DELAYED CLUSTERS ACCOMPANYING NM WEAK DECAY OF Λ - HYPERNUCLEI

II. TWO NUCLEON INDUCED MECHANISM

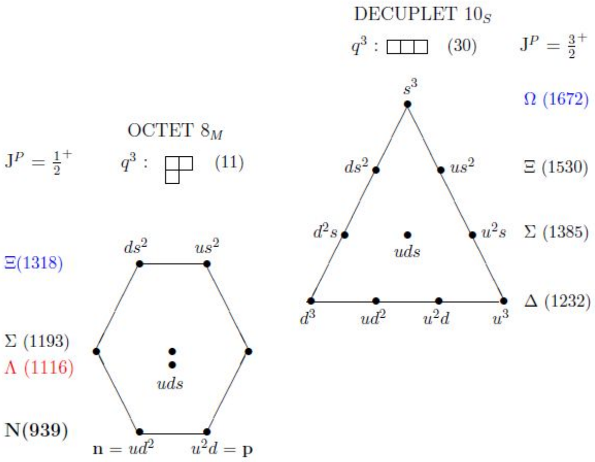
Lubomir Majling[1,2] and Olga Majlingova [3]

[1] Nuclear Physics Institute, Academy of Sciences, Řež, Czech Republic
[2] Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna
[3] Dept. of Mathematics, Czech Technical University, Prague

XX Baldin ISHEPP, Dubna, October 4 - 9, 2010

Outline

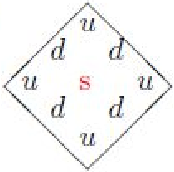
1. **Λ-HYPERNUCLEI**
2. **PRODUCTION**
   Heavy Hyper Hydrogen: ${}^{6}_{\Lambda}$H, ${}^{8}_{\Lambda}$H
3. **WEAK DECAY**
   Free Λ
   Nonmesonic WD
4. **DELAYED CLUSTERS**
   α
   3N
5. **EXPECTATIONS**

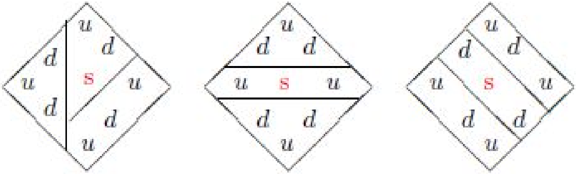


SU(3) multiplets of baryons made of *u*, *d* and *s* quarks

Y	S	M, MeV	τ	Decay	J^π	I
Λ	-1	1 115.7	$2.6 \cdot 10^{-10}$	$N\pi$	$\frac{1}{2}^+$	0
Σ^+	-1	1 189.4	$0.8 \cdot 10^{-10}$	$N\pi$	$\frac{1}{2}^+$	1
Σ^0	-1	1 192.6	$7.4 \cdot 10^{-20}$	$\Lambda\gamma$	$\frac{1}{2}^+$	1
Σ^-	-1	1 197.4	$1.5 \cdot 10^{-10}$	$N\pi$	$\frac{1}{2}^+$	1
Ξ^0	-2	1 314.8	$2.9 \cdot 10^{-10}$	$\Lambda\pi$	$\frac{1}{2}^+$	$\frac{1}{2}$
Ξ^-	-2	1 321.3	$1.6 \cdot 10^{-10}$	$\Lambda\pi$	$\frac{1}{2}^+$	$\frac{1}{2}$
Ω^-	-3	1 672.5	$0.8 \cdot 10^{-10}$	ΛK	$\frac{3}{2}^+$	0

$^{3}_{\Lambda}\mathrm{H}$ $\quad q^9 : \; s \, d^4 \, u^4$





$n \; \Lambda \; p$ $\qquad n \; \Sigma^+ \; n$ $\qquad p \; \Sigma^- \; p$

Hadronisation of the s quark in $^{3}_{\Lambda}\mathrm{H}$

SPHERE Network :

Strange **P**articles in **H**adronic **E**nvironment **R**esearch in **E**urope

coordinates studies of hypernuclei at

FINUDA@DAΦNE	(Frascati)
KAOS@MAMI	(Mainz)
HypHI@GSI	(Darmstadt)
$\bar{\mathrm{P}}$ANDA@FAIR	(Darmstadt)
J-PARC	Tokai, Japan
CEBAF	USA

”The Network supports the exchange of new ideas and technologies and tightens the relations among the various experimental and theoretical groups in Europe *and beyond*”.

