Report on Technical Issues for J-PARC E18 Experiment
(Revised Version for the two-step plan):
"*Coincidence Measurement of the Weak Decay of $^{12}{}_{\Lambda}C$ Hypernucleus and the Three-body Weak Interaction Process*"

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FIFC(PAC) presentation
Jan. 14-16, 2011

I. The Aim of E18 and the revised two-step run plan.
II. Physics Motivations and Recent progress on 3-body NMWD.
III. 1st step Proposal and the Expected Results
IV. Setup and Technical Issues
V. Run strategy

The Revised Two-step Plan

1. Revised Two-step Run plan;

   - Current duty factor of K1.8 beamline remains 10-15 %.

   - Expected improvement; at most ~ 30 % in a couple of years,

   1) E18_1st-step run; for solid confirmation of 2N-NMWD with ~30% df beam.

   2) E18_Main run; for full statistics run

      for 10% stat. error for Γ_{2N}, Γ_n, Γ_p, Γ_n/Γ_p with high df beam.

2. First-step run ; total 0.8×10^{12} $\pi+$ beam (70 shifts) on 4g/cm^2 ^{12}C target, 3kW, 2×10^6 π/2s(spill), 30% duty factor beam.

3. Physics Output;

   - can achieve a direct and exclusive confirmation of 3-body NMWD by measuring the triple coin and N_{NN}(nbb).

   - can achieve a solid confirmation of the branching ratio b_{2N} of at least 3-4 σ confidence level instead of the current 2σ.

4. N_{NNN} ~ 52(6), N_{NN}(nbb) ~90(35), N_{pp}(bb) ~ 50(8).

   These results can be published to meet the urgent need of a solid confirmation of 2N-NMWD in the weak decay research community.

Summary of the Two-step Plan

	E508	E18_main	E18_1st-step
N_π^{tot}	2T	5T (80shifts)	0.8T (70 shifts)
n_π/spill	4 M/4sec	10 M/spill(6sec)	2 M/spill(6sec)
d.f.	~1	~1	~0.3
N_{np}(bb)	116	(×7×2.5) ~2030	(×7×.5) ~320
N_{nn}(bb)	43	(×3.5×2.5) ~376	(×3.5×.5) ~60
N_{pp}(bb)	8	(4×4×2.5) ~320	(4x4×.5) ~51
N_{np}(nbb)	9	(×12×2.5) ~270	(×12×.5) ~43
N_{nn}(nbb)	16	(×4.5×2.5) ~280	(×4.5×.5) ~45
N_{NNN}	6	(×12×1.8×2.5) ~325	(×12×1.8×.5) ~52

I. Weak Decay Modes of Λ Hypernucleus

$\Gamma_{tot}(=1/\tau)$

- Γ_m
  - $\Gamma_{\pi^-}(\Lambda \to p\pi^-)$
  - $\Gamma_{\pi^0}(\Lambda \to n\pi^0)$

  Mesonic

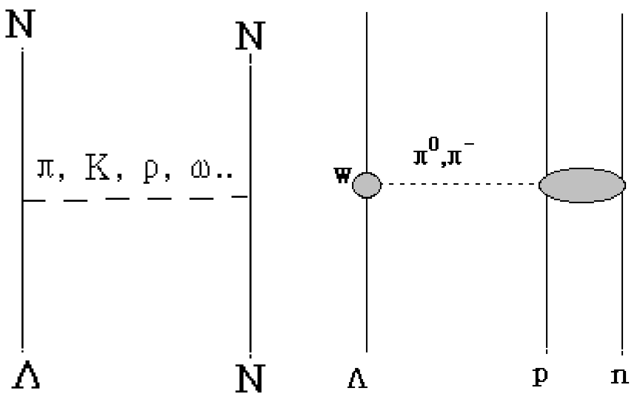
  q~ 100 MeV/c

- Γ_{nm}
  - $\Gamma_p(\Lambda p \to np)$
  - $\Gamma_n(\Lambda n \to nn)$ (1N)
  - $\Gamma_{2N}(\Lambda NN \to nNN)$ (2N)

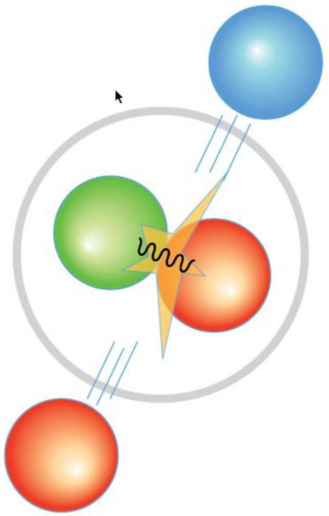
  Nonmesonic

  q~ 400 MeV/c

Γ_n/Γ_p **puzzle**



(2N-NMWD)



II. Why NMWD?

1. The fundamental Motivation to study NMWD is
   to study the elementary B-B Weak Interaction ;

   Λ + N (n or p) → N + N (ΔS=1 B-B Weak Interaction)

   - NMWD is the only window to observe this interaction so far.

2. Decay Observables ;

   - Decay widths; Γ_n, Γ_p ; difficult to measure them directly.
   - Asymmetry;
   - Γ_n/Γ_p and the asymmetry have been mainly studied so far.

Where $\Gamma_{tot} = \Gamma_m + \Gamma_{nm}$

$\Gamma_{nm} = \Gamma_n + \Gamma_p$

$= \Gamma_{tot} - \Gamma_m = \Gamma_p (1 + \Gamma_n/\Gamma_p)$; Γ_n/Γ_p puzzle problem

→ $\Gamma_n + \Gamma_p + \Gamma_{2N}$

$\Gamma_{nm} - \Gamma_{2N} = \Gamma_p (1 + \Gamma_n/\Gamma_p)$

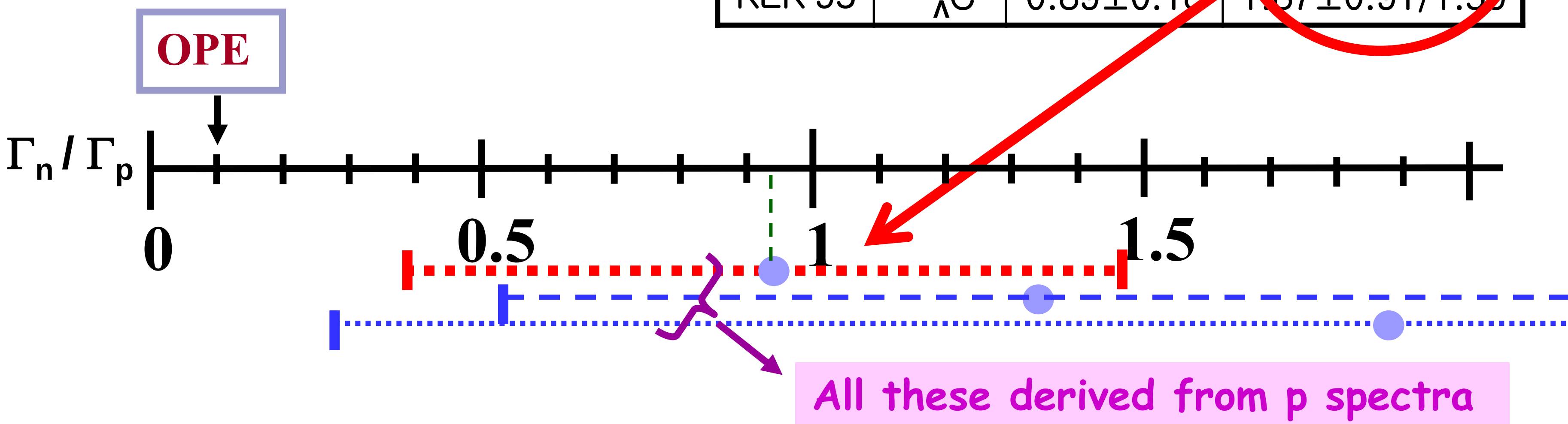
Γ_n/Γ_p puzzle and the previous searches

