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Coherent Λ-Σ Coupling in Asymmetric Hypernuclei

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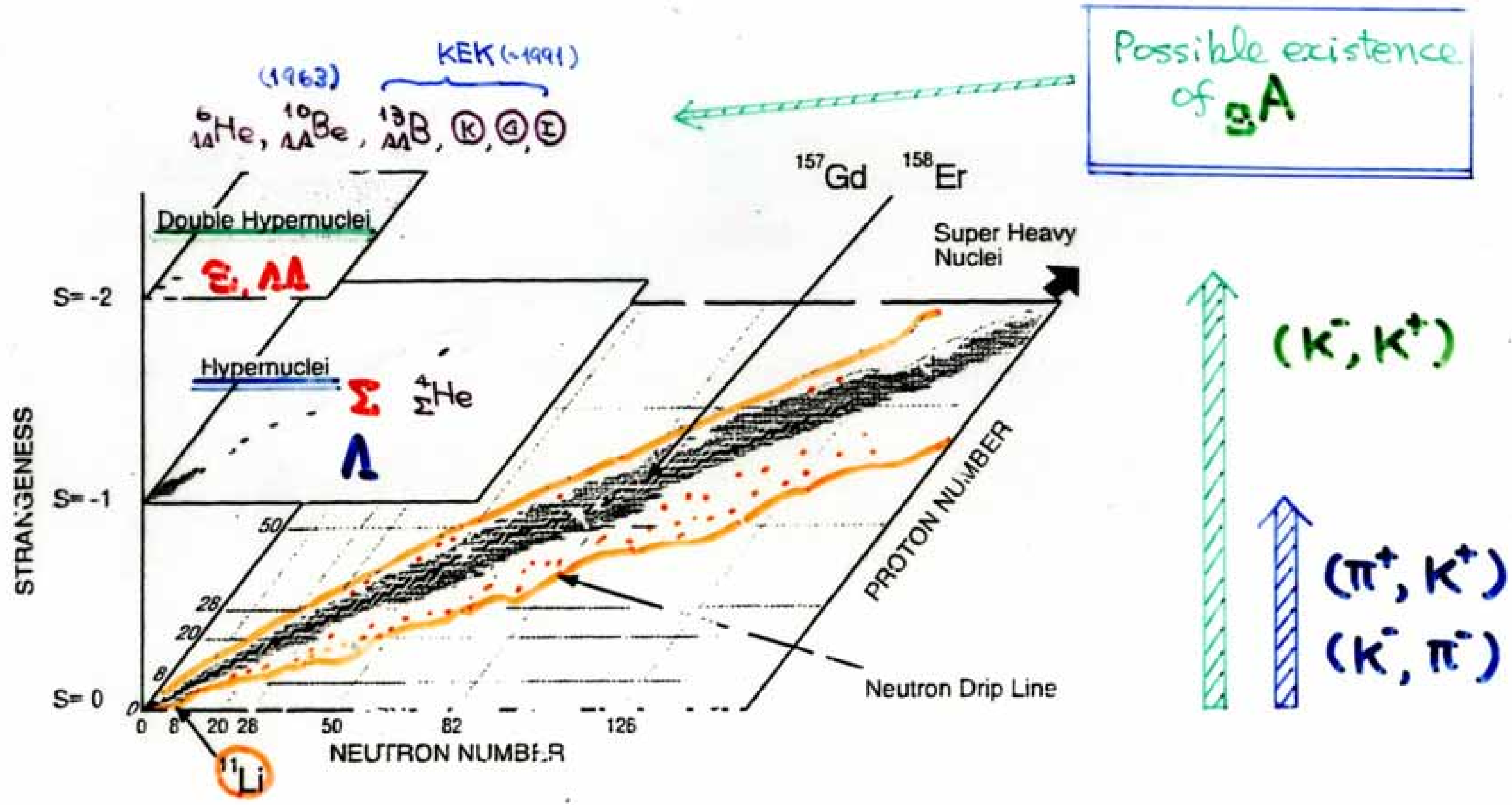
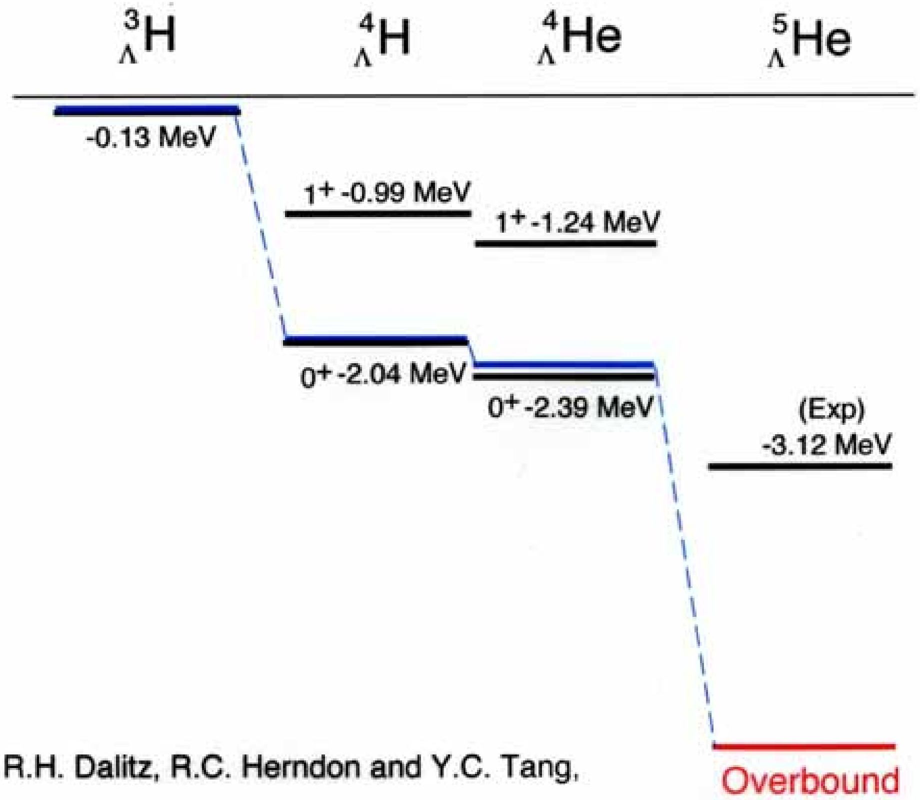


KEK (~1991)
(1963)
$^{6}_{\Lambda\Lambda}$He, $^{10}_{\Lambda\Lambda}$Be, $^{13}_{\Lambda\Lambda}$B, K, 4, I
Possible existence of $_{s}$A
Double Hypernuclei
Ξ, ΛΛ
S= -2
Hypernuclei
Σ
$^{4}_{\Sigma}$He
Λ
S= -1
STRANGENESS
S= 0
157Gd
158Er
Super Heavy Nuclei
PROTON NUMBER
Neutron Drip Line
NEUTRON NUMBER
0 8 20 28 50 82 126
8 20 28 50
11Li
(K⁻, K⁺)
(π⁺, K⁺)
(K⁻, π⁻)

The Overbinding Problem



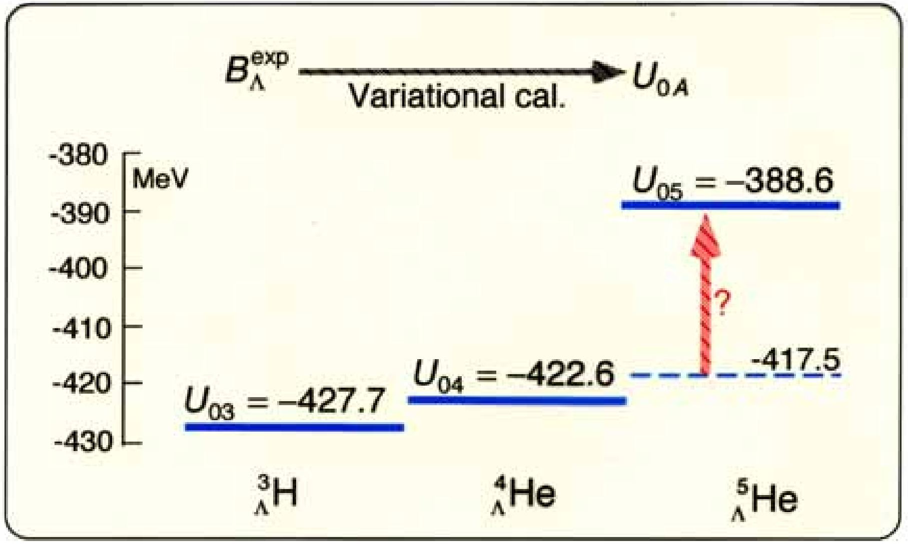
R.H. Dalitz, R.C. Herndon and Y.C. Tang,

Nucl. Phys. **B47** (1972) 109

Dalitz et al's analysis

$$V_{\Lambda N}(r)=\begin{cases}\infty, & r<d\\ U_{0A}\exp[-\lambda(r-d)], & r>d\end{cases}$$

$\lambda = 3.219\ \mathrm{fm}^{-1}$, $d = 0.45$ fm

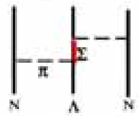


$$U_{03}=\frac{1}{4}U_0^t+\frac{3}{4}U_0^s$$
$$U_{04}=\frac{1}{2}U_0^t+\frac{1}{2}U_0^s$$
$$U_{05}=\frac{3}{4}U_0^t+\frac{1}{4}U_0^s$$

$$\rightarrow \boxed{\frac{1}{2}(U_{03}+U_{05})-U_{04}=0}\ .03W_3$$

$W_3 \approx 480$ MeV

$W_3 = 1.43$ MeV



Nogami's 3BF

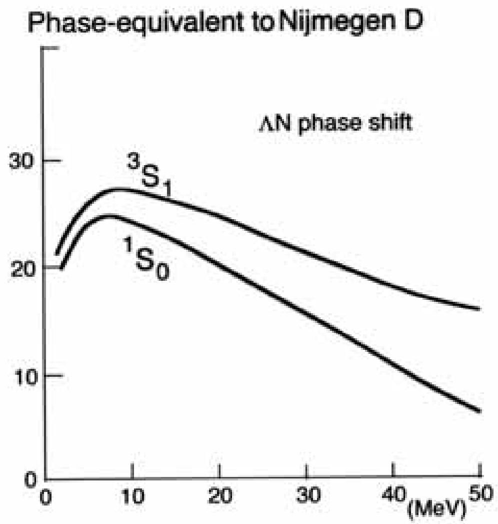
$$V_{\Lambda NN}=-\frac{1}{3}W_3(\vec{\sigma}_1\vec{\sigma}_2)(\vec{\tau}_1\vec{\tau}_2)\frac{\exp(-\mu r_{1\Lambda})}{\mu r_{1\Lambda}}\frac{\exp(-\mu r_{2\Lambda})}{\mu r_{2\Lambda}}$$

Singlet int. is more attractive than triplet int.

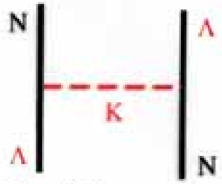
Central YN interaction

	ΛN	ΣN	
D0	○		**1-channel picture**
D2	○ ← ΛN-ΣN coupling →	○	**2-channel picture**

A.R. Bodmer
(1966)



Brueckner-Hartree-Fock Calculation on Gaussian Basis



<u>Hyperon-nucleus potential</u>

$$U_{\mu}^{\rm eq}(\vec{r}_1)\varphi_\mu(\vec{r}_1) \equiv U_{\rm H}(\vec{r}_1)\varphi_\mu(\vec{r}_1) + \int d\vec{r}_2 U_{\rm F}(\vec{r}_1,\vec{r}_2)\varphi_\mu(\vec{r}_2)$$

g-matrix

$$U_{\rm H}(\vec{r}_1) = \int d\vec{r}_2 \sum_\nu \varphi_\nu^*(\vec{r}_2) g(\vec{r}_1,\vec{r}_2) \varphi_\nu(\vec{r}_2)$$

$$U_{\rm F}(\vec{r}_1,\vec{r}_2) = -\sum_\nu \varphi_\nu^*(\vec{r}_2) g(\vec{r}_1,\vec{r}_2) \varphi_\nu(\vec{r}_1)$$

$$g(\vec{r}_1-\vec{r}_2) = \sum_j \gamma_j^\mu \exp\left\{-\left((\vec{r}_1-\vec{r}_2)/c_j\right)^2\right\}, \quad c_1,\dots,c_{20} \text{ fixed}$$

$$U_\mu^{\rm eq}(\vec{r}_1) = \sum_j \alpha_j^\mu \exp\left\{-\left(r_1/a_j\right)^2\right\}, \quad a_1,\dots,a_{10} \text{ fixed}$$

$$\varphi_\mu(\vec{r}_1) = \sum_j \beta_j^\mu \exp\left\{-\left(r_1/b_j\right)^2\right\} r_1^\ell y_{\ell_1 s_1 j_1 m_1}(\hat{r}_1), \quad b_1,\dots,b_{20} \text{ f}$$

Self-consistently determined

Matrix elements for s-shell hyperon:

$$\sum_{\phi_2}\sum_{\mu_2}\left\langle (a_1'' j_1\mu_1\phi_1)(a_2'' j_2\mu_2\phi_2)\right| g \left|(a_1 j_1\mu_1\phi_1)(a_2 j_2\mu_2\phi_2) - \text{exch.}\right\rangle$$