NUCLEI
Experiment

Studying of Hypernuclei in Nuclotron Beams*

A. V. Aver'yanov[1)], S. A. Avramenko[1)], V. D. Aksinenko[1)], M. Kh. Anikina[1)], S. N. Bazylev[1)], V. P. Balandin[1)], Yu. A. Batusov[1)], Yu. A. Belikov[1)], Yu. T. Borzunov[1)], O. V. Borodina[1)], A. I. Golokhvastov[1)], L. B. Golovanov[1)], C. Granja[2)], A. B. Ivanov[1)], Yu. L. Ivanov[1)], A. Yu. Isupov[1)], Z. Kohout[3)], A. M. Korotkova[1)], A. G. Litvinenko[1)], J. Lukstiņš[1)*], A. I. Malakhov[1)], L. Majling[4)], O. Majlingova[3)], P. K. Man'yakov[1)], V. T. Matyushin[1)], I. I. Migulina[1)], G. P. Nikolaevskii[1)], O. B. Okhrimenko[1)], A. N. Parfenov[1)], N. G. Parfenova[1)], V. F. Peresedov[1)], S. N. Plyashkevich[1)], S. Pospišil[2)], P. A. Rukoyatkin[1)], I. S. Saitov[1)], R. A. Salmin[1)], V. M. Slepnev[1)], I. V. Slepnev[1)], M. Solar[3)], B. Sopko[3)], V. Sopko[2)], E. A. Strokovskii[1)], V. V. Tereshchenko[1)], A. A. Feshchenko[1)], T. Horazdovski[3)], D. Chren[3)], Yu. A. Chentsov[1)], and I. P. Yudin[1)]

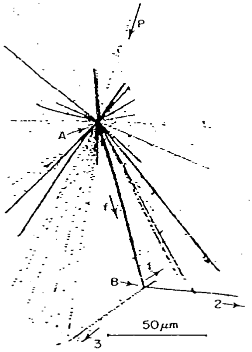
Received March 21, 2008; in final form, June 16, 2008

Abstract—A spectrometer is created to study relativistic hypernuclei produced in beams of accelerated nuclei from the Nuclotron facility (Dubna, JINR). Test runs have been carried out and the conclusion are drawn that the properties of the facility meet the requirements of the task of searching for unknown and studying poorly known neutron-rich hypernuclei.

PACS numbers: 21.80.+a, 29.30.Aj
DOI: 10.1134/S1063778808120119

Physics of Atomic Nuclei, **71** 2101 (2008)

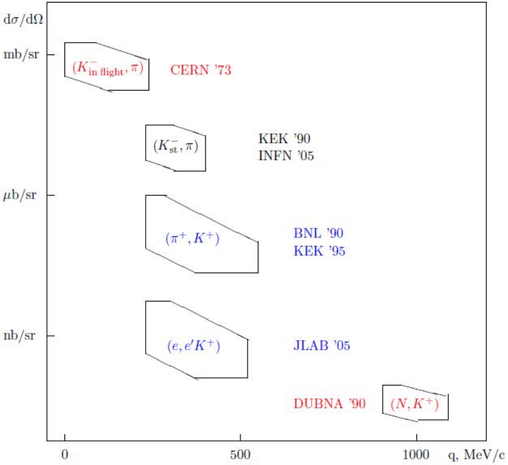
1952: First hypernucleus “twin stars”



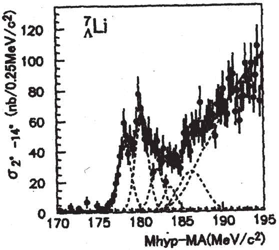
A: PRODUCTION

B: WEAK DECAY

Nucleus as a detector

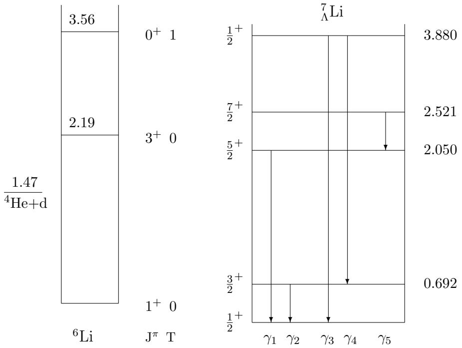


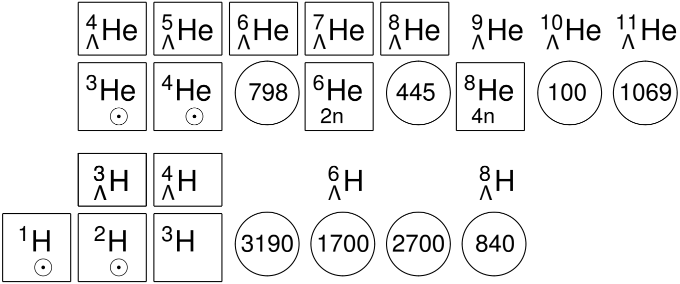
Various production reactions



Production 1998 (π^+, K^+)

