ハイパー核の少数多体系の構造研究

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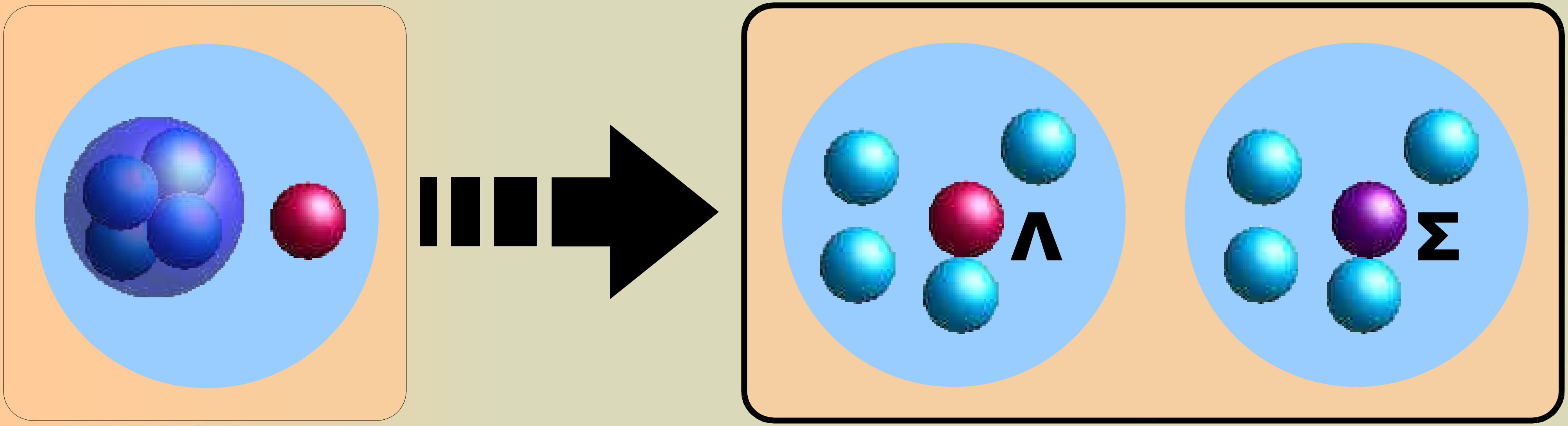


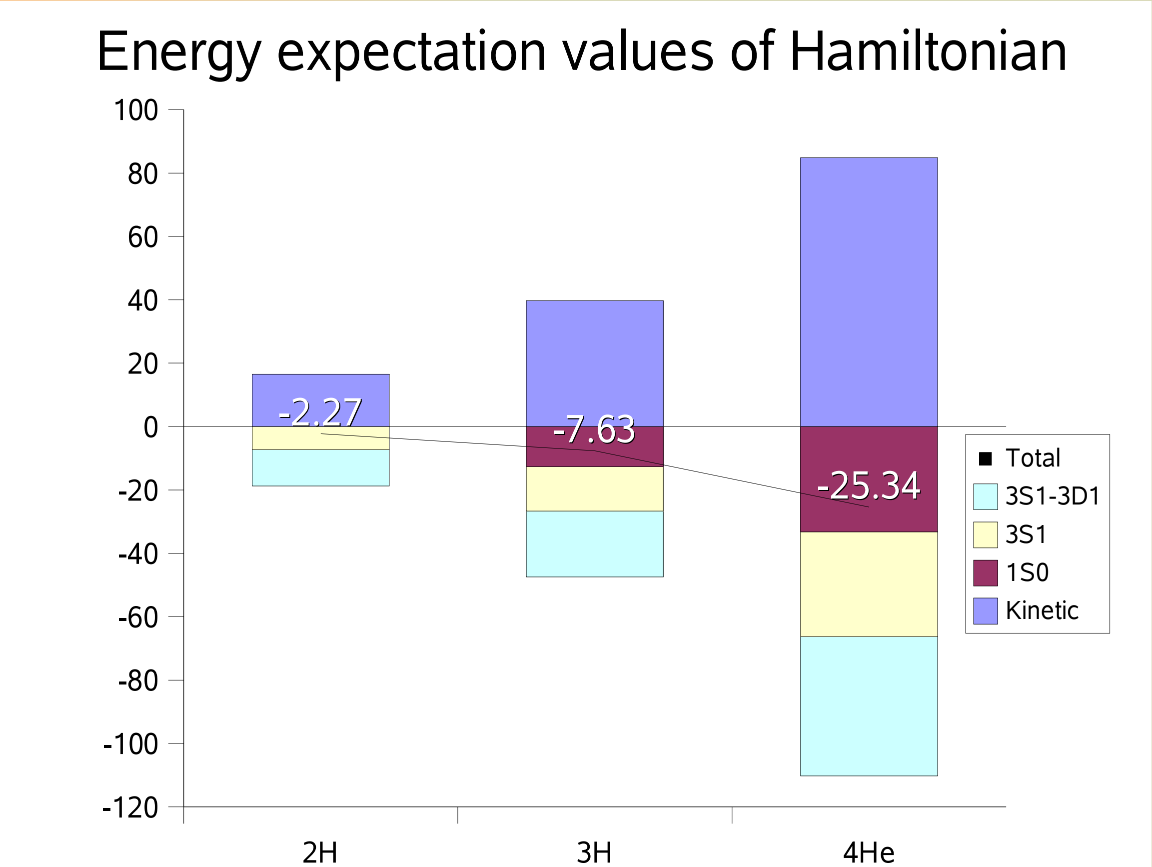
Contents of the talk:

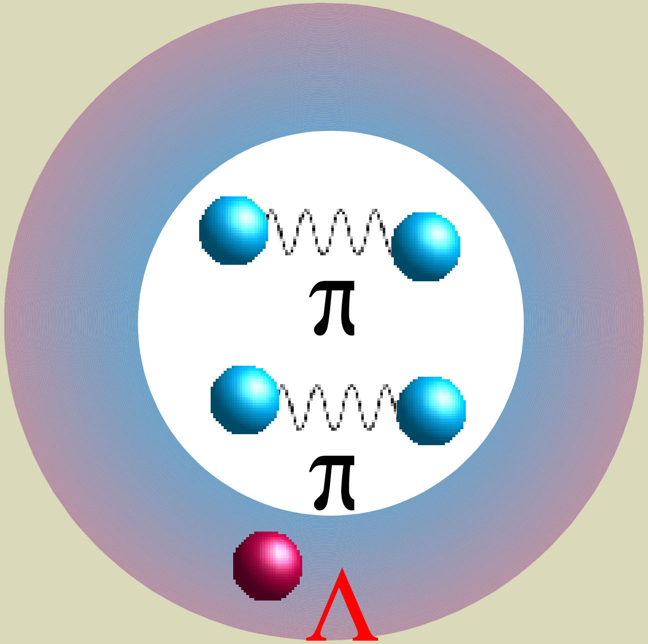
- Requests from superorganizer:
  - What is interesting about hypernuclei?
  - What is new topic other than the conventional nuclear physics?
  - Why do you study the hypernuclear physics?
- The plan of my talk is:
  - ${}^{5}_{\Lambda}$He anomaly and tensor ΛN-ΣN coupling.
    - Which gives new view of hypernuclear structure beyond *core nucleus* + Λ model.
  - First-ever 5-body calculation of doubly strange hypernuclei in fully coupled channel scheme of particle basis.
    - Exciting and challenging problem toward the future experiment @J-PARC.

I. ${}^{5}_{\Lambda}He$ anomaly and tensor ΛN-ΣN coupling

Introduction:

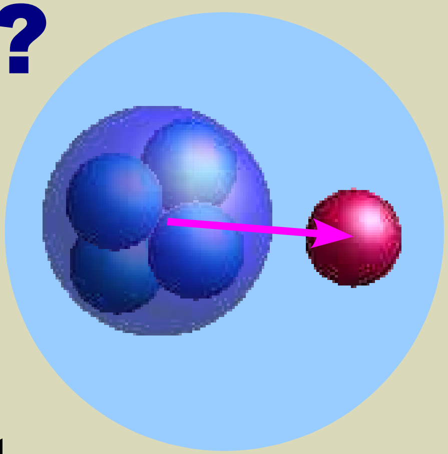
Tensor interaction plays an important role for light normal nuclei.





- G3RS *NN* potential is used.

What is the hypernuclear structure due to the presence of a Λ?



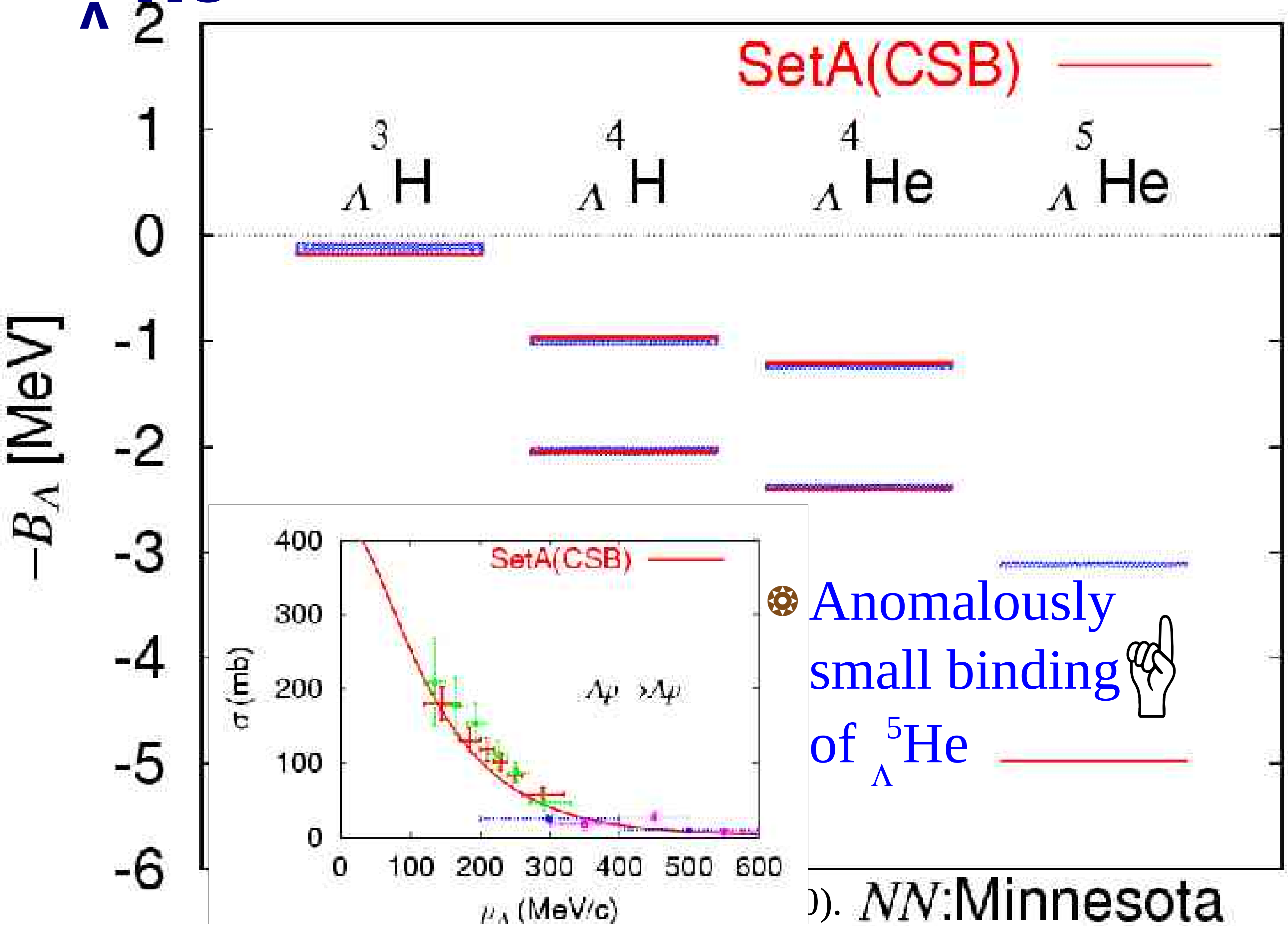
- $B(^4\text{He}) \sim 28$ MeV
- $B_\Lambda({}_\Lambda^5\text{He}) \sim 3$ MeV ➔ ${}_\Lambda^5\text{He} \sim \alpha+\Lambda$

Rigid core+Λ picture

  - $J_c=0$ ➔ No tensor Λ*N* interaction
  - $I_c=0$ ➔ No Λ*N*-Σ*N* coupling

- Is the conventional picture acceptable? ➔ No!
  - Anomalously small binding of ${}_\Lambda^5\text{He}$

Anomalously small binding of $_{\Lambda}^{5}$He



- Anomalously small binding of $_{\Lambda}^{5}$He

0)). *NN*:Minnesota

Anomalously small binding of ${}^{5}_{\Lambda}$He

- A phenomenological ΛN potential reproducing $B_\Lambda({}^{3}_{\Lambda}\mathrm{H})$, $B_\Lambda({}^{4}_{\Lambda}\mathrm{H})$, $B_\Lambda({}^{4}_{\Lambda}\mathrm{He})$, $B_\Lambda({}^{4}_{\Lambda}\mathrm{H}^*)$, and $B_\Lambda({}^{4}_{\Lambda}\mathrm{He}^*)$ values as well as the Λp total cross section, predicts (about two times) larger $B_\Lambda({}^{5}_{\Lambda}\mathrm{He})$ value than the experimental value.

