

# Perspectives on SFB Few- and Many-Body Theory

Robert Roth

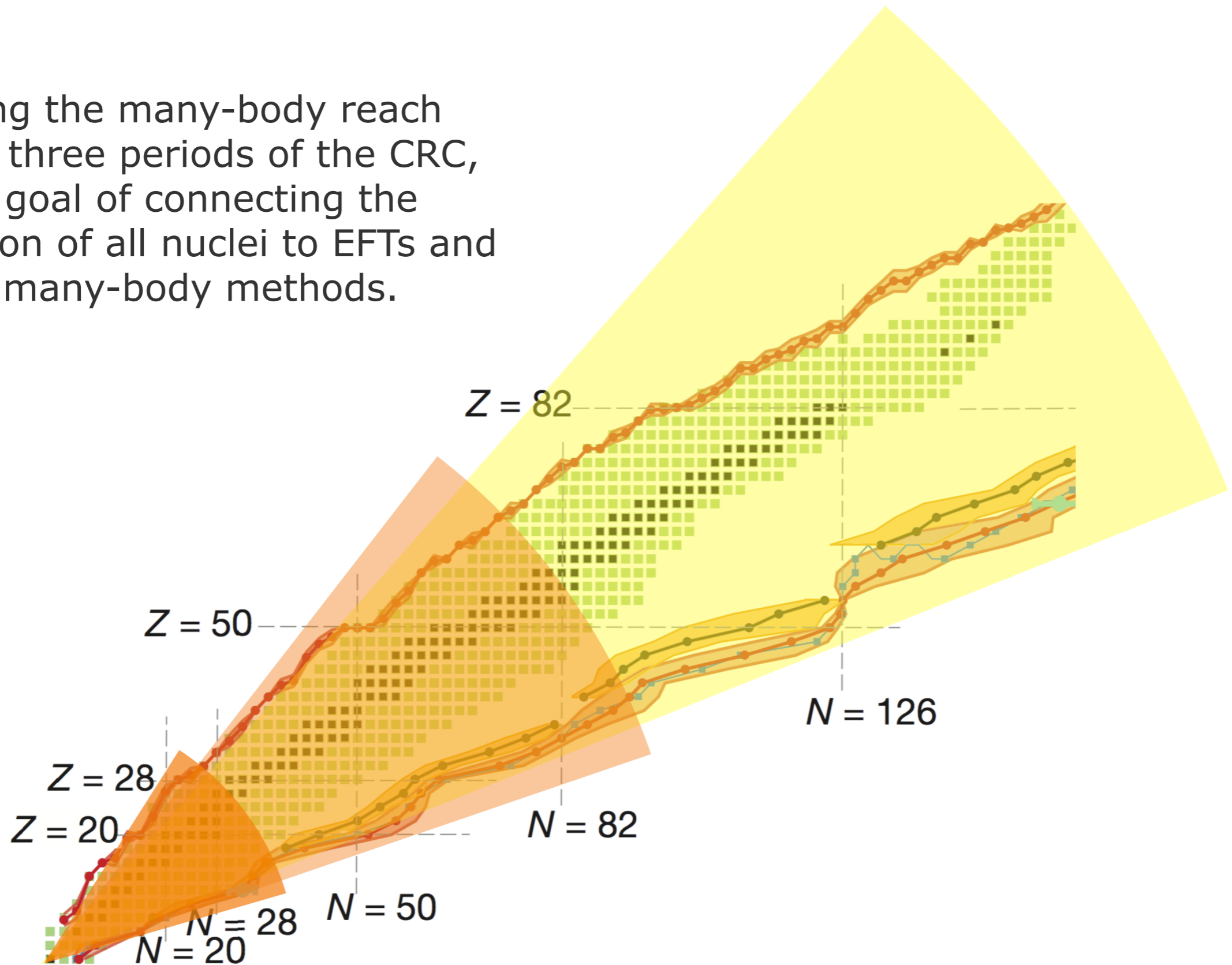


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# Big Picture

Advancing the many-body reach over the three periods of the CRC, with the goal of connecting the description of all nuclei to EFTs and ab initio many-body methods.



