Structure of *p-sd* shell Λ hypernuclei modified and probed by Λ hyperon

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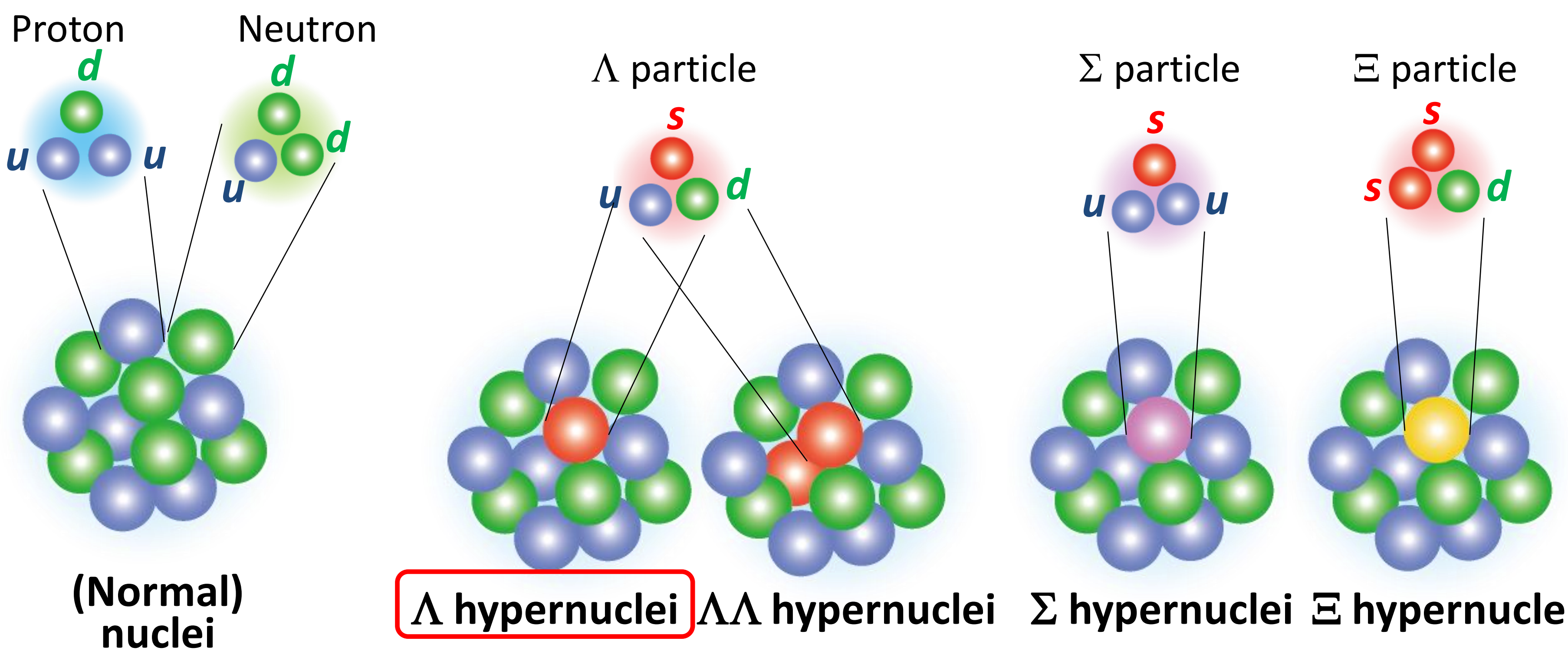
Hypernucleus

- **Normal nuclei**
  - **Nucleons**
    - **proton**
    - **neutron**

- **Hypernuclei**
  - **Nucleons and hyperon(s) (Λ, Σ, Ξ)**
  - **Hyperons have strange quark(s)**

→ Hypernuclei are nuclei with *s* quark(s)



Extended to baryon (p, n and hyperons) many-body system

Grand challenge of hypernuclear physics

<u>Interaction: To understand baryon-baryon interaction</u>

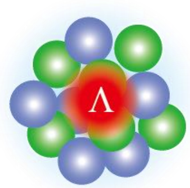
- **2 body interaction between baryons (nucleon, hyperon)**
  - hyperon-nucleon (YN)
  - hyperon-hyperon (YY)

  } A major issue in hypernuclear physics

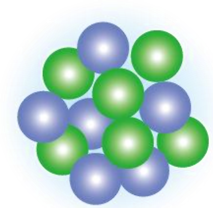
<u>Structure: To understand properties of baryon many-body system</u>

- **Structure change caused by hyperon(s)**
  - No Pauli exclusion between N and Y
  - YN interaction is different from NN

  } "Hyperon as an impurity in nuclei"



Λ hypernucleus



Normal nucleus

+

As an impurity

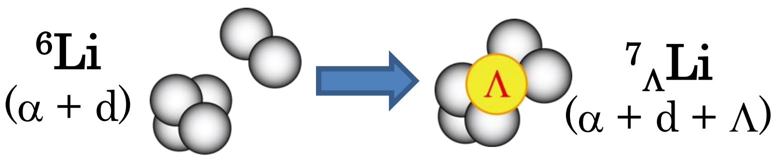
Unique aspects of Λ hypernuclei

- Λ has **no Pauli blocking** to nucleons
- ΛN **attraction** (different from NN)

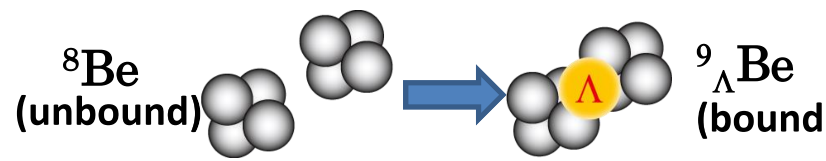
Unique phenomena

Structure change:

Shrinkage of the inter-cluster distance

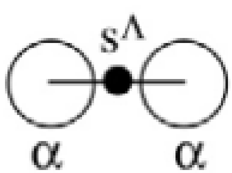


"Glue-like role" of Λ



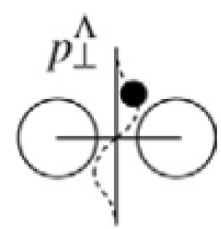
Genuine hypernuclear (super symmetric) states:

$^{9}_{\Lambda}$Be



ground state

Genuine hypernuclear state
(Super-symmetric state)



^{9}Be analog

A unique probe: Λ can penetrate into nuclear interior

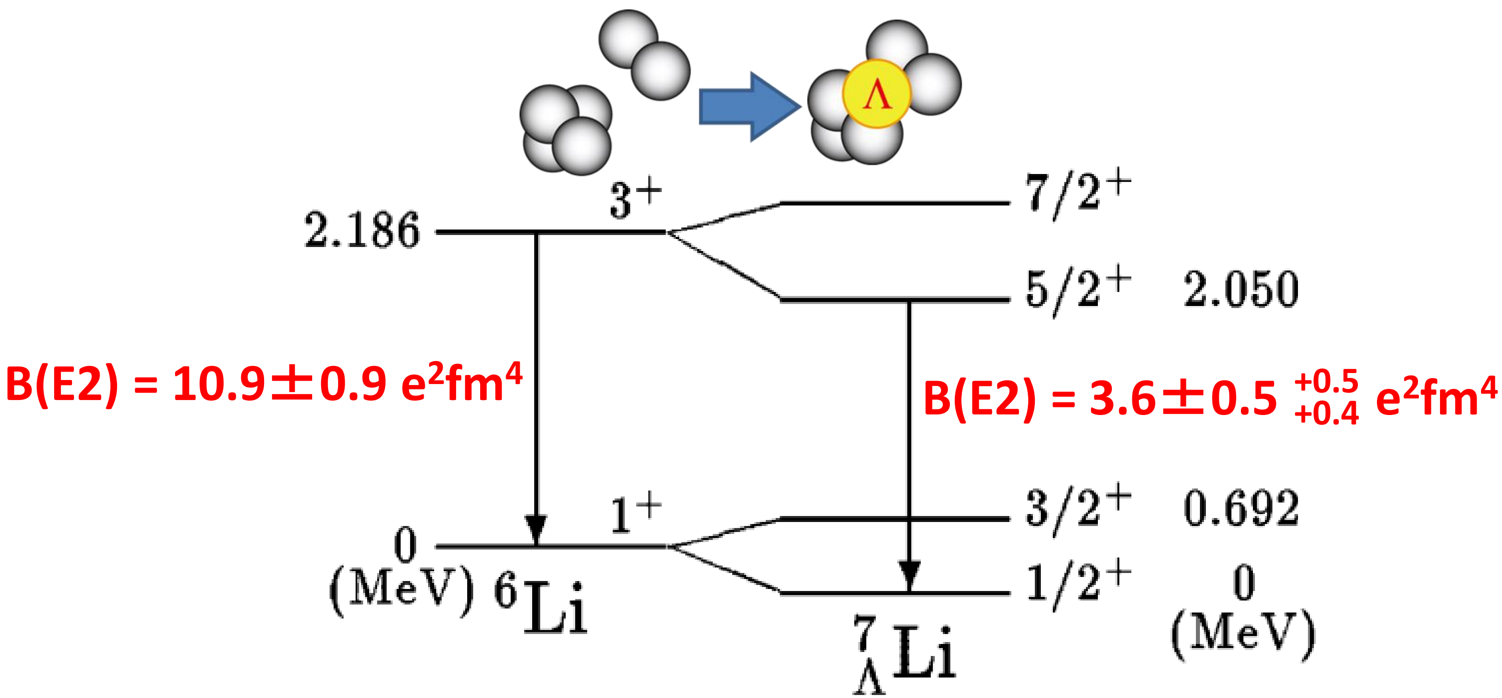
Structure change by Λ: "Shrinkage effect"

Shrinkage effect: Λ hyperon makes nucleus compact

Example: $^{7}_{\Lambda}$Li [1,2]

T. Motoba, et al., PTP **70**, 189 (1983); T. Motoba, et al., PTPS **81**, 42(1985).
E. Hiyama, et al., Phys. Rev. C**59** (1999), 2351.
K. Tanida, et al., Phys. Rev. Lett. **86** (2001), 1982.

- **^{6}Li: α + d cluster structure**
- **Λ hyperon penetrates into the nuclear interior**
- **Λ hyperon reduces α + d distance** ⟶ **B(E2) reduction (Observable)**

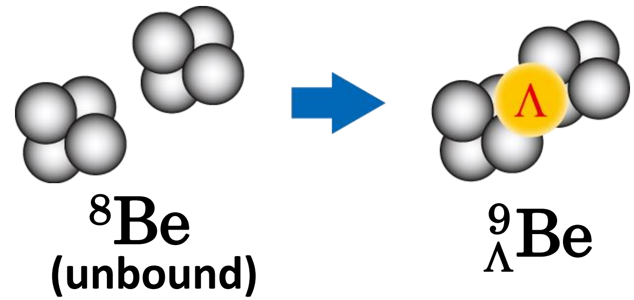


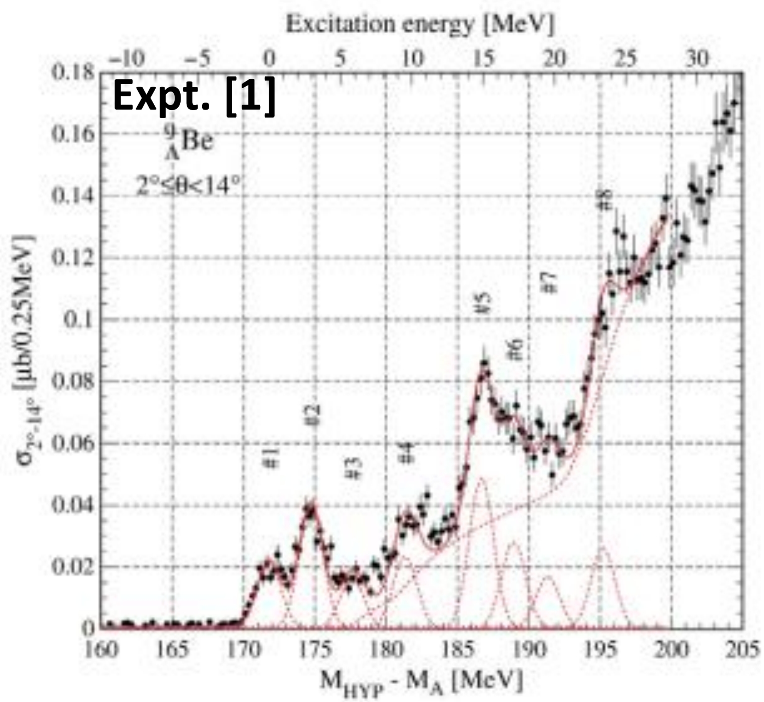
Structure change by Λ: "Glue-like role"

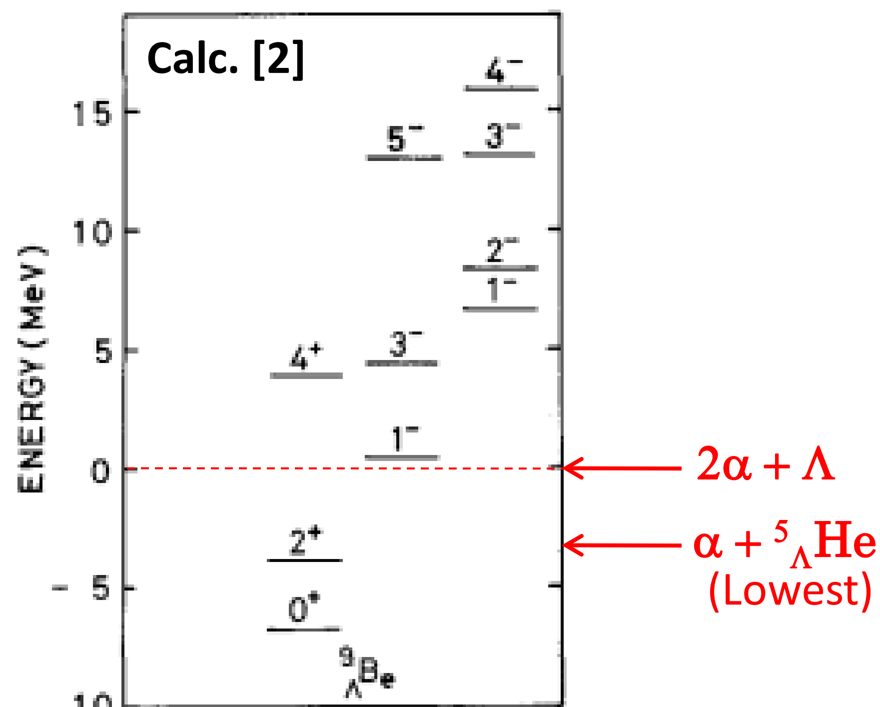
Glue-like role: Λ hyperon stabilizes unbound state

Example: $^{9}_{\Lambda}\mathrm{Be}$

- **^{8}Be is an unstable nucleus**
  - **Its g.s. lies at about 100 keV above $\alpha + \alpha$ threshold**
- **$^{9}_{\Lambda}$Be is bound with an $\alpha + \alpha + \Lambda$ structure**







[1] O. Hashimoto, et. al., NPA **639** (1998) 93c. [2] H. Bando, et. al., PTP **69** (1982) 913.

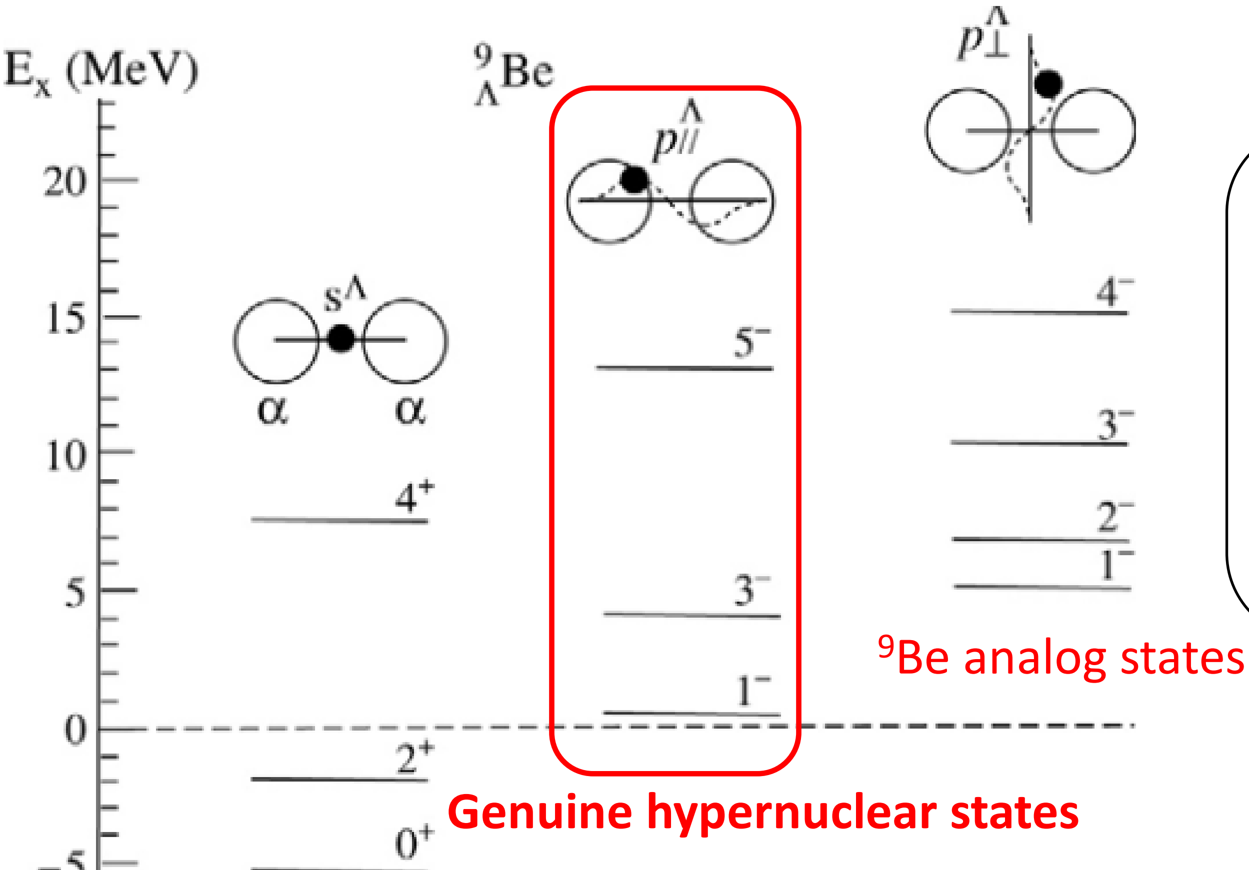
Genuine hypernuclear (super symmetric) state

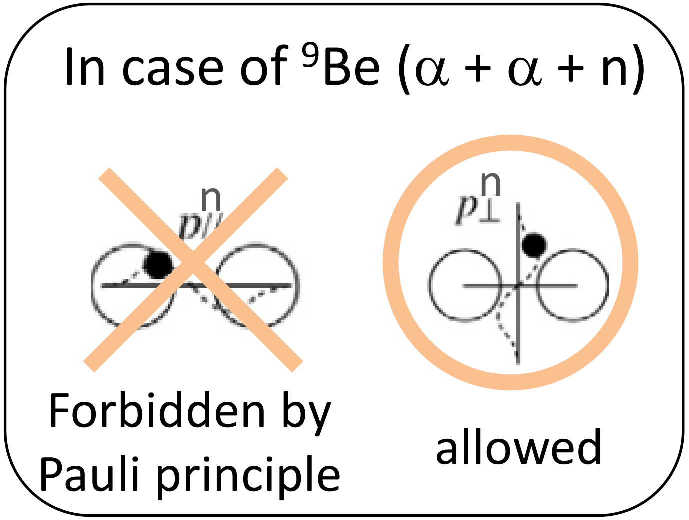
Genuine hypernuclear states cannot be formed in ordinary ^{9}Be