1. Γ_n/Γ_p Puzzle :

$\Gamma_n/\Gamma_p^{exp} >> \Gamma_n/\Gamma_p^{th(OPE)}$

~ 1 ~0.1

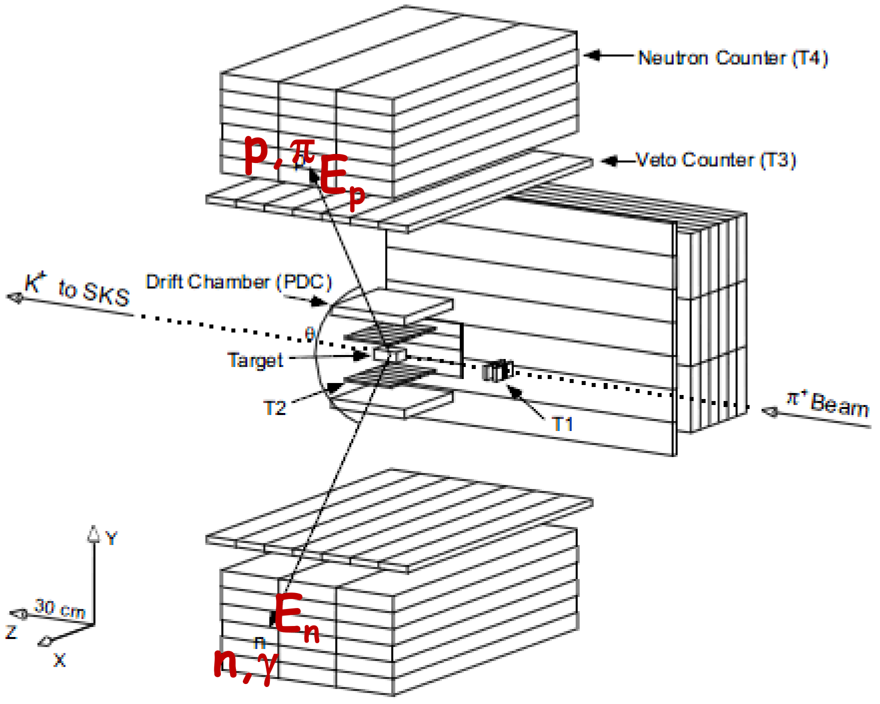
	Hyp. Nuc.	Γ_{nm}	Γ_n/Γ_p
BNL	$^5{}_\Lambda$He	0.41±0.14	.93±0.55
	$^{12}{}_\Lambda$C	1,14±0.2	1.33±1.12/0.81
KEK'95	$^{12}{}_\Lambda$C	0.89±0.18	1.87±0.91/1.59



2. Recent Development of $\Gamma_n/\Gamma_p^{theory}$: 0.3 ~ 0.7

K.Sasaki (Direct Quark), Nucl. Phys. A669 (2000) 371

Coincidence Meas. (KEK-PS E462/E508) and Γ_n/Γ_p resolution



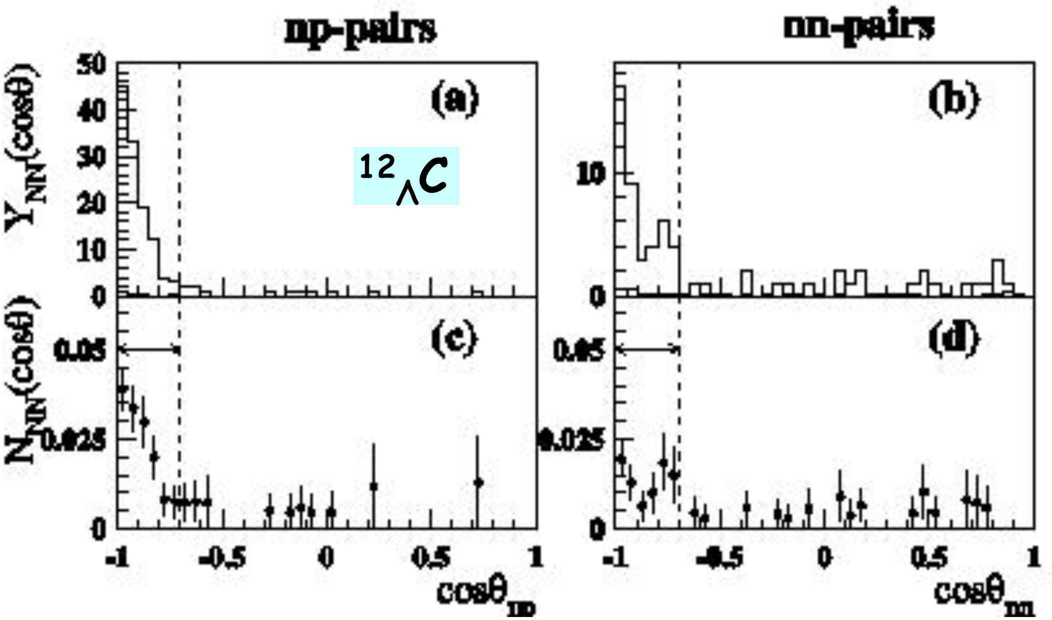
- Measure; n, p → $N_n(E)$, $N_p(E)$

- Measure Pair yields wrt θ; to measure Γ_n/Γ_p unambiguously.
$\{Y_{nn}(\theta), Y_{np}(\theta)\}/Y_{nm} \equiv \{N_{nn}(\theta), N_{np}(\theta)\}$

- Seperate back-to-back(bb) and non-bb(nbb) kinematic events.

- Require back-to-back ($\cos\theta < -0.7$) condition.
→ to supress FSI and 2N-NMWD.

