Recent Improvement in the in-medium similarity renormalization group

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Acknowledgements

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TRIUMF

NUCLEI
Nuclear Computational Low-Energy Initiative

ICER

Overview

- **In-Medium Similarity Renormalization Group(IM-SRG)**
- **Reformulating the IM-SRG**
- **Improving IM-SRG approximations**

IM-SRG Summary

- Powerful, Flexible Framework
  - Closed/Open Shell Ground States
  - Valence Space/EOM Excited States
  - Affordable N^6 scaling for IM-SRG(2) truncation

- A few difficulties to overcome
  - Consistent (expensive) evolution of observables
  - Stiff ODE's need high order solver (big memory)
  - Next level of approximation, IM-SRG(3) is prohibitively costly at N^9

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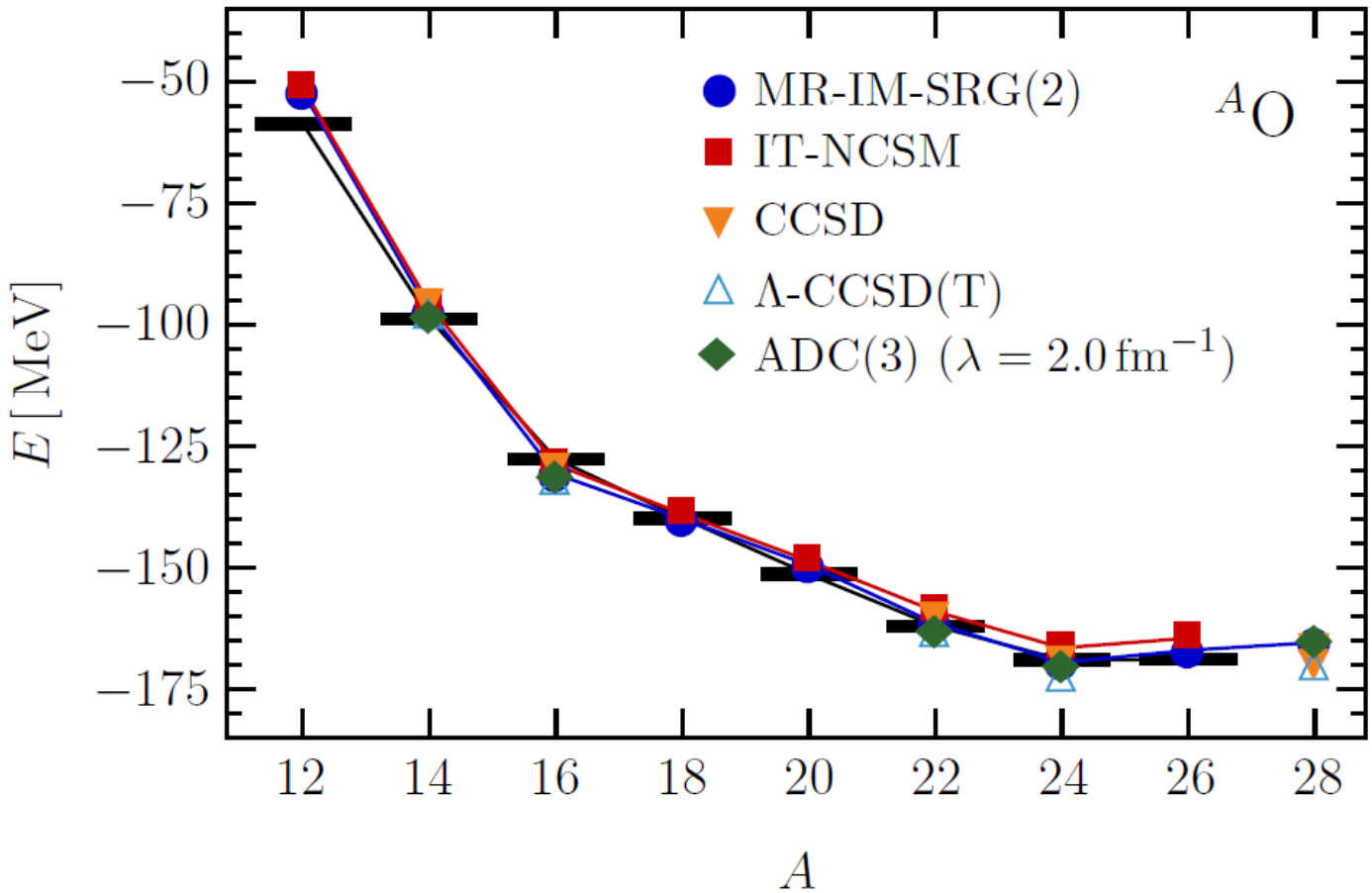
Closed/Open Shell Ground States



Phys. Rev. Lett. **111**, 062501 (2013).