Example: $^{9}_{\Lambda}$Be

R.H. Dalitz, A. Gal, Phys. Rev. Lett. **36** (1976) 362
H. Bando, Nuclear Phys. A **450** (1986) 217c

- **$^{9}_{\Lambda}$Be: $\alpha + \alpha + \Lambda$ structure**



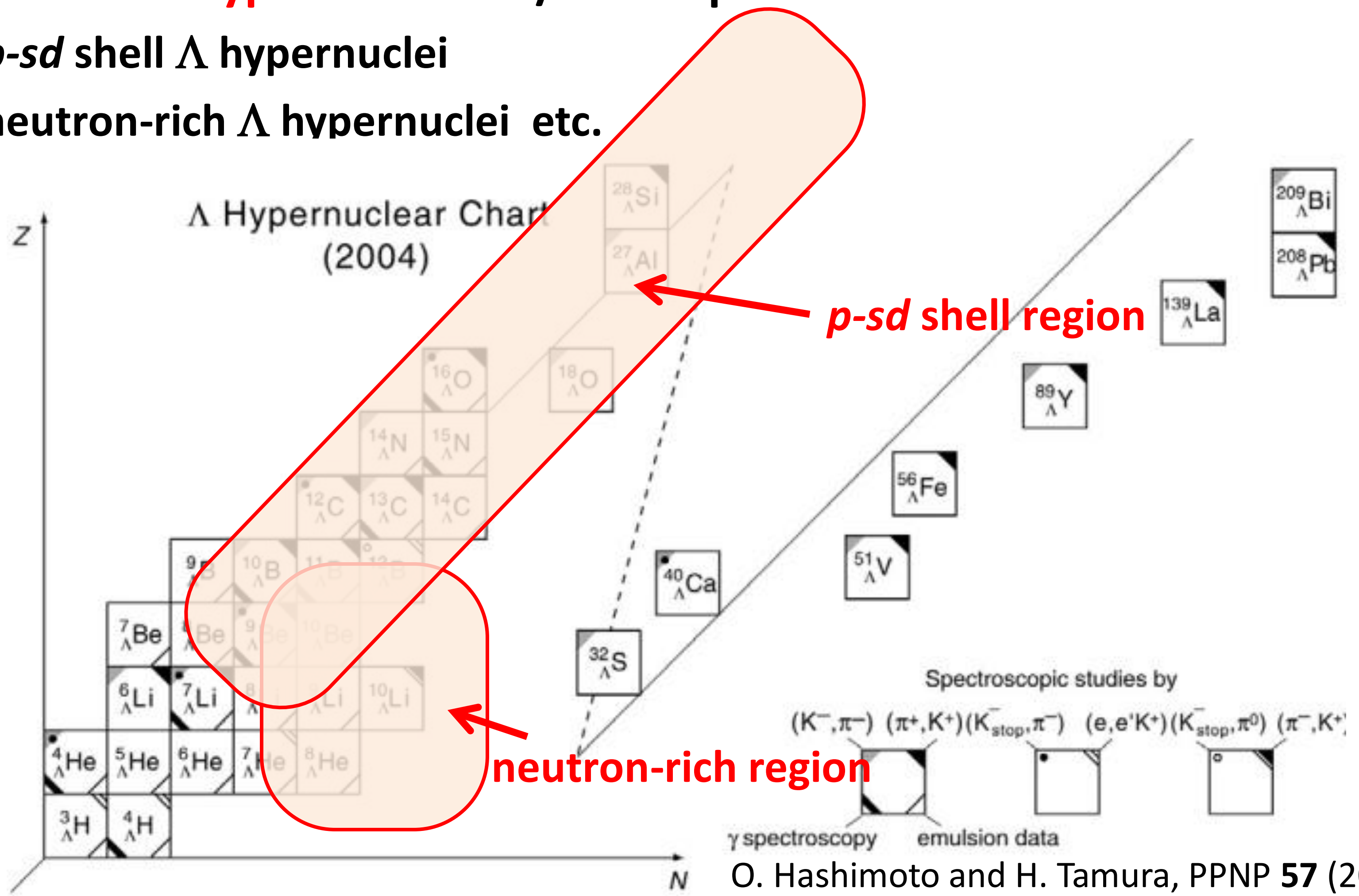


H. Bando, Nuclear Phys. A **450** (1986) 217c

Toward heavier and exotic Λ hypernuclei

Experiments at J-PARC, JLab and Mainz etc.

- **Various Λ hypernuclei will/can be produced**
  - ***p-sd*** **shell Λ hypernuclei**
  - **neutron-rich Λ hypernuclei etc.**



O. Hashimoto and H. Tamura, PPNP **57** (2006), 564.

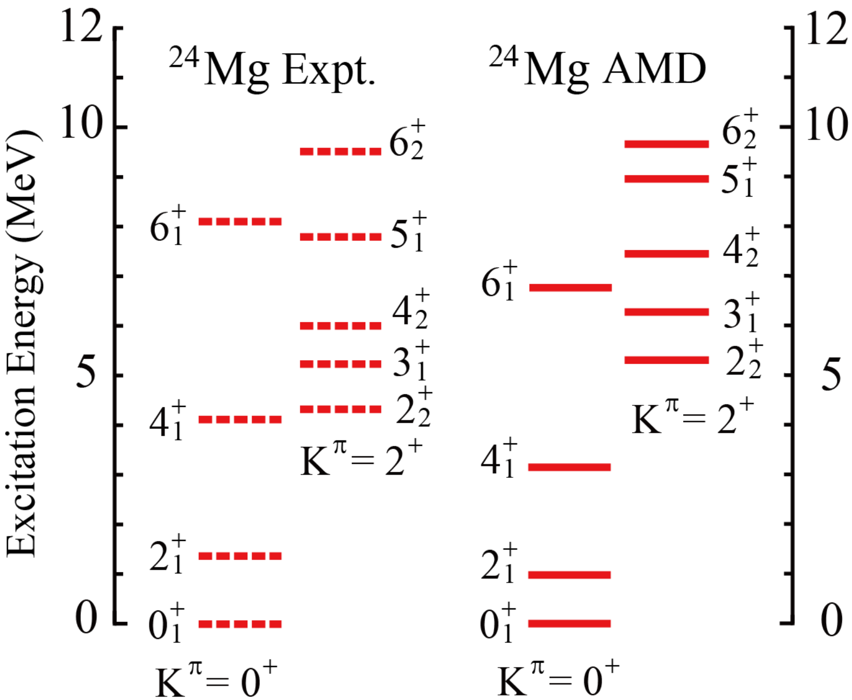
Structure study of such hypernuclei becomes one of interesting topics

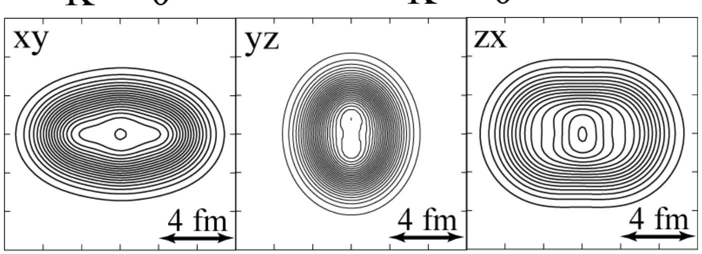
Structure of *sd* shell and neutron-rich nuclei

● Various structures

Ex) ^{24}Mg: typical *sd*-shell nucleus

- Large deformation
- Candidate of triaxial deformed nucleus

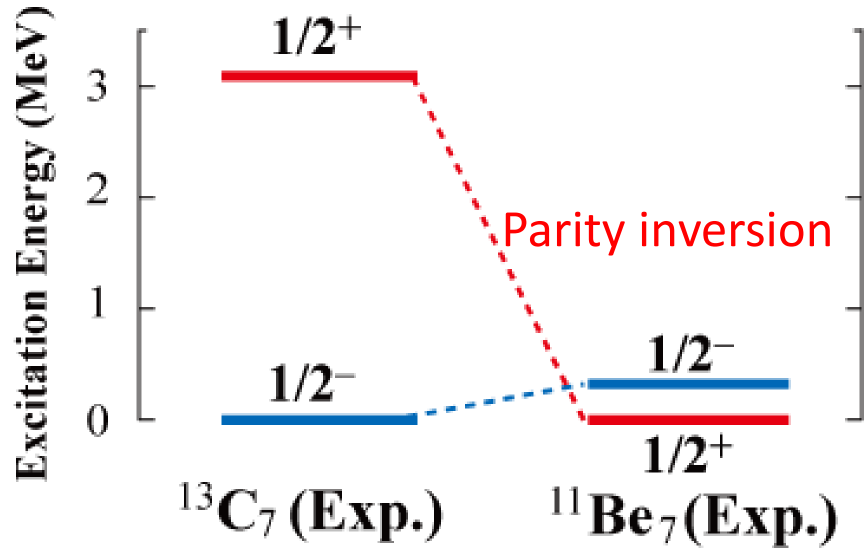


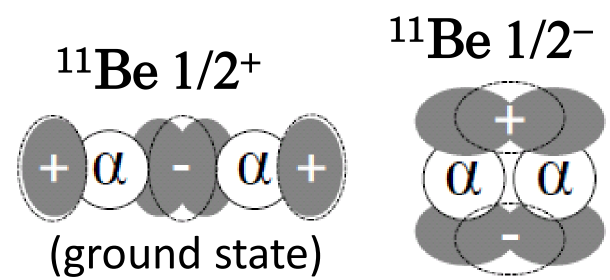


● Exotic (cluster) structure in n-rich nuclei

Ex) ^{11}Be: n-rich nucleus

- Parity inverted ground state
- Molecular orbit of extra neutrons





Y. Kanada-En'yo and H. Horiuchi, PRC **66** (2002), 024305.

Purpose of this study

◆ Purpose

- **To reveal structure of Λ hypernuclei in (*p*-)*sd* shell and n-rich region**
  - "Structure change"
  - "Λ as a probe to study nuclear structure"

◆ Individual problems (In this talk)

- **Possible structure changes caused by Λ**

  As general trends
  - Deformation change by adding Λ

  Λ's effects to the observables (excitation spectra)
  - Parity reversion of the ground state in n-rich $^{12}{}_{\Lambda}$Be
  - Changes of excitation spectrum in triaxially deformed $^{25}{}_{\Lambda}$Mg
- **Probing nuclear deformation by using Λ**
  - $^{25}{}_{\Lambda}\mathrm{Mg}$: to reveal triaxial deformation of $^{24}\mathrm{Mg}$

Strategy: based on the developments

Developments of hypernuclear physics: interaction

- Knowledge of ΛN effective interaction

E. Hiyama, NPA **805** (2008), 190c.
O. Hashimoto and H. Tamura, PPNP **57** (2006), 564.

Development of theoretical models

- Through the study of unstable nuclei

Ex.: Antisymmetrized Molecular Dynamics (AMD)

Y. Kanada-En'yo et al., PTP **93** (1995), 115.

- AMD describes dynamical changes of various structure
- No assumption on clustering and deformation

→ **Constructing a new model to describe hypernuclear structure**

"Systematic study of Λ hypernuclear structure"

Forthcoming experiments

- **To compare our prediction with the forthcoming experiments**
  - Variety of *p-sd* shell Λ hypernuclei

Theoretical framework: HyperAMD

We extended the AMD to hypernuclei

HyperAMD (Antisymmetrized Molecular Dynamics for hypernuclei)

◆Hamiltonian

$$\hat{H} = \hat{T}_N + \hat{V}_{NN} + \hat{T}_\Lambda + \hat{V}_{\Lambda N}$$

NN : Gogny D1S
ΛN : YNG interaction (Central force) [1]

◆Wave function

- **Nucleon part : Slater determinant**
  Spatial part of single particle w.f. is described as Gaussian packet

$$\varphi_N(\vec{r}) = \frac{1}{\sqrt{A!}} \det\left[\varphi_i(\vec{r}_j)\right]$$

$$\varphi_i(r) \propto \exp\left[-\sum_{\sigma=x,y,z} \nu_\sigma (r - Z_i)_\sigma^2\right] \chi_i \eta_i \qquad \chi_i = \alpha_i \chi_\uparrow + \beta_i \chi_\downarrow$$

- **Single particle w.f. of Λ hyperon:**
  Superposition of Gaussian packets

$$\varphi_\Lambda(r) = \sum_m c_m \varphi_m(r)$$

$$\varphi_m(r) \propto \exp\left[-\sum_{\sigma=x,y,z} \mu\nu_\sigma (r - z_m)_\sigma^2\right] \chi_m \qquad \chi_m = a_m \chi_\uparrow + b_m \chi_\downarrow$$

- **Total w.f. :**

$$\psi(\vec{r}) = \sum_m c_m \varphi_m(r_\Lambda) \otimes \frac{1}{\sqrt{A!}} \det\left[\varphi_i(\vec{r}_j)\right]$$

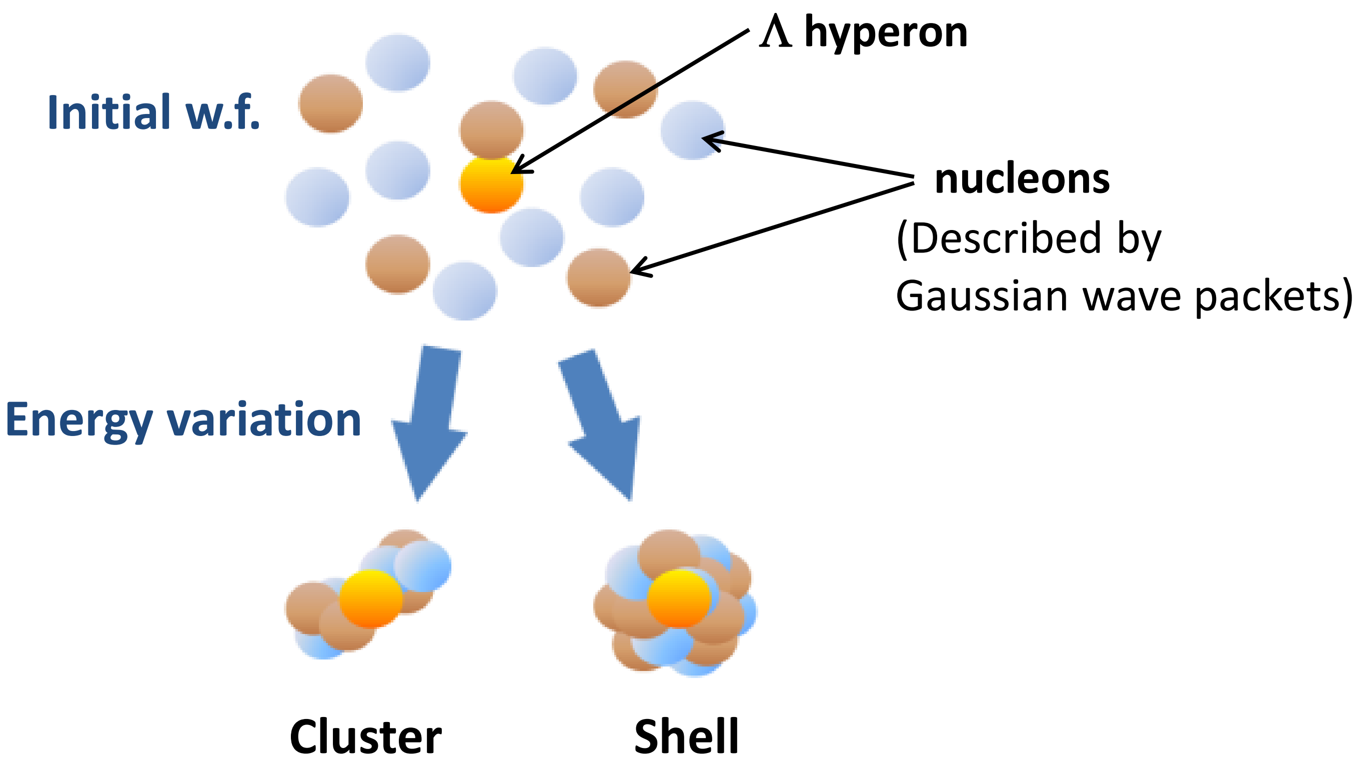
[1] Y. Yamamoto, T. Motoba, H. Himeno, K. Ikeda and S. Nagata, Prog. Theor. Phys. Suppl. **117** (1994), 361.

Theoretical framework: HyperAMD

◆ Procedure of the calculation

Variational Calculation

- Imaginary time development method $\frac{dX_i}{dt} = \frac{\kappa}{\hbar}\frac{\partial H^{\pm}}{\partial X_i^*} \qquad \kappa < 0$
- Variational parameters: $X_i = Z_i, z_i, \alpha_i, \beta_i, a_i, b_i, \nu_i, c_i$



Theoretical framework: HyperAMD

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↓

Angular Momentum Projection

$$\left|\Phi_K^s; JM\right\rangle = \int d\Omega D_{MK}^{J*}(\Omega) R(\Omega) \left|\Phi^{s+}\right\rangle$$

↓

Generator Coordinate Method(GCM)

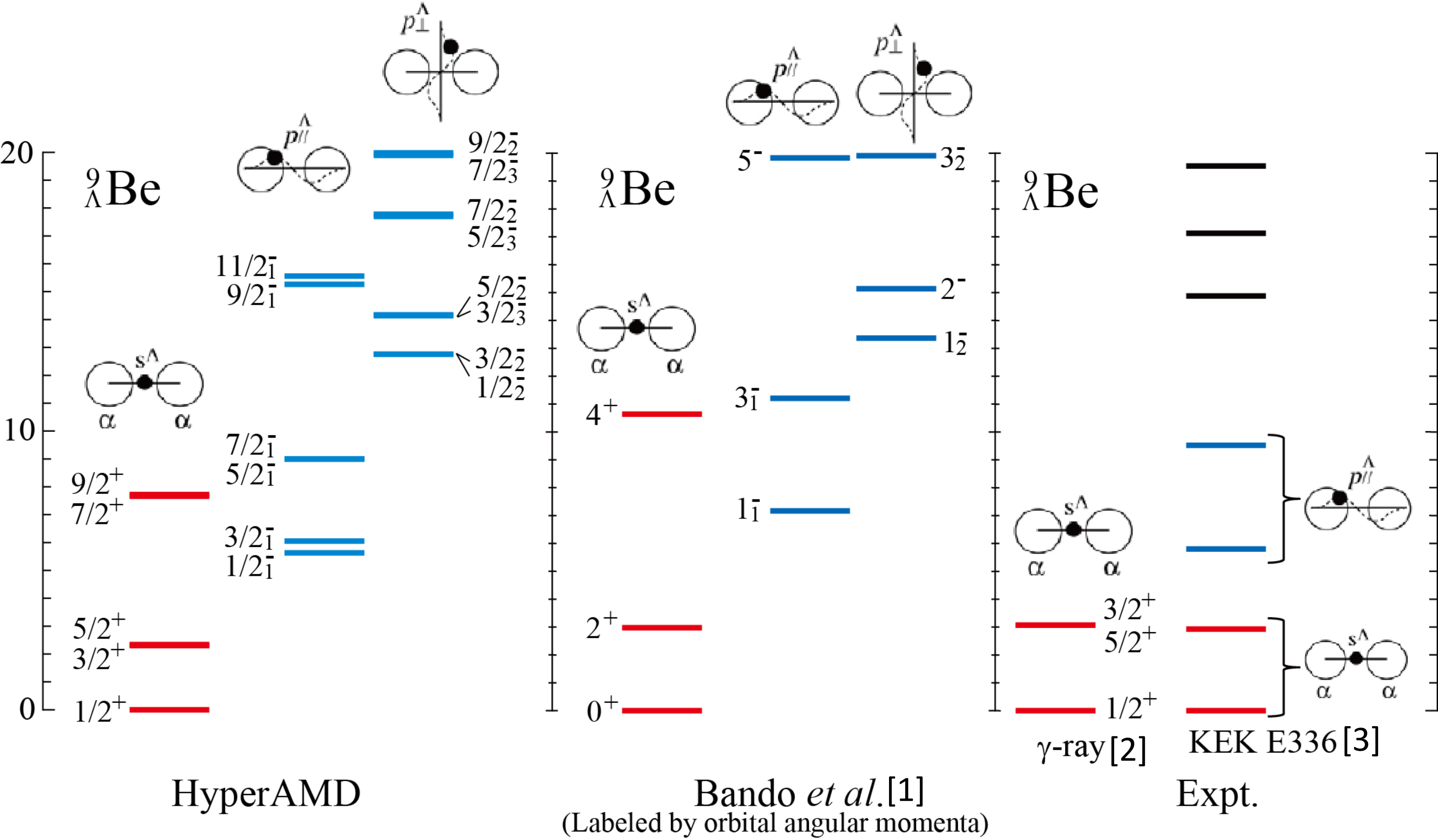
- Superposition of the w.f. with different configuration
- Diagonalization of $H_{sK,s'K'}^{J\pm}$ and $N_{sK,s'K'}^{J\pm}$

$$H_{sK,s'K'}^{J\pm} = \left\langle \Phi_K^s; J^{\pm}M \left| \hat{H} \right| \Phi_{K'}^{s'}; J^{\pm}M \right\rangle$$

$$N_{sK,s'K'}^{J\pm} = \left\langle \Phi_K^s; J^{\pm}M \middle| \Phi_{K'}^{s'}; J^{\pm}M \right\rangle$$

$$\left|\Psi^{J\pm M}\right\rangle = \sum_{sK} g_{sK} \left|\Phi_K^s; J^{\pm}M\right\rangle$$

