Discussion on Nuclear Level Densities

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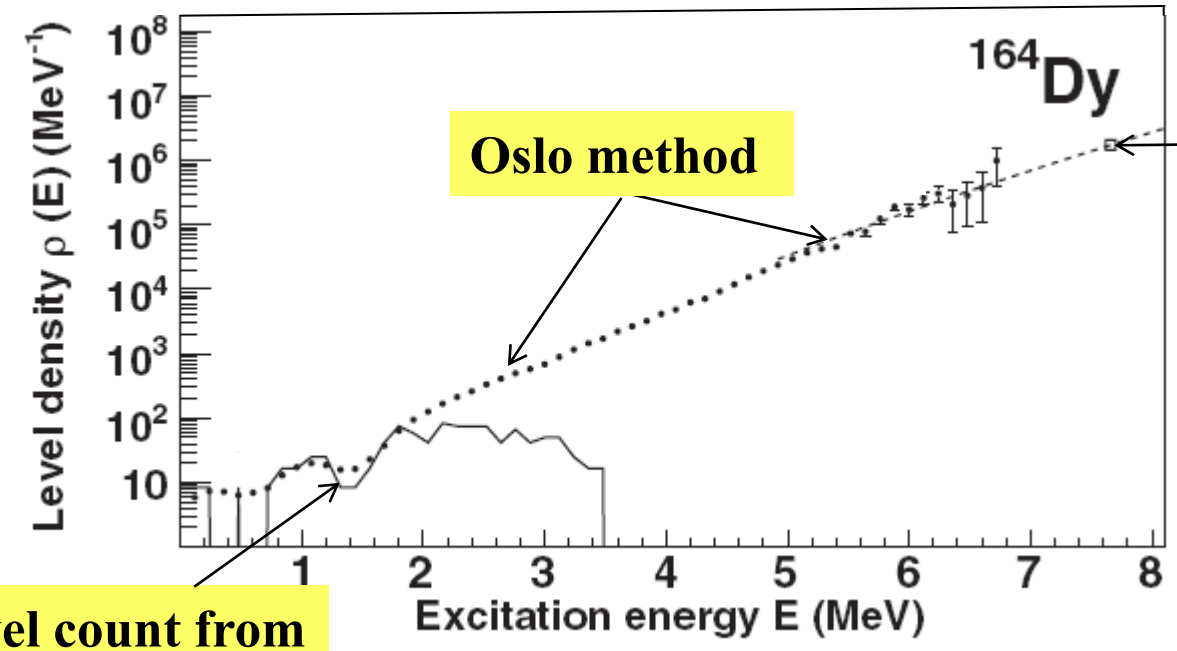
Level densities from experimental data

Level density in finite many-body system: $\rho \propto \exp\left(2\sqrt{aE_{Exc}}\right)$

Experimental information:



Questions on Level Densities

1. Improvements of experimental data:

- **Complete spectroscopy?**
- **Oslo method?**
- **n-resonances?**
- **Can level densities in unstable nuclei be measured?**
- **Level densities on co-existing shapes? Superdeformations?**
- **Level densities above n-resonance.**
- **Level densities at high spin?**

Questions on Level Densities

2. Experimental information on:

- Spin distributions?
- Parity enhancement?
- Angular momentum specific level densities?

Parity and angular momentum dependence

$$\rho(E_{exc}, I, \pi) = P(E_{exc}, \pi) F(E_{exc}, I) \rho(E_{exc})$$

where *P* and *F* project out parity and angular momentum, resp.

