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THEIA/Reimei seminar

In-medium modification of baryons studied from hypernuclear beta decay

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plum liquor

Letter of Intent for J-PARC 50 GeV Synchrotron

Modification of baryon structure in nuclear matter studied from beta-decay rate of a Λ hypernucleus

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abstract

Although the EMC effect indicates that structure of baryons in nuclear matter is modified from that in the free space, no clear evidence for baryon modification in matter has been found in low energy nuclear phenomena and detailed mechanism of the modification is not understood yet. In order to challenge this problem, we propose to measure the beta-decay rate of a Λ hyperon in a nucleus. The hyperon beta-decay rate can be significantly reduced in a nucleus, if an u (and d) quark wave functions is more spread due to meson field in a nucleus than an s quark wave function, which reduces overlap between u and s quark wavefunctions in the beta-decay. The quark-meson-coupling (QMC) model predicts reduction of the Λ's beta-decay rate by 20% at maximum.

We will measure the beta-decay rate of ${}^{5}_{\Lambda}$He in 4.5% accuracy. In large nuclei, neutron beta-decay rate is greatly suppressed due to nuclear many-body effects and meson-exchange-current effects. To avoid such "g_A quenching" effects we chose ${}^{5}_{\Lambda}$He hypernucleus.

The experiment will be carried out at the K1.1 beam line by employing the ^{6}Li$(\pi^+, K^+){}^{5}_{\Lambda}He+p$ reaction with the SKS spectrometer. The branching ratio of the beta-decay will be determined in

<u>Contents</u>

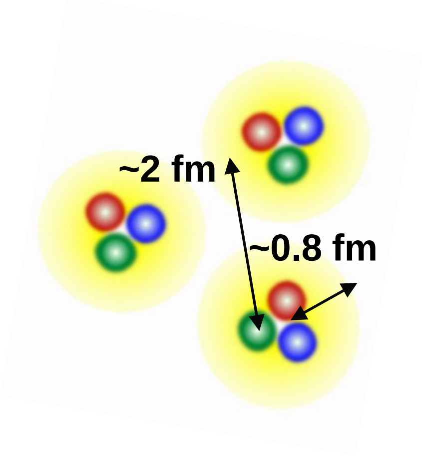
It is a rough and premature experimental proposal.

Please give me your advice and critical comments.

1. Introduction

The hierarchies of quarks, nucleons, and nuclei are really well separated?

- Low energy nuclear phenomena seem to be well described in terms of nucleons (+ nuclear force), where inner structure of nucleons is assumed to be unchanged. (=Without using the word "quarks".)
- Size of a nucleon (r~0.8 fm) and inter-nucleon distance in nuclear matter (r~2 fm) are of the same order. Also the same as the pion range (~1.4 fm), thus in a nucleus the space is full of meson field.



=> How rigid is the identity of nucleons in nuclei?

=> Investigate modification of nucleons in nuclear matter.

=> Phenomenological parts of nuclear force (the short range part) effectively include effects of the lower (quark) hierarchy.

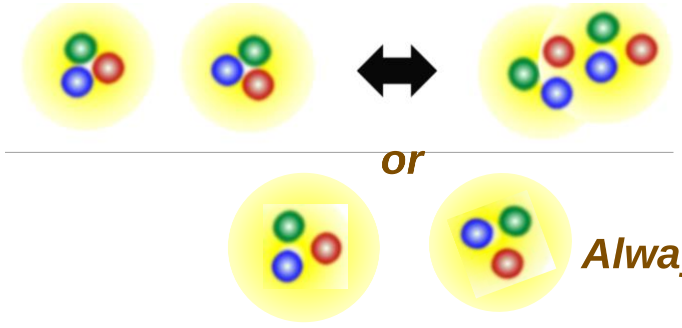
=> Understand nuclear force (BB forces) from quark level.

“Modifications” of baryons in nuclear matter

■ **EMC effect (Change of structure function in DIS)**

-- Experimentally established but not well understood.

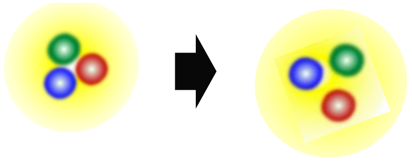
Short Range Correlation data at JLab give suggestions.



short range correlation

Always modified in nuclei?

■ **Nucleon swelling?**



-- Various experimental and theoretical suggestions/conjectures but no clear evidence

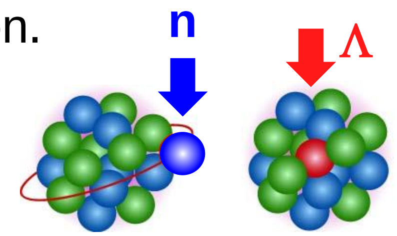
TABLE I. The magnitudes of nucleon swelling inferred from experiments and predicted from various models.

Experiment/model	Size of nucleon swelling
Quasielastic scattering [49]	<3–6% for ^{3}He
K^{+}-nucleus scattering [50]	10–30% for ^{12}C and ^{40}Ca
nIMParton [20]	2.0–8.1% for ^{3}He-^{208}Pb
QMC [48]	5.5% for typical nuclei
Binding potential [54]	A few % for typical nuclei
Skyrmion model [55]	3–4%
Quark-*N* interaction [56]	≈2% for nuclear matter
Chiral quark-soliton [57]	≈2.4% for heavy nuclei
Chiral symmetry [58]	<10% for nuclear matter
N-*N* overlapping [37]	4.7–22% for ^{3}He-^{208}Pb
Weak stretching [59]	4.5–9.4% for ^{4}He-^{208}Pb
PLC suppression [60]	1–3%
Statistical model [61]	2.2–5.0% for ^{4}He-^{197}Au
Quark-quark correlation [62]	15%
Chiral quark-meson [63]	≈19% for nuclear matter
String model [64]	40%

PRC 99 (2019) 035205

-- What are the good probes sensitive to “baryon modification” in low energy phenomena ? Modification of N in a nucleus often comes from valence nucleons located at a low density region.

Hyperons are free from Pauli blocking from nucleons
-> They can stay in the 0s orbit => a suitable probe



-- How to discriminate between “baryon modification” and hadronic effects (meson exchange current, baryon mixing...) as well as nuclear many-body effects?

Need to study with various baryons (N, Λ, Σ, ..) in various environment

What probe should be used?

- Compare electro/weak properties of hyperons in free space and in nuclear matter
  - Magnetic moment of Λ => *On-going* Λ's spin-flip B(M1) (J-PARC E63)
  - Electromagnetic decay of $\Sigma^0 \rightarrow \Lambda\gamma$ => *Later*
  - Weak decays of Λ

- Avoid strongly interacting probes – Medium effects are hidden by FSI.
  - 😢 Mesonic weak decay ($\Lambda \rightarrow N\pi$)
  - 😢 Nonmesonic weak decay ($\Lambda N \rightarrow NN$)
  - 😊 Beta decay ($\Lambda \rightarrow p\, e^- \nu^{bar}$) ***=> Today's talk***

2. Beta-decay of Λ in nuclear matter

Weak decay of Λ

Λ DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$p\pi^-$		(63.9 ± 0.5) %		101
$n\pi^0$		(35.8 ± 0.5) %		104
$n\gamma$		$(1.75 \pm 0.15) \times 10^{-3}$		162
$p\pi^-\gamma$	[c]	$(8.4 \pm 1.4) \times 10^{-4}$		101
$pe^-\overline{\nu}_e$		$(8.32 \pm 0.14) \times 10^{-4}$		163
$p\mu^-\overline{\nu}_\mu$		$(1.57 \pm 0.35) \times 10^{-4}$		131

$s \to u\, e^-\, \nu^{bar}$ $g_A/g_V =$ -1 / 1 in the quark level

$\Lambda \to pe^-\overline{\nu}_e$ $g_A/g_V = -0.718 \pm 0.015$ [b] due to hadron structure

(… measured from $p\ e^-$ angular correlation)

Beta decay and axial vector coupling

- g_V (n->p) ≒ 1 [CVC], g_V (Λ->p) ≈ 1 [Ademollo-Gatto theorem (PRL 13 (1964) 264)]
- g_A/g_V (n->p) = −1.2732±0.0023 [= F+D for $SU(3)_f$]
- g_A/g_V (Λ->p) = −0.718 ± 0.015 [= F+D/3 for $SU(3)_f$]
- g_A^*(n->p) quenching in nuclear beta decay (GT quenching) has been a long standing problem.

  ---- Not clearly understood

  (1) Nuclear many-body effect

  (2) Hadronic effect (meson exchange current, Δ excitation, ..)

  (3) Quark effect (baryon structure change) ?

  => How well can we estimate (1) and (2)?

  How can we separate (3) from (1) and (2)?

But (1) and (2) should be small for light nuclei, say, ${}^5_\Lambda$He

- g_A^* is important for double beta decay -> Majorana neutrino mass

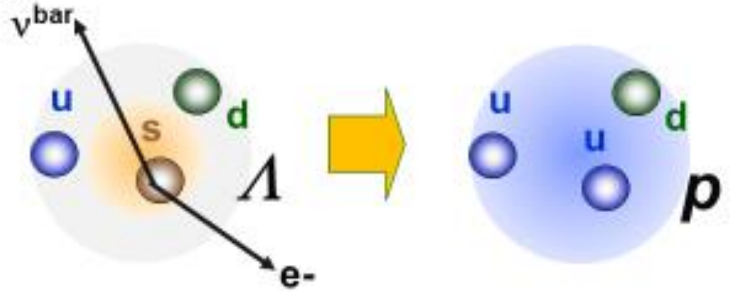
  and also for astrophysics

Modification of g_A^{Λ} due to baryon “swelling” in medium

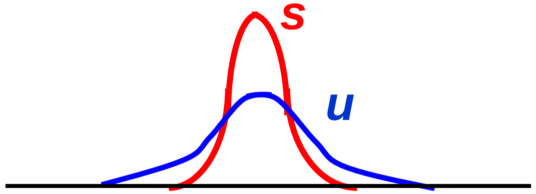
$\Lambda \to p\, e^- \nu^{bar}$ **Sensitive to overlap of u and s quark w.f.**