Application to $^{9}{}_{\Lambda}$Be hypernucleus



[1] Bando *et al.*, PTP **66** (1981) 2118.
[2] M. May *et al.*, PRL **51** (1983) 2085; H. Akikawa *et al.*, PRL **88** (2002) 082501.
[3] O. Hashimoto et al., NPA **639** (1998) 93c

Structure change by Λ

- **Nuclear deformation change by Λ (in *s* and *p* orbits)**

  Examples: $^{9}_{\Lambda}$Be, $^{13}_{\Lambda}$C, $^{20}_{\Lambda}$Ne and $^{21}_{\Lambda}$Ne

  M. Isaka, M. Kimura, A. Dote and A. Ohnishi, PRC **83** (2011), 044323.

- **Parity reversion of the ground state in n-rich $^{12}_{\Lambda}$Be**

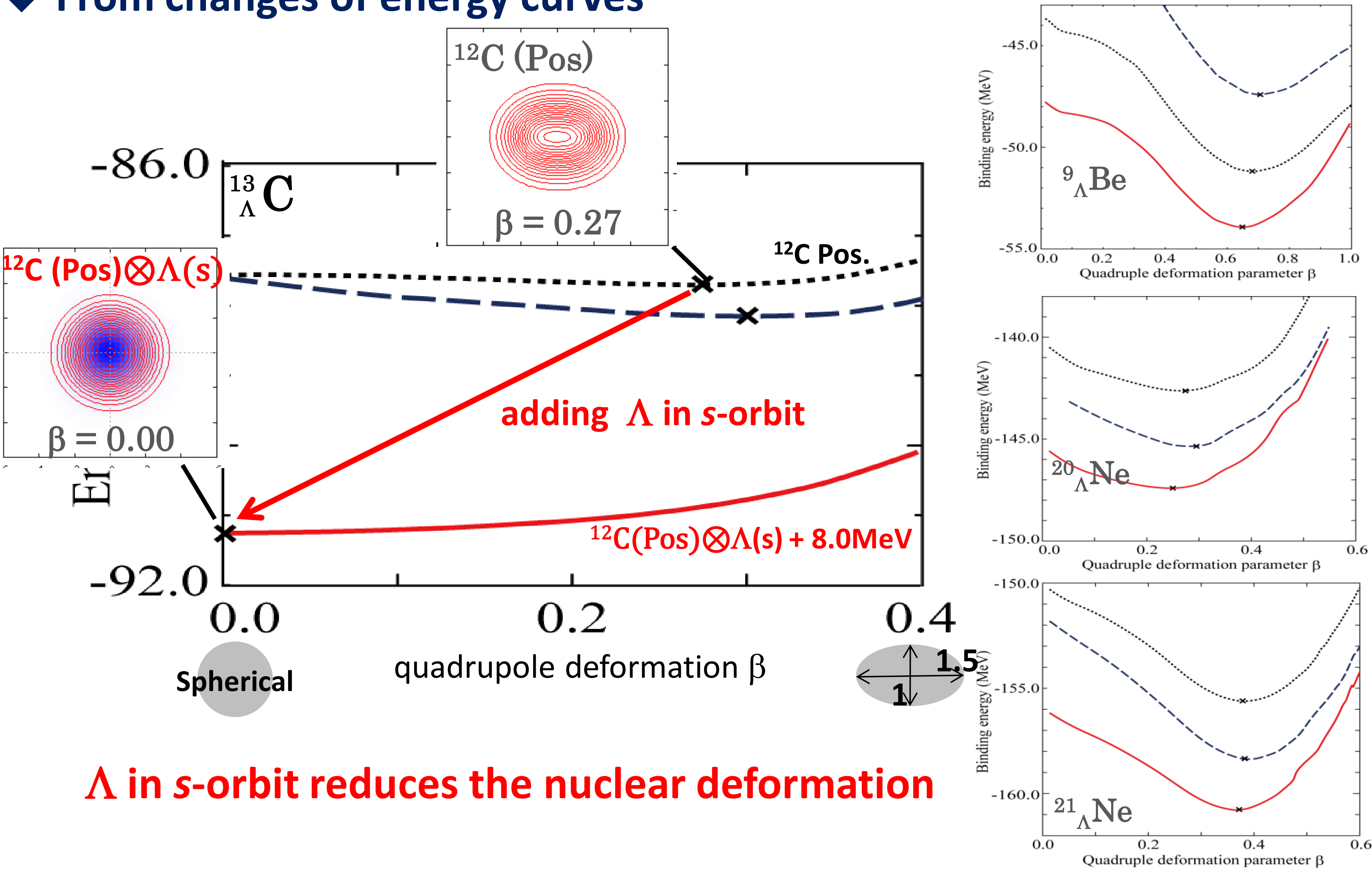
  H. Homma, M. Isaka and M. Kimura, to be submitted

- **Changes of excitation spectrum in triaxially deformed $^{25}_{\Lambda}$Mg**

  M. Isaka, M. Kimura, A. Dote and A. Ohnishi, PRC **85** (2012), 034303.

Deformation change by Λ in *s*-orbit

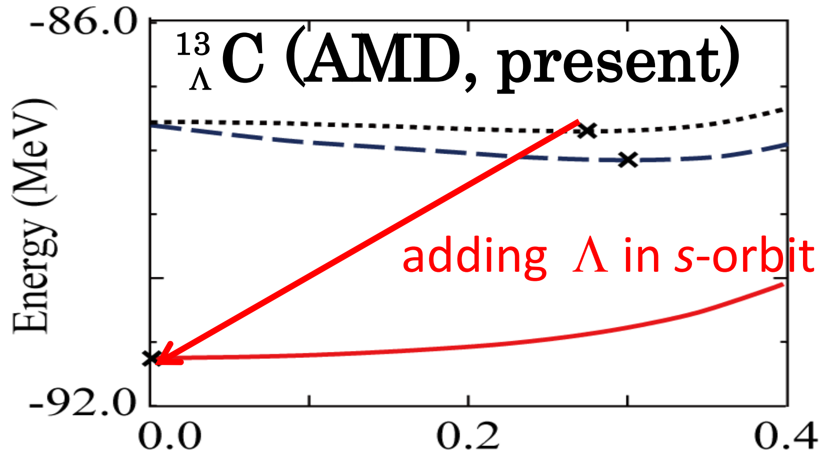
◆ **From changes of energy curves**



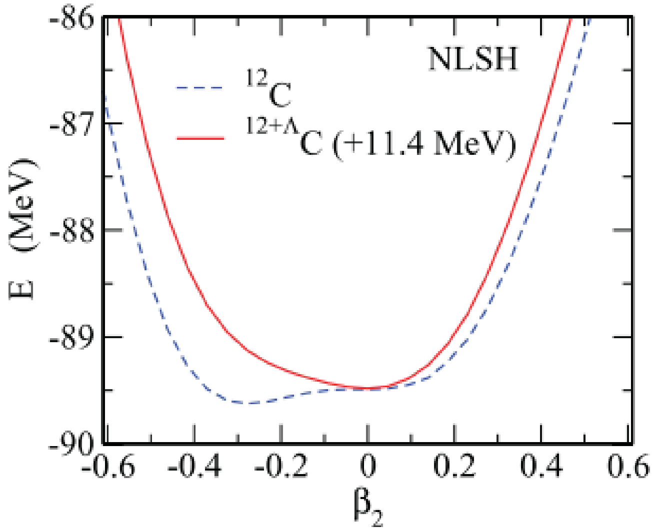
Λ in *s*-orbit reduces the nuclear deformation

Deformation change by Λ in *s*-orbit

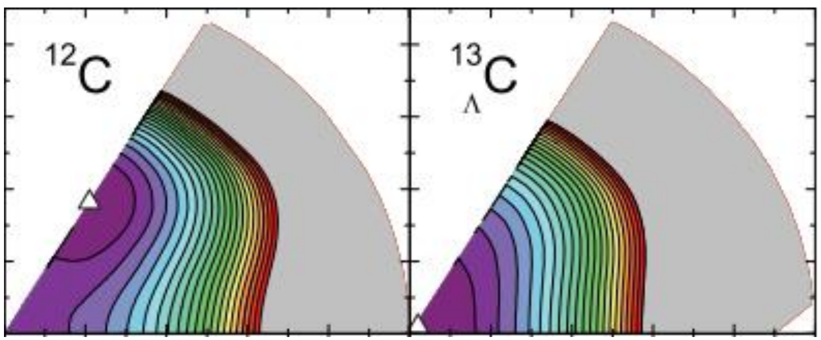
- **Many authors predict the deformation change by Λ in *s*-orbit**



Ex.) Deformation change in $^{13}{}_{\Lambda}$C predicted by RMF calc.



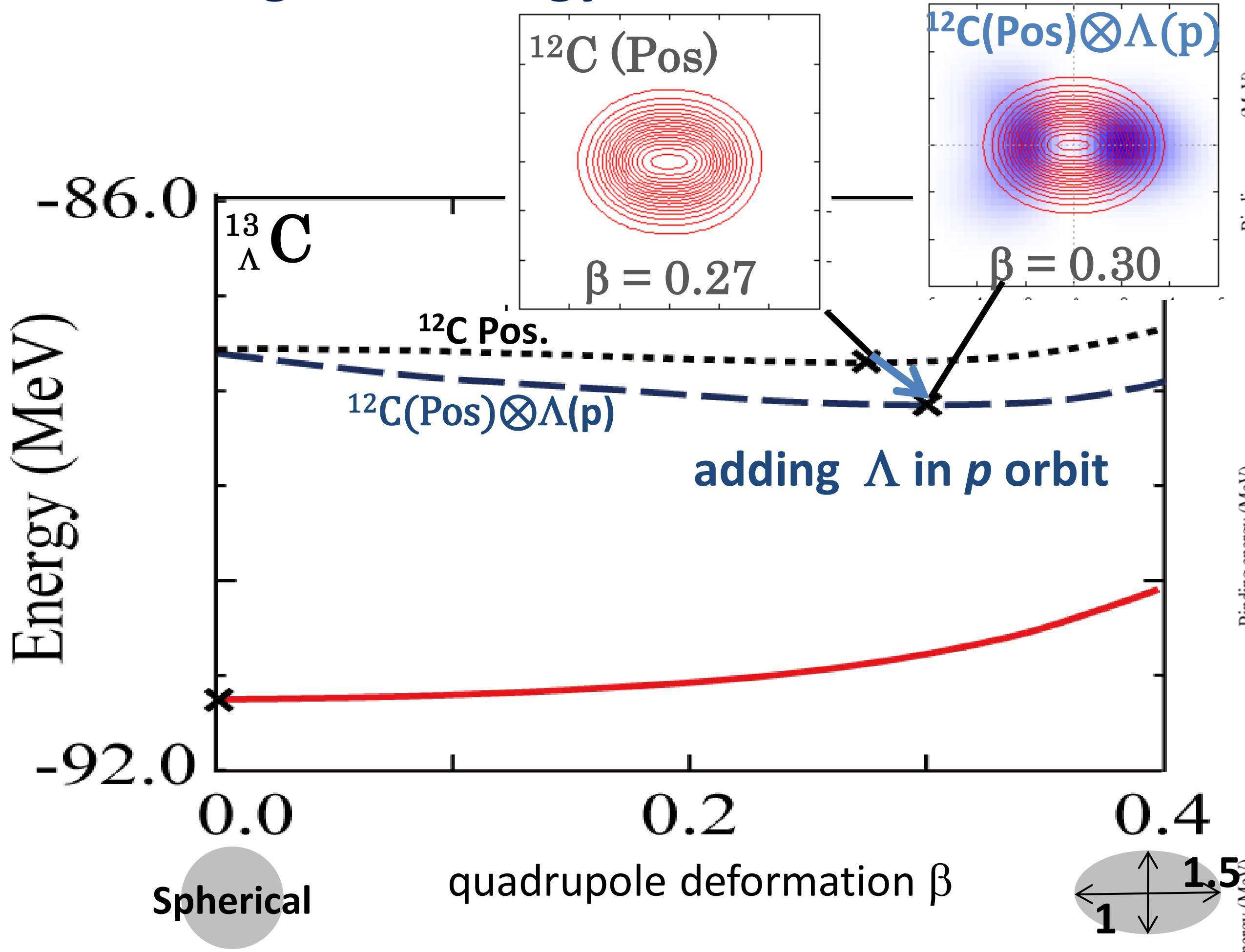
M. T. Win and K. Hagino, Phys. Rev. C **78**, 054311(2008)

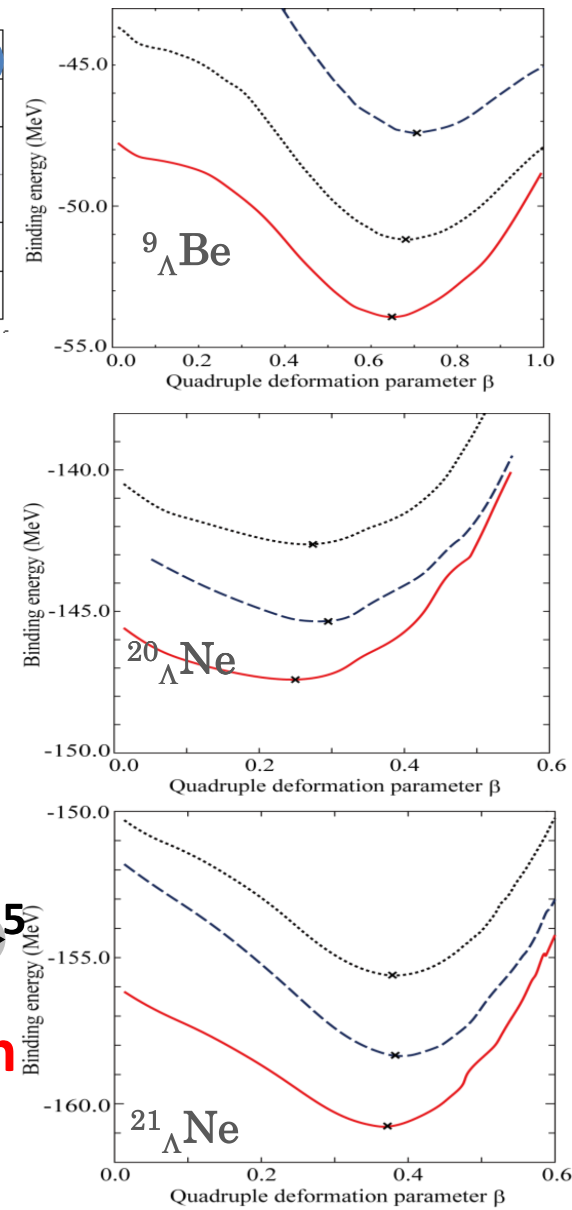


Bing-Nan Lu, et al., Phys. Rev. C **84**, 014328 (2011)

Deformation change by Λ in *p*-orbit

- **From changes of energy curves**





Λ in *p*-orbit enhances the nuclear deformation

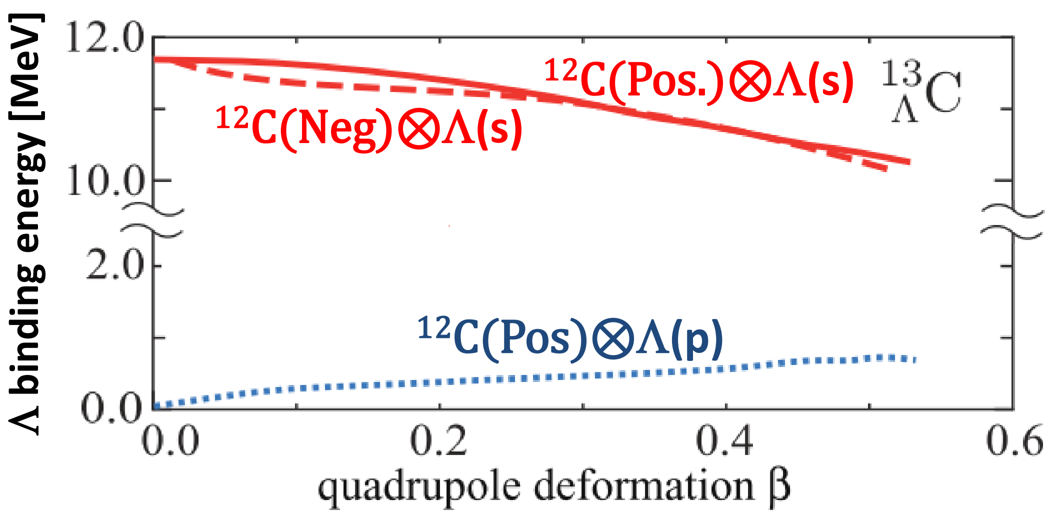
→ **Opposite trend to Λ in *s*-orbit**

Λ binding energy

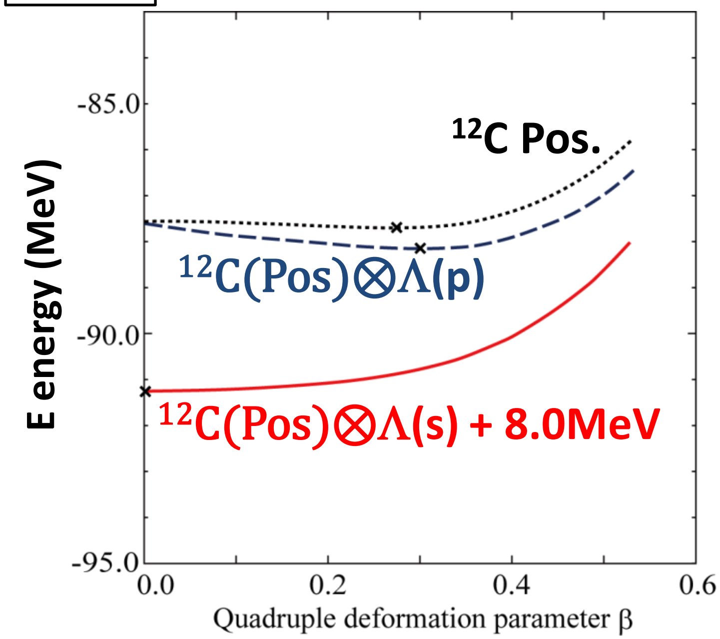
◆ Variation of the Λ binding Energy

- Λ in *s*-orbit is deeply bound at smaller deformation
- Λ in *p*-orbit is deeply bound at larger deformation

