Few body systems with S=-1 and -2

E. Hiyama (RIKEN)

Outline:

(1) Introduction

(2) Four-body structure of ${}^{7}_{\Lambda}\mathrm{He}(\alpha+\Lambda+n+n)$

(3) Five-body structure of ${}^{11}_{\Lambda\Lambda}\mathrm{Be}$

(4) Four-body structure of ${}^{7}_{\Xi}\mathrm{H}$ and ${}^{10}_{\Xi}\mathrm{Li}$

(5) Conclusion

Major goals of hypernuclear physics

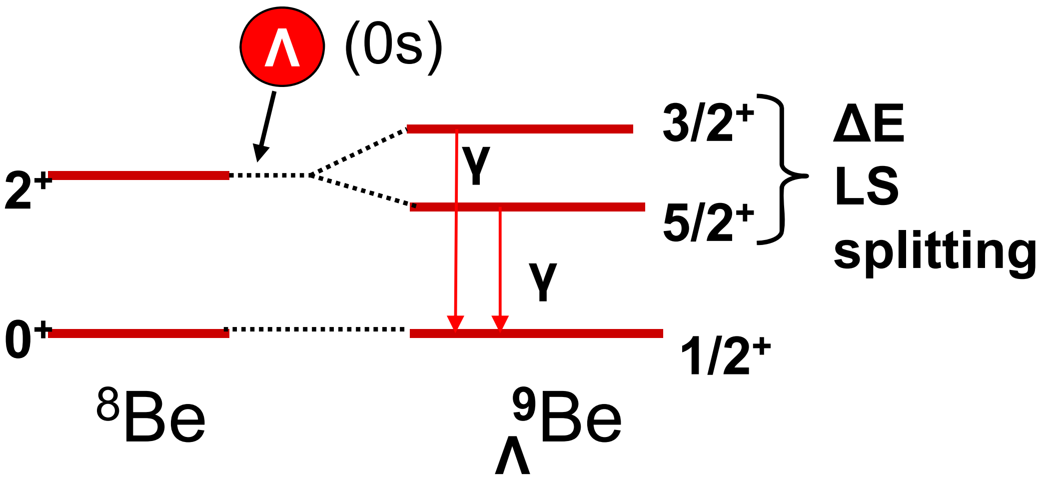
1) To understand baryon-baryon interactions

Fundamental and important for the study of nuclear physics

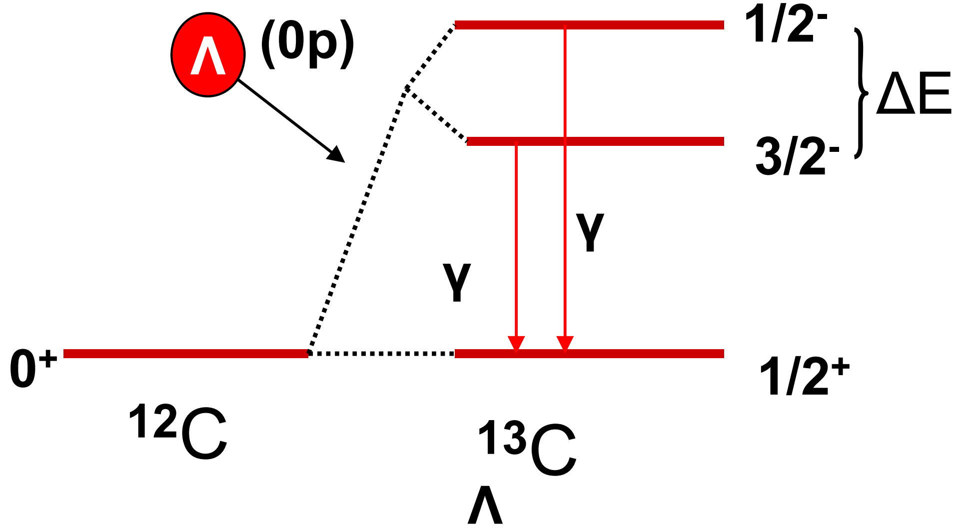
2) To study the structure of multi-strangeness systems

Due to the difficulty of YN and YY 2-body scattering experiment for the study of baryon-baryon interaction, the systematic investigation of the structure of light hypernuclei is essential.

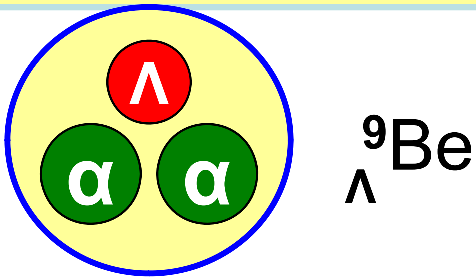
BNL-E930

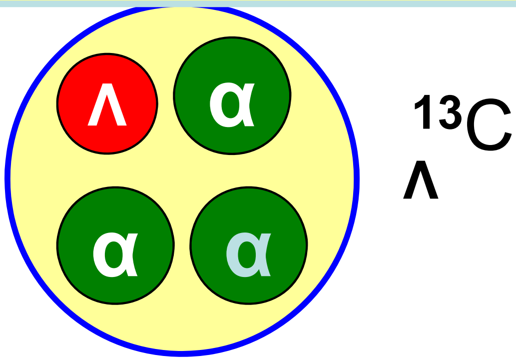


BNL-E929



3- and 4-body calculations:
E. Hiyama, M. Kamimura, T. Motoba, T. Yamada and Y. Yamamoto
Phys. Rev. Lett. 85 (2000) 270.

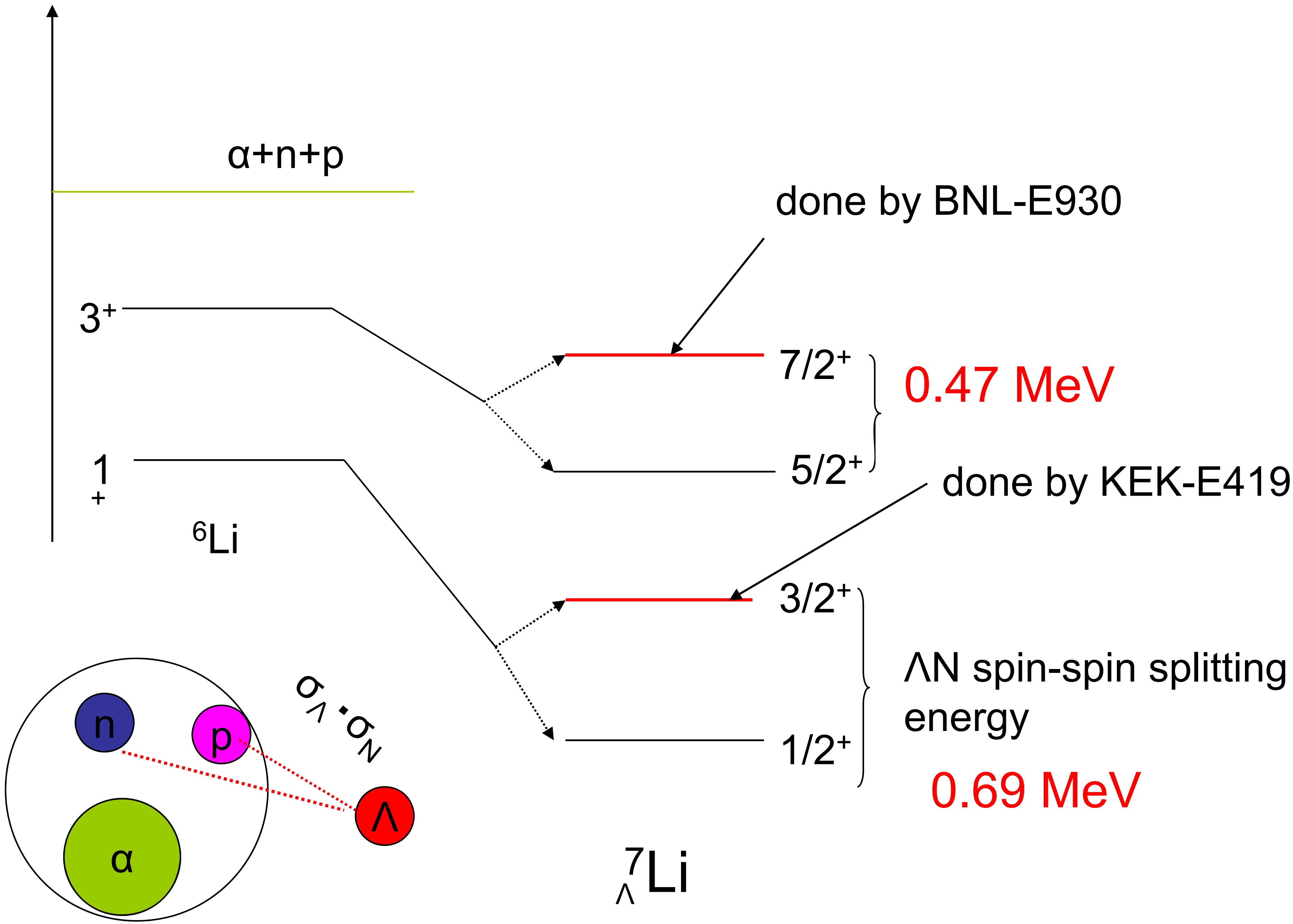




YN LS force

1) Meson theory : Nijmegen Model D, F, soft core’97 a – f.

2) Qurak model : Kyoto-Niigata, FSS



α+n+p
3+
1+
6Li
done by BNL-E930
7/2+
5/2+
0.47 MeV
done by KEK-E419
3/2+
1/2+
ΛN spin-spin splitting energy
0.69 MeV
n
p
α
Λ
σΛ・σN
7ΛLi

ΛN interaction (effectively including ΛN -ΣN coupling)

$$V_{\Lambda N} = V_0 + \boldsymbol{\sigma}_\Lambda \cdot \boldsymbol{\sigma}_N V_{\sigma\cdot\sigma} + \mathbf{L}\cdot(\mathbf{s}_\Lambda + \mathbf{s}_N) V_{\mathrm{SLS}} + \mathbf{L}\cdot(\mathbf{s}_\Lambda - \mathbf{s}_N) V_{\mathrm{ALS}} + S_{12} V_{\mathrm{tensor}} + \cdots\cdots$$

Comparing the theoretical study using few-body technique and shell-model approach (done by Millener, Motoba) with the experimental results, we could succeed in extracting the information about ΛN interaction.

$^{7}_{\Lambda}He$

In S= -1 sector,
what are the open questions in YN interaction?

(1) Charge symmetry breaking

(2) $\Lambda N - \Sigma N$ coupling

J-PARC : Day-1 experiment

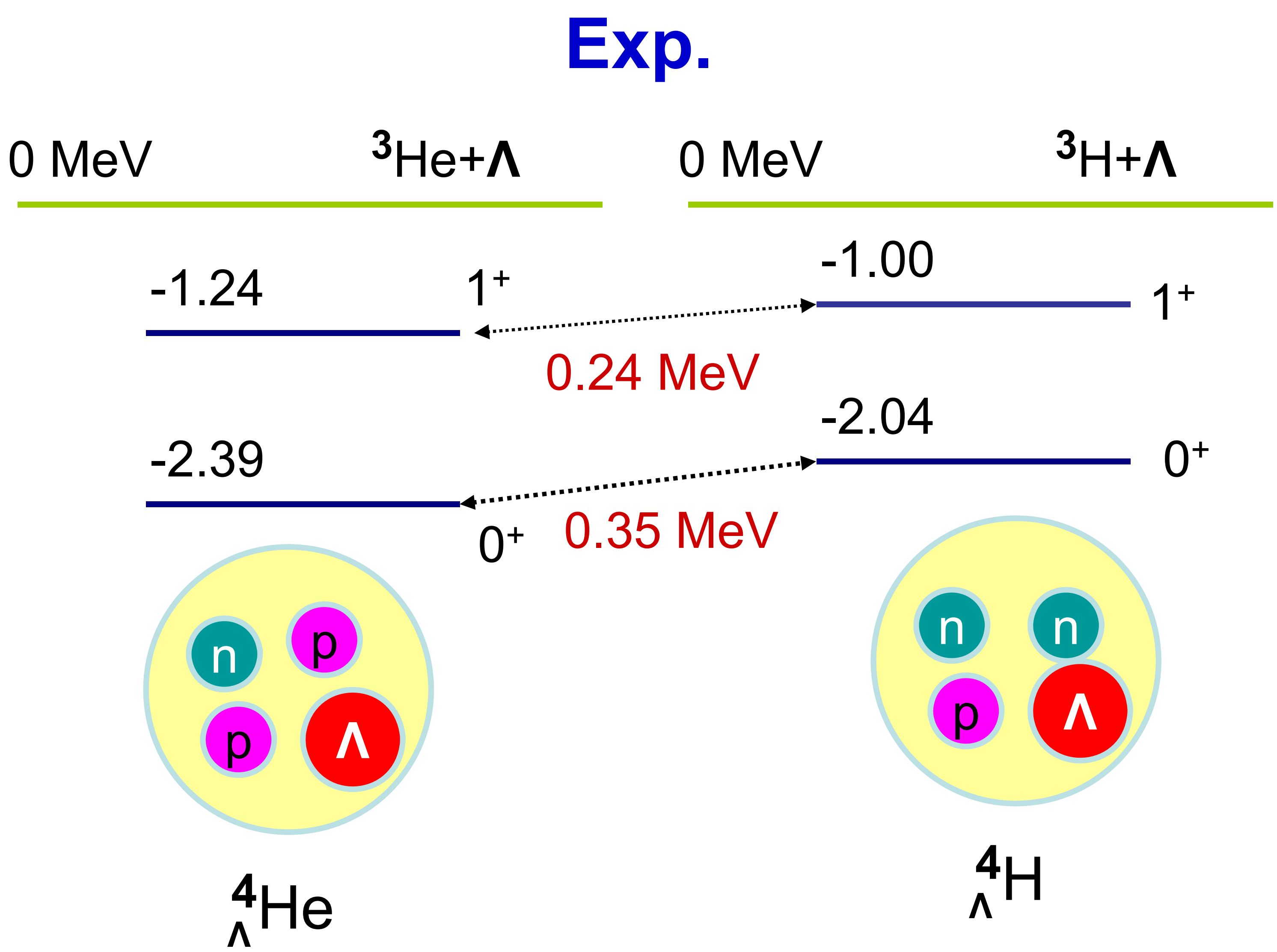
・E13 “γ-ray spectroscopy of light hypernuclei”
by Tamura and his collaborators

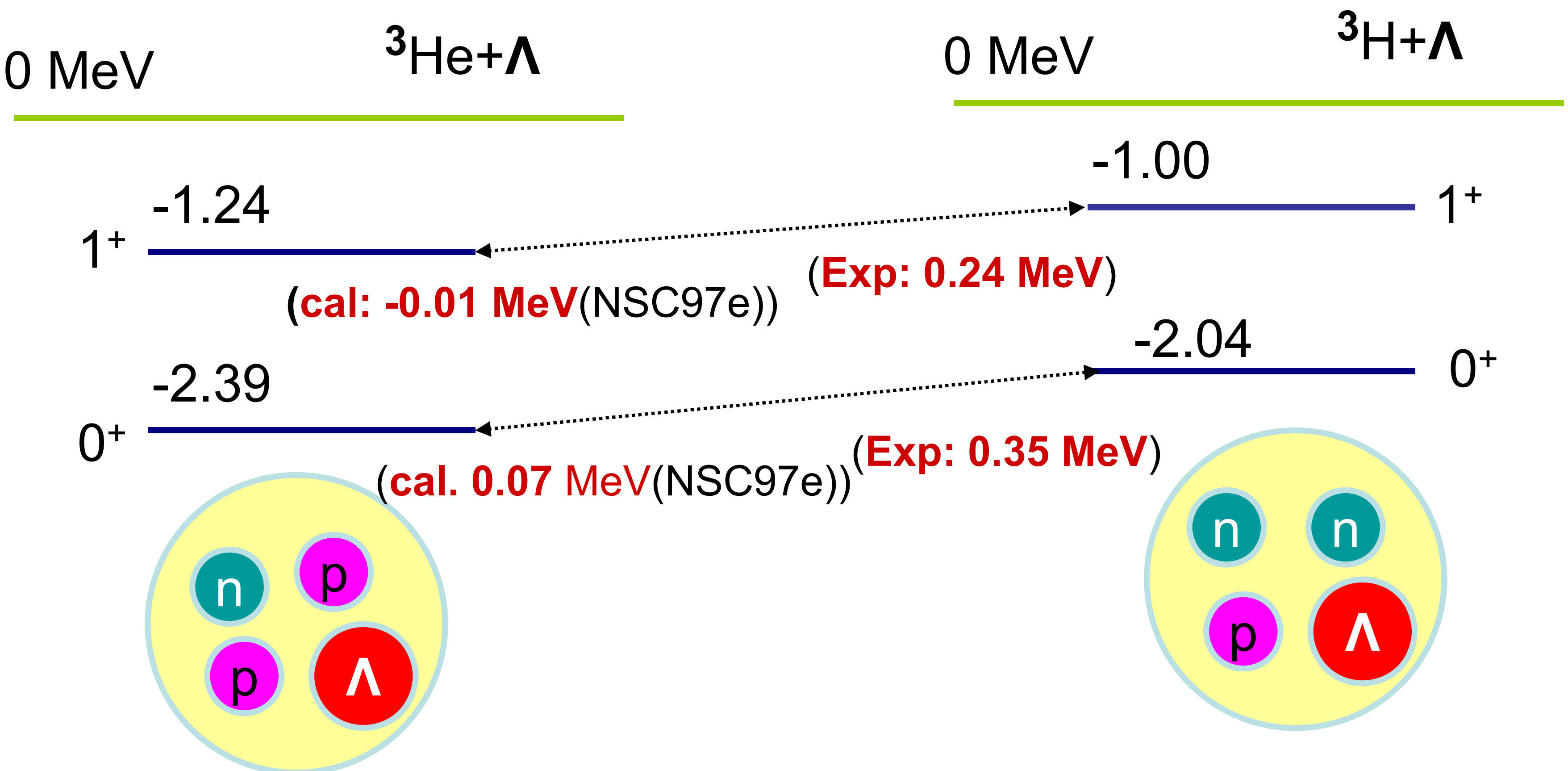
$^{11}_{\Lambda}B$ $^{4}_{\Lambda}He$

・E10 “Study on Λ-hypernuclei with the doubleCharge-Exchange reaction”
by Sakaguchi , Fukuda and his collaboratiors

$^{9}_{\Lambda}He$ $^{6}_{\Lambda}H$

Charge Symmetry breaking





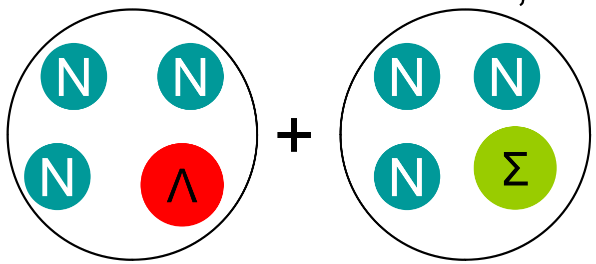
$^{4}_{\Lambda}He$

・A. Nogga, H. Kamada and W. Gloeckle, Phys. Rev. Lett. 88, 172501 (2002)

