分科会
“Strangeness Nuclear Physics experiments ”

Ⅰ．背景と物理的動機

Ⅱ．現在の実験の状況と目標

Ⅲ．施設

研究計画委員会報告
2002.2.22
家入正治

Activities

LOI

for the Experiments on Strangeness Nuclear Physics at the 50 GeV Proton Synchrotron, July 2000
http://www-jhf.kek.jp/JHF_WWW/LOI/50GeVNP-LOI-v1.0.pdf

出席者数：WG#1@NP01

25（国外5）

Conferences

会議名	開催日	開催場所	参加者数	日本
HYP97	13-18 Oct, 1997	BNL [USA]	**97**	30
SNP99	19-22 Feb, 1999	Seoul [Korea]	**98**	42
HYP2000	23-27 Oct, 2000	Torino [Italy]	**135**	40

Speakers at WG#1

WG#1 Strangeness Nuclear Physics experiments

Letter of Intent (July 12, 2000)

- **T. Nagae** "Strangeness Nuclear Physics experiments at 50-GeV PS"
- T. Fukuda "Double-Lambda at BNL"
- K. Nakazawa "Next step on the coming hybrid experiment(AGS-E964)"
- M. Ieiri "Hyperon-proton scattering experiment"
- K. Tanida "Gamma-ray spectroscopy of hypernuclei"

- **Y. Akaishi** "Characteristic features of Strangeness Nuclear Systems"
- V. Kopeliovich "Multibaryons with Strangeness and Charm"
- E. Hiyama "Comments from the theoretical side"

- T. Yamazaki "Kbar-nucleus bound state spectroscopy"
- M. Iwasaki "Experimental search for Kbar-nucleus bound state"
- A. Sakaguchi "Feasibility of Production and Detection of Relativistic Hypernuclei "

- H. Noumi "Secondary beam lines"
- H. Hotchi "Possibility of moving the BNL-AGS D6 line to JHF"

•Discussion

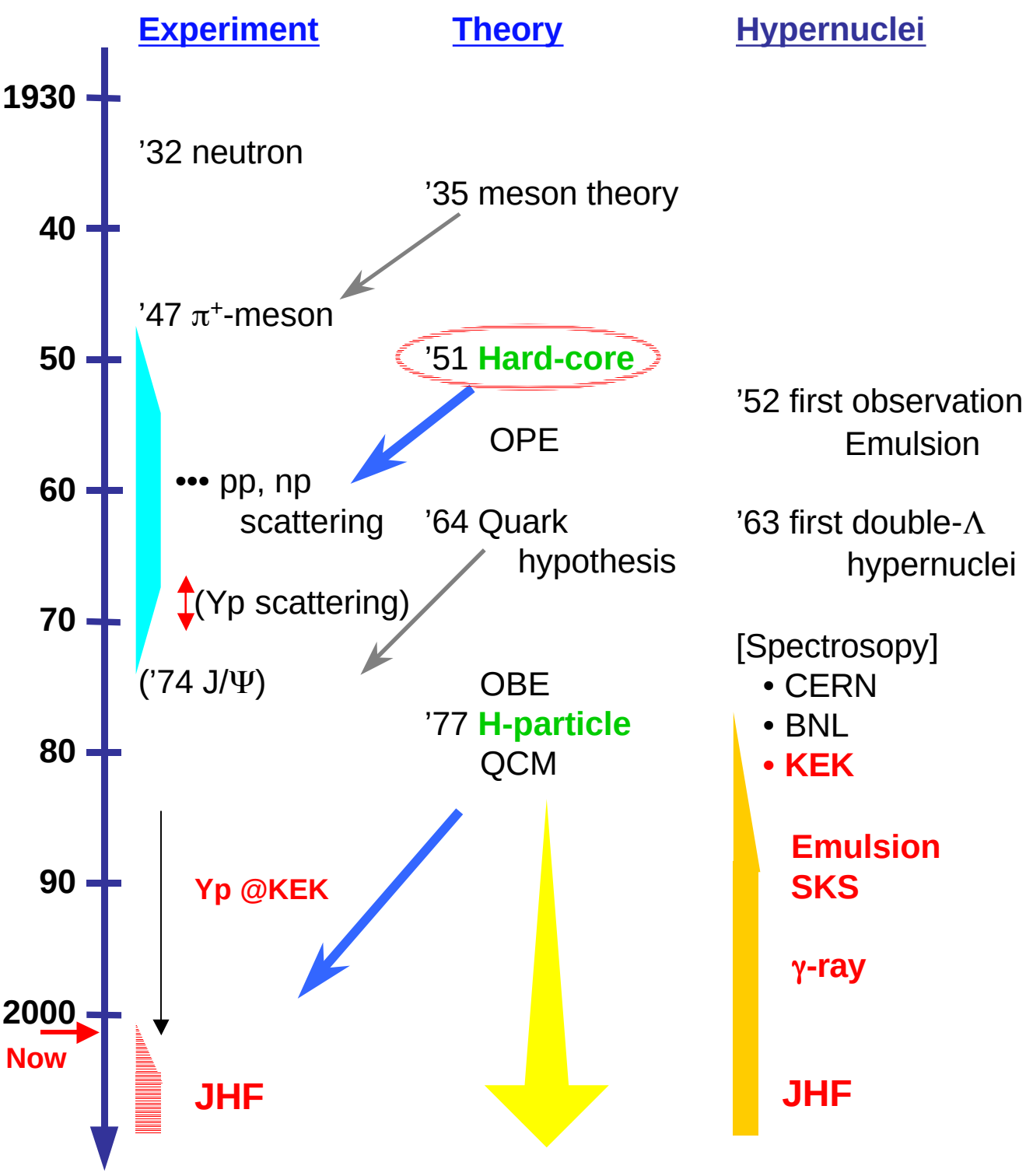
どうして“ストレンジネス”で原子核か

- ‘核力’から‘バリオン間力’へ
- 原子核の‘深部’を探る
- 核図表の‘境界’領域へ

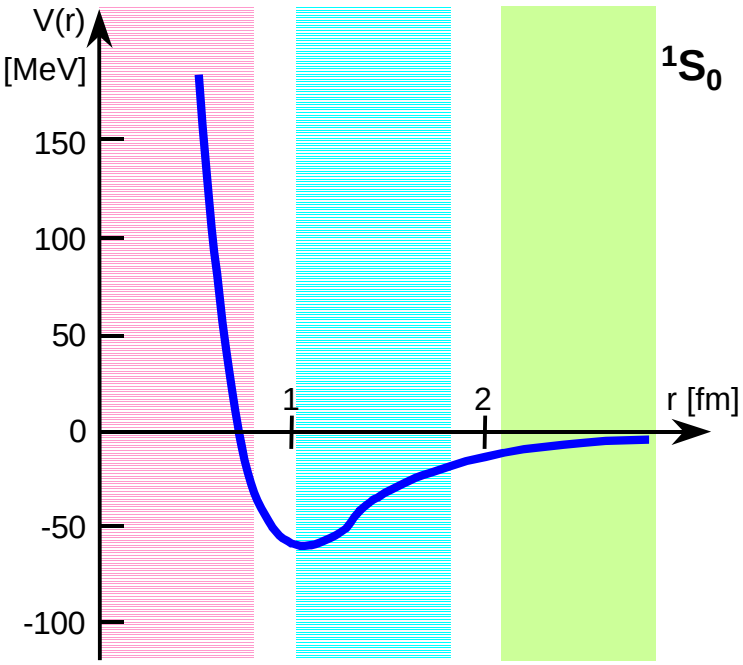
- 描象：OBE and/or QCM under $SU(3)_F$
- 核構造のより質的な理解
- 新現象・新事実の探査