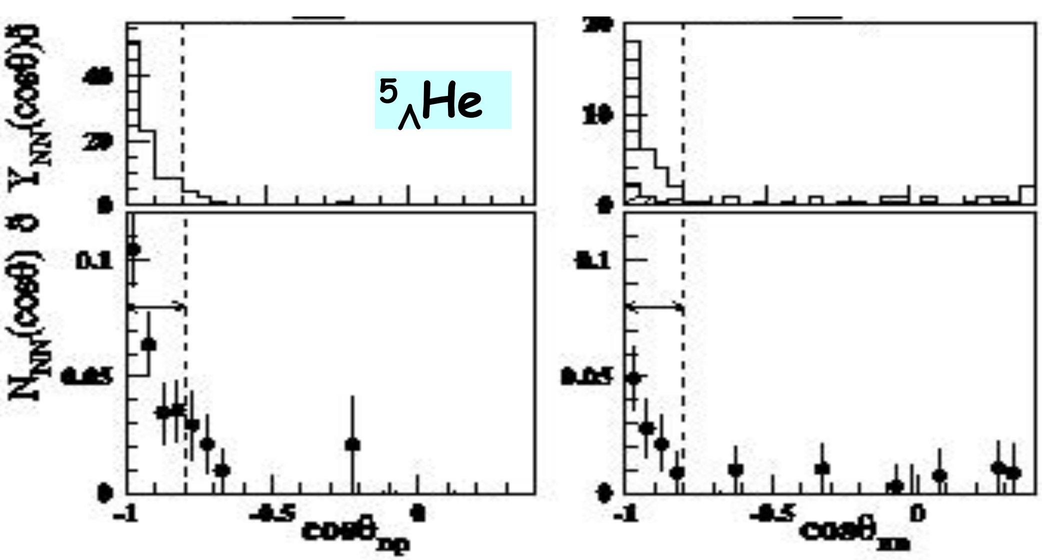
Coincidence Yields (NN angular correlations)



- bb ; $\cos\theta < -0.7$
- FSI/3-B broaden the angular corr.

$(N_{nn}/N_{np})_{bb} \rightarrow \Gamma_n/\Gamma_p$

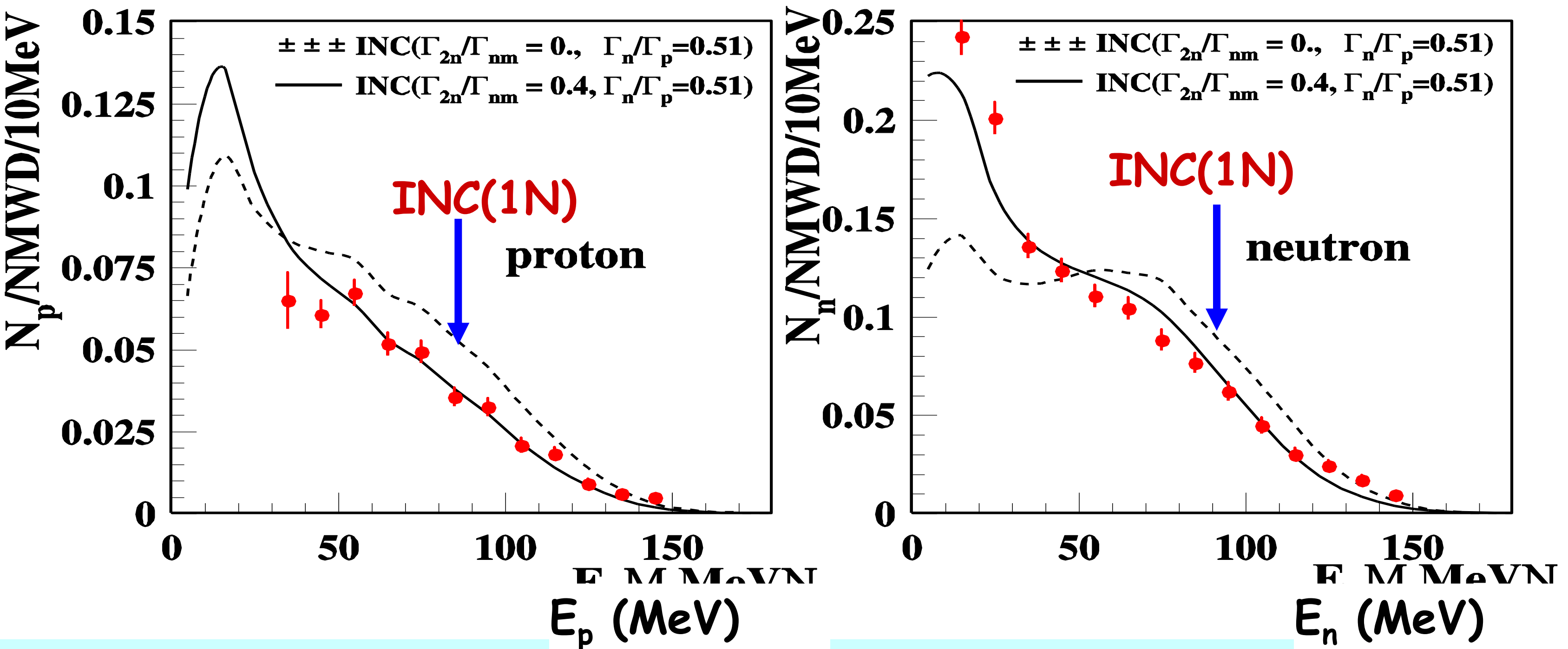
$\Gamma_n/\Gamma_p = 0.51 \pm 0.13 \pm 0.05$
M. Kim et al., PLB ('06)



$\Gamma_n/\Gamma_p = 0.45 \pm 0.11 \pm 0.03$
B.Kang et al., PRL 96 ('06)

1. Well agreed with those of Th.
2. Γ_n/Γ_p puzzle finally solved.
3. Why the exp. Γ_n/Γ_p ratio has been so high?

Quenching of Singles Yield



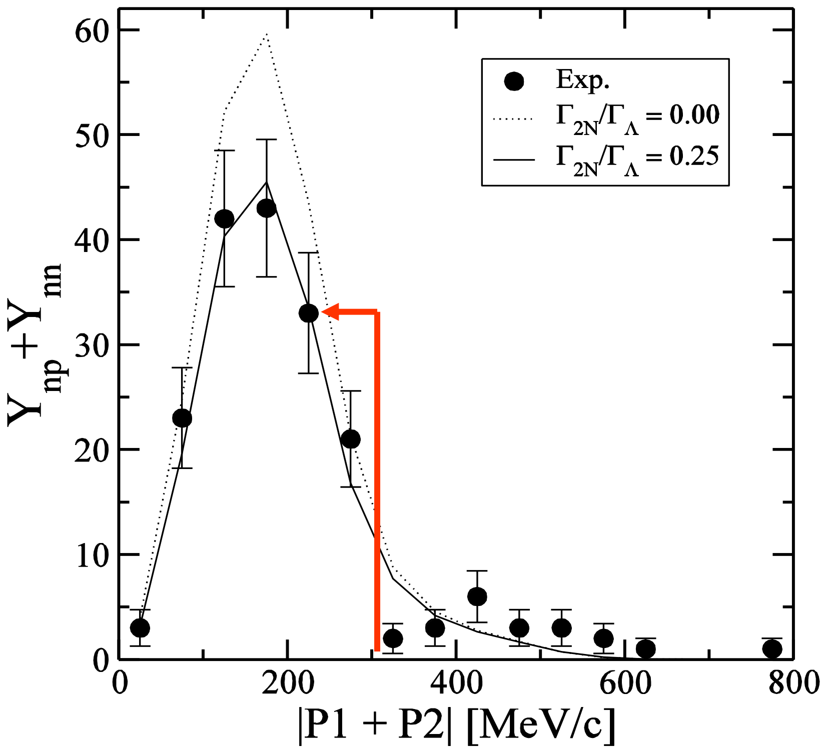
1. Quenching in both p and n spectra from those of INC(1N).
2. What would be the mechanism for the nucleon Quenching?

