Exploring sd-shell nuclei from two- and three-nucleon interactions with realistic saturation properties

Johannes Simonis

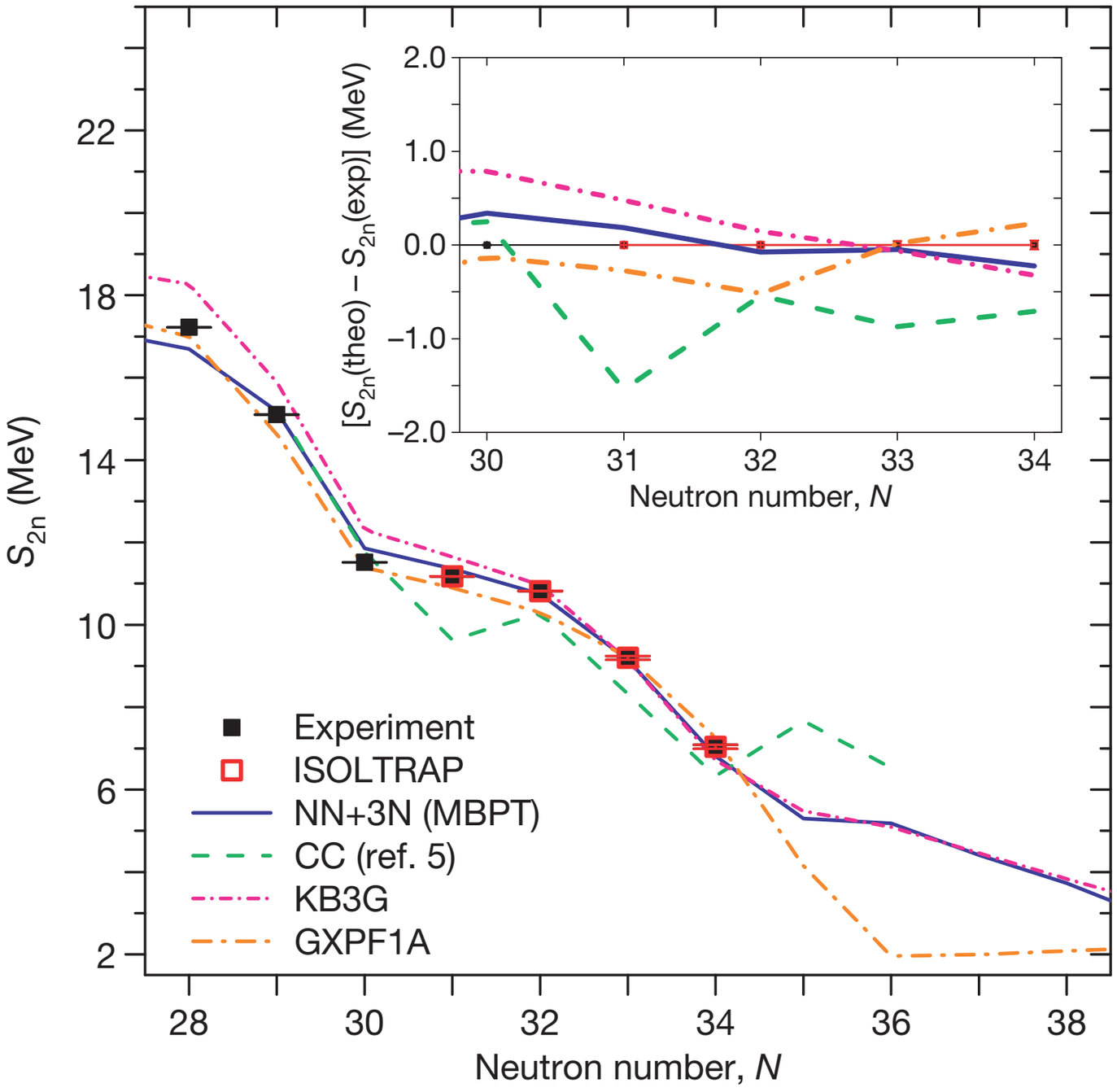
Institut für Kernphysik, TU Darmstadt & ExtreMe Matter Institute EMMI, GSI

with Kai Hebeler, Achim Schwenk (EMMI/ TU Darmstadt)
Jason D. Holt (TRIUMF)
Javier Menéndez (University of Tokyo)