- ハイペロン–核子散乱
- ハイパー核の核分光：反応＆γ線
- Ｓ＝－２の核の束縛エネルギー

Study of B-B Strong Interactions



Baryon-Baryon potential



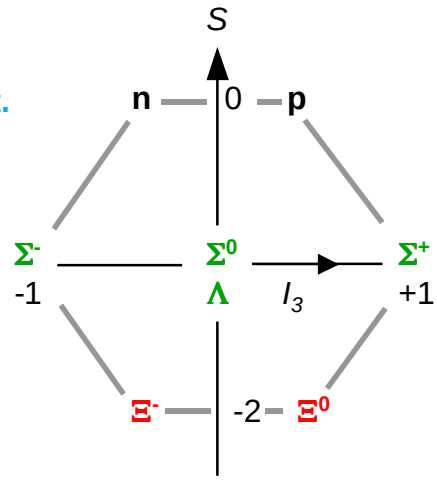
OBE **HC, ω ρ,σ, ••• π**

- Paris
- Nijmegen
- Bonn-Julich

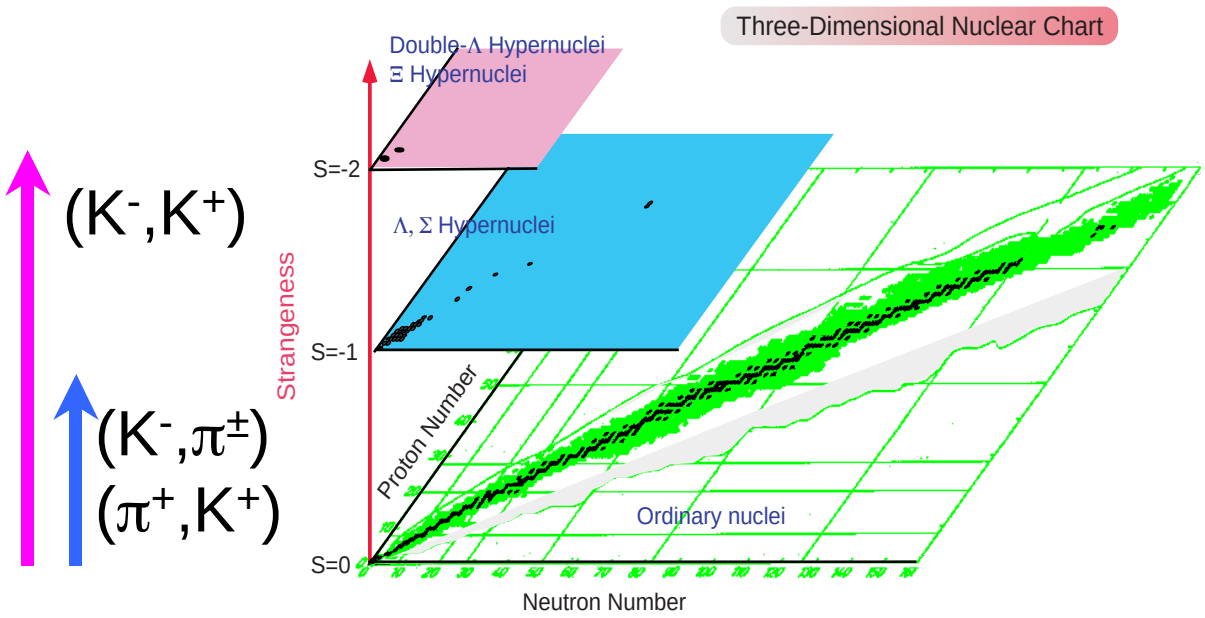
QCM **(λ•λ)(σ•σ)** **Eff.Meson Exch. pot.**
Pauli