→ FSI & 3-Body process.

→ The 3-body NMWD (or 2N-NMWD) has been calculated first by Alberico-Ericson for Nuc. matter ('91). Then Ramos-Oset extended to finite nuclei ('94). Recently Bauer-Garbarino further extended it.

→ Γ_{2N} =~0.27 Γ_Λ ($^{12}{}_\Lambda C$)

Γ_{2N} and the quenching of yields



	Present Experiment
Γ_n/Γ_p	0.51±0.13±0.05
Γ_{nm}	0.95±0.04
b_{2N}	0.29±.13
Γ_{2N}	0.27±.13
Γ_n	0.23±0.08
Γ_p	0.45±0.10

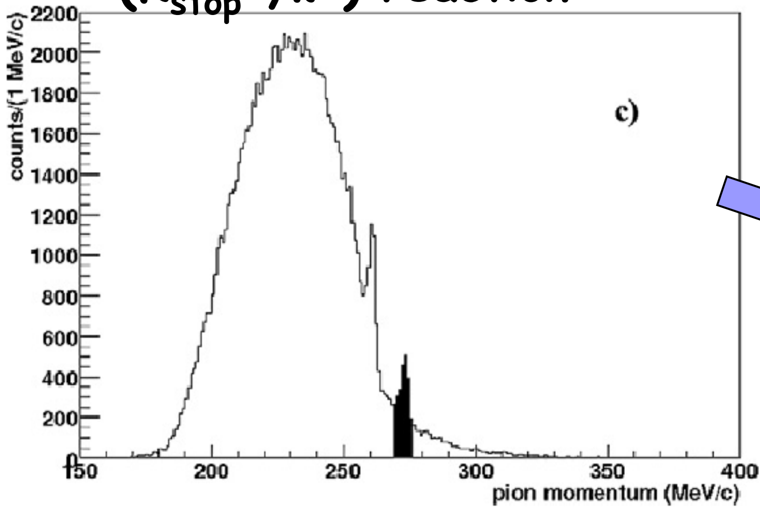
Phys. Rev. Lett. 103 ('09) 182502

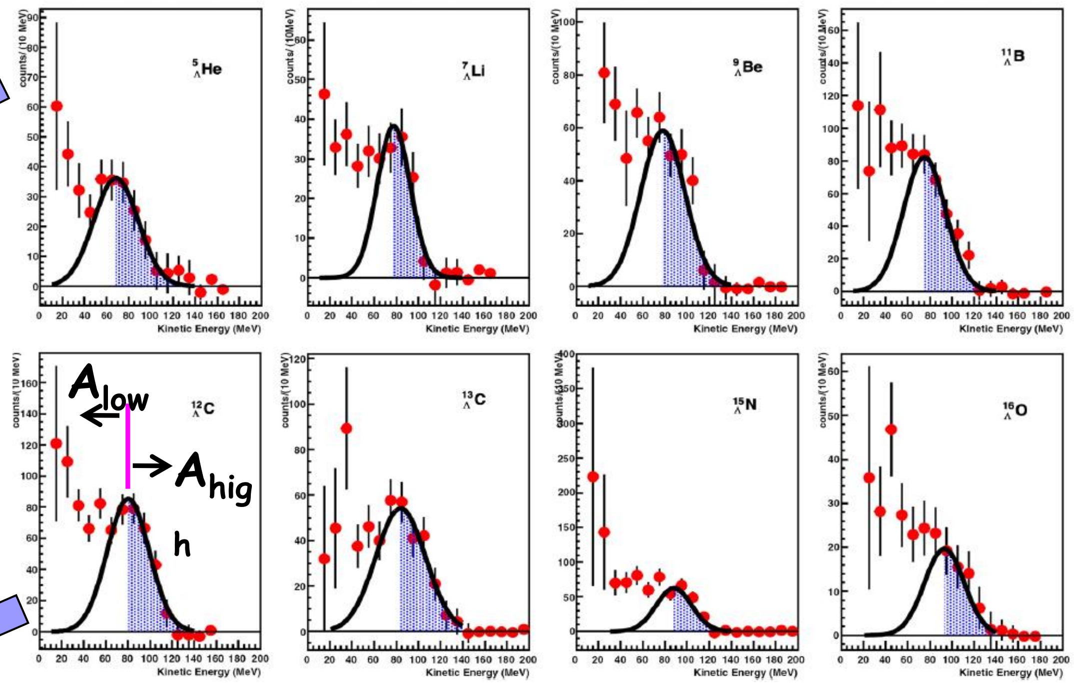
- **Total sum of the yields under 300 MeV/c is reproduced with the branching ratio, b_{2N}=0.29.**
- **$b_{2N} \equiv \Gamma_{2N}/\Gamma_{nm}$ =0.29±0.13**

- Errors are large, .25-.45.
- Need a better measurement.
→ E18 (J-PARC)