In Fermi gas model:

$$P(E_{exc}, \pi) = 0.5$$

$$F(E_{exc}, I) = \frac{I + 0.5}{\sigma^2} \exp\left(- \frac{(I + 0.5)^2}{2\sigma^2} \right)$$

Parity and spin distributions from microscopic models may deviate from Fermi gas model

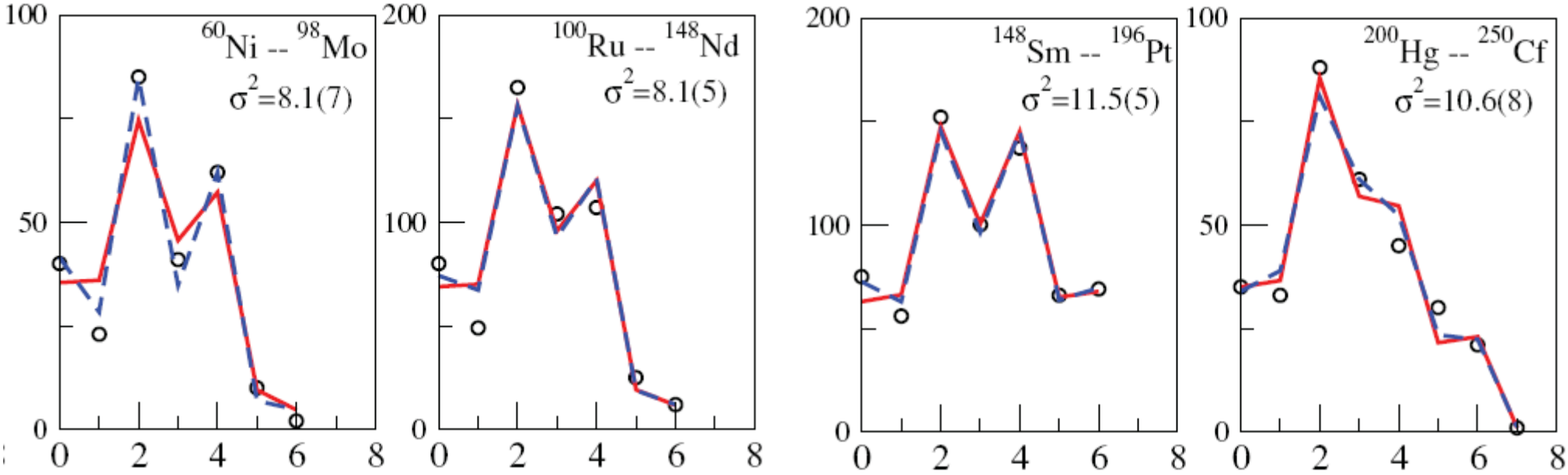
- **also at high E_{exc} (Alhassid)!?**

Experimental data?

Extraction of total level densities from n-sep data?

Observed structure effects in spin distributions [1]

Discrete levels in even-even nuclei – low E_{exc}



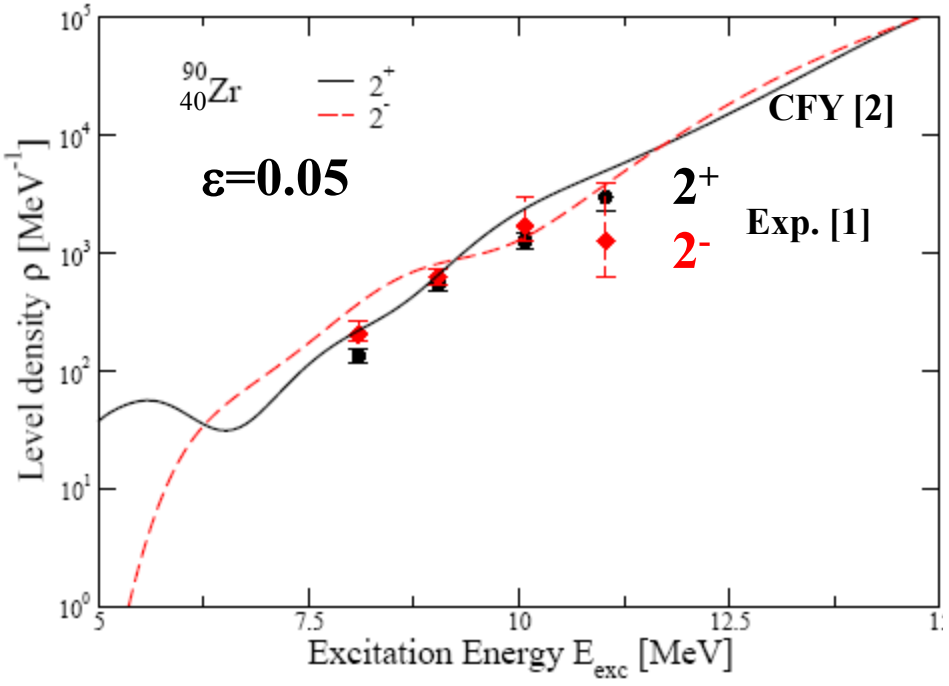
Odd-even staggering!

