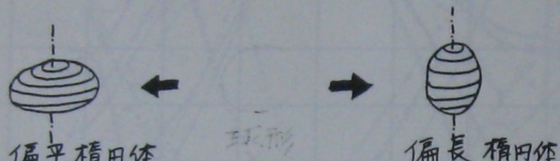
核変形の偏長・偏平と対相関

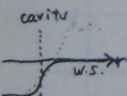
福井大工 田嶋直樹　九州大理 清水良文



原子核の基底状態での変形は
偏長形が圧倒的に多いらしい。

★ その起源は？

- 巨視的効果（クーロン反発，集団運動）→ 弱いので主因たりえない
  W. Zickendraht, 1985



- ポテンシャルの Woods・Saxon 型動径依存性 → 重…
  H. Frisk, 1990
- スピン軌道ポテンシャル（2000年春学会）→ 同じ位重要，強く干渉
- 対相関（今回）→ 意外な向きに影響

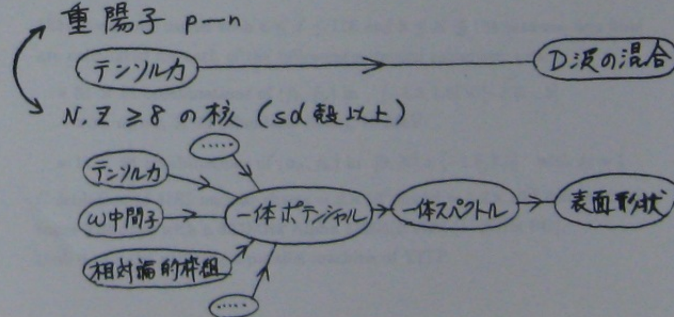
★ 中性子の過剰による平均ポテンシャルの変化の影響は？

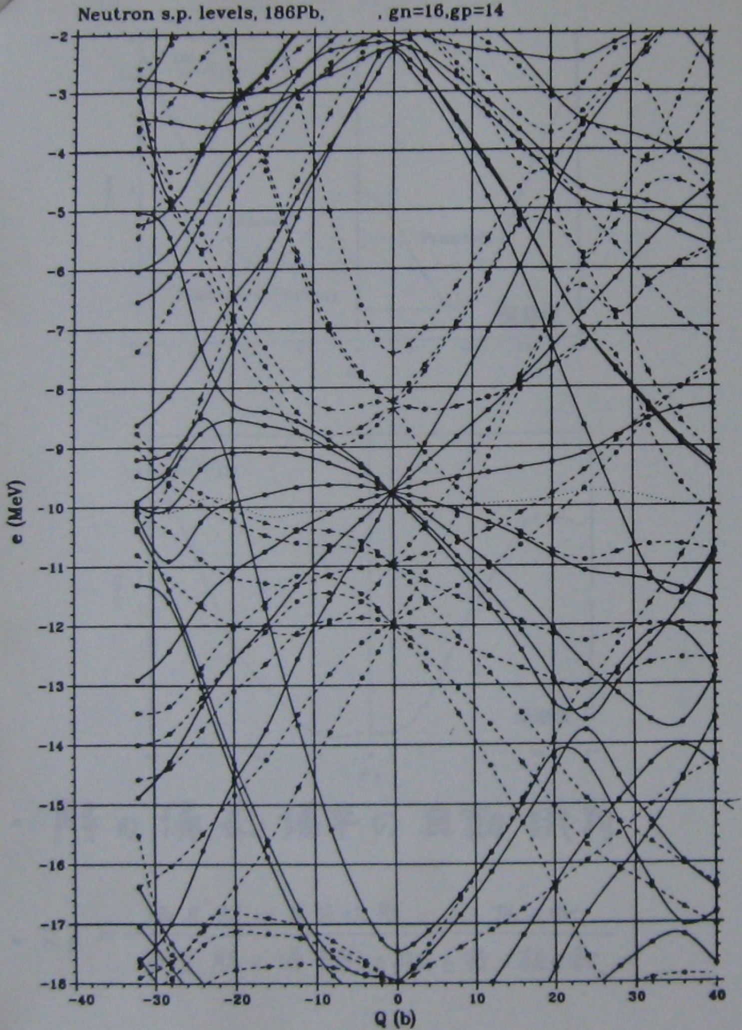
- 偏平優勢へ

Ref. Phys. Rev. C64, 037301 (2001) + new results

[研究のスタンス]