- Tokyo
- Kyoto
- Tubingen

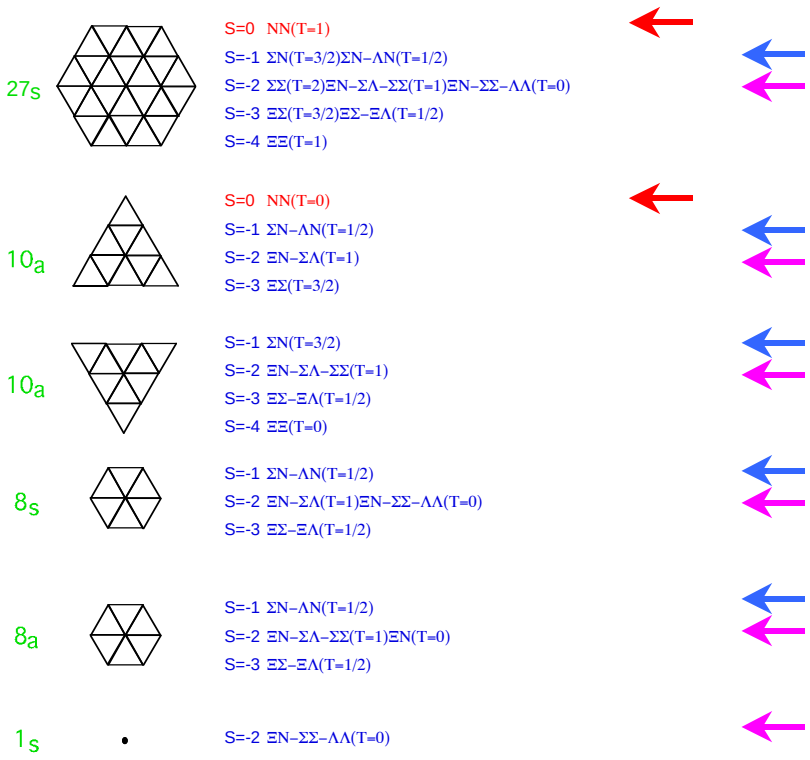
••• **Flavor SU(3)**



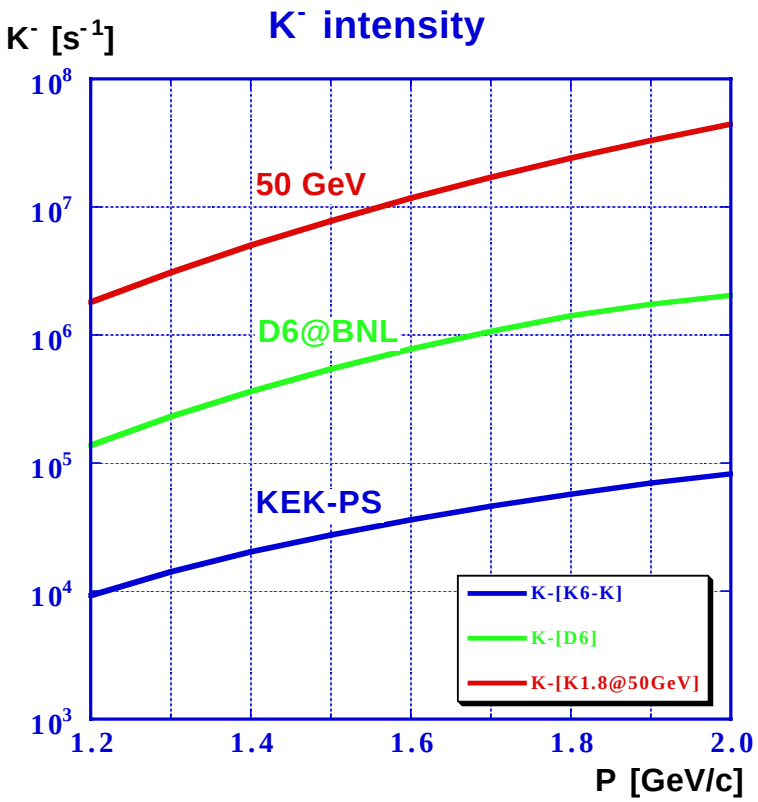
playground

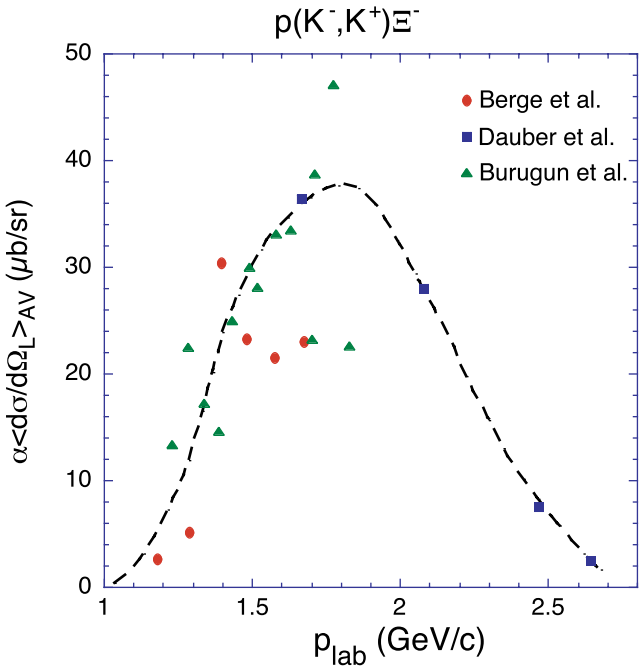


バリオンーバリオン系のＳＵ（３）による分類



二次ビーム強度

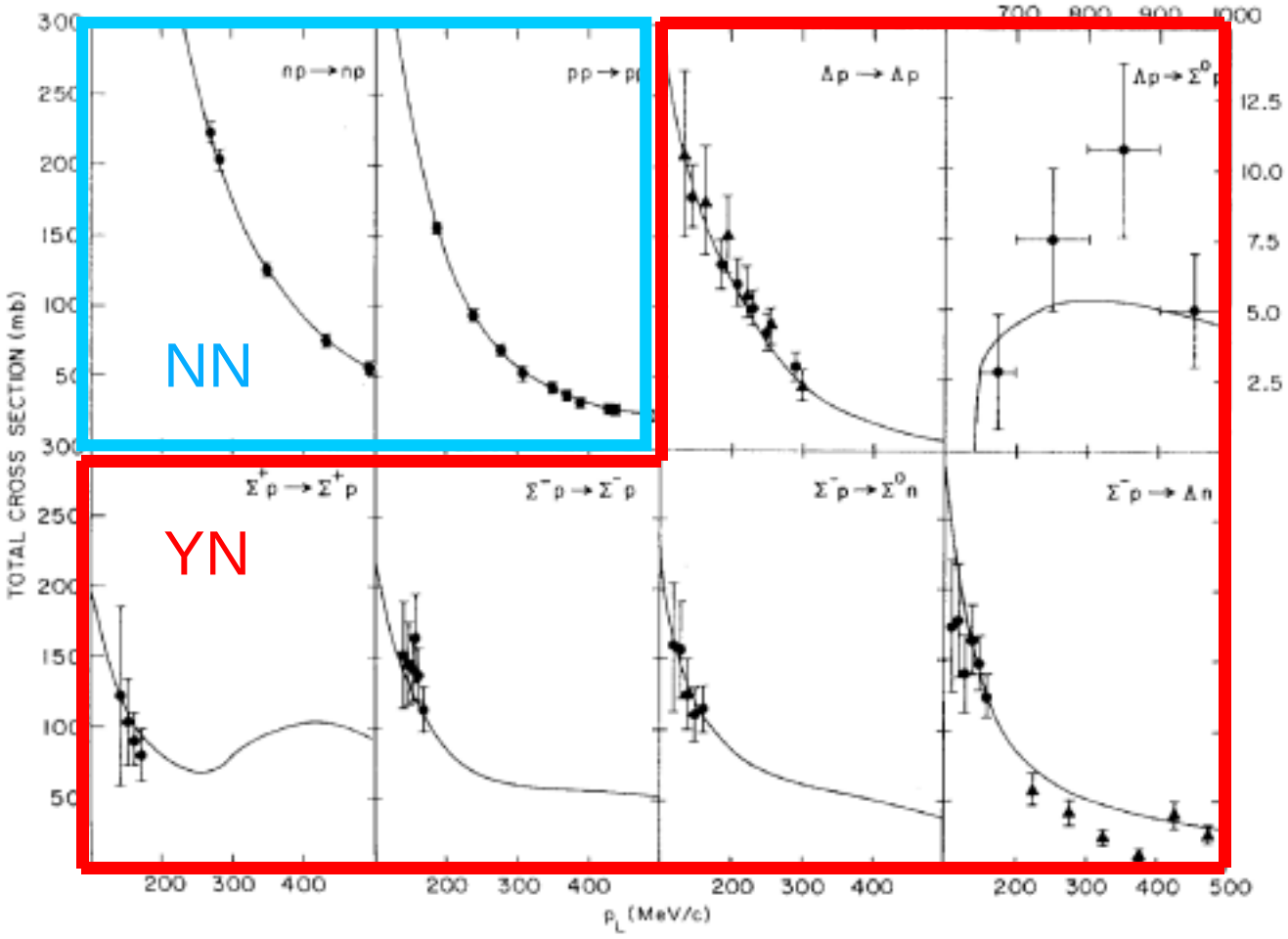

K⁻ intensity
K⁻ [s⁻¹]
10⁸
10⁷
10⁶
10⁵
10⁴
10³
50 GeV
D6@BNL
KEK-PS
K-[K6-K]
K-[D6]
K-[K1.8@50GeV]
1.2
1.4
1.6
1.8
2.0
P [GeV/c]


p(K⁻,K⁺)Ξ⁻
Berge et al.
Dauber et al.
Burugun et al.
α<dσ/dΩL>AV (μb/sr)
50
40
30
20
10
0
1
1.5
2
2.5
plab (GeV/c)