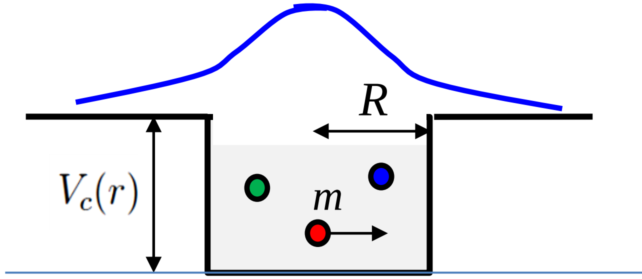
Bag model picture

In free space



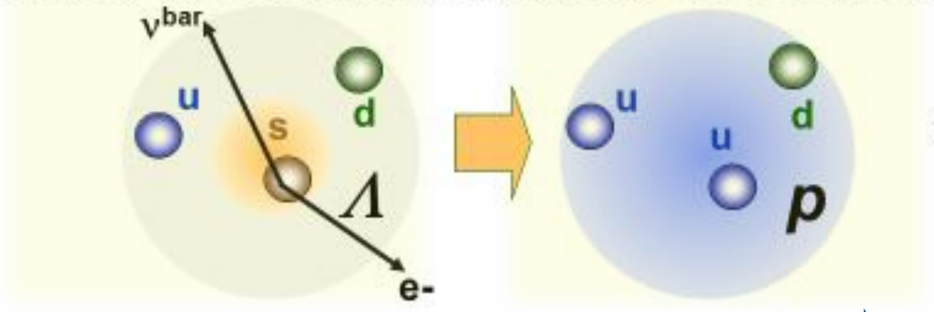
g_A^{Λ}



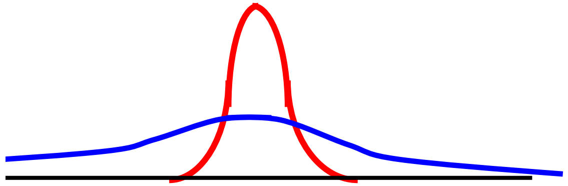


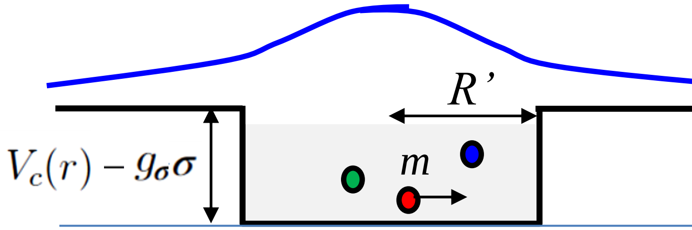
In nuclear medium if u,d quarks are more spread, but s quark is not spread, then

$$[i\gamma \cdot \partial - m_q - V_c(r)]\psi_q(r) = 0$$



$g_A^{\Lambda *}$





Less overlap between s and u quarks ⇒ *Reduction of beta decay rate in medium*

$$[i\gamma \cdot \partial - \underbrace{(m_q - g_\sigma \sigma)}_{m^*} - V_c(r)\,]\psi_q(r) = 0$$

Prediction by Quark Meson Coupling Model

Lambda beta-decay in-medium

P.A.M. Guichon, A.W. Thomas / Physics Letters B 773 (2017) 332–335

QMC model: u,d quarks couple to σ, ρ, ω fields in a nucleus but s quark does not.

- $m^* = m - g_{q\sigma}\sigma$ and w,f. of u,d quarks in a baryon change due to scalar field σ.
- m^* and w.f. of s quark do not change.

- For $n\text{->}p$, $g_V - 1 \propto (m^*_d - m^*_u)^2$
- For $\Lambda\text{->}p$, $g_V - 1 \propto (m^*_s - m^*_u)^2$
  $= (m_s - m_u + g_{q\sigma}\sigma)^2$

$g_{q\sigma}$ determined from saturation density via various many-body theoretical treatments

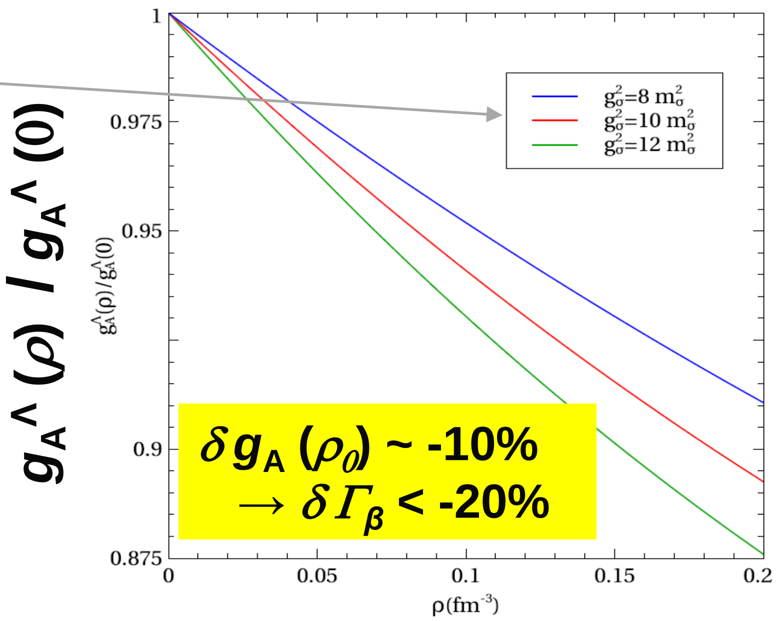


Fig. 1. Relative variation of the axial coupling as a function of density.

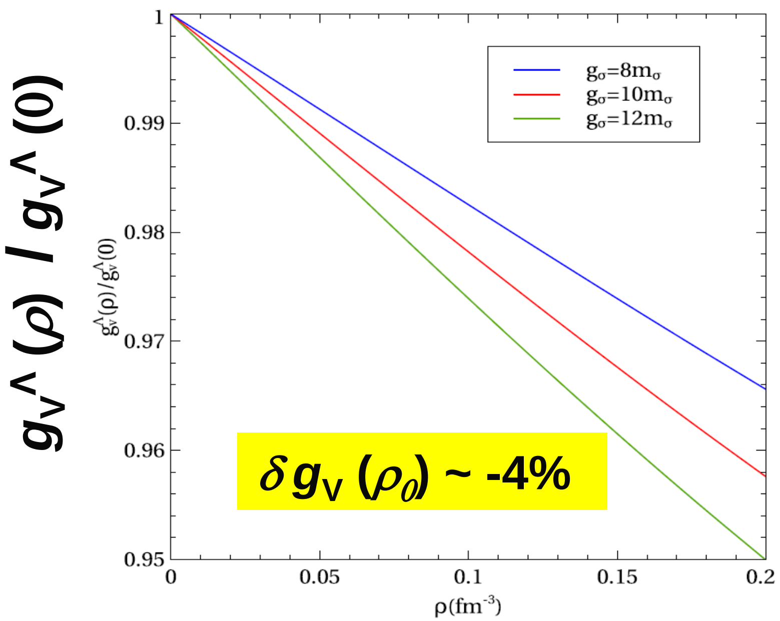
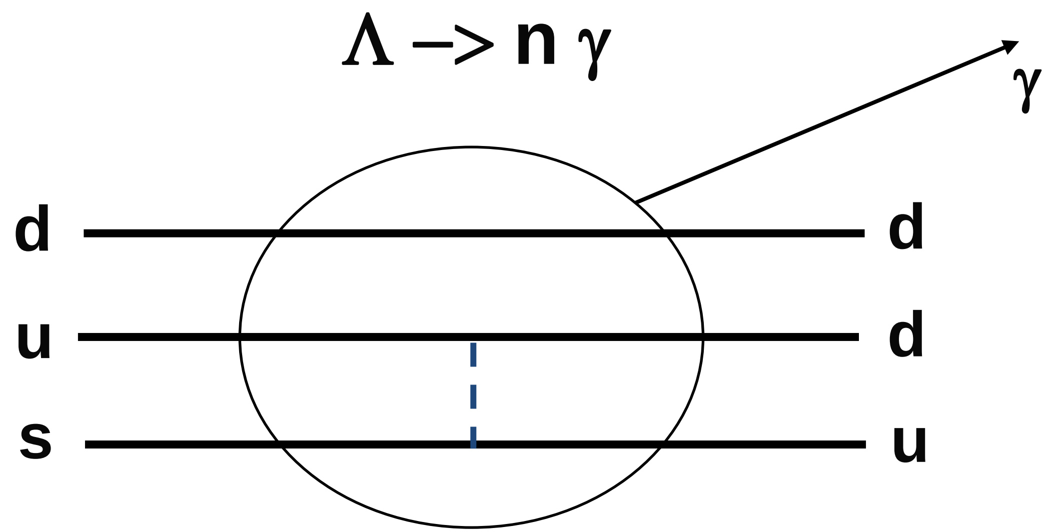


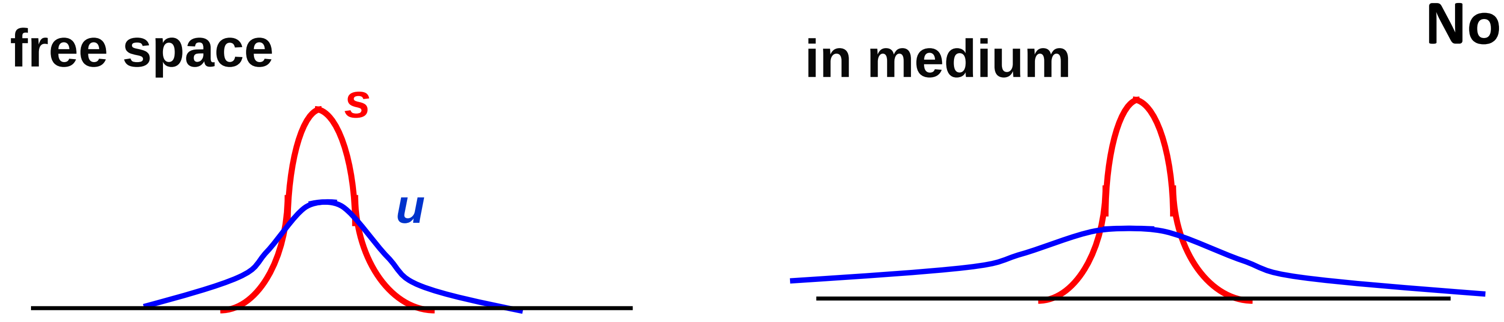
Fig. 2. Relative variation of the vector coupling as a function of density for m_s = 300 MeV.

Another interesting channel: $\Lambda \to n\, \gamma$



Sensitive to overlap of u and s quark w.f.

No calculation?



3. g_A quenching effects

Gamov-Teller matrix elements for beta decays of light nuclei

W.T. Chou et al., PRC 47 (1993) 163

Reaction	$2J^{\pi}_{k},2T$ (i)	(f)	$\log f_A t$	$M(GT)$ (exp)	$M(GT)$ th(free)	$M(GT)_{exp}$ / $M(GT)_{th(free)}$
$^{1}n(\beta^-)^{1}H$	$1^+,1$	$1^+_1,1$	3.024(1)	3.100(7)	3.096	1.00
$^{3}H(\beta^-)^{3}He$	$1^+,1$	$1^+_1,1$	3.058(1)	2.929(5)	3.096	0.946
$^{6}He(\beta^-)^{6}Li$	$0^+,2$	$2^+_1,0$	2.910(1)	2.748(4)	3.031	0.907
$^{7}Be(EC)^{7}Li$	$3^-,1$	$3^-_1,1$	3.300(1)	2.882(4)	3.187	0.904
$^{11}C(\beta^+)^{11}B$	$3^-,1$	$3^-_1,1$	3.598(2)	1.480(9)	2.084	0.710
$^{13}N(\beta^+)^{13}C$	$1^-,1$	$1^-_1,1$	3.671(2)	0.788(8)	0.891	0.884
$^{15}C(\beta^-)^{15}N$	$1^+,3$	$1^+_1,1$	4.114(6)	0.972(6)	1.206	0.806

Experimentally, $g_A^* = -1.27 \rightarrow \sim -1$ for larger A

$g_A^{*}{}_{exp} / g_A$

g_A quenching has been theoretically studied in terms of MEC, chiral condensate, ... by many theorists.

