KEK theory center workshop on
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Production of ΣNN quasibound states

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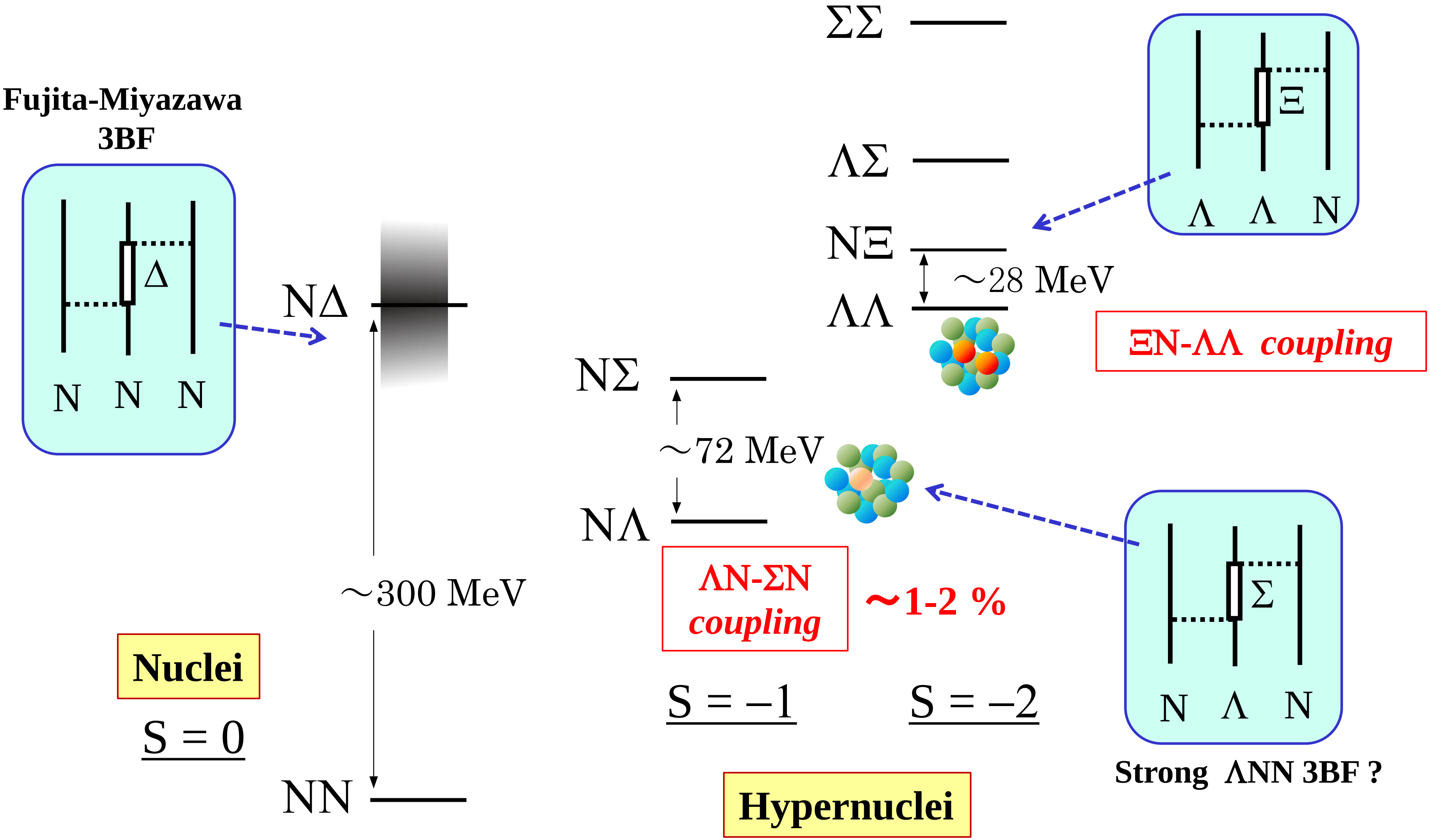
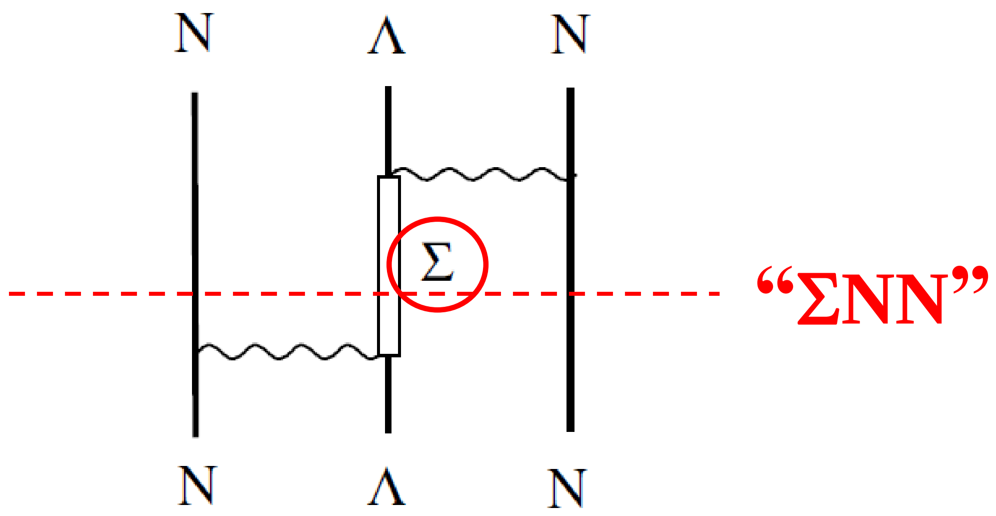
Dynamics in Strangeness Nuclear Systems



- Various effects on the hyperon mixing
- Related to the 3BF in nuclei

Keyword: ***Hyperon-mixing***

Important role of
Σ hyperons in nuclear matter



ΛNN 3BF

A=3, ΣNN

PHYSICAL REVIEW C 47, 1000 (1993)

Resonances in Λd scattering and the Σ hypertriton

I.R. Afnan, B.F. Gibson

Separable pot.+Faddeev calc.

"This suggests that a certain class of ΛN-ΣN potentials we can form a Σ hypertriton with a width of about 8 MeV."

Nuclear Physics A 611 (1996) 461–483

Structure of the $A = 3$ Σ-hypernuclei

Yoshimitsu H. Koike[a,1], Toru Harada[b,c,2]

"There exist unstable bound (quasibound) states of S=1/2, T=1 ($_{\Sigma}{}^{3}$H, $_{\Sigma}{}^{3}$He, $_{\Sigma}{}^{3}$n), due to the coupling through the ΣN potential which strongly admixtures $^{3}S_{1}$, T_{NN}=0 and $^{1}S_{0}$, T_{NN}=1 states in the NN pair."

PHYSICAL REVIEW C 76, 034001 (2007)

ΛNN and ΣNN systems at threshold. II. The effect of D waves

H. Garcilazo, A. Valcarce, T. Fernandez-Carames

Chiral constituent quark model pot+ Faddeev calc.

"We find that the ΣNN system has a quasibound state in the (I,J)=(1,1/2) channel very near threshold with a width of about 2.1 MeV. "

Our Purpose

- We demonstrate the inclusive and semi-exclusive spectra in the ^{3}He($K^{-},\pi^{\mp}$) reactions theoretically within a distorted-wave impulse approximation by using a coupled (2N-Λ)+(2N-Σ) model with a *spreading* potential.

- *Is there a quasibound in ΣNN systems ?*

I will focus on
(1) the structure of the ΣNN quasibound states,
(2) the ΣNN signal appeared in the π^{-} and π^{+} spectra,
(3) an important role of the channel coupling in ΣNN.

Keyword: ***Hyperon-mixing***

Outline

1. Σ hyperon in nuclei (Introduction)

2. Calculations

   - Microscopic Y-(2N) folding-model potential

   - ΣNN quasibound states $^{3}_{\Sigma}\mathrm{He}$, $^{3}_{\Sigma}\mathrm{H}$, $^{3}_{\Sigma}\mathrm{n}$

   - Production within DWIA (K^-, π^-), (K^-, π^+) reactions

3. Results and Discussion

   - π^- and π^+ spectra for the ΣNN quasibound states $^{3}_{\Sigma}\mathrm{He}$, $^{3}_{\Sigma}\mathrm{n}$

   - no peak of the π^+ spectrum in BNL-E774 data

4. Summary

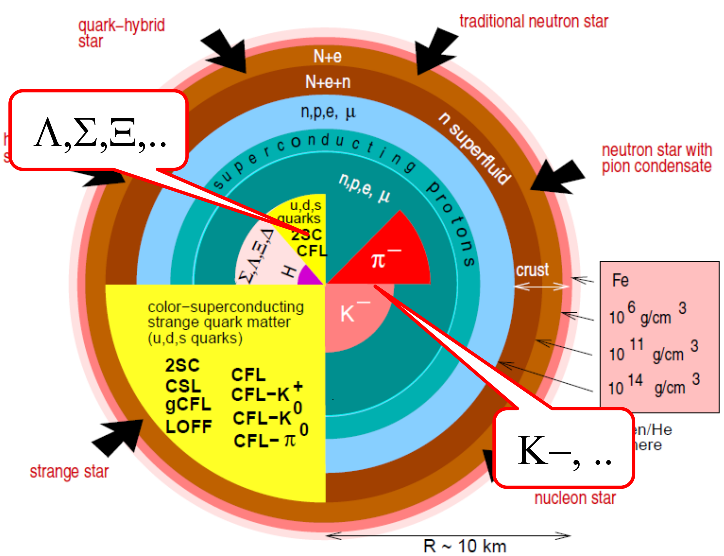
1. Σ hyperon in nuclei

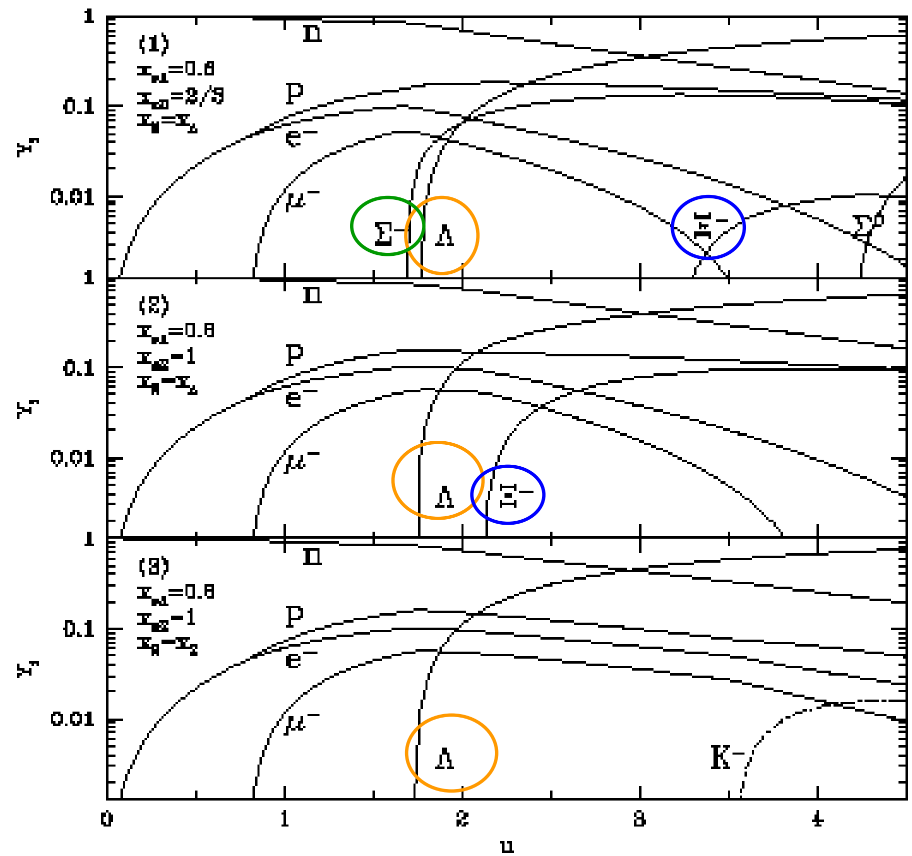
(Introduction)

Study of a Σ-hyperon in Nuclei (1)

- **Neutron star core**
  = "An interesting neutron-rich hypernuclear system"

[F. Weber, PPNP 54(2005)193]





attractive

$U_\Sigma < 0$

$U_\Xi < 0$

repulsive

$U_\Sigma > 0$

$U_\Xi < 0$

$U_\Sigma > 0$

$U_\Xi > 0$

[R. Knorren, M. Prakash, P.J.Ellis, PRC52(1995)3470]

NS cooling processes
(Direct/Modified Uruca)

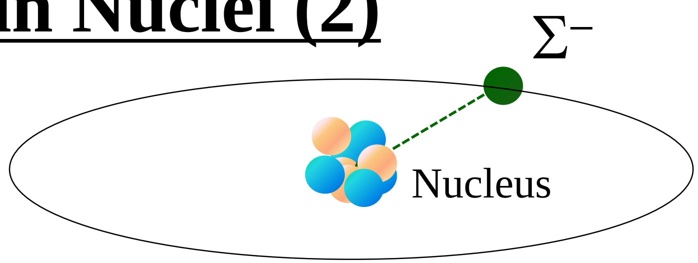
$\Lambda \rightarrow p + e^- + \bar{\nu}_e$

$\Sigma^- \rightarrow \Lambda + e^- + \bar{\nu}_e$

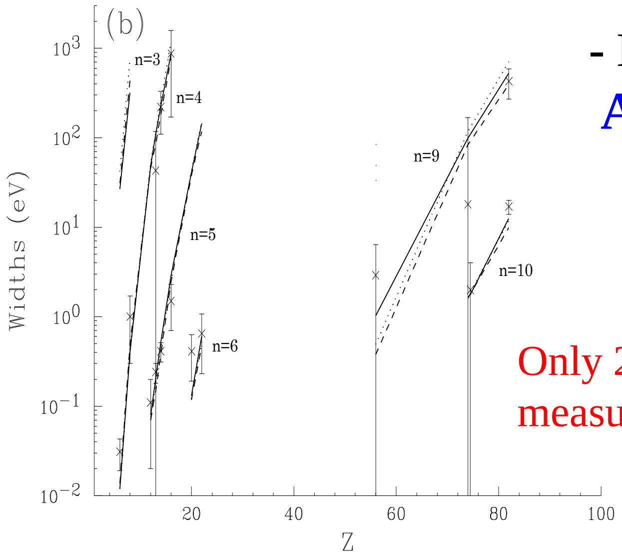
Negative charged particle

Behavior of Σ^- hyperon in nuclear medium is very important to understand properties of Neutron star core.