現在の実験の状況と目標

- Yp scattering
- (π^+, K^+) spectroscopy
- γ-ray spectroscopy
- S = -2

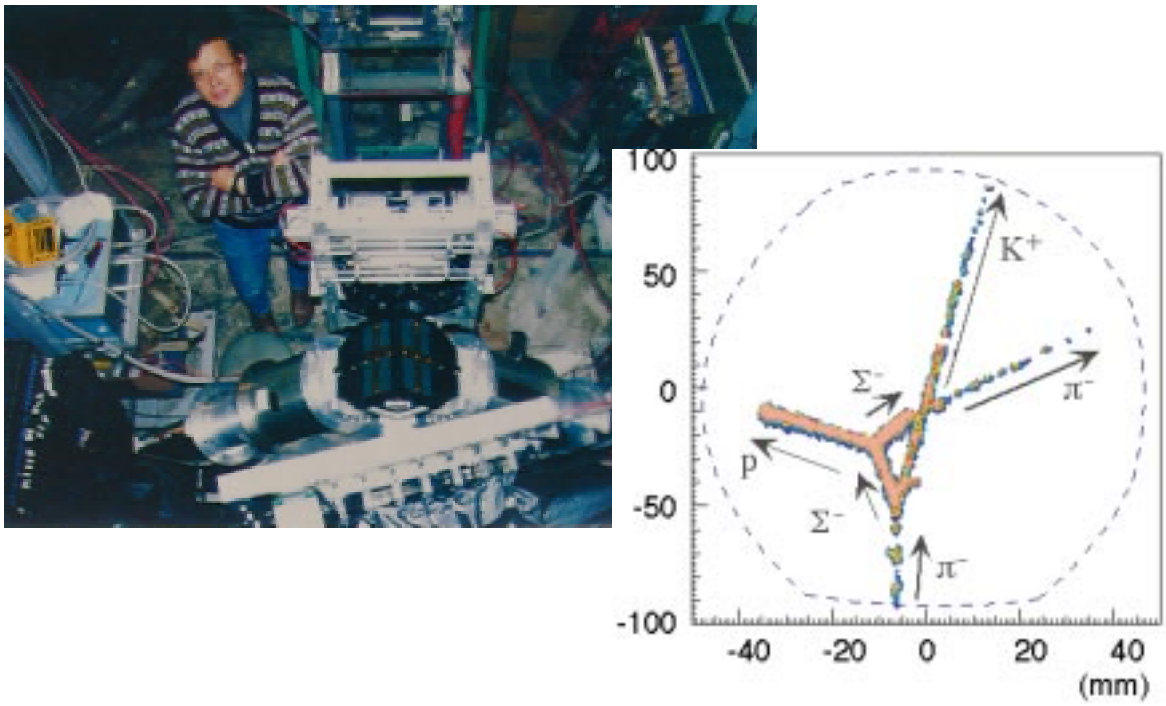
Available Yp scattering data

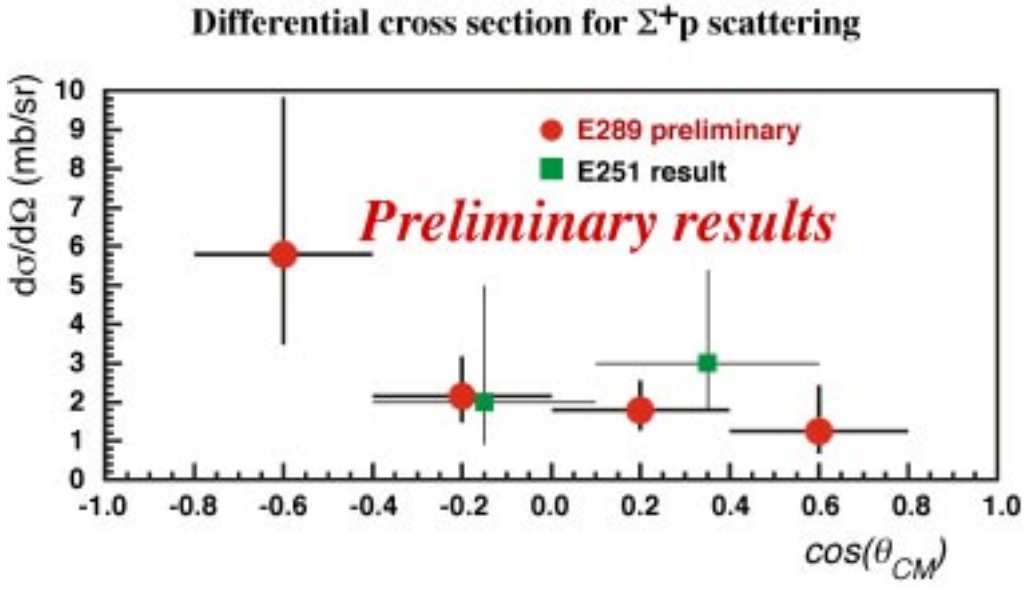


from Dover & Feshbach Ann.Phys.198(90)321

Yp scattering @ KEK

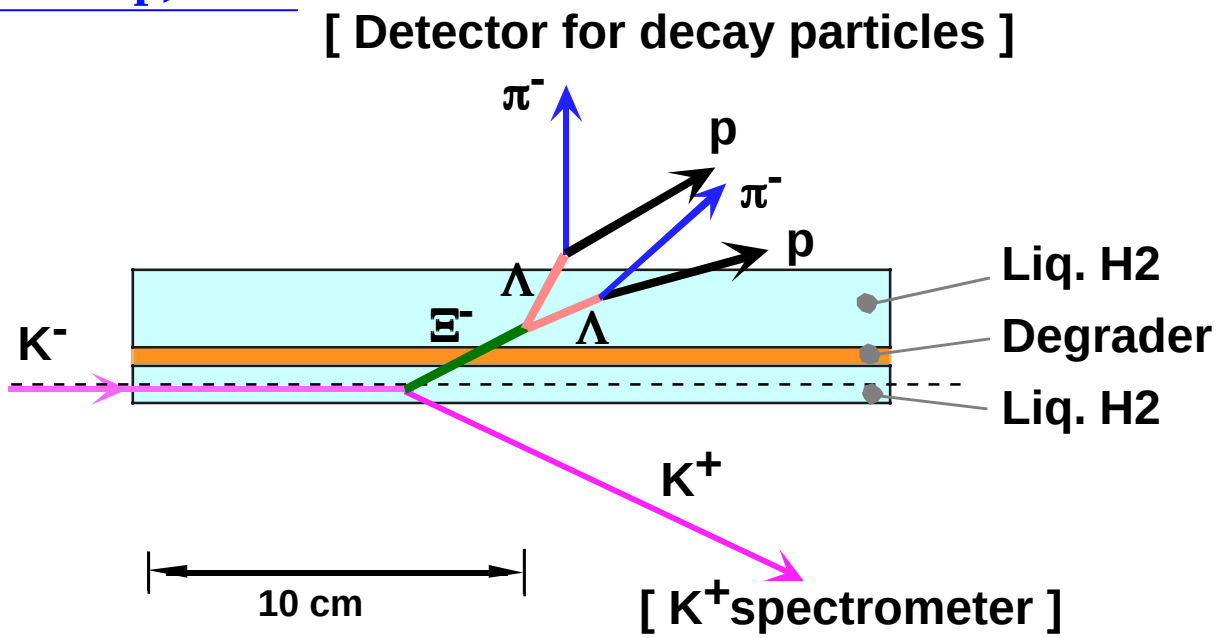
Scintillating Fiber / Liq. Sci. & IIT





Yp scattering @ 50GeV

$\Xi^- p \rightarrow \Xi^- p,\ \Lambda\Lambda$

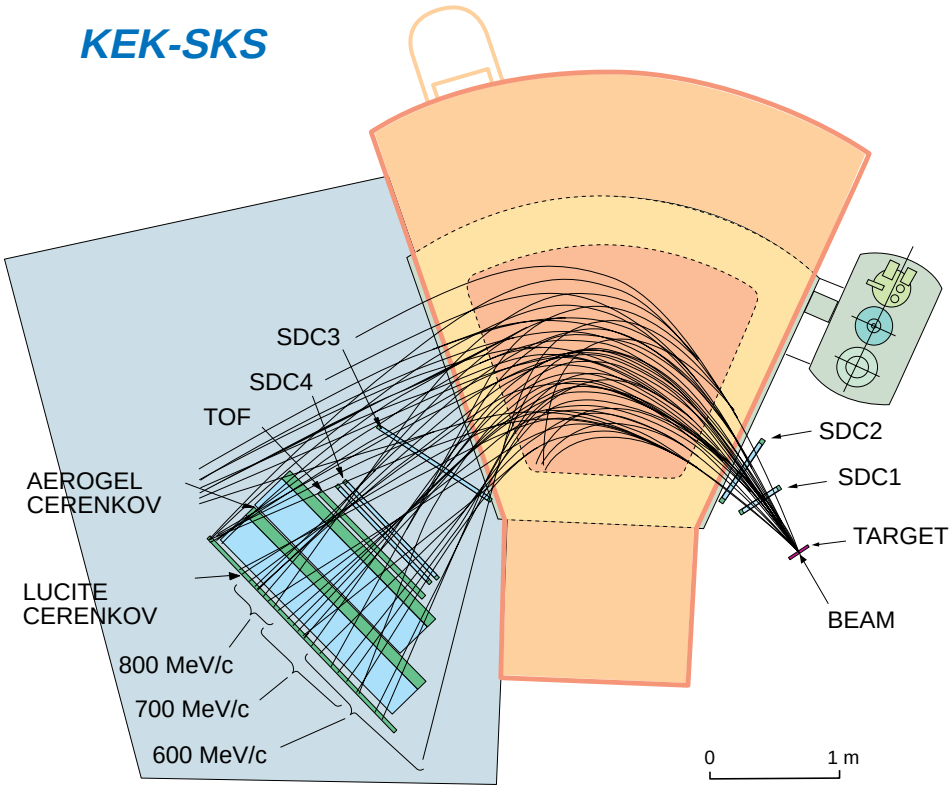


Anti-symmetric spin-orbit in $\Sigma^+ p$ & Λp

$$M = a + c(\sigma_n^1 + \sigma_n^2) + b(\sigma_n^1 - \sigma_n^2) + m\,\sigma_n^1\,\sigma_n^2 + g(\sigma_P^1\,\sigma_P^2 + \sigma_K^1\,\sigma_K^2) + h(\sigma_P^1\,\sigma_P^2 - \sigma_K^1\,\sigma_K^2)$$

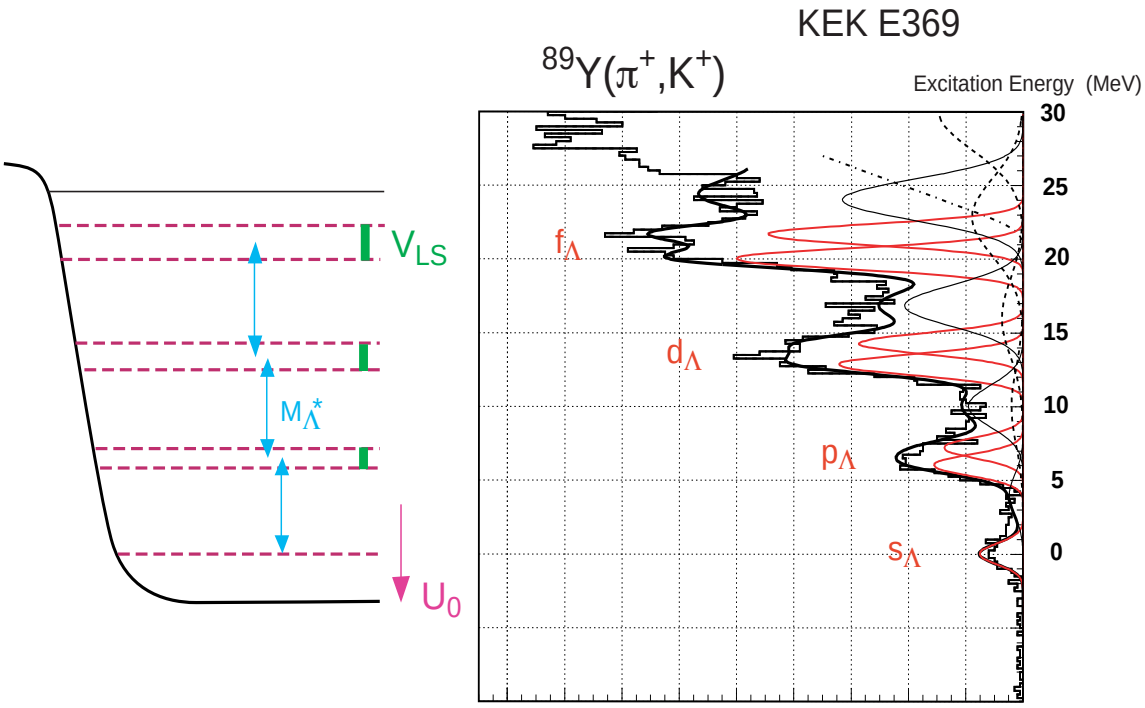
$$I_0 P_y = 1/4\ \mathrm{Tr}(MM\dagger\ \sigma_n^1) = 2\ \mathrm{Re}[(a+m)c^* + (a-m)b^*]$$
$$I_0 A_y^T = 1/4\ \mathrm{Tr}(M\ \sigma_n^2\ M\dagger) = 2\ \mathrm{Re}[(a+m)c^* - (a-m)b^*]$$

