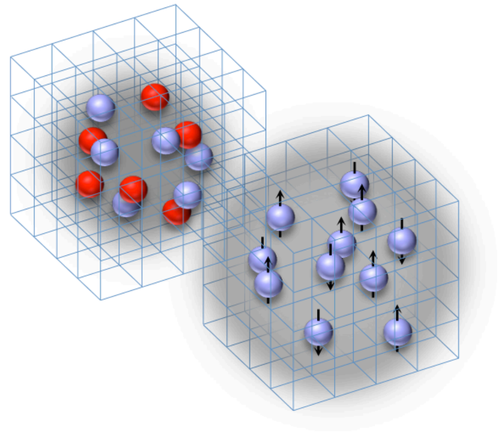

NLEFT Simulation with Woods-Saxon Potential

Myungkuk Kim
Center for Exotic Nuclear Studies / IBS

In Collaboration with Y. H. Song, Y. Kim, D. Lee. Y. Ma

Frontiers in Nuclear Lattice EFT: From Ab Initio
Nuclear Structure to Reactions

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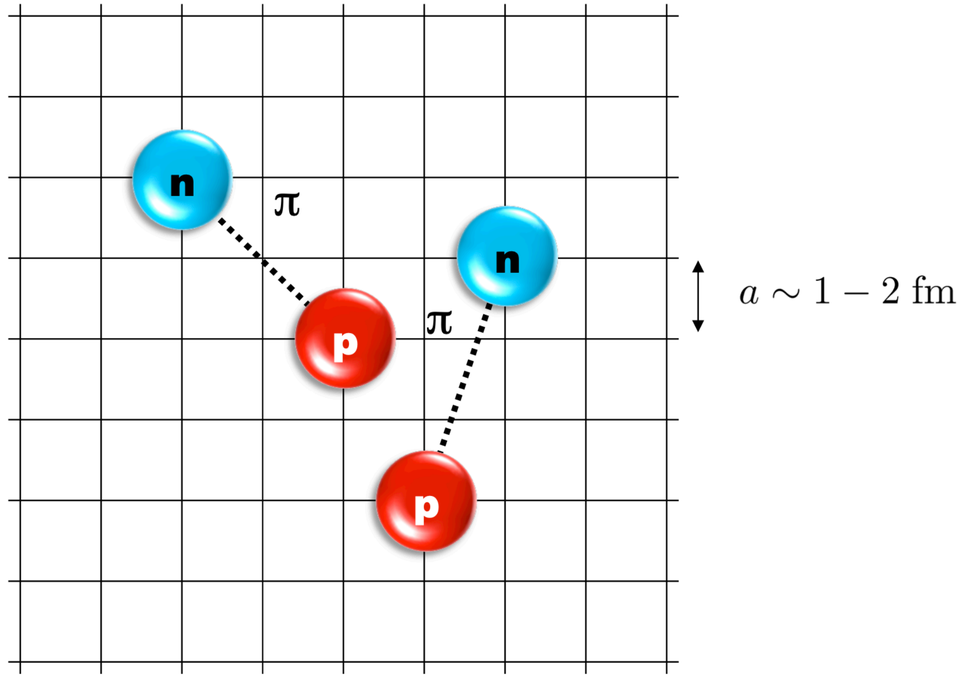
NUCLEAR STUDIES

Lattice effective field theory

- one of *ab initio* method for few-, many-fermion system
- powerful numerical method formulated in the framework of chiral EFT
- EFT (theory) + Lattice method + Monte Carlo algorithm

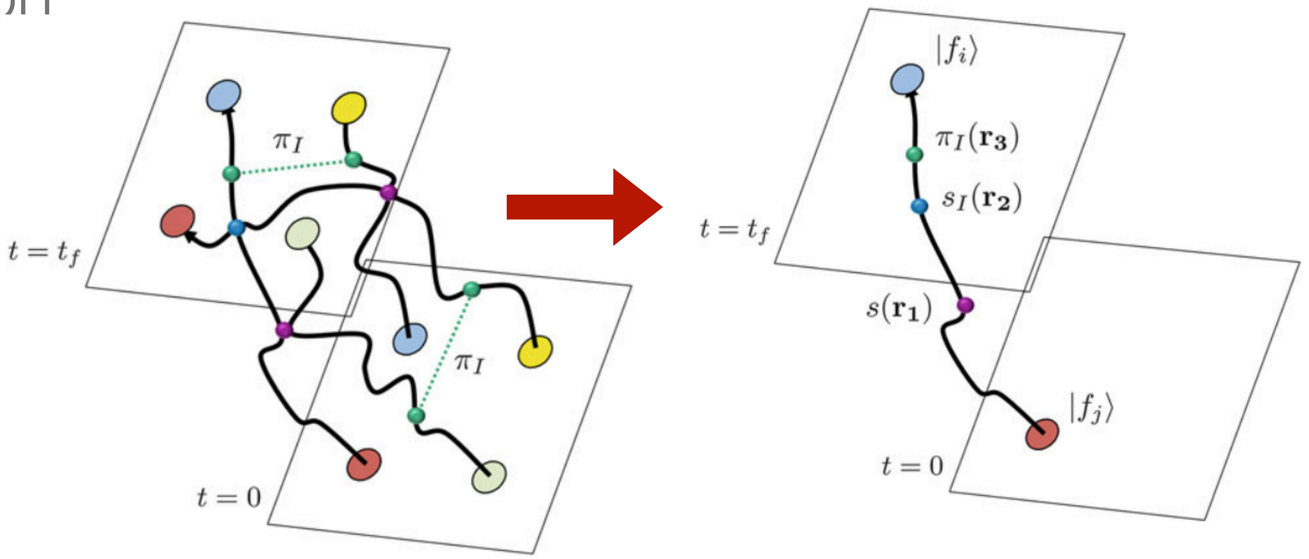


Review: D.L, Prog. Part. Nucl. Phys. 63 117-154 (2009)