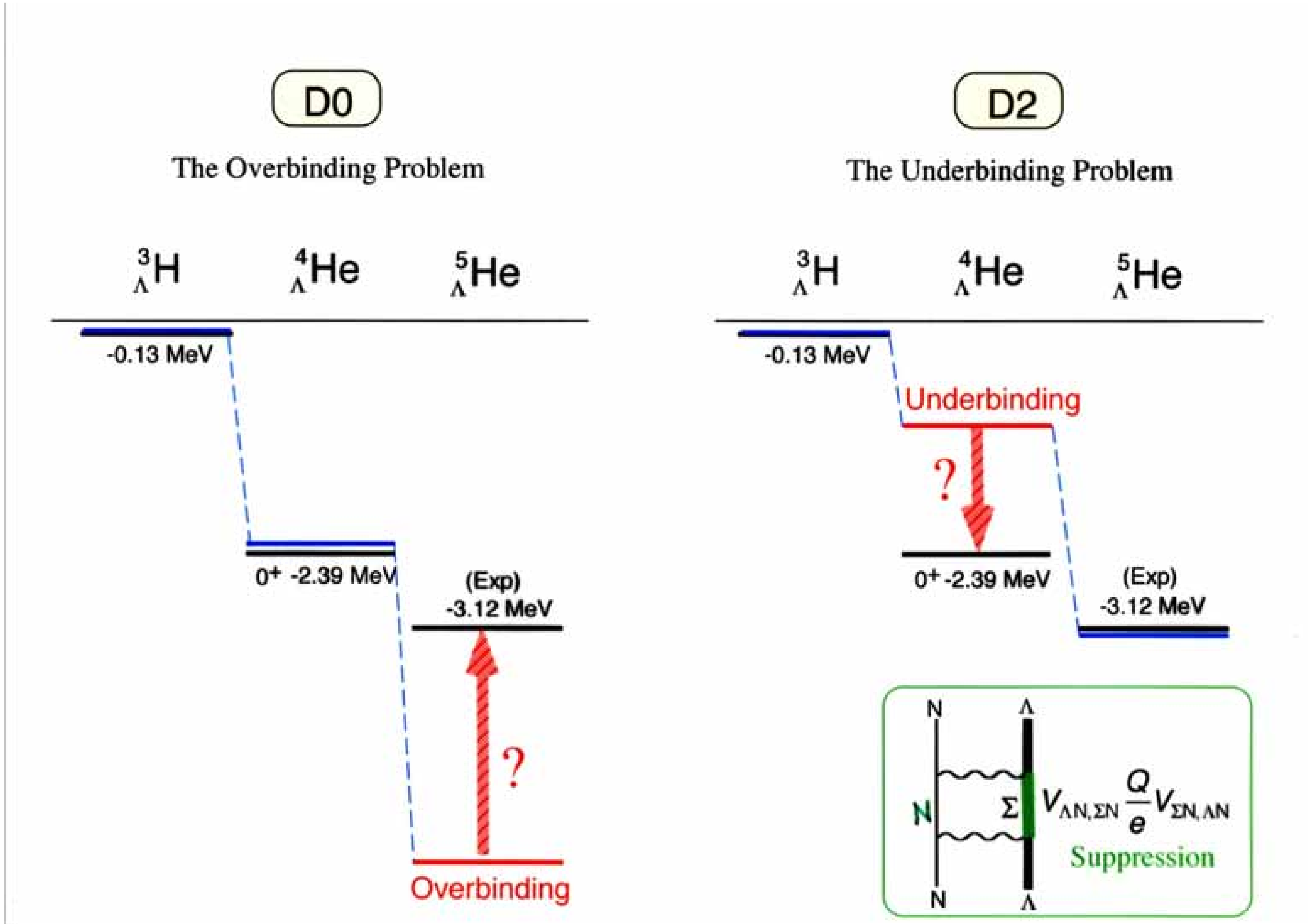
$$= (2j_2+1)(2\ell_2+1)^2 \sum_{\ell'=0}^{\ell_2}\sum_{\ell'''=0}^{\ell_2}\left(\frac{M_1}{M_1+M_2}\right)^{\ell'+\ell'''}\sqrt{\binom{2\ell_2}{2\ell'}\binom{2\ell_2}{2\ell'''}}\sum_n\sum_{n''}(2n+1)(2n''+1)$$

$$\times\sum_\kappa \int_0^\infty dr\, r^{\ell'+\ell'''+2}\exp\left(-\left(A_{12}''+A_{12}+c_\kappa^2\right)r^2\right)\int_0^\infty dR\, R^{2\ell_2-\ell'-\ell'''+2}\exp\left(-(a_1''+a_2''+a_1+a_2)R^2\right) \times i^{n''} j_{n''}(ia_{12}''rR)\, i^n j_n(ia_{12}rR)$$

$$\times\sum_{\bar\ell}\left(\ell' n 00|\bar\ell 0\right)\left(\ell''' n'' 00|\bar\ell 0\right)\sum_{\bar L}\left(\ell_2-\ell' n 00|\bar L 0\right)\left(\ell_2-\ell''' n'' 00|\bar L 0\right)\begin{Bmatrix} n & \ell' & \bar\ell \\ \ell_2 & \bar L & \ell_2-\ell' \end{Bmatrix}\begin{Bmatrix} n'' & \ell''' & \bar\ell \\ \ell_2 & \bar L & \ell_2-\ell''' \end{Bmatrix}$$

$$\times\left[\sum_{K=\ell_2}\frac{2K+1}{2}\begin{Bmatrix} j_2 & K & \frac12 \\ 0 & \frac12 & \ell_2\end{Bmatrix}^2 \sum_{J=\bar\ell}(2J+1)\begin{Bmatrix}\bar\ell & 0 & J \\ K & \bar L & \ell_2\end{Bmatrix}^2 \frac{1-(-)^{n-\ell}}{2}\left\{V_{\bar\ell,S=0}^{J,F=0}(\kappa)\right\}_{\text{Yn and Yp}}\right.$$

$$\left. +\cdots\left\{V_{\bar\ell,S=0}^{J,F=1}(\kappa)\right\}_{\text{Yn and Yp}} +\cdots\left\{V_{\bar\ell,S=1}^{J,F=0}(\kappa)\right\}_{\text{Yn and Yp}} +\cdots\left\{V_{\bar\ell,S=1}^{J,F=1}(\kappa)\right\}_{\text{Yn and Yp}}\right]$$


D0
The Overbinding Problem
$^{3}_{\Lambda}$H
$^{4}_{\Lambda}$He
$^{5}_{\Lambda}$He
-0.13 MeV
0+ -2.39 MeV
(Exp)
-3.12 MeV
?
Overbinding
D2
The Underbinding Problem
$^{3}_{\Lambda}$H
$^{4}_{\Lambda}$He
$^{5}_{\Lambda}$He
-0.13 MeV
Underbinding
?
0+ -2.39 MeV
(Exp)
-3.12 MeV
N
Λ
N
Σ
$V_{\Lambda N,\Sigma N}\frac{Q}{e}V_{\Sigma N,\Lambda N}$
Suppression
N
Λ

Λ-Σ Coupling

B.F. Gibson, A.Goldberg and M.S. Weiss, Phys. Rev. C6 (1972) 741;
J. Dabrowski, Phys. Rev. C8 (1973) 835.

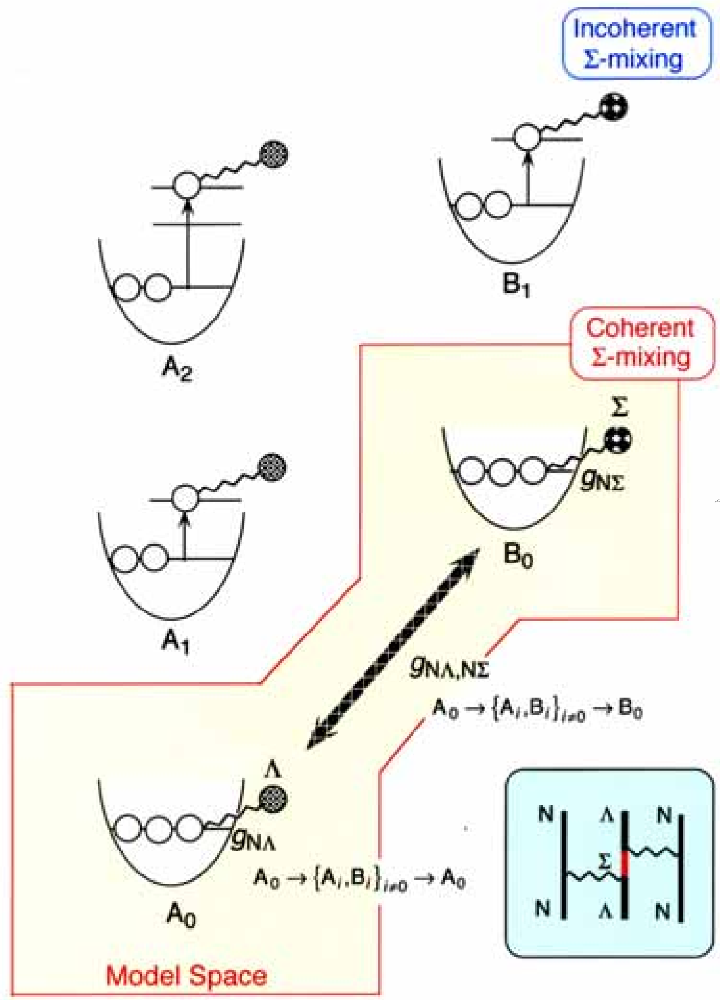
$$\left|{}^{5}_{\Lambda}\mathrm{He}\right\rangle = \Phi_\Lambda(\vec{r})\left|{}^{4}\mathrm{He}\right\rangle \qquad T=0$$

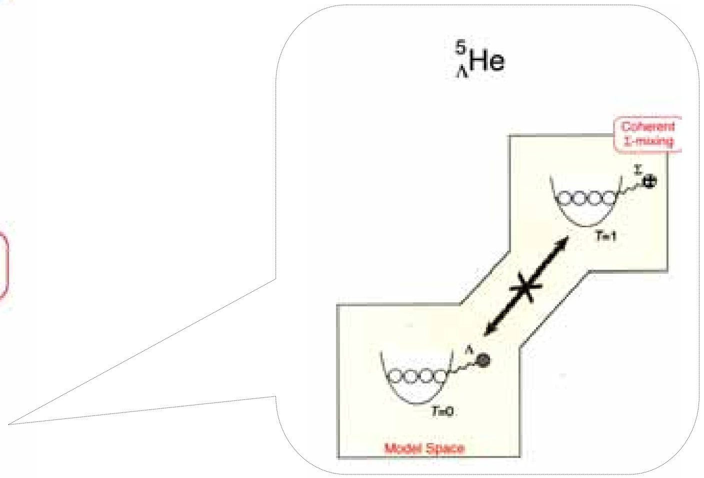
$$\left|{}^{4}_{\Lambda}\mathrm{He}\right\rangle = \Phi_\Lambda(\vec{r})\left|{}^{3}\mathrm{He}\right\rangle \boxed{+\sqrt{\tfrac{2}{3}}\Phi_{\Sigma^+}(\vec{r})\left|{}^{3}\mathrm{H}\right\rangle - \sqrt{\tfrac{1}{3}}\Phi_{\Sigma^0}(\vec{r})\left|{}^{3}\mathrm{He}\right\rangle}$$

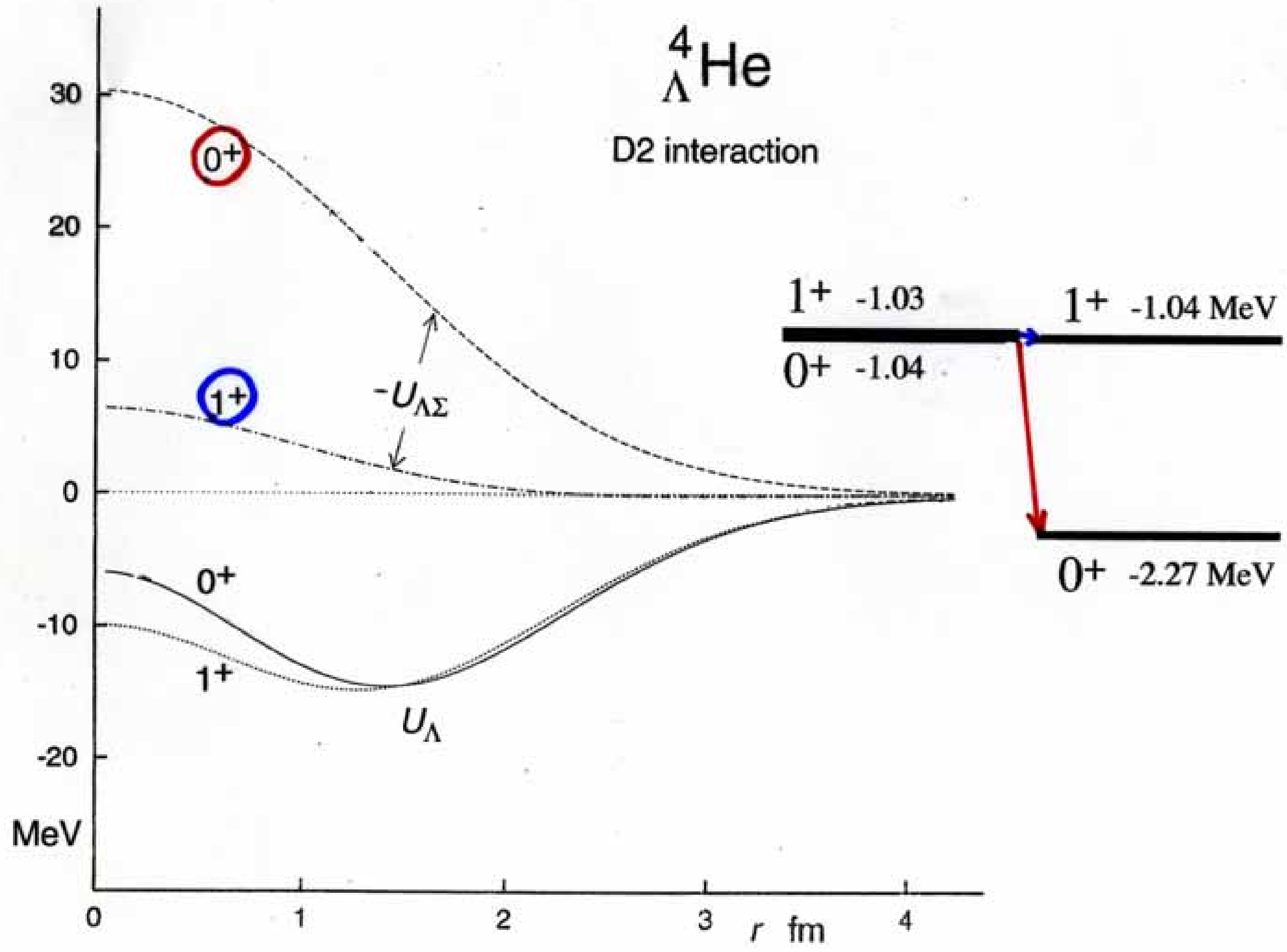
$$T=1/2$$

${}^{4}_{\Sigma}\mathrm{He}(0^+)$	
$\frac{9}{6}\,{}^3g_{\Sigma N} + \frac{1}{6}\,{}^1g_{\Sigma N} + \frac{8}{6}\,{}^1g_{\Sigma N}^{T=3/2}$	$\frac{7}{6}\,{}^3g_{\Sigma N} + \frac{3}{6}\,{}^1g_{\Sigma N} + \frac{8}{6}\,{}^3g_{\Sigma N}^{T=3/2}$
$\updownarrow$	$\updownarrow$
$\frac{3}{2}\,{}^3g_{\Lambda N,\Sigma N} - \frac{1}{2}\,{}^1g_{\Lambda N,\Sigma N}$	$\frac{1}{2}\,{}^3g_{\Lambda N,\Sigma N} + \frac{1}{2}\,{}^1g_{\Lambda N,\Sigma N}$
$\updownarrow$	$\updownarrow$
$\frac{3}{2}\,{}^3g_{\Lambda N} + \frac{3}{2}\,{}^1g_{\Lambda N}$	$\frac{5}{2}\,{}^3g_{\Lambda N} + \frac{1}{2}\,{}^1g_{\Lambda N}$
${}^{4}_{\Lambda}\mathrm{He}(0^+)$	${}^{4}_{\Lambda}\mathrm{He}(1^+)$

