Exclusive Measurement of NMWD of $^{12}_{\Lambda}C$ and the Three-body Weak Decay Process

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I. Motivation of the Experiment (J-PARC E18)
II. Strong indications of 2N NMWD process.
III. E18 experiment;
IV. Summary

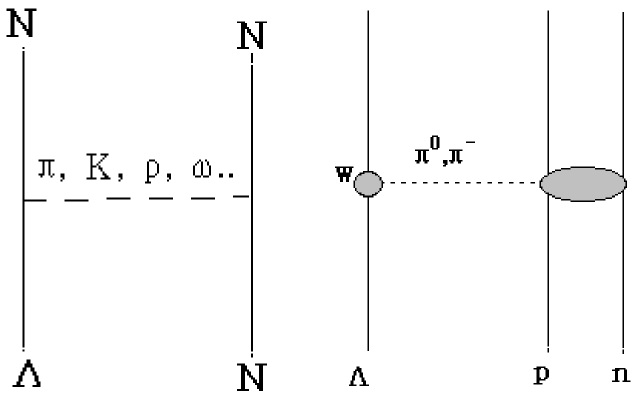
I. Decay Modes and Motivation

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

- Γ_m
  - Γ_{π^-} ($\Lambda \rightarrow p\pi^-$)
  - Γ_{π^o} ($\Lambda \rightarrow n\pi^o$)
  - Mesonic, q~ 100 MeV/c
- Γ_{nm}
  - Γ_p ($\Lambda p \rightarrow np$) (1N)
  - Γ_n ($\Lambda n \rightarrow nn$) (1N)
  - Γ_{2N} ($\Lambda NN \rightarrow nNN$) (2N)
  - Nonmesonic, q~ 400 MeV/c

Previous Searches

3-Body Process



(2N-NMWD)

- 2N NMWD; Predicted theoretically, but not exp. idendtified yet.

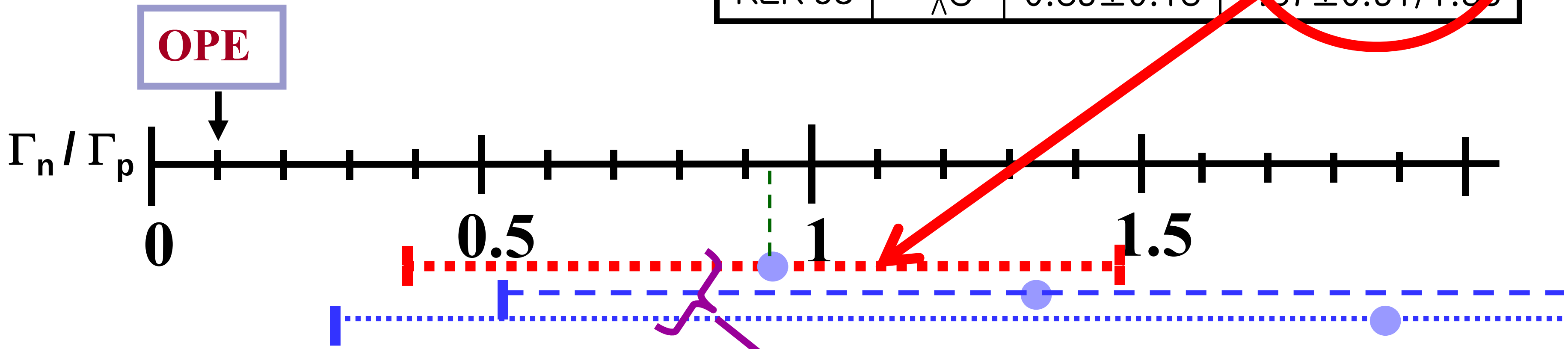
Γ_n/Γ_p puzzle and the previous searches

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



All these derived from p spectra

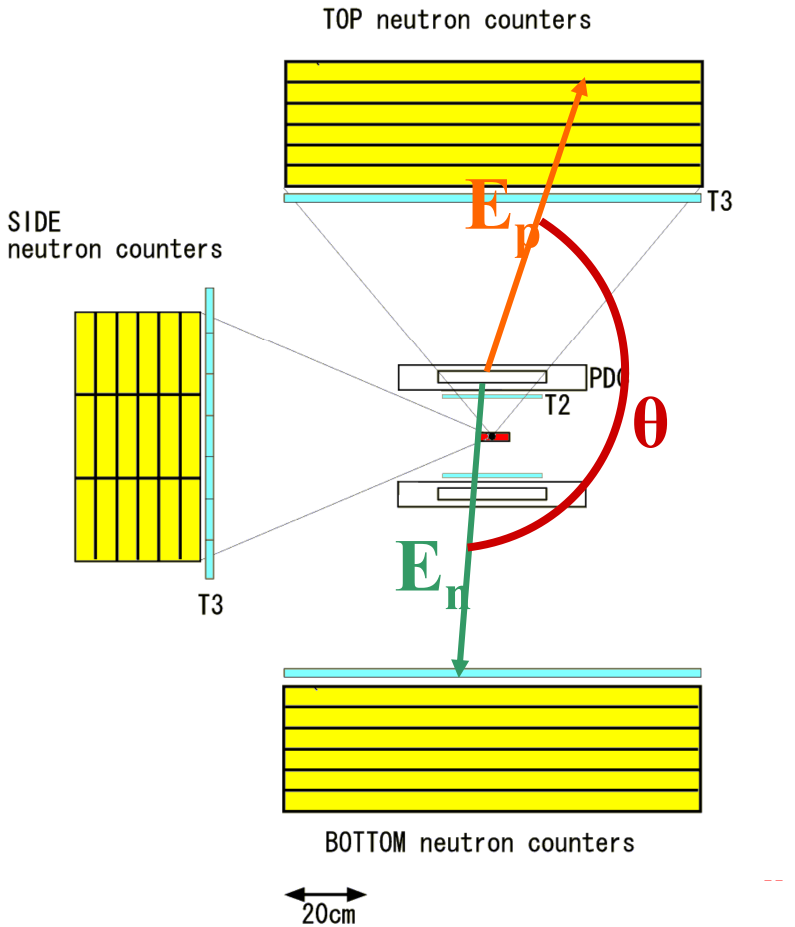
2. Recent Development of $\Gamma_n/\Gamma_p{}^{theory}$: 0.3 ~ 0.7