$g_A^{\Lambda *} = -0.718 \rightarrow ?\ -1$?? for larger A

Change of g_A^* is ~5% for s-shell

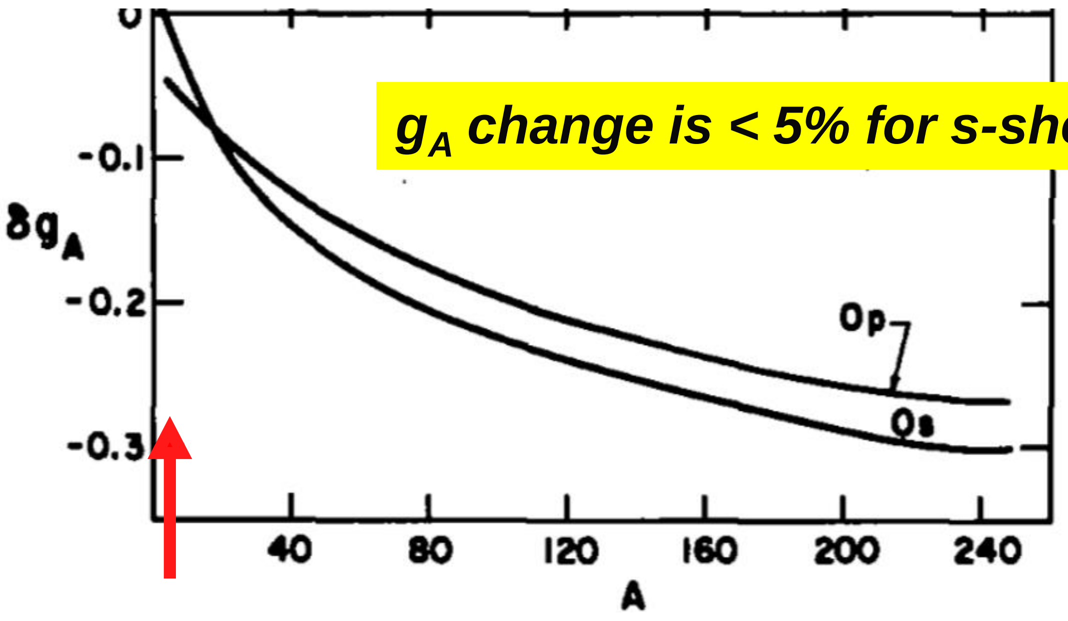
Estimated change of g_A by meson exchange current

Nuclear Physics A305 (1978) 349–356

QUENCHING OF AXIAL-VECTOR COUPLING CONSTANT IN THE β-DECAY OF FINITE NUCLEI

F. C. KHANNA, I. S. TOWNER and H. C. LEE

Atomic Energy of Canada Limited, Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada K0J 1J0



g_A change is < 5% for s-shell

Variation of δg_A and Γ_P with the single-particle orbit and with A [a])

	$A = 4$		$A = 16$		$A = 40$		$A = 80$		$A = 140$		$A = 224$	
	δg_A	Γ_P	δg_A	Γ_P	δg_A	Γ_P	δg_A	Γ_P	δg_A	Γ_P	δg_A	Γ_P
0s	0.007		−0.068		−0.143		−0.206		−0.256		−0.294	
	0.046		−0.001		−0.054		−0.100		−0.136		−0.165	
0p	−0.044	0.181	−0.071	0.116	−0.124	0.074	−0.176	0.049	−0.222	0.034	−0.260	0.025
	−0.023	0.114	−0.023	0.068	−0.053	0.039	−0.088	0.023	−0.119	0.013	−0.146	0.008
0d			−0.080	0.139	−0.112	0.096	−0.154	0.066	−0.194	0.047	−0.229	0.035
			−0.047	0.085	−0.058	0.054	−0.081	0.033	−0.106	0.020	−0.130	0.012
1s			−0.101		−0.129		−0.165		−0.202		−0.235	
			−0.066		−0.072		−0.091		−0.113		−0.135	
0f					−0.106	0.110	−0.137	0.080	−0.171	0.058	−0.203	0.043
					−0.065	0.065	−0.079	0.042	−0.097	0.026	−0.117	0.016
1p					−0.131	0.105	−0.156	0.080	−0.185	0.060	−0.213	0.045
					−0.087	0.057	−0.095	0.040	−0.109	0.026	−0.125	0.017
0g							−0.123	0.090	−0.151	0.068	−0.180	0.052
							−0.077	0.050	−0.091	0.033	−0.107	0.021
1d							−0.150	0.088	−0.172	0.069	−0.195	0.054
							−0.100	0.045	−0.108	0.032	−0.119	0.021
2s							−0.161		−0.180		−0.202	
							−0.109		−0.115		−0.125	
0h									−0.134	0.075	−0.160	0.058
									−0.086	0.039	−0.098	0.026
1f									−0.161	0.079	−0.180	0.060
									−0.107	0.036	−0.116	0.025

First line: PCAC; second line: phenomenological Lagrangian.

To avoid nuclear effects and MEC effects, s-shell hypernucleus, $^{5}_{\Lambda}$He, is desirable.

Many theoretical works later...

4. Proposed experiment

How to measure $g_A{}^\Lambda$ in a nucleus?

(1) Branching ratio BR(β) and lifetime τ of a hypernucleus

$\Gamma_\beta = BR(\beta)/\tau \propto (g_V{}^\Lambda)^2 \,|\int 1|^2 + (g_A{}^\Lambda)^2 \,|\int \sigma|^2$

Free Λ, ${}^5_\Lambda$He, ${}^{13}_\Lambda$C : $= (g_V{}^\Lambda)^2 + 3\,(g_A{}^\Lambda)^2 \sim 1 + 1.5$

<- $g_V{}^\Lambda = 1$, $g_A{}^\Lambda / g_V{}^\Lambda = -0.718 \pm 0.015$

${}^5_\Lambda$He case: statistical accuracy of

ΔBR(β) ~4% and $\Delta\tau$ ~ 2% => $\Delta\Gamma_\beta$ ~ 4.5% => $\Delta g_A{}^\Lambda$ (${}^5_\Lambda$He) ~3.7% is possible.

=> Today's talk

(2) beta-ray asymmetry (angular distribution) *A* -> $g_A{}^\Lambda / g_V{}^\Lambda$

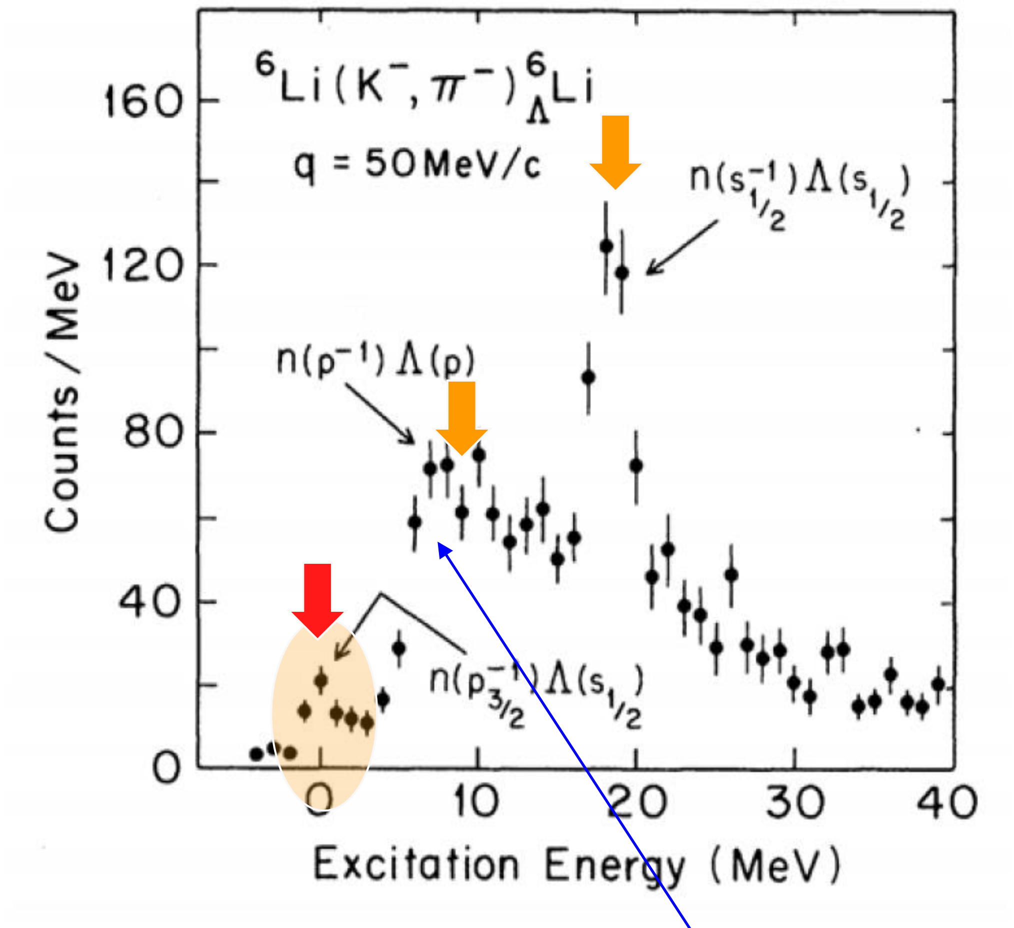
n(π^+,K^+)Λ @1.1 GeV/c *Pol.* ~ 1.0 But polarization should be known precisely.