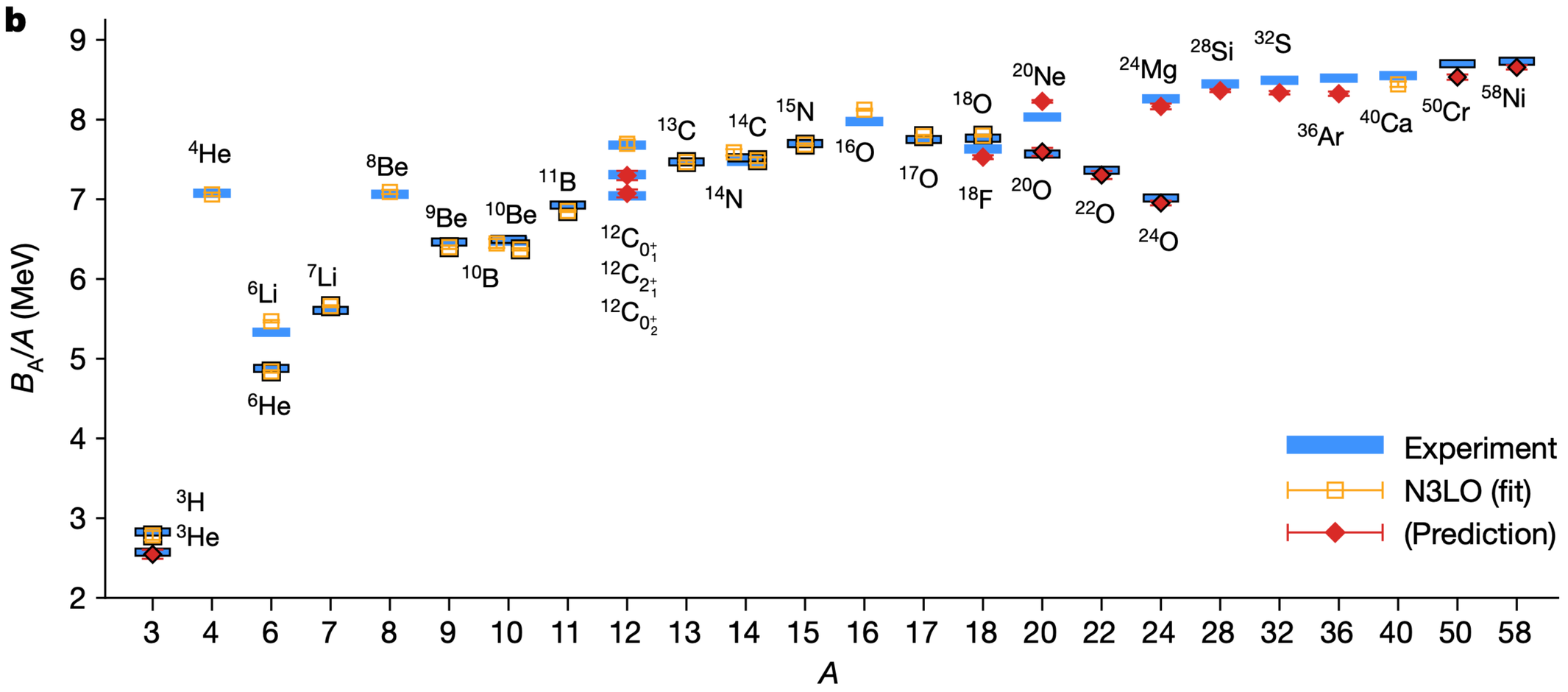
Lattice method + MC algorithm

- Euclidean time projection: exponential decay of excited states, revealing the ground state as the dominant contribution
- Auxiliary field quantum Monte-Carlo: many-body problem is mapped into a problem of nucleons propagating in fluctuating auxiliary field
- Hubbard-Stratonovich transformation

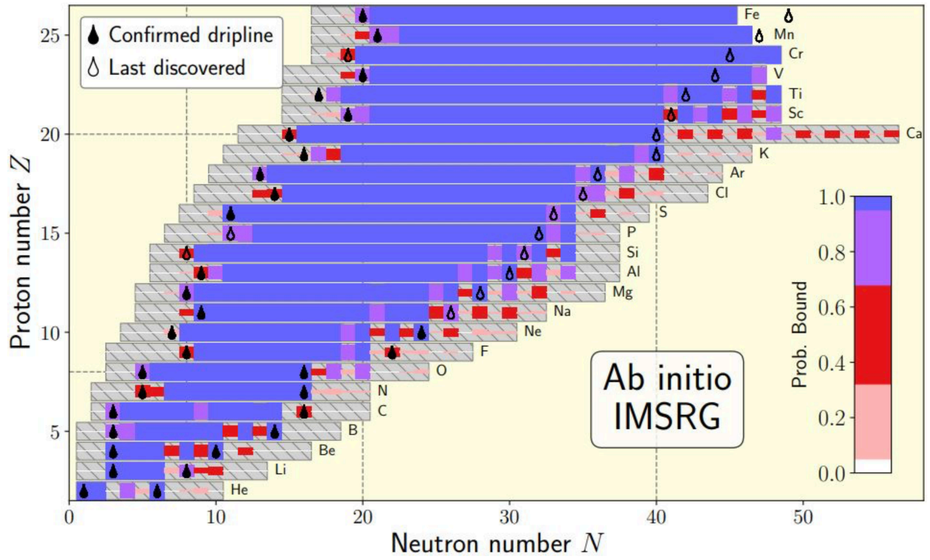
$$\exp\left[\frac{-2}{C}(N^\dagger N)^2\right] = \sqrt{\frac{1}{2\pi}}\int_{-\infty}^{\infty} ds \exp\left[-\frac{1}{2}s^2 + \sqrt{-C}s(N^\dagger N)\right]$$