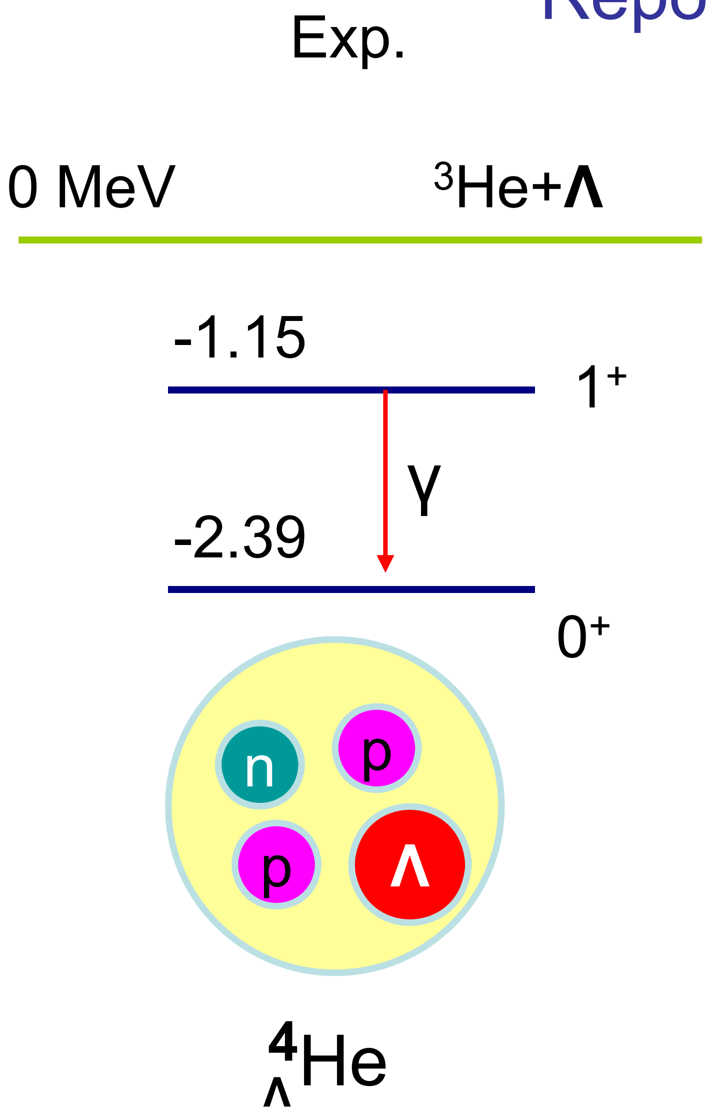
$^{4}_{\Lambda}H$

・E. Hiyama, M. Kamimura, T. Motoba, T. Yamada and Y. Yamamoto, Phys. Rev. C65, 011301(R) (2001).

・H. Nemura. Y. Akaishi and Y. Suzuki, Phys. Rev. Lett.89, 142504 (2002).



Reported by Tamura in 14th September



Recently, Tamura et al. pointed out that it is necessary to perform γ-ray experiment about this hypernucleus again .

"Because the measurement of this data was once reported in 1970's. At that time, the statistical quality of the $^4_\Lambda He$ γ- ray spectrum was extremely poor "

↓

J-PARC: Day-1 experiment

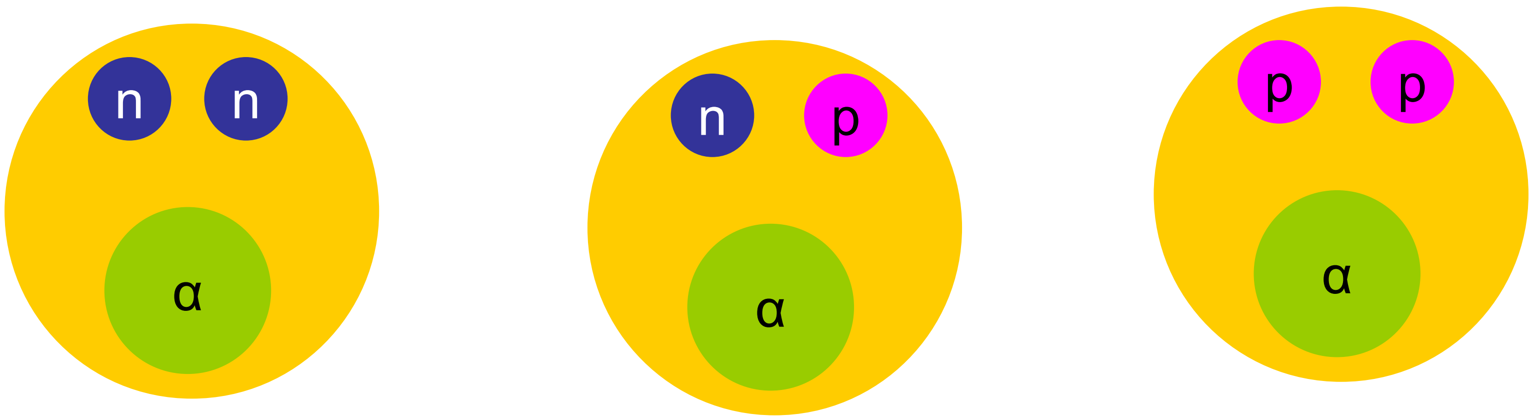
- E13 "γ-ray spectroscopy of light hypernuclei" by Tamura and his collaborators

We should wait for their data at J-PARC.

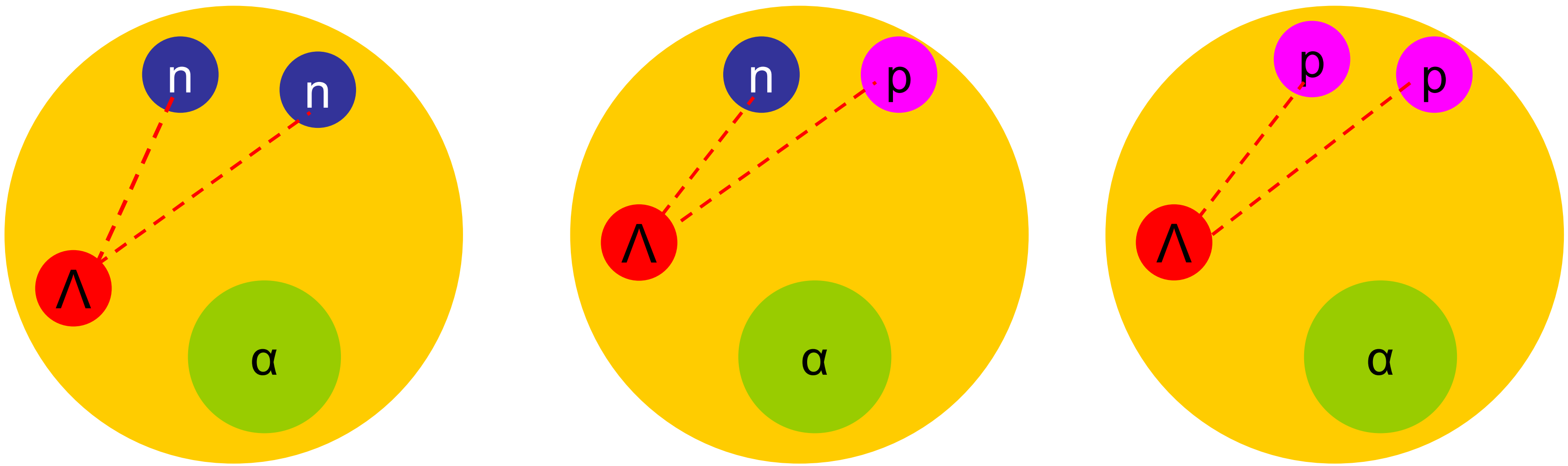
It is interesting to investigate the charge symmetry breaking effect in p-shell Λ hypernuclei as well as s-shell Λ hypernuclei.

For this purpose, to study structure of A=7 Λ hypernuclei is suited.

Because, core nuclei with A=6 are iso-triplet states.



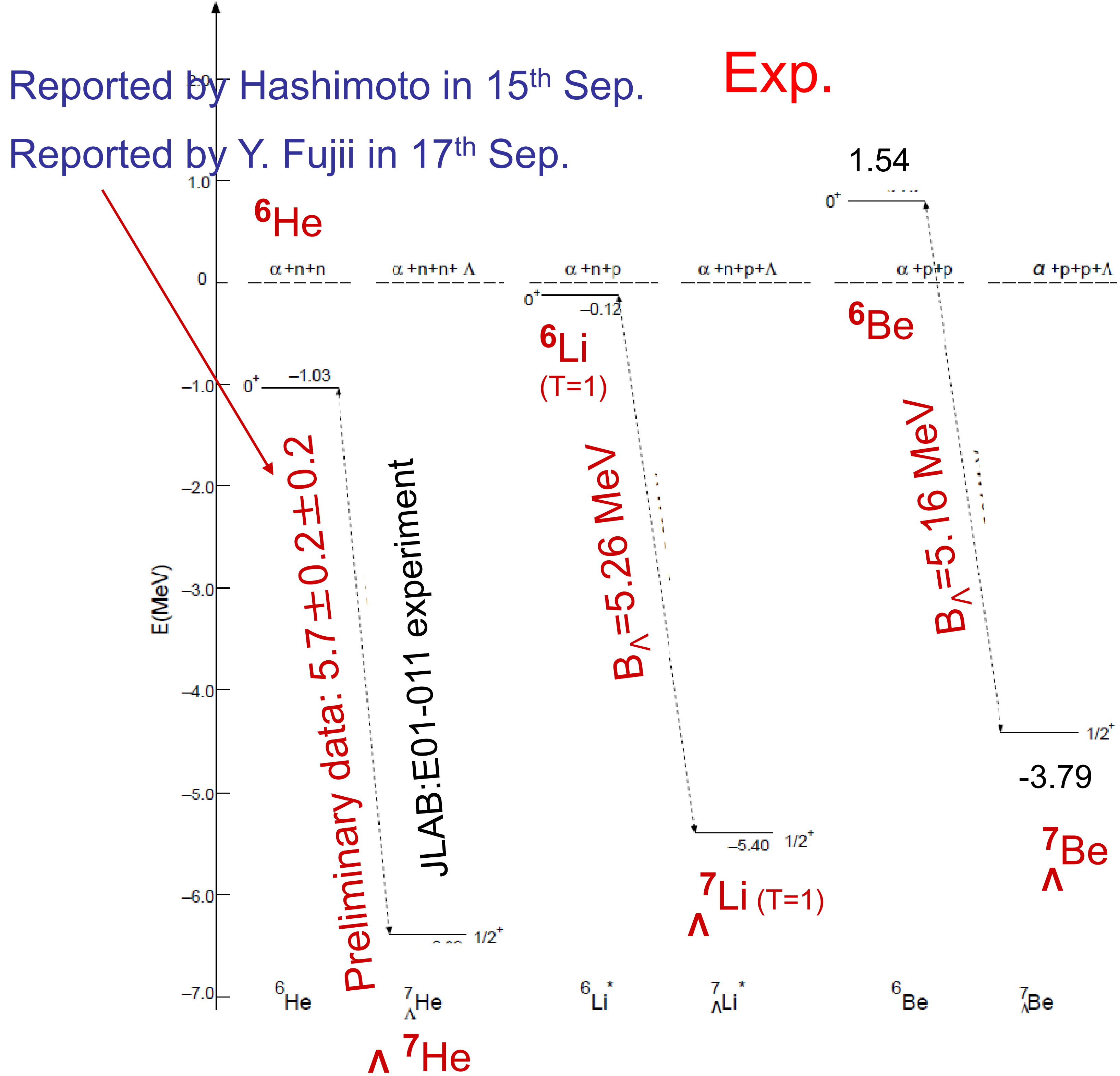
^{6}He ^{6}Li(T=1) ^{6}Be



$^{7}_{\Lambda}$He $^{7}_{\Lambda}$Li(T=1) $^{7}_{\Lambda}$Be

Then, A=7 Λ hypernuclei are also iso-triplet states.

It is possible that CSB interaction between Λ and valence nucleons contribute to the Λ-binding energies in these hypernuclei.

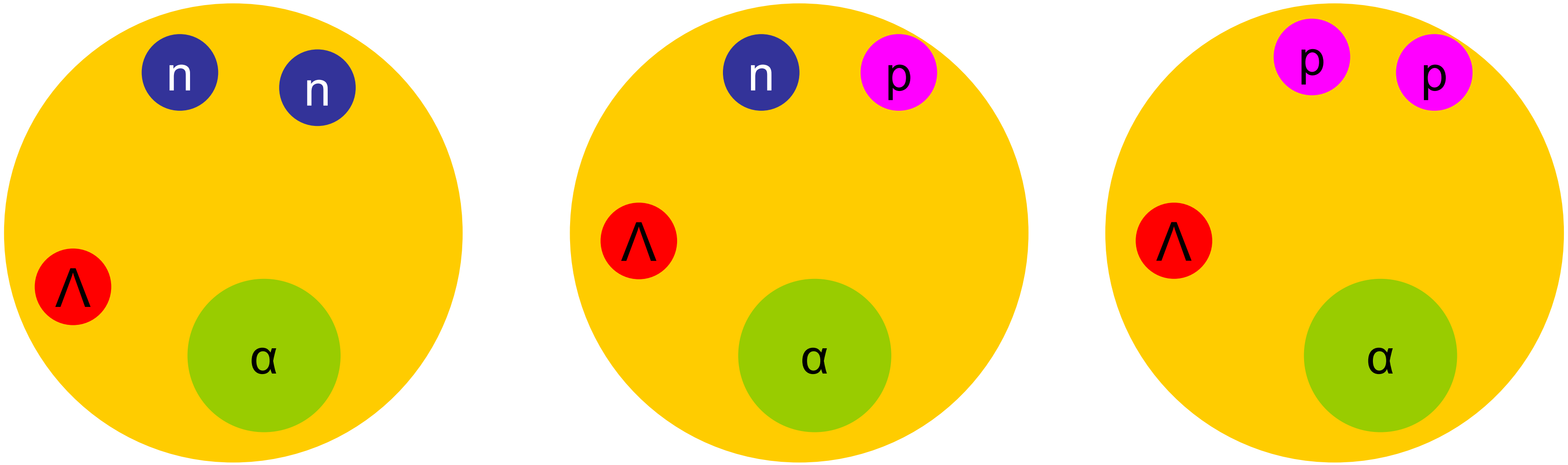


Reported by Hashimoto in 15th Sep.
Reported by Y. Fujii in 17th Sep.
Exp.
6He
α+n+n
α+n+n+Λ
α+n+p
α+n+p+Λ
α+p+p
α+p+p+Λ
1.54
0+
-0.12
-1.03
6Li (T=1)
6Be
Preliminary data: 5.7±0.2±0.2
JLAB:E01-011 experiment
BΛ=5.26 MeV
BΛ=5.16 MeV
1/2+
-3.79
-5.40
7ΛBe
7ΛLi (T=1)
E(MeV)
1.0
0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
6He
7ΛHe
6Li*
7ΛLi*
6Be
7ΛBe
Λ7He

Important issue:

To predict the Λ binding energy of ${}^{7}_{\Lambda}$He whose analysis is in progress at JLAB using ΛN interaction to reproduce the Λ binding energies of ${}^{7}_{\Lambda}$Li (T=1) and ${}^{7}_{\Lambda}$Be

To study the effect of CSB in iso-triplet A=7 hypernuclei.

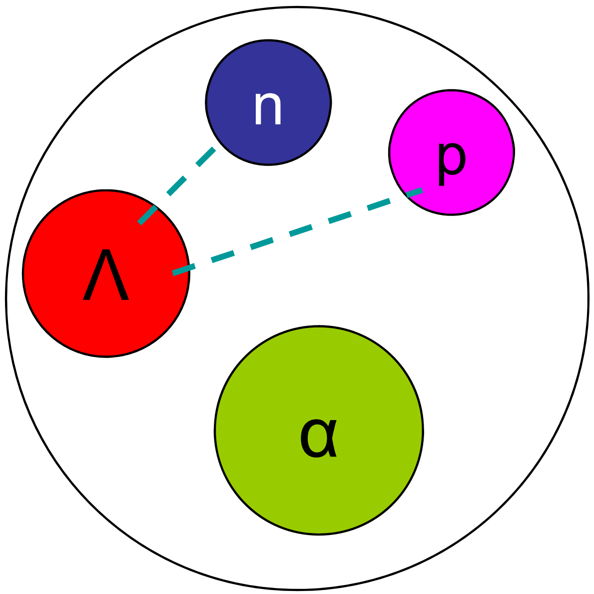


${}^{7}_{\Lambda}$He ${}^{7}_{\Lambda}$Li(T=1) ${}^{7}_{\Lambda}$Be

For this purpose, we study structure of A=7 hypernuclei within the framework of α+Λ+N+N 4-body model.

Submitted to PRC

$^{7}_{\Lambda}$Li



ΛN interaction: Nijmegen '97f

Not original one but simulated one

The ΛN-ΣN coupling interaction can be renomalized into the ΛN-ΛN interaction effectively.

$$V_{\Lambda N}=V_0+\sigma_\Lambda\cdot\sigma_N V_s+(\sigma_\Lambda+\sigma_N)/2\cdot V_{SLS}+(\sigma_\Lambda-\sigma_N)/2\cdot V_{ALS}$$

Made by Yamamoto so as to reproduce the phase shifts given by the original one

Strengths of V_s,V_{SLS},V_{ALS} are adjusted so as to reproduce of the observed data of $_\Lambda{}^{4}$H, $_\Lambda{}^{7}$Li(T=0), $_\Lambda{}^{9}$Be and $^{13}_{\Lambda}$C.

