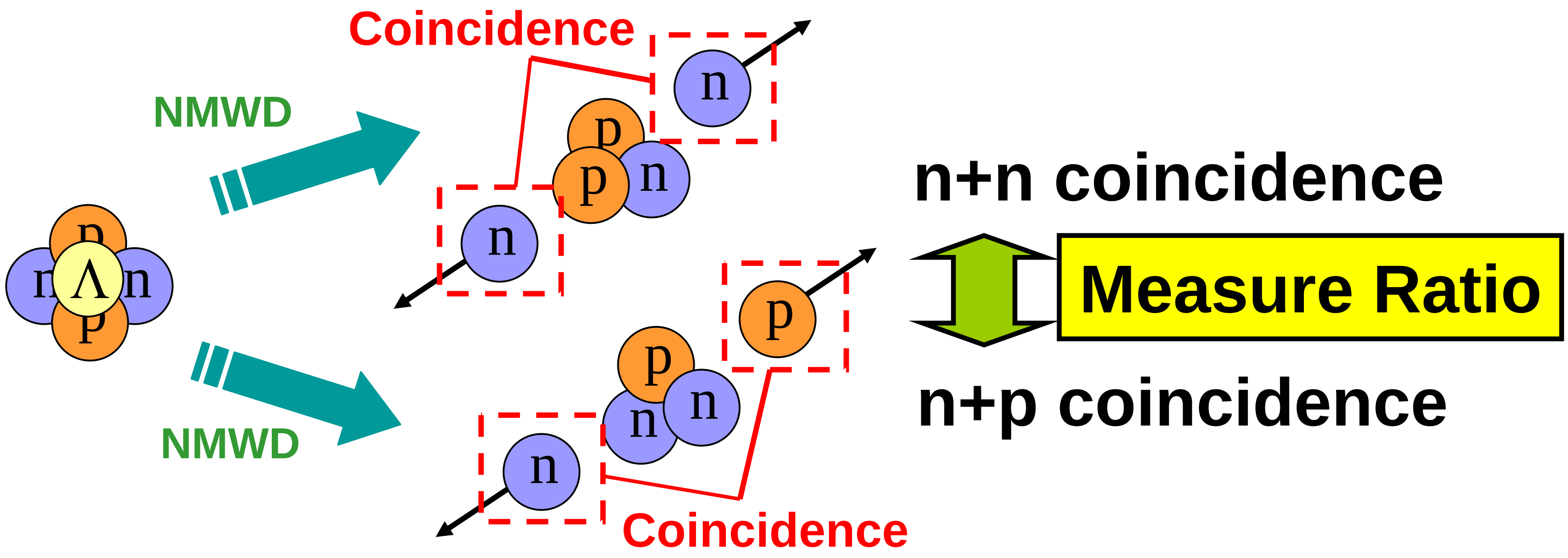
2003.10.14 HYP2003 (JLAB)

Hypernuclear Weak Decay experiments at KEK: n-n and n-p Coincidence Measurements

KEK-PS E462/E508 collaboration

H.Outa (RIKEN)



KEK-PS E462/508 collaboration

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Contents of my talk…

Hypernuclear weak decay measurements for $^{5}_{\Lambda}$He and $^{12}_{\Lambda}$C with ~ 10 times more statistics

- **n+n/n+p coincidence measurement**

  → **Energy/Opening angle correlation**

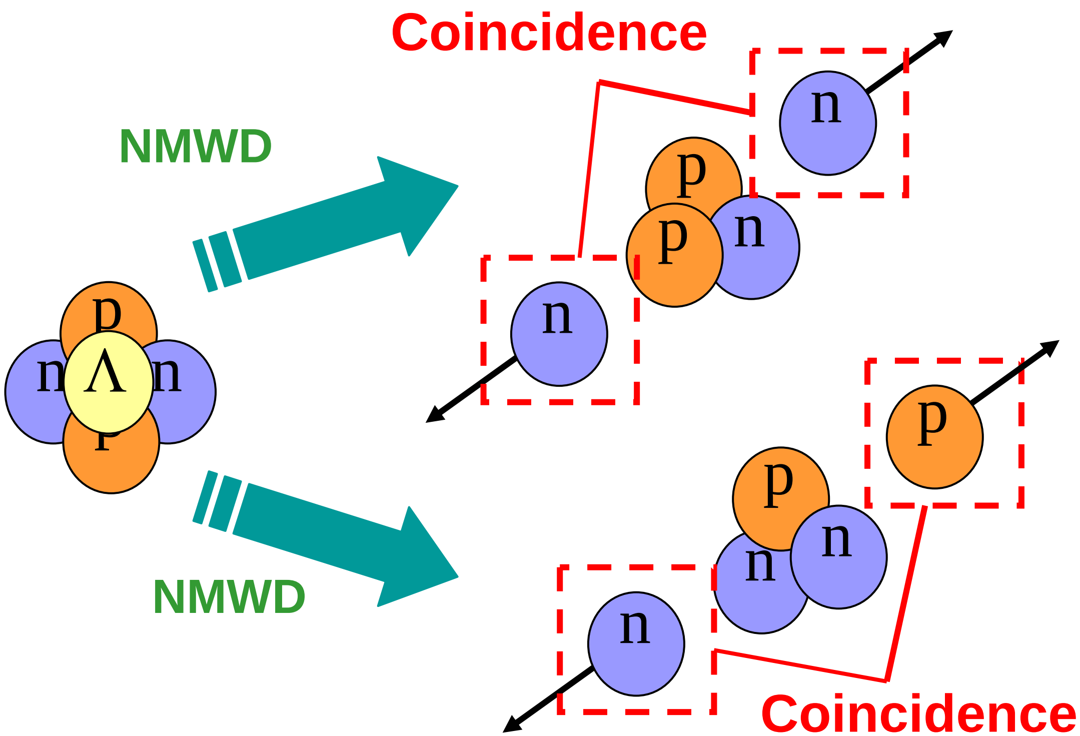
  $\Gamma n/\Gamma p\ (^{5}_{\Lambda}He) = 0.44 \pm 0.11 \pm 0.03$

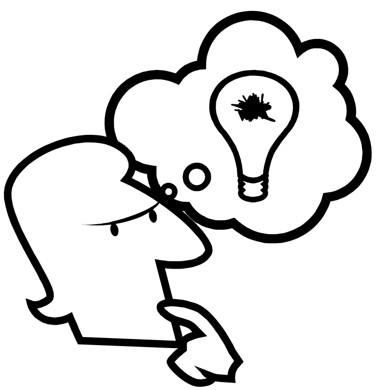
- **High accuracy measurements of $\Gamma\pi/\Gamma nm$**

  $\Gamma nm = 1/\tau * (1 - Br(\pi^-) - Br(\pi^0))$

  → **Overlap of Λ-α in $^{5}_{\Lambda}$He found to be large**

1. np/nn double coincidence detection from ${}^{5}_{\Lambda}He$ & ${}^{12}_{\Lambda}C$





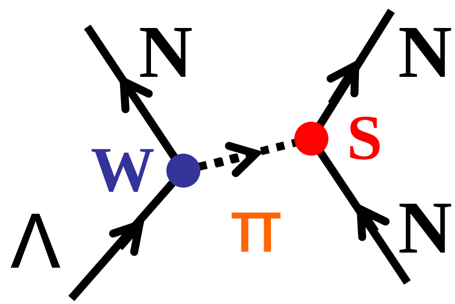
Motivation

Γ_p (Λ+"p"→ n + p)
Γ_n (Λ+"n"→ n + n)

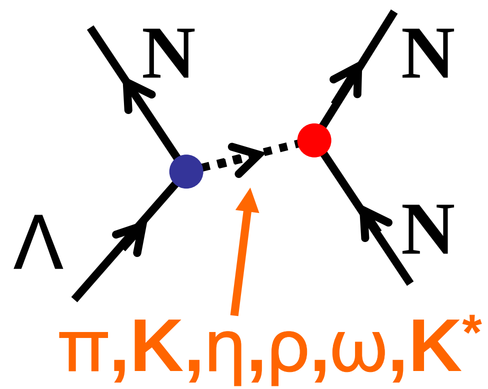
Γ_n / Γ_p ratio (theoretical & experimental results)

Theoretical

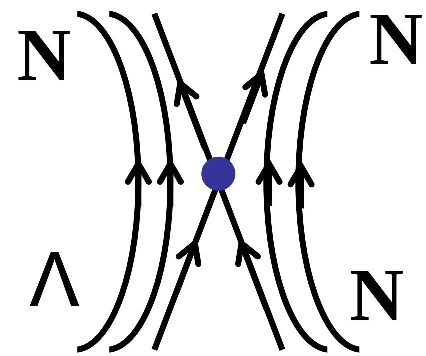
One Pion Exchange (OPE)

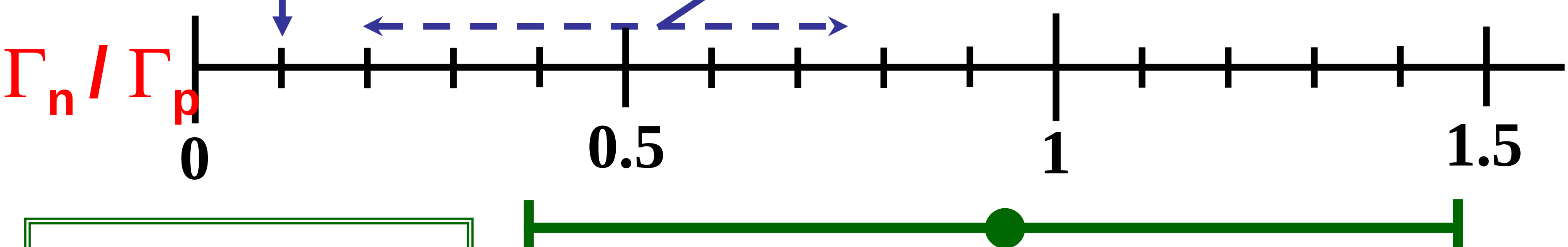


Meson Exchange mechanism



Direct Quark mechanism





Exp. (for $^{5}_{\Lambda}He$)

0.93±0.55 (Szymanski et al.)

Difficulty in previous experiment

N_p/N_{nmwd}

1. Γn from subtraction
   → missing process Γn/Γp ↑
2. Directly affected by the FSI loss/Γ_{2N}
3. Large error of Br(NMWD) from large Br(π^0) error

N_n/N_p

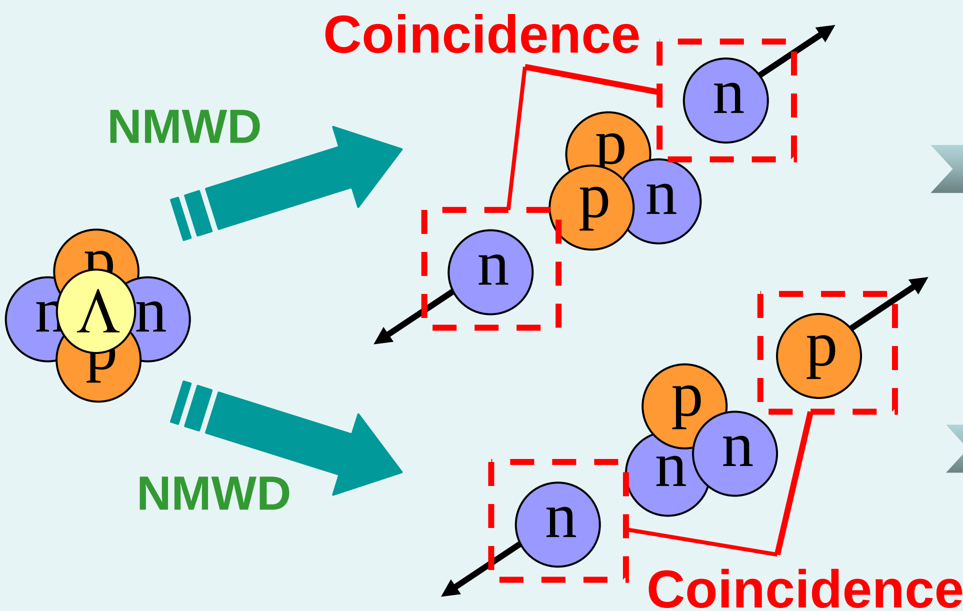
N_{nn}/N_{pn}

1. Measure neutron to obtain the number ratio at the "same" energy threshold
2. N_n/N_p → Γn/Γp less affected by FSI only in 2nd order; n/p→p/n influx term (Talk by Bhang)
3. Analysis requires assumption of Γ_{2N} ~ 0 → Is this correct??

