Collective excitations of Λ hypernuclei

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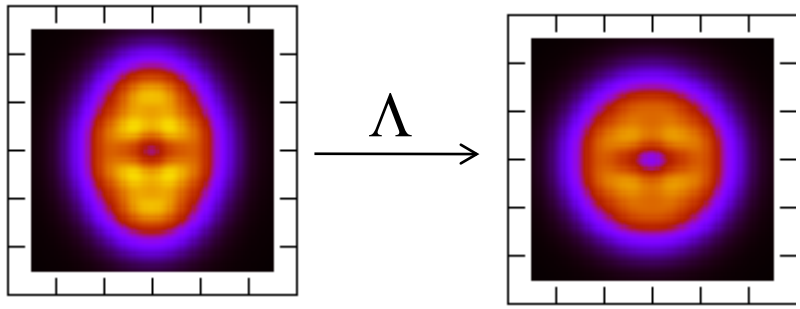

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3. Vibrational excitations of spherical hypernuclei
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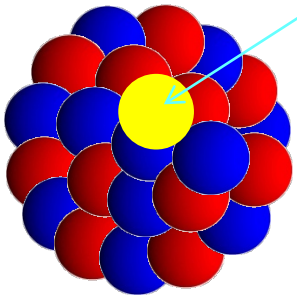
Introduction

Λ hypernucleus

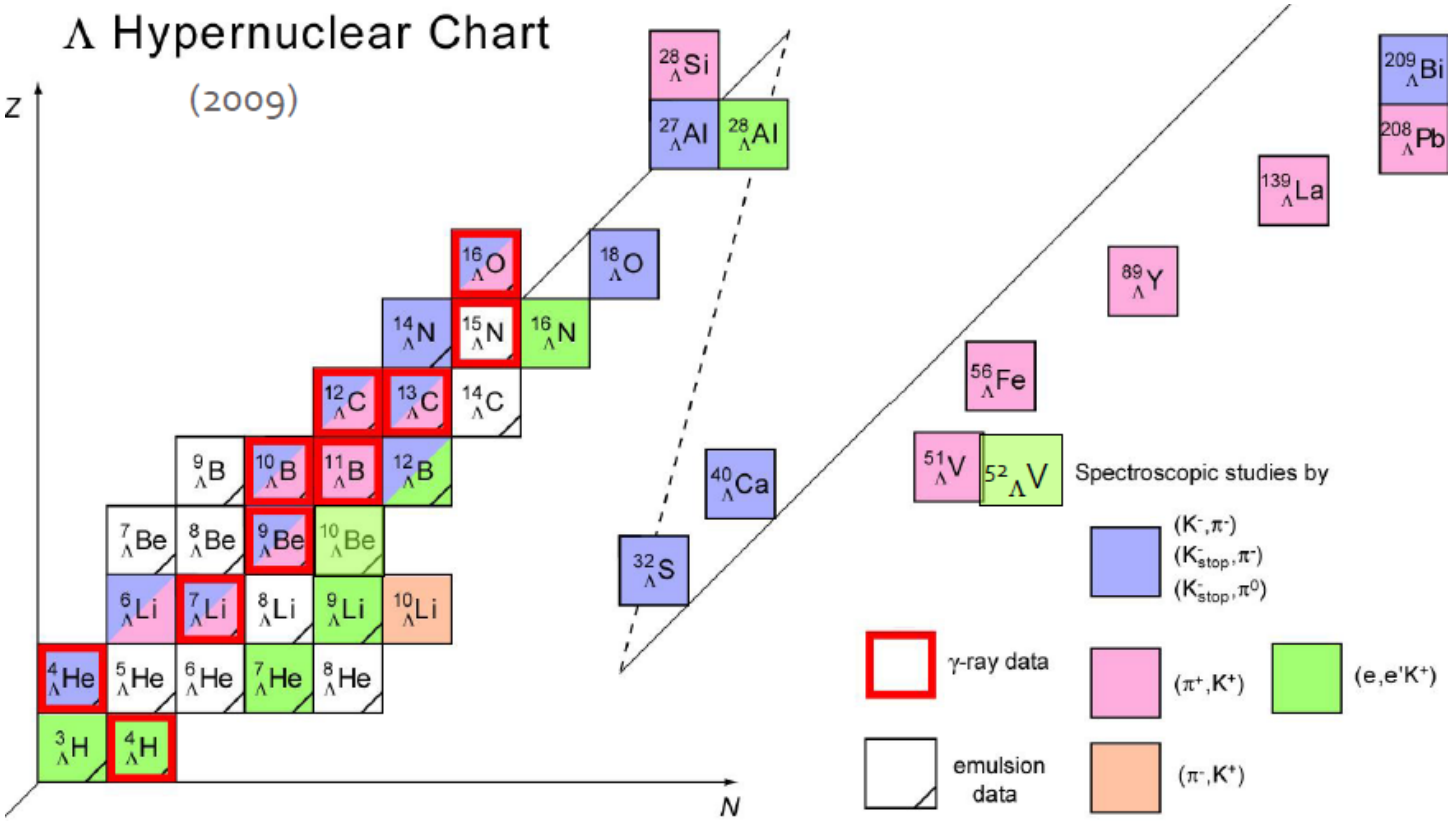


Λparticle: the lightest hyperon
(no charge, no isospin)

