**
- **slow convergence** in many-body calculations w.r.t. model space
- apply **unitary transformation**

Similarity Renormalization Group (SRG)

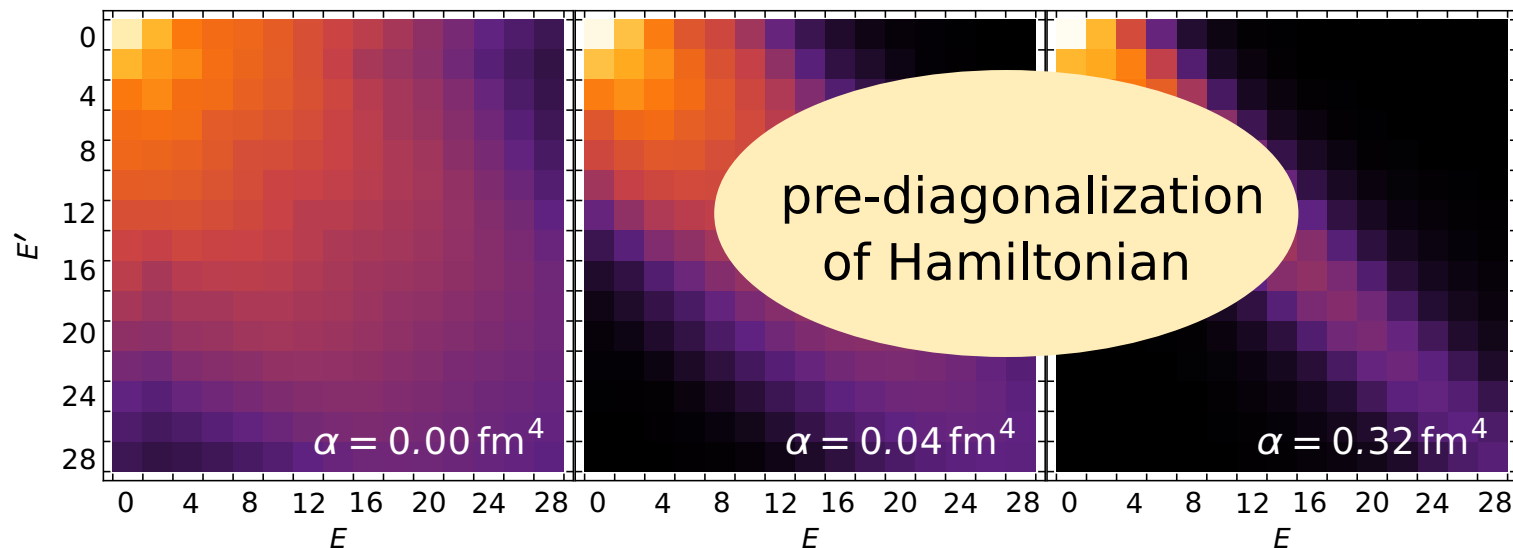
accelerate convergence by **pre-diagonalizing** the Hamiltonian with respect to the many-body basis

- **unitary transformation** leads to **evolution equation**

$$\frac{d}{d\alpha} \tilde{H}_\alpha = [\eta_\alpha, \tilde{H}_\alpha] \quad \text{with} \quad \eta_\alpha = (2\mu)^2 [T_{\text{int}}, \tilde{H}_\alpha] = -\eta_\alpha^\dagger$$

advantages of SRG: **flexibility** and **simplicity**

3B-Jacobi HO matrix elements



$$\langle E' i' J T | \tilde{H}_\alpha - T_{\text{int}} | E i j T \rangle$$

E-Block averages
 $J^\pi = \frac{1}{2}^+, T = \frac{1}{2}$
 $\hbar\Omega = 20 \text{ MeV}$

SRG Evolution in A -Body Space

- SRG induces **irreducible** many-body **contributions**

$$U_{\alpha}^{\dagger} H U_{\alpha} = \tilde{H}_{\alpha}^{[2]} + \tilde{H}_{\alpha}^{[3]} + \dots + \tilde{H}_{\alpha}^{[A]}$$

- restricted to a SRG evolution in 2B or 3B space
- formal **violation of unitarity**