In even-even nuclei
at low E_{exc} mainly K=0, v=0 states, that is: I=0, 2, 4,…
at high E_{exc} mainly K=0, v=2,4,.. states, that is: I=0, 1, 2, 3,….

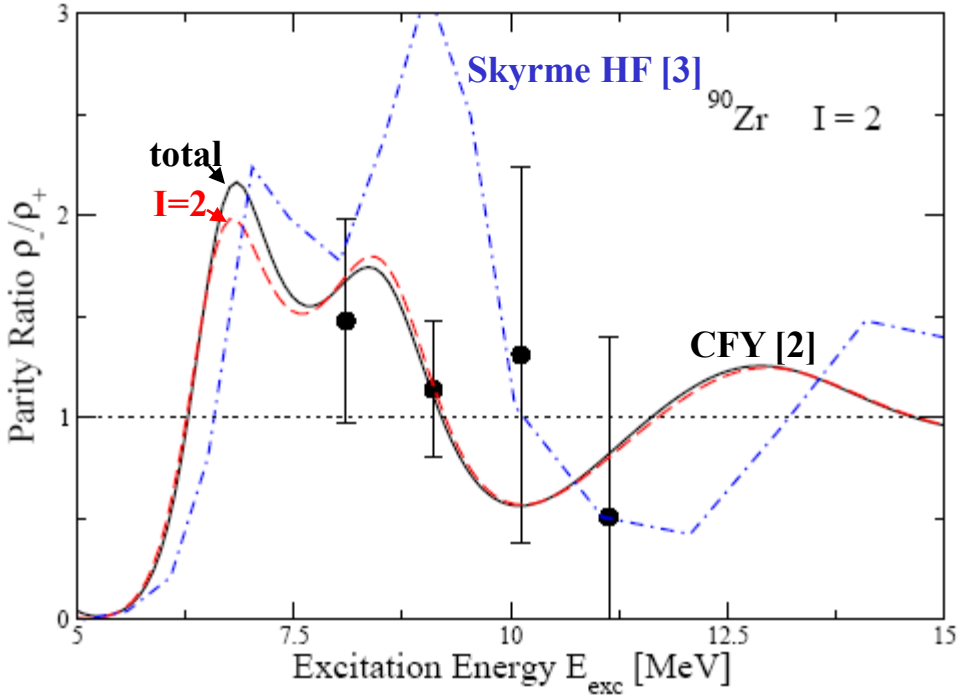
[1] T. von Egidy and D. Bucurescu, PRC 78, 051301 (R) (2008)

Parity enhancement in ^{90}Zr

Individual 2^+ and 2^- level dens.



Parity ratio



[1] High-res E2 (p-scatt.) and M2 (el. scatt.) giant res.
Y. Kalmykov et al Phys Rev Lett 99 (2007) 202502 (Richter exp.)

[2] Combinatorial Folded Yukawa calc.
H. Uhrenholt et al, Nucl. Phys. 2013

[3] Skyrme-Hartree-Fock calc.
S. Hilaire and G. Goriely, Nucl. Phys. A779 (2006) 63

Questions on Level Densities

3. ”Brink hypothesis”

Is it correct that:

”*any* collective decay mode has the same properties built on ground states as on excited states”?