Coincidence analysis

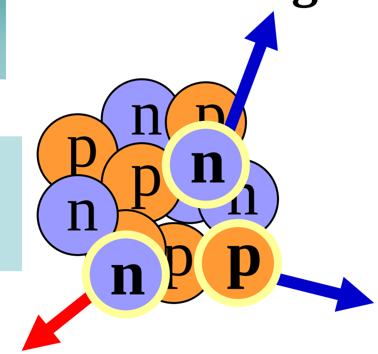
E462($^{5}_{\Lambda}$He) / E508($^{12}_{\Lambda}$C)

NMWD : ΛN→NN



1) **Angular correlation**
(back-to-back, cosθ<-0.8)
2) **Energy correlation**
(Q ~ E(N1)+E(N2) ~ 152MeV)

Final state interaction (FSI)



$$N(\Lambda n \rightarrow nn)\times(\Omega_n \times \Omega_n)_{av.} \times \varepsilon_n^2 \times (1 - R_{FSI})$$

$$N(\Lambda p \rightarrow np)\times(\Omega_n \times \Omega_p)_{av.} \times \varepsilon_n \times \varepsilon_p \times (1 - R_{FSI})$$

* cosθ< - 0.8
* E(N1)+E(N2) cut

$$\frac{\Gamma_n}{\Gamma_p} = \frac{N(nn - \text{pair coin})}{N(np - \text{pair coin})} \times \frac{\varepsilon_p}{\varepsilon_n}$$

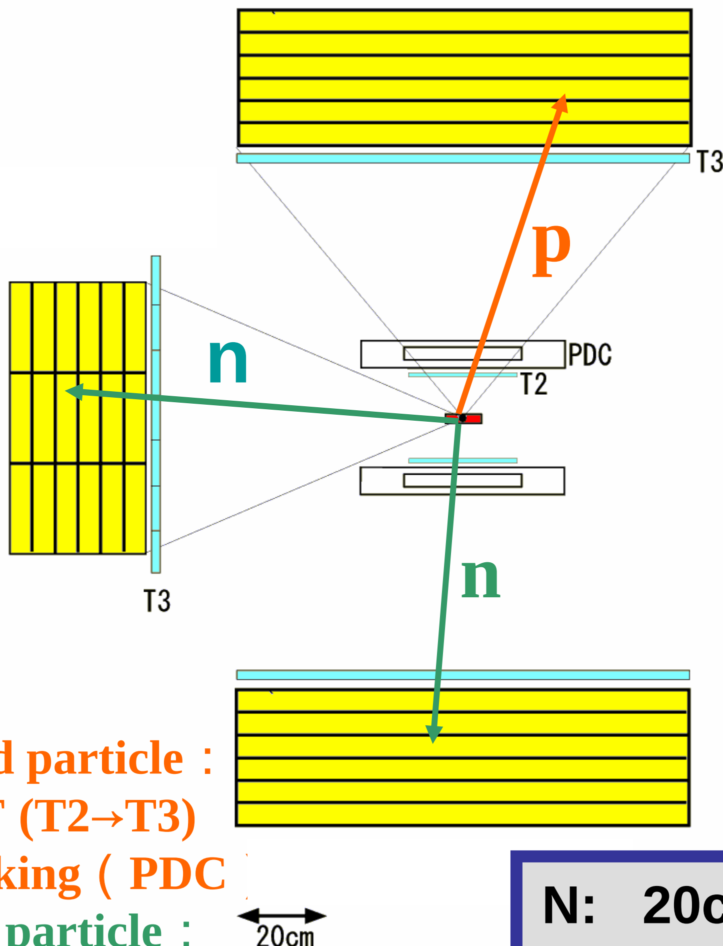
Select ΛN→NN events without ΛNN→NNN & FSI effect

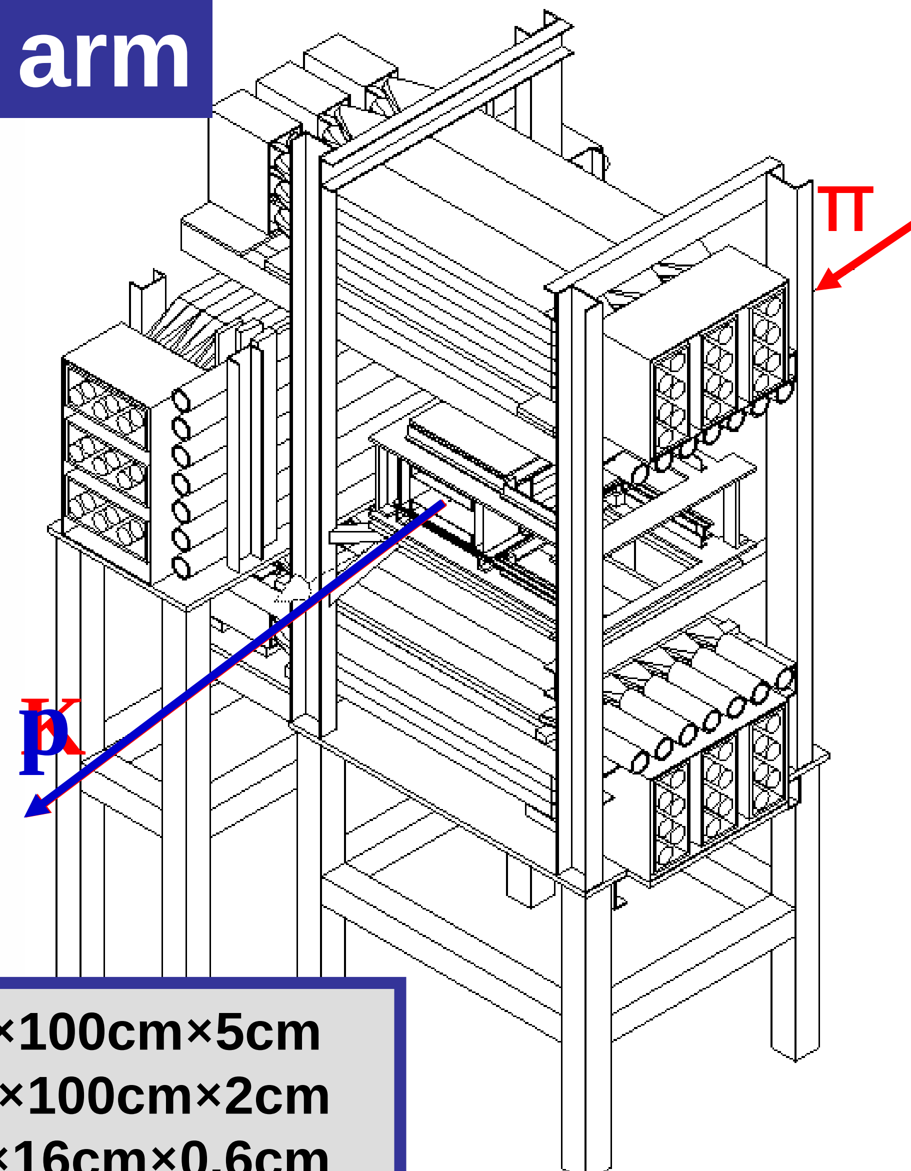
Setup

(KEK-PS K6 & SKS)

Decay arm

Solid angle: 26%
9(T)+9(B)+8(S)%



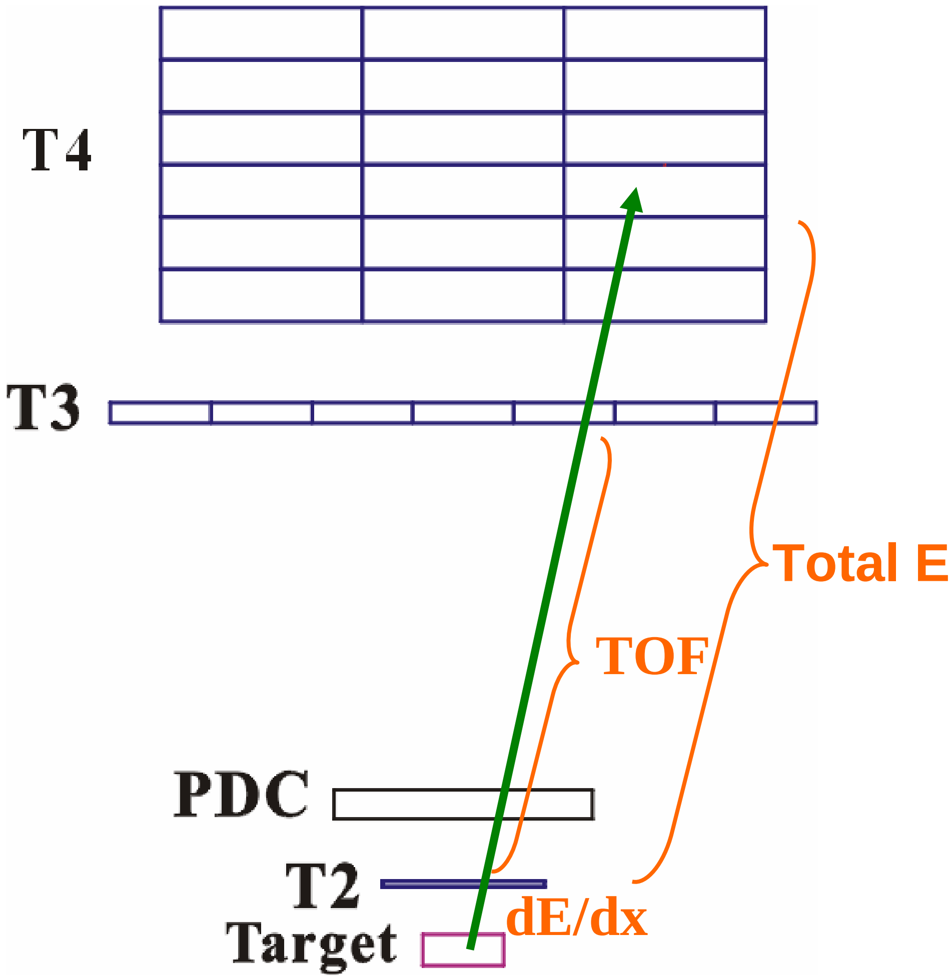


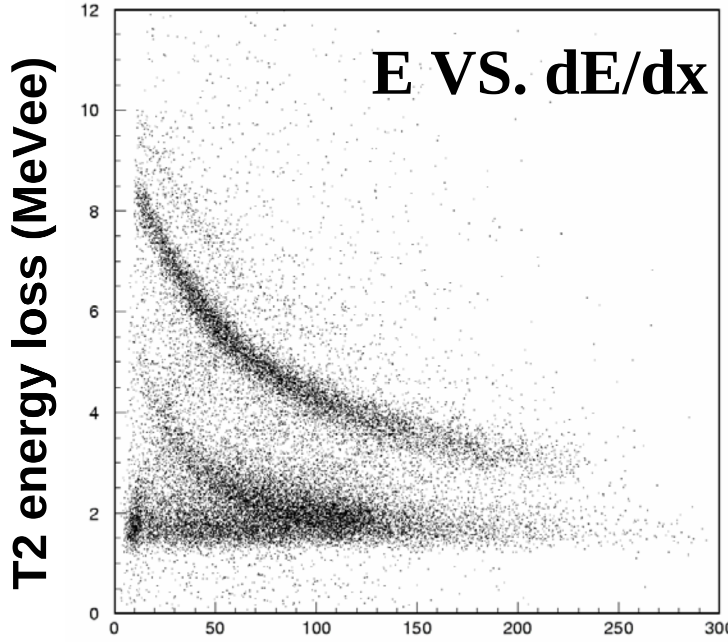
Charged particle：
- TOF (T2→T3)
- tracking（PDC