# Ab Initio Nuclear Structure

**Nuclear Structure &  
Continuum Observables**

**Many-Body Solution**  
NCSM, VSSM, IM-SRG

**Pre-Processing**  
Similarity Renorm. Group

**Chiral EFT**  
Interactions & Operators

**Low-Energy QCD**

- systematic and improvable input for all ab initio calculations
- only “selected” chiral interactions used in nuclear structure so far
- next-generation chiral EFT interactions give opportunity to quantify uncertainties
- consistent electroweak operators from chiral EFT

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**Low-Energy QCD**

- drastically improves convergence of many-body calculation
- induces many-body interactions that can be sizeable
- challenge: include or suppress induced many-body contributions

# Ab Initio Nuclear Structure

## Nuclear Structure & Continuum Observables

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Interactions & Operators

**Low-Energy QCD**

- different many-body methods for different mass regions and different observables
- frontiers: precision, continuum & open-shell medium-mass nuclei

# Research Program

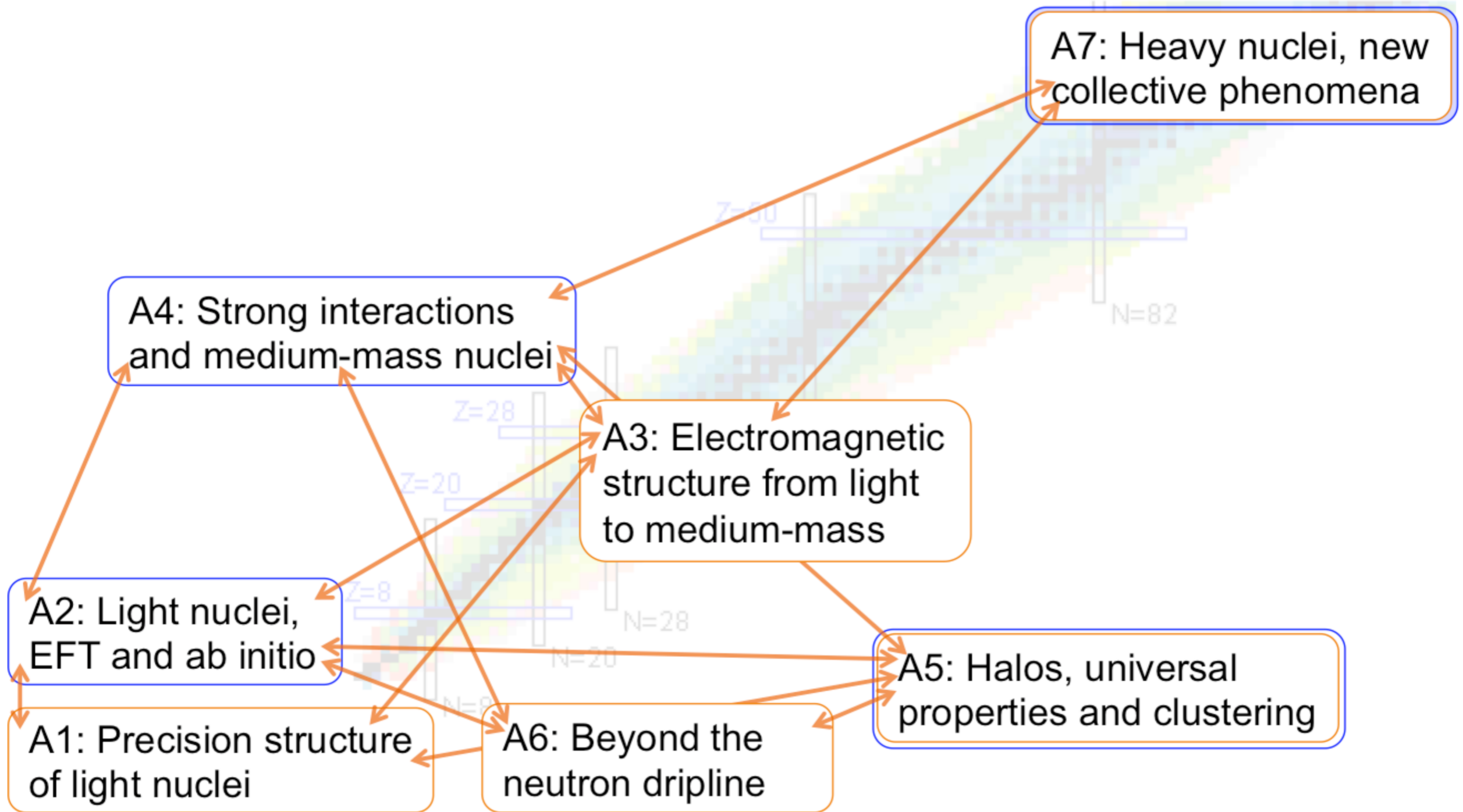
## A02

- **interactions & light nuclei**
- consistent chiral EFT interactions up to N<sup>3</sup>LO (NN+3N+4N)
- convergence and uncertainties of chiral EFT interactions
- ab initio NCSM calculations of electromagnetic observables with quantified uncertainties
- bridge to effective field theories to address difficult observables and exploit correlations
- inclusion of continuum degrees of freedom in the NCSM

## A04

- **medium-mass nuclei**
- development of many-body methods build on IM-SRG
- valence-space SM with effective interactions and operators from an IM-SRG evolution
- NCSM with interactions and operators from a multi-reference IM-SRG evolution
- IM-SRG with continuum basis for loosely bound and unbound nuclei
- consistent IM-SRG evolution of scalar and non-scalar operators

# Connections to Experiment



# Selected Papers: A02

Text

- J. Braun, R. Roth, H.-W. Hammer  
*Universal Correlations in Shallow D-Wave Systems*  
submitted to Phys. Lett. B (2018)