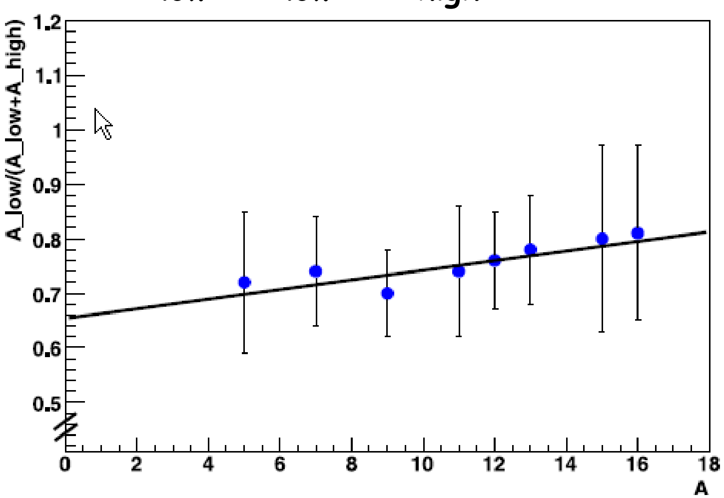
Γ_{2N} of Finuda experiment

(K_{stop}^{-}, π^{-}) reaction





Mass dependence of $A_{low}/(A_{low}+A_{high})$



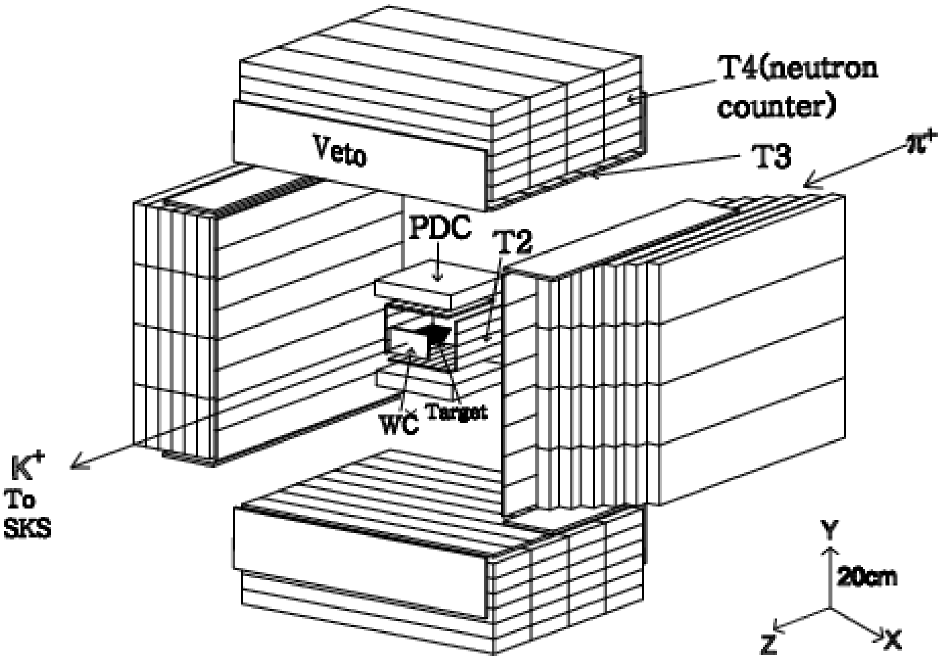
$\Gamma_{2N}/\Gamma_{nm} = 0.24 \pm 0.10$

Phys. Lett. B685 ('10) 247

- Though two results are consistent each other, both of them are extracted rather indirectly and have so large uncertainty that the confidence levels for b_{2N} are only those of 2σ.
- Need more direct and exclusive confirmation of 2N-NMWD and the accurate measurement of b_{2N}.

E18 Decay Counter Setup

J-PARC 50GeV E18

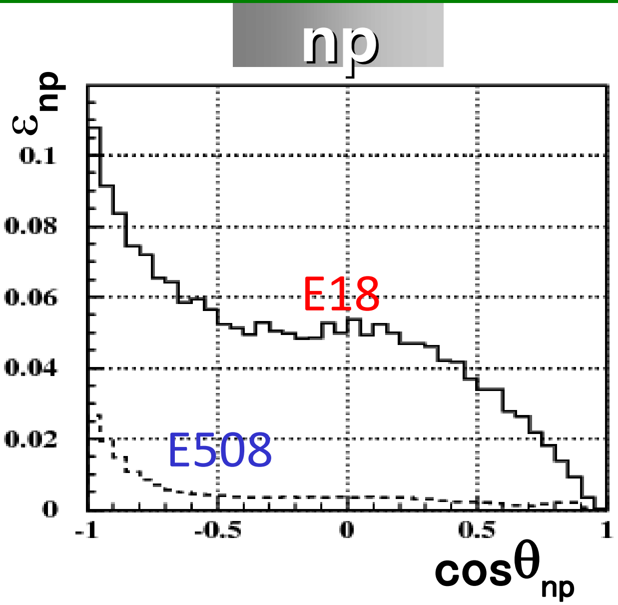


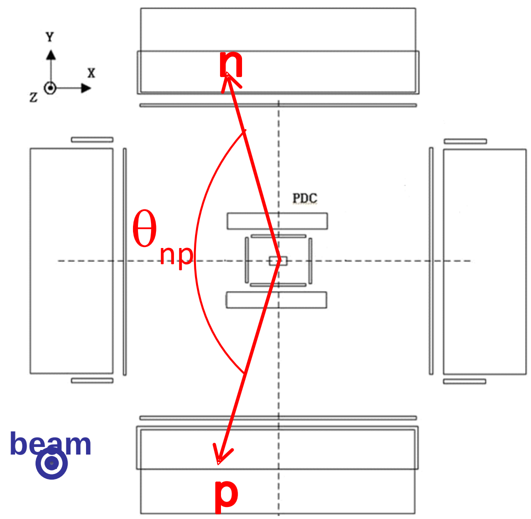
T4: 20 cm x 100 cm x 5cm
T3: 10 cm x 100 cm x 2cm
T2: 4 cm x 20 cm x 0.4 cm

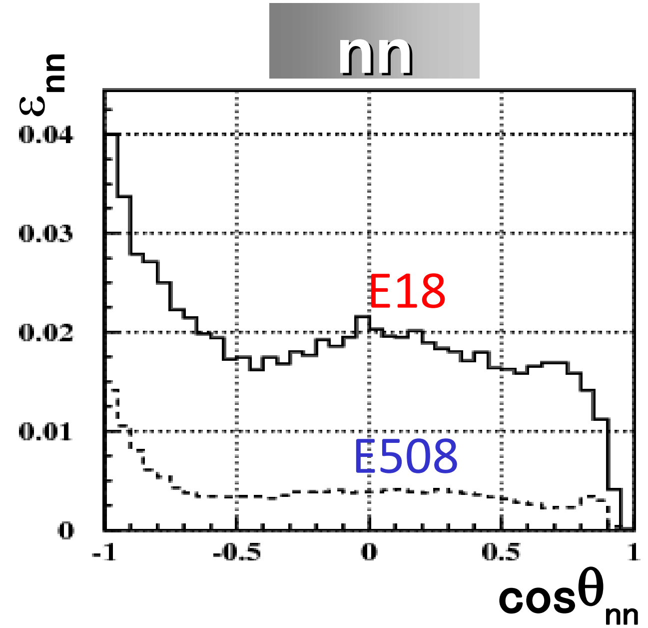
- Ω_n ~47 %
- Ω_p ~40%

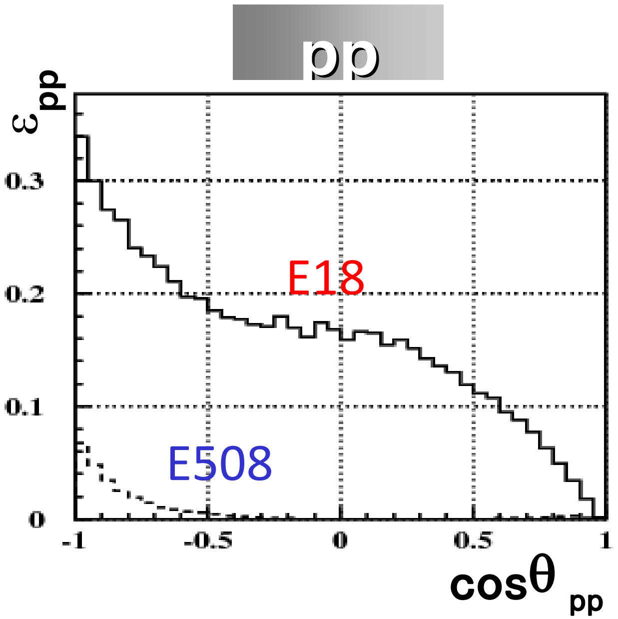
	E508	E18 (1st-step)
N_π tot	2T	0.8T
n_π/spill	4×10^6/4sec	2×10^6/6sec
d.f.	~1	~0.3
N_{np}(bb)	116	~320
N_{nn}(bb)	43	~60
N_{pp}(bb)	8	~51
N_{np}(nbb)	9	~43
N_{nn}(nbb)	16	~45
N_{NNN}	6	~52