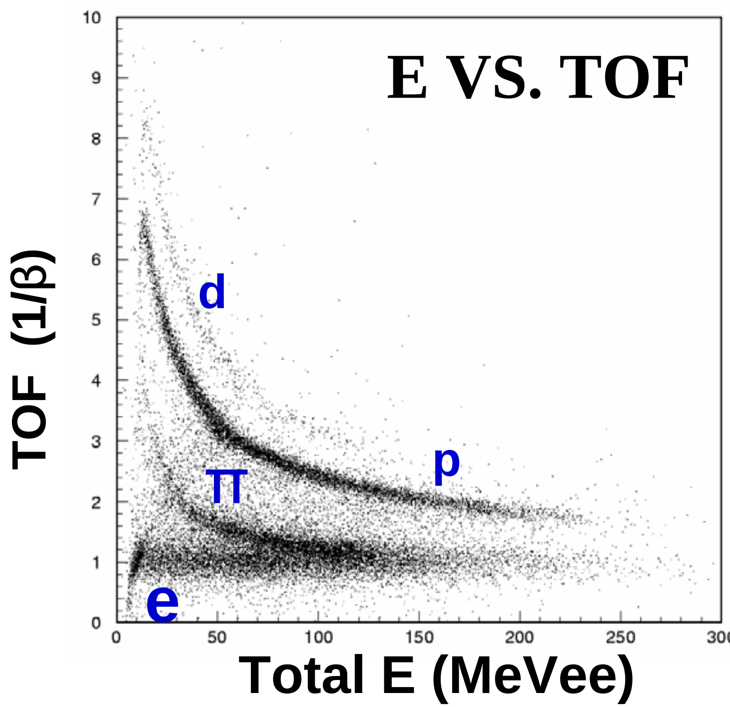
Neutral particle：
- TOF (target→NT)
- T2/T3 VETO

N:	20cm×100cm×5cm
T3:	10cm×100cm×2cm
T2:	4cm×16cm×0.6cm

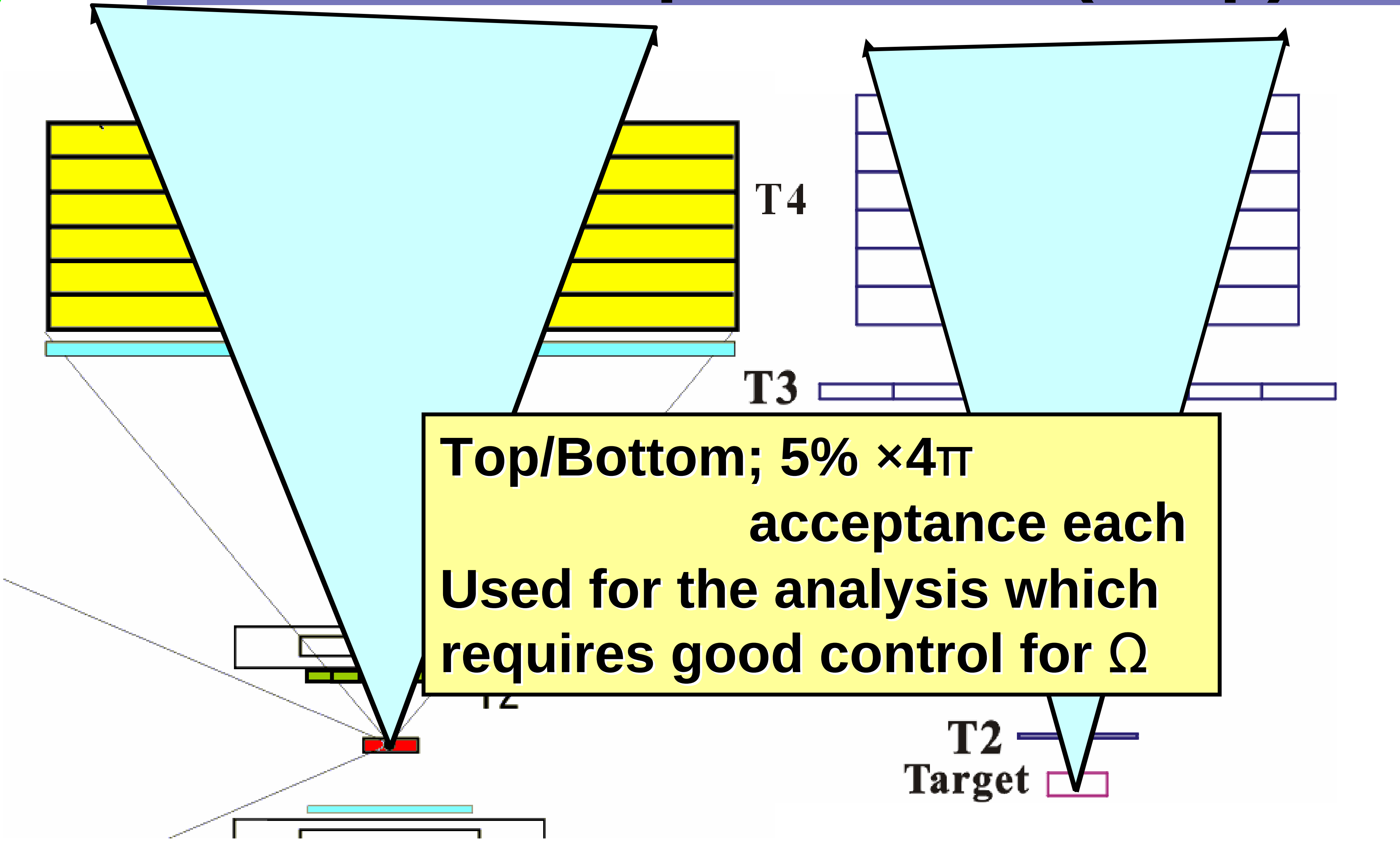
Charged PID


T4
T3
Total E
TOF
PDC
T2
Target
dE/dx


E VS. dE/dx
T2 energy loss (MeVee)
12
10
8
6
4
2
0
0
50
100
150
200
250
300


E VS. TOF
TOF (1/β)
d
p
π
e
10
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
250
300
Total E (MeVee)

Core-acceptance cut (for p)



Top/Bottom; 5% ×4π acceptance each
Used for the analysis which requires good control for Ω

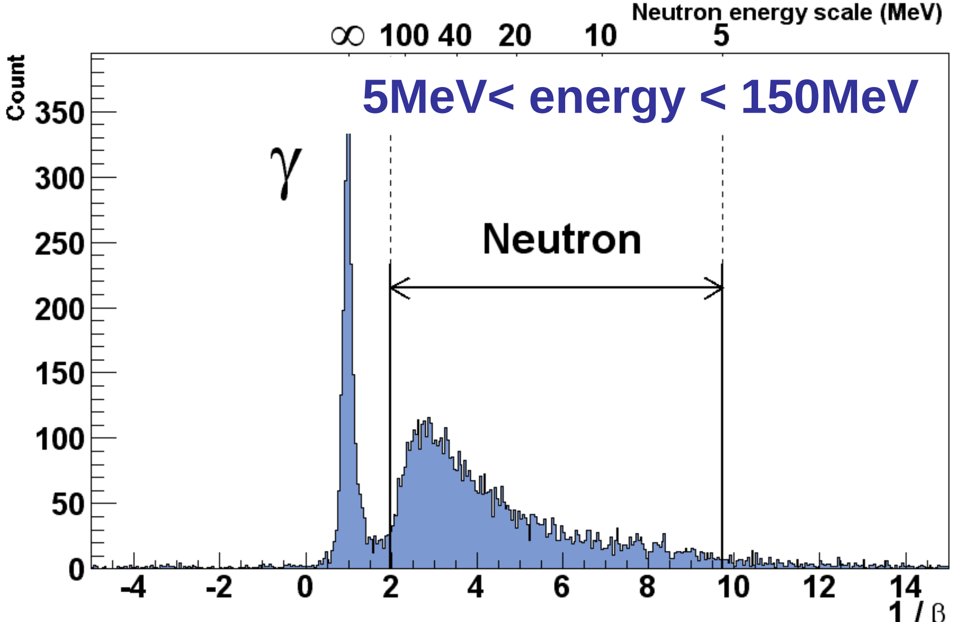
View from backward **View from side**

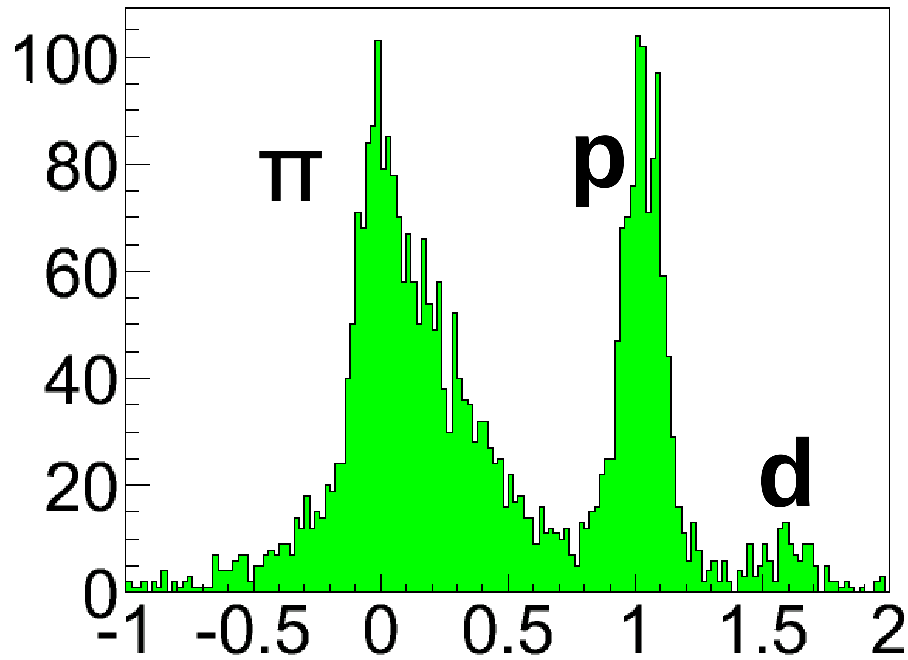
Particle identification

Neutral particle

Charged particle

1 / β spectra





Energy resolution
σ ~ 8MeV
(around 80MeV)

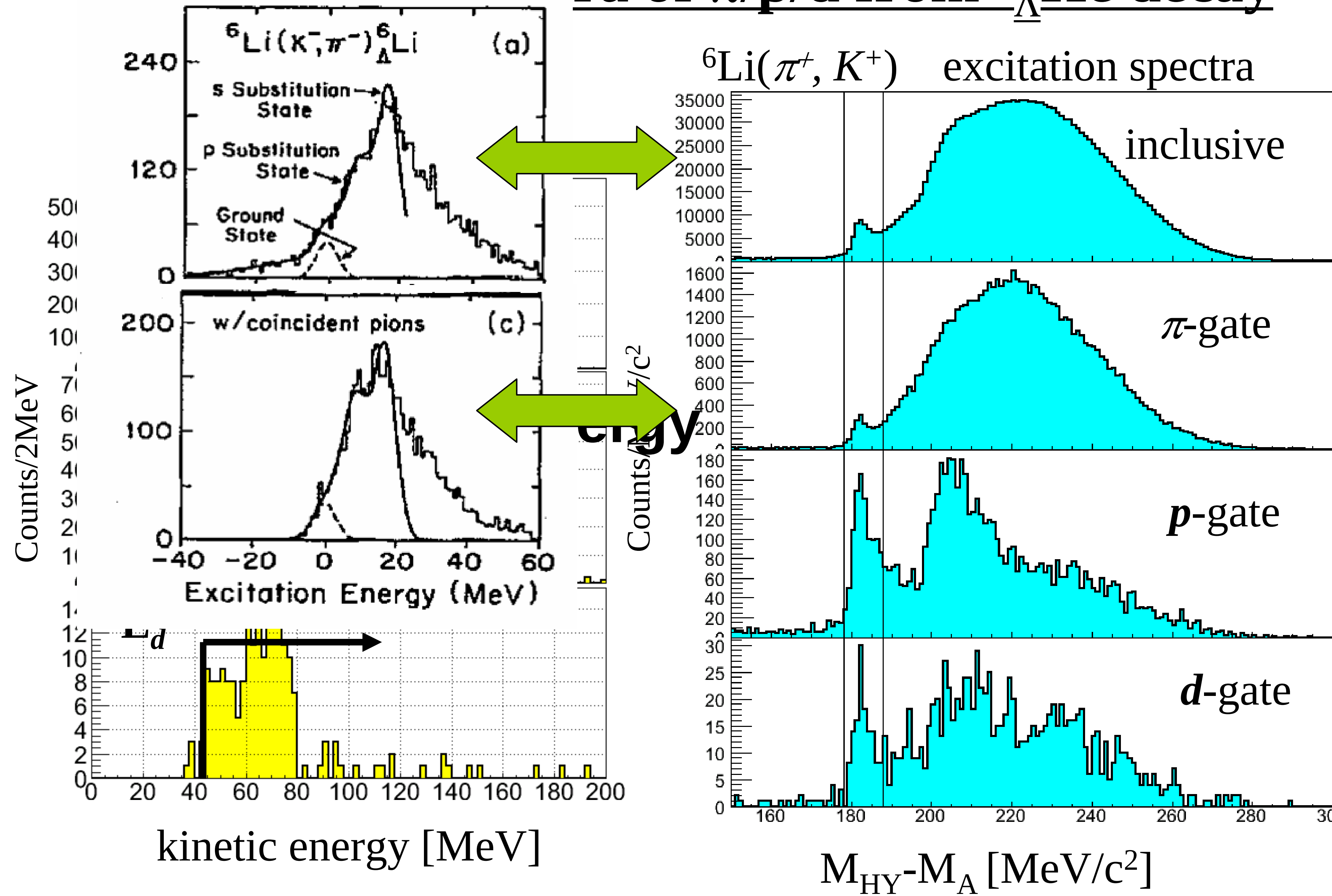
✓ Statistis ×200
✓ S/N improvement ×15
✓ Lower threshold ×1/5

