"From bound states to the continuum: Connecting bound state calculations with scattering and reaction theory."

Workshop Summary

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Theory Alliance
FACILITY FOR RARE ISOTOPE BEAMS

FRIB, East Lansing, MI, June 11-22, 2018.

Challenges:

* Localized basis e.g. HO basis, usually used in structure approach..

* How to efficiently account for collectivity, clusterization?

* How to take into account the non-resonant continuum?

* How to handle the large dimensionality of the problem?

* How to obtain a sufficiently precise and accurate reproduction of thresholds ? How to construct effective interactions for reaction models?

No Core Shell Model/Resonating Group Method

S. Quaglioni

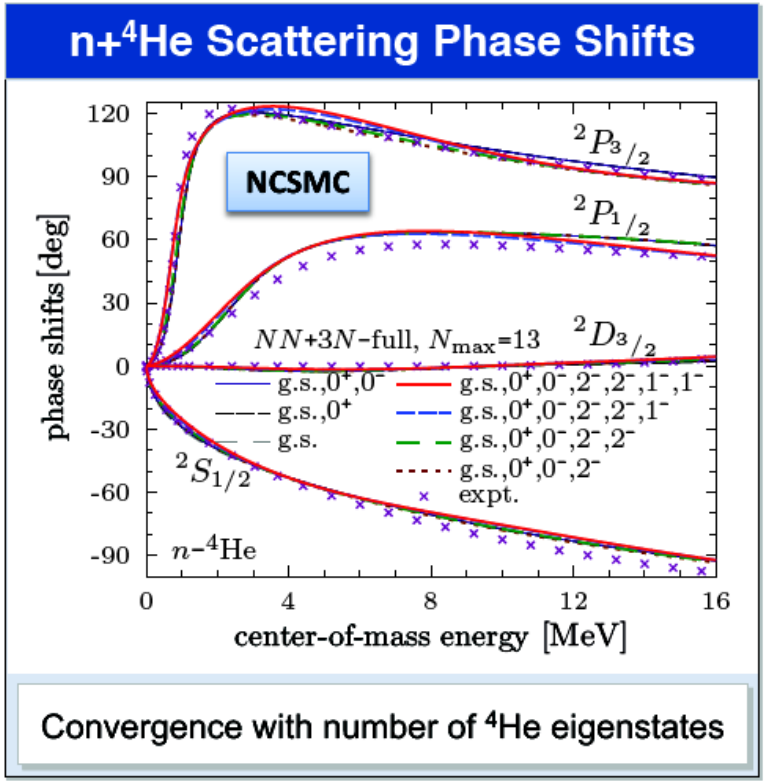
NCSM eigenstates

NCSM/RGM continuous states

$$\Psi^{(A)} = \sum_{\lambda} c_{\lambda} \left| (A), \lambda \right\rangle + \sum_{\nu} \int d\vec{r}\, u_{\nu}(\vec{r})\, \hat{A}_{\nu} \left| \vec{r} \; (a) \; (A-a), \nu \right\rangle$$

