

ハイパー核の生成と崩壊 (とつきあって)

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研究会「ハイパー核物理の発展と今後の展開」
2013. 7. 7-8 志摩

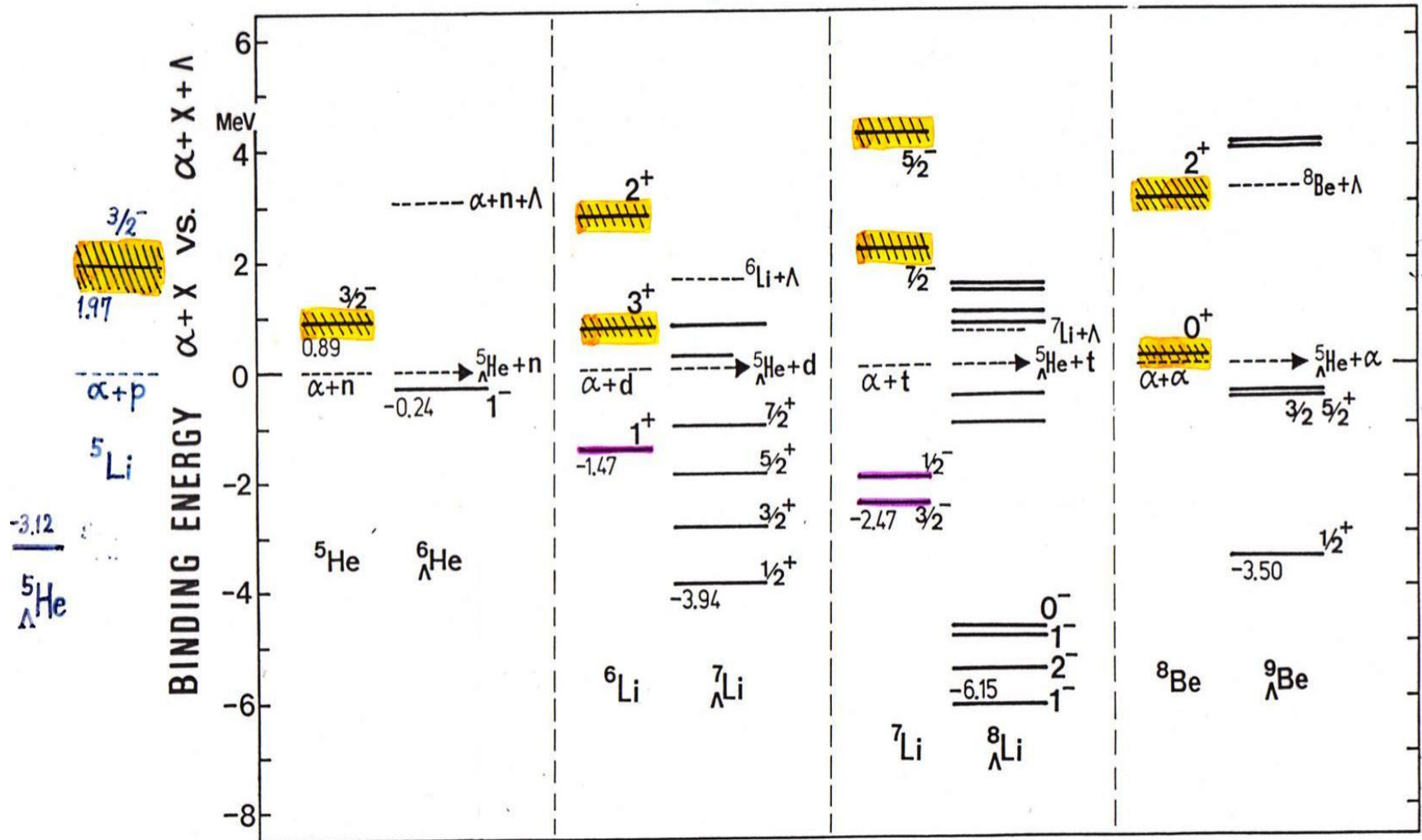
内容

1. 軽いハイパー核へのCluster modelの適用
2. ハイパー核生成反応
3. Weak decay (pionic)
4. $(e, e'K^+)$ reaction spectroscopy beyond p-shell
5. 雑

1. 軽いハイパー核構造の面白さ クラスターモデルの適用と展開

- Cluster modelの適用可能性 ($\alpha+x+\Lambda$)
まず OCM, $V(\Lambda N) = \text{ORG} \quad \& \quad \text{YNG}$
- ハイパー核構造の特徴・新奇性を明らかに
- 計算できる物理量は全部やる
- Core核と Λ のcoupling dynamics
- 生成断面積、崩壊幅、電磁遷移確率、 μ
- 3つの側面(生成、構造、崩壊)の意識

Hyp. N provides us with new opportunities to study of dynamics of baryon many-body systems.



$${}^6\text{Li} = 3p + 3n$$

$${}^7_{\Lambda}\text{Li} = 3p + 3n + \Lambda$$

$${}^{11}\text{C} = 6p + 5n$$

$${}^{12}_{\Lambda}\text{C} = 6p + 5n + \Lambda$$

$${}^{12}_{\Xi}\text{B} = 6p + 5n + \Xi^-$$

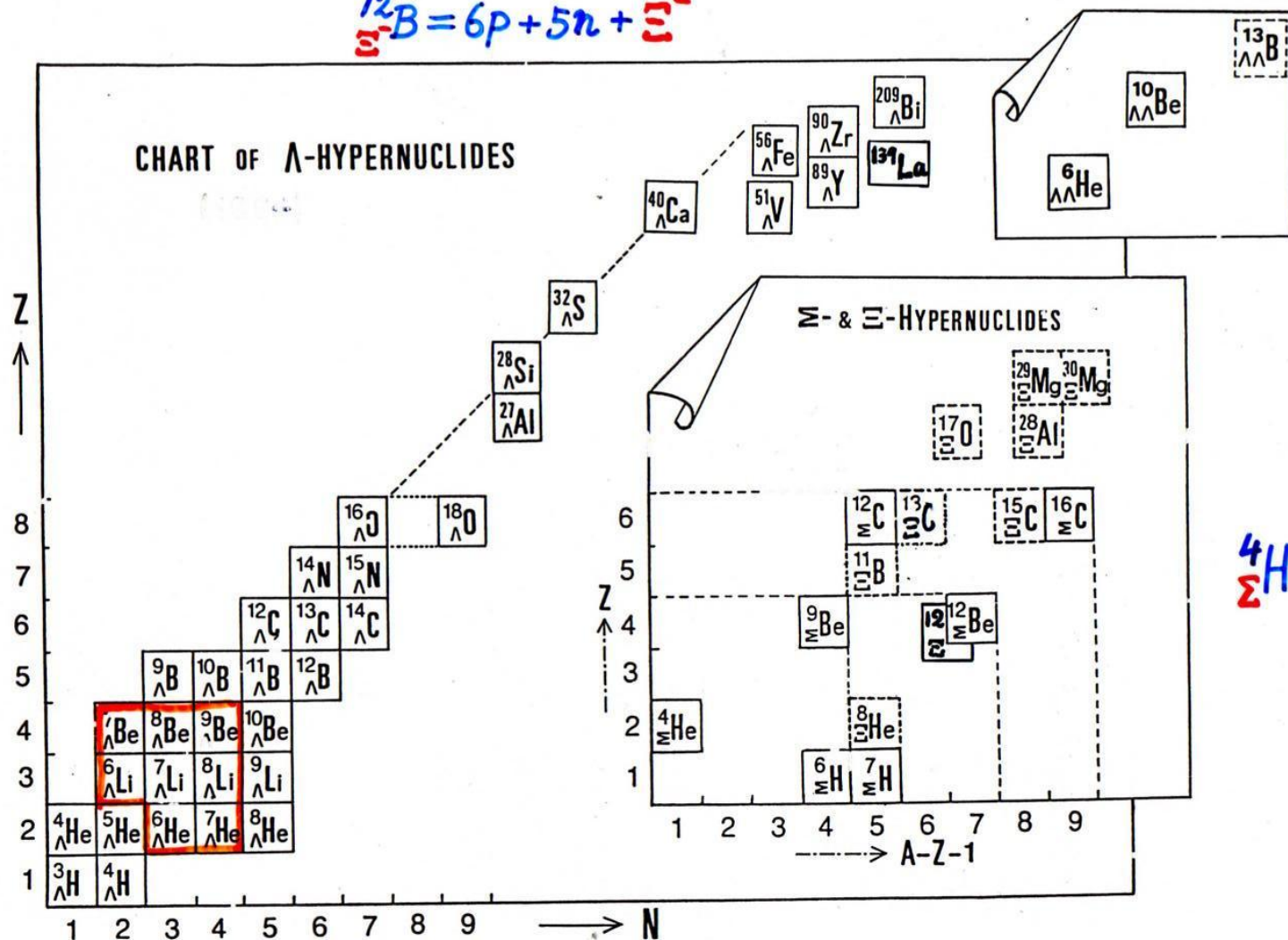


Fig. 1-1

Applications of microscopic cluster models

Hypernuclear Cluster Model

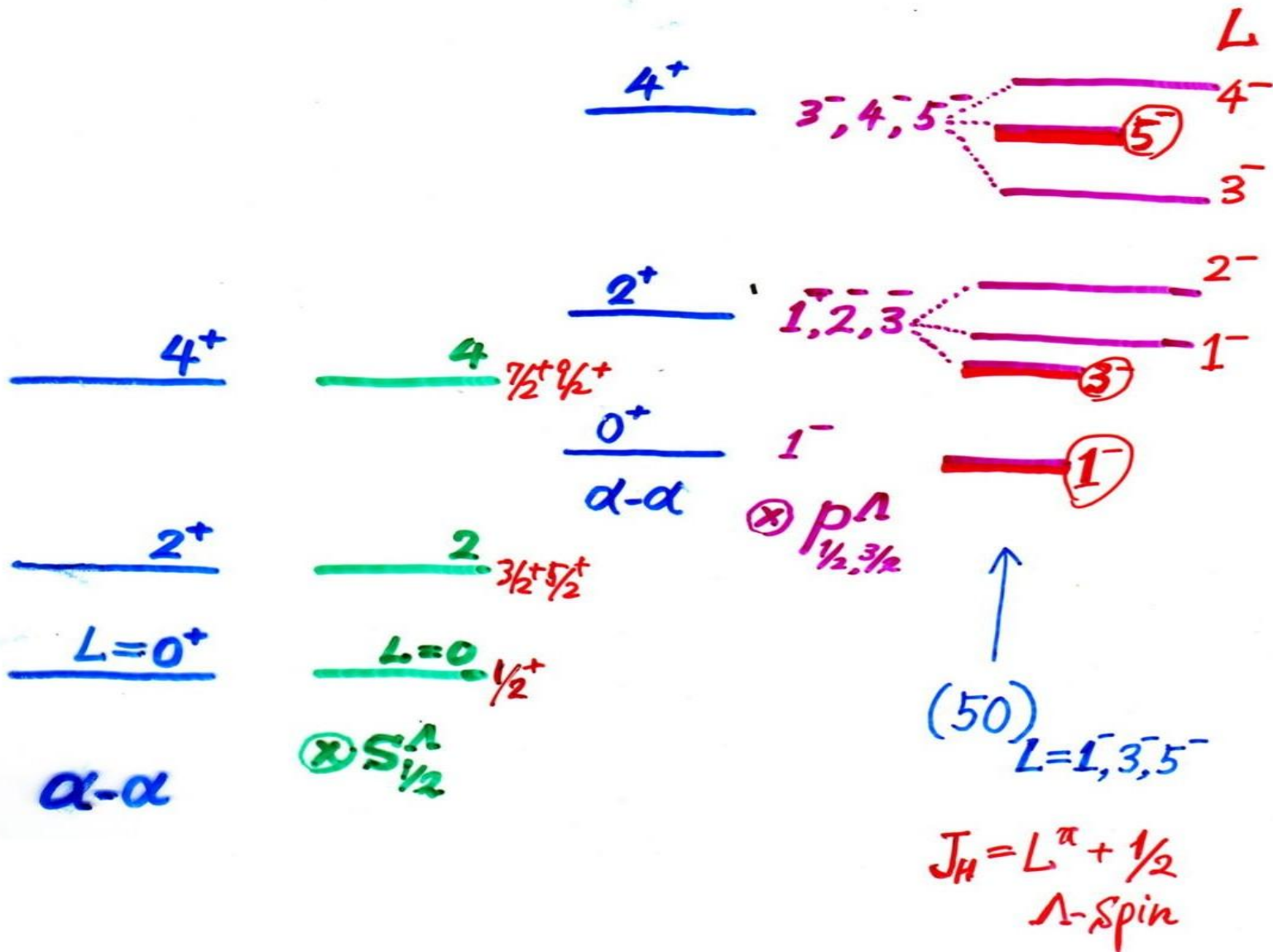
	$S = -1$	$S = -2$	$S \leq -3$
→	$t + \Lambda$ $\alpha + \Lambda$	$t + \Lambda + \Lambda$ $\alpha + \Lambda + \Lambda$	
⇒	$\alpha + x + \Lambda$ $\alpha + \alpha + \alpha + \Lambda$ $\alpha + {}^{16}\text{O} + \Lambda$ $t + \Sigma$ $\alpha + \Sigma$ $\alpha + t + \Sigma$ $\alpha + \alpha + \Sigma$	$\alpha + x + \Lambda + \Lambda$	$\alpha + \alpha + n\Lambda$ ($n=3,4$) $\hat{\alpha} + \hat{\alpha}$ $\hat{\alpha} + \hat{\alpha} + \hat{\alpha}$
		(Ξ Hy.)	

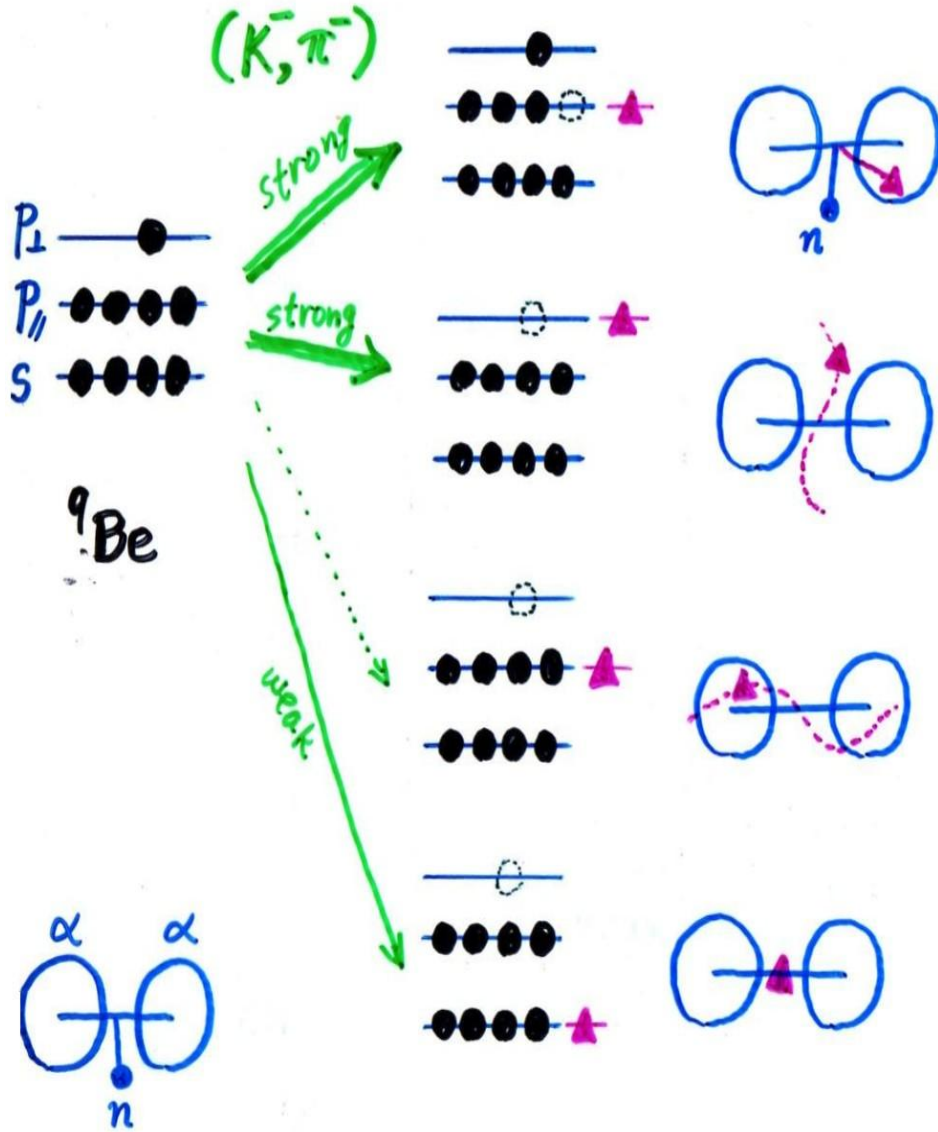
($x \equiv p, n, d, t, h, \alpha$)