PID1 : total energy vs dE/dx
PID2 : total energy vs TOF
→ (PID1+PID2) / 2

gated $^{12}_{\Lambda}C$ ground state

gated $^{5}_{\Lambda}He$ ground state

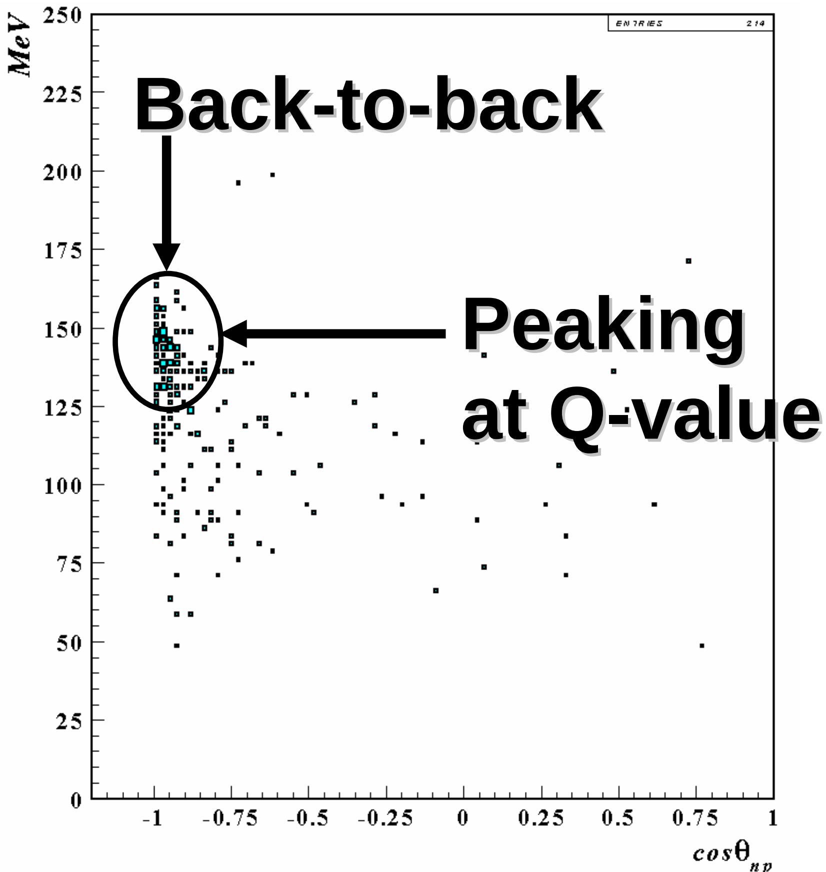
Energy spectra of π/p/d from $^{5}_{\Lambda}$He decay



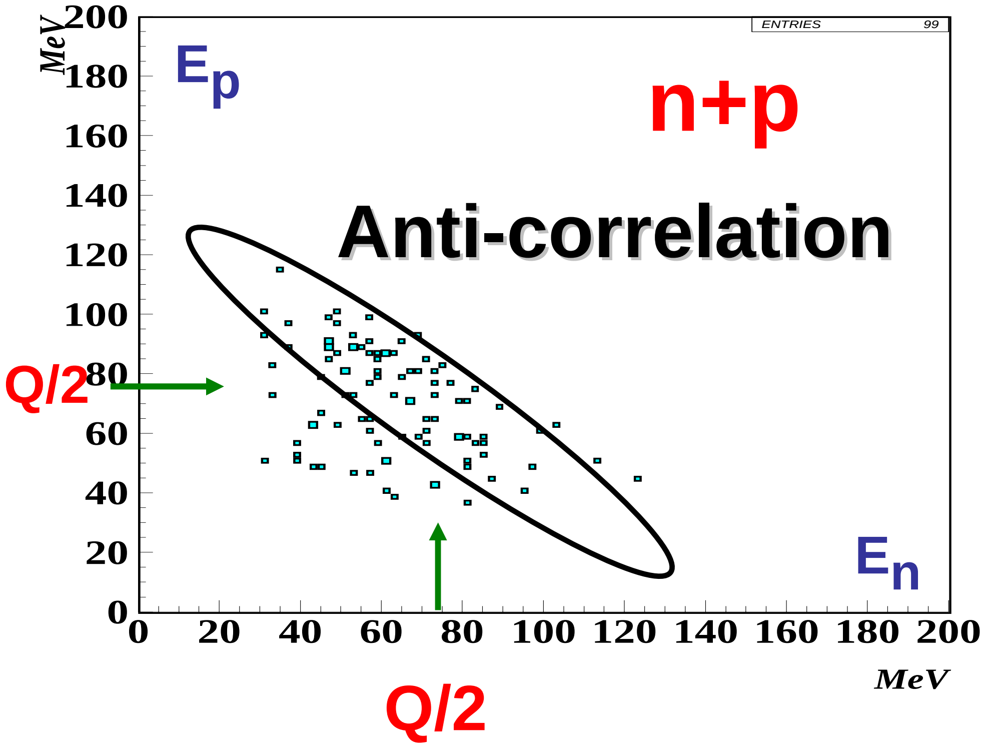
n+p Energy Sum .vs. $\cos\theta_{np}$

Energy sum .vs. angle

n + p pair from $^{5}_{\Lambda}He$



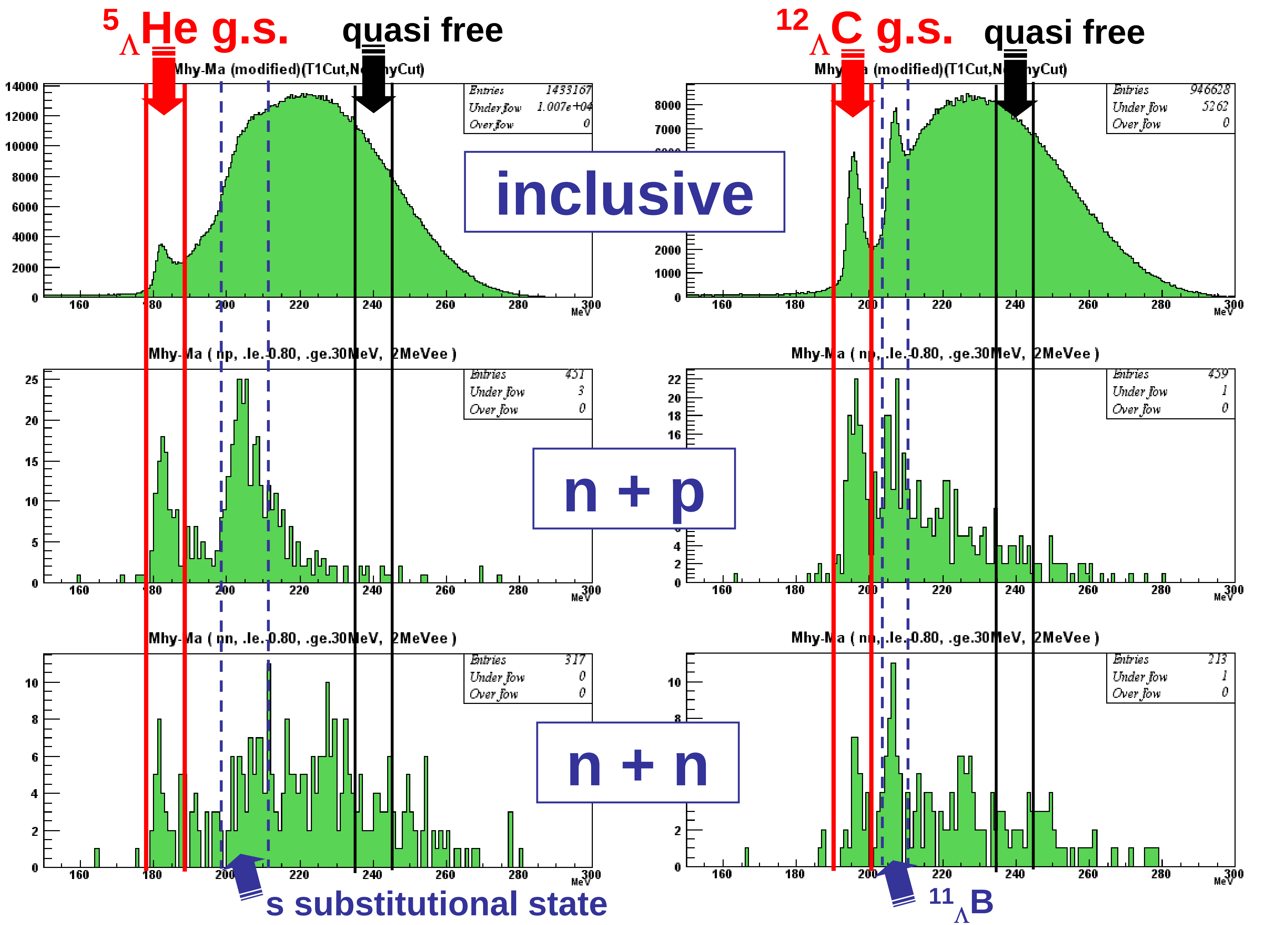
Ep .vs. En correlation



$\cos\theta<0.8; E_{N1}, E_{N2}>30 MeV$

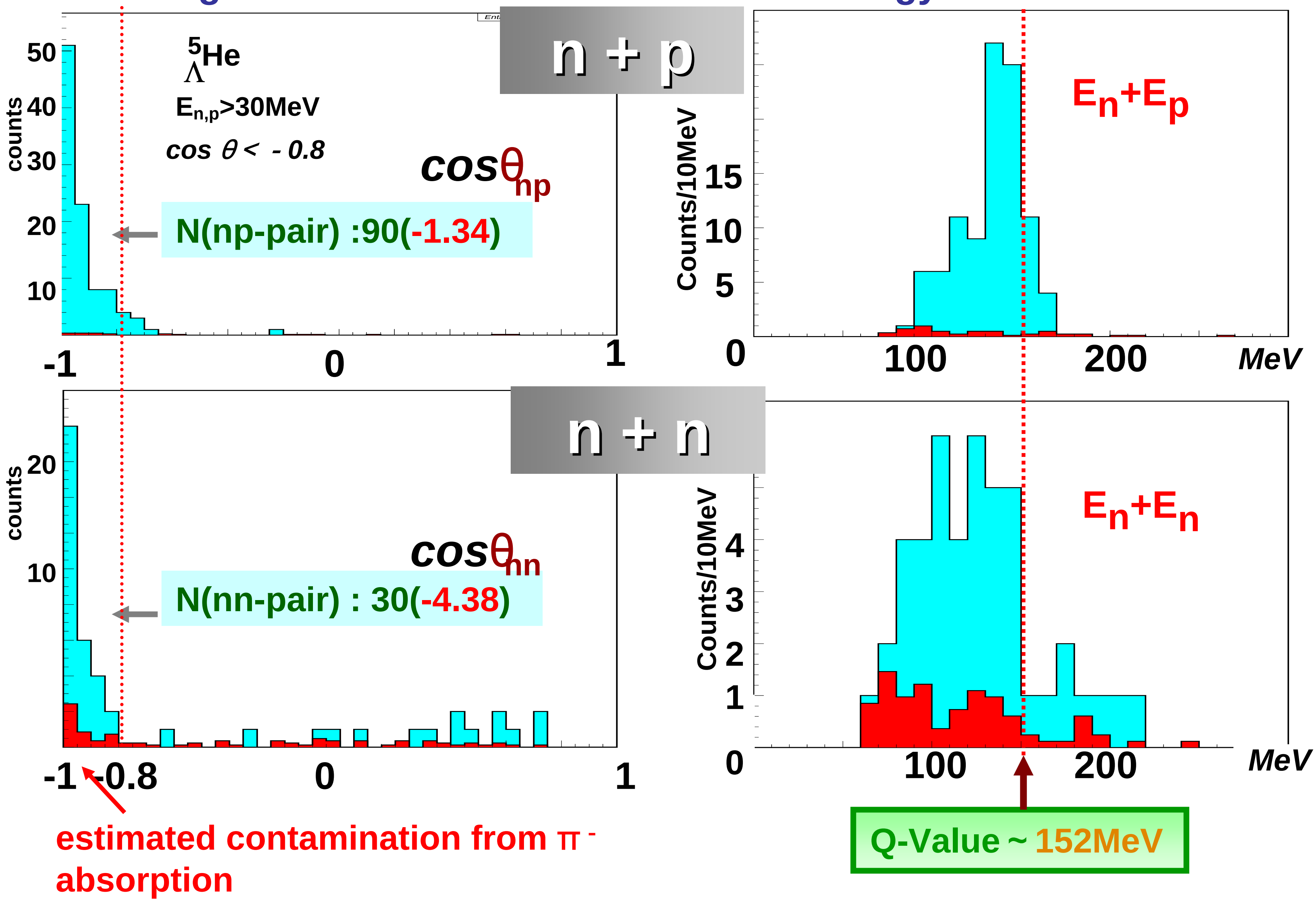
Mass spectra for $^{6}Li(\pi^{+},K^{+})$