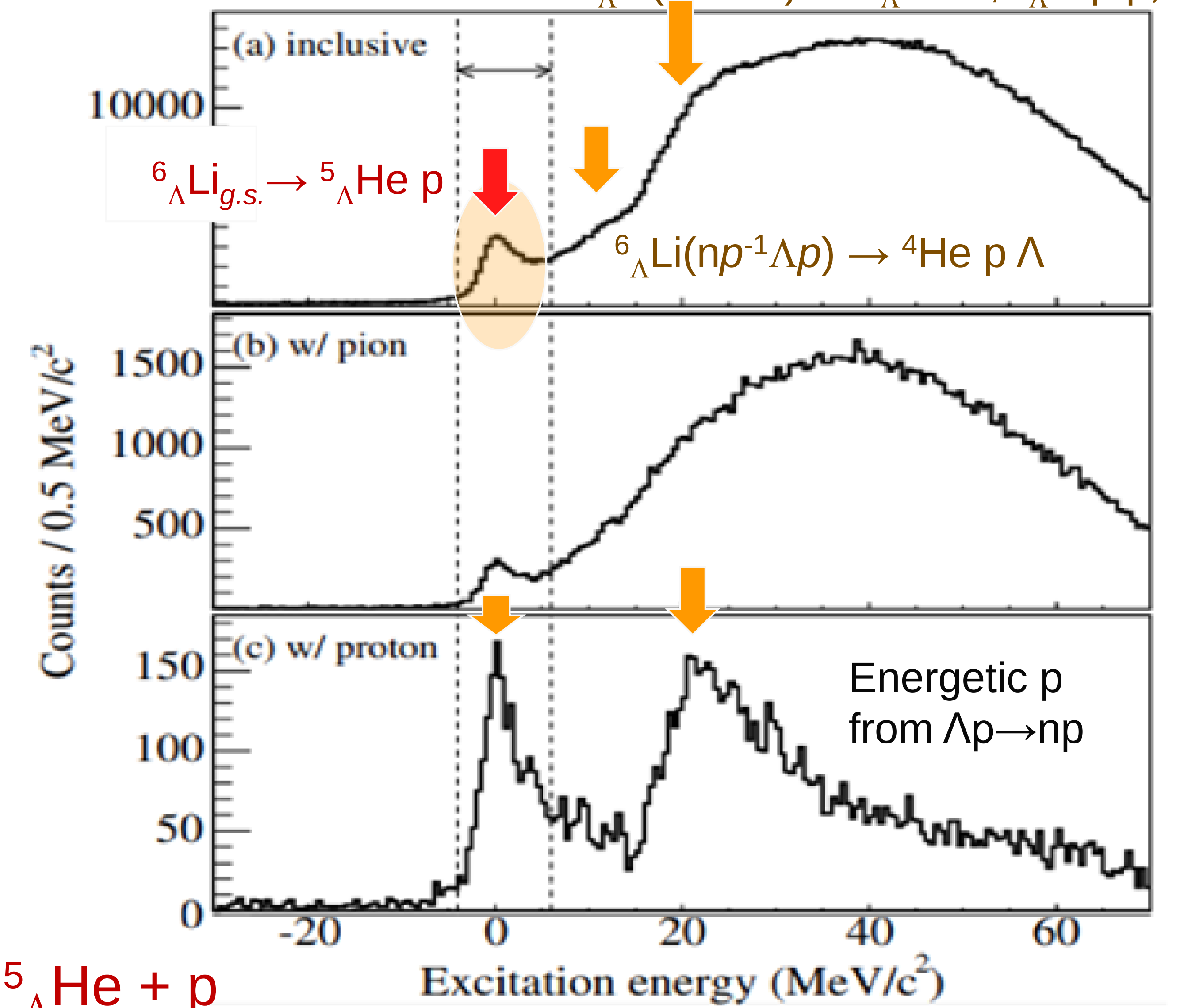
${}^5_\Lambda$He case: ^{6}Li(π^+,K^+) ${}^6_\Lambda$Li, ${}^6_\Lambda$Li -> ${}^5_\Lambda$He+p ; ${}^5_\Lambda$He polarization unknown.

${}^{13}_\Lambda$C case: ^{13}C(π^+,K^+) ${}^{13}_\Lambda$C ; Polarization (^{12}C core pol. effect) can be estimated ?

=> Seems difficult

(K⁻,π⁻) or (π⁺,K⁺) ?





$^{6}_{\Lambda}Li_{g.s.} \rightarrow {}^{5}_{\Lambda}He + p$

With a thick (~20 g/cm²) target, the $n(p^{-1})\Lambda(p)$ substitutional states will be contaminated in the (K⁻, π⁻) case.

${}^{5}_{\Lambda}$He weak decay : one of the best known

Table 1: Total and partial weak decay rates of ${}^{5}_{\Lambda}$He hypernucleus shown in the unit of the free Λ decay rate, Γ_Λ.

	Experiment/Theory	$\Gamma_{tot}/\Gamma_\Lambda$	$\Gamma_{\pi^-}/\Gamma_\Lambda$	$\Gamma_{\pi^0}/\Gamma_\Lambda$	$\Gamma_{nm}/\Gamma_\Lambda$
	Exp. (K^-,π^-), BNL [7]	1.03±0.08	0.44±0.11	0.18±0.20	0.41±0.14
KEK E462	Exp. (π^+,K^+), KEK [8, 9]	0.947±0.038	0.340±0.016	0.201±0.011	0.406±0.020
	Theor. [10] (YNG)		0.393	0.215	
	Theor. [11]		0.386	0.196	
	Theor. [12]	0.966			0.358
	Theor. [13] (NSC97f)			0.317	
	Theor. [14]			0.43	

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[9] S. Okada et al., Phys. Lett. B 597 (2004) 249; S. Okada et al., Nucl. Phys. A754 (2005) 178c.

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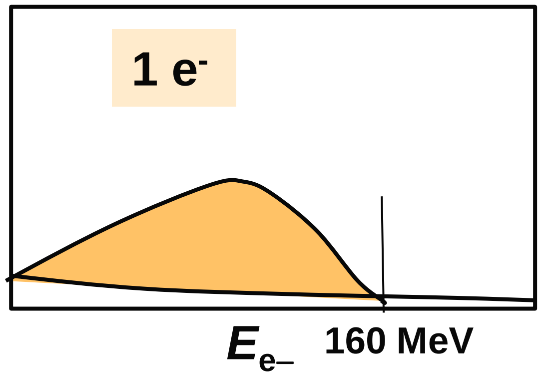
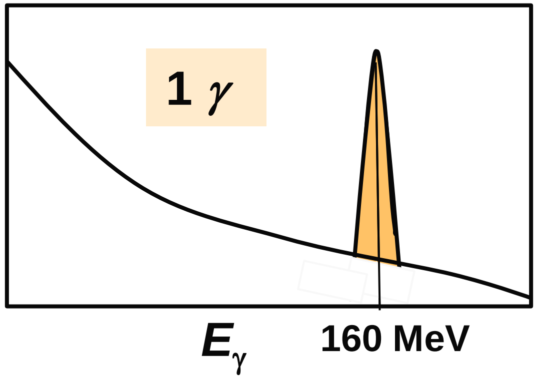
Signal and backgrounds

- Signal: $^{5}_{\Lambda}He \rightarrow {}^{4}He\ p\ e^{-}\ \nu^{bar}$ E_e = 0–160 MeV, BR(β) = **8x10^{-4}**

10^3 times larger

- Backgrounds: BR(π^-) = **0.40,** p_π = 50--150 MeV/c
  - Mesonic decay Λ -> p π^- , π^- pn -> n n
  - Mesonic decay Λ -> n π^0 , π^0 -> $\gamma\ \gamma$ BR(π^0) = **0.20**
  - Nonmesonic decays Λn -> n n, Λp -> n p BR(nm) = **0.40**





Select one charged particle with plastic counter -> photon conversion in target/plastic ~4%
e /π, *p* separation with n=1.5 lucite Cerenkov -> π, *p* misID of ~4%
One cluster in a 4π calorimeter -> one of γ's from π^0 escapes from calorimeter holes ~3%

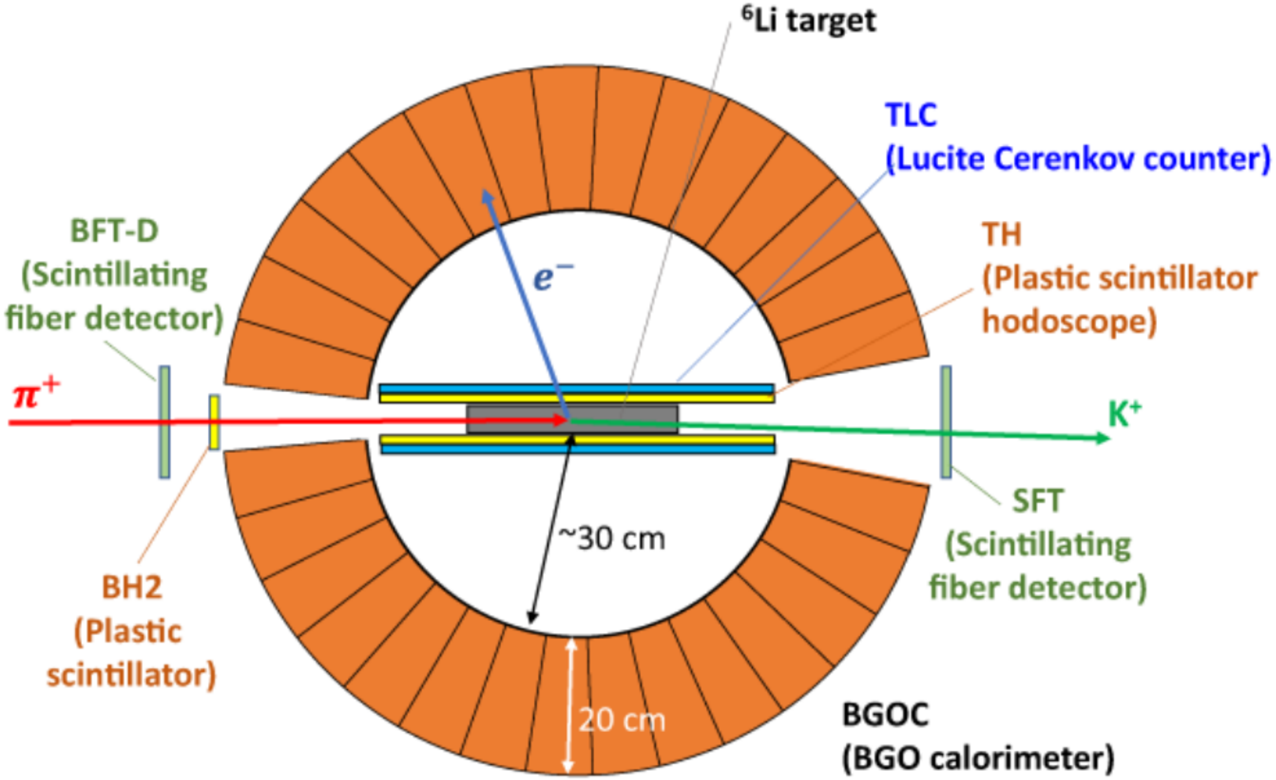
BG from π^0 /signal = 0.2x0.02x0.04 / 0.0008 = 0.2
BG from π^- /signal = 0.4x0.045 / 0.0008 = 22.5

Can we suppress these backgrounds by ~ 10^{-4} --10^{-5} ?