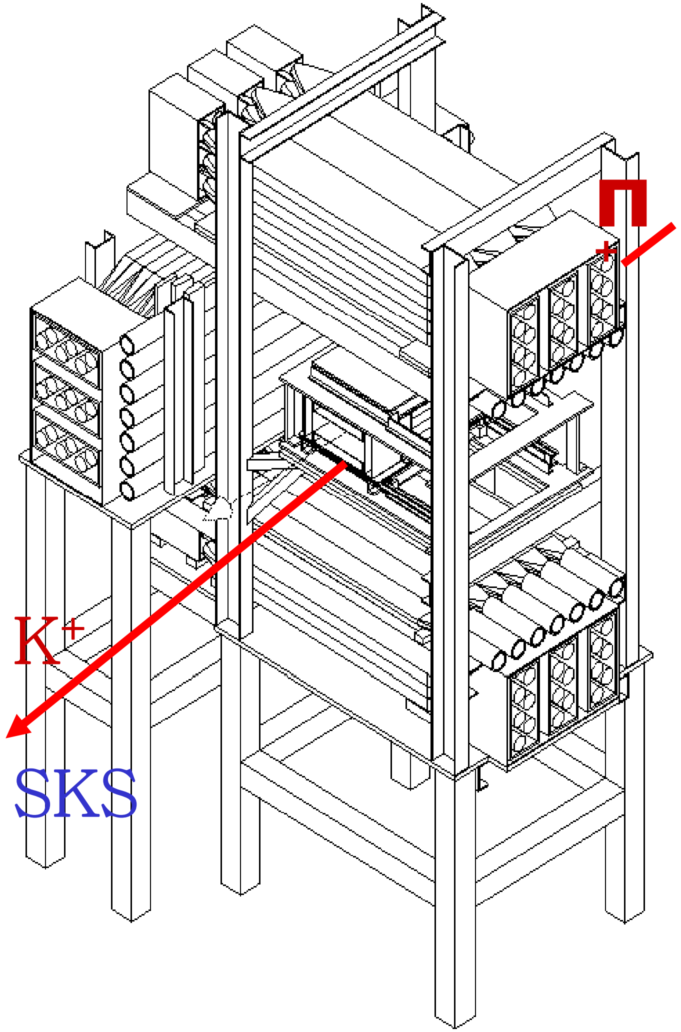
K.Sasaki (Direct Quark), Nucl. Phys. A669 (2000) 371

D. Jido (Heavy Meson Exc), Nucl. Phys. A694 (2001) 525

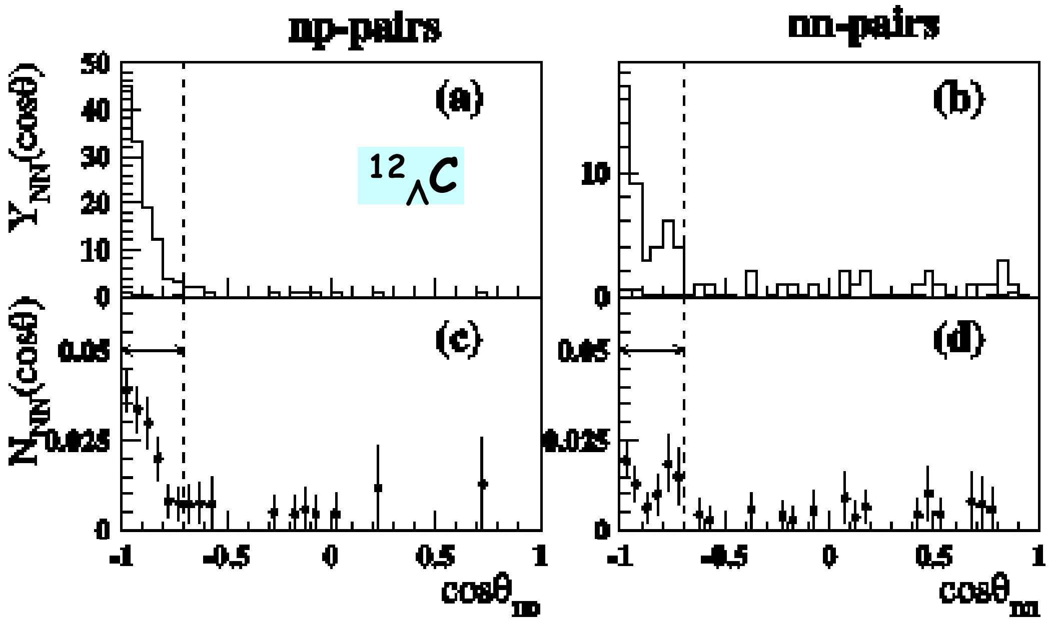
Coincidence Measurement (KEK-PS E462/E508)

To exclude FSI effect and 3-body decay in Γn/Γp and to identify 2N channel,
→ Exclusive meas. of each decay channel.