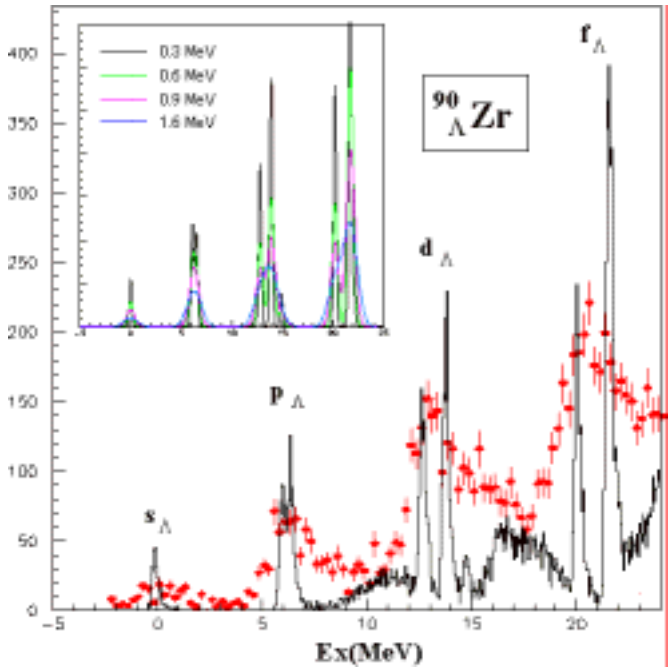
Spectroscopy @ KEK



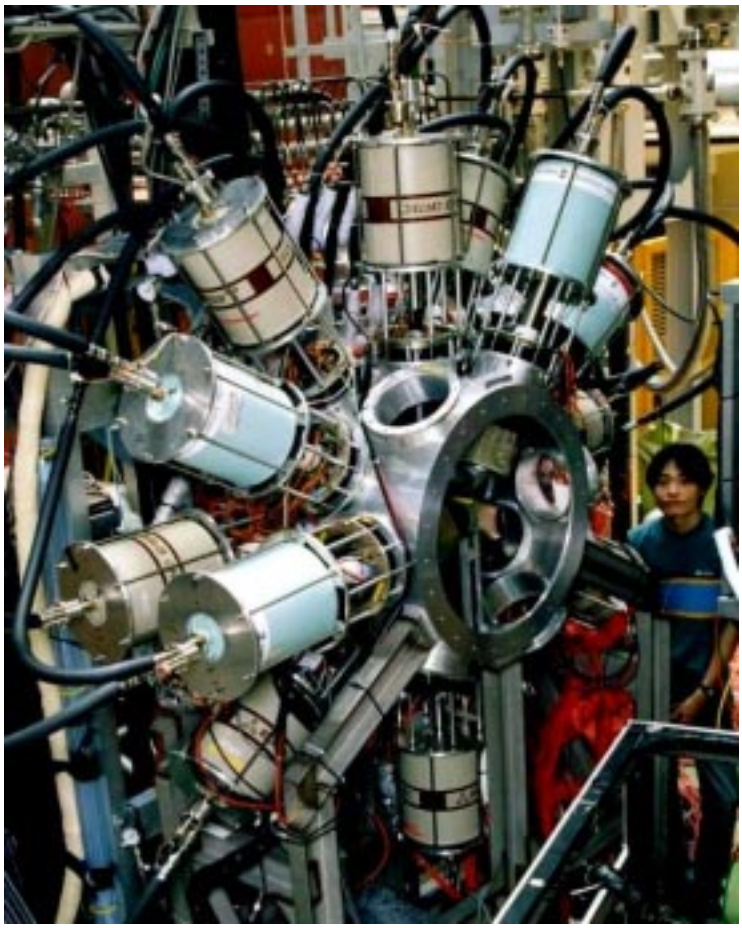
- Large solid angle: 100 msr
- Good Energy Resolution < 2 MeV
- Max. field: 3T
- (π^+,K^+) Reaction
  at 1.05 GeV/c

Spectroscopy @ 50 GeV

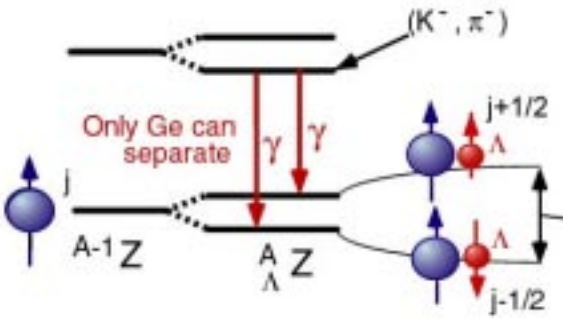




γ-ray Spectroscopy @ KEK



"Hypernuclear fine structure"

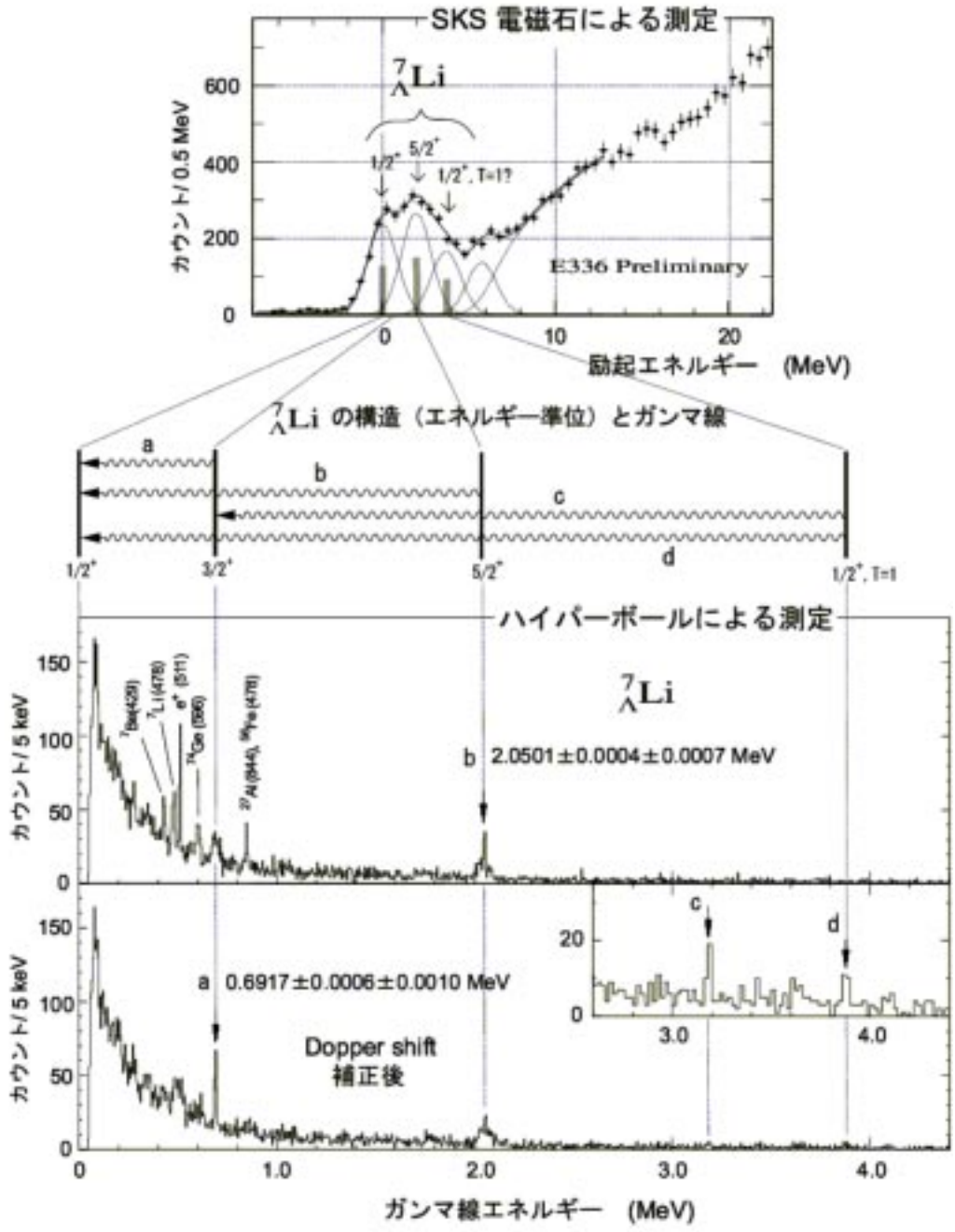


$$V_{\Lambda N}^{eff} = V_0(r) + \Delta + V_\sigma(r)\,\vec{s}_\Lambda\vec{s}_N + V_\Lambda(r)\,\vec{l}_{\Lambda N}\vec{s}_\Lambda + V_N(r)\,\vec{l}_{\Lambda N}\vec{s}_N + V_T(r)\,S_{12}$$

S_Λ S_N T

Integrated with shell-model w.f.
(Millener's parameterization)