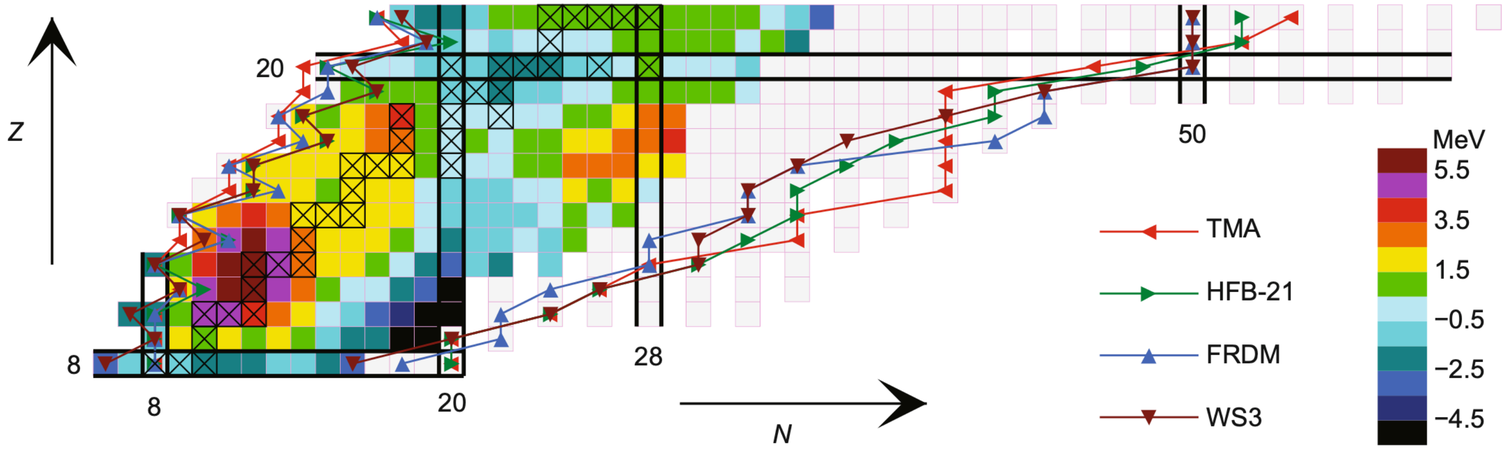
Nuclear binding energies



Neutron Driplines



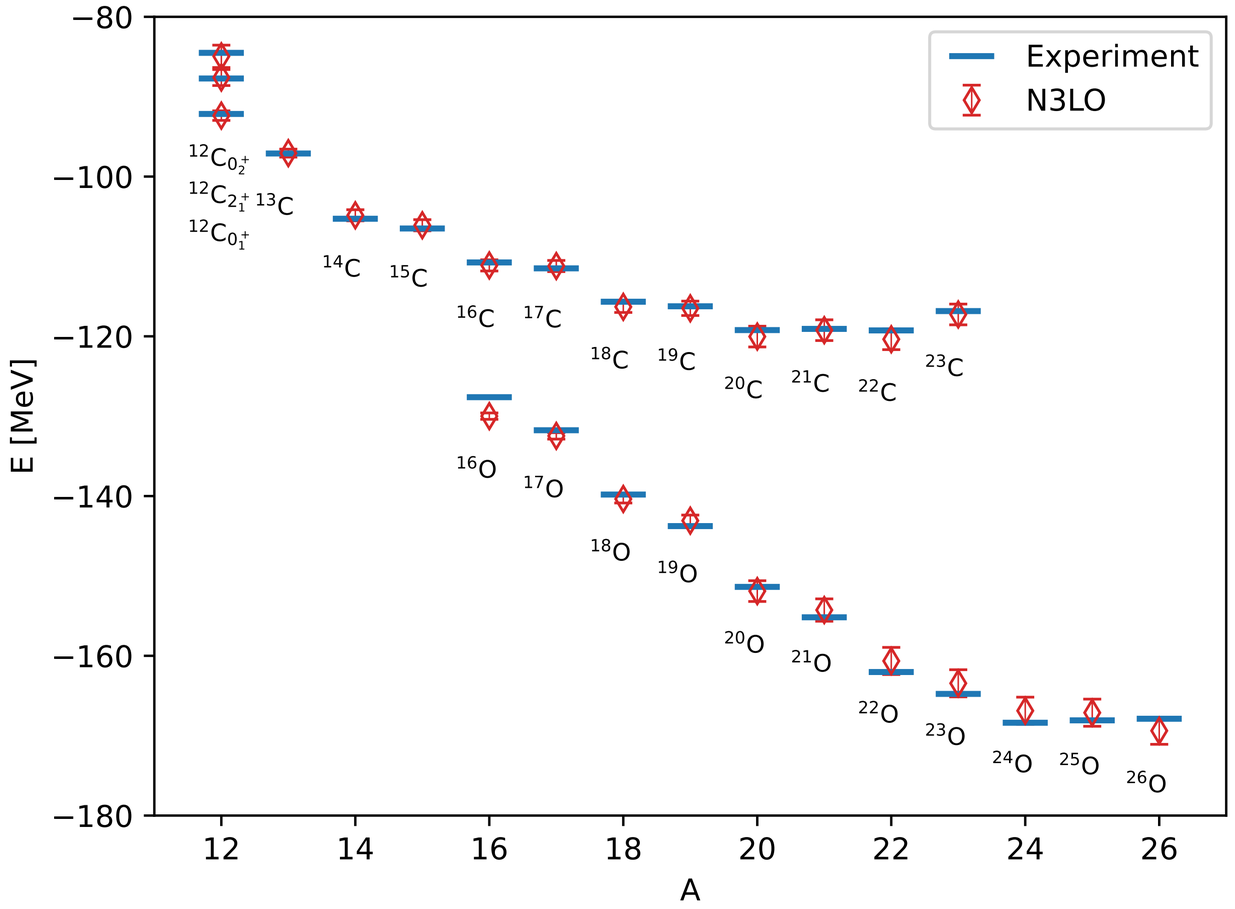
Stroberg et al., PRL (2021)



Qu, et al., Sci China-Phys Mech Astron (2013)

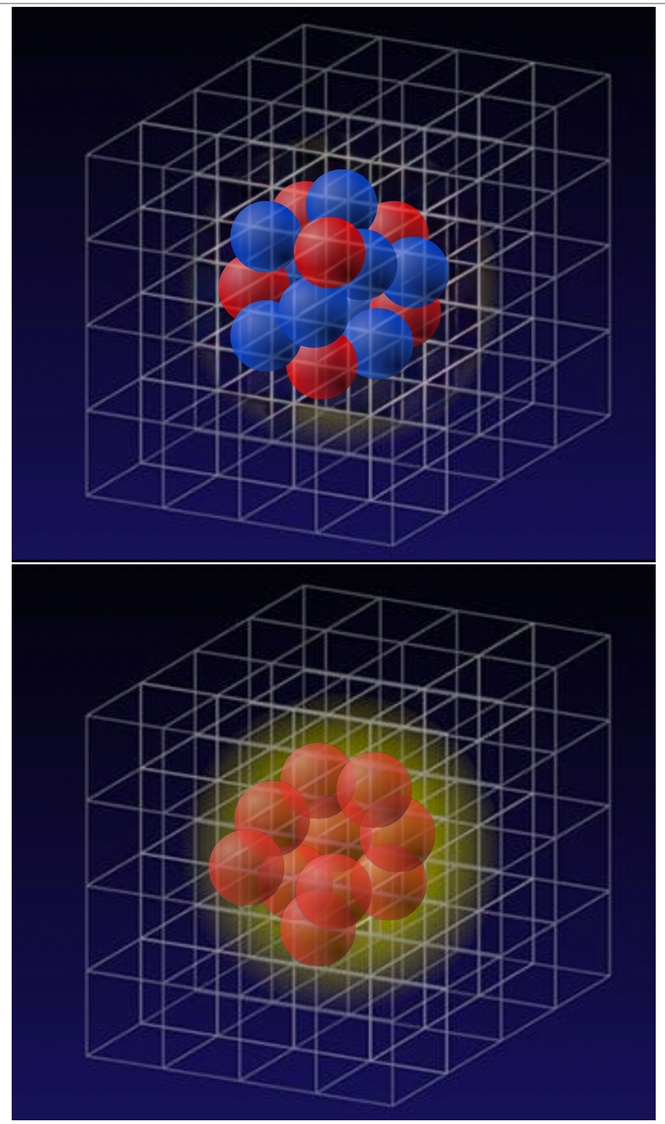
- boundary where adding more neutrons to a nucleus
- determine how the strong nuclear force behaves in n-rich systems

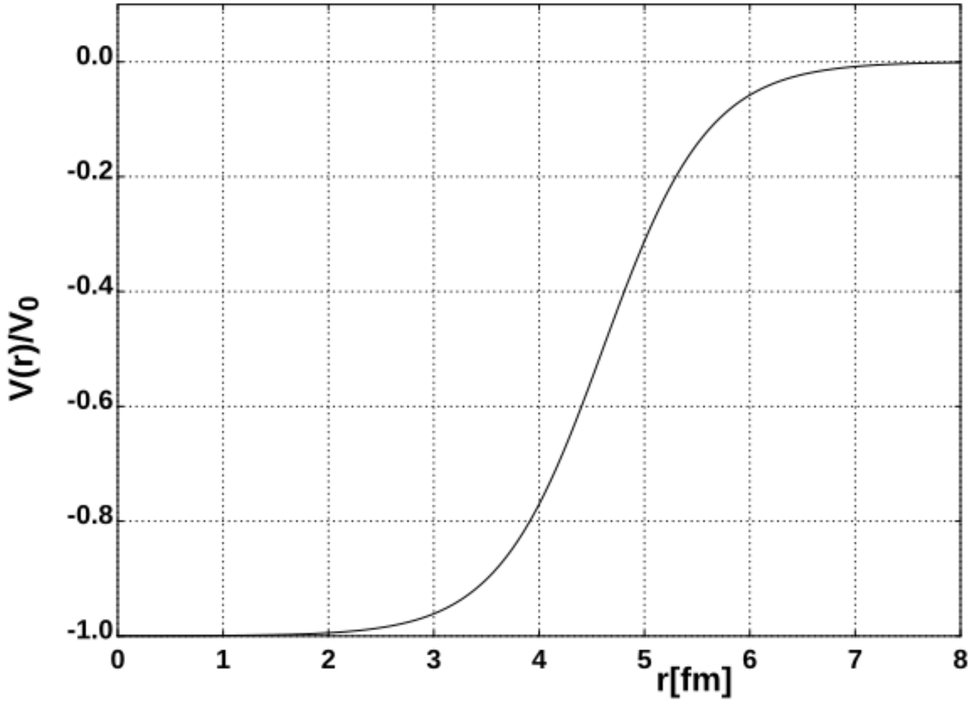
Binding Energies: Carbon & Oxygen isotope