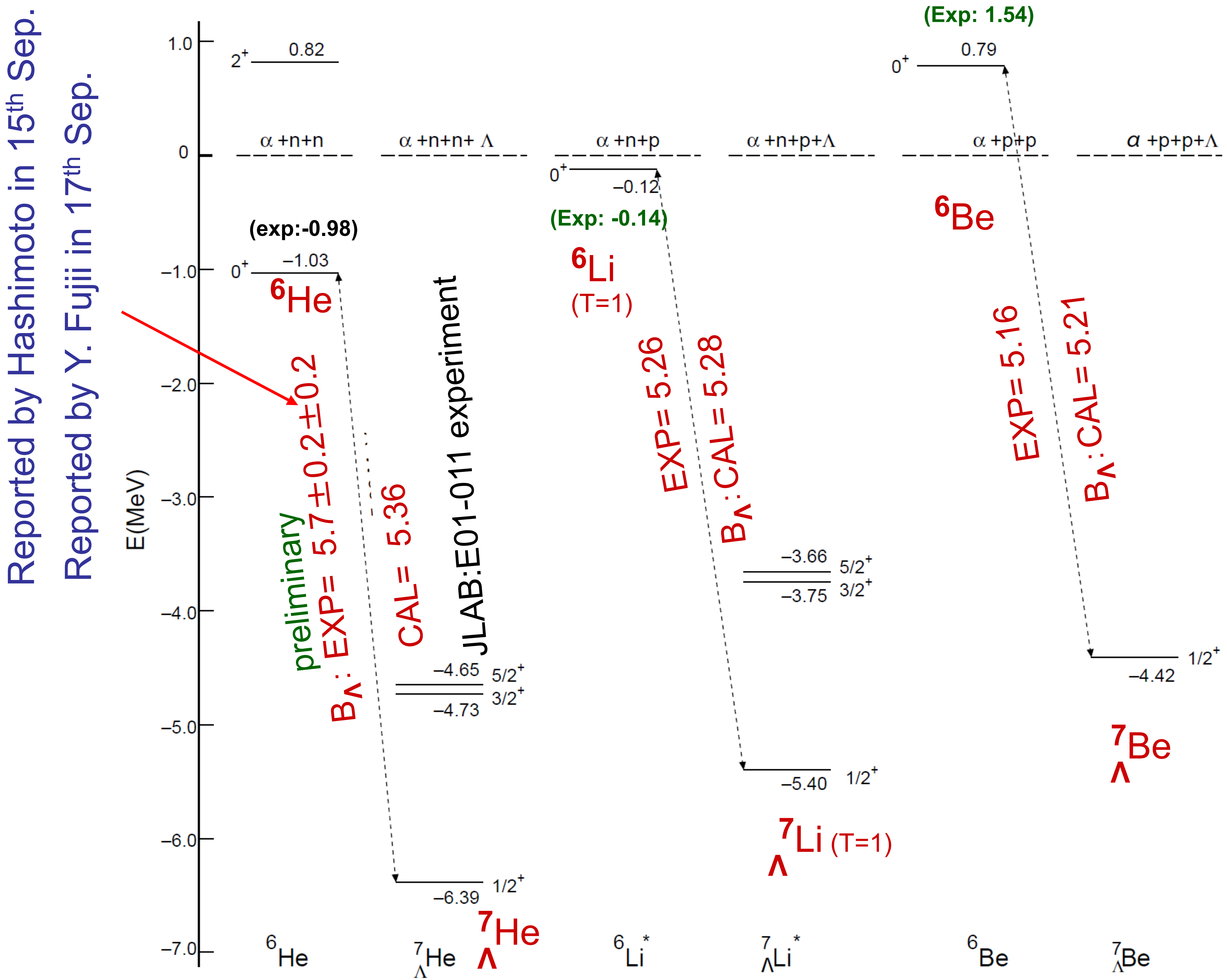
The CSB ΛN interaction is not included.

For the study of the CSB effect in A=7 hypernuclei, we compare the data with our calculated results with no CSB interaction.

If there is significant difference between the calculated B_{Λ} and the observed B_{Λ}, then, it is considered that there is CSB effect in A=7 hypernuclei.

If not, then, it is considered that there is NO CSB effect in A=7 hypernuclei.

How is the calculated result?



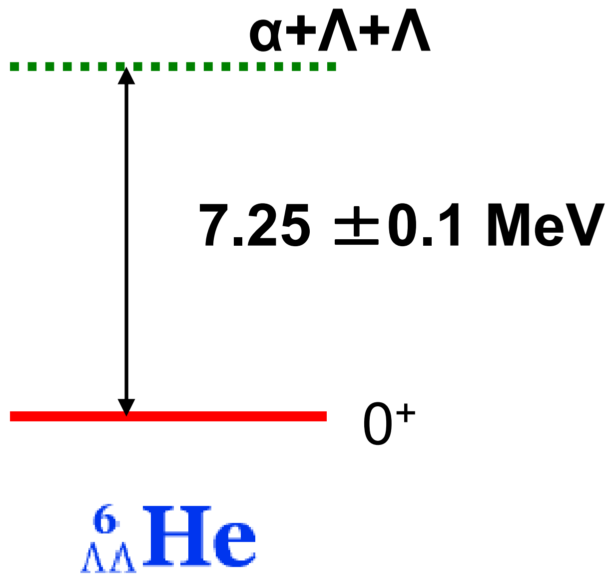
Reported by Hashimoto in 15th Sep.
Reported by Y. Fujii in 17th Sep.
E(MeV)
1.0
0
−1.0
−2.0
−3.0
−4.0
−5.0
−6.0
−7.0
2+ 0.82
α +n+n
(exp:-0.98)
0+ −1.03
6He
preliminary
BΛ: EXP= 5.7±0.2±0.2
CAL= 5.36
JLAB:E01-011 experiment
α +n+n+ Λ
−4.65 5/2+
3/2+ −4.73
1/2+ −6.39
7ΛHe
α +n+p
0+ −0.12
(Exp: -0.14)
6Li
(T=1)
EXP= 5.26
BΛ:CAL= 5.28
α +n+p+Λ
−3.66 5/2+
−3.75 3/2+
1/2+ −5.40
7ΛLi (T=1)
(Exp: 1.54)
0+ 0.79
α +p+p
6Be
EXP= 5.16
BΛ:CAL= 5.21
α +p+p+Λ
1/2+ −4.42
7ΛBe
6He
7ΛHe
6Li*
7ΛLi*
6Be
7ΛBe

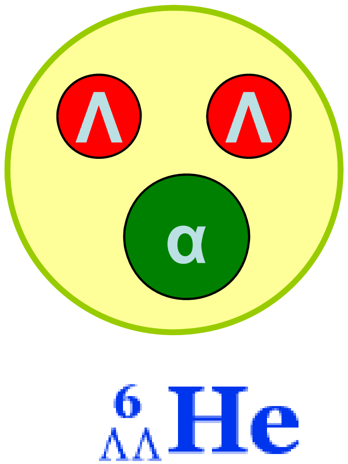
S=-2 system

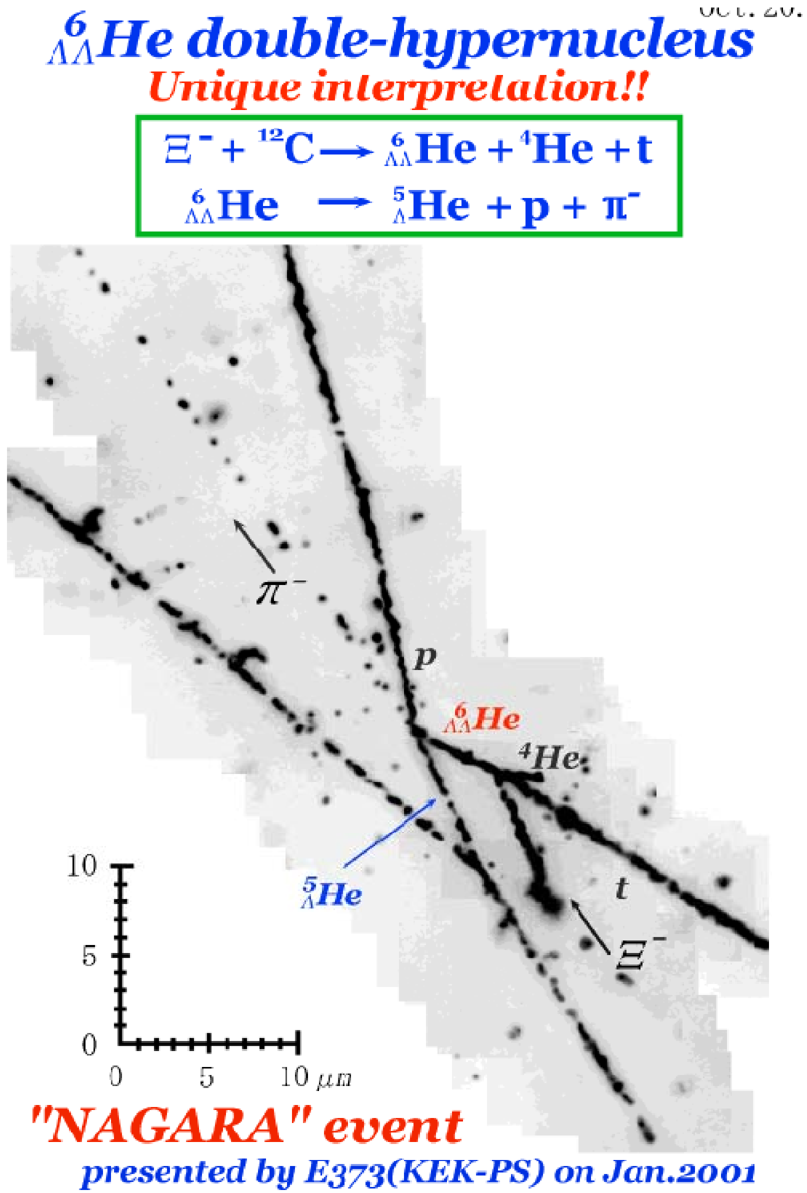
in 2001, KEK-E373 experiment.

Observation of $_{\Lambda\Lambda}{}^{6}He$

Uniquely identified without ambiguity for the first time



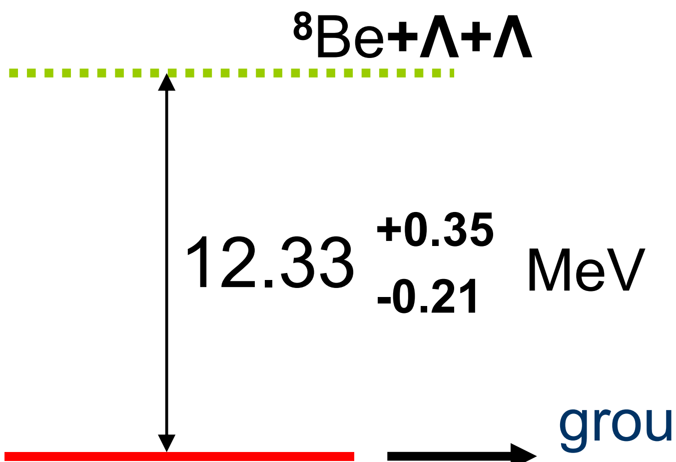




H. Takahashi *et al.*, PRL 87, 212502-1 (2001)

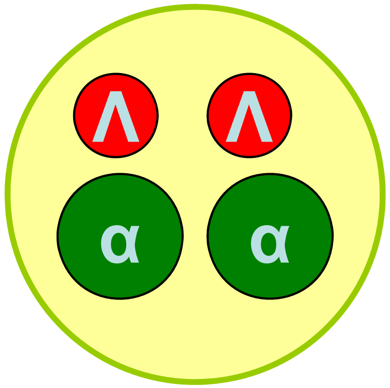
Observation of $^{10}_{\Lambda\Lambda}Be$ --- KEK-E373 experiment

Demachi-Yanagi event

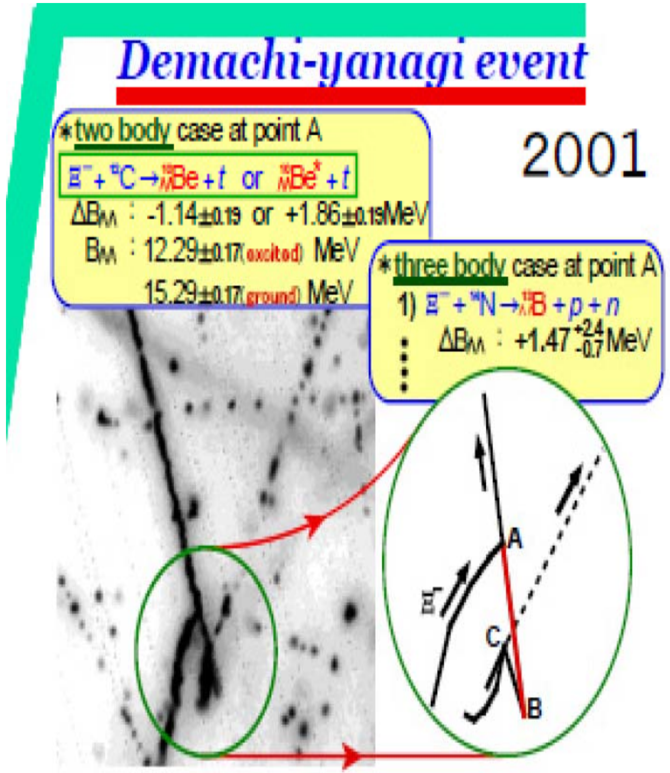


ground state ?
excited state ?

$^{10}_{\Lambda\Lambda}Be$



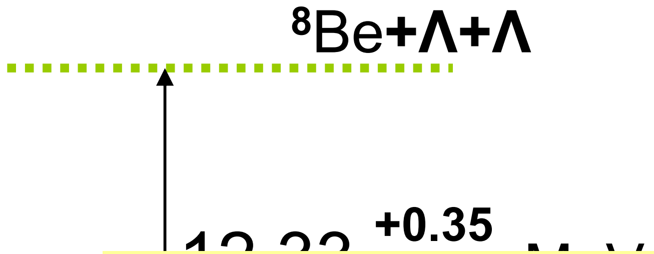
$^{10}_{\Lambda\Lambda}Be$

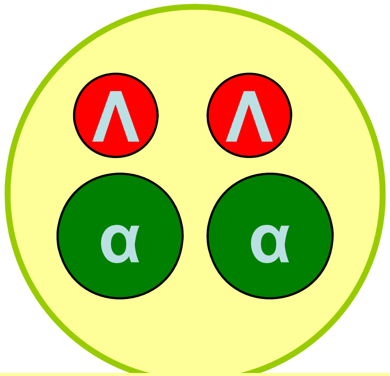


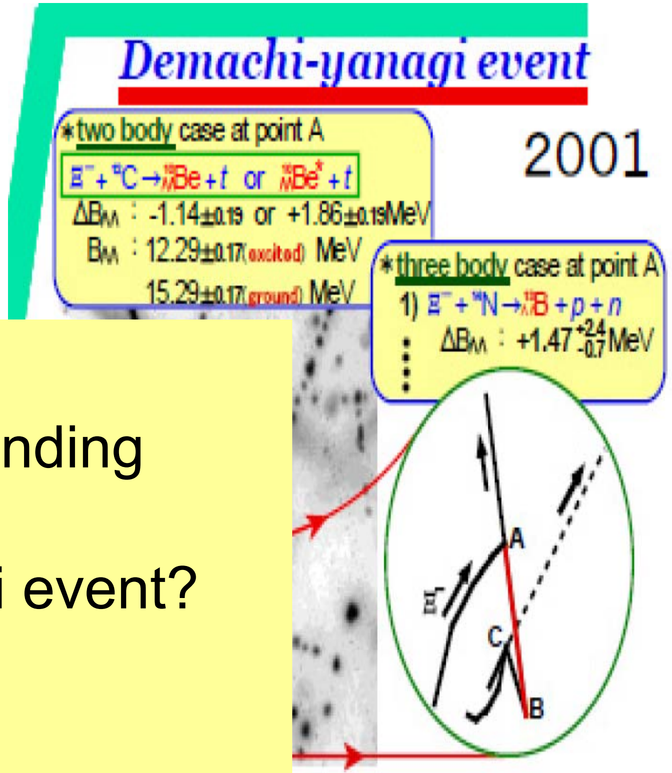
Demachi-Yanagi event

Observation of $^{10}_{\Lambda\Lambda}Be$ --- KEK-E373 experiment

Demachi-Yanagi event





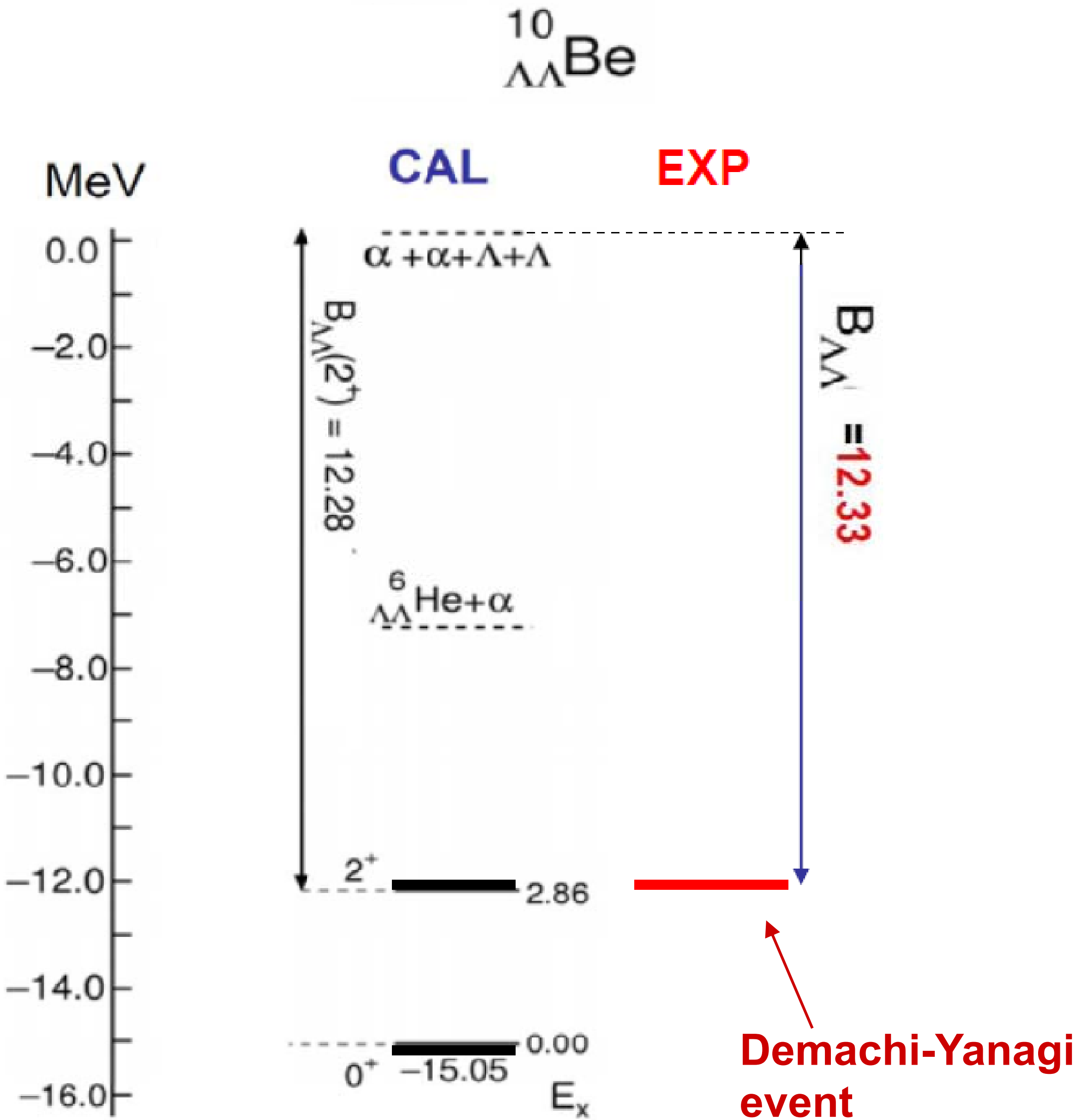


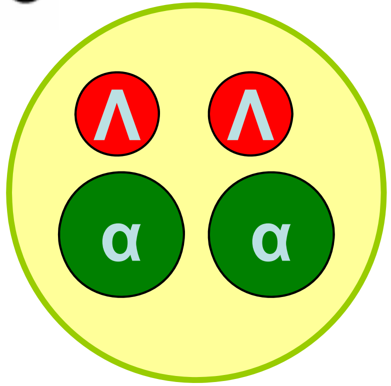
Important issue:

(1) Using ΛΛ interaction which reproduce the binding energy of NAGARA event (7.25±0.1 MeV), is it possible to reproduce the Demachi-Yanagi event?