$\hat{\alpha} \equiv {}^6_{\Lambda}\text{He} = \alpha + \Lambda + \Lambda$

⇒ $\alpha^* + \alpha + \Lambda$
 $\alpha^* + p + \Lambda$

weak coupling with $\Lambda(s)$,
strong coupling with $\Lambda(p)$,





Substitutional

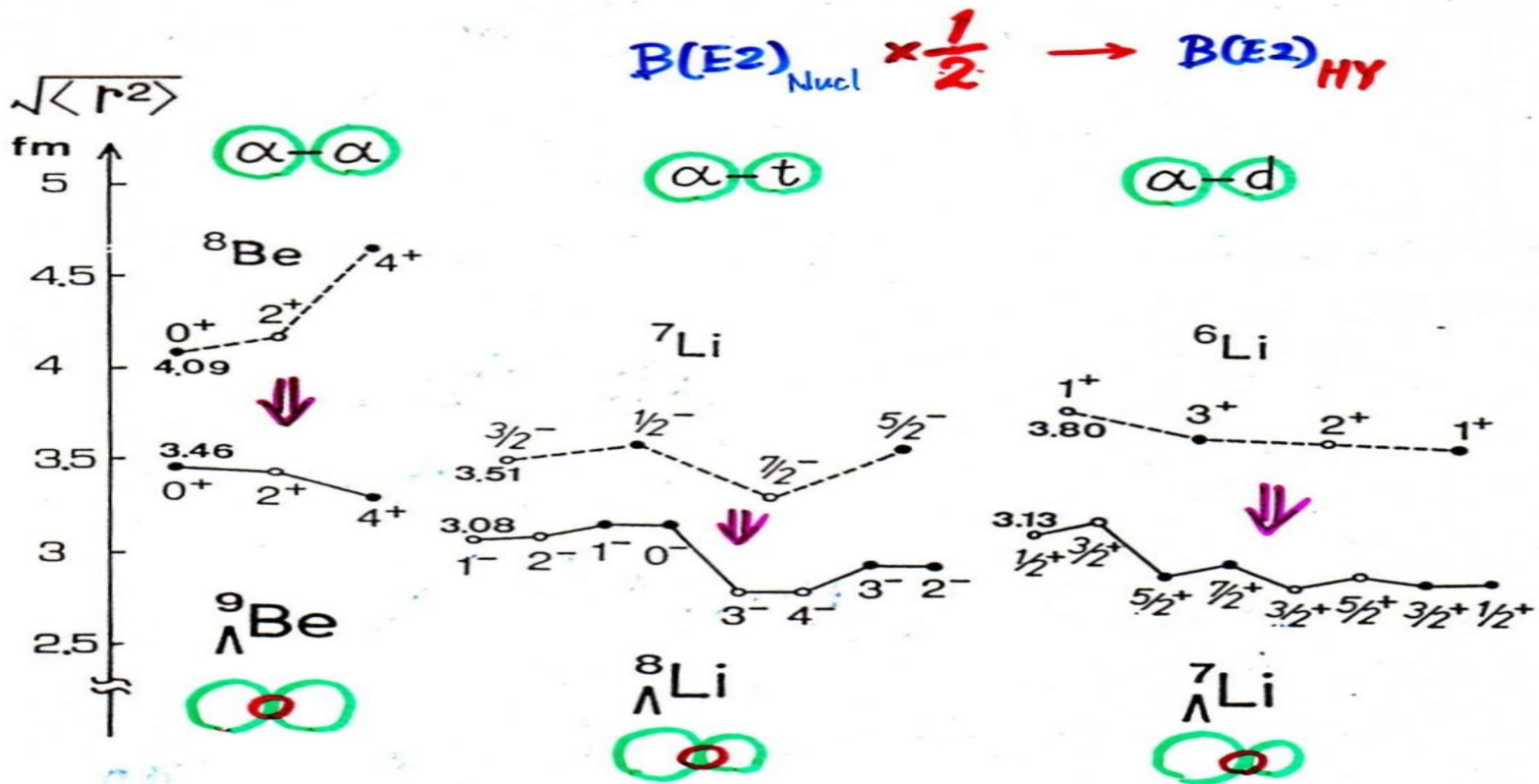
$S = \frac{1}{2}; L = 1^-, 2^-, 3^-, 4^- (K = 1^-)$
 substitutional ${}^9\text{Be}$ -analogue

$S = \frac{1}{2}; L = 1^-, 3^-, 5^- (K = 0^-)$
 $[50][50]_L \uparrow$ genuinely hypernuclear

$S = \frac{1}{2}; L = 0^+, 2^+, 4^+$
 ${}^8\text{Be}$ -analogue

Shrinkage due to Λ participation (“glue-like role” of Λ)

T. Motoba, H. Bando and K. Ikeda, P. T.P.70(1983)



10~18 % contraction of $\alpha-x$ distance (shrinkage)
→ glue-like role of Λ particle

Microscopic cluster modelの展開

- Yamadaらの展開

$\alpha^* + \alpha + \Lambda$ 計算、S行列による幅の計算

$\alpha + {}^{16}\text{O} + \Lambda$

- Hiyamaらの展開

${}^5_\Lambda\text{He} + p + n$ 、 $\alpha + \Lambda + p + n$ 精密計算

ダブルハイパー核へ

Experiment



B_A

$0.0 \quad 1/2^+$

$10.8 \quad 1/2^+$

$0.0 \quad 1/2^+$

neutron

(K^-, π^-)

$(K^-, \pi^- \gamma)$

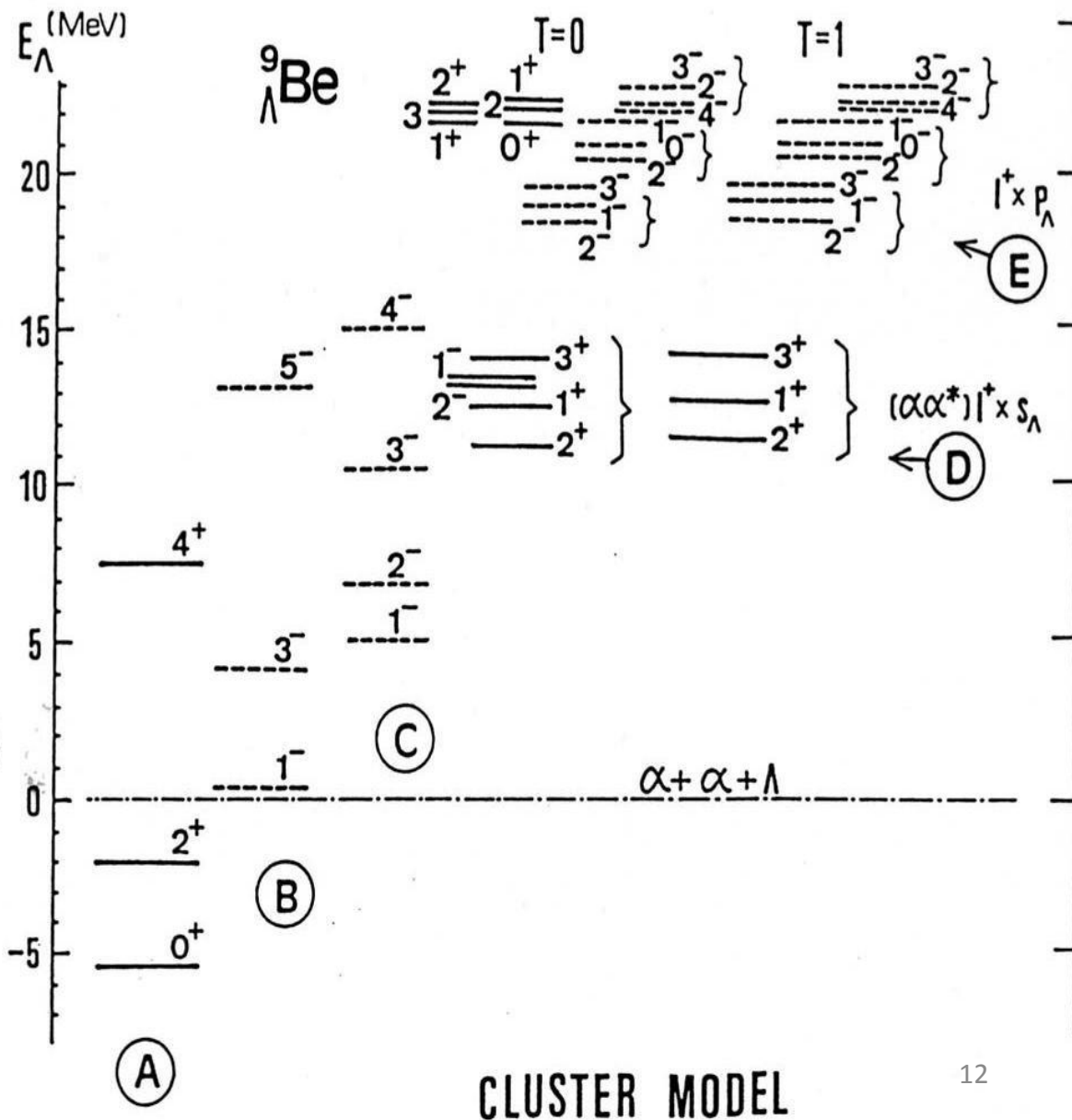
(π^+, K^+)

963,65

1979

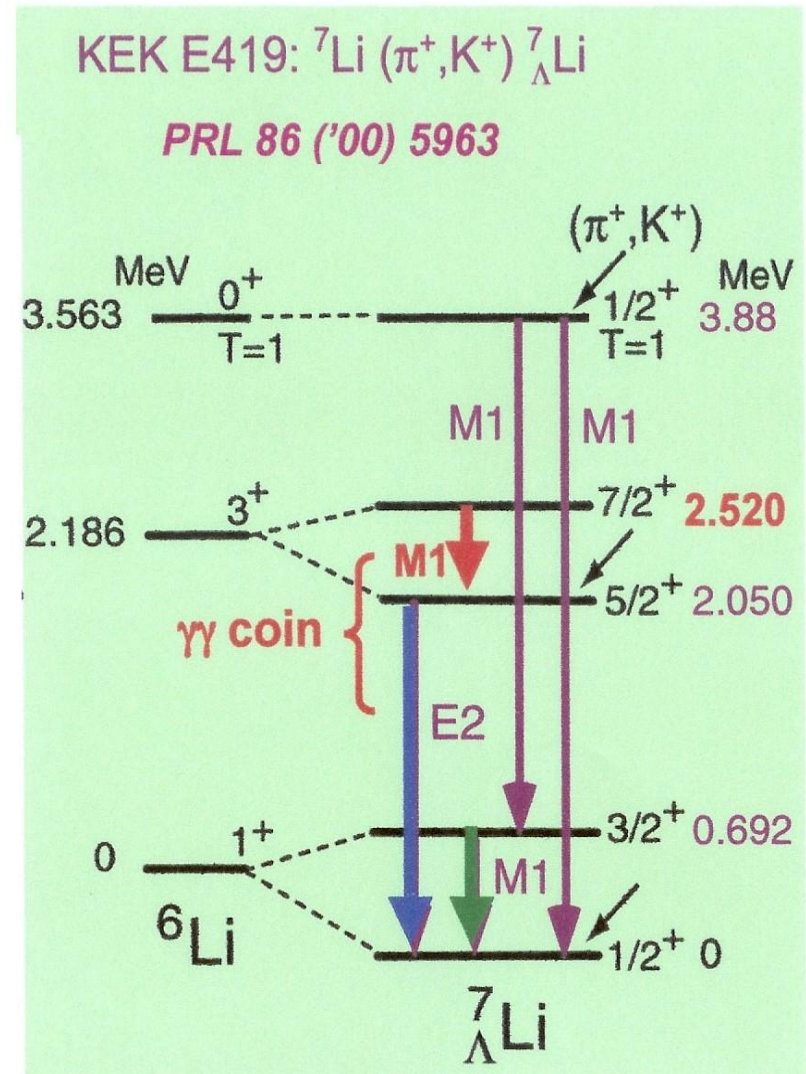
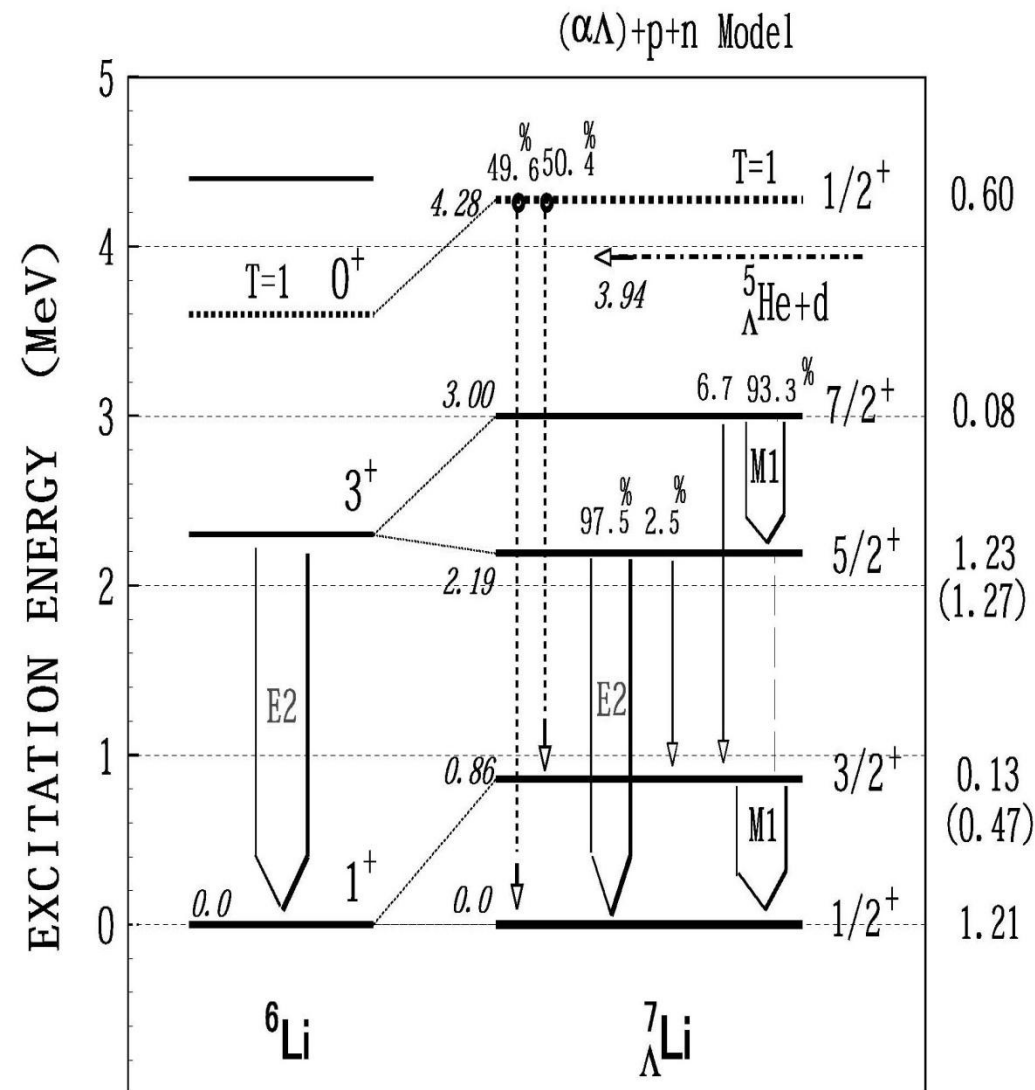
1983

1987



CLUSTER MODEL

B(${}^6\text{Li}$, E2: $3^+ \rightarrow 1^+$) vs. B($\Lambda{}^7\text{Li}$, E2: $5/2^+ \rightarrow 1/2^+$)



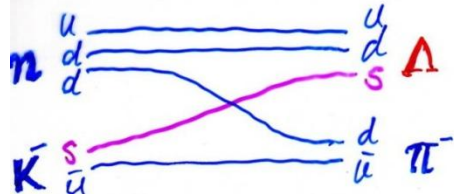
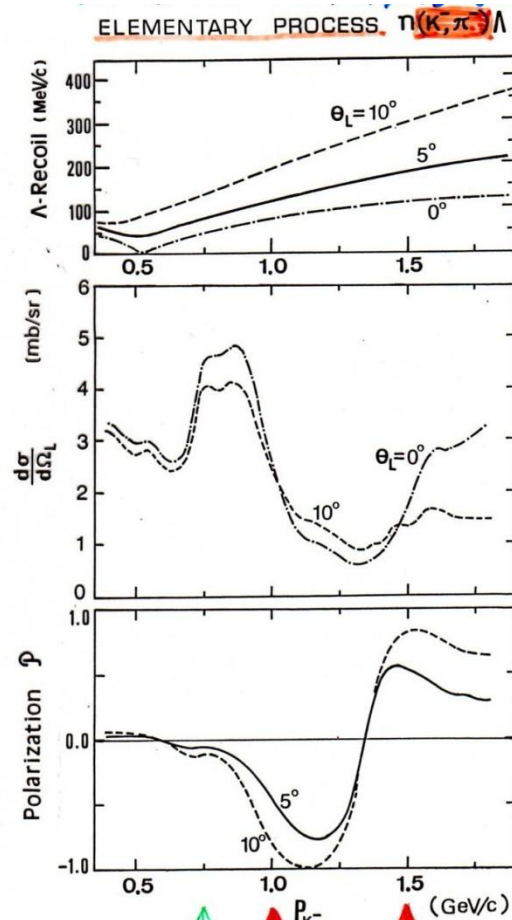
All the bound states determined

2. ハイパー核生成反応

Characteristics of the (K^- , π^-), (π^+ , K^+), (γ , K^+) reactions

- DWIA treatment based on the elementary amplitudes (spin-flip, spin non-flip)
- Nuclear and hypernuclear wave functions including core excitation effects