TRIUMF, Vancouver

Progress in Ab Initio Techniques in Nuclear Physics, February 19th, 2015

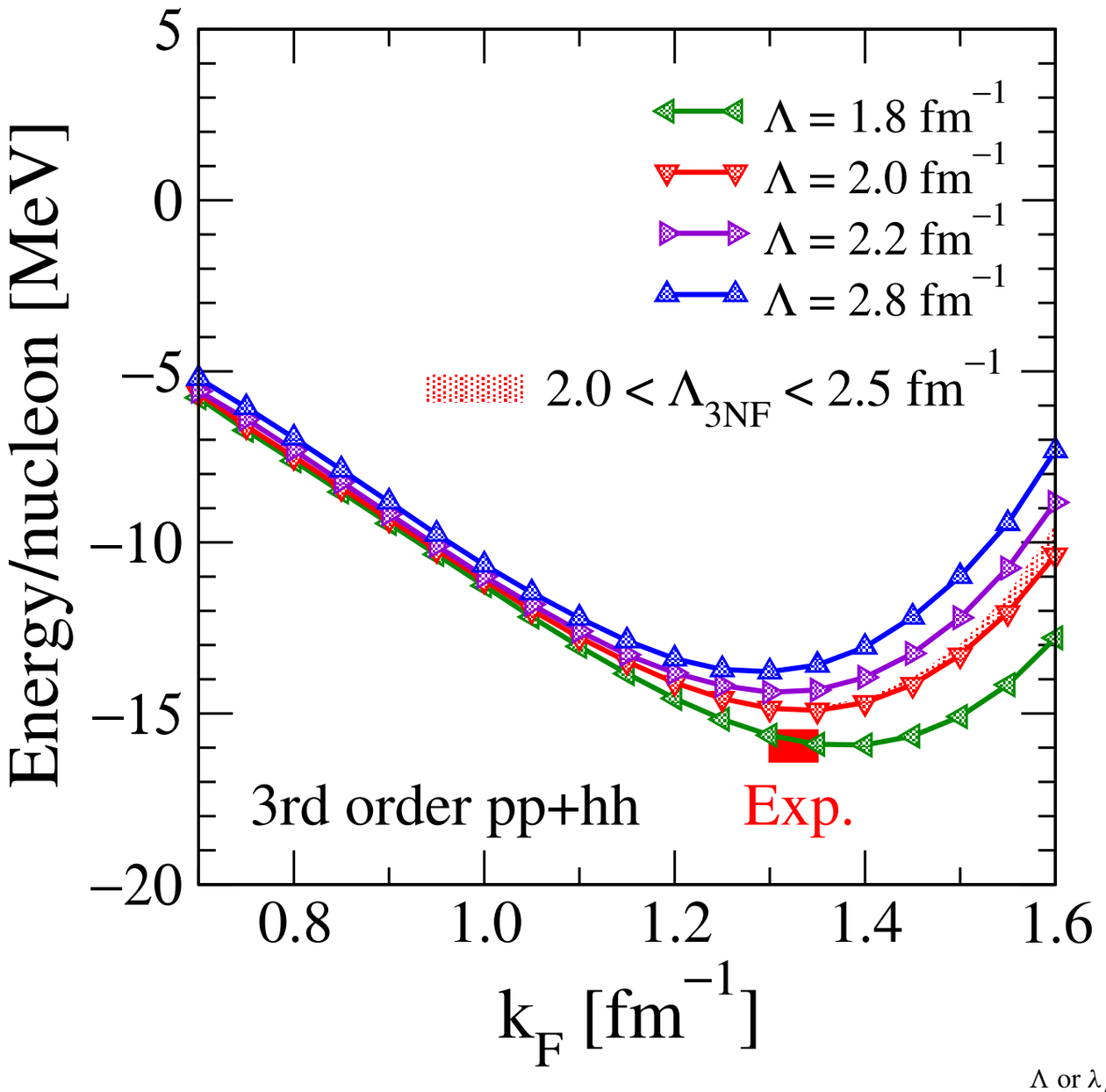
Motivation



- Excellent agreement with new ^{53,54}Ca separation energies measured at ISOLTRAP/ISOLDE
- Clearly establish N=32 shell closure
- But: Results based on a single-resolution scale!