proton

neutron

*no Pauli principle between nucleons and a Λ particle



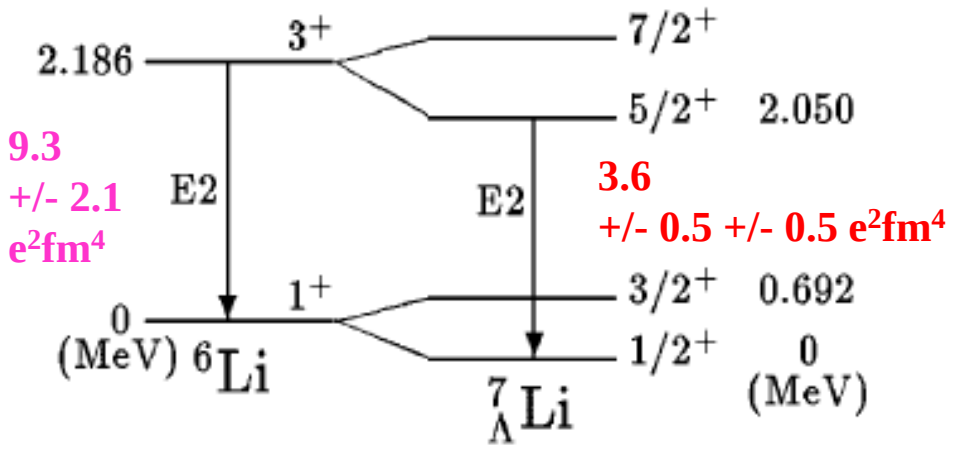
O. Hashimoto and H. Tamura, Prog. Part. Nucl. Phys. 57(‘06)564

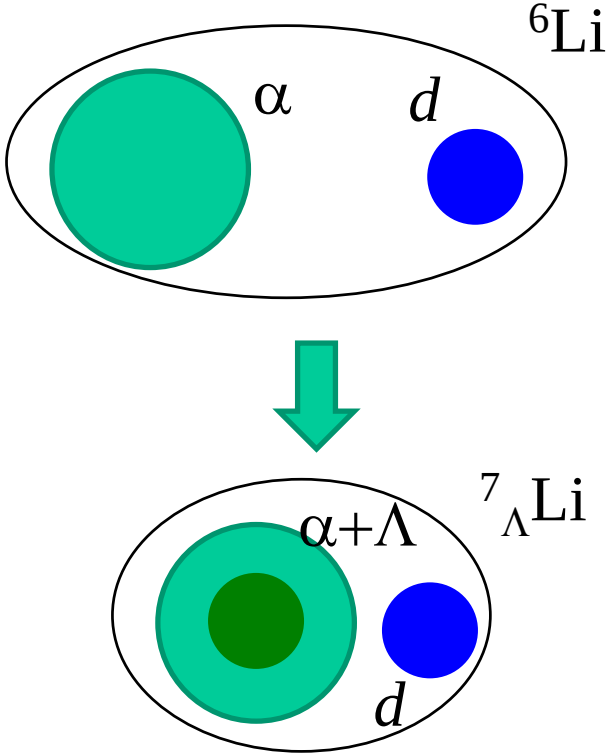
Impurity effects: one of the main interests of hypernuclear physics

how does Λ affect several properties of atomic nuclei?

- size, shape, density distribution, single-particle energy, shell structure, fission barrier……

the most prominent example:
the reduction of B(E2) in $^{7}_{\Lambda}$Li



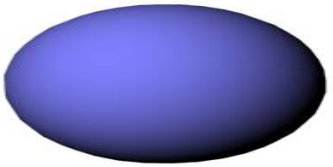


about 19% reduction of nuclear size (shrinkage effect)

K. Tanida et al., PRL86(‘01)1982

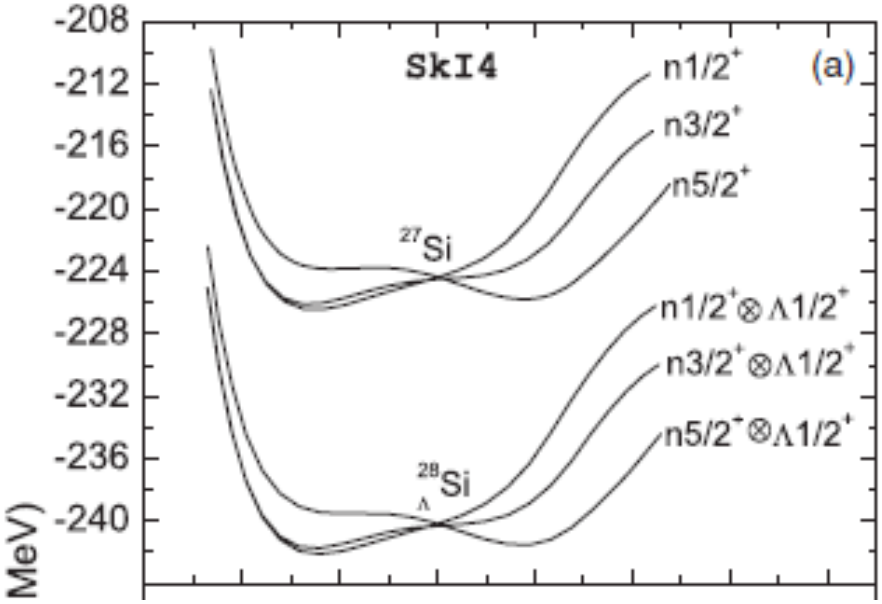
Shape of hypernuclei

Self-consistent mean-field (Hartree-Fock) method:



optimized shape can be automatically determined
= suitable for a discussion on shape of hypernuclei

➢Recent Skyrme-Hartree-Fock +BCS calculation by Zhou *et al.*



✓similar deformation between the hypernuclei and the core nuclei

✓hypernuclei: slightly smaller deformation than the core

X.-R. Zhou *et al.*, PRC76(‘07) 034312

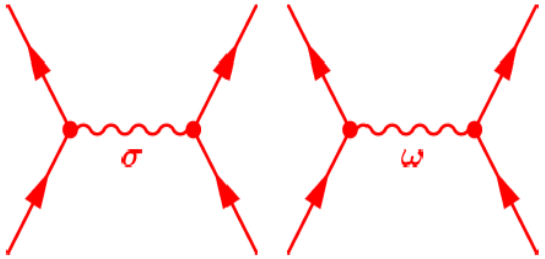
RMF for deformed hypernuclei

$$\mathcal{L} = \mathcal{L}_N + \bar{\psi}_\Lambda \left[\gamma_\mu \left(i\partial^\mu - g_{\omega\Lambda}\omega^\mu \right) - m_\Lambda - g_{\sigma\Lambda}\sigma \right] \psi_\Lambda$$