$^{13}_{\Lambda}C$ Binding energy of Λ



$^{13}_{\Lambda}C$ Energy curves



Variation of the Λ binding energies causes the deformation change (reduction or enhancement)

Structure change by Λ

- **Nuclear deformation change by Λ (in *s* and *p* orbits)**

  Examples: $^{9}_{\Lambda}$Be, $^{13}_{\Lambda}$C, $^{20}_{\Lambda}$Ne and $^{21}_{\Lambda}$Ne

  M. Isaka, M. Kimura, A. Dote and A. Ohnishi, PRC **83** (2011), 044323.

- **Parity reversion of the ground state in n-rich $^{12}_{\Lambda}$Be**

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- **Changes of excitation spectrum in triaxially deformed $^{25}_{\Lambda}$Mg**

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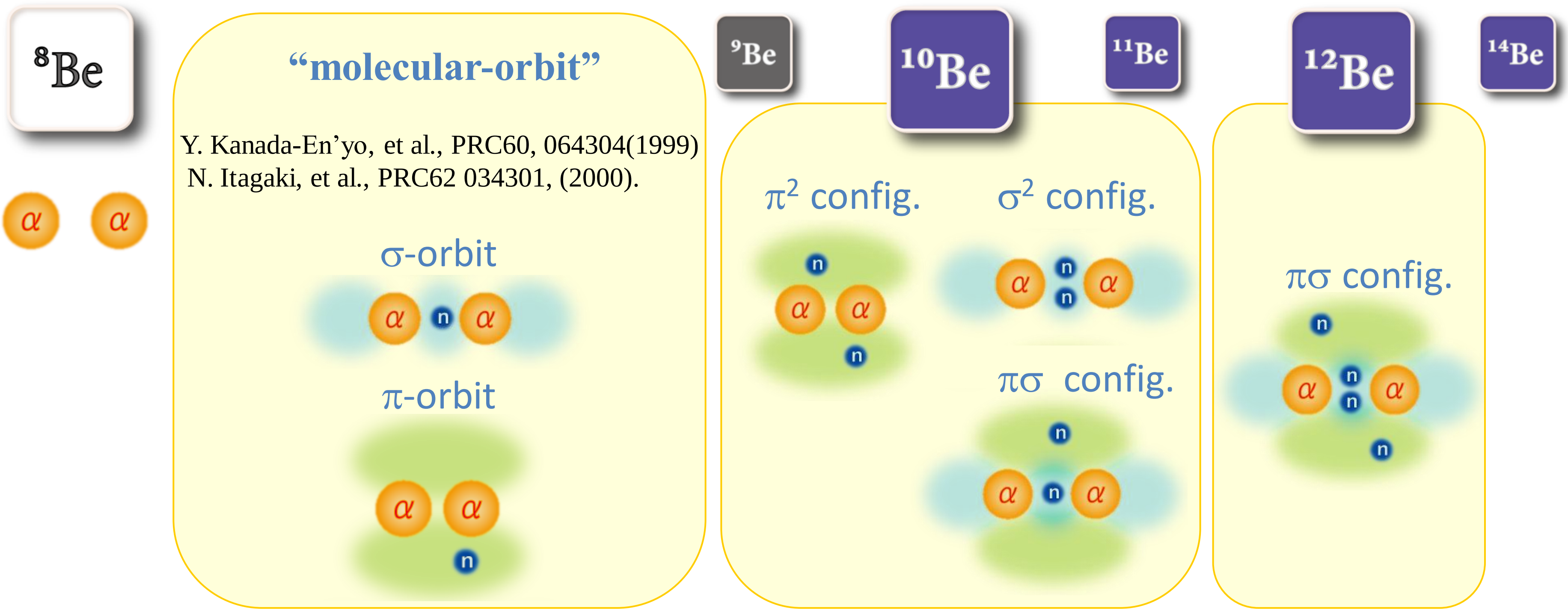
Structure of Be isotopes



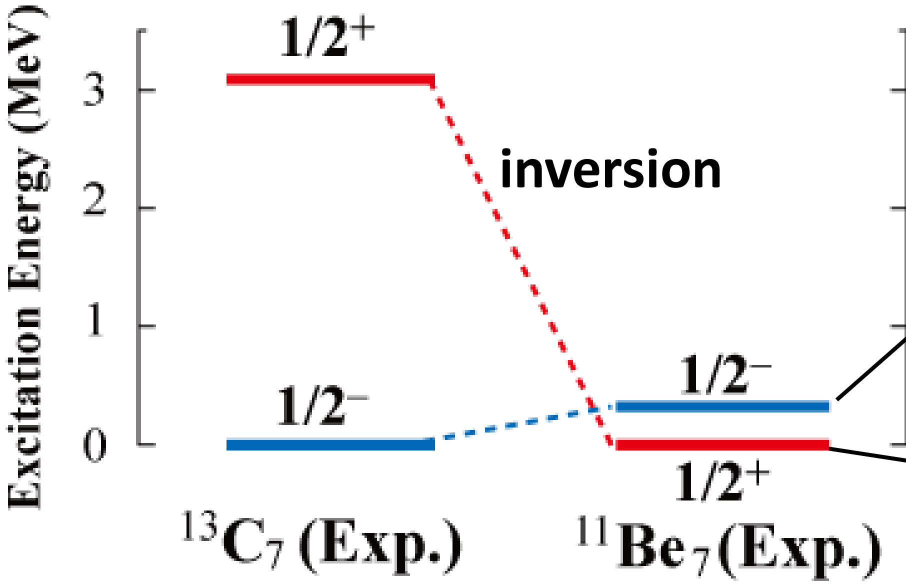
- **Be isotopes have 2α cluster structure**
  - **2α cluster structure is changed depending on the neutron number**

Exotic structure of ^{11}Be

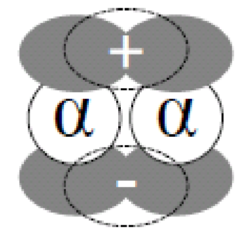
◆ Parity inversion of the $^{11}_{4}Be_{7}$ ground state

- **The ground state of ^{11}Be is $1/2^{+}$**

  → **Vanishing of the magic number N=8**

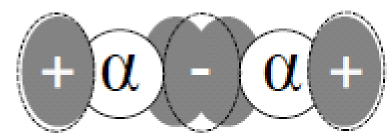


^{11}Be $1/2^{-}$



Extra neutrons in π orbit[1]
(small deformation)

^{11}Be $1/2^{+}$



Extra neutrons in σ orbit[1]
(large deformation)

- **One of the reasons of the parity inversion is the molecular orbit structure of the 1/2+ and 1/2- states.** → **Difference of deformation**

[1] Y. Kanada-En'yo and H. Horiuchi, PRC **66** (2002), 024305.

Purpose of this study

◆ Purpose of this study

- **To reveal how Λ hyperon affects and modifies the low-lying states of Be isotopes with different deformation**

  Examples:

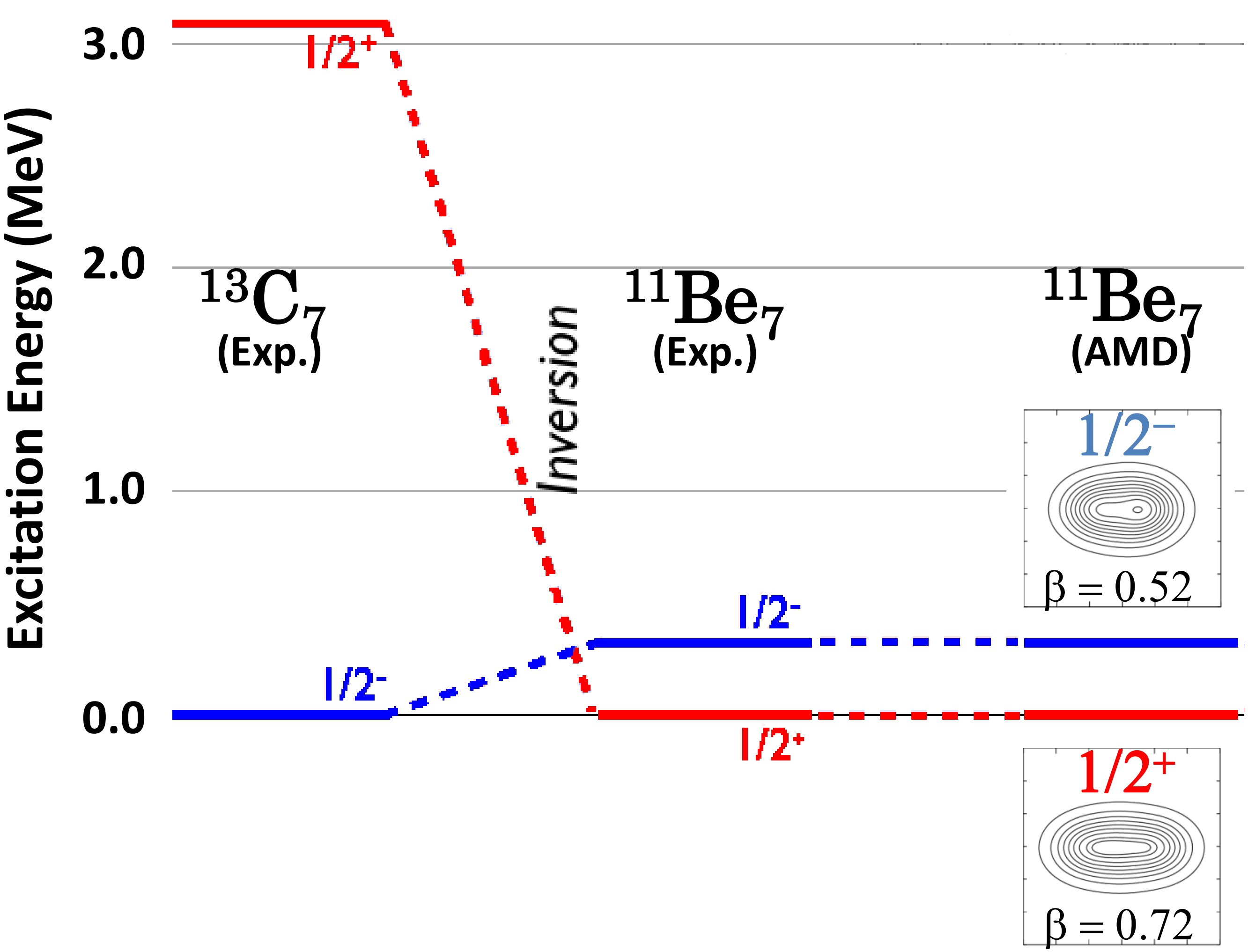
  $^{12}_{\Lambda}$Be: abnormal parity ground state of ^{11}Be

◆ Method: HyperAMD

- **Energy variation with β constraint**
  - No assumption on 2α cluster structure
  - AMD has succeeded in the structure studies of Be isotopes
- **Angular momentum projection**
- **GCM calculation**
  - Prediction of the Excitation spectrum

Structure change in n-rich $^{12}{}_{\Lambda}Be$

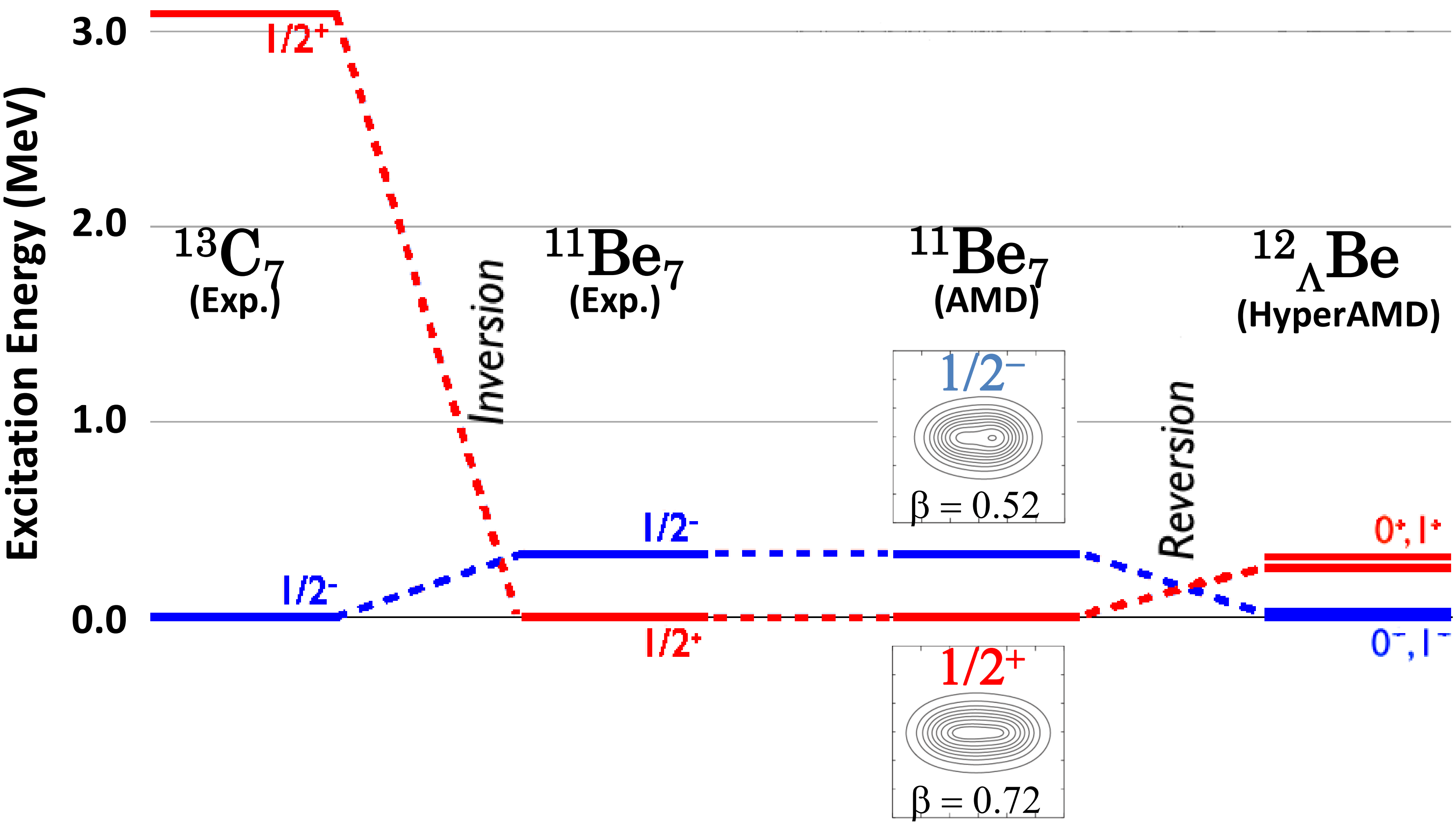
◆ Ground state of $^{12}{}_{\Lambda}Be$



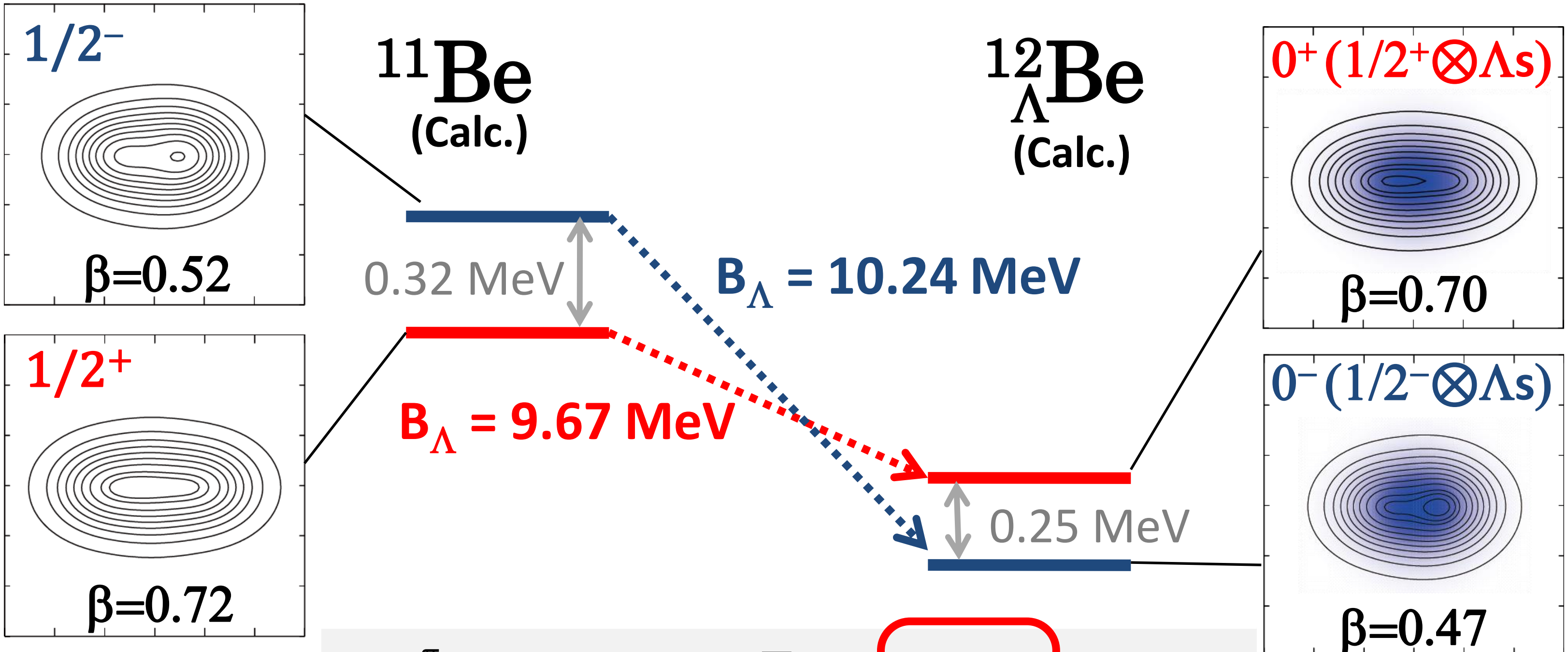
Structure change in n-rich $^{12}{}_{\Lambda}$Be

◆ Ground state of $^{12}{}_{\Lambda}$Be

- **The parity reversion of the $^{12}{}_{\Lambda}$Be g.s. occurs by the Λ hyperon**



Deformation and Λ binding energy



J^π	E_{tot}	T_Λ	$V_{\Lambda N}$	E_{nucl}
0^-(GS)	−74.69	6.71	−16.93	−64.47
0^+	−74.44	6.68	−16.42	−64.70

- **Λ hyperon coupled to the $1/2^-$ state is more deeply bound than that coupled to the $1/2^+$ state**
  - **This is because the deformation of the $1/2^-$ state is smaller than that of the $1/2^+$ state**

Structure change by Λ

- **Nuclear deformation change by Λ (in *s* and *p* orbits)**

  Examples: $^{9}_{\Lambda}$Be, $^{13}_{\Lambda}$C, $^{20}_{\Lambda}$Ne and $^{21}_{\Lambda}$Ne

