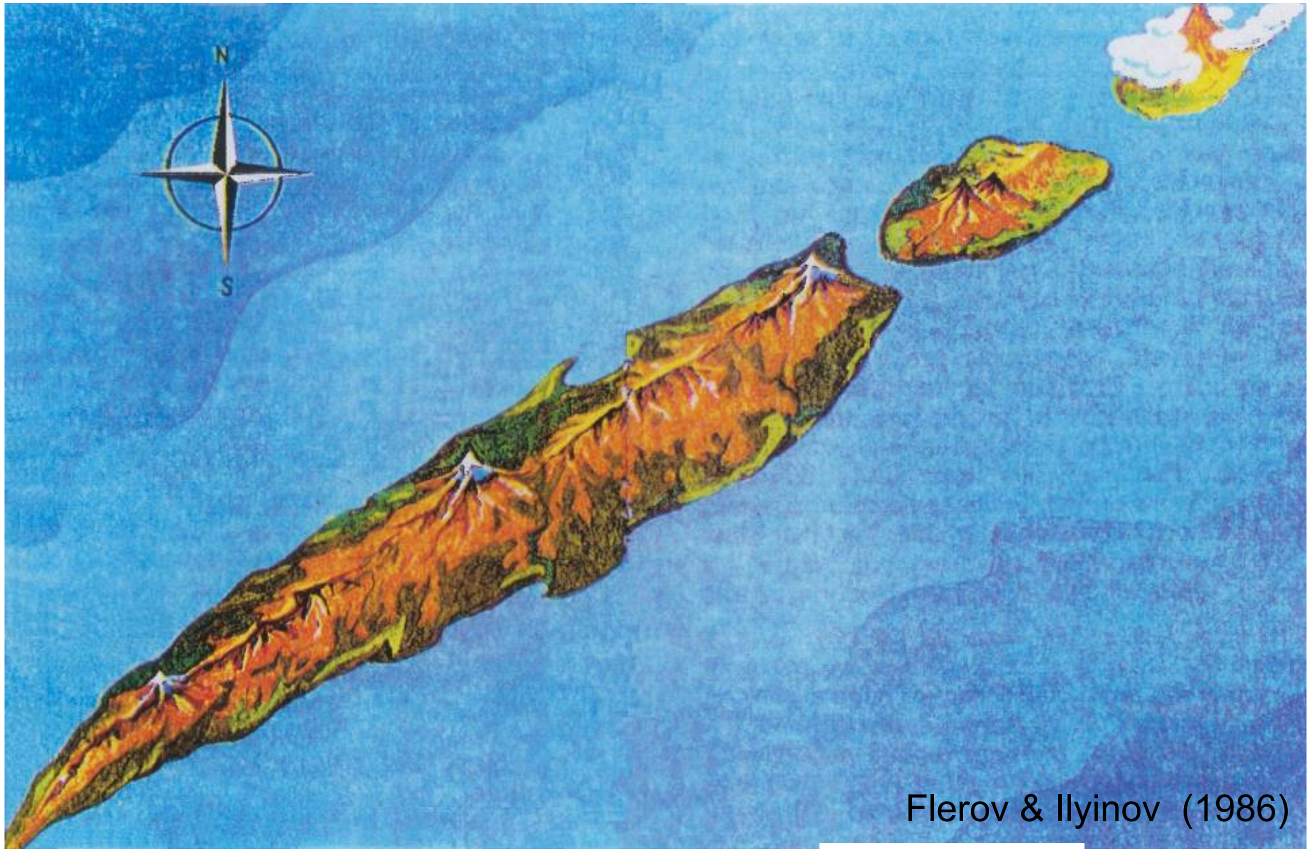
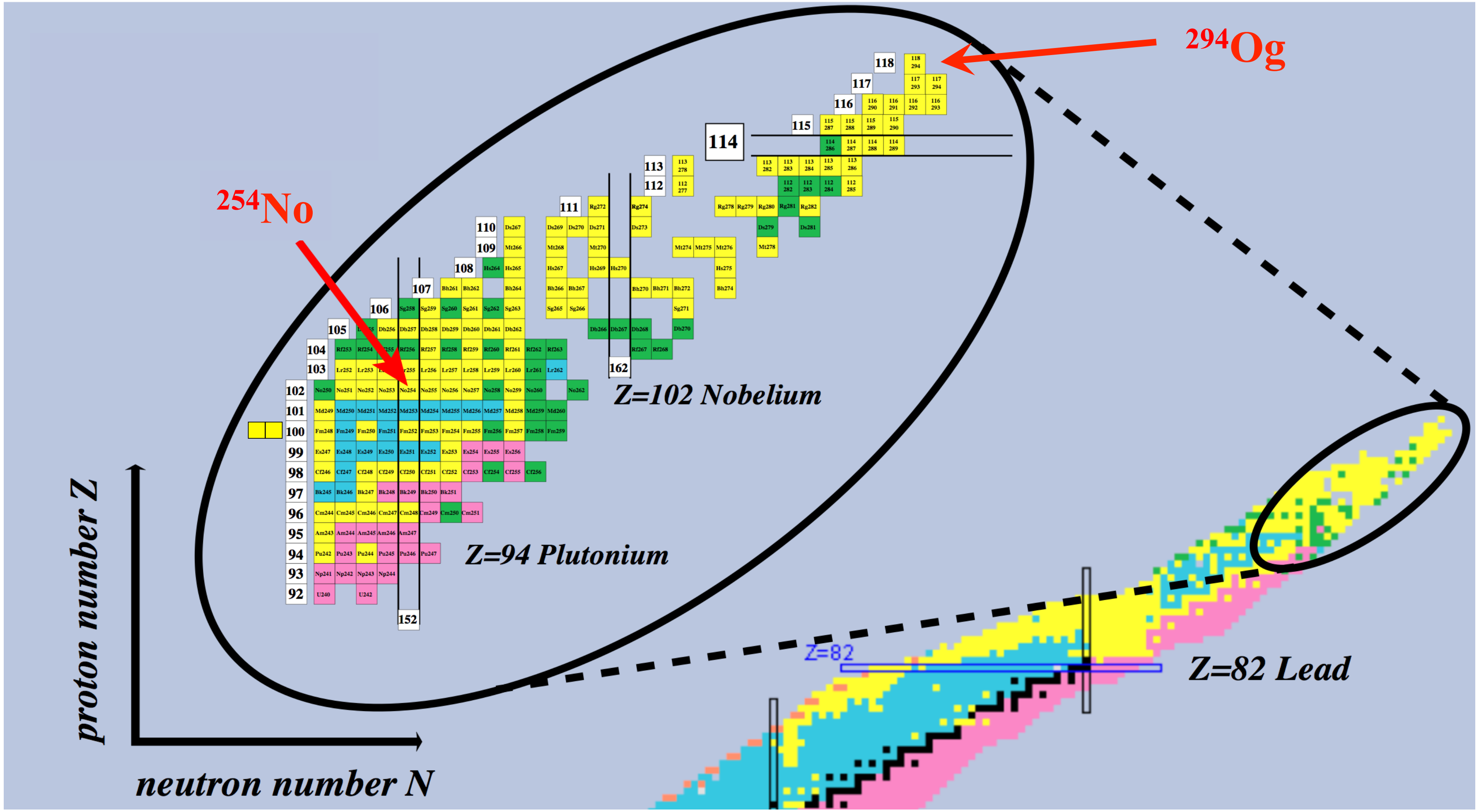
Super heavy nuclei: open questions
(from a structure point of view…)