Study of a Σ-hyperon in Nuclei (2)



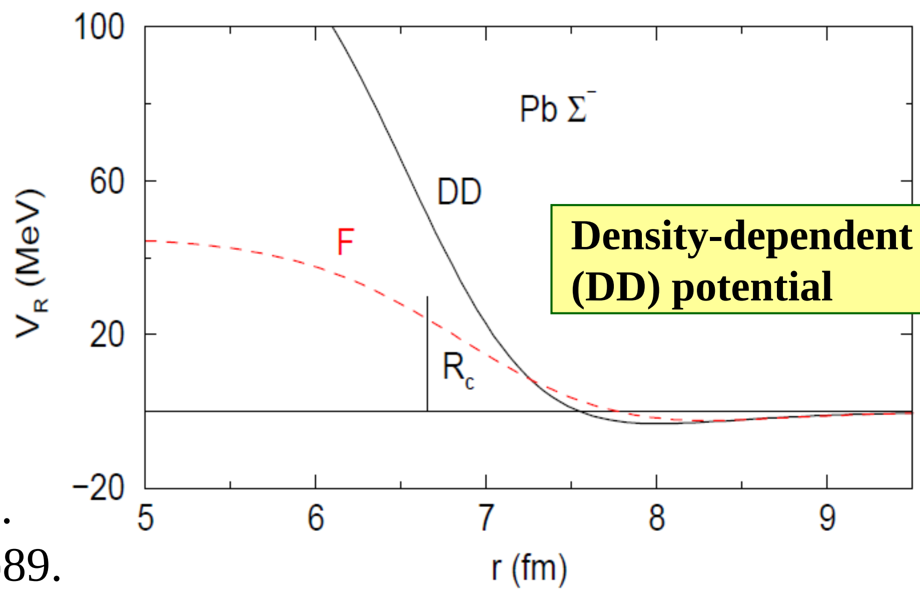
- **Analysis of the shifts and widths of the Σ^- atomic X-ray data**



- Batty-Gal-Toker, NPA402(1983)349: the earlier analysis

Attractive in the real part of Σ-potential (–27 MeV)

Only 23 measurements !!



Density-dependent (DD) potential

- Batty-Friedman-Gal, PTP.Suppl.117(1994) 227.
- E. Friedman and A. Gal, Phys. Rep. 452 (2007)89.

Repulsion inside the nucleus and shallow attraction outside the nucleus

Due to the insufficient quality of the these data, the potential is not so sensitive to the radial behavior of U_Σ inside the nucleus.

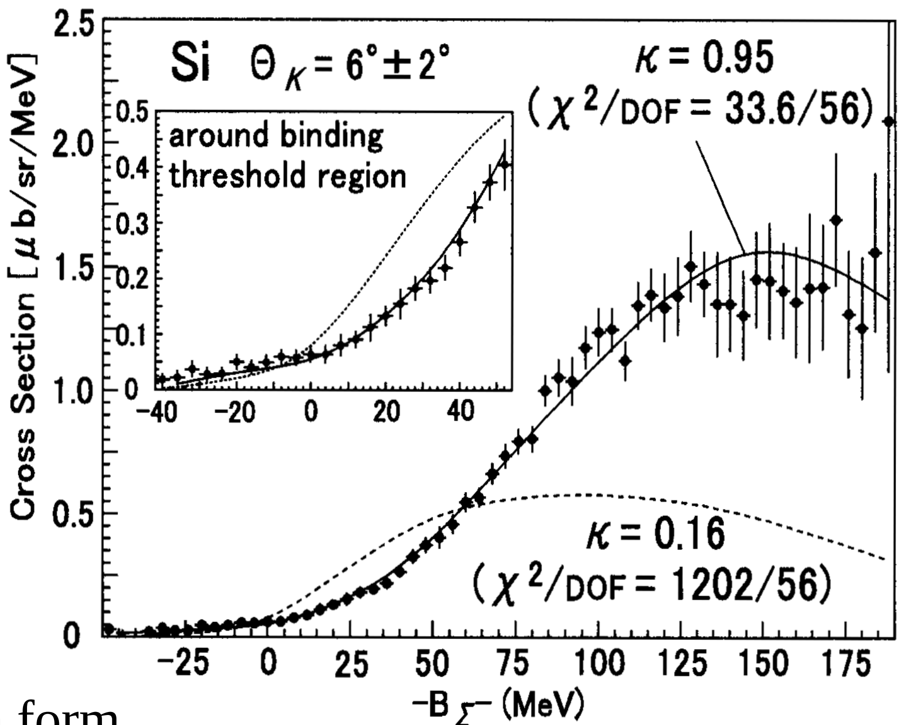
Study of a Σ-hyperon in Nuclei (3)

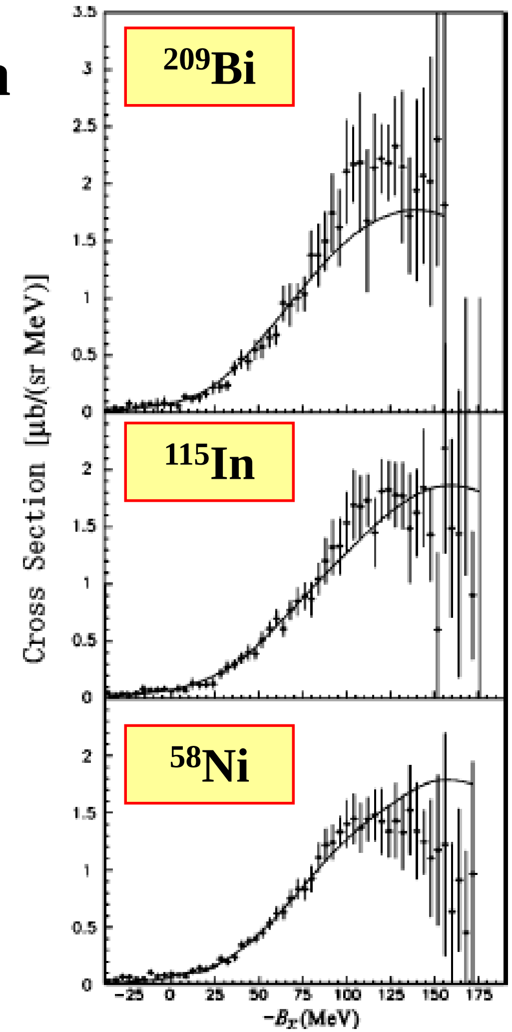
- **DWIA analysis of the (π^-,K^+) inclusive spectra**

H.Noumi, et al. PRL89(2002)072301
P.K.Saha, et al., PRC70(2004)044613

C, Si, Ni, In, Bi

^{28}Si





Woods-Saxon form

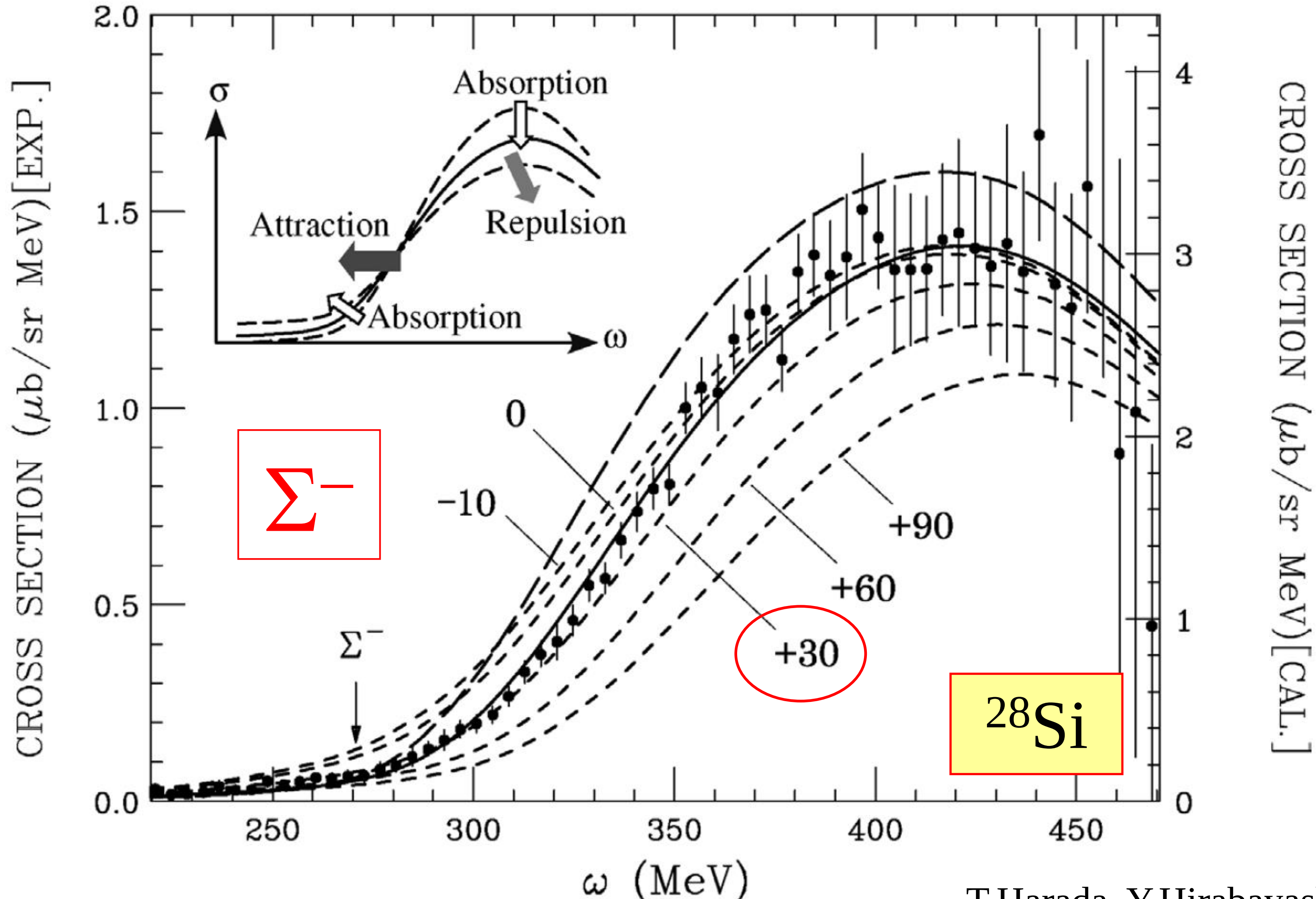
$$U_\Sigma = \frac{V_\Sigma + iW_\Sigma}{1 + \exp[(r-R)/a]}$$

(V, W) = (+90 MeV, –40MeV)

This analysis suggests that the Σ-nucleus potential has a repulsion with a sizable imaginary.

