Location of the Neutron Dripline at Fluorine and Neon

How does mass formula predict the dripline?

$$E = mc^2$$

separation energy:

$$S_n = B(A, Z) - B(A-1, Z)$$

when $S_n, S_{2n} > 0$,the nucleus is bound.

How to test the accuracy of the model ?

- the accuracy in predicting the dripline
- the root-mean-square deviation of mass or S_n

$$\mathrm{rms} = \left[\frac{1}{n}\sum_{i=1}^{n}\left(M^i_{\mathrm{exp}} - M^i_{\mathrm{th}}\right)^2\right]^{\frac{1}{2}}$$

Finite Range Droplet Model (FRDM) 1984-2012

$$E(Z, N, \text{shape}) = E_{\text{mac}}(Z, N, \text{shape}) + E_{\mathrm{s+p}}(Z, N, \text{shape})$$

E_{mac} :macroscopic term, the droplet part.

liquid drop model includes Volume term, Surface term, Asymmetry term, Pairing term, Coulomb term.

Similarity between a liquid drop and a nucleus:

- The nuclear mass density is a constant throughout the volumn, and drops to zero near the boundary surface.
- Each nucleon inside the nucleus interacts strongly with its nearest neighbouring nucleons, like molecules do in a liquid.
- Both liquid drop and nucleus show surface tension effect.

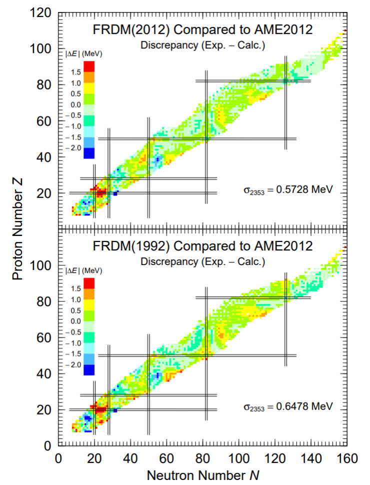
add an exponential term $E_{exp} = -CAe^{-\gamma A^{1/3}}\bar{\varepsilon}$ to improve compressibility effect.

minimize $\bar{\delta}$ and $\bar{\varepsilon}$ to get the parameters.

$E_{\mathrm{s+p}}$:shell and pairing correction. use folded Yukawa single potential and Nilsson-Strutinsky method.

Möller, P.etc.; Mass Formula with a Finite-Range Droplet Model and a Folded-Yukawa Single-Particle Potential.

Results



Möller, P.; Myers, W. D.; Sagawa, H.; Yoshida, S. New Finite-Range Droplet Mass Model and Equation-of-State Parameters. Phys. Rev. Lett. 2012, 108 (5)

KTUY: a spherical basis model

$M(Z,N) = M_{\text{gross}}(Z,N) + M_{\text{eo}}(Z,N) + M_{\text{shell}}(Z,N)$

$M_{\text{gross}}(Z,N)$: gross term, include volumn, surface, wigner, asymmetry, coulomb term.

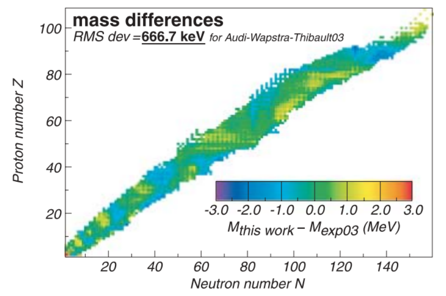
$M_{\text{eo}}(Z,N)$:even-odd term

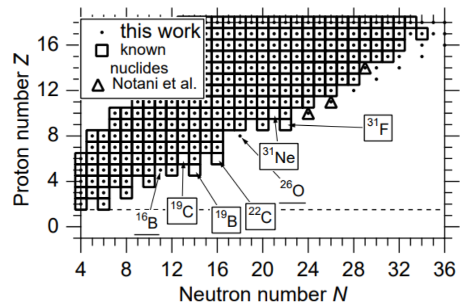
$M_{\text{shell}}(Z,N)$:Consider deformation the basis of spherical nucleus.

- start from single-particle potentials, add them to get crude energy
- modify crude energy: BCS pairing
- refined spherical shell energy :apply phenomenological reduction to these modified shell energy
- the final shell energy(for deformed nucleus):mix refined spherical shell energies in a suitable way

Koura, H.; Uno, M.; Tachibana, T.; Yamada, M. Nuclear Mass Formula with Shell Energies Calculated by a New Method. Nucl. Phys. A 2000, 674 (1–2), 47–76

Results

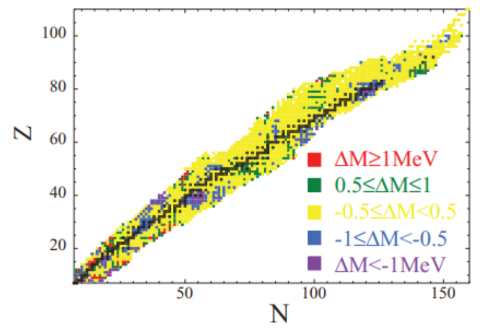




Koura, H.; Tachibana, T.; Uno, M.; Yamada, M. Nuclidic Mass Formula on a Spherical Basis with an Improved Even-Odd Term. Prog. Theor. Phys. 2005, 113 (2), 305–325.

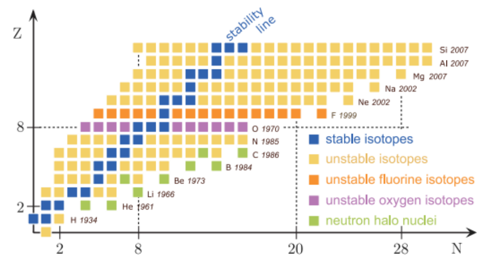
Hartree–Fock–Bogoliubov Model

use skyrme forces and pair force;
add phenomenological Wigner terms;
use HFB method to calculate.
rms=0.500MeV



Goriely, S.; Chamel, N.; Pearson, J. M. Hartree-Fock-Bogoliubov Nuclear Mass Model with 0.50 MeV Accuracy Based on Standard Forms of Skyrme and Pairing Functionals. Phys. Rev. C 2013, 88 (6), 061302.

Microscopic mass predictions by large scale shell model



shell model : nuclear properties can be described in terms of neutron and proton coordinates and in these coordinates the nuclear Hamiltonian contains at most two body interactions.

introduce three-body forces: the heaviest oxygen isotope ^{24}O.

Otsuka, T.; Suzuki, T.; Holt, J. D.; Schwenk, A.; Akaishi, Y. Three-Body Forces and the Limit of Oxygen Isotopes. Phys. Rev. Lett. 2010, 105 (3), 032501