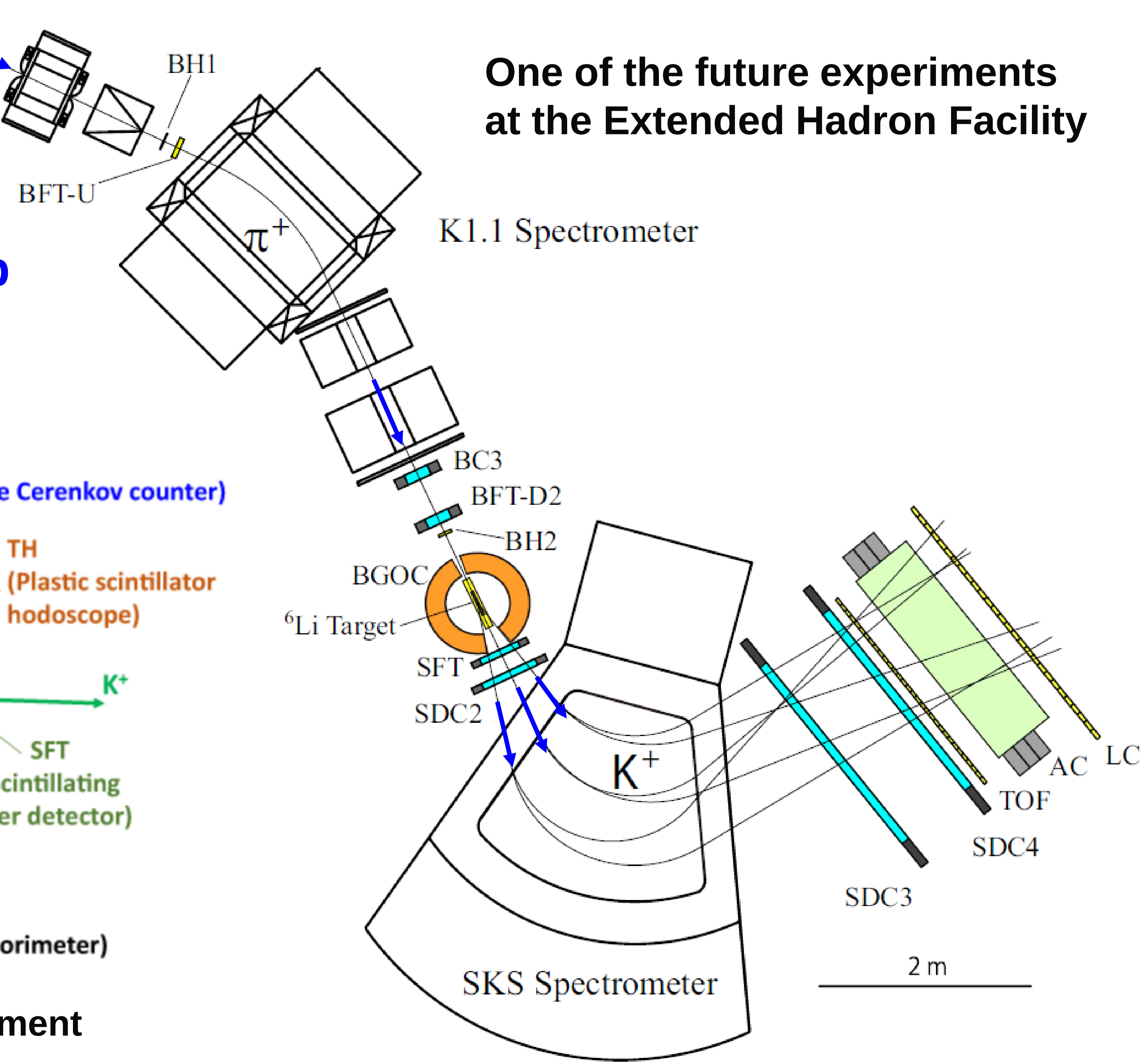
Setup at K1.1 beam line

One of the future experiments at the Extended Hadron Facility

$^{6}Li(\pi^+,K^+)\,^{6}_{\Lambda}Li$, $^{6}_{\Lambda}Li \rightarrow {}^{5}_{\Lambda}He + p$



Setup around the target for BR measurement



Yield and statistical error for BR

Table 2: Expected yield of the ${}^{5}_{\Lambda}$He hypernuclei and its beta decay events estimated in comparison with the ${}^{5}_{\Lambda}$He ylied measured in KEK E462 experiment.

Experiment	E462	Proposed experiment (${}^{5}_{\Lambda}$He)	${}^{13}_{\Lambda}$C
Number of π^+ beam	2.5×10^{12}	43×10^{12}	
^{6}Li target thickness	3.70 g/cm^2 (80 mm)	14 g/cm^2 (300 mm)	^{13}C target 20g/cm^2
${}^{5}_{\Lambda}$He counts after SKS analysis	45653	2.0×10^{6}	${}^{13}_{\Lambda}$C counts $1.3\text{x}10^{6}$
BR_β		8×10^{-4}	
Pauli suppression effect		0.6	0.3
e^- detection efficiency		0.7	
Beta-ray counts N_e		673	222
		$\sqrt{N_e}/N_e$ = 3.9%	6.7%

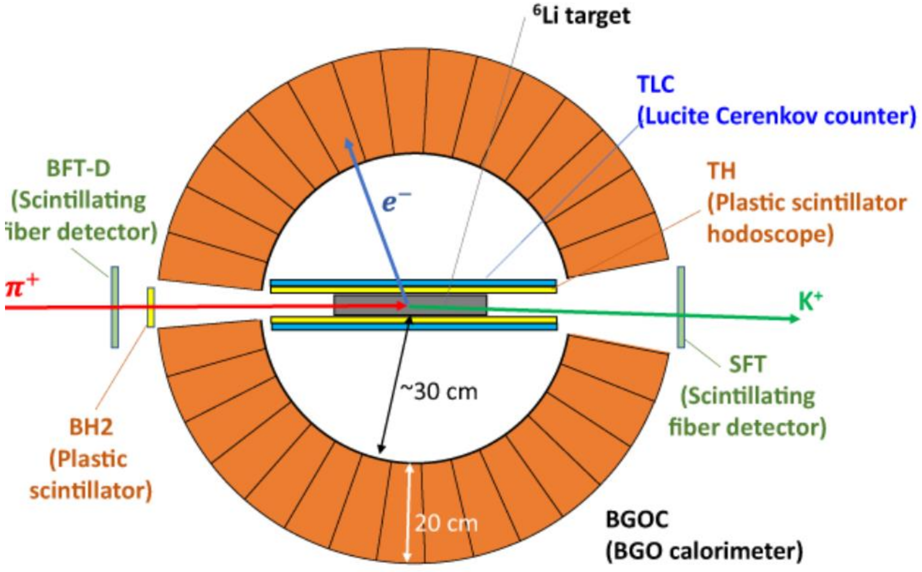
….Assuming the same as mesonic decay, $\Lambda \rightarrow N\pi$

= mesonic decay branching ratio → 0.6

1400 hours (2 months) for <u>$3\text{x}10^7$ π^+/spill</u>

…challenging

5. BR measurement



GEANT4 simulation

by K. Kamada and M. Fujita

Tentative parameters (to be optimized later)

- Target: 90%-^{6}Li, 4cmϕ x30cm (14 g/cm^2)
- Calorimeter: BGO
  Acceptance: 4π – beam holes (30+90msr)
  → inefficiency of 0.96%
  Thickness: 20cm (18L_R)
  Segmentation: 15(θ) x15(φ) = 225
  (7cmx7cmx20cm for each crystal)
- Plastic (TH) : 0.5cm x 50cm
- Lucite Cerenkov (TLC): 0.5cm x 50cm