Unknowns

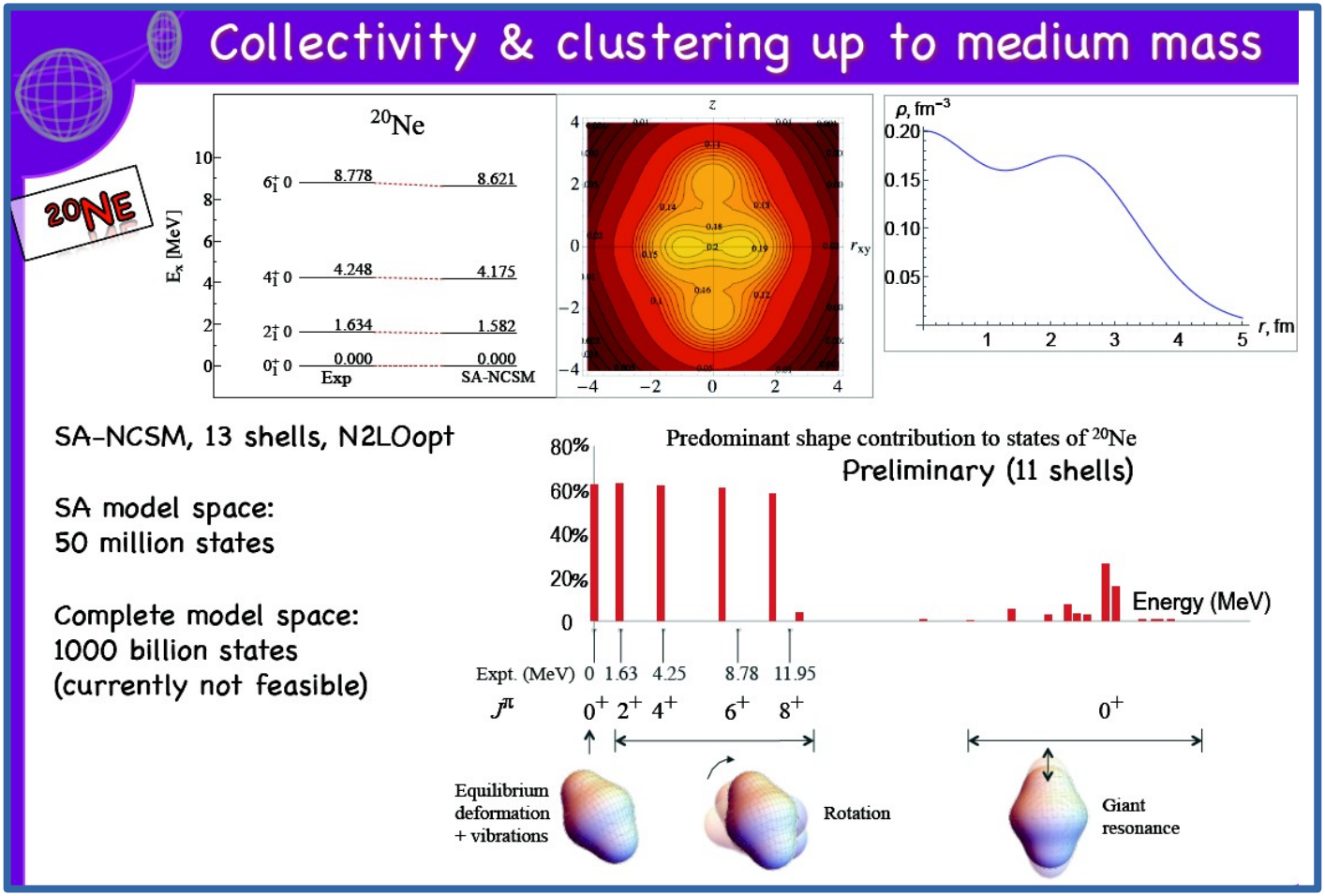
* mixed basis
* NN,NNN interaction
*description of short-range many-body and long-range cluster correlations
* applied to nucleon-nucleus, deuteron-nucleus, ^{3}H/He-nucleus collision……
* complexity of formalism and implementation increases with number of nucleons in the continuum



G. Hupin, S. Quaglioni, and P. Navratil, JPC Conf. Proc. in print, (2015)

Symmetry Adapted No-Core Shell Model (SA-NCSM)

Collectivity & clustering up to medium mass



A. Mercenne, K Launey
M. Caprio

48Ca

2^+
SA-NCSM (selected): ……3,055,554
Complete model space: …14,522,234,982

^{48}Ti, Q(2^+) [e fm^2]

