17th. Oct. 2003 HYP2003

Direct measurement of the π^0 decay width of ${}^{5}_{\Lambda}He$ and ${}^{12}_{\Lambda}C$ hypernuclei

For ${}^{5}_{\Lambda}He$ and ${}^{12}_{\Lambda}C$

- **Direct measurement of π^0 decay width**
- **Non-mesonic decay width**

Titech S.Okada

for KEK-PS E462/E508 collaboration

Motivation

Weak decay mode of Λ hypernucleus

$$1 / \tau_{HY} = \Gamma_{tot} \begin{cases} \Gamma_m & \begin{cases} \Gamma_{\pi^-} (\Lambda \to \pi^- p) \\ \Gamma_{\pi^0} (\Lambda \to \pi^0 n) \end{cases} \\ \Gamma_{nm} & \begin{cases} \Gamma_p (\Lambda\text{“p”} \to np) \\ \Gamma_n (\Lambda\text{“n”} \to nn) \\ \Gamma_{NN} (\Lambda\text{“N”“N”} \to nNN)\ ? \end{cases} \end{cases}$$

Mesonic Weak Decay (Γ_m)

Non-Mesonic Weak Decay (NMWD) (Γ_{nm})

Γ_{nm} is important to study NMWD.

Determination of each decay width of NMWD (Γ_p, Γ_n , Γ_{NN}) is difficult due to FSI effect, especially for Γ_{NN}.

$$\Rightarrow \Gamma_{nm} = \Gamma_p + \Gamma_n + \Gamma_{NN}\ ??$$

$$\Gamma_{nm} = \Gamma_{tot} - \Gamma_{\pi^-} - \Gamma_{\pi^0}$$

↑ ($\Gamma_{tot} - \Gamma_{\pi^-}$) reported in previous talk (by Kameoka)

Present status of Γ_{nm}

$$\Gamma_{nm} = \Gamma_{tot} - \Gamma_{\pi^-} - \Gamma_{\pi^0}$$

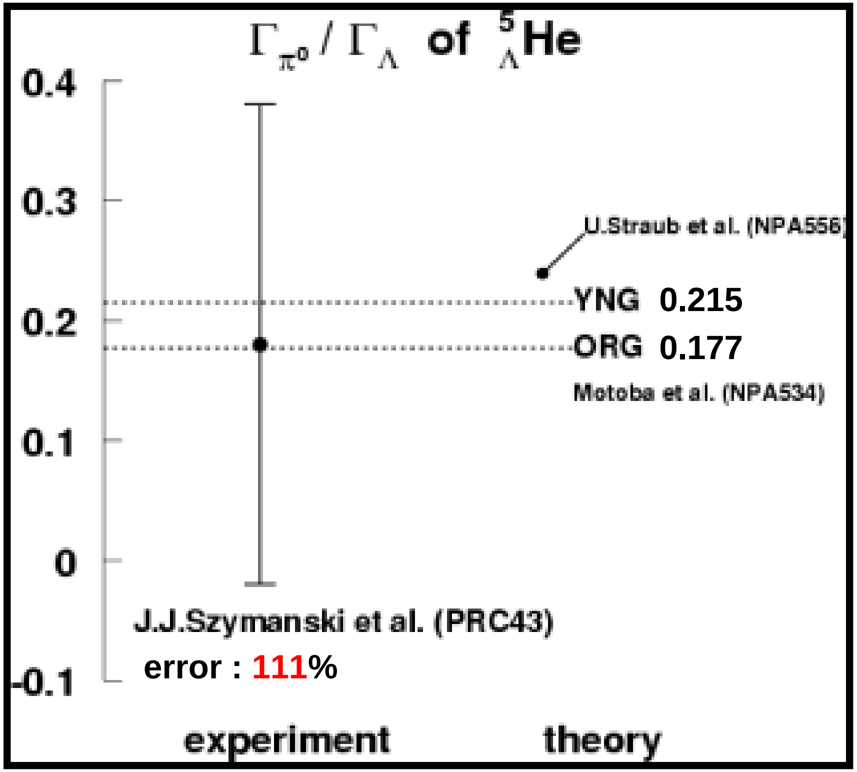
	${}^{5}_{\Lambda}He$	error	${}^{12}_{\Lambda}C$	error
$\Gamma_{tot} / \Gamma_\Lambda$	1.03 ± 0.08	8%	1.141 ± 0.08	7%
$\Gamma_{\pi^-} / \Gamma_\Lambda$	0.44 ± 0.11	25%	0.113 ± 0.015	13%
$\Gamma_{\pi^0} / \Gamma_\Lambda$	0.18 ± 0.20	111%	0.200 ± 0.068	34%
$\Gamma_{nm} / \Gamma_\Lambda$	0.41 ± 0.14	34%	0.828 ± 0.087	11%

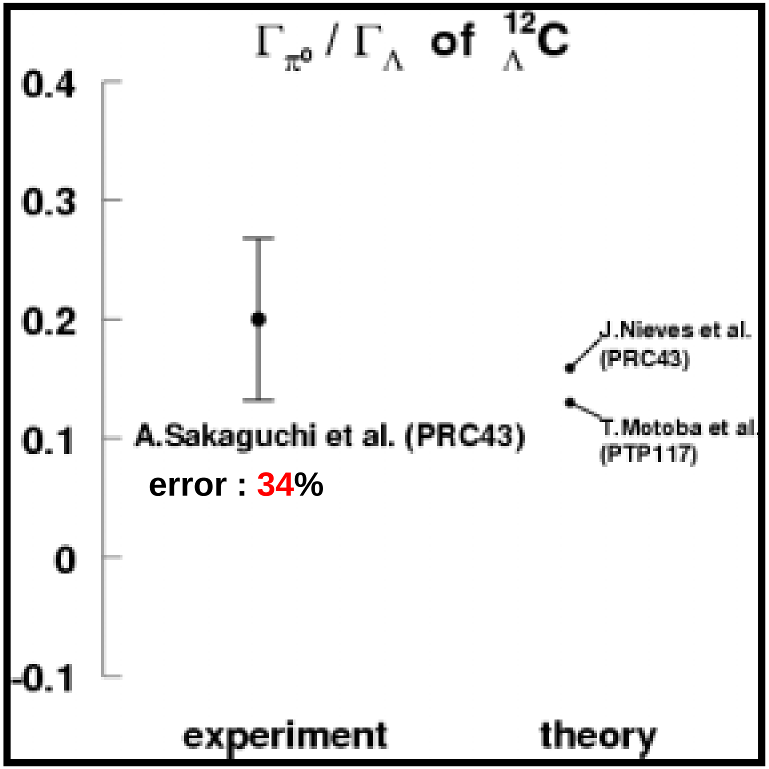
(J.J.Szymanski *et al.* : PRC43) (Y.Sato *et al.* : PRC submitted)

Γ_{π^0} : indirect measurement

➡ Γ_{π^0} is the largest error source of Γ_{nm}.