Inclusive spectrum in $^{28}Si(\pi^{-}, K^{+})$ reaction at 1.2GeV/c

Exp. Data from P.K.Saha, H. Noumi, et al., PRC70(2004)044613



$(V_\Sigma, W_\Sigma) = (+30, -40)$ MeV by χ^2/N-fitting

T.Harada, Y.Hirabayashi, NPA759 (2005) 143

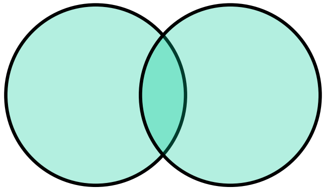
Short-range repulsive core in baryon-baryon intreaction

Quark Cluster Model

M.Oka,K.Shimizu,K.Yazaki, PLB130(1983)365; NPA464(1987)700

Spin-flavor SU(6) symmetry

Quark-exchange
(anti-symmetrized)



symmetric antisymmetric

$$[3]\otimes[3]=[6]\oplus[42]\oplus[51]\oplus[33]$$

orbital x flavor-spin x color singlet ↓ L=0

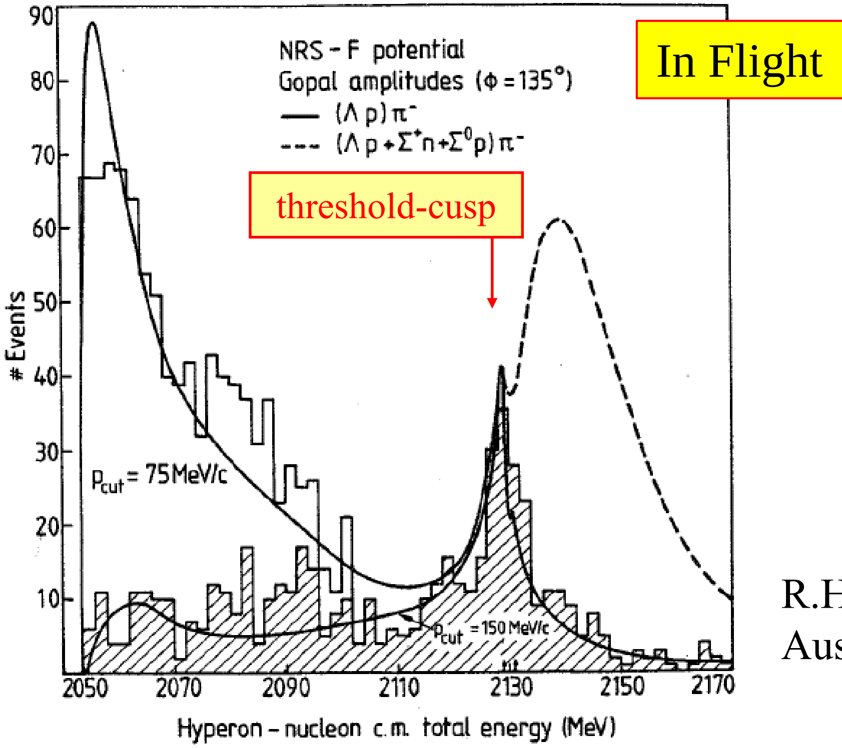
Pauli forbidden state

S = 0 state	**[51]**	**[33]**	
1			ΛΛ-ΞN-ΣΣ(I=0), H-dibaryon
$\mathbf{8_S}$	**1**		ΣN(I=1/2,$^1S_0$) ***Pauli forbidden***
27	4/9	5/9	NN($^1S_0$)

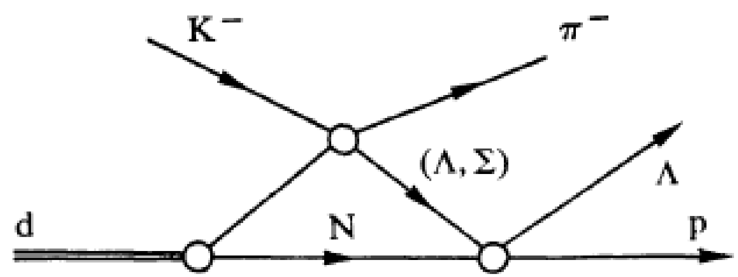
S = 1 state	**[51]**	**[33]**	
$\mathbf{8_A}$	5/9	4/9	
10	**8/9**	1/9	ΣN(I=3/2,$^3S_1$) ***almost Pauli forbidden***
10*	4/9	5/9	NN($^3S_1$), ΛN-ΣN(I=1/2, $^3S_1$)

- **SU(6) symm. → Strongly spin-isospin dependence**

ΣN threshold cusp (I =1/2, $^3S_1$) in $K^- d \to \pi^- \Lambda p$ Reactions

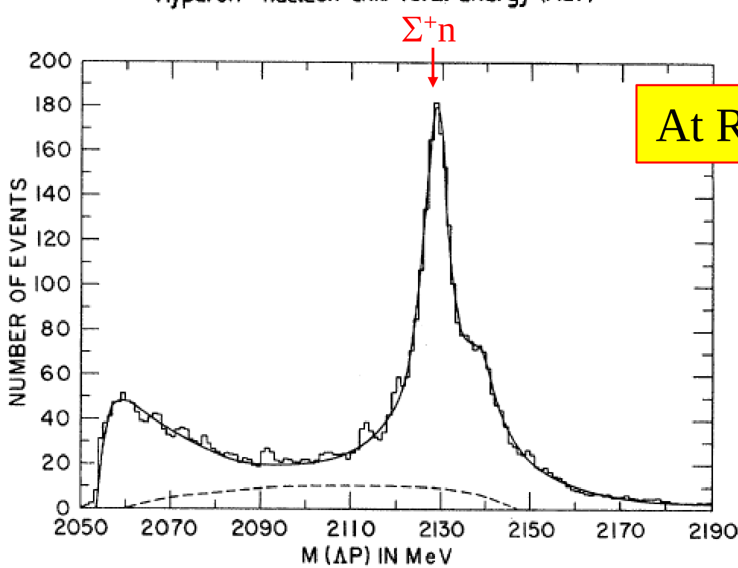


ΣN $^3S_1$ [10*]:
"Strangeness partner of deuteron"

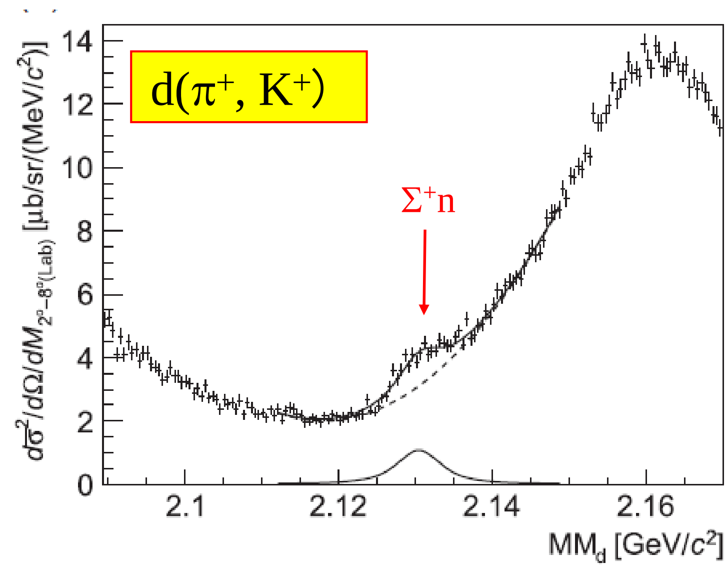


R.H.Dalitz, A. Deloff,
Aust. J. Phys., 36 (1983) 617

Y. Ichikawa et al.,
PTEP2014, 101D03



T.H.Tan,
PRL23(1969)395.



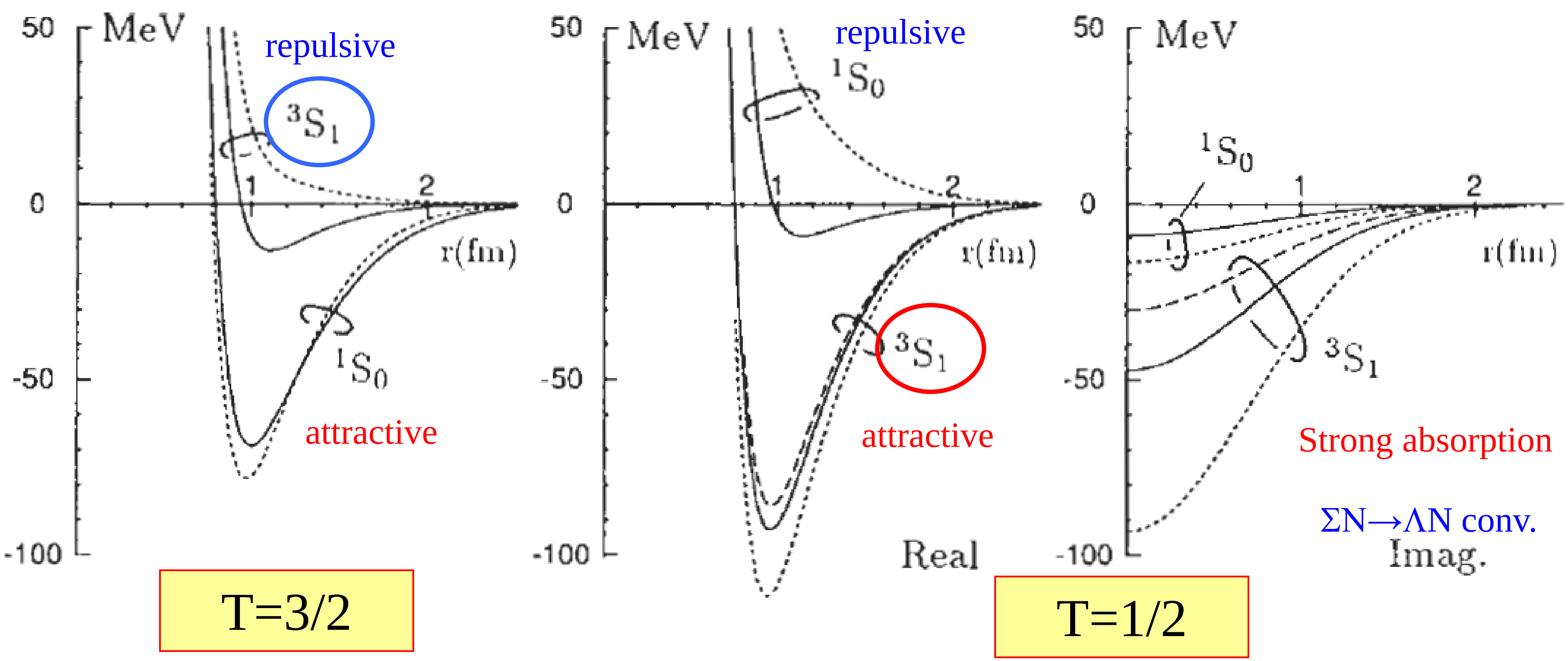
Two-body ΣN potentials in free space

Simple, But easy to understand

Effective Sigma-nucleon (absorptive) potential : SAP

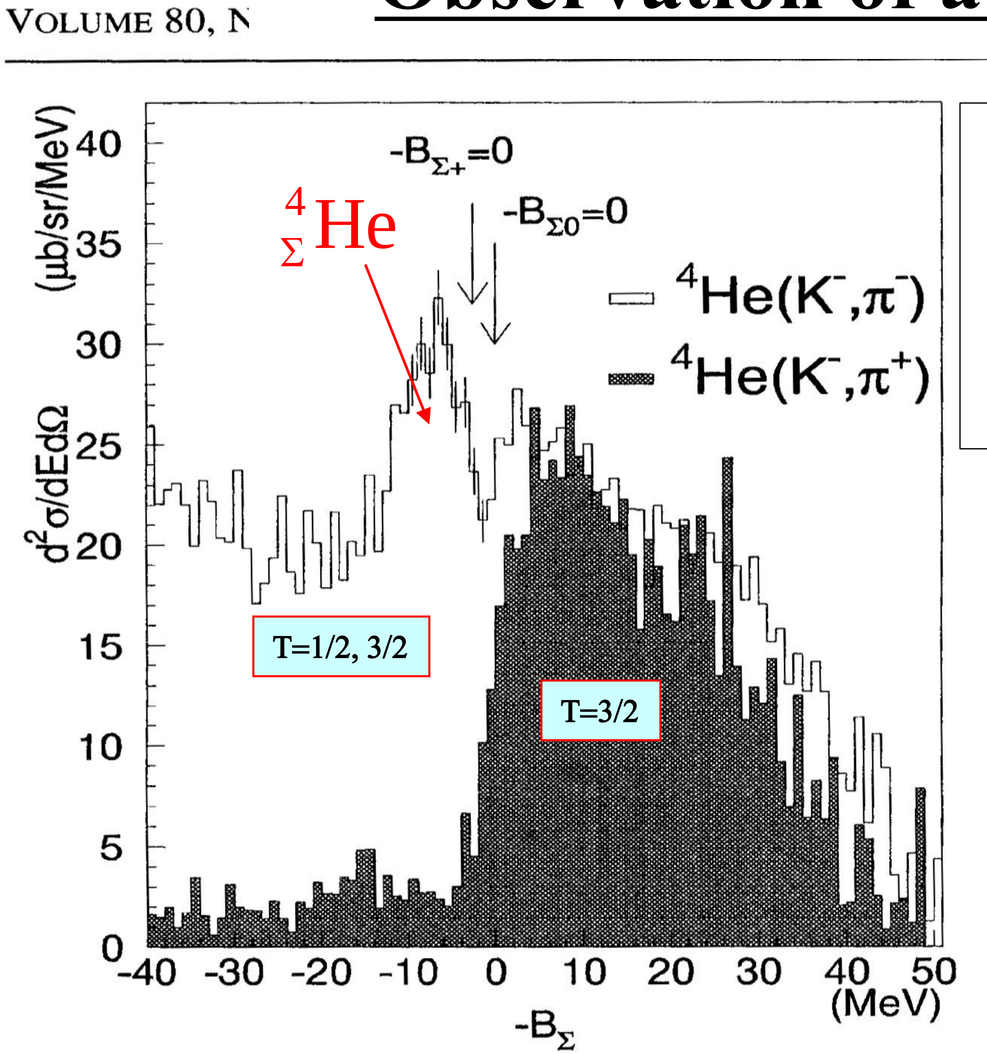
T.Harara, S.Shinmura, Y.Akaishi, H.Tanaka, NPA507 (1990) 715.