How to produce hyperons and hypernuclei

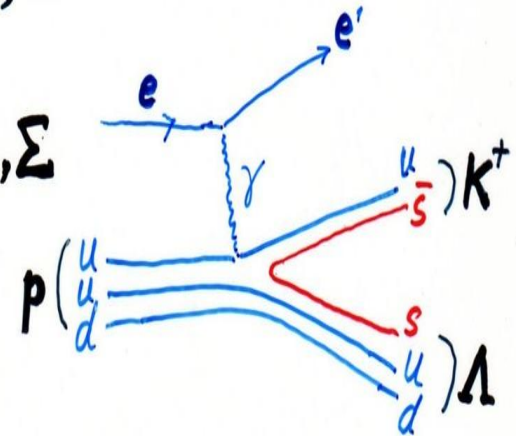


large P

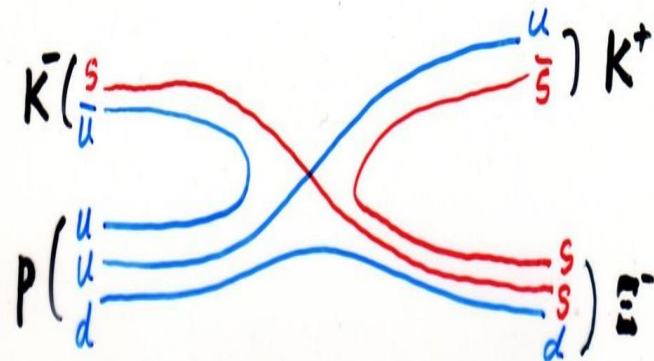
- $\pi(K^-, \pi^-) \Lambda, \Sigma$

- $N(\pi^\pm, K^+) \Lambda, \Sigma$

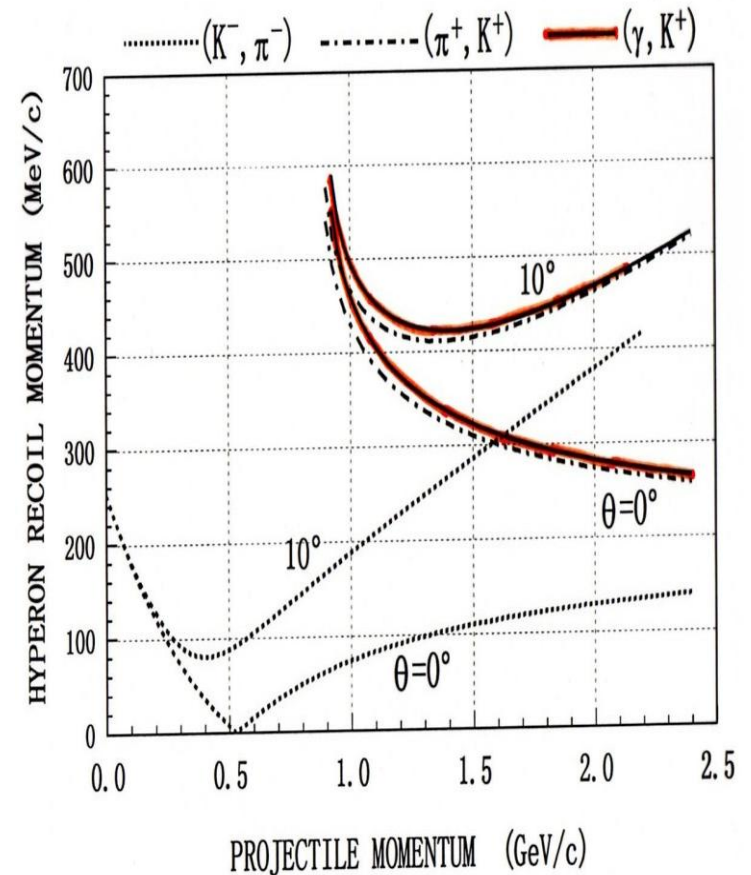
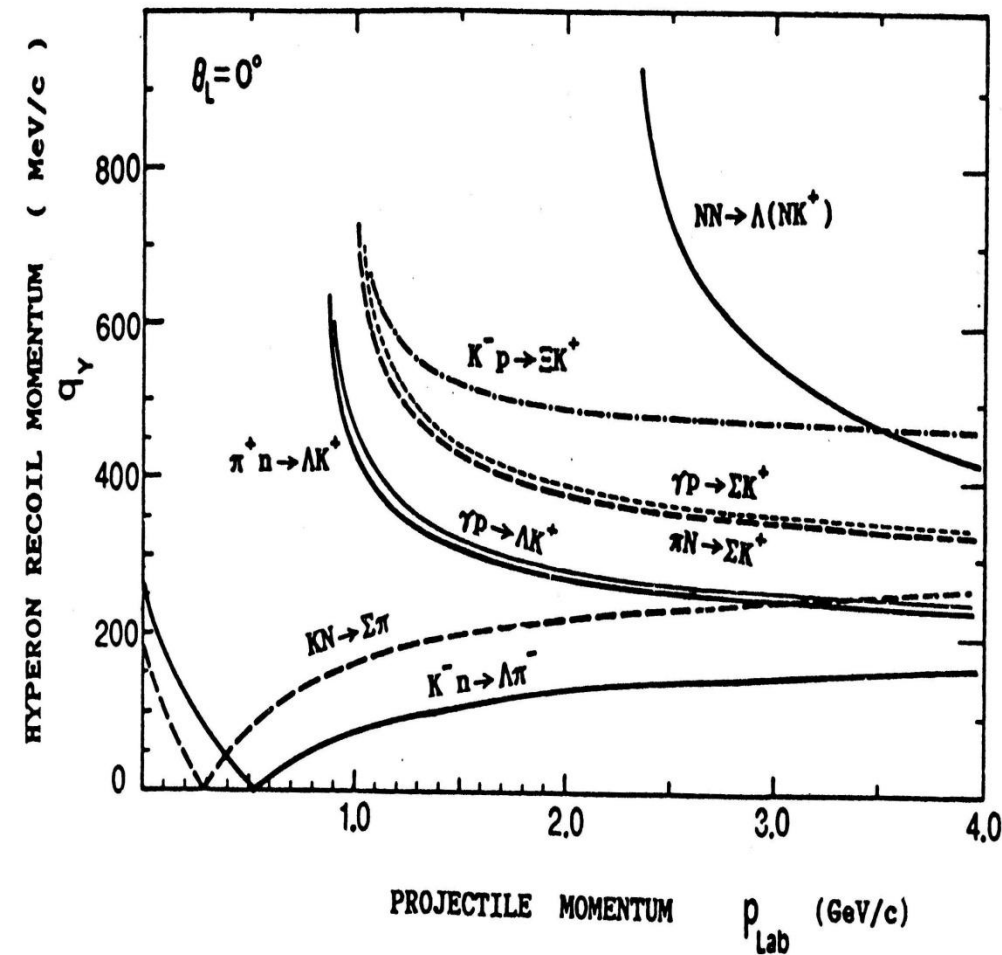
- $p(e, e' K^+) \Lambda, \Sigma$



- $p(K^-, K^+) \Xi^-$



Hyperon recoil momentum and the transition operator determine the reaction characteristics



$q = 350 - 420 \text{ MeV/c}$ at $E_\gamma \approx 1.3 \text{ GeV}$

Selectivity in hypernuclear productions

(K^-, π^-) at $p=0.8$ GeV/c:

*Recoilless production of Λ
substitutional states with $\Delta L=0,1$*

(π^+, K^+) at $p=1.05$ GeV/c:

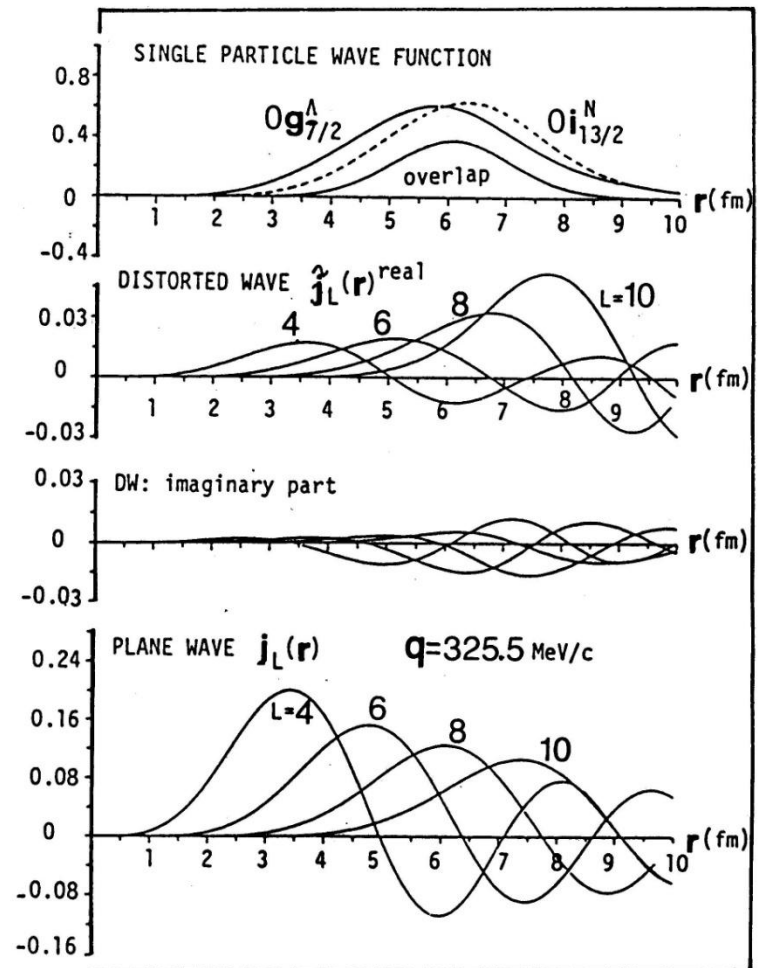
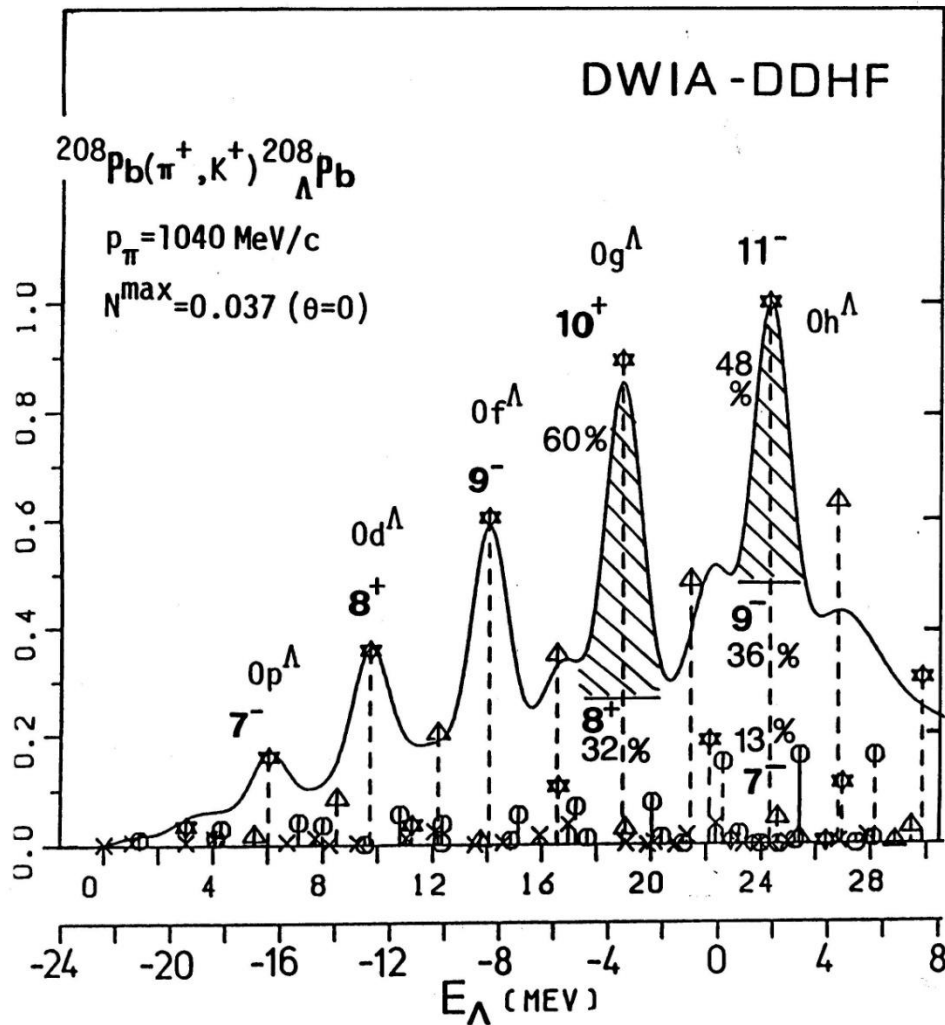
Natural parity high-spin stretched states

(γ, K^+) at $p=1.3$ GeV/c:

Unnatural parity high-spin states

Well-separated pronounced peaks

(Weidenmuller), Dover-Ludeking-Walker, Motoba-Bando



Estimates of E2/M1 transitions and reaction cross sections using Nuc. & Hyp. WF

In the "frozen-nucleon" approximation,

$$|\overline{T}_{if}^L|^2 = \sum_{M_f} R(J_f J_i; M_f),$$

$$R(J_f J_i; M_f) \equiv \frac{1}{2J_i+1} \sum_{M_i} |\langle J_f M_f | \hat{\theta}_{ba} | J_i M_i \rangle|^2$$

Frame $\{\hat{x} = \hat{y} \times \hat{z}, \hat{y} // \hat{q}, \hat{z} \equiv \hat{n}\}$

$$\hat{z} \equiv \hat{p}_a - \hat{p}_b$$

M is quantized along the direction $\hat{n}$

$$R(J_f J_i; M_f)$$

$$= \lambda^2 \{ |f|^2 \rho^{ff}(M_f) + |g|^2 \rho^{gg}(M_f) + 2 \operatorname{Im}[f g^*] \rho^{fg}(M_f) \}$$

$$N^{ff}(J_i, J_f) \equiv \sum_{M_f} \rho^{ff}(M_f), \text{ etc}$$

reduced eff. number (cf. H. Bandet et al. P.R. C39(1989) 587)

$|\overline{T}_{if}^L|^2$ consists of N^{ff} , N^{gg} and N^{fg} .

generalization of eff. nucleon number

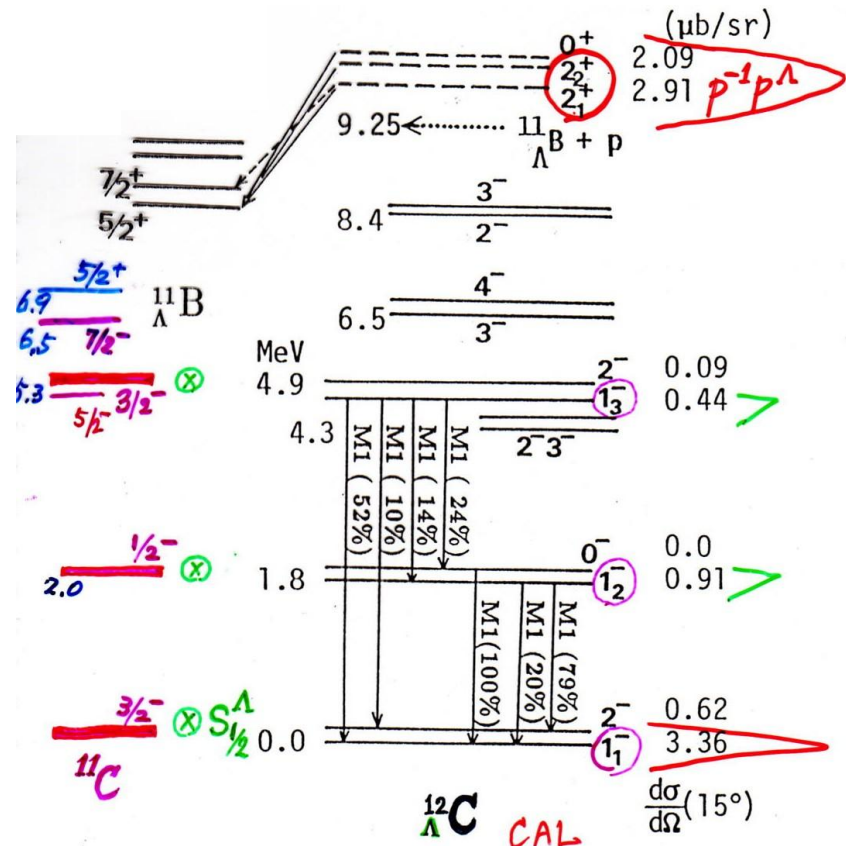


Figure 2 Calculated decay scheme of ^{12}C

(π^+, K^+) at $p=1.05$ GeV/c:

CAL (Itonaga et al 1994) VS. EXP (Hotchi et al, 2001)

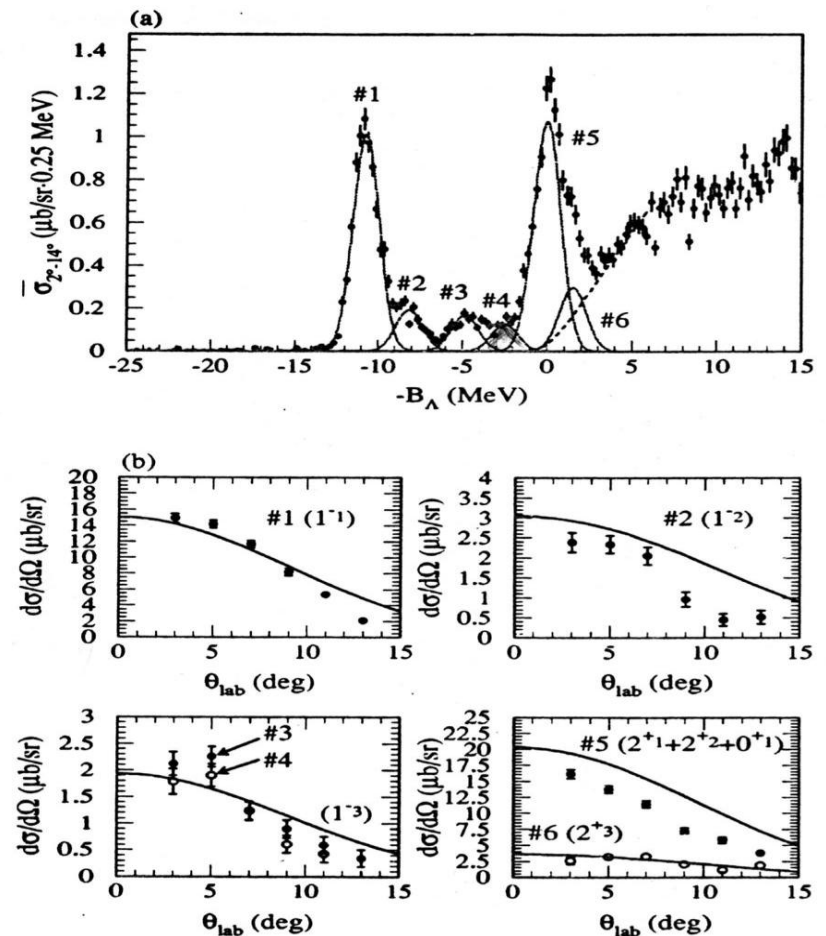
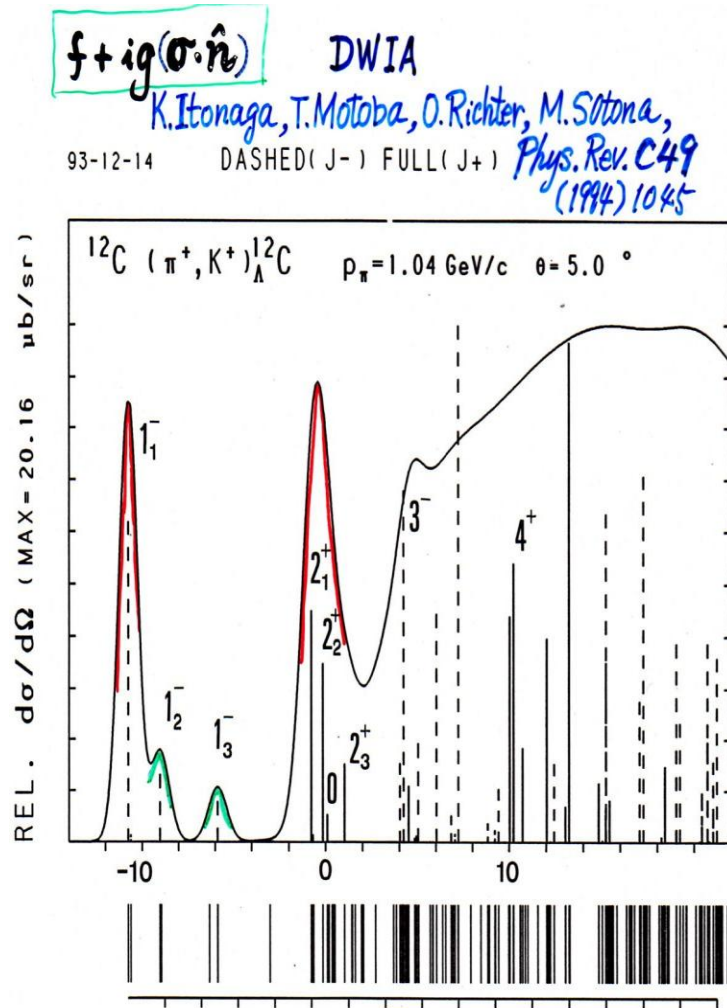