$$g_{\omega\Lambda} = \frac{2}{3} g_{\omega N} \longleftarrow \text{quark model}$$

$$g_{\sigma\Lambda} = 0.621 g_{\sigma N} \longleftarrow {}^{17}_{\Lambda}\mathrm{O}$$

cf. D. Vretenar et al.,
PRC57('98)R1060



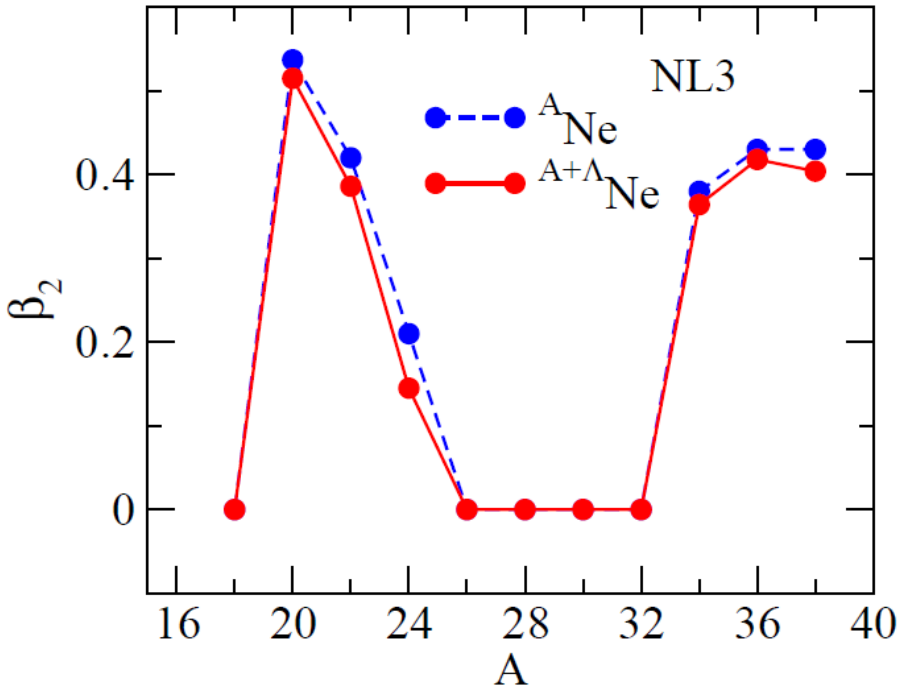
Λσ and Λω couplings

- parameter sets: NL3 and NLSH
- **Axial symmetry**
- pairing among nucleons: Const. gap approach

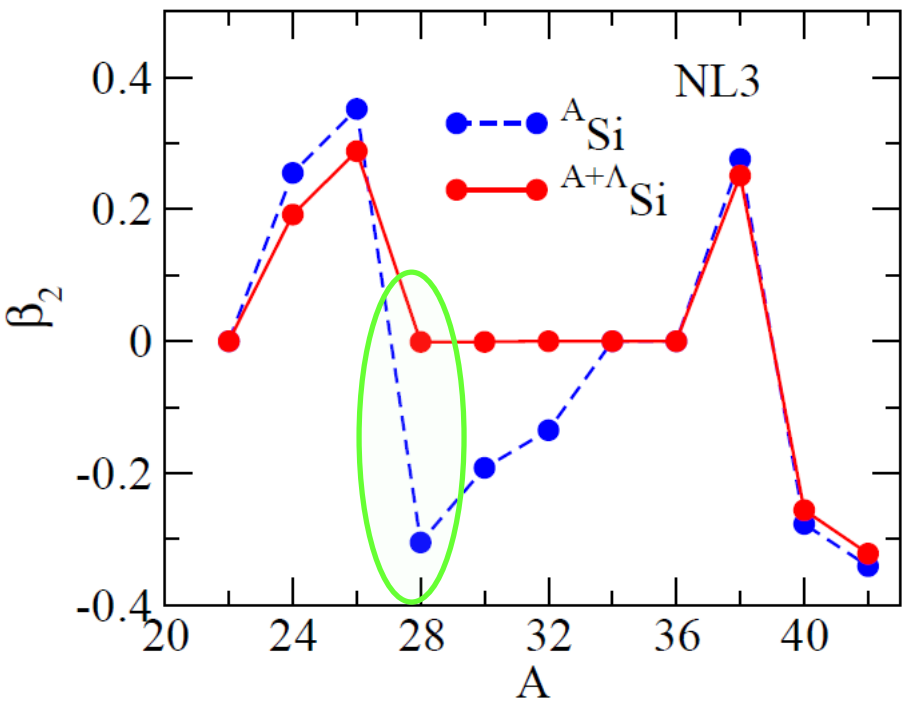
  $\Delta_n = 4.8/N^{1/3}$ $\Delta_p = 4.8/Z^{1/3}$ (MeV)
- **Λ particle: the lowest s.p. level ($K^\pi = 1/2^+$)**
- Basis expansion with deformed H.O. wf