Present status of Γ_{π^0}





Pionic decay width of $^5_\Lambda$He is sensitive to α-Λ potential shape.

ORG : No repulsive core
YNG : having repulsive core

We have measured the Γ_{π^0} of $^5_\Lambda$He and $^{12}_\Lambda$C within ~5% error level.

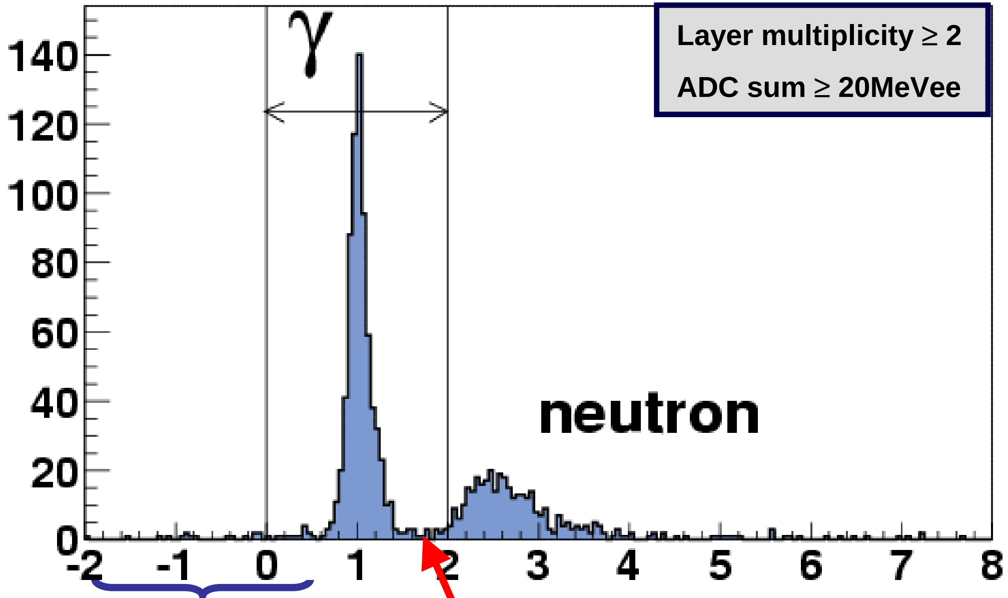
For observing π^0 particle,

one gamma ray from "$\pi^0 \rightarrow 2\gamma$" process was detected.

Neutral particle identification

Gated ground state of hypernuclei ($^{5}_{\Lambda}$He, $^{12}_{\Lambda}$C)

1 / β (TOF) spectrum



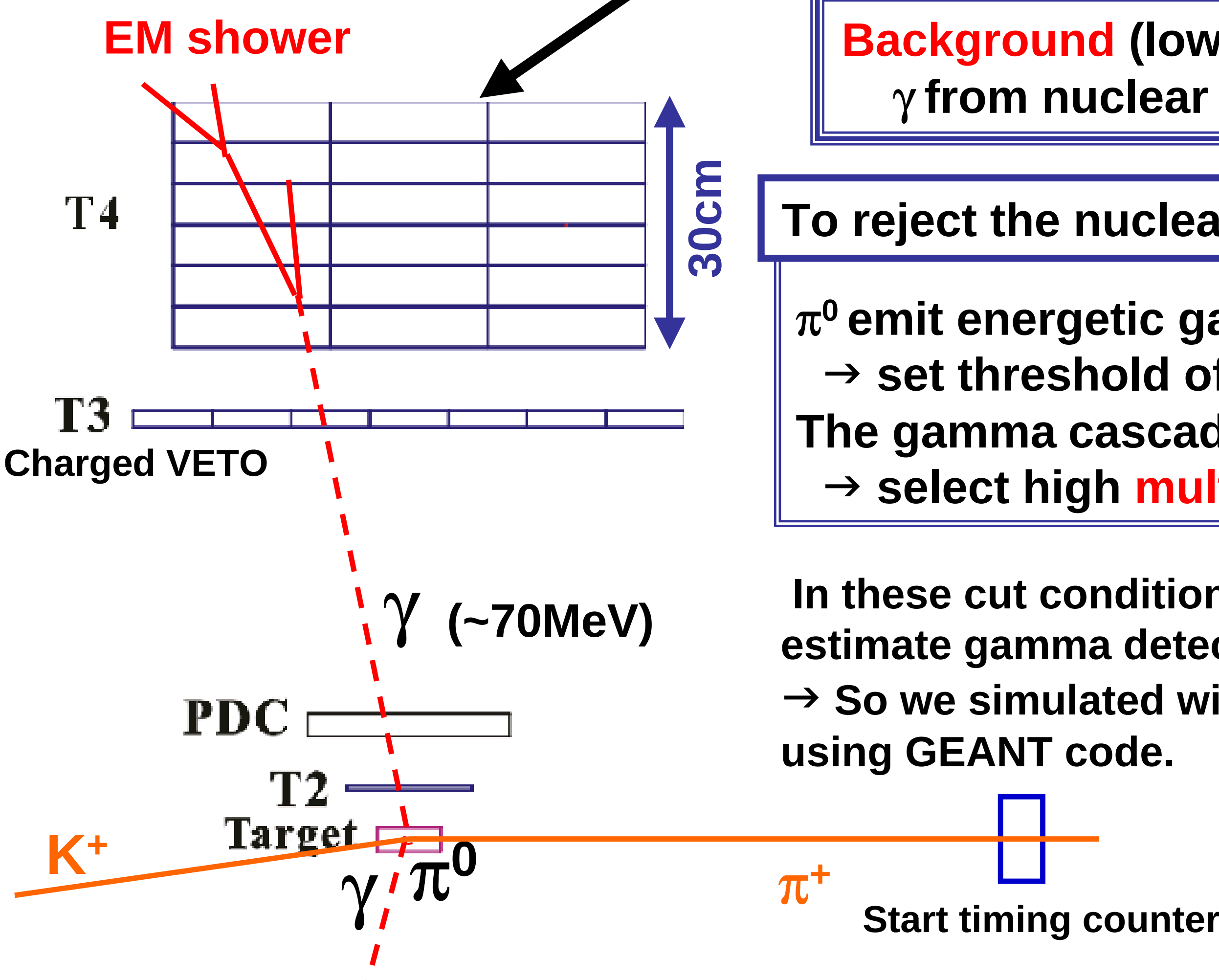
Constant background level is very low (~3%).