FIG. 8. (a) $^{12}\text{C}_{\Lambda}$ spectrum obtained with the thick carbon target. (b) Angular distributions of kaons leading to the observed peaks for the $^{12}\text{C}(\pi^+ K^+)$ reaction, derived from the above high-statistics

(Example) How to understand $_{\Lambda}^{89}\text{Y}$ data

H. HOTCHI *et al.* PHYSICAL REVIEW C 64 044302

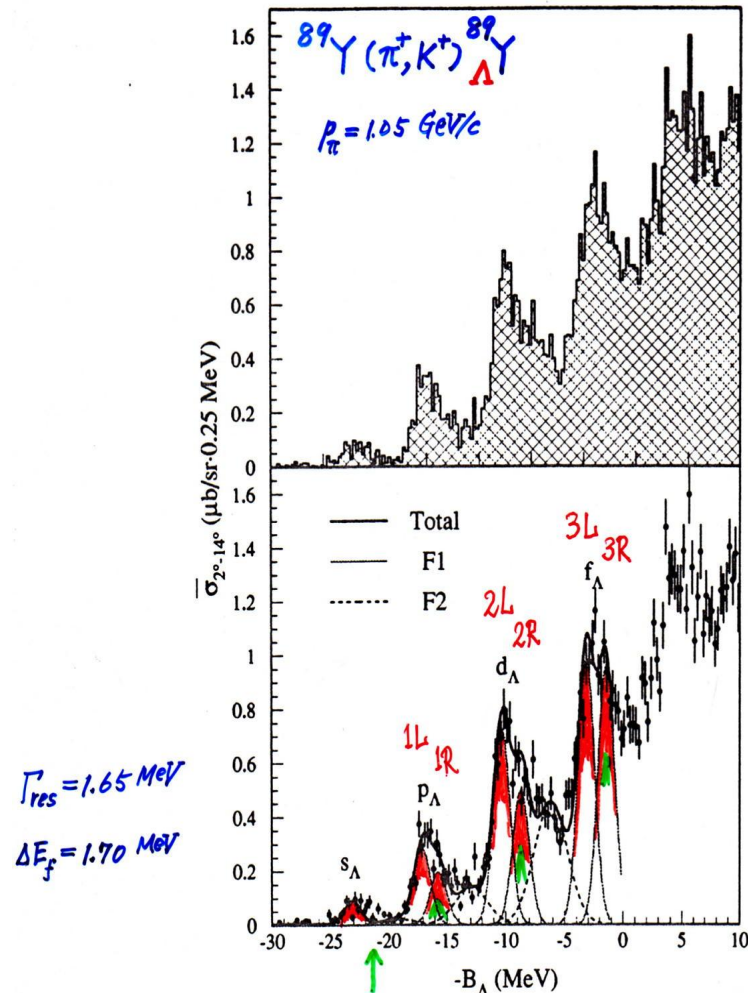
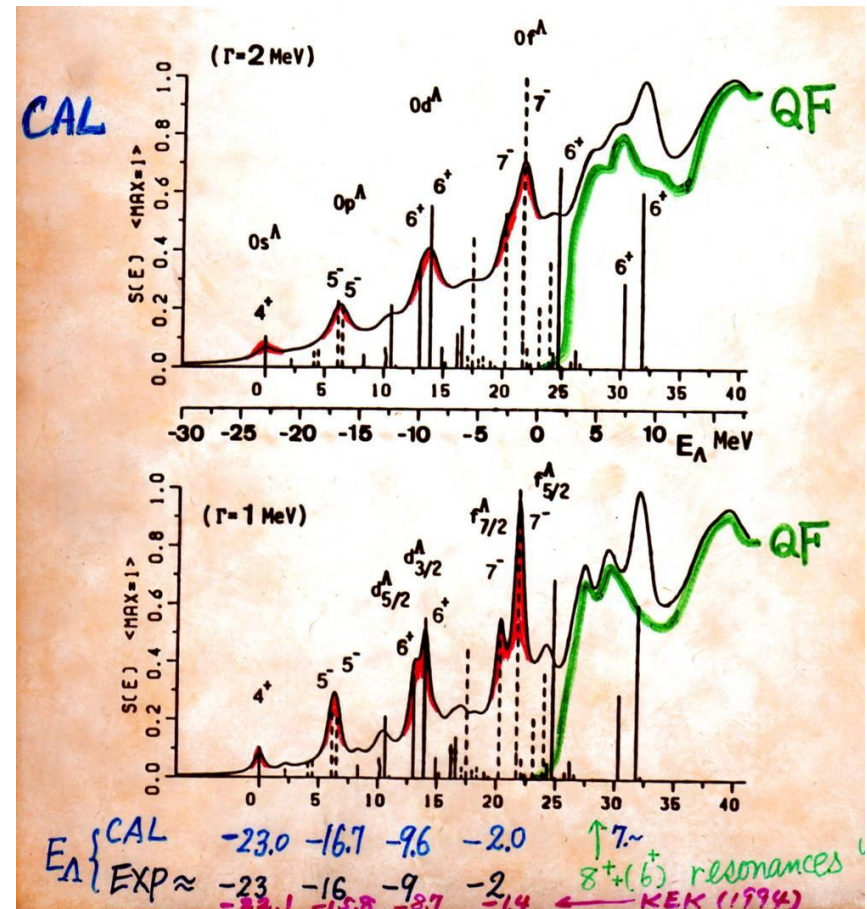


FIG. 5. Hypernuclear mass spectra of $_{\Lambda}^{89}\text{Y}$ without (up) and with (down) fitting curves described in the text. The quoted errors are statistical.



If we assume that each doublet corresponds to $j_>$ and $j_<$,

Two Serious problems arise:

- (1) Energy splittings are **not** proportional to $(2l+1)$.

Peaks	E_Λ (MeV)	ΔE_Λ	(ΔE_Λ ratio)		
		(<i>EXP</i>)	(<i>HO</i>)	(<i>WS-CAL</i>)	
$l=0$	-23.11				
$l=1$	L -17.10 R -15.73	}	1.37	(1.0)	(1.0)
$l=2$	L -10.32 R -8.69	}	1.63	(1.19)	(1.67)
$l=3$	L -3.13 R -1.43	}	1.70	(1.24)	(2.33)
					(3.36)

If we assume that each doublet corresponds to $j_>$ and $j_<$,

Two Serious problems arise:

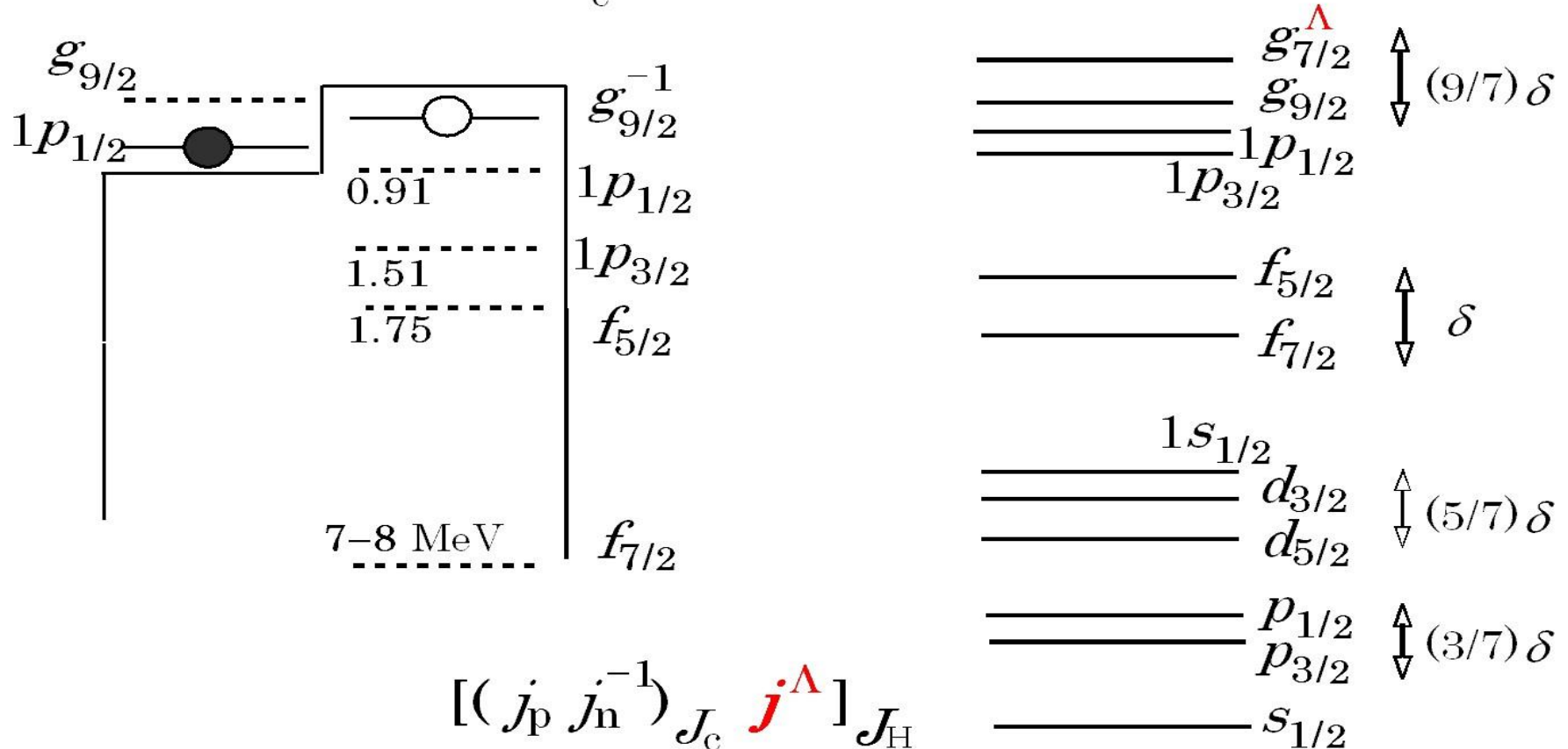
(2) Cross section ratio is opposite to the theory .

Peaks	E_Λ (MeV)	σ ($\mu\text{b/sr}$)	<i>L/R ratio</i>	
			(<i>EXP</i>)	(<i><u>DWIA-CAL</u></i>)
$l=0$	-23.11	0.60		
$l=1$ L	-17.10	2.00	} 1.45	1.00 (<u>L=R</u>)
R	-15.73	1.38		
$l=2$ L	-10.32	5.10	} 1.45	0.55 (<u>L<R</u>)
R	-8.69	3.52		
$l=3$ L	-3.13	6.87	} 1.01	0.44 (<u>L<R</u>)
R	-1.43	6.79		

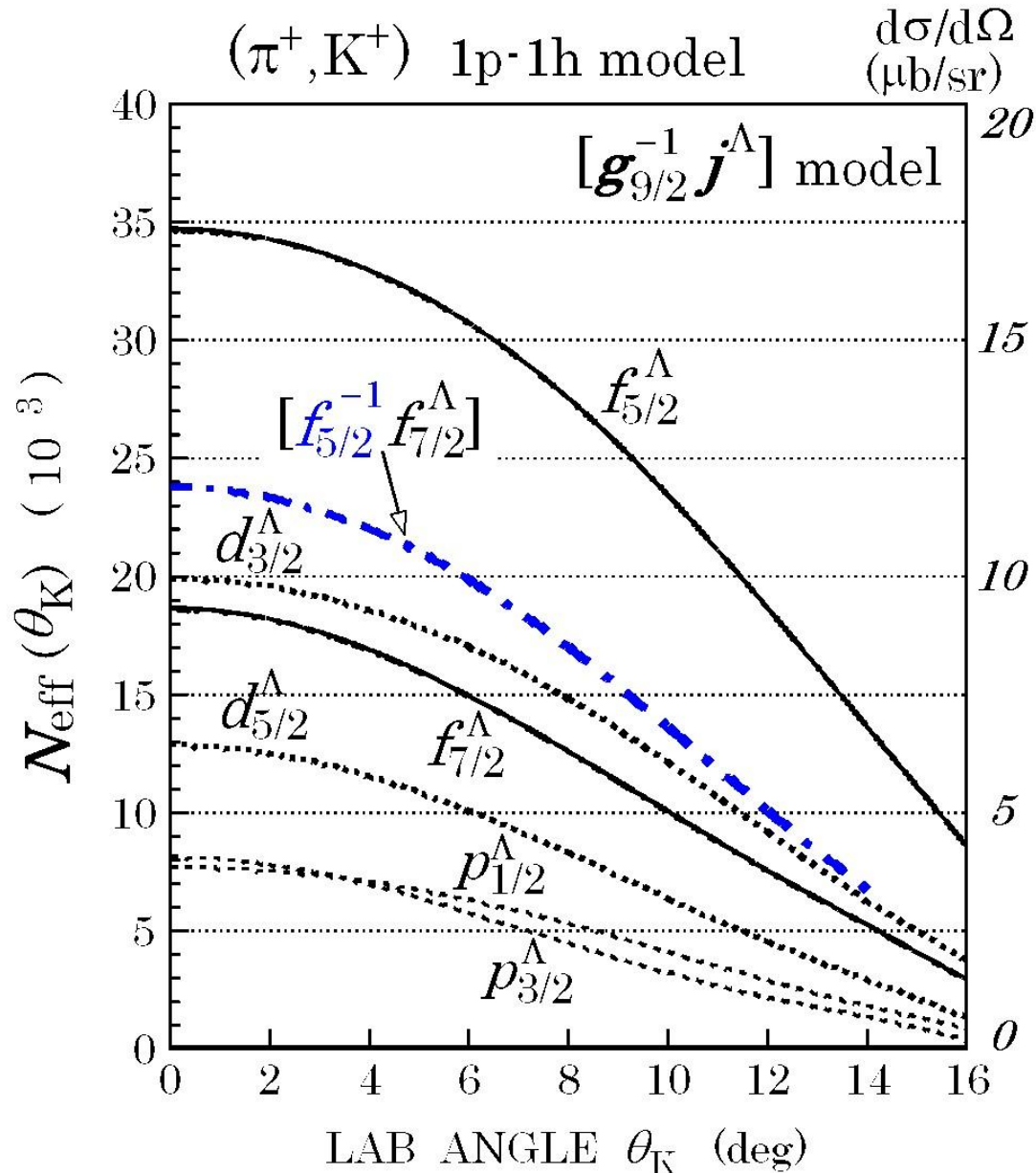
Models for Structure of $^{89}_{\Lambda}\text{Y}$:

- (3) Many $[1p-1h]_{J_c}$ multiplets of the ^{88}Y core excitation due to V_{NN} .