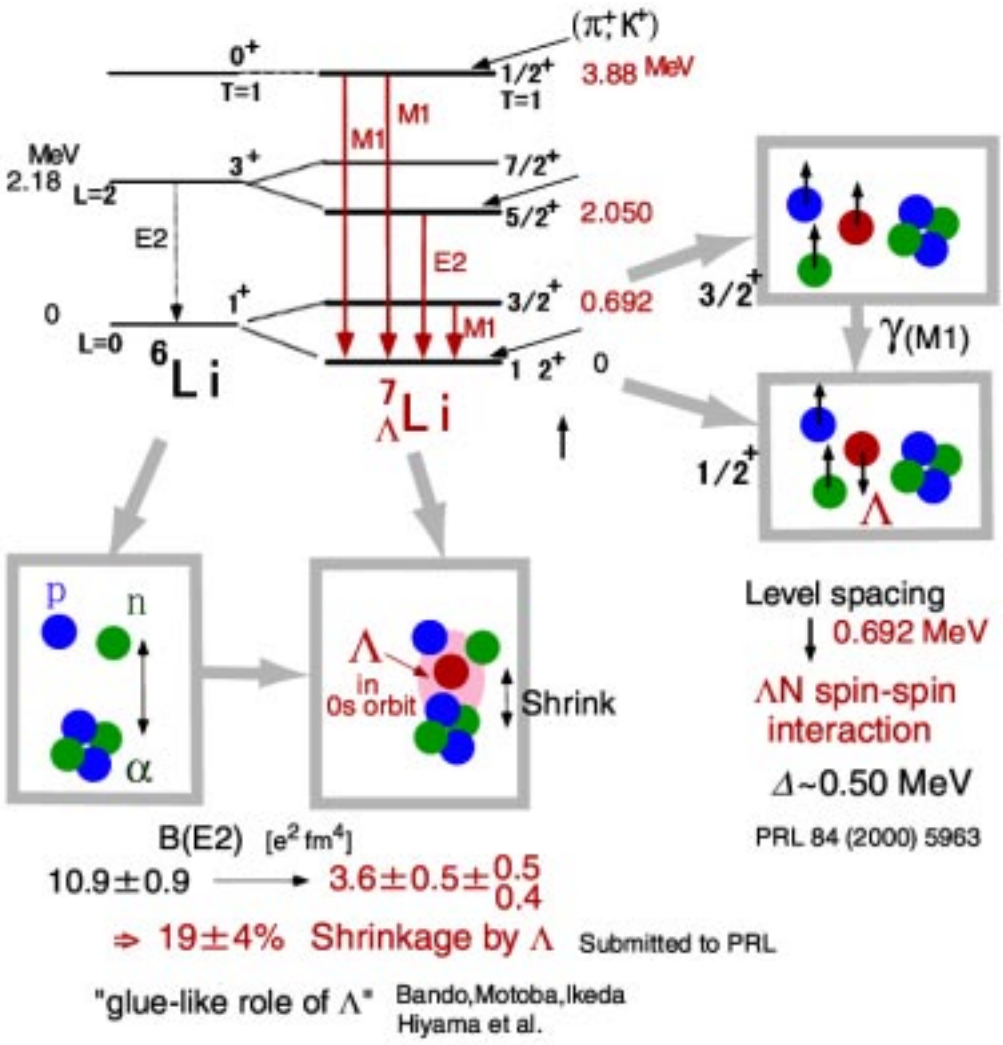
γ-ray Spectroscopy @ KEK



γ-ray Spectroscopy @ KEK

KEK-PS E419 May-June,1998

$^{7}_{\Lambda}$Li spectroscopy with Hyperball



γ-ray Spectroscopy @ 50 GeV

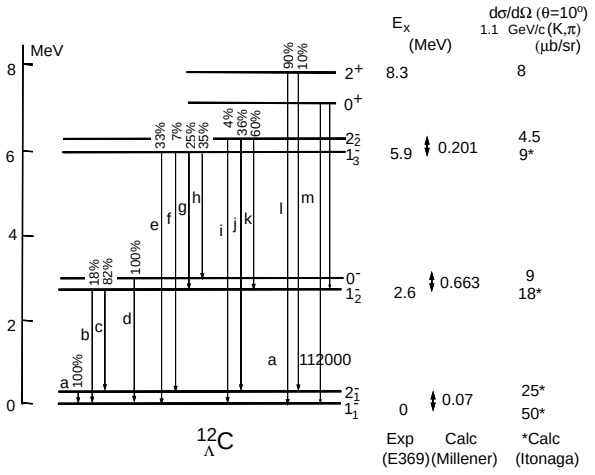
- Spectroscopy of Light and Heavy Hypernuclei
  $^{12}_{\Lambda}$C, $^{12}_{\Lambda}$B, $^{208}_{\Lambda}$Pb
  ΛN effective two-body interaction, CSB

- "Impurity N.P." - Nuclear Structure Change Induced by Λ
  $^{7}_{\Lambda}$He Λ in neutron-skin
  $^{20}_{\Lambda}$Ne effective ΛN spin-dependent int.

- B(M1) : g-Factor of Λ in Nuclear Matter; $^{12}_{\Lambda}$C
  size of baryon in nuclear matter

- Spectroscopy of ΛΛ Hypernuclei
  $^{4}_{\Lambda\Lambda}$H, $^{13}_{\Lambda\Lambda}$B ΛΛ spin-orbit force

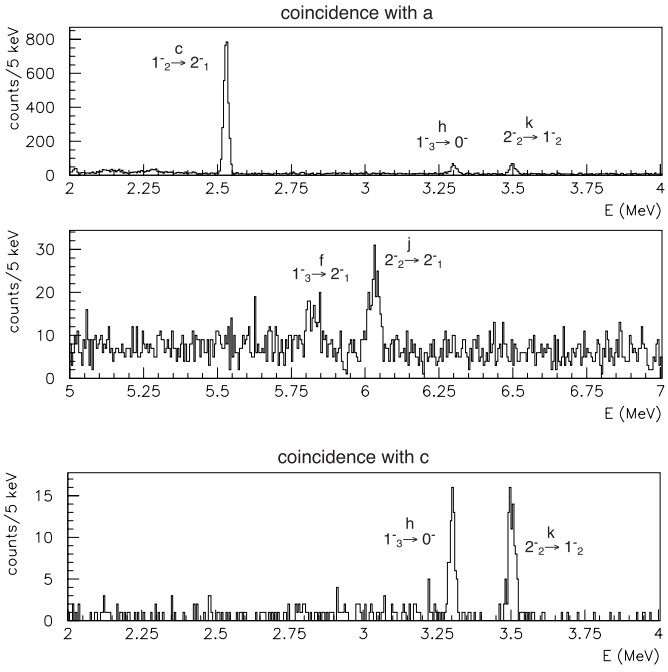
- Ξ^--atom X-ray
  Ξ - nucleus interaction



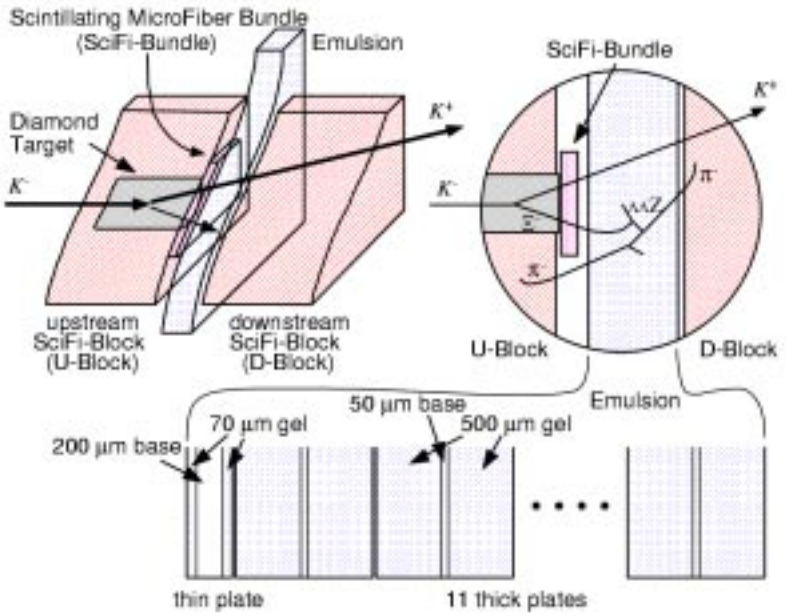
Expected Yield (5 days)

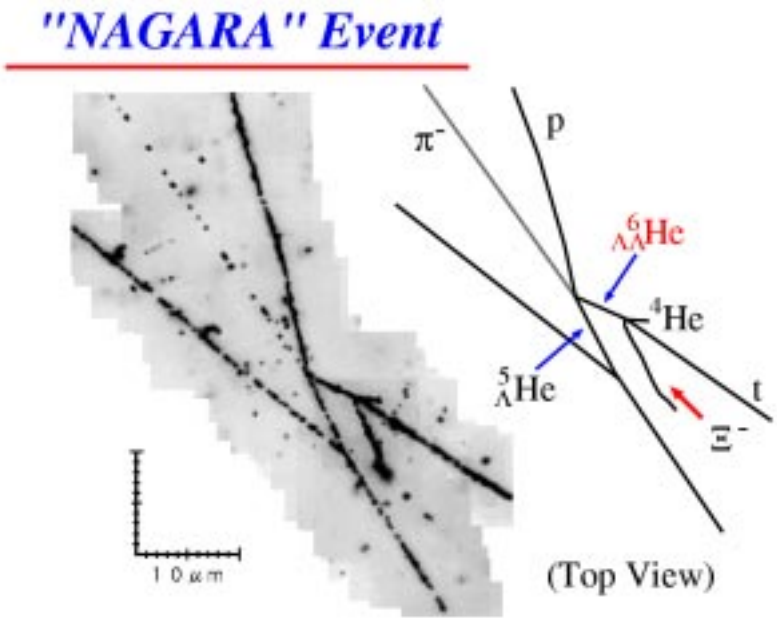
	single			γγ coincidnece with a		with c		with d
a	112000	h	1700	c	1900	a	1900	h 55
b	2600	i	64	f	50	g	39	
c	12000	j	580	g	150	k	50	
d	7500	k	1400	j	94			
e	1100	l	2000	k	170			
f	240	m	230	m	31			
g	1300							