Wienholtz *et al.*, Nature **498** 346 (2013).

Input Hamiltonian



- Realistic saturation properties within theoretical uncertainties

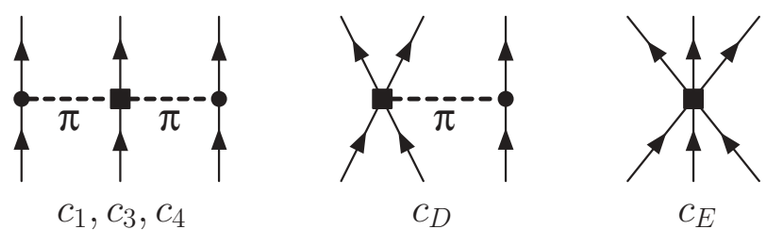
- Evolve N^{3}LO NN potential EM 500 MeV to low-momentum interaction $V_{low\ k}$

- For each $V_{low\ k}$ cutoff Λ fit two couplings c_D,c_E to $E(^3H)$ and $r(^4He)$ using non-local regulator

- In addition, vary 3N cutoff Λ_{3NF} independently of Λ

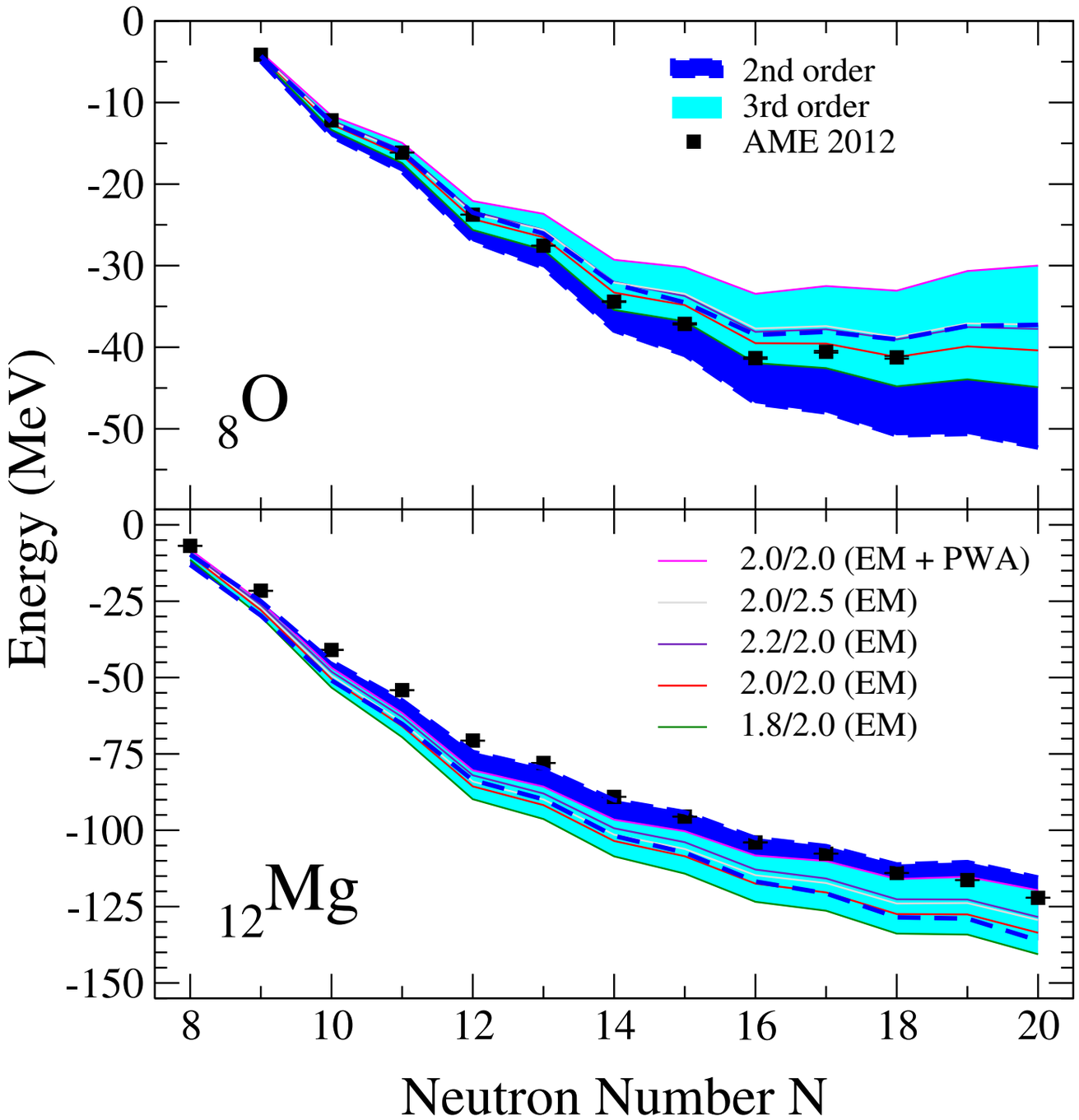
- Include uncertainties in c_i's by using PWA values in 3N force