Flerov & Ilyinov (1986)

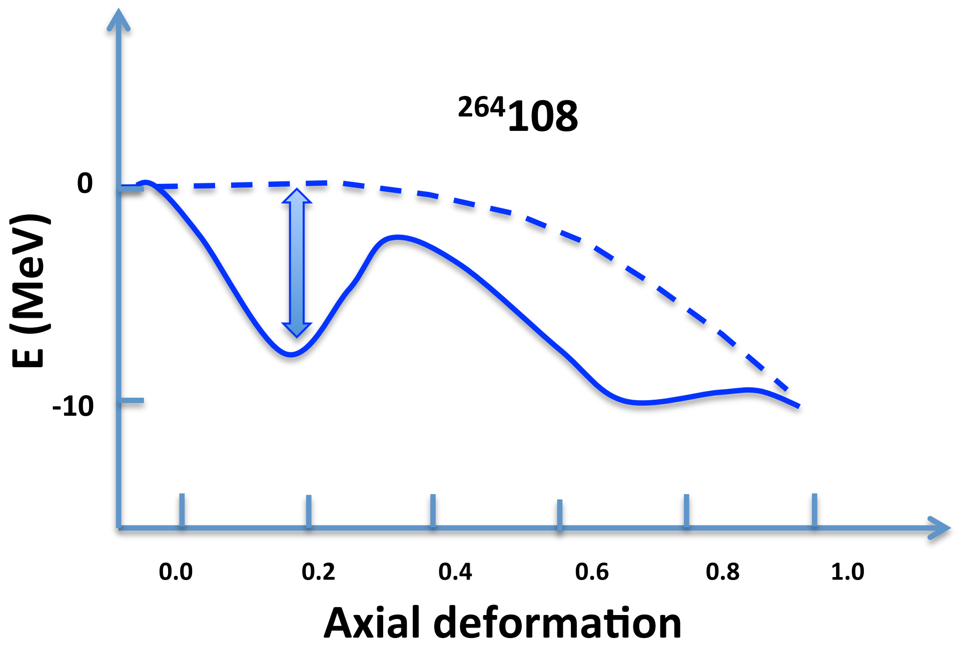
Region of Interest



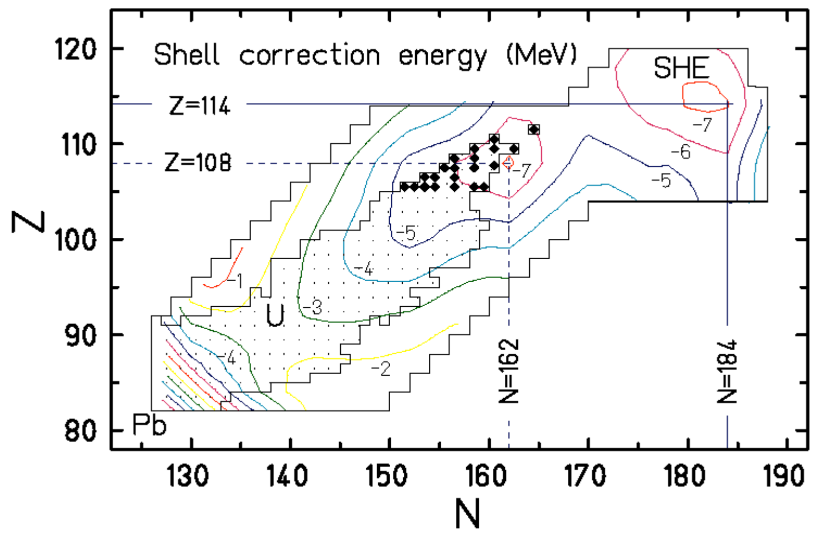
Properties of matter in extreme conditions of mass & charge ?
Limits of the nuclear chart ?