E18 Decay Counter pair nucleon detection efficiency

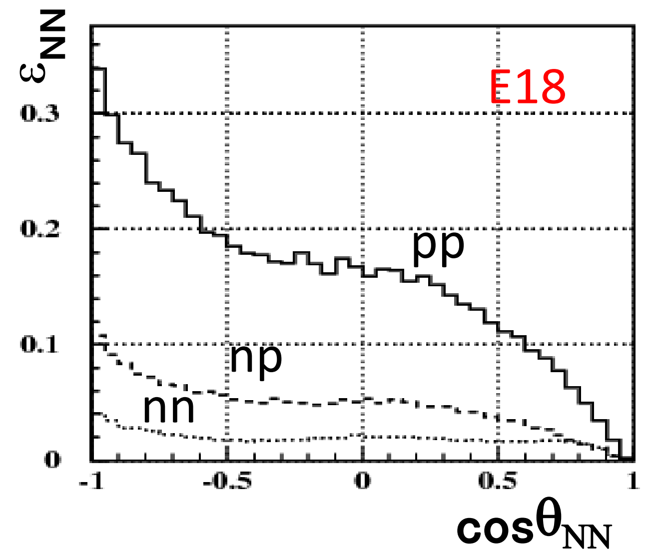






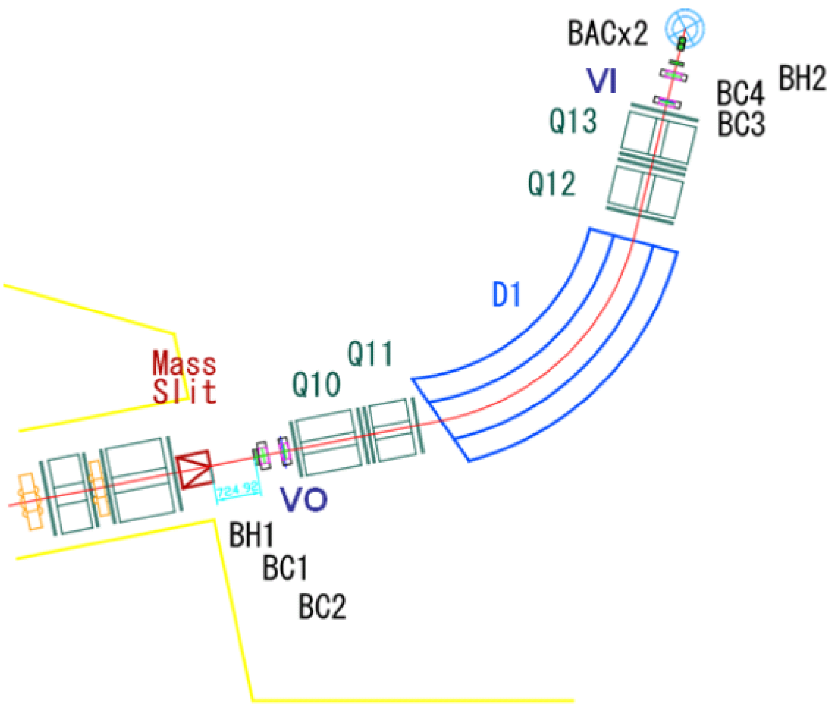


Double coincidence eff.
at E_N=75MeV
→ Much increased!!!!!!!!



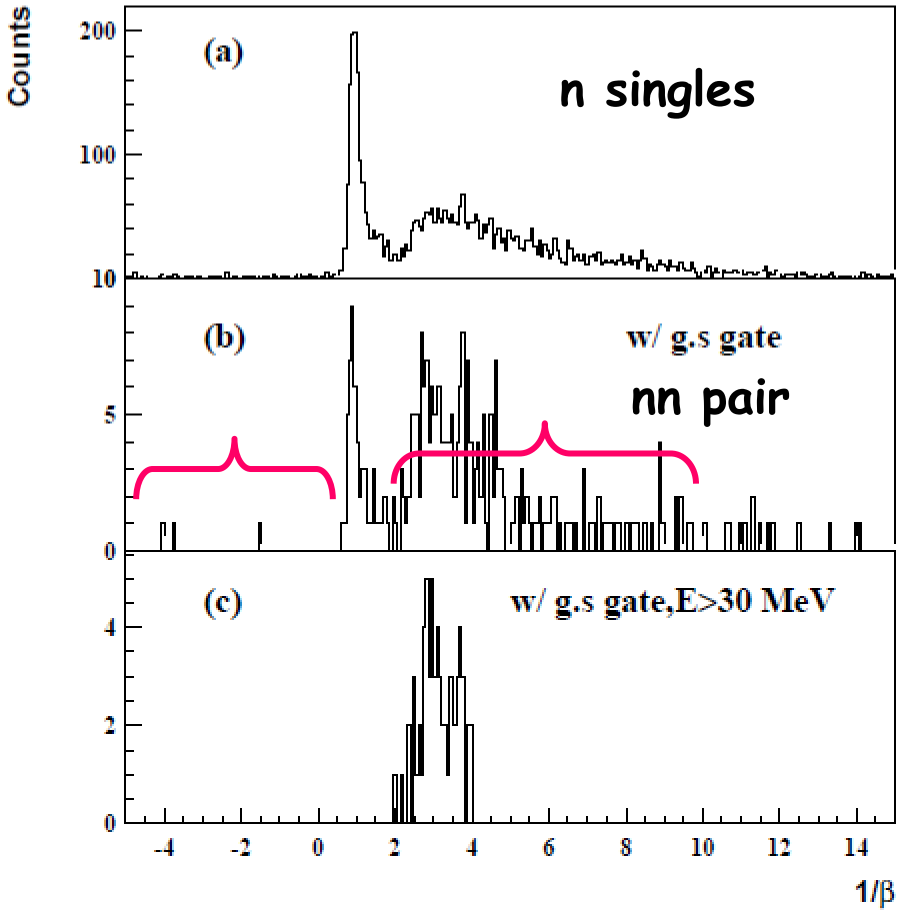
Technical Issues;
High rate capabilities of Beam line detectors.

- Original run;
  - High Beam intensity;
    - ~$5 \times 10^{6}\ \pi^{+}/s$ (~$10^{7}\ \pi^{+}/2s$(spill))
- To meet this high beam intensity,
  - BDC(1-4) ; - 1/1/3/3 mm wire spacing.
    - BDC4 needs further consideration.
  - SDC(1,2) ; 1mm chambers.(Osaka coll.)



- In '10 autumn run, all beamline detectors (BDC, SDC) were working fine with $1 \times 10^{6}\ \pi/2s$ spill(10% d.f.) beam, which corresponds to
  - ~$5 \times 10^{6}\ \pi^{+}/s$ (100% d.f.) = $10^{7}\ \pi^{+}$/spill
  - ~$1.5 \times 10^{6}\ \pi^{+}/s$ (30% d.f.)= $3 \times 10^{6}\ \pi^{+}$/spill
- All SKS detectors are ready except A(erogel)C, for which a new wider acceptance AC will be installed by the Osaka collaboration in this month.