	$V_{low\,k}$	
Λ or λ/Λ_{3NF} (fm)	c_D	c_E
1.8/2.0 (EM c_i's)	+1.621	−0.143
2.0/2.0 (EM c_i's)	+1.705	−0.109
2.0/2.5 (EM c_i's)	+0.230	−0.538
2.2/2.0 (EM c_i's)	+1.575	−0.102
2.8/2.0 (EM c_i's)	+1.463	−0.029
2.0/2.0 (EGM c_i's)	−4.381	−1.126
2.0/2.0 (PWA c_i's)	−2.632	−0.677



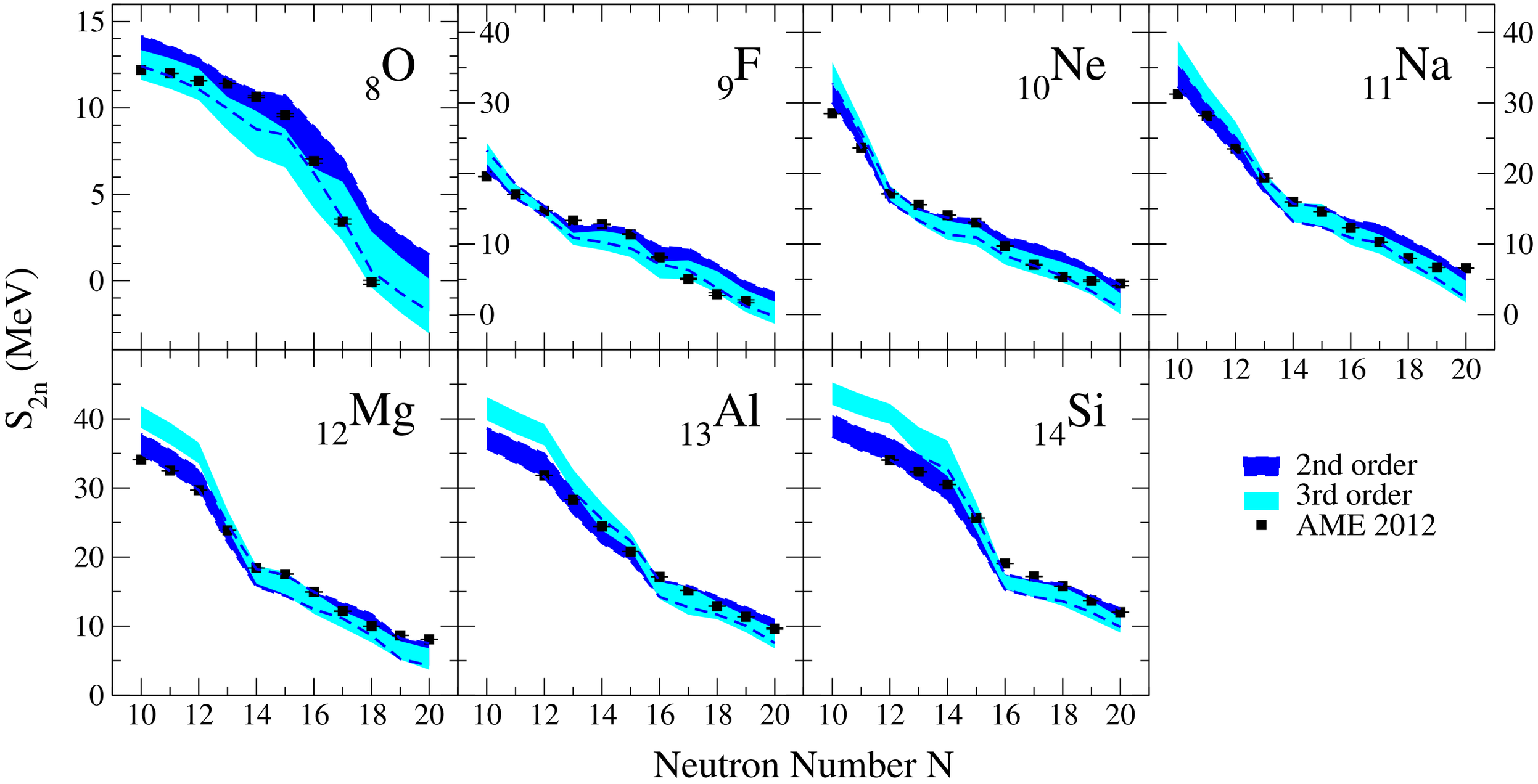
Hebeler *et al.*, Phys. Rev. C **83** 031301(R) (2011).