  Dalitz, *et al.*, NPB**47**, 109 (1972).
- The experimental $B_\Lambda({}^{5}_{\Lambda}\mathrm{He})$ implies that ΛN interaction in ${}^{5}_{\Lambda}$He is weaker than the ΛN interaction in free space. ➔ ${}^{5}_{\Lambda}$He anomaly

Ab initio Approach to *s*-Shell Hypernuclei $^3_\Lambda$H, $^4_\Lambda$H, $^4_\Lambda$He, and $^5_\Lambda$He with a ΛN-ΣN Interaction

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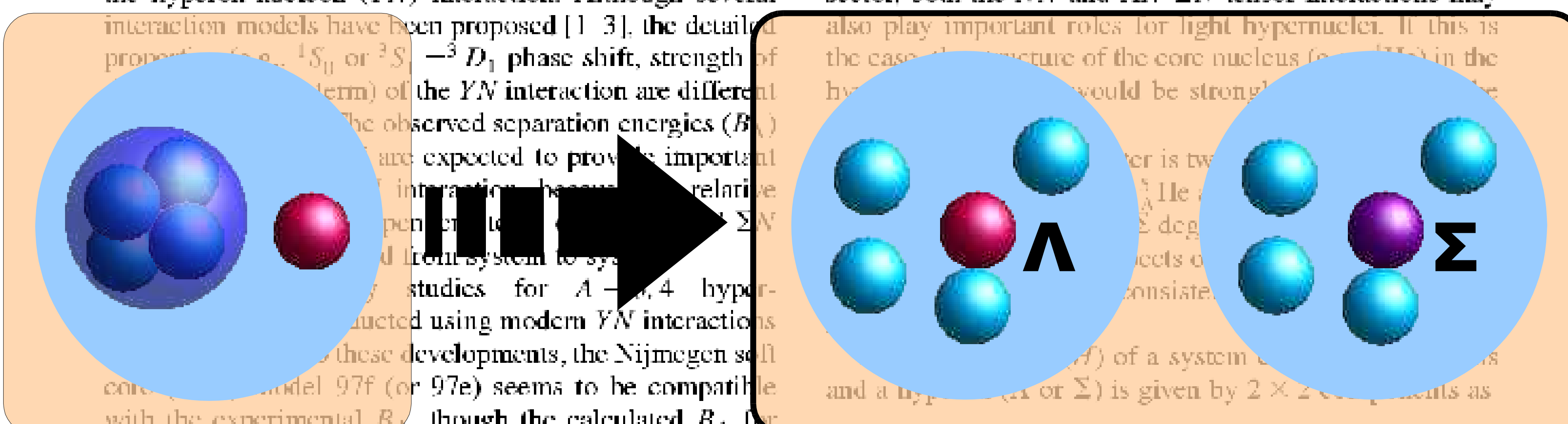
Variational calculations for *s*-shell hypernuclei are performed by explicitly including Σ degrees of freedom. Four sets of YN interactions [SC97d(S), SC97e(S), SC97f(S), and SC89(S)] are used. The bound-state solution of $^5_\Lambda$He is obtained and a large energy expectation value of the tensor ΛN-ΣN transition part is found. The internal energy of the ^{4}He subsystem is strongly affected by the presence of a Λ particle with the strong tensor ΛN-ΣN transition potential.

DOI: 10.1103/PhysRevLett.89.142504 PACS numbers: 21.80.+a, 13.75.Ev, 21.10.Dr, 21.45.+v

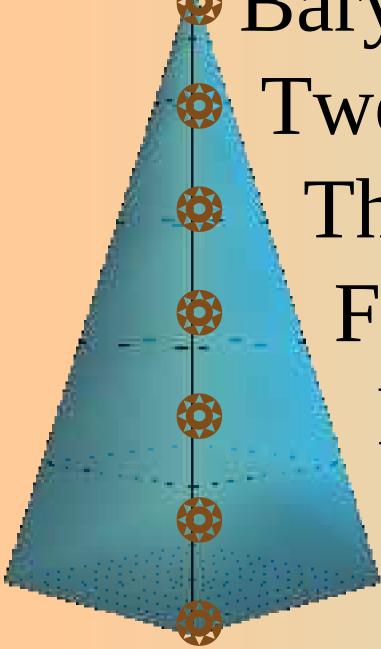
ΛN-ΣN coupling plays a significant role in hypernucleus $_\Lambda^5$He



The purpose of this work

- To describe an *ab initio* calculation of ${}^{5}_{\Lambda}$He as well as *A*=3, 4 hypernuclei explicitly including Σ degrees of freedom,
- To conduct a new view of the ${}^{5}_{\Lambda}$He, due to taking account of explicit Σ admixture, beyond $\alpha+\Lambda$ model.
- We would also like to discuss,
  - Why the *YN* interaction in ${}^{5}_{\Lambda}$He is so weaker than that in free space or in *A*=3, 4 systems?

NN and YN potentials

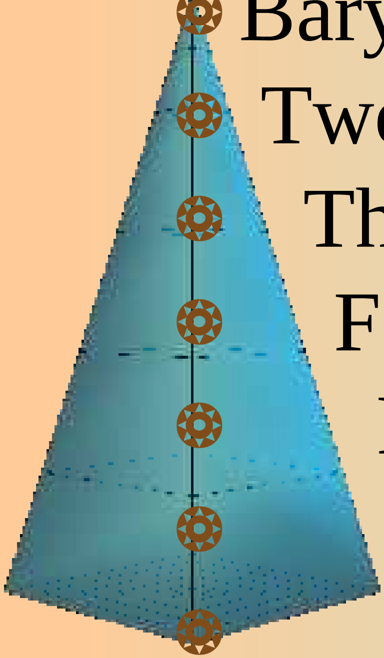


- Baryon-baryon interaction
- Two-body system
- Three-body system
- Four-body system
- Five-body system
- ...
- Many-body systems

Top-down approach

- In the nuclear physics,
  - *NN* potential is given by a modern interaction model, such as Nijmegen model.
    - Few-body calculation is made using the interaction.

NN and YN potentials



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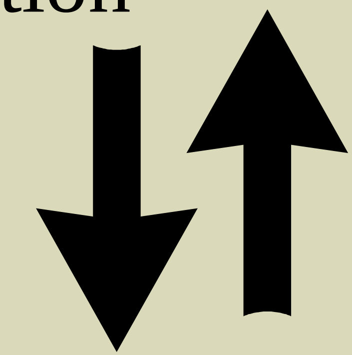


Top-down and bottom-up approach

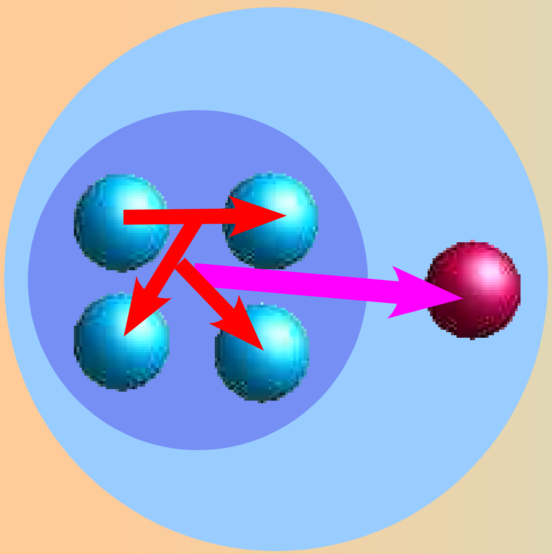
- In the hypernuclear physics, phase-shift analysis has not been confirmed yet.
- A phenomenological potential is used, which is phase-equivalent to the modern interaction model (e.g. Nijmegen model), and which reproduces the experimental data of the few-body systems.

NN and YN potentials

- *NN* interaction:
  - G3RS (central+tensor)
  - The *NN* interaction reproduces the low energy *NN* phase shifts.
- *YN* interaction:
  - SC97e(S) (central+tensor+spin-orbit; $\Lambda N+\Sigma N$); it is phase equivalent to the Nijmegen soft core model NSC97e.
  - The *YN* interaction reproduces the experimental B_Λ of A=3, 4 hypernuclei as well as the Λp total cross section.

Hamiltonian of a system comprising (A-1) nucleons and a hyperon

- Hamiltonian (H) is divided into the internal motion of the core nucleus (H_{core}) and relative motion between the core and the hyperon ($H_{Y\text{-core}}$).



$$H = \sum_{i=1}^{A}\left(m_i c^2 + \frac{\boldsymbol{p}_i^2}{2} m_i \right) - T_{CM} + \sum_{i<j}^{A-1} v_{ij}^{(NN)} + \sum_{i=1}^{A-1} v_{iY}^{(NY)},$$

$$= H_{\text{core}} + H_{Y-\text{core}},$$

$$H_{\text{core}} = \sum_{i=1}^{A-1} \frac{\boldsymbol{p}_i^2}{2} m_N - \frac{\left(\sum_{i=1}^{A-1} \boldsymbol{p}_i \right)^2}{2(A-1) m_N} + \sum_{i<j}^{A-1} v_{ij}^{(NN)},$$

$$= T_{\text{core}} + V_{NN},$$

$$H_{Y-\text{core}} = \frac{\pi_{Y-\text{core}}^2}{2\mu_Y} + (m_Y - m_\Lambda) c^2 + \sum_{i=1}^{A-1} v_{iY}^{(NY)},$$

$$= T_{Y-\text{core}} + V_{YN}.$$

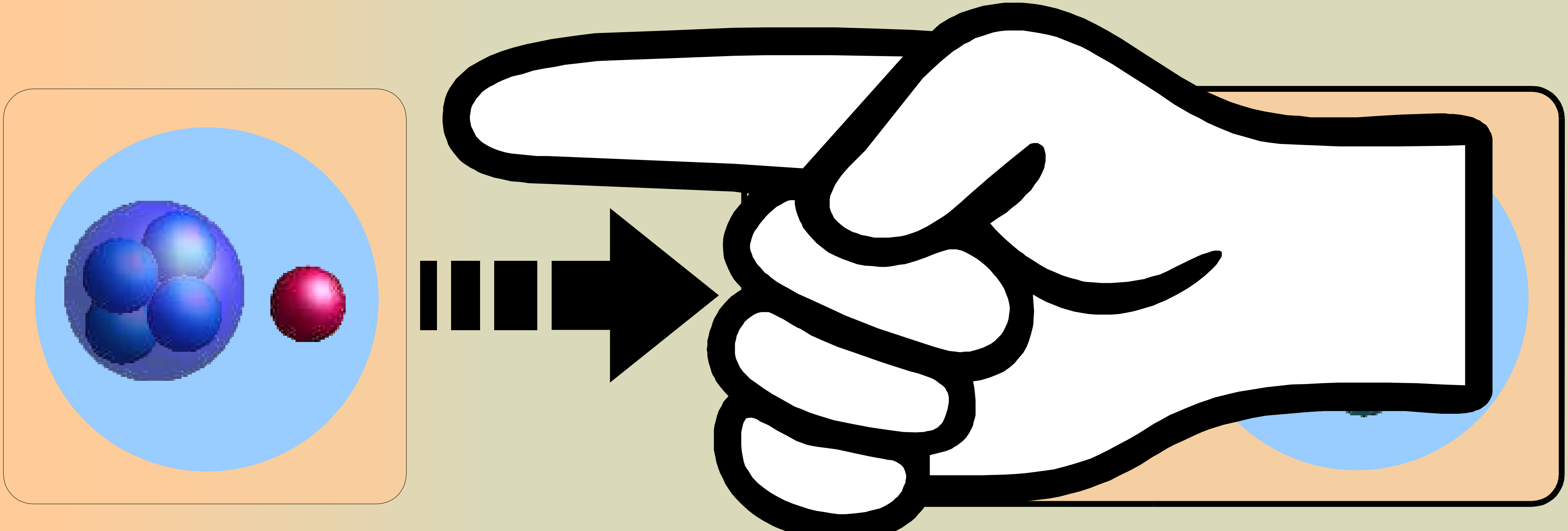
$$\mu_Y = \frac{(A-1) m_N m_Y}{(A-1) m_N + m_Y}, \quad (Y = \Lambda, \Sigma).$$