Giant states are very collective and depend on global properties like mass number and deformation.
Low-lying collective states are structure dependent and change from nucleus to nucleus.
Pygmy resonance?
Scissors mode?

Questions on Level Densities

4. Vibrational enhancement of level density

Can n-phonon states (quadrupole and octupole) be built on *all* excited states, where n=1,2,3,4?
Attenuated phonon model gives enhancements of level density a factor 2 - 7.

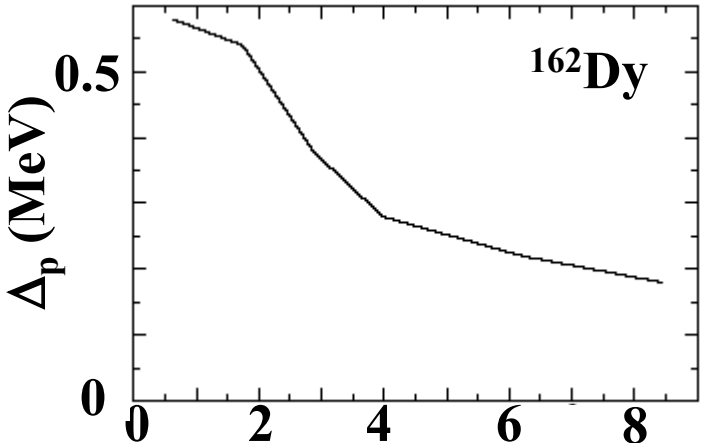
Can Tsonera's model calculation settle this question? Özen's study?

Questions on Level Densities

5. Pairing at high E_{exc}

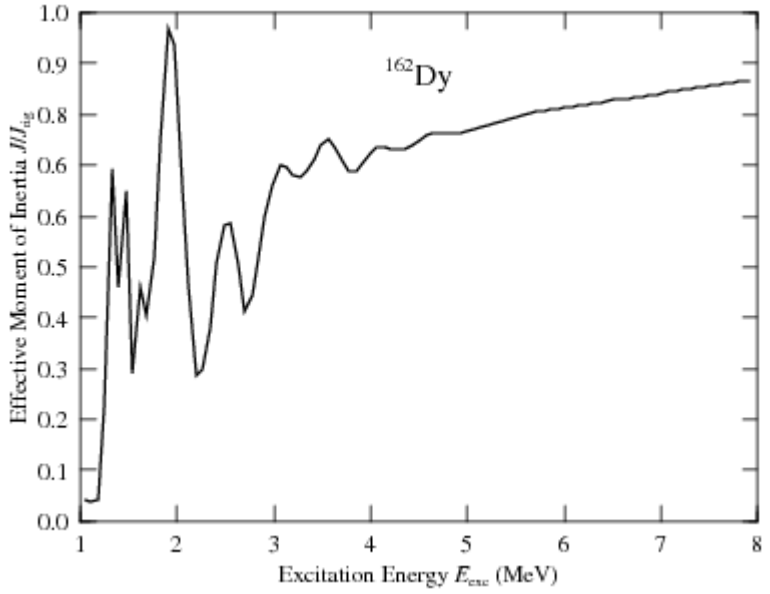
Moretto: Mean pairing gaps remain non-zero above ”phase transition”.
What is the role of pairing at high excitation energies?

Calculation:
mean proton pair gap
vs excitation energy:



Pairing remains at high excitation energies!

Pairing implies a reduced moment of inertia up to high exc. energies:



Can effects from pairing at high E_{exc} be detected?