S-matrix equivalent to Nijmegen model-D (model-F)



➢ *There is strong spin-isospin dependence in ΣN potential.*

Observation of a ${}^{4}_{\Sigma}$He Bound State



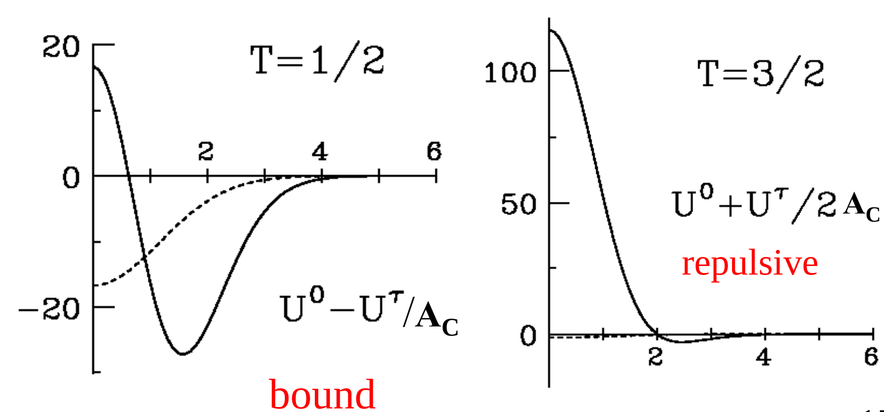
$$B_{\Sigma^+} = 4.4 \pm 0.3 \text{ MeV}$$
$$\Gamma = 7 \pm 0.7 \text{ MeV}$$
$$J^{\pi} = 0^{+} \quad T \simeq 1/2$$

@BNL-AGS

T. Nagae, et al., PRL. 80(1998)1605.

BBBB (T=1/2,S=0) [28*]:
"Strangeness partner of α-particle"

Σ-3N potentials



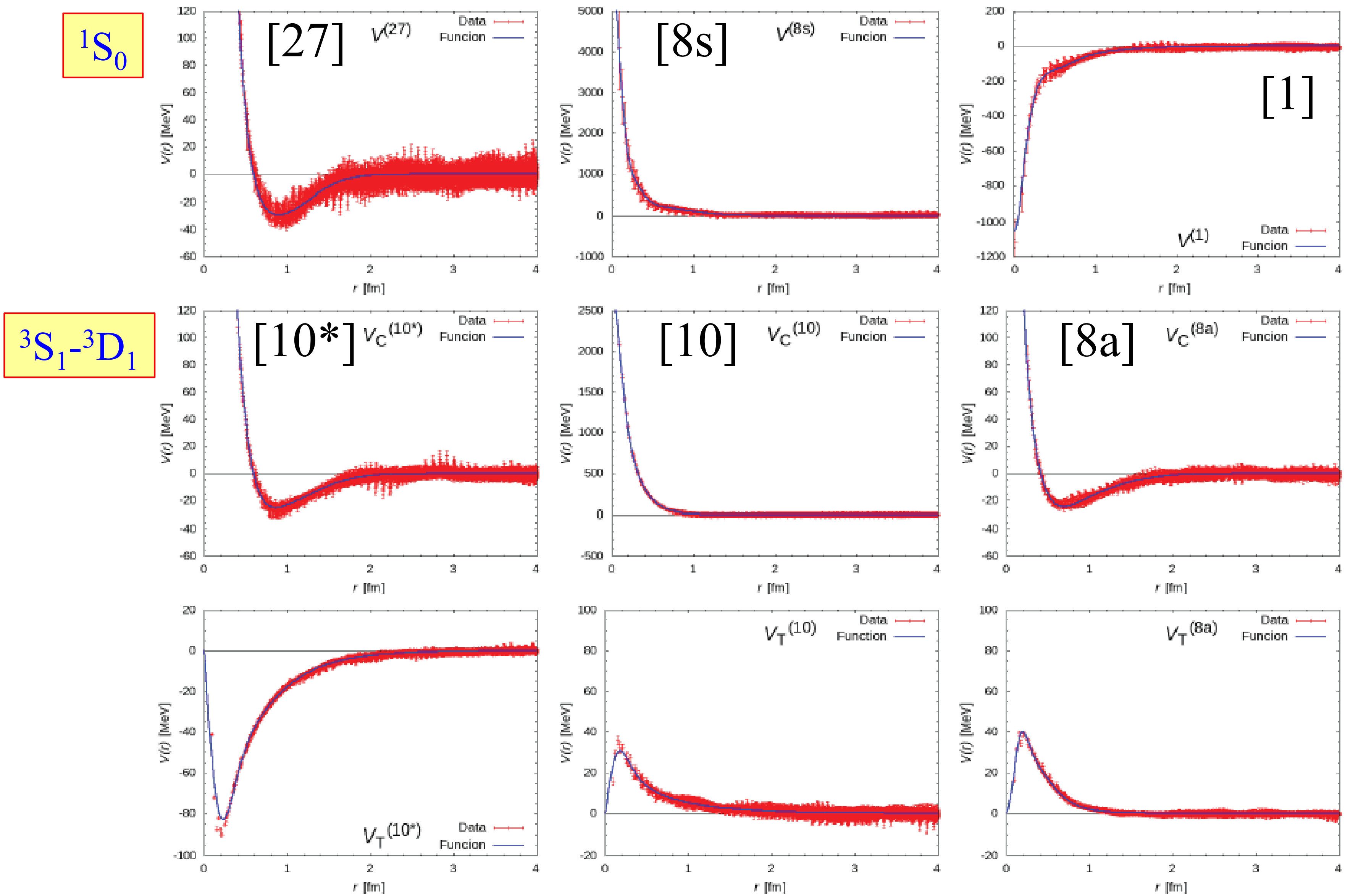
Theoretical calculation

T. Harada, et al., NPA507(1990)715.

Baryon-Baryon force in SU(3) basis from lattice QCD

T. Inoue et al., HAL QCD Collaboration, arXiv:1612.08399v1.

$$[8]\otimes[8]=[27]\oplus[8_s]\oplus[1]\oplus[10^*]\oplus[10]\oplus[8_a]$$



2. Calculations

(ΣNN quasibound state and its production)

Y-2N folding-model potentials

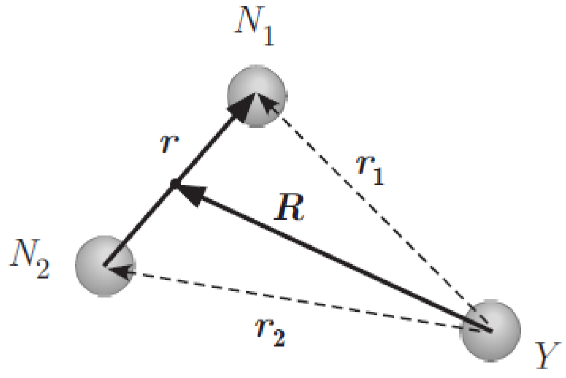
Microscopic (2N)-Y folding-model potentials

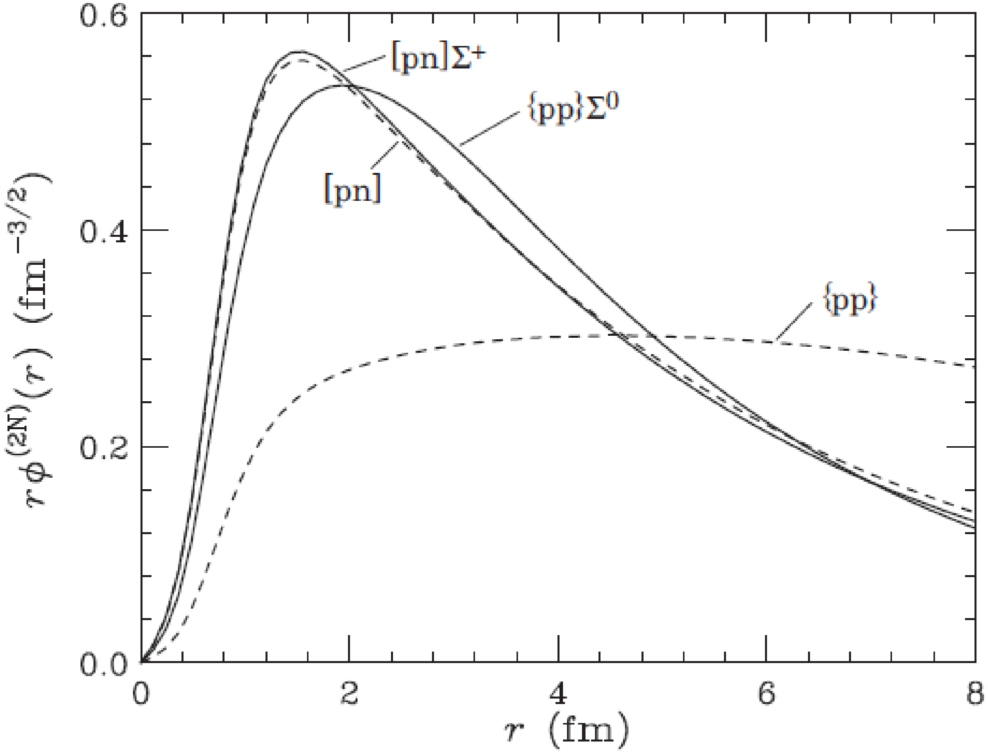
$$U_{\alpha\alpha'}(\boldsymbol{R}) = \int \rho_{\alpha\alpha'}(\boldsymbol{r})\left(\bar{g}_{\alpha\alpha'}(\boldsymbol{r}_1) + \bar{g}_{\alpha\alpha'}(\boldsymbol{r}_2)\right) d\boldsymbol{r},$$

YN g-matrices obtained by D2'

Nucleon or transition density for NN (CDCC)

$$\rho_{\alpha\alpha'}(\boldsymbol{r}) = \langle \phi_{\alpha}^{(2N)} | \sum_i \delta(\boldsymbol{r} - \boldsymbol{r}_i) | \phi_{\alpha'}^{(2N)} \rangle$$

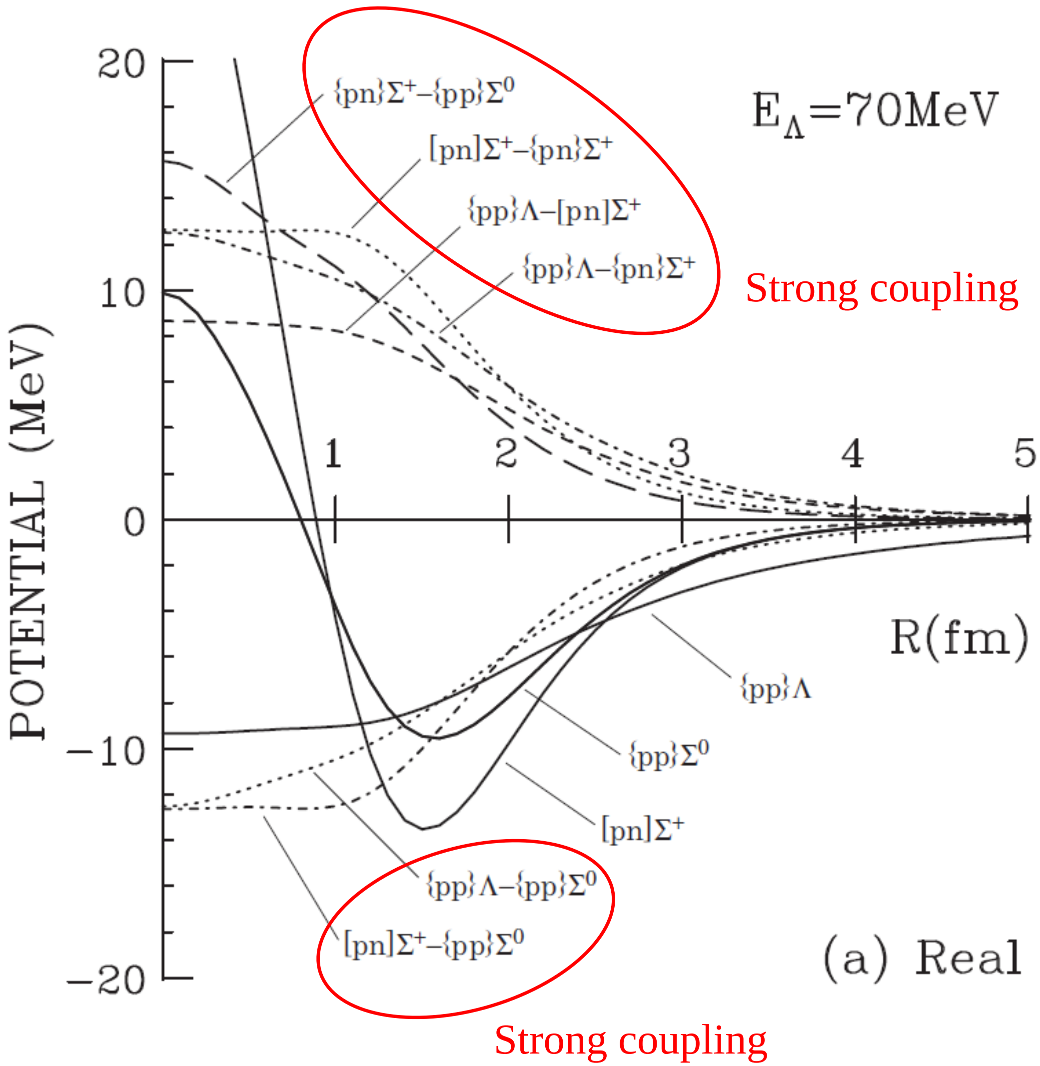


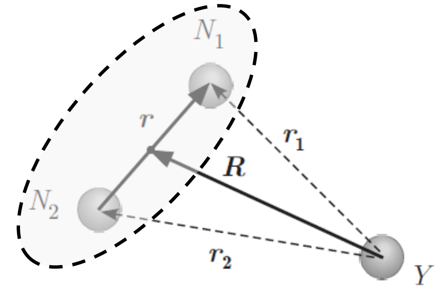


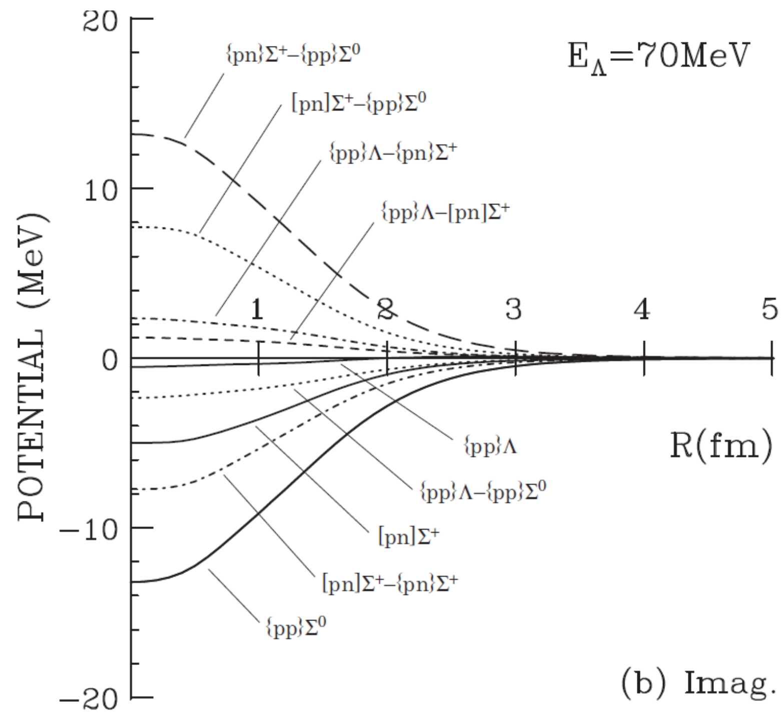
Coupled Bethe-Goldstone eq.

$$\begin{bmatrix} \Psi_\Lambda \\ \Psi_\Sigma \end{bmatrix} = \begin{bmatrix} \Phi_\Lambda \\ 0 \end{bmatrix} + \frac{Q}{e} v \begin{bmatrix} \Psi_\Lambda \\ \Psi_\Sigma \end{bmatrix}$$

Microscopic Y-(2N) folding-model potentials







➤ The channel coupling is important to describe the YNN systems.