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

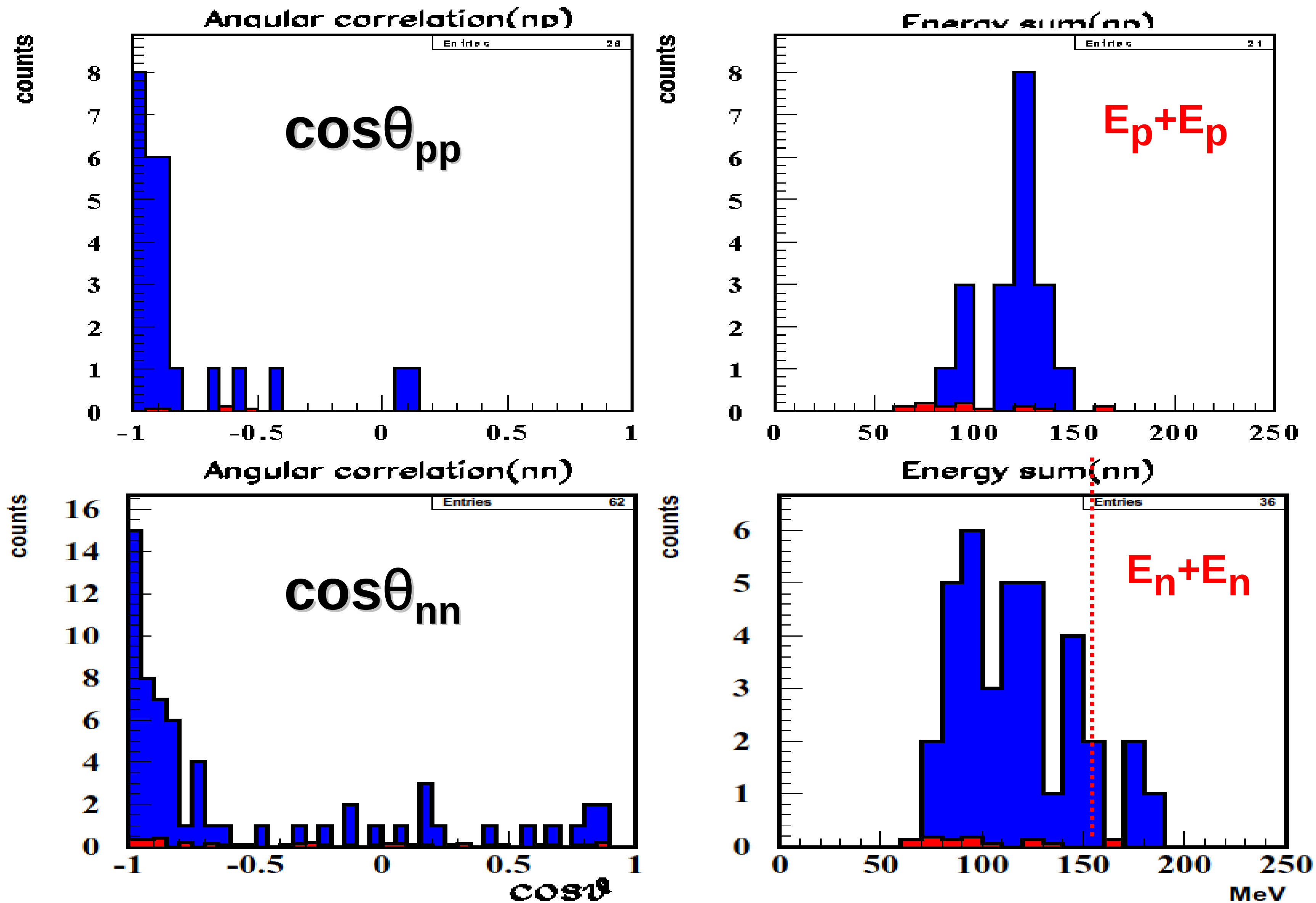


coincidence analysis for $^{5}_{\Lambda}He$

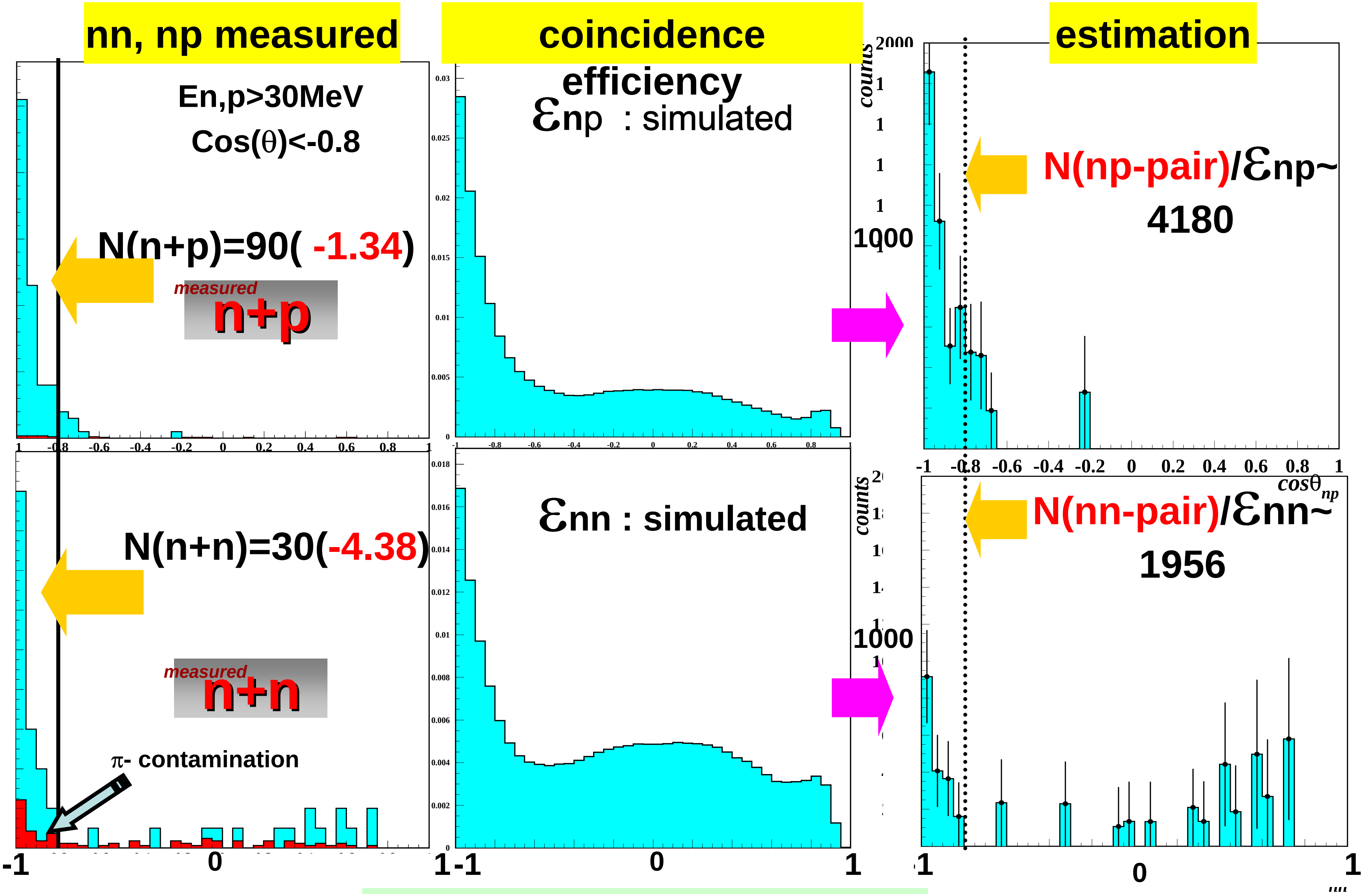
Angular correlation | **Energy-sum distribution**



coincidence analysis for $^{12}_{\Lambda}C$



Estimation of N(n+p), N(n+n)



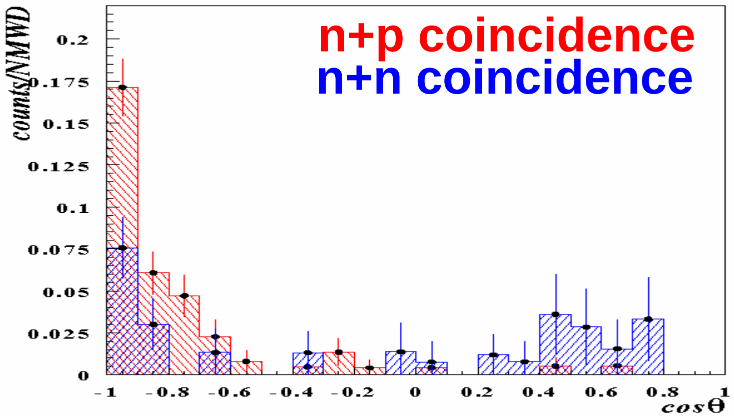
Angular correlation cos(θ)

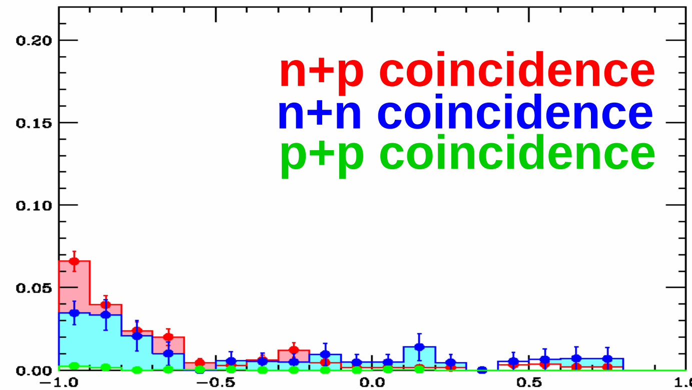
Comparison with theoretical calc. for angular correlation

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

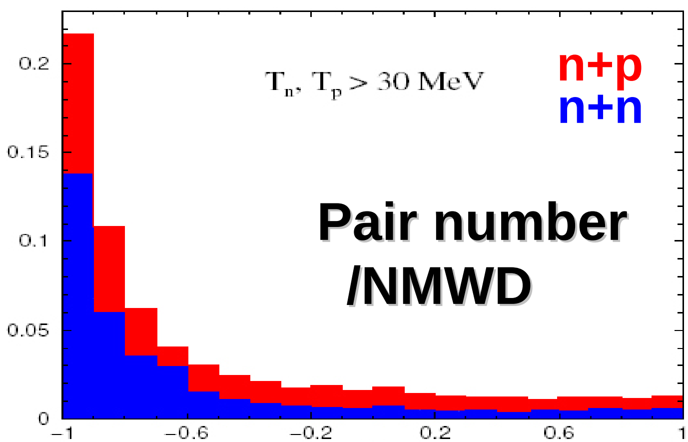
$^{12}_{\Lambda}$C (E508)

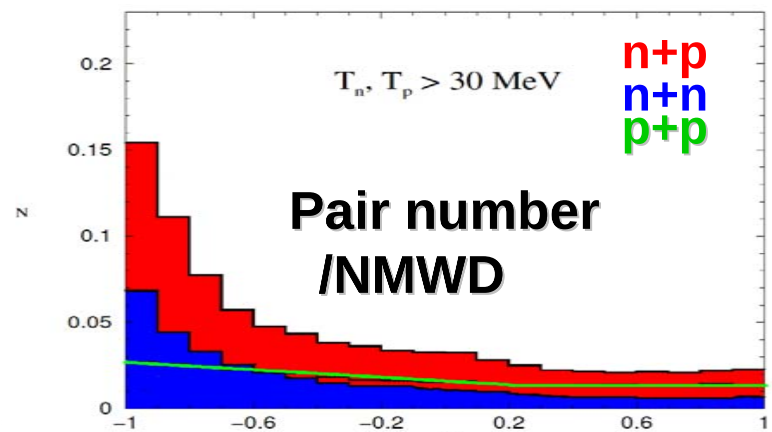
experimental data





theoretical calc.





