

# Chiral Two- plus Three-Body Interactions in the Importance Truncated NCSM

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# Similarity Transformed Interaction

## Interaction from $\chi$ EFT

- interaction based on the fundamental **symmetries of QCD**
- provides NN + 3N interaction **consistently**
  - NN at N<sup>3</sup>LO (Entem & Machleidt)
  - 3N at N<sup>2</sup>LO (low energy constants  $c_D$  &  $c_E$  from triton fit)

## Similarity Renormalization Group (SRG)

- **unitary** transformation leading to the **evolution equation**

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

- **dynamic generator  $\eta_\alpha$**  accelerates convergence

HK 41.5  
J. Langhammer

# Consideration of Induced Contributions

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

- **NN only**: start with NN-only initial Hamiltonian and evolve in two-body space

- **NN+3N-induced**: start with NN-only initial Hamiltonian and evolve in three-body space

- **NN+3N-full**: start with NN+3N initial Hamiltonian and evolve in three-body space

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

# From Jacobi to $\mathcal{JT}$ -coupled Scheme

## effective interaction in 3B-Jacobi basis

### 1. problem

many-body calculations ( $A > 6$ ) in Jacobi coordinates not feasible  
→ advantageous to use ***m*-scheme**

### 2. problem

*m*-scheme matrix elements become intractable for  $N_{max} > 8$  (p-shell)

**transformation from Jacobi into  
 $\mathcal{JT}$ -coupled scheme**

**key for efficient application  
up to  $N_{max} = 14$  for p-shell nuclei**

**Ab initio many-body calculation**

# (Importance Truncated) NCSM

- **solving the eigenvalue problem:**  $\mathbf{H}|\Psi_n\rangle = E_n|\Psi_n\rangle$
- **model space:** spanned by  $m$ -scheme states  $|\Phi_\nu\rangle$  with unperturbed excitation energy of up to  $N_{max}\hbar\Omega$