2006 Hypernuclear gamma transitions





$^{4}_{\Lambda}He$ $^{5}_{\Lambda}He$ $^{6}_{\Lambda}He$ $^{7}_{\Lambda}He$ $^{8}_{\Lambda}He$ $^{9}_{\Lambda}He$ $^{10}_{\Lambda}He$ $^{11}_{\Lambda}He$
^{3}He ^{4}He 798 ^{6}He 2n 445 ^{8}He 4n 100 1069
$^{3}_{\Lambda}H$ $^{4}_{\Lambda}H$ $^{6}_{\Lambda}H$ $^{8}_{\Lambda}H$
^{1}H ^{2}H ^{3}H 3190 1700 2700 840

0^+

^{4}He

$[s_\lambda \, s_\pi^{-1}] \cdot {}^4\text{He}:$

1^+

Δ_4 0^+

${}^4_\Lambda$H

$\frac{N}{Z} = 2$

0^+

^{6}He

$[s_\lambda \, s_\pi^{-1}] \cdot {}^6\text{He}:$

1^+

Δ_6 0^+

${}^6_\Lambda$H

$\frac{N}{Z} = 4$

0^+

^{8}He

$[s_\lambda \, s_\pi^{-1}] \cdot {}^8\text{He}:$

1^+

Δ_8 0^+

${}^8_\Lambda$H

$\frac{N}{Z} = 6$

The strangeness changing process, the release of 176 MeV

$$\begin{array}{ll} \Lambda \rightarrow n & s \rightarrow d \\ \Lambda \rightarrow p & s \rightarrow u \end{array}$$

$$H_{\Delta S=1} = \frac{\mathrm{G_F}}{\sqrt{2}} \sin\theta_W \cos\theta_W \sum_i^6 c_i \, O_i,$$

Charged electro weak currents

	lepton currents			hadron currents						
	$e\nu_e$	$\mu\nu_\mu$	$\tau\nu_\tau$	ud	**us**	ub	cd	cs	cb	td
$(e\nu_e)$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$		$\surd$	$\surd$	
$(\mu\nu_\mu)$		$\surd$	$\surd$	$\surd$	$\surd$	$\surd$		$\surd$	$\surd$	
$(\tau\nu_\tau)$				$\surd$	$\surd$					
(ud)				$\surd$	$\surd$	$\surd$			$\surd$	

leptonic processes			semi leptonic processes		
$(e\nu_e)\,(e\nu_e)$	$\nu_e\, e \rightarrow$	$\nu_e\, e$	$(e\nu_e)$ (du)	$n \rightarrow$	$p\, e\, \nu_e$
$(e\nu_e)\,(\mu\nu_\mu)$	$\mu \rightarrow$	$e\, \nu_e\, \nu_\mu$	$(e\nu_e)$ (us)	K $\rightarrow$	$\pi\, e\, \nu_e$

non leptonic processes

(ud) (ud)	P viol	NN	**(ud) (cs)**	D $\rightarrow$	K $\pi\pi$
(ud) (us)	$\Lambda \rightarrow$	N π	**(ud) (cb)**	B $\rightarrow$	D $\pi\pi$

	Free Λ decay modes				Q, MeV
Γ_1	$p\,\pi^-$	0.639	$\pm$	0.005	101
Γ_2	$n\,\pi^0$	0.358	$\pm$	0.005	104
Γ_3	$n\,\gamma$	0.00175	$\pm$	0.00015	162
Γ_4	$p\,\pi^-\,\gamma$	0.00084	$\pm$	0.000014	101
Γ_5	$p\,e^-\bar{\nu}_e$	0.000832	$\pm$	0.000014	163
Γ_6	$p\,\mu^-\bar{\nu}_\mu$	0.000157	$\pm$	0.000035	131

$\Gamma_1 + \Gamma_2$ 0.997

$\Gamma_5 + \Gamma_6$ 0.000989 *neutron star !*

from *Review of Particle Physics,*
Phys. Lett. B **667** (2008) (p. 1127)
http: pdg.LBL.gov