Hamiltonian of a system comprising (A-1) nucleons and a hyperon

- If *rigid core* + Λ is good approximation for the hypernucleus, there is no rearrangement energy;

$$\left\langle H_{\mathrm{core}} \right\rangle_{{}^{A}_{\Lambda}\mathrm{Z}} \approx \left\langle H_{\mathrm{core}} \right\rangle_{{}^{(A-1)}\mathrm{Z}},$$

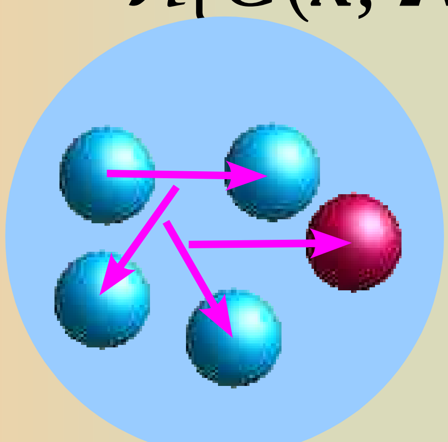
$$\left\langle H_{Y-\mathrm{core}} \right\rangle_{{}^{A}_{\Lambda}\mathrm{Z}} \approx -B_{\Lambda}\left({}^{A}_{\Lambda}\mathrm{Z} \right).$$



Ab initio calculation with stochastic variational method

- The variational trial function must be flexible enough to incorporate both
  - Explicit Σ degrees of freedom and
  - Higher orbital angular momenta.
- $\Psi \Sigma_i c_i \, \Phi_{JMTM_T}(x; \mathbf{A}_i, u_i)$
- $\Phi_{JMIM_I}(x, \mathbf{A}_i, u_i)$

$= \mathcal{A}\{G(x; \mathbf{A}_i)[\theta_{(kl)_i}(x; u_i) \times \chi_{S_i}]_{JM} \eta_{IM_I}\}$



Complete five-body treatment

Ab initio calculation with stochastic variational method

- Correlated Gaussian

$$G(x; \mathbf{A}_i) = \exp\{-(1/2)\Sigma_{m<n} \alpha_{i,mn} (\boldsymbol{r}_m - \boldsymbol{r}_n)^2\}$$

$$= \exp\{-(1/2)\Sigma_{m,n} \mathbf{A}_{i,mn} \boldsymbol{x}_m \cdot \boldsymbol{x}_n\}$$

- Global vector representation

$$\theta_{(kl)_i}(\boldsymbol{x}; u_i) = v_i^{2k+l} Y_{l_i}(\boldsymbol{v}_i), \text{ with } \boldsymbol{v}_i = \Sigma_m u_{i,m} \boldsymbol{x}_m$$

- Spin function $\chi_{s_i} = [[[\boldsymbol{s}_1 \times \boldsymbol{s}_2]_{s_{12}} \times]_{s_{1234}} \times \boldsymbol{s}_5]$

$$_{s_i} \sim |\uparrow\downarrow\uparrow\downarrow\uparrow\rangle + \ldots$$

- Isospin function $\eta_{IM_I} = [[[N_1 \times N_4]_{I_{12}} \times]_{I_{1234}} \times Y]_{IM_I}$

$$\sim |pnpn\Lambda\rangle + \ldots \text{ or } \sim |pnpn\Sigma^0\rangle + \ldots$$

Ab initio calculation with stochastic variational method

- An example of spin function
  - The case of ${}^{3}_{\Lambda}$H, (J=1/2, T=0)
  - $[(L=0)\times(S=1/2)]_{J=1/2}$
    - $\chi_{S=1/2} = (1/\sqrt{2})\ (|\uparrow\downarrow\uparrow\rangle - |\downarrow\uparrow\uparrow\rangle)$, or
    - $\chi_{S=1/2} = (1/\sqrt{6})\ (2|\uparrow\uparrow\downarrow\rangle - |\uparrow\downarrow\uparrow\rangle - |\downarrow\uparrow\uparrow\rangle)$
  - $[(L=2)\times(S=3/2)]_{J=1/2}$
    - $\chi_{S=3/2} = |\uparrow\uparrow\uparrow\rangle$

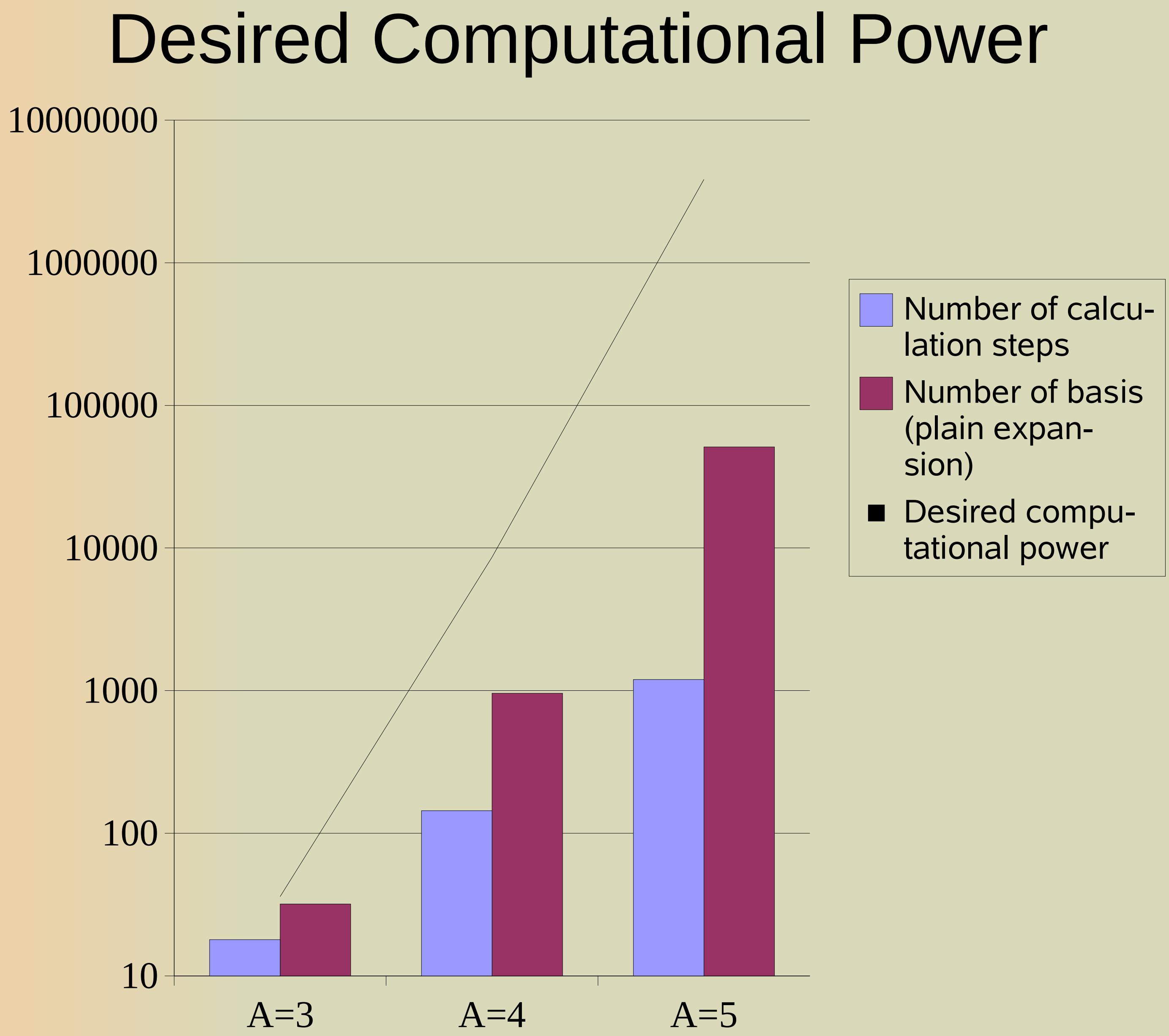
Ab initio calculation with stochastic variational method

- An example of isospin function
  - The case of ${}^{3}_{\Lambda}\mathrm{H}$, ($J$=1/2, I=0)
    - $\eta_{IM_I} = (1/\sqrt{2})(|pn\Lambda\rangle - |np\Lambda\rangle)$
    - $\eta_{IM_I} = (1/\sqrt{3})(|nn\Sigma^{+}\rangle + |pp\Sigma^{-}\rangle)$

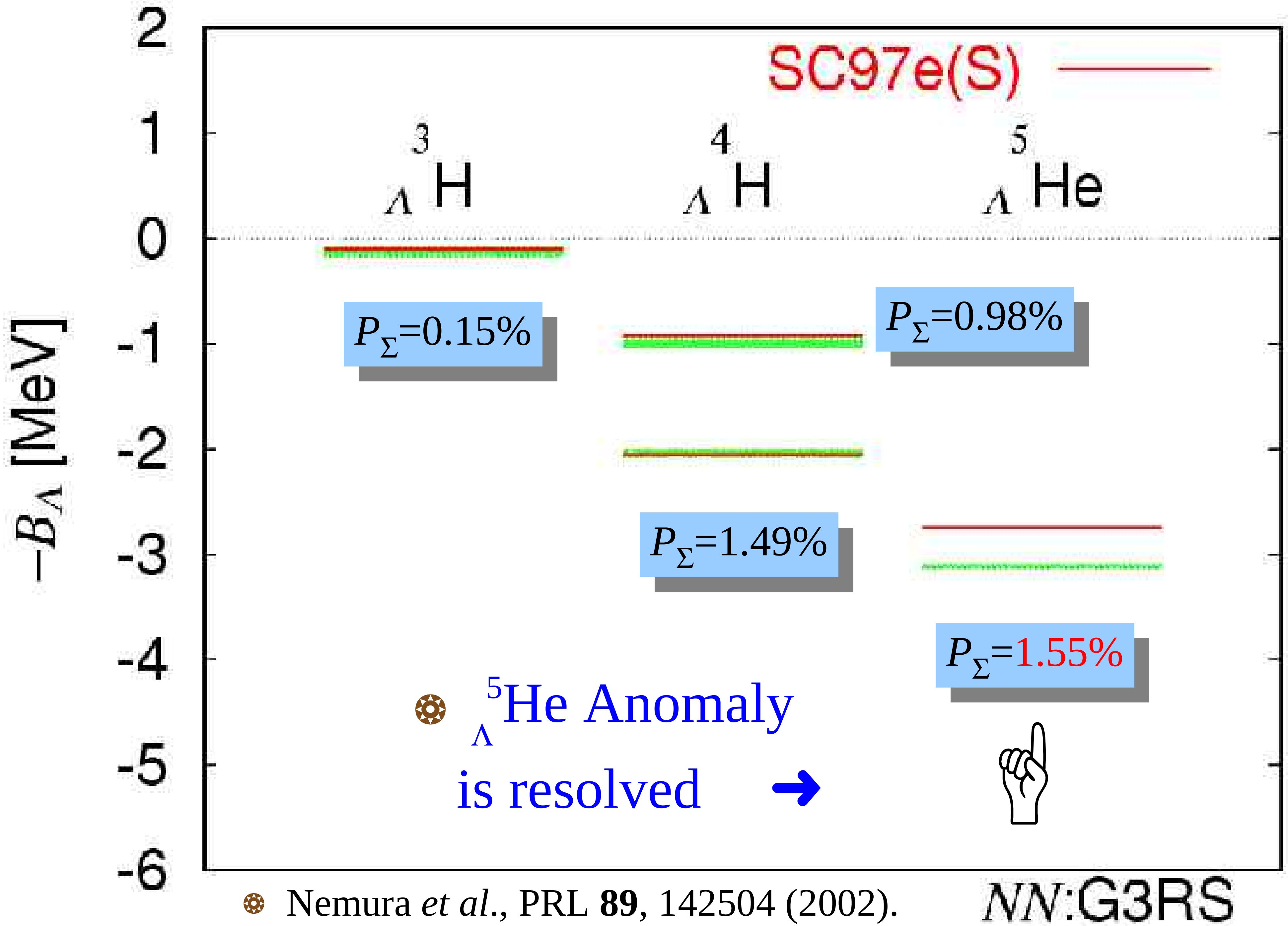
      $- (1/\sqrt{6})(|pn\Sigma^{0}\rangle + |np\Sigma^{0}\rangle)$

Ab initio calculation with SVM

- SVM is capable of handling the massive calculation.