Coherent Λ-Σ Coupling





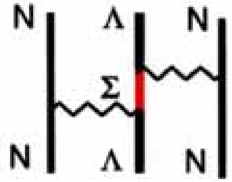


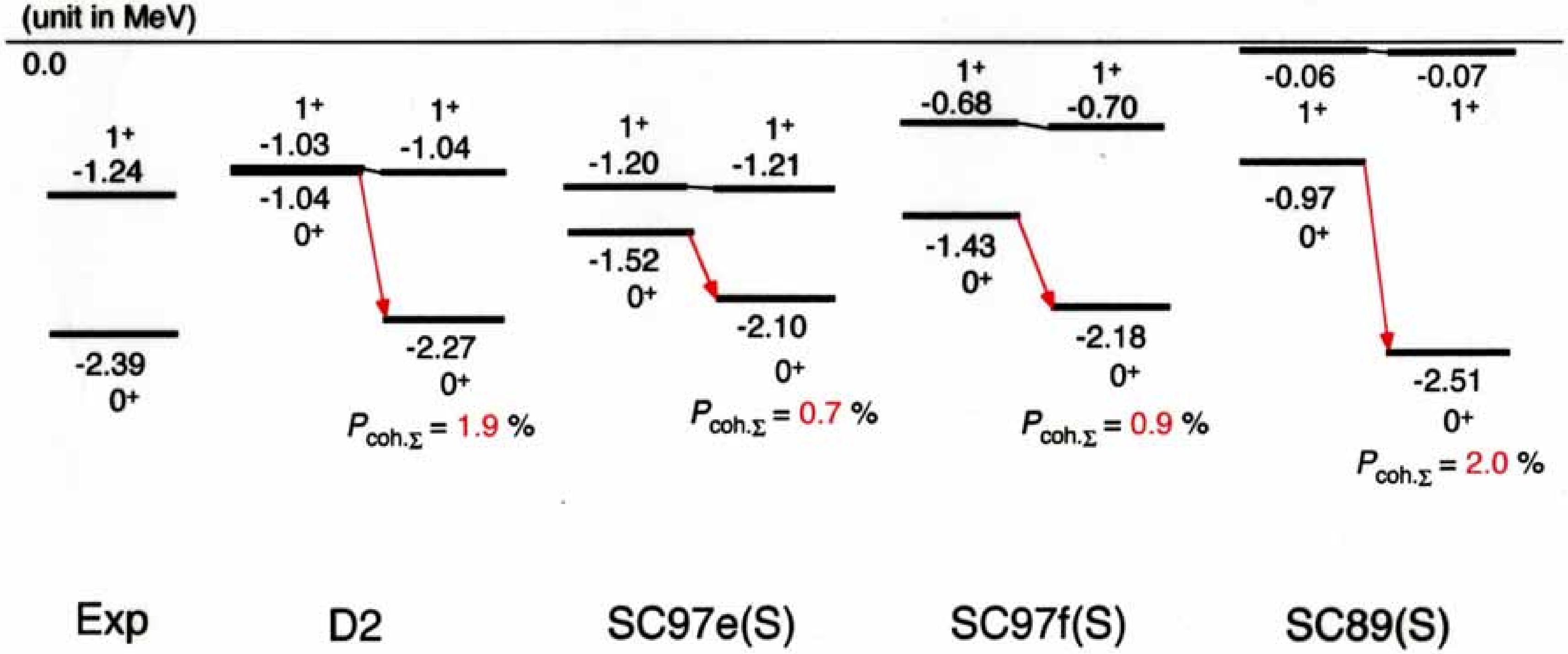
$^4_\Lambda$He
D2 interaction
30
20
10
0
-10
-20
MeV
0
1
2
3
4
r fm
0+
1+
$-U_{\Lambda\Sigma}$
0+
1+
U_Λ
1+ -1.03
0+ -1.04
1+ -1.04 MeV
0+ -2.27 MeV

"The 0^+-1^+ difference is not a measure of ΛN spin-spin interaction."

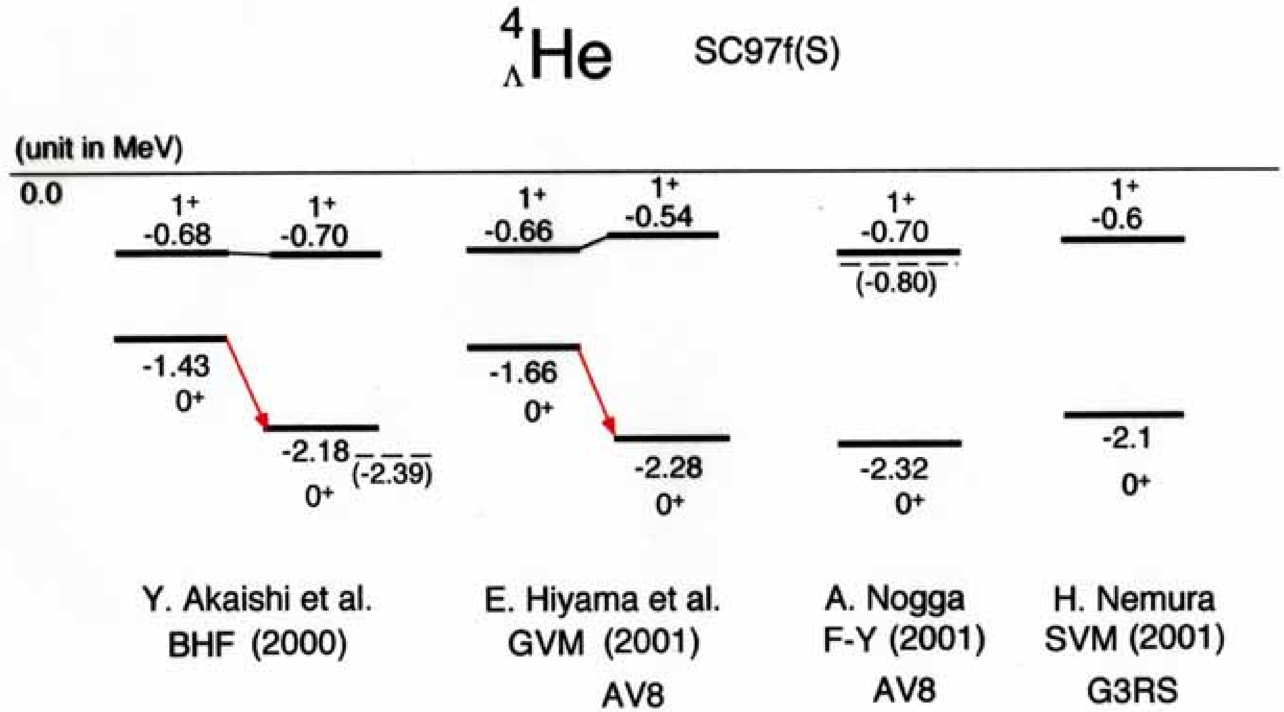
B. Gibson

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





T. Rijken et al., Phys. Rev. C59 (1999) 21.



E. Hiyama, M. Kamimura, T. Motoba, T. Yamada & Y. Yamamoto, Phys. Rev. **C65** (2001) 011301(R).
A. Nogga, Doctoral dissertation.

Faddeev-Yakubovsky calculations for ${}^{4}_{\Lambda}$He

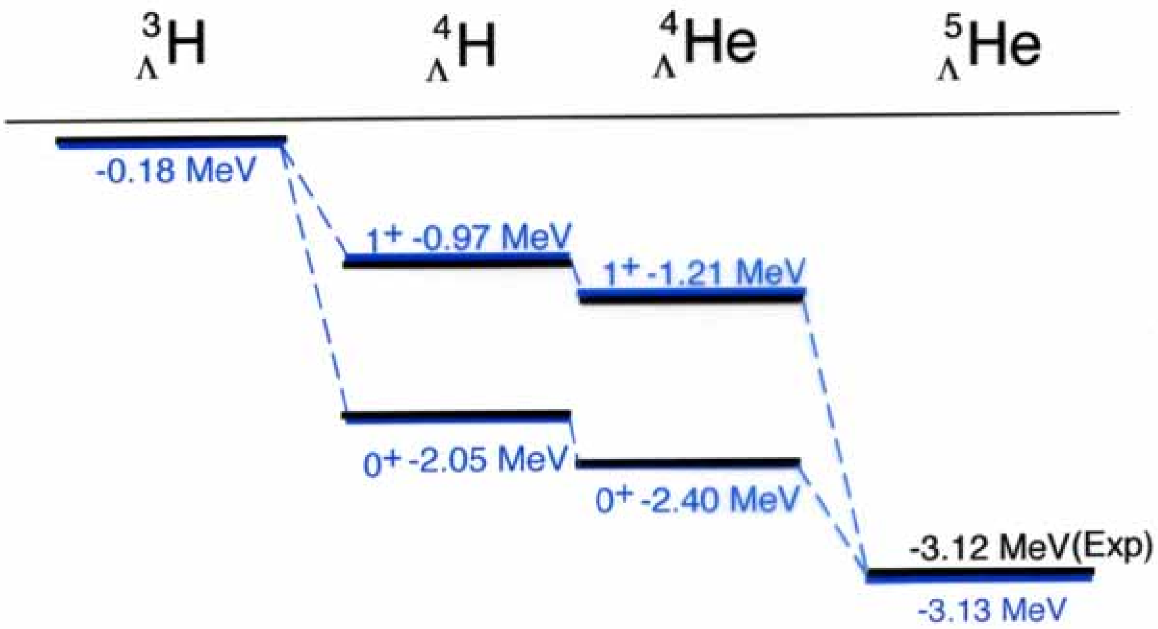
A. Nogga, H. Kamada and W. Glöckle, Phys. Rev. Lett. **88** (2002) 172501

YNF	$E^{\Lambda}_{\rm sep}(0^+)$	$E^{\Lambda}_{\rm sep}(1^+)$	Δ
SC89	2.14	0.02	2.06
SC97*f*	1.72	0.53	1.16
SC97*e*	1.54	0.72	0.79
SC97*d*	1.29	0.80	0.47
Expt.	2.39(3)	1.24(5)	1.15

		${}^{4}_{\Lambda}\mathrm{H}$	
S=1 pairs		1^{+}	0^{+}
$\Lambda p \Leftrightarrow -\sqrt{\frac{1}{3}}\,\Sigma^{0}p + \sqrt{\frac{2}{3}}\,\Sigma^{+}n$	$S_3 = 1$	-1/3	
	$S_3 = 0$	cancel each other	
	$S_3 = -1$		
$\Lambda n \Leftrightarrow \sqrt{\frac{1}{3}}\,\Sigma^{0}n - \sqrt{\frac{2}{3}}\,\Sigma^{-}p$	$S_3 = 1$	+1/3	+1/2
	$S_3 = 0$	+1/2	+1/2 coherently added
	$S_3 = -1$		+1/2
Contribution to $U_{\Sigma\Lambda}$		1/2	3/2
Λ-Σ coupling effect (~ΛNN force)		1 : 9	

The Overbinding Problem

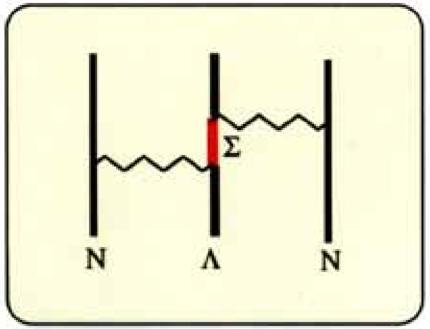
has been solved.



H. Nemura: D2'+Minnesota NN

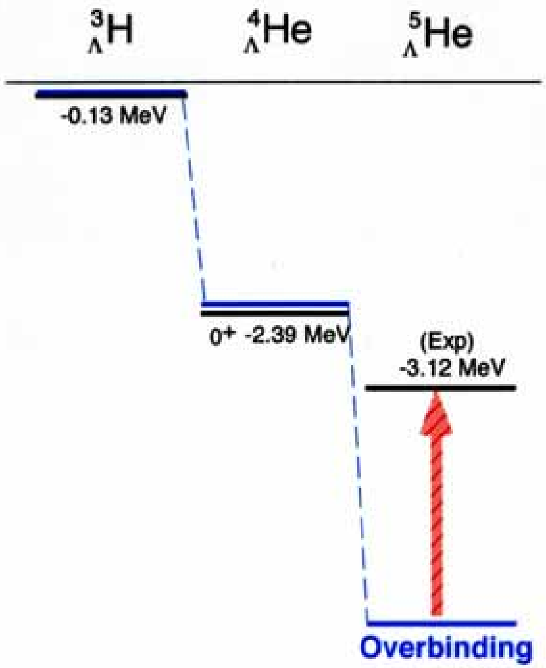
Repulsion !

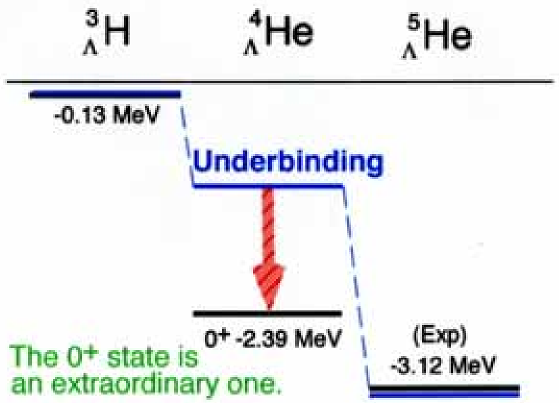
Y. Nogami et al.
Nucl. Phys. B19 (1970) 93

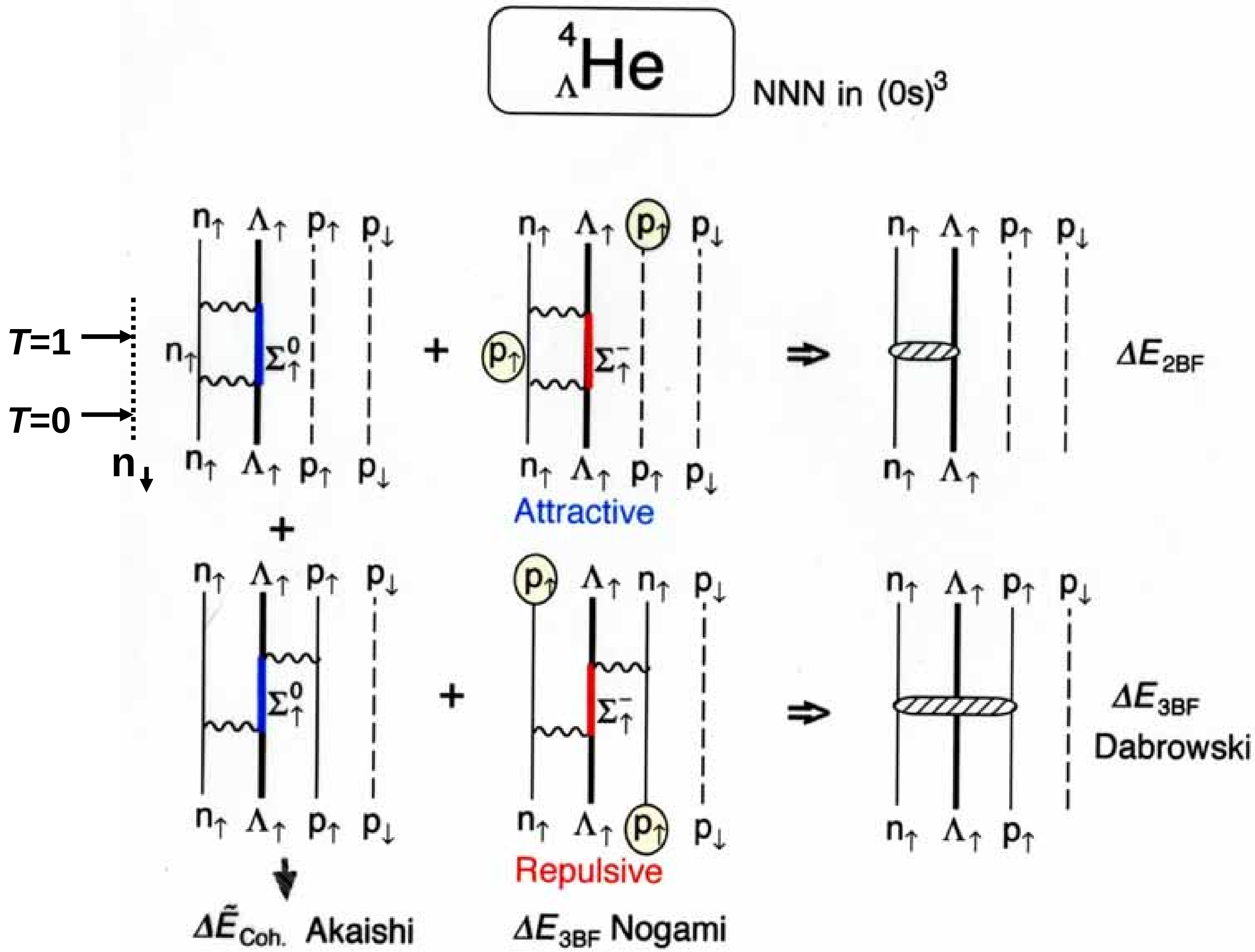


Attraction !