Y. H. Song et al., in preparation

Woods-Saxon Potentials

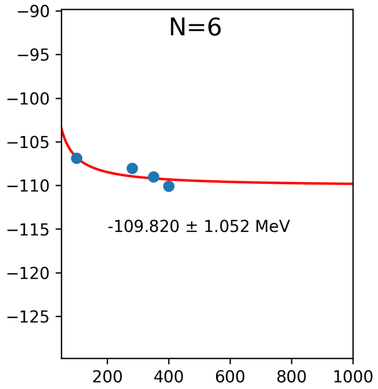


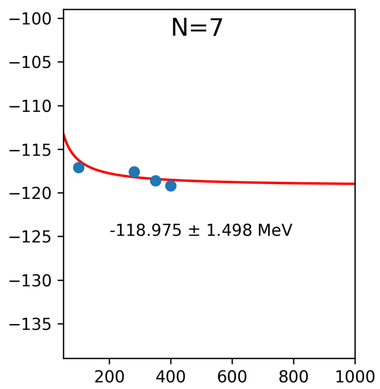


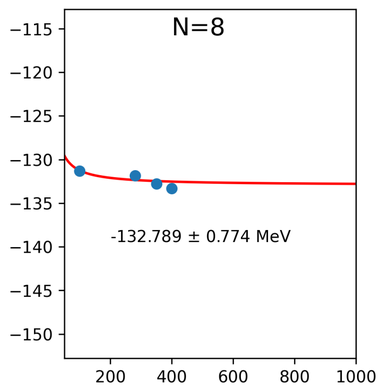
$$V_0 = -45\,\mathrm{MeV}, a_0 = 0.5\,\mathrm{fm}, R = 1.26 \times 8^{1/3}$$