Phys. Rev. Lett. **110**, 242501 (2013).

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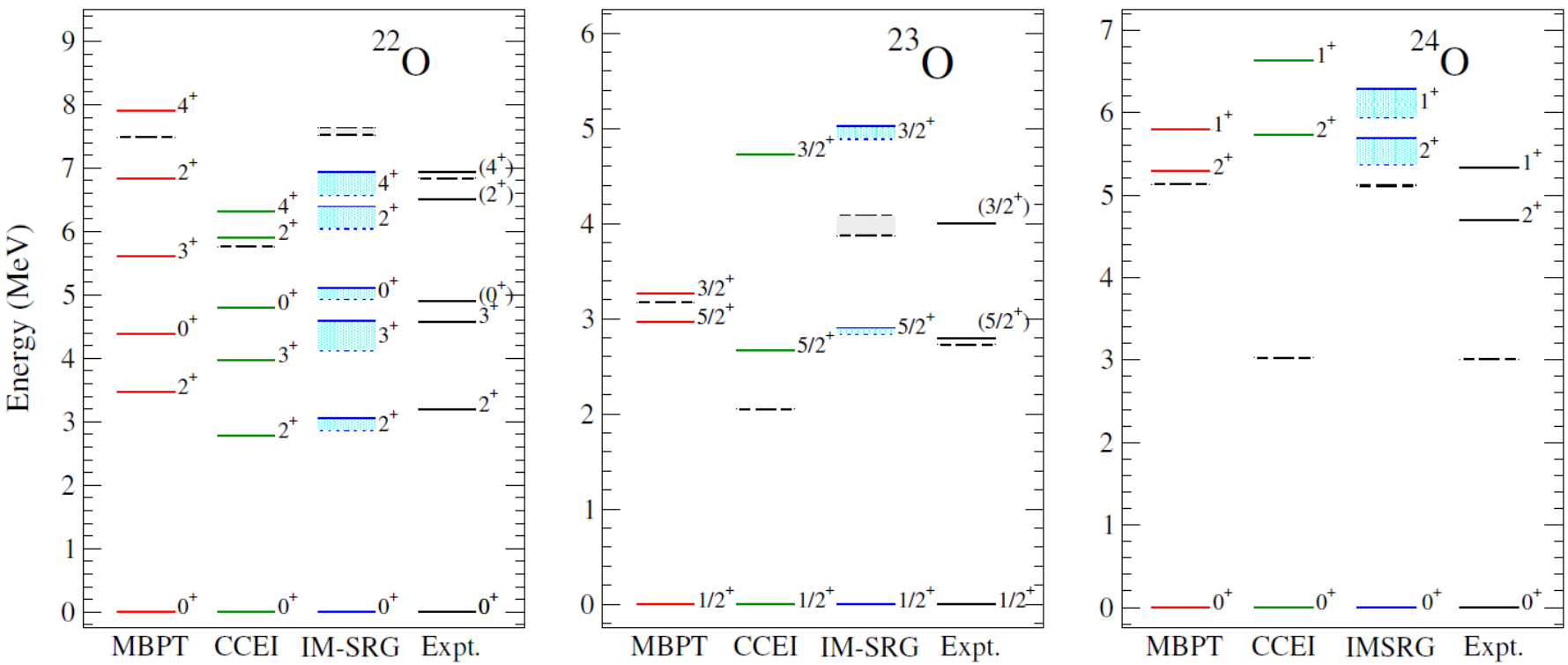
Valence Space/EOM Excited States



Entem Machleidt N3LO (400) $\lambda = 2.00\ fm^{-1}$

Phys. Rev. Lett. **113**, 142501 (2014).

Eur. Phys. J. A **49**, 1 (2013).

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Magnus expansion within the IM-SRG

T.D.Morris, N. Parzuchowski, S.K. Bogner. Phys. Rev. C **92**, 034331 (2015)
W. Magnus. Comm. Pure and Appl. Math. **VII**:649–673, (1954).

