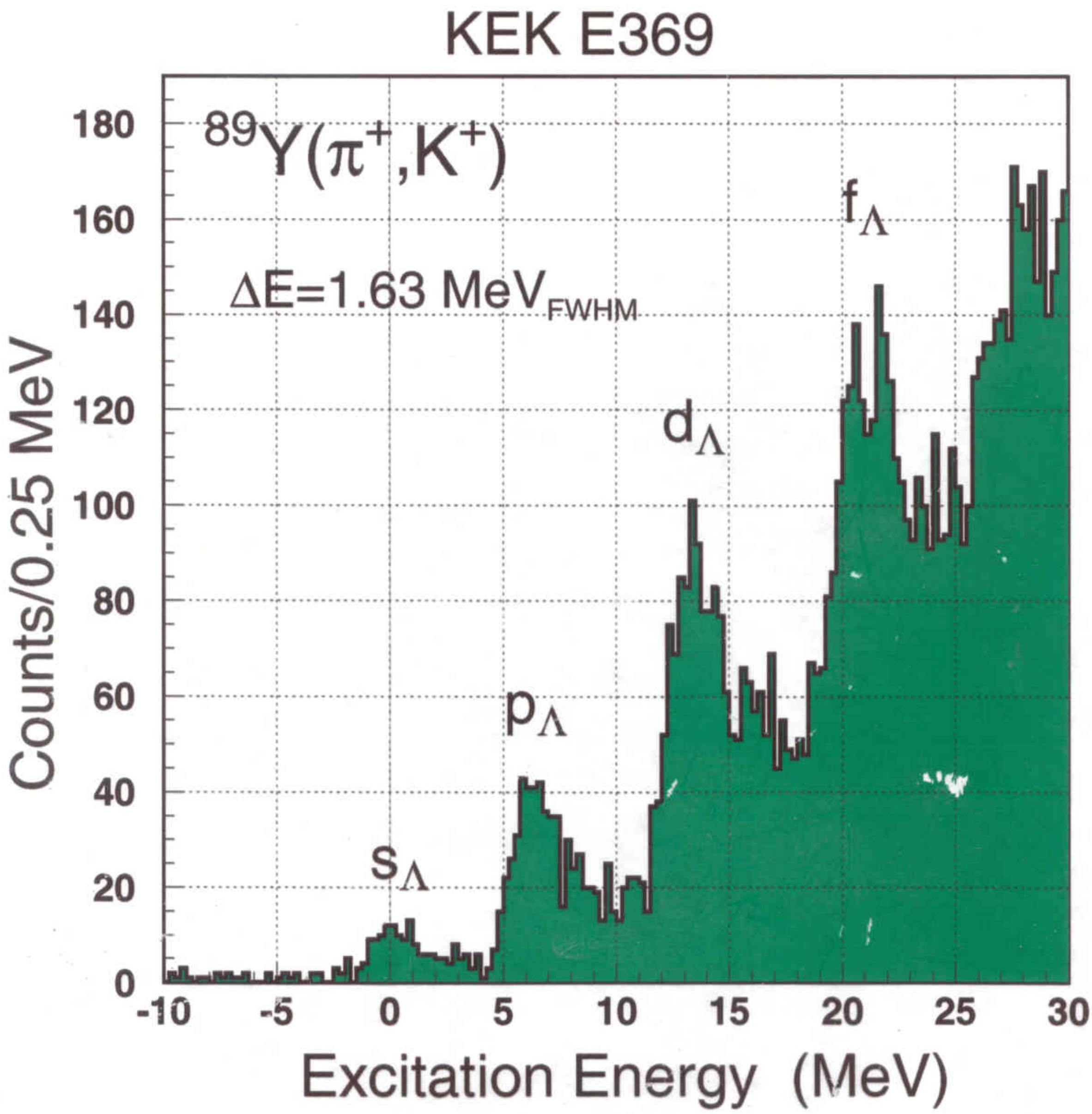
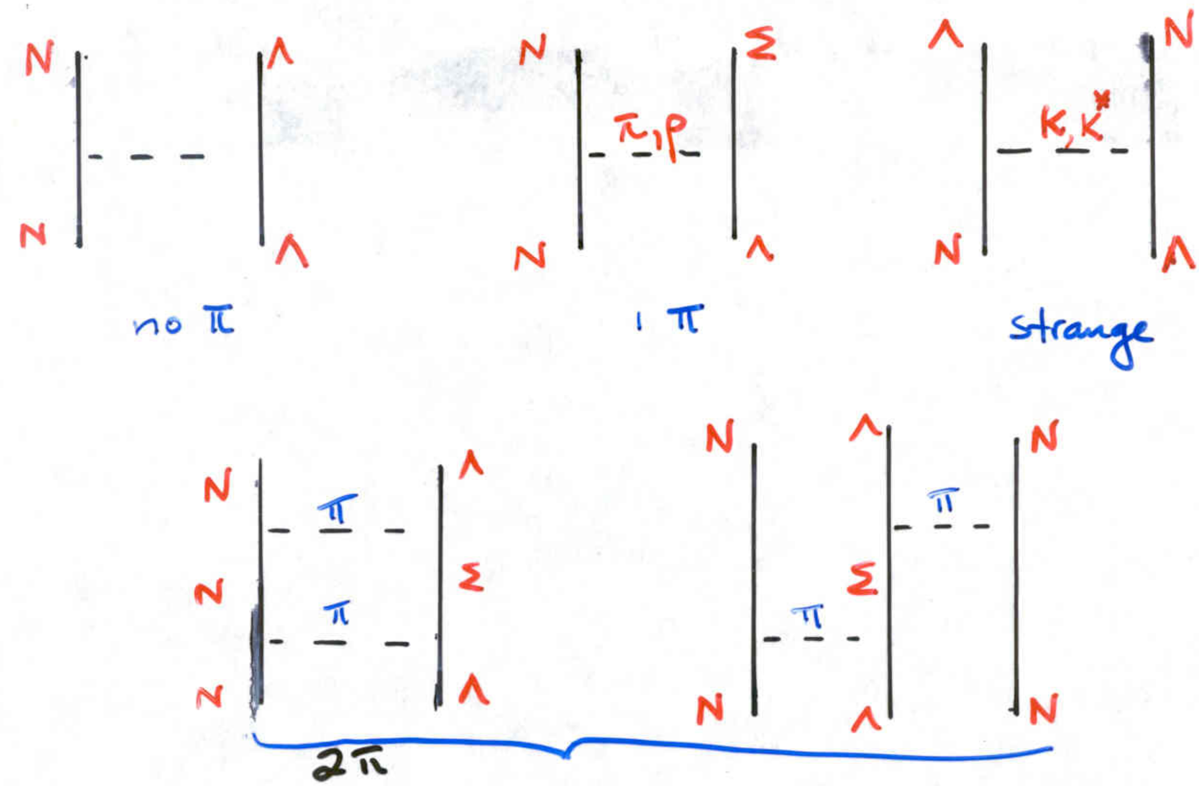
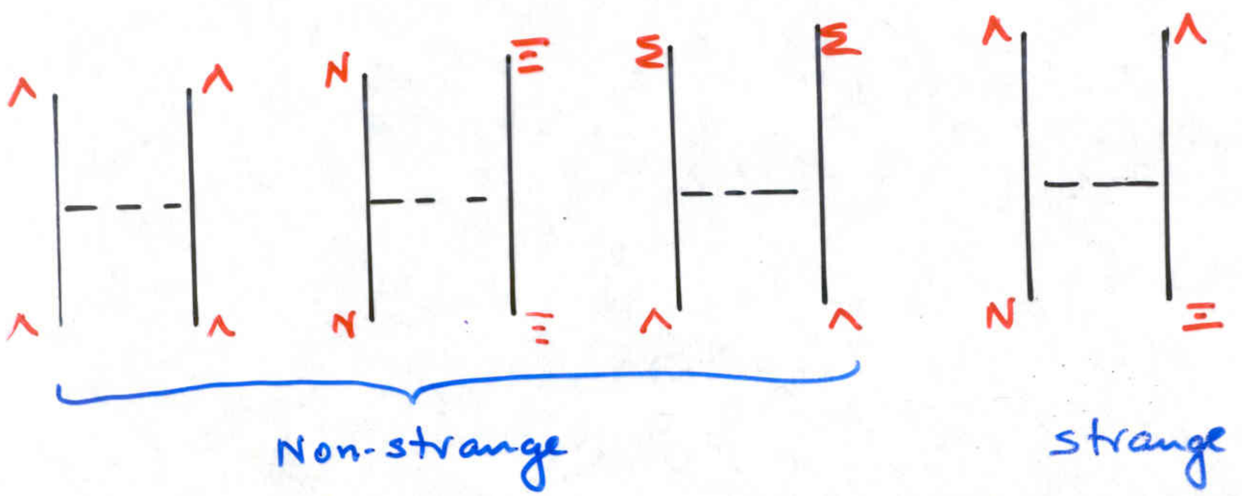


H. Hotchi et al., PRC 64 (2001) 044302

$S = -1 \quad T = 1/2 \qquad \Lambda N - \Sigma N$



$S = -2 \quad T = 0 \qquad \Lambda\Lambda - \Xi N - \Sigma\Sigma$



dnp01-2

ΛN (YN) interaction parameters

$V_{N\Lambda}$	$s_N s_\Lambda$	$p_N s_\Lambda$	${}^7_\Lambda$Li values MeV
V_0	I_0^e	$\bar{V} = \frac{1}{2}(I_0^e + I_1^o)$	(−1.22)
$V_\sigma s_N . s_\Lambda$	I_0^e	$\Delta = \frac{1}{2}(I_0^e + I_1^o)$	0.480
$V_\Lambda l_{N\Lambda} . s_\Lambda$		$S_\Lambda = \frac{1}{2} I_1^o$	−0.010
$V_N l_{N\Lambda} . s_N$		$S_N = \frac{1}{2} I_1^o$	−0.400
$V_T S_{12}$		$T = \frac{1}{3} I_1^o$	0.021

Free-Space YN Interactions

- Spin-spin interaction (Δ) is basically undetermined
- Similarly for odd-state central interaction
- Similarly for strength of $\Lambda - \Sigma$ coupling
- NSC97 models - Th.A. Rijken, V.J.G. Stoks, and Y. Yamamoto Phys. Rev. C 59 (1999) 21
- NSC97a,b,c $\Delta < 0$, NSC97d,e,f $\Delta > 0$; models e and f favored on these grounds

anl02-2

S-Shell Λ Hypernuclei

Hypernucleus	$J^{\pi}(gs)$	B_{Λ} MeV	J^{π}	E_x MeV
${}^{3}_{\Lambda}H$	$1/2^+$	0.13(5)		
${}^{4}_{\Lambda}H$	0^+	2.04(4)	1^+	1.04(5)
${}^{4}_{\Lambda}He$	0^+	2.39(3)	1^+	1.15(4)
${}^{5}_{\Lambda}He$	$1/2^+$	3.12(2)		

Recent "Exact" Calculations

- $A = 3, 4$ A. Nogga et al., PRL 88 (2002) 172501
  Faddeev and Faddeev-Yakubovsky
- $A = 4$ E. Hiyama et al., PRC 65 (2002) 011301(R)
  Jacobi-coordinate Gaussian basis
- $A = 3, 4, 5$ H. Nemura et al., PRL 89 (2002) 142504
  Stochastic variation with correlated Gaussians

dnp 01-3

$\Lambda - \Sigma$ coupling for ${}^4_\Lambda$H and ${}^4_\Lambda$He

Y. Akaishi, T. Harada, S. Shinmura, and Khin Swe Myint
PRL 84 (2000) 3539

$|{}^4_\Lambda\mathrm{He}(\mathrm{T} = 1/2)\rangle = \alpha s^3 s_\Lambda + \beta s^3 s_\Sigma$

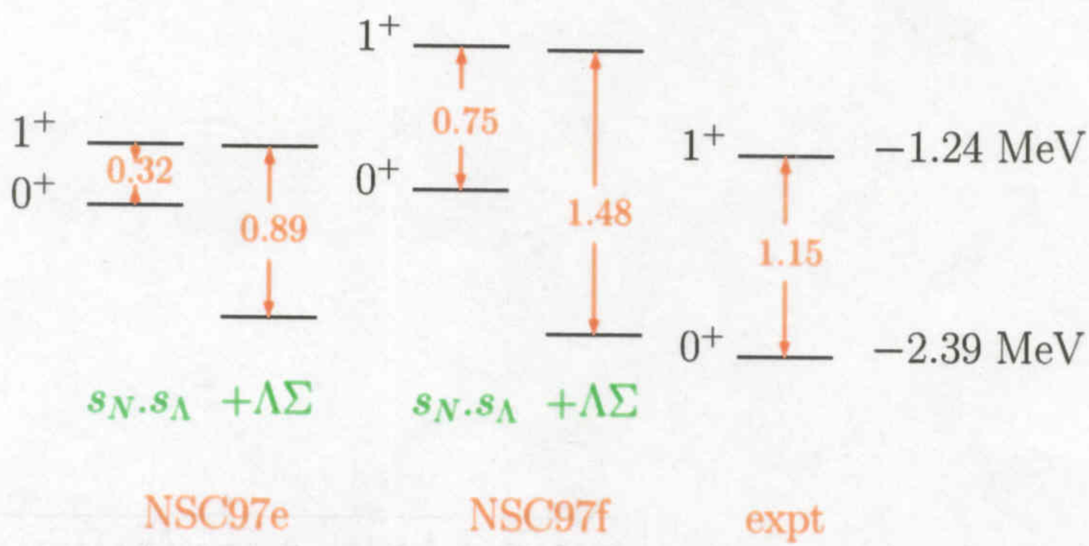
From ΛN$-\Sigma$N g matrix for 0s orbits

$v = \langle s^3 s_\Lambda | g | s^3 s_\Sigma \rangle, \quad \Delta E \sim 80$ MeV

$0^+ \qquad v = \frac{3}{2}\,{}^3g_{ss} - \frac{1}{2}\,{}^1g_{ss} \qquad$ Admixture $\sim v/\Delta E$