Y. Akaishi et al.
Phys. Rev. Lett. 84 (2000) 3539

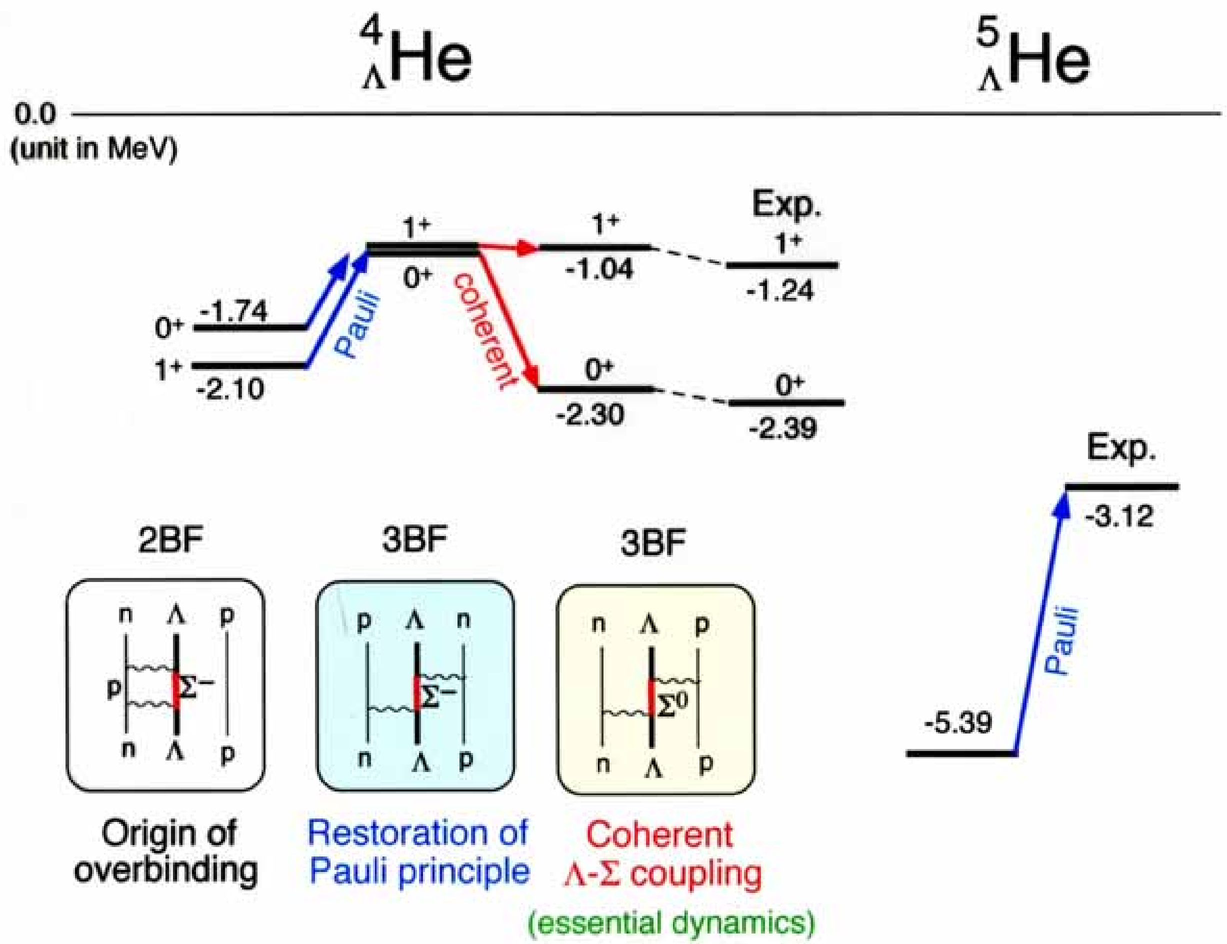






$^{4}_{\Lambda}\mathrm{He}$
NNN in $(0s)^3$
T=1
T=0
$n_\downarrow$
$n_\uparrow$ $\Lambda_\uparrow$ $p_\uparrow$ $p_\downarrow$
$\Sigma^0_\uparrow$
$\Sigma^-_\uparrow$
Attractive
Repulsive
ΔE_{2BF}
ΔE_{3BF}
Dabrowski
$\Delta\tilde{E}_{Coh.}$ Akaishi
ΔE_{3BF} Nogami

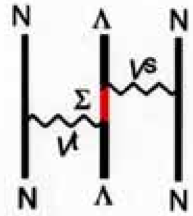
Effects of ΛNN Three-Body Force



Three-Body Force due to Coherent Λ-Σ Coupling : [for D0]

$$U_{\Lambda NN} = \sum_{\alpha=tt,ts,ss} W_3^{\alpha}(r_{1\Lambda}, r_{\Lambda 2})\left[a_\alpha + b_\alpha(\vec{\sigma}_1\vec{\sigma}_2) + c_\alpha \frac{1}{2}\underbrace{\vec{\sigma}_\Lambda(\vec{\sigma}_1+\vec{\sigma}_2)}_{\Lambda\text{N spin-spin}}\right]$$

$$\begin{pmatrix} a_{tt} & b_{tt} & c_{tt} \\ a_{ts} & b_{ts} & c_{ts} \\ a_{ss} & b_{ss} & c_{ss} \end{pmatrix} = \begin{pmatrix} \frac{7}{16} & \frac{3}{16} & \frac{3}{8} \\ \frac{1}{8} & \frac{1}{8} & -\frac{1}{4} \\ \frac{5}{48} & \frac{1}{48} & -\frac{1}{8} \end{pmatrix}$$



$$W_3^{ts}(r_{1\Lambda}, r_{\Lambda 2}) = V^t_{\Lambda N,\Sigma N}(r_{1\Lambda})\frac{1}{\Delta M^*}V^s_{\Sigma N,\Lambda N}(r_{\Lambda 2}) + V^s_{\Lambda N,\Sigma N}(r_{1\Lambda})\frac{1}{\Delta M^*}V^t_{\Sigma N,\Lambda N}(r_{\Lambda 2})$$

$$\langle V^s_{\Sigma N,\Lambda N}\rangle = -\beta\langle V^t_{\Sigma N,\Lambda N}\rangle \qquad \beta = 0.67, \quad \langle W_3^t\rangle_4 = 0.74\ \text{MeV}$$

${}^5_\Lambda$He	$\frac{1}{2}(3+\beta^2)\langle W_3^t\rangle_5$	≈ 3 MeV
${}^4_\Lambda$H$^*(1^+)$	$\frac{1}{8}(9+2\beta+\beta^2)\langle W_3^t\rangle_4$	≈ 1.0 MeV
${}^4_\Lambda$H(0^+)	$\frac{1}{8}(-3-6\beta+5\beta^2)\langle W_3^t\rangle_4$	≈ -0.44 MeV
${}^3_\Lambda$H	$\frac{1}{8}(-1-6\beta+3\beta^2)\langle W_3^t\rangle_3$	≈ -0.05 MeV

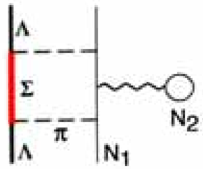
Light Hypernuclei

A.R. Bodmer and Q.N. Usmani, Nucl. Phys. **A477** (1988) 621.
R. Sinha and Q.N. Usmani, Nucl. Phys. **A684** (2001) 586c.

$$V_{\Lambda N} = \left[\left(V_{\text{core}}(r) - \overline{V} \right) (1 - \varepsilon + \varepsilon P_x) + \underbrace{\frac{1}{4} V_\sigma \vec{\sigma}_\Lambda \vec{\sigma}_N}_{\text{spin-spin}} \right] T_\pi^2(r)$$

$$V_{\Lambda NN} = W_p\{\text{Nogami}\} + V_{\Lambda NN}^{DS}\{\text{Dispersive}\}$$

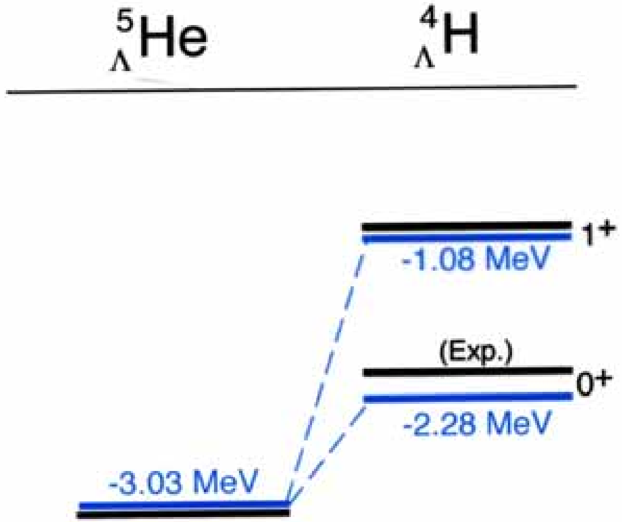
$$V_{\Lambda NN}^{DS}(r_{ij\Lambda}) = W_0 T_\pi^2(r_{i\Lambda}) T_\pi^2(r_{j\Lambda}) \left[1 + \underbrace{\frac{1}{6} \vec{\sigma}_\Lambda \left(\vec{\sigma}_i + \vec{\sigma}_j \right)}_{\text{spin-spin}} \right]$$



The 0+-1+ splitting
0.38 + 0.86 MeV
(70%)

The major part is attributed to ΛNN and not to ΛN.

0.56 + 0.92 MeV for SC97f
(62%)
-0.17 + 1.40 MeV for D2
(114%)

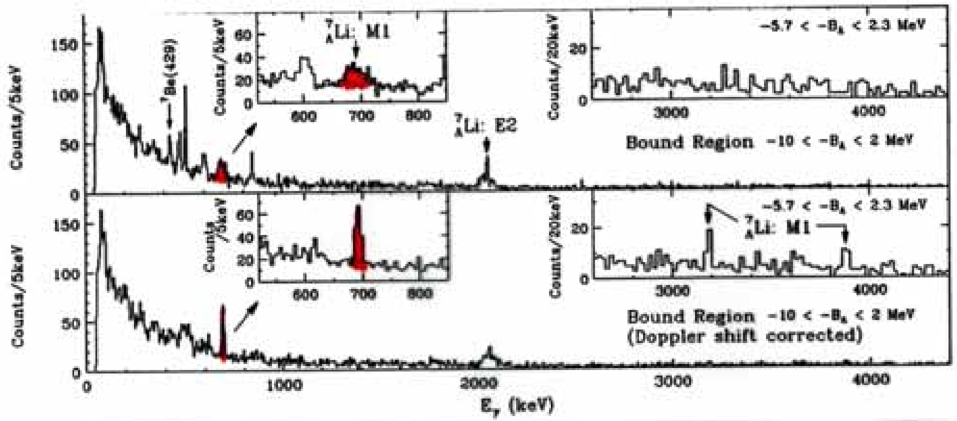


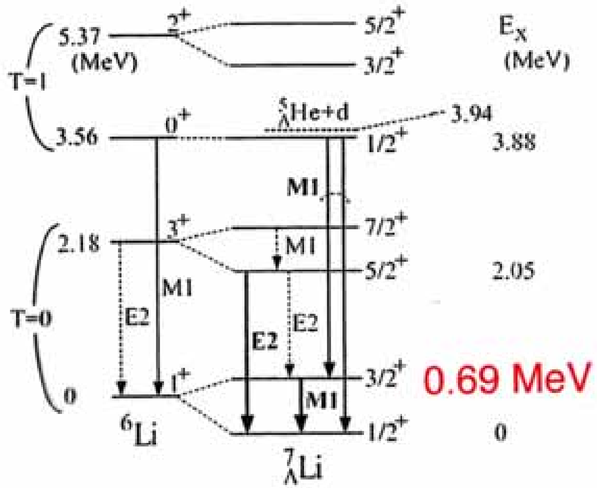
Variational Monte-Carlo

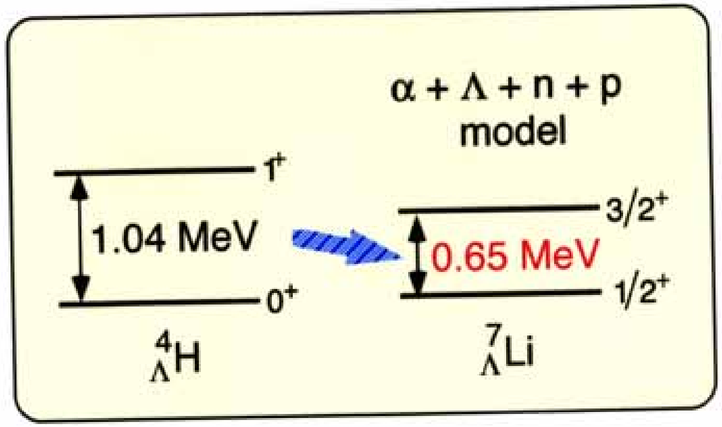
J. Lomnitz-Adler, V.R. Pandharipande & R.A. Smith, Nucl. Phys. **A361** (1981) 399.