Special Nuclei

The heaviest nuclei owe their stability against spontaneous fission to quantum shell effects

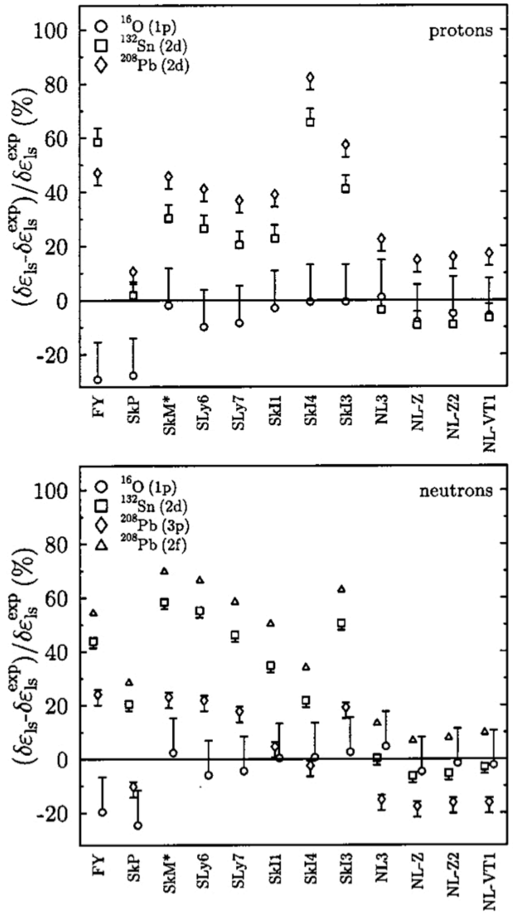


R. Smolanczuk, Phys. Rev. C56 (1997) 812

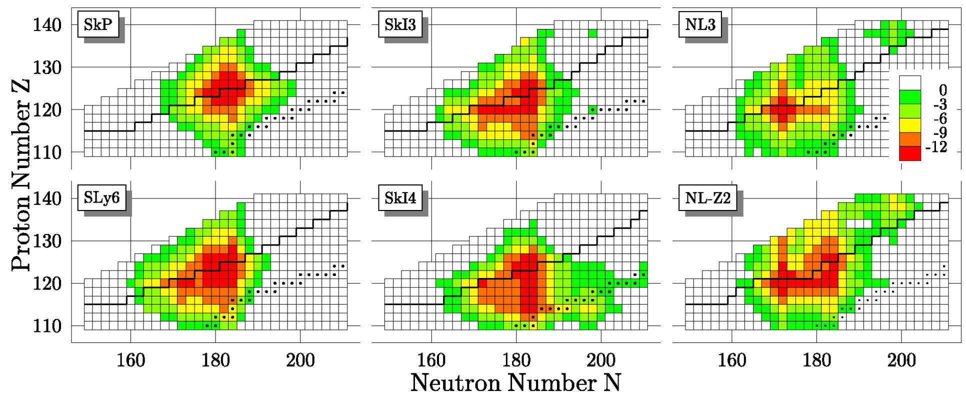


Magicity of super heavy nuclei

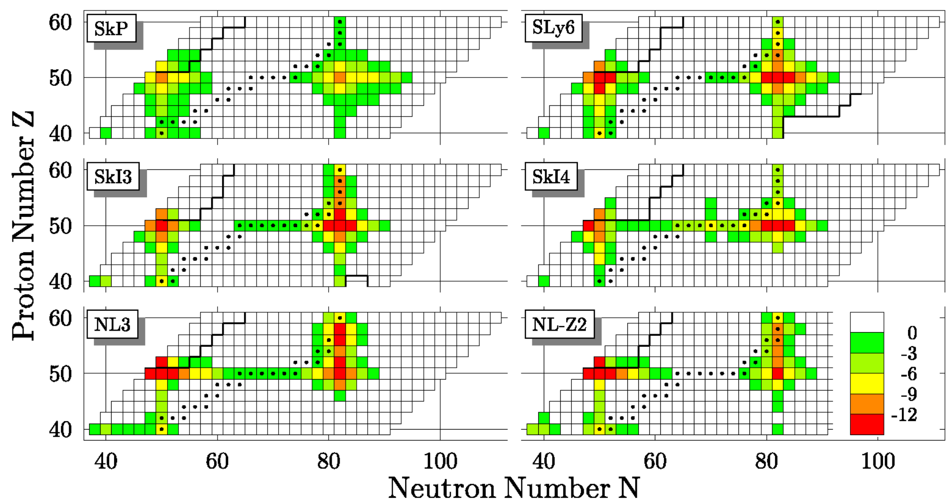
M. Bender et al., Phys. Rev. C 60 (1999) 034304