Good separation (between γ and neutron)

π^0 identification

γ detection system

Large plastic scintillator arrays were used as γ detector.



Background (low energy):
γ from nuclear decay process

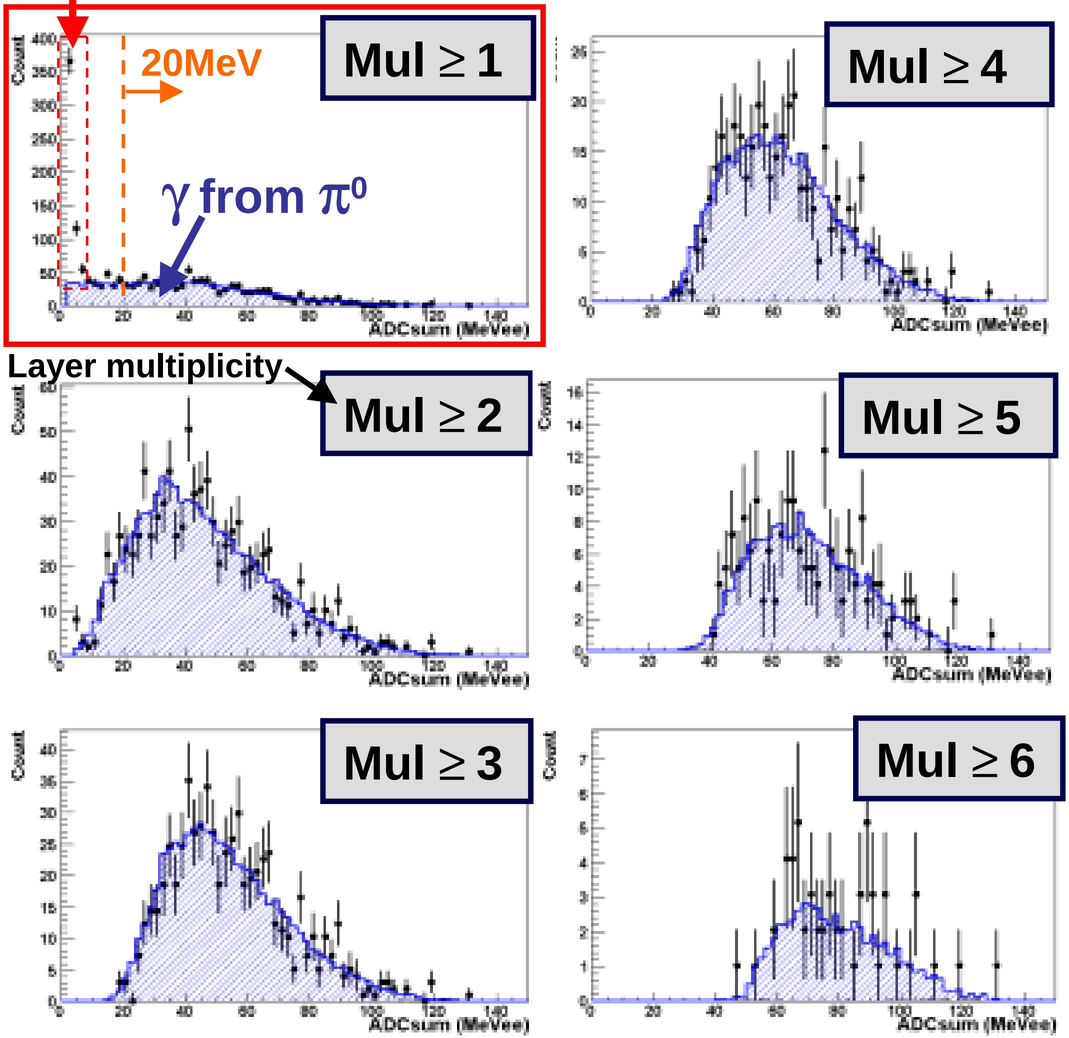
To reject the nuclear decay γ

π^0 emit energetic gamma. (~70MeV)
→ set threshold of ADC sum.
The gamma cascade in many layers.
→ select high multiplicity event.

In these cut conditions, It is hard to estimate gamma detection efficiency.
→ So we simulated with same conditions using GEANT code.