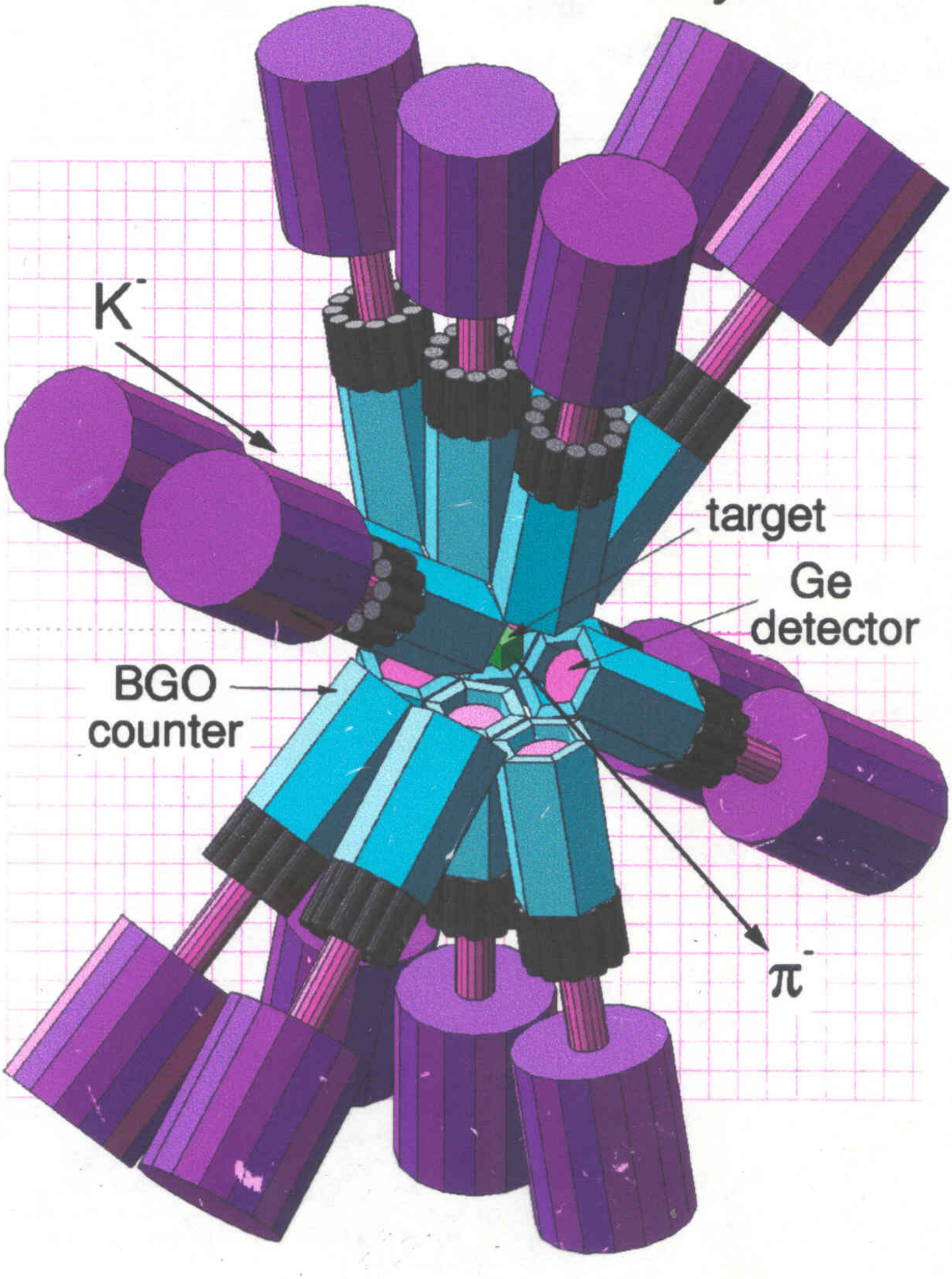
$1^+ \qquad v = \frac{1}{2}\,{}^3g_{ss} + \frac{1}{2}\,{}^1g_{ss} \qquad E^{shift} \sim v^2/\Delta E$

NSC97f: $v \sim 7.6$ MeV $\Rightarrow$ $E^{shift} \sim 0.72$ MeV



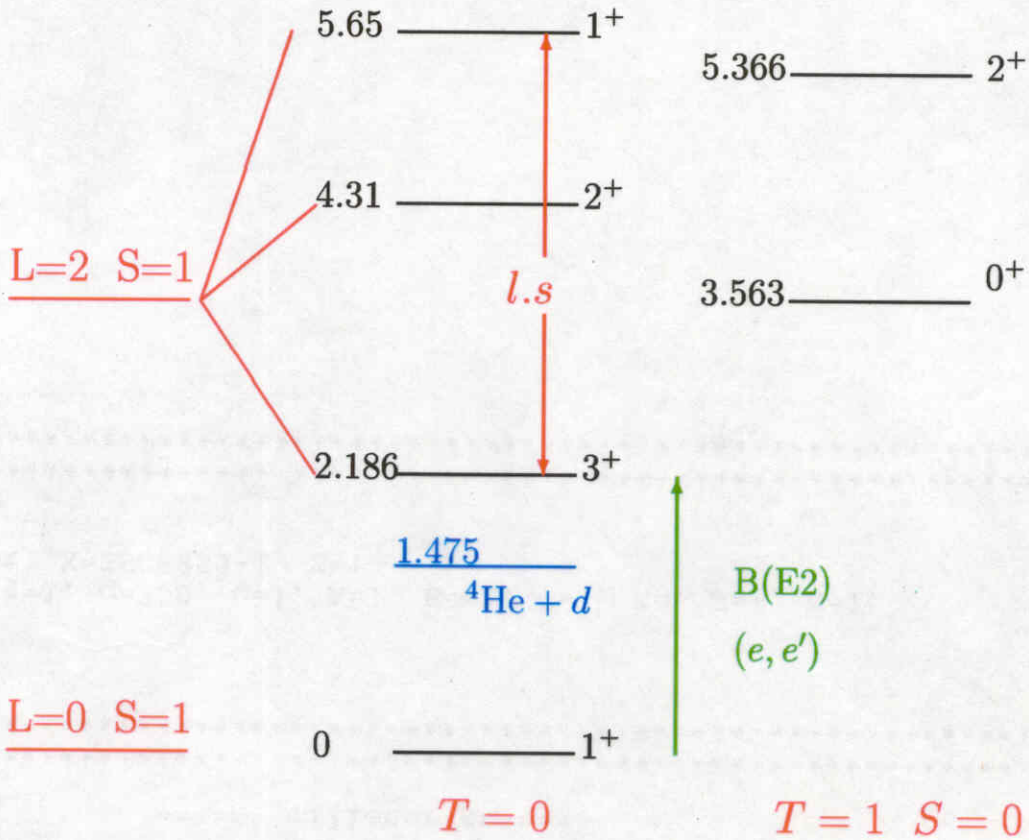
E. Hiyama et al., nucl-th/0106070, obtain similar results using a large model space for the 4-body calculation and the free YN interaction.

Germanium detector system



snp99-3

^{6}Li core for $^7_\Lambda$Li



$$^6\mathrm{Li(gs)} = \alpha\, {}^3\mathrm{S}_1 + \beta\, {}^3\mathrm{D}_1 + \gamma\, {}^1\mathrm{P}_1$$

CK616	0.9576	−0.2777	−0.0761
DJM	0.9873	−0.0422	−0.1532

$$Q(^6\mathrm{Li}) = e^0\sqrt{2/5}(\sqrt{8}\alpha\beta + \sqrt{5/2}\gamma^2 - 7/2\sqrt{10}\beta^2)b^2$$ (Elliott, 1953)

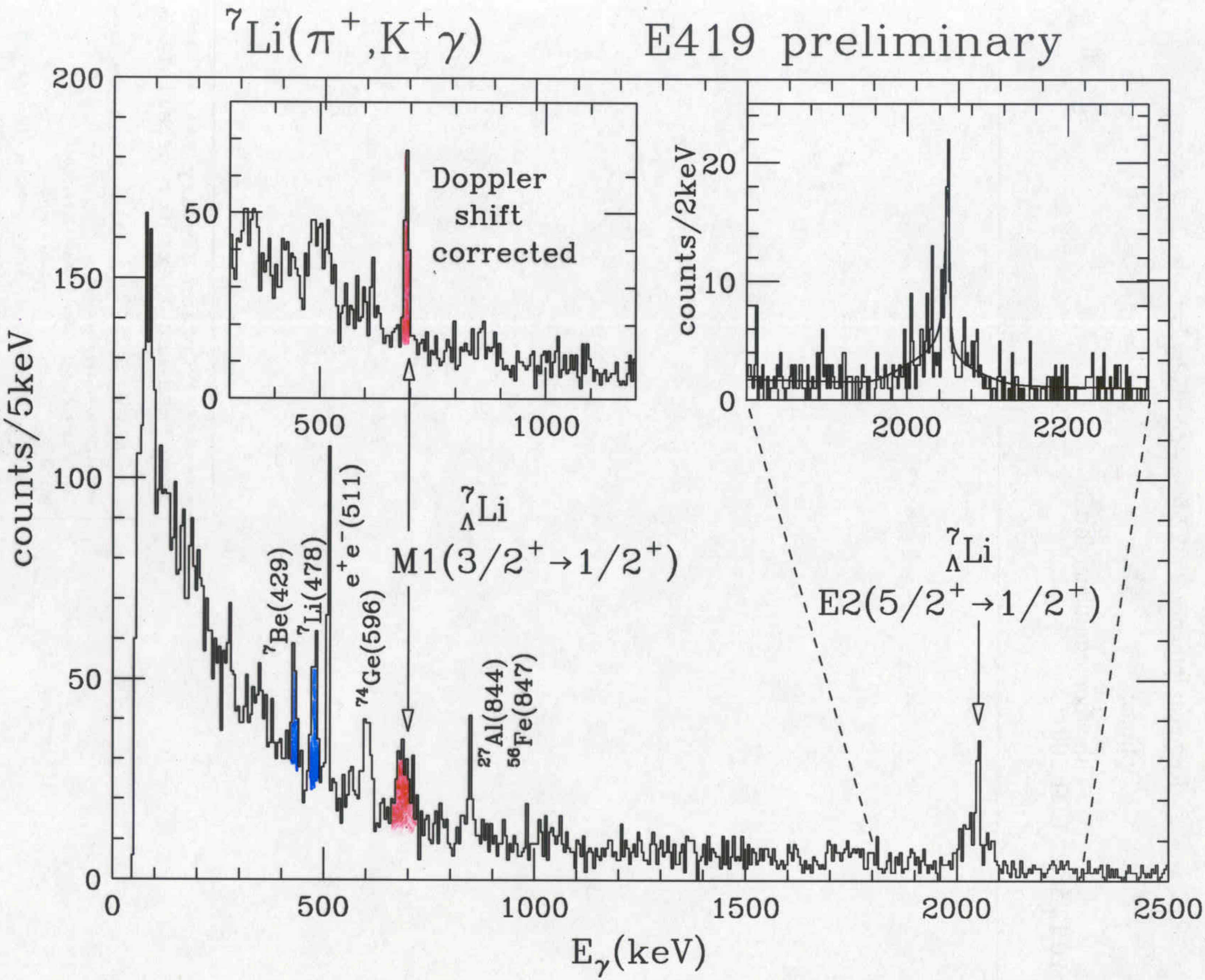
$Q = -0.083\ \mathrm{fm}^2$ Experiment

$Q = -0.126\ \mathrm{fm}^2$ DJM $Q = -1.26\ \mathrm{fm}^2$ CK616 jlab05-3.ps

$\Lambda N - \Sigma N$ Coupling for $\langle p_N s_\Lambda | V | p_N s_\Sigma \rangle$

Can use the same parametrization as for ΛN

$$|\bar{V}| = 1.45\text{MeV} \qquad |\Delta| = 3.04\text{MeV}$$



K. TANIDA

H. TAMURA (PANIC99)

lanl05-1

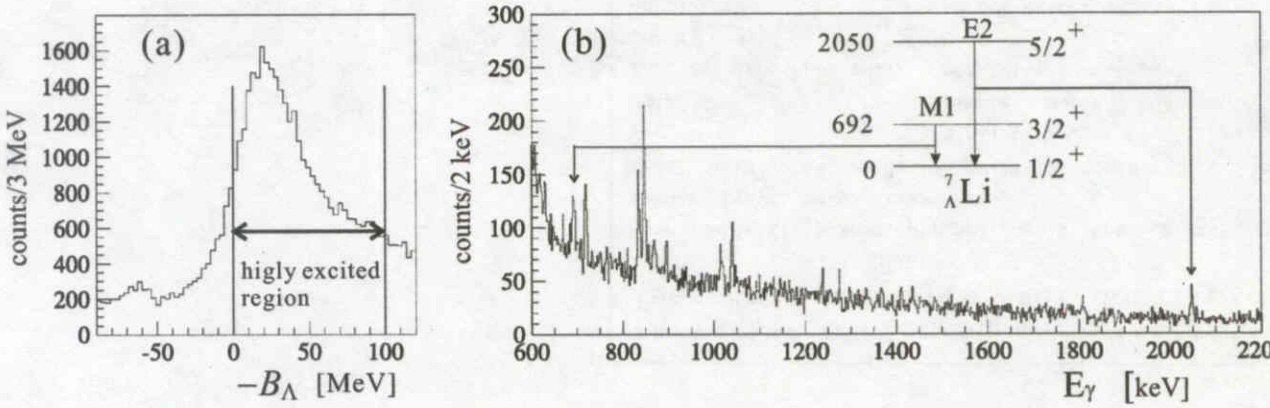


FIG. 1: (a) Mass spectrum of $^{10}_{\Lambda}$B

(b) γ-ray spectrum for the mass region shown in (a).