In NUCLEUS, new channels are open: π^+

and non-mesonic: $\Lambda + N \rightarrow n + N$

signature: two fast nucleons, 170 MeV, back-to-back

The total decay width, Γ_{tot}, is defined in terms of its mesonic (m) and non-mesonic (nm) decay modes

$$\tau^{-1} = \Gamma_{\rm tot} = \overbrace{\Gamma^{\pi^-} + \Gamma^{\pi^0} + (\Gamma^{\pi^+})}^{\Gamma_{\rm m}} + \overbrace{\Gamma^{p} + \Gamma^{n} + \Gamma^{mb}}^{\Gamma_{\rm nm}}$$

$$\Gamma^N = \sum_i \Gamma_i^N$$

$$\Gamma_i^N = |\langle \Psi^{A-2}(\{i\}) \otimes \psi^{NN}(JT) \mid V_{weak} \mid [\Psi^{A-1}(\{c\}) \otimes \psi^{\Lambda}(\tfrac{1}{2})\,]^{\mathcal{J}} \rangle|^2$$

$$\mid s^4\, p^{A-5} J_c T_c \otimes s_\Lambda : \mathcal{J}\rangle$$

Long-standing puzzle on the Γ^n/Γ^p

"Old" data : $\Gamma^n = \Gamma_{\rm tot} - \Gamma_{\rm m} - \Gamma^p - \underline{\Gamma^{mb}}$

Γ_2 *Alberico, De Pace, M. Ericson, Molinari,* PL B **256** ('91)

Polarization propagator method
Intranuclear cascade code   ENERGY SPECTRA

Present status:
theory   *Chumillas, Garbarino, Parreno, Ramos,* NP A **804** ('08)

experiment: proton energy spectra

$^{5}_{\Lambda}$He, $^{7}_{\Lambda}$Li, $^{9}_{\Lambda}$Be, $^{11}_{\Lambda}$B, $^{12}_{\Lambda}$C, $^{13}_{\Lambda}$C, $^{15}_{\Lambda}$N, $^{16}_{\Lambda}$O

FINUDA Collaboration,   Phys.Lett. B **685** 247 (2010)

Two recent papers:

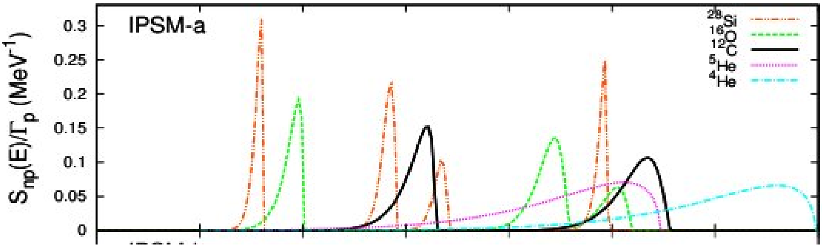
1. C. Barbero, A. Galeao, M.S. Hussein, F. Krmpotic

Kinetic energy sum spectra in NMWD of hypernuclei

Phys.Rev. C 78, 044312 (2008)

"When the **shell model structure** is also taken into account, the energy spectra will have **a bump at each s.p. state.**

In fact, a single-particle state $|\mathbf{j_N}>$ that is **deeply bound** in the hypernucleus, after NMWD can become a **highly excited hole-state** $|\mathbf{j_N^{-1}}>$ in the **continuum** of the residual nucleus."



C. Barbero *et al.,* Phys. Rev. C **78** 044312 (2008)

2. E. Bauer and G. Garbarino

A theoretical determination of N_{nn}/N_{np} in hypernuclear NM WD

`Proc.HYPX : Nucl.Phys. A 835, 430 (2010)`

"One should note that the **only observables** in HN WD are

- the lifetime τ ;
- the mesonic rates Γ_{π^-} and Γ_{π^0} ;
- the spectra of the emitted particles (N, π, γ).

None of the **non-mesonic partial decay rates** (Γ_n, Γ_p, Γ_{np}) is an **observable** from a quantum-mechanical point of view."

Our response

We will try to convinced you
that the **nuclear structure** aspects of the problem,
often an unwelcome part of the theory,
in **some peculiar cases** can be very useful.

Stripping

In some light *p*- shell nuclei

stripping of nucleon from the ground state

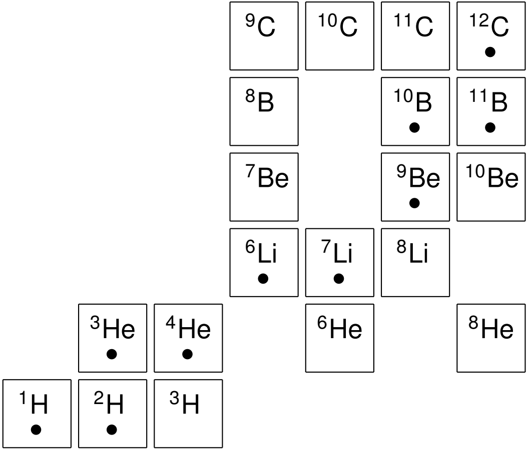
results in a RESONANCE STATE :

$$^{A}_{\Lambda}Z \rightarrow (n+N) \quad + \quad {}^{A_f}Z_f^*(E \;\; J^\pi T)$$

$$170\ MeV$$

$$^{A_f}Z_f^*(E \;\; J^\pi T) \begin{array}{l} \nearrow \; {}^{A_1}Z_1 \\ \\ \searrow \; {}^{A_2}Z_2 \end{array} \qquad E \Rightarrow J^\pi T$$