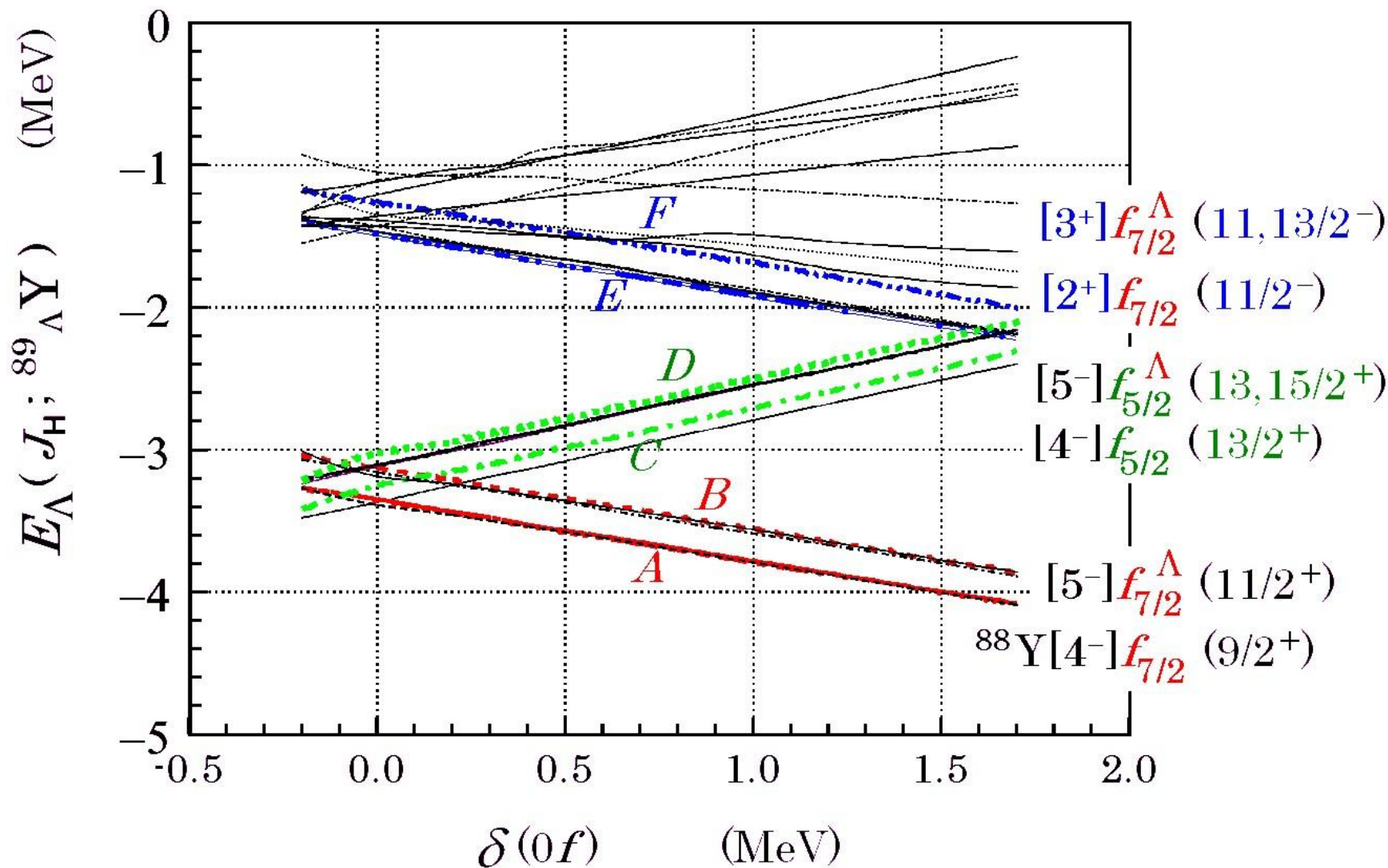
$$^{88}\text{Y} (j_p j_n^{-1})_{J_c} \quad \otimes \quad \Lambda \text{ orbits } (j^{\Lambda})$$

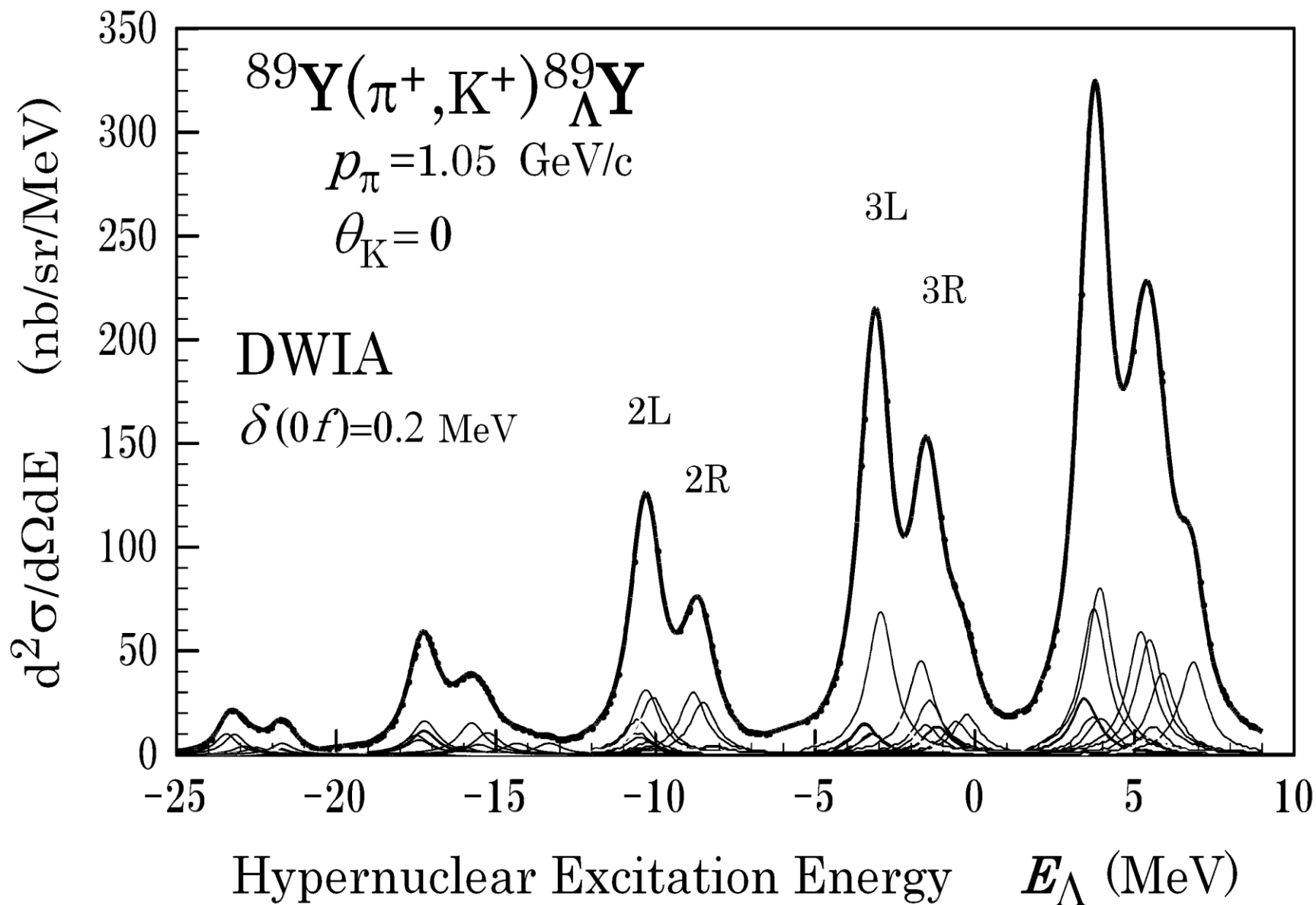


Cross section estimates



Change of energies as a function of δ





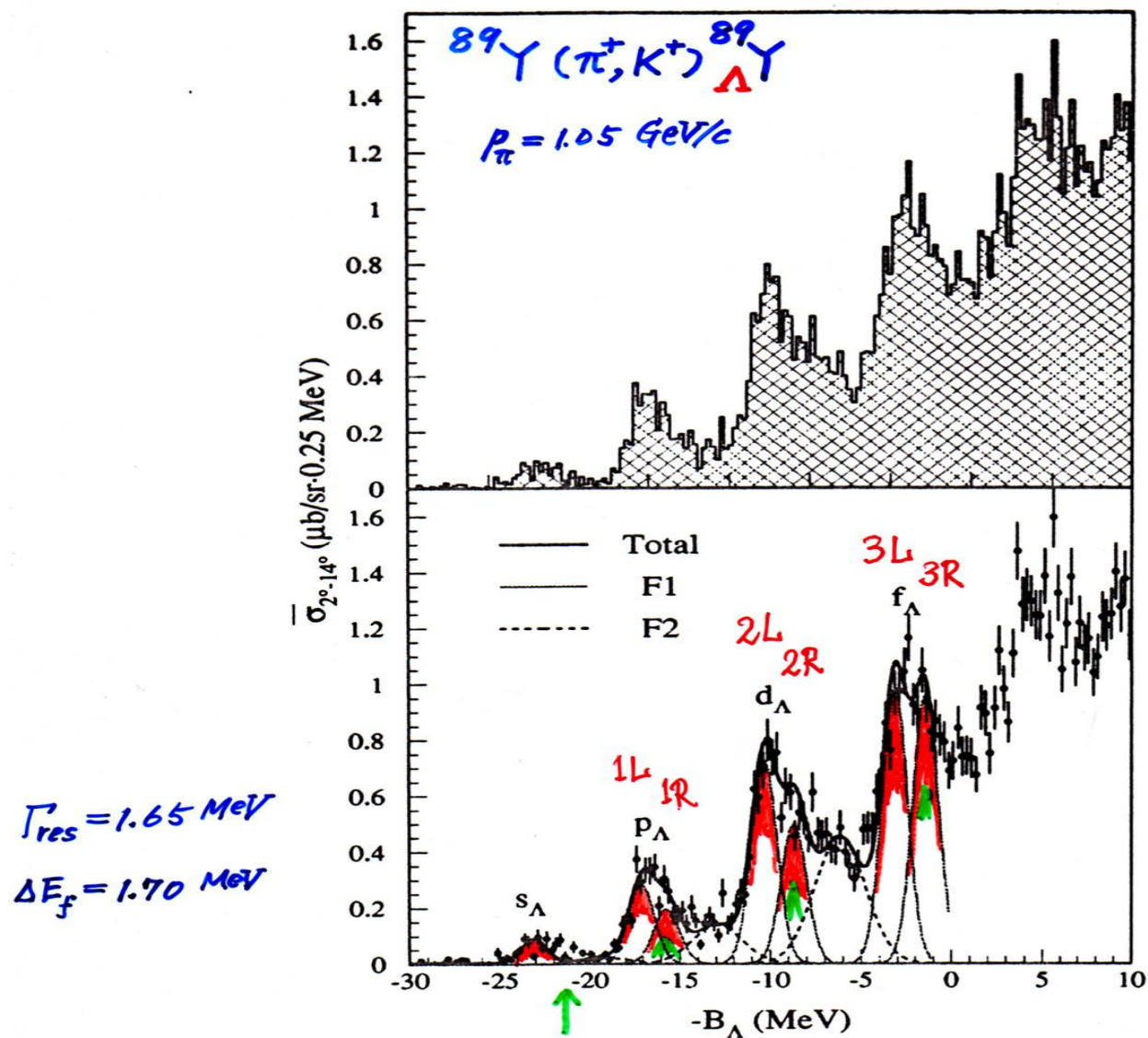


FIG. 5. Hypernuclear mass spectra of $^{89}_{\Lambda}\text{Y}$ without (up) and with (down) fitting curves described in the text. The quoted errors are statistical.

橋本、永江らの(π^+ , K^+)実験は、 原子構造のFrank-Hertzの実験に相当

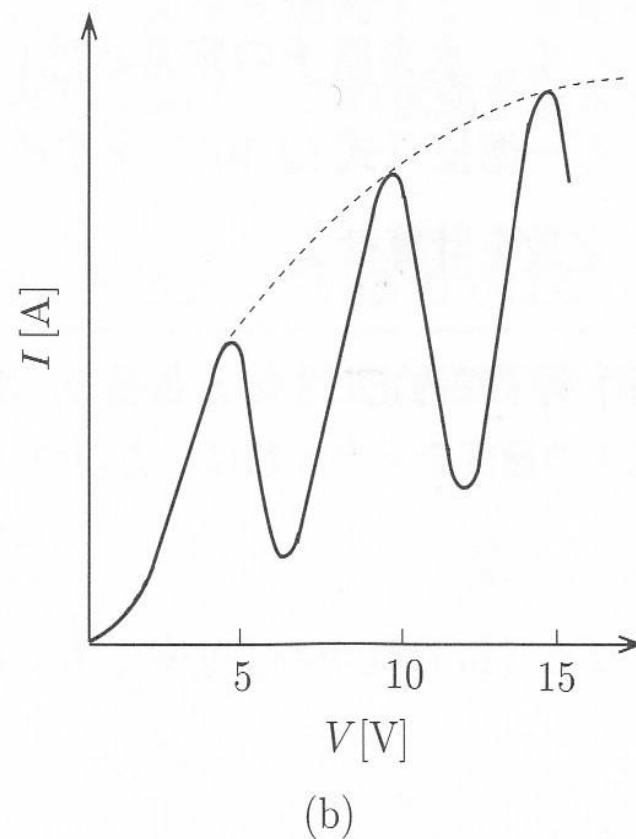
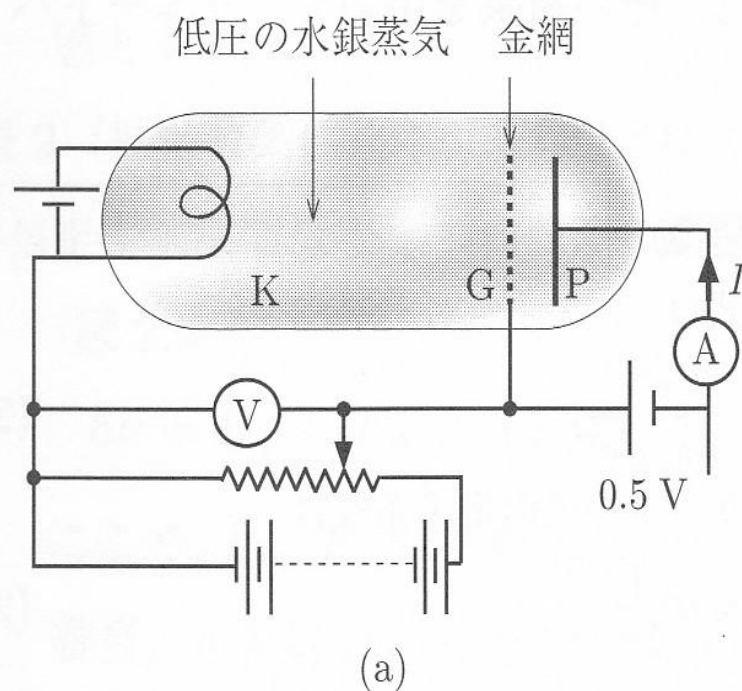


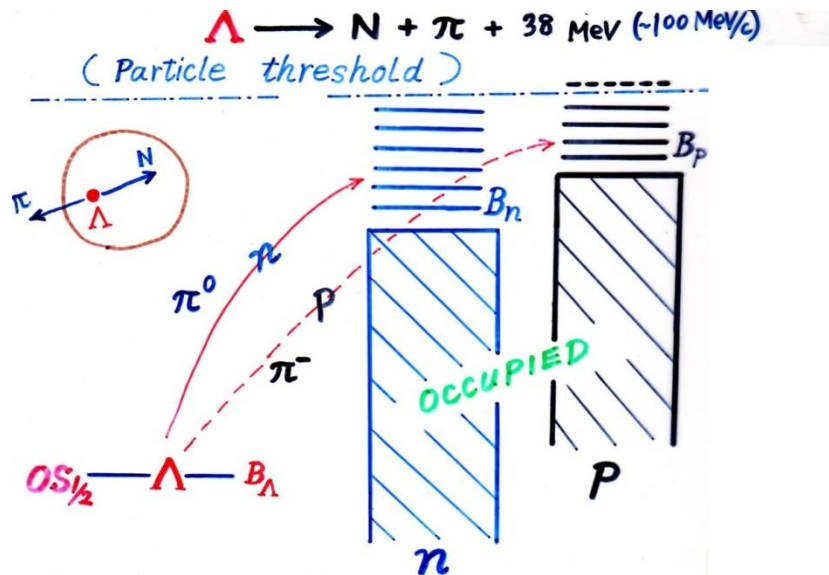
図 2.10 (a) フランク・ヘルツの実験の概念図と (b) 金網 G の電圧 V と電流 I の関係

3. 弱崩壊

π -decay, NM-decay

- Itonagaらと計算
- 波動関数はYamamotoらのYNG interactions
により構造計算

4. Mesonic decay of p-shell hypernuclei: The shell model works nicely to explain data.



Pion distorted waves $\chi_\pi^{(-)*}(q;r)$
solve Klein-Gordon Eq.

Optical potential (MSU group)

J.A. Carr et al. P.R. C25(1982)952

effective form:

$$2\omega U_\pi = -4\pi [b_{\text{eff}} \rho(r) - c_{\text{eff}} \nabla \rho(r) \nabla + c_{\text{eff}} \frac{\omega}{2M} \nabla^2 \rho(r)]$$

adopted

general form:

⊕ Vertex renormalization

M. Ericson & H. Bandō, P.L. B273(1990)89

$$2\omega U_\pi = -4\pi [b(r) + B(r)] + 4\pi \nabla \cdot \{ \tilde{\mathcal{L}}(r) [C(r) + C(r)] \} \nabla - 4\pi \{ \frac{P_1-1}{2} \nabla^2 C(r) + \frac{P_2-1}{2} \nabla^2 C(r) \}$$

LLEE

$$b(r) = p_1 [b_0 \rho(r) - \epsilon_\pi h_1 \delta \rho(r)]$$

$$c(r) = \frac{1}{p_1} [c_0 \rho(r) - \epsilon_\pi h_1 \delta \rho(r)]$$

$$B(r) = p_2 B_0 \rho(r)^2$$

$$C(r) = \frac{1}{f_2} c_0 \rho(r)^2$$

$$\tilde{\mathcal{L}}(r) = \{ 1 + \frac{4\pi\lambda}{3} [C(r) + C(r)] \}^{-1}$$

$$\begin{aligned} \tilde{\mathcal{L}}^{(s)}(r) &= 1 \\ \tilde{\mathcal{L}}^{(p)}(r) &= \tilde{\mathcal{L}}(r) \end{aligned}$$

Increase of nucleon occupation
(Pauli blocking) $A \rightarrow \infty$

Approx. orthogonality $\langle \psi_N | \phi_\Lambda \rangle \approx 0$

No distortion: $F_{\pi^0}/F_\Lambda < 10^{-4}$ for $100 < A$

Pion distortion induces high- q components.

→ Restore $\langle \psi_N | \chi_\pi | \phi_\Lambda \rangle$

Shell & Cluster Structure Effects

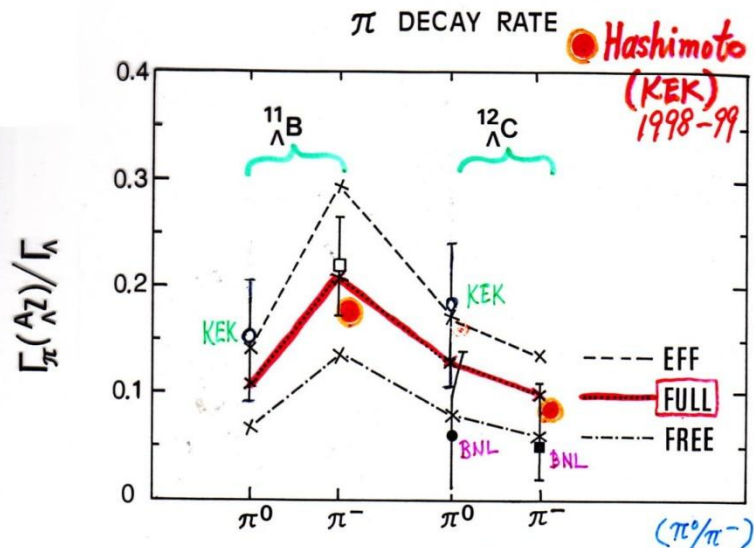
Suppression

Competition

← V.R.