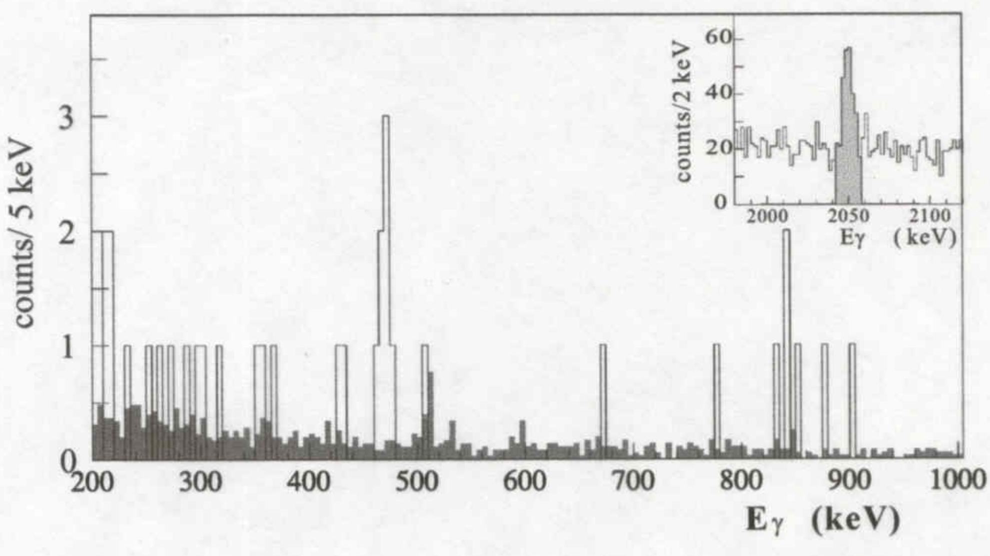


FIG. 2: $\gamma - \gamma$ coincidence spectrum from the ^{10}B(K^-, π^-) reaction.

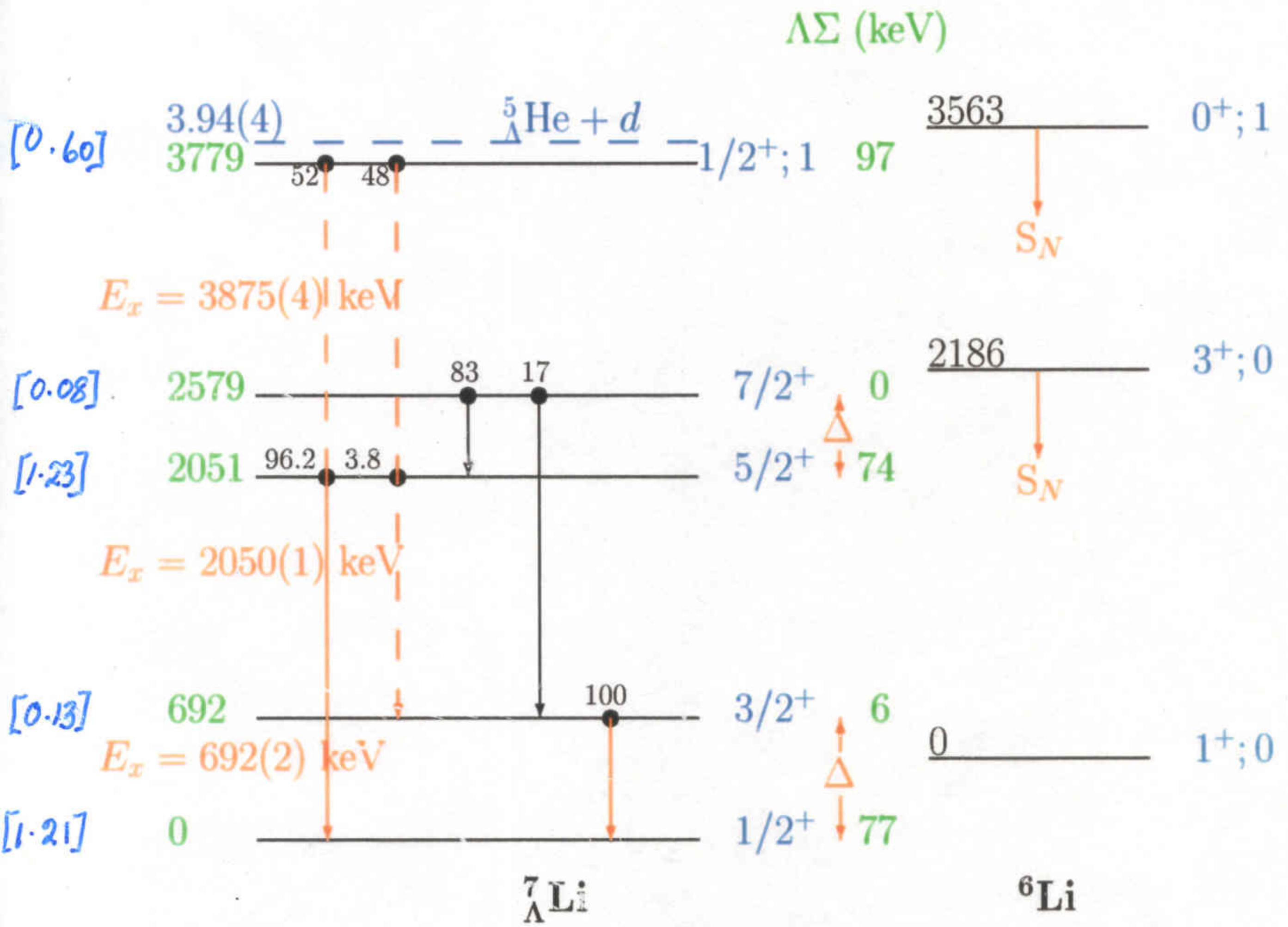
$$E_\gamma = 470.8 \pm 1.9 \pm 0.6 \quad \text{keV}$$

dnp02-1.tex

$^{7}_{\Lambda}$Li γ rays – Hyperball, KEK E419

H. Tamura et al., PRL 84 (2000) 5963

K. Tanida et al., PRL 86 (2001) 1982



$\Delta = 0.432 \quad S_\Lambda = -0.010 \quad S_N = -0.380 \quad T = 0.021$

$T = 0.028$

$\Delta E(7/2^+ - 5/2^+)$ $\gamma\gamma$ Tamura

↑ reduced by larger S_Λ, T

dF

dnp01-5

Energy spacings in ${}^{7}_{\Lambda}$Li

Energy shifts in keV due to $\Lambda - \Sigma$ coupling for the lowest $T = 0$ (left) and $T = 1$ (right) states of ${}^{7}_{\Lambda}$Li.

$T = 0$ shift	$T = 0$ state	$T = 1$ shift	$T = 1$ state
0	$7/2^+$		
		95	$3/2^+$
74	$5/2^+$	101	$5/2^+$
6	$3/2^+$		
77	$1/2^+$	97	$1/2^+$

$T = 0$ $\qquad\qquad$ $T = 1$

Contributions to the energy splitting are (in keV).

$\Delta = 0.432 \quad S_\Lambda = -0.010 \quad S_N = -0.380 \quad T = 0.021$

$3/2^+ - 1/2^+$ ground-state doublet separation

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
71	625	−1	−7	−4	692

$5/2^+ - 1/2^+$ separation $\Delta E = 2186 + \Delta E_{\Lambda N}$

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
3	76	11	−266	24	2051

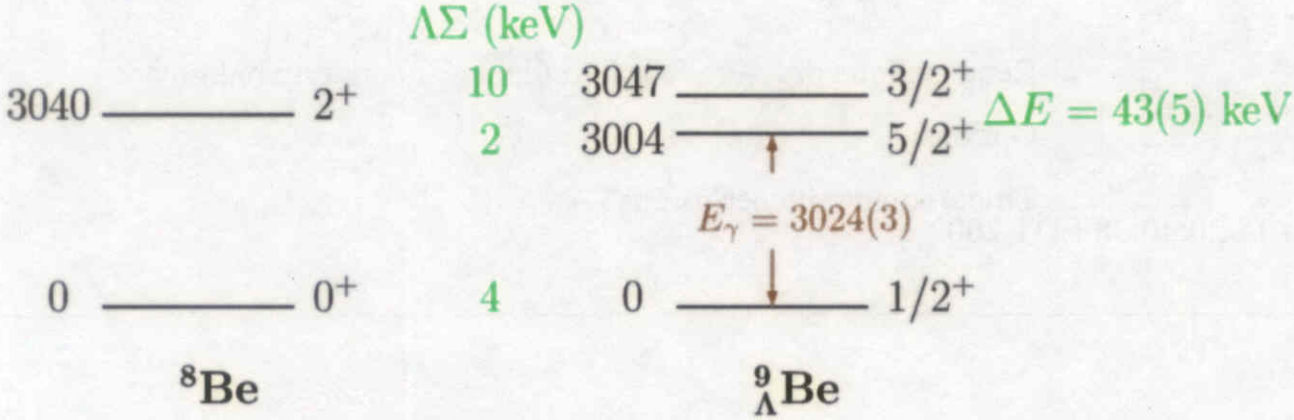
$1/2^+ - 1/2^+$ separation $\Delta E = 3565 + \Delta E_{\Lambda N}$

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
−20	415	0	−179	−2	3779

$7/2^+ - 5/2^+$ excited-state doublet separation

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
74	557	−22	−7	−50	528

hyp03-9



Old BNL E930 - H. Akikawa et al., PRL 88 (2002) 082501

$E_\gamma = 3029(2), \quad 3060(2)$ keV, $\quad \Delta E = 31(3)$ keV

$\Delta = 0.557 \quad \mathrm{S}_\Lambda = -0.013 \quad \mathrm{S}_\mathrm{N} = -0.549 \quad T = 0.038$

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
−8	−20	32	−1	38	43 keV
	−0.037	−2.464	0.003	0.994	

Order of $3/2^+$, $5/2^+$ not determined from this experiment.

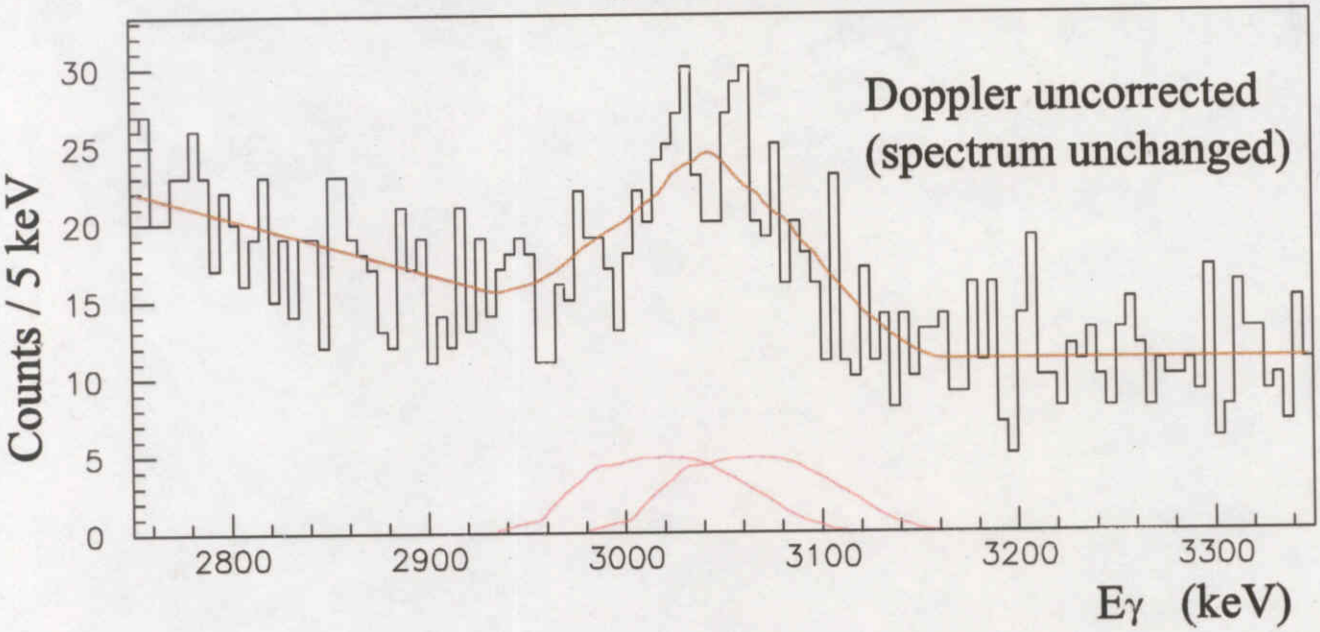
In 2001 run on ^{10}B target, the upper level is seen following

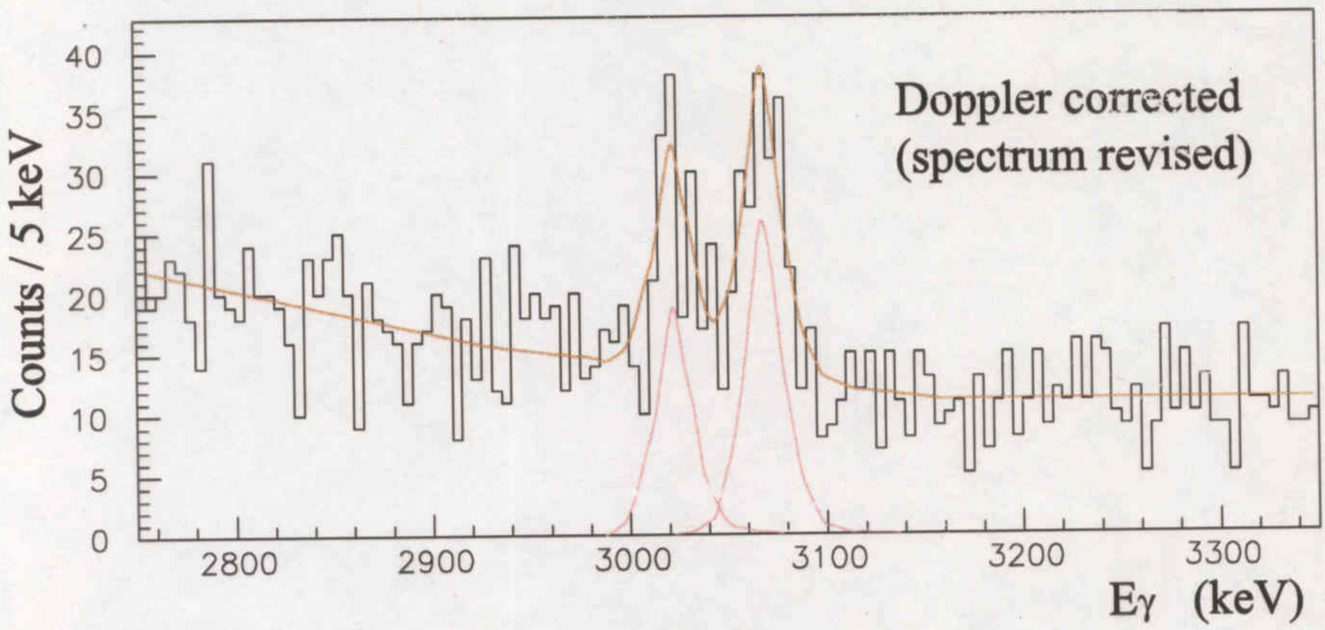
$^{10}_{\Lambda}\mathrm{B} \to {}^{9}_{\Lambda}\mathrm{Be} + p$

enabling us to deduce $J^\pi = 3/2^+$ for the upper member of the doublet.