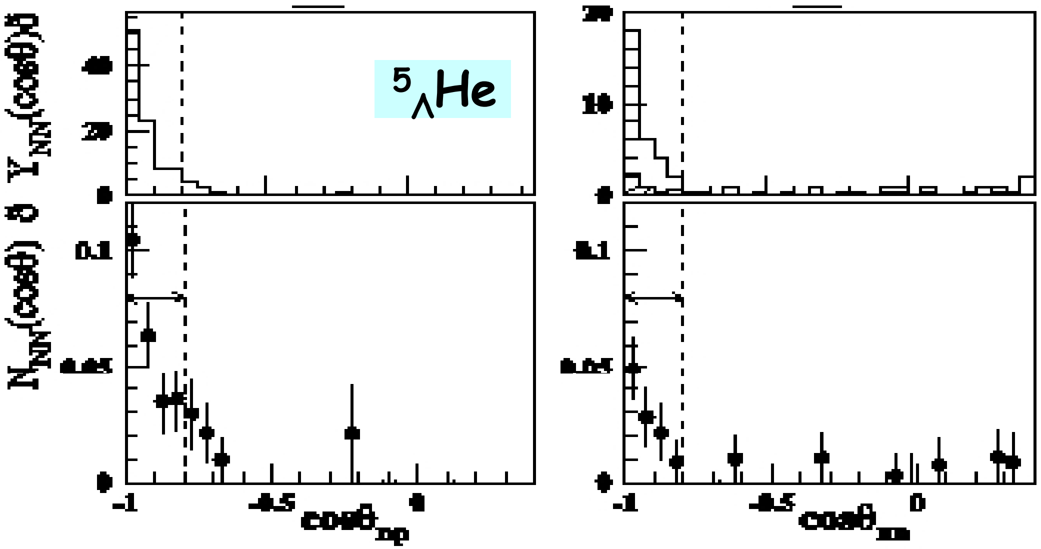


Coincidence Yields (NN correlations)



Γ_n/Γ_p = 0.51±0.13±0.0

M. Kim et al., PLB ('06)

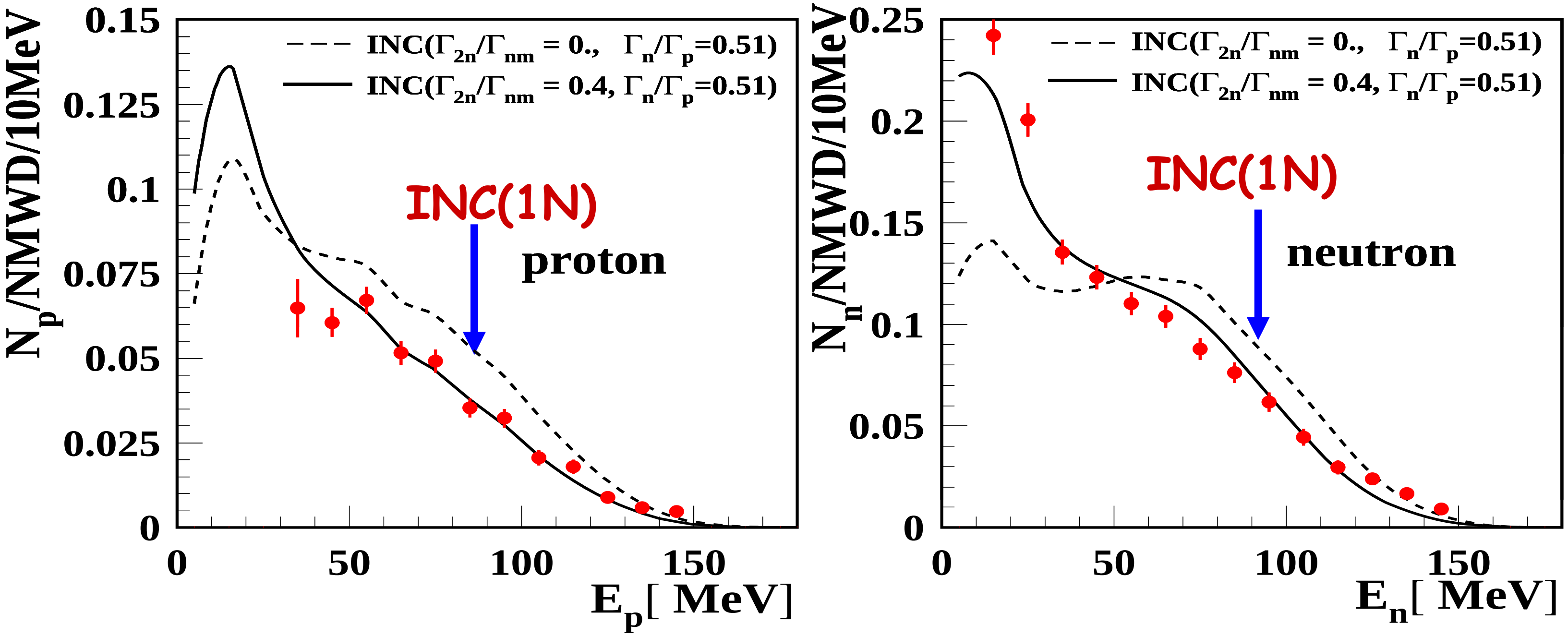


Γ_n/Γ_p = 0.45±0.11±0.03

B.Kang et al., PRL 96 ('06)

Nnn/Nnp ≈ Γn/Γp

Quenching of Singles Yield



1. Quenching in both p and n spectra from that of INC.
2. What would be the mechanism for the nucleon Quenching?
   → FSI & 3-Body process.
3. FSI ; n & p are indistingushable (isospin indep.) → HE similarity.
   LE behavior ; Cross over effect → LE enhancement in p expected.
4. Instead, What observed → LE enhancement in n spec.
5. What would be the source of the LE n enhancement???

Theoretical Prediction of 3-body process (Γ_{2N}) of NMWD.