Experiment…… -17.7

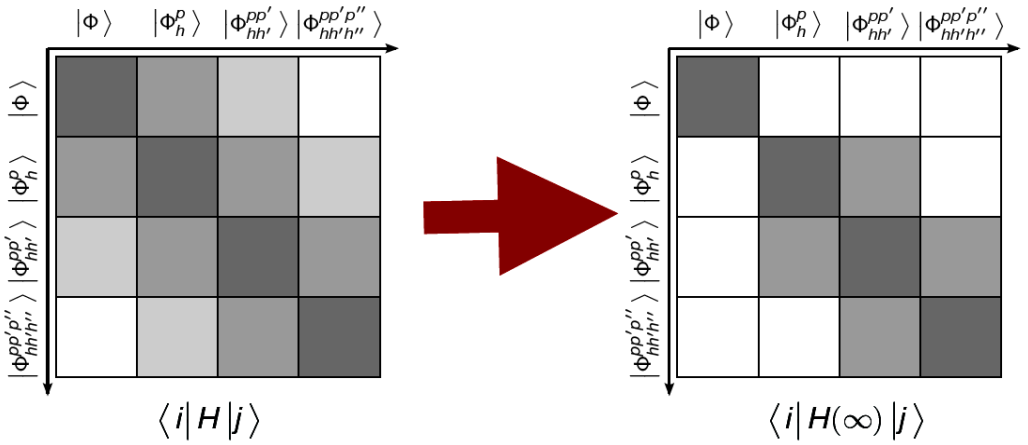
8 shells …… -19.3

(no effective charges)

*Basis adapted to describe collective degrees of freedom: rotation, vibration, clusterization.
*Future application to reaction : SA-NSCM/RGM

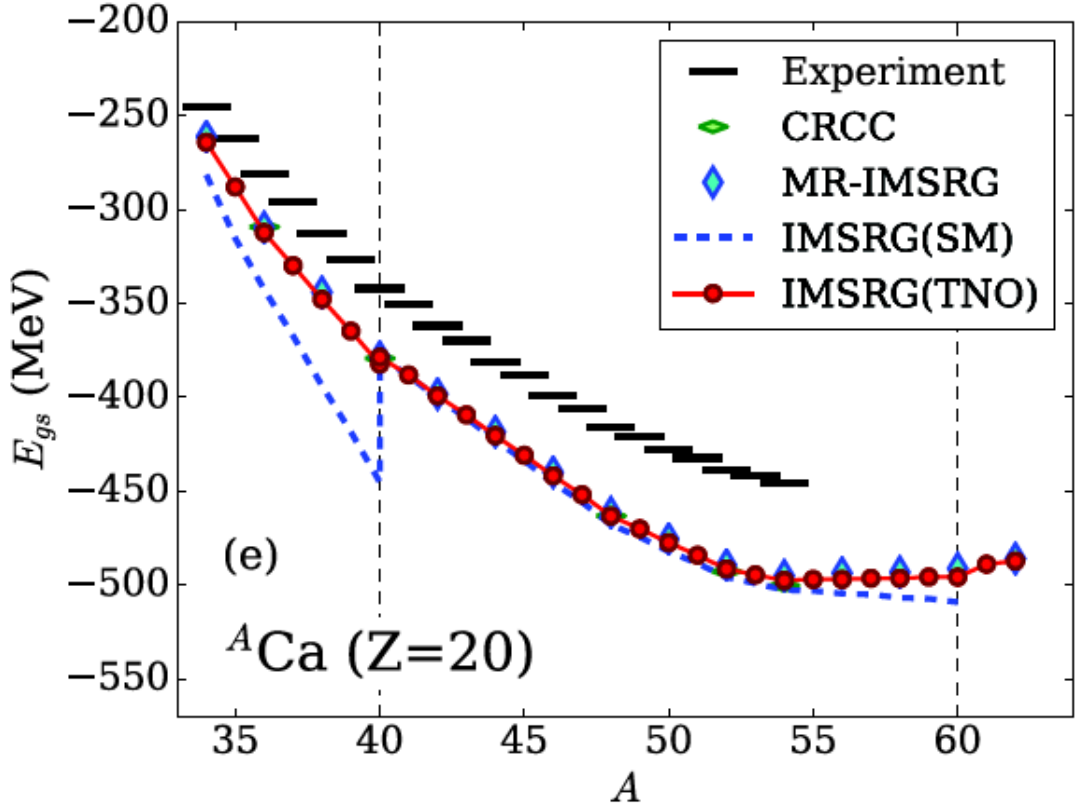
In Medium Similarity Renormalization Group: (IM-SRG)

H. Hergert



*decoupling of the reference state from excitations.

