中国原子能科学研究院
中核集团 CHINA INSTITUTE OF ATOMIC ENERGY

Studies of the yrast and yrare bands in neutron-deficient Hg isotopes

中国原子能科学研究院　核物理所
陈芳祁
2014年10月

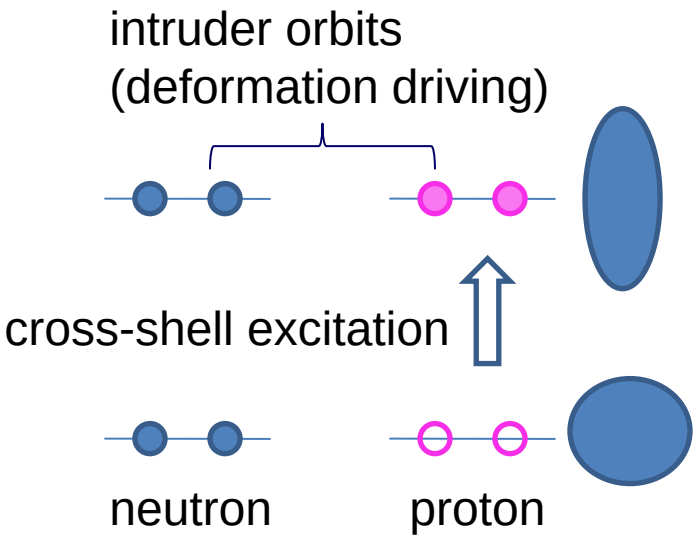
Outline

- Introduction
- Model framework
- Results and discussions
- Summary

Introduction

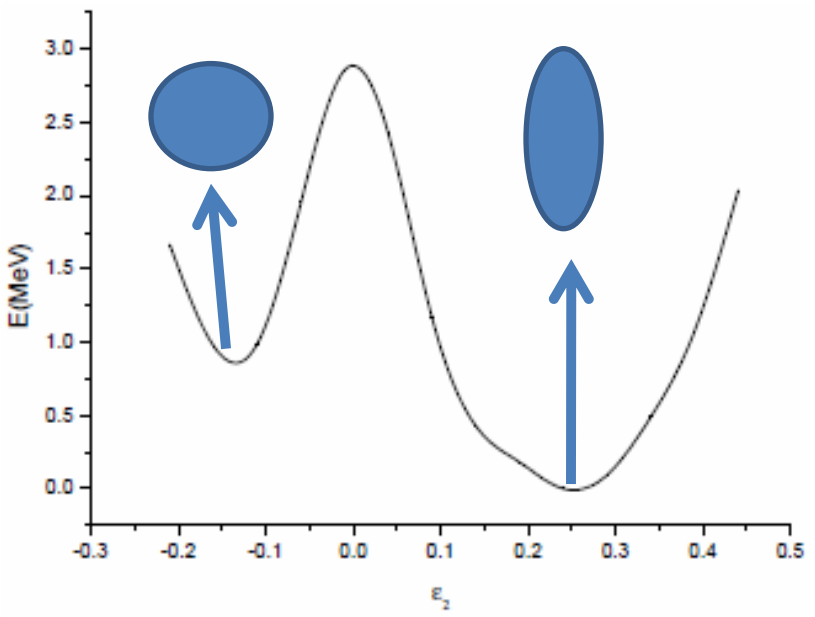
description of shape coexistence:

shell model



dimension explosion for heavy nuclei

mean-field approach



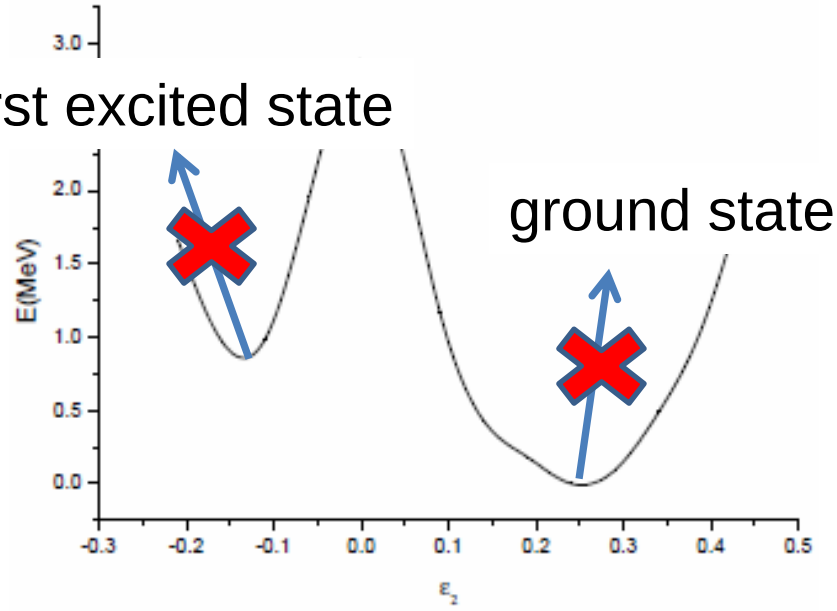
widely used for heavy nuclei

shortcomings of the mean-field approach

broken rotational symmetry

shape fluctuation missed

first excited state



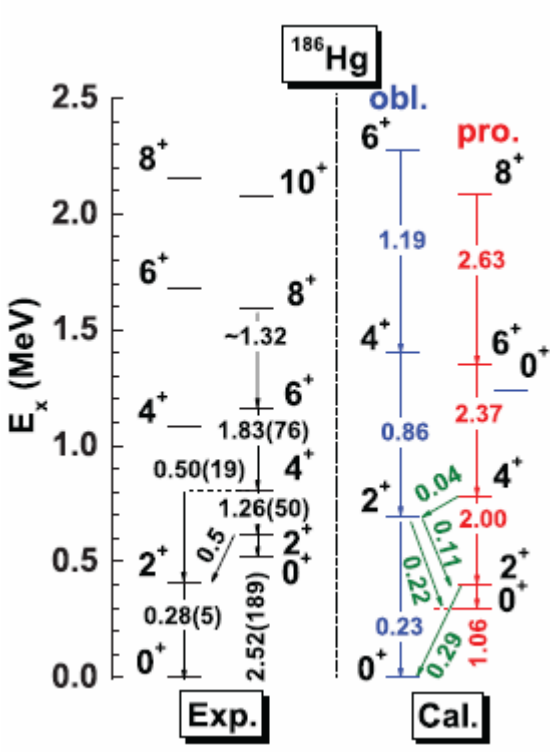
ground state

beyond mean field methods required:

symmetry projection
quasiparticle excitation
generator coordinate method
…

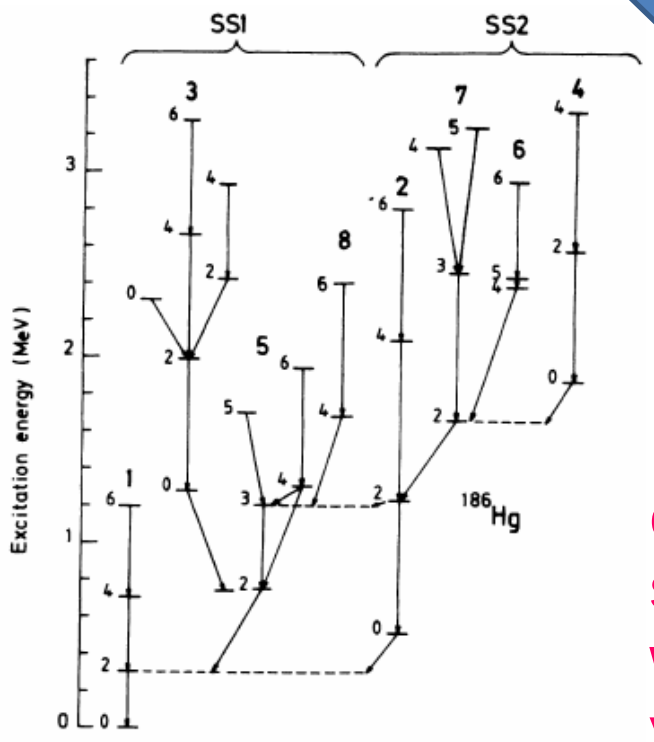
direct comparison with data prohibited

GCM calculations for neutron-deficient Hg isotopes



axial symmetric
Skyrme SLy6

J. M. Yao et al, PRC 87 034322 (2013)



triaxial; GOA
Gogny

J. P. Delaroche et al, PRC 50, 2332 (1994)

shape coexistence: bands with different deformations

our focus: shape evolution within yrast and yrare bands

Model framework

GCM wavefunction:

$$|\psi\rangle = \int d\varepsilon_2 f(\varepsilon_2) P |\Phi(\varepsilon_2)\rangle$$

axial symmetry preserved

weight function

Nilsson+BCS qp vacuum (deformation ε_2) *projected onto good spin and particle numbers*

Hill-Wheeler equation:

$$\int (\langle \Phi(\varepsilon_2)| HP |\Phi(\varepsilon_2')\rangle - E \langle \Phi(\varepsilon_2)| P |\Phi(\varepsilon_2')\rangle) f(\varepsilon_2') d\varepsilon_2' = 0$$

Hamiltonian (pairing plus quadrupole interaction):

$$H = H_0 - \frac{\chi}{2} \sum_\mu : Q_\mu^+ Q_\mu : - G_M P^+ P - G_Q \sum_\mu P_\mu^+ P_\mu$$

collective wavefunction:

$$g(\varepsilon_2) = \int d\varepsilon_2 N^{1/2}(\varepsilon_2, \varepsilon_2') f(\varepsilon_2')$$

$$N(\varepsilon_2, \varepsilon_2') = \langle \Phi(\varepsilon_2) | P | \Phi(\varepsilon_2') \rangle$$

$$\int (\langle \Phi(\varepsilon_2) | HP | \Phi(\varepsilon_2') \rangle - E \langle \Phi(\varepsilon_2) | P | \Phi(\varepsilon_2') \rangle) f(\varepsilon_2') d\varepsilon_2' = 0$$

$$H_{coll}(\varepsilon_2, \frac{\partial}{\partial \varepsilon_2}) g(\varepsilon_2) = E g(\varepsilon_2)$$

equation of motion of the Bohr model

P. Ring, *The Nuclear Many Body Problem*

on particle number projection:
overlap matrix elements of rotation in the gauge space

Onishi formula: suffered from sign ambiguity

$$<\exp(-i\hat{G})> = \left\{\det X\right\}^{\frac{1}{2}} \exp\left[-\frac{i}{2}\mathrm{Tr}\{G\}\right]$$