- S. Binder, A. Calci, E. Epelbaum, R.J. Furnstahl, J. Golak, K. Hebeler, T. Huether, H. Kamada, H. Krebs, P. Maris, U.-G. Meißner, A. Nogga, R. Roth, R. Skibinski, ...  
*Few- and Many-Nucleon Systems with Semilocal Coordinate-Space Regularized Chiral Nucleon-Nucleon Forces*  
submitted to Phys. Rev. C (2018)
- A. Kumar, R. Kanungo, A. Calci, P. Navratil, A. Sanetullaev, M. Alcorta, V. Bildstein, G. Christian, B. Davids, J. Dohet-Eraly, J. Fallis, A. T. Gallant, ...  
*Nuclear Force Imprints Revealed on the Elastic Scattering of Protons with  $^{10}\text{C}$*   
Phys. Rev. Lett. 118, 262502 (2017)
- A. Calci, P. Navratil, R. Roth, J. Dohet-Eraly, S. Quaglioni, G. Hupin  
*Can Ab Initio Theory Explain the Phenomenon of Parity Inversion in  $^{11}\text{Be}$ ?*  
Phys. Rev. Lett. 117, 242501 (2016)
- A.M. Shirokov, G. Papadimitriou, A.I. Mazur, I.A. Mazur, R. Roth, J.P. Vary  
*Prediction for a Four-Neutron Resonance*  
Phys. Rev. Lett. 117, 182502 (2016)



# Selected Papers: A04

Text

- E. Leistenschneider, M.P. Reiter, S. Ayet San Andrés, B. Kootte, J.D. Holt, P. Navrátil, C. Babcock, C. Barbieri, B.R. Barquest, J. Bergmann, J. Bollig,...  
*Dawning of the  $N=32$  Shell Closure Seen through Precision Mass Measurements of Neutron-Rich Titanium Isotopes*  
Phys. Rev. Lett. 120, 62503 (2018)
- T.D. Morris, J. Simonis, S.R. Stroberg, C. Stumpf, G. Hagen, J.D. Holt, G.R. Jansen, T. Papenbrock, R. Roth, A. Schwenk  
*Structure of the lightest tin isotopes*  
Phys. Rev. Lett. 120, 152503 (2018)
- E. Gebrerufael, K. Vobig, H. Hergert, R. Roth  
*Ab Initio Description of Open-Shell Nuclei: Merging No-Core Shell Model and In-Medium Similarity Renormalization Group,*  
Phys. Rev. Lett. 118, 152503 (2017)
- S. R. Stroberg, A. Calci, H. Hergert, J. D. Holt, S. K. Bogner, R. Roth, A. Schwenk  
*Nucleus-Dependent Valence-Space Approach to Nuclear Structure*  
Phys. Rev. Lett. 118, 32502 (2017)
- A. Tichai, J. Langhammer, S. Binder, R. Roth  
*Hartree-Fock Many-Body Perturbation Theory for Nuclear Ground-States*  
Phys. Lett. B 756, 283 (2016)

# Big Picture - Again

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