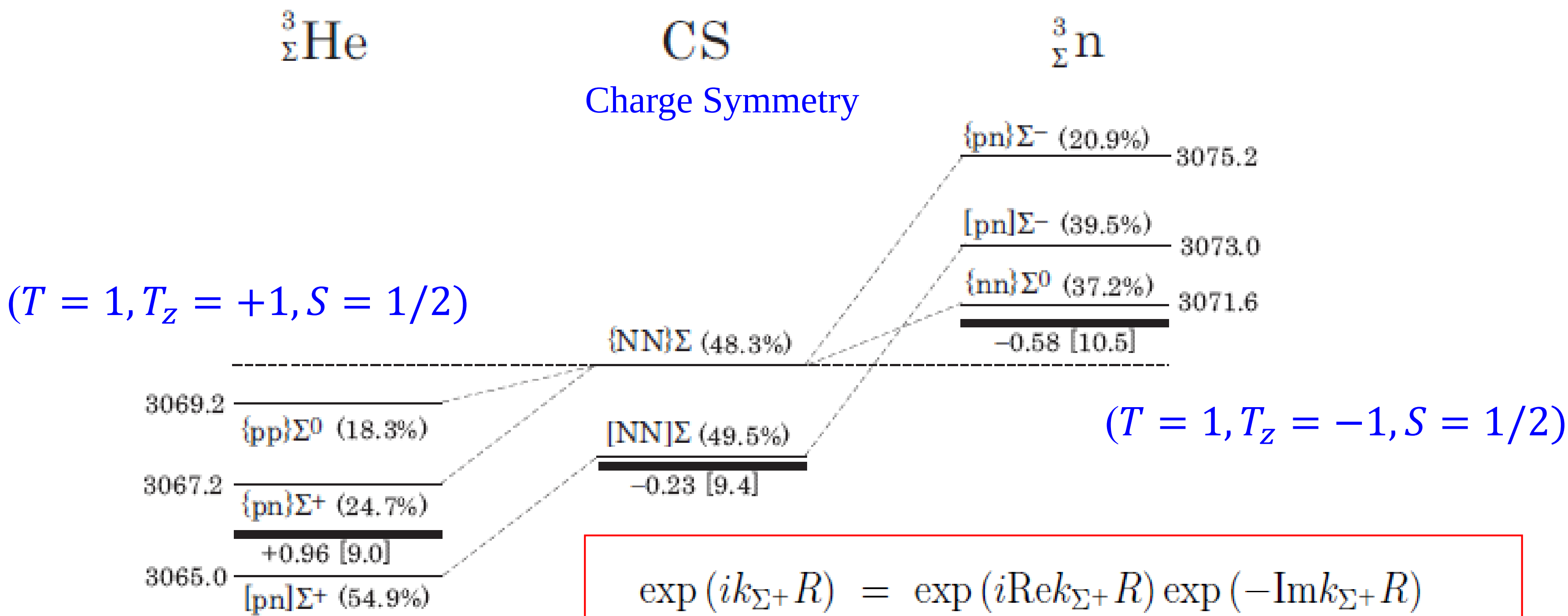
ΣNN quasibound states

$$^{3}_{\Sigma}\mathrm{He},\ ^{3}_{\Sigma}\mathrm{H},\ ^{3}_{\Sigma}\mathrm{n}$$
$$(T = 1, S = 1/2)$$

$(T = 1, S = \frac{3}{2})$ $(T = 0, 2, S = \frac{1}{2}, \frac{3}{2})$ repulsive

T. Harada, Y. Hirabayashi, PRC89(2014) 054603.

Energies and widths of ΣNN (S=1/2, T=1)



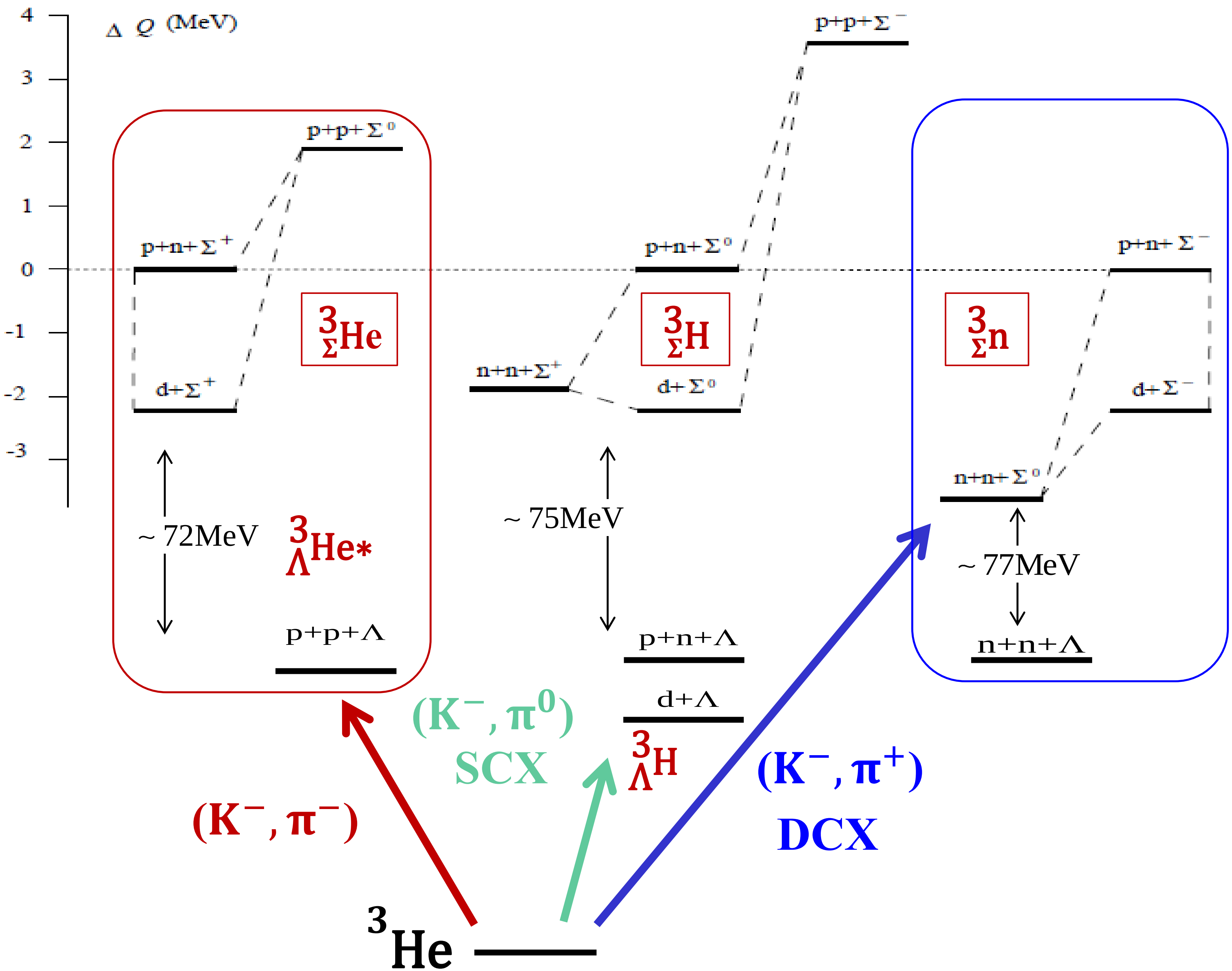
$$\exp\left(ik_{\Sigma^+}R\right) = \exp\left(i\mathrm{Re}k_{\Sigma^+}R\right)\exp\left(-\mathrm{Im}k_{\Sigma^+}R\right)$$
$$\to 0$$
(quasibound state)

	(J^π, T)	E_Λ (MeV)	$E_{\Sigma^\pm}$ (MeV)	E_{Σ^0} (MeV)	Γ_Σ (MeV)	$k_{\Sigma^\pm}$ (fm^{-1})
$^3_\Sigma$He	$(\frac{1}{2}^+, 1)$	$+73.7$	$+0.96$[a]	-3.24	9.0	$-0.322 + i0.260$
$^3_\Sigma n$	$(\frac{1}{2}^+, 1)$	$+76.4$	-1.87[b]	-0.58	10.5	$-0.263 + i0.374$

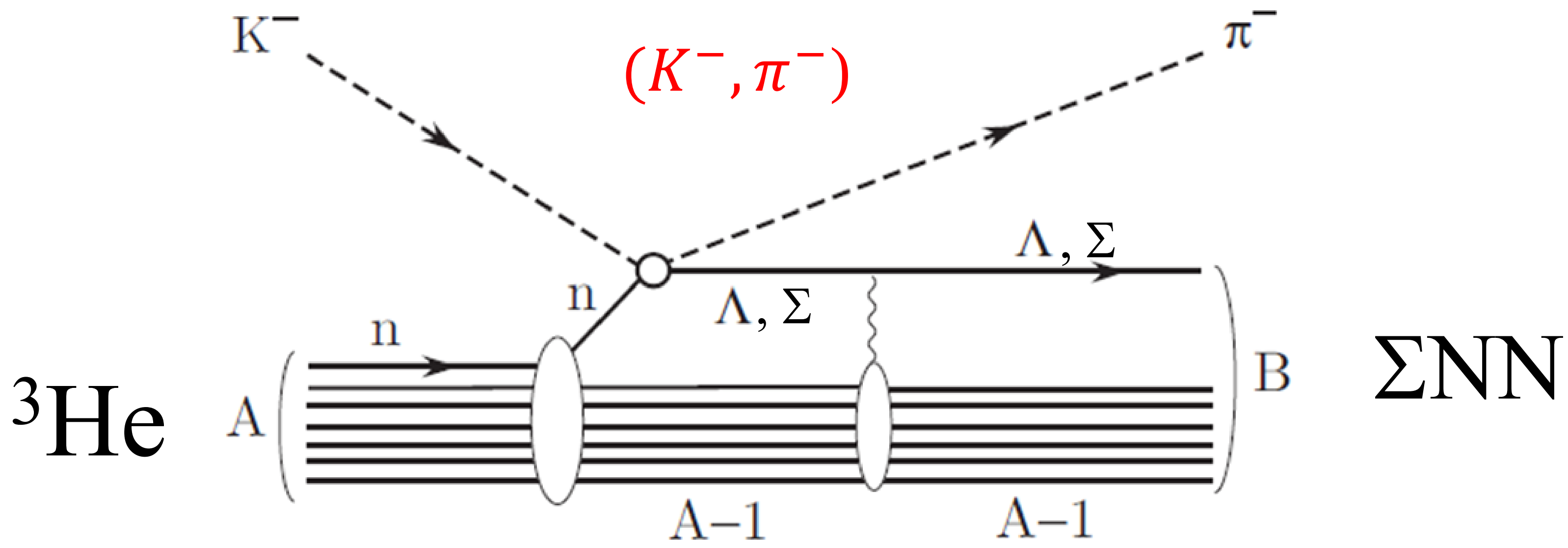
Hyperon mixing probabilities of the ΣNN states

States	Components	Probabilities (%)	
${}^{3}_{\Sigma}\mathrm{He}$	$\{pp\}\Lambda \quad (T=1)$	$\boxed{2.07}$	
	$[pn]\Sigma^{+}$	54.9	
	$\{pn\}\Sigma^{+}$	24.7	99.6%
	$\{pp\}\Sigma^{0}$	18.3	
$\{N_1,N_2\}=N_1N_2+N_2N_1$: ${}^1S_0$	$T=1\,(I_2=0, S_2=1)$	54.9	(97.4%)
$[N_1,N_2]=N_1N_2-N_2N_1$: ${}^3S_1$	$T=1\,(I_2=1, S_2=0)$	42.5	
	$T=2$	0.45	
${}^{3}_{\Sigma}n$	$\{nn\}\Lambda \quad (T=1)$	$\boxed{2.42}$	
	$[pn]\Sigma^{-}$	39.5	
	$\{pn\}\Sigma^{-}$	20.9	97.9%
	$\{nn\}\Sigma^{0}$	37.2	
	$T=1\,(I_2=0, S_2=1)$	39.5	(95.5%)
	$T=1\,(I_2=1, S_2=0)$	56.0	
	$T=2$	2.10	

Production by K^- beam from ^{3}He targets



Distorted-wave impulse approximation (DWIA)



Double differential cross sections within the DWIA

$$\frac{d^2\sigma}{dE_\pi d\Omega_\pi} = \beta \frac{1}{[J_A]} \sum_{M_A} \sum_{B} |\langle \Psi_B | \hat{F} | \Psi_A \rangle|^2 \, \delta(E_\pi + E_B - E_{\rm K} - E_A)$$

Production operators with zero-range interaction

$$\hat{F} = \int d\boldsymbol{r} \, \chi_\pi^{(-)*}(\boldsymbol{p}_\pi, \boldsymbol{r}) \chi_K^{(+)}(\boldsymbol{p}_K, \boldsymbol{r}) \sum_{j=1}^{A} \bar{f}_{(Y\pi)}(\omega_{\bar{K}N}) \delta(\boldsymbol{r} - \boldsymbol{r}_j) \hat{O}_j$$

Mesons distorted-waves

Transition-amplitude for $K^{-}N \rightarrow \pi Y$.