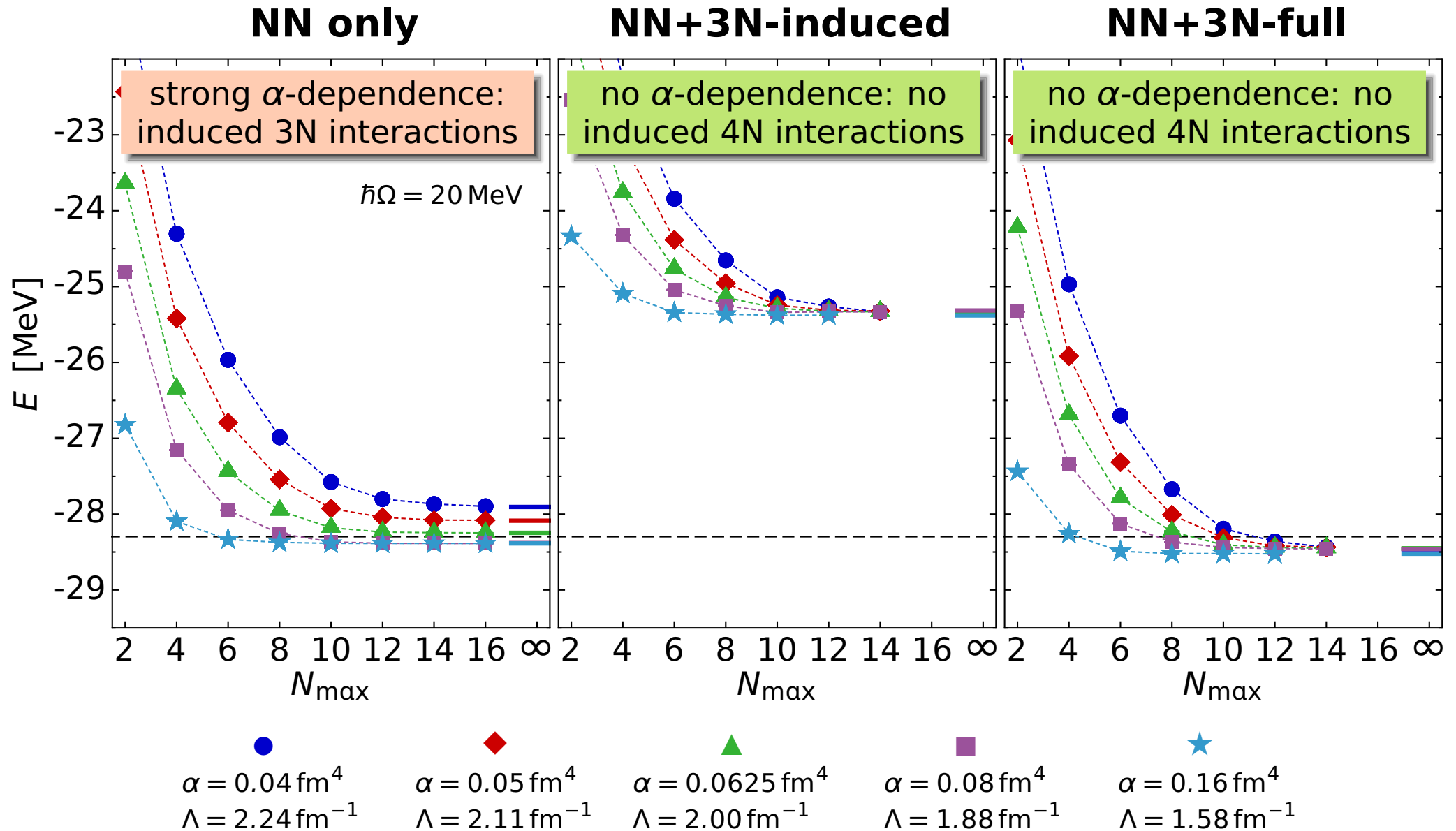
## problem of NCSM

enormous increase of model space with particle number  $A$

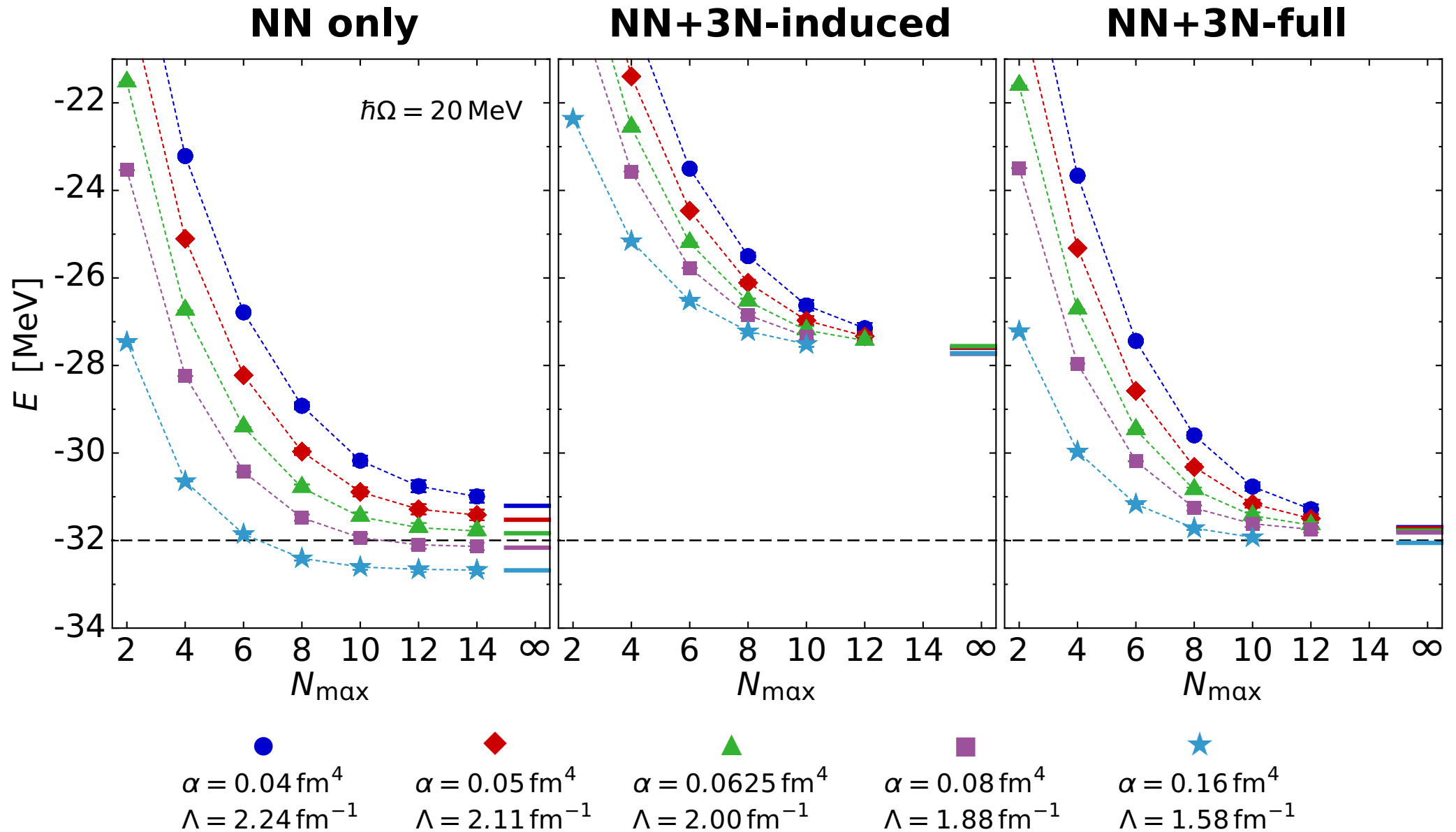
## Importance Truncated NCSM

- a priori determination of  $K_{min}$  by first-order perturbation theory
  - IT-NCSM provides **same results** as the full NCSM keeping all its advantages
  - expands **application range** to higher  $A$
- **importance truncation** with  $|K_\nu| \geq K_{min}$