1LBenew.eps

E930 $^{9}_{\Lambda}Be$ revised results





Both spectra are simultaneously fitted
with simulated peak shapes

Best fit for $\tau \sim 0.01$ ps

Results

$\tau < 0.10$ ps

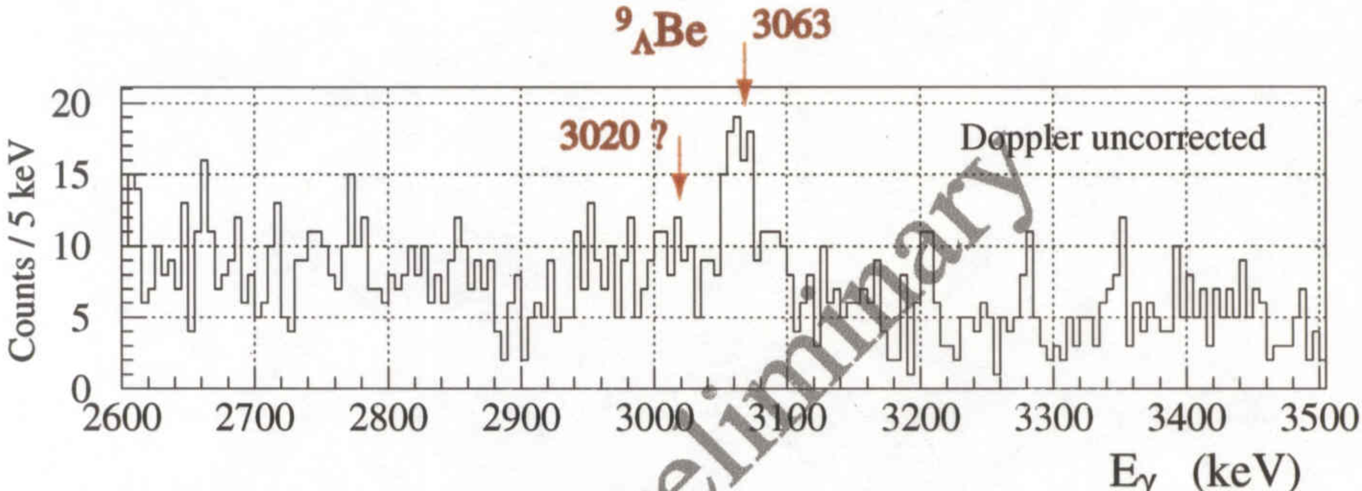
$\Delta E = 43 \pm 5$ keV

$\chi^2/\mathrm{dof} = 1.22$

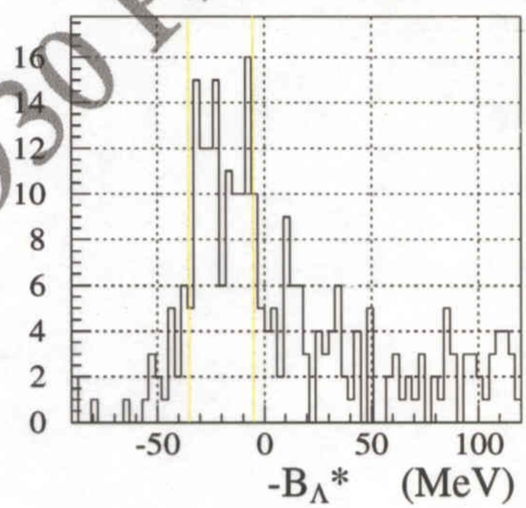
9LBefrag.eps

Hyperfragments from $^{10}B\ (K^-, \pi^-)$ reaction : $^{9}_{\Lambda}Be$

$-35 < -B_\Lambda{}^* < -5$ MeV *uncalibrated

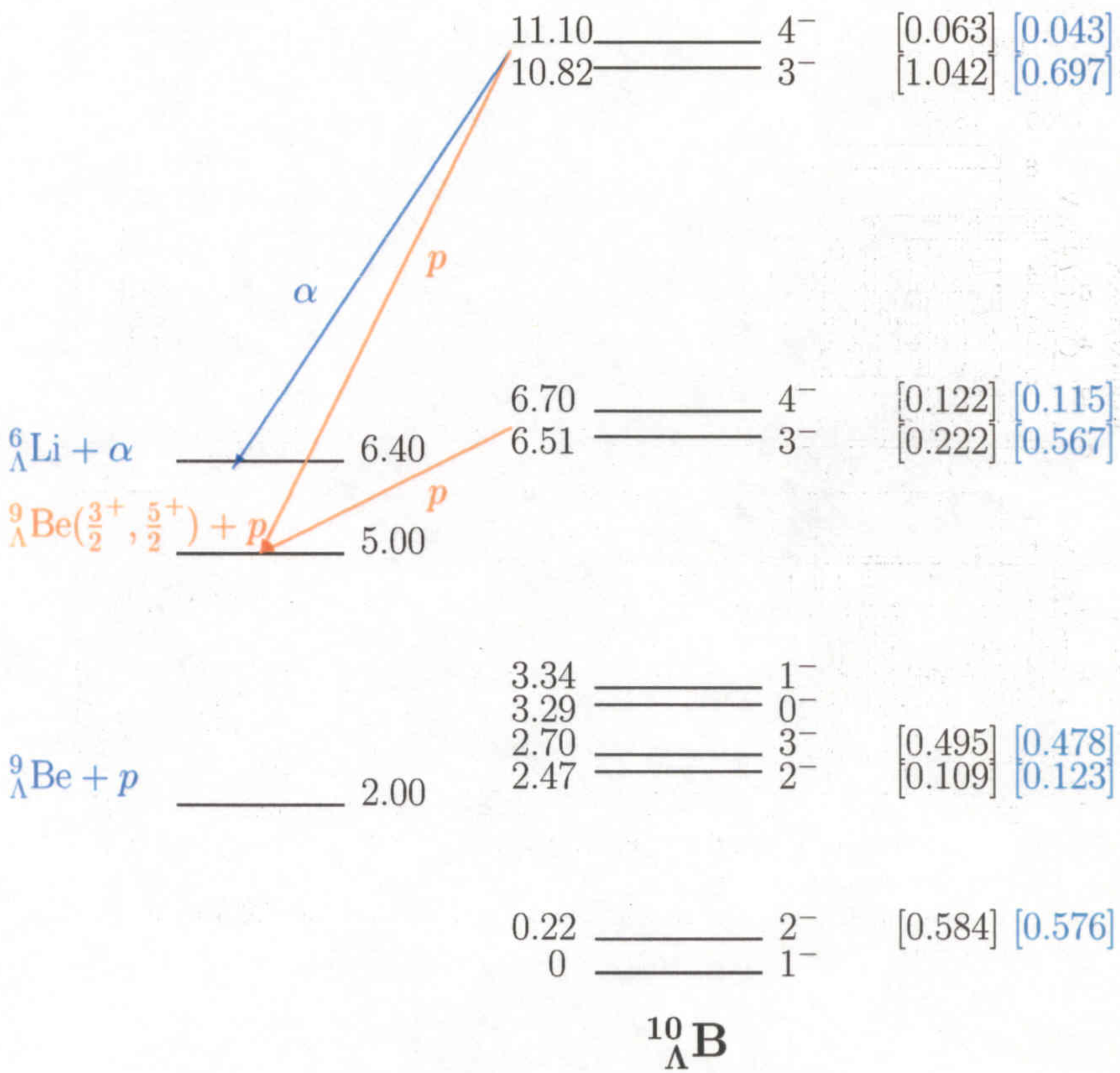


Excitation spectrum for 3063 keV peak



hyp03-4

Proton decay of $^{10}_{\Lambda}$B to $^{9}_{\Lambda}$Be



hyp03 - 1

Formation and decay of ${}^{10}_{\Lambda}$B

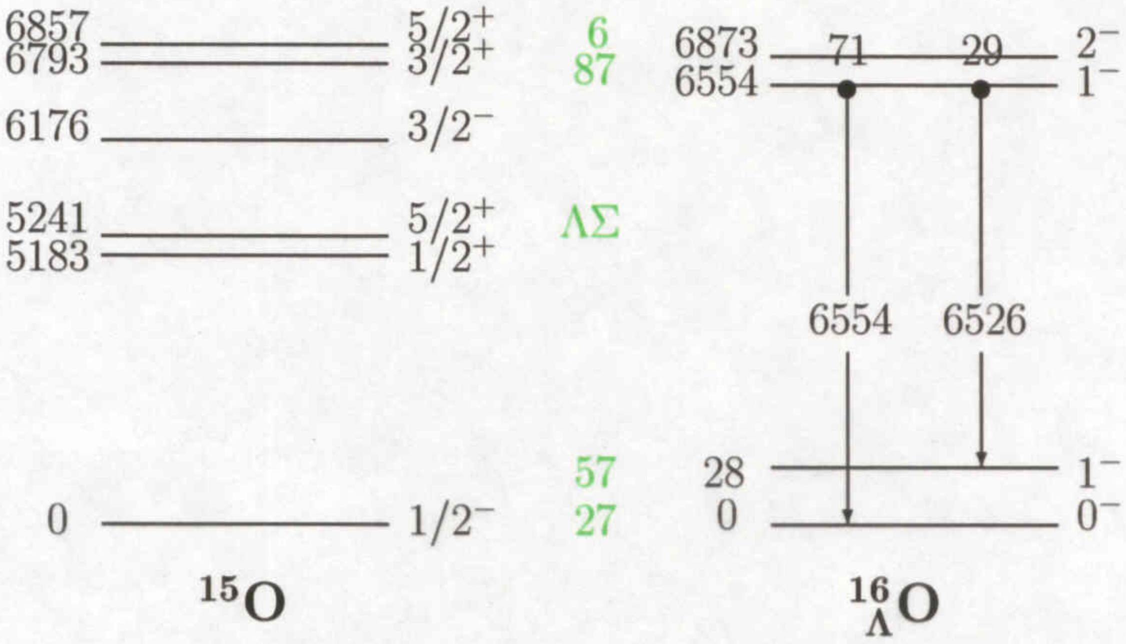
- Four states of ^{9}B reached strongly by neutron removal from ^{10}B
- The two $7/2^-$ states give rise to 3^- and 4^- states of ${}^{10}_{\Lambda}$B above the ${}^{9}_{\Lambda}\mathrm{Be}^* + p$ threshold
- 3^- is favored for the dominant $p_{3/2}$ removal by the coupling to get $\Delta L = 1$ and $\Delta S = 0$. Details depend on the amplitudes for $p_{1/2}$ and $p_{3/2}$
- Decay arises from ${}^{9}\mathrm{B}(7/2^-) \rightarrow {}^{8}\mathrm{Be}(2^+) + p$
- Recouple $(2^+ \times p_{3/2})7/2^- \times s_\Lambda \rightarrow (2^+ \times s_\Lambda)J_f \times p_{3/2}$
- 4^- decays to ${}^{9}_{\Lambda}\mathrm{Be}(5/2^+)$
- 3^- decays to $3/2^+$, $5/2^+$ in ratio of 32 to 3
- Overall: $3/2^+$ is strongly favored by proton emission
- Caveat: uppermost 3^- state doesn't α decay too much

~~N. Paar~~ hyp03-7

Tensor Interaction updated

For pure $p_{1/2}^{-1} s_\Lambda$, the combination of parameters governing the doublet splitting is

$$E(1_1^-) - E(0^-) = -\frac{1}{3}\Delta + \frac{4}{3}S_\Lambda + 8T$$



$\Delta = 0.468 \quad S_\Lambda = -0.011 \quad S_N = -0.354 \quad T = 0.030$

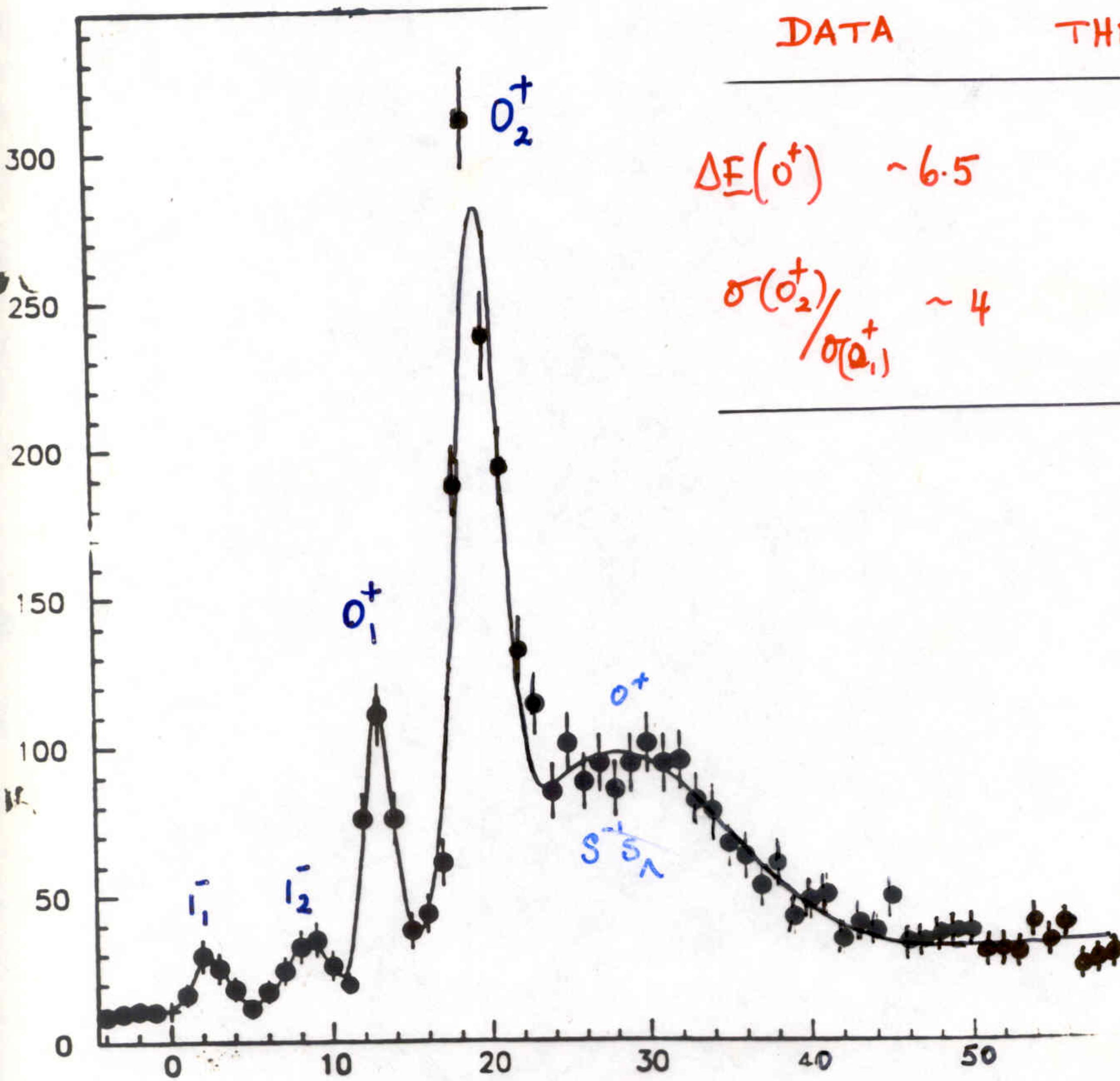
M. Ukai *et al.* – **Phys. Rev. Lett. 93 (2004) 232501**