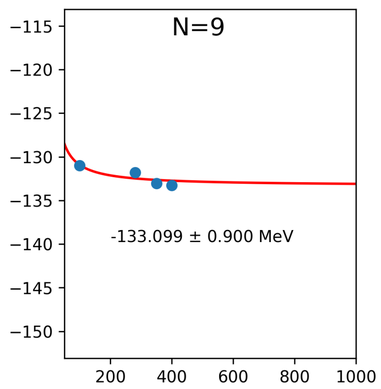
14O

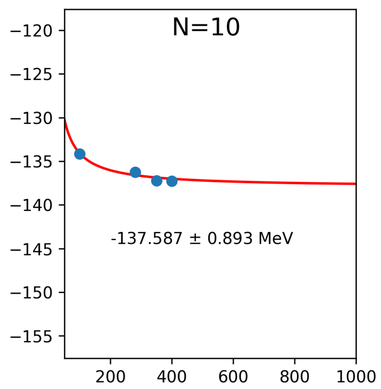
16O

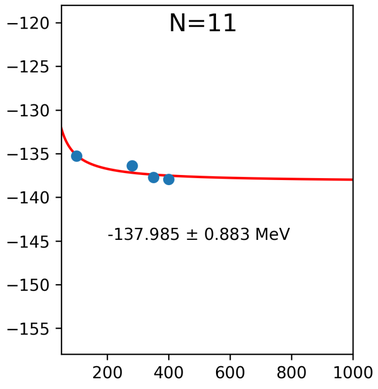

N=6
-109.820 ± 1.052 MeV

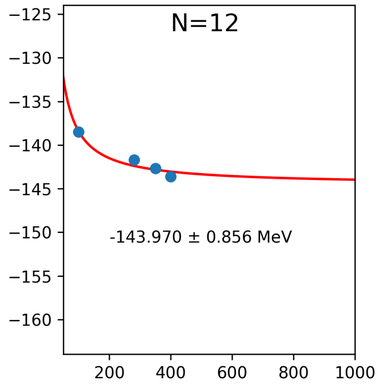

N=7
-118.975 ± 1.498 MeV

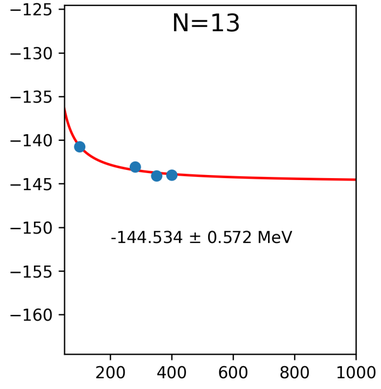

N=8
-132.789 ± 0.774 MeV

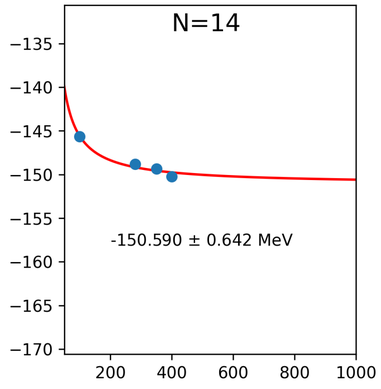

N=9
-133.099 ± 0.900 MeV

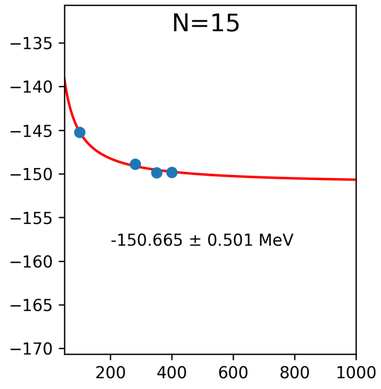

N=10
-137.587 ± 0.893 MeV

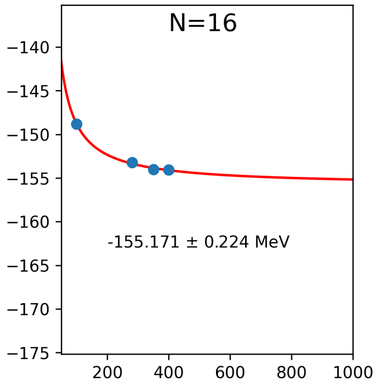

N=11
-137.985 ± 0.883 MeV

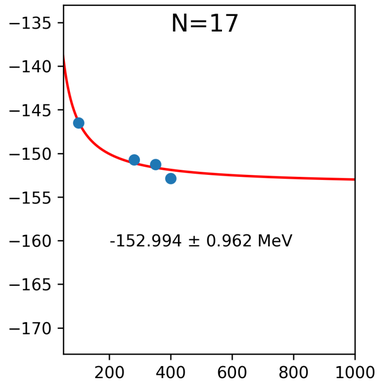

N=12
-143.970 ± 0.856 MeV

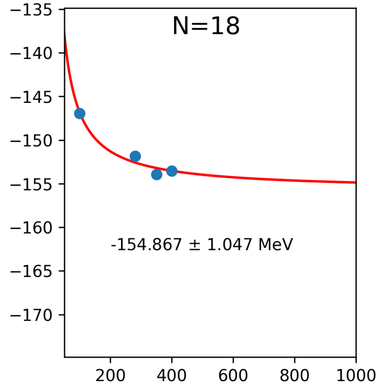

N=13
-144.534 ± 0.572 MeV

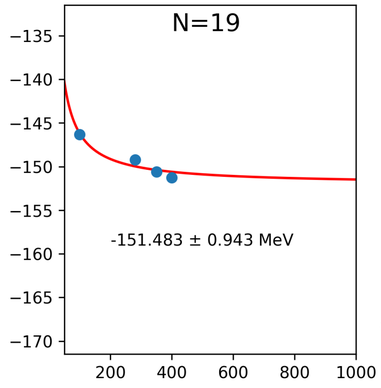

N=14
-150.590 ± 0.642 MeV


N=15
-150.665 ± 0.501 MeV


N=16
-155.171 ± 0.224 MeV


N=17
-152.994 ± 0.962 MeV


N=18
-154.867 ± 1.047 MeV

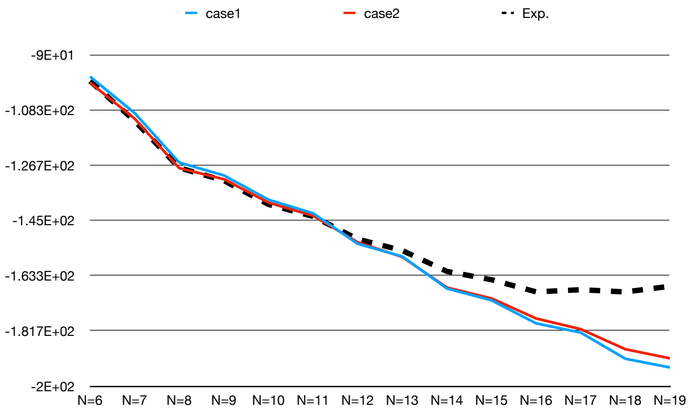

N=19
-151.483 ± 0.943 MeV

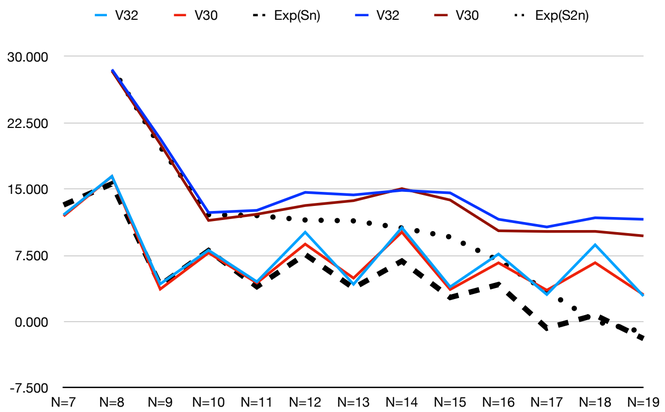
27O

Woods-Saxon parameter searches

case 1 - $V_0 = -30\,\mathrm{MeV}, a_0 = 0.45\,\mathrm{fm}, R = 1.39 \times 16^{1/3}$

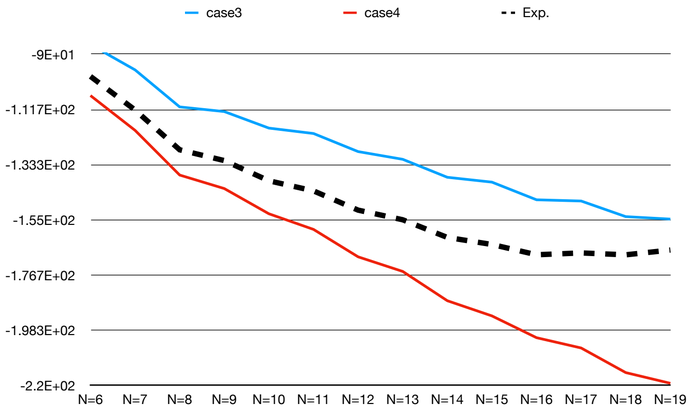
case 2 - $V_0 = -32\,\mathrm{MeV}, a_0 = 0.5\,\mathrm{fm}, R = 1.33 \times 16^{1/3}$

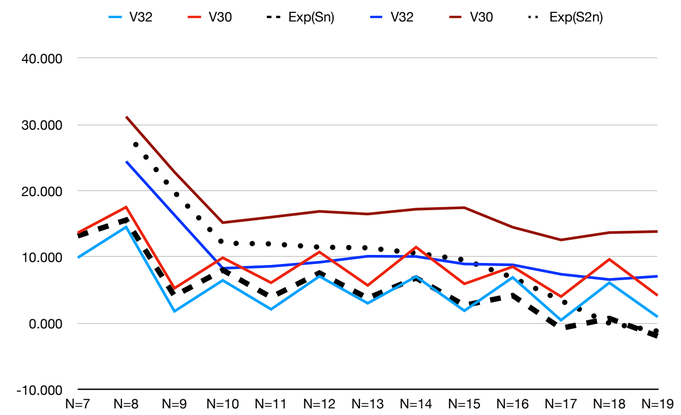




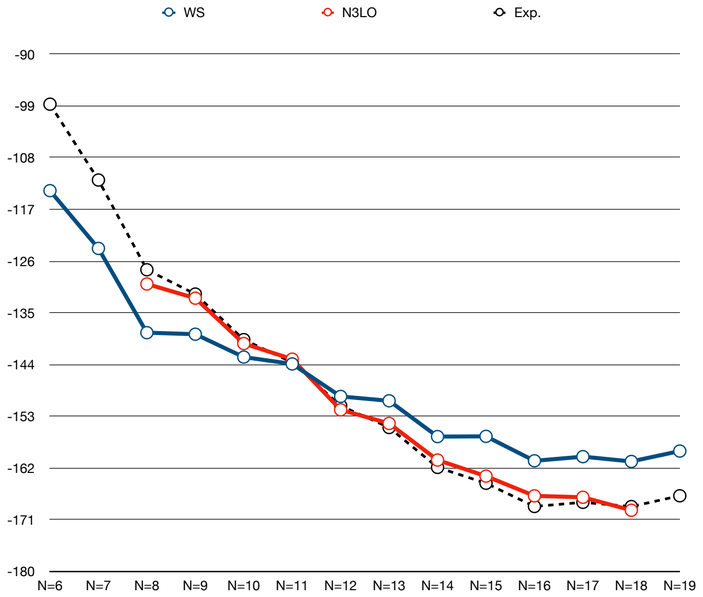
case 3 - $V_0 = -30\,\mathrm{MeV}, a_0 = 0.5\,\mathrm{fm}, R = 1.3 \times 16^{1/3}$

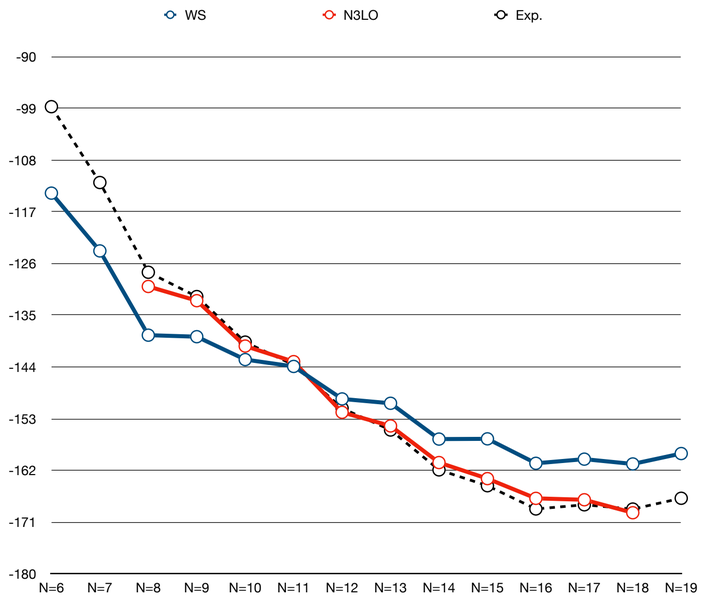
case 4 - $V_0 = -32\,\mathrm{MeV}, a_0 = 0.5\,\mathrm{fm}, R = 1.4 \times 16^{1/3}$