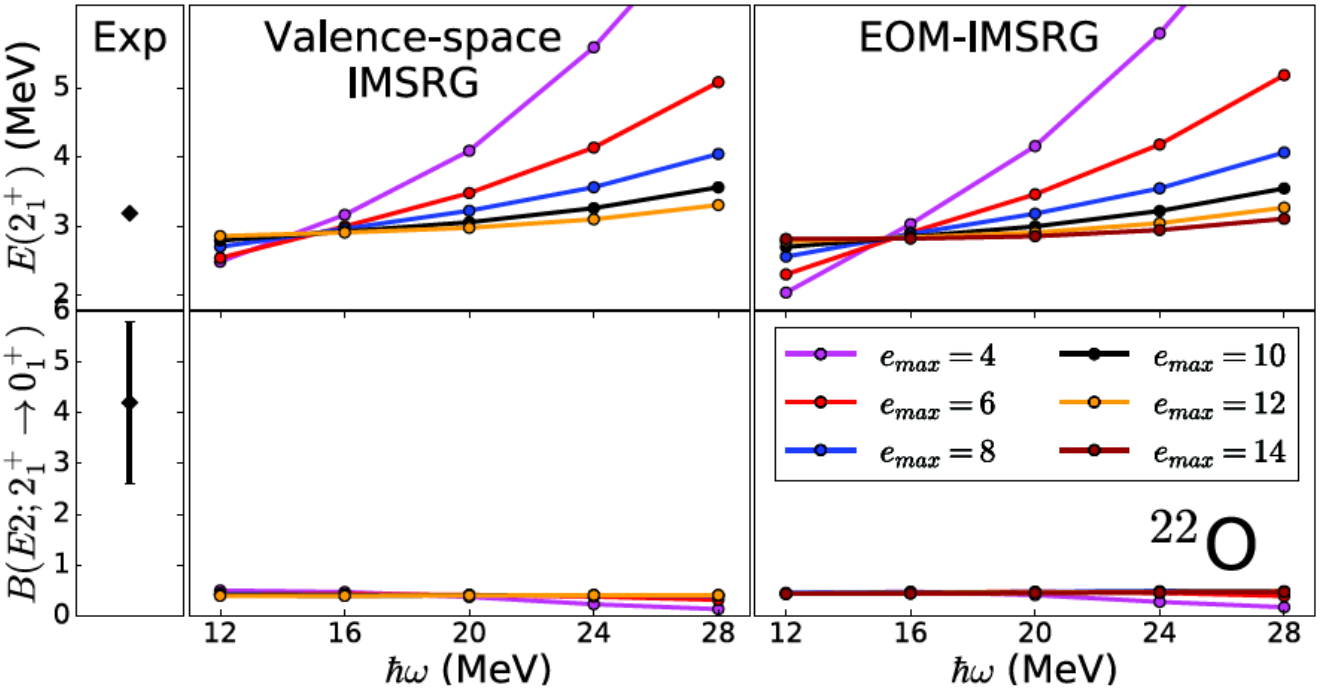
S. R. Stroberg, A. Calci, HH, J. D. Holt, S. K.Bogner, R. Roth, A. Schwenk, PRL **118**, 032502 (2017)



In Medium Similarity Renormalization Group: (IM SRG)

H. Hergert

*N. M. Parzuchowski, S. R. Stroberg et al., PRC **96**, 034324; EOM-IMSRG: N. M. Parzuchowski et al., PRC **95**, 044304*



* complementary correlations can be accounted for by using a reference state obtained from NCSM,HFB, GCM...