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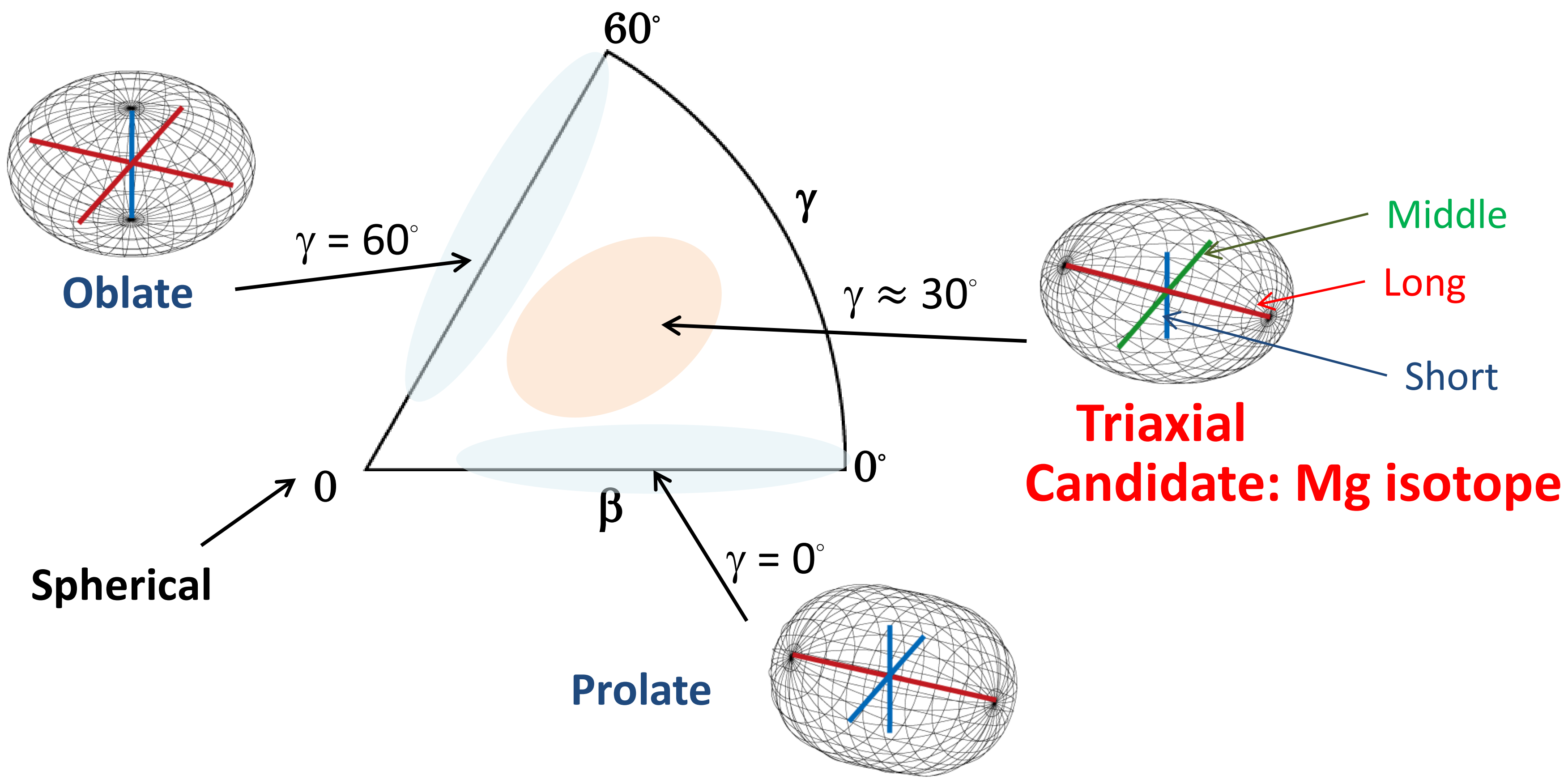
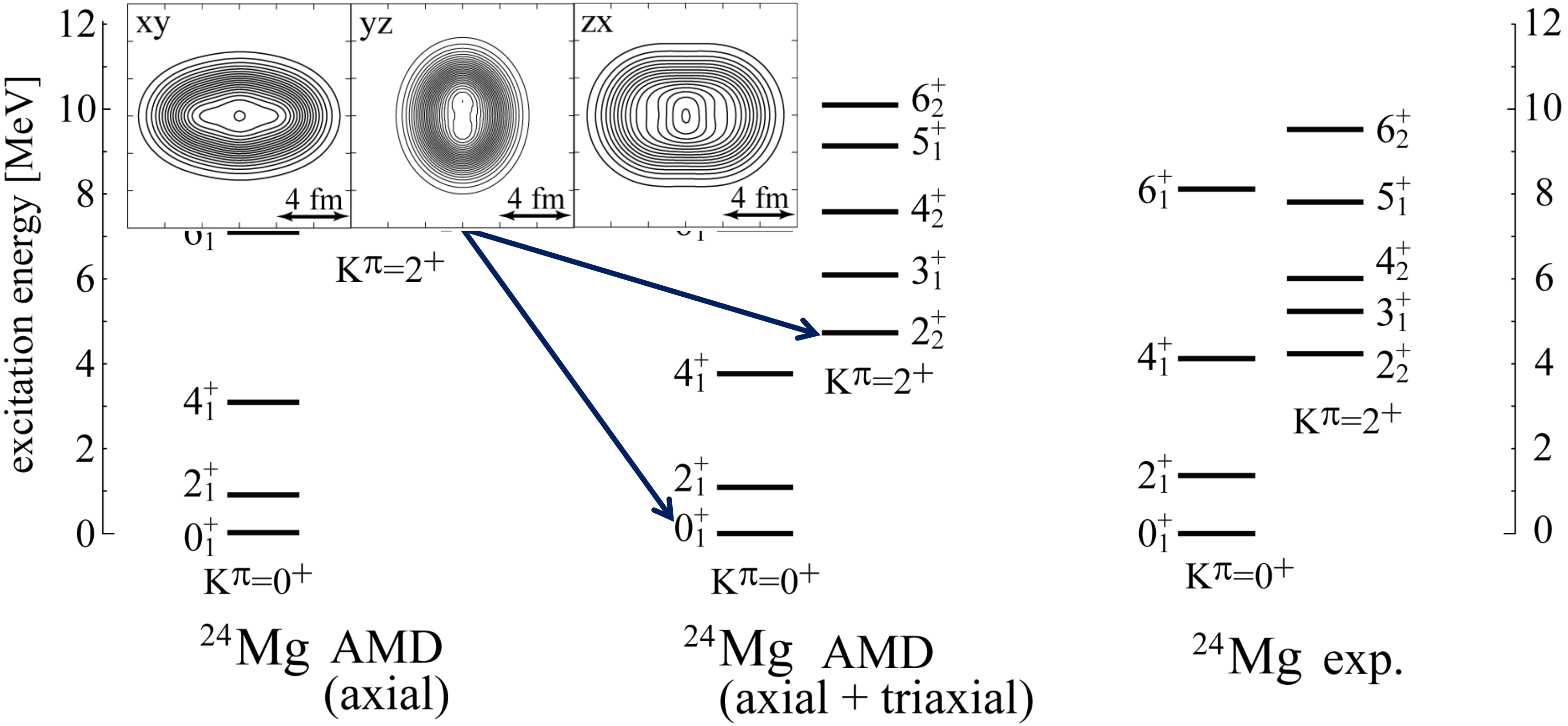
Deformation of nuclei

- **Many nuclei manifests various quadrupole deformation**
  (parameterized by quadrupole deformation parameters β and γ)
- **Most of them are prolate or oblate deformed (axially symmetric)**



Structure of ^{24}Mg

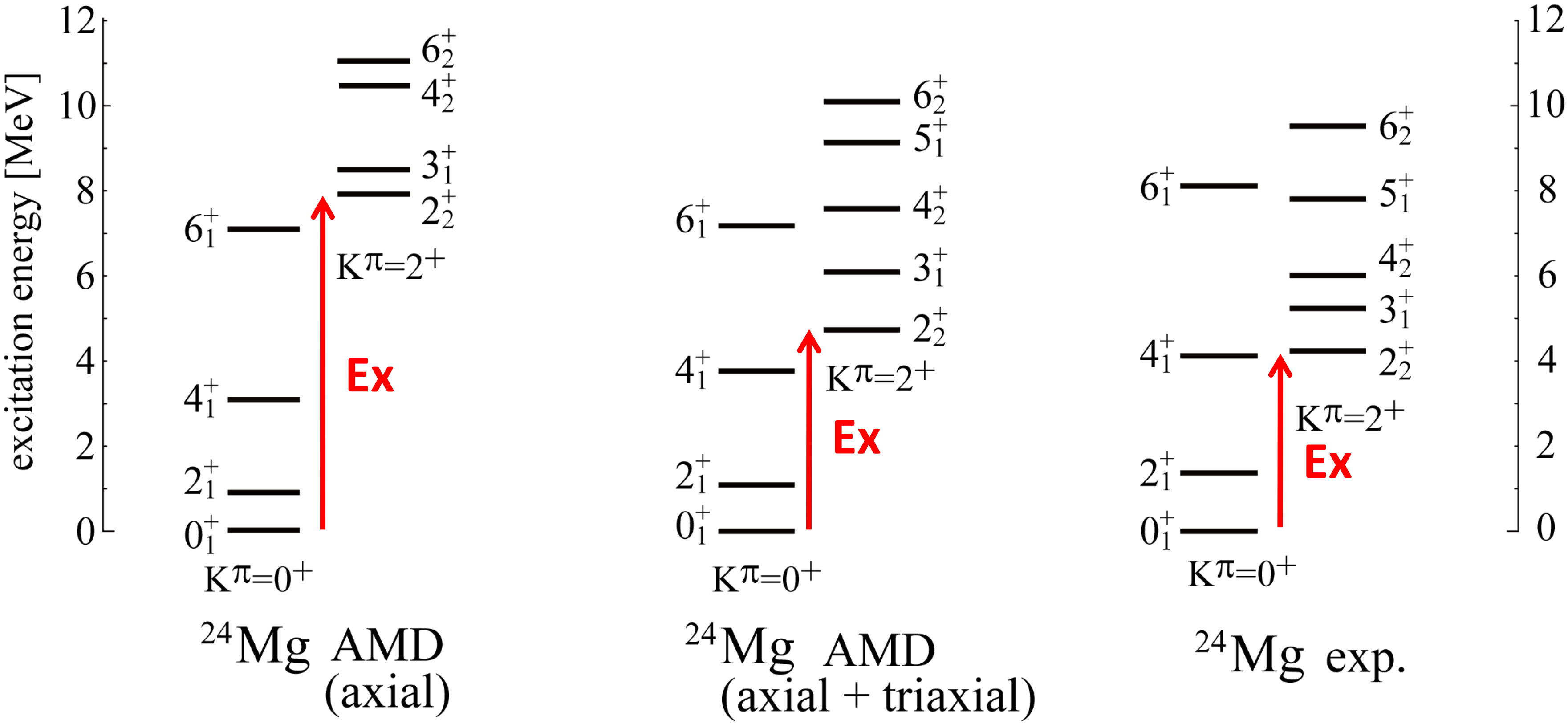
- **Large deformation ･･･ Candidate of triaxial deformed nuclei**
- **Excitation energy of $K^\pi=2^+$ band depends on the triaxial deformation [1,2]**



[1] M. Bender and P-H. Heenen, Phys. Rev. **C78**, 024309 (2008).
[2] M. Kimura, R. Yoshida and M.Isaka, Prog. Theor. Phys. **127** , 287(2011).

Structure of ^{24}Mg

- **Large deformation ･･･ Candidate of triaxial deformed nuclei**
- **Excitation energy of $K^{\pi}=2^{+}$ band depends on the triaxial deformation [1,2]**



$K^{\pi} = 2^{+}$ band is rigid against the exclusion of the triaxial deformation

How does Λ modify triaxial deformation of ^{24}Mg ?

[1] M. Bender and P-H. Heenen, Phys. Rev. **C78**, 024309 (2008).
[2] M. Kimura, R. Yoshida and M.Isaka, Prog. Theor. Phys. **127** , 287(2011).

Predictions for $^{25}{}_{\Lambda}$Mg

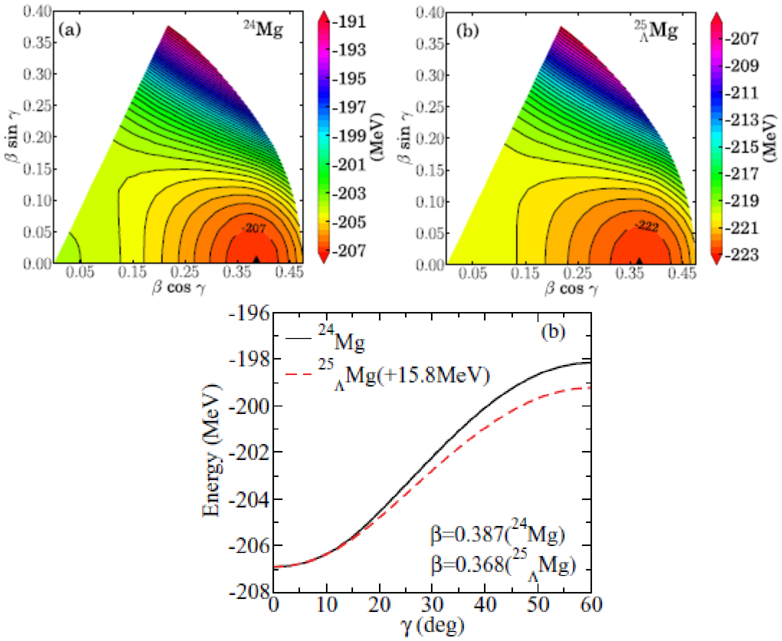
Predicted Structure changes by Λ (in *s*-orbit)

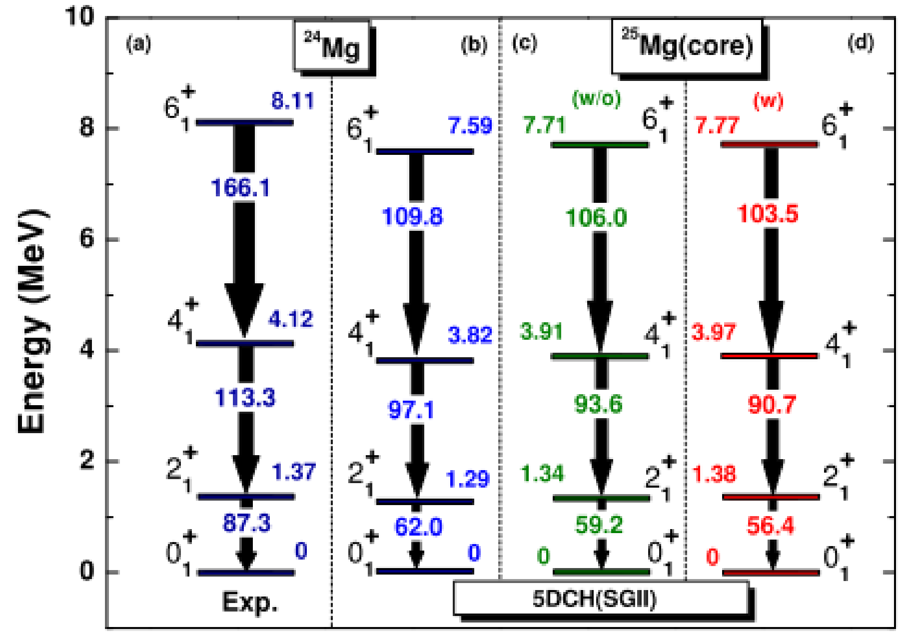
- **Energy surface becomes slightly soft against γ deformation**

  Myaing Thi Win, et al., Phys. Rev. C**83**, 014301 (2011).

- **Λ reduces the deformation and stretches the level spacing of the ground band**

  J. M. Yao, et al., Nucl. Phys. A**868** (2011), 12.



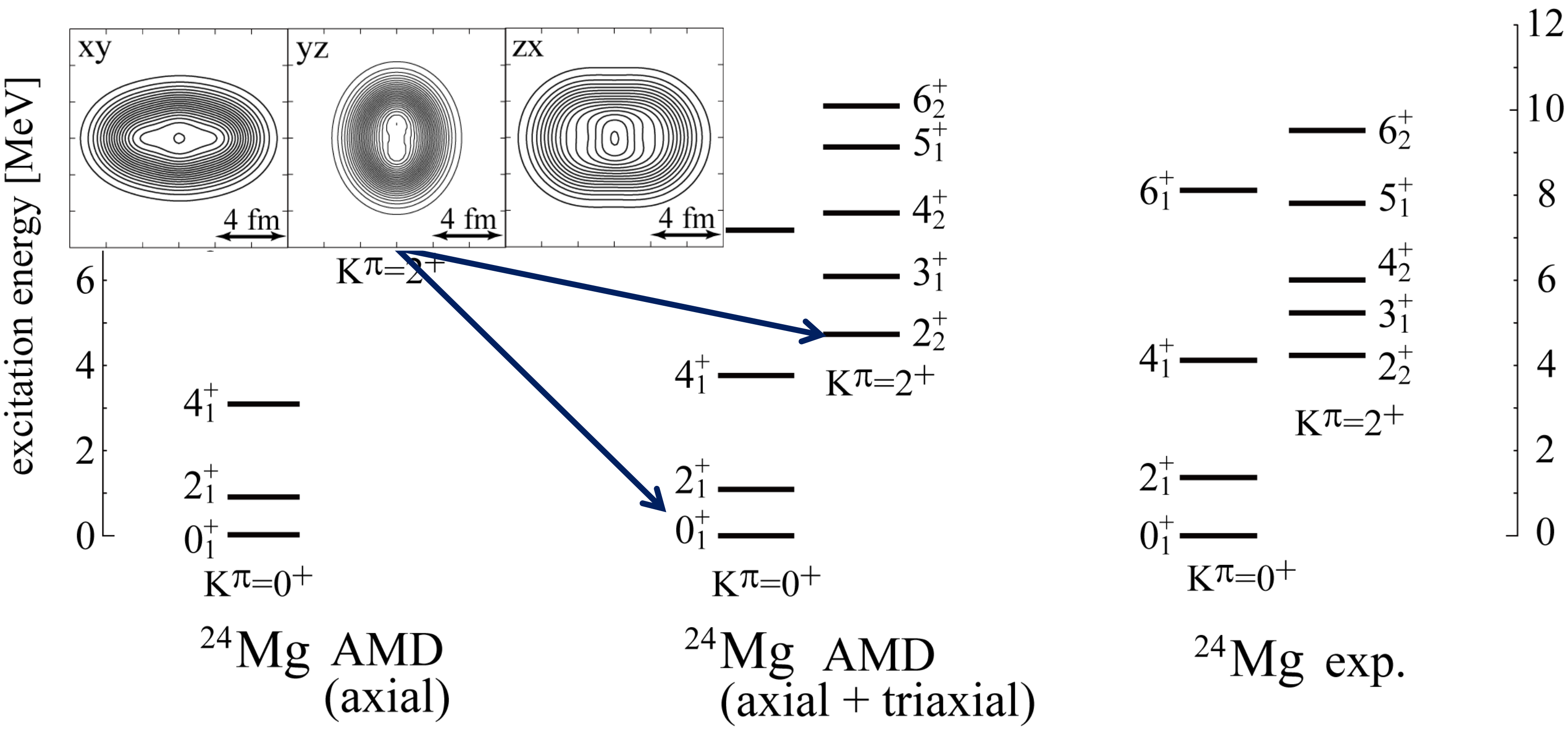


In triaxial deformed nuclei, the response to the addition of Λ hyperon will be different from axial symmetric nuclei