(2)Is this observation of the ground state or any excited state ?

Successful interpetation of spin-parity of $^{10}_{\Lambda\Lambda}Be$

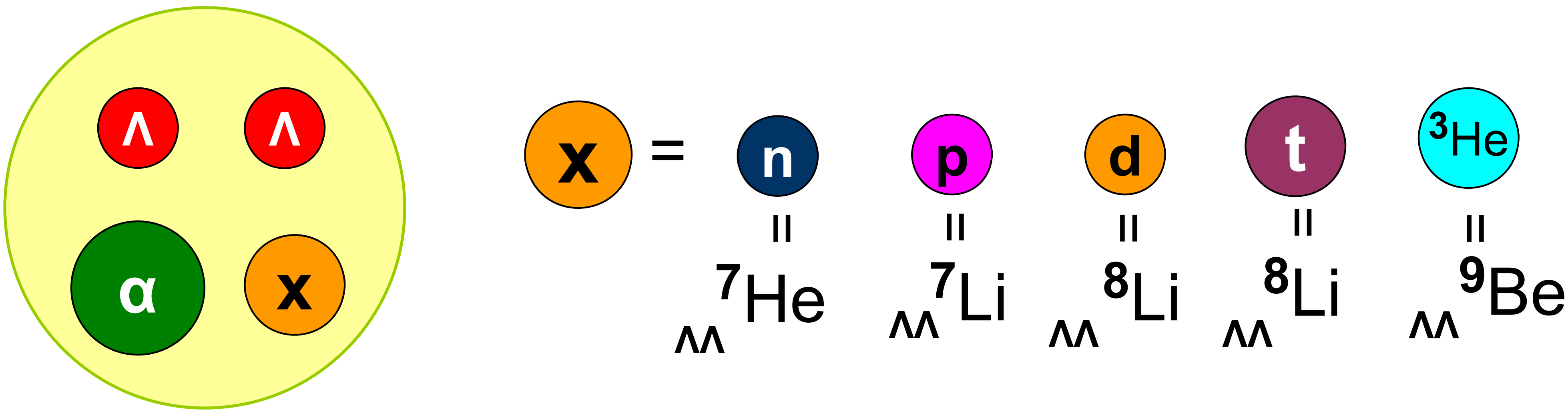




E. Hiyama, M. Kamimura, T.Motoba, T. Yamada and Y. Yamamoto
Phys. Rev. 66 (2002) , 024007

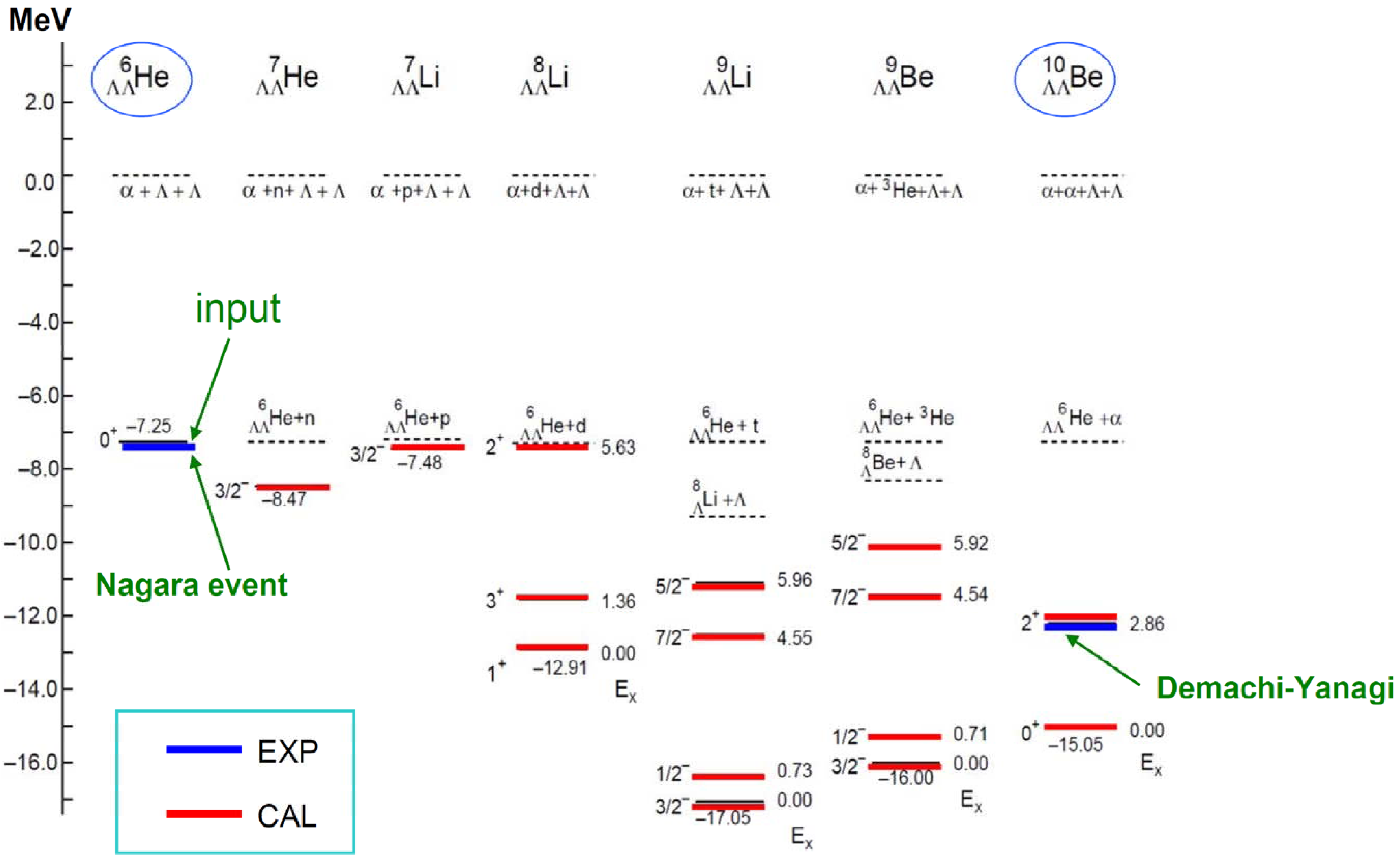
Hoping to observe new double **Λ** hypernuclei in future experiments, I predicted level structures of these double **Λ** hypernuclei within the framework of the α+x+**Λ**+**Λ** 4-body model.

E. Hiyama, M. Kamimura, T. Motoba, T.Yamada and Y. Yamamoto
Phys. Rev. C66, 024007 (2002)



Spectroscopy of ΛΛ-hypernuclei

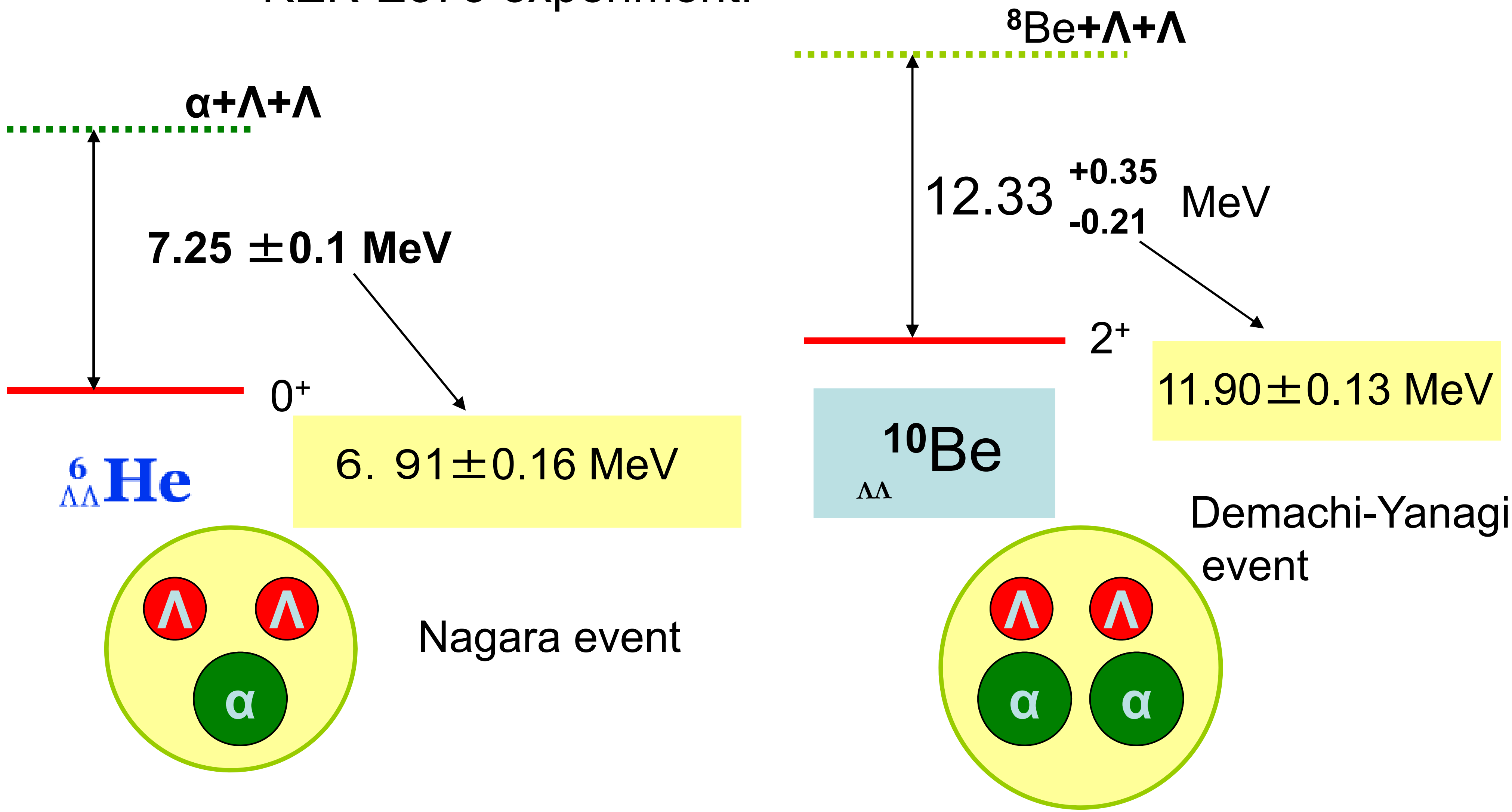
E. Hiyama, M. Kamimura, T.Motoba, T. Yamada and Y. Yamamoto
Phys. Rev. 66 (2002) , 024007



By comparing this theoretical prediction and future experimental data, we can interpret the spectroscopy of those double Λ hypernuclei.

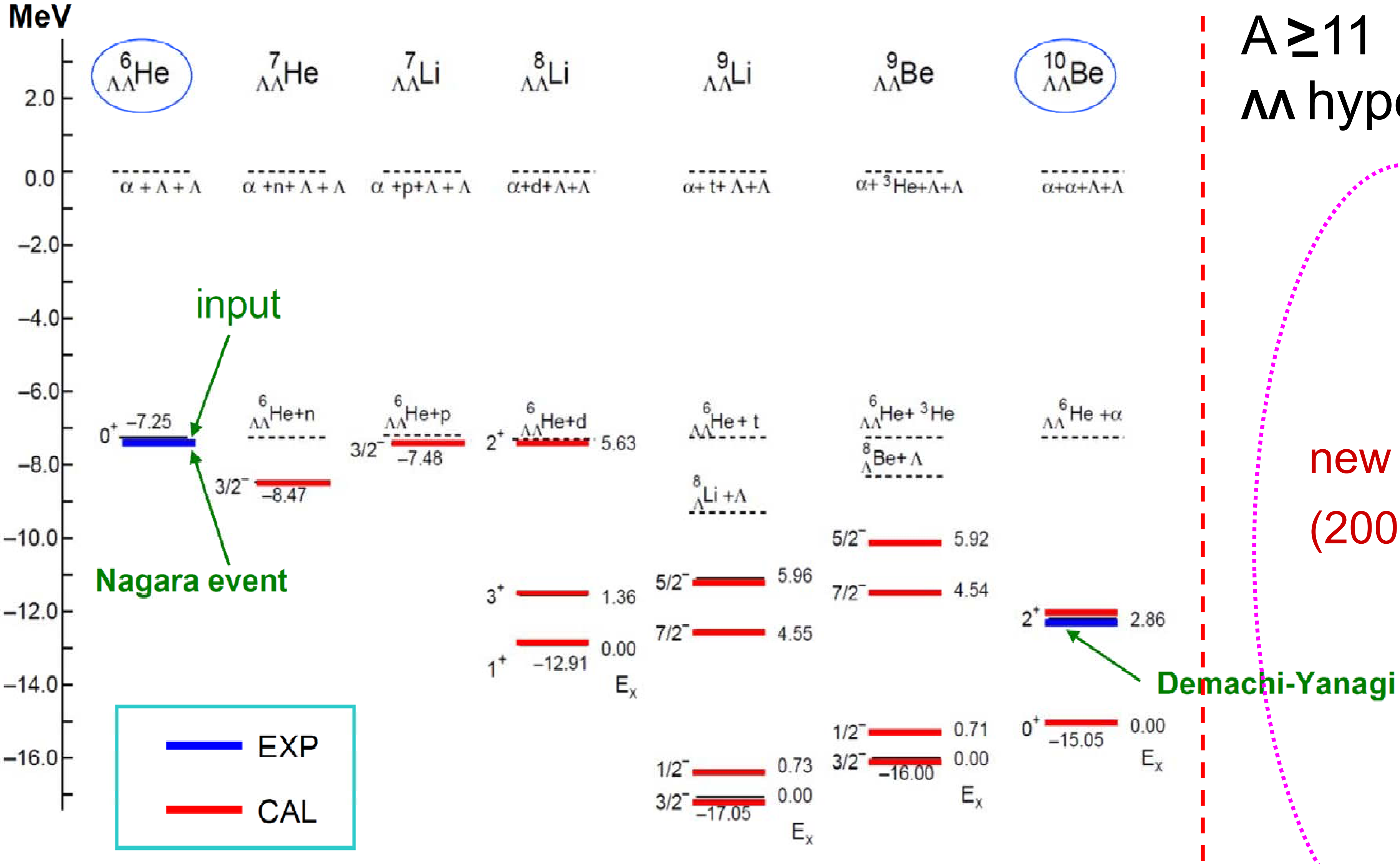
Data have been changed as mentioned by the previous speaker.

KEK-E373 experiment.

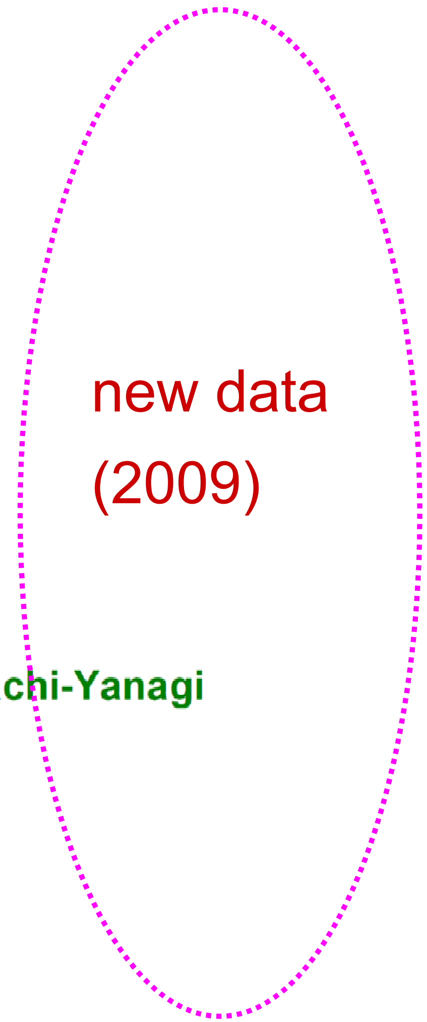


Spectroscopy of ΛΛ-hypernuclei

E. Hiyama, M. Kamimura, T. Motoba, T. Yamada and Y. Yamamoto
Phys. Rev. 66 (2002), 024007

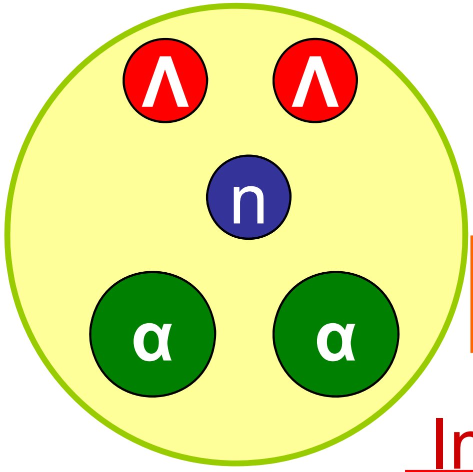


A ≥11
ΛΛ hypernuclei



I have been looking forward to having new data in this mass-number region.

As was reported by the previous speaker,
KEK-E373 experiment gave another new data of double **Λ** hypernucleus.