γ efficiency estimation using GEANT simulation

ADC sum distribution



* Blue histogram :
GEANT simulation
* Plot (with error bar) :
Experimental data

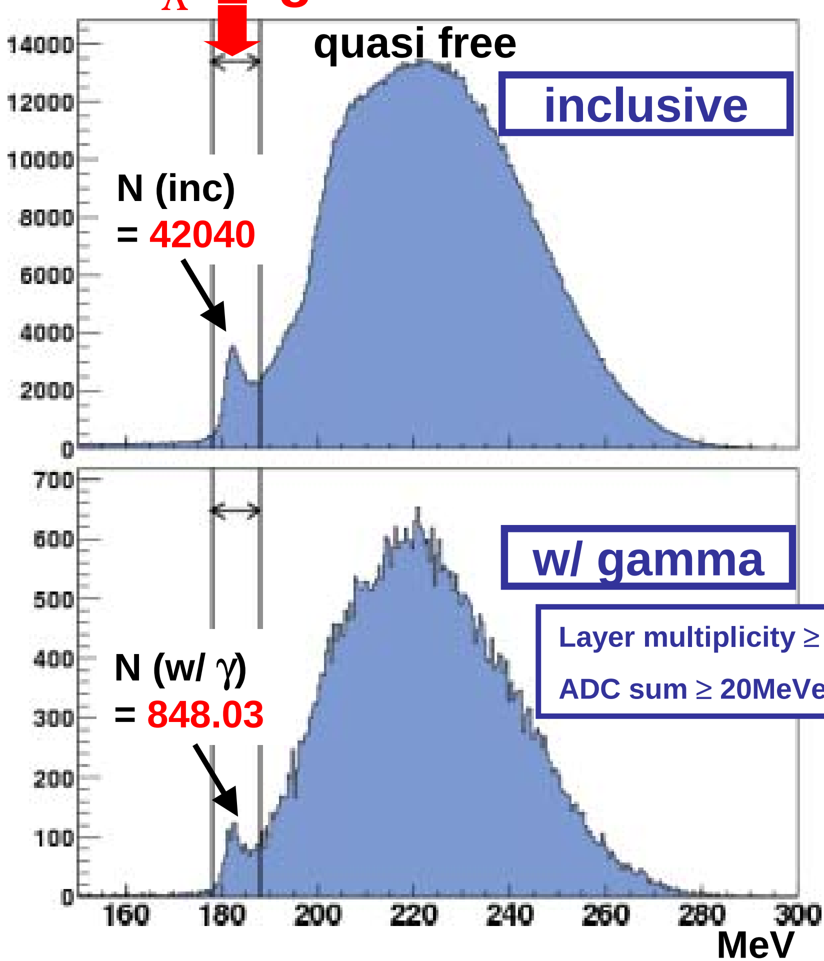
assuming π^0 momentum in GEANT simulation as
${}^{5}_{\Lambda}$He : 104.9 MeV (mono)
${}^{12}_{\Lambda}$C : Motoba's calculation
PTP117(1994)

➡ **Well agree with Geant simulation.**

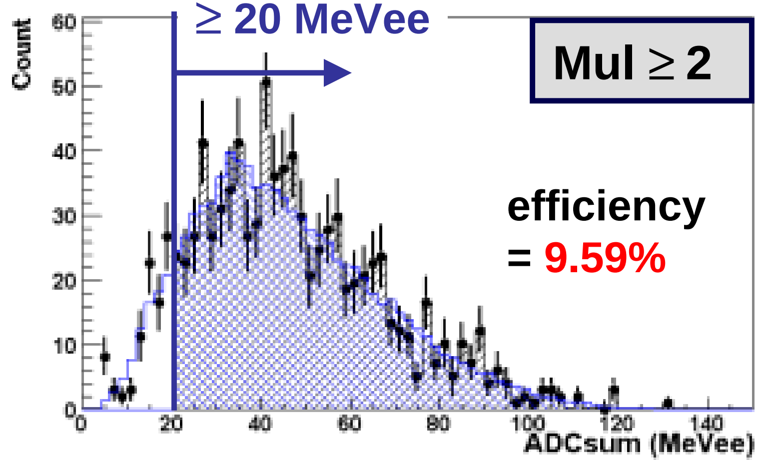
Nuclear γ is shown only Mul $\geq$ 1.
To remove it completely, we apply **Mul $\geq$ 2 and ADCsum $\geq$ 20MeVee** .

π^0 branching ratio of $^5_\Lambda$He

Mass spectra for ^{6}Li(π^+,K$^+$)



ADC sum w/GEANT sim



b_{π^0} = N (w/ γ) / N (inc) $\times$ eff

= **0.212 ± 0.008**

$^5_\Lambda$He : b_{π^-} / b_{π^0} = **1.75 ± 0.08**

(b_{π^-} : 0.371 ± 0.009) referring previous talk

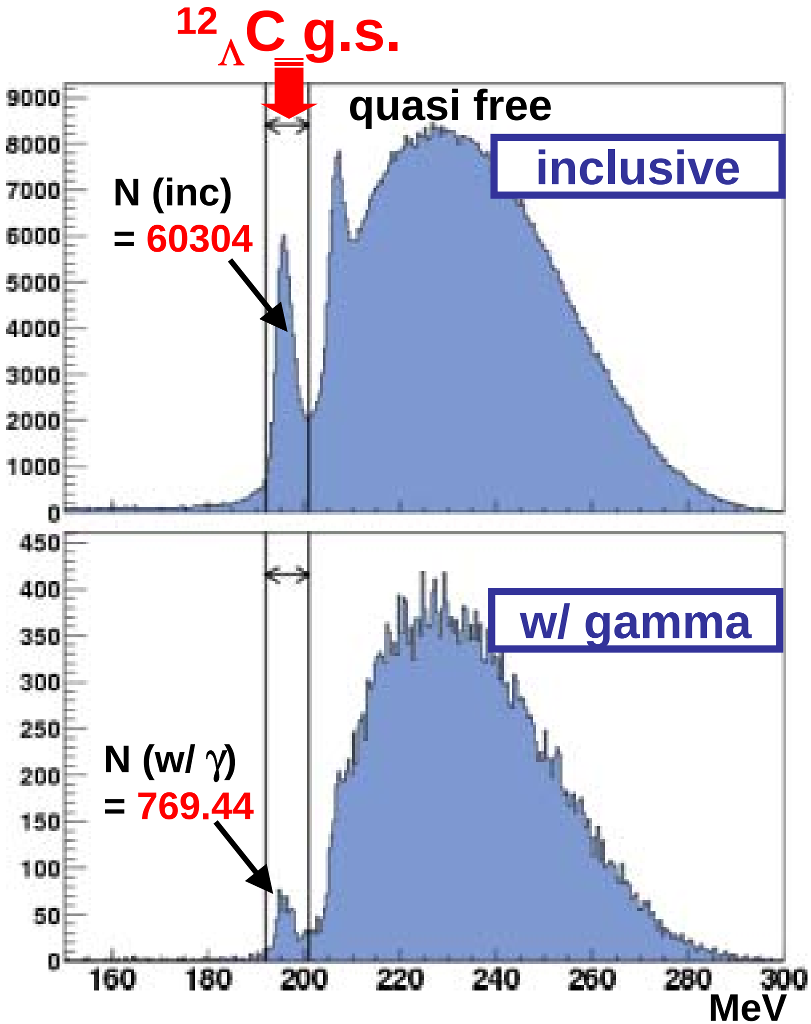
	$^5_\Lambda$He	
$\alpha + p + \pi^-$		$\alpha + n + \pi^0$