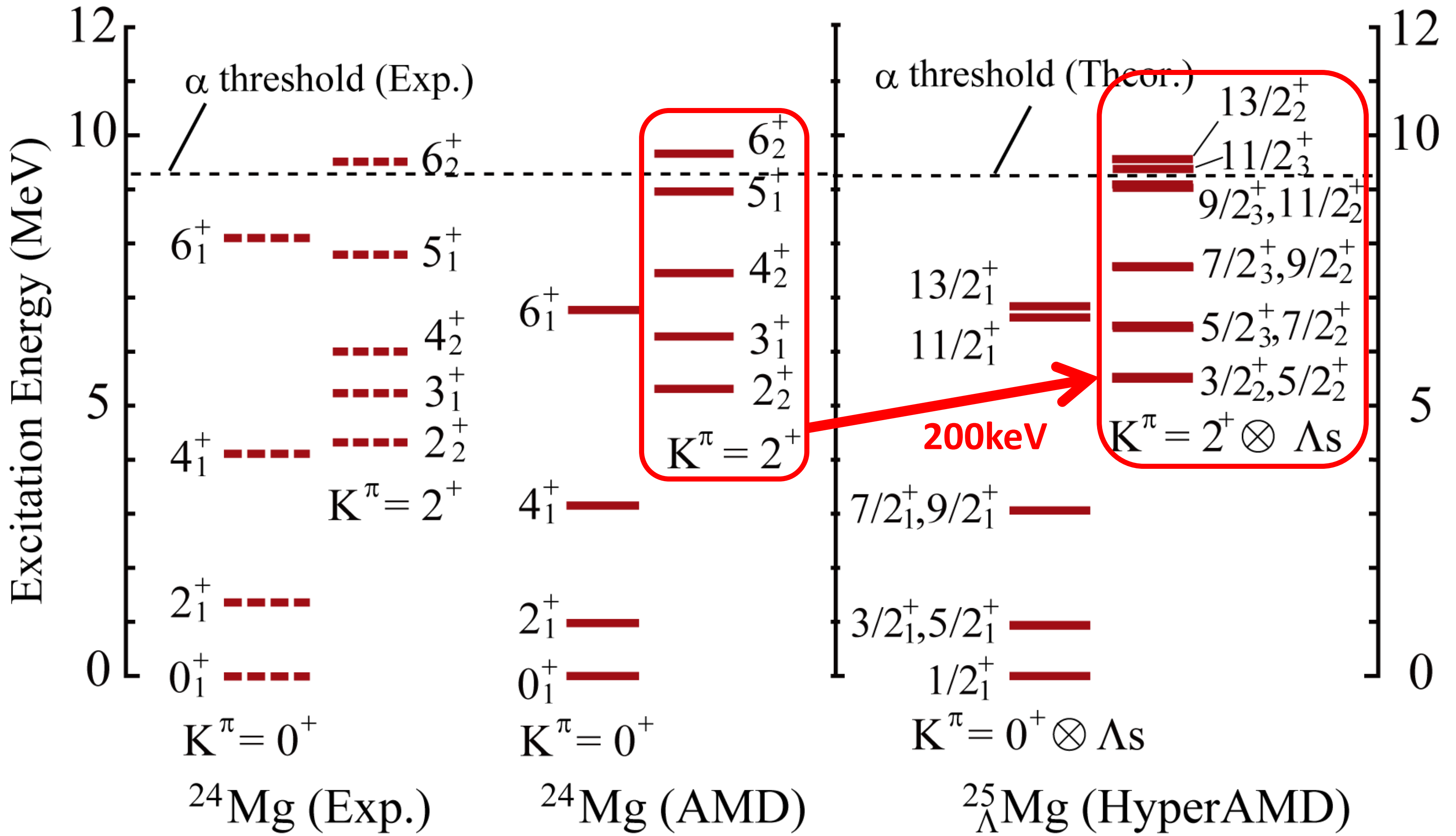
Individual Problem ($^{25}{}_{\Lambda}$Mg)

◆ Purpose of this study

- To reveal **how Λ hyperon affects the triaxial deformation and observables such as excitation energies**
- Example : $^{25}{}_{\Lambda}$Mg
  - $K^{\pi} = 0^{+} \otimes \Lambda(s)$ band ・・・ (ground band of ^{24}Mg) $\otimes \Lambda$(*s* orbit)
  - $K^{\pi} = 2^{+} \otimes \Lambda(s)$ band ・・・ ($K^{\pi}=2^{+}$ band of ^{24}Mg) $\otimes \Lambda$(*s* orbit)



Results: Excitation spectra of $^{25}{}_{\Lambda}$Mg

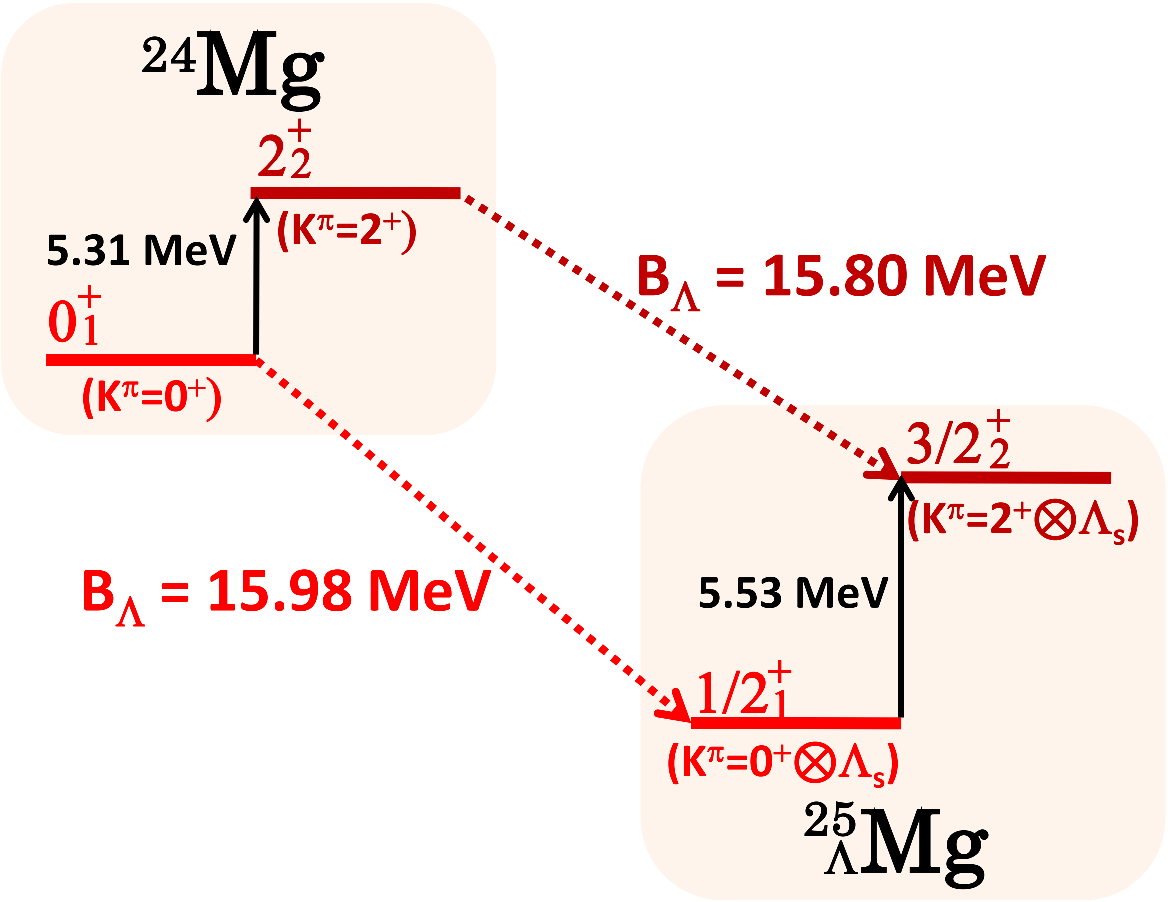


Excitation energy of $K^{\pi}=2^+\otimes\Lambda_s$ band is shifted up by about 200 keV

Results: Reasons for the shift up

- **Difference of the Λ binding energy B_Λ**
  - **B_Λ for the $K^\pi=0^+\otimes\Lambda_s$ band is larger than that for the $K^\pi=2^+\otimes\Lambda_s$ band**

    ⟶ Energy shift of the $K^\pi=2^+\otimes\Lambda_s$ band

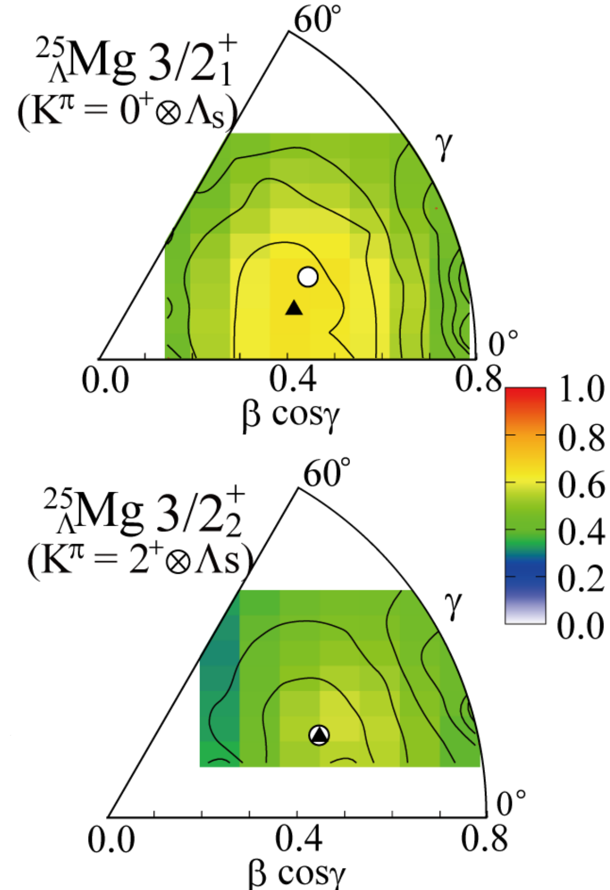


Results: Deformation change by Λ hyperon

- **Large B_Λ of the $K^\pi=0^+\otimes\Lambda_s$ band is due to the smaller deformation**
- **Λ reduces the (β, γ) deformation in the $K^\pi=0^+\otimes\Lambda_s$ band, while the deformation of the $K^\pi=2^+\otimes\Lambda_s$ band is almost unchanged**

Changes of GCM overlap

$$O_{n\alpha}^{J\pi}(\beta_i,\gamma_i) = |\langle\Psi_n^{J\pi}(\beta_i,\gamma_i)|\Psi_\alpha^{J\pi}\rangle|^2$$



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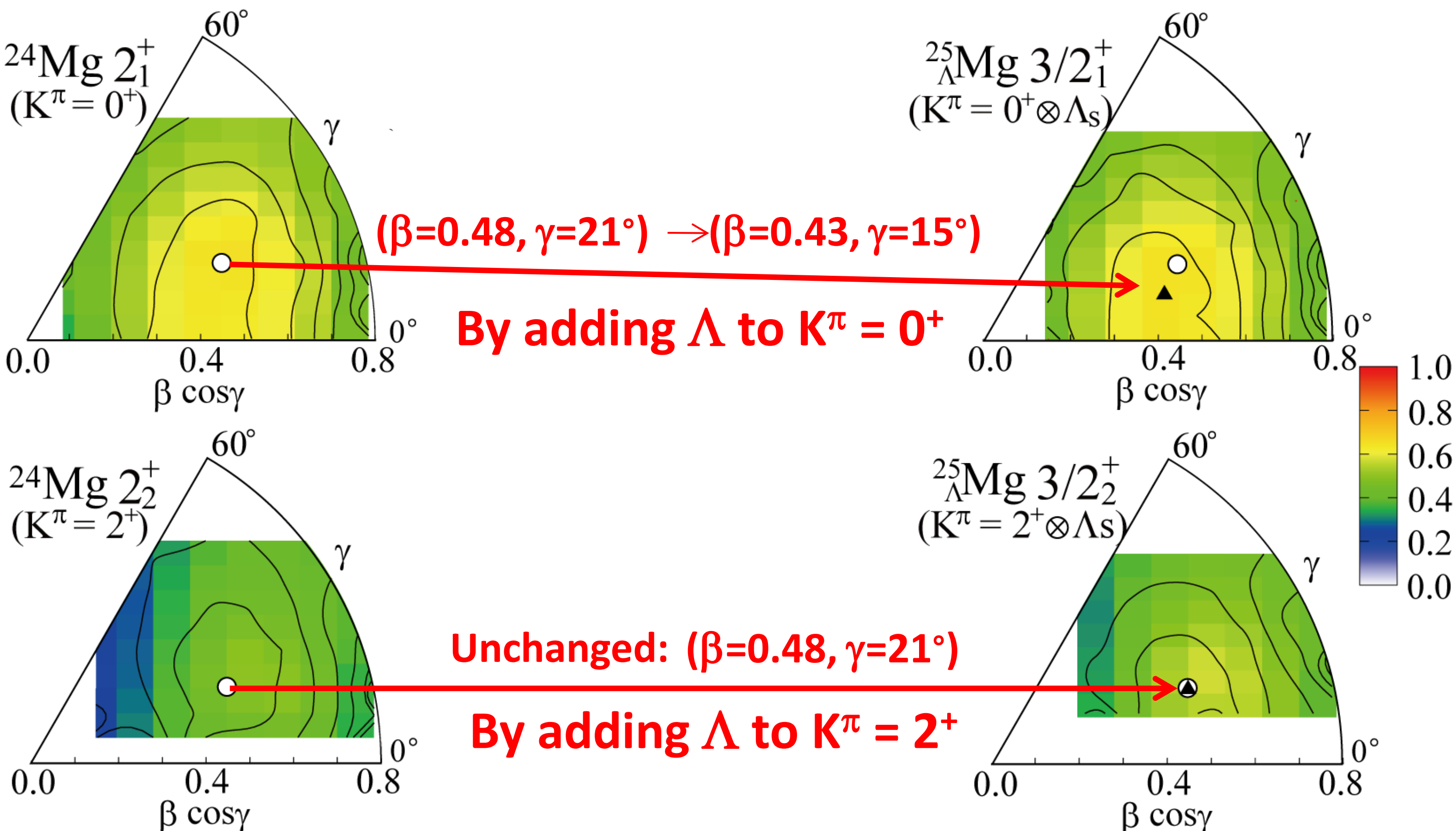
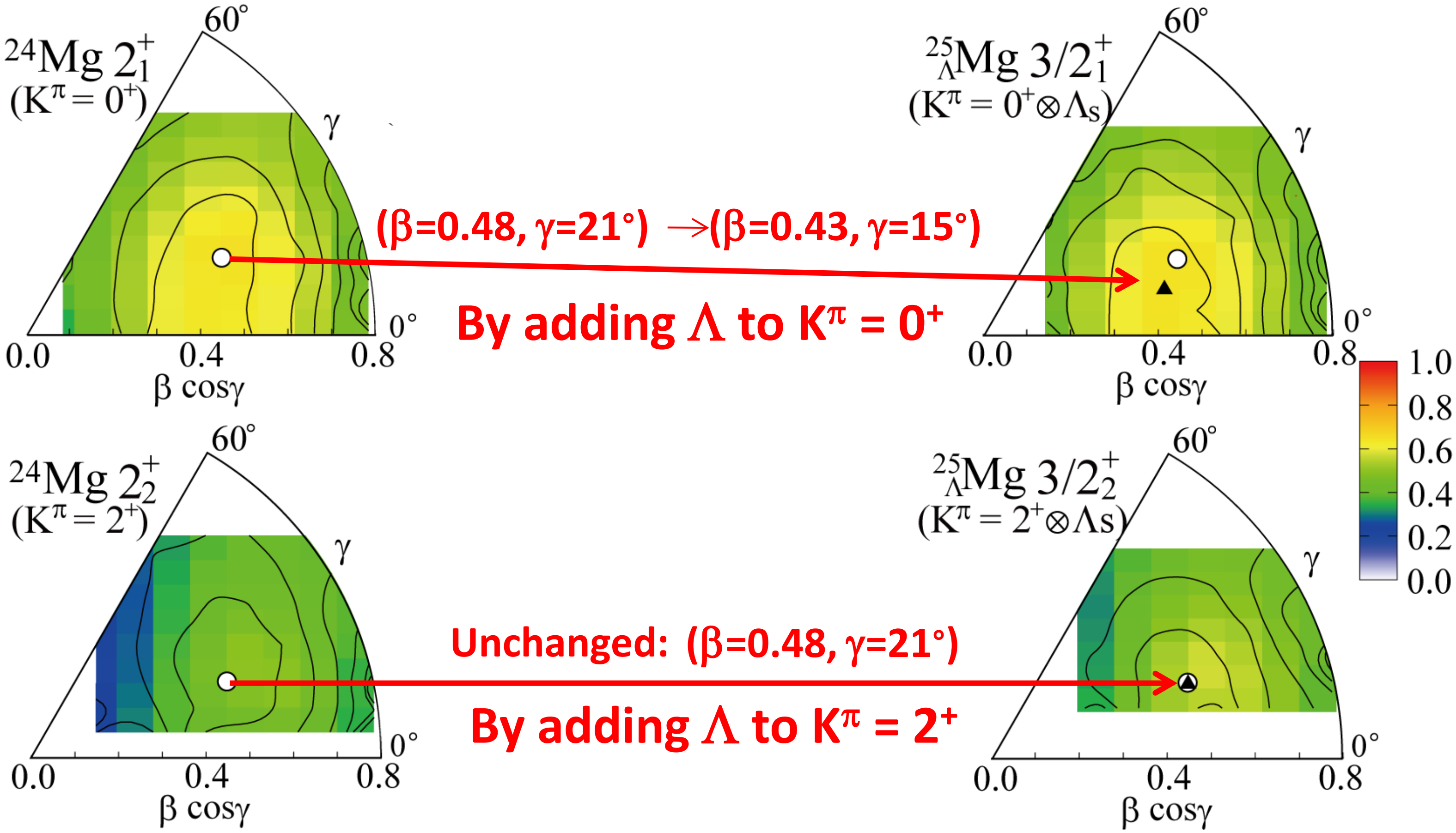


Results: Deformation change by Λ hyperon



Color plots: GCM overlap

Contour lines: energy surface

- **K^π=0^+ band: Energy surface is soft (flat) against the (β, γ) reduction**
- **K^π=2^+ band: rigid against the deformation change**