$^{11}_{\Lambda\Lambda}Be$

Observation of $^{11}_{\Lambda\Lambda}Be$ (Hida event)

$B_{\Lambda\Lambda}$ = 20.49±1.15 MeV → E = - 22.06±1.15 MeV from **α**+ **α**+ n +Λ+Λ breakup threshold

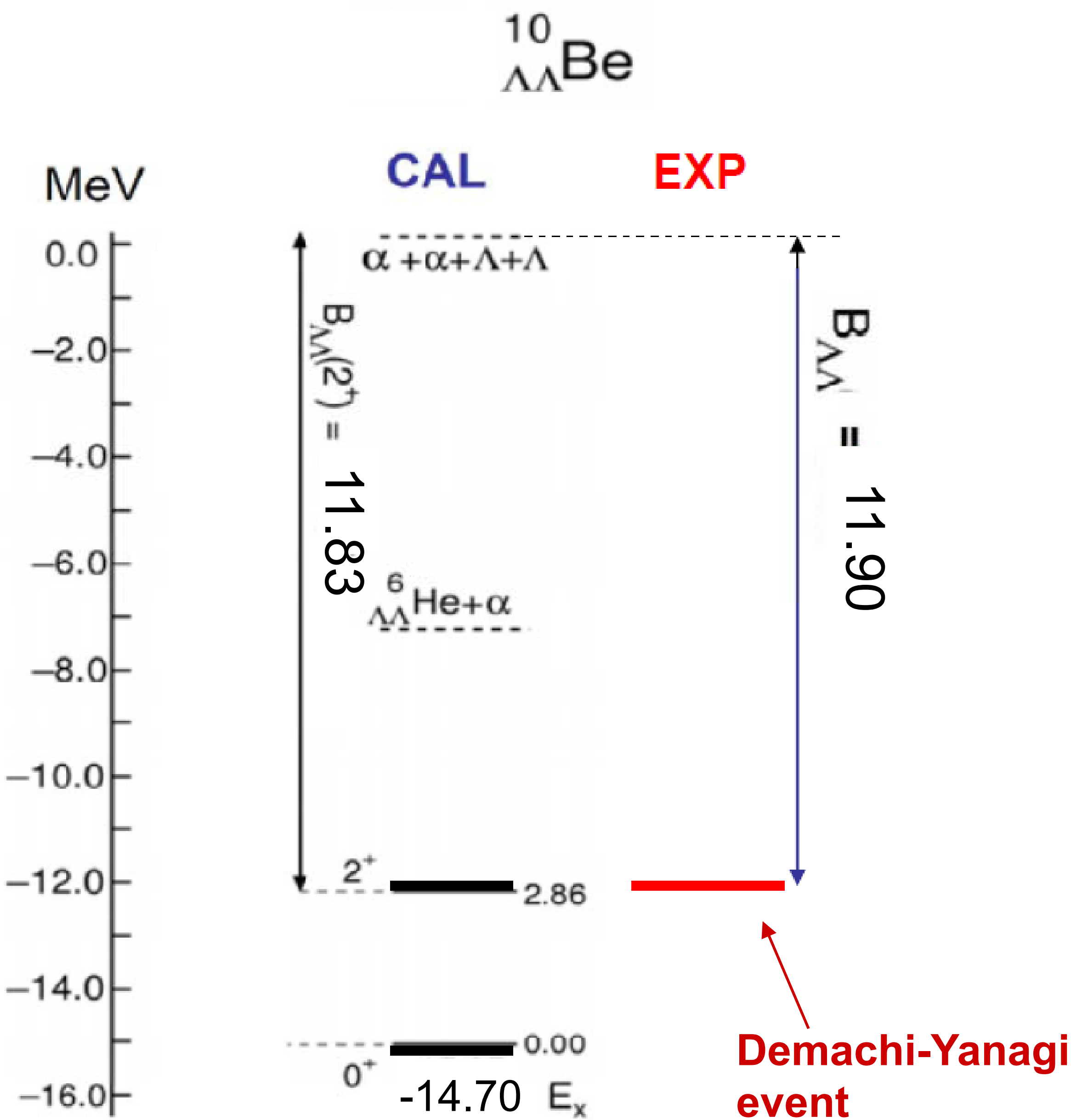
Important issues:

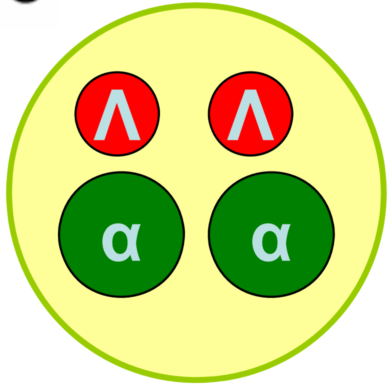
1)Can we reproduce the revised Demachi-Yanagi event using ΛΛ interaction which reproduce the revised NARAGA event?

2) Is it possible to reproduce theoretically
the observed energy of Hida event?

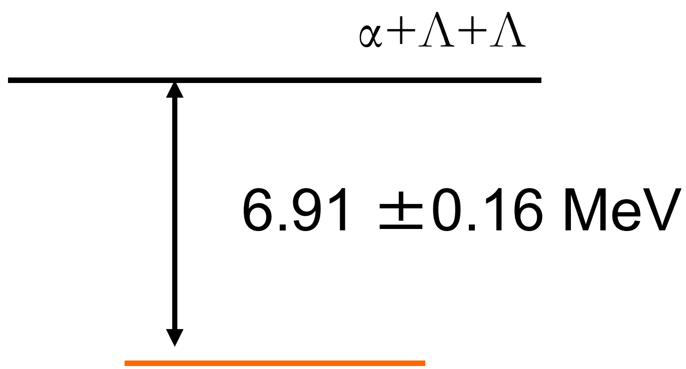
3) Is this event observation of
the ground state or any excited state?

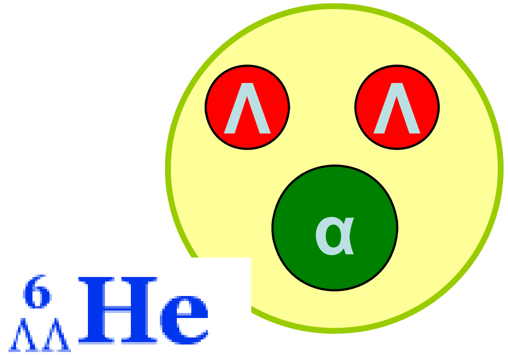
Successful interplitation of spin-parity of $^{10}_{\Lambda\Lambda}\mathrm{Be}$



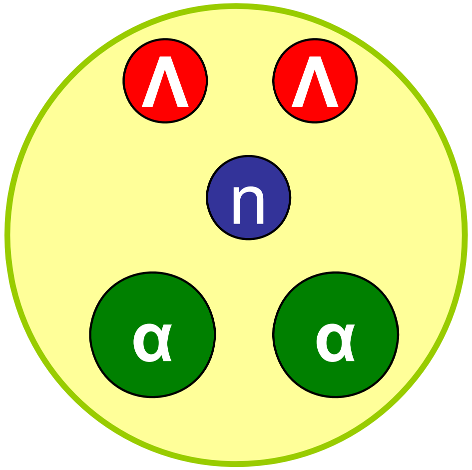


E. Hiyama, M. Kamimura, T.Motoba, T. Yamada and Y. Yamamoto Phys. Rev. 66 (2002) , 024007





Observation of ${}^{11}_{\Lambda\Lambda}Be$ (Hida event)



${}^{11}_{\Lambda\Lambda}Be$

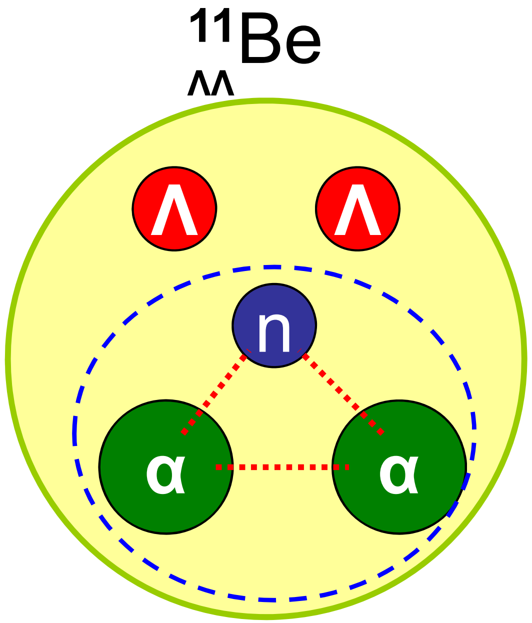
$B_{\Lambda\Lambda} = 20.49 \pm 1.15$ MeV

Important issues:

1)Can we reproduce the Demachi-Yanagi event using ΛΛ interaction which reproduce the revised NARAGA event?

2) Is it possible to reproduce theoretically the observed energy of Hida event?

3) Is this event observation of the ground state or any excited state?



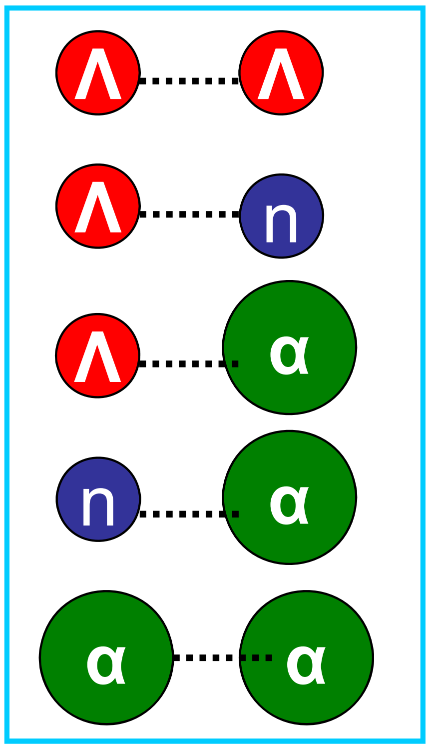
Core nucleus, ^{9}Be is well described as $\alpha + \alpha + n$ three-cluster model.

Then, $^{11}_{\Lambda\Lambda}$Be is considered to be suited for studying with $\alpha + \alpha + n + \Lambda + \Lambda$ 5-body model.

Difficult 5-body calculation:

1) 3 kinds of particles (**α**, Λ, **n**)

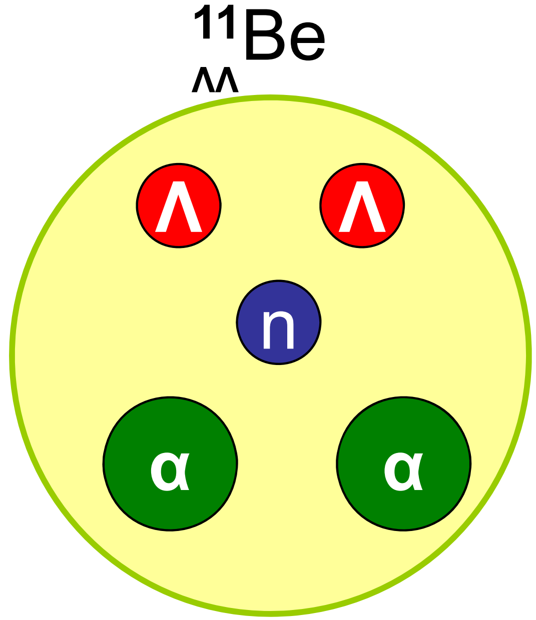
2) 5 different kinds of interactions



3) Pauli principle between **α** and **α**, and between **α** and **n**

But, I have succeeded in performing this calculation.

5-body calculation of $^{11}_{\Lambda\Lambda}\mathrm{Be}$



$$(H - E)\,\Psi_{JM}({}^{11}_{\Lambda\Lambda}\mathrm{Be}) = 0$$

A variational method:

Gaussian Expansion Method (GEM)

(review paper) E. H., Y. Kino and M. Kamimura,
Prog. Part. Nucl. Phys., 51 (2003) 223.

$$\Psi_{JM}({}^{11}_{\Lambda\Lambda}\mathrm{Be}) = \sum_{c} \sum_{\boldsymbol{\beta}_5} A^{(c)}_{\boldsymbol{\beta}_5}\, \Phi^{(c)}_{JM,\boldsymbol{\beta}_5} (\text{5-body basis})$$

expansion coefficient ($A^{(c)}_{\boldsymbol{\beta}_5}$)

c: specifies many sets of Jacobi coordinates

$\boldsymbol{\beta}_5$: specifies 5-body basis functions of each Jacobi-coordinate set

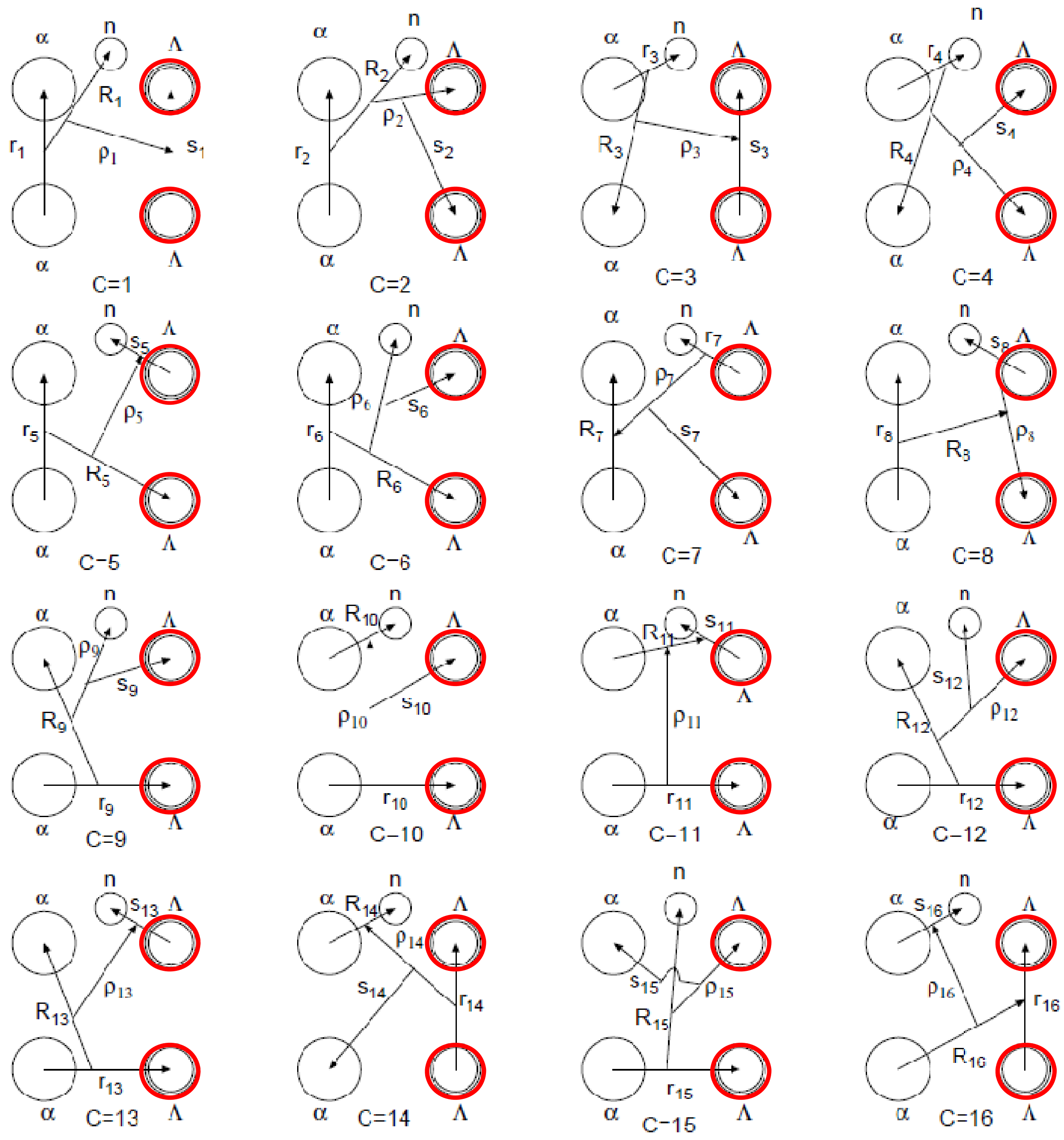
Some of important Jacobi corrdinates of the α+ α+ n + Λ+ Λ system.

Two α particles are symmetrized.

Two Λ particles are antisymmetrized.

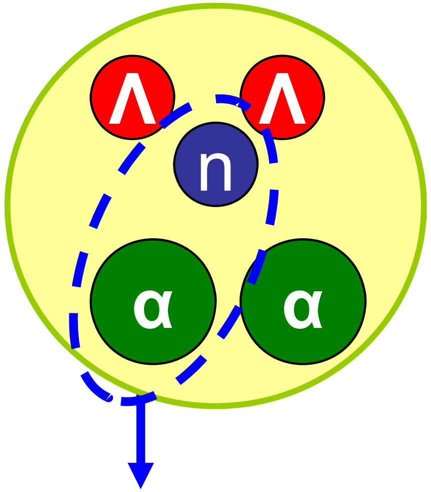
↓

63 sets of Jacobi corrdinates are employed.



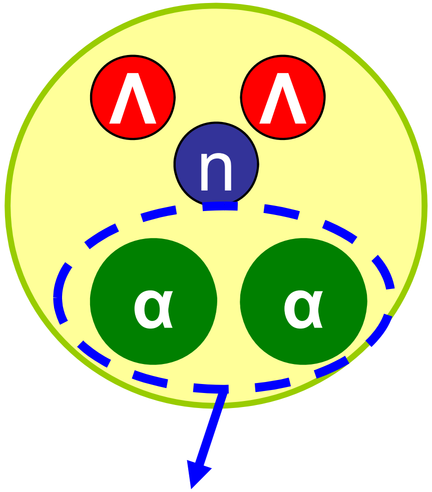
Before doing full 5-body calculation,
it is important and necessary to reproduce the observed binding energies of all the sets of subsystems in ${}^{11}_{\Lambda\Lambda}Be$.