$$E(1_2^- - 0_1^-) = 6561.7 \pm 1.1 \pm 1.7 \text{ keV} \quad (183 \pm 15 \pm 5 \text{ counts})$$
$$E(1_2^- - 1_1^-) = 6535.3 \pm 1.2 \pm 1.7 \text{ keV} \quad (127 \pm 15 \pm 5 \text{ counts})$$

$$\Delta E = 26.4 \pm 1.6 \pm 0.5 \text{ keV}$$

CERN

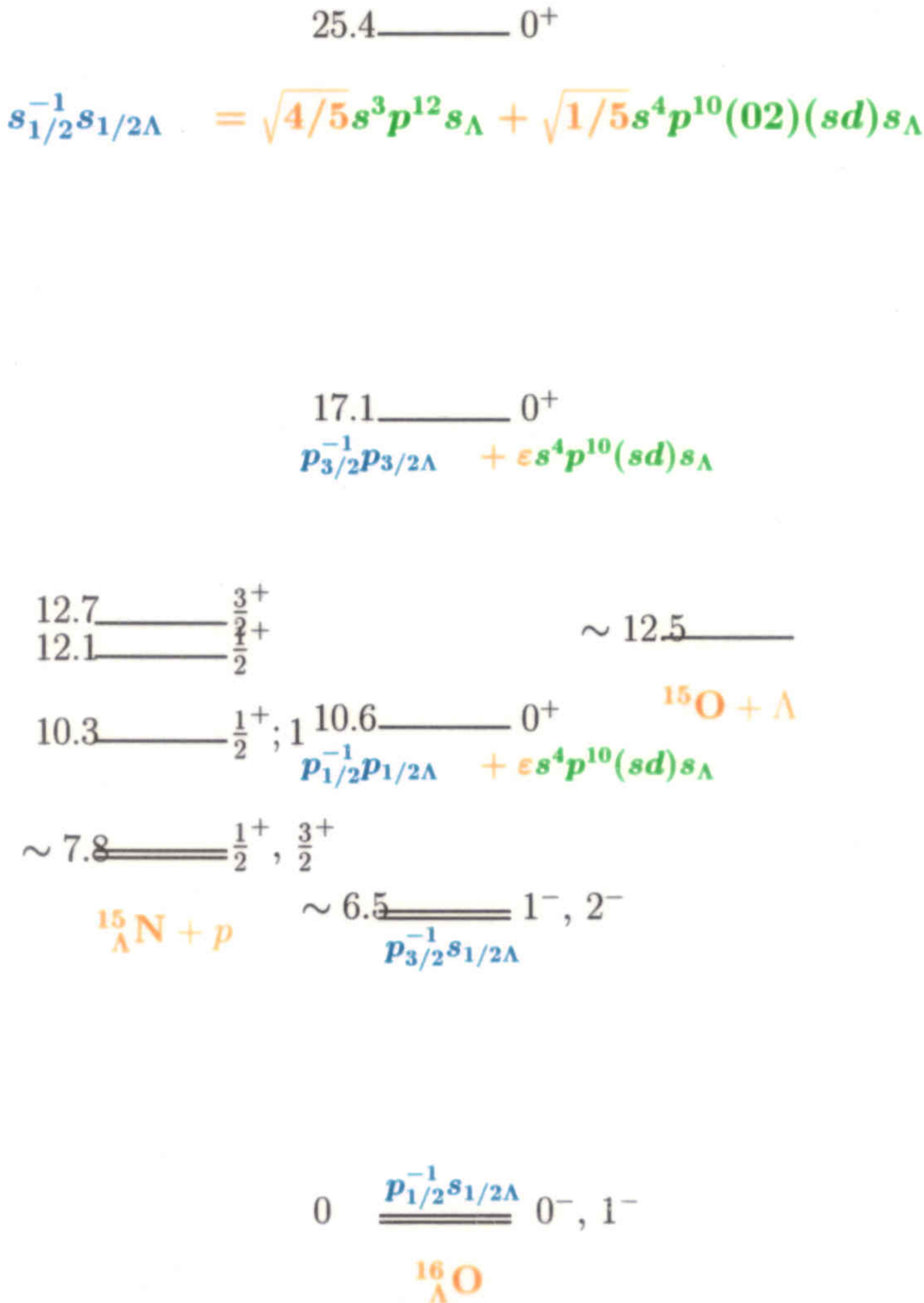
$^{16}O(K^-,\pi^-)\,^{16}_{\Lambda}O$



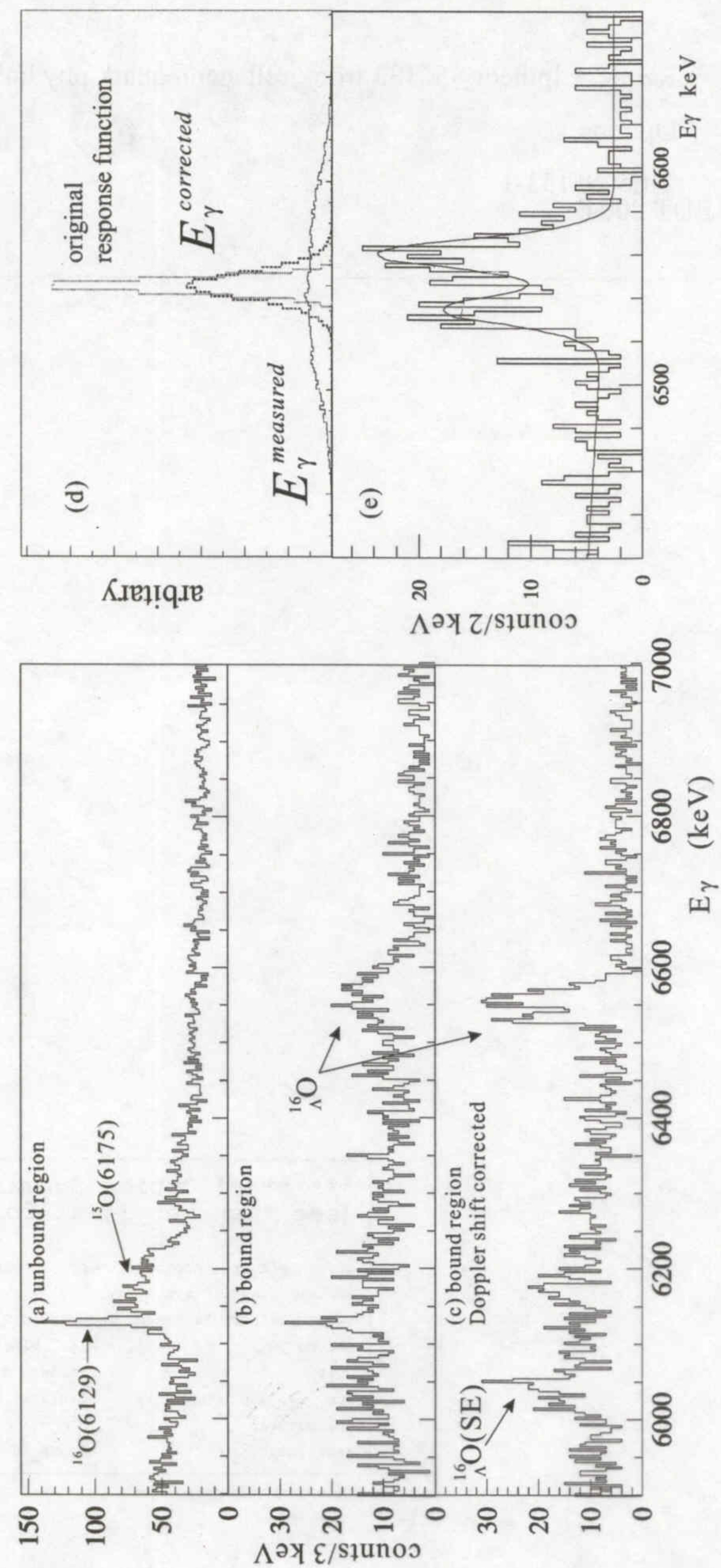
	DATA	THEORY
$\Delta E(0^+)$	~ 6.5	~ 6.6
$\sigma(0_2^+)/\sigma(0_1^+)$	~ 4	~ 3.5

anl02-3

Strong 1^- and 0^+ states in $^{16}\mathrm{O}(K^-,\pi^-)^{16}_{\Lambda}\mathrm{O}$

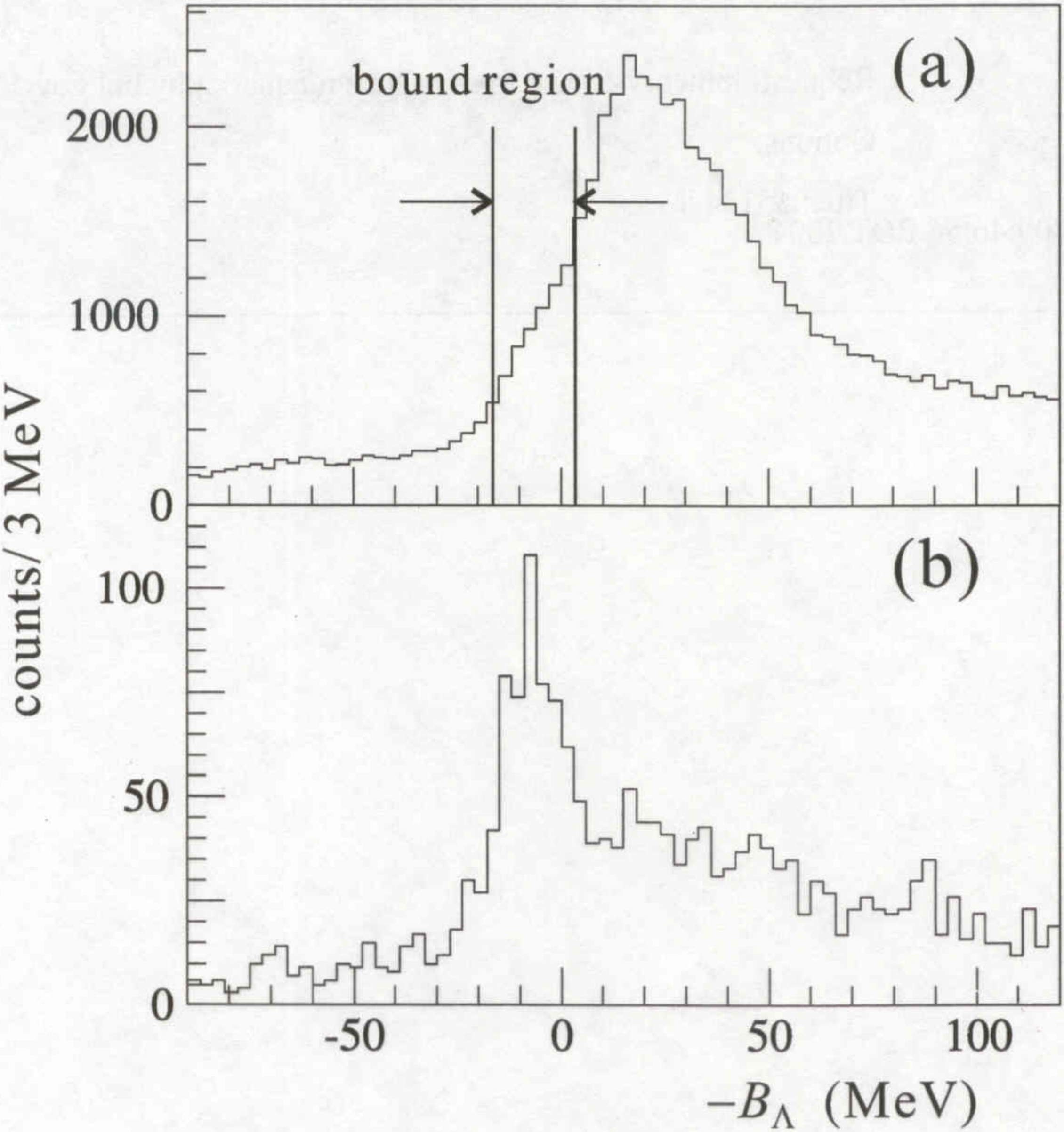


bnl05_1.tex



(a) unbound region
^{16}O(6129)
^{15}O(6175)
(b) bound region
$^{16}_{\Lambda}$O
(c) bound region
Doppler shift corrected
$^{16}_{\Lambda}$O(SE)
counts/3 keV
E_γ (keV)
(d)
original
response function
$E_\gamma^{measured}$
$E_\gamma^{corrected}$
arbitary
(e)
counts/2 keV
Eγ keV

bnl05_2



bound region
(a)
2000
1000
0
counts/ 3 MeV
(b)
100
50
0
-50
0
50
100
$-B_\Lambda$ (MeV)

hypo3_8

${}^{16}_{\Lambda}\mathrm{O}\quad \Delta E(1^- - 0^-)$ Experiment $\sim$ 27 keV

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
	−0.382	1.378	−0.004	7.850	
−30	−179	−15	1	235	28 keV