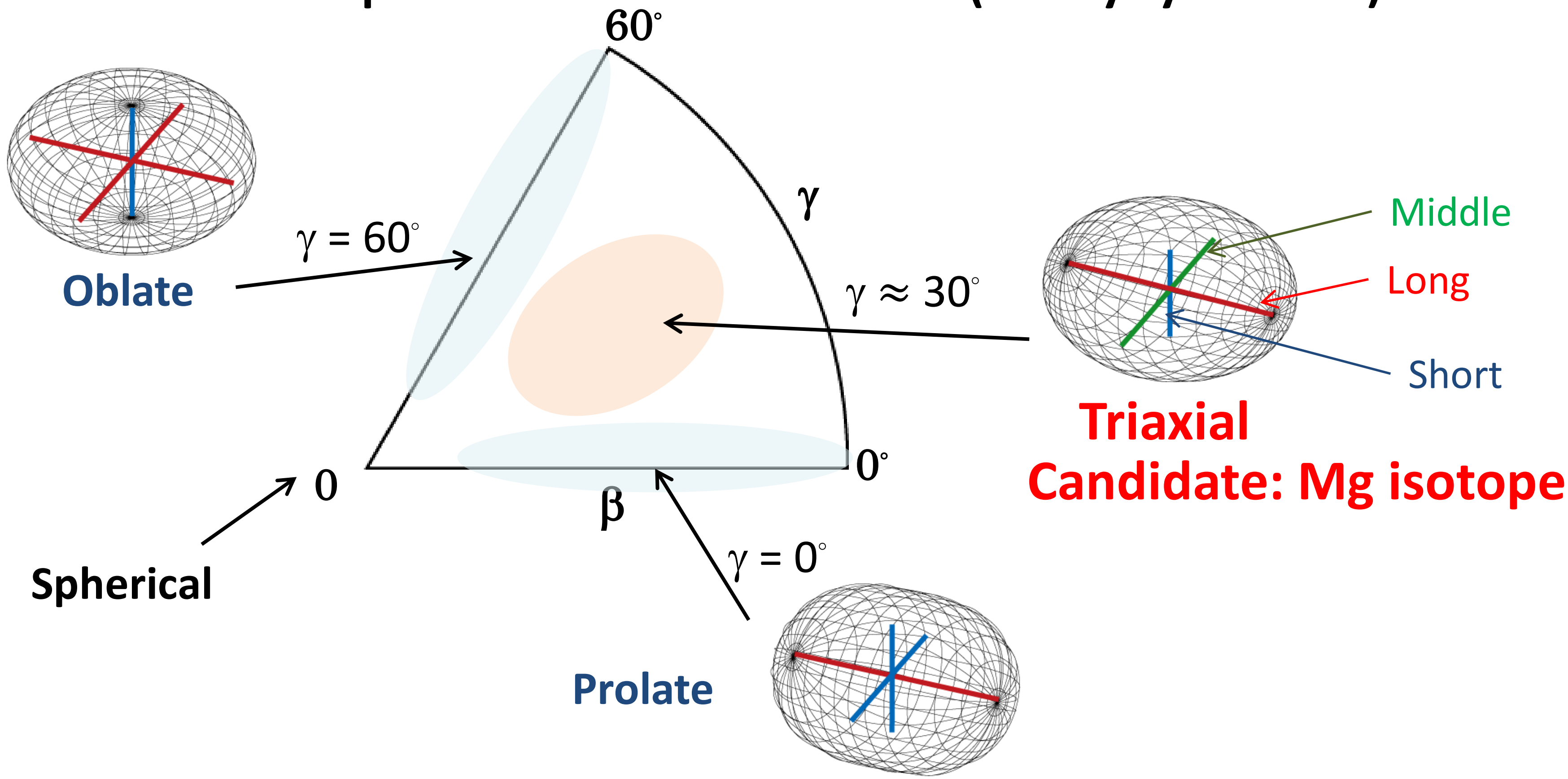
Probing nuclear deformation by using Λ

Example: Triaxial deformation of Mg

M. Isaka, *et al.*, PRC **87**, 021304(R) (2013)

Deformation of nuclei

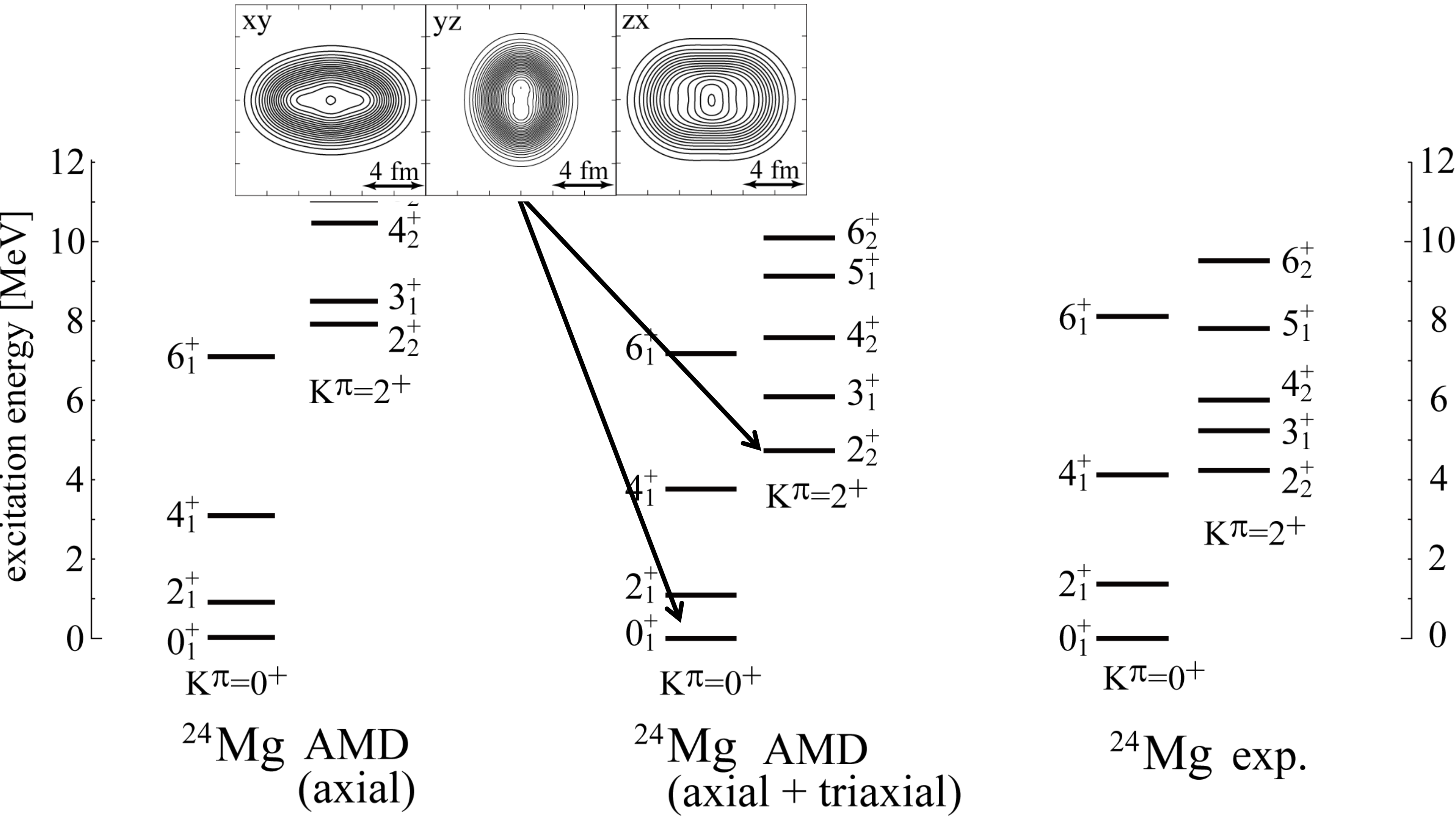
- **Many nuclei manifests various quadrupole deformation**
  (parameterized by quadrupole deformation parameters β and γ)
- **Most of them are prolate or oblate deformed (axially symmetric)**



Triaxial deformed nuclei are not many and its identification is not easy.

Deformation of ^{24}Mg

- ^{24}**Mg: candidate of triaxially deformed nuclei** [1,2]



[1,2] R. Batchelor, et al., Nucl. Phys. 16, 38 (1969)., A. Cohen and J. Cookson, Nucl. Phys. 29, 604 (1962).

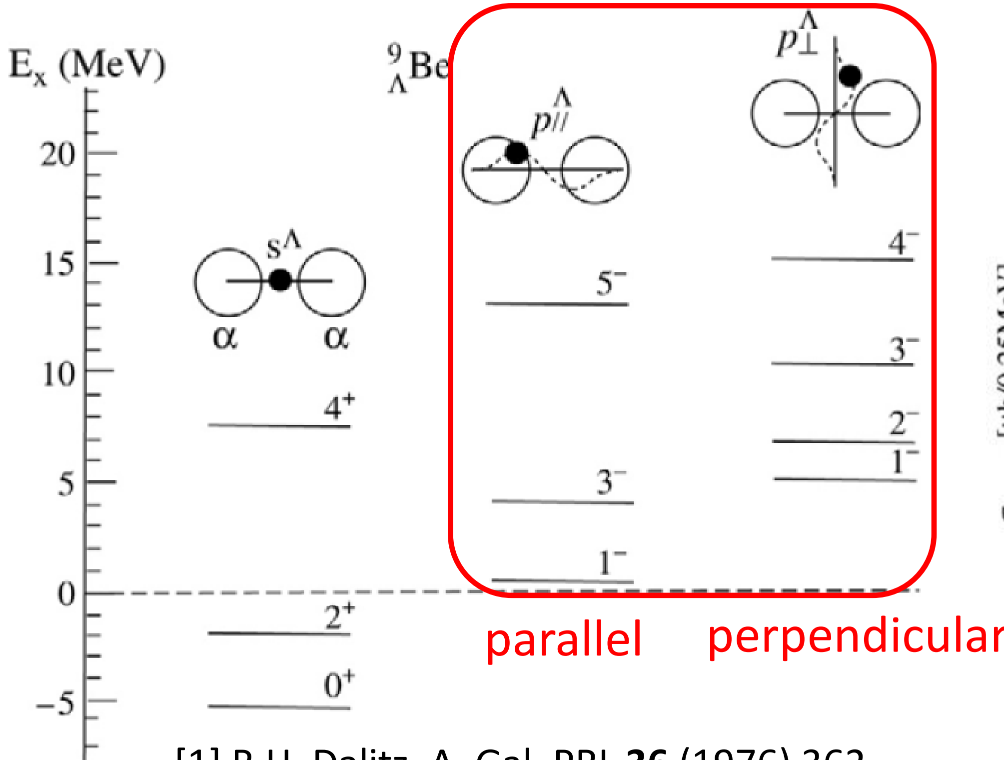
Example: p-states of $^{9}_{\Lambda}$Be

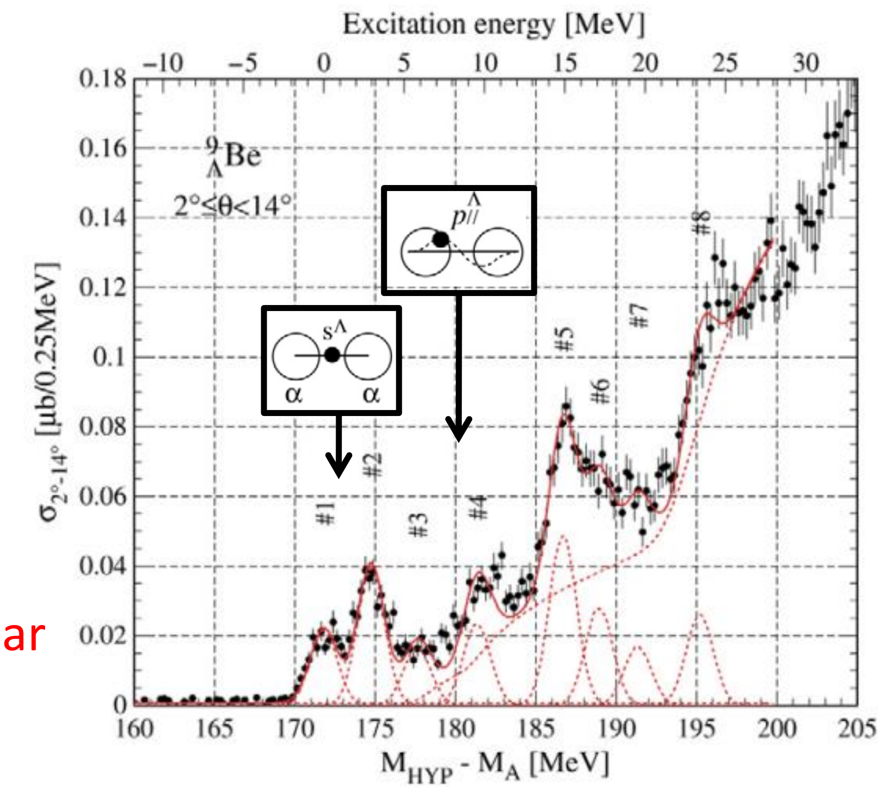
$^{9}_{\Lambda}$Be: axially symmetric 2α clustering

Two bands will be generated as *p*-states [1,2]

- **Anisotropic *p* orbit of Λ hyperon**
- **Axial symmetry of 2α clustering**

→ ***p*-orbit parallel to/perpendicular to the 2α clustering**



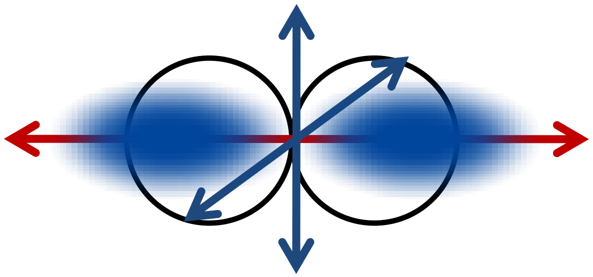


[1] R.H. Dalitz, A. Gal, PRL **36** (1976) 362.
[2] H. Bando, et al., PTP **66** (1981) 2118.; H. Bando, et al., IJMP **21** (1990) 4021.
[3] O. Hashimoto et al., NPA **639** (1998) 93c.

Split of *p*-state in $^{9}_{\Lambda}$Be

◆ $^{9}_{\Lambda}$Be with 2α cluster structure

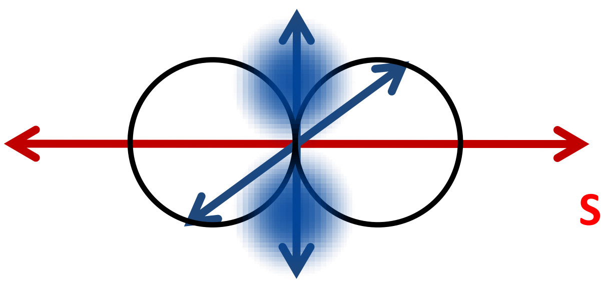
<u>*p* orbit parallel to 2α (long axis)</u>



Large overlap

Deeply bound

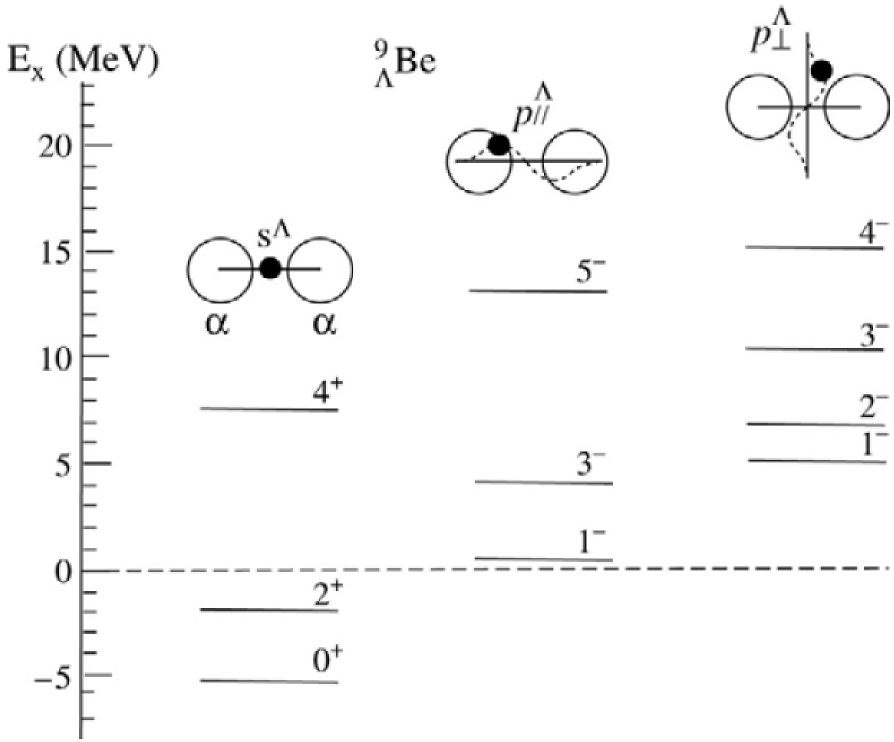
<u>*p* orbit perpendicular to 2α (short axes)</u>



Small overlap

Shallowly bound

Split corresponding to long/short axes



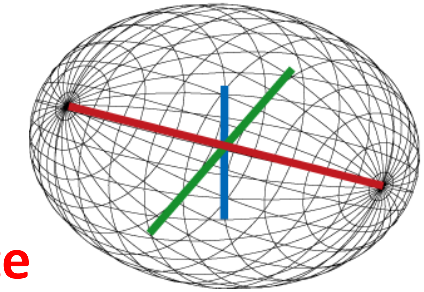
R.H. Dalitz, A. Gal, PRL **36** (1976) 362.
H. Bando, et al., PTP **66** (1981) 2118.;
H. Bando, et al., IJMP **21** (1990) 4021.