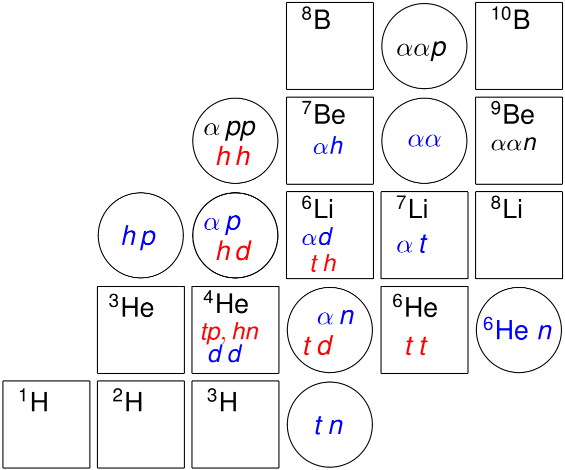
CHART of light nuclei



One-nucleon induced weak decay in light p-shell hypernuclei

$$
\begin{array}{ccccc}
 & & & \alpha + & \text{“}(k-1)\text{”} \\
 & & & \uparrow & \uparrow \\
 & \nearrow & s_\Lambda\, p \;\; + & s^4 & p^{\,k-1} \\
s^4\, p^{\,k}\, s_\Lambda & & & & \\
 & \searrow & s_\Lambda\, s \;\; + & s^3 & p^{\,k} \\
 & & & \downarrow & \downarrow \\
 & & & 3N + & \text{“}k\text{”}
\end{array}
$$

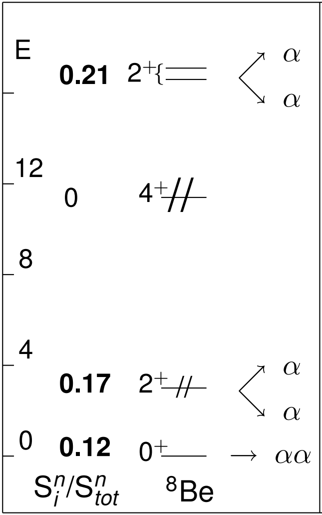
Cluster structure of light nuclei



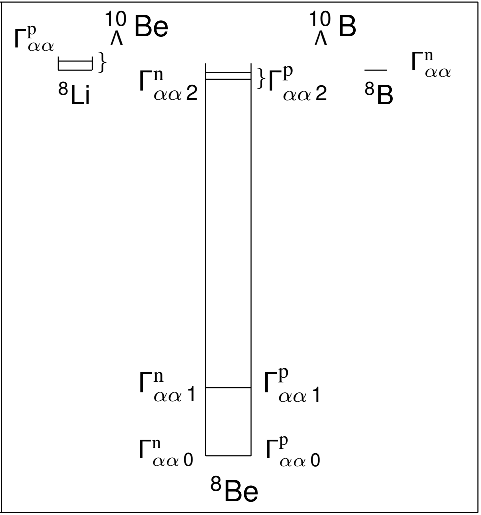
Delayed α clusters
References

LM, Batusov, NP A **691** (2001) HYP VII
LM, Batusov, Lukstins, Parfenov, NP A **754** (2005) HYP VIII
Batusov, Lukstins, LM, Parfenov,
Phys. Particles & Nuclei, **36** (2005)

LM, Kuz'min, Tetereva, Phys. At. Nuclei **69** (2006)