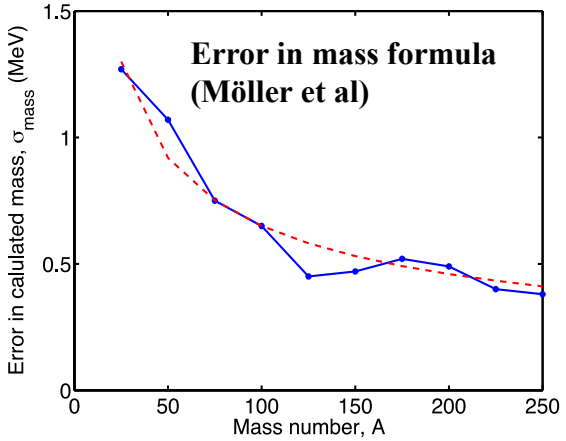
Questions on Level Densities

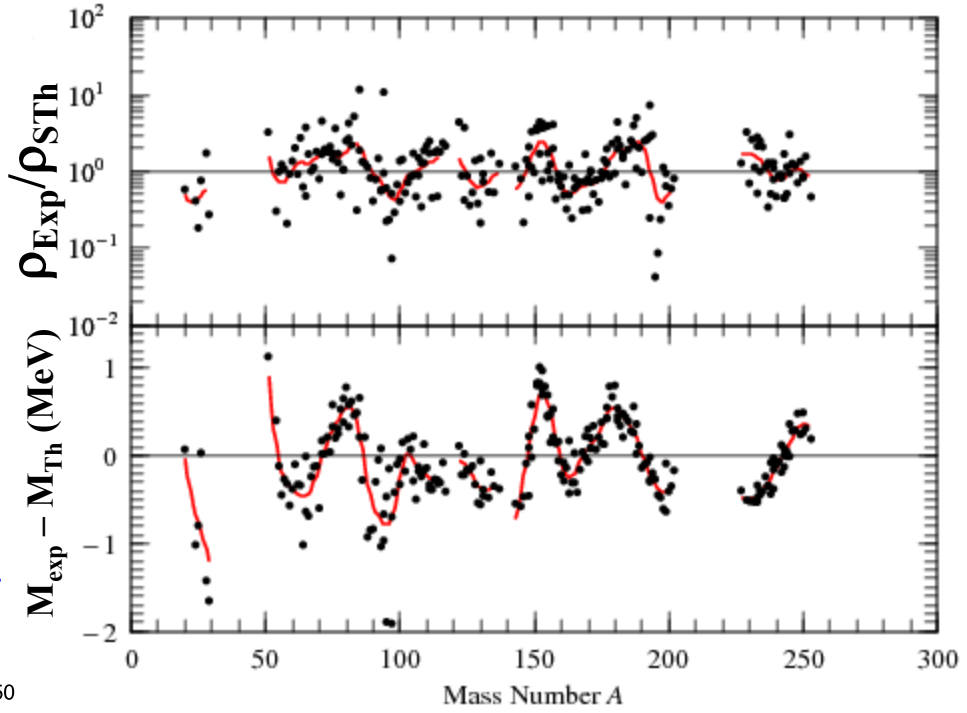
6. Are there upper limits to calculate level densities?

Probably not in principle, but present global microscopic models cannot calculated masses better than about 600 keV.
Implications for level density?

Error in mass calculations sets lower limit

Is error related to discrepancy in mass calc. obtained with same potential [1]:





correction : exp(Δm/T)

Mass dependence of error: $s \approx 6.5/\sqrt{A}$ MeV **(average error ≈600 keV [1])**

Mass dependence of temperature: $T \approx 0.5\sqrt{B_n/a} \approx 4.7/\sqrt{A}$ MeV

Implies a mass-independent error in level density of about a factor 4.

[1] P. Möller et al, Nucl Data Tables, 59 (1995) 185.

Questions on Level Densities

7. Transition region between spherical and deformed coupling schemes?

Theoretical description? (cf Özen's and Døssing's talks)
Experimental signatures? Oslo experiments?

Questions on Level Densities

8. Monte-Carlo shell model versus combinatorial mean field model? (Alhassid)

Description of *all* correlations?
Description of *all* nuclei?
Description of *all* deformations?
Including *all* correlations?

Consequences of canonical (fixed temperature) instead of micro-canonical (fixed energy) calculations?

Questions on Level Densities

9. K-selection rule at neutron resonance?

What is experimental status of today?