- **^{12}C(K^-, π^-) in 5 days**

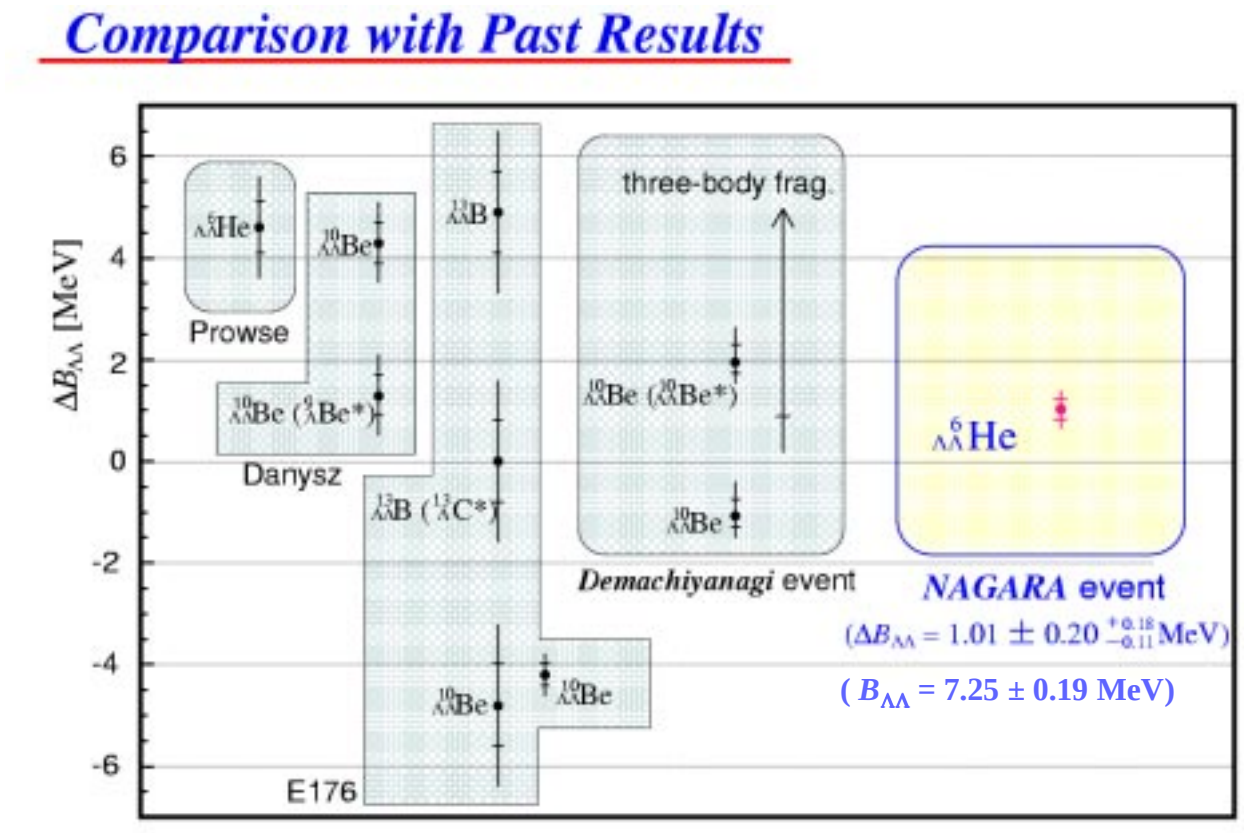


S= -2 @ KEK


Scintillating MicroFiber Bundle
(SciFi-Bundle)
Emulsion
Diamond
Target
K+
K-
upstream
SciFi-Block
(U-Block)
downstream
SciFi-Block
(D-Block)
SciFi-Bundle
K+
K-
π-
ΛΛ?
U-Block
D-Block
Emulsion
50 μm base
70 μm gel
500 μm gel
200 μm base
thin plate
11 thick plates

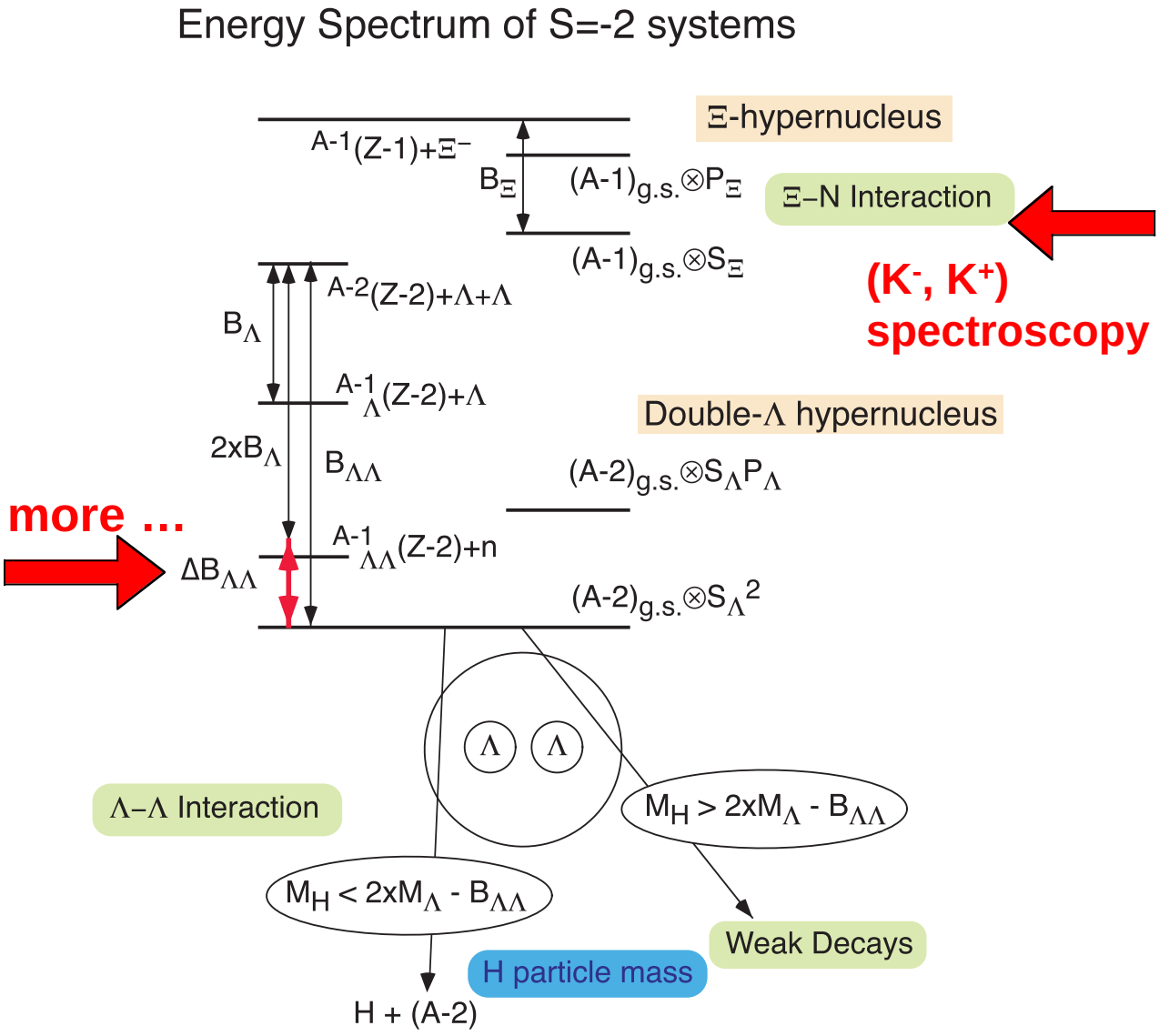

"NAGARA" Event
π-
p
$^{6}_{\Lambda\Lambda}$He
^{4}He
$^{5}_{\Lambda}$He
t
Ξ-
10 μm
(Top View)