_p_-states splits into 2 bands depending on the direction of _p_-orbits

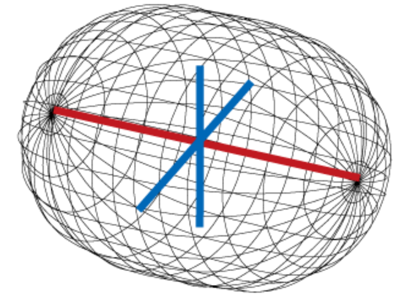
Triaxial deformation

If ^{24}Mg is triaxially deformed nuclei

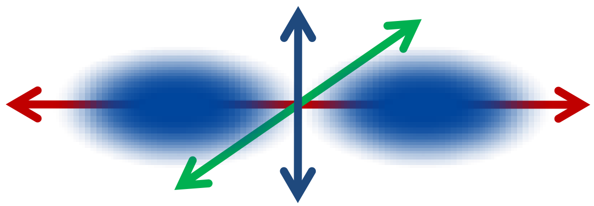
→ ***p*-states split into 3 different state**



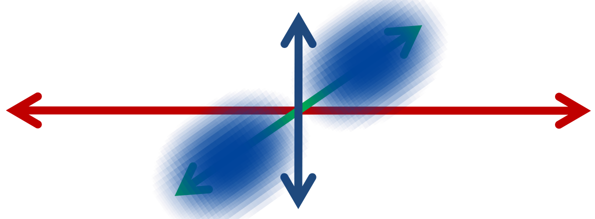
Triaxial deformation



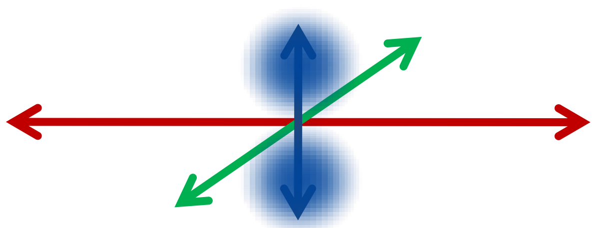
Prolate deformation



Large overlap leads deep binding



Middle

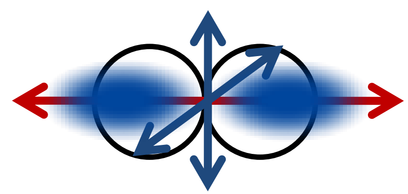


Small overlap leads shallow binding

cf. prolate deformation

Ex.) $^{9}_{\Lambda}$Be

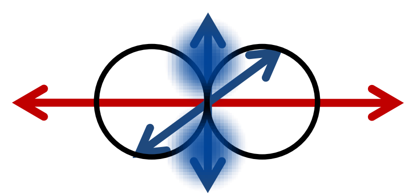
***p* orbit parallel to 2α (long axis)**



Large overlap

Deeply bound

***p* orbit perpendicular to 2α (short axes)**



Small overlap

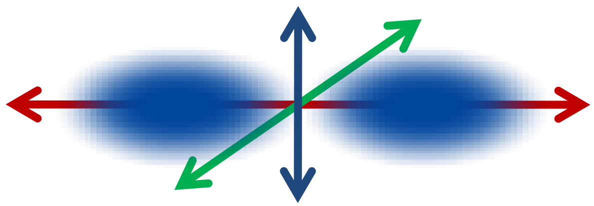
Shallowly bound

Split corresponding to long/short axes

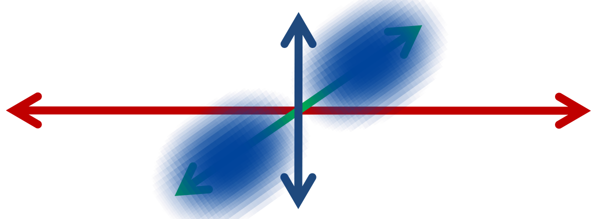
Triaxial deformation

If ^{24}Mg is triaxially deformed nuclei

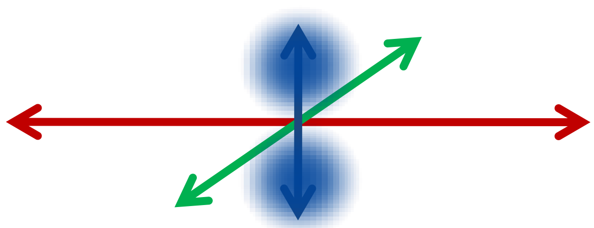
→ *p*-states split into 3 different state



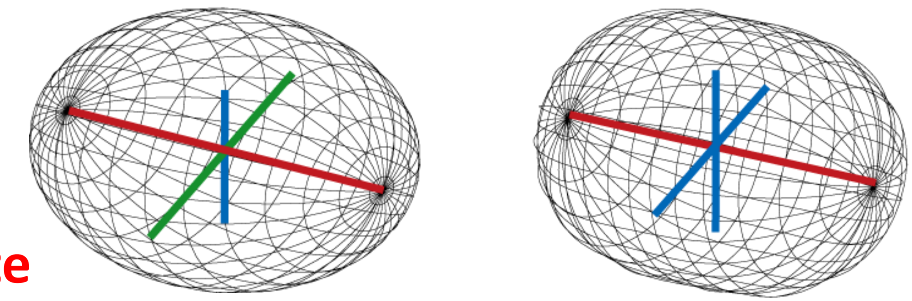
Large overlap leads deep binding



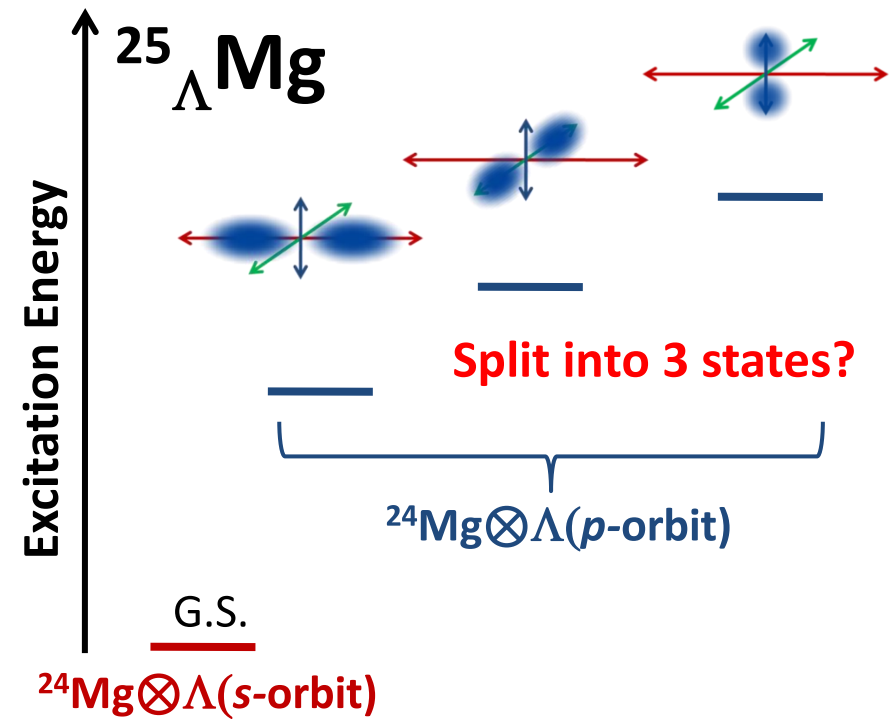
Middle



Small overlap leads shallow binding



Triaxial deformation   Prolate deformation

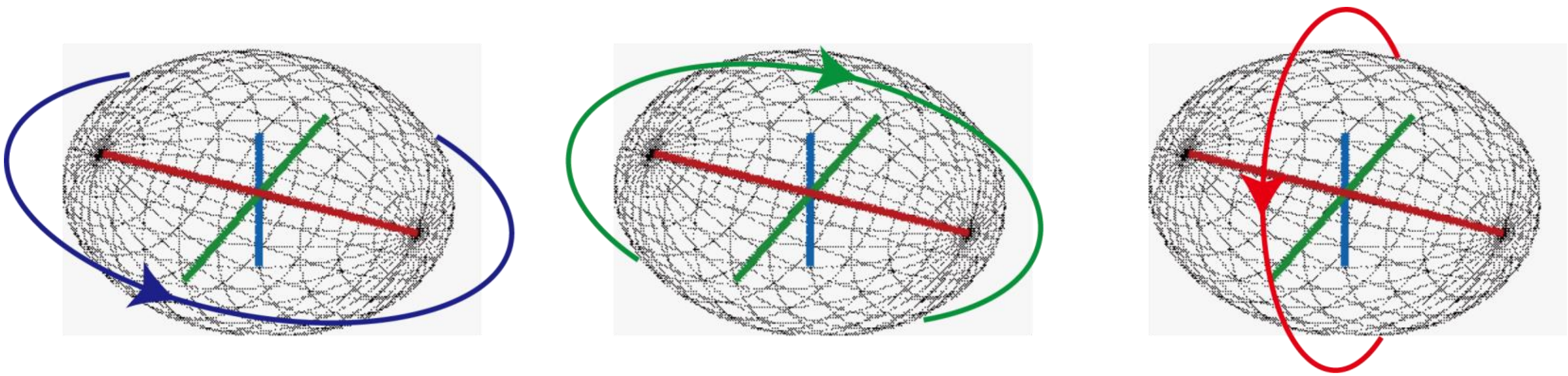


Observing such 3 different states is strong evidence for triaxial deformation of ^{24}Mg

Purpose

◆ Purpose and problem

- **To reveal triaxial deformation of ^{24}Mg, we will predict the level structure of the p states in $^{25}_{\Lambda}$Mg**
- $^{25}_{\Lambda}$Mg
  - ***p*-states will split into 3 different states, if ^{24}Mg is triaxially deformed**



◆ Method

- **HyperAMD + GCM calculation**

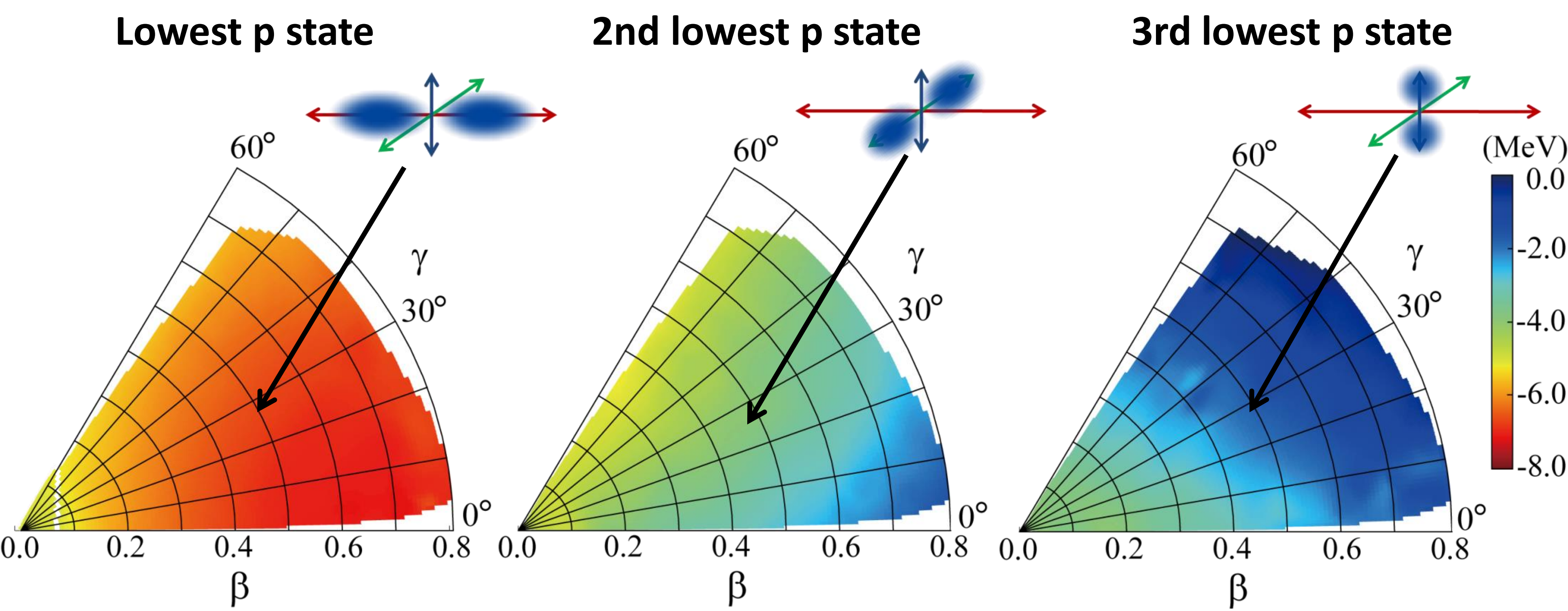
  (Antisymmetrized Molecular Dynamics for hypernuclei)
  - Constraints on (β, γ), and single particle w.f. of Λ
- **YNG-NSC97f interaction**

Results：Single particle energy of Λ hyperon

◆ **Λ single particle energy on (β, γ) plane**

$$\varepsilon_\Lambda(\beta_i,\gamma_i)=\left\langle \Psi^\pi(\beta_i,\gamma_i)\middle|\left(\hat{T}_\Lambda+\hat{V}_{\Lambda N}\right)\middle|\Psi^\pi(\beta_i,\gamma_i)\right\rangle$$

$^{25}_{\Lambda}$Mg (AMD, Λ in *p* orbit)

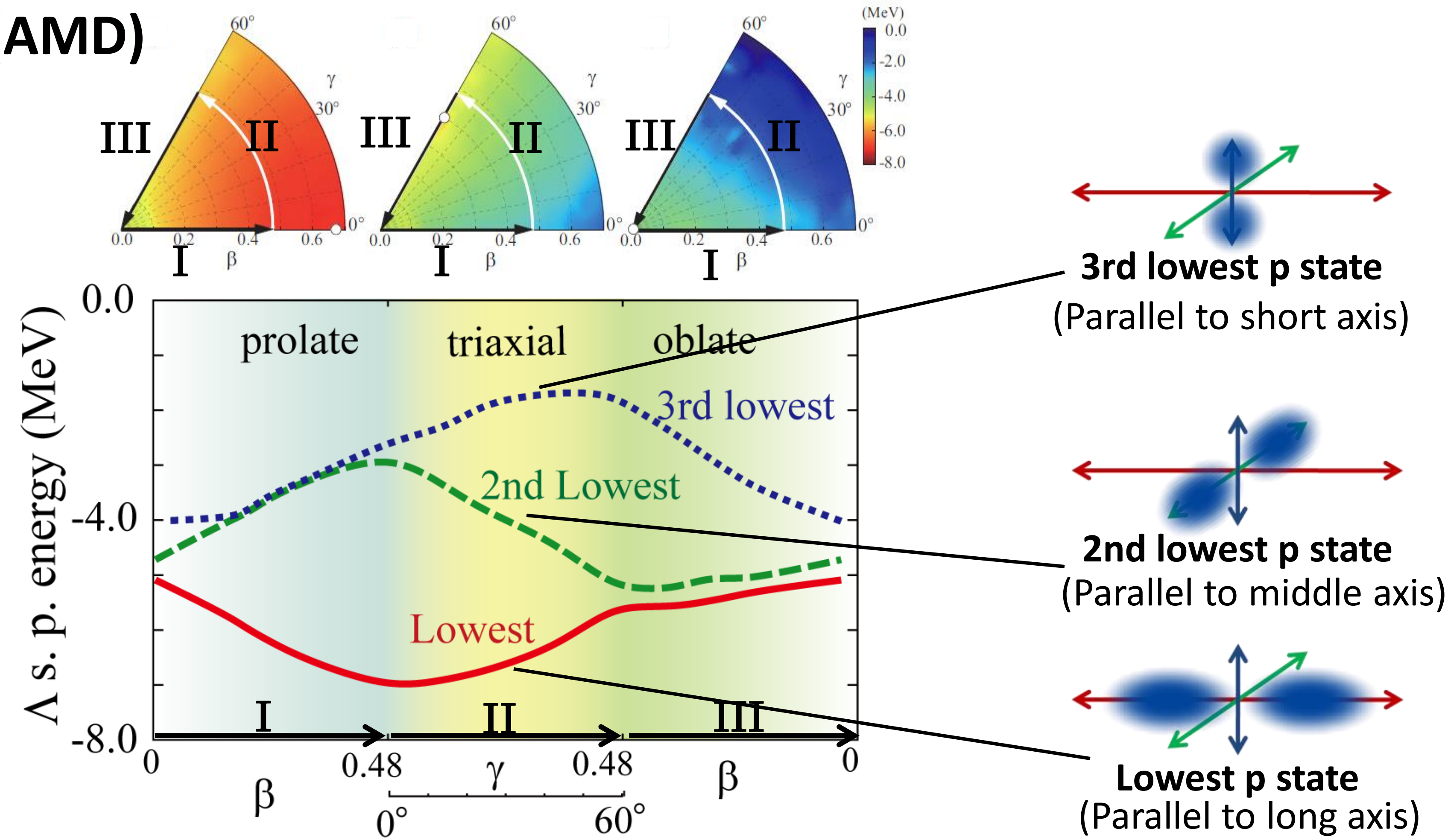


- **Single particle energy of Λ hyperon is different from each p state**
  - **This is due to the difference of overlap between Λ and nucleons**

Results： Single particle energy of Λ hyperon

◆ **Λ single particle energy in axial/triaxial deformed nucleus**

$^{25}_{\Lambda}$Mg (AMD)

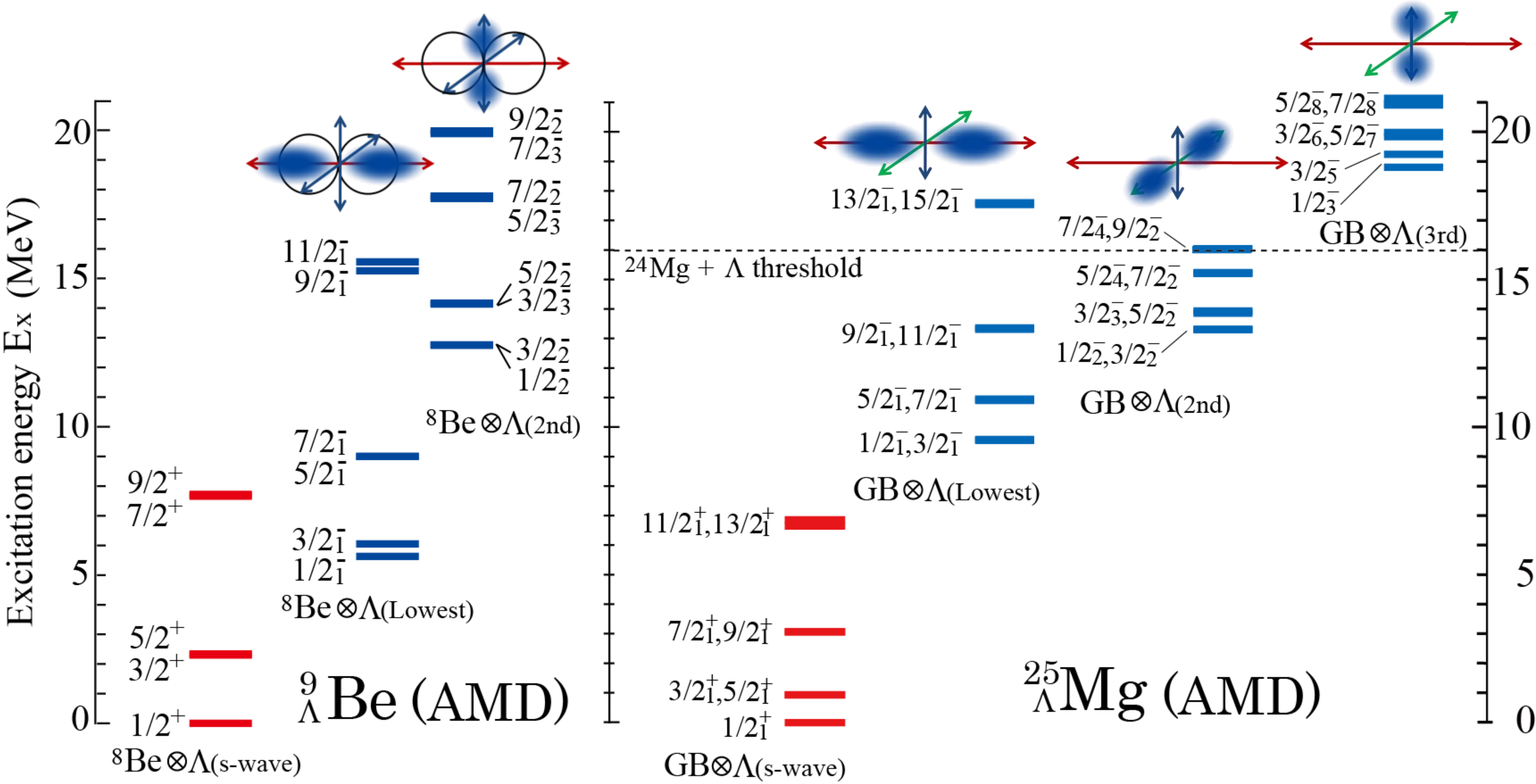


Λ s. p. energy is different from each other with triaxial deformation

⟶ **split into 3 p-orbit states**

Results: Excitation spectra

- **3 bands are obtained by Λ hyperon in *p*-orbit** → **Splitting of the *p* states**
  - **^{24}Mg⊗Λp(lowest), ^{24}Mg⊗Λp(2nd lowest), ^{24}Mg⊗Λp(3rd lowest)**



Lowest threshold $^{21}_{\Lambda}\mathrm{Ne}+\Lambda$: in between 8.3 and 12.5 MeV

Summary

Knowledge of YN interaction will allow us to reveal structure of hypernuclei

- Structure change and modification of nuclear properties by adding a hyperon
- Bounding unbound systems by using hyperons as a glue
- Probing nuclear structure (deformation) by using hyperon

Combination of the modern YN interaction with nuclear models

- Antisymmetrized molecular dynamics + effective YN interaction

Structure changes caused by Λ

- Λ in *p*-orbit enhances the nuclear deformation, while Λ in *s*-orbit reduces it.
- Difference of the Λ binding energy causes the changes of the excitation spectra in n-rich $^{12}{}_{\Lambda}$Be, and triaxially deformed $^{25}{}_{\Lambda}$Mg hypernuclei

Probing nuclear deformation by using Λ

- Splitting of the *p* orbits in $^{25}{}_{\Lambda}$Mg due to triaxial deformation