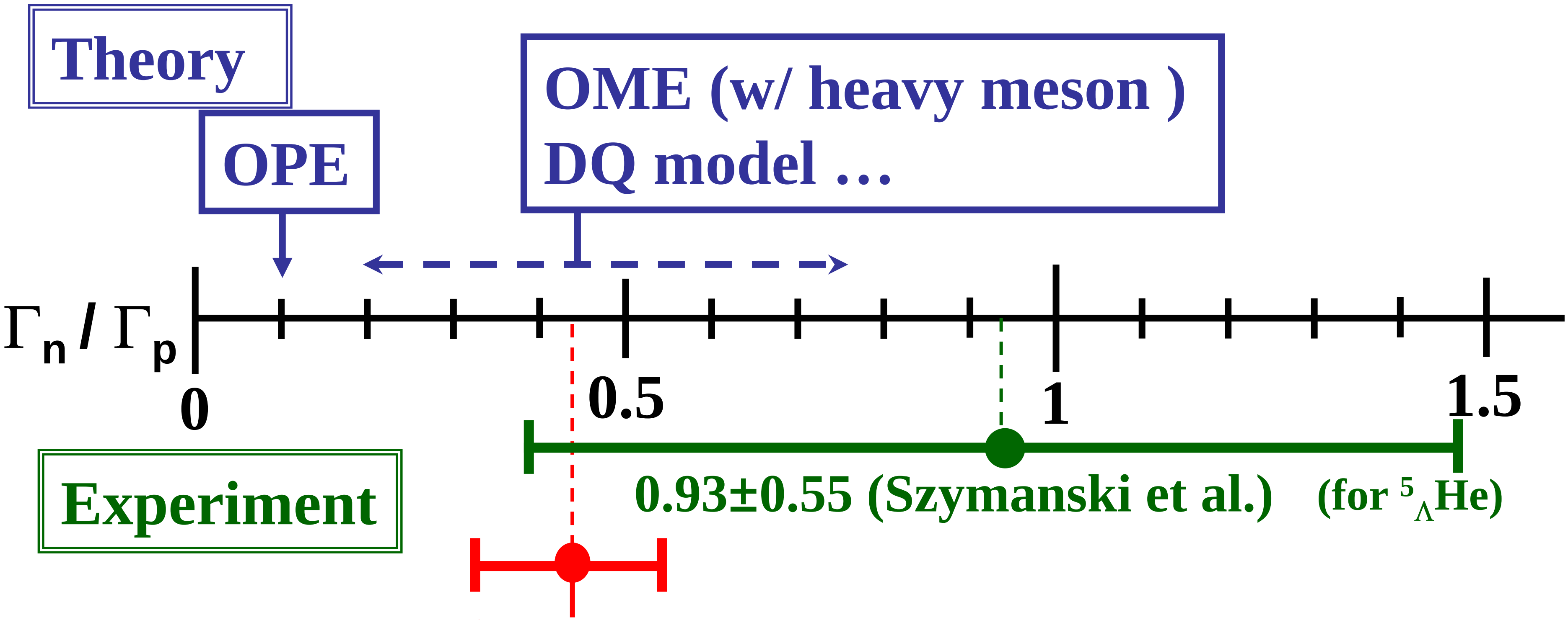
cosθ **cosθ**

Garbarino's calc.

assuming Gn/Gp = 0.46 (for $^{5}_{\Lambda}$He), 0.34 (for $^{12}_{\Lambda}$C)
considered 2N-induced(~ 20%), FSI

Phys. Rev. Lett. 91 (2003) 112501

Results of Γn / Γp



$^{5}_{\Lambda}$He (E462) : **0.44±0.11±0.03**

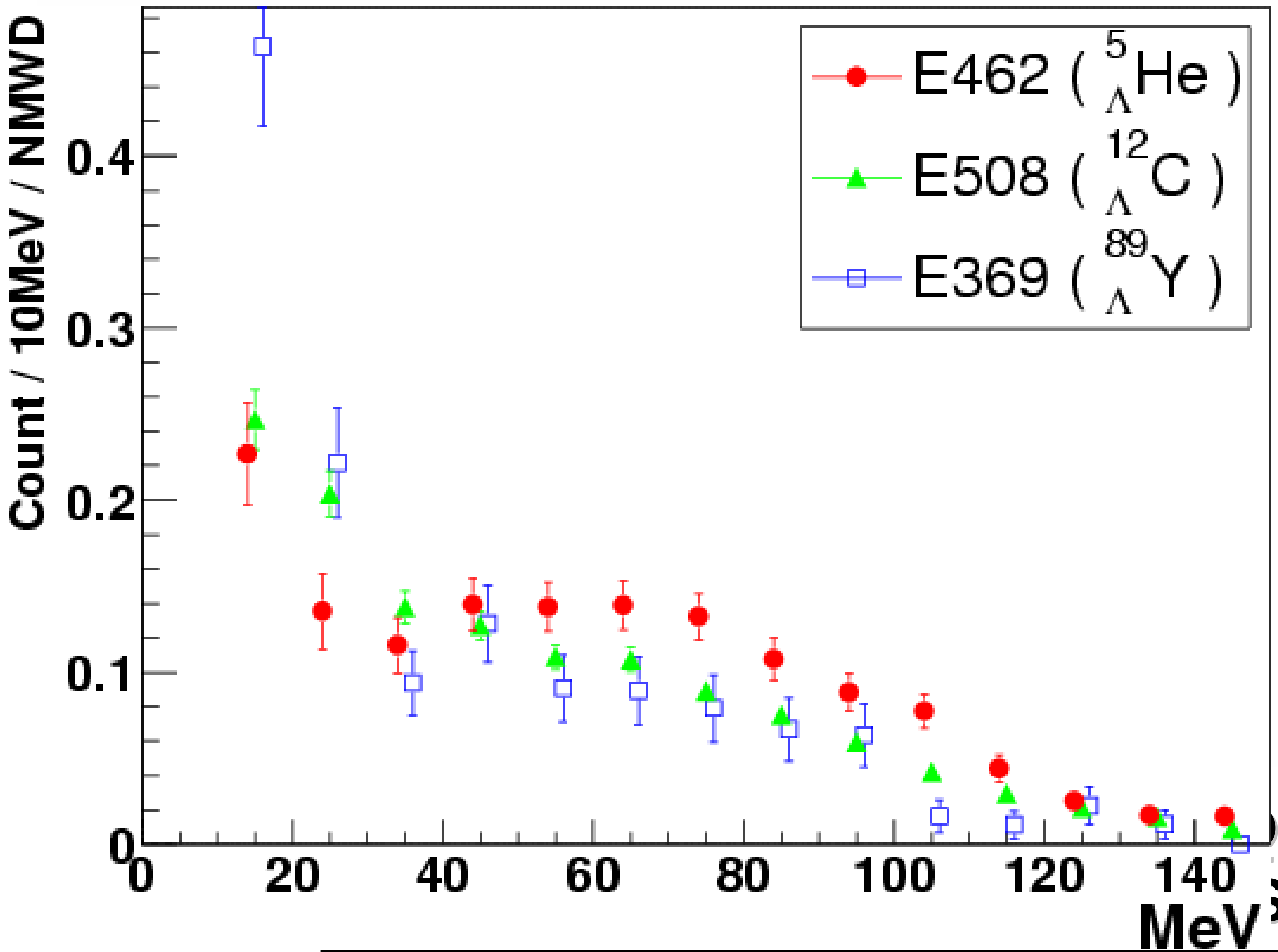
systematic error :
neutron efficiency(6%) + acceptance (3%)

Nearly final

Garbarino's suggestion for the correction

Phys. Rev. Lett. 91 (2003) 112501

Γ2N process….?



Single neutron spectra

Okada; poster

-value/2 seems

I and/or Γ_{2N}

We need good control of FSI effect estimation from the theory

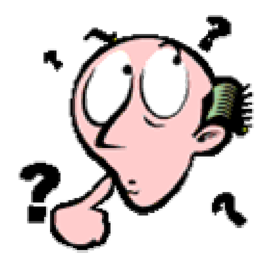
Compare w/ Garbarino's calc.

Gross feature are well explained but……

1. **No peaking in single neutron energy spectrum even from $^{5}_{\Lambda}\mathrm{He}$**
2. **Both of nn/pp-pair numbers/NMWD are lower especially for $^{12}_{\Lambda}\mathrm{C}$**

→ **Suggesting <u>larger</u> FSI/Γ2N**

3. **Smaller contribution in cosθ ~ 0 region**
4. **p+p emission rate is ~1/10**



→ **Suggesting <u>smaller</u> FSI/Γ2N**

Summary of NMWD results:

* Γ_n / Γ_p **ratio:**

  Nnn/Nnp at cosθ< - 0.8; E>30MeV

  $^5_\Lambda$He (E462) ~ **0.44±0.11±0.03**

  → ***Consistent w/ recent theory***

* **Angular & Energy correlation**

  Contribution of ΛNN →NNN ??

  → ***Still open question..***

* **Asymmetry parameter results (~ 0)**

  [Maruta's parallel talk]