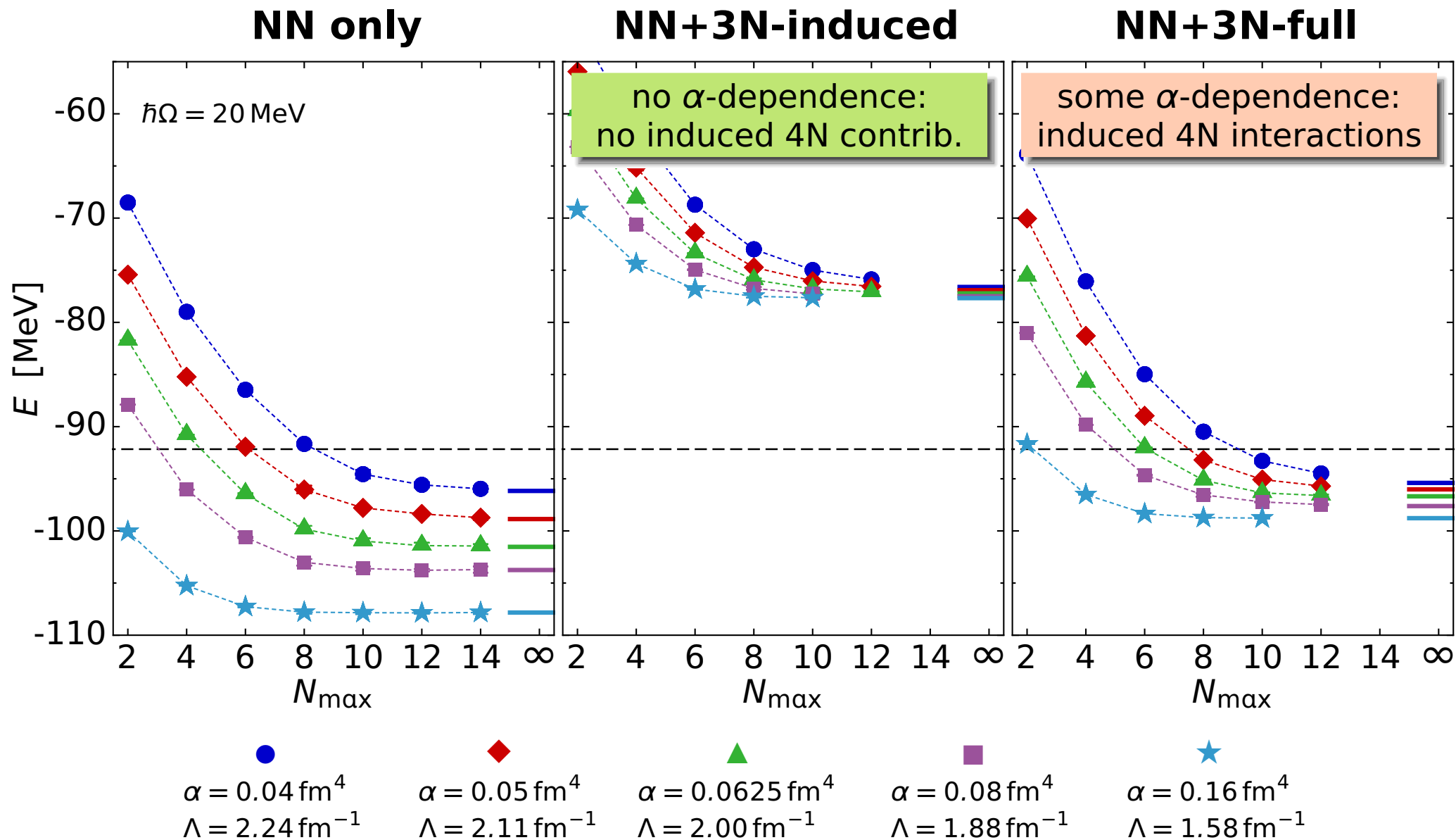
# ${}^4\text{He}$ : Ground-State Energies