Harmonic Oscillator Representation of Scattering Equations (HORSE) /J-matrix

A.Shirokov

GENERAL IDEA:

❖NCSM + HORSE = continuum spectrum

T + V

T

Infinite set of algebraic equations

$$\sum_{n'=0}^{N} (T^l_{nn'} + V^l_{nn'} - \delta_{nn'}E)\, a_{n'l}(E) = 0, \quad n \le N-1$$

Matching condition at $n = N$:

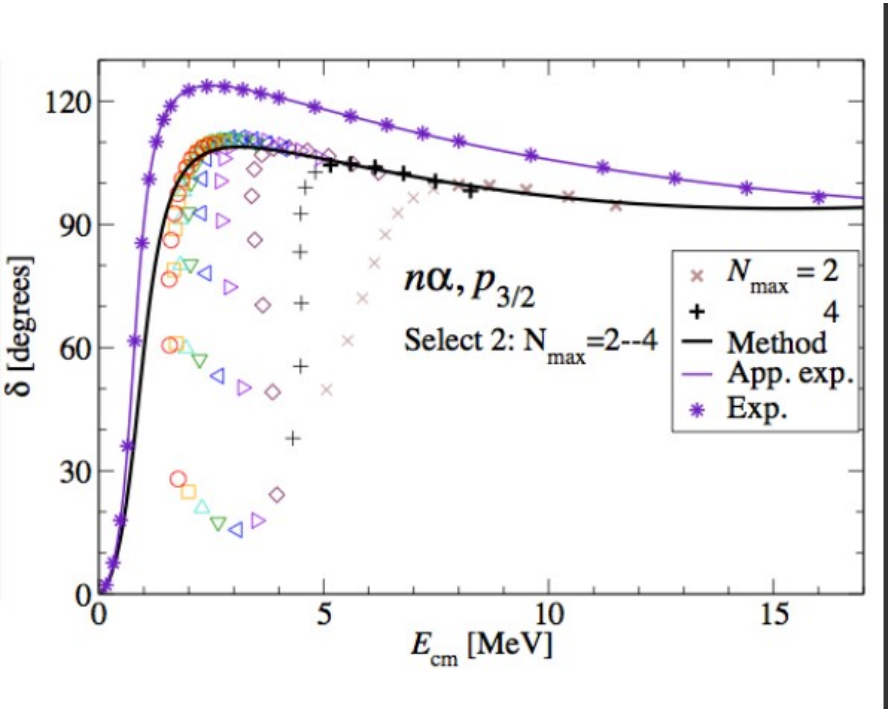
$$\sum_{n'=0}^{N} \left[(T^l_{Nn'} + V^l_{Nn'} - \delta_{Nn'}E)\, a_{n'l}(E)\right] + T^l_{N,N+1} a_{N+1,l}(E) = 0$$

$$\sum_{n'=0}^{\infty} (T^l_{nn'} - \delta_{nn'}E)\, a_{n'l}(E) = 0, \quad n \ge N+1$$

$$T^l_{n,n-1}\, a_{n-1,l}(E) + (T^l_{nn} - E)\, a_{nl}(E) + T^l_{n,n+1}\, a_{n+1,l}(E) =$$

This is an exactly solvable algebraic problem!

And this looks like a natural extension of SM where both potential and kinetic energies are truncated