  → ***Hard to be explained by theory***

2. Accurate measurement of $\Gamma\pi^-$, $\Gamma\pi^0$ and Γnm

For detail; parallel talks by Kameoka/Okada

$$\Gamma\pi^- = 1/\tau \times Br(\pi^-)$$

$$\Gamma\pi^0 = 1/\tau \times Br(\pi^0)$$

$$\Gamma nm = 1/\tau \times (1- Br(\pi^-) - Br(\pi^0))$$

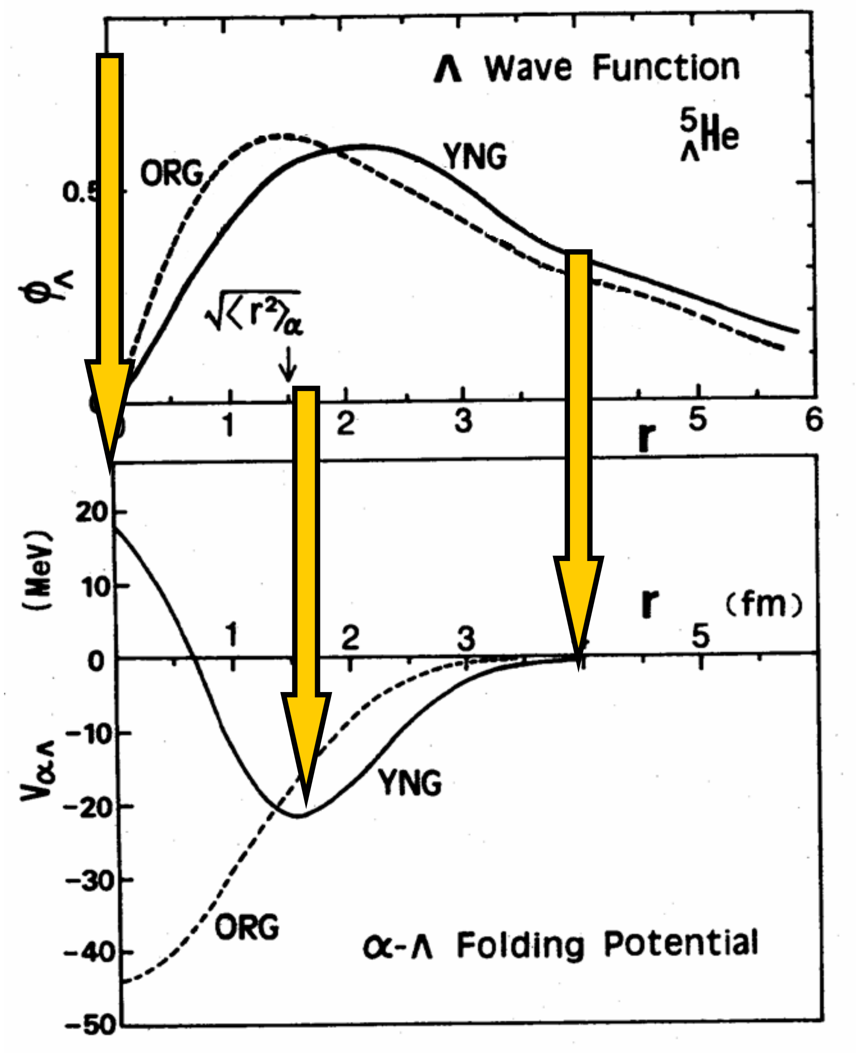
Lifetime

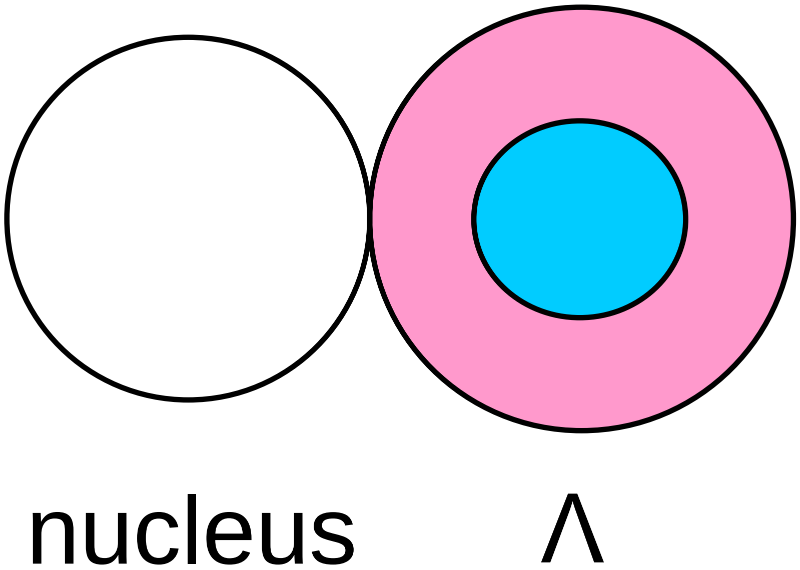
π^- branching ratio

π^0 branching ratio

Needs good accuracy for all of them

Γπ: test of Λ-nucleus potential





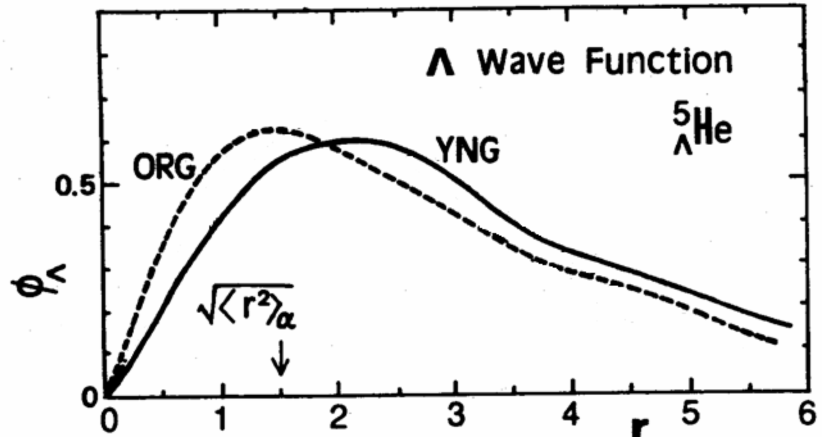
YN interaction
attraction ~ repulsion

Repusive core is the common feature of Y-nucleus potential

Γπ/Γnm and Λ-Nucleus Potential

$$\int \frac{\psi_N^2}{\rho_0} \cdot \psi_\Lambda^2 d\vec{r} \quad ??$$

YNG: 20% overlap
ORG: 40% overlap



Mesonic decay rate

Γπ(YNG) > Γπ(ORG)

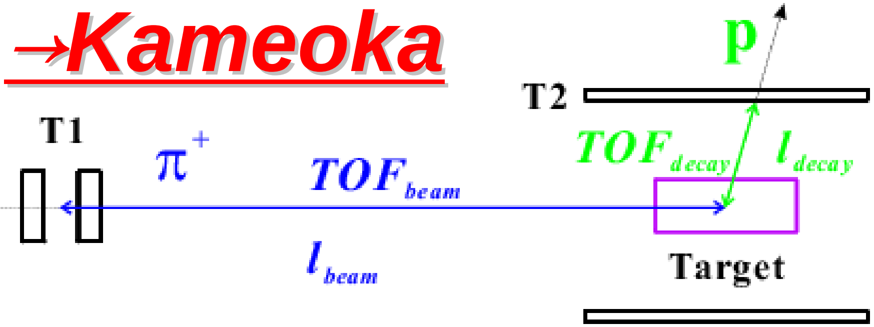
Non-mesonic decay rate

$$\Gamma_{nm} \propto \int \frac{\psi_N^2}{\rho_0} \cdot \psi_\Lambda^2 d\vec{r} \quad ??$$

Γnm(ORG) <Γnm(YNG)

Lifetime

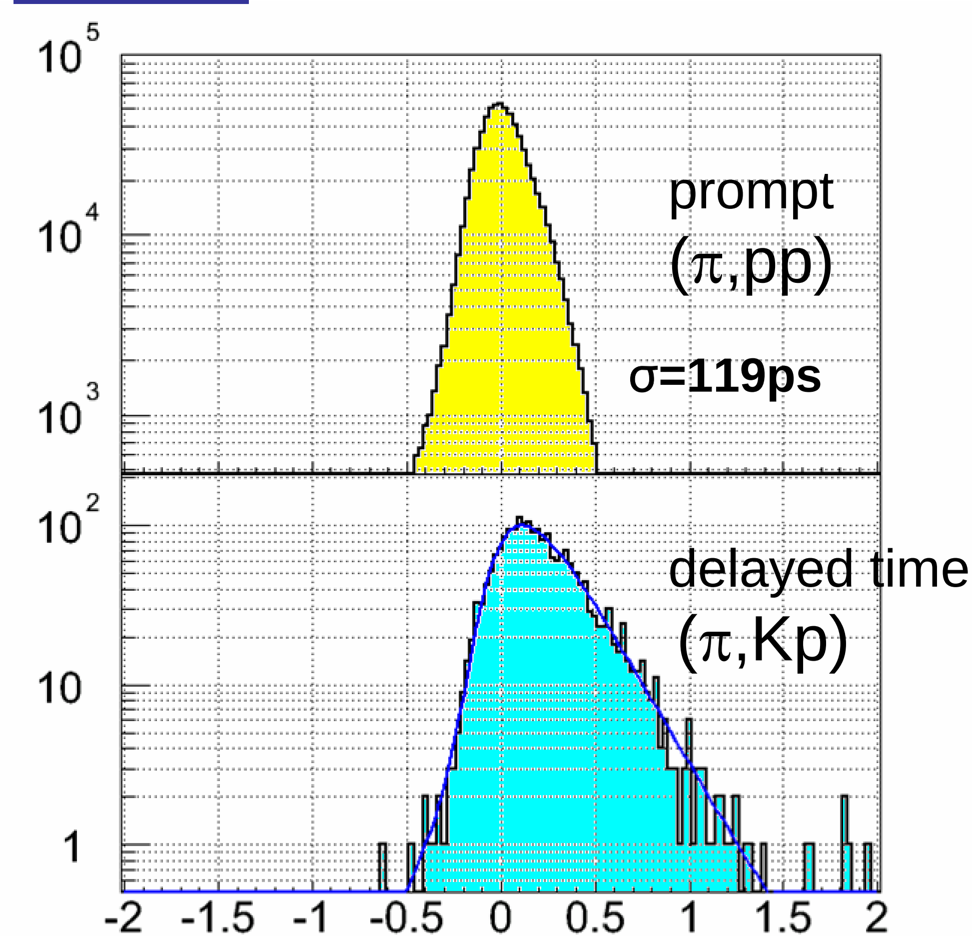
→Kameoka



$$\Delta t = t_{T2} - TOF_p - TOF_\pi - t_{T1}$$

$$= t_{T2} - \frac{l_p}{\beta_p c} - \frac{l_\pi}{\beta_\pi c} - t_{T1}$$

$^5_\Lambda He$



preliminary

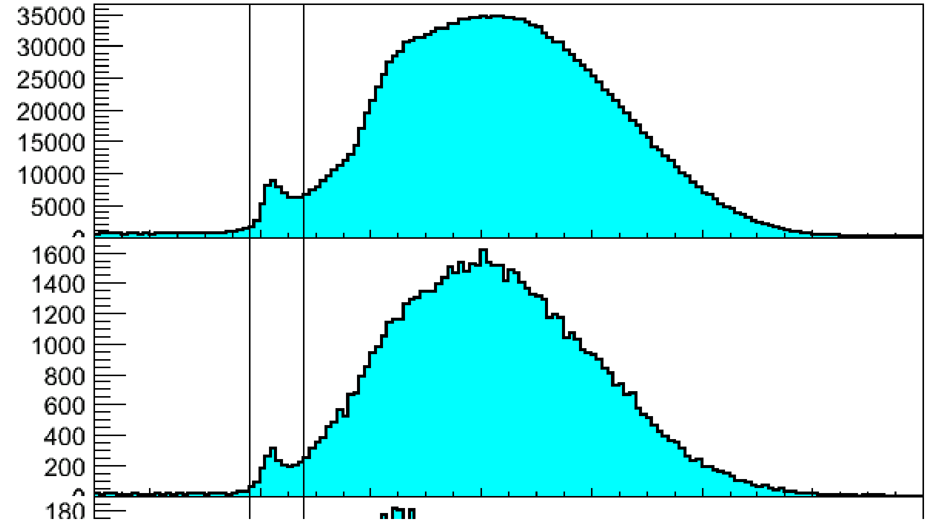
τ = 212 ± 6 ps for $^{12}_\Lambda C$

τ = 278 ± 10 ps for $^5_\Lambda He$

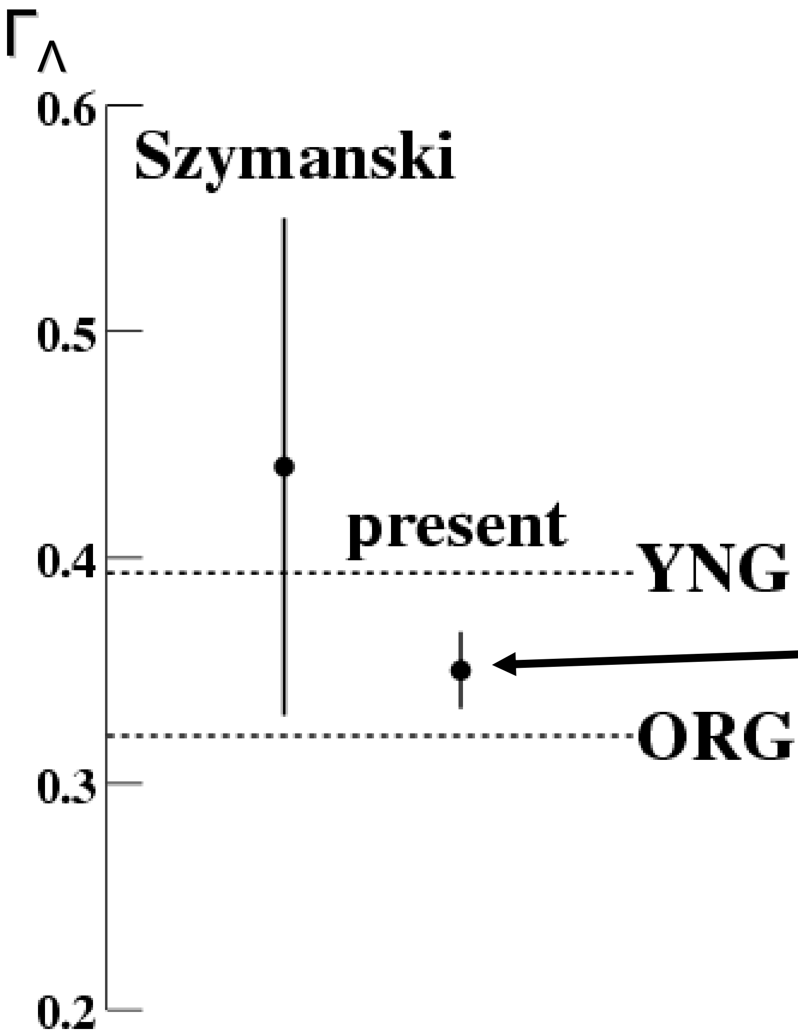
Error: ~ 2.5 times improved over previous experiments