HK 10.2
S. Binder

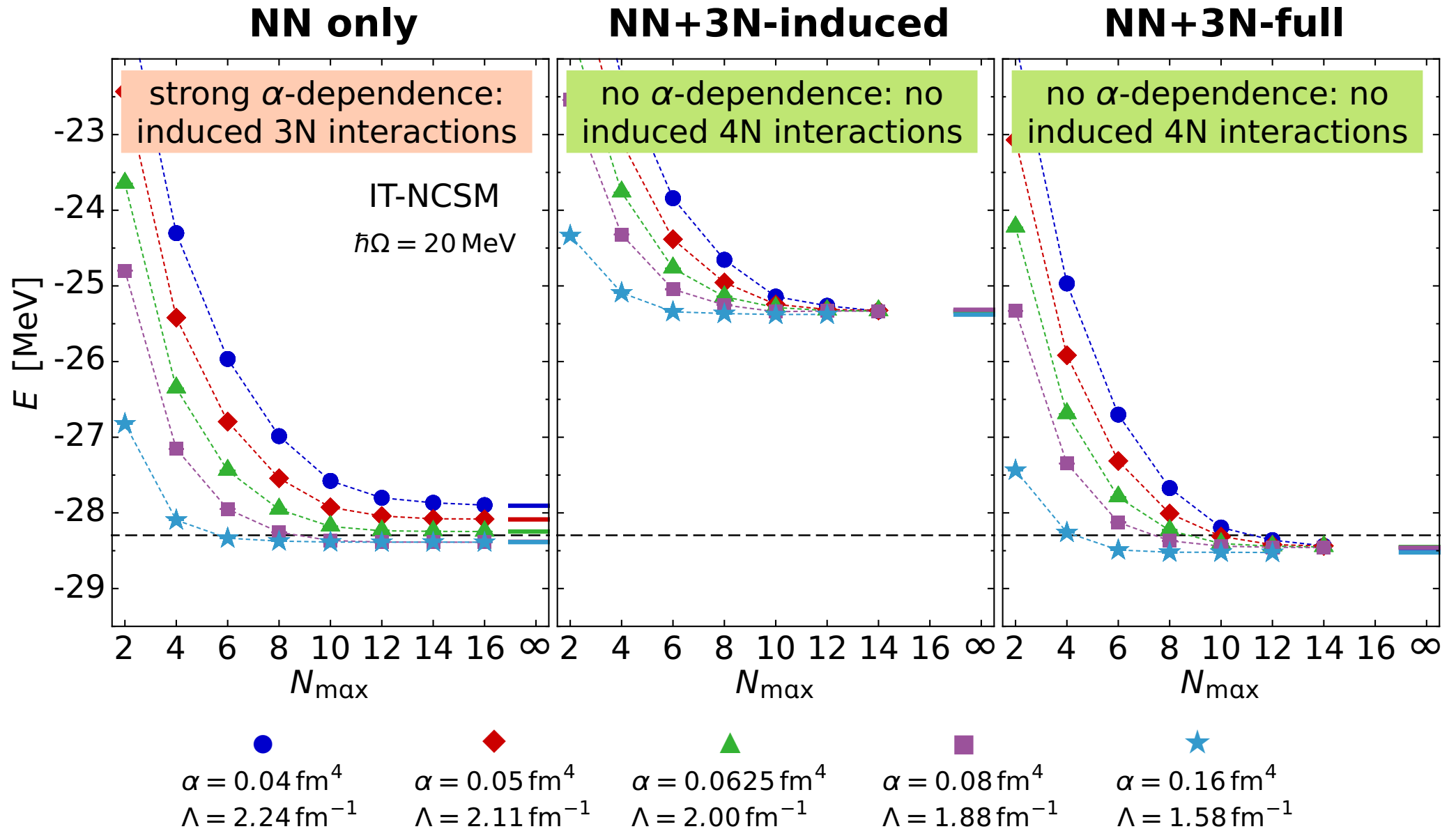
SRG-evolved Hamiltonians

- **NN only**: start with NN initial Hamiltonian and keep two-body terms only
- **NN+3N-induced**: start with NN initial Hamiltonian and keep two- and three-body terms
- **NN+3N-full**: start with NN+3N initial Hamiltonian and keep all two- and three-body terms