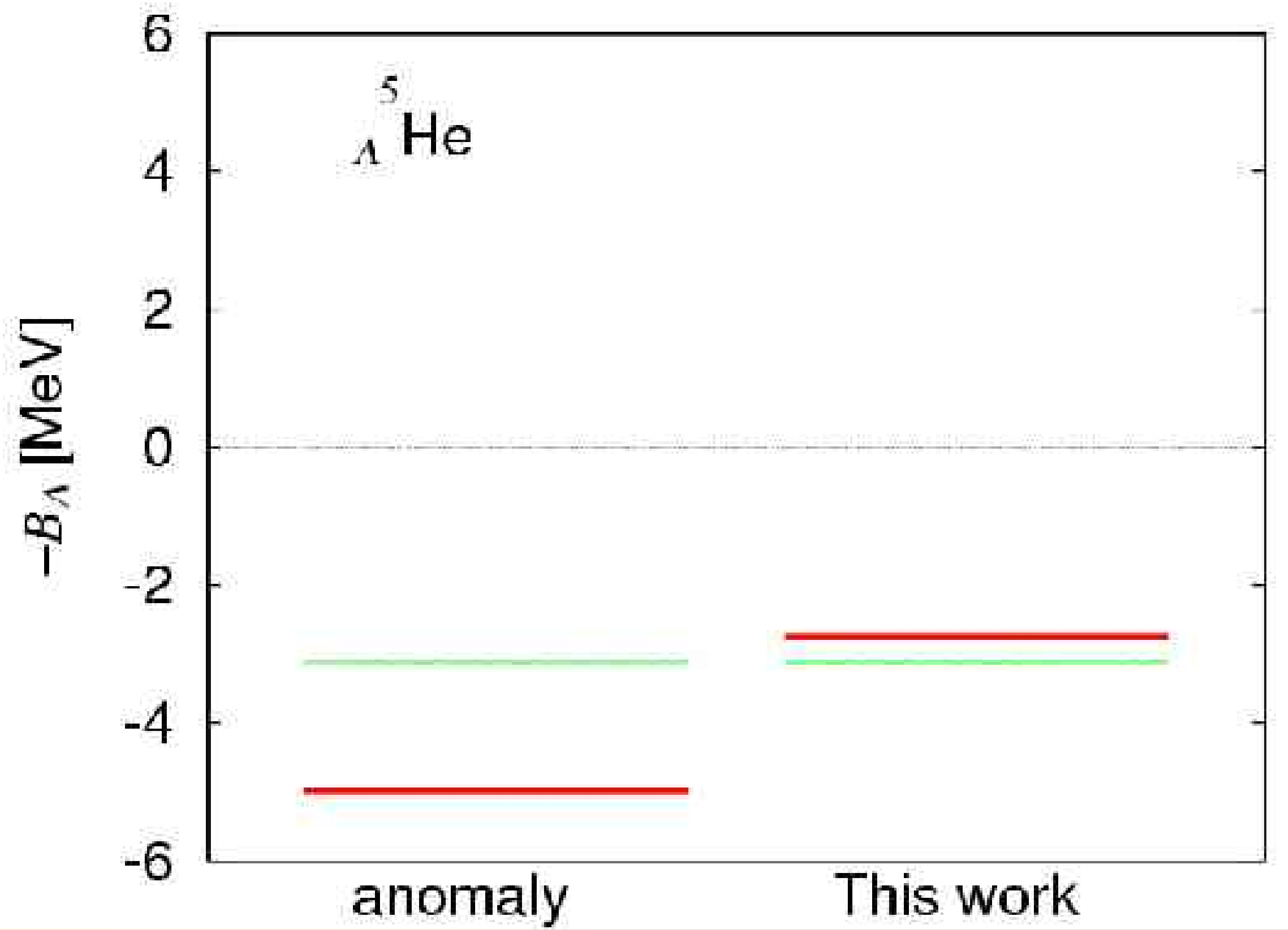


Results



Nemura *et al*., PRL **89**, 142504 (2002).

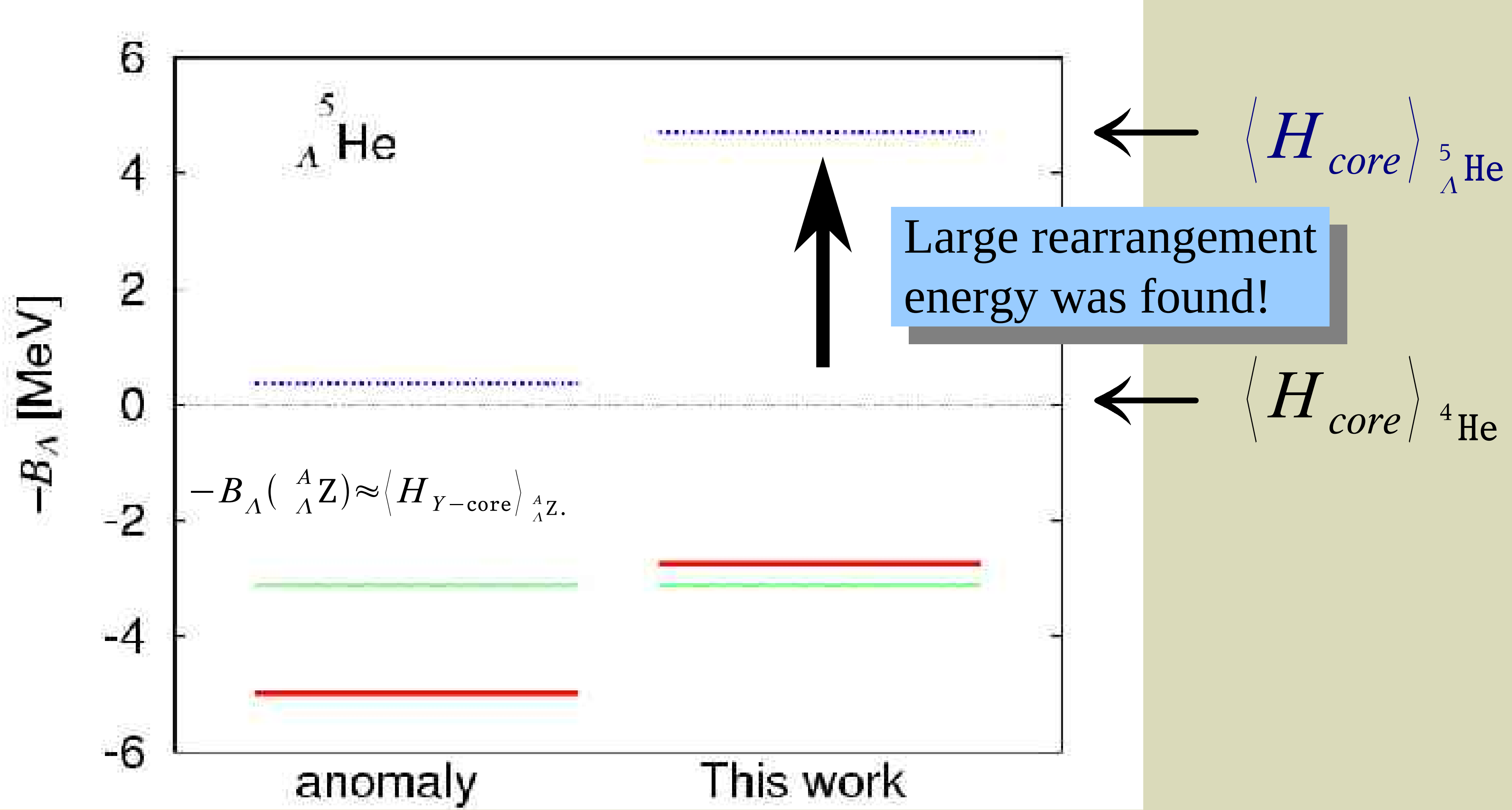
Rearrangement energy of ^{4}He in $_{\Lambda}^{5}$He



$\leftarrow \langle H_{core} \rangle_{^4\mathrm{He}}$

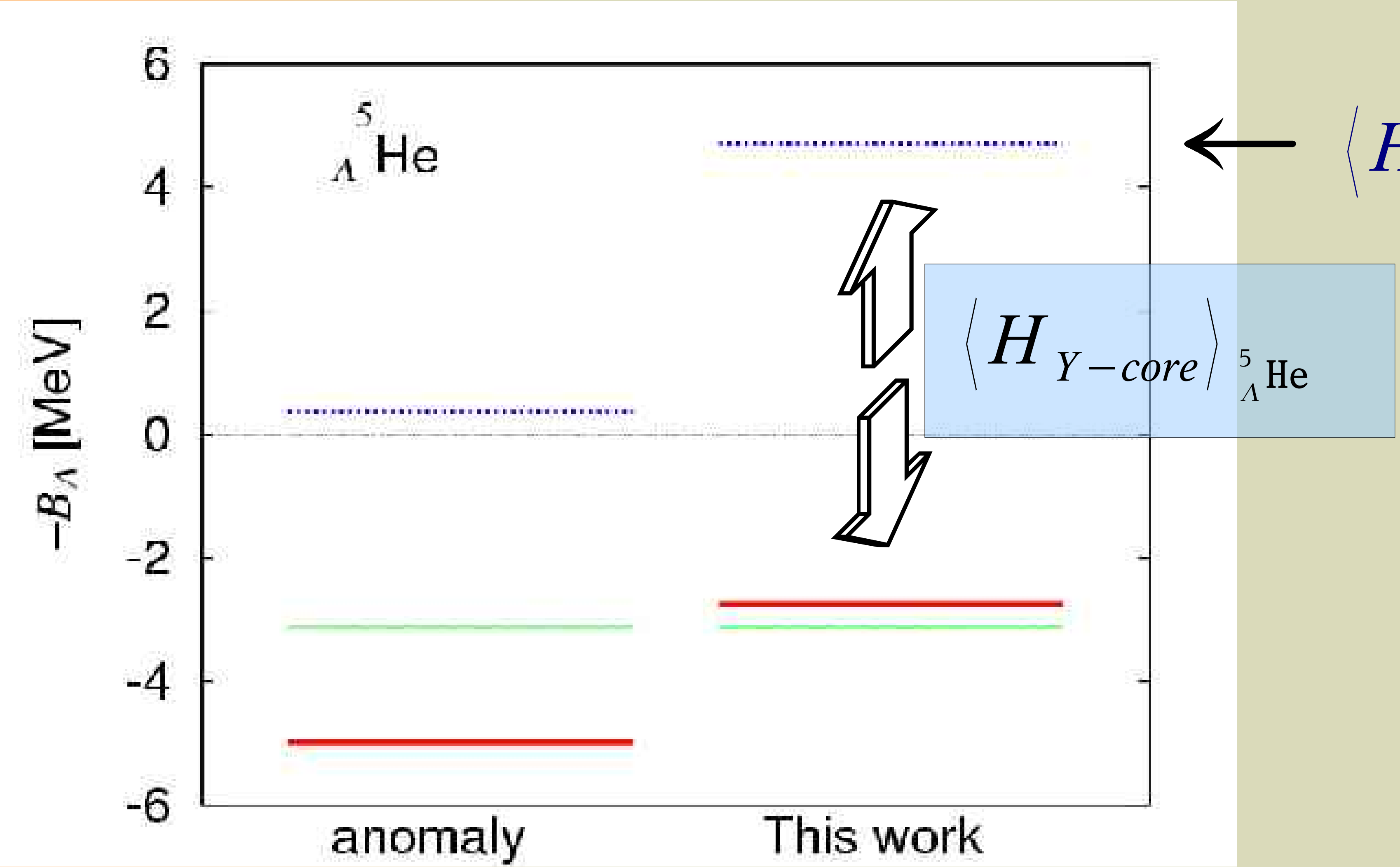
- $_{\Lambda}^{5}$He anomaly is resolved by taking account of explicit Σ degrees of freedom.