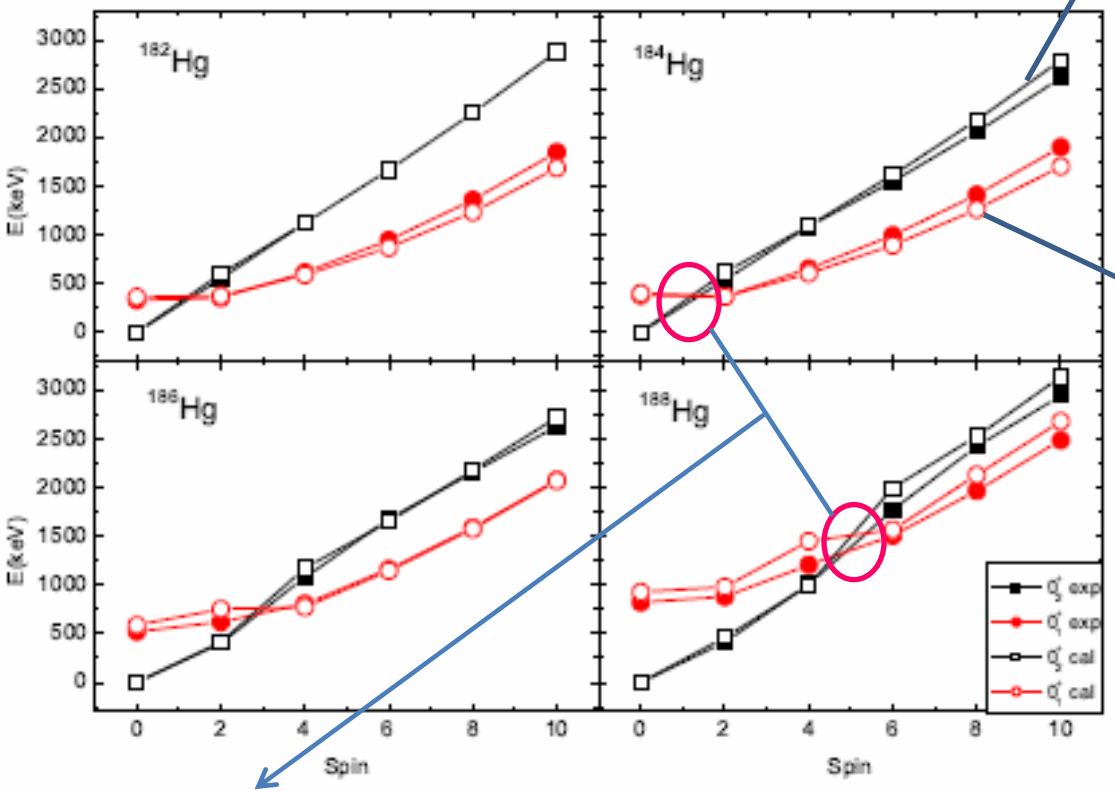
Pfaffian formula: without sign ambiguity

$$\langle w|\mathcal{R}|w'\rangle = (-1)^n \frac{\det C^* \det C'}{\prod_\alpha^n v_\alpha v'_\alpha} \mathrm{pf}\begin{bmatrix} V^T U & V^T R^T V'^* \\ -V'^\dagger R V & U'^\dagger V'^* \end{bmatrix}$$

PRL **108,** 042505 (2012)

Results and discussions

level spectrum



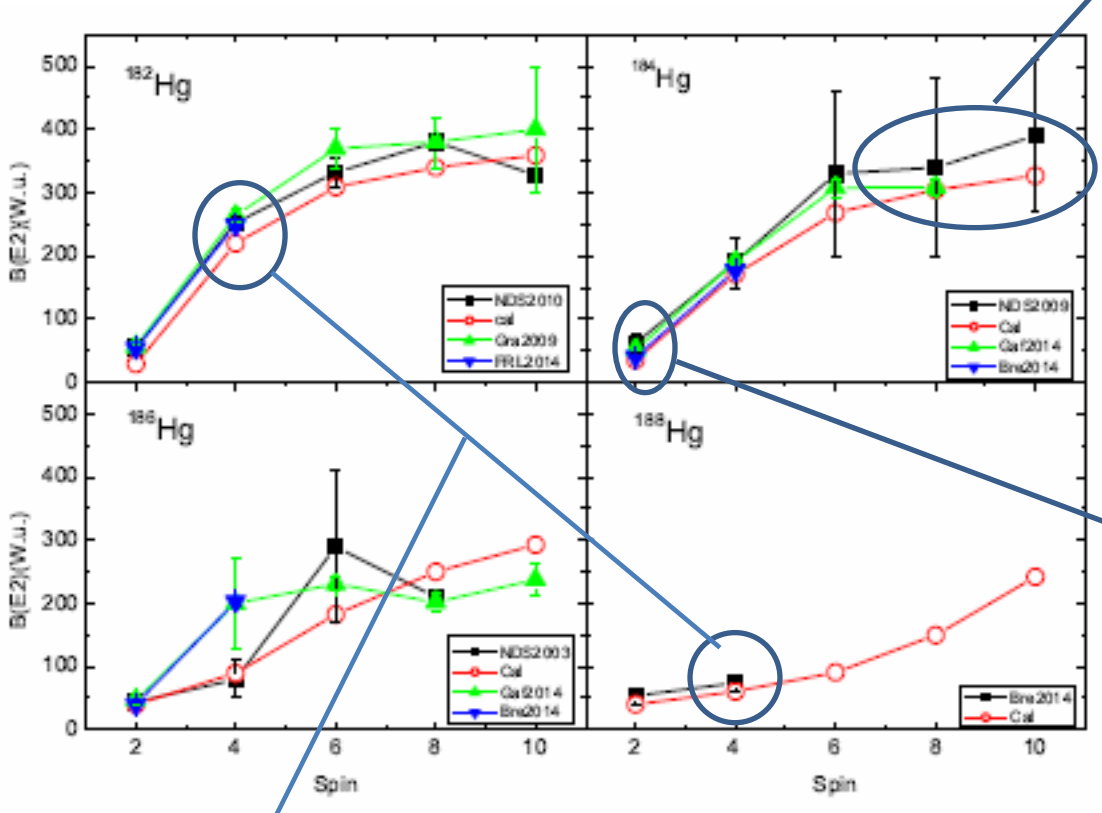
vibrational-like
↓
near spherical?