Maximal shell correction spread over a broad region of N & Z

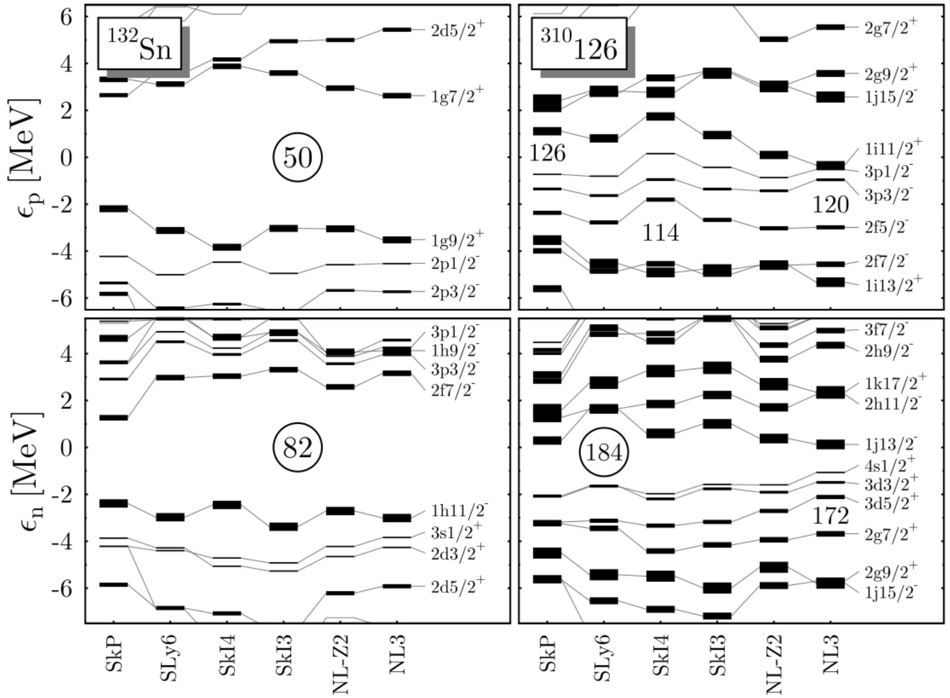


M. Bender et al., Phys. Lett. B 515 (2001) 42



Z = 114 shell closure only appears in models which overestimate the spin-orbit splitting in heavy nuclei by more than ~ 40%