ニルソン準位図を使って個々の核ごとにその変形を説明する
のではなく。
変形の傾向を全核種にわたって一括して理解する
ことをめざす。
ただし、
元のハミルトニアン（即ち2体相互作用）まで遡る
のは将来の課題にとっておき、
一体の平均ポテンシャルの性質に帰着させる
ことをまずめざす。





Framework of the Calculation

We study

the proportion of prolate nuclei among well deformed nuclei, R_p,

as a function of the strengths of ls and l^2 potentials of the Nilsson model,

$$U(\mathbf{r}) = \frac{1}{2}\left(\omega_\perp^2 x^2 + \omega_\perp^2 y^2 + \omega_\parallel^2 z^2\right) + 2\hbar\omega_0 r_t^2 \sqrt{\frac{4\pi}{9}}\epsilon_4 Y_{40}(\hat{r})$$
$$+\boxed{f_{ls}}2\kappa\hbar\omega_0 \mathbf{l}_t\cdot\mathbf{s} - \boxed{f_{ll}}\kappa\mu\hbar\omega_0\left(\mathbf{l}_t^2 - \langle \mathbf{l}_t^2\rangle_N\right)$$

and the pairing force strength, which reproduces average pairing gap of

$$\bar{\Delta} = \frac{\boxed{a_\Delta}}{\sqrt{A}}.$$

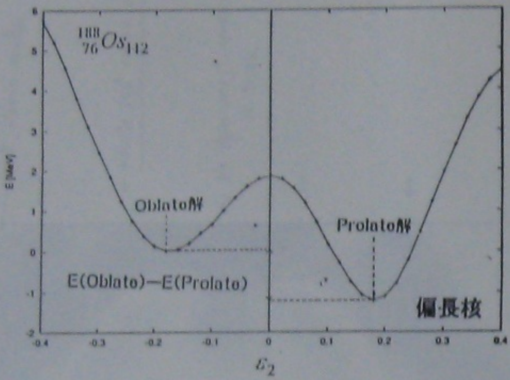
Some details:

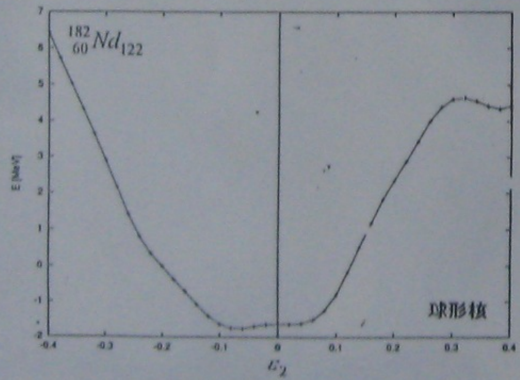
- volume conservation: $\omega_\perp^2\omega_\parallel = \text{constant.} \to \omega_\perp(\epsilon_2), \omega_\parallel(\epsilon_2)$
- ϵ_4 optimized for each ϵ_2
  $-0.5 \le \epsilon_2 \le 0.5,\quad \Delta\epsilon_2 = 0.02,\qquad -0.3 \le \epsilon_4 \le 0.3,\quad \Delta\epsilon_4 = 0.02$
  i.e. $51 \times 31 = 1581$ deformations for a nucleus
- standard κ and μ of Bengtsson and Ragnarsson (1985)
- Strutinsky method

1834 even-even nuclei with $8 \le Z \le 126$ and $8 \le N \le 184$ between drip lines are calculated for each of the following potential parameter sets:

- 31×31 combinations of (f_{ll}, f_{ls}) in $[-1.5, 1.5] \times [-1.5, 1.5]$
  with a_Δ=0, 9, 13 (standard value), 16 MeV.
- $11 \times$ ~~31~~ 61 combinations of (a_Δ, f_{ls}) in $[0, 30] \times [-1.5, 1.5]$ with $f_{ll} = 1$

Calculation of 4185 nuclear charts $= 8 \times 10^6$ nuclei $= 1.2 \times 10^{10}$ deformations takes 320 days with a 833MHz Alpha 21264(EV68) ($\sim$ 2GHz PC), took 4 months utilizing a parallel machine of YITP.