Myaing Thi Win and K.H., PRC78('08)054311

Ne isotopes



Si isotopes



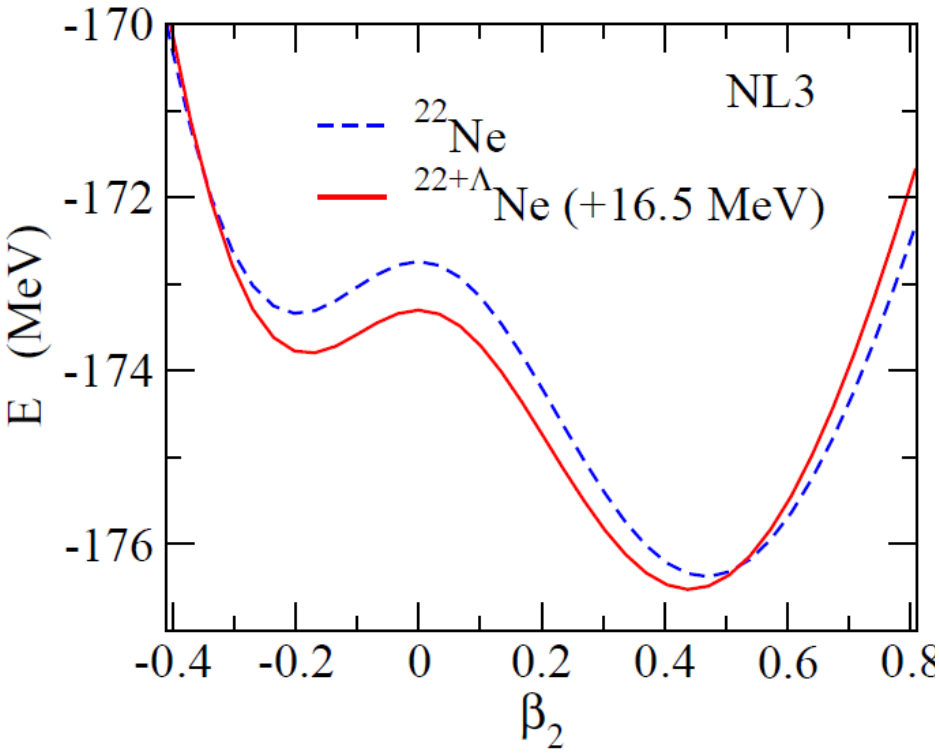
- in most cases, similar deformation between the core and the hypernuclei
- hypernuclei: slightly smaller deformation than the core

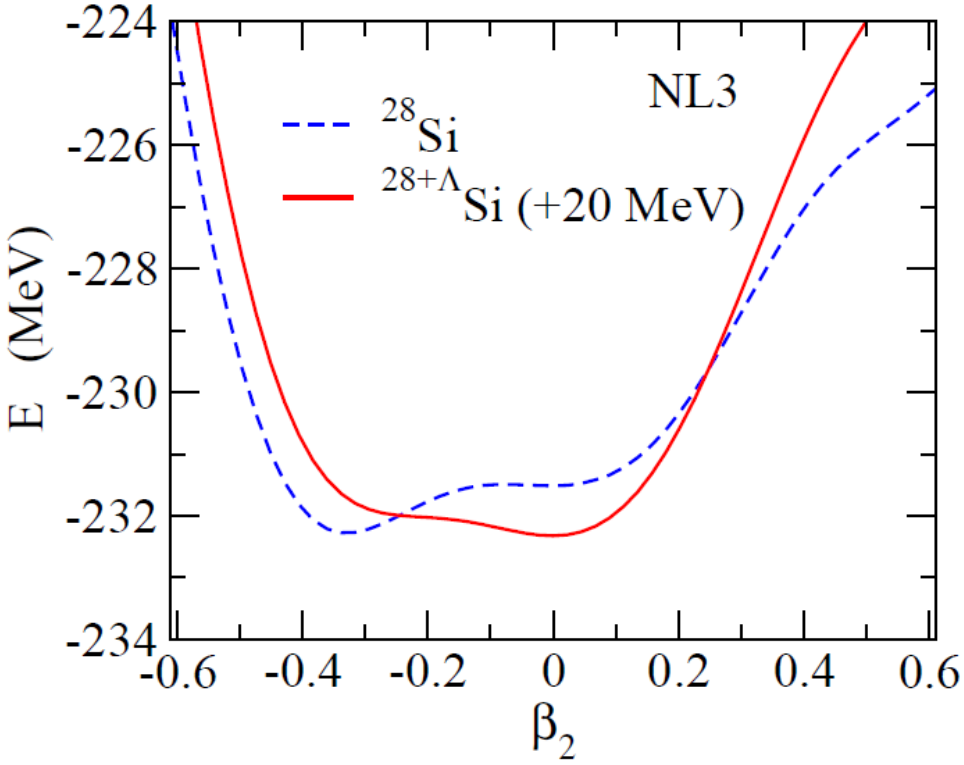
Exception: $^{29}_{\Lambda}$Si Disappearance of deformation

$$\text{oblate } (^{28}\text{Si}) \xrightarrow{\Lambda} \text{spherical } (^{29}_{\Lambda}\text{Si})$$

Myaing Thi Win and K.H., PRC78(‘08)054311

Potential energy surface (constraint Hartree-Fock)