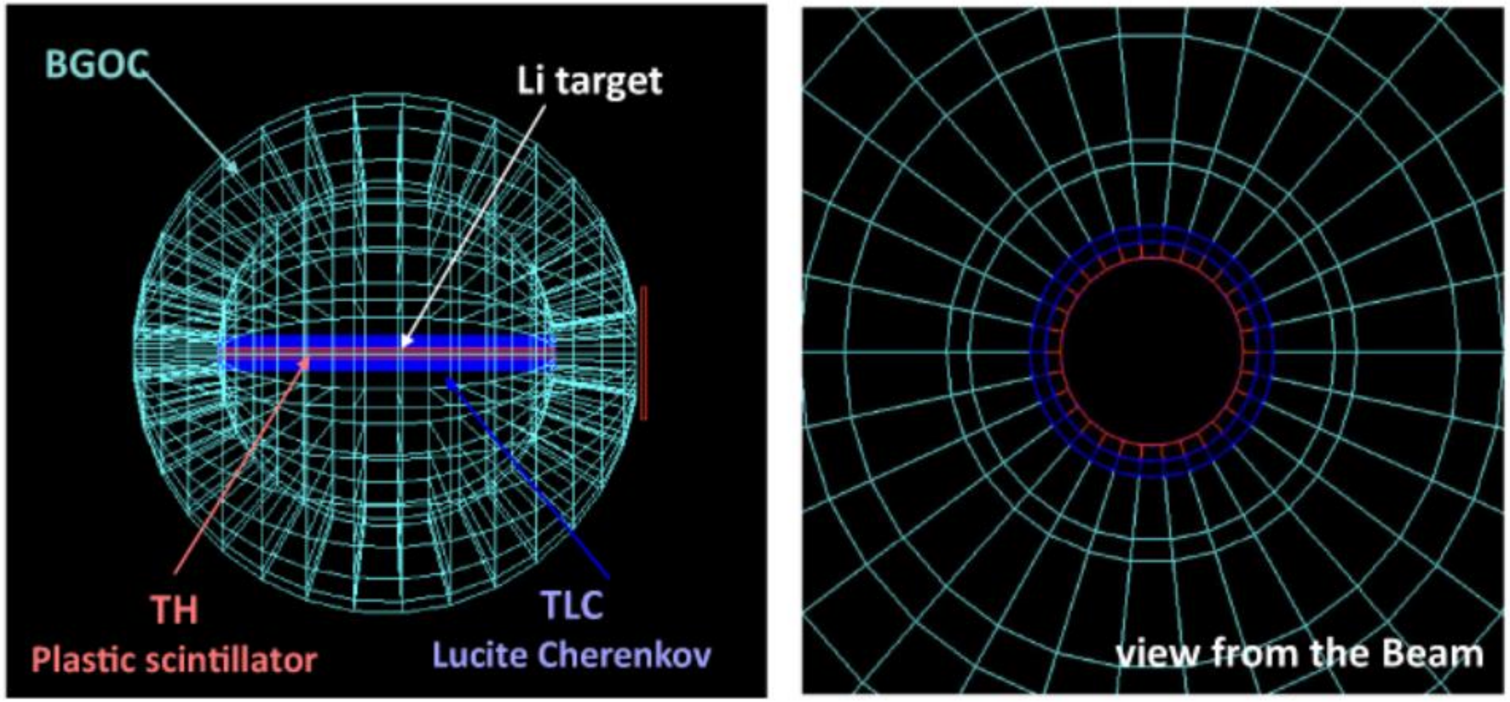
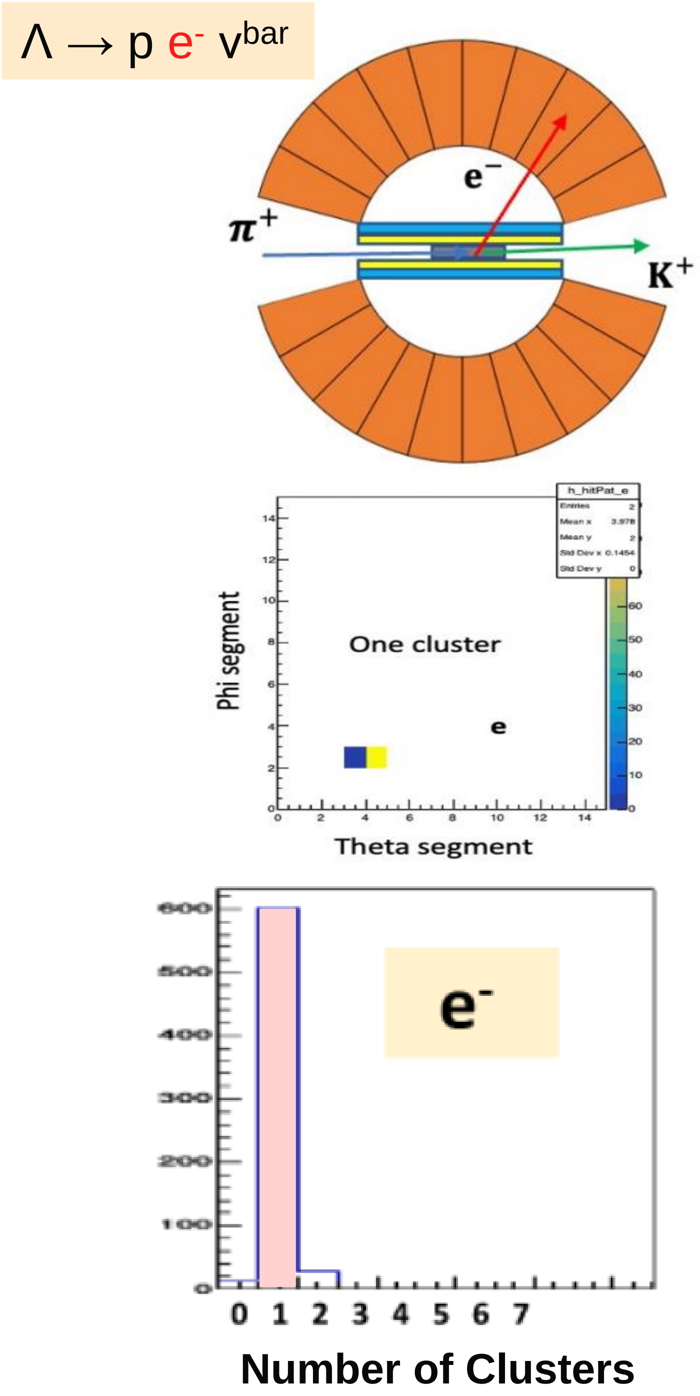
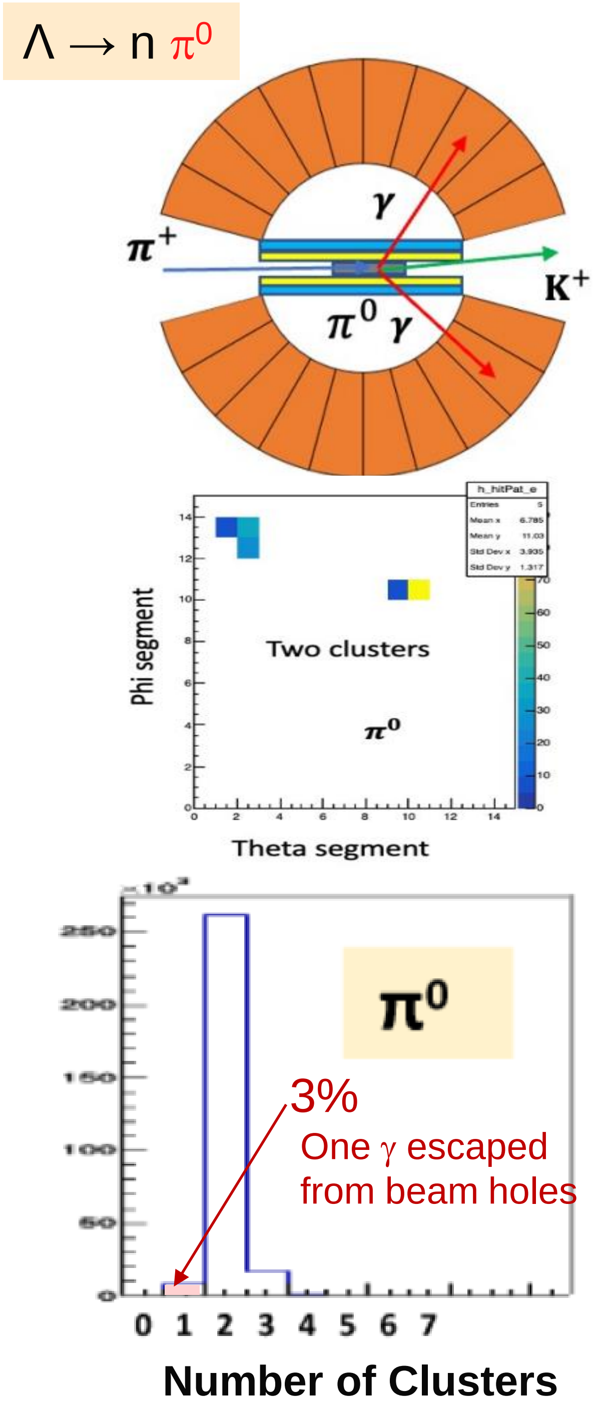
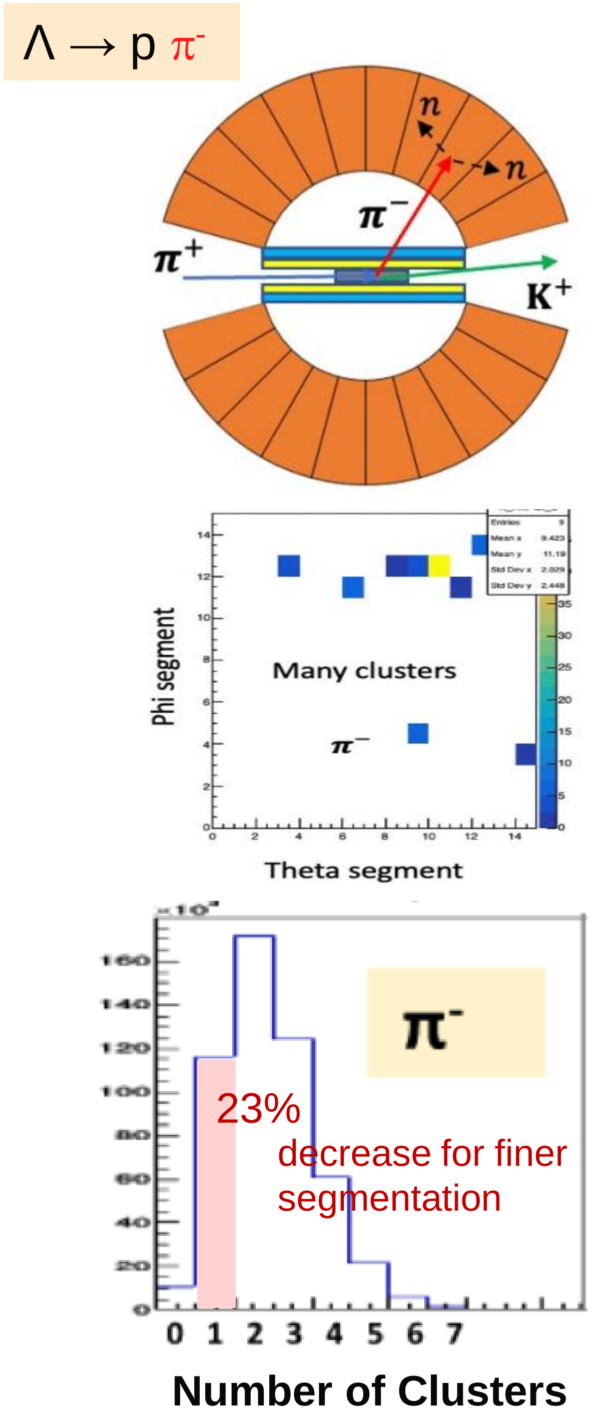


Figure 8: GEANT4 geometory of the setup around the target used in the present simulatic