${}^{15}_{\Lambda}\mathrm{N}\quad \Delta E(1/2^+ - 3/2^+)$

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
	0.756	−2.250	0.035	−9.864	
44	354	25	−12	−296	110 keV

${}^{16}_{\Lambda}\mathrm{O}\quad E(1^-_2 - 1^-_1) = 6176 + \Delta E$ Experiment $\sim$ 6532 keV

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
	−0.234	−1.257	−1.496	−0.708	
−30	−110	14	530	−21	350 keV

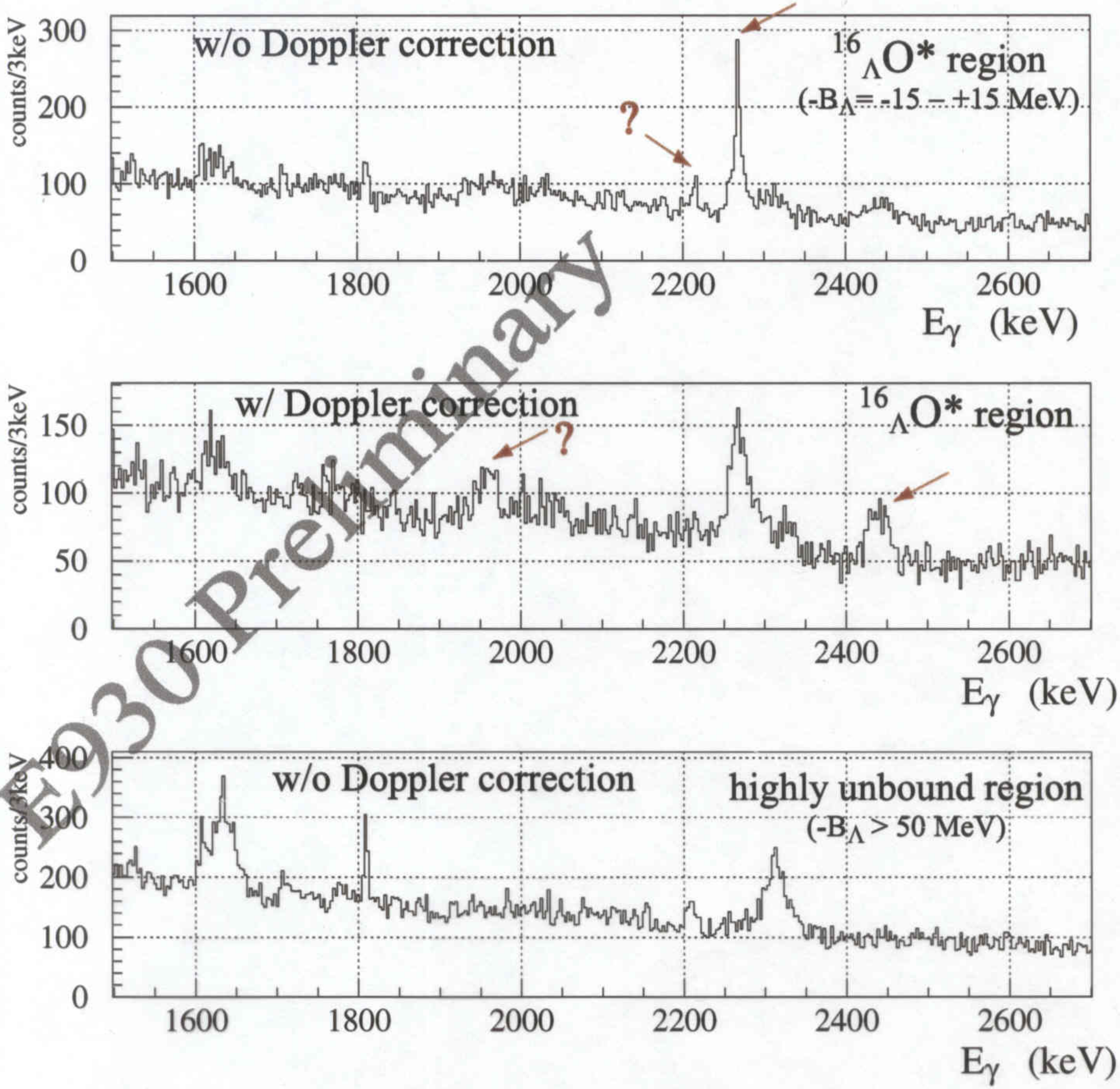
${}^{15}_{\Lambda}\mathrm{N}\quad E(1/2^+;1 - 3/2^+) = 2313 + \Delta E$ Experiment $\sim$ 2263 keV

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
	0.284	−0.778	−0.249	−3.197	
−46	133	9	88	−96	85 keV

$\Delta = 0.468 \quad S_\Lambda = -0.011 \quad S_N = -0.354 \quad T = 0.030$

15LN.eps

Candidates of $^{15}_{\Lambda}N$ γ rays by $^{16}O\,(K^-, \pi^-)^{15}_{\Lambda}N + p$ reaction

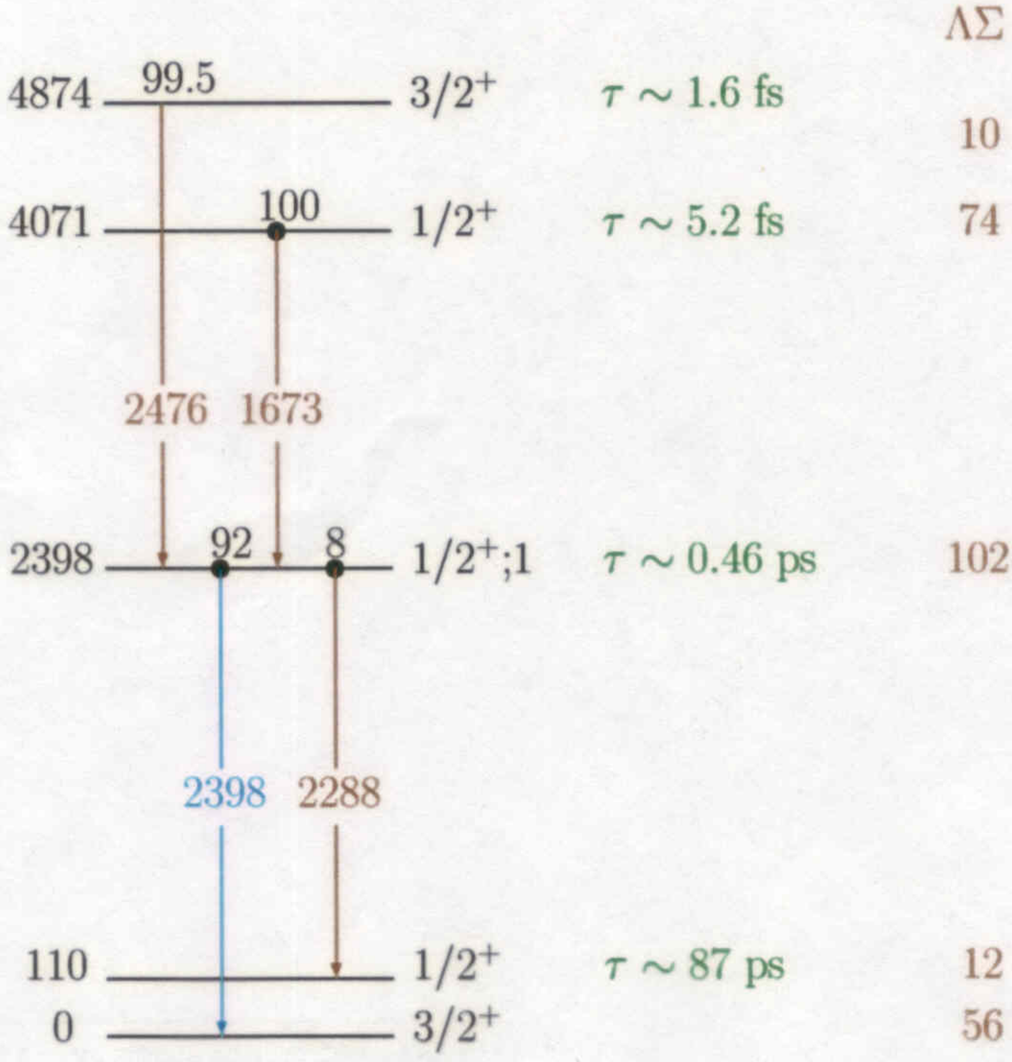


anl02-6

The $^{15}_{\Lambda}$N spectrum based on the three lowest levels of the core using the (8-16)2BME interaction of Cohen and Kurath for

$$\Delta = 0.468 \quad S_{\Lambda} = -0.011 \quad S_{N} = -0.354 \quad T = 0.030\ .$$

which fit the results of E930 for $^{16}_{\Lambda}$O.



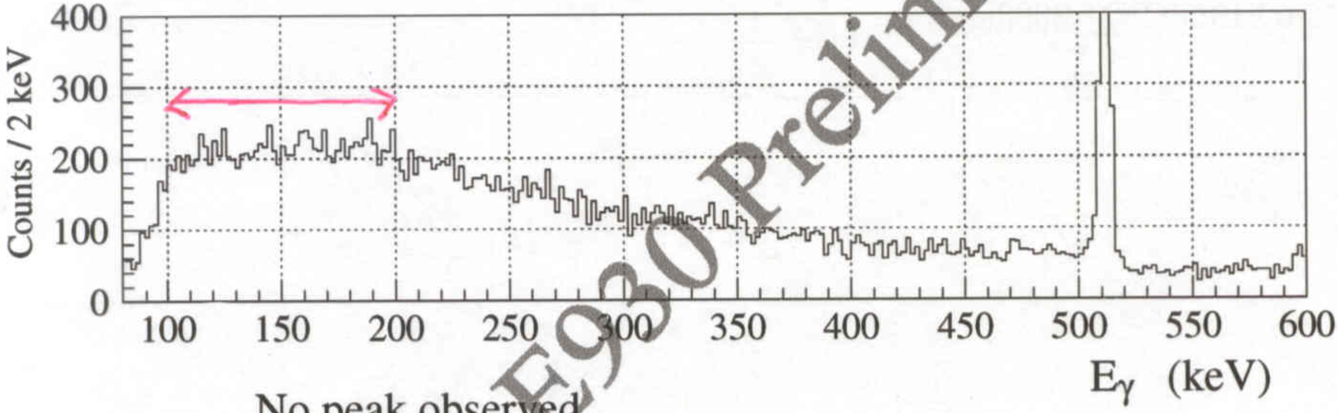
$$E(1/2^+) - E(3/2^+) = 0.756\Delta - 2.250S_{\Lambda} + 0.035S_N - 9.862T$$

ΛΣ contribution = 44 keV

hyp03_6

$^{10}B\,(K^-, \pi^-)\,^{10}_{\Lambda}B$ reaction

$-40 < -B_{\Lambda}^{*} < -10$ MeV *uncalibrated
(5 MeV lower than the $^{9}_{\Lambda}Be$ gate)



No peak observed
(upper limit to be derived)

R.E. Chrien et al., PRC 41 (1990) 1062 no γ ray

ΛΣ (keV)

180 ——— 2^- 49

0 ——— 1^- 34

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

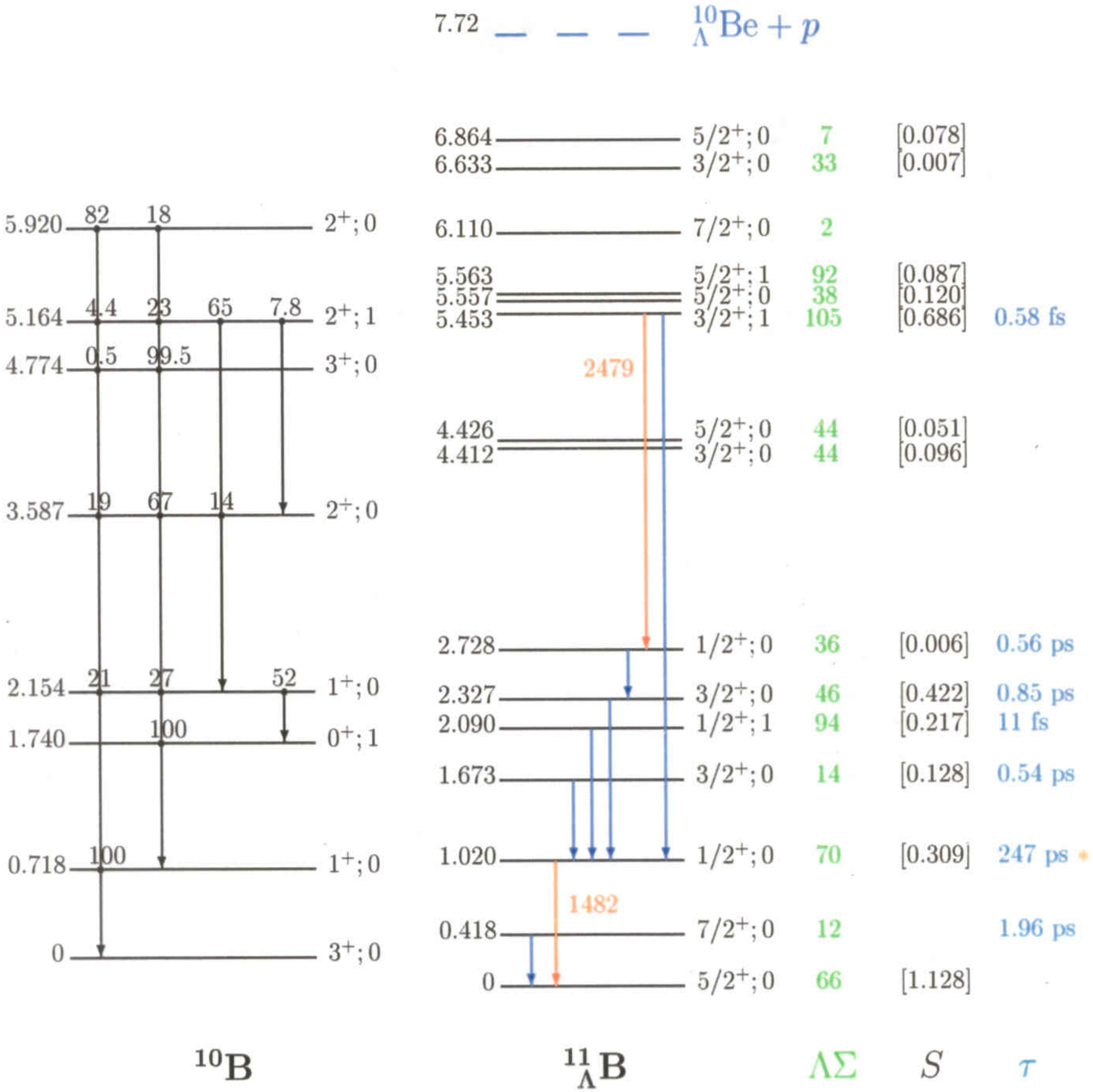
Only case in which Δ and $\Lambda\Sigma$ oppose one another