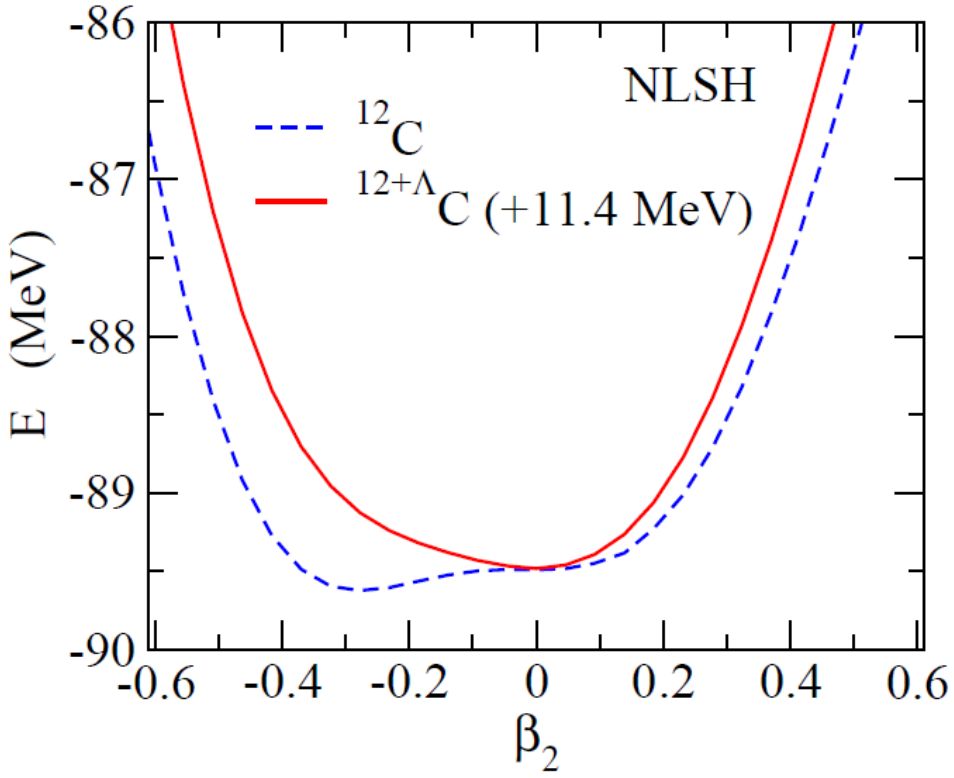
a flat energy curve

⟶ a large change in nuclear deformation due to a Λ particle

the same conclusion also with NLSH
and/or with constant G approach to pairing

Myaing Thi Win and K.H., PRC78(‘08)054311

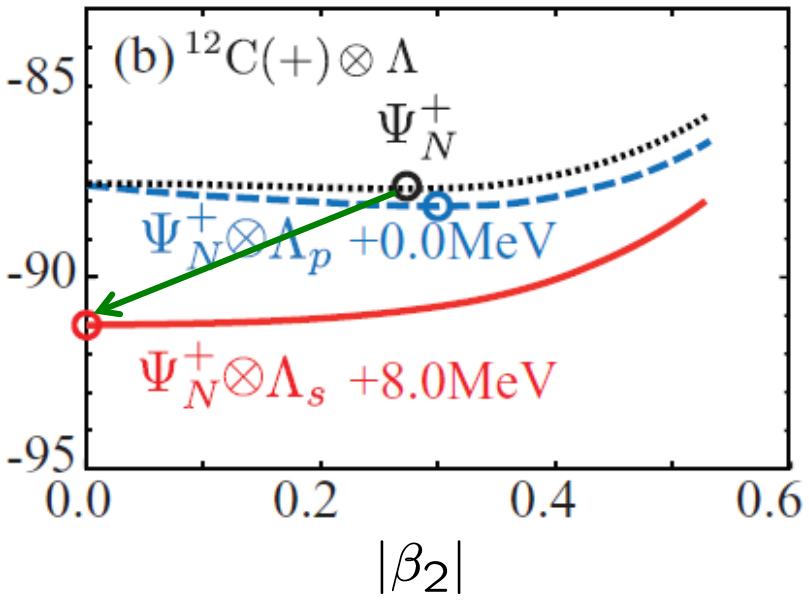
Another example: $^{13}_{\Lambda}$C



oblate ⟶ spherical

Myaing Thi Win and K.H.,
PRC78(‘08)054311

cf. recent AMD calculations



M. Isaka, K. Kimura, A. Dote,
and A. Ohnishi, PRC83(‘11)044323

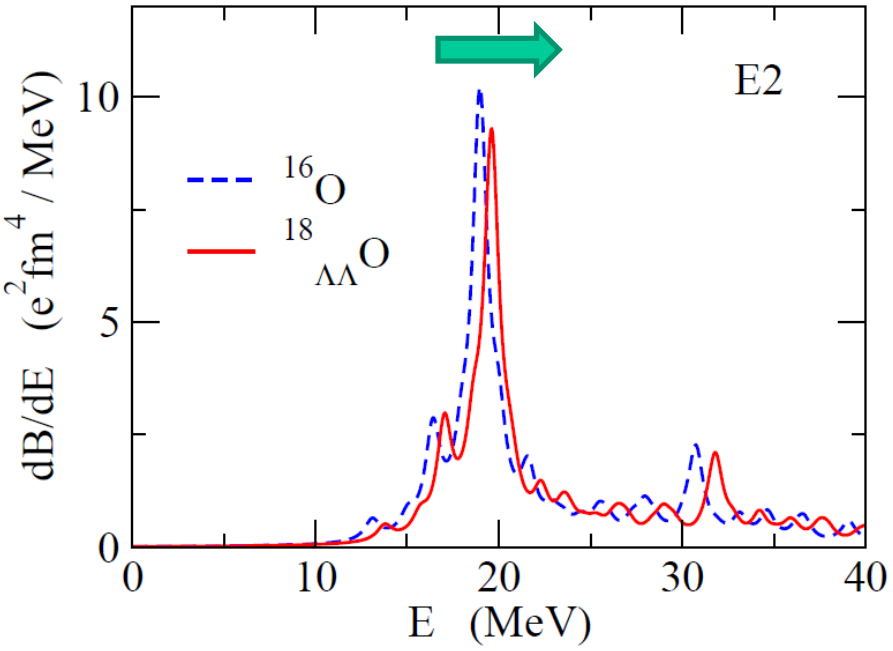
Vibrational Excitation of spherical Λ hypernuclei

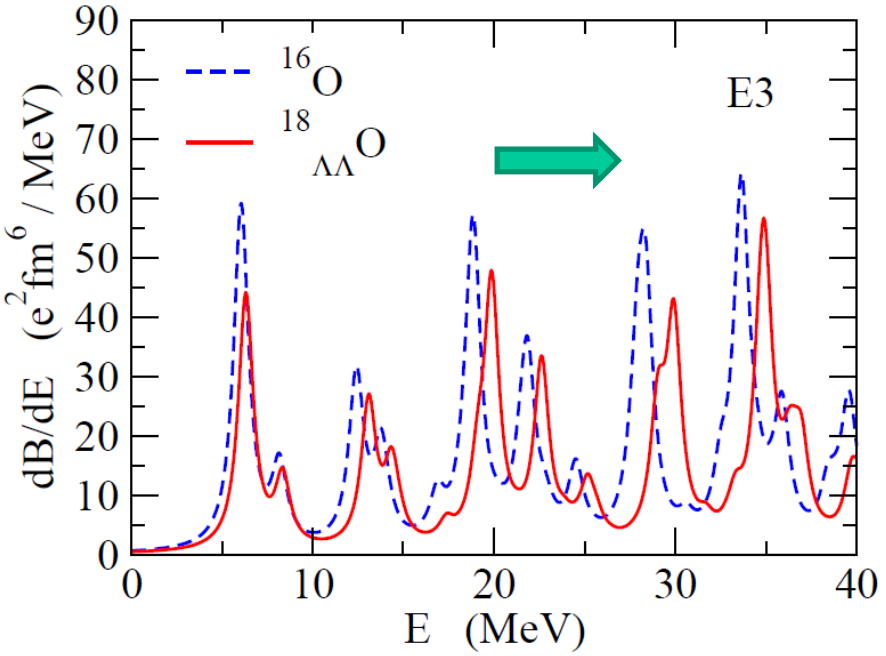
Application of **RPA**

$$Q^\dagger = \sum_{p,h \in p,n,\Lambda} \left(X_{ph} a_p^\dagger a_h - Y_{ph} a_h^\dagger a_p \right)$$

