17th/Oct/2003
HYP2003

Proton asymmetry from non-mesonic weak decay in light hypernuclei

Outline

- Motivation
- Analysis results
  - s-shell(${}^{5}_{\Lambda}\mathrm{He}$)
  - p-shell(${}^{12}_{\Lambda}\mathrm{C}$, ${}^{11}_{\Lambda}\mathrm{B}$)
- Summary

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Asymmetry measurement of decay proton

Asymmetry : Volume of the asymmetric emission from NM

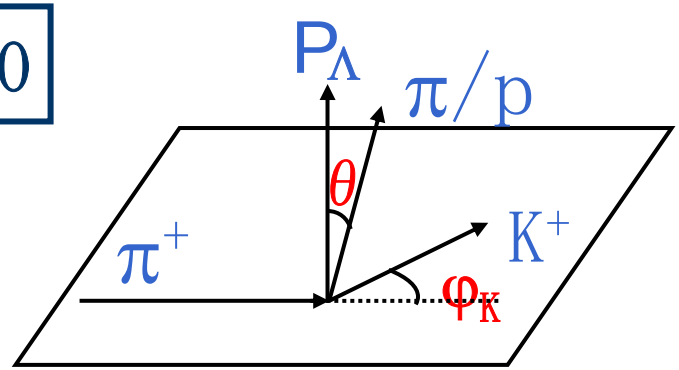
$$N(\theta) = N_0(1 + \underbrace{A}_{\text{Asymmetry}}\cos\theta)$$

$$= N_0(1 + \underbrace{\alpha_\Lambda P}_{\text{Asymmetry Parameter}}\cos\theta)$$

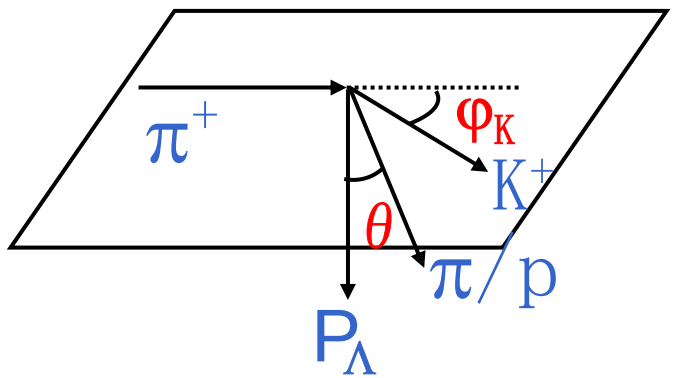
$$A = \frac{(r+1)}{(r-1)}, \quad r = \frac{N(\theta^+)}{N(\theta^-)}$$

$$r = \left\{ \frac{N(\theta^+(+\varphi)) \times N(\theta^-(-\varphi))}{N(\theta^+(-\varphi)) \times N(\theta^-(+\varphi))} \right\}^{1/2}$$

$\varphi_K > 0$



$\varphi_K < 0$



Difference of acceptance & efficiency is canceled out !

Motivation

Present status

Asymmetry Parameter

Previous experiments		Theoretical prediction
${}^{5}_{\Lambda}$He : 0.24±0.22	⟷	-0.6～-0.7
${}^{12}_{\Lambda}$C, ${}^{11}_{\Lambda}$B : -1.3±0.4 (Ajimura *et al.*)		