Same Q-value as that of free Λ

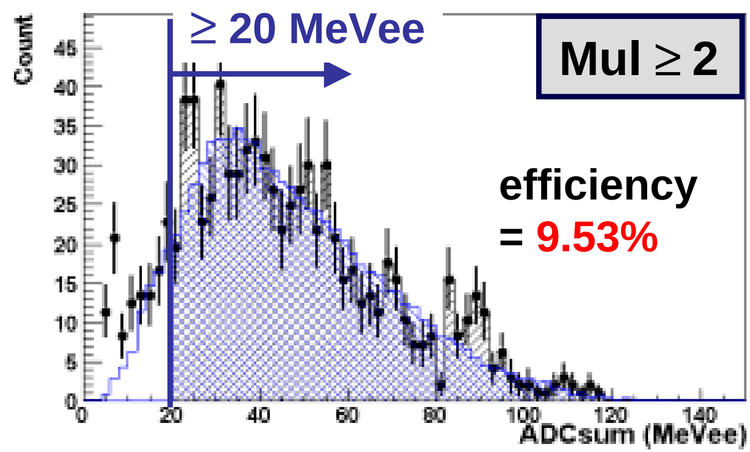
Free Λ : b_{π^-} / b_{π^0} = **1.78 ± 0.03**

π^0 branching ratio of ${}^{12}_{\Lambda}C$

Mass spectra for ${}^{12}C(\pi^+,K^+)$



ADC sum w/GEANT sim



b_{π^0} = N (w/ γ) / N (inc) × eff
= 0.133 ± 0.005

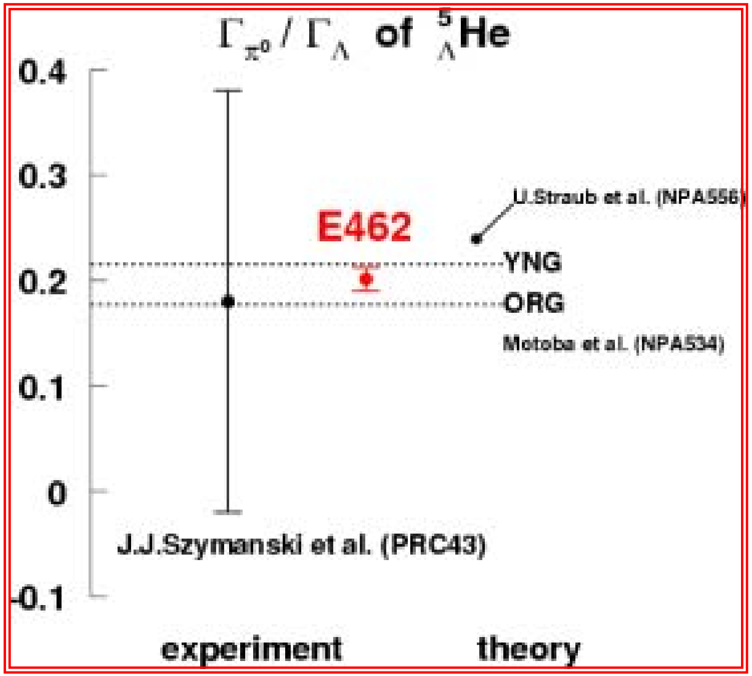
Results of Γ_{π^0}

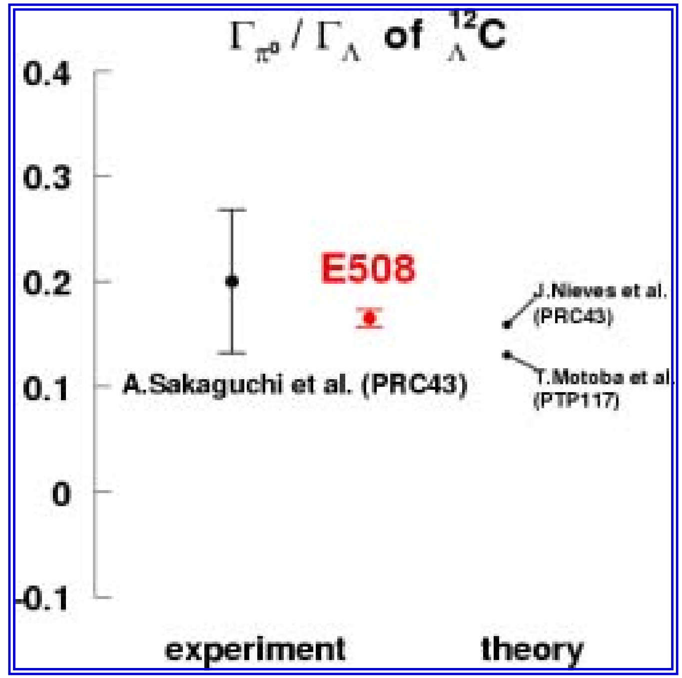
Lifetime : 278^{+11}_{-10} ps (E462)

Lifetime : 212^{+7}_{-6} ps (E508)

${}^{5}_{\Lambda}$He : $\Gamma_{\pi^0} / \Gamma_{\Lambda}$ = **0.201±0.011**

${}^{12}_{\Lambda}$C : $\Gamma_{\pi^0} / \Gamma_{\Lambda}$ = **0.165±0.008**





This error level is improved extremely (~5%error level) !!

This Γ_{π^0} result is also shown the middle of YNG and ORG as our result of Γ_{π^-}.