Rearrangement energy of ^{4}He in $_\Lambda^5$He



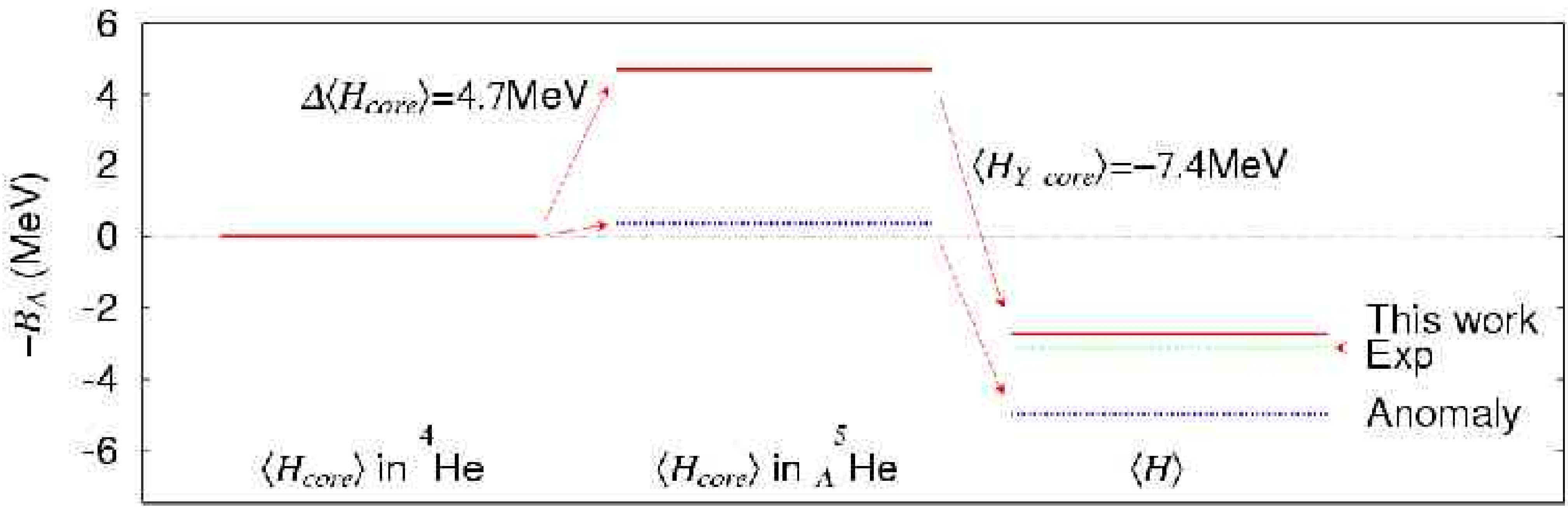
- Taking account of explicit Σ admixture, particularly using tensor ΛN-ΣN interaction, rearrangement energy is significant.

Rearrangement energy of ^{4}He in $_\Lambda^5$He



- $\langle H_{Y\text{-core}} \rangle$ = –7.4 MeV (with tensor *ΛN*-*ΣN* interaction)
- The *YN* interaction in $_\Lambda^5$He is much stronger than what the experimental B_Λ(=3.12 MeV) implies.

Rearrangement effect of ${}_{\Lambda}^{5}$He

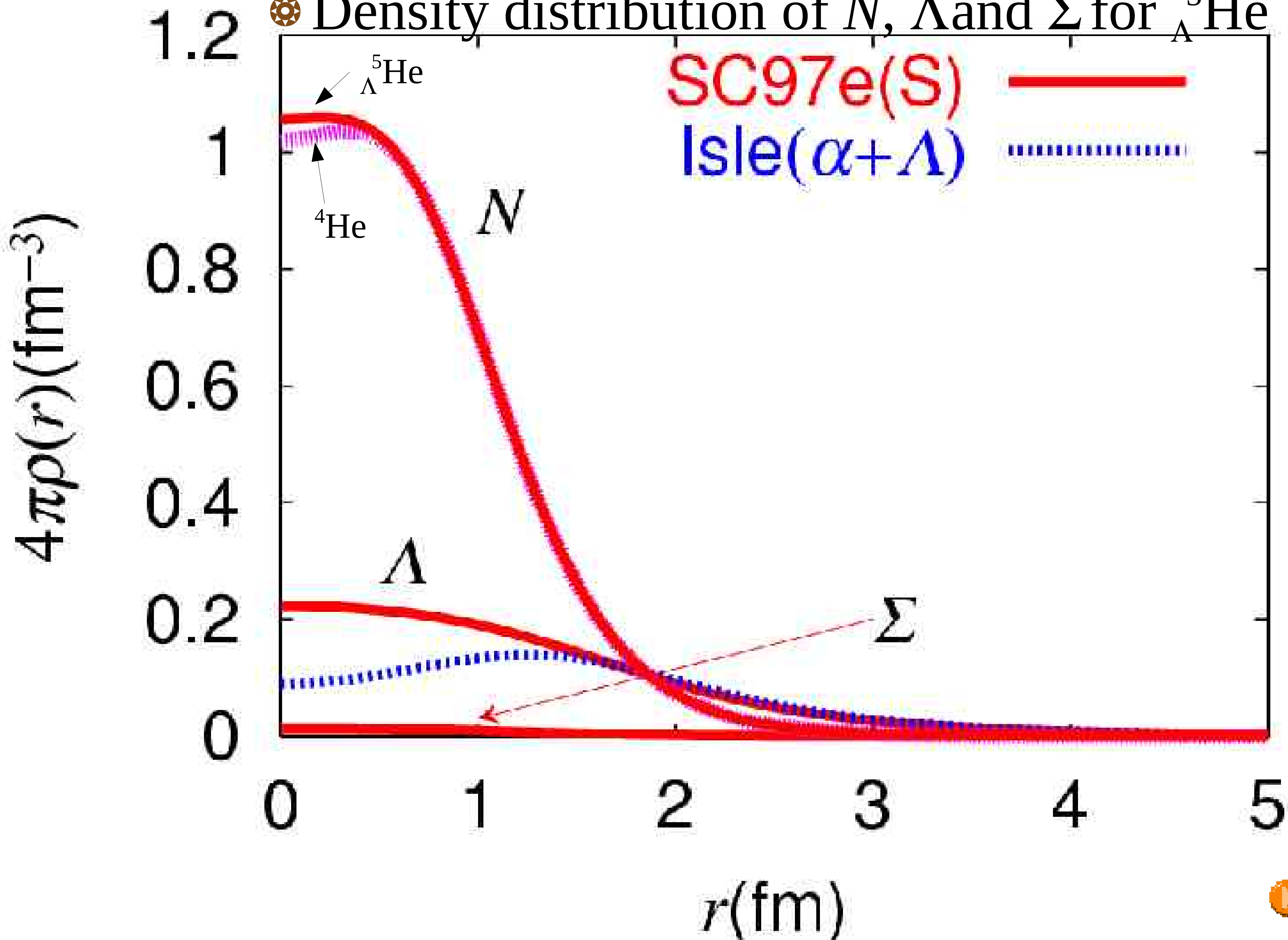


$$H = \sum_{i=1}^{A}\left(m_i c^2 + \frac{\boldsymbol{p}_i^2}{2} m_i\right) - T_{CM} + \sum_{i<j}^{A-1} v_{ij}^{(NN)} + \sum_{i=1}^{A-1} v_{iY}^{(NY)} = H_{\mathrm{core}} + H_{Y-\mathrm{core}} \quad ,$$

$$H_{\mathrm{core}} = \sum_{i=1}^{A-1} \frac{\boldsymbol{p}_i^2}{2} m_N - \frac{\left(\sum_{i=1}^{A-1} \boldsymbol{p}_i\right)^2}{2(A-1)m_N} + \sum_{i<j}^{A-1} v_{ij}^{(NN)} = T_{\mathrm{core}} + V_{NN} \quad .$$