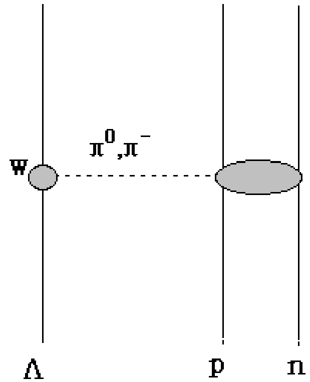
Ramos-Oset Model ;

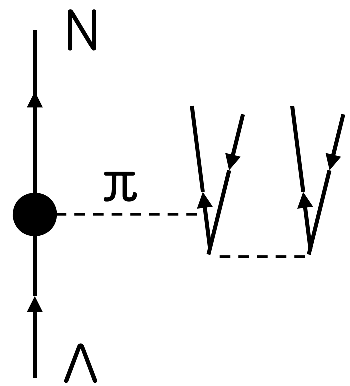
- Absorption of virtual pion by 2p-2h states.
- $\Lambda \rightarrow p\pi^-$ is dominant at the weak vertex and
- Pions are absorbed dominantly on the pn pair.

In the process 3 nucleons are emitted;

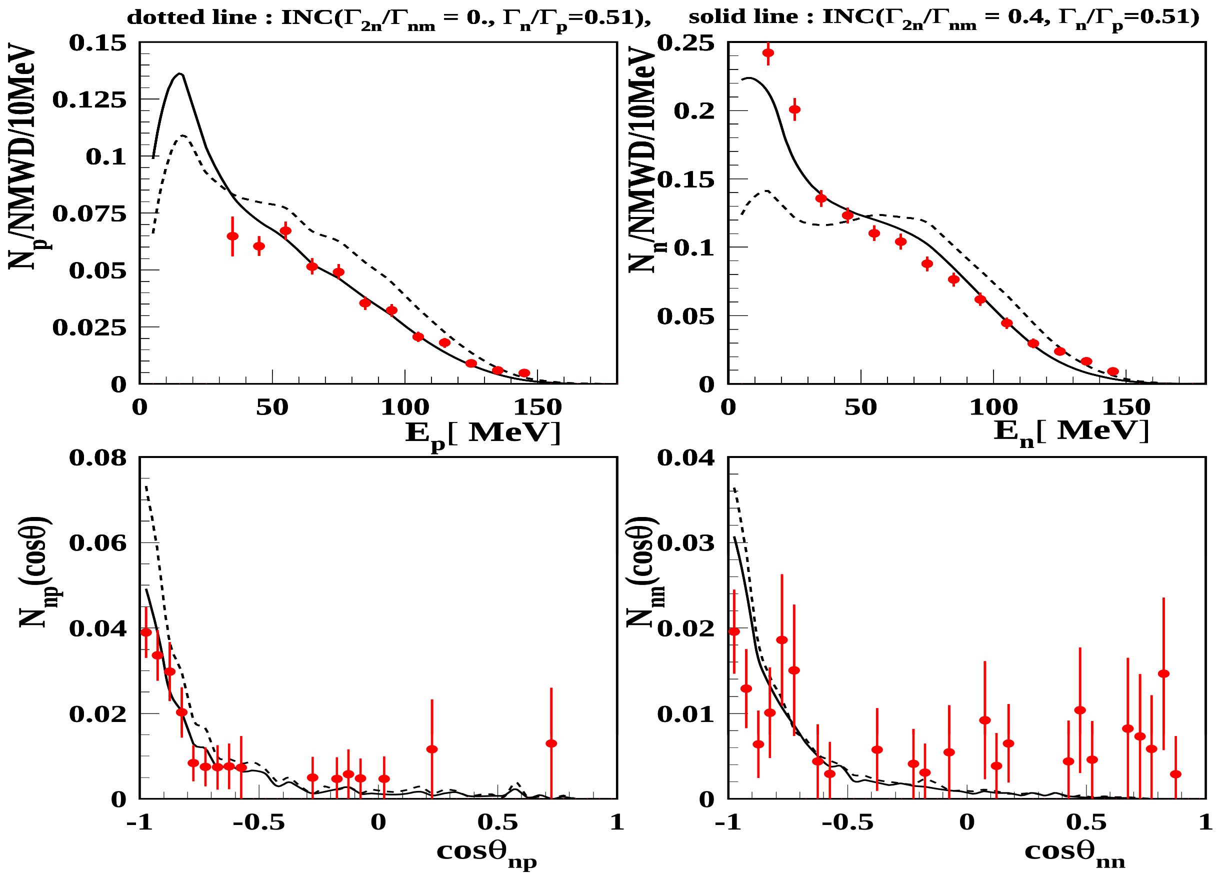
1p(LE) + 2n (HE)

- $\Gamma_{2N} \sim 0.2\ \Gamma_{nm}$





Singles and Coin. Yields Reproduction with INC.



For 2N-NMWD, we adopted the kinematics of uniform phase space sharing of 3 nucleons (Dalitz kinematics).