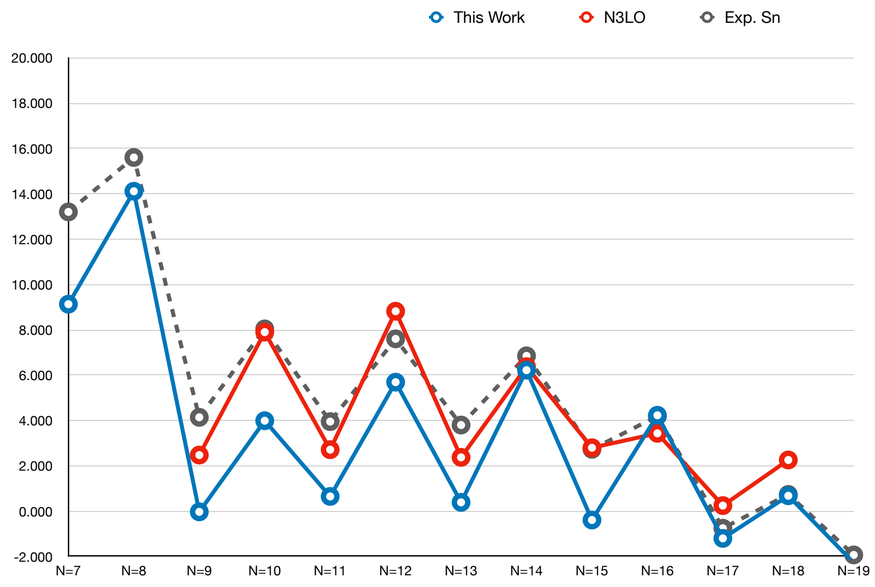


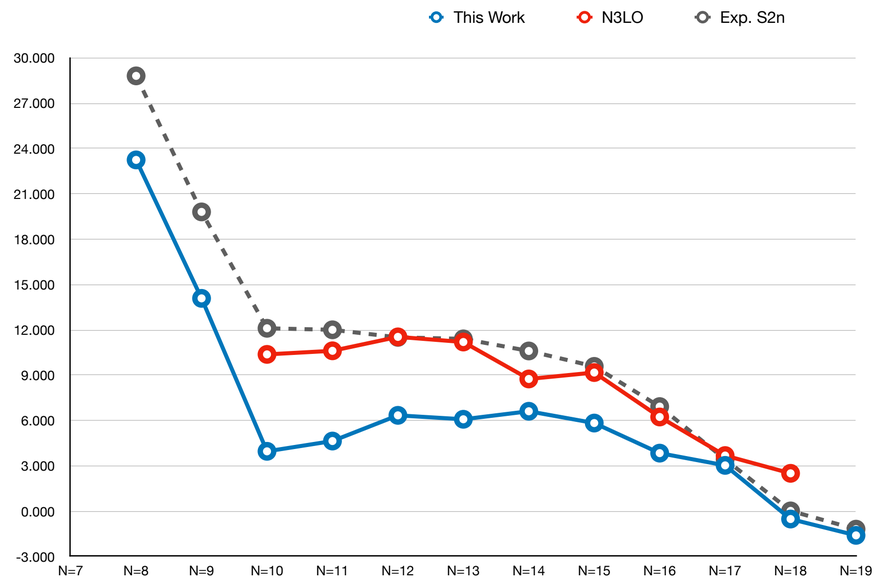


$V_0 = -45\,\mathrm{MeV}, a_0 = 0.5\,\mathrm{fm}, R = 1.0 \times 16^{1/3}$





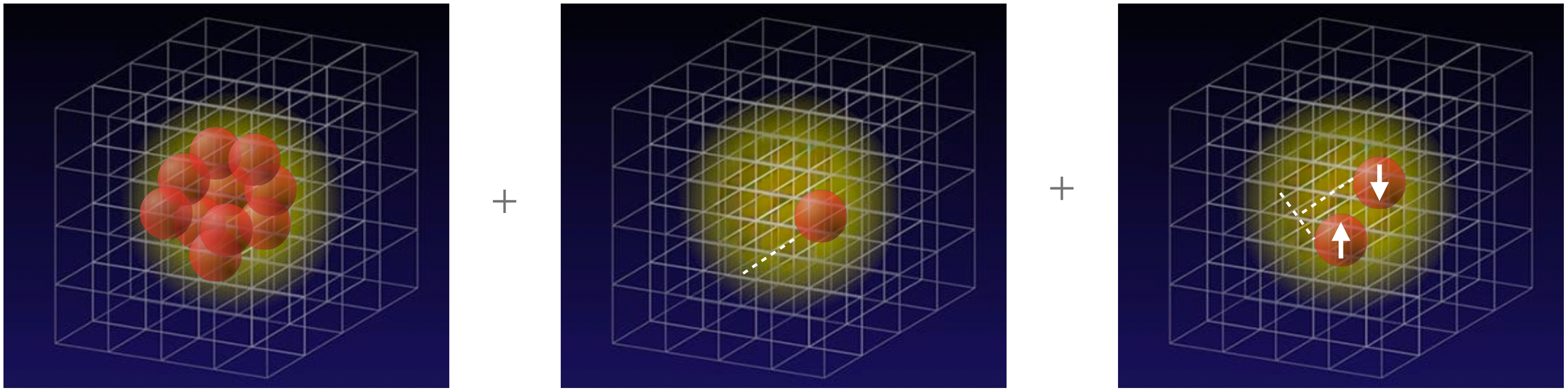




$$V_0 = -45\,\mathrm{MeV}, a_0 = 0.5\,\mathrm{fm}, R = 1.0 \times 16^{1/3}$$

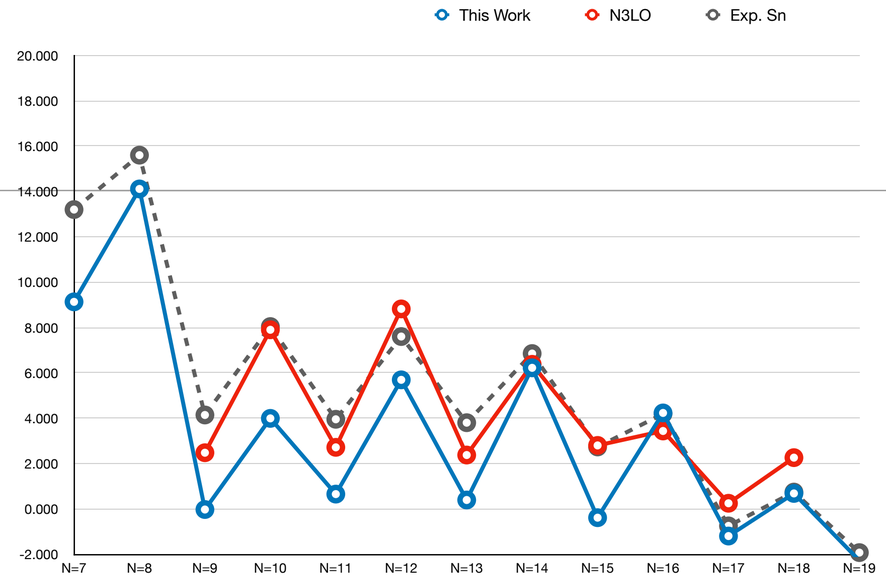
Energy corrections

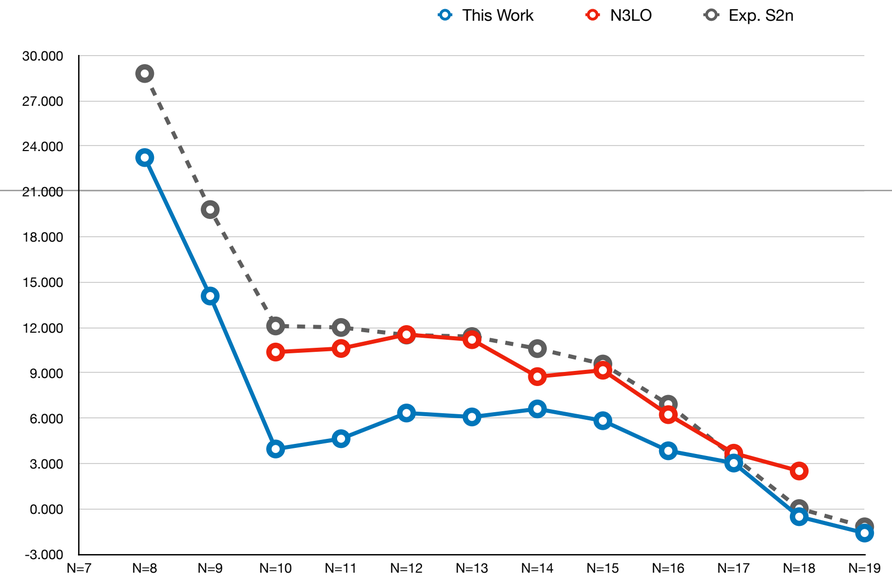
$$E_{\mathrm{g.s}} = EHn3lo + E_{\mathrm{p'n}} + E_{\mathrm{p'nn}}$$