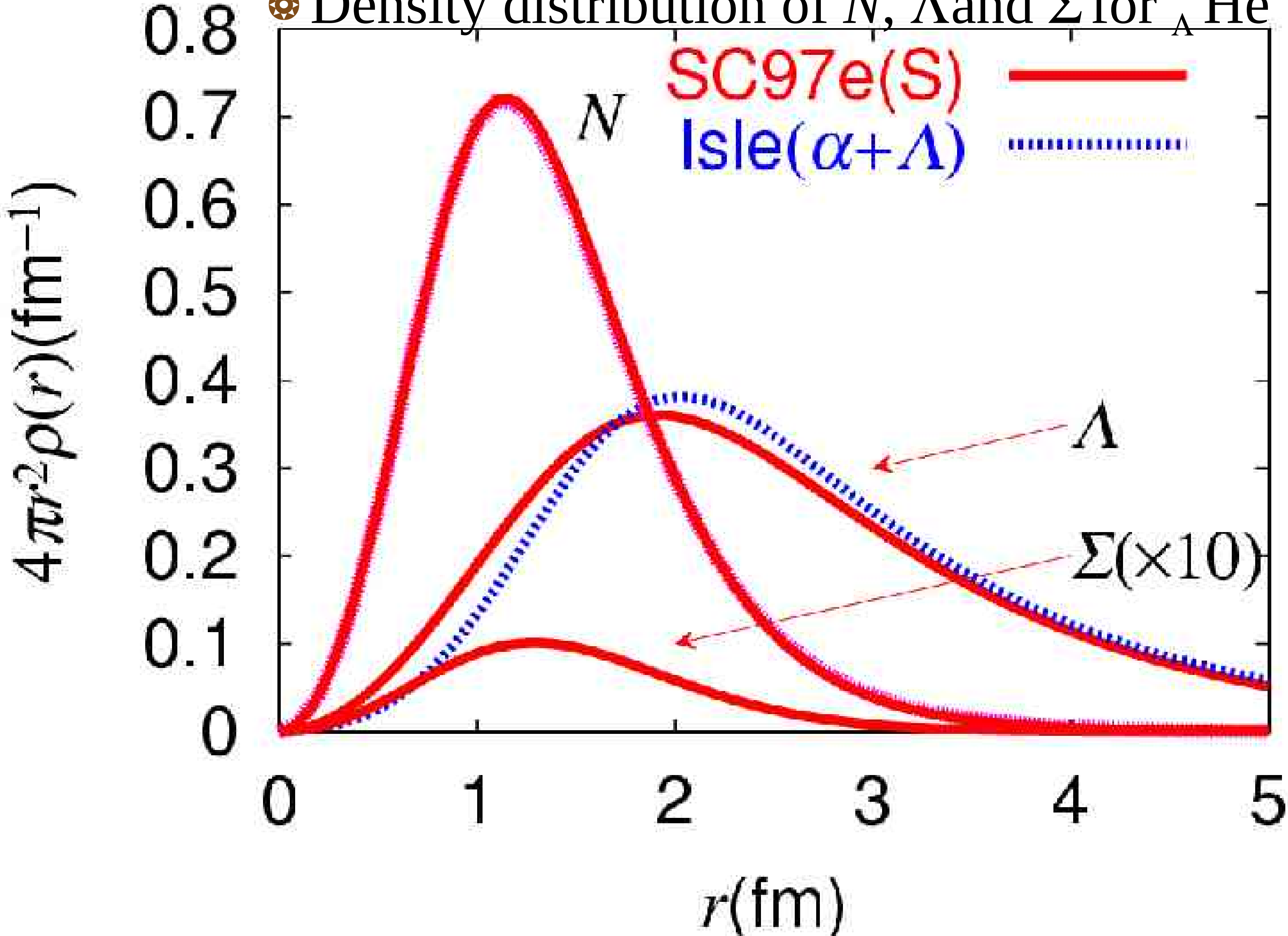
Results for light hypernuclei

- Density distribution of N, Λ and Σ for $^{5}_{\Lambda}He$



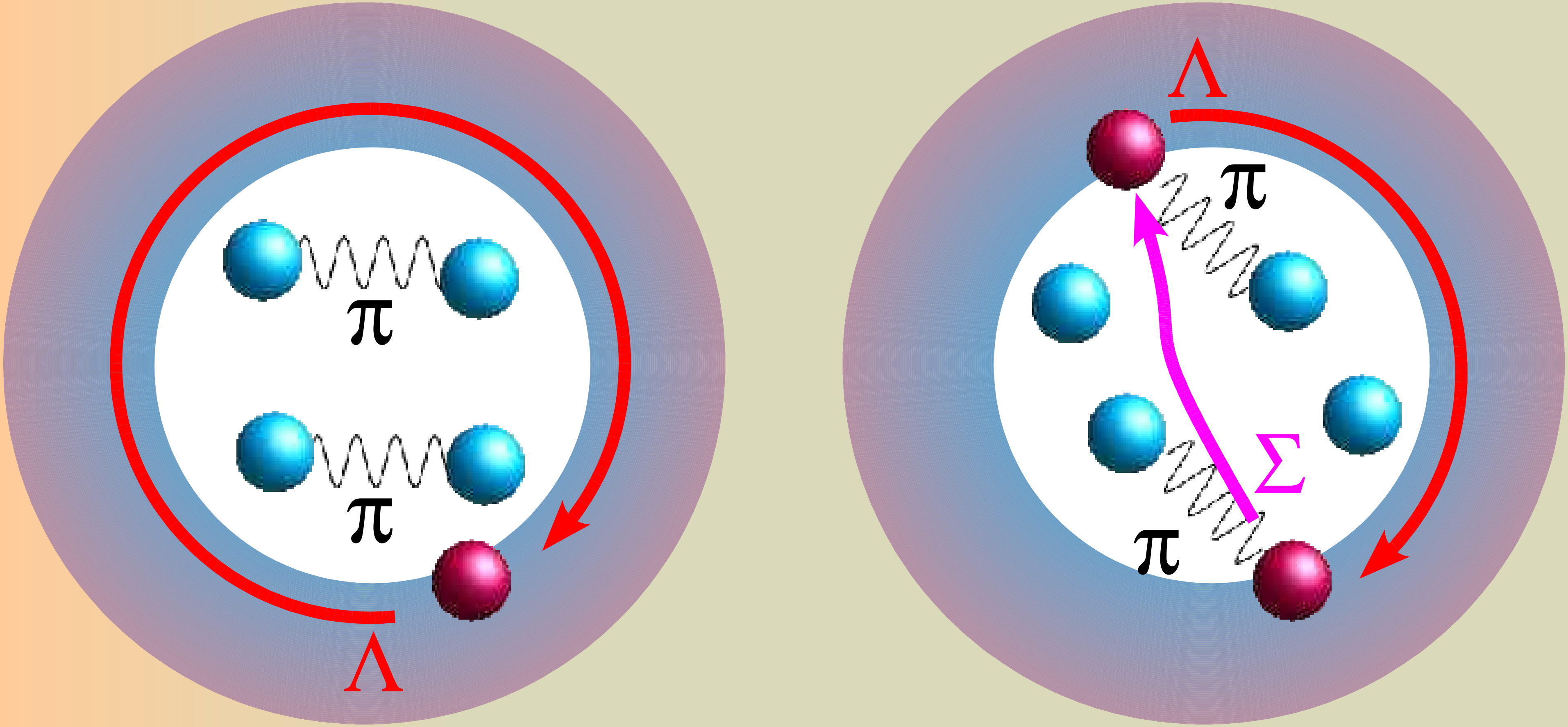
Results for light hypernuclei

- Density distribution of N, Λ and Σ for $^{5}_{\Lambda}$He



Rearrangement effect of ${}_{\Lambda}^{5}$He

- Left: A conventional picture of ${}_{\Lambda}^{5}$He
- Right: A new picture due to strong ΛN-ΣN tensor coupling



Summary

- Five-body calculation of ${}^{5}_{\Lambda}\mathrm{He}$ was performed with a *YN* interaction explicitly including Σ degrees of freedom.
- This is the first *ab initio* calculation of ${}^{5}_{\Lambda}\mathrm{He}$ using tensor *ΛN*–*ΣN* interaction which gives a bound-state solution.
- A new view of ${}^{5}_{\Lambda}\mathrm{He}$:
  - We found the large rearrangement energy for the core nucleus in ${}^{5}_{\Lambda}\mathrm{He}$; $\Delta\langle H_{\mathrm{core}}\rangle = 4.7$ MeV

    $-B_{\Lambda} \neq \langle H_{Y\text{-core}}\rangle = -7.4$ MeV
  - Tensor *ΛN*-*ΣN* interaction is strongly attractive and affects the internal energy of the core nucleus.
  - ${}^{4}\mathrm{He}$ is no longer rigid in interacting with a Λ particle.

II. First-ever 5-body calculations of doubly strange hypernuclei in fully coupled-channel scheme of particle basis

The purpose of this work

- To describe the first-ever 5-body calculation of doubly strange hypernuclei (${}^{5}_{\Lambda\Lambda}\mathrm{H}$ -- ${}^{5}_{\Xi}\mathrm{H}$ -- ${}^{5}_{\Lambda\Sigma}\mathrm{H}$ -- ${}^{5}_{\Sigma\Sigma}\mathrm{H}$ and ${}^{5}_{\Lambda\Lambda}\mathrm{He}$ -- ${}^{5}_{\Xi}\mathrm{He}$ -- ${}^{5}_{\Lambda\Sigma}\mathrm{He}$ -- ${}^{5}_{\Sigma\Sigma}\mathrm{He}$) in fully coupled channel scheme of particle basis.

- If the Ξ-, ΛΣ-, and ΣΣ-hypernuclear states exist, they must decay via ΛΛ-*N*Ξ-ΛΣ-ΣΣ and Λ*N*-Σ*N* strong interaction.

- How can we calculate the Ξ-, ΛΣ-, and ΣΣ-hypernuclear states?

The strategies to solve the problem

- How can we calculate the Ξ-, $\Lambda\Sigma$-, and $\Sigma\Sigma$-hypernuclear states?
- Let us consider the Ξ-hypernucleus as an example.
  - Single channel calculation of each particle basis, such as $ppnn\Xi^-$ or $ppnn\Xi^0$:
    - This makes bound state of the Ξ-hypernuclei, if the ΞN potential is so attractive, but not realistic.
  - Fully coupled channel calculation
    - Mixed state among $ppnn\Xi^- \leftrightarrow pnn\Lambda\Lambda$

$$\leftrightarrow ppn\Lambda\Sigma^-, \ldots$$

$$\leftrightarrow ppn\Sigma^-\Sigma^0, \ldots$$

NN, YN and YY potentials

- *NN* interaction: Minnesota potential
  - The *NN* interaction reproduces the low energy *NN* scattering data, and also reproduces reasonably well both the BEs and sizes of ^{2}H, ^{3}H, ^{3}He, and ^{4}He.
- *YN* interaction: D2' potential
  - The *YN* interaction reproduces the experimental B_Λ of A=3-5 hypernuclei; Free from the ${}_\Lambda^5$He anomaly.
- *YY* interaction: Simulating Nijmegen model (mND$_S$)
  - Fully coupled channel;

hard-core radius

ND: r_c=(0.56, 0.45) fm

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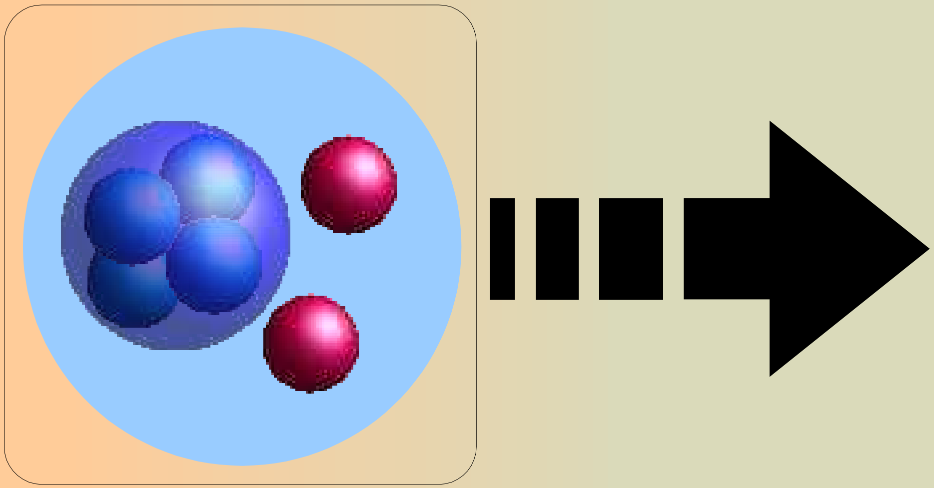
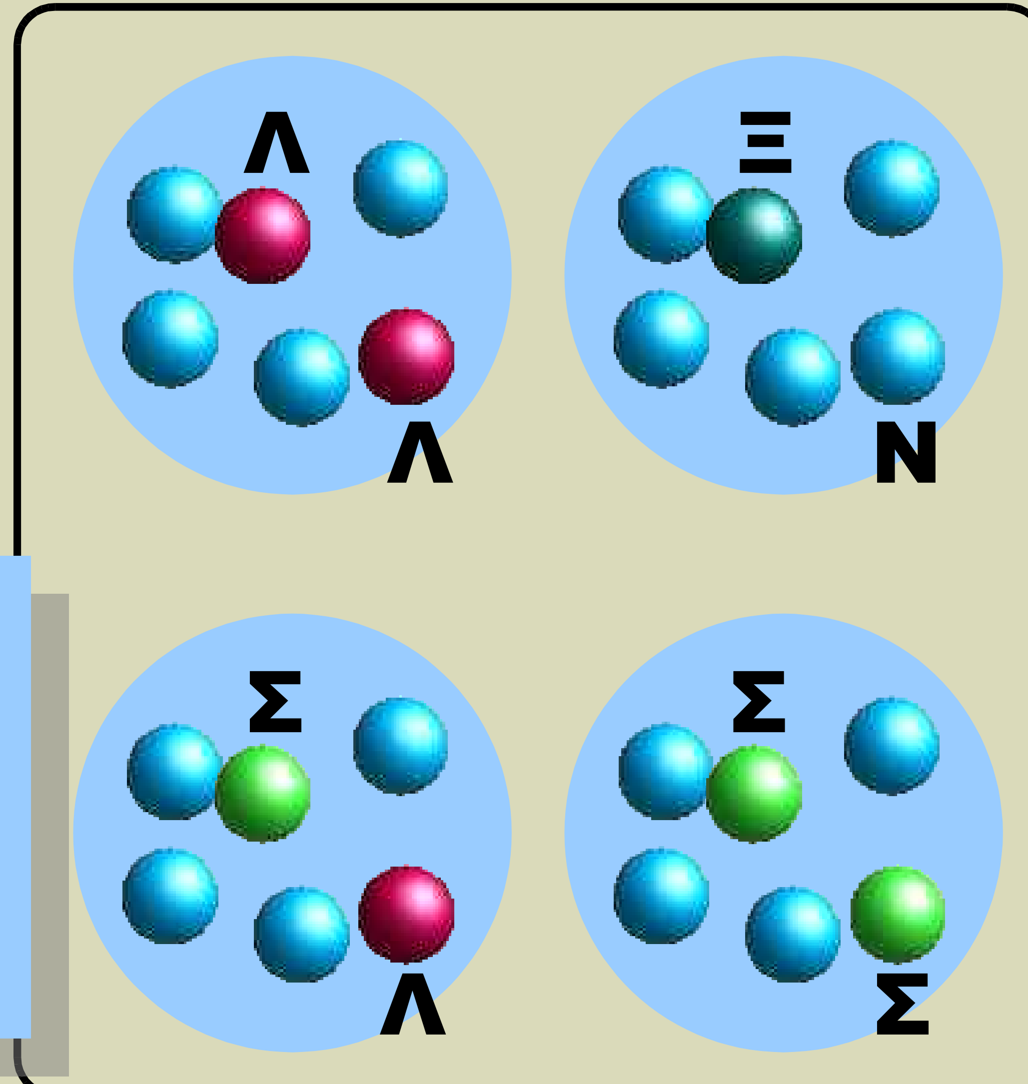
	$^1S_0$	$^3S_1$
I=0	ΛΛ-NΞ-ΣΣ	NΞ
I=1	NΞ-ΛΣ	NΞ-ΛΣ-ΣΣ
I=2	ΣΣ	

Ab initio calculation of S=-2 hypernucleus ${}_{\Lambda\Lambda}^{6}He$ in a fully coupled channel scheme