In our calculation, this was successfully done using the same interactions for the following 9 subsystems:



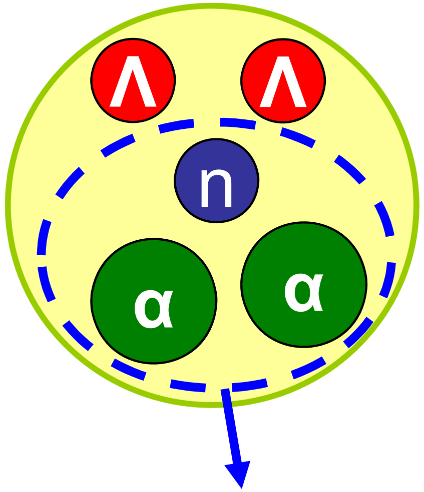
$^{5}He\ (3/2^-)$

CAL : +0.80 MeV
EXP : +0.80 MeV



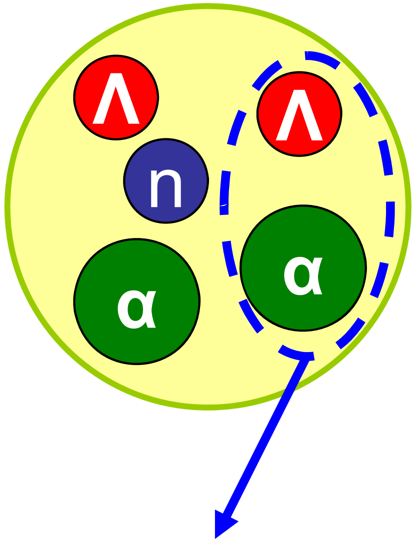
$^{8}Be\ (0^+)$

CAL : +0.09 MeV
EXP : +0.09 MeV



$^{9}Be\ (3/2^-)$

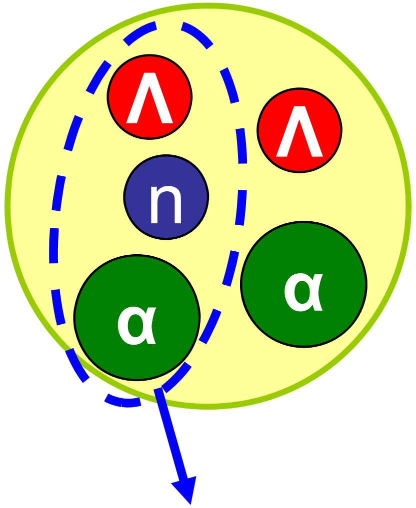
CAL : -1.57 MeV
EXP : -1.57 MeV



$^{5}_{\Lambda}$He (1/2^{-})

CAL : -0.32 MeV

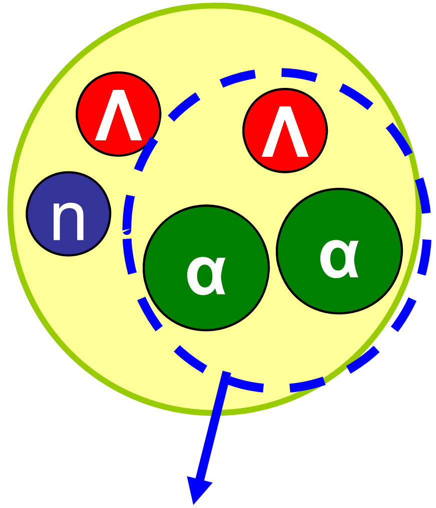
EXP : -0.32 MeV



$^{6}_{\Lambda}$He (1^{-})

CAL : -3.29 MeV

EXP : -3.29 MeV



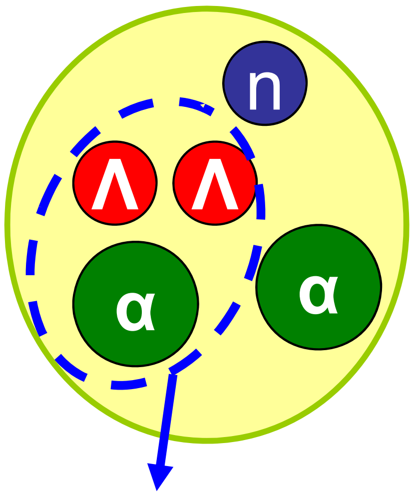
$^{9}_{\Lambda}$Be (1/2^{+})

CAL : -6.64 MeV

EXP : -6.62 MeV

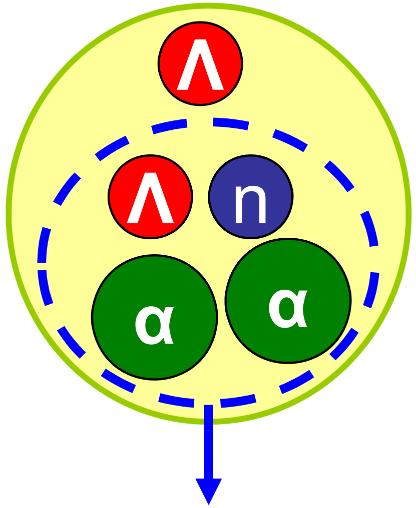
(The energy is measured from the full-breakup threshold of each subsystem)

← adjusted | predicted →



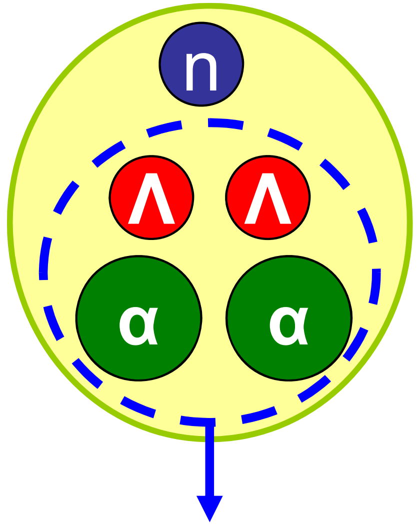
$^{6}_{\Lambda\Lambda}$He (0^+)

CAL (0^+): -6.93 MeV
EXP (0^+): -6.93 MeV



$^{10}_{\Lambda}$Be (1^-)

CAL : -10.64 MeV
EXP : -10.64 MeV



$^{10}_{\Lambda\Lambda}$Be (0^+, 2^+)

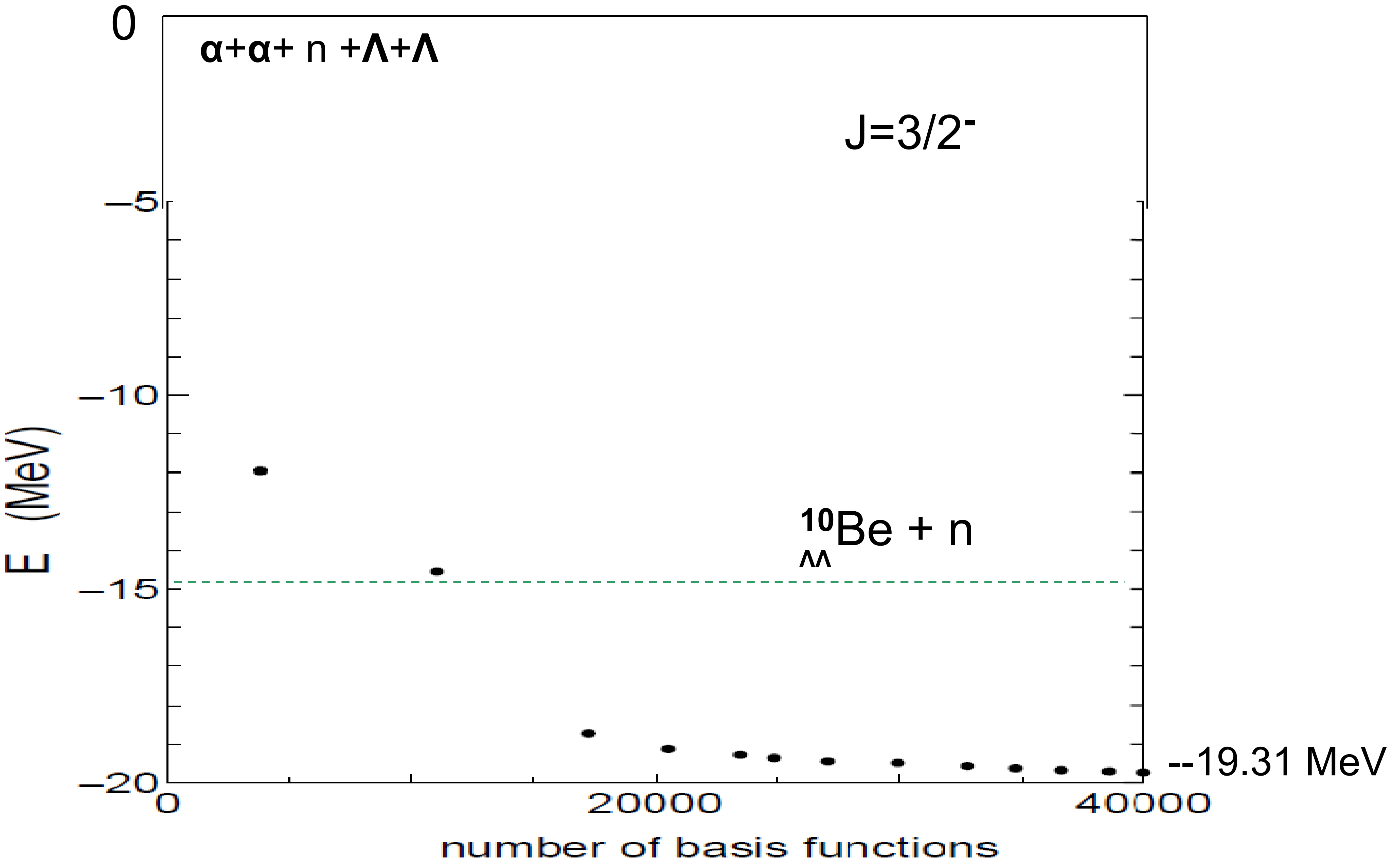
CAL (2^+): -10.96 MeV
EXP (2^+): -10.98 MeV

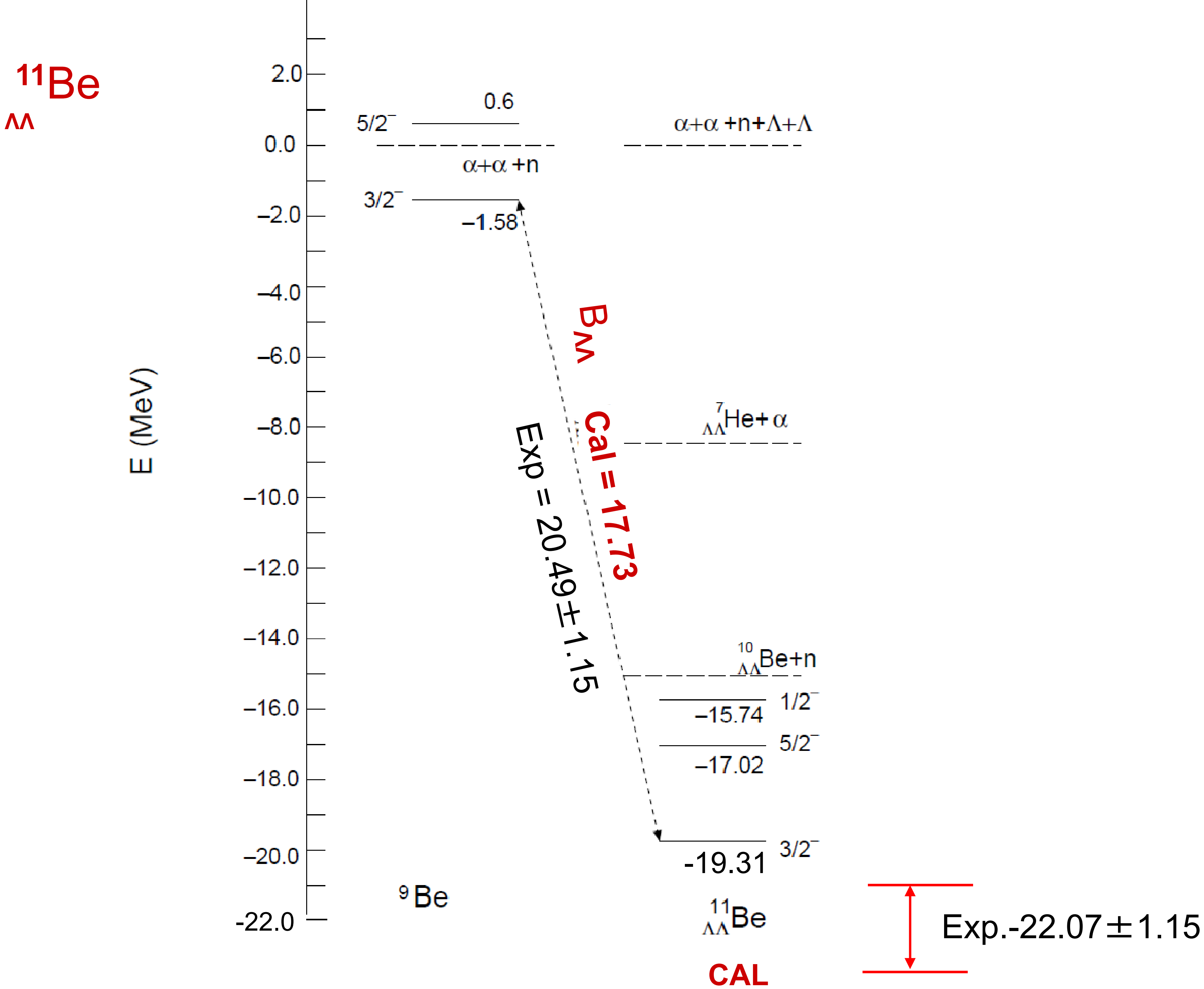
CAL (0^+): -14.74 MeV
EXP (0^+): -14.69 MeV

All the potential parameters have been adjusted in the 2- and 3-body subsystems.

Therefore, energies of these 4-body susbsystems and the 5-body system $^{11}_{\Lambda\Lambda}$Be are predicted with no adjustable pameters.

Convergence of the ground-state energy of the α+α+ n +Λ+Λ 5-body system ($^{11}_{\Lambda\Lambda}Be$)





11 Be ΛΛ
E (MeV)
2.0
0.0
−2.0
−4.0
−6.0
−8.0
−10.0
−12.0
−14.0
−16.0
−18.0
−20.0
-22.0
5/2⁻
0.6
α+α +n
3/2⁻
−1.58
9 Be
α+α +n+Λ+Λ
BΛΛ
Cal = 17.73
Exp = 20.49±1.15
7 ΛΛ He+ α
10 ΛΛ Be+n
1/2⁻
−15.74
5/2⁻
−17.02
3/2⁻
-19.31
11 ΛΛ Be
CAL
Exp.-22.07±1.15

Prof. Nakazawa suggested that this event has another possibility, namely, observation of ${}^{12}_{\Lambda\Lambda}$Be.

However, in his talk, he did not explicitly employ this possibility because of the following reason:

(1) Λ binding energy of single Λ hypernucleus, ${}^{11}_{\Lambda}$Be is not observed.

(2) Then, $\Delta B_{\Lambda\Lambda}$ cannot be extracted.

(3) Then, one cannot check the reality of $\Delta B_{\Lambda\Lambda}$ of ${}^{12}_{\Lambda\Lambda}$Be.

(4) Therefore, possibility of observation of ${}^{11}_{\Lambda\Lambda}$Be is higher than ${}^{12}_{\Lambda\Lambda}$Be.

However, I don't think that the possibility of observation of ${}^{12}_{\Lambda\Lambda}$Be Is low even if there is no observed data of ${}^{11}_{\Lambda}$Be.

However, if this Hida event is confirmed to be an observation of ${}_{\Lambda\Lambda}^{11}$Be, we should study something missing part in this Hida event.
At present, I did my best for this 5-body calculation.
Then, I have no idea what is missing part.

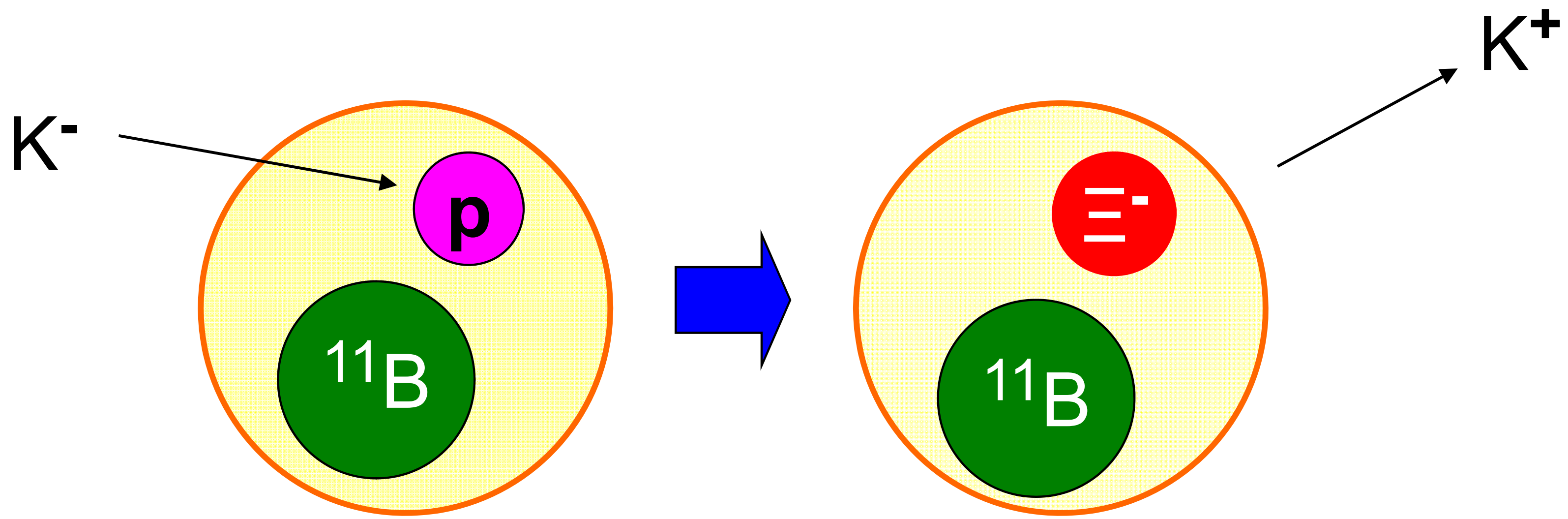
For the confirmation of Hida event, we expect to have more precise data in ${}_{\Lambda\Lambda}^{11}$Be at J-PARC.

Ξ hypernuclei

For the study of ΞN interaction, it is important to study the structure of Ξ hypernuclei.

Approved proposal at J-PARC : Day-1 experiment

- E05 "Spectroscopic study of Ξ-Hypernucleus, $^{12}_{\Xi^-}Be$, via the $^{12}C(K^-,K^+)$ Reaction" by Nagae and his collaborators



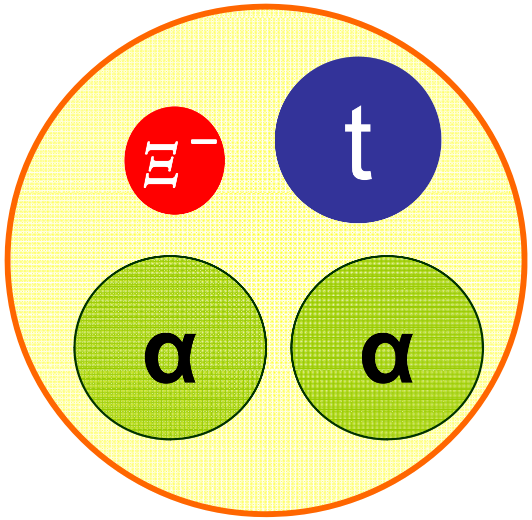
^{12}C Ξ hypernucleus

This will be the first observation of Ξ hypernucleus

$^{12}C(K^-, K^+)\ ^{12}_{\Xi^-}Be$ Day-1 experiment at J-PARC

What part's information of the ΞN interaction do we extract?

$$V_{\Xi N} = V_0 + \boldsymbol{\sigma}\cdot\boldsymbol{\sigma}\, V_{\sigma\cdot\sigma} + \boldsymbol{\tau}\cdot\boldsymbol{\tau}\, V_{\tau\cdot\tau} + (\boldsymbol{\sigma}\cdot\boldsymbol{\sigma})(\boldsymbol{\tau}\cdot\boldsymbol{\tau})\, V_{\sigma\cdot\sigma\ \tau\cdot\tau}$$



$^{12}_{\Xi^-}Be$

($T=1$, $J=1^-$)

All of the terms contribute to binding energy of $^{12}_{\Xi^-}Be$ (^{11}B is not spin-, isospin- saturated).