Momentum and energy transfer

$$\boldsymbol{q} = \boldsymbol{p}_K - \boldsymbol{p}_\pi, \qquad \omega = E_K - E_\pi,$$

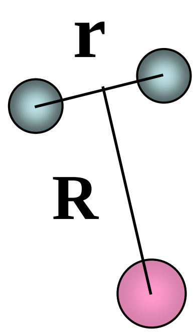
Kinematical factor

$$\beta = \left(1 + \frac{E_\pi^{(0)}}{E_{\rm Y}^{(0)}} \frac{p_\pi^{(0)} - p_K^{(0)} \cos\theta_{\rm lab}}{p_\pi^{(0)}} \right) \frac{p_\pi E_\pi}{p_\pi^{(0)} E_\pi^{(0)}},$$

Wavefunction of the initial state for a 3He target nucleus

$$|\Psi_A\rangle = \hat{\mathcal{A}}\left[\left[\phi_0^{(2N)} \otimes \varphi_0^{(N)}\right]_{L_A} \otimes X^A_{T_A,S_A}\right]^{M_A}_{J_A},$$

$$X^A_{T_A,S_A} = \left[\chi^{(2N)}_{I_2,S_2} \otimes \chi^{(N)}_{1/2,1/2}\right]_{1/2,1/2},$$



Wavefunctions of final states for ppY

$$|\Psi_B\rangle = \sum_\alpha \left[\left[\phi_\alpha^{(2N)} \otimes \varphi_{\ell_Y}^{(Y)}\right]_{L_B} \otimes X^B_{Y_\alpha,S_\alpha}\right]^{M_B}_{J_B},$$

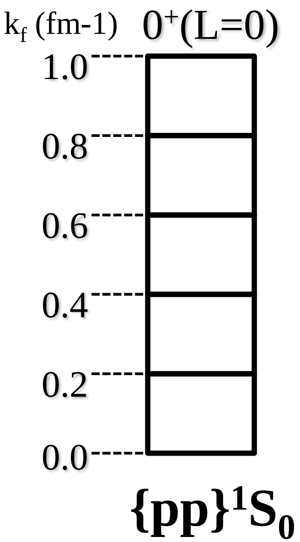
$$X^B_{Y_\alpha,S_\alpha} = \left[\chi^{(2N)}_{I_2,S_2} \otimes \chi^{(Y)}_{I_Y,1/2}\right]_{Y_\alpha,S_\alpha},$$

Continuum-discretized coupled-channel (CDCC) w.f.

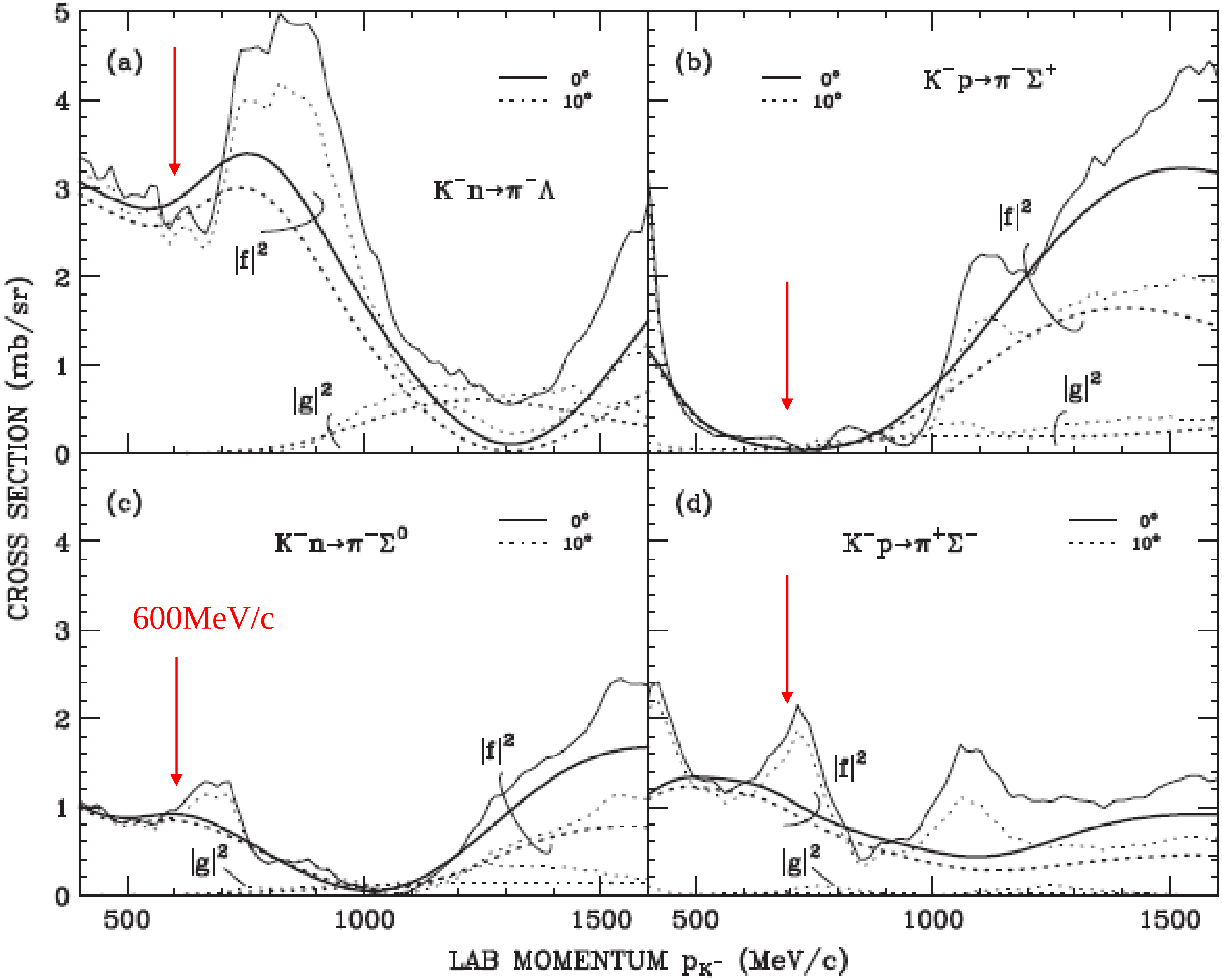
$$\tilde{\phi}^{(2N)}_{\alpha,i}(\boldsymbol{r}) = \frac{1}{\sqrt{\Delta k}} \int_{k_i}^{k_{i+1}} \phi_\alpha^{(2N)}(k,\boldsymbol{r})dk,$$

The momentum bin method for the pp-systems

$$\left(T_\alpha + v_\alpha^{(NN)}(\boldsymbol{r}) - \varepsilon_\alpha\right)\phi_\alpha^{(2N)}(k,\boldsymbol{r}) = 0$$



Fermi-averaged amplitude for $K^{-}N \rightarrow \pi Y$ elementary processes



■ Multichannel Green's function ($N \times N$)

Green's function method

Morimatsu, Yazaki, NPA483 (1988) 493.

$$\sum_B |\Psi_B\rangle\langle\Psi_B|\delta(E-E_B) = -\frac{1}{\pi}\mathrm{Im}\hat{G}(E).$$

■ Inclusive spectra for the production cross sections

$$\frac{d^2\sigma}{dE_\pi d\Omega_\pi} = \beta\frac{1}{[J_A]}\sum_{M_A} S_\pi, \qquad S_\pi = -\frac{1}{\pi}\mathrm{Im}\langle F|\hat{G}(E)|F\rangle,$$

<u>For 3He(K-,π-) reactions</u>

$$\mathrm{Im}\hat{G} = \hat{\Omega}^{(-)\dagger}(\mathrm{Im}\hat{G}^{(0)})\hat{\Omega}^{(-)} + \hat{G}^\dagger(\mathrm{Im}\hat{U})\hat{G},$$

$$S_{\pi^-} = S_{\pi^-}^{\{pp\}\Lambda} + S_{\pi^-}^{[pn]\Sigma^+} + S_{\pi^-}^{\{pn\}\Sigma^+} + S_{\pi^-}^{\{pp\}\Sigma^0} + S_{\pi^-}^{(\mathrm{Conv})} \qquad (4\times 4)$$

$$S_\pi^\alpha = -\frac{1}{\pi}\langle F|\hat{\Omega}^{(-)\dagger}(\mathrm{Im}\hat{G}_\alpha^{(0)})\hat{\Omega}^{(-)}|F\rangle$$

$$S_\pi^{(\mathrm{Conv})} = -\frac{1}{\pi}\sum_{\alpha\alpha'}\langle F|\hat{G}_\alpha^\dagger W_{\alpha\alpha'}\hat{G}_{\alpha'}|F\rangle$$

<u>For 3He(K-,π+) reactions</u>

$$S_{\pi^+} = S_{\pi^+}^{[pn]\Sigma^-} + S_{\pi^+}^{\{pn\}\Sigma^-} + S_{\pi^+}^{\{nn\}\Sigma^0} + S_{\pi^+}^{(\mathrm{Conv})} \qquad (4\times 4)$$

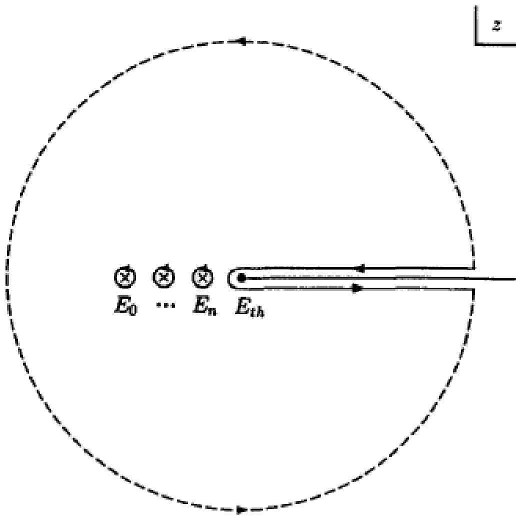
Multichannels Green's functions

Complete Green's function

T.Harada, NPA672(2000)181

$$\hat{\mathbf{G}}(E_f) = \hat{\mathbf{G}}^{(0)}(E_f) + \hat{\mathbf{G}}^{(0)}(E_f)\hat{\mathbf{U}}\hat{\mathbf{G}}(E_f)$$

$$\hat{\mathbf{G}}^{(0)}(E_f) = \begin{bmatrix} G^{(0)}_{\Lambda_0} & & & \\ & G^{(0)}_{\Lambda_1} & & \\ & & \ddots & \\ & & & G^{(0)}_{\Lambda_N} \end{bmatrix} \quad \hat{\mathbf{U}} = \begin{bmatrix} U_{0,0} & U_{0,1} & \cdots & U_{0,N} \\ U_{1,0} & U_{1,1} & & \vdots \\ \vdots & & \ddots & \\ U_{N,0} & \cdots & & U_{N,N} \end{bmatrix}$$



Green's function method

$$\sum_B |\Psi_B\rangle\langle\Psi_B|\delta(E-E_B) = -\frac{1}{\pi}\mathrm{Im}\hat{G}(E)$$