The result is higher than some of theoretical predictions.

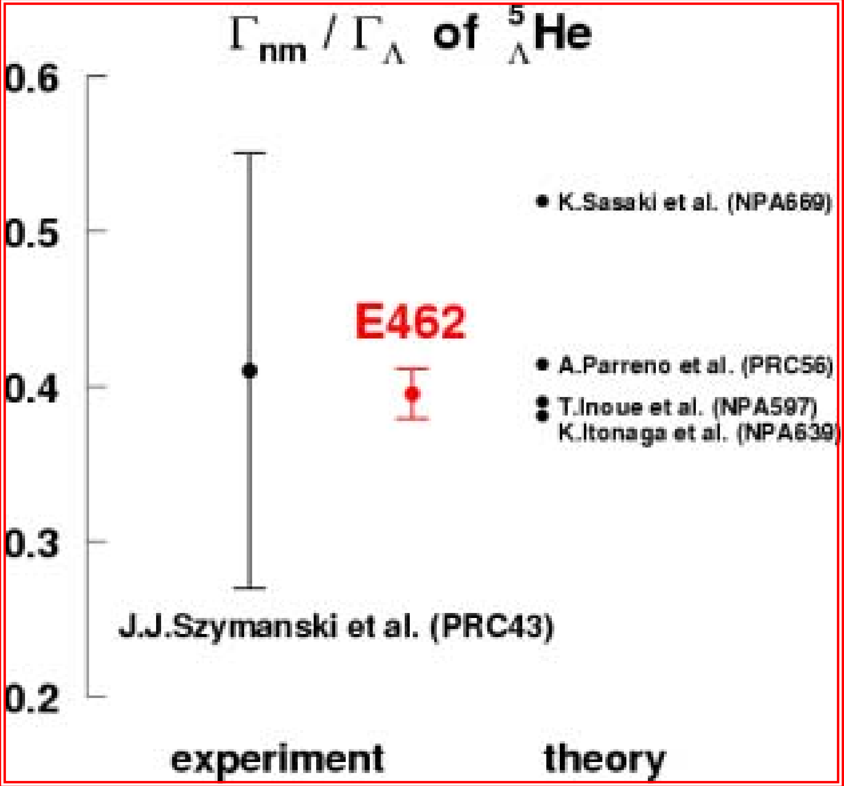
Results of Γ_{nm}

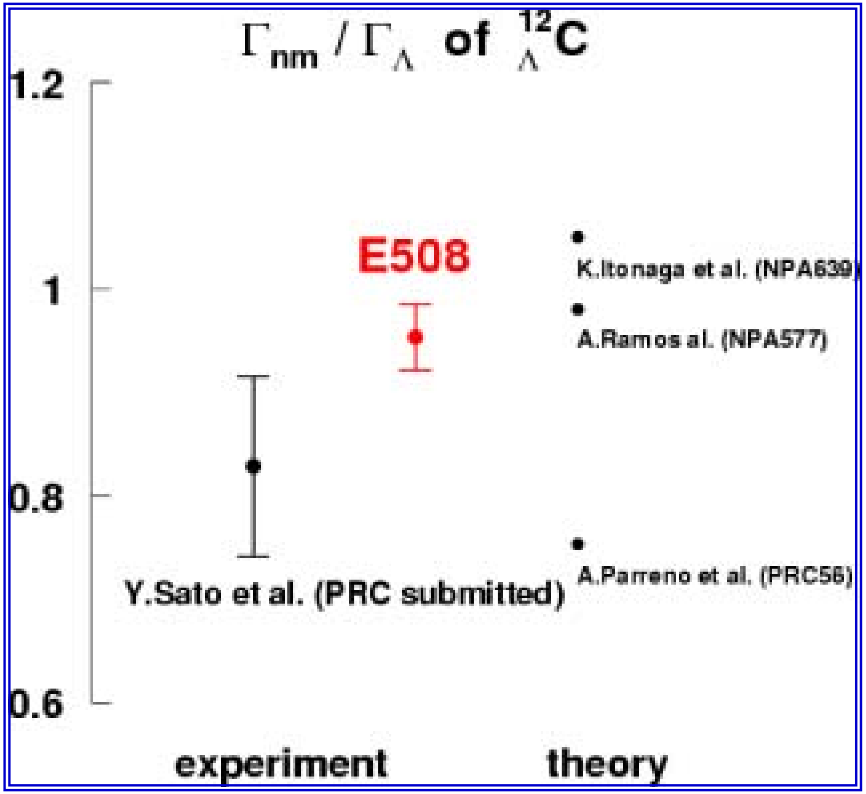
$\Gamma_{\pi^-} / \Gamma_\Lambda$: 0.351±0.017 (E462)
$\Gamma_{tot} / \Gamma_\Lambda$: 0.947±0.038 (E462)

$\Gamma_{\pi^-} / \Gamma_\Lambda$: 0.123±0.028 (E307)
$\Gamma_{tot} / \Gamma_\Lambda$: 1.242±0.042 (E508)

${}^{5}_{\Lambda}$He : $\Gamma_{nm} / \Gamma_\Lambda$ = **0.395±0.016**

${}^{12}_{\Lambda}$C : $\Gamma_{nm} / \Gamma_\Lambda$ = **0.953±0.032**





Summary

- ◆ π^0 branching ratio
  - ✓ $^{5}_{\Lambda}$He : Direct measurement for the first time.
  - ✓ $^{12}_{\Lambda}$C : measured with high statistics.
- ◆ π^0 decay width
  - ➢ $^{5}_{\Lambda}$He : between YNG and ORG (α–Λ potential).
  - ➢ $^{12}_{\Lambda}$C : higher than most of theoretical calc.

$\Gamma_{\pi^0} / \Gamma_\Lambda$ = 0.201±0.011 ($^{5}_{\Lambda}$He), 0.165±0.008 ($^{12}_{\Lambda}$C)

- ◆ Furthermore, we extracted non-mesonic weak decay width from these results.