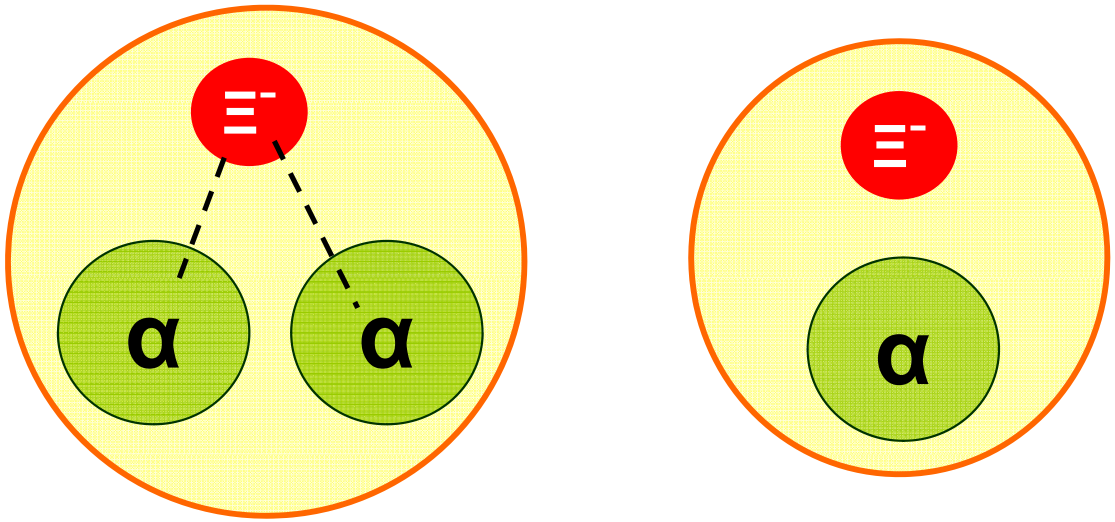
Then, even if we observe this system as a bound state, we shall get only information that $V_{\Xi N}$ itself is attractive.

Therefore, after the Day-1 experiment, next, we want to know desirable strength of V_0, the spin-,isospin-independent term.

$$V_{\Xi N} = V_0 + \boldsymbol{\sigma}\cdot\boldsymbol{\sigma}\, V_{\sigma\cdot\sigma} + \boldsymbol{\tau}\cdot\boldsymbol{\tau}\, V_{\tau\cdot\tau} + (\boldsymbol{\sigma}\cdot\boldsymbol{\sigma})(\boldsymbol{\tau}\cdot\boldsymbol{\tau})\, V_{\sigma\cdot\sigma\ \tau\cdot\tau}$$

In order to obtain useful information about V_0,
the following systems are suited, because

the $(\sigma\cdot\sigma)$, $(\tau\cdot\tau)$ and $(\sigma\cdot\sigma)(\tau\cdot\tau)$ terms of $V_{\Xi N}$ vanish by folding them into the **α**-cluster wave function that are spin-, isospin-satulated.



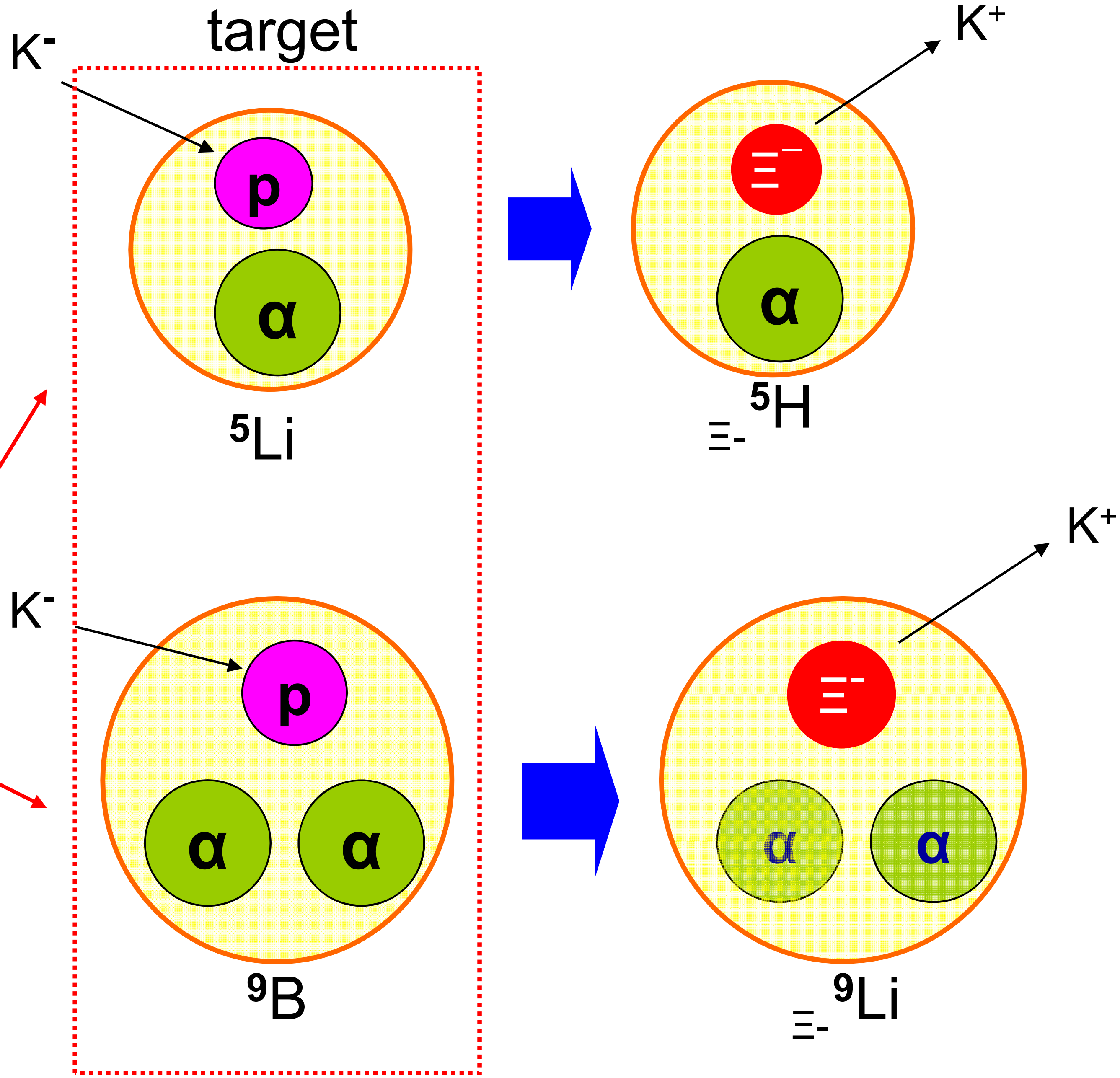
problem : there is NO target to produce them
by the (K^-, K^+) experiment .

Because, ・・・

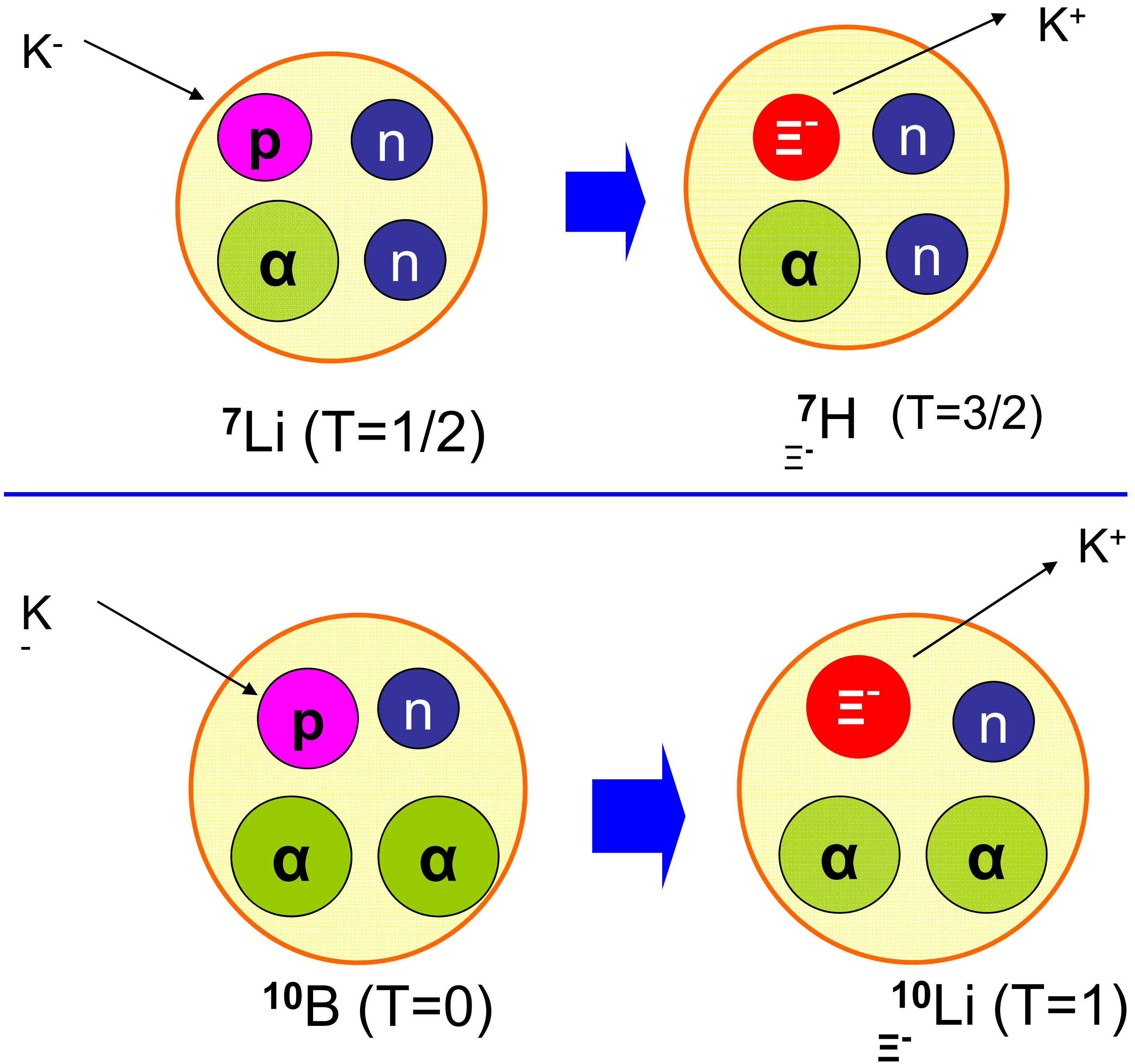
To produce $\alpha\Xi^-$ and $\alpha\alpha\Xi^-$ systems by (K^-, K^+) reaction,

These systems are unbound.

Then, we cannot use them as targets.

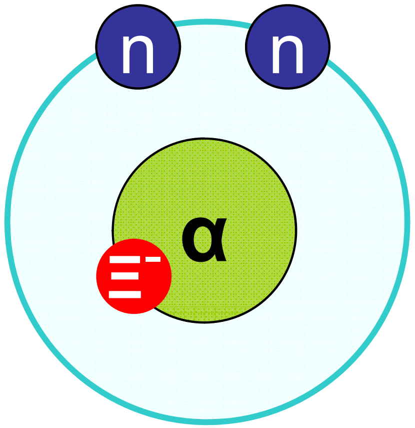


As the second best candidates to extract information about the spin-, isospin-independent term V_0, we propose to perform…

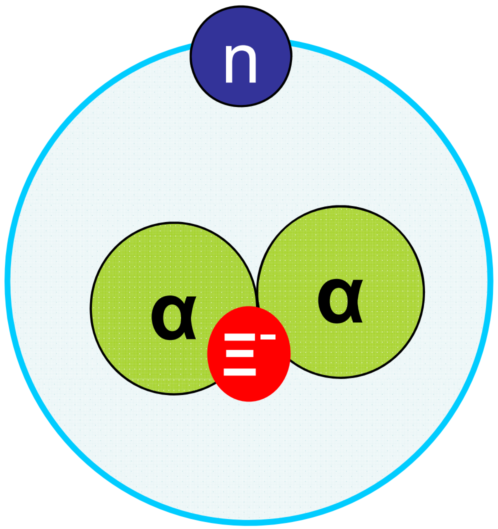


Why they are suited for investigating V_0?

(more realistic illustration)



$^{7}_{\Xi^-}H$ (T=3/2)



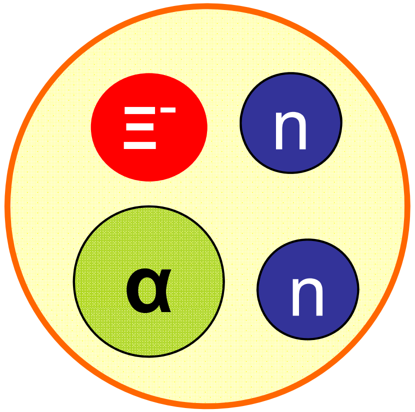
$^{10}_{\Xi^-}Li$ (T=1)

Core nucleus ^{6}He is known to be halo nucleus. Then, valence neutrons are located far away from α particle.

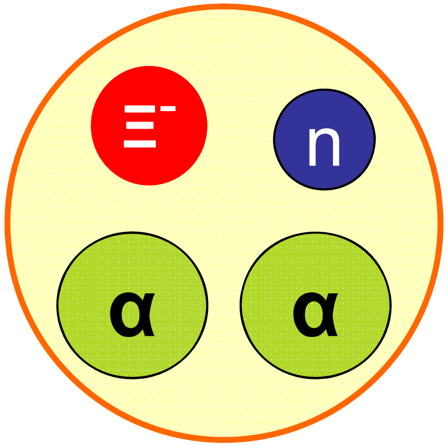
Valence neutrons n are located in p-orbit, whereas Ξparticle Ξ^- is located in 0s-orbit.

Then, distance between Ξ and **n** is much larger than the interaction range of Ξ and **n**.

Then, αΞ potential, in which only V_0 term works, plays a dominant role in the binding energies of these system.



${}^{7}_{\Xi^-}H$ (T=3/2)



${}^{10}_{\Xi^-}Li$ (T=1)

Before the experiments will be done,
we should predict whether these Ξ^-
hypernuclei will be observed as
bound states or not.

Namely, we calculate the binding energies
of these hypernuclei.

ΞN interaction

Only one experimental information about ΞN interaction

Y. Yamamoto, Gensikaku kenkyu 39, 23 (1996),

T. Fukuda *et al*. Phys. Rev. C58, 1306, (1998);

P.Khaustov *et al*., Phys. Rev. C61, 054603 (2000).

Well-depth of the potential between Ξ and ^{11}B: -14 MeV

Among all of the Nijmegen model,

ESC04 (Nijmegen soft core) and ND (Nijmegen Model D)

reproduce the experimental value.

OtherΞN interaction are repulsive or weak attractive.

We employ ESC04 and ND.

The properties of ESC04 and ND are quite different from each other.

Property of the spin- and isospin-components of ESC04 and ND

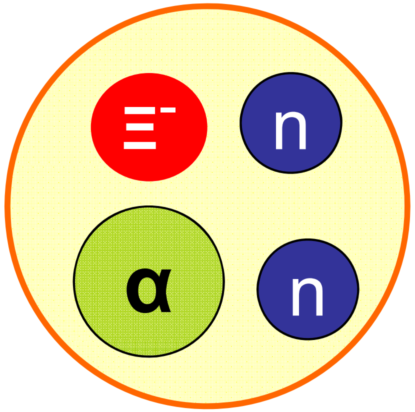
V(T,S)	ESC04	ND
T=0, S=1	strongly attractive (a bound state)	weakly attractive
T=0, S=0	weakly repulsive	
T=1, S=1	weakly attractive	
T=1, S=0	weakly repulsive	

Although the spin- and isospin-components of these two models are very different between them (due to the different meson contributions),

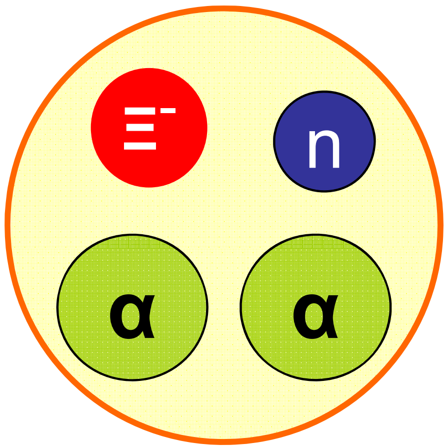
we find that the spin- and isospin-averaged property,

$$V_0 = [\, V(0,0) + 3V(0,1) + 3V(1,0) + 9V(1,1) \,] / 16,$$

namely, strength of the V_0- term is similar to each other.



$^{7}_{\Xi^-}$H (T=3/2)



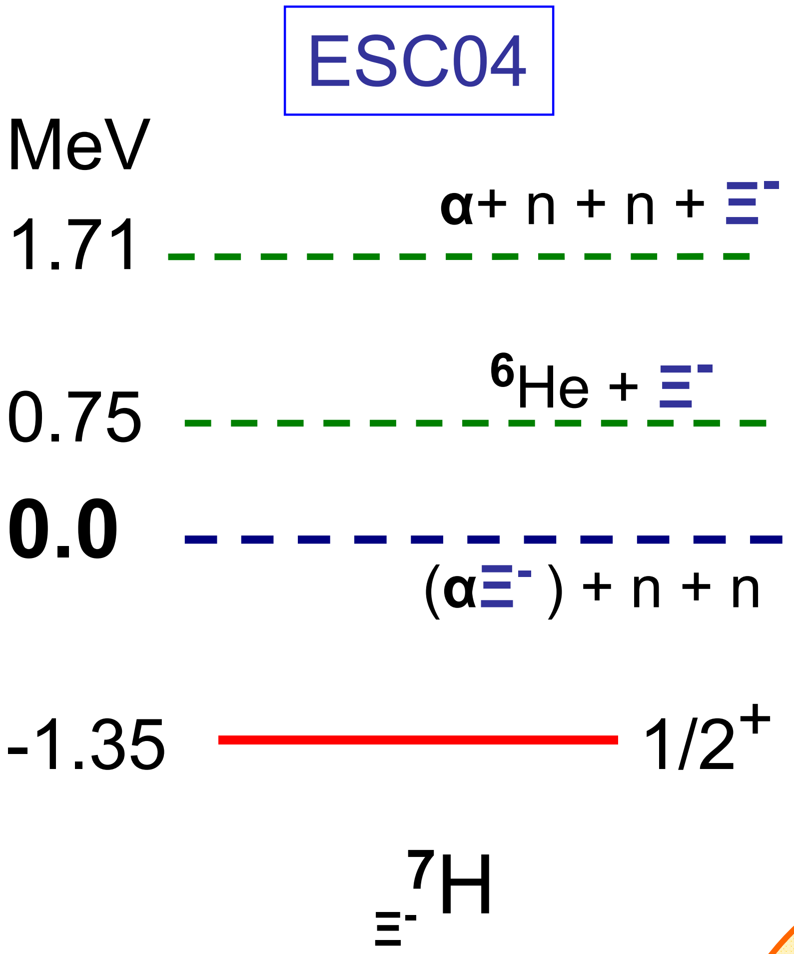
$^{10}_{\Xi^-}$Li (T=1)

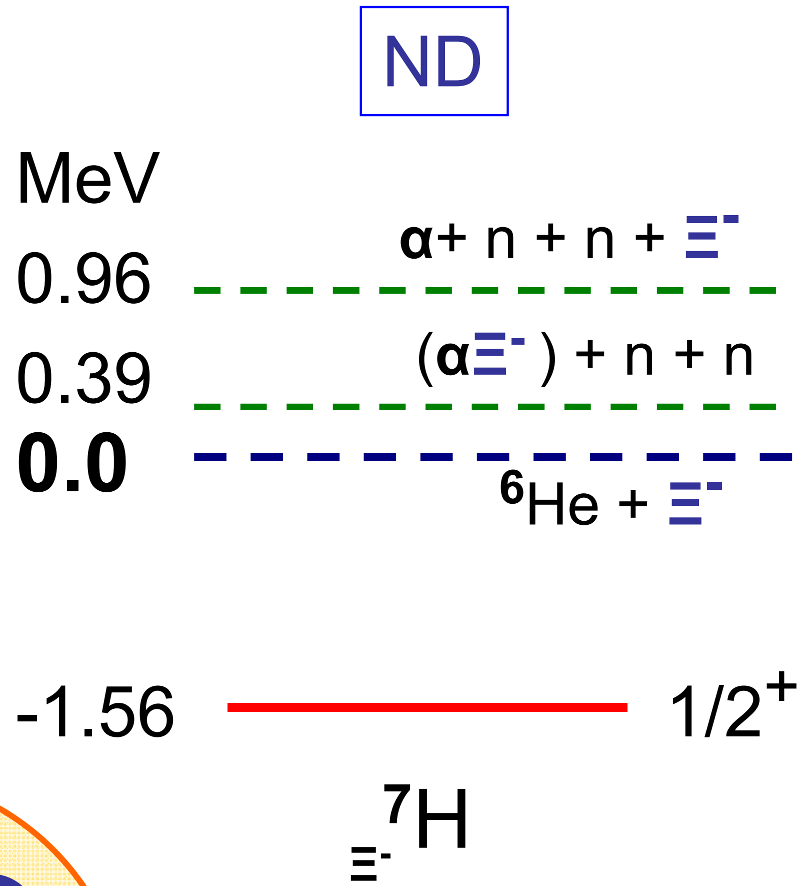
As mentioned before,
αΞ potential, in which only **V_0** term works,
plays a dominant role in the binding
energies of these system.