ΛN spin-spin interaction

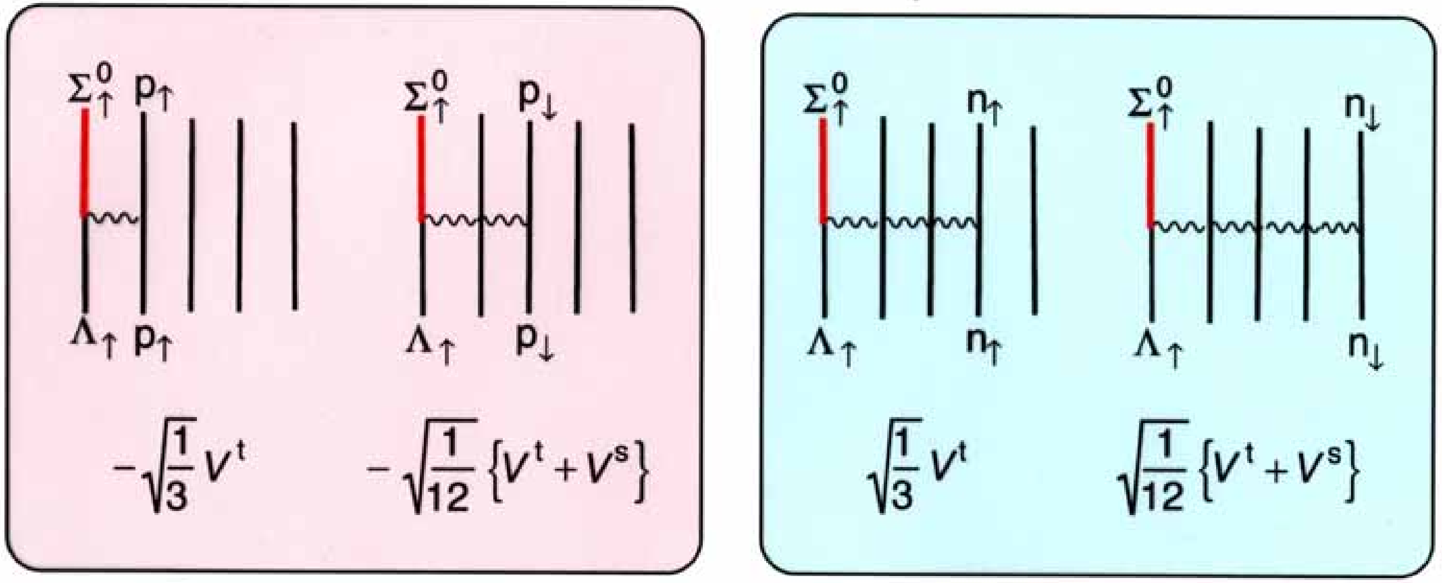
H. Tamura et al., Phys. Rev. Lett. **84** (2000) 5963







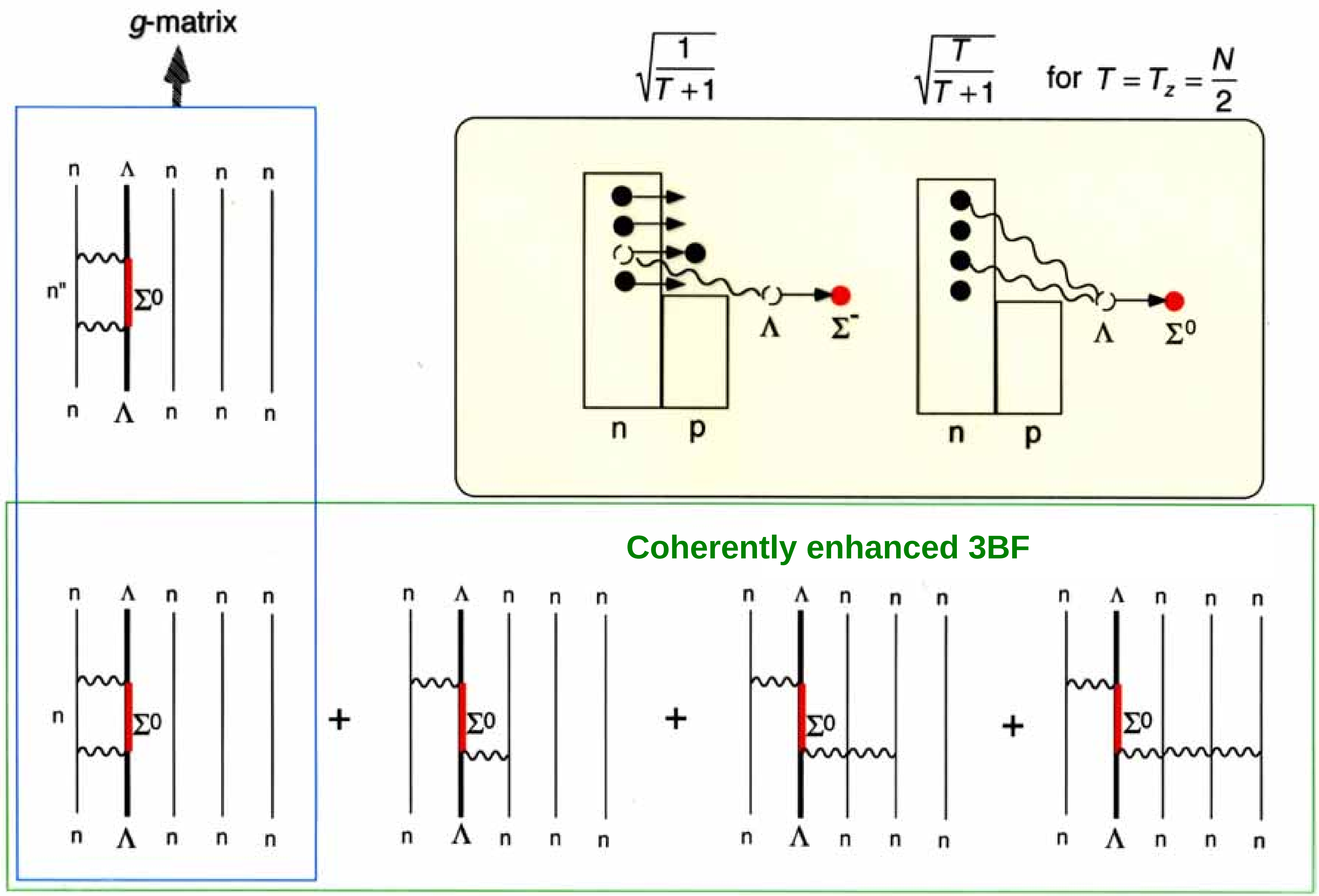
E. Hiyama et al., Nucl. Phys. **A639** (1998) 173c

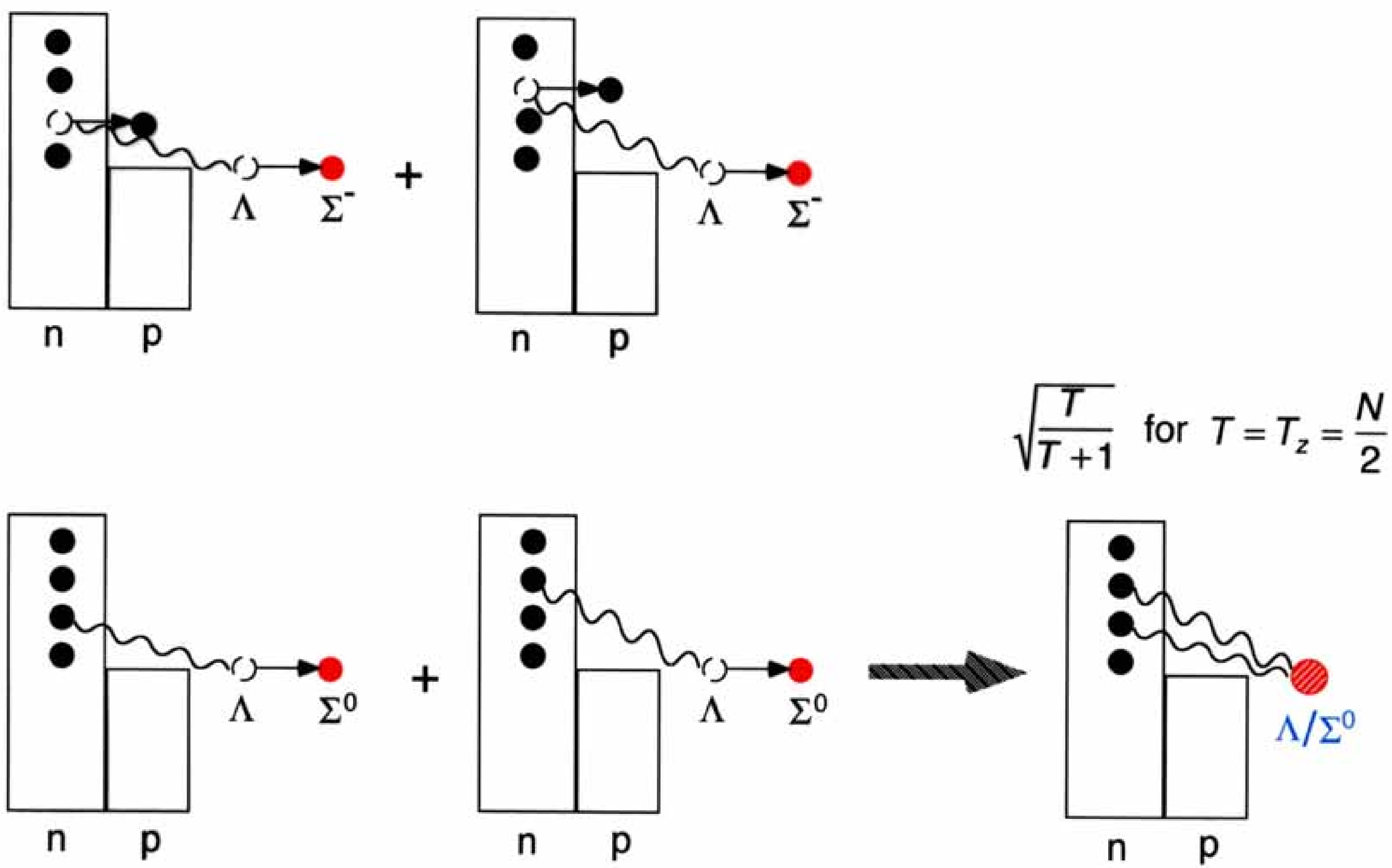


Proton contribution   Neutron contribution

Cancellation
due to isospin selection.

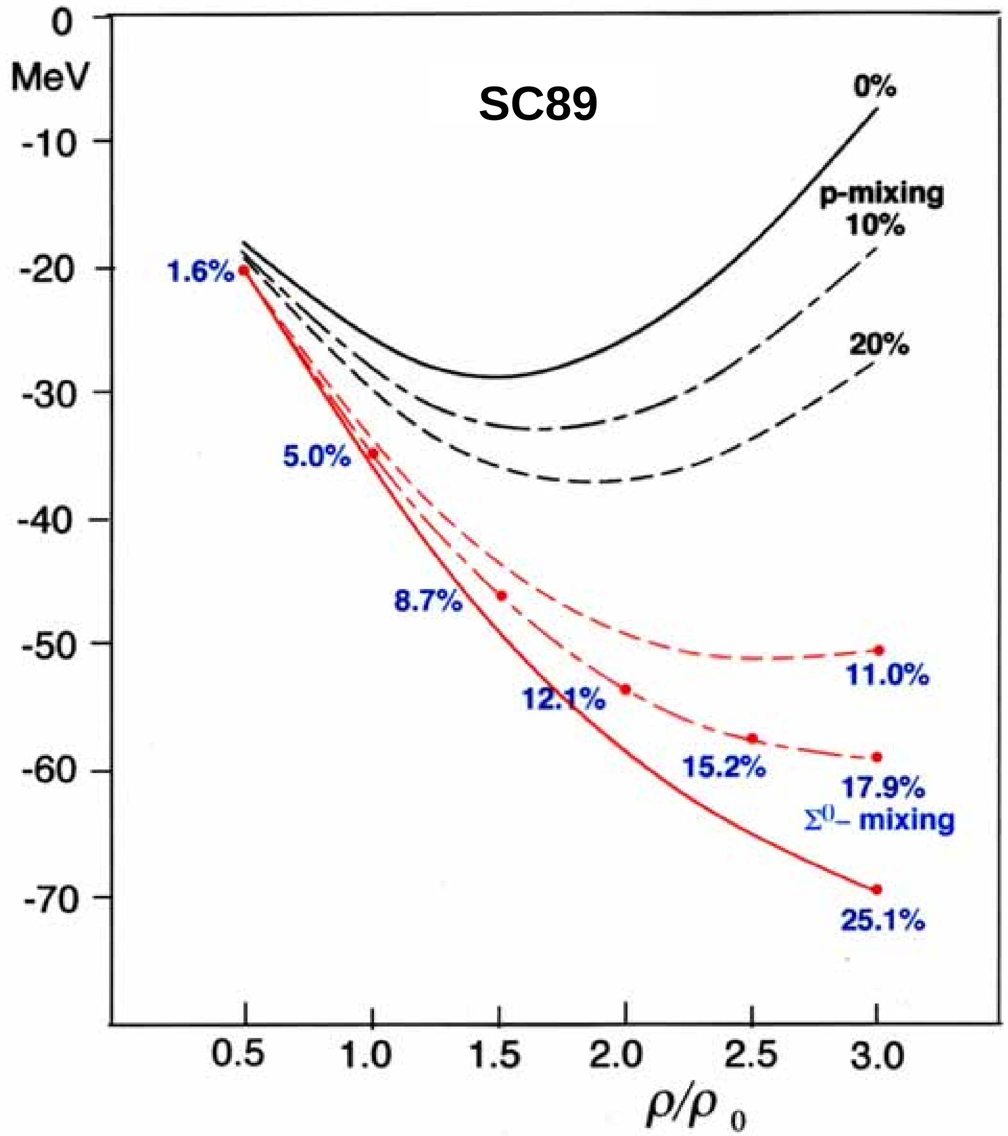
$$\left\{P^{+}_{\Sigma N}(^3S_1)V^tP_{\Lambda N}(^3S_1)+P^{+}_{\Sigma N}(^1S_0)V^sP_{\Lambda N}(^1S_0)\right\}\Lambda^{+}_{\uparrow}p^{+}_{\uparrow}p^{+}_{\downarrow}n^{+}_{\uparrow}n^{+}_{\downarrow}|0\rangle$$


g-matrix
$\sqrt{\frac{1}{T+1}}$
$\sqrt{\frac{T}{T+1}}$
for $T = T_z = \frac{N}{2}$
n p
Λ
Σ^-
Σ^0
n Λ n n n
n"
Σ0
Coherently enhanced 3BF
+