Shell structure of SH nuclei

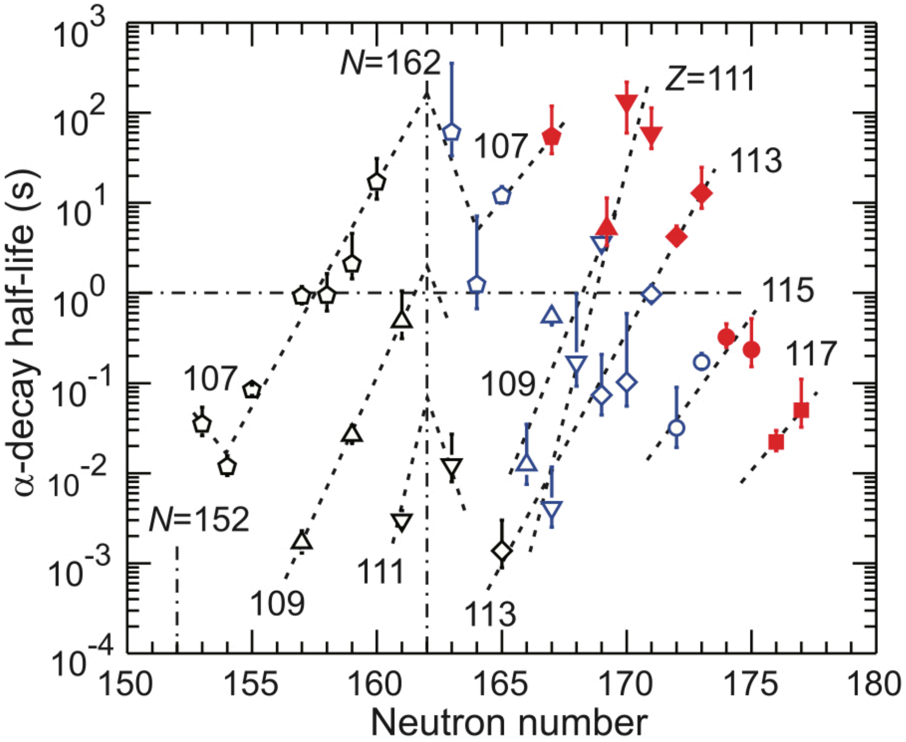


M. Bender et al., Phys. Lett. B 515 (2001) 42

Magnitude of gaps in single particle spectra is small

General consensus on N=184 neutron gap

Supported by increasing half-lives of the heaviest nuclei with N

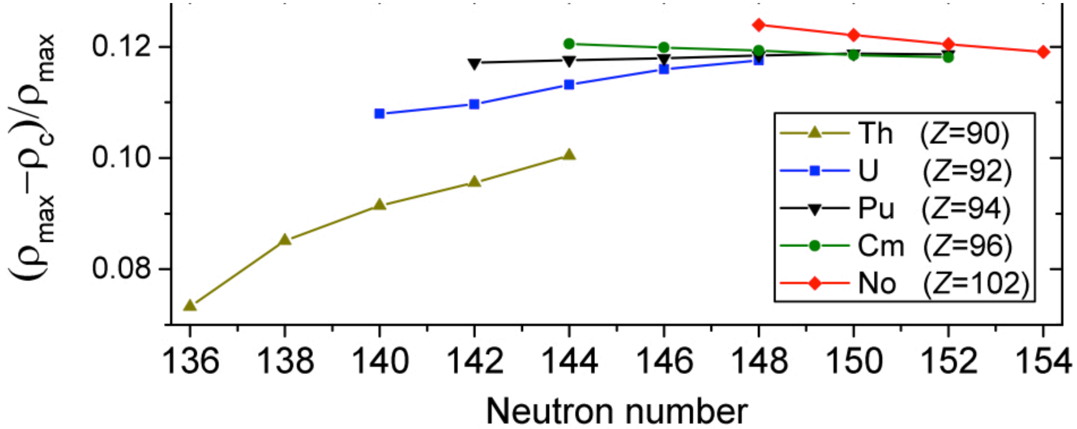


Yu.Ts. Oganessian, et al., Phys. Rev. C 87 (2013) 054621

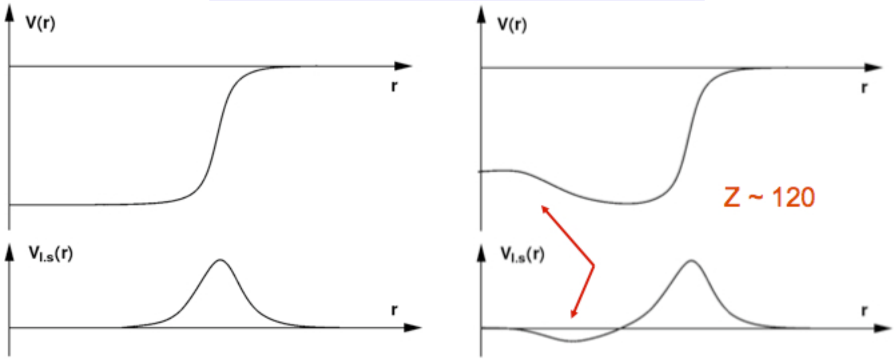
Theoretical challenge

- Large density of states
- Strong Coulomb field

S. Raeder et la., Phys. Rev. Lett. 120 (2018) 232503

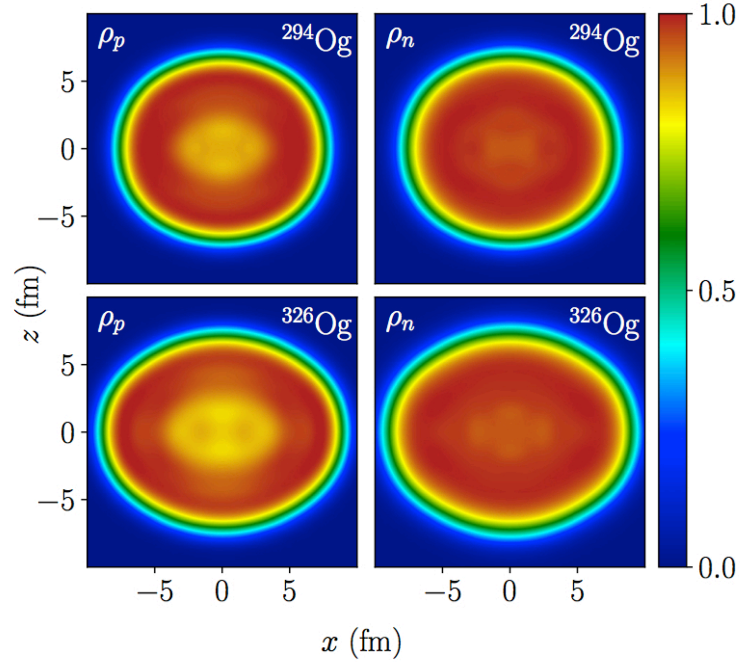


$$V_{l.s}(r) = -\frac{1}{r}\frac{\partial V(r)}{\partial r}$$



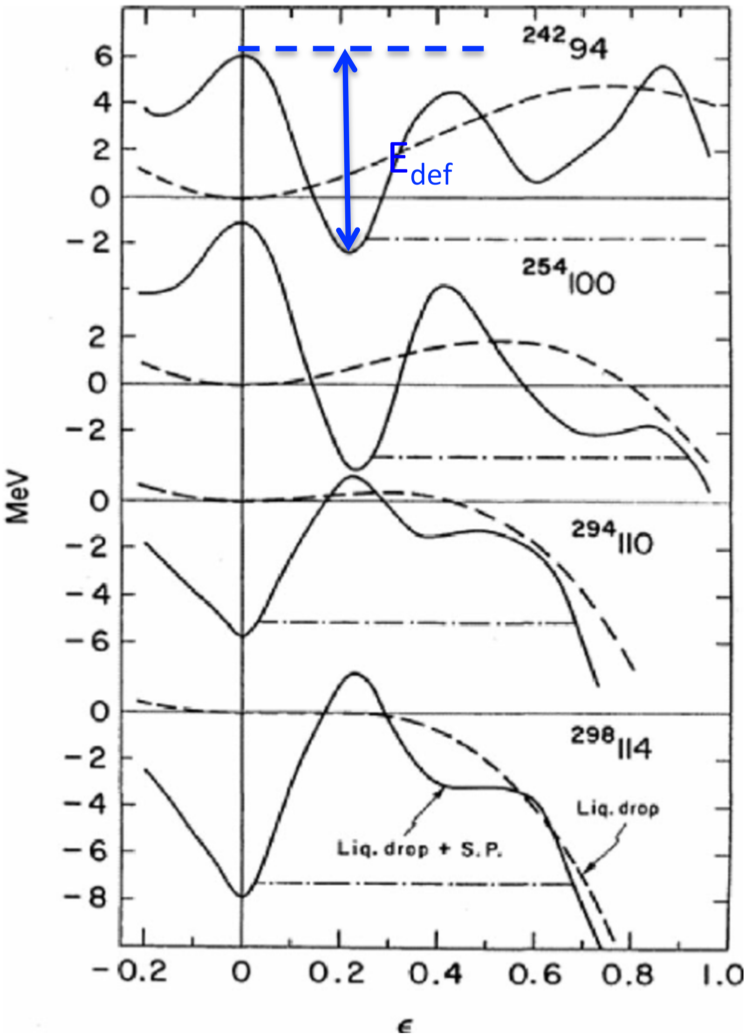
Total spin-orbit spliting depends on the location of the radial wavefunctions