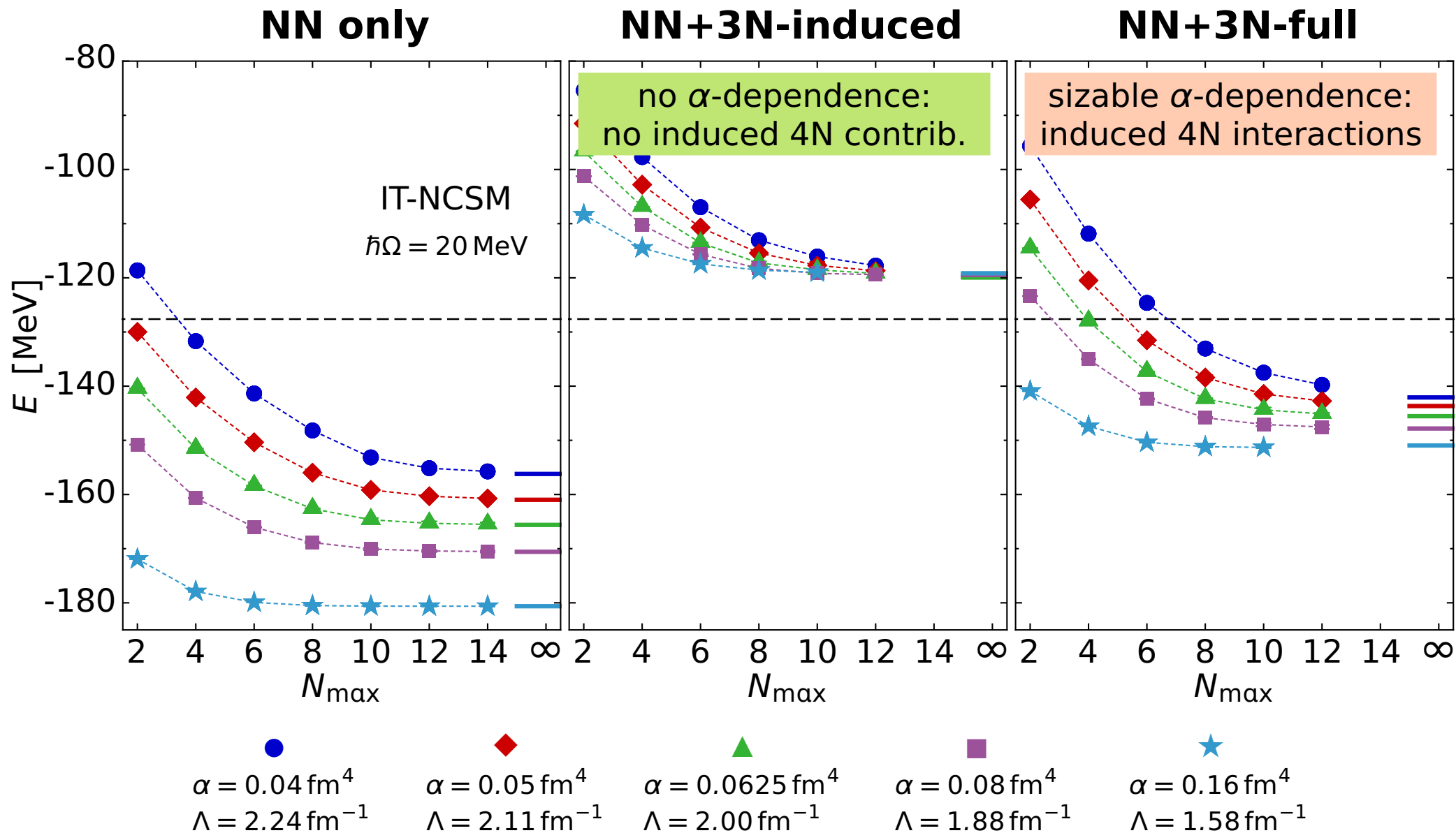
HK 36.5
J. Langhammer

α -variation provides a **diagnostic tool** to assess the contributions of omitted many-body interactions