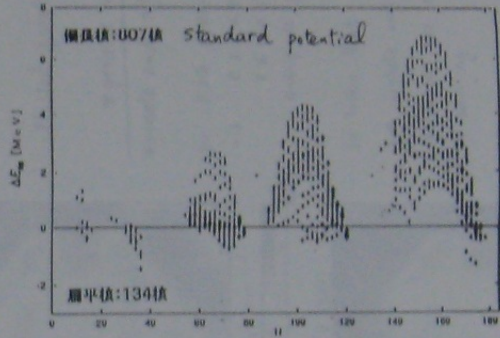


図 5.4: $f_{ls} = f_{ll} = 1$ としたとき、それぞれの核の ΔE_{op}

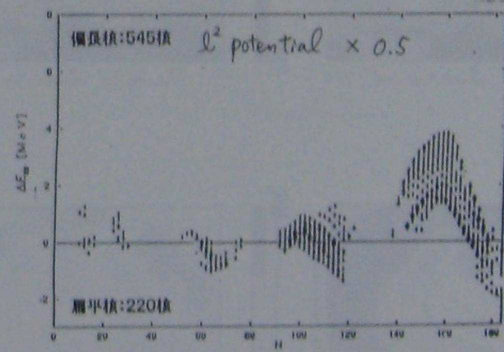
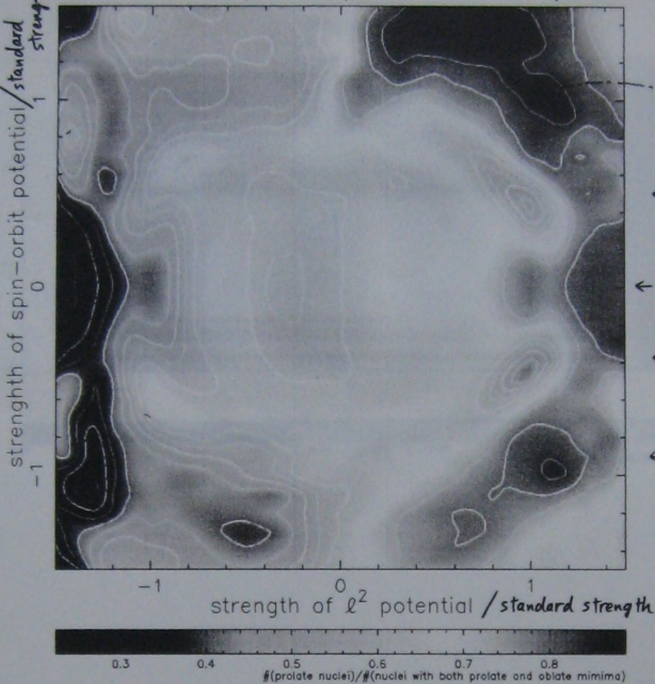


図 5.5: $f_{ls} = 1, \underline{f_{ll} = 0.5}$ としたとき、それぞれの核の ΔE_{op}

・解の偏長・偏平の自動識別

・$R_p = \dfrac{\text{偏長解が基底状態である核の数}}{\text{偏長解と偏平解の両方を持つ核の数}}$

< Proportion of prolate nuclei > = #prolate nucl. / (#prolate nucl. + #oblate nucl.) among 1834 even-even nuclei



← real atomic nuclei 86% prolate

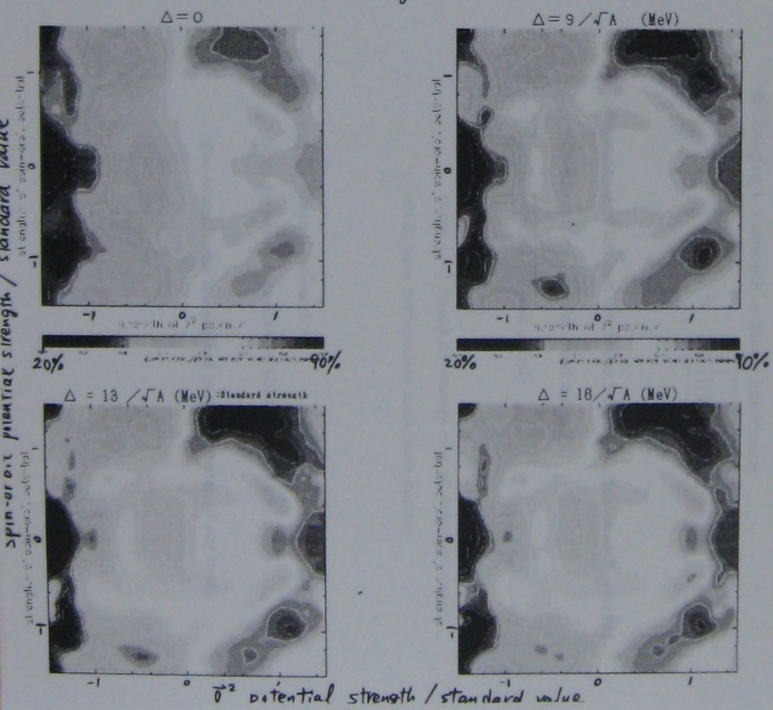
← oblate 60% region in between!