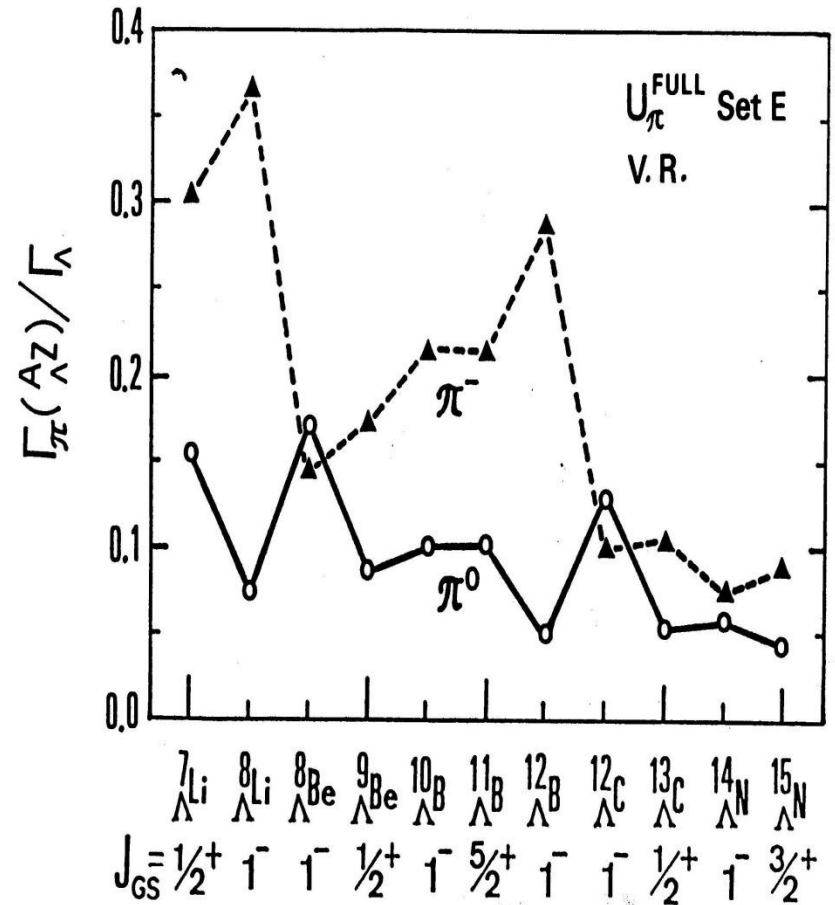
Shell dependence predicted explained.

BNL • J.J. Szymanski et al., P.R. C43 (1991)
 KEK ○ A. Sakaguchi et al., P.R. C43 (1991)

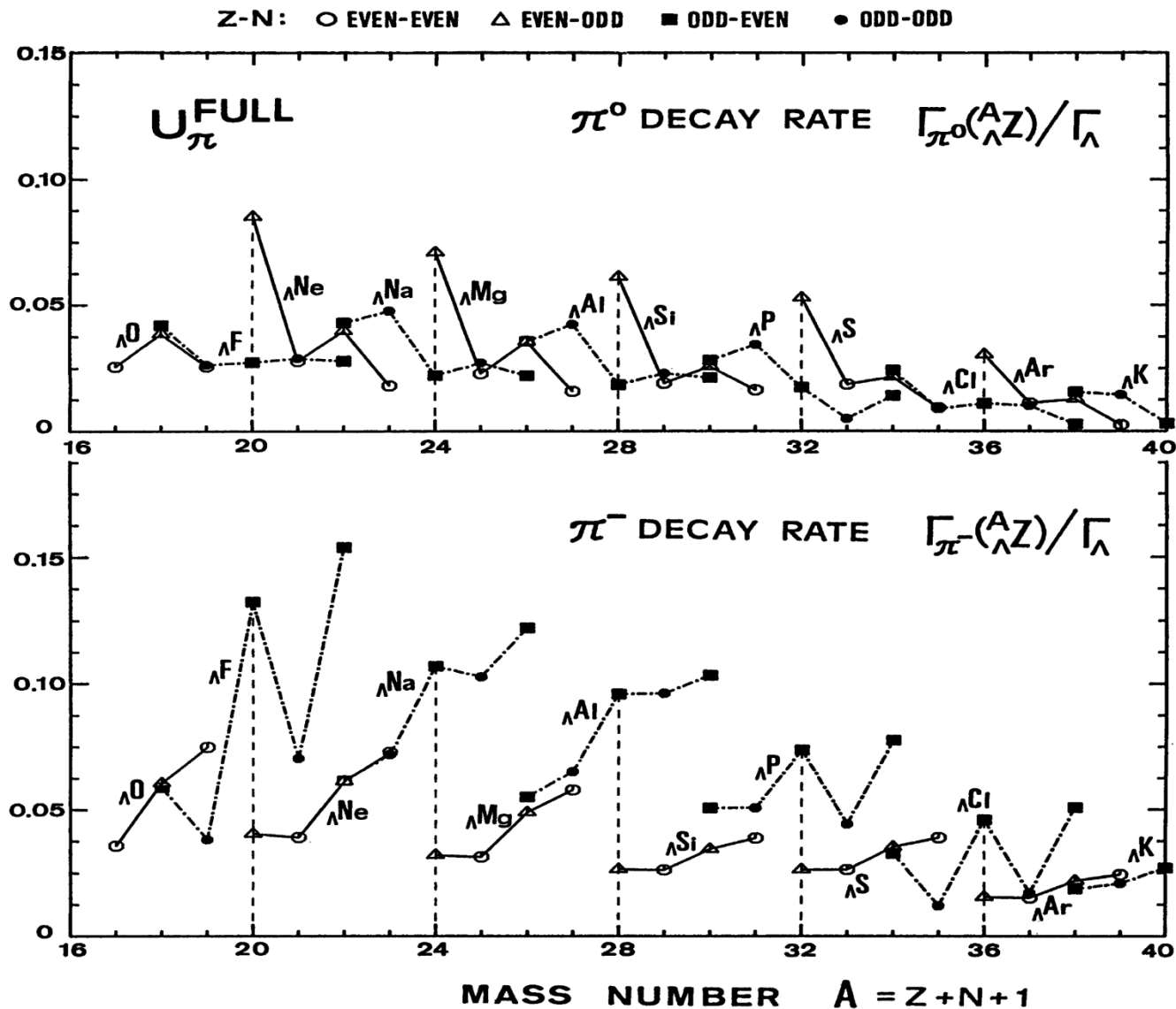


CAL.	0.103	0.213	0.130	0.098	(1.32)
BNL			$0.06^{+0.08}_{-0.05}$	$0.05^{+0.06}_{-0.03}$	(1.16)
KEK	0.192 ± 0.090		0.217 ± 0.085		
Hashimoto (1998)		0.163 ± 0.026		0.092 ± 0.020	
Oset et al. (priv. comm. 1992)		0.159	0.086		(1.86)

1. Importance of π -DW 30~40% enhancement in p-shell
2. $\Gamma_{\pi^0} > \Gamma_{\pi^-}$ in $^{12}\Lambda\text{C}$ has been confirmed by Exp.
 $\rightarrow$ sensitive to shell structure



sd-shell hypernuclear π -decays



ダブルハイパー核の弱崩壊

EXAMPLES ONLY

Production and decay

Motoba, Bando, Fukuda, and Zofka, Nucl. Phys. A534 (1991) 597.

Yamamoto, Wakai, Motoba, and Fukuda, Nucl. Phys. A625 (1997) 101.

Structure

Hiyama, Kamimura, Motoba, Yamada, and Yamamoto,
Phys. Rev. C 65 (2002) 011301

4. $(e,e'K^+)$ Reaction Spectroscopy

With Bydzovsky, Sotona, Itonaga,(Hiyama)

(K^-, π^-)

(π^+, K^+)

played a great role of
exciting high-spin series

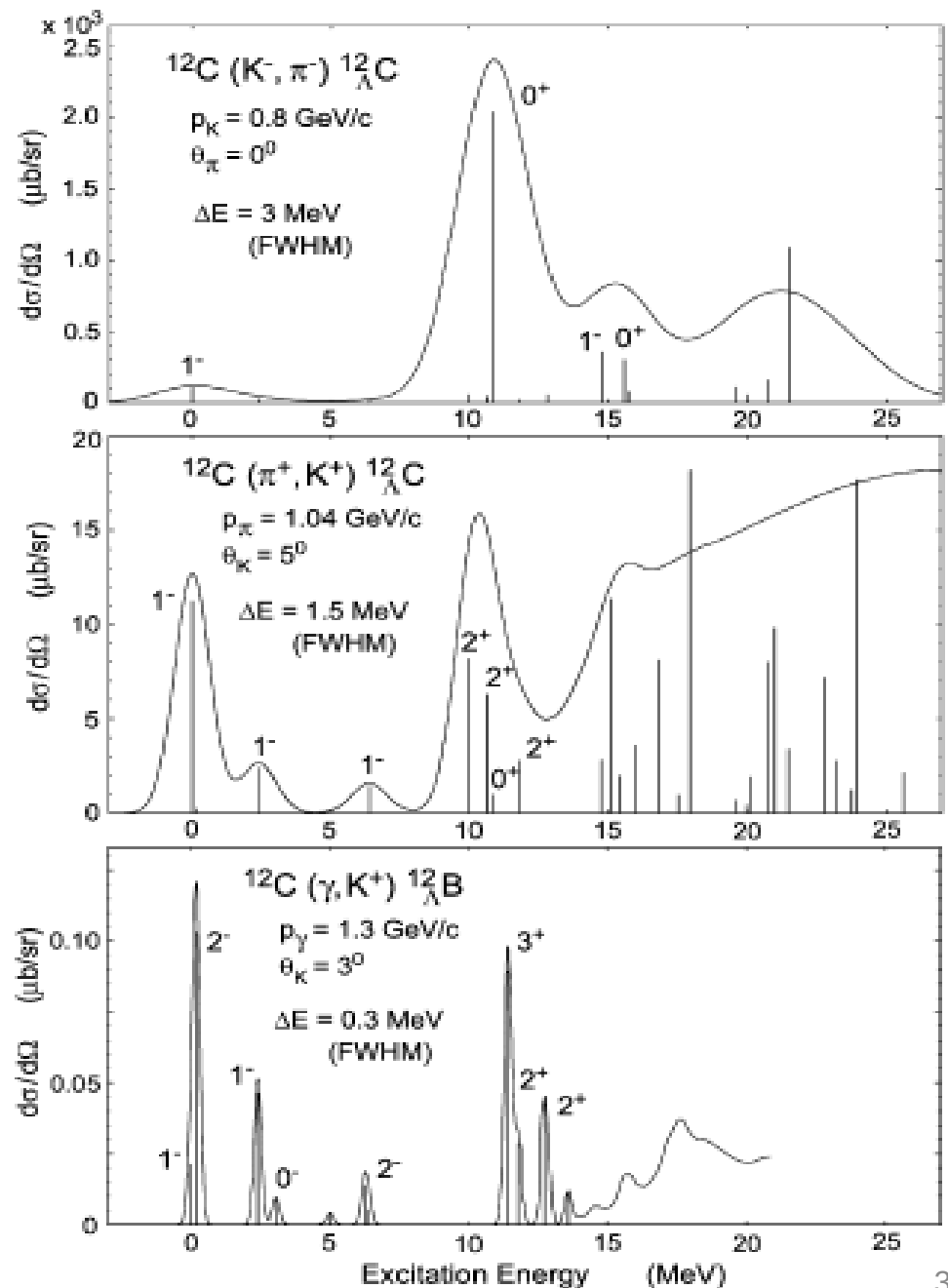
$\Gamma = 1.5 \text{ MeV (best)}$

$(e, e' K^+), (\gamma, K^+)$

Motoba, Sotona, Itonaga,
Prog.Theor.Phys.S.[117](#)(1994)

T.M. Mesons & Light Nuclei (2000)
updated w/NSC97f.

JLab Exp't : $\Gamma = 0.5 \text{ MeV}$



Why medium-mass hypernuclei ?

Basic motivation (2)

Unique characteristics of the $(e, e' K^+)$, (γ, K^+) process are based on the **basic properties** of elementary amplitudes for $\gamma p \rightarrow \Lambda K^+$:

- **sizable momentum transfer** to excite high-spin states, like (π^+, K^+)
- **spin-flip dominance** of the operator, leading to unnatural parity states

Lab $d\sigma/d\Omega$ for photoproduction (2Lab)

$$\left. \frac{d\sigma}{d\Omega} \right|_{2\text{Lab}} = \frac{(2\pi)^4 p^2 E_K E_\gamma E_A}{k \{ p(E_A + E_K) - k E_K \cos \theta_L \}} \left| \langle \mathbf{k} - \mathbf{p}, \mathbf{p} | t | \mathbf{k}, 0 \rangle_L \right|^2, \quad (2.4)$$

$$\langle \mathbf{k} - \mathbf{p}, \mathbf{p} | t | \mathbf{k}, 0 \rangle_L = a_1(\boldsymbol{\sigma} \cdot \boldsymbol{\epsilon}) + a_2(\boldsymbol{\sigma} \cdot \hat{\mathbf{k}})(\hat{\mathbf{p}} \cdot \boldsymbol{\epsilon}) + a_3(\boldsymbol{\sigma} \cdot \hat{\mathbf{p}})(\hat{\mathbf{p}} \cdot \boldsymbol{\epsilon}) + a_4\{(\hat{\mathbf{k}} \times \hat{\mathbf{p}}) \cdot \boldsymbol{\epsilon}\}. \quad (2.5)$$

$$\langle \mathbf{k} - \mathbf{p}, \mathbf{p} | t | \mathbf{k}, 0 \rangle_L = \epsilon_0 \underbrace{(f_0 + g_0 \sigma_0)}_{\text{Spin non-flip term}} + \epsilon_x \underbrace{(g_1 \sigma_1 + g_{-1} \sigma_{-1})}_{\text{Spin-flip terms}} \quad (2.11)$$

with definitions of the coefficients:

$$f_0 = a_4 \sin \theta_L,$$

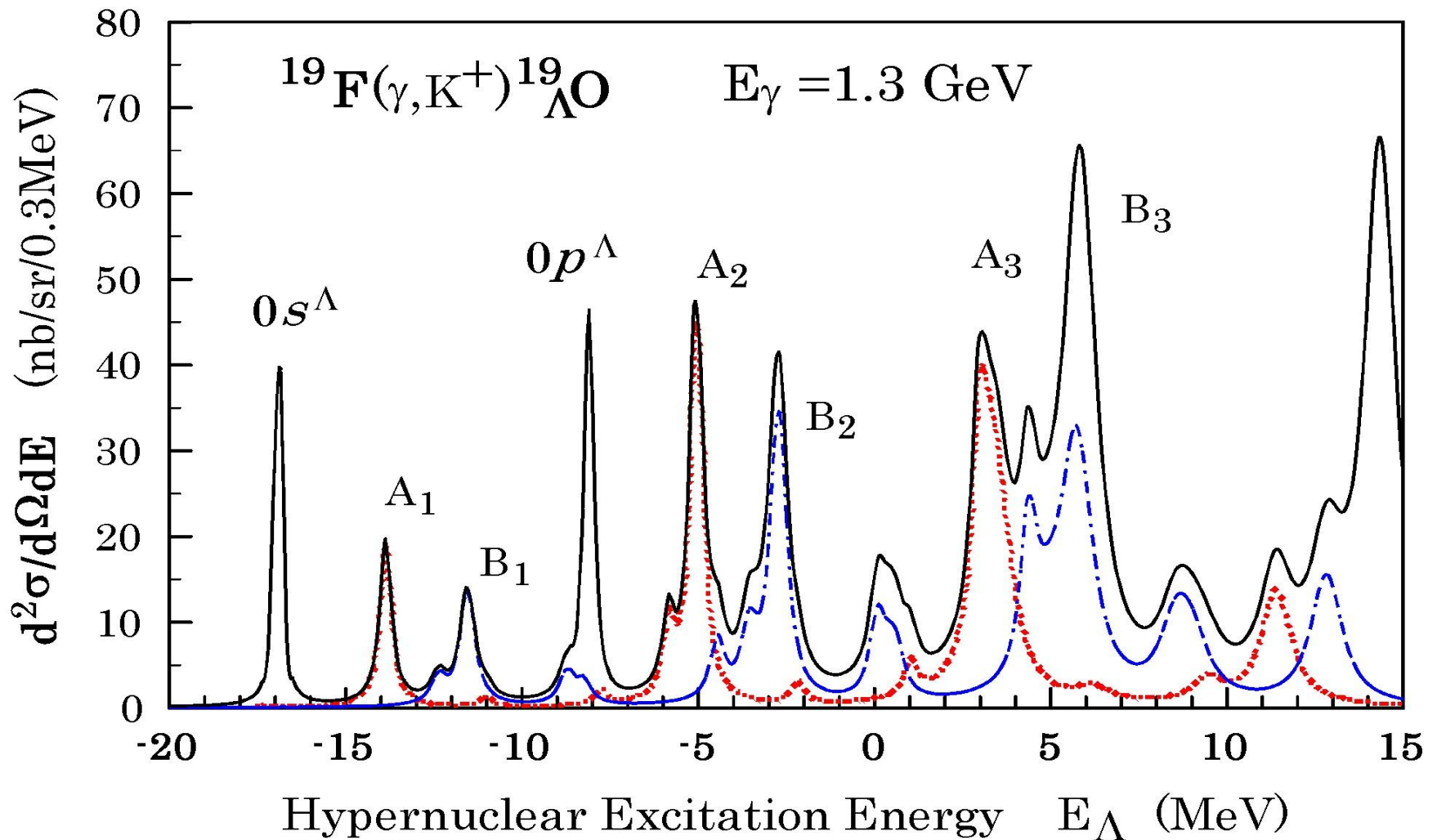
$$g_0 = a_1,$$

$$g_{\pm 1} = \frac{1}{\sqrt{2}} \{ \mp (a_1 + a_3 \sin^2 \theta_L) - i \sin \theta_L (a_2 + a_3 \cos \theta_L) \}. \quad (2.12)$$