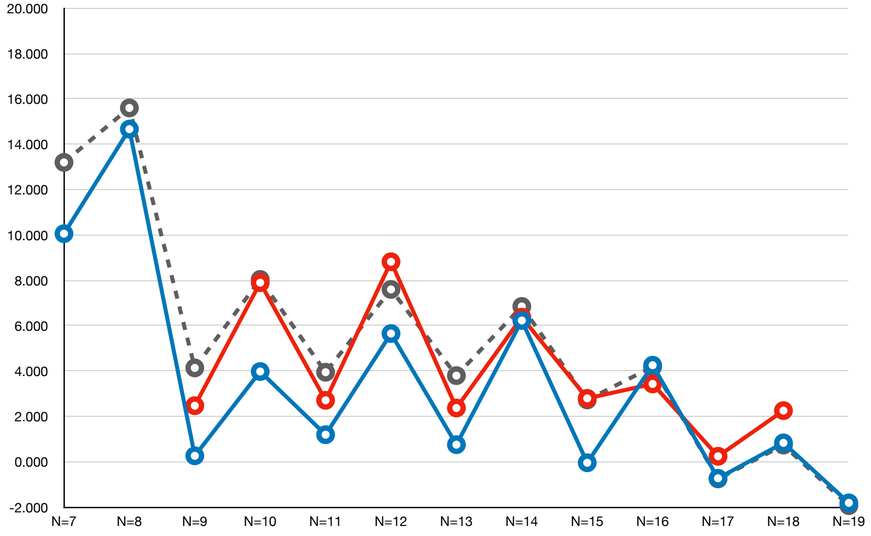
- $H_{pn} = C_1 \times \sum_{x,y,z} WS(x,y,z) * \rho(x,y,z)$
- $H_{pnn} = C_2 \times \sum_{x,y,z} WS(x,y,z) * \rho_{\uparrow}(x,y,z) * \rho_{\downarrow}(x,y,z)$