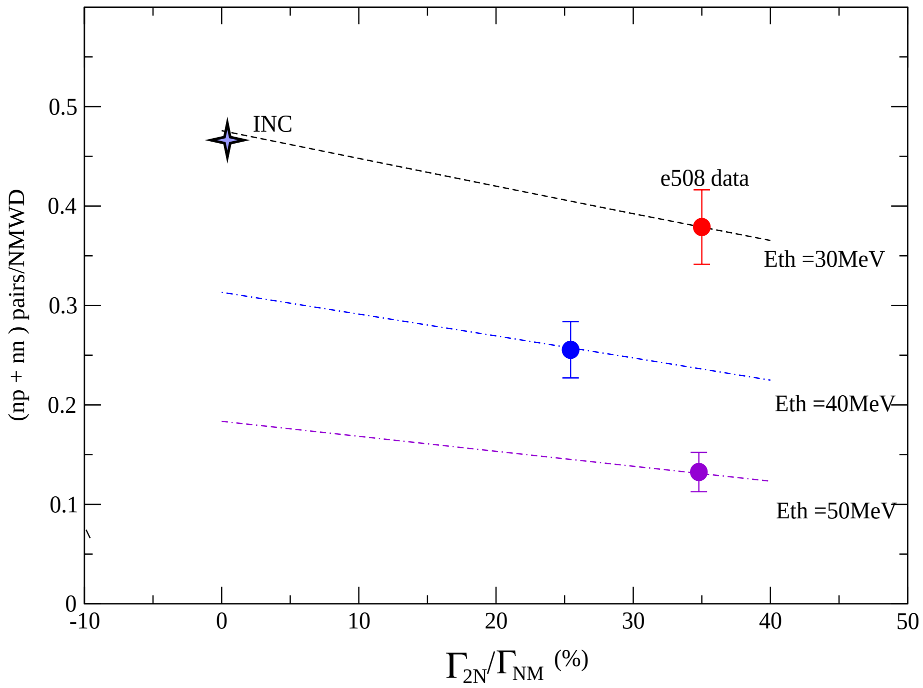
In order to explain the quenching,

$\rightarrow \Gamma_{2N}=0.4\Gamma_{nm}$

1. Singles Quenching
2. LE n enhancement
3. Pair Quenching

are reasonably well reproduced.

Quenching of Pair Yields



	N_{np}(bb)	N_{np}(nbb)	N_{nn}(bb)	N_{nn}(nbb)
E508	0.138 ±0.014	0.060 ±0.018	0.083 ±0.014	0.083 ±0.014
INC (1N only)	0.229	0.084	0.117	0.045

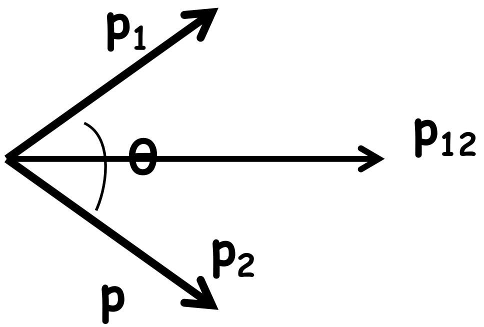
	N_{NN}(bb)	N_{NN}(nbb)	N_{NN}(all)
E508	0,221 ±0.020	0,143 ±0.023	0,363 ±0.031
INC (1N only)	0.346	0.129	0.475
INC (Γ_{2N}=0.4Γ_{NM})	0.257	0.105	0.362

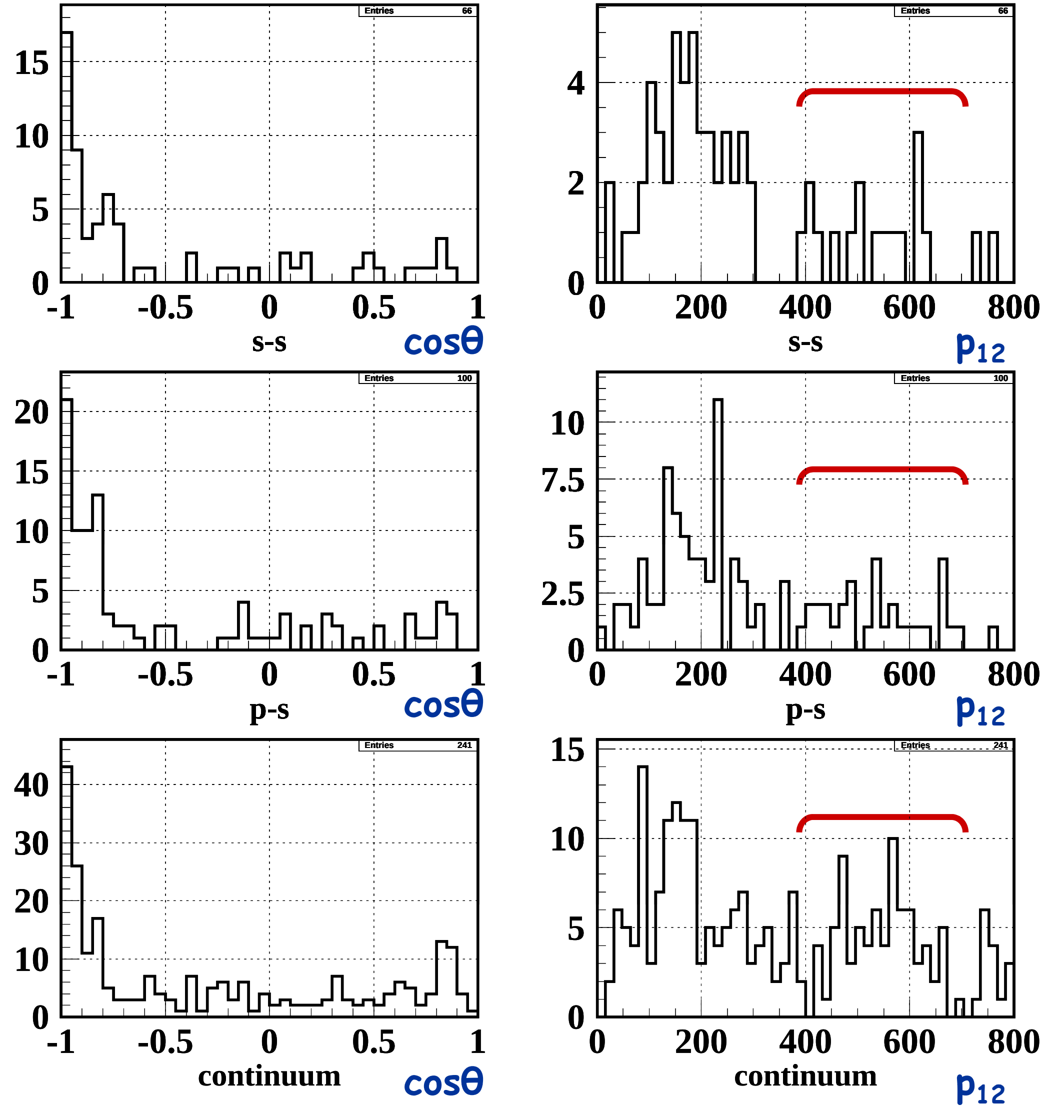
Though INC reproduce the N_{NN} including 2N-NM, but it has a difficulty to reproduce the nbb/bb ratio.