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
	0.579	1.413	0.013	−1.073	
−15	250	−14	−5	−32	180 keV

$^{7}_{\Lambda}Li$: $\Delta = 0.432$ $S_\Lambda = -0.010$ $S_N = -0.380$ $T = 0.030$

CK616 gives $\Delta E = 164$ keV - larger coefficient of T

anl02_11



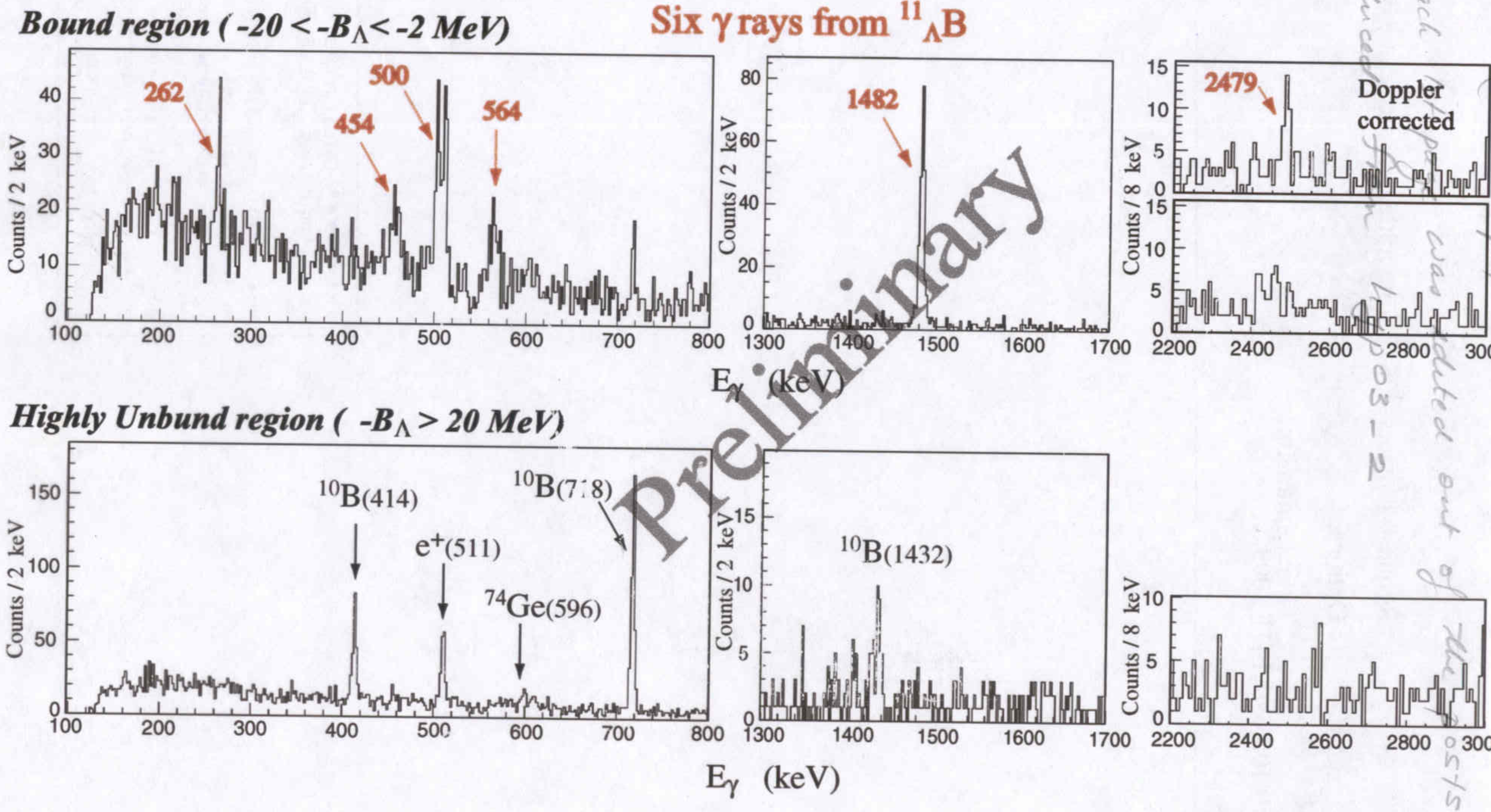
* τ (weak) $\sim$ 200 ps

For $E_\gamma = 1482$ keV, τ (EM) $\sim$ 38 ps

This level serves as a collection point for γ rays

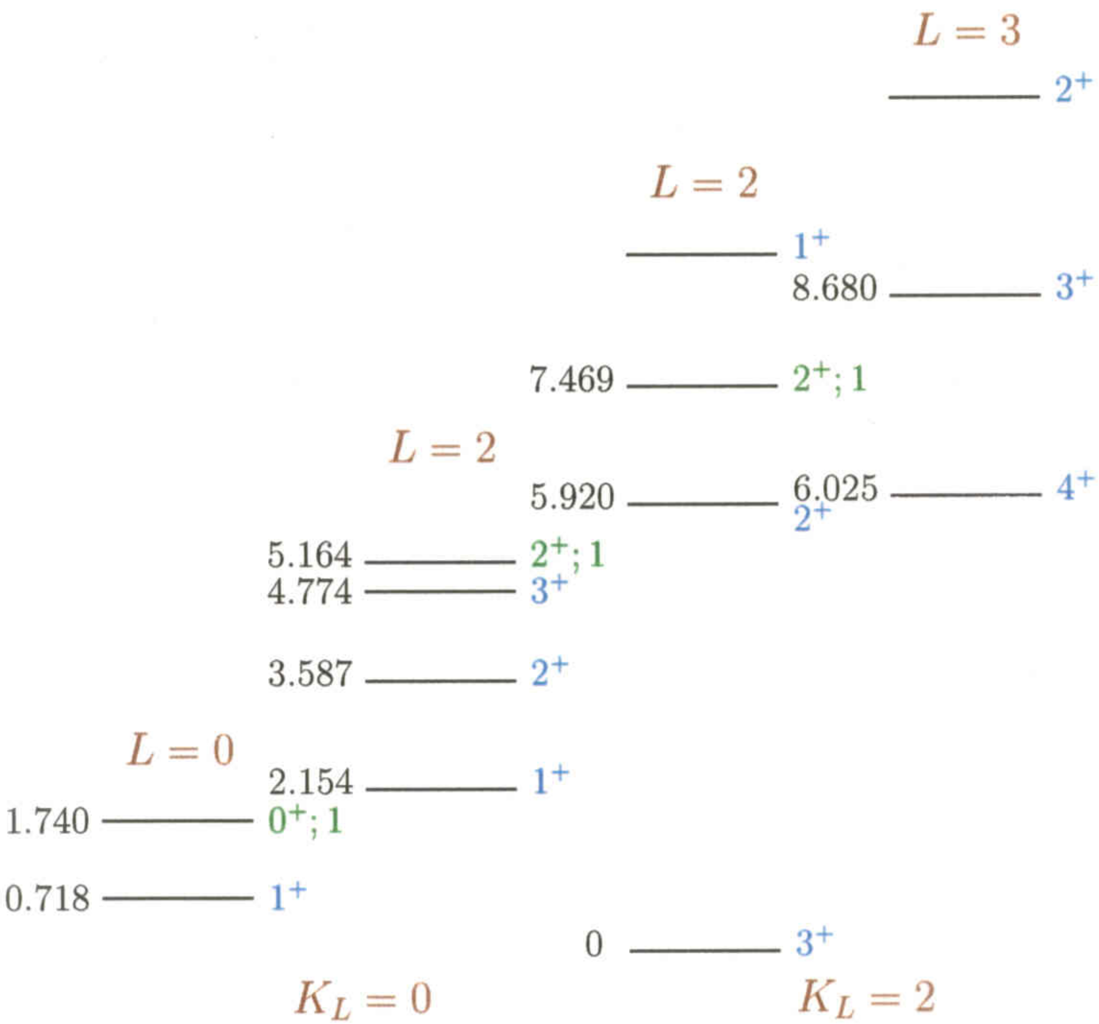
hyp03-2.ps (11LB.eps)
Note: A black [illegible] was edited out of the postscript file produced from hyp03-2

KEK E518 $^{11}B\,(\pi^+,K^+\gamma)\,^{11}_{\Lambda}B$



hyp03-3

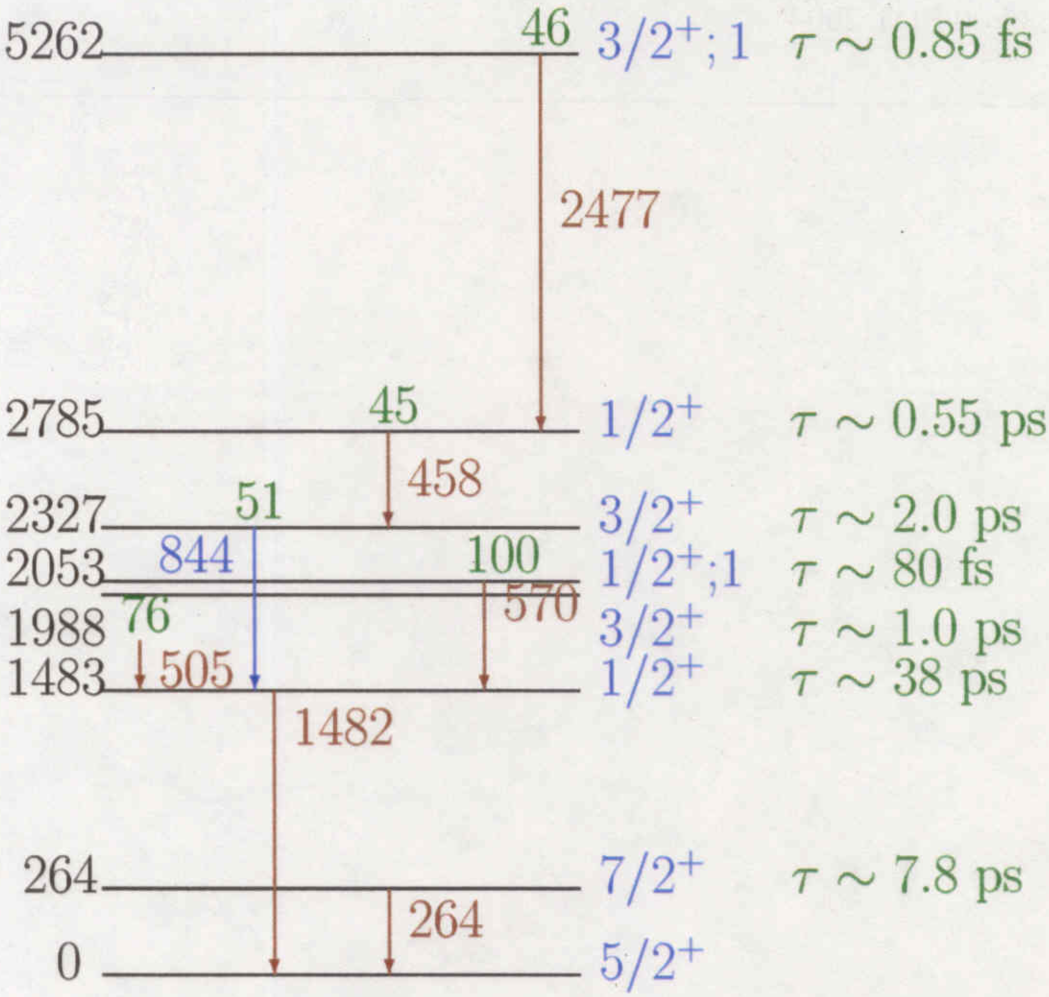
P-shell states of ^{10}B with [42] symmetry.



$T = 0$ states have $S = 1$ and $T = 1$ states have $S = 0$

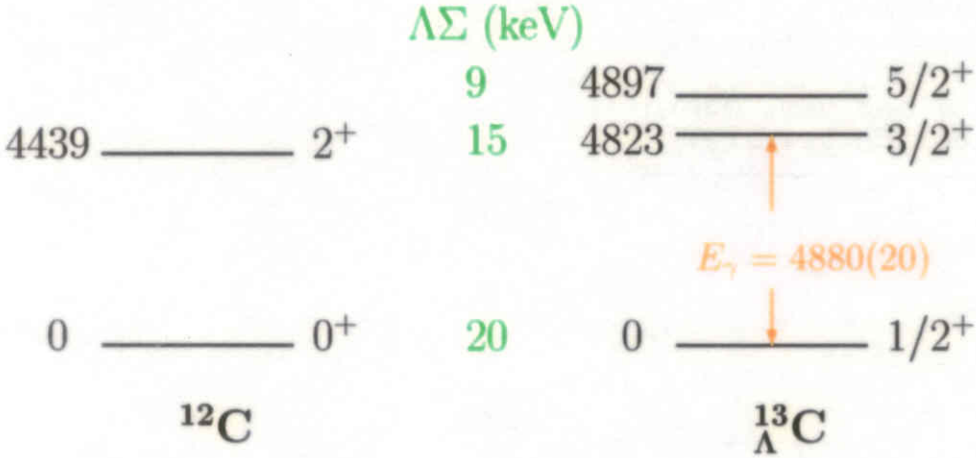
hyp03–11

Speculations on the placement of $^{11}_{\Lambda}$B γ rays.