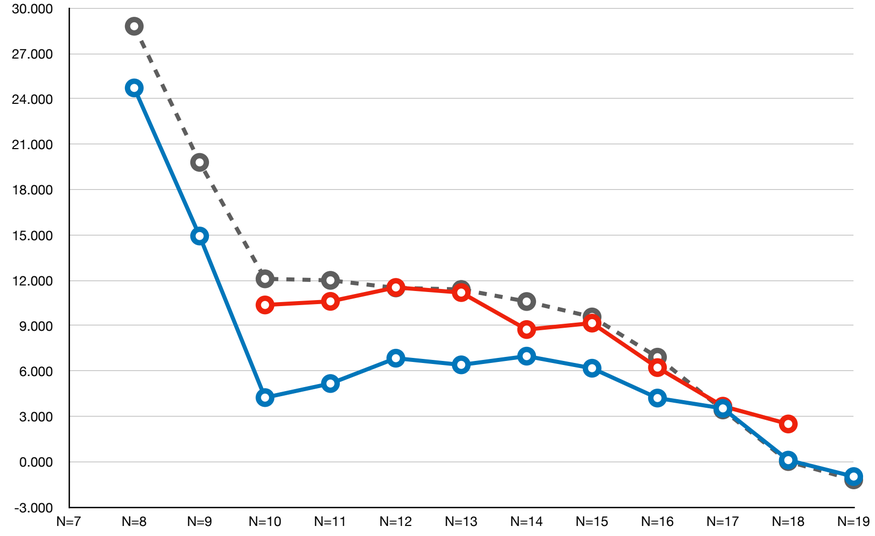
before



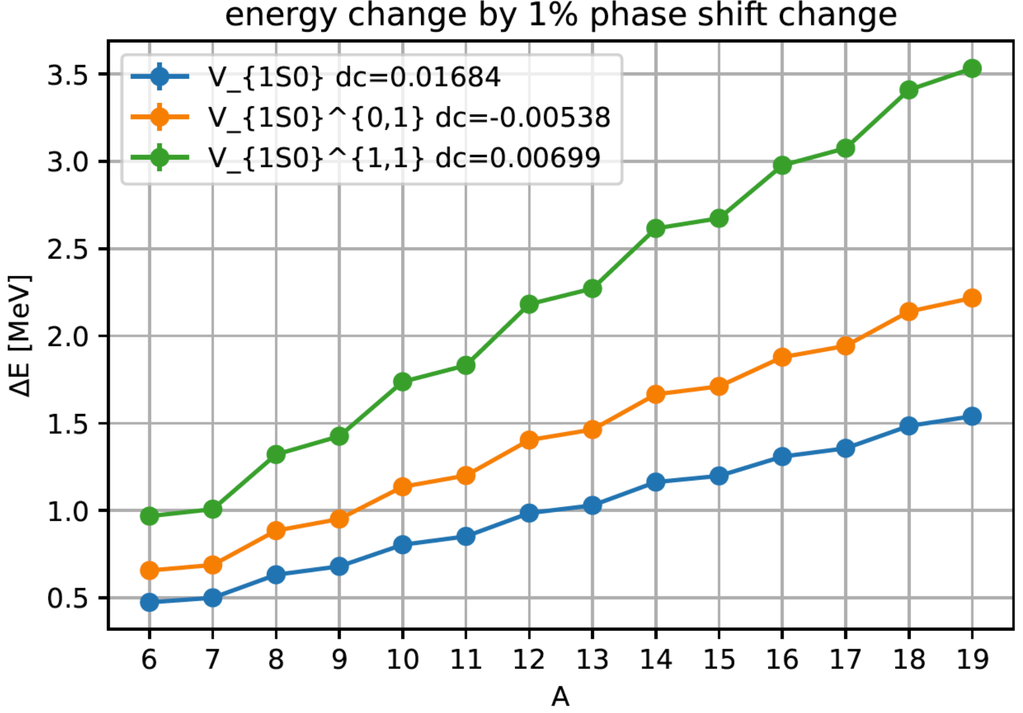


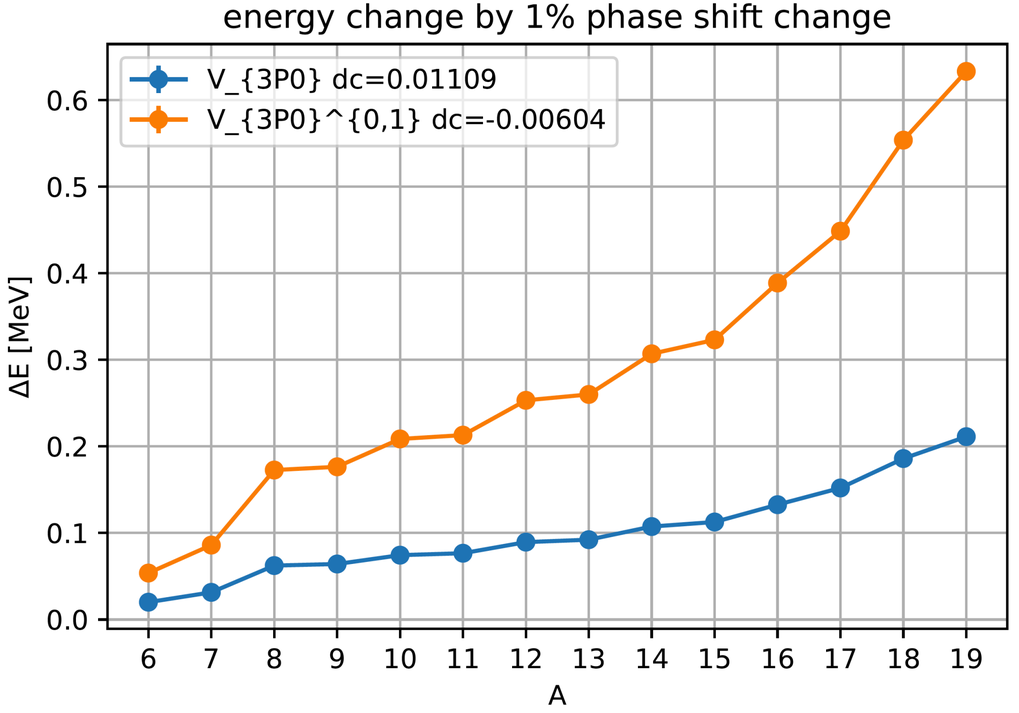
after



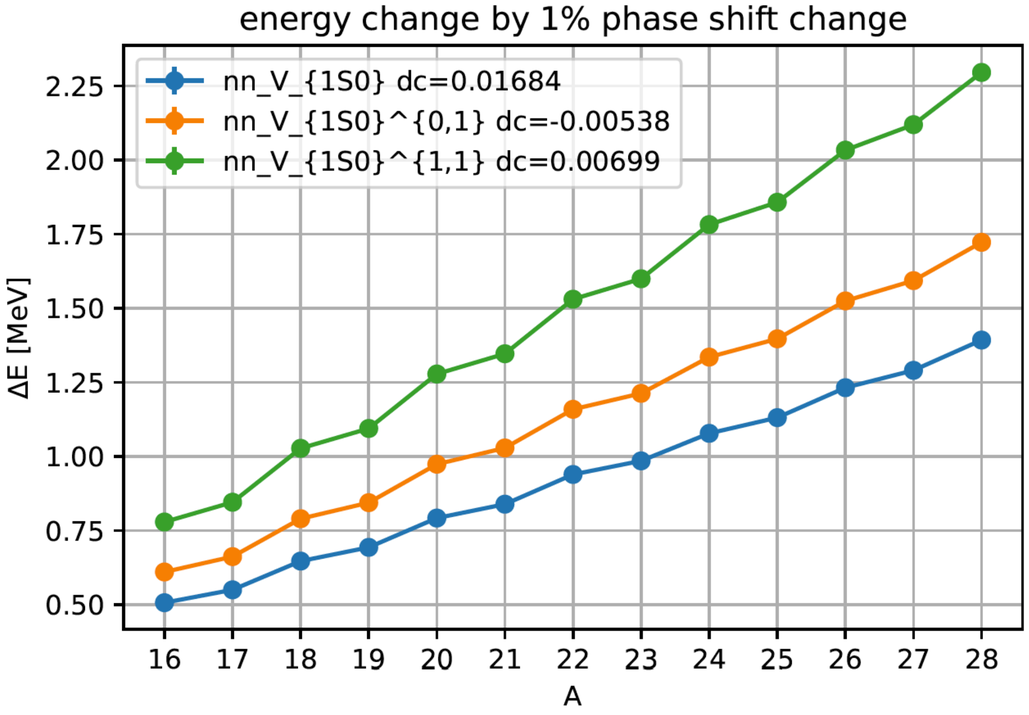


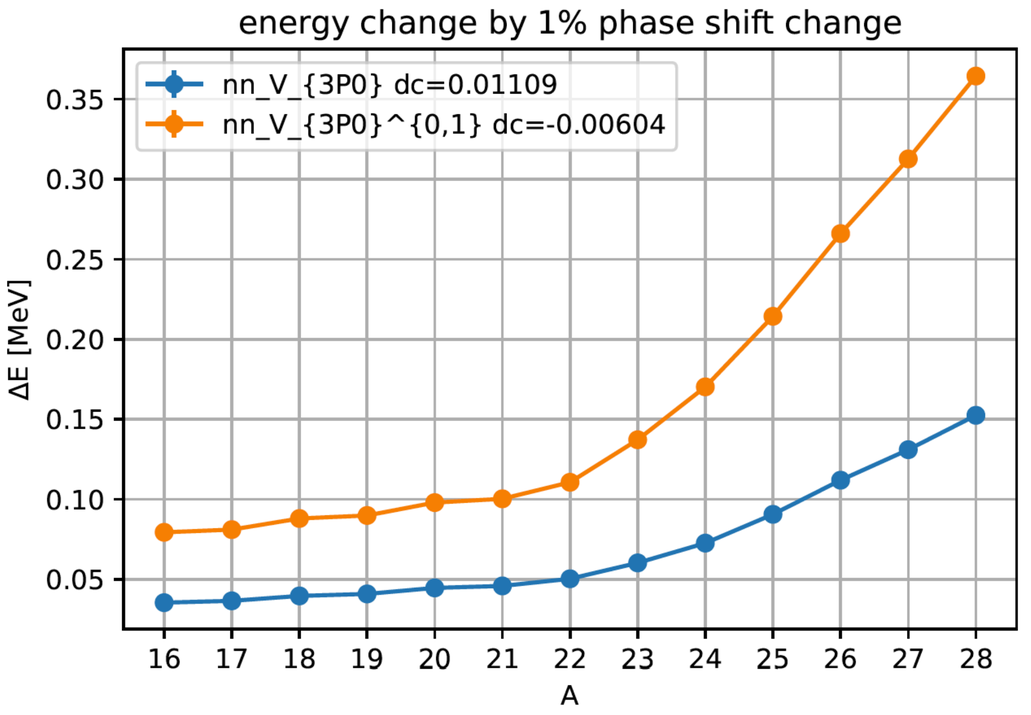
WS


energy change by 1% phase shift change
V_{1S0} dc=0.01684
V_{1S0}^{0,1} dc=-0.00538
V_{1S0}^{1,1} dc=0.00699
ΔE [MeV]
A


energy change by 1% phase shift change
V_{3P0} dc=0.01109
V_{3P0}^{0,1} dc=-0.00604
ΔE [MeV]
A

WFM


energy change by 1% phase shift change
nn_V_{1S0} dc=0.01684
nn_V_{1S0}^{0,1} dc=-0.00538
nn_V_{1S0}^{1,1} dc=0.00699
ΔE [MeV]
A


energy change by 1% phase shift change
nn_V_{3P0} dc=0.01109
nn_V_{3P0}^{0,1} dc=-0.00604
ΔE [MeV]
A

Summary & Outlook

- Wavefunction matching allows for the use of high-fidelity chiral effective field theory interactions and the lattice simulations provide reliable predictions for experiments as well as deeper insights into the underlying physics.
- Wavefunction matching method can be applied to n-rich region and provide reliable predictions and insights to understand the structure of carbon and oxygen isotopes.
- Using Woods-Saxon potential is alternative approach to provide for understanding general behavior of neutron dripline.