Application to $^{18}_{\Lambda\Lambda}$O ⟵ even mass hypernucleus

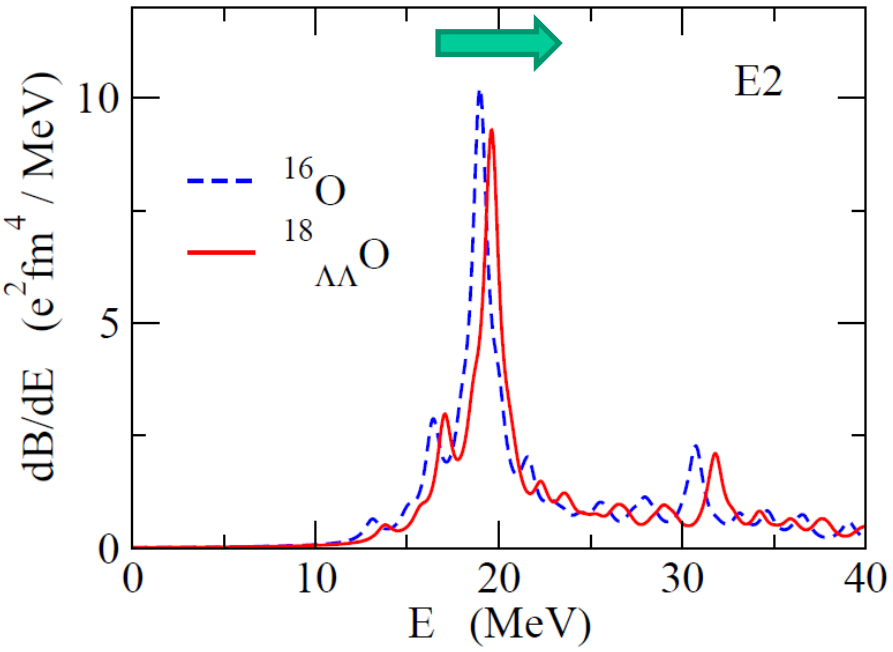
Skyrme HF + RPA
SkM* + Yamamoto No. 5 + Lanskoy SΛΛ1