- To reproduce the definitive 1482 keV line, the centroid of the lowest $1/2^+$, $3/2^+$ doublet needs to be high (small coefficient of S_N) and the separation needs to be small (Δ).
- Natural to identify the 2479 keV line with the strong M1 from the $3/2^+; 1$ level.
- For different core wave functions, ground-state doublet and T=1 levels are quite stable while $1/2^+$ and $3/2^+$ T=0 states are volatile.

anl02_9



BNL E929 - H. Kohri et al., PRC 65 (2002) 034607 S. Ajimura et al., Phys. Rev. Lett. 86 (2001) 4255

$\Lambda\Sigma$	Δ	S_Λ	S_N	T	ΔE
5	-27	19	472	-32	4831 keV
	-0.051	-1.449	-0.867	-1.100	

$\Delta = 0.532$ $S_\Lambda = -0.013$ $S_N = -0.545$ $T = 0.027$

KEK E336 $E_x = 4.85(7)$ MeV from $^{13}C(\pi^+, K^+)^{13}_{\Lambda}C$

L12

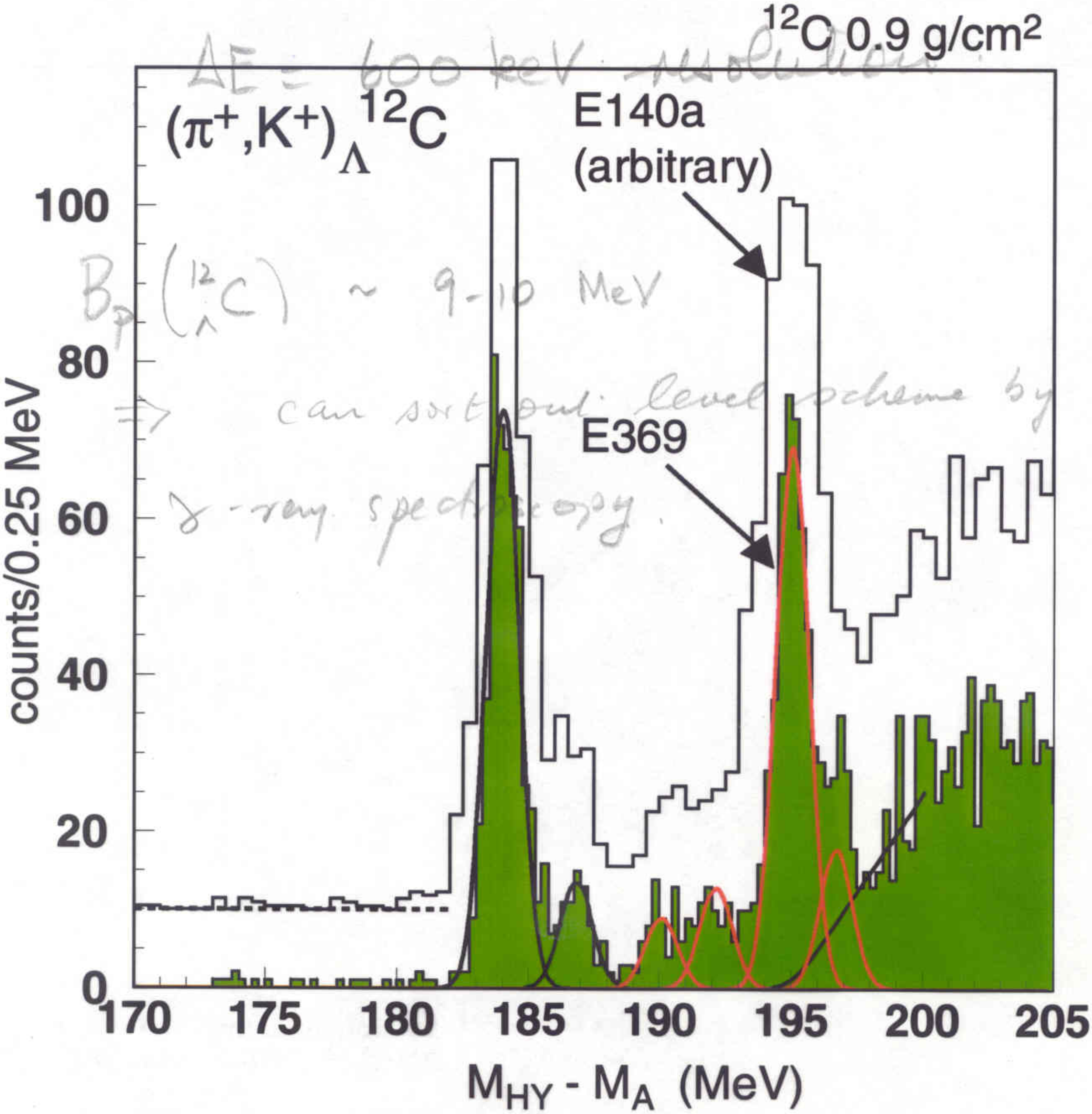
12c.eps

$^{12}C(e,e'K^+)^{12}_{\Lambda}B$

ΔE = 600 keV resolution

$B_p(^{12}_{\Lambda}C) \sim$ 9-10 MeV

⇒ can sort out level scheme by γ-ray spectroscopy

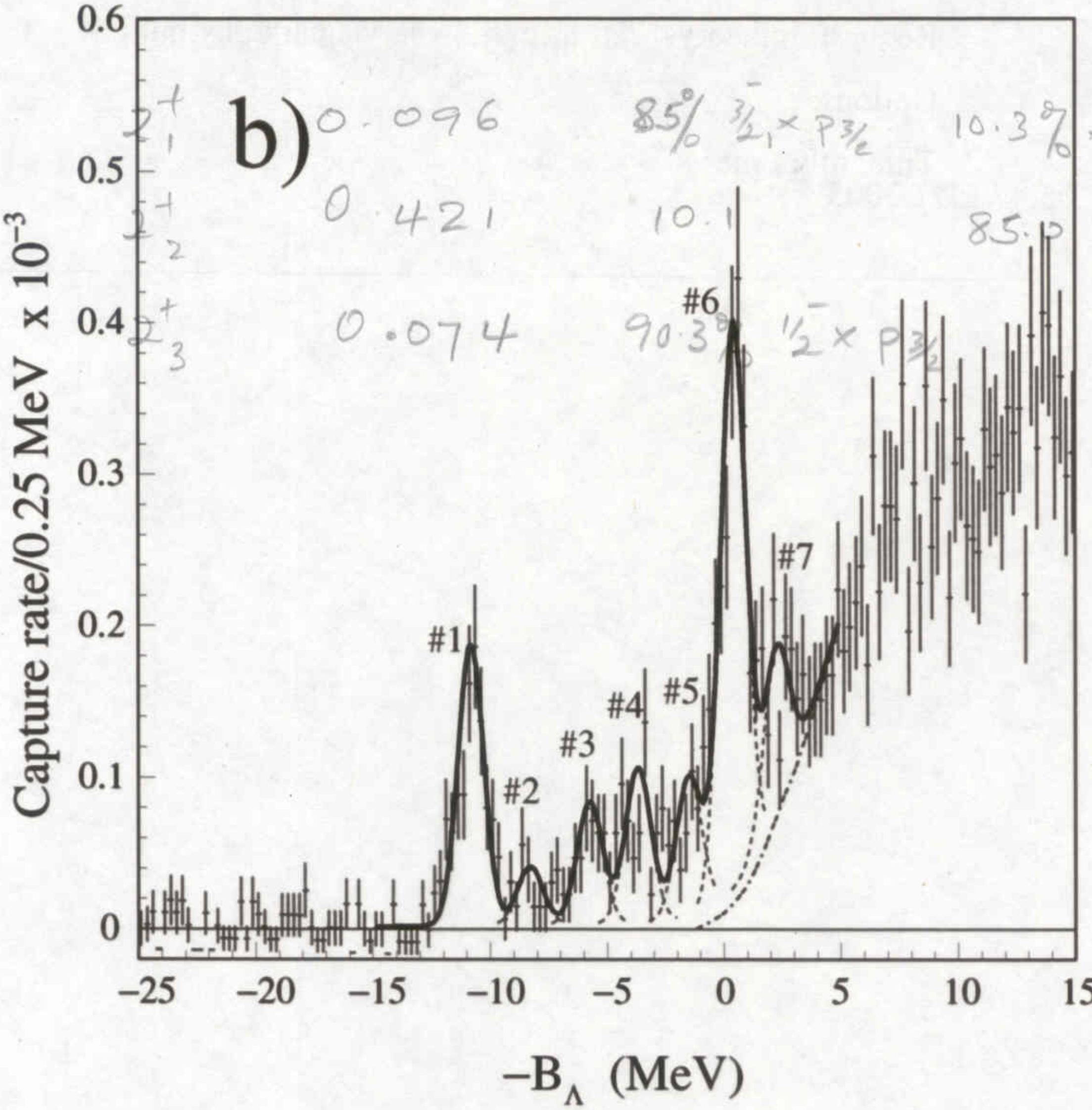


ΔE = 1.45 MeV

T. NAGAE

jlab05_1.

FINUDA: $^{12}_{\Lambda}C$ Phys. Lett. B 622 (2005) 35



Peak number	$-B_\Lambda$ (MeV)	E_x (MeV)	Capture rate/(stopped K^-)[$\times 10^{-3}$]
1	-10.94 ± 0.06	0	$1.01 \pm 0.11_{stat} \pm 0.10_{syst}$
2	-8.4 ± 0.2	2.54 ± 0.21	0.21 ± 0.05
3	-5.9 ± 0.1	5.04 ± 0.12	0.44 ± 0.07
4	-3.8 ± 0.1	7.14 ± 0.12	0.56 ± 0.08
5	-1.6 ± 0.2	9.34 ± 0.21	0.50 ± 0.08
6	0.27 ± 0.06	11.21 ± 0.09	2.01 ± 0.17
7	2.1 ± 0.2	13.04 ± 0.21	0.58 ± 0.18

dnp01-7

Energy spacings in $^{12}_{\Lambda}\mathrm{C}$

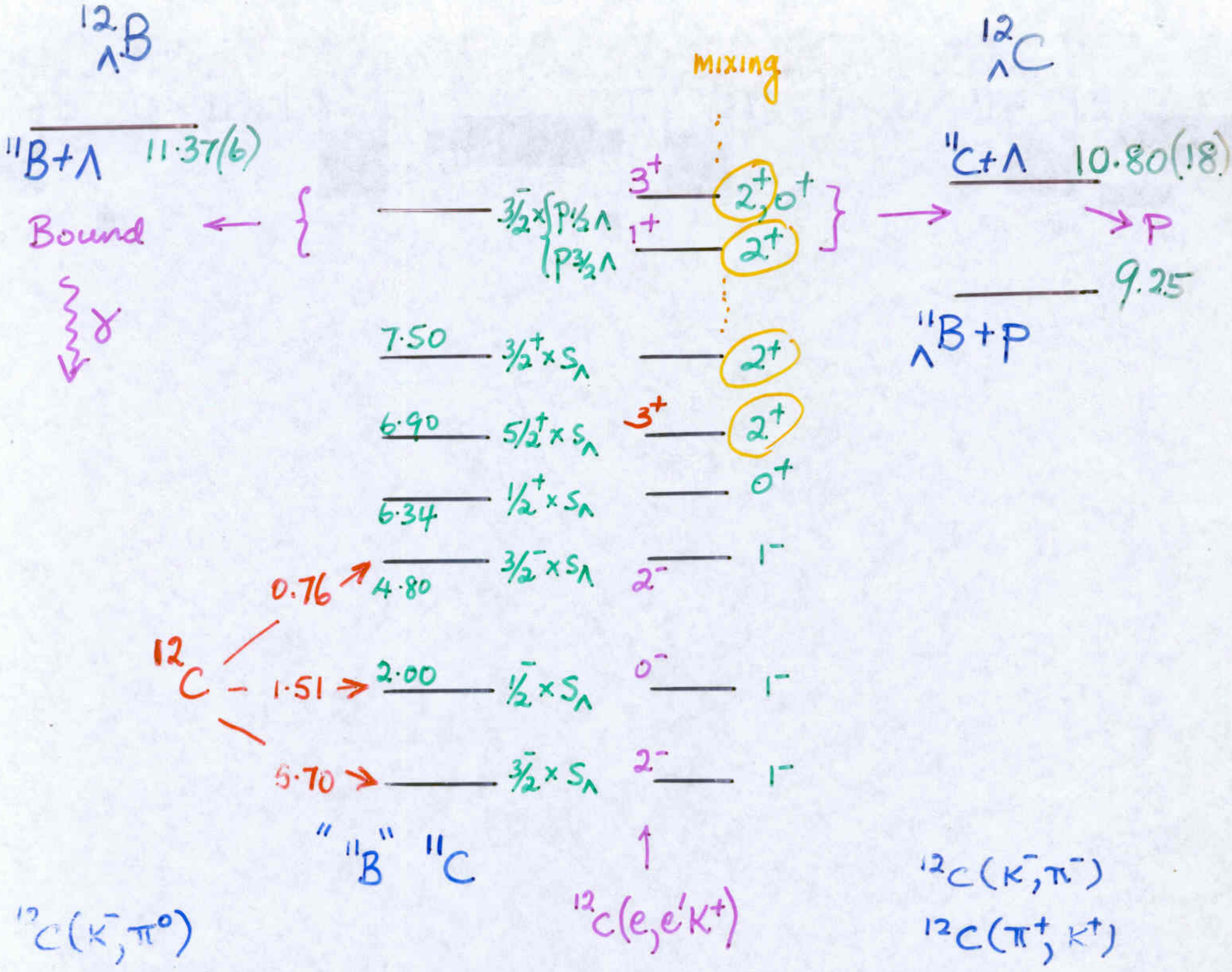
Energy	J^π	$\Lambda\Sigma$ (keV)
5826	1^-	28
5707	2^-	35
5169	3^-	15
4687	2^-	106
2673	0^-	23
2632	1^-	49
233	2^-	40
0	1^-	97

J^π_n	$\Lambda\Sigma$	Δ	S_Λ	S_N	T	Ex
1^-_2	48	186	-13	464	23	2632 keV
1^-_3	70	226	6	751	34	5826 keV
2^-_1	57	264	-17	-24	-77	233 keV

KEK Experiment

$Ex(1^-_2)$ ($E_{core} = 2.00$) 2.51, 2.62 (E369), 2.70 (E336)

$Ex(1^-_3)$ ($E_{core} = 4.80$) 6.30, 5.92 (E369), 6.22 (E336)



Full shell-model basis

$$A=11\,(0\hbar\omega)\times p_\Lambda \;+\; A=11\,(1\hbar\omega)\times s_\Lambda$$

$$\langle p_N p_\Lambda \,|\, V_{\Lambda N} \,|\, (sd)_N\, s_\Lambda \rangle$$

Center of mass constraint