B. Schuetrumpf et al., Phys. Rev. C 96 (2017) 024306

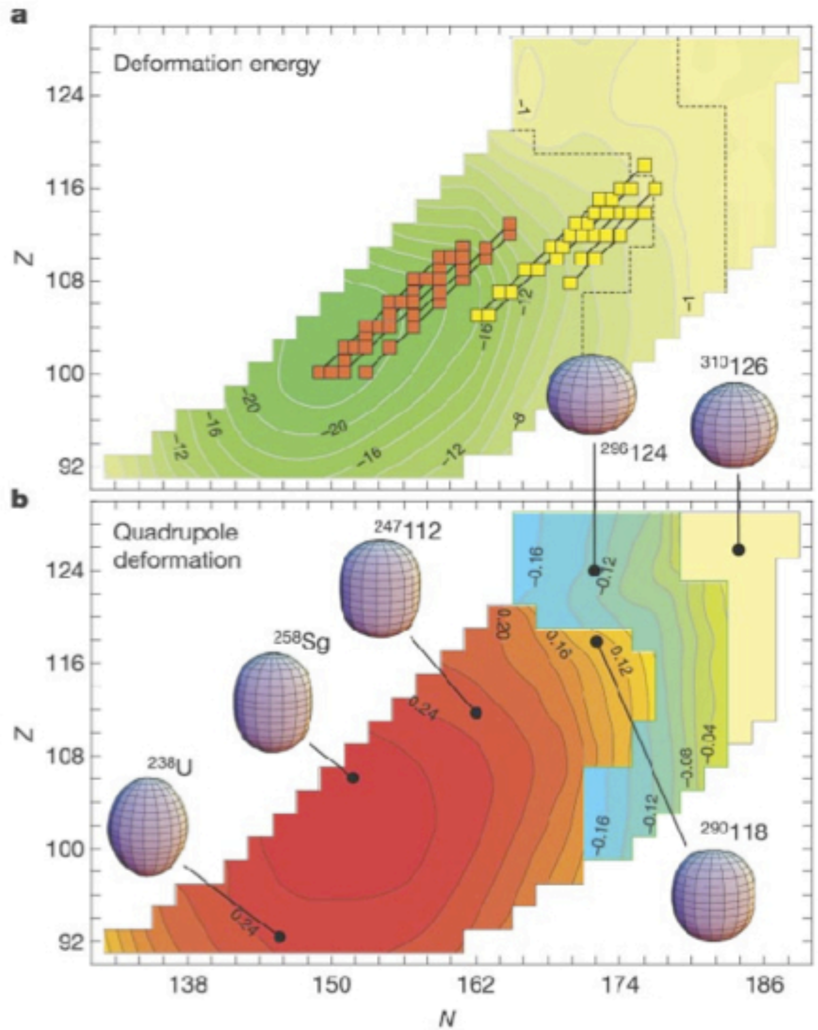


Deformed axial shapes

C.F. Tsang and S.G. Nilsson Nucl. Phys. *A* 140, 289 (1970)



S. Ćwiok, P.-H. Heenen, W. Nazarewicz, Nature 433 (2005) 709



Qualitatively similar results in most models

Experimental shapes & sizes

Coulex with α-particles:

^{252}Cf: B(E2) ↑ = 16.7(1.1) e^2b^2

⇨ Q_0 = 12.9(0.4) b

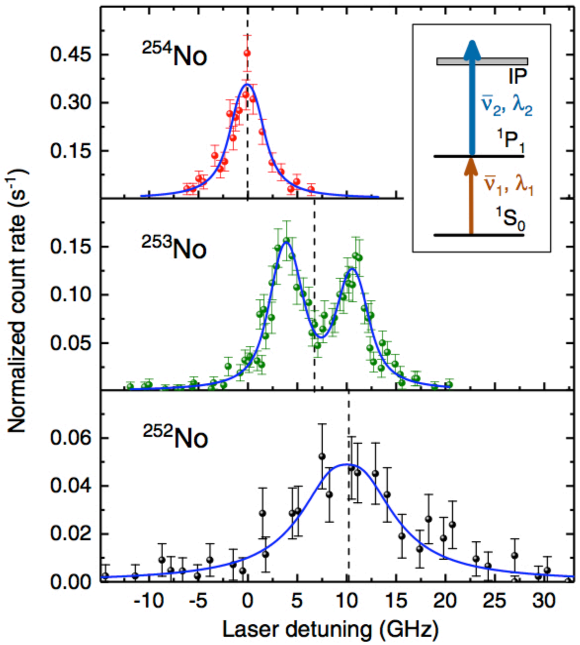
J.L.C. Ford et al., Phys. Rev. Lett. 27 (1971) 1232

Laser spectroscopy:

^{253}No Qs(gs:9/2)= 5.9(1.4)(0.9) b

⇨ Q_0 = 10.8(2.6)(1.6) b

S. Raeder et la., Phys. Rev. Lett. 120 (2018) 232503



Atomic beam magnetic resonance:

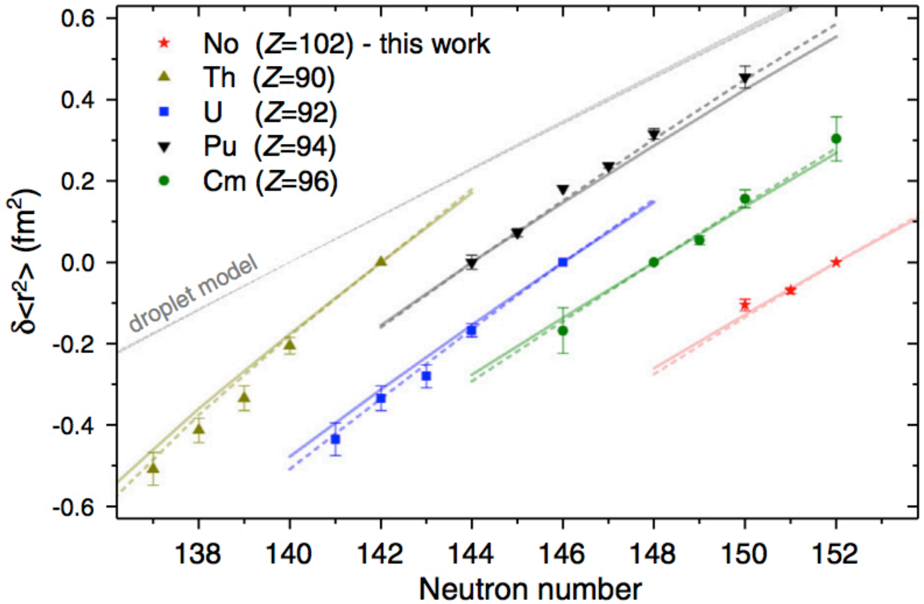
^{254m}Es: Q_s(2+) = 3.7(5) b

⇨ Q_0 = 12.9(1.6) b

^{253}Es: Q_s(gs:7/2+) = 6.7(8) b

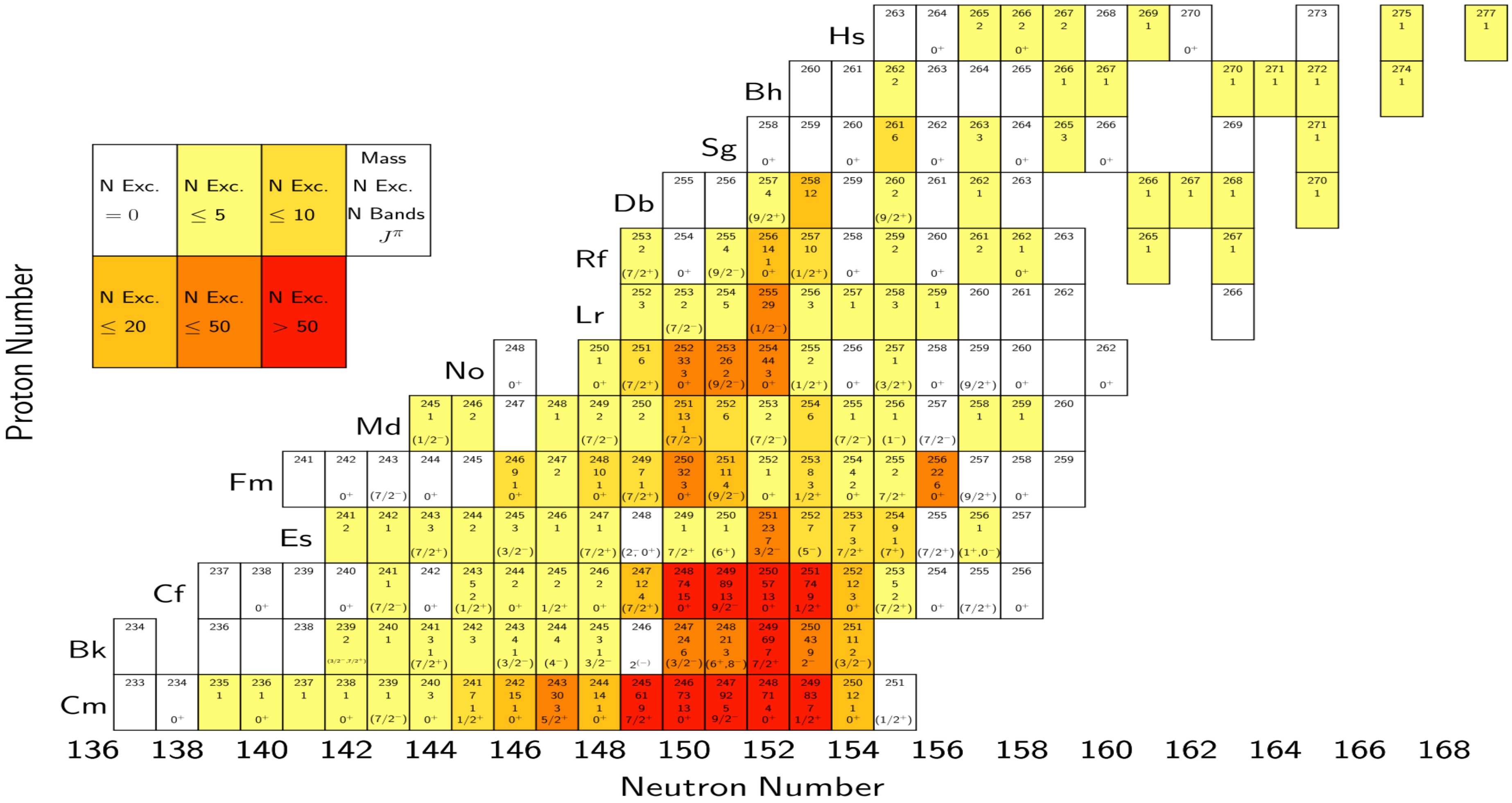
⇨ Q_0 = 14.3(1.7) b

L.S. Goodman et al., Phys. Rev. A 11 (1975) 499



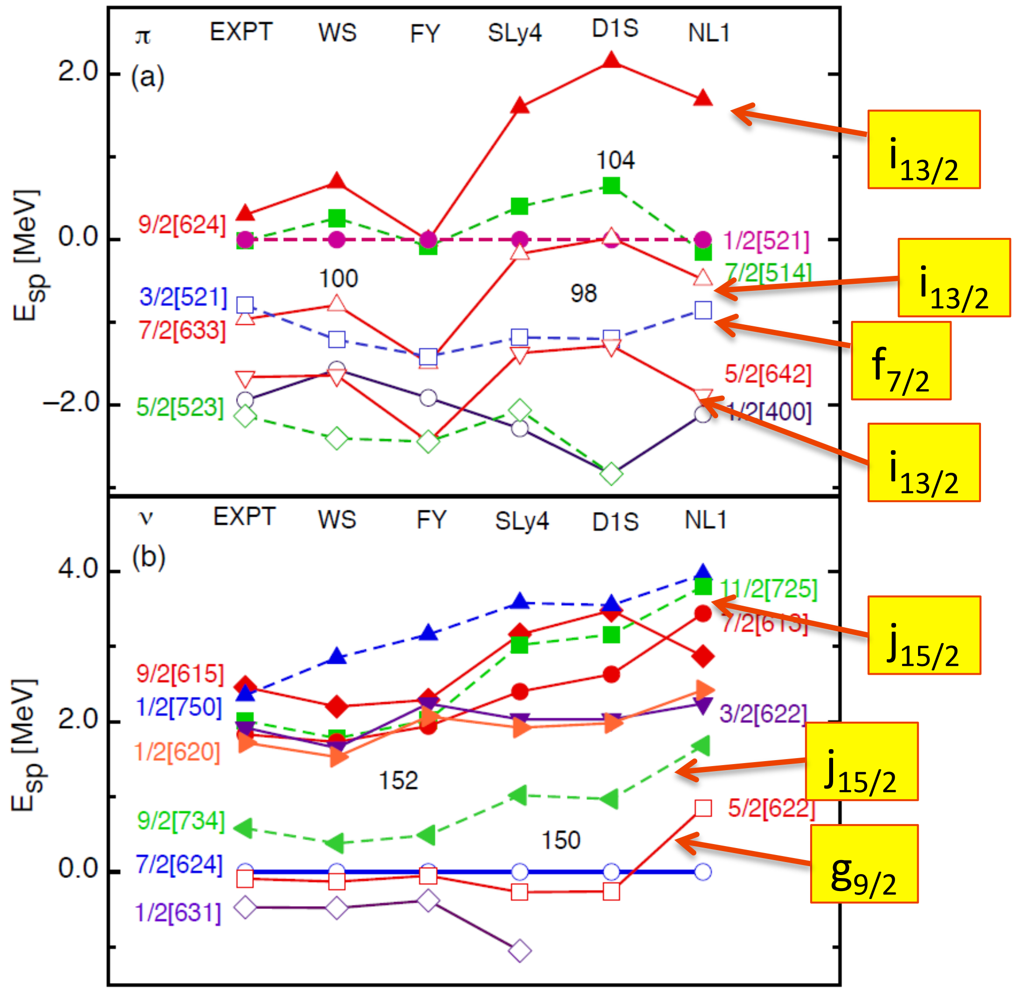
12% central depression in charge density predicted

Spectroscopic information



Ch. Theisen et al., Nucl. Phys. A 944 (2015) 333

Deformed shell structure from fine structure α-decay spectroscopy



T.L. Khoo, private comm.

Single particle energies extracted from quasiparticle energies in ^{247,249}Bk, ^{251}Es & ^{247}Cm, ^{251}Cf

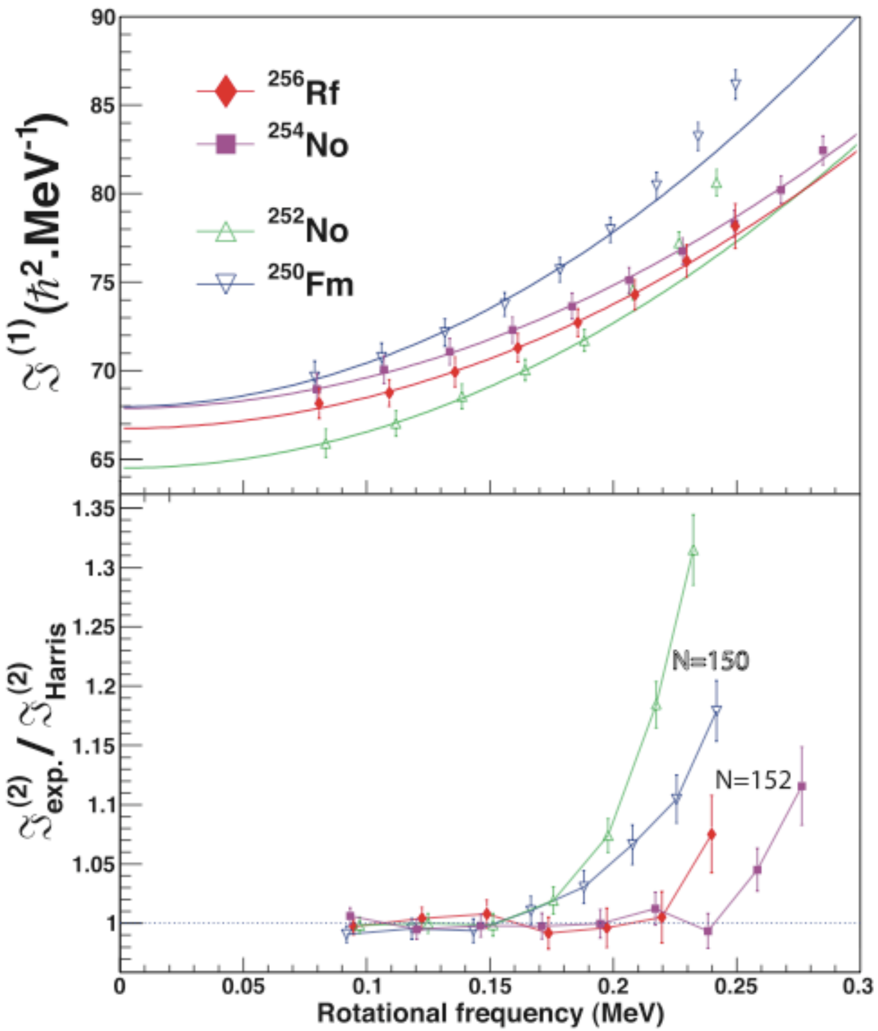
Origin of the deficiencies of DFTs ?

Single-particle nature of observed states ?

Evolution with Z & N ?

Dynamic properties

P.T. Greenlees, Phys. Rev. Lett. 109 (2012) 012501



Magnitude of $\Im$ sensitive to pairing

Sensitivity to the presence of high j orbitals at the Fermi surface

Predicted backbends just above the current observational limit

Alignment blocking in odd nuclei

Conclusions & perspectives

More & more detailed data is clearly needed to benchmark theories (Z & N evolution is crucial)

What relevant (model independent) observables are there to compare with theory or/and constrain theory with?

Combined prompt & decay spectroscopy can give more information: decay modes and branching ratios, isomers, resonances, fission barriers,…

Impact of correlations (excitation spectra, masses, transition strengths….) needs to be investigated