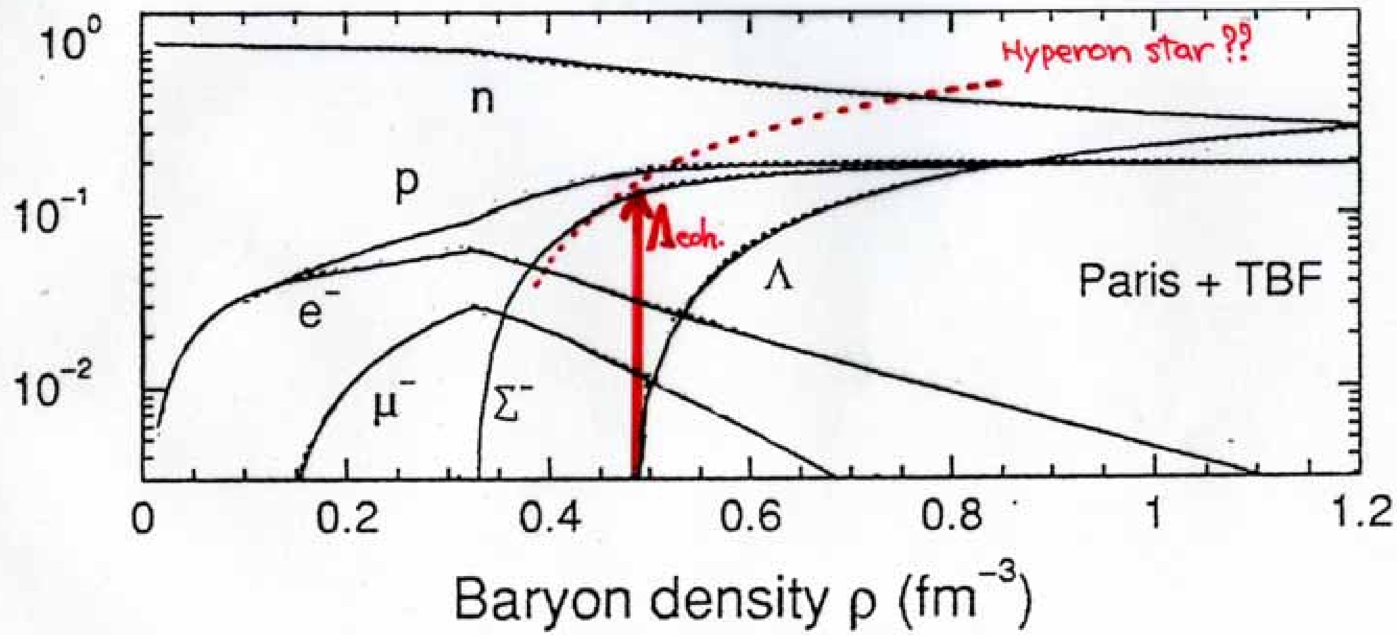
n
p
Λ
Σ⁻
+
n
p
Λ
Σ⁻
$\sqrt{\frac{T}{T+1}}$ for $T = T_z = \frac{N}{2}$
n
p
Λ
Σ⁰
+
n
p
Λ
Σ⁰
Λ/Σ⁰
n
p

U_Λ in neutron matter



Composition of neutron star matter

M. Baldo and G.F. Burgio, Phys. Rev. C61 (2000) 055801.
(Brueckner-Bethe-Goldstone theory)



Relativistic Mean-Field Model

Lagrangian density

$$L = L_B^0 + L_M^0 + L_{int}$$

Baryons : n, p, Λ, Σ^0, Σ^-

Mesons : σ, ρ, ω

For Λ and Σ^0

$$\left(\not{p} - \gamma^0 g_{\Lambda\Lambda\omega}\omega_0 - M_\Lambda + g_{\Lambda\Lambda\sigma}\sigma\right)\Lambda - \boxed{\gamma^0 g_{\Lambda\Sigma\rho}\rho_0}\Sigma^0 = 0$$

$$\left(\not{p} - \gamma^0 g_{\Sigma\Sigma\omega}\omega_0 - M_\Sigma + g_{\Sigma\Sigma\sigma}\sigma\right)\Sigma^0 - \boxed{\gamma^0 g_{\Sigma\Lambda\rho}\rho_0}\Lambda = 0$$

For mesons

$$m_\sigma^2\sigma = \sum g_{BB\sigma}\langle \bar{B}B\rangle$$

$$m_\omega^2\omega^0 = \sum g_{BB\omega}\langle \bar{B}\gamma^0 B\rangle$$

$$m_\rho^2\rho^0 = \sum g_{BB\rho}\langle \bar{B}\gamma^0 B\rangle + \boxed{g_{\Lambda\Sigma\rho}\left(\langle \bar{\Lambda}\gamma^0\Sigma\rangle + \langle \bar{\Sigma}\gamma^0\Lambda\rangle\right)}$$

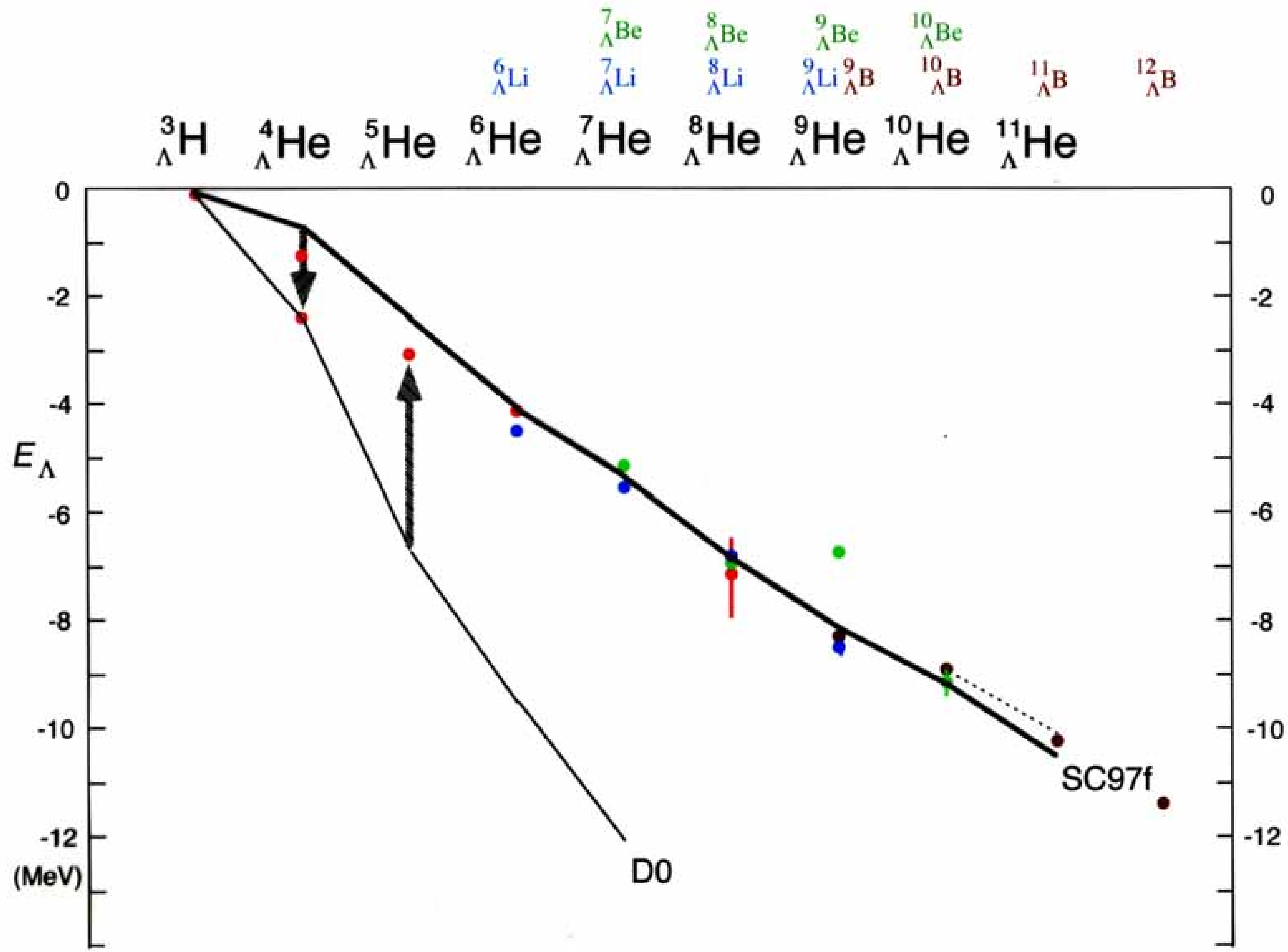
The normal state of infinite matter :

N.K. Glendenning, Astrophys. J. **293** (1985) 470.

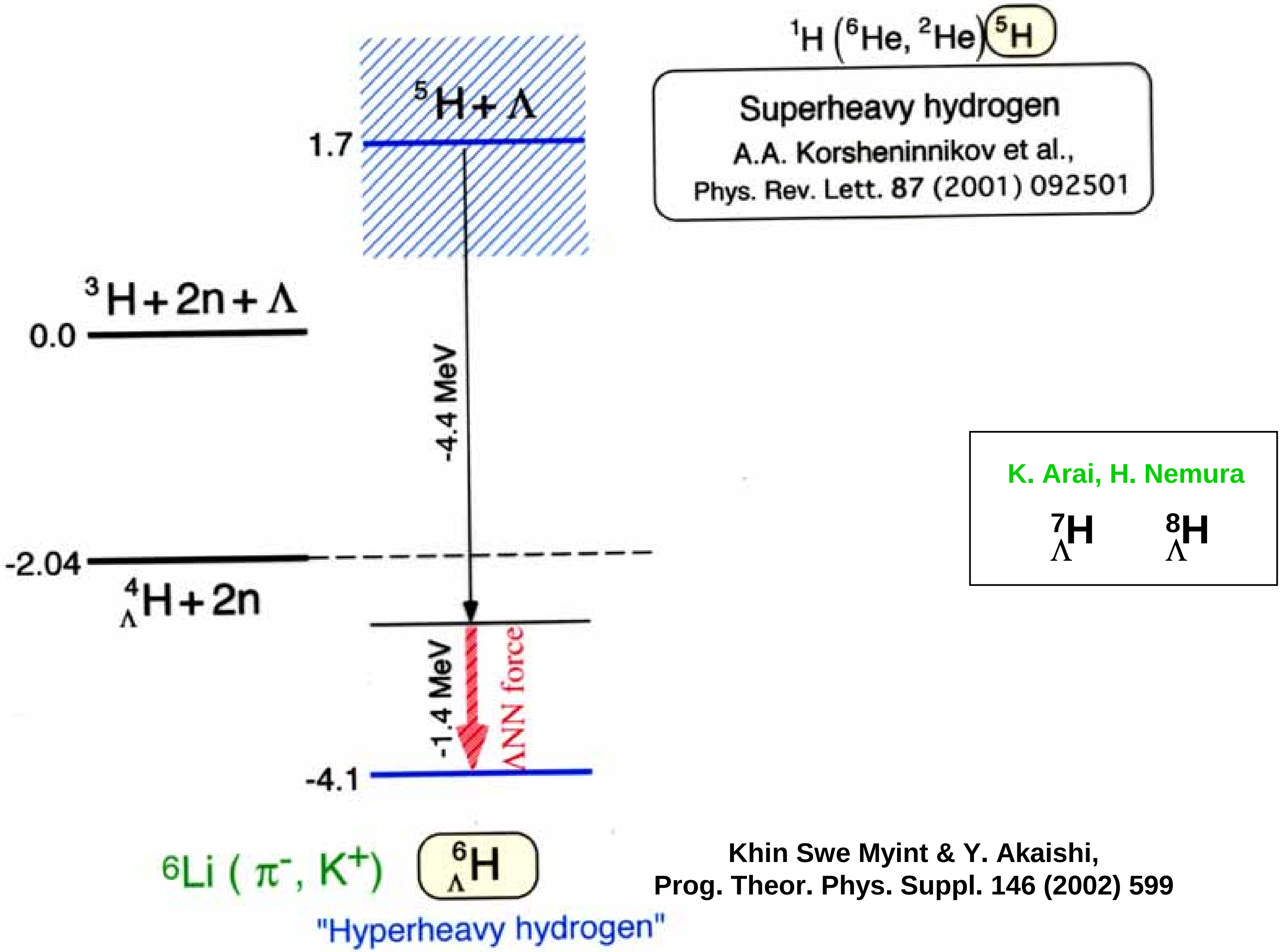
Baryons in the medium carry the same Q.N.'s as in vacuum.

$\boxed{} = 0$

M. Serra



$^{7}_{\Lambda}$Be
$^{8}_{\Lambda}$Be
$^{9}_{\Lambda}$Be
$^{10}_{\Lambda}$Be
$^{6}_{\Lambda}$Li
$^{7}_{\Lambda}$Li
$^{8}_{\Lambda}$Li
$^{9}_{\Lambda}$Li
$^{9}_{\Lambda}$B
$^{10}_{\Lambda}$B
$^{11}_{\Lambda}$B
$^{12}_{\Lambda}$B
$^{3}_{\Lambda}$H
$^{4}_{\Lambda}$He
$^{5}_{\Lambda}$He
$^{6}_{\Lambda}$He
$^{7}_{\Lambda}$He
$^{8}_{\Lambda}$He
$^{9}_{\Lambda}$He
$^{10}_{\Lambda}$He
$^{11}_{\Lambda}$He
E_{Λ}
(MeV)
0
-2
-4
-6
-8
-10
-12
SC97f
D0

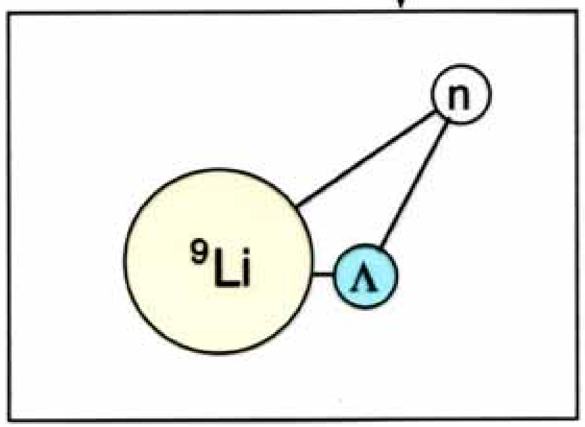


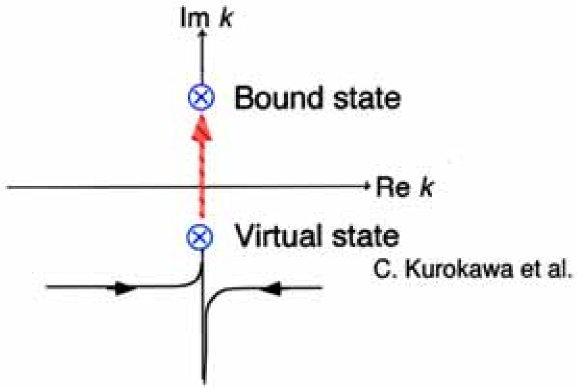
$^{1}H(^{6}He, ^{2}He)^{5}H$
Superheavy hydrogen
A.A. Korsheninnikov et al.,
Phys. Rev. Lett. 87 (2001) 092501
$^{5}H + \Lambda$
1.7
$^{3}H + 2n + \Lambda$
0.0
-4.4 MeV
K. Arai, H. Nemura
$^{7}_{\Lambda}H$ $^{8}_{\Lambda}H$
-2.04
$^{4}_{\Lambda}H + 2n$
-1.4 MeV
ΛNN force
-4.1
$^{6}Li(\pi^{-}, K^{+})$ $^{6}_{\Lambda}H$
"Hyperheavy hydrogen"
Khin Swe Myint & Y. Akaishi,
Prog. Theor. Phys. Suppl. 146 (2002) 599