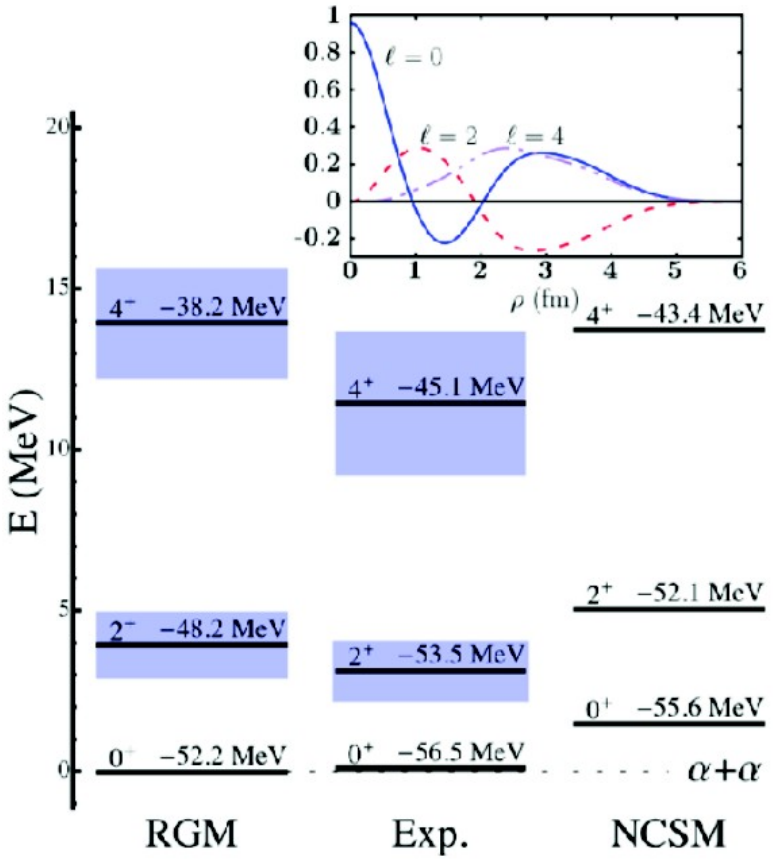


*algebraic version of RGM

Reactions with Clusters in Harmonic Oscillator Basis

A.Volya, K.Kravvaris

Resonating group method ^{8}Be results



$\hbar\Omega = 25$ MeV

		Theory	Exp.
I=0	ev	8.7	5.6
I=2	MeV	1.3	1.5
I=4	MeV	2.1	3.5

$$\Gamma = 2P_L(\rho_c)|g(\rho_c)|^2$$

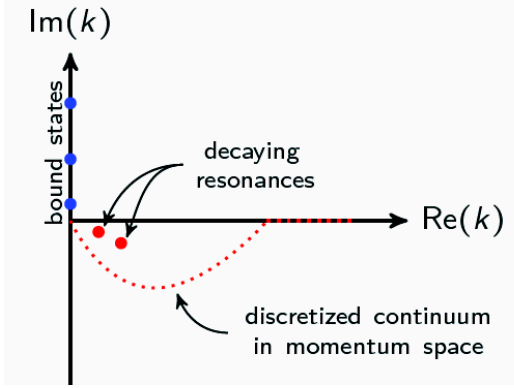
K Kravvaris and A. Volya, Phys.Rev.Lett, 119(6), 062501 (2017)

Continuum/Berggren basis approaches

Nazarewicz, Fossez, Ploszajczak, Xu, Barrett, Hu, Id Betan, Rotureau

- > Gamow Shell Model (GSM), GSM/Coupled Channel:
phenomenological interaction, halo-EFT "inspired" interaction, MBPT-derived interaction..

$$\sum_{n\in(b,d)} |u_\ell(k_n)\rangle \langle \tilde{u}_\ell(k_n)| + \int_{\mathcal{L}^+} dk\, |u_\ell(k)\rangle \langle \tilde{u}_\ell(k)| = \hat{\mathbb{1}}_{\ell,j}.$$