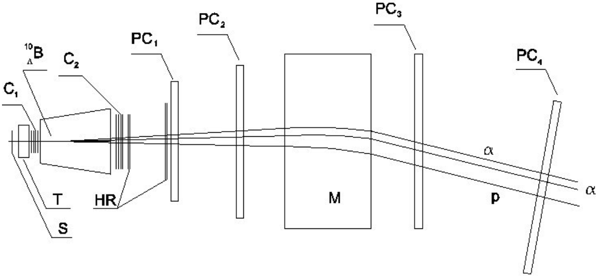


^{9}Be spectroscopic factors



Notation of the partial widths

GIBS - NIS detector



40 cm to be compare with 50 μm in emulsion

${}^{7}_{\Lambda}\mathrm{Li}$		$s_{\Lambda} \times {}^{6}\mathbf{Li}$		$[f] = [42]$
Γ_{1N}	"${}^{5}\mathrm{He}$"		"${}^{5}\mathrm{Li}$"	
	αn		αp	[41]
	hd		td	[32]
Γ_{2N} "${}^{4}\mathrm{H}$"		${}^{4}\mathrm{He}$	"${}^{4}\mathrm{Li}$"	
		α		[4]
tn		$hn + tp$	hp	[31]
		dd		[22]

Delayed 3N clusters

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

^{6}Li - g.s. $s^4\ p^2\quad 1^+\ 0$

model		$^{2T+1,2S+1}L_J$ [f]	$^{13}S_1$ [42]	$^{13}D_1$ [42]	$^{11}P_1$ [411]
SM	Barker	'66	0.992	-0.028	0.120
GFMC	Pudliner	'97	0.987	0.117	0.111
	Pieper	'04	0.986	0.117	0.098

$6 = 4 + 2$

			g_f	g_n	g_t		
$\Phi_0[4]$	^{11}S	$\phi_0\ \varphi_2$	$\frac{1}{9}$	$\frac{27}{40}$	1	$=$	$\frac{27}{360}$
$\Phi_0[4]$	^{11}S	$\phi_2\varphi_0$		$\frac{12}{40}$	1	$=$	$\frac{12}{360}$
$\Phi_2[4]$	^{11}S	$\phi_0\varphi_0$		$\frac{1}{40}$	1	$=$	$\frac{1}{360}$
$\Phi_1[31]$	^{33}P	$\phi_1\ \varphi_0$	$\frac{3}{9}$	1	$\frac{6}{10}$	$=$	$\frac{72}{360}$
$\Phi_1[31]$	^{31}P	$\phi_1\varphi_0$		1	$\frac{3}{10}$	$=$	$\frac{36}{360}$
$\Phi_1[31]$	^{13}P	$\phi_1\varphi_0$		1	$\frac{1}{10}$	$=$	$\frac{12}{360}$
$\Phi_1[31]$	^{13}P	$\phi_0\ \varphi_1$	$\frac{3}{9}$	$\frac{3}{4}$	$\frac{2}{5}$	$=$	$\frac{36}{360}$
$\Phi_2[31]$	^{13}P	$\phi_0\varphi_0$		$\frac{1}{4}$	$\frac{2}{5}$	$=$	$\frac{12}{360}$
$\Phi_1[31]$	^{33}P	$\phi_0\varphi_1$		$\frac{3}{4}$	$\frac{3}{5}$	$=$	$\frac{54}{360}$
$\Phi_2[31]$	^{33}P	$\phi_0\varphi_0$		$\frac{1}{4}$	$\frac{3}{5}$	$=$	$\frac{18}{360}$
$\Phi_2[22]$	^{11}S	$\phi_0\ \varphi_0$	$\frac{2}{9}$	1	$\frac{1}{20}$	$=$	$\frac{4}{360}$
$\Phi_2[22]$	^{33}S	$\phi_0\varphi_0$		1	$\frac{9}{20}$	$=$	$\frac{36}{360}$
$\Phi_2[22]$	^{15}D	$\phi_0\varphi_0$		1	$\frac{10}{20}$	$=$	$\frac{40}{360}$

CLUSTER IDENTIFICATION $\quad A = 4:$

$$\alpha \equiv \Phi_0^{(4)}[4]\ {}^{11}S_0; \qquad h/t \equiv \phi_0^{(3)}[3]\ {}^{22}S_{\frac{1}{2}}; \qquad d \equiv \phi_0^{(2)}[2]\ {}^{13}S_1.$$

$$\Phi_1^{(4)}[31]\ (10): \quad \tfrac{1}{3}\ \underline{\phi_0^{(3)}[3]}\ \varphi_1 \qquad \tfrac{2}{3}\ \phi_1^{(3)}[21]\ \varphi_0$$

$$\Phi_2^{(4)}[31]\ (20): \quad \tfrac{1}{3}\ \underline{\phi_0^{(3)}[3]}\ \varphi_2 \qquad \tfrac{2}{3}\ \phi_1^{(3)}[21]\ \varphi_1$$