Ground-state energies



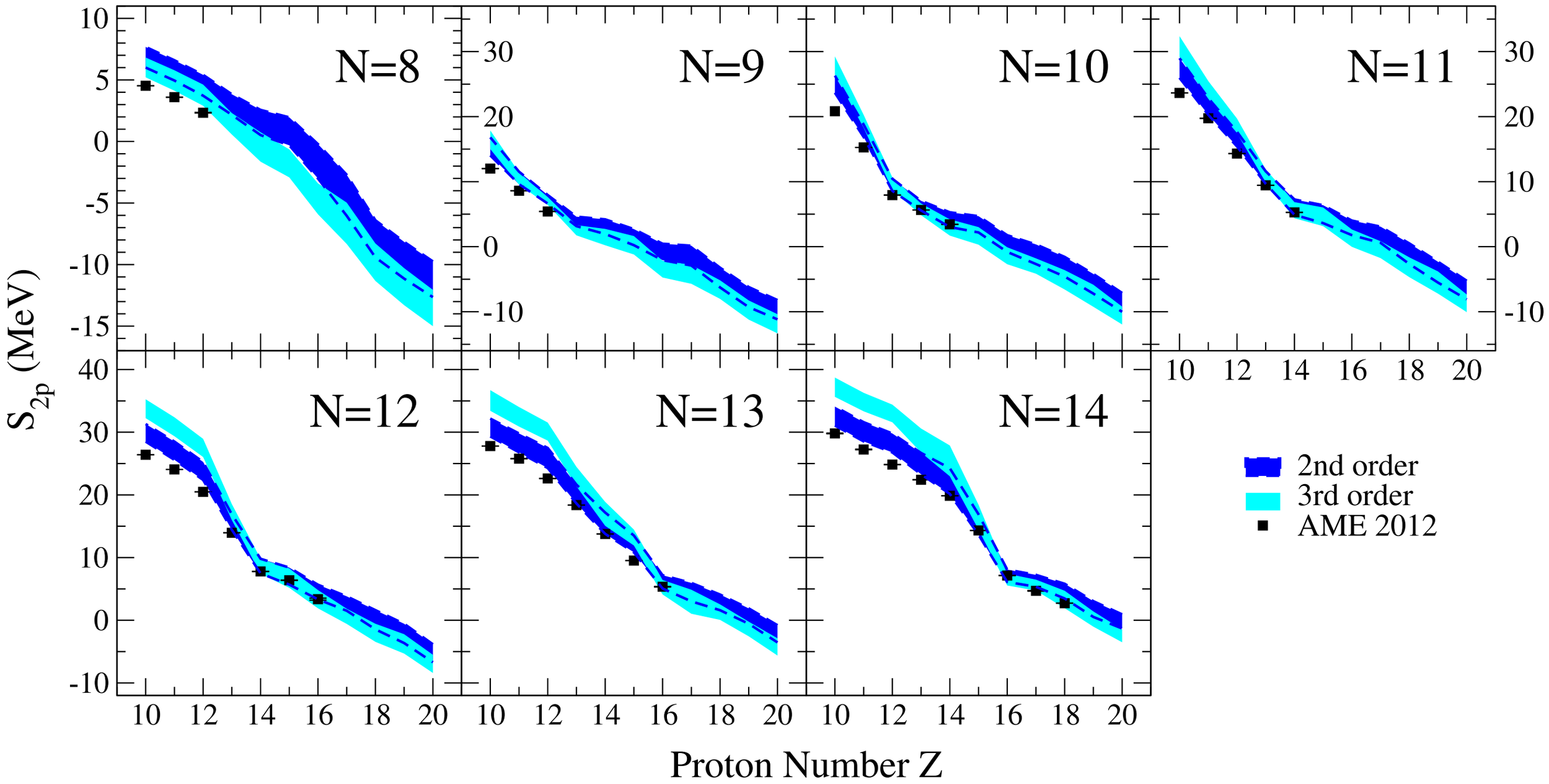
- Single-particle energies and two-body matrix elements calculated to 2nd and 3rd order in MBPT
- Uncertainty due to input Hamiltonian 1.2 MeV per valence particle in ^{28}O
- Difference between 2nd- and 3rd-order results 0.6 MeV per valence particle in ^{28}O
- Overbinding in Mg due to pn (T=0) part of the effective interaction