Momentum sum distribution.

- Missing momentum dist.
  - $|p_1+p_2| \equiv p_{12}$
  - Top fig.; $^{12}C(gs)$
  - Middle ; $^{12}C(1p)$
  - Bottom; $^{12}C(Continuum)$
- We observe two groups;
  - low mom(<350); 1N NMWD?
  - high mom(>350); 2N NMWD?

  → Here what we observe is the missing momentum.





Momentum sum distribution.

- Missing momentum dist.
  - Upper one; gs+1p
  - Lower one; gs+1p+cont

  We summed gs and 1p states to increase the statistics.

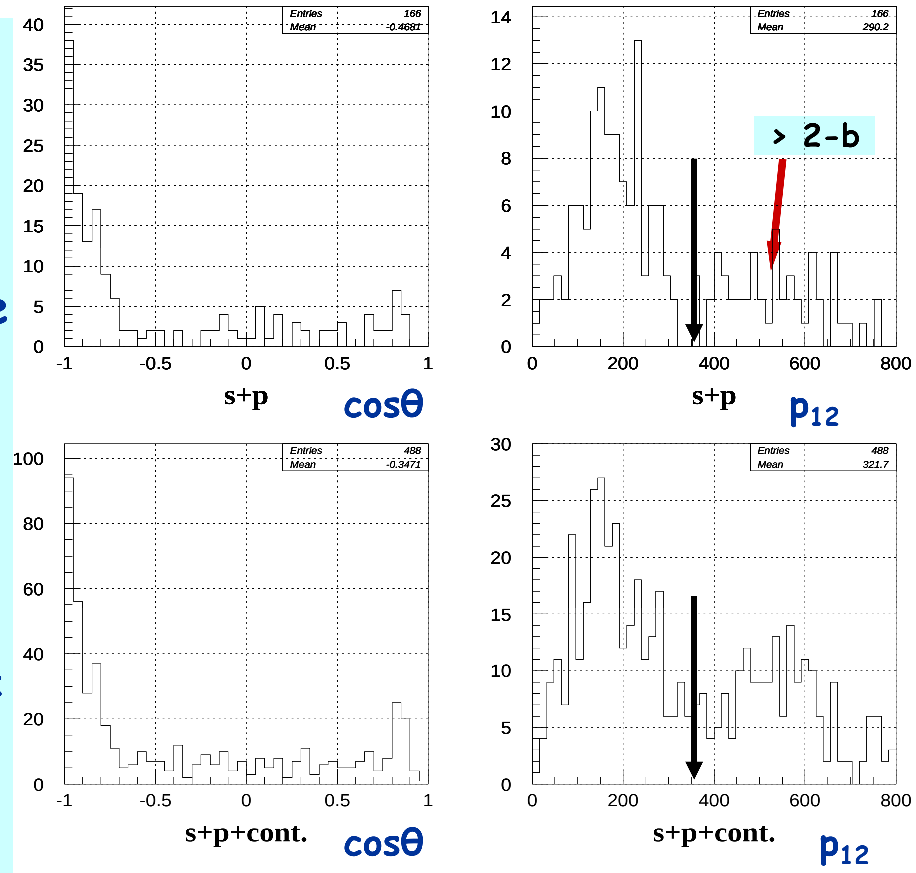
- Observation ;

  1. Two groups clearly shown; low mom (LMG) and high mom group (HMG);

     Low momentum group around 200 MeV/c

     is the 2-b process with Fermi mom.

- Question is "What is this HM group?"



Angular and Energy sum correlation gated to low and high momentum sum.