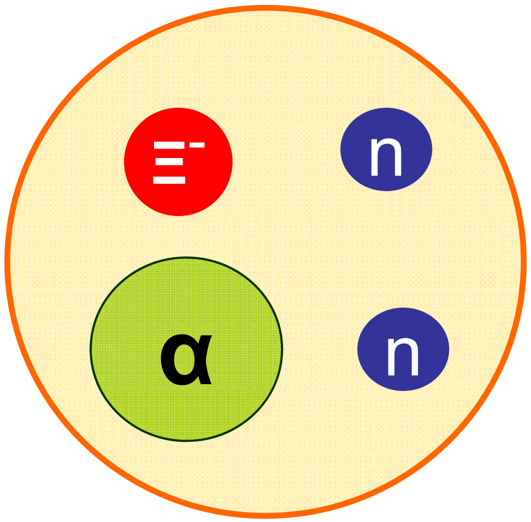
Therefore, interestingly,
we may expect to have similar binding
energies between ESC04 and ND,
although the spin- and isospin-components
are very different between the two.

4-body calculation of ${}^{7}_{\Xi^-}H$

E. Hiyama et al.,
PRC**78** (2008) 054316







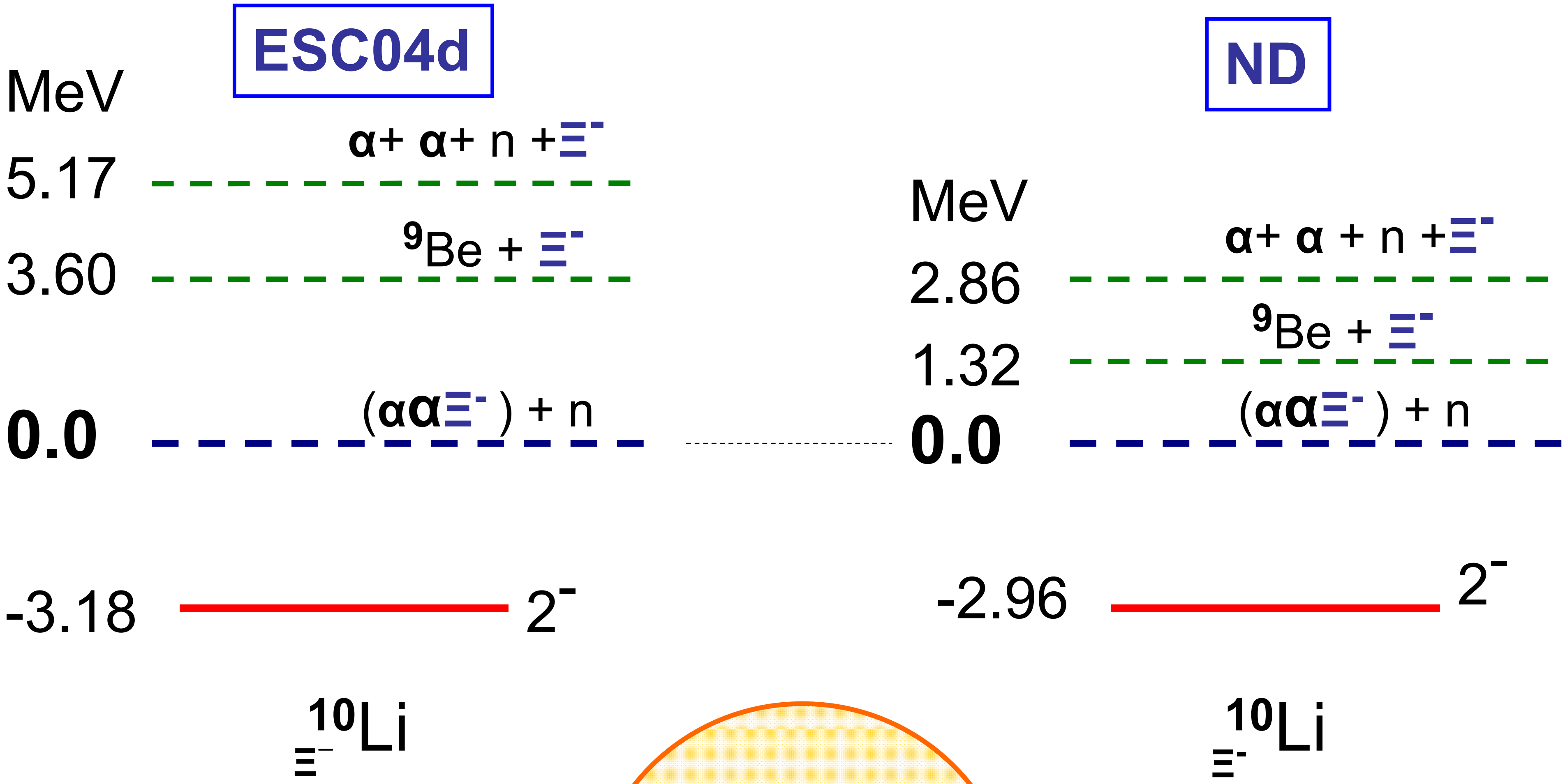
In experiments,
we can expect
a bound state.

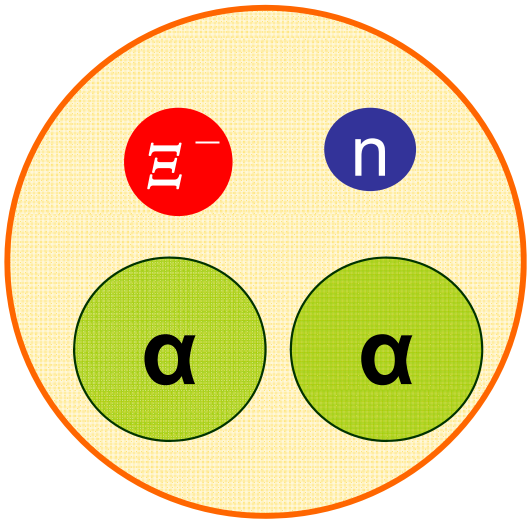
Similar binding energies using ND and ESC04.

Independent on employed ΞN potential

4-body calculation of $^{10}_{\Xi^-}\mathrm{Li}$

E. Hiyama et al., PRC**78** (2008) 054316





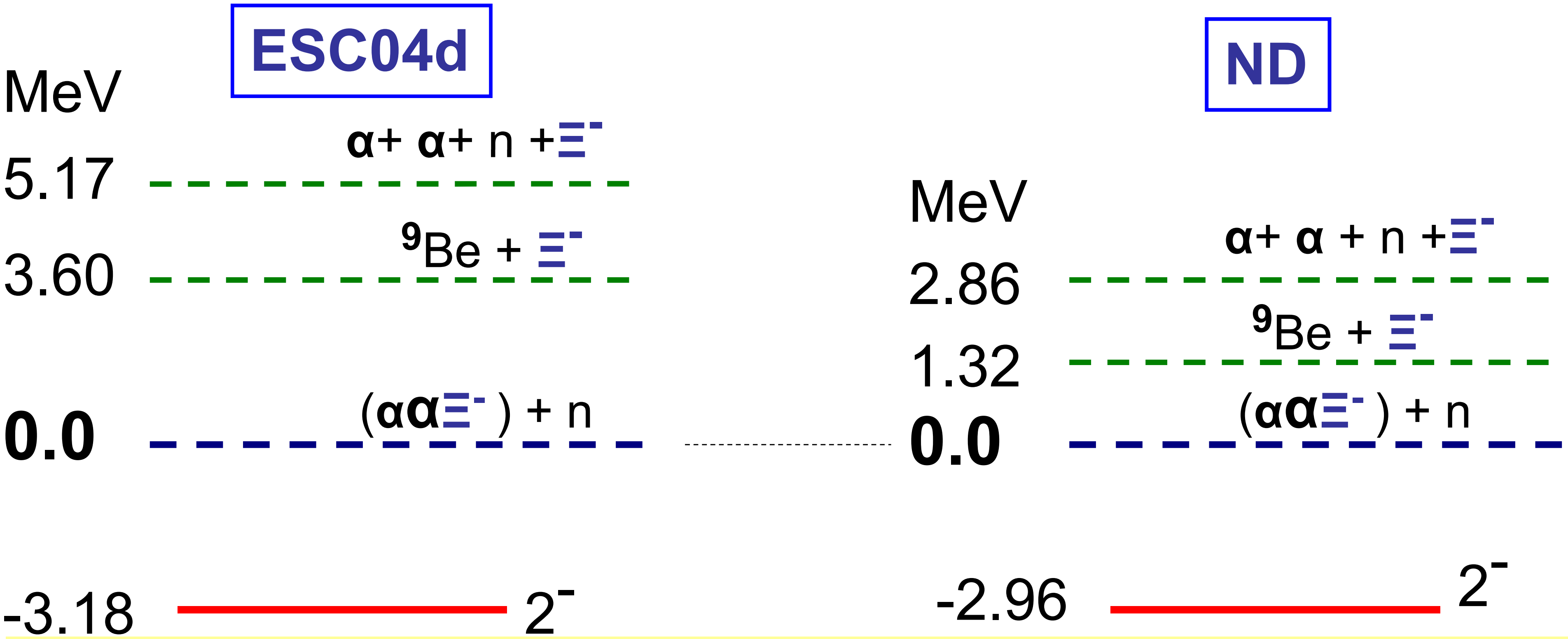
Similar binding energies using ND and ESC04d.

Independent on employed ΞN potential

In experiments, we can expect a bound state.

4-body calculation of $^{10}_{\Xi^-}Li$

E. Hiyama et al., PRC**78** (2008) 054316



In this way, the binding energies of Ξ hypernuclei with A=7 and 10 are dominated by αΞ potential, namely, spin-, and iso-spin independent ΞN interaction (V_0).

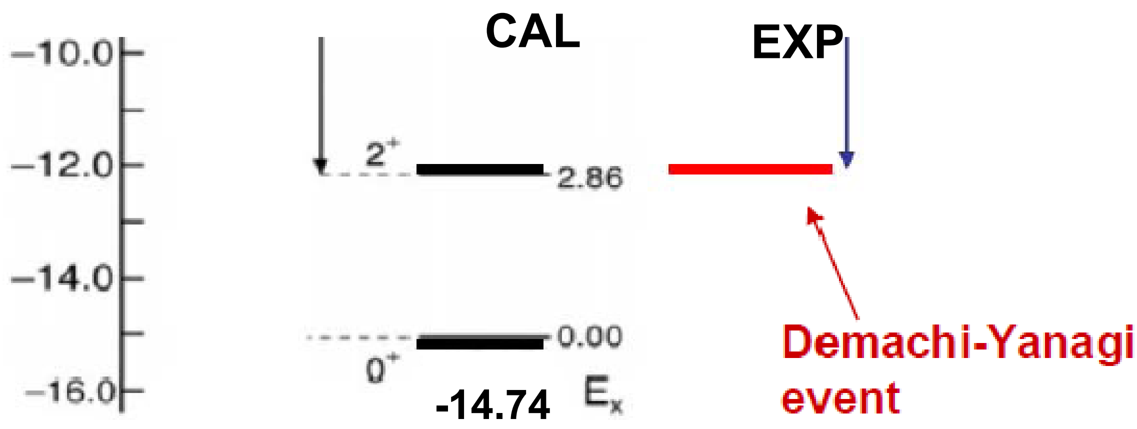
Then, to get information about this part, we propose to perform the (K^-,K^+) experiment by using ^7Li and ^{10}B targets at J-PARC after the Day-1 experiment with ^{12}C target.

Concluding remark

- Four-body structure of $^{7}_{\Lambda}He(\alpha+\Lambda+n+n)$ and CSB effect
- Five-body structure of $^{11}_{\Lambda\Lambda}Be$
- Four-body structure of $^{7}_{\Xi}H$ and $^{10}_{\Xi}Li$

For further study of structure of these hypernuclei, we hope to have many experimental data at J-PARC.

Thank you.



$^{10}_{\Lambda\Lambda}$Be

$^{10}_{\Lambda\Lambda}$Be

CAL (0^+): -14.74 MeV

EXP (0^+): -14.69 MeV

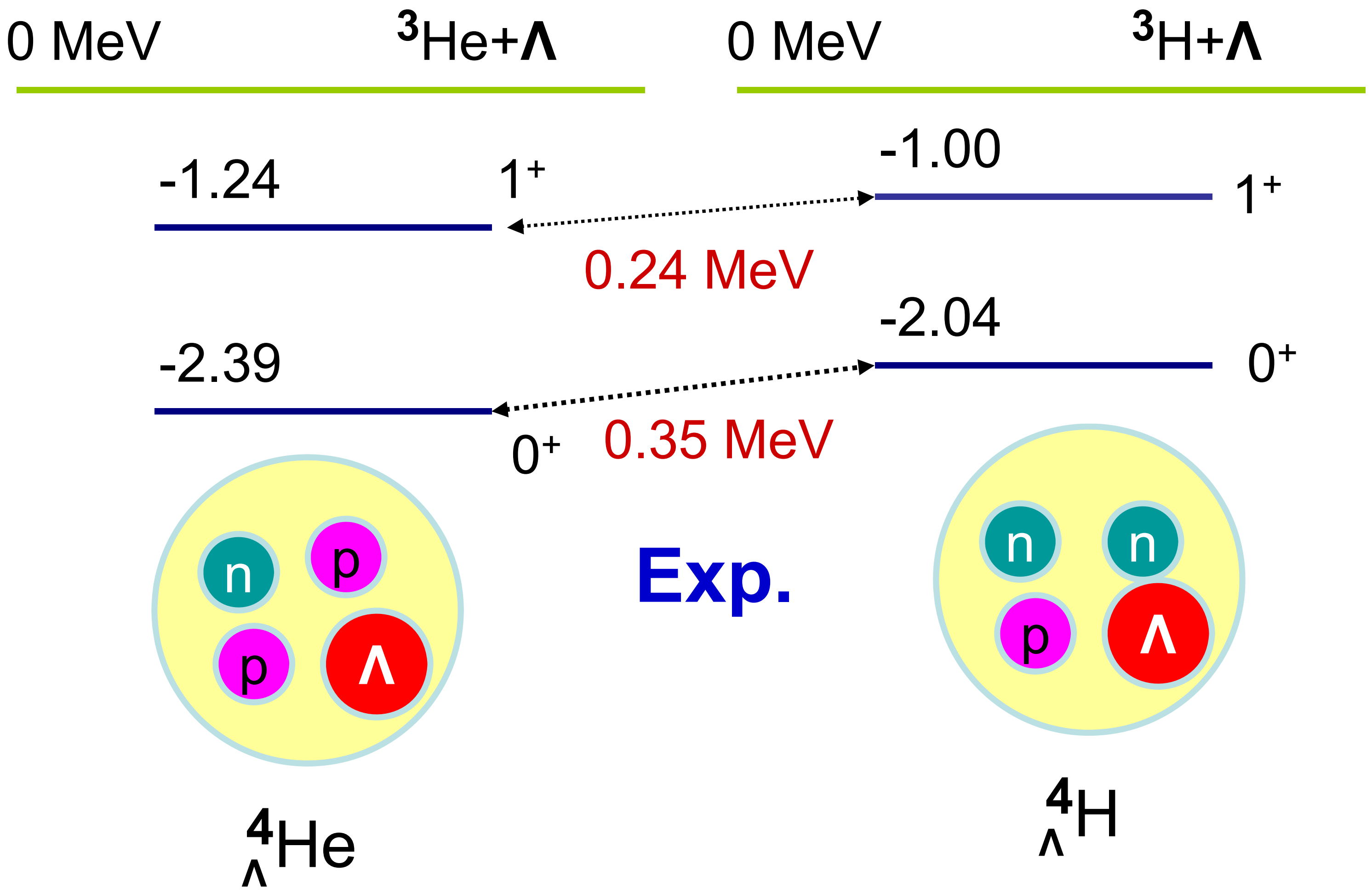
$B_{\Lambda\Lambda}$=14.6 MeV

On the other hand, the earlier experiment by Danysz *et al.* [2] on the pionic decay of $^{10}_{\Lambda\Lambda}\mathrm{Be}(0^+)\rightarrow{}^{9}_{\Lambda}\mathrm{Be}(1/2^+)+p+\pi^-$ gave $B^{\mathrm{exp}}_{\Lambda\Lambda}(^{10}_{\Lambda\Lambda}\mathrm{Be}(0^+))=17.7\pm0.4$ MeV. This value has been used for a long time, which implies a strongly attractive $\Lambda\Lambda$ interaction. However, it should be noted that the authors also suggested the possibility of another decay $^{10}_{\Lambda\Lambda}\mathrm{Be}(0^+)\rightarrow{}^{9}_{\Lambda}\mathrm{Be}(3/2^+,5/2^+)+p+\pi^-$ (Table 5 of Ref. [2]); the same was pointed out in Ref. [12]. In this case, the value of $B^{\mathrm{exp}}_{\Lambda\Lambda}(_{\Lambda\Lambda}{}^{10}\mathrm{Be}(0^+))$ is modified to 14.6 ± 0.4 MeV, which is obtained by using 3.05 MeV [36] as the excitation energy of $^{9}_{\Lambda}\mathrm{Be}(3/2^+,5/2^+)$. This modified value turns out to

(i)

(ii)

First step : adjust the level-energies by introducing
a phenomenological ΛN CSB interaction.



Second step : use the the ΛN CSB interaction
in the calculation of the A=7 hypernuclei.

Second step : use the the ΛN CSB interaction in the calculation of the A=7 hypernuclei.