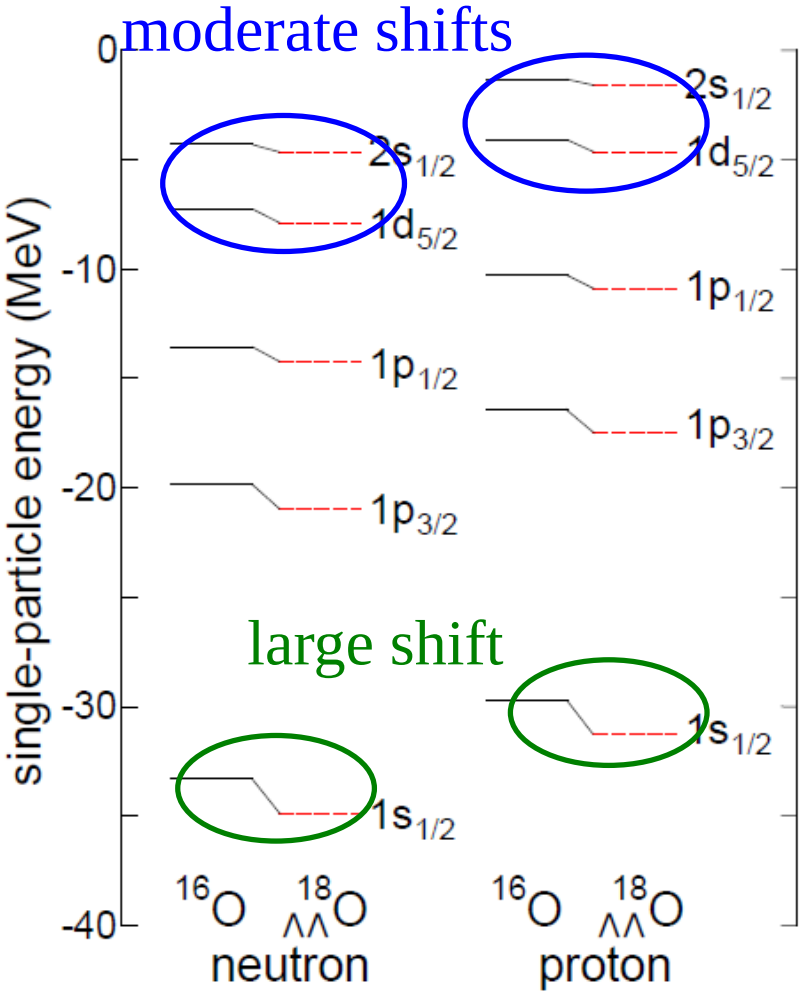
F. Minato and K.H., PRC85(‘12)924316

shifts toward high energy



moderate shifts

large shift

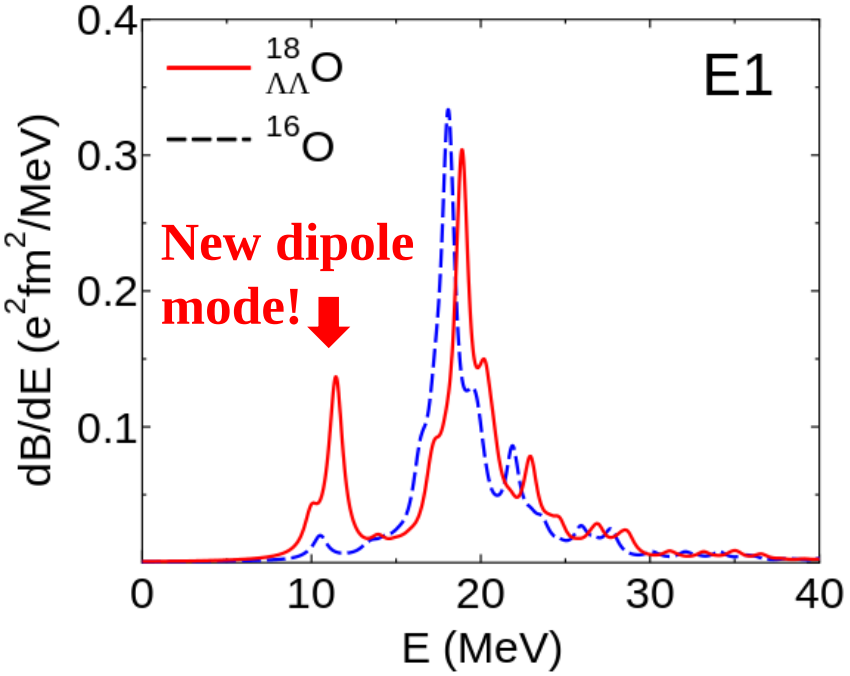


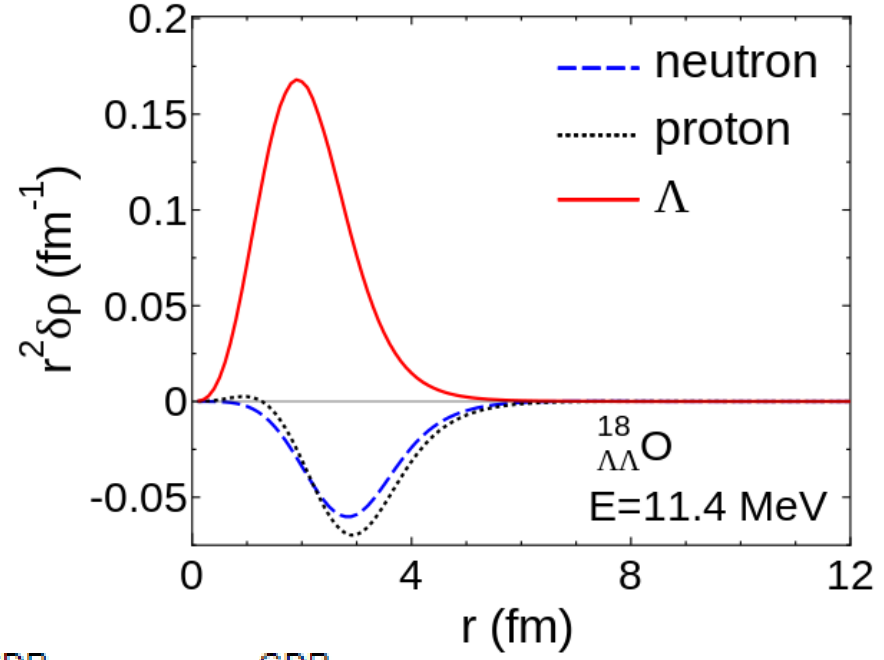
low-lying collective states

	2_1^+		3_1^-	
nucleus	E (MeV)	B(E2) (e^{2}fm^4)	E(MeV)	B(E3) (e^{2}fm^6)
^{16}O	13.1	0.726	6.06	91.1
$^{18}_{\Lambda\Lambda}$O	13.8	0.529	6.32	67.7

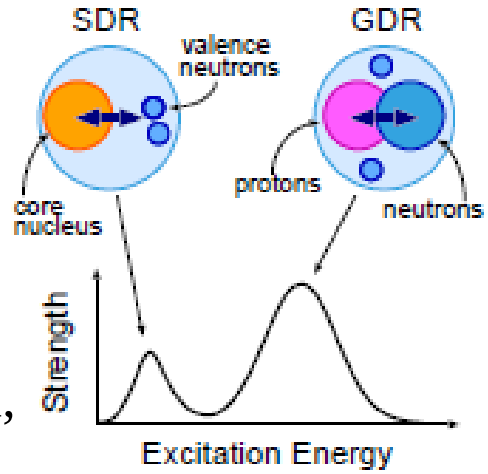
Dipole motion: soft dipole Lambda mode

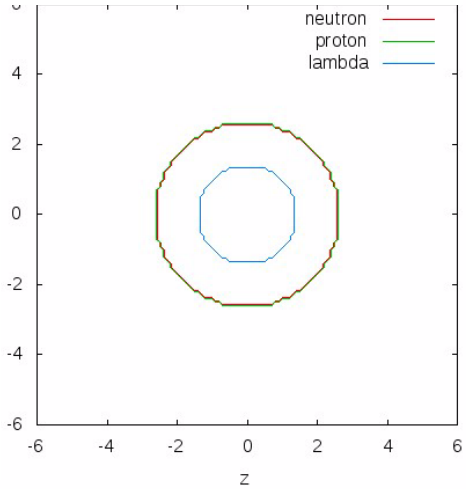
dipole oscillation of Λ particles around the core nucleus