Γ_{π^-} for $^{5}_{\Lambda}He$

→*Kameoka*



$b_{\pi^-} = 0.371 \pm 0.009$



$0.393\Gamma_\Lambda$

$0.351 \pm 0.017\Gamma_\Lambda$

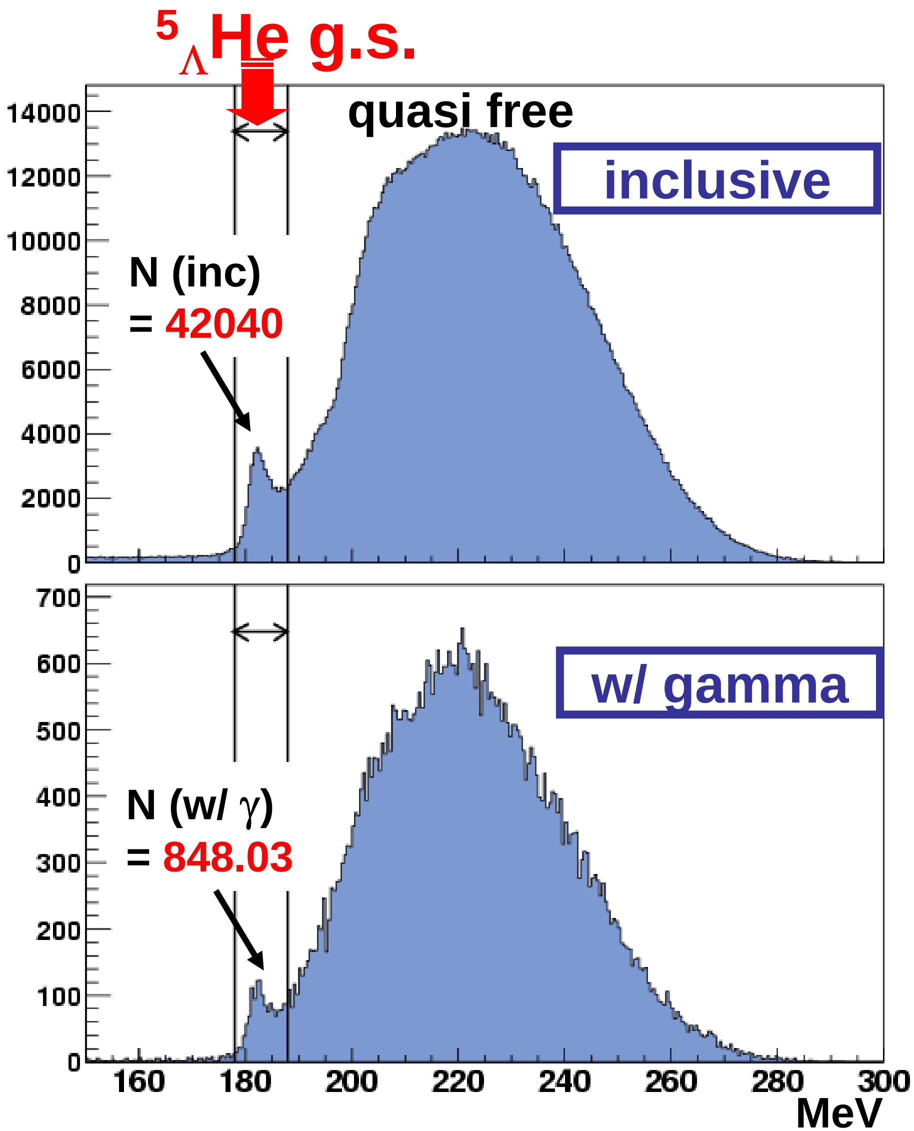
$0.321\Gamma_\Lambda$

~30% overlap??
; larger than YNG

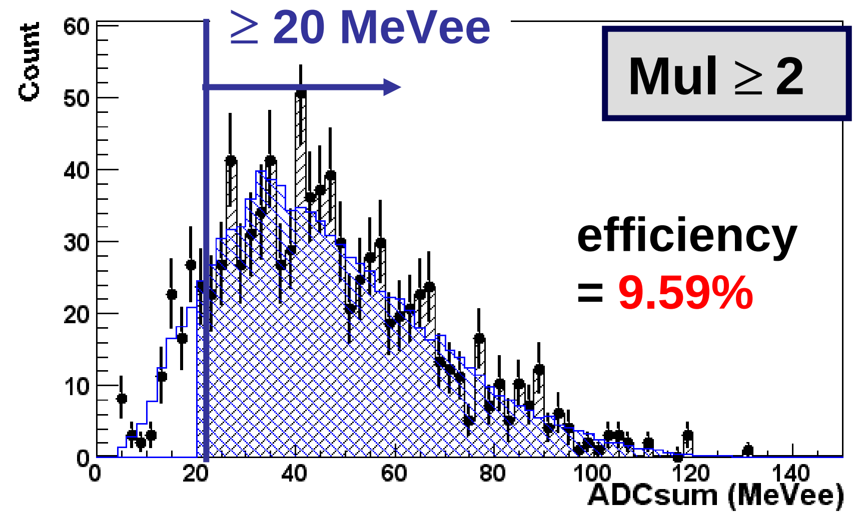
π^0 branching ratio of $^5_\Lambda$He

Okada

Mass spectra for ^{6}Li(π^+,K$^+$)



ADC sum w/ Geant sim



b_{π^0} = N (w/ γ) / N (inc) × 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 → α + p + π^-
$^5_\Lambda$He → α + n + π^0

Same Q-value as that of free Λ

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

Non-mesonic deca rate ${}^{5}_{\Lambda}He$ and ${}^{12}_{\Lambda}C$

Γ_{tot} = 0.947±0.038 Γ_{Λ}
$b\pi^{-}$ = 0.371±0.009
$b\pi^{0}$ = 0.212±0.008

Γ_{tot} = 1.242±0.042 Γ_{Λ}
$b\pi^{-}$ = 0.099±0.011
$b\pi^{0}$ = 0.133±0.005

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

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

0.41±0.14

0.83±0.09

Γtotal (${}^{56}_{\Lambda}$Fe) ~ Γnm(A→∞) ~ 1.2Γ_{Λ} （E307）

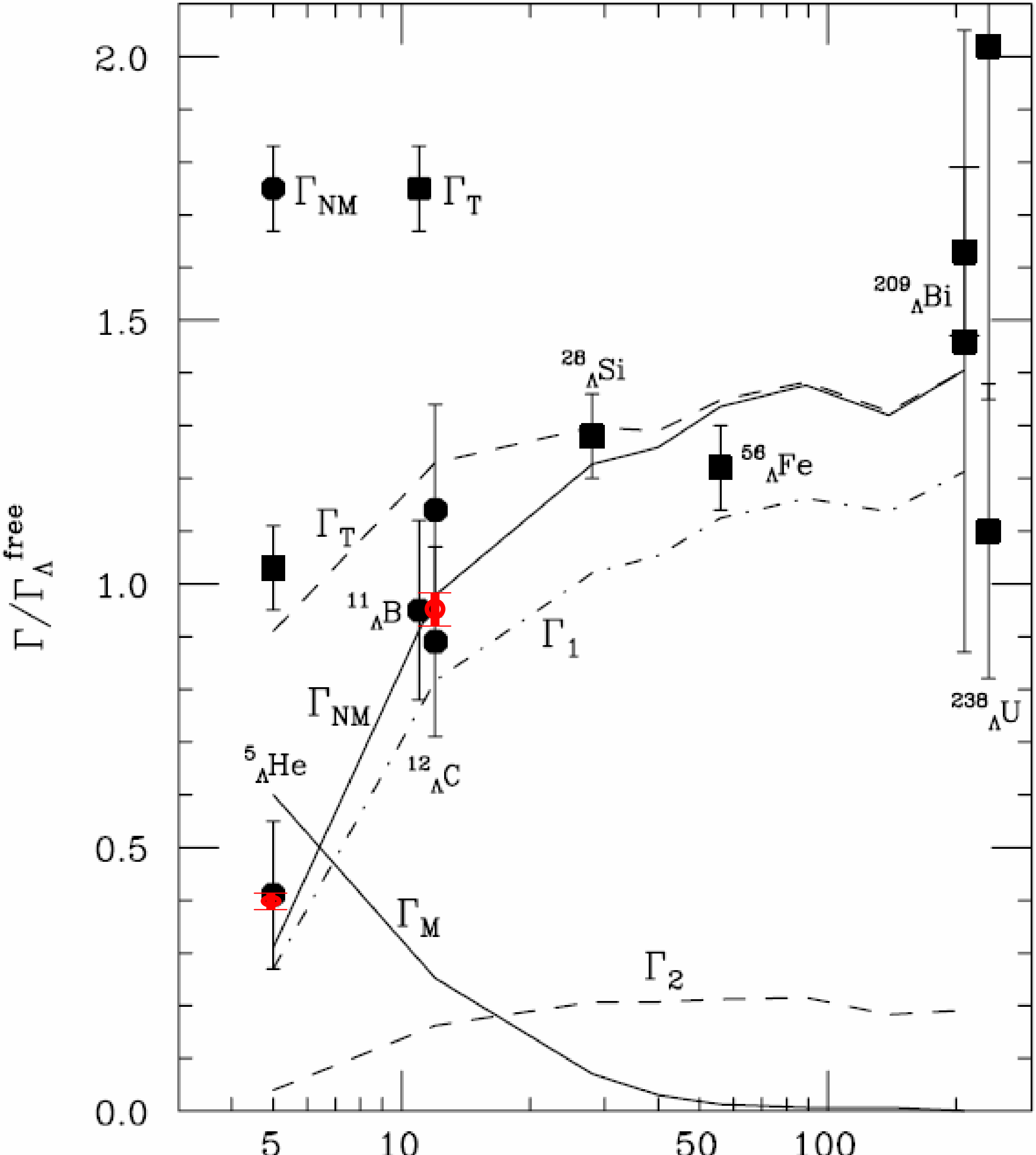
Γnm (${}^{5}_{\Lambda}$He) = 0.4Γ_{Λ} （Present)

If $$\Gamma_{nm} \propto \int \frac{\psi_N^2}{\rho_0} \cdot \psi_\Lambda^2 d\vec{r}$$

1/3 of Λ is inside α

Γnm calculation must use the Λ w.f. which can well reproduce Γπ

Mass number dependence of Γ_{NM}



Contents of talks from E462/508

Parallel

Maruta — **Asymmetry** of proton from the NMWD of $^{5}_{\Lambda}He$ and $^{12}_{\Lambda}C$, $^{11}_{\Lambda}B$

Kameoka — π^- **decay** branching ratio of $^{5}_{\Lambda}He$
Lifetime analysis for $^{5}_{\Lambda}He$, $^{12}_{\Lambda}C$

Okada — π^0 **decay** branching ratio of $^{5}_{\Lambda}He$, $^{12}_{\Lambda}C$
NMWD rate of $^{5}_{\Lambda}He$, $^{12}_{\Lambda}C$

Posters

Okada — **Single nucleon** spectra from $^{5}_{\Lambda}He$, $^{12}_{\Lambda}C$
Nn/Np ratio from NMWD of $^{5}_{\Lambda}He$, $^{12}_{\Lambda}C$

Kang — n+p and n+n coincidence for $^{5}_{\Lambda}He$ **Γ_n/Γ_p ratio**

Kim — **n+p and n+n** coincidence for $^{12}_{\Lambda}C$

Summary table *(preliminary)*

Width unit :Γ_Λ	$^{5}_{\Lambda}$He	$^{12}_{\Lambda}$C
Total decay width	0.947±0.038	1.242±0.042
Γnm	0.395±0.016	0.953±0.032
Nn/Np(@50MeV)	2.20±0.13±0.15	1.80±0.07±0.12
Nnn/Nnp b-to-b	0.44±0.11±0.03	in analysis
αnm	0.07±0.08	- 0.24±0.26 ($^{12}_{\Lambda}$C and $^{11}_{\Lambda}$B)
	0.351±0.017	in analysis
	0.201±0.011	0.165±0.008

e 2 ~ 20 times more accurate
ous measurements