Morimatsu, Yazaki, NPA483(1988)493

Strength function

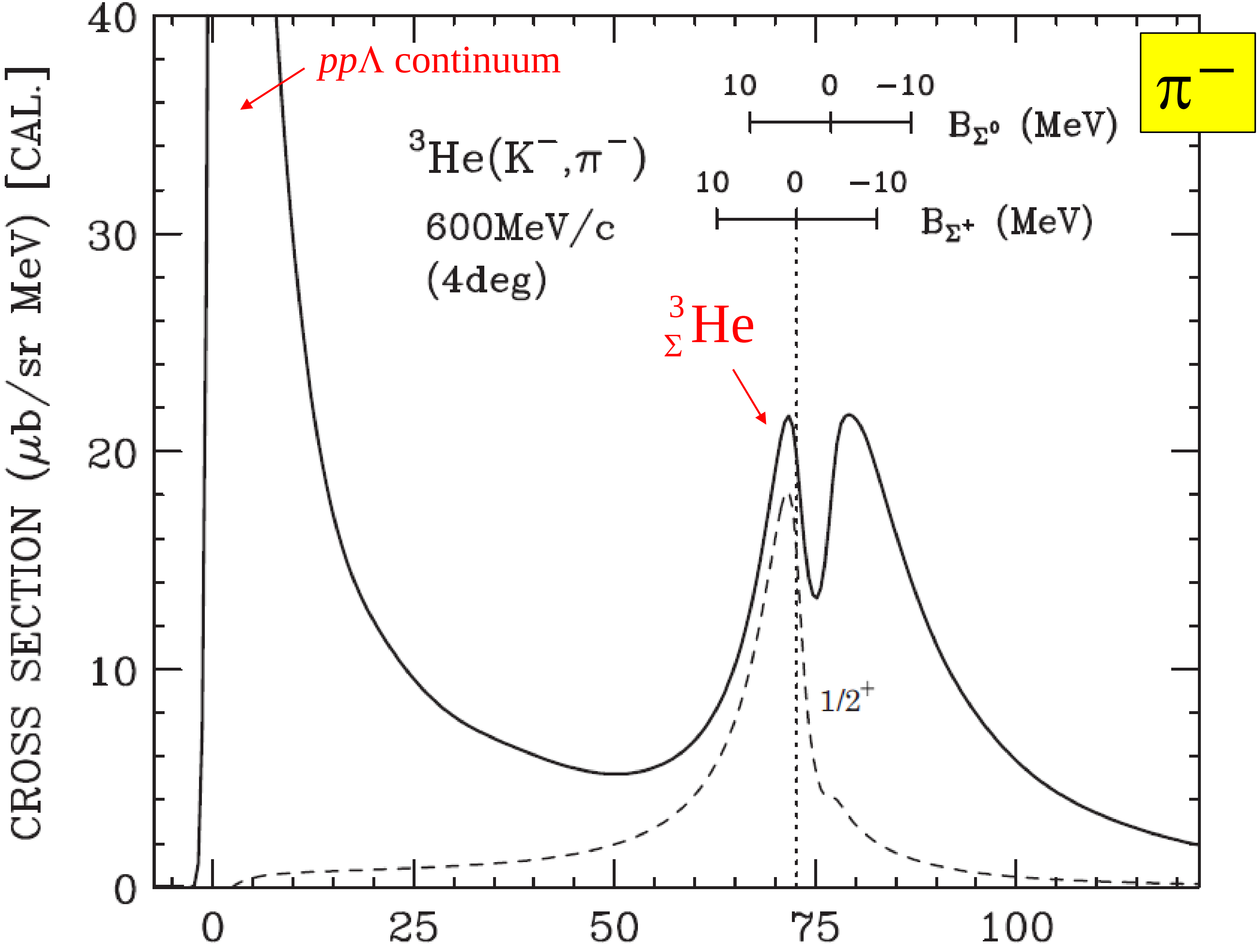
$$S(E_B) = \sum_B |\langle\Psi_B|\hat{F}|\Psi_A\rangle|^2\delta(E_\pi + E_B - E_K - E_A)$$

Green's function

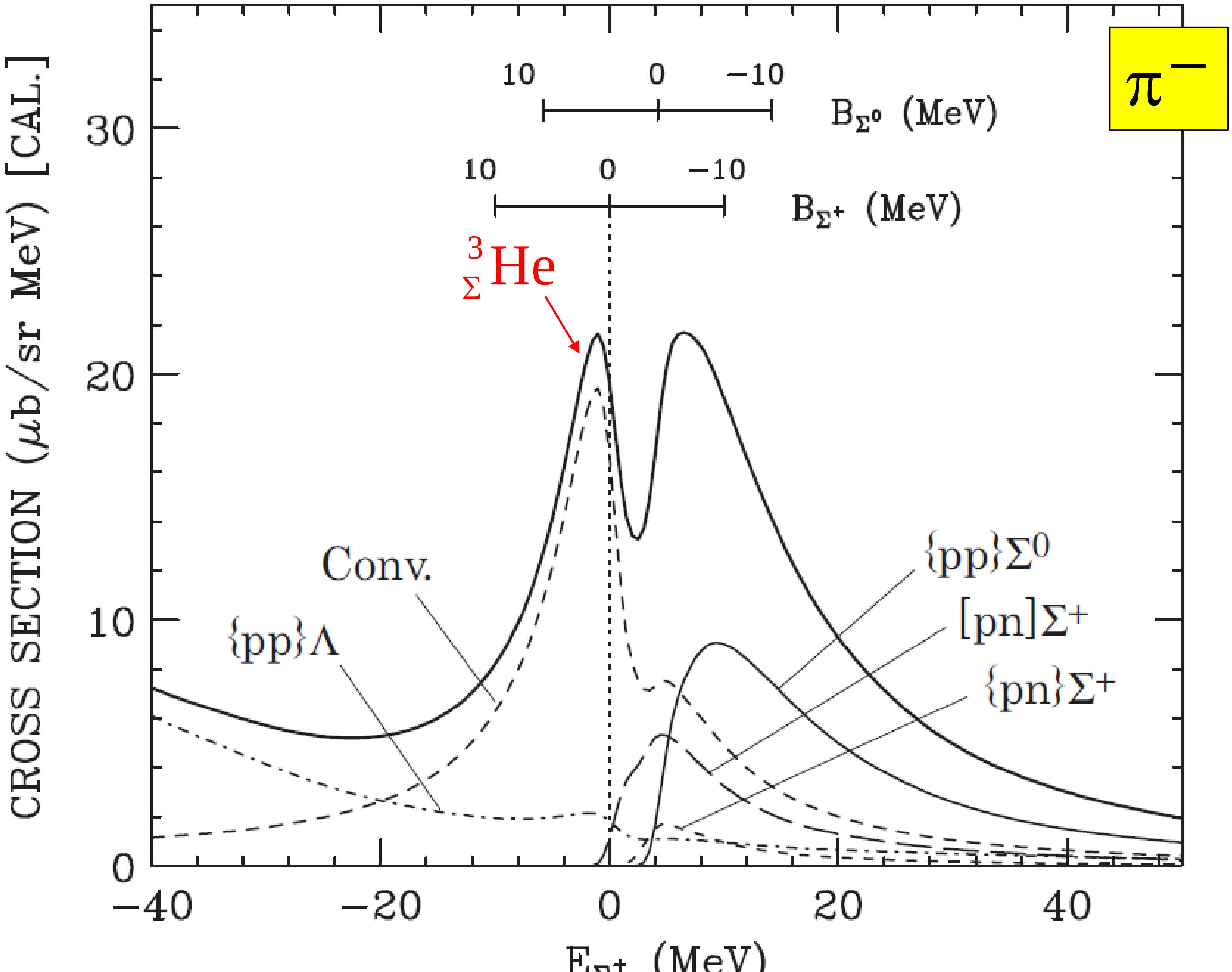
$$= (-)\frac{1}{\pi}\mathrm{Im}\sum_{\alpha\alpha'}\int d\mathbf{R}d\mathbf{R}'F^\dagger_\alpha(\mathbf{R})\boxed{G_{\alpha\alpha'}(E_B;\mathbf{R},\mathbf{R}')}F_{\alpha'}(\mathbf{R}')$$

3. Results and Discussion

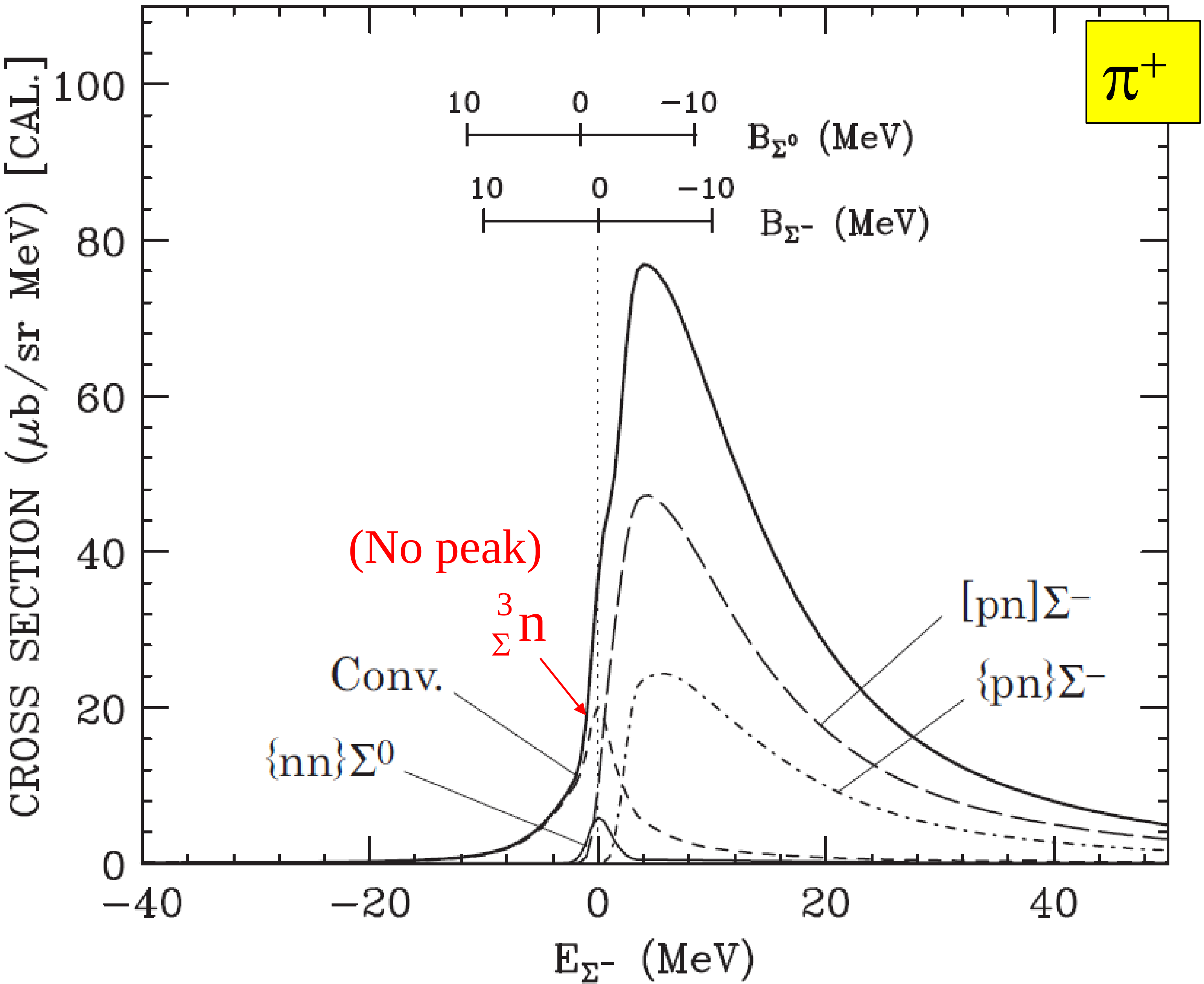
Inclusive spectrum in ^{3}He(K^-,π^-) reactions at 600MeV/c



Inclusive spectrum in $^3He(K^-,\pi^-)$ reactions at 600MeV/c



Inclusive spectrum in $^{3}He(K^{-},\pi^{+})$ reactions at 600MeV/c



Remarks

- There is a quasibound in ΣNN systems with $J^p = 1/2^+$, L = 0, S = 1/2 state. ${}^3_\Sigma\mathrm{He}$, ${}^3_\Sigma\mathrm{H}$, ${}^3_\Sigma\mathrm{n}$

- The pole is located as

$$\mathcal{E}^{(\mathrm{pole})}_{\Sigma^+}({}^3_\Sigma\mathrm{He}) = +0.96 - i\,4.5\ \mathrm{MeV} \qquad (K^-, \pi^-)$$

$$\mathcal{E}^{(\mathrm{pole})}_{\Sigma^0}({}^3_\Sigma n) = -0.58 - i\,5.3\ \mathrm{MeV} \qquad (K^-, \pi^+)$$

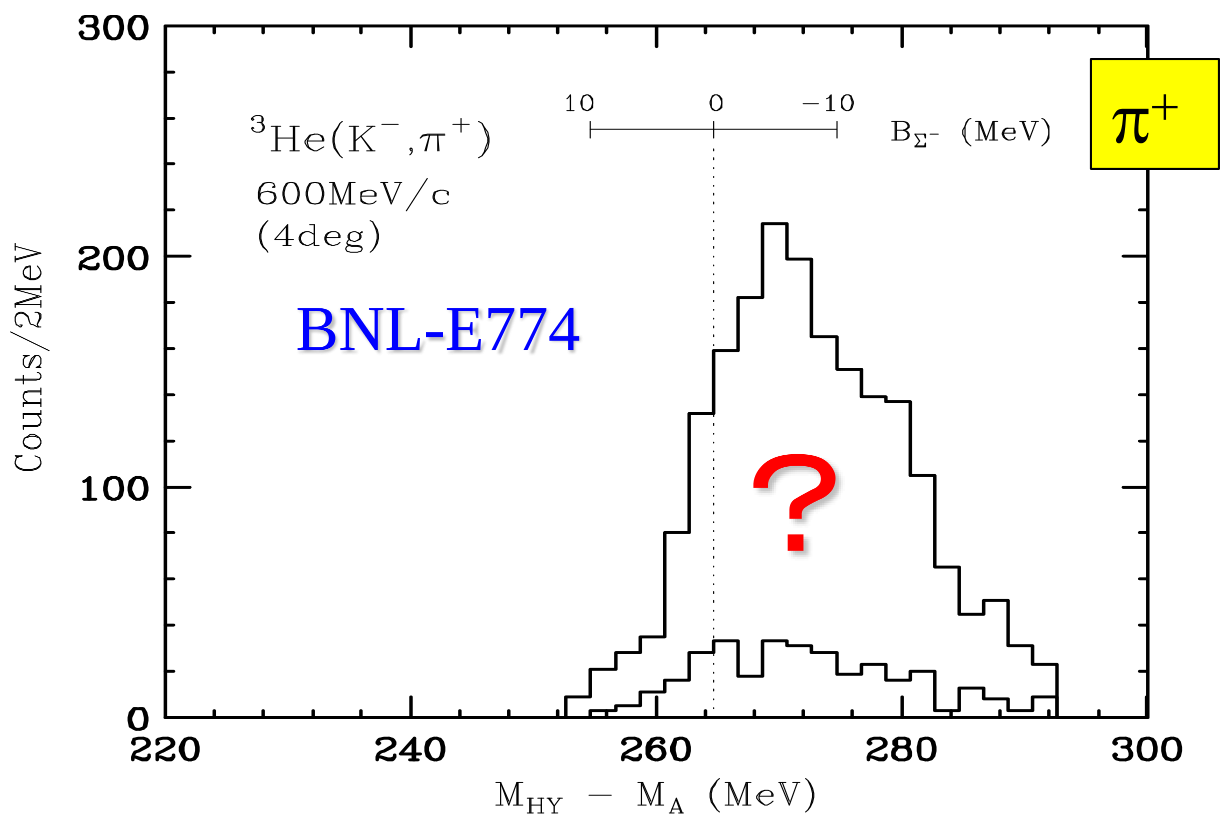
measured from the $d + \Sigma^+$ threshold .