Two-neutron separation energies



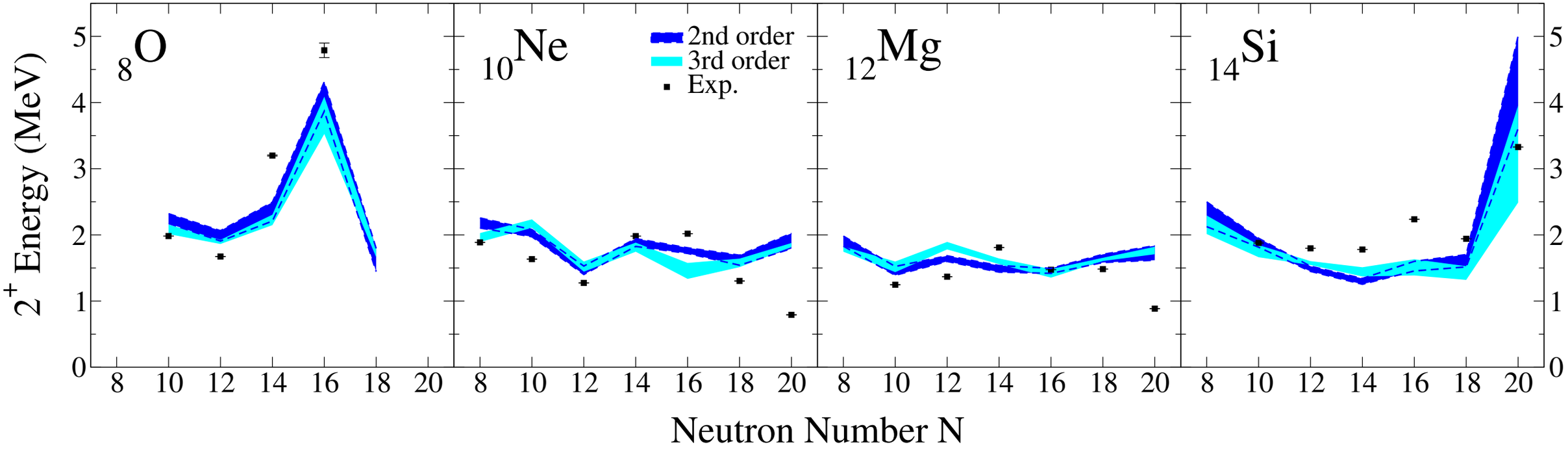
- Uncertainty of ~5 MeV for neutron-rich isotopes, dominated by input Hamiltonian
- For some $N \leq Z$ isotopes many-body uncertainty comparable, in total ~10 MeV

Two-proton separation energies



- Experimental trends of proton-rich isotones are reasonably well reproduced
- S_{2p}'s are over predicted for proton-deficient isotones by 1-3 MeV

2^+ excitation energies



- Uncertainty from input Hamiltonian typically a few hundred keV

- Not all experimental excitation energies are reproduced,
  especially deformed 2^+ states in ^{30}Ne, ^{32}Mg not described in sd-shell calculations