Neutron random background;
E508 Neutral particle TOF spectrum



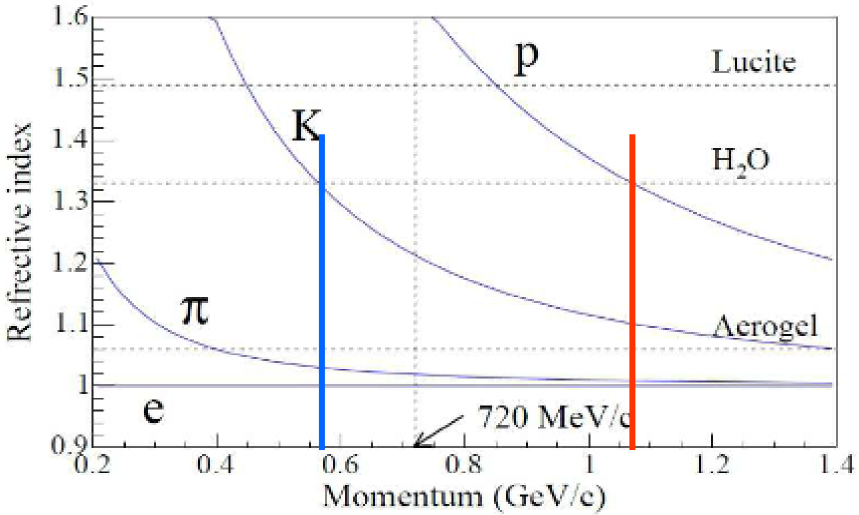
~2% nn background

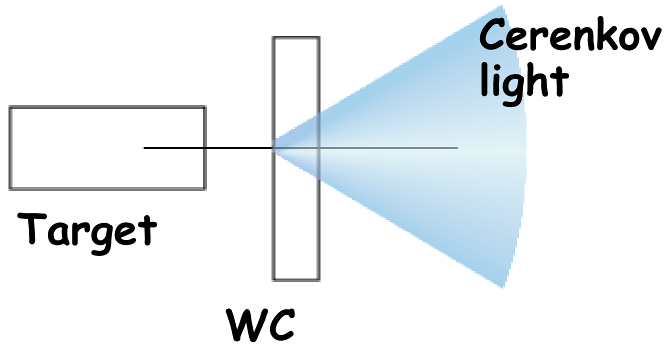
Neutron Backgrond

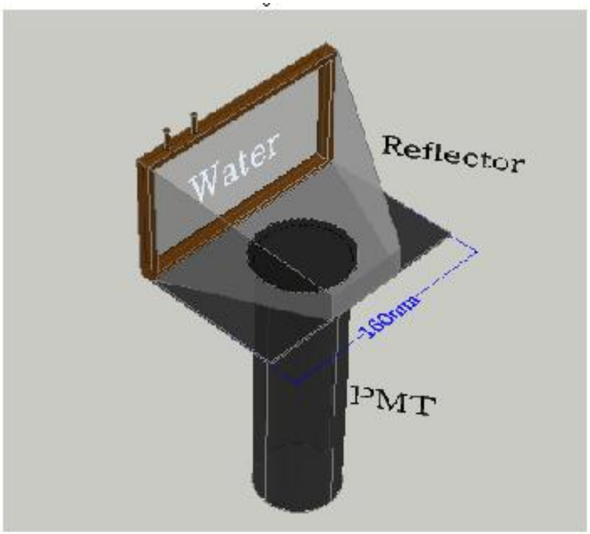
	E508	E18_org	E18(1^{st}-step)
Instant beam rate	4M/1.8s =2.2 M/s (* df~1.0)	10M/1.8s=5.5 M/s (* df~1.0)	2M/(2×0.3)s=3.3 M/s (* df~0.3)
n det. rate	1	1.8x5/2	1.8x3/2
nn random bg	1	$(1.8x5/2)^2$	$(1.8x3/2)^2$
nn Yields	1	1.8^2 x5/2	1.8^2 x3/2
Y_B/Y_{nn}	0.02	0.02x5/2=0.05	0.02x3.2 = 0.03
$(Y_B/Y_{nn})_{nbb}$	0.02x(13/16)/(16/59) =0.06 (* Y_{nn}(bb/nbb)=43/16)	=0.135 (with improved ε(nbb))	0.08 (* with improved ε(nbb))

- With 2 Mπ/spill and df~0.3, we can maintain the instant beam current and the random background rate below those of original E18 proposal.
- However, it is important to keep the neutron random background rate below the level of 2-3% of singles neutron. (Need n background check in the area.)
- We can maintain the σ_{bg} below 10% level with a similar neutron background.

Trigger rate;
A WC counter to reject proton



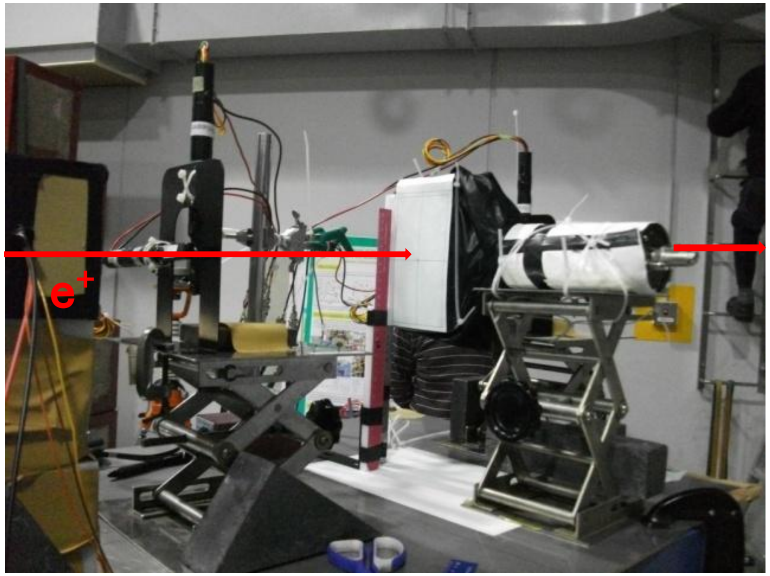


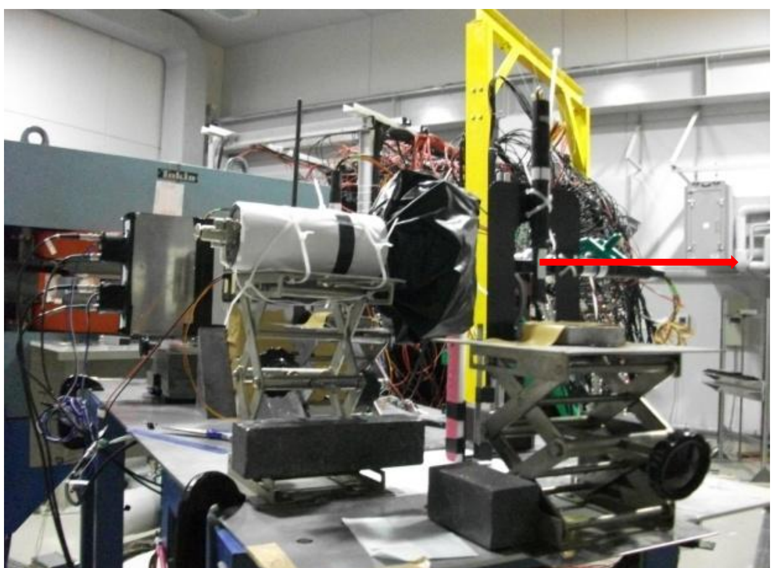


1 mm thickness Water C.