Double-charge & Strangeness Exchange Reaction

$^{10}\mathrm{B}(\pi^-, K^+)\boxed{^{10}_{\Lambda}\mathrm{Li}} = {}^{6}_{\Lambda}\mathrm{H} + \alpha = {}^{4}_{\Lambda}\mathrm{H} + 2n + \alpha$

$^{11}\mathrm{B}(\pi^-, K^+)\boxed{^{11}_{\Lambda}\mathrm{Li}}$





YN interaction from p-shell nucleons

$$\frac{22}{27}\,{}^3g^{E,O}_{\Sigma N} + \frac{14}{27}\,{}^1g^{E,O}_{\Sigma N} : \left(T = \tfrac{3}{2}\right)$$

$$\frac{23}{27}\,{}^3g^{E,O}_{\Sigma N} + \frac{17}{54}\,{}^1g^{E,O}_{\Sigma N}$$

$$\frac{4\sqrt{5}}{9}\,{}^3g^{E,O}_{\Sigma N,\Lambda N} + \frac{\sqrt{5}}{18}\,{}^1g^{E,O}_{\Sigma N,\Lambda N}$$

$$\frac{5}{3}\,{}^3g^{E,O}_{\Lambda N} + \frac{5}{6}\,{}^1g^{E,O}_{\Lambda N}$$

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

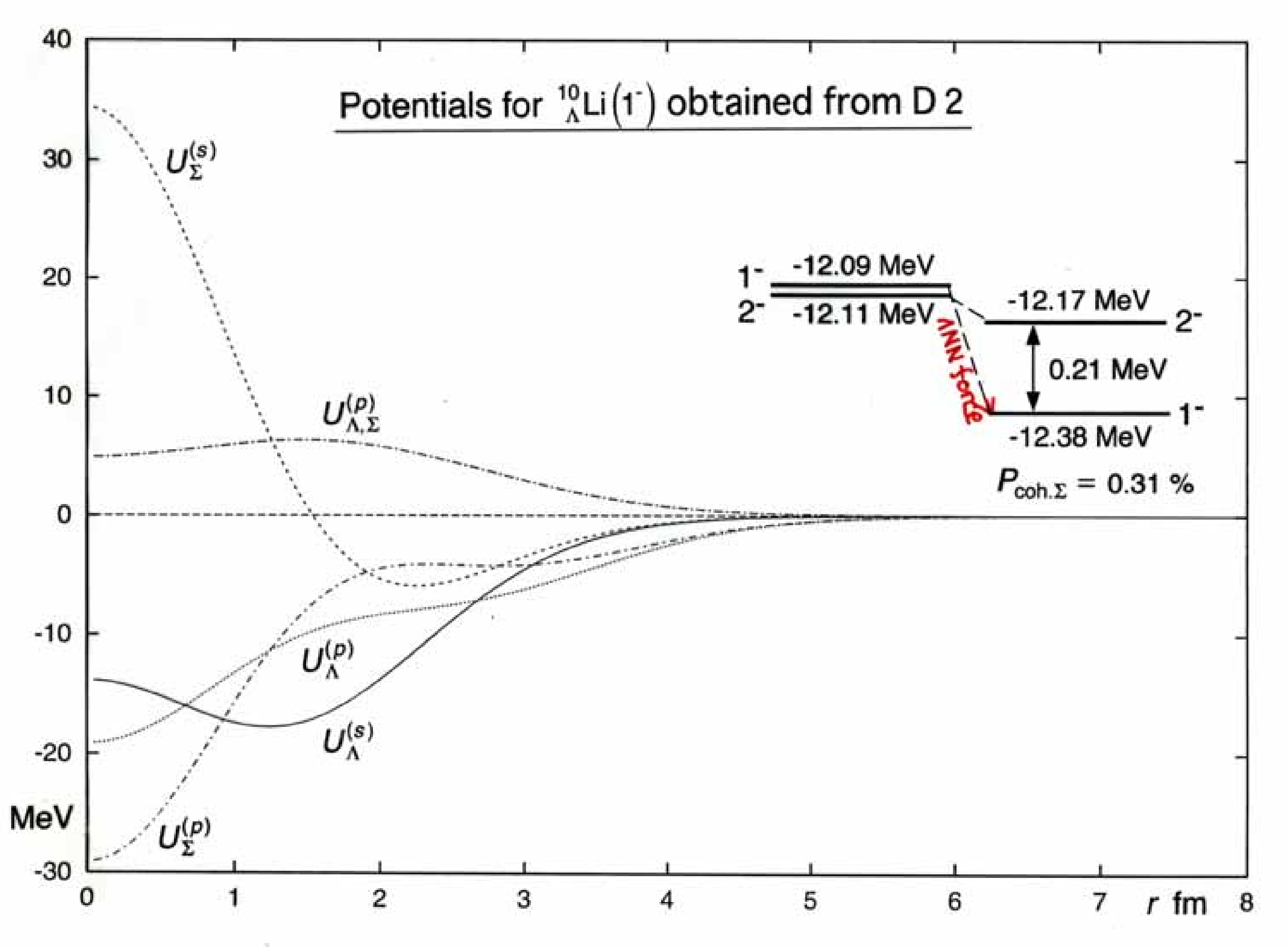
$$\frac{10}{9}\,{}^3g^{E,O}_{\Sigma N} + \frac{2}{9}\,{}^1g^{E,O}_{\Sigma N} : \left(T = \tfrac{3}{2}\right)$$

$$\frac{8}{9}\,{}^3g^{E,O}_{\Sigma N} + \frac{5}{18}\,{}^1g^{E,O}_{\Sigma N}$$

$$\frac{\sqrt{5}}{3}\,{}^3g^{E,O}_{\Sigma N,\Lambda N} + \frac{\sqrt{5}}{6}\,{}^1g^{E,O}_{\Sigma N,\Lambda N}$$

$$2\,{}^3g^{E,O}_{\Lambda N} + \frac{1}{2}\,{}^1g^{E,O}_{\Lambda N}$$

${}^{10}_{\Lambda}\mathrm{Li}\ (2^-)$

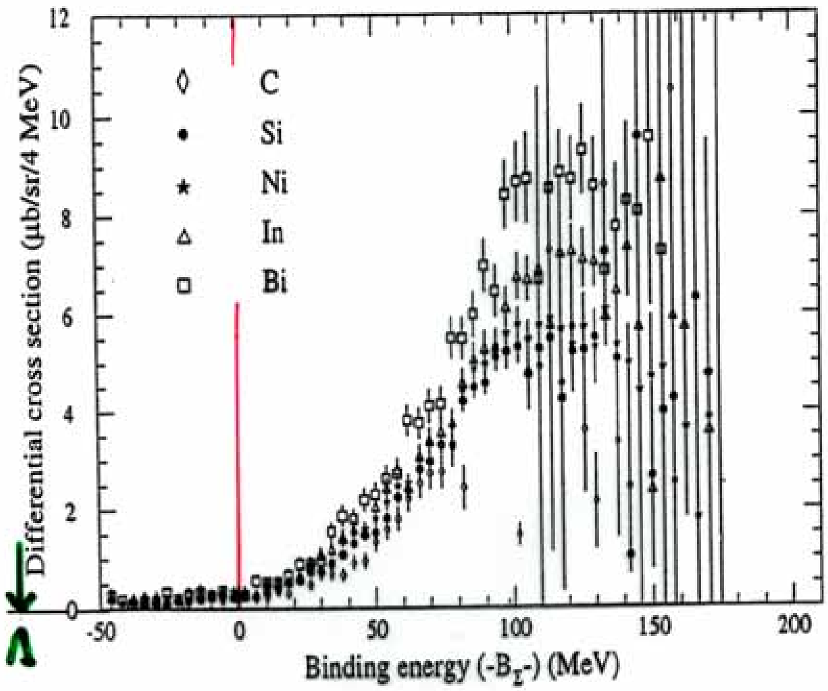


AMD cal.; Y. Enyo, A. Dote et al.

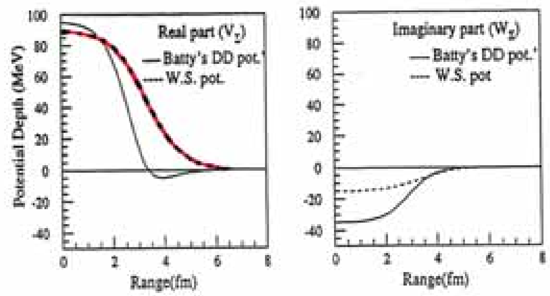
Double-Charge Exchange Experiment
(π^-, K^+) at KEK

H. Noumi, P.K. Saha et al., Phys. Rev. Lett. **89** (2002) 072301

Σ^-



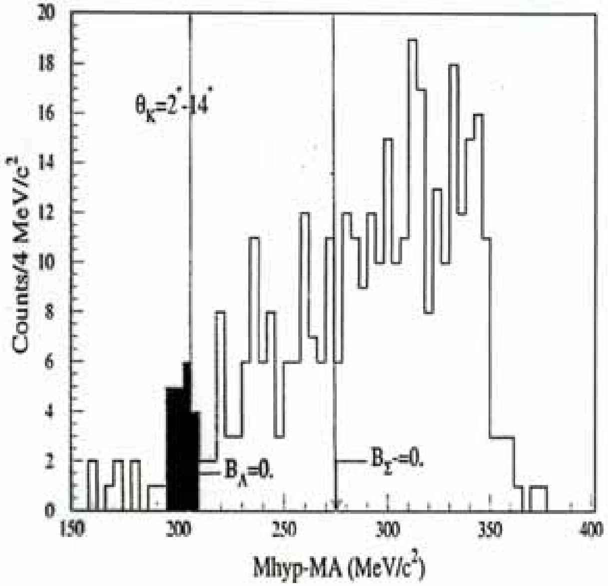
Strongly repulsive !?