$$\Phi_2^{(4)}[4]\ \ (20): \quad \tfrac{1}{3}\ \underline{\phi_0^{(2)}}\ \underline{\phi_0^{(2)}} \qquad \tfrac{1}{3}\ \underline{\phi_0^{(2)}}\ \phi_2^{(2)}, \qquad \tfrac{1}{3}\ \phi_2^{(2)}\ \underline{\phi_0^{(2)}}$$

$$\Phi_2^{(4)}[22]\ (20): \quad \tfrac{1}{3}\ \underline{\phi_0^{(2)}}\ \underline{\phi_0^{(2)}} \qquad \tfrac{1}{12}\ \underline{\phi_0^{(2)}}\ \phi_2^{(2)}, \ \tfrac{1}{12}\ \phi_2^{(2)}\ \underline{\phi_0^{(2)}}; \ \tfrac{1}{2}\phi_1^{(2)}\phi_1^{(2)}$$

$${}^{11}S: \quad \tfrac{1}{2}\ \underline{{}^{13}S}\ \underline{{}^{13}S} \qquad \tfrac{1}{2}\ {}^{31}S\ {}^{31}S$$

$${}^{15}S: \quad 1\ \underline{{}^{13}S}\ \underline{{}^{13}S}$$

$${}^{33}S: \quad \tfrac{1}{2}\ \underline{{}^{13}S}\ {}^{31}S \qquad \tfrac{1}{2}\ {}^{31}S\ \underline{{}^{13}S}$$

SUMMARY :	α	*hn*, *tp*	*dd*	*dpn*	break
$\Phi_0^{(4)}$ [4] (00) ^{11}S	1				
$\Phi_1^{(4)}$[31] (10)		$\frac{1}{3}$			$\frac{2}{3}$
$\Phi_2^{(4)}$[31] (20)		$\frac{1}{3}$			$\frac{2}{3}$
$\Phi_2^{(4)}$ [4] (20) ^{11}S			$\frac{1}{6}$	$\frac{1}{3}$	$\frac{1}{2}$
$\Phi_2^{(4)}$[22] (20) ^{11}S			$\frac{1}{6}$	$\frac{1}{12}$	$\frac{9}{12}$
$\Phi_2^{(4)}$[22] (20) ^{15}S			$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{2}$
$\Phi_2^{(4)}$[22] (20) ^{33}S				$\frac{5}{12}$	$\frac{7}{12}$

${}^{7}_{\Lambda}$Li	Γ_n "^{5}Li"	Γ_p "^{5}He"	Γ_{nn} "^{4}Li"	$\Gamma_{np:1}$ ^{4}He*(T=1)	$\Gamma_{np:\,0}$ ^{4}He (T=0)	Γ_{pp} "^{4}H"
αp	(nn) (αp)	(np) (αn)			(nnp) α	
hd	(nn) (hd)					
tdp		(np) (td)				
hp	(nn) (hpn)		(nnn) (hp)	(nnp) (hn)	(nnp) (hn)	
tpp		(np) (tpn)		(nnp) (tp)	(nnp) (tp)	(npp) (tn)
ddp					(nnp) (dd)	
dpp	(nn) $(dppn)$	(np) $(dpnn)$	(nnn) (dpp)	(nnp) (dpn)	(nnp) (dpn)	(npp) $dnn)$

RESULT:

$^{7}_{\Lambda}$Li	Γ_n "^{5}Li"	Γ_p "^{5}He"	Γ_{nn} "^{4}Li"	$\Gamma_{np:1}$ ^{4}He*(T=1)	$\Gamma_{np:\,0}$ ^{4}He (T=0)	Γ_{pp} "^{4}H"
αp	(nn) (αp) 20 %	(np) (αn) 20 %			(nnp) α 10 %	
hd	(nn) (hd) 4 %					
tdp		(np) (td) 4 %				
ddp					(nnp) (dd) 4 %	

Output: Phenomenological analysis

Block & Dalitz

PRL **11**, 96 (1963)

$$\Gamma_{\rm nm}({}^{3}_{\Lambda}\mathrm{H}) = \frac{\varrho_3}{8} \cdot (3\,\mathrm{R}_{n0} + 1\,\mathrm{R}_{n1} + 3\,\mathrm{R}_{p0} + 1\,\mathrm{R}_{p1})$$

$$\Gamma_{\rm nm}({}^{4}_{\Lambda}\mathrm{H}) \equiv \Gamma^{n}_{\rm H} + \Gamma^{p}_{\rm H} = \frac{\varrho_4}{6} \cdot (1\,\mathrm{R}_{n0} + 3\,\mathrm{R}_{n1} + 2\,\mathrm{R}_{p0} + 0\,\mathrm{R}_{p1})$$