$\Gamma_{nm} / \Gamma_\Lambda$ = 0.395±0.016 ($^{5}_{\Lambda}$He), 0.953±0.032 ($^{12}_{\Lambda}$C)

⇨ These results will contribute more theoretical understanding for α-Λ potential shape and also the study of NMWD.

Spare OHPs

Calculated strength function leading to the final nuclear state in π^- decay of $^{12}{}_{\Lambda}B$

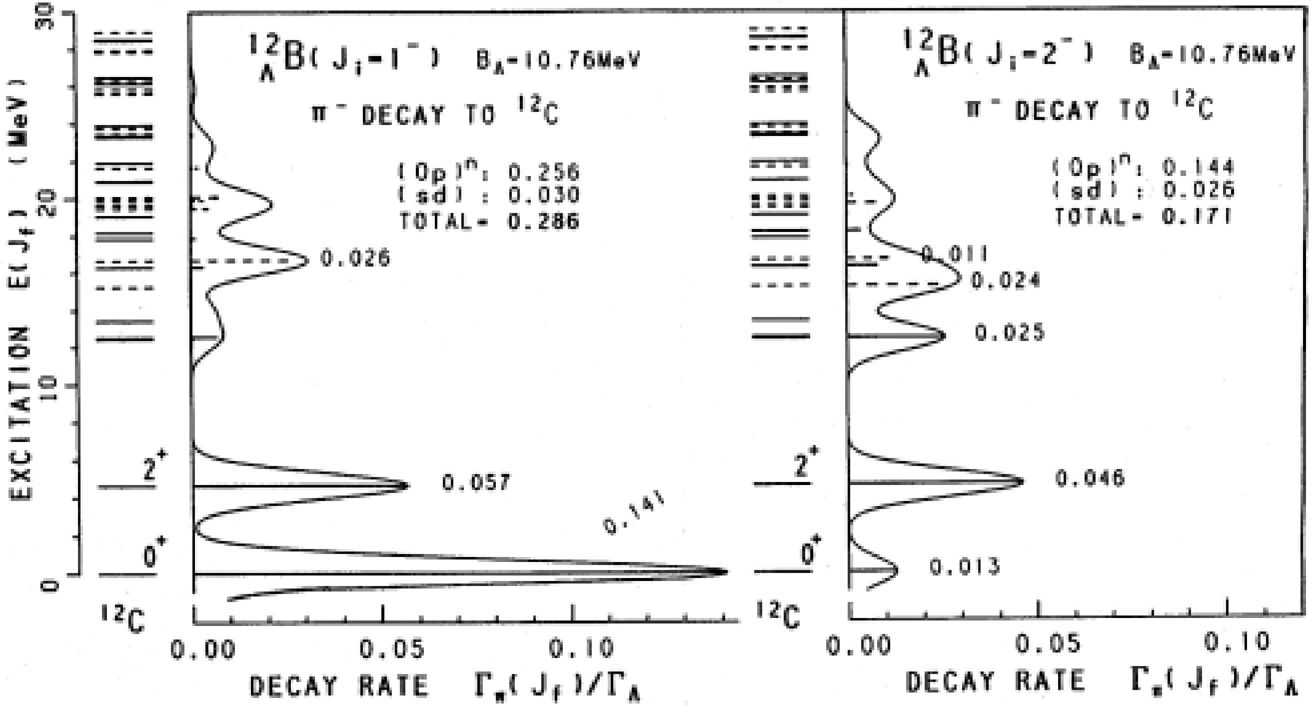


Fig. A-5. Same comment as for Fig. A-1 except $^{12}_{\Lambda}B$ calculated by assuming $J_{gs}=1^-$ (left) and 2^- (right). The π^0 decay of the mirror hypernucleus $^{12}_{\Lambda}C$ results in an analogous pattern to the above ones except the strengths.

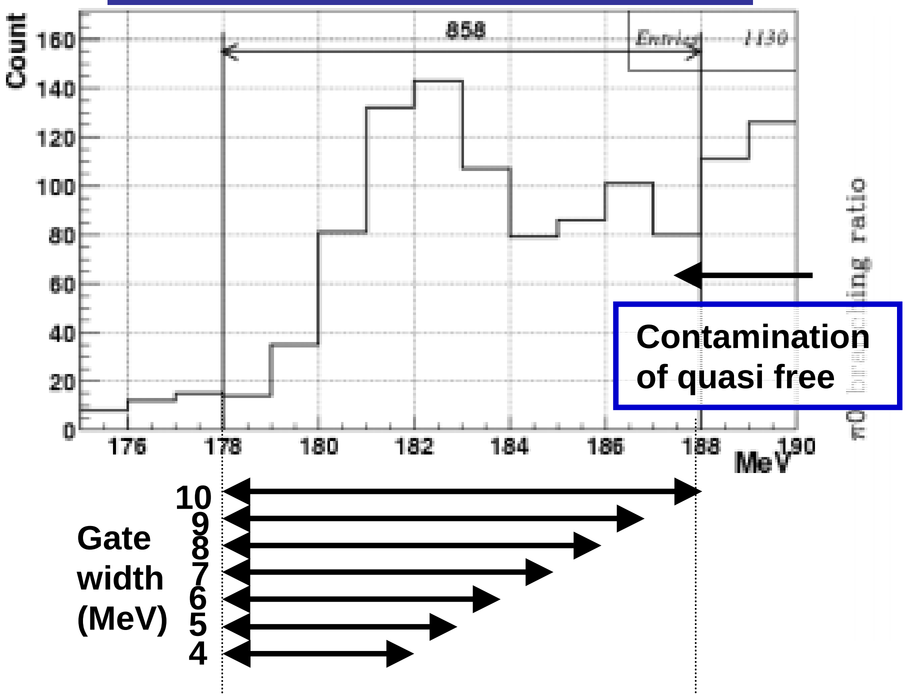
T.Motoba and K.Itonaga
Progress of Theoretical Physics Supplement No.117, 1994 (p496)