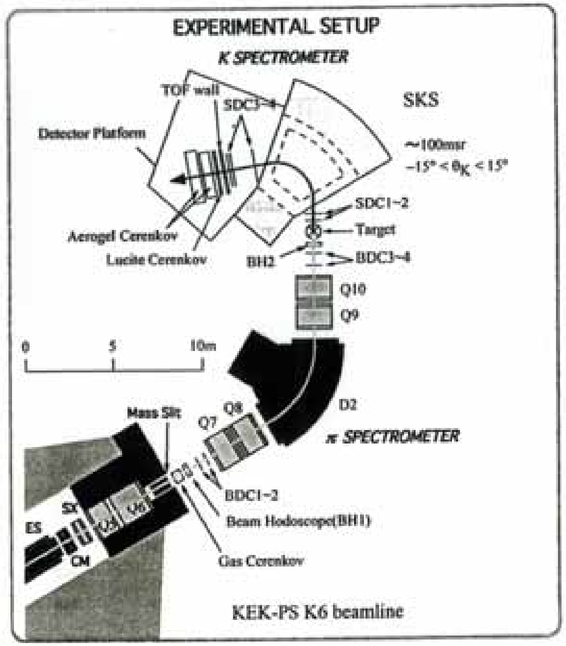


$^{12}C(\pi^-, K^+)$ spectrum from the CH_2 target

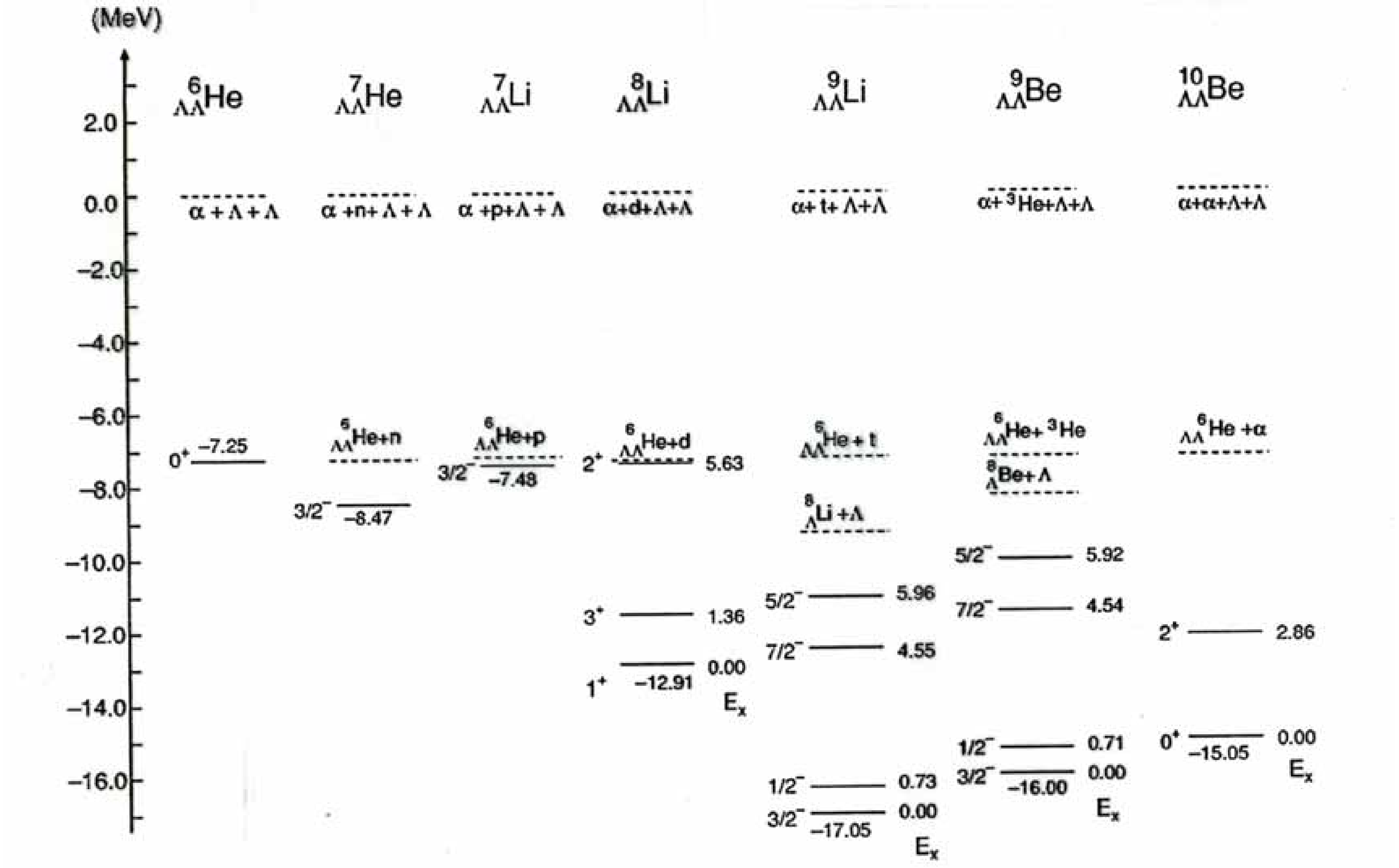
by Saha, Fukuda, Noumi

H contribution from CH_2 is removed

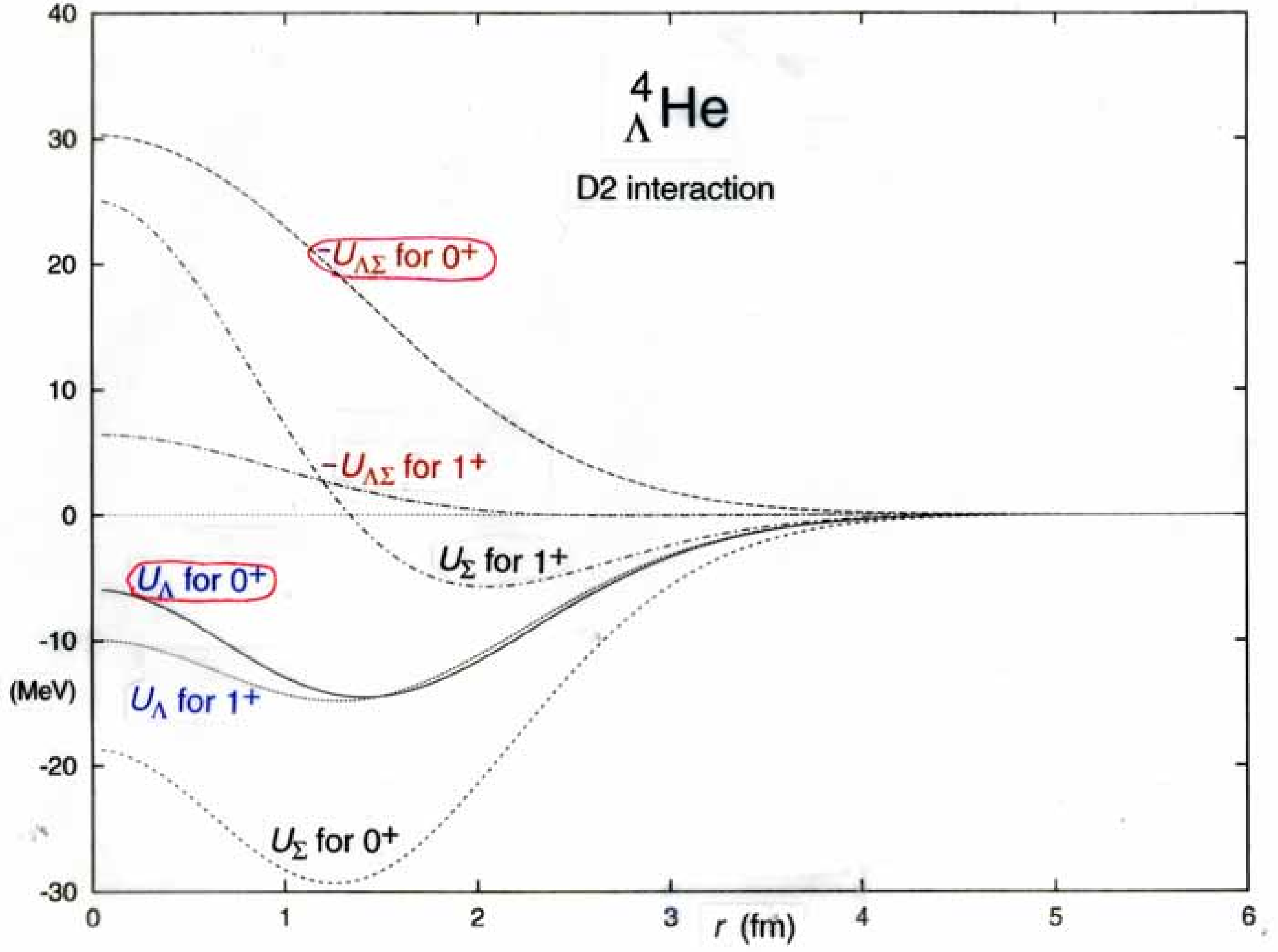




$^{10}B\ (\pi^-, K^+)$; **W. Imoto, P.K. Saha et al.; this evening**

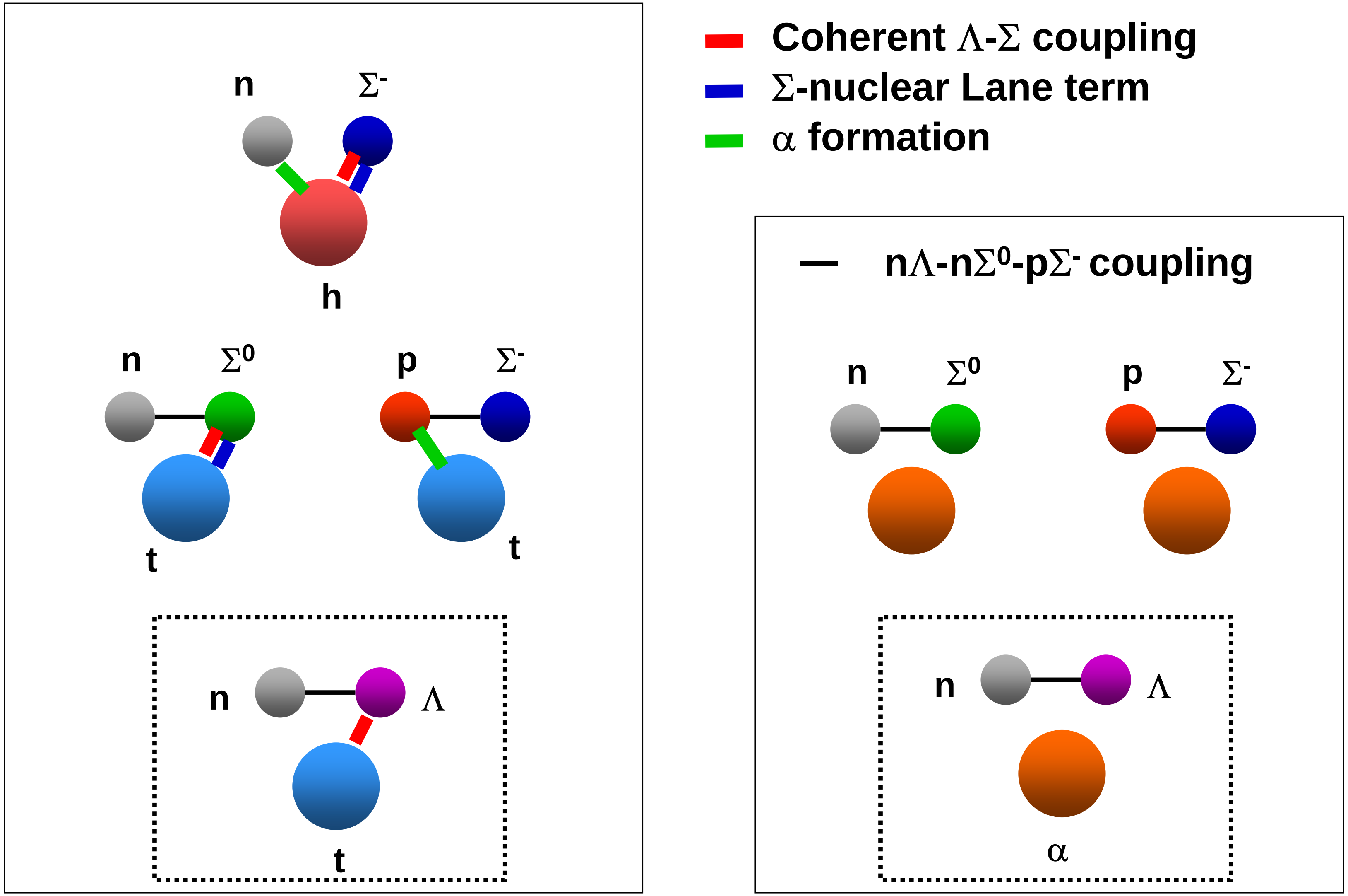


E. Hiyama, M. Kamimura, T. Motoba, T. Yamada & Y. Yamamoto, Phys. Rev. C **66** (2002) 024007.

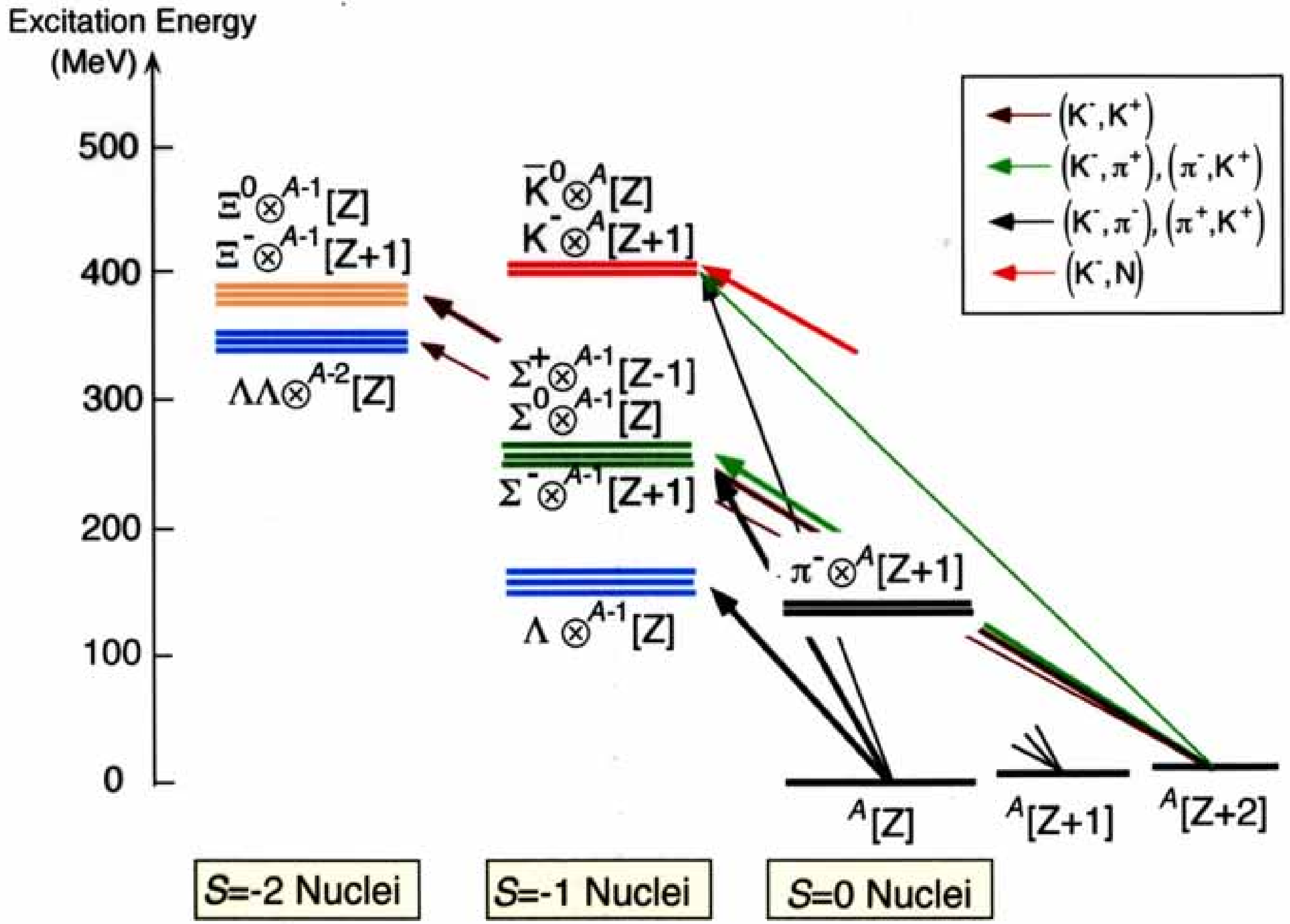


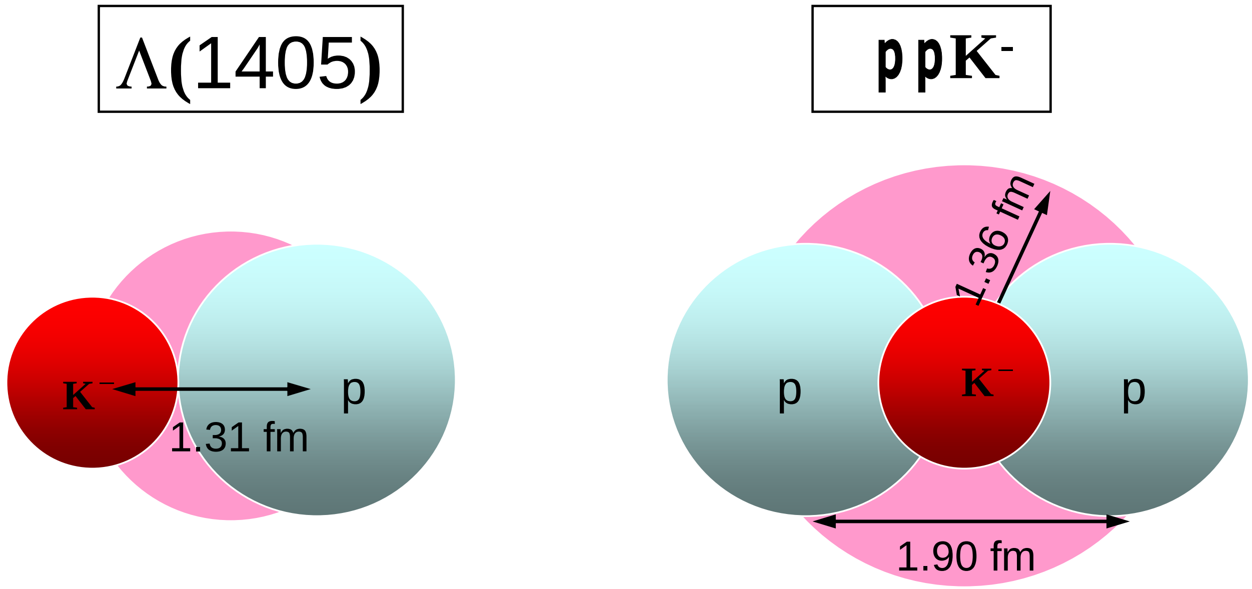
$^{4}_{\Lambda}$He
D2 interaction
$-U_{\Lambda\Sigma}$ for 0^+
$-U_{\Lambda\Sigma}$ for 1^+
U_Σ for 1^+
U_Λ for 0^+
U_Λ for 1^+
U_Σ for 0^+
(MeV)
r (fm)
40
30
20
10
0
-10
-20
-30
0
1
2
3
4
5
6

Coupling Scheme



Yamazaki's diagram





Λ(1405)
ppK-
K−
p
1.31 fm
p
K−
p
1.36 fm
1.90 fm