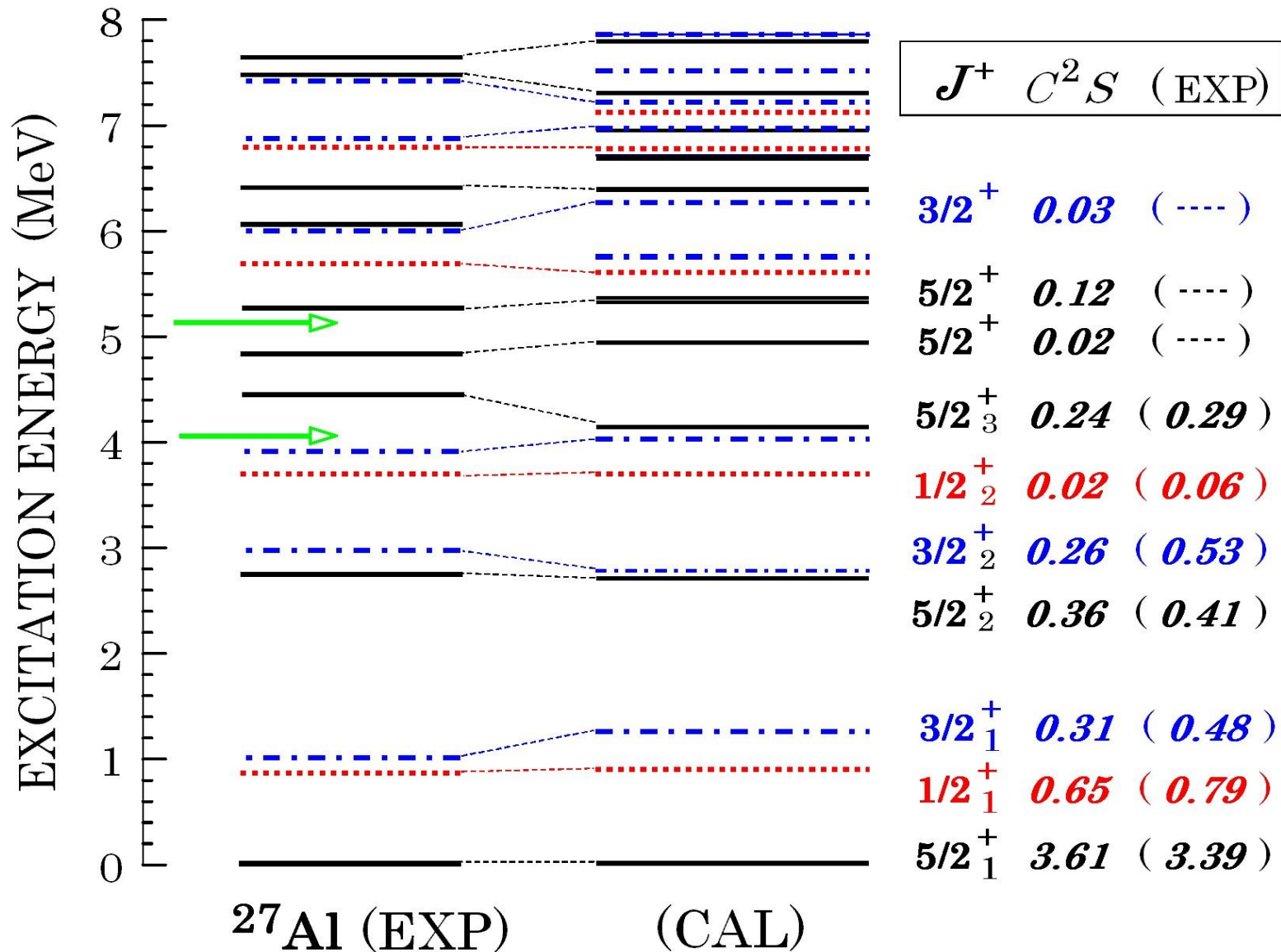
Spin-flip interaction are dominant

Lightest sd-shell target: ^{19}F

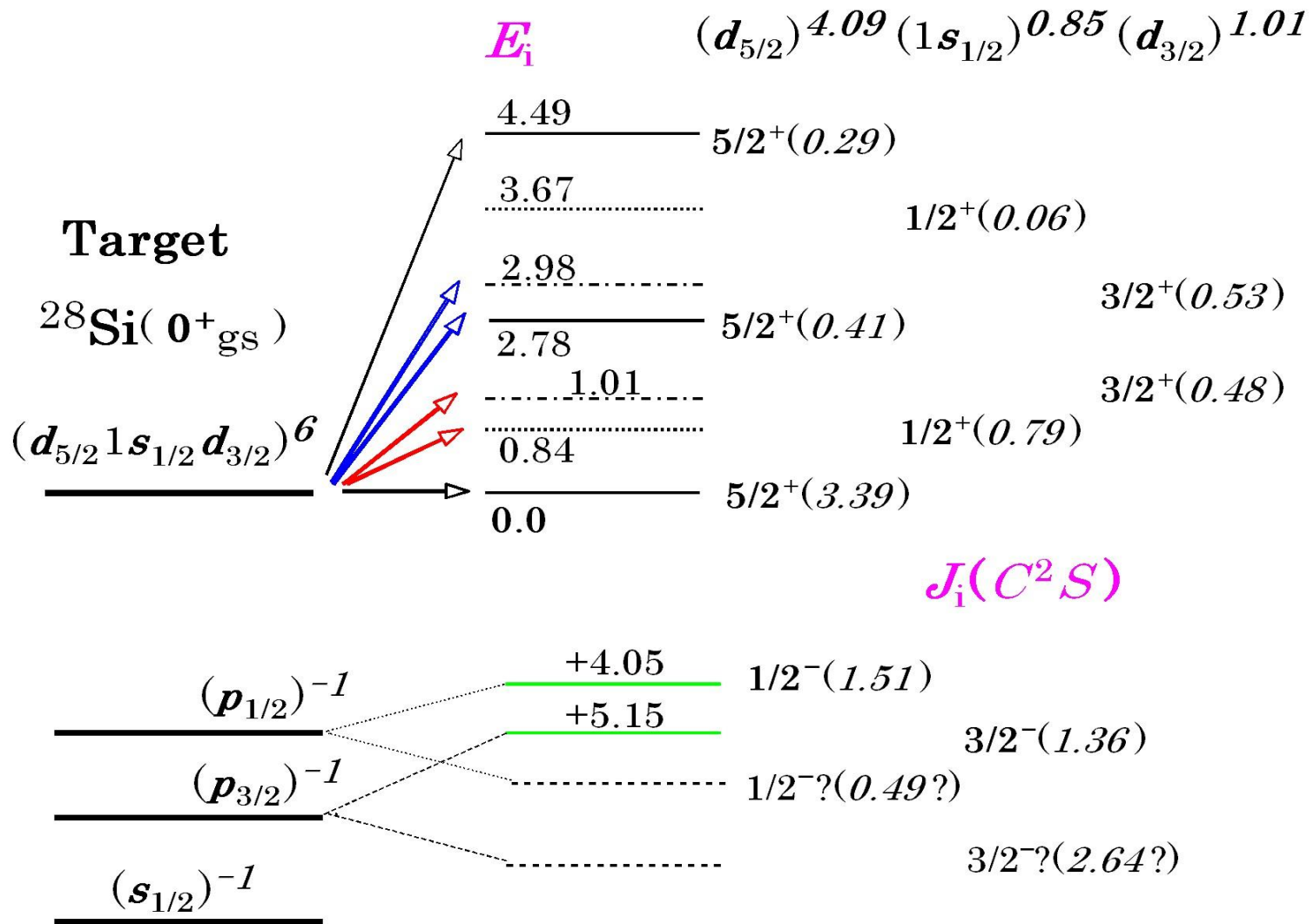
A's: $p_{1/2}$ -hole series, B's: $p_{3/2}$ -hole series



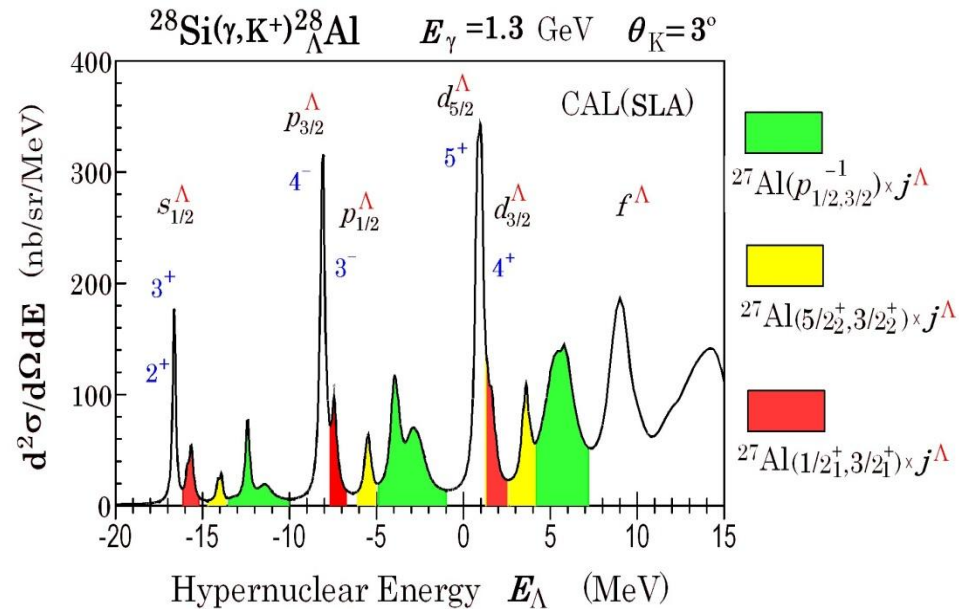
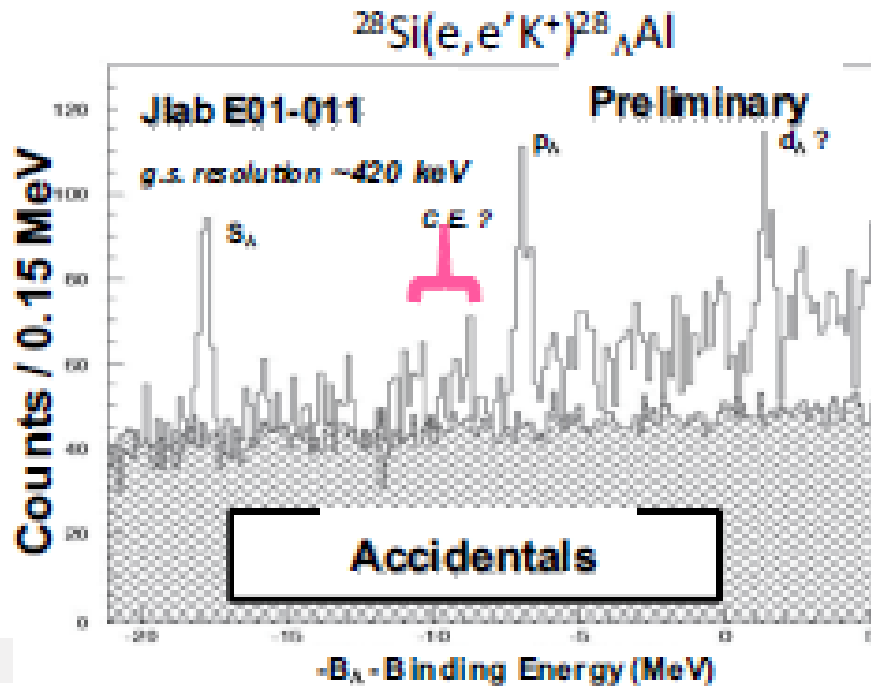
Proton pickup from $^{28}\text{Si}(0^+):(sd)^6=(d_{5/2})^{4.1}(1s_{1/2})^{0.9}(d_{3/2})^{1.0}$



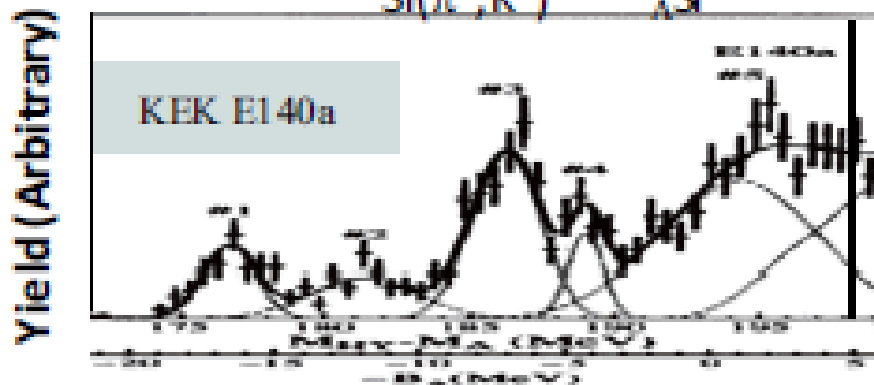
proton-state fragmentations should be taken into account *to be realistic*



$^{28}\text{Si}(e,e'\text{K}^+)^{28}_{\Lambda}\text{Al}$ – First Spectroscopy of $^{28}_{\Lambda}\text{Al}$



Major peak series : $[^{27}\text{Al}(5/2_1^+) \times j^{\Lambda}]_J$ with $j^{\Lambda}=s, p, d, \dots$



Exp. data: O. Hashimoto et al,
Nucl. Phys. A 835 (2010) 121

(waiting for the finalization of analysis)

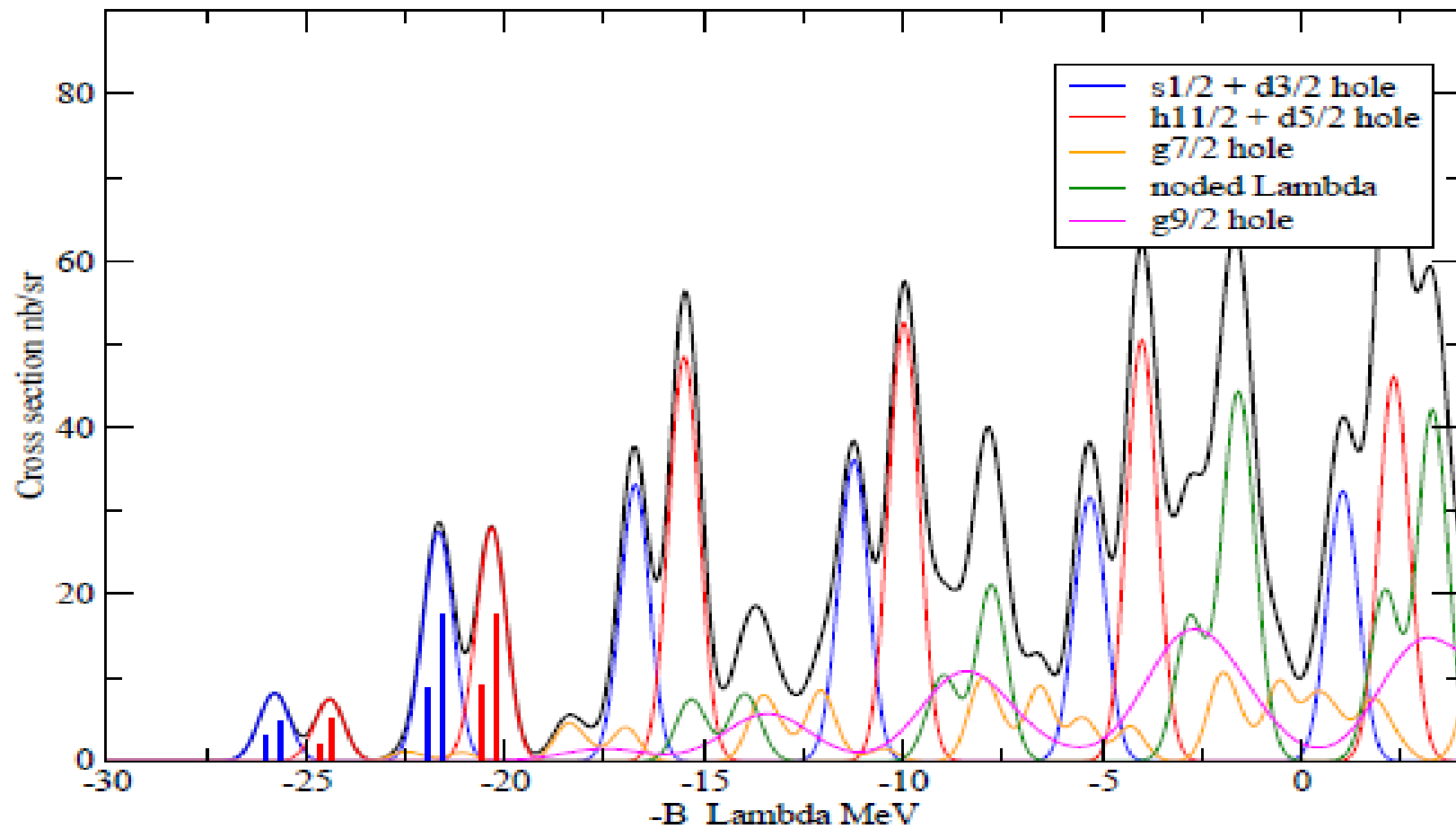
$$d^2\sigma/dE d\Omega$$

Two series of pronounced peaks (d3/2 hole, h11/2 hole),
Energy separation of 1.1—1.2 MeV, depending on Λ (nlj),