- The pole positions reside on the second Riemann sheet [− + + +] on the complex E plane.

$$[\mathrm{Im}k_{\{pp\}\Lambda},\ \mathrm{Im}k_{[pn]\Sigma+},\ \mathrm{Im}k_{\{pn\}\Sigma+},\ \mathrm{Im}k_{\{nn\}\Sigma0}]$$

Inclusive spectrum by $^{3}He(K^{-},\pi^{+})$ reactions at 600MeV/c

BNL-E774: Barakat, Hungerford, NPA547(1992)157c



"There is no evidence for a state below Σ-d threshold."

➢ *Why can we see no peak of the $^{3}_{\Sigma}n$ quasibound state?*

Production cross sections on $^3He(K^-,\pi^{-/+})$ reactions

Dover and Gal, PLB110(1982)433

Table 2
Production cross sections on ^{3}He and width quenching factors Q for states in ${}^3_\Sigma$He and ${}^3_\Sigma$n of spin S, isospin I and core isospin T ($I = 0$ production is forbidden, since $I_3 = \pm 1$).

	$I(T)$	S	Q	$\sigma(K^-, \pi^-)$ π^-	$\sigma(K^-, \pi^+)$ π^+
	0(1)	1/2	3	–	–
Σ[pn] →	1(0)	1/2	1/3	$3/2 \lvert f_{p\to\Sigma^+} \rvert^2$	$\boxed{3/2 \lvert f_{p\to\Sigma^-} \rvert^2}$
	1(0)	3/2	4/3	0	0
Σ{pn} →	1(1)	1/2	2	$1/2 \lvert f_{n\to\Sigma^\circ} + 1/\sqrt{2} f_{p\to\Sigma^+} \rvert^2$	$\boxed{1/4 \lvert f_{p\to\Sigma^-} \rvert^2}$
	2(1)	1/2	0	$1/2 \lvert f_{n\to\Sigma^\circ} - 1/\sqrt{2} f_{p\to\Sigma^+} \rvert^2$	$1/4 \lvert f_{p\to\Sigma^-} \rvert^2$

- Because Σ[pn] and Σ{pn} states couple each other, we must take into account the coupling effects in the $^3He(K^-,\pi^+)$ reaction.

Interference between K^-N-πY amplitudes in the spectra (I)

For ^{3}He(K^-,π^-) reactions

$$T^{(K^-,\pi^-)} \simeq f_{\Sigma^0}\langle\{pp\}\Sigma^0|^3\mathrm{He}\rangle + f_{\Sigma^+}\langle\{pn\}\Sigma^+|^3\mathrm{He}\rangle + f_{\Sigma^+}\langle[pn]\Sigma^+|^3\mathrm{He}\rangle$$

$$= \sqrt{\frac{1}{2}}f^{(3/2)}\langle T=2|^3\mathrm{He}\rangle + \sqrt{\frac{1}{2}}f_s^{(1/2)}\langle T=1_s|^3\mathrm{He}\rangle + \sqrt{\frac{1}{2}}f_t^{(1/2)}\langle T=1_t|^3\mathrm{He}\rangle$$

dynamically admixtures
due to the ΣN potential

$$= \sqrt{\frac{1}{2}}\left\{\sqrt{\frac{1}{2}}f_{\Sigma^+} - f_{\Sigma^0}\right\}\langle T=2|^3\mathrm{He}\rangle + \underline{\left\{\left(\frac{\sqrt{3}+1}{2}\right)f_{\Sigma^+} + \frac{1}{2}f_{\Sigma^0}\right\}}\langle T=1^{(-)}|^3\mathrm{He}\rangle \quad {}^{3}_{\Sigma}\mathrm{He}_{g.s.}$$

most attractive

$$+\underline{\left\{\left(\frac{\sqrt{3}-1}{2}\right)f_{\Sigma^+} - \frac{1}{2}f_{\Sigma^0}\right\}}\langle T=1^{(+)}|^3\mathrm{He}\rangle \quad {}^{3}_{\Sigma}\mathrm{He}^{*}$$

interference between
$K^-p \rightarrow \pi^-\Sigma^+$ and $K^-n \rightarrow \pi^-\Sigma^0$ production amplitudes

Interference between K^-N-πY amplitudes in the spectra (II)

For ^{3}He(K^-,π^+) reactions

$$T^{(K^-,\pi^+)} \simeq \cancel{f_{\Sigma^0}}\langle\{nn\}\Sigma^0|^3\mathrm{He}\rangle + f_{\Sigma^-}\langle\{pn\}\Sigma^-|^3\mathrm{He}\rangle + f_{\Sigma^-}\langle[pn]\Sigma^-|^3\mathrm{He}\rangle$$

$$= f_{\Sigma^-}\left(\frac{1}{2}\langle T=2|^3\mathrm{He}\rangle + \underbrace{\frac{1}{2}\langle T=1_s|^3\mathrm{He}\rangle + \sqrt{\frac{3}{2}}\langle T=1_t|^3\mathrm{He}\rangle}_{\text{dynamically admixtures}}\right)$$

We assume $\langle T=1^{(-)}| = \frac{1}{\sqrt{2}}\langle T=1_s| - \frac{1}{\sqrt{2}}\langle T=1_t|$, but it depends on (2N)-Y pot.

$$= f_{\Sigma^-}\left(\frac{1}{2}\langle T=2|^3\mathrm{He}\rangle + \frac{2\sqrt{3}-\sqrt{2}}{4}\langle T=1^{(-)}|^3\mathrm{He}\rangle \quad {}^3_\Sigma\mathrm{n}_{\mathrm{g.s.}}\right.$$

most attractive

Reduced

0.51

Enhanced

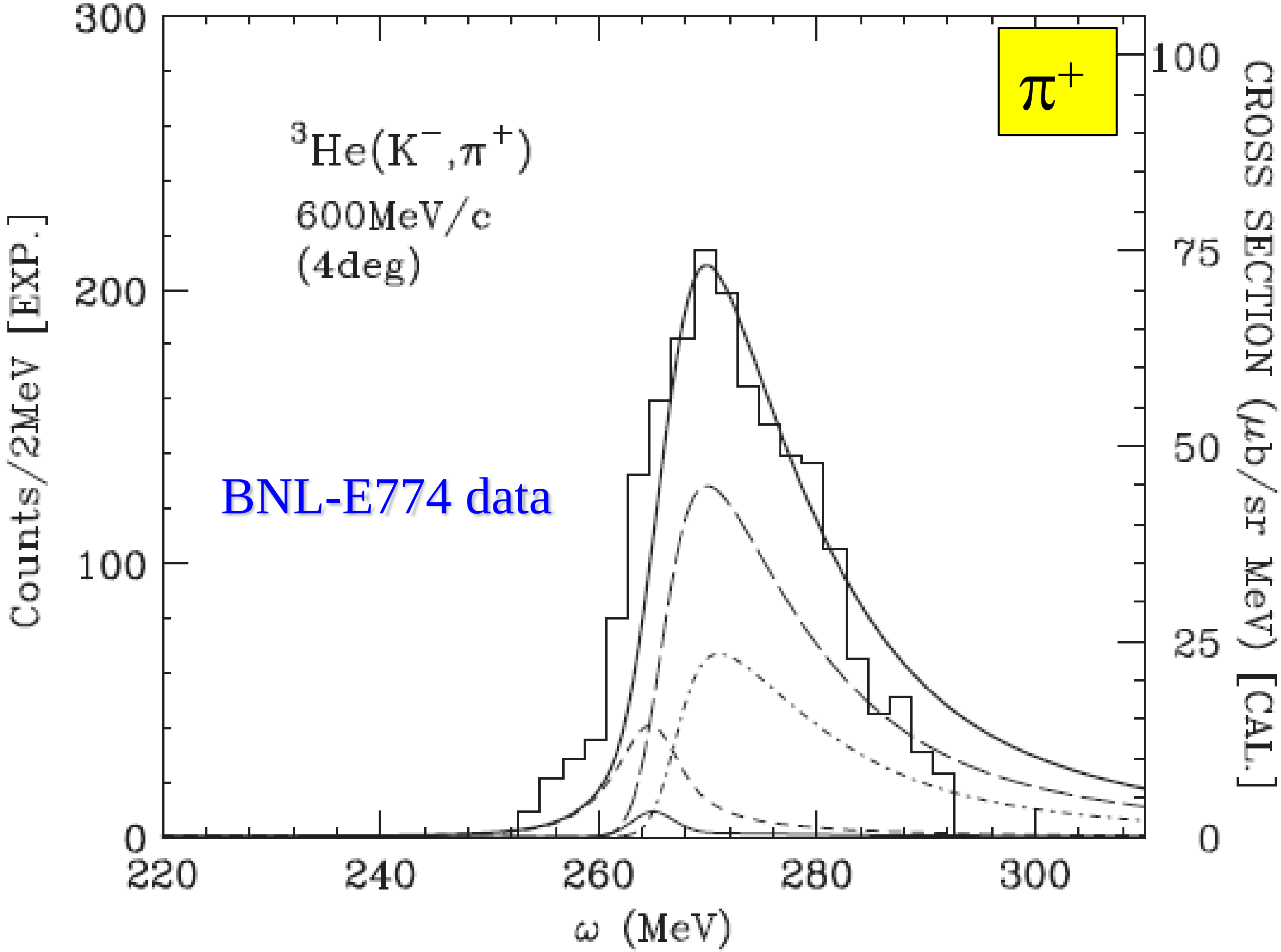
$$\left. + \frac{2\sqrt{3}+\sqrt{2}}{4}\langle T=1^{(+)}|^3\mathrm{He}\rangle\right) \quad {}^3_\Sigma\mathrm{n}^*$$

1.219

- This reduction mechanism must appear in ^{3}He(K^-,π^+) reactions !

"There is no evidence for a state below Σ-d threshold."

^{3}He(K$^-$,π$^+$) reactions at 600MeV/c

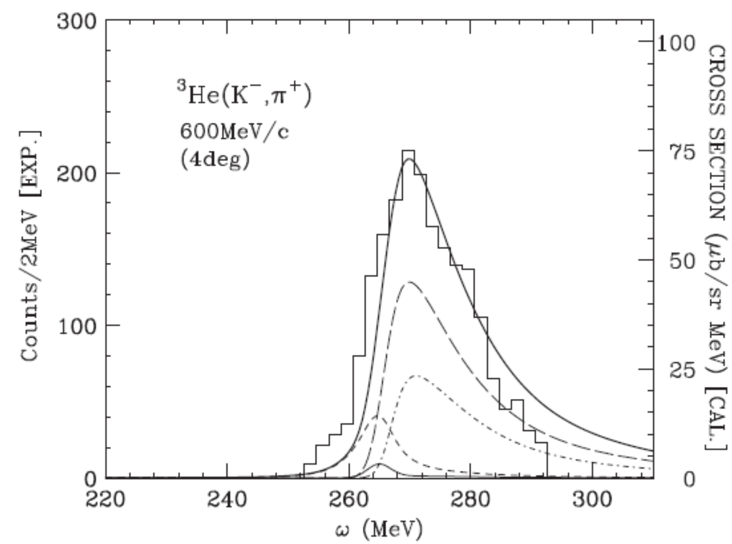


Barakat, Hungerford, NPA547(1992)157c

- The calculated spectrum is in good agreement with the BNL-E774 data.

Remarks

- The calculated inclusive spectrum of the ^{3}He(K$^-$, π^+) reaction shows no peak of the $^3_\Sigma n$ quasibound state that is located near the Σ-threshold with the width of 10.5 MeV.



- This spectrum is consistent with the BNL-E774 data.

- The reason is because the interference effects caused by $^3S_1$-$^1S_0$ admixture in the NN pair for $^3_\Sigma n$ and properties of the ΣN interactions.

Summary

There is a quasibound in ΣNN systems !!

- The coupled-channel framework is very important for calculating the spectra of the ^{3}He(K^-,$\pi^\mp$) reactions.

  Keyword: ***Hyperon-mixing***

- The calculated spectra of the ^{3}He(K^-,π^+) reaction may be consistent with the E774 data due to the admixture of the NN core states.

  the ΣNN structure depending on the 2N-Y potential.

- Both the π^- and π^+ spectra provide valuable information to understand the nature of the ΣNN quasibound states and also the YN (ΣN) interactions.

  To determine a quasibound state [+ –] or cusp state [– +].

Thank you very much for your attention.