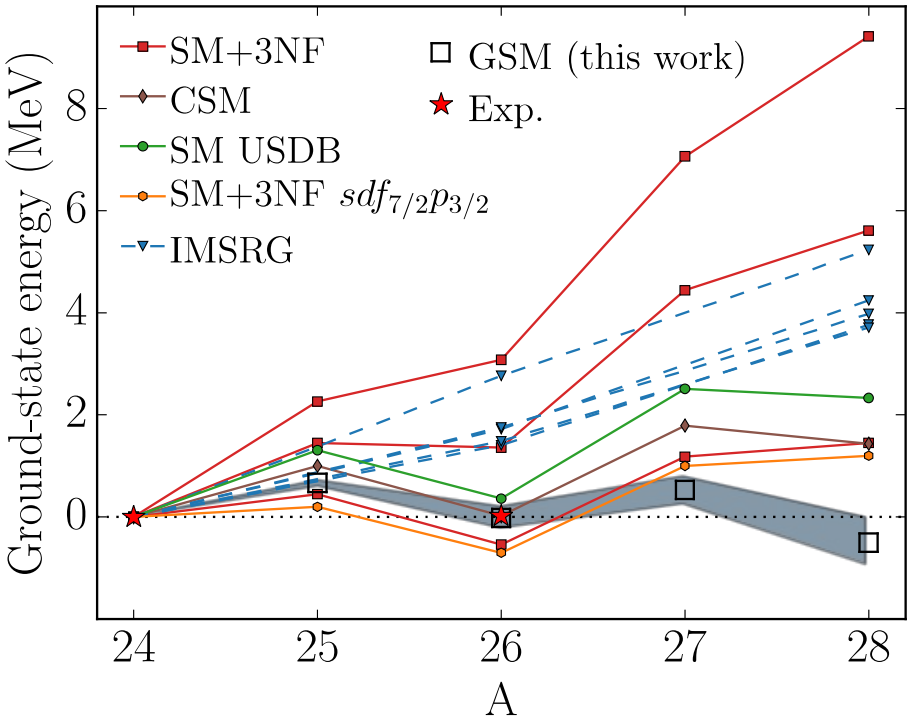


*eigenstates: E=Er-iΓ/2
(for bound states Γ=0 as a result of the calculation.)

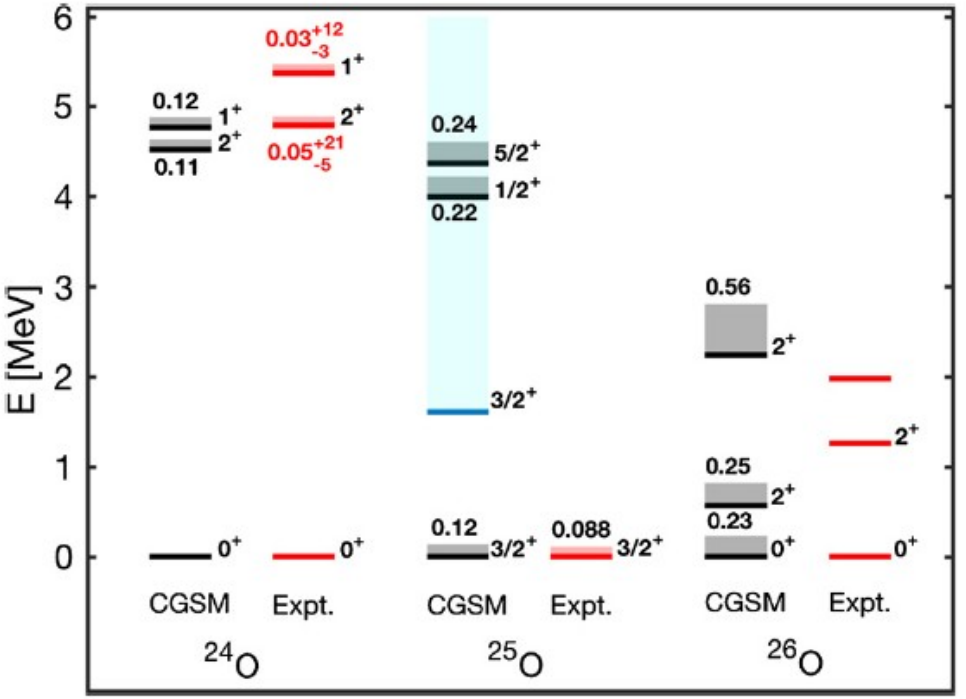
→ No Core GSM: chiral-EFT interaction, benchmarked with exact approach, nuclei with A<=5 so far.

→ Coupled Cluster in the Berggren Basis

Continuum/Berggren basis approaches



K. Fossez, J.R, N. Michel, W. Nazarewicz, PRC 2017



Z.H. Sun, Q. Wu, Z.H. Zhao, B.S. Hu , S.J. Dai, F.R. Xu, PLB 2017