For generated π^0 momentum in Geant simulation for $^{12}{}_{\Lambda}C$,

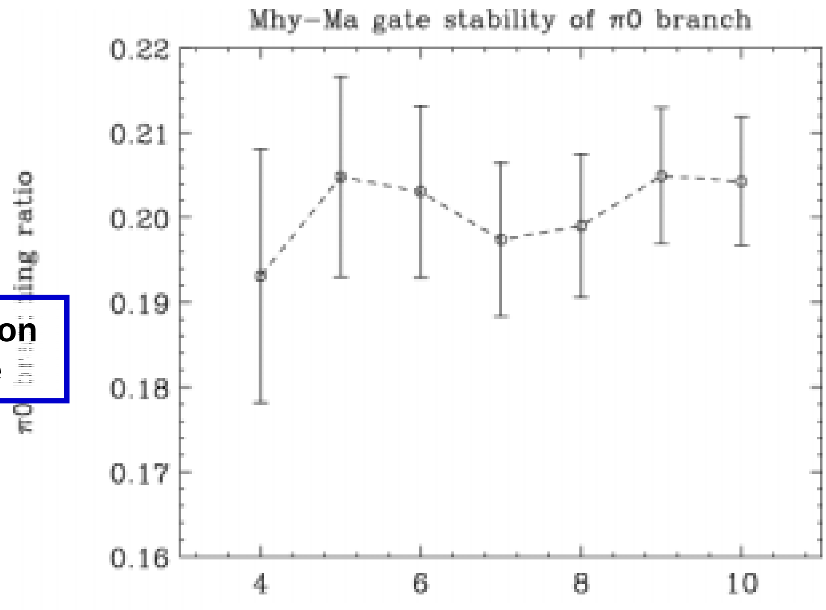
Assuming this ratio pattern for 1^-: b_{π^0} = 0.133±0.005 (final result)
Case of coming from only 0^+ : b_{π^0} = 0.135±0.005 (systematic error: ~1.5%)

Mass spectra gate dependence of π^0 branching ratio

Mass spectra for $^6Li(\pi^+,K^+)$



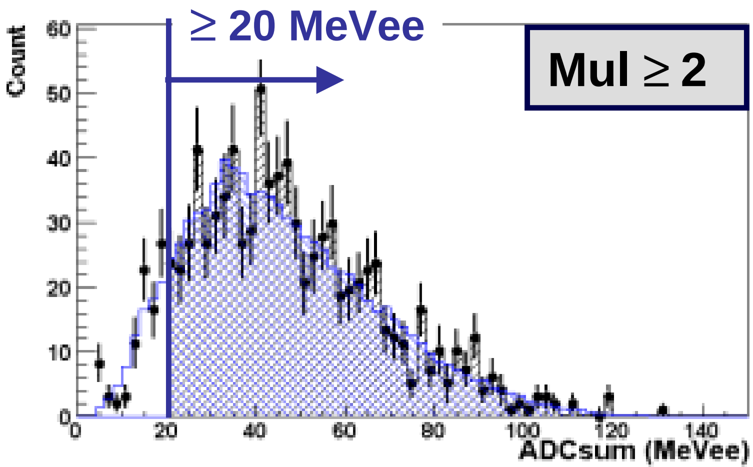
Gate stability of π^0 branching ratio



systematic error : ~ 1% (average)

Stability for absolute gain adjustment

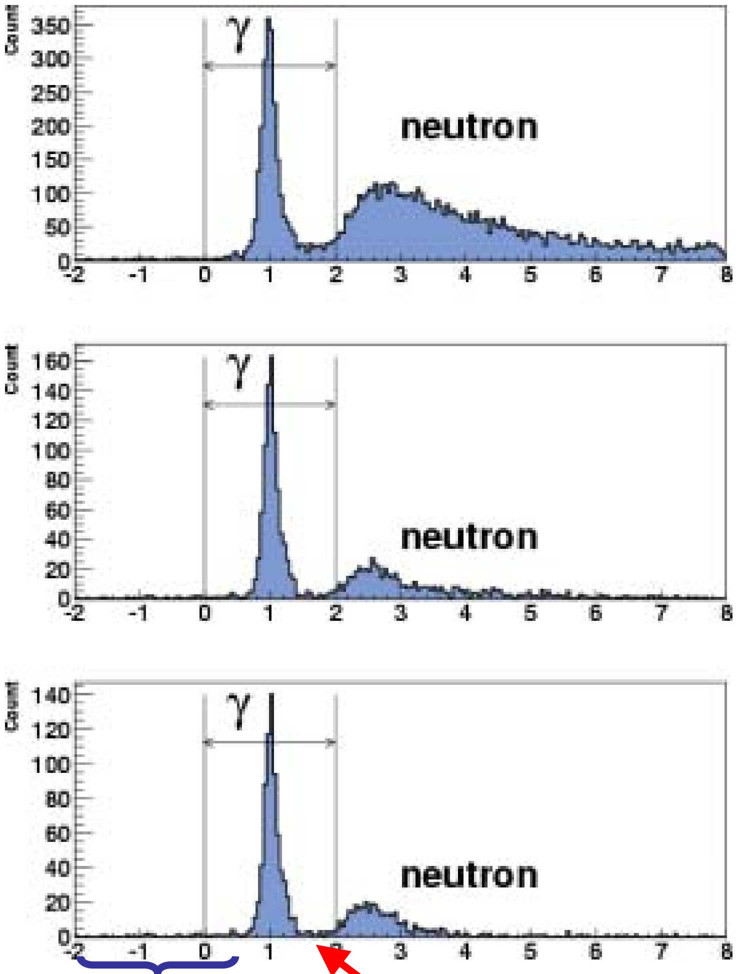
ADC sum for $^{5}_{\Lambda}He$ w/ Geant sim



Decrease absolute gain 5% : b_{π^0} = 0.209±0.008
Final result : b_{π^0} = 0.212±0.008
Increase absolute gain 5% : b_{π^0} = 0.216±0.008
(For changing gain 5%) : systematic error= ~1.7%

$1 / \beta$ (TOF) spectra

Gated ground state
of hypernuclei ($^{5}_{\Lambda}He$, $^{12}_{\Lambda}C$)



No cut

Layer multiplicity ≥ 2

Layer multiplicity ≥ 2
ADC sum ≥ 20MeVee

Constant background
level is very low (~3%).

Good separation (between γ and neutron)