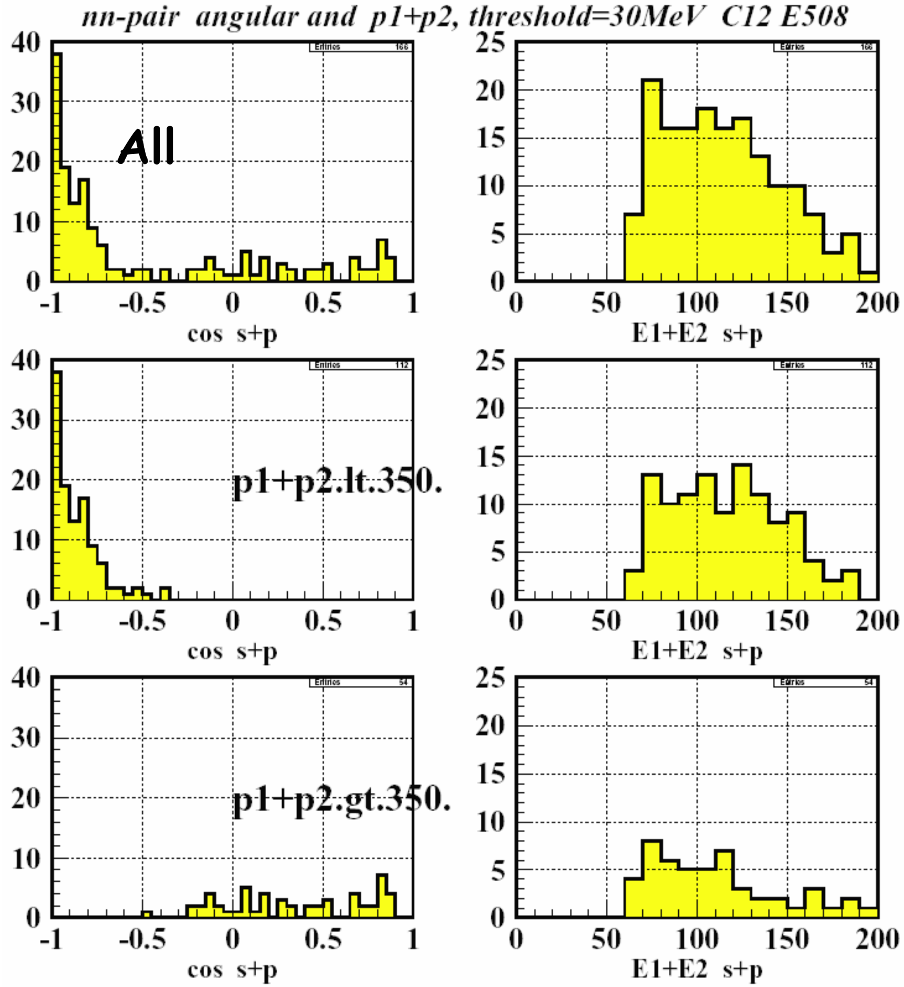
-Top ; all mom region

-Middle ; low P_{12}

-Bottom ; high p_{12}

- High p12 → nbb kin. Region
  & → large missing En.

- Indicates multi-body (>2) process.

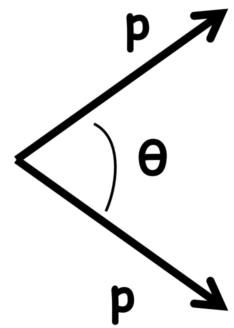


• It seems that not only the 3-body, but also many-body NMD exists. However, due to the statistics, at the moment it is not easy to show its existence convincingly.

• It is one of the main purpose to determine the contribution of 3-b process in the J-PARC E18. We now expect we also can study the many-body process.

Recoil Mass

- "What is this HM group?"



- For a rough calculation,

P_R=2p cosθ/2,

= 1.4 p for cosθ=0.

∴ p=500/1.4= 355 MeV/c,

E_n= 65 MeV

→ Q(145 MeV) - 2.*65 = 15 MeV, for 3-b NMWD,

Though the recoil momentum is high,

the recoil energy should be very small!!!

→ E_R = $P_R^2/2M$

=0.25/2*.94n =0.133, n=1 (X)

=0.044, n=3

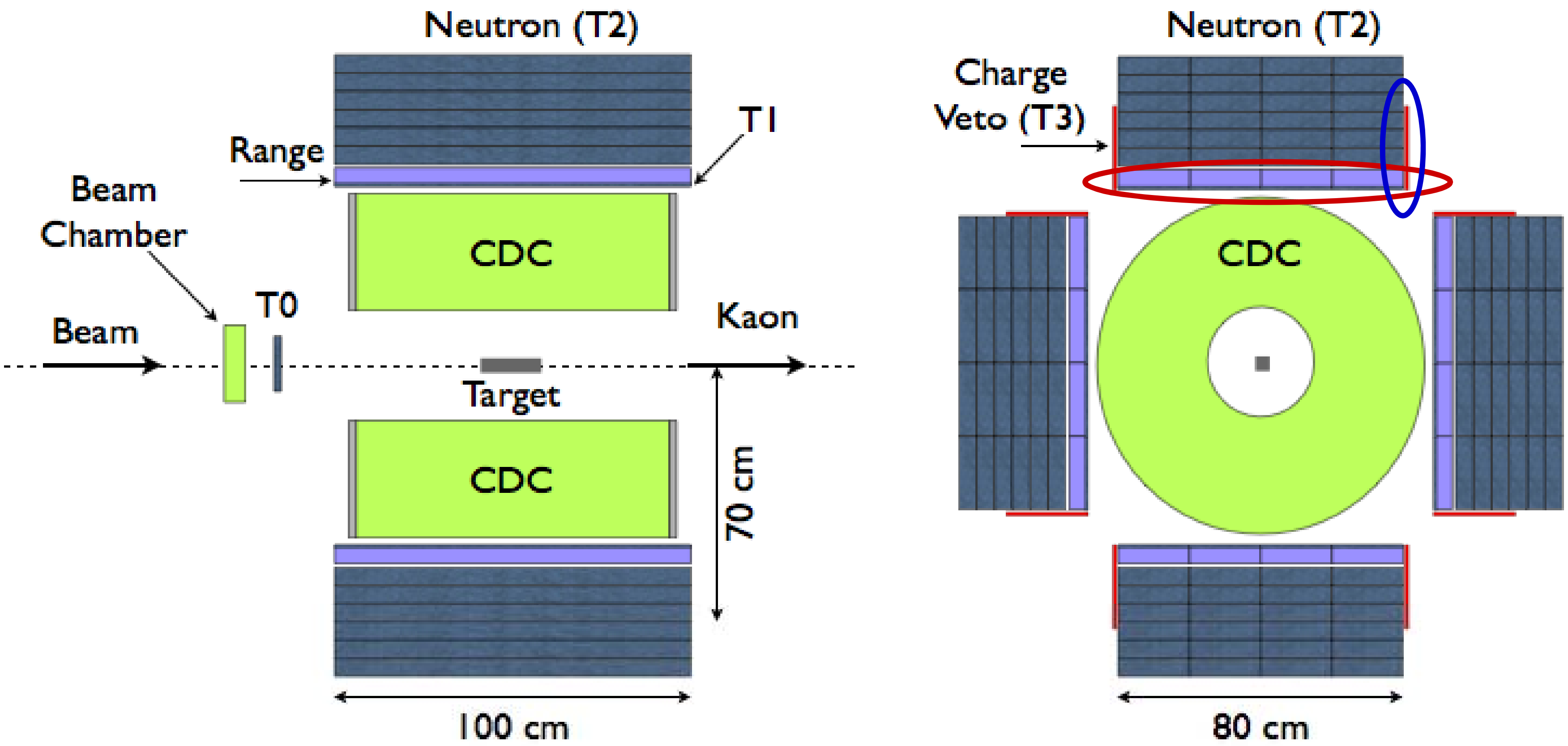
= 0.013, n =10.