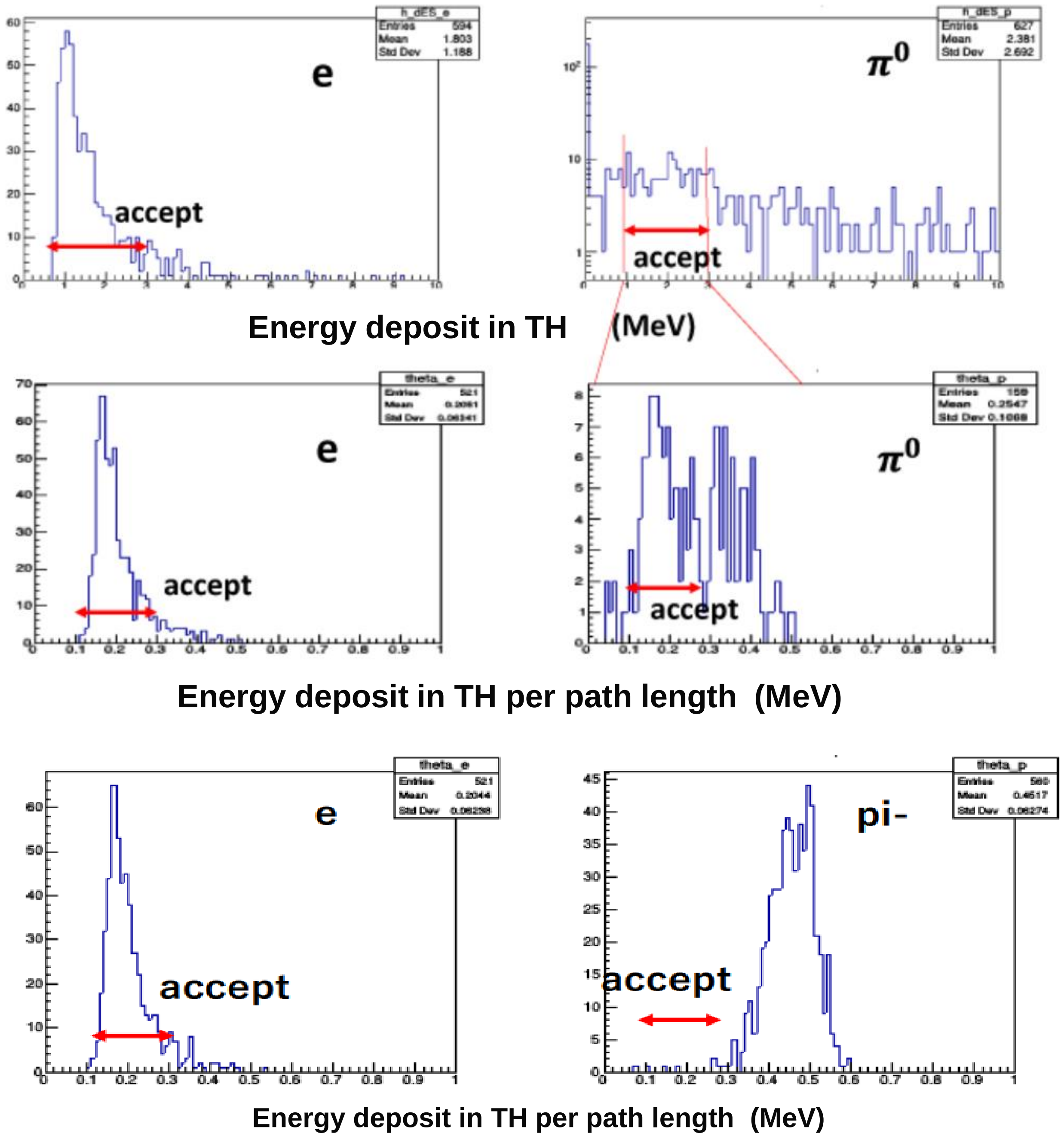
Number of Clusters in BGO







Further selection with ΔE in TH



Background reduction

● $\Lambda \rightarrow n\ \pi^0$ BR=0.20
- $\gamma \rightarrow e$ conversion x0.04
- BGO 1-cluster x0.03
- TH ΔE/path cut, TH hit position cut x0.29
- Install photon veto counters around the downstream spectrometer x0.5
- => BR= 0.35×10^{-4}

● $\Lambda \rightarrow p\ \pi^-$ BR=0.40
- TLC hit x0.045
- BGO 1 cluster x0.23
- \# of hit segments x0.46
- TH ΔE/path and hit position cut x0.002
- => BR= 0.04×10^{-4}

● $\Lambda p \rightarrow np$, $\Lambda n \rightarrow nn$ BR=0.40
- The same cut as above => BR< 0.04×10^{-4}

The same cut reduces the beta-ray events to 68%.

Expected beta-ray spectrum

Background/ Signal

$\approx$ BR(π^0 bg)/ 0.68 BR(β)

= 0.35×10^{-4} / (0.68 x 8.3×10^{-4})

= 0.06

If background level can be experimentally estimated within 30% accuracy,
the systematic error in BR(β) will be < 2%

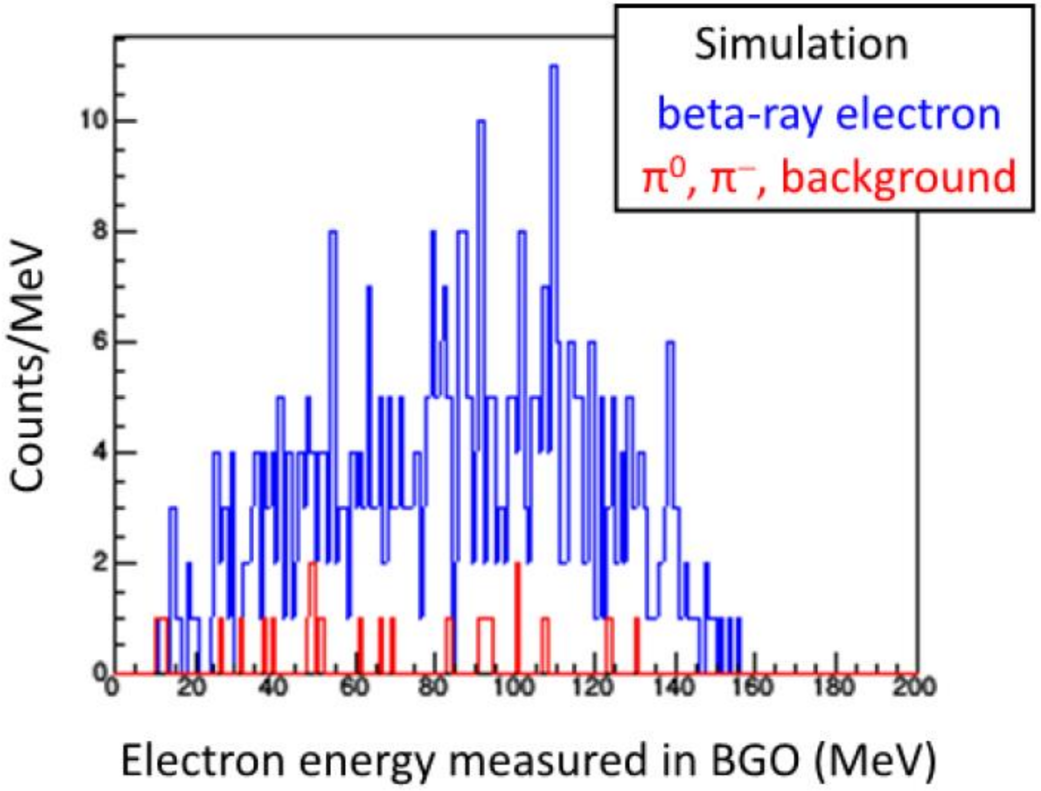


Figure 11: Simulated spectrum of the beta-ray electron energy (blue) and the contaminated background events (red) after all the background rejection analysis. The number of the background events is 4% of that of the beta-ray electron.

6. Lifetime measurement

Setup around the target for lifetime measurement

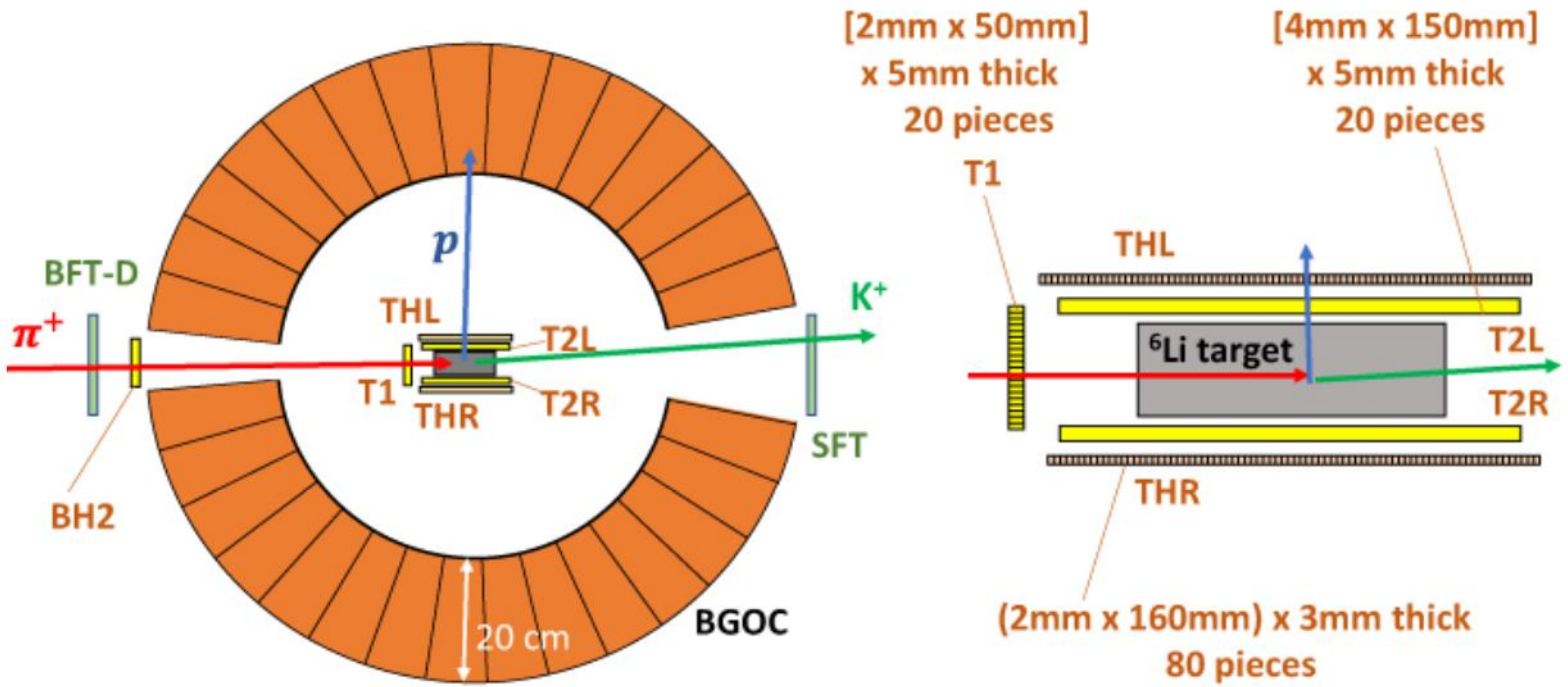
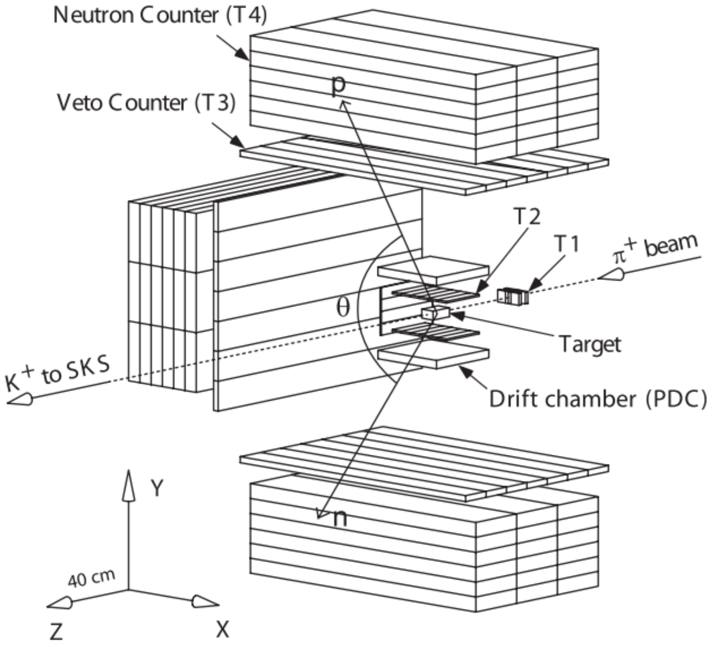