^4He : Ground-State Energies

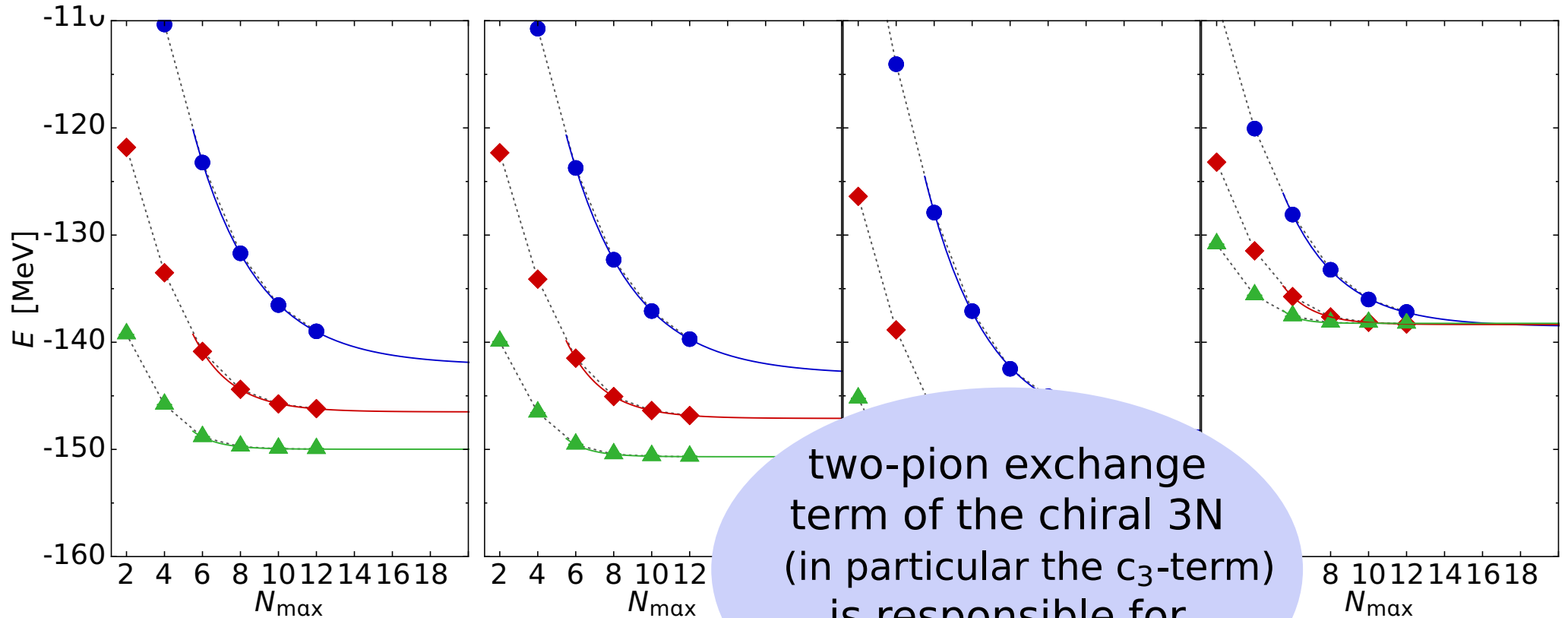
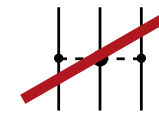
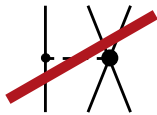
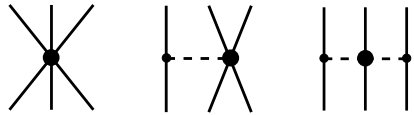


^{16}O : Ground-State Energies



^{16}O : Origin of Induced 4N

switch off individual contributions of the 3N interaction



two-pion exchange term of the chiral 3N (in particular the c_3 -term) is responsible for induced 4N

NN+3N-full
 $\hbar\Omega = 20 \text{ MeV}$

$\alpha = 0.04 \text{ fm}^4$
 $\Lambda = 2.24 \text{ fm}^{-1}$

$\alpha = 0.06 \text{ fm}^4$
 $\Lambda = 1.88 \text{ fm}^{-1}$

$\alpha = 0.08 \text{ fm}^4$
 $\Lambda = 1.58 \text{ fm}^{-1}$

Conclusions

- **consistent SRG** evolution in 3B space
 - indispensable for converged IT-NCSM calculations
 - initial NN interaction under control
- **two-pion** exchange term of 3N **induces 4N** contributions
 - lowering the cutoff reduces induced contributions

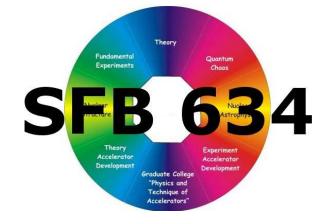
Outlook: Alternative Generators

- ① **exclude initial 3N**: include only NN+3N-induced in generator
 - ② **restrict range**: introduce explicit range in generator definition
- search **trade-off** between induced 4N & convergence acceleration

Epilogue

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