Complete six-body

+

Full-coupled channel treatment

PRL 94, 202502 (2005) PHYSICAL REVIEW LETTERS week ending 27 MAY 2005

Fully Coupled Channel Approach to Doubly Strange s-Shell Hypernuclei

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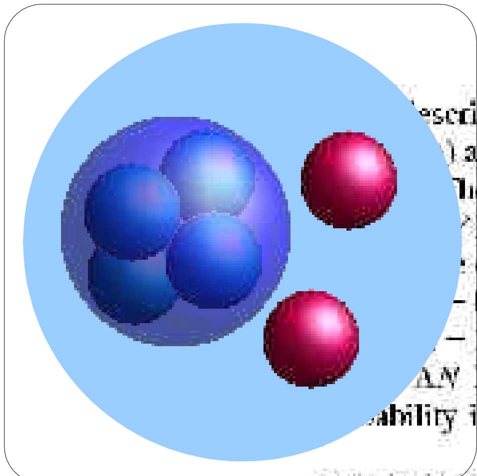
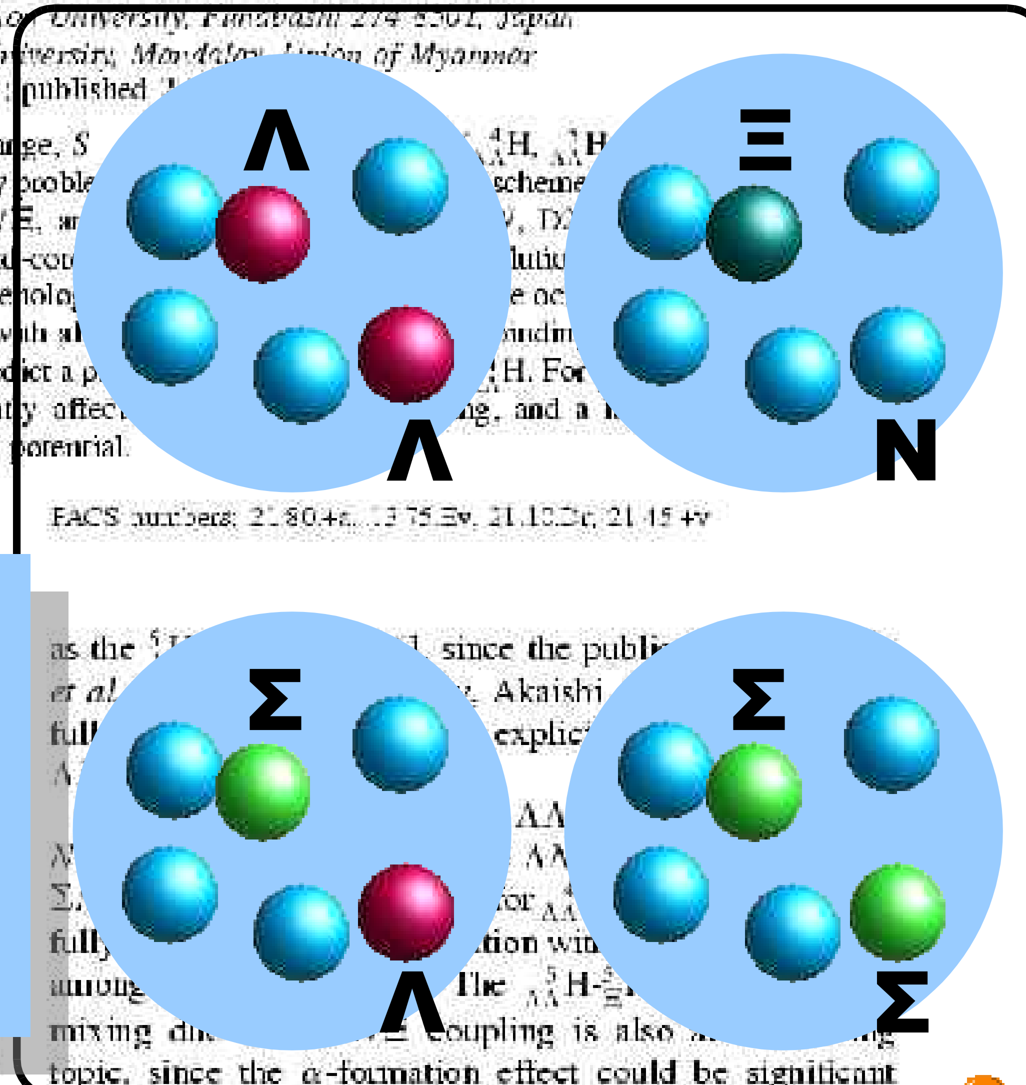
(Received 10 July 2004; published





DOI: 10.1103/PhysRevLett.94.202502 PACS numbers: 21.80.+a, 13.75.Ev, 21.10.Dr, 21.45.+v

Complete six-body

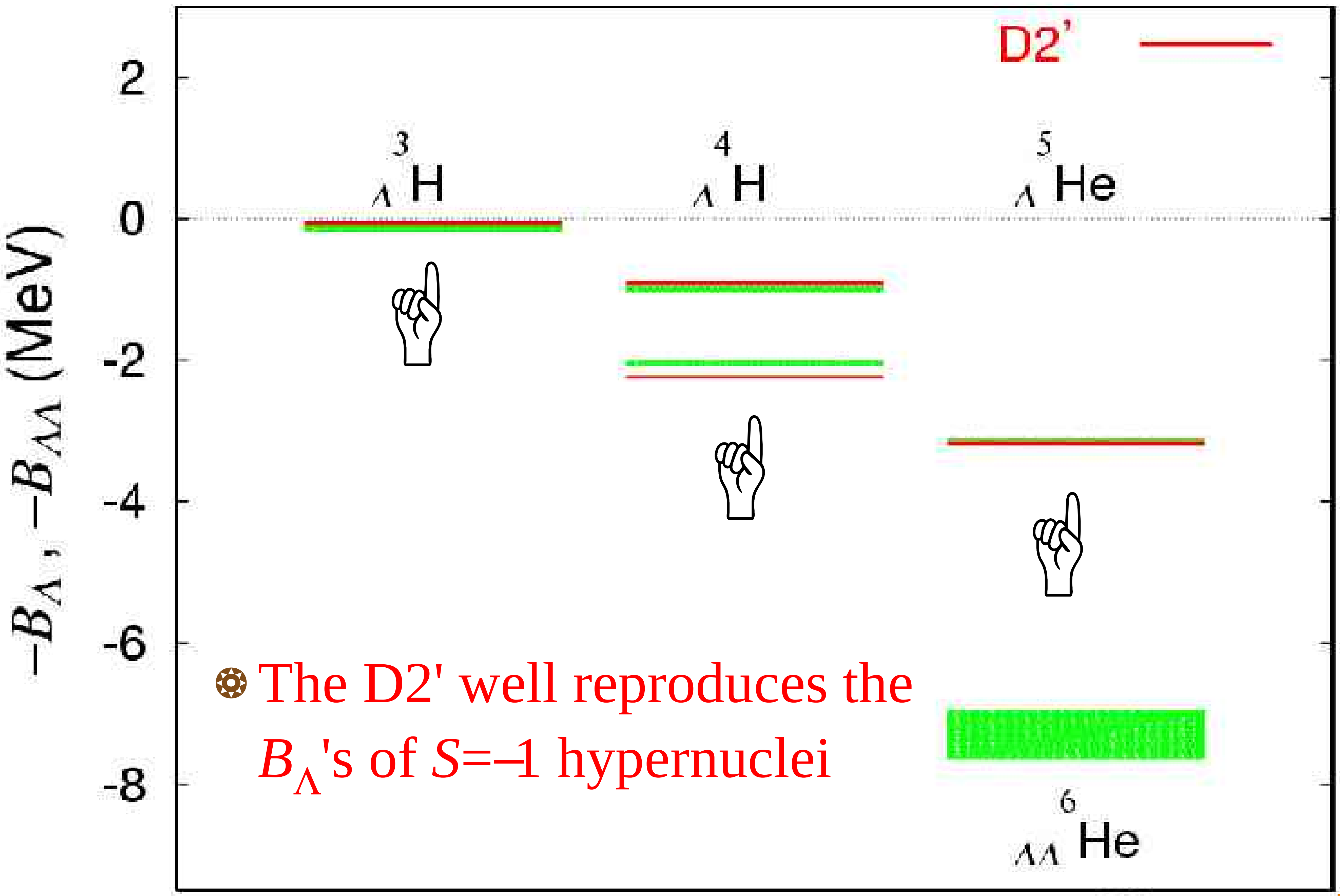
+

Full-coupled channel treatment

formation of $^{4}_{\Lambda\Lambda}$H, in accordance with our earlier predictions [13,14] that $^{4}_{\Lambda\Lambda}$H would exist as a particle stable bound state against strong decay. If this is the case, the

topic, since the α-formation effect could be significant [7,9]. Thus, the purpose of this study is threefold: First, it is to describe a systematic study for the complete set of