- R_{tot}~270/spill
- $R_{\pi K}$ ~150/spill
- Need to maintain $R_{\pi K}$ but increase the real K trigger.
- Most of the K trigger was proton.
- Need to remove p contamination.

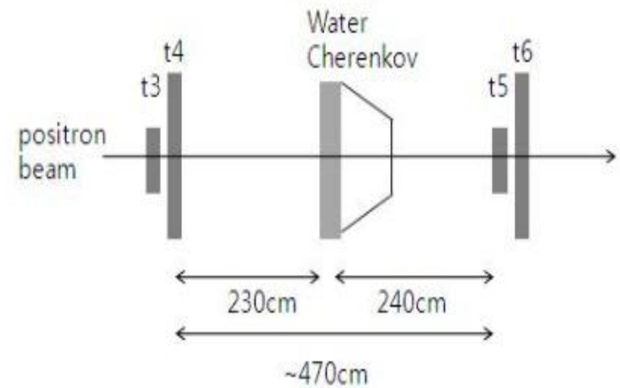
Test Exp. at the e-LINAC of Tohoku Univ.

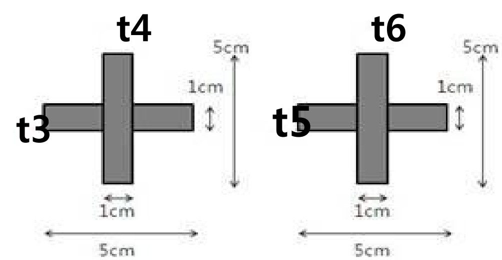




e+ 450MeV

β~1

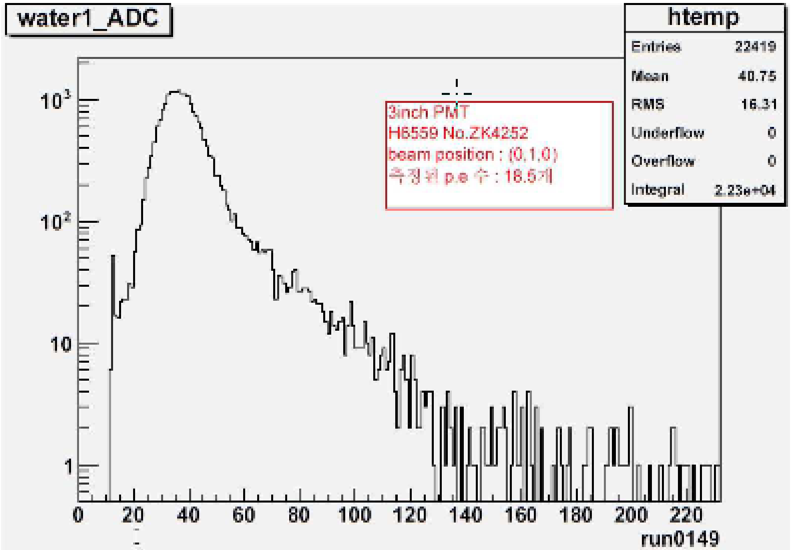


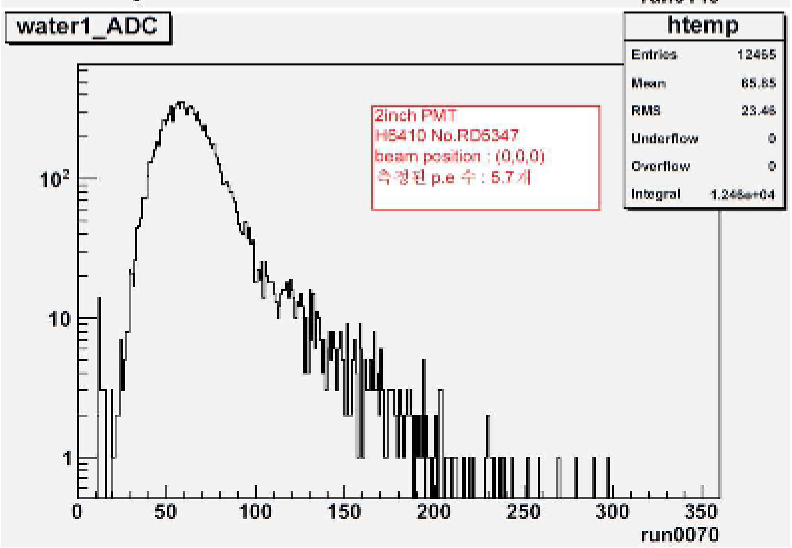


Beam Trigger: t3⊗4⊗t5⊗t6

Cerenkov light Trigger: BeamxWČ

WC light collected





- N_{pe}=18.6(3”), 5.7(2”)

  → This gives 7 pe for K so that an efficient WC counter can be made.

- The incident position and angle dependence varies down to 60%, but acceptable.

Decay Counter Status

Counters	Unit No. (cm)	Unit cost	Total cost	Purchased	To purchase	Inst.
Neutron	42(96) $(5 \times 20 \times 100)$	4000	168000	168000	0	SNU, Osaka U.
T2	20(20) $(0.4 \times 4 \times 30)$	2500	50000	0	50000	RIKEN
T3	12(32) $(2 \times 10 \times 100)$	3200	38400	24000	14400	SNU
Veto	8(8) $(1 \times 15 \times 100)$	2800	22400	22400	0	SNU
Water Ceren. C.	1(1) $(1.5 \times 8 \times 15)$		10000	7000	3000	SNU Kyoto U.
Target			5000	0	5000	SNU
Supporter			20000	0	20000	SNU
PDC	0(2)				Repairment	
Total			313800	221400	92400	

Collaboration

Institution	Members
Seoul National University	H.C. Bhang Seonho Choi Kiyoshi Tanida M.J. Kim C.J. Yoon
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Kyoto University	T. Nagae
Osaka Electrocommunication University	T. Fukuta
JAEA	Pranab K. Saha
Pusan National University	J.K. Ahn
Hanyang University	Y.K. Kim B.H. Kang
LNF(INFN)	S. Okada
GSI	Takehiko Saito

Physics Outputs and the Run request and Strategy

1. First-run ;
   - total 0.8×10^{12} $\pi+$ beam (70 shifts),
   - 3 kW,
   - 2×10^{6} π/2s(spill) with d.f.~ 30%.
2. Physics Output;
   - The direct and exclusive confirmation of b_{2N} with triple coin and N_{NN}(nbb).
   - A solid confirmation of Γ_{2N} of at least 3-4 σ confidence level.
   - N_{NNN} ~ 52(6), N_{NN}(nbb) ~90(35), N_{pp}(bb) >50(8).
3. These results can be published to meet the urgent need of a solid confirmation of 2N-NMWD of the weak decay research community.
4. The requirement can be met with a low power beam as low as 3 kW so that it would be a proper experiment in the initial stage of the commissioning. Since the beamline detectors, being developed in E10 experiment, are common to E18, it is prefered to run E18 following E10 spectroscopy experiment.