$^{208}\text{Pb}(\gamma, K+)$ $p_\gamma=1.56$, $p_K=1.2$ GeV/c

$^{208}\text{Pb}(\text{gamma}, K+)$ Motoba/Millener

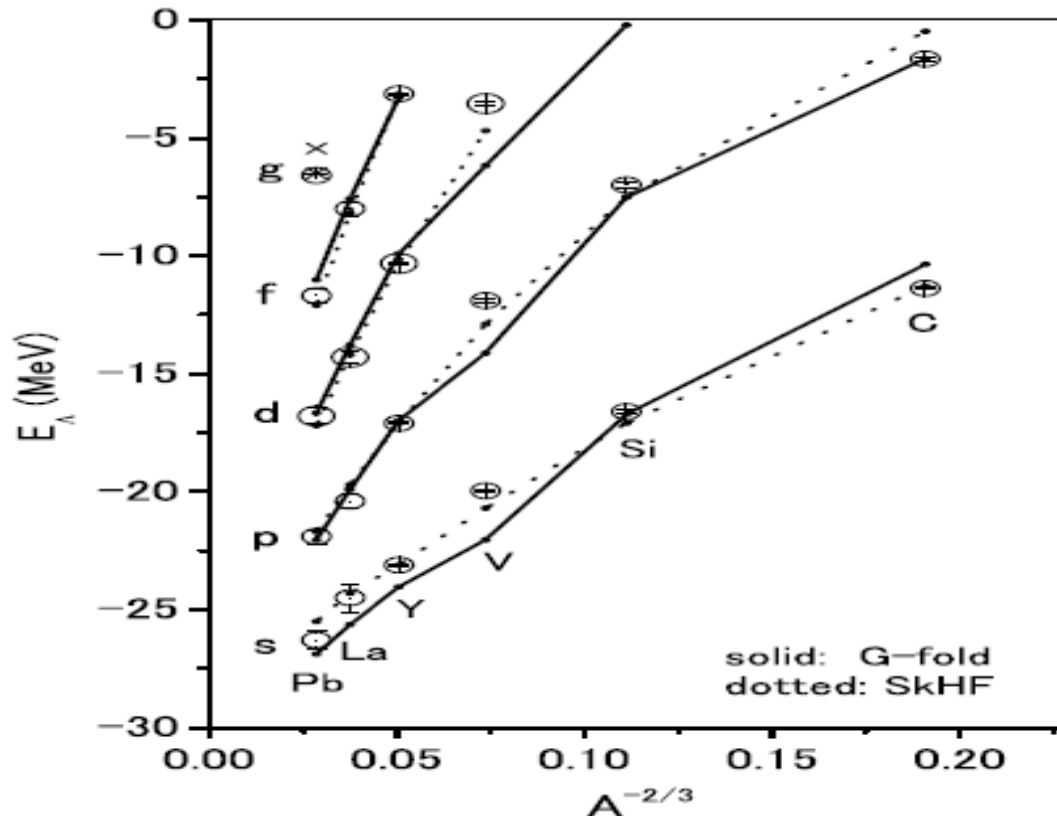
Resolution = 800 keV



Single-particle energies of Λ

G-matrix results vs. experiments

(Y. Yamamoto et al.: Prog. Ther. Phys. S.185 (2010) 72.)



Sd- and *fp*-shell data are quite Important to extract the Λ behavior in nuclear matter.

Fig. 1. Energy spectra of ${}^{13}_\Lambda\text{C}$, ${}^{28}_\Lambda\text{Si}$, ${}^{51}_\Lambda\text{V}$, ${}^{89}_\Lambda\text{Y}$, ${}^{139}_\Lambda\text{La}$ and ${}^{208}_\Lambda\text{Pb}$ are given as a function of $A^{-2/3}$, A being mass numbers of core nuclei. Solid (dashed) lines show calculated values by the G-matrix folding model derived from ESC08a (the Skyrme-HF model). Open circles denote the experimental values taken from Ref. 17).

PROSPECTS

- 1) Based on the elementary amplitudes, the microscopic theoretical framework for hypernuclear production XS were discussed.
- 2) Several photo-production spectra have been calculated by taking account of major core-excitation effects. The prediction for $^{28}_{\Lambda}\text{Al}$ is well compared with the recent experiments.
- 3) Predictions are made also for heavier typical targets, ^{40}Ca and ^{52}Cr , showing fruitful aspects.

- 4) **Medium-mass hypernuclear production by $(e,e'K^+)$** .
provide us with good opportunities in understanding the *details* of the hyperon motion in nuclear matter.
(Λ -s.p.e. to establish “textbook”, Rotation/Vib.- Λ coupling, Auger effect, μ_Λ , $e_{\text{eff}}(\Lambda)$, etc)

Remark:

The present frameworks apply also to Ξ -hypernuclear production with sd-shell targets which might be fruitful at J-PARC.

その他（追加の雑談3つ）

(1) Prospects of Strangeness Nuclear Physics

(2) 高校生へのストレンジネス核物理の魅力発信

(3) 中学生からの国語力＝思考力の確実な育成

(1) H. Bando's Prospects

P.T.P. Suppl. 81 (1985)

Three directions and three aspects of baryon many-body physics

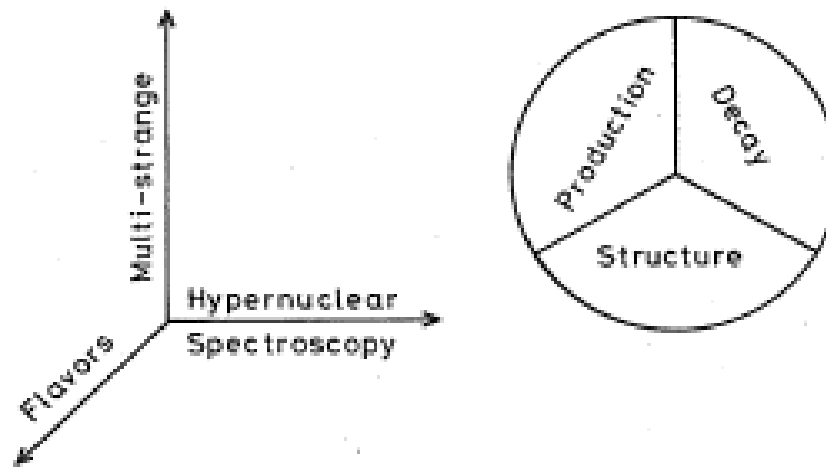


Fig. 1. Three directions and three aspects expected for the development of hypernuclear physics in future.

Three-dimensional nuclear chart

(from H. Tamura)

$N_u \sim N_d \sim N_s$



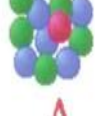
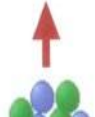
Strangeness in neutron stars ($\rho > 3 - 4 \rho_0$)

$S = -\infty$

Strange hadronic matter ($A \rightarrow \infty$)

$p, n, \Lambda, \Xi^0, \Xi^-$

↑ higher density



$\Lambda\Lambda, \Xi$ hypernuclei

→ ΛN interaction

Λ, Σ hypernuclei

Proton-rich nuclei

Neutron-rich nuclei

non-strange nuclei



neutron halo

neutron number

3-dimensional nuclear chart

(First 3D illustration

appeared in literature:

Genshikaku Kenkyu **32**
(1987) 97.

See P.T.P. S.185 (2010) 1.)

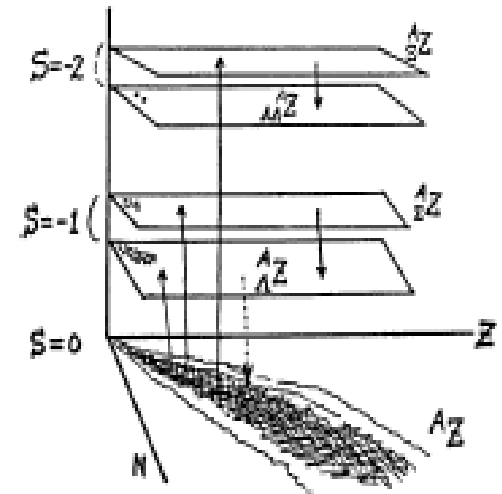
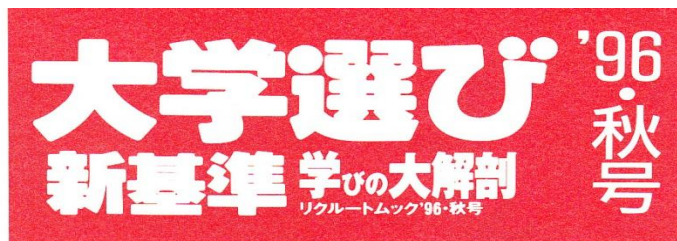


Fig. 3. 3D-illustration of hypernuclear chart drawn for the first time with the strangeness axis added (1986).⁶¹⁾

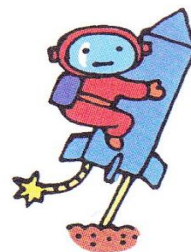
(2) 高校生への学問アピールの必要性

橋本さんからのTELで偶然知った記事(1996)



大学の基本といえば、やっぱり学問。だからこそ『興味のあることを思いっきり学べるか』って、すごく大事なことなんだ。本誌では、キミたちの後悔しない大学選びを応援すべく、41テーマで大学の学問を徹底紹介していくぞ。キミが「ホントに学びたいこと」をしっかり探してみよう！

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自然の原理を
追究したい

物理

物質をめぐる面白ワールド

ミクロの世界の 相互作用解明 が宇宙へも

大阪電気通信大学
工学部数理科学研究センター
物理学研究室

角砂糖大にすると約2億トンになるという超高密度な世界が原子核。元場俊雄教授の研究室では、この原子核にラムダなど奇妙な粒子が侵入した「ハイパー原子核」を研究。原子核に中間子を衝突させてハイパー核を生成する確率を予測するなど、その構造を分析している。「ハイペロン粒子に働く未知の相互作用の研究は宇宙の物質様式解明にもつながる」(元場教授)という壮大な研究なのだ。



「ロマンのある研究です」と語る元場教授

その3 ハイパー原子核

高温超伝導の 磁界中の特性 を探究する

千葉大学
理学部物理学科
低温物理学研究室

超伝導とは、低温状態で電気抵抗がなくなる。つまり、一度電流を流せば、永遠に流れ続けるという夢の現象だ。「研究室ではマイナス170度で超伝導になる高温超伝導体と構造の類似する人工超伝導体の磁場中での量子磁束線、簡単にいうと『超伝導に生じる特殊な磁力線』の運動を研究」(桑沢好則助教授)。これにより、将来、高温超伝導物質のリニャモーターカーや電力送電線等への応用も夢じゃない。



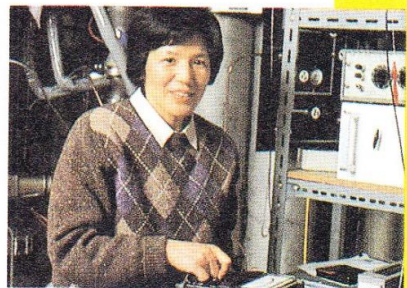
超伝導にはまだ未知の部分が多く残されている

その2 高温超伝導

低温状態でお きる現象を解 明する

岡山理科大学
理学部応用物理学科
低温物性研究室

常温では見られず、超低温状態になると発生する現象を研究しているのがこの研究室。テーマは超流動ヘリウム。液体ヘリウムは温度を下げると、粘性がないようにふるまう。この状態が超流動ヘリウムで、この時にできる渦の発生メカニズムを研究している。超流動ヘリウムは「超伝導磁石やロケットの赤外線センサーのより有効な冷却に応用できる」(藤井佳子教授)という今後が注目の研究だ。



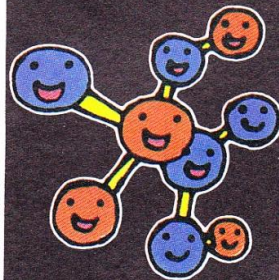
さまざまな装置を駆使し、超低温の現象を探究

その1 超流動ヘリウム

学びの大解剖

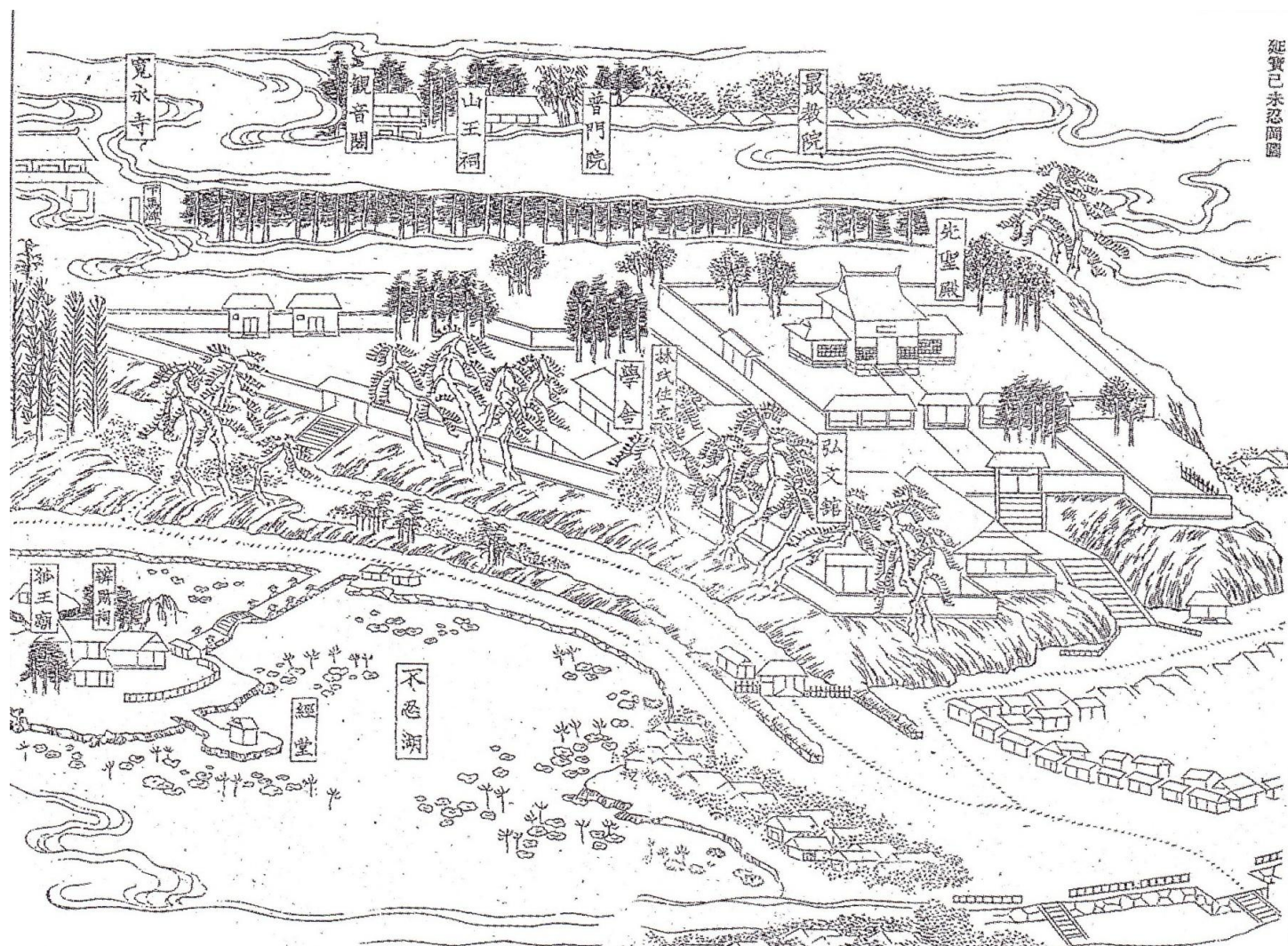
25

物理



(3) 中学生の国語力育成を強調したい

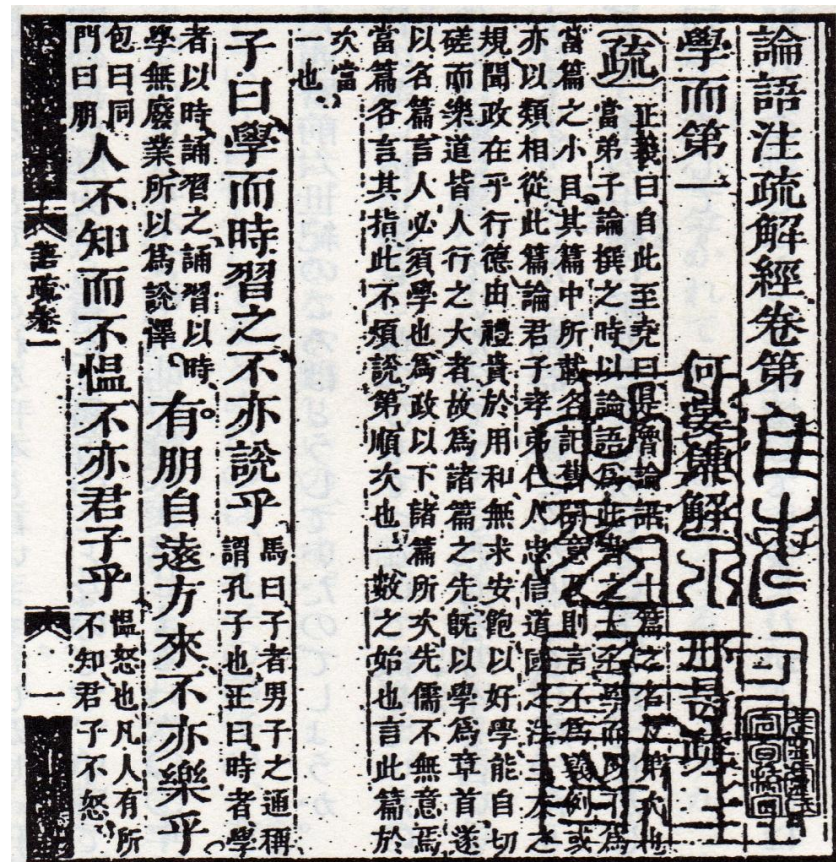
下の図面は？(東京)





Confucious 孔子(551—479B.C.)

A great philosopher of ancient China



Other examples:

子曰、由、誨女知之乎。
知之為知之、不知為不知。
是知也。

子曰、学而不思則罔。
思而不学則殆。

どうもありがとうございました

- 志摩研究会へのご参加
- 長年の議論とご協力、激励、寄せ書き
- 長年の共同研究
- 研究会世話人の方々への感謝
- そして今後の発展へ