Magnus IM-SRG

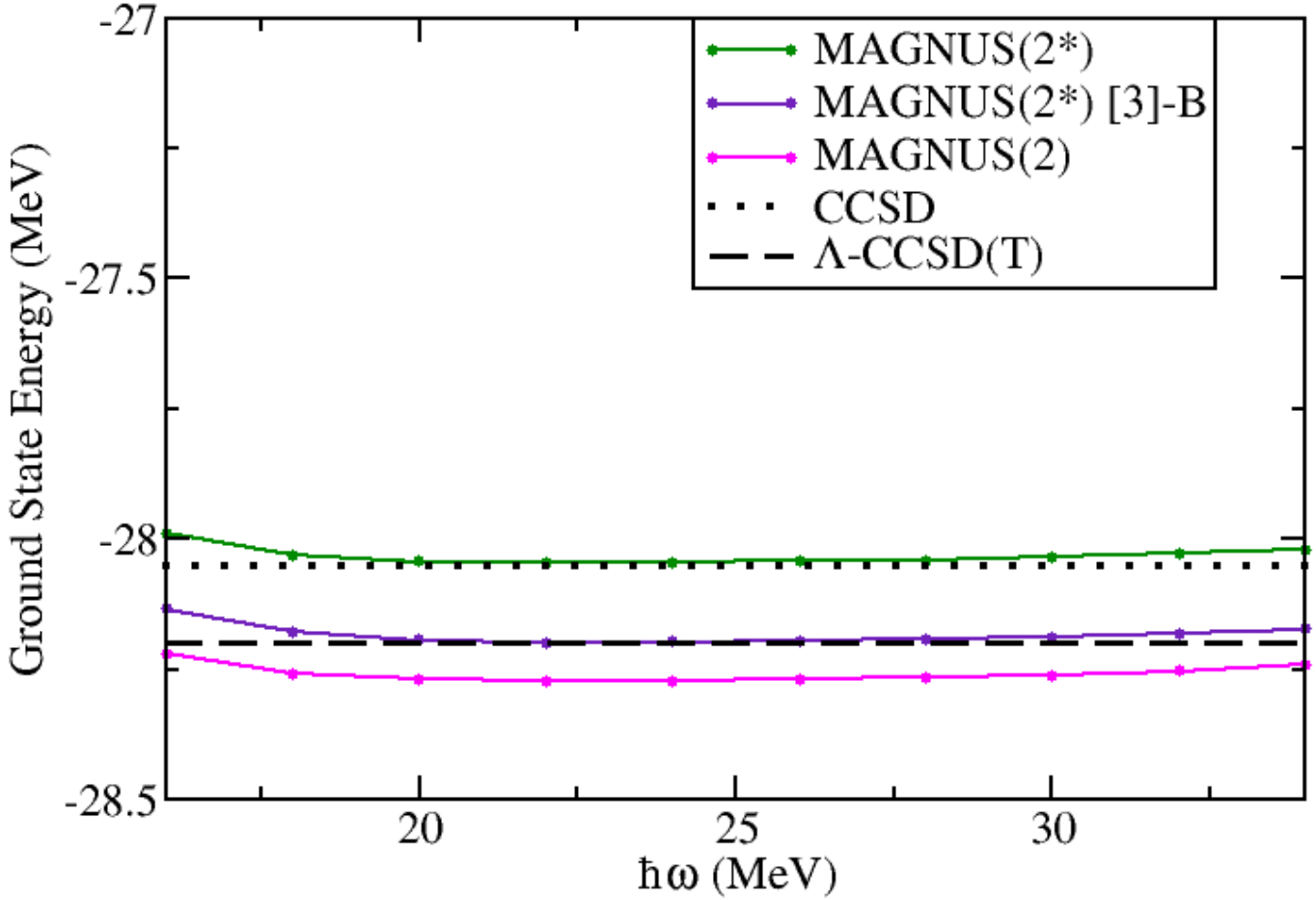
- $\frac{dH_s}{ds} = [\eta, H_s]$ $\longrightarrow$ $U_s = exp(\Omega_s)$

  $H_s = \exp(\Omega_s) H \exp(-\Omega_s)$

- Powerful, Flexible Framework
  - Closed/Open Shell Ground States
  - Valence Space/EOM Excited States
  - Affordable N^6 scaling for IM-SRG(2) truncation

- A few difficulties to overcome
  - Consistent (inexpensive) evolution of observables
  - Solve with very low order solver (1-2 copies)
  - Can approximate IM-SRG(3) at N^7

Nuclear Results in ^{4}He



Entem and Machleidt N3LO (500) NN $\lambda = 2.0\ fm^{-1}$

Summary

- IM-SRG(2) applicability ever increasing
  - Closed Shell/Open Shell ground states
  - Valence Space/EOM excited states
- IM-SRG(2) augmented by Magnus formalism
  - Easier to solve
  - Observables at will (Big win for Valence Space)
- Approximations to IM-SRG(3) available for first time
  - Great results from closed shell G.S.
  - Paves way for MR-IMSRG formalism, Valence Space, EOM