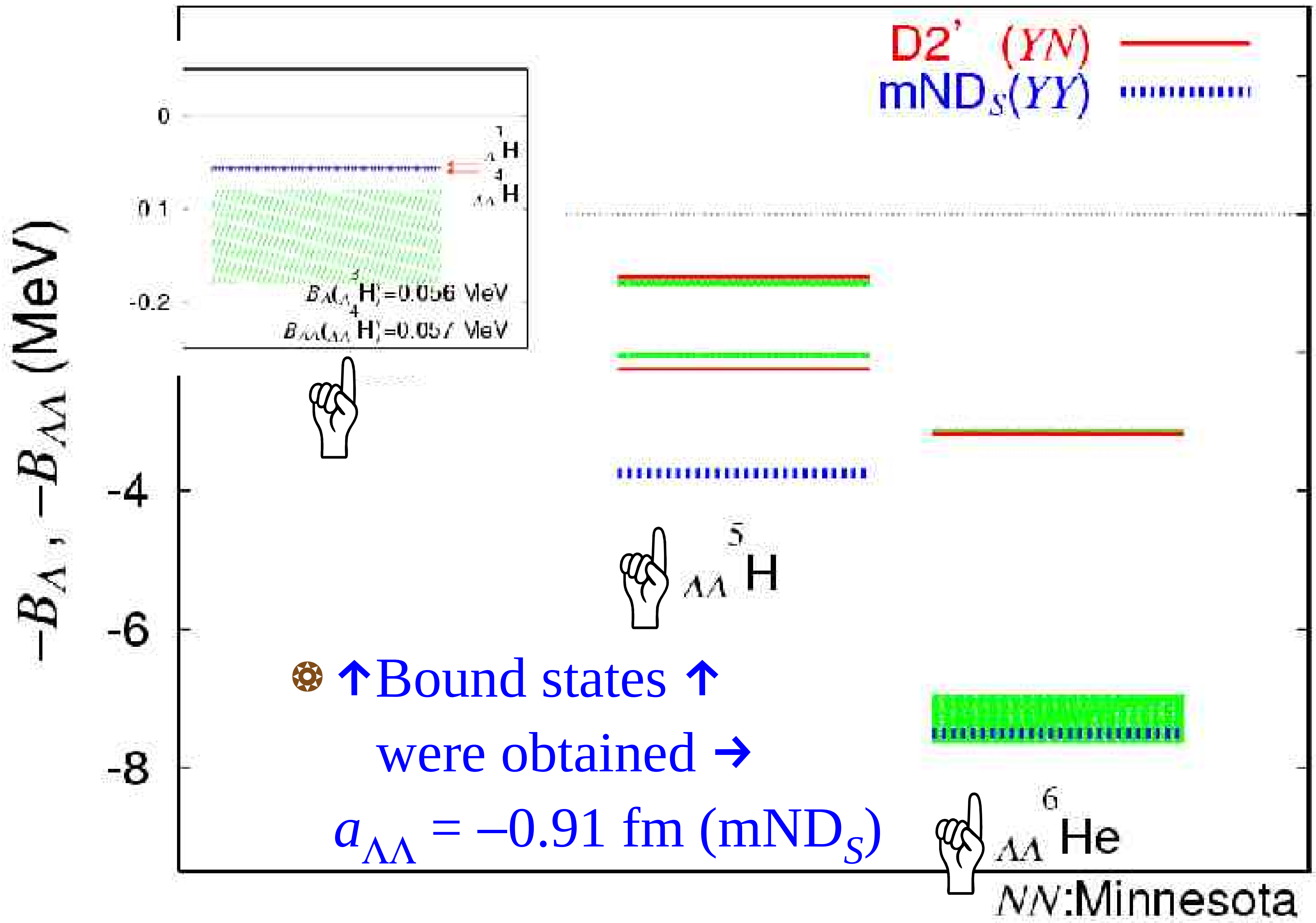
Results



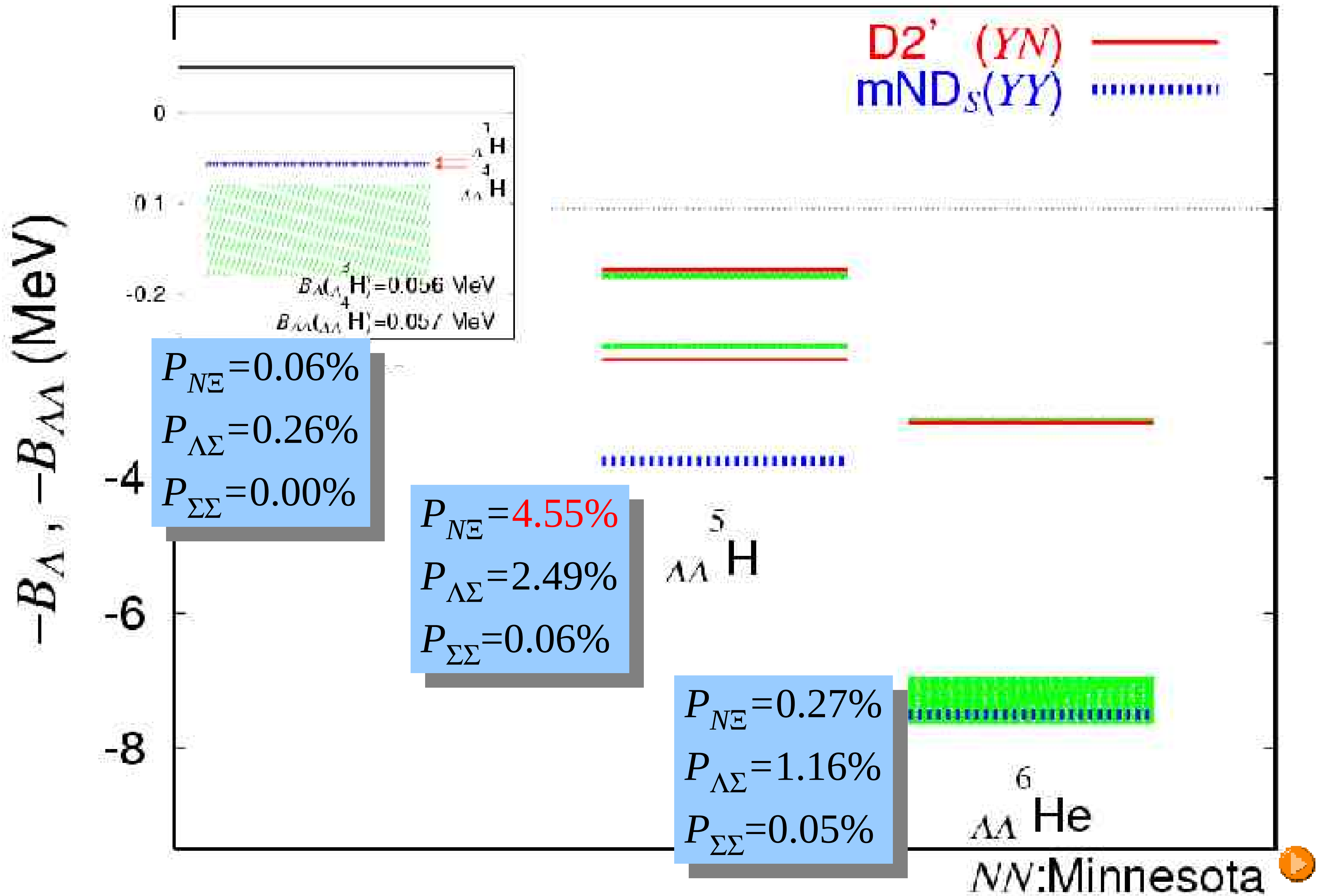
- The D2' well reproduces the B_{Λ}'s of S=–1 hypernuclei

NN:Minnesota

Results


D2' (YN)
mNDS(YY)
0
-0.1
-0.2
3ΛH
4ΛΛH
BΛ(3ΛH)=0.056 MeV
BΛΛ(4ΛΛH)=0.057 MeV
−BΛ, −BΛΛ (MeV)
-4
-6
-8
5ΛΛH
6ΛΛHe
NN:Minnesota
↑Bound states ↑
were obtained →
aΛΛ = –0.91 fm (mNDS)

Results



D2' (YN)
mNDs(YY)
$-B_{\Lambda}, -B_{\Lambda\Lambda}$ (MeV)
0
-0.1
-0.2
$^{3}_{\Lambda}$H
$^{4}_{\Lambda\Lambda}$H
$B_{\Lambda}(^{3}_{\Lambda}H)$=0.056 MeV
$B_{\Lambda\Lambda}(^{4}_{\Lambda\Lambda}H)$=0.057 MeV
-4
-6
-8
$^{5}_{\Lambda\Lambda}$H
$^{6}_{\Lambda\Lambda}$He
NN:Minnesota
$P_{N\Xi}$=0.06%
$P_{\Lambda\Sigma}$=0.26%
$P_{\Sigma\Sigma}$=0.00%
$P_{N\Xi}$=4.55%
$P_{\Lambda\Sigma}$=2.49%
$P_{\Sigma\Sigma}$=0.06%
$P_{N\Xi}$=0.27%
$P_{\Lambda\Sigma}$=1.16%
$P_{\Sigma\Sigma}$=0.05%

Preliminary results

- ${}_{\Lambda\Lambda}{}^{5}\mathrm{H}$ -- ${}_{\Xi}{}^{5}\mathrm{H}$ -- ${}_{\Lambda\Sigma}{}^{5}\mathrm{H}$ -- ${}_{\Sigma\Sigma}{}^{5}\mathrm{H}$:
- Single channel calculation of $ppnn\Xi^{-}$:
  - We obtained a bound state with $B_{\Xi} = 0.55$ MeV.

- Fully coupled channel calculation:
  - We found that there are five states below the $^{4}\mathrm{He}+\Xi^{-}$ threshold, so far.
  - The lowest is the ground state of ${}_{\Lambda\Lambda}{}^{5}\mathrm{H}$.
  - Then, we calculate the probabilities of $\Lambda\Lambda$- and Ξ-channels.

Preliminary results

- ${}_{\Lambda\Lambda}^{5}\mathrm{He}$ -- ${}_{\Xi}^{5}\mathrm{He}$ -- ${}_{\Lambda\Sigma}^{5}\mathrm{He}$ -- ${}_{\Sigma\Sigma}^{5}\mathrm{He}$:
- Single channel calculation of $ppnn\Xi^0$:
  - We obtained no bound state, so far.

- Fully coupled channel calculation:
  - We found that there are three states below the $^4\mathrm{He}+\Xi^0$ threshold, so far.
  - The lowest is the ground state of ${}_{\Lambda\Lambda}^{5}\mathrm{He}$.
  - Then, we calculate the probabilities of $\Lambda\Lambda$- and Ξ-channels.

Discussions about Ξ-hypernuclei

- The present study uses mND$_s$ YY potential, which well reproduces the $\Delta B_{\Lambda\Lambda}$ of the Nagara event, and which is consistent with the recent experimental data of Ξ-nucleus potential.
- The preliminary calculations seem to imply that a Ξ-hypernuclear state exists below the ^{4}He+Ξ^- or ^{4}He+Ξ^0 threshold.
- More precise calculations must be made in the fully coupled channel scheme:
  - Correct energies and widths.
    - ☑Complex scaling method with SVM.

Summary

- We calculated the first-ever 5-body problems of $^{5}_{\Xi}\mathrm{H}$ and $^{5}_{\Xi}\mathrm{He}$ in fully coupled-channel scheme of particle basis, though the present results are still preliminary.
- The present result seems that the Ξ-hypernuclear state exists below the $^{4}\mathrm{He}+\Xi$ threshold. If so, the coupling effects play significant roles to make a bound state of $^{5}_{\Xi}\mathrm{He}$, because the single channel calculation makes no bound state.

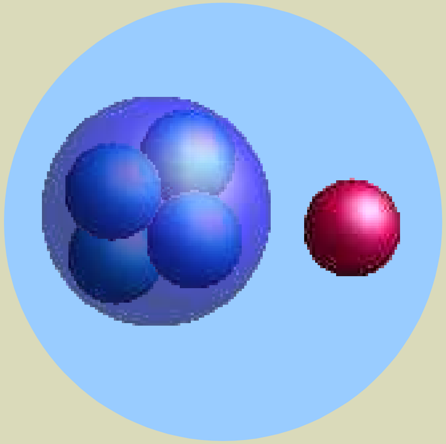
Summary contd. :

- Questions:
  - What is interesting about hypernuclei?
  - What is new topic other than the standard nuclear physics?
  - Why do you study the hypernuclear physics?
- Answers:
  - The goal of nuclear physics is to understand the strong interaction and the strongly interacting world. The hypernuclear physics gives a new point of view to see our world.
  - The strangeness may play a important role as a bridge with the traditional nuclear physics meeting the hadron physics.
    - ($\Lambda(1405)$, pentaquark, K-nucleus, H dibaryon, etc.)
    - The experimentally small B_Λ value does not mean that the Λ is just the spectator in the system. The Λ influences the internal structure of the core nucleus. This is due to the pion exchange between the baryons.
  - The multistrange hypernucleus can be a Laboratory for the study of hyperon-hyperon interaction, which is hardly performed by the real scattering experiment. The precise few-body calc helps this approach.

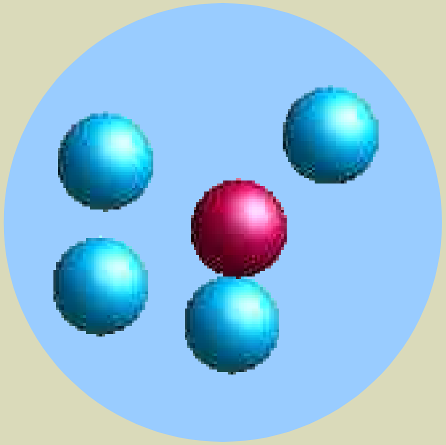
In the future study:
What is the structure of ${}_{\Lambda\Lambda}^{6}$He?

- $B(\text{total}) = B(^4\text{He}) + B_\Lambda({}_\Lambda^5\text{He})$

- A conventional picture:
  $B(\text{total})$
  $= B(^4\text{He}) + B_\Lambda({}_\Lambda^5\text{He})$
  = 28+3 MeV.



- A new picture:
  $B(\text{total})$
  $= (B(^4\text{He}) - \Delta E_c) + (B_\Lambda({}_\Lambda^5\text{He}) + \Delta E_c)$
  = 23+8 MeV.



In the future study:

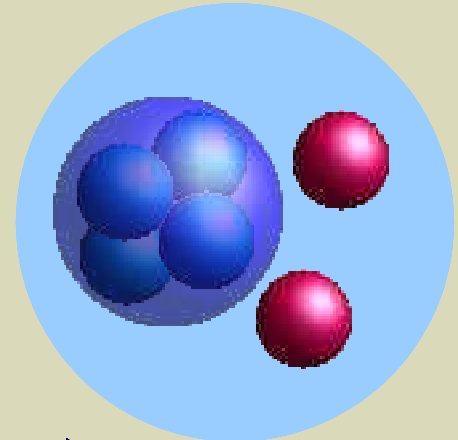
What is the structure of $^{6}_{\Lambda\Lambda}$He?

- $B(\text{total}) = B(^{4}\text{He}) + 2B_{\Lambda}(^{5}_{\Lambda}\text{He}) + \Delta B_{\Lambda\Lambda}(^{6}_{\Lambda\Lambda}\text{He})$
- A conventional picture:

  $B(\text{total})$

  $= B(^{4}\text{He}) + 2B_{\Lambda}(^{5}_{\Lambda}\text{He}) + \Delta B_{\Lambda\Lambda}(^{6}_{\Lambda\Lambda}\text{He})$

  $= 28 + 2\times 3 + 1 = 35$ MeV.



- A conjecture: $\Delta E_c(^{6}_{\Lambda\Lambda}\text{He}) = 2\Delta E_c(^{5}_{\Lambda}\text{He})$,

  $B(\text{total})$

  $= (B(^{4}\text{He}) - 2\Delta E_c(^{5}_{\Lambda}\text{He})) + 2(B_{\Lambda}(^{5}_{\Lambda}\text{He}) + \Delta E_c(^{5}_{\Lambda}\text{He}))$

  $+ \Delta B_{\Lambda\Lambda}(^{6}_{\Lambda\Lambda}\text{He})$

  $= 18 + 2\times 8 + 1 = 35$ MeV,

  (or $= 19 + 2\times 7 + 2 = 35$ MeV)