# ${}^6\text{Li}$ : Ground-State Energies

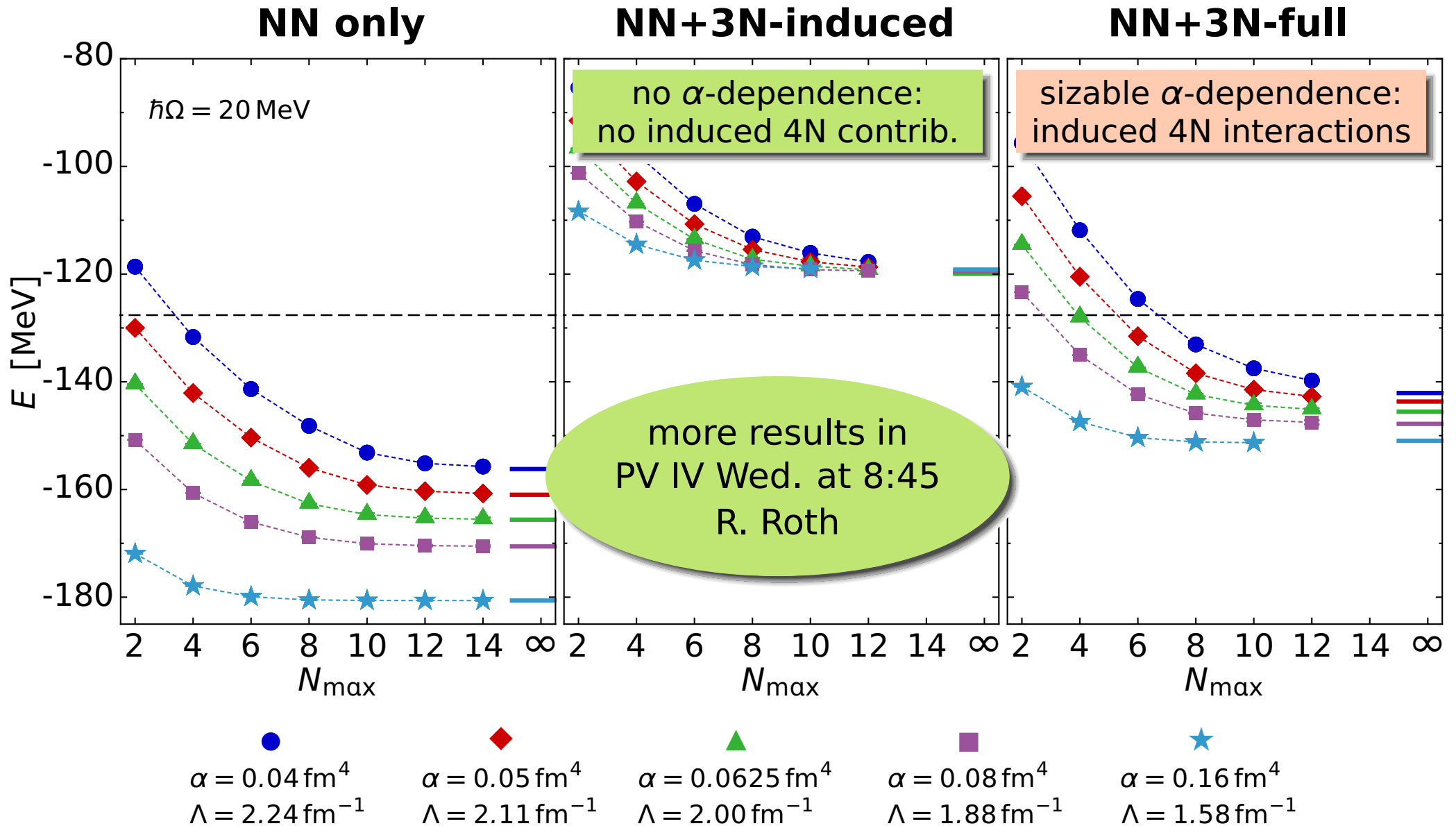


# $^{12}\text{C}$ : Ground-State Energies





# $^{16}\text{O}$ : Ground-State Energies



# Conclusions

## Benchmark of chiral NN+3N interactions

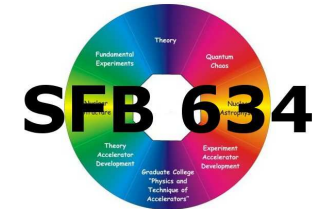
- consistent SRG evolution in 3B space
- efficient transformation of Jacobi matrix elements to  $\mathcal{JT}$ -coupled scheme
  - key for application to  **$N_{max} > 8$  calculations** (p-shell)
- IT-NCSM with full chiral 3N interactions up to  $N_{max} = 12$  (14) for all p-shell (and lower sd-shell) nuclei
- **induced 4N contributions** from initial 3N interaction become significant beyond mid-p-shell
  - ⇒ modify SRG generator to prevent induced 4N contributions from the beginning
- many other applications (Hartree Fock, RPA, ...)

# Epilogue

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# Thank you for your attention!



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