shape coexistence

rotational-like
↓
large prolate?

retardation of band-crossing ⇒ increase of 0_2^+ energy ⇒ decrease of valence neutron number

intra-band B(E2) of yrast bands



after crossing:
large deformation

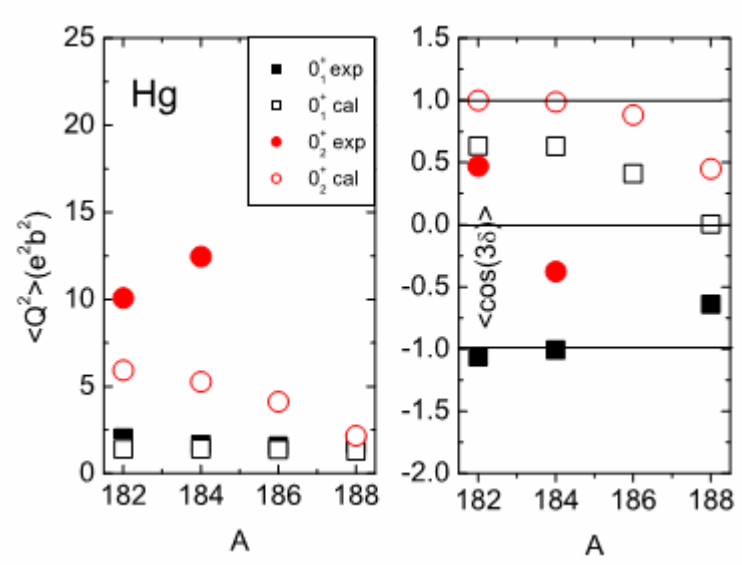
before crossing:
small deformation

retardation of B(E2) increase ⟺ retardation of band crossing

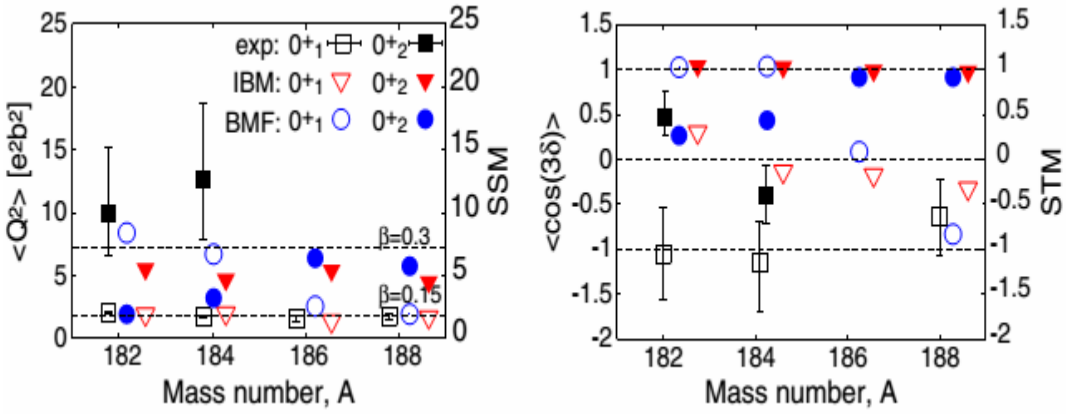
shape invariance obtained from reduced E2 matrix elements

our results

IBM & GCM(Skyrme) results



~ β ~ γ



~ β ~ γ

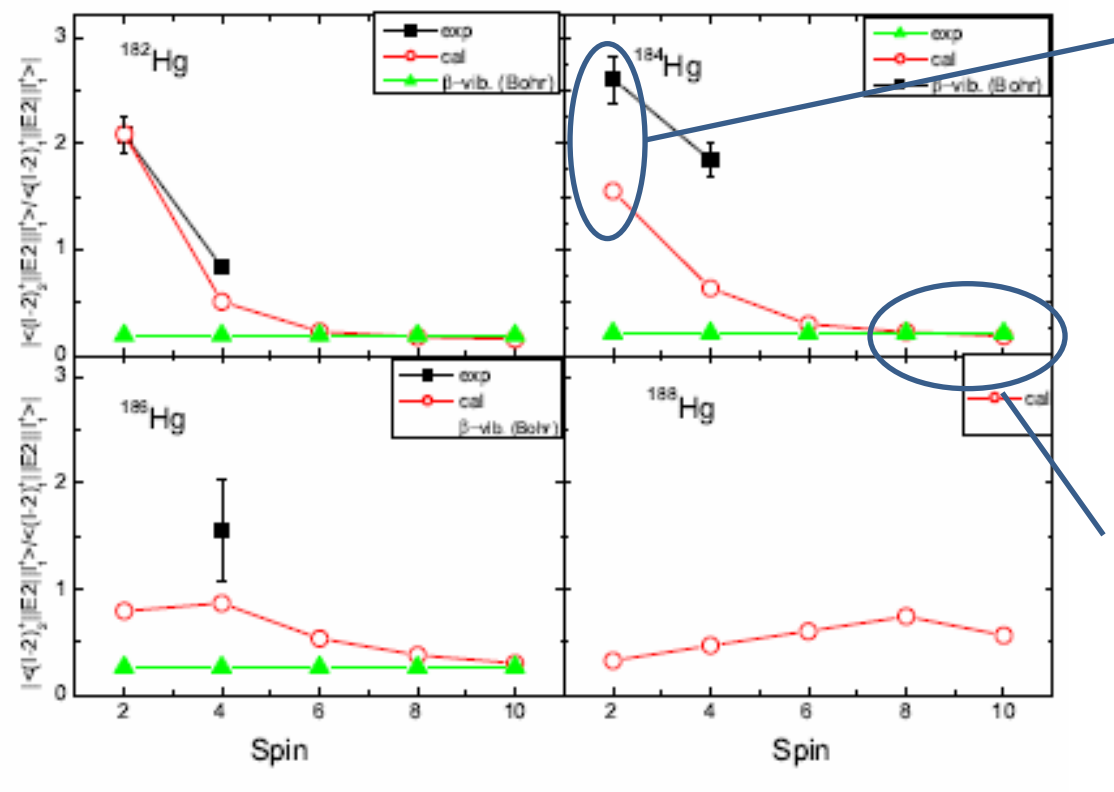
deformation parameters extracted from shape invariants $\langle Q^2 \rangle$