← No spin-orbit coupling H. Frisk

←

←

《 Effects of the Pairing Correlation 》



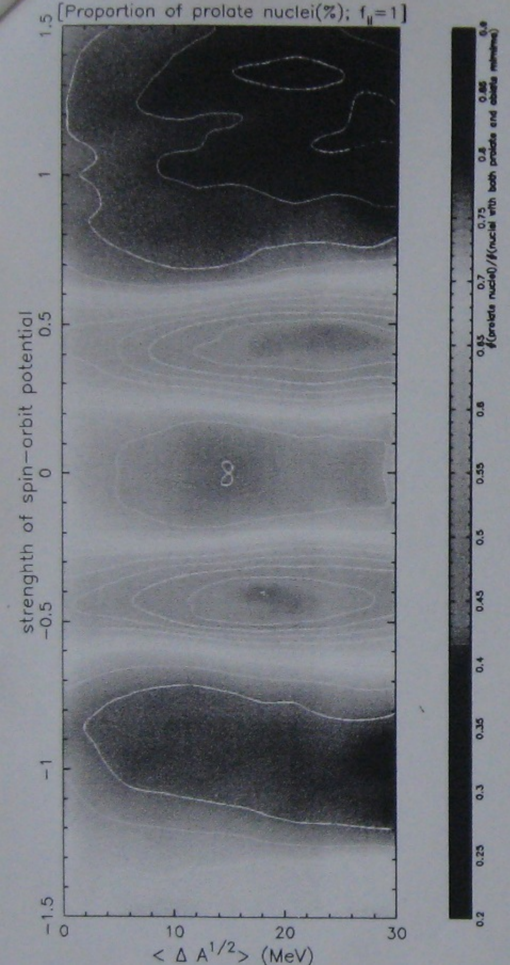
Plotted quantity is

$$\frac{\#\text{prolate nuclei}}{\#\text{prolate nucl.} + \#\text{oblate nucl.}}$$

for 1834 even-even nuclei with
- $8 \leq Z \leq 126$
- $8 \leq N \leq 184$
- n-drip to p-drip

It looks that both prolate and oblate dominances are enhanced by pairing.

$31^2 = 961$ points calc. in each panel
80 days it with 833 MHz EV68 alpha
YITP computer facility
parallel machine



Summary of the results

1. • Prolate dominance reproduced. ($f_{ll} = f_{ls} = 1$ point)

   Standard $\mathbf{l}\cdot\mathbf{s}$ and $\mathbf{l}^2 \Rightarrow R_p = 0.86$.

   • Castel's idea tested. ($f_{ll} = f_{ls} = 0$ point)

   Harmonic oscillator has a weak prolate preference of R_p=0.55.

   • H. Frisk's idea confirmed. ($f_{ls} = 0$ line)

   ● Changing $\mathbf{l}\cdot\mathbf{s}$ strength ⇒ Strong interference:

   with $f_{ll} = 1$,

f_{ls}	−1	−0.5	0	0.5	1
R_p	0.81	0.44	0.78	0.45	0.86

2. Independence of the last conclusion from the definition of R_p checked.

   a. (#prolate nuclei) / (#deformed nuclei)

   b. (#prolate nuclei) / (#all nuclei)

   c. $\langle E(\text{oblate}) - E(\text{prolate})\rangle$

   where $\langle\cdots\rangle$ means an average over all deformed nuclei which have both prolate and oblate minima

● Pairing correlation enhances both prolate dominance and oblate dominance.

The reason to be understood in the next step of our study.