S= -2 @ KEK



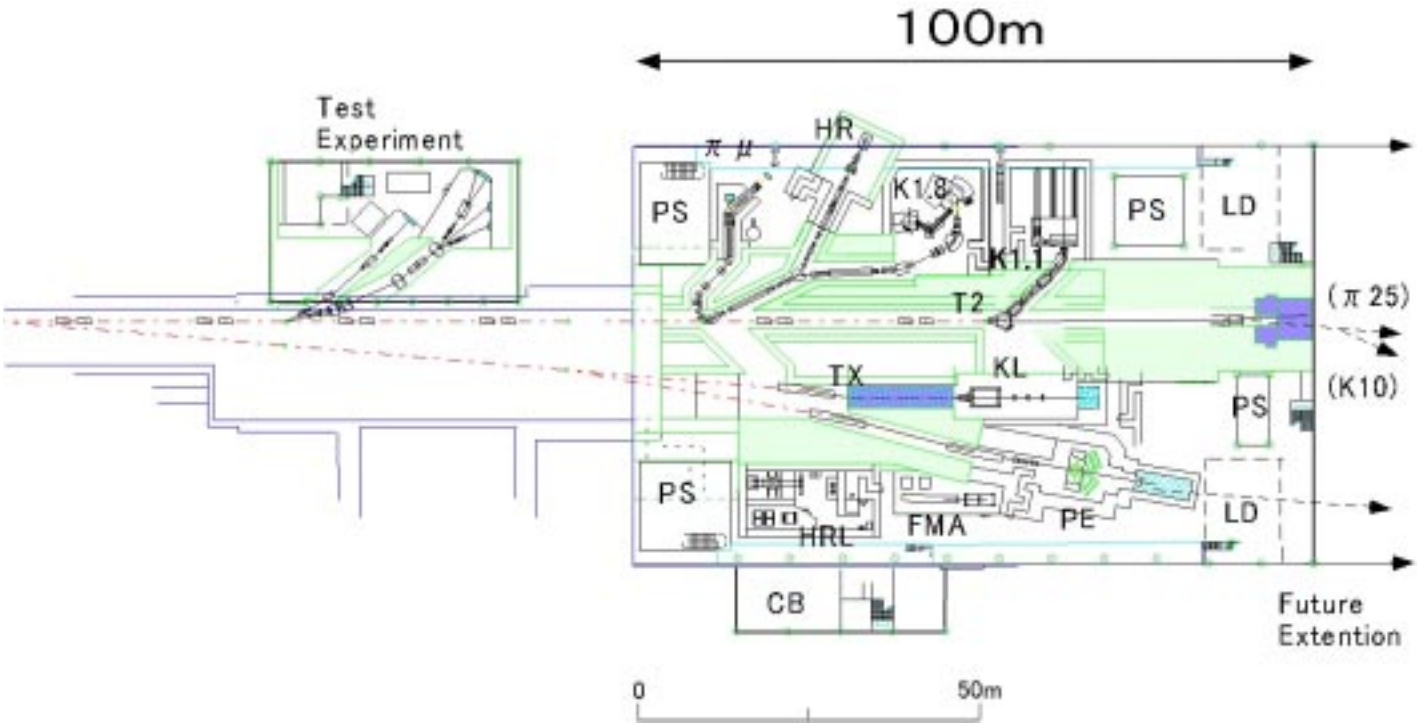
$M_H > 2223.7$ MeV/c^2

S= -2 @ 50 GeV

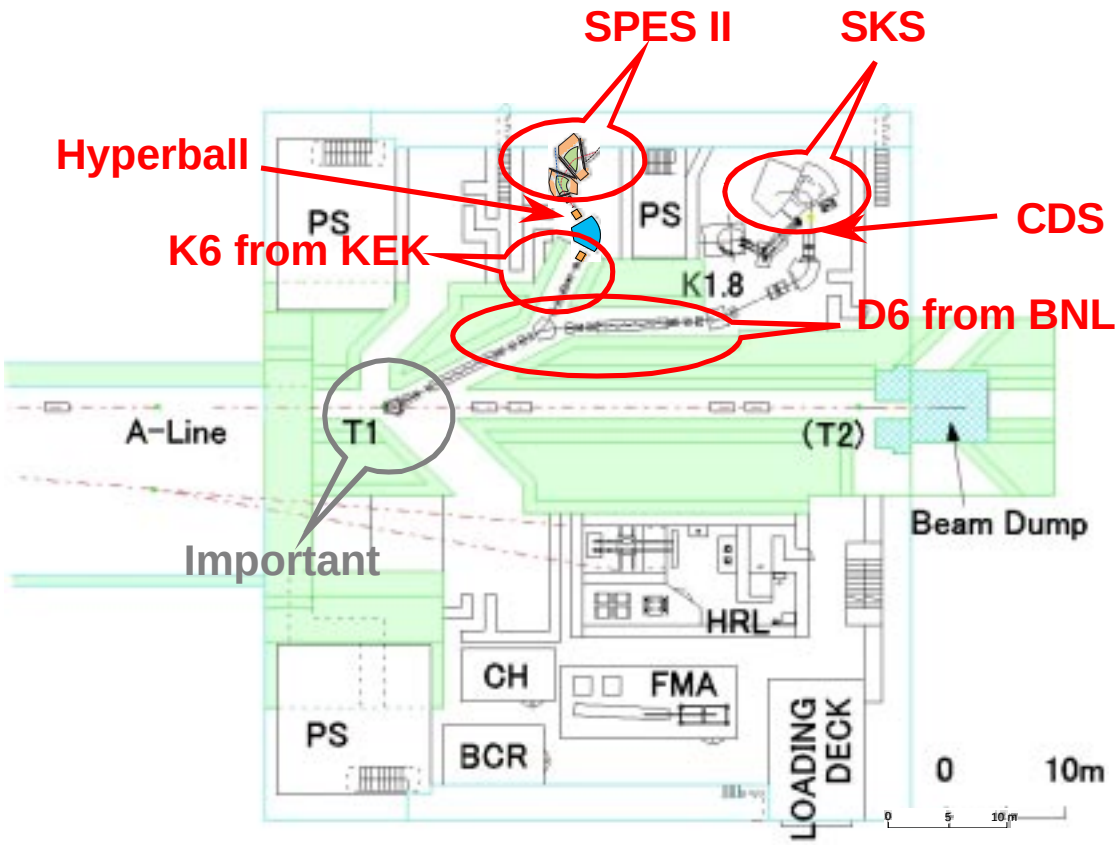

Energy Spectrum of S=-2 systems
Ξ-hypernucleus
A-1(Z-1)+Ξ⁻
BΞ
(A-1)g.s.⊗PΞ
(A-1)g.s.⊗SΞ
Ξ–N Interaction
(K-, K+)
spectroscopy
A-2(Z-2)+Λ+Λ
BΛ
A-1 Λ(Z-2)+Λ
Double-Λ hypernucleus
2xBΛ
BΛΛ
(A-2)g.s.⊗SΛPΛ
more …
A-1 ΛΛ(Z-2)+n
ΔBΛΛ
(A-2)g.s.⊗SΛ2
Λ
Λ
Λ–Λ Interaction
MH > 2xMΛ - BΛΛ
MH < 2xMΛ - BΛΛ
Weak Decays
H particle mass
H + (A-2)

Subjects	Beamline	Specials	Beamtime	estimated counts	output
			(days)		
Spectroscopic Study of S=-2 Systems					
• Spectroscopy of Ξ Hypernuclei		upgraded SKS			
production of Ξ Hypernuclei	K1.8		20	~ 120 events/MeV/(^{208}Pb)	Ξ-N potential
production of ΛΛ Hypernuclei	K1.8		100	~ 60 events/peak	excited states of ΛΛ hypernuclei
• ΛΛ Hypernuclei by Sequential Pionic Decays	K1.8	CDS	not yet	-	g.s. mass of ΛΛ hypernuclei
• Double-Strangeness Nuclei by an Emulsion-Counter	K1.8	Emulsion	36	~ 10000 X stopping	B.E.
Hyperon Proton Scattering		Liq. H2 & CDS			
• Ξp→Ξp, ΛΛ	K1.8		100	2300, 550	direct input to BB strong interaction Models
• Asymmetry	K1.8		not yet	-	direct input to BB strong interaction Models
Hypernuclear γ-ray spectroscopy					
• Spectroscopy of Light and Heavy Hypernuclei		Hyperball			ΛN effective two-body interaction
$^{12}_{\Lambda}$C	K1.1		5	single ~10000, γγ ~100	
$^{12}_{\Lambda}$B	K1.1		30	single ~10000, γγ ~100	(CSB)
$^{208}_{\Lambda}$Pb	K1.8		5	~1000 /transitions	
• "Impurity N.P." - Nuclear Structure Change Induced by Λ					
$^{7}_{\Lambda}$He	K1.1		10	330 E2 γ-rays	Λ in neutron-skin
$^{20}_{\Lambda}$Ne	K1.1		a few	1000-10000 ?	spectroscpoy & effective ΛN spin-dependent int.
• B(M1) : g-Factor of Λ in Nuclear Matter; $^{12}_{\Lambda}$C	K1.1		17	~ 15000	size of baryon in nuclear matter
• Spectroscopy of ΛΛ Hypernuclei					
$^{4}_{\Lambda\Lambda}$H	K1.8		10	~ 3100, γγ ~110	ΛΛ spin-orbit force
$^{13}_{\Lambda\Lambda}$B	K1.8		10	~ 100	ΛΛ spin-orbit force
• Spectroscopy of neutron-rich Hypernuclei	?		not yet		
• Ξ$^-$-atom X-ray	K1.8				Ξ$^-$ nucleus interaction
High Resolution Reaction Spectroscopy of S=-1Hypernuclei		HRBL			
• Fine structure of Λ-single particle potential; $^{90}_{\Lambda}$Zr	K1.8		10	~ 1700 for g.s.	further decomposition of spin-orbit splitting
• Precision spectroscopy of light hypernuclei; $^{12}_{\Lambda}$C	K1.8		10	~ 1000	check of inter-shell mixed configuration
• Spectroscopy of neutron-halo Λ hypernuclei; $^{12}_{\Lambda}$Be	K1.8		10	~ 200	Λ-neutron interaction
• Spectroscopy of Σ hypernuclei; $^{208}_{\Sigma}$Hg	K1.8		10	~ 100	
Kbar-nucleus bound state spectroscopy	K1.1				hadron dynamics in cold dense matter
Hypernuclei production with Heavy Ion					Life time, decay, size

実験室レイアウト


100m
Test
Experiment
HR
π μ
PS
K1.8
K1.1
T2
PS
LD
(π 25)
(K10)
TX
KL
PS
PS
HRL
FMA
PE
LD
CB
Future
Extention
0
50m

第１期レイアウト案



KEK共同開発研究申請

「高強度ハドロン２次ビームライン設計の検討と
ビームモニタリング技術の確立」