All possible considering the error of high momentum neutron

II. Decay Counter Setup

Basic concepts are based on the setup of E462/E508 expeiments.

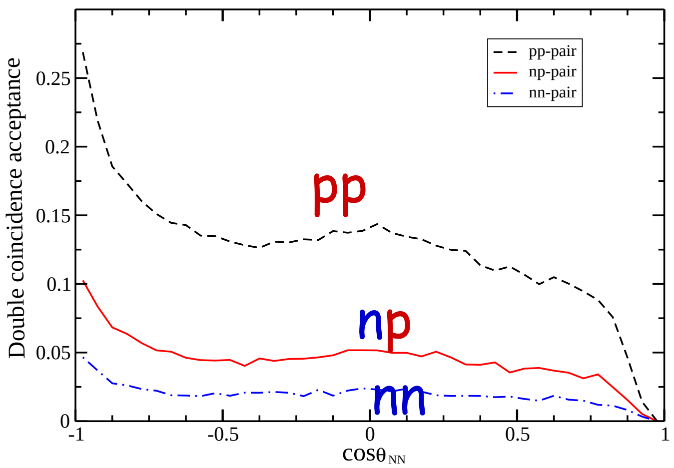
- CDC+T1(Timing for charged one)+T2(neutron)
- Side veto to reject passing through ptls
- Share most of the detection system with E22



Detection Efficiency of nucleon pairs and Expected Yields

	E508	E18
N_π	2×10^{12}	5×10^{12}
dN_π/dt	4×10^{6}/spill	10^{7}/spill
T(arget)	4.3g/cm^2	4.3g/cm^2
N_{HY}(g.s.)	~62K	2.5*62K
Y_{bb} (np)	116	~1160
Y_{bb} (nn)	43	~430
Y_{bb} (pp)	8	~90
Y_{nbb} (np)	12	~375
Y_{nbb} (nn)	23	~300
Y_{nnn}	3	(~45)
Y_{nnp}	2	(~80)
$\sigma_{stat}(\Gamma_n/\Gamma_p)$	28%	~10%
$\sigma_{stat}(\Gamma_{2N})$		~10%

bb: back-to-back
nbb: non-back-to-back



Proposal

- Main Objects :
  - To measure the 3-body decay process, namely Γ_{2N}, the 2-nucleon induced NMWD in 10% error level
  - To measure all decay widths of NMWD in 10% error level.
- Reaction : $^{12}C(\pi^+,K^+)$ at P_π=1.05 GeV/c with $10^7\pi$/spill.
- Spectrometer & Detector :
  - SKS Kaon spectrometer; 100 mSr.
  - Coincidence Detectors; 2π Sr
- Yield Estimation and Expected Results:

For 80 shifts,

- $N_{nbb}(nn)$ ~ 300 (23)
- $N_{nbb}(np)$ ~ 375 (12)
- $N_{bb}(pp)$ ~ 90 (8)
- N(NNN) ~ (125) (5)

Summary

1. Now after the Γ_n/Γ_p puzzle problem solved finally, the measurement of 2N-NMWD, 3-body decay process, is most urgent before we determine the more fundamental decay observables, Γ_n andΓ_p of NMWD.
2. The signatures of (2N)-NMWD processes were found both in the singles and coincidence data. All of them indicates fairly large Γ_{2N} comparabel to Γ_{1N}.
3. We still can not say much on each decay width of each channel of NMWD. It is because ot the large Γ_{2N} and its large error bar.
4. The experiment E18 (1st phase approval) is to determine;
   1) Γ_{2N} : The strength of 3-body decay proces 2) Γ_n, Γ_p ; have to determine their magnitudes.
5. We are working on the preparation of the experiment. Please join us.

J-PARC 50-GeV E18 collaboration

KEK, RIKEN, Seoul Univ.,Tohoku Univ., Osaka Univ., Univ. Tokyo, Osaka Elec. Comm. Univ.[G], Tokyo Inst. Tech., KRISS, Pusan N. Univ., Kyungbuk N. Univ.

J.K. Ahn, K. Aoki, H. Bhang, S. Choi, T. Fukuda, O. Hashimoto, S. Kameoka, B. H. Kang, J. H. Kim, M. J. Kim, W. Kim, Y. Lee, T. Maruta, Y. Miura, Y. Miyake, T. Nagae, M. Nakamura, S. N. Nakamura, H. Noumi, S. Okada, Y. Okatasu, H. Outa, H. Park,P. K. Saha, Y. Sato, M. Sekimoto, T. Takahashi, H. Tamura, K. Tanida, A. Toyoda, K. Tshoo, K.Tsukada, T. Watanabe, H. J. Yim