shape coexistence
reproduced qualitatively

	0_1^+ exp	0_1^+ cal	0_2^+ exp	0_2^+ cal
^{182}Hg	0.161	0.134	0.359	0.275
^{184}Hg	0.145	0.134	0.396	0.260
^{186}Hg	0.139	0.130	—	0.226
^{188}Hg	0.145	0.126	—	0.163

inter-intra M(E2) ratio $|\langle (I-2)_2^+ \| E2 \| I_1^+ \rangle / \langle (I-2)_1^+ \| E2 \| I_1^+ \rangle|$

reflecting mixing extent between yrast and yrare bands



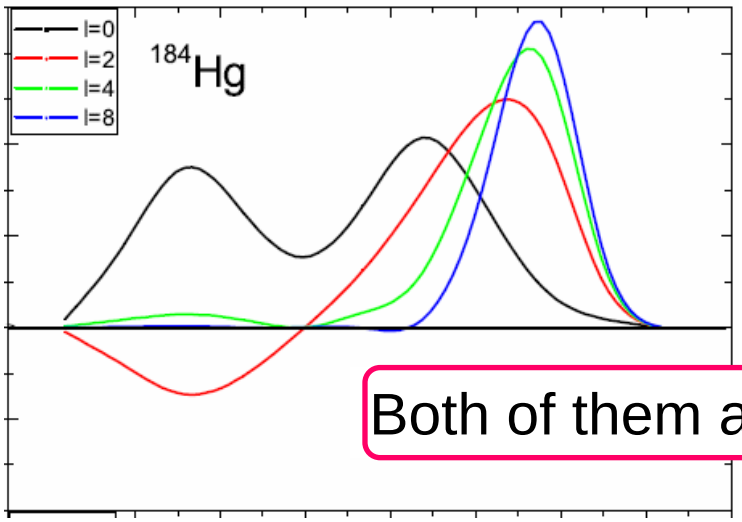
maximum:
band crossing point

convergent value:
coincidence with
estimations based on
β -vibration
assumption

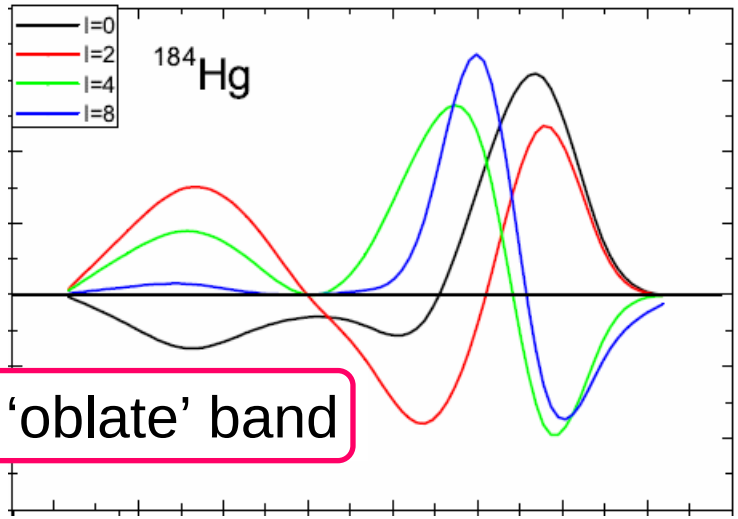
Yrare states with higher spins may be β -vibrations on top of yrast states

representive collective wave functions

yrast band



yrare band



Both of them are not ‘oblate’ band

I=0 (before crossing):
near spherical

after crossing:
basically prolate

I=0(before crossing):
basically prolate

after crossing:
dominated by β - vibration

Summary

1.The yrast and yrare bands in $^{182\text{-}188}$Hg are studied by the generator coordinate method.

2.Shape coexistence at low spins is demonstrated.

3.Yrare states at higher spins are dominated by β -vibration on top of the yrast states.

合作者：

孙扬老师
高早春老师

Thank you!