$$\Gamma_{\rm nm}({}^{4}_{\Lambda}\mathrm{He}) \equiv \Gamma^{n}_{\rm He} + \Gamma^{p}_{\rm He} = \frac{\varrho_4}{6} \cdot (2\,\mathrm{R}_{n0} + 0\,\mathrm{R}_{n1} + 1\,\mathrm{R}_{p0} + 3\,\mathrm{R}_{p1})$$

$$\Gamma_{\rm nm}({}^{5}_{\Lambda}\mathrm{He}) = \frac{\varrho_5}{8} \cdot (1\,\mathrm{R}_{n0} + 3\,\mathrm{R}_{n1} + 1\,\mathrm{R}_{p0} + 3\,\mathrm{R}_{p1})$$

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

$$
\begin{array}{lllll}
nn & + & {}^5\mathrm{Li}\ (\frac{3}{2}^+\frac{1}{2};\,16.6): & \frac{5}{9}\cdot\frac{1}{2}\cdot\frac{4}{5}\times & 1\ w_{11}^{0n} \\
nn & + & {}^5\mathrm{Li}\ (\frac{1}{2}^+\frac{1}{2};\,20.3): & \frac{5}{9}\cdot\frac{1}{2}\cdot\frac{1}{5}\times & \frac{1}{4}\,(1\ w_{11}^{0n} + 3\ w_{00}^{0n}) \\
np & + & {}^5\mathrm{He}\ (\frac{3}{2}^+\frac{1}{2};\,16.7): & \frac{5}{9}\cdot\frac{1}{2}\cdot\frac{4}{5}\times & 1\ w_{11}^{0p} \\
np & + & {}^5\mathrm{He}\ (\frac{1}{2}^+\frac{1}{2};\,20.3): & \frac{5}{9}\cdot\frac{1}{2}\cdot\frac{1}{5}\times & \frac{1}{4}\,(1\ w_{11}^{0p} + 3\ w_{00}^{0p})
\end{array}
$$

$$\mathcal{R}_1 \equiv \frac{\mathrm{5Li}(1/2^+)}{\mathrm{5Li}(3/2^+)} \qquad \mathcal{R}_2 \equiv \frac{\mathrm{5He}(1/2^+)}{\mathrm{5He}(3/2^+)} \qquad \mathcal{R}_3 \equiv \frac{\mathrm{5Li}(3/2^+)}{\mathrm{5He}(3/2^+)}$$

		$^4_\Lambda$H	$^4_\Lambda$He	$^7_\Lambda$Li		
Ref.	model	Γ_n/Γ_p	Γ_n/Γ_p	$\kappa\mathcal{R}_1$	$\kappa\mathcal{R}_2$	$\mathcal{R}_3$
[1]	π	4.1192	0.0475	3.890	1.108	0.075
	$+2\pi/\rho$	9.2497	0.0452	2.090	1.102	0.188
	$+2\pi/\sigma+\omega$	2.7243	0.1302	6.238	1.302	0.116
	$+\rho$	2.1709	0.3631	8.719	1.896	0.233
[2]	ME	2.705	0.417	6.308	2.068	0.397
	DQ+	0.693	0.269	4.600	5.500	0.500
[3]	PSVE	9.98	0.062	2.007	1.138	0.284
	PKE	27.9	0.031	1.360	1.063	0.372
	SPKE	2.70	0.068	1.831	1.127	0.368
[4]	Exp.		$\leq$0.19			

[1] Itonaga *e.a* PR **C 65**

[2] Sasaki *e.a.* PR **C 71**

[3] Bauer *e.a.* PL **B 674**

[4] Parker *e.a.* PR **C 76**

Expectations : *p* - shell hypernuclei

STRONG interaction

gamma transitions
doublet splitting

⇕

Δ, S_Λ, S_N, T

⇕

Nijmegen
Bonn

WEAK interaction

delayed clusters
e.g. $\Gamma^N(J_i^\pi)$

⇕

R_{NS}

⇕

OBE
DQ

Problems:

Spurious states of Center-of Mass — TISM

Continuum — Gamow SM

Channel coupling

Kinematics

RESUME

- Catalogue of weak decay modes
  - nonmesonic 1N stimulated
  - nonmesonic 2N stimulated
- List of hypernuclei with possible delayed clusters
  - 1. Favorites : ${}^{10}_{\Lambda}$B, ${}^{10}_{\Lambda}$Be
  - 2. Favorite ${}^{7}_{\Lambda}$Li
- Phenomenological analysis (Block & Dalitz) for ${}^{7}_{\Lambda}$Li