cf. soft dipole motion in neutron-rich nucleus





K. Ikeda, T. Myo, K. Kato, and H. Toki, Lecture Note in Phys., vol. 818

Dipole motion: soft dipole Lambda mode

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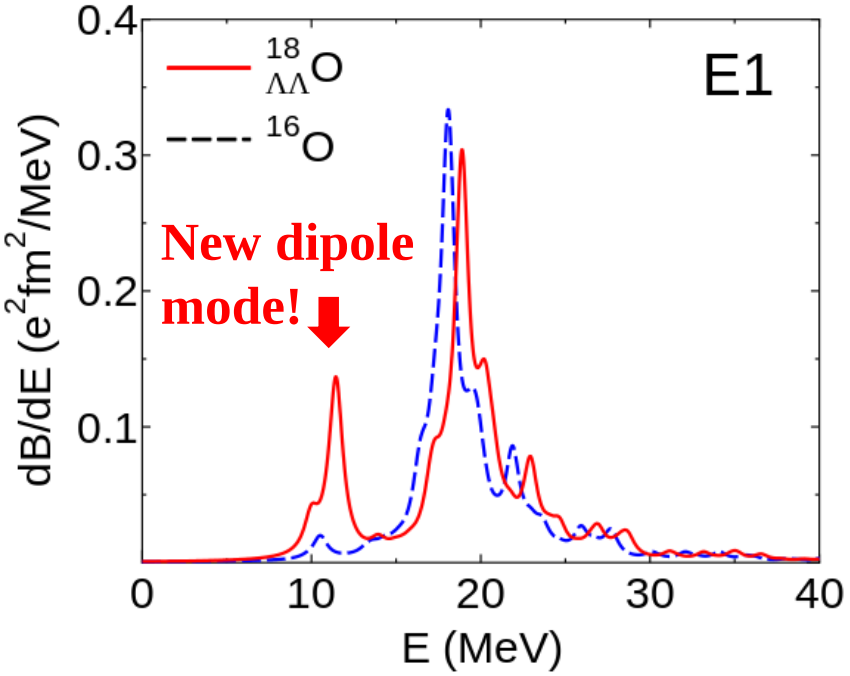

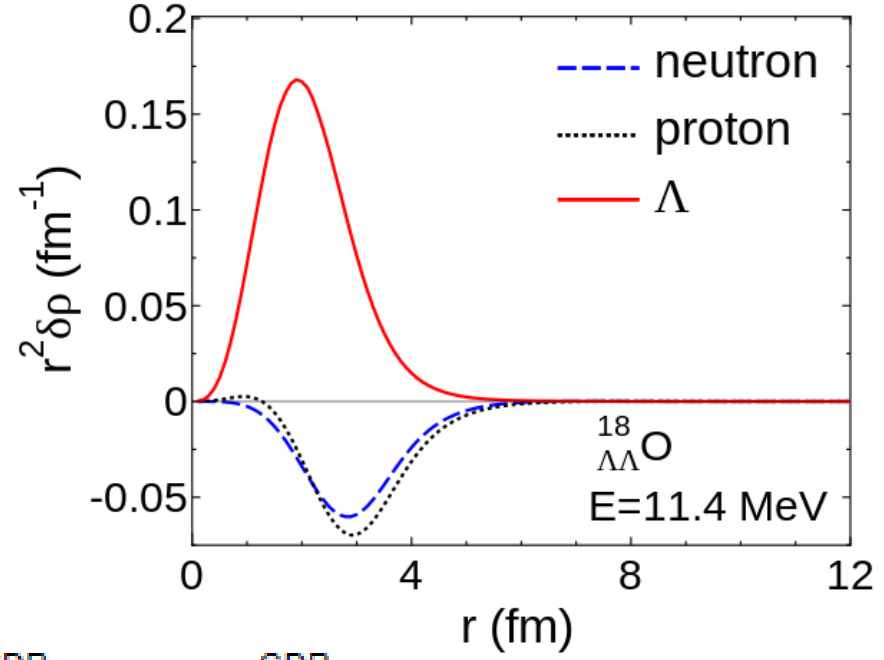

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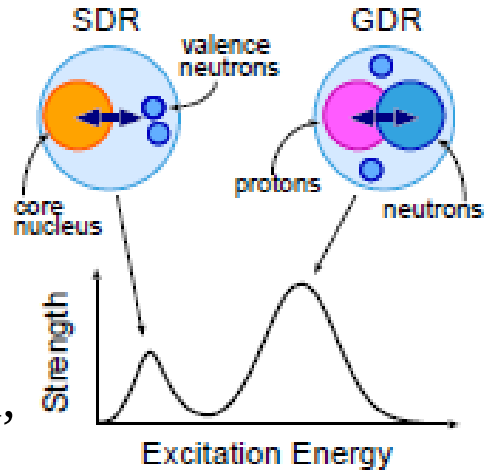

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Summary

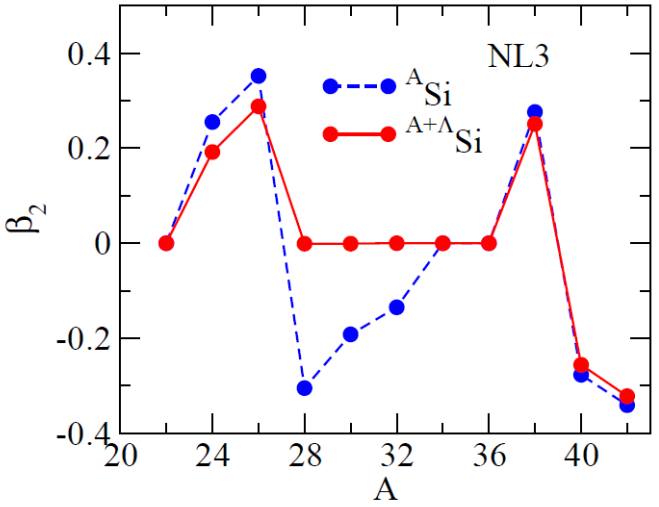
Shape of Λ hypernuclei: from the view point of mean-field theory (RMF)

- deformation: an important key word in the sd-shell region
- small effect of Λ in most of hypernuclei

  ⟶ Shape of ^{28}Si : drastically changed due to Λ

Vibrational excitations of Λ hypernuclei

- **New dipole mode (soft dipole Λ mode)**



A challenging problem

- full spectrum of a single Λ hypernucleus

  odd mass, broken time reversal symmetry, half-integer spins