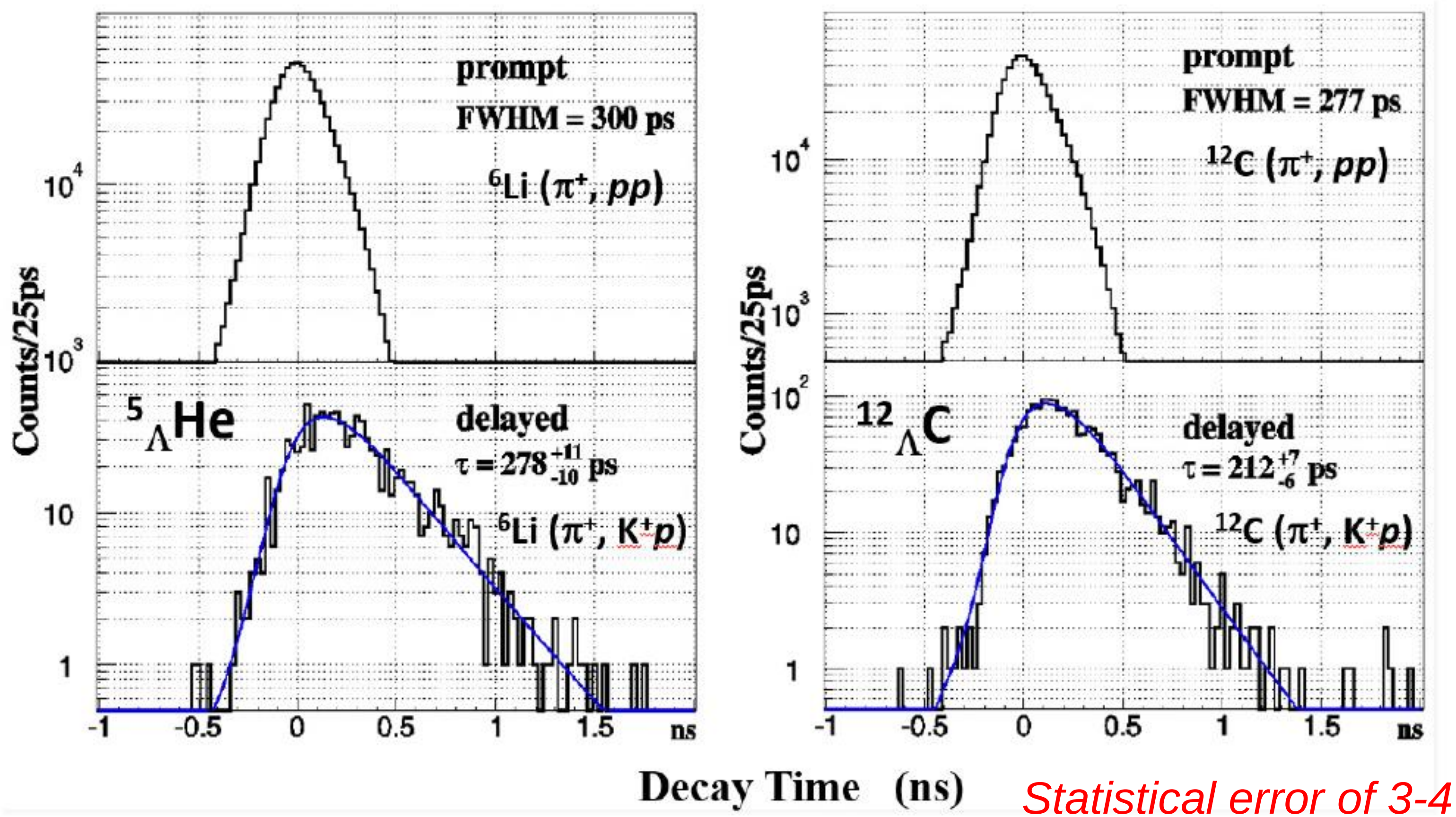
Figure 13: Schematic view of the setup around the target for the lifetime measurement.

$^{5}_{\Lambda}$He lifetime measurement (KEK E462)



E462 setup

B.H. Kang et al., PRL 96 (2006) 062301



Statistical error of 3-4%

Figure 12: Decay time spectra for $^{5}_{\Lambda}$He and $^{12}_{\Lambda}$C measured in KEK E462 experiment. The upper panels show "response function" of the spectrum measured with the prompt reaction of (π^+, pp), while the lower panels show decay time spectra for $^{5}_{\Lambda}$He and $^{12}_{\Lambda}$C hypernuclei via (π^+, K^+p) reaction.

Yield and statistical error for lifetime

Table 3: Expected yields of the $^{5}_{\Lambda}$He hypernuclei and their nonmesonic proton events, and then the expected lifetime accuracy, are estimated in comparison with the KEK E462 results.

Experiment	E462	Proposed experiment
Number of π^+ beam	2.5×10^{12}	2.5×10^{12}
^{6}Li target thickness	3.70 g/cm^2 (80 mm)	4.6 g/cm^2 (100 mm)
$^{5}_{\Lambda}$He counts after SKS analysis	45653	5.7×10^4
BR_p[16]	0.28	0.28
proton detection efficiency	?	0.3
Proton counts	~1030	4768
Time resolution (rms)	128 ps	128 ps
Statistical error of lifetime	4.0%	1.9%

ΔBR(*β*) ~4% and Δτ ~ 2% => $\Delta\Gamma_{\beta}$ ~ 4.5% => Δg_A^{Λ} ($^{5}_{\Lambda}$He) ~3.7%

Measurement of the $^{5}_{\Lambda}$He beta-decay rate in $\Delta\Gamma_{\beta}$ ~ 4.5% (Δg_A^{Λ} ~3.7%) accuracy seems feasible.

7. Theoretical calculations

Theoretical calculations for $^{5}_{\Lambda}$He (and $^{13}_{\Lambda}$C)?

- Nuclear effects of the daughter proton
  ---- Precise estimate of Pauli effect incl. ^{5}Li structure
- Hadronic effects
  ---- Meson exchange current had better be estimated.
- Estimate “quark effects” from the effective density which a daughter proton feels
  -> may not be large for $^{5}_{\Lambda}$He? $^{13}_{\Lambda}$C is better?

608 T. Motoba et al. / Continuum pion spectra

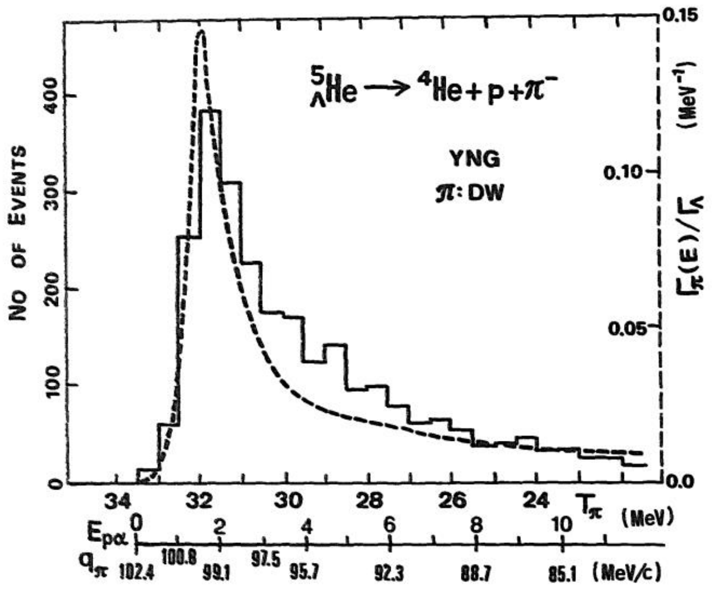


Fig. 4. The theoretical π^- decay spectrum $\Gamma_{\pi^-}(^{5}_{\Lambda}\mathrm{He})/\Gamma_\Lambda$ with YNG drawn as a function of the pα relative energy $E_{p\alpha}$ is compared with the observed π^- decay spectrum taken in the emulsion experiment [18,33]. The calculated π^- decay rate is compared with the experimental values [12,20] in table 1 and fig. 5.

T. Motoba et al., NPA 534 (1991) 597.

Precise few-body calculation with N^{3}LO chiral perturbation theory for ^{6}He→ ^{6}Li beta decay

PHYSICAL REVIEW C **79**, 065501 (2009)

^{6}He β-decay rate and the suppression of the axial constant in nuclear matter

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Toward understanding the quenching g_A problem

^{6}He→ ^{6}Li beta decay calculation

S.Vaintraub, N. Barnea, D. Gazit, PRC 79 (2009) 065501

- ***Chiral perturbation theory (N^{3}LO) to determine the axial weak current***
- *Triton beta-decay rate is used to determine the LEC relevant to MEC.*
- *Very small dependence on the cutoff parameter.*
- *Nuclear many-body calculation using Hyperspherical-Harmonics expansion.*

⇩

The experimental 9.3% quenching is almost explained without reducing g_A.

TABLE III. The JISP16 NN interaction ^{6}He, ^{6}Li binding energies, rms matter radii, and the leading order GT matrix element as a function of K_{max}.

K_{max}	^{6}He		^{6}Li		$GT\|_{LO}$
	B.E.	radius	B.E.	radius	
4	18.367	1.840	19.392	1.859	2.263
6	24.103	1.902	26.124	1.909	2.247
8	26.392	1.979	28.854	1.984	2.234
10	27.560	2.051	30.156	2.051	2.232
12	28.112	2.112	30.797	2.110	2.229
14	28.424	2.165	31.132	2.160	2.227
∞	28.70(13)		31.46(5)		2.225(2)
[21]	28.32(28)		31.00(31)		*produced within 3%*
Exp.	29.269	2.18	31.995	2.09	2.161

If a similar calculation is done for $^5{}_\Lambda$He, a measured g_A deviation can be attributed to quark effects.

...But how to measure/estimate LEC is a problem for Λ.

Summary and prospect

- Electro-weak properties of hyperons in hypernuclei are good probes to investigate possible modification of baryons in nuclear matter.
- We propose to measure Λ's beta decay rate from BR and lifetime.
- Experimentally, measurement with ~ 4% statistical accuracy is possible for ${}^{5}_{\Lambda}He$.
- Simulation shows that huge background can be sufficiently suppressed and **the experiment seems feasible.**

What to do

- More realistic simulation (BGO response by n and γ, include detector resolution, ...)
- Counting rate problem (BGO -> faster scintillator)
- Optimization of the setup

To theorists:

- Give me your comments. Is this experiment interesting? meaningful?
- Please give us theoretical estimates on

  Pauli and nuclear many-body effects, and hadronic (MEC) effects,

  hopefully via precise few-body calculation.