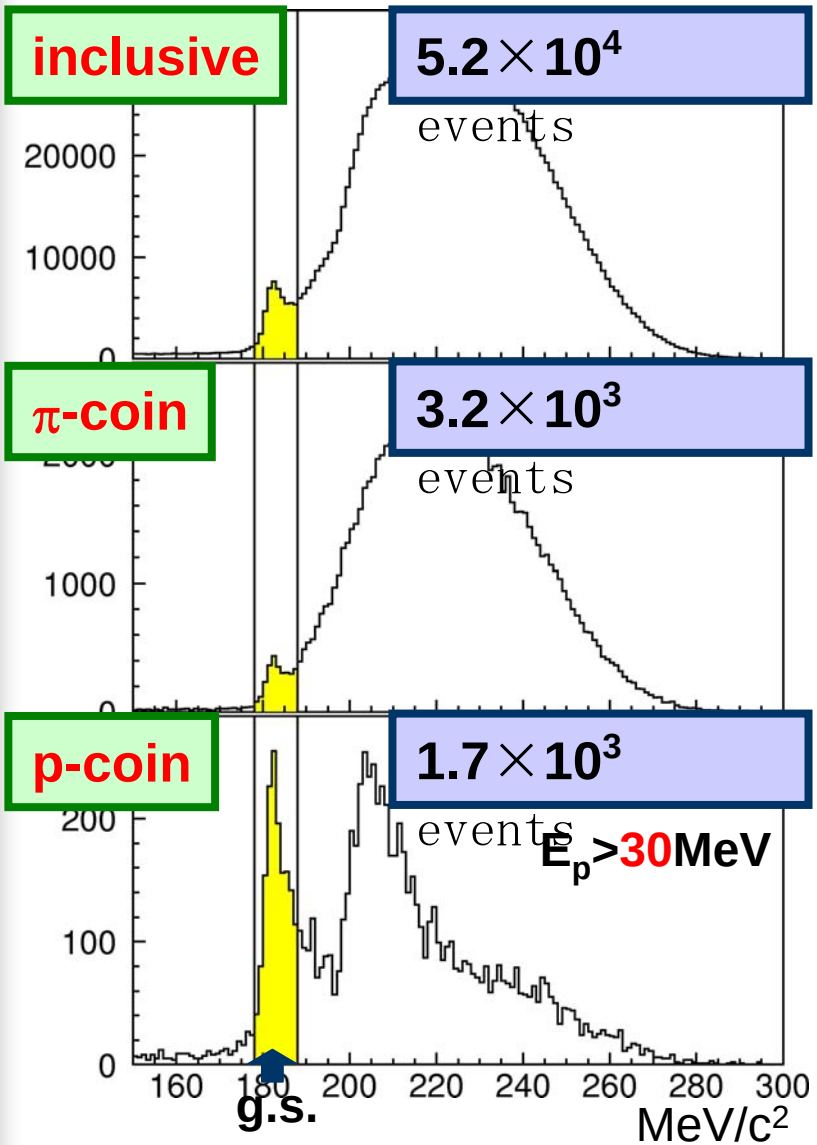
The aim of E462/E508 experiment

→ Precise measurement of Asymmetry parameter

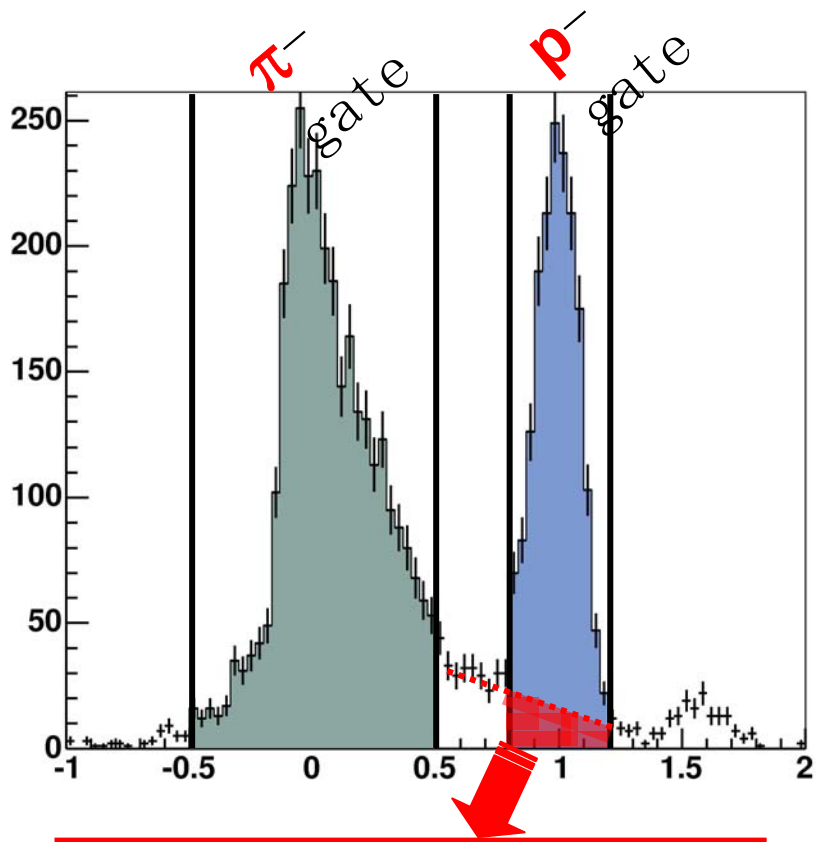
- with high statistics
- with np back-to-back events
  - $\Lambda p \rightarrow np$

Event selection ($^{5}_{\Lambda}He$)

$^{6}_{\Lambda}$Li mass spectra



Particle identification



π
→ contamination

Systematic error

Instrumental Asymmetry

(π,pC) reaction : Only Strong Interaction

→ **Asymmetry = 0** expected

	Horizontal Scattering Angle	Asymmetry ^{6}Li target	Asymmetry ^{12}C target
Proton	$2<\|\theta\|<6°$	-0.000 ± 0.002	0.000 ± 0.002
	$6<\|\theta\|<9°$	0.003 ± 0.002	-0.003 ± 0.003
	$9<\|\theta\|<15°$	0.003 ± 0.002	0.001 ± 0.002
Pion	$2<\|\theta\|<6°$	-0.001 ± 0.001	-0.002 ± 0.002
	$6<\|\theta\|<9°$	0.003 ± 0.001	0.002 ± 0.002
	$9<\|\theta\|<15°$	0.000 ± 0.001	-0.003 ± 0.002

→ **Instrumental Asymmetry < 0.3%**

Procedure for α^{NM} calculation ($^{5}_{\Lambda}He$)

- Polarization of Λ ➡ Estimated from mesonic decay

$$A_\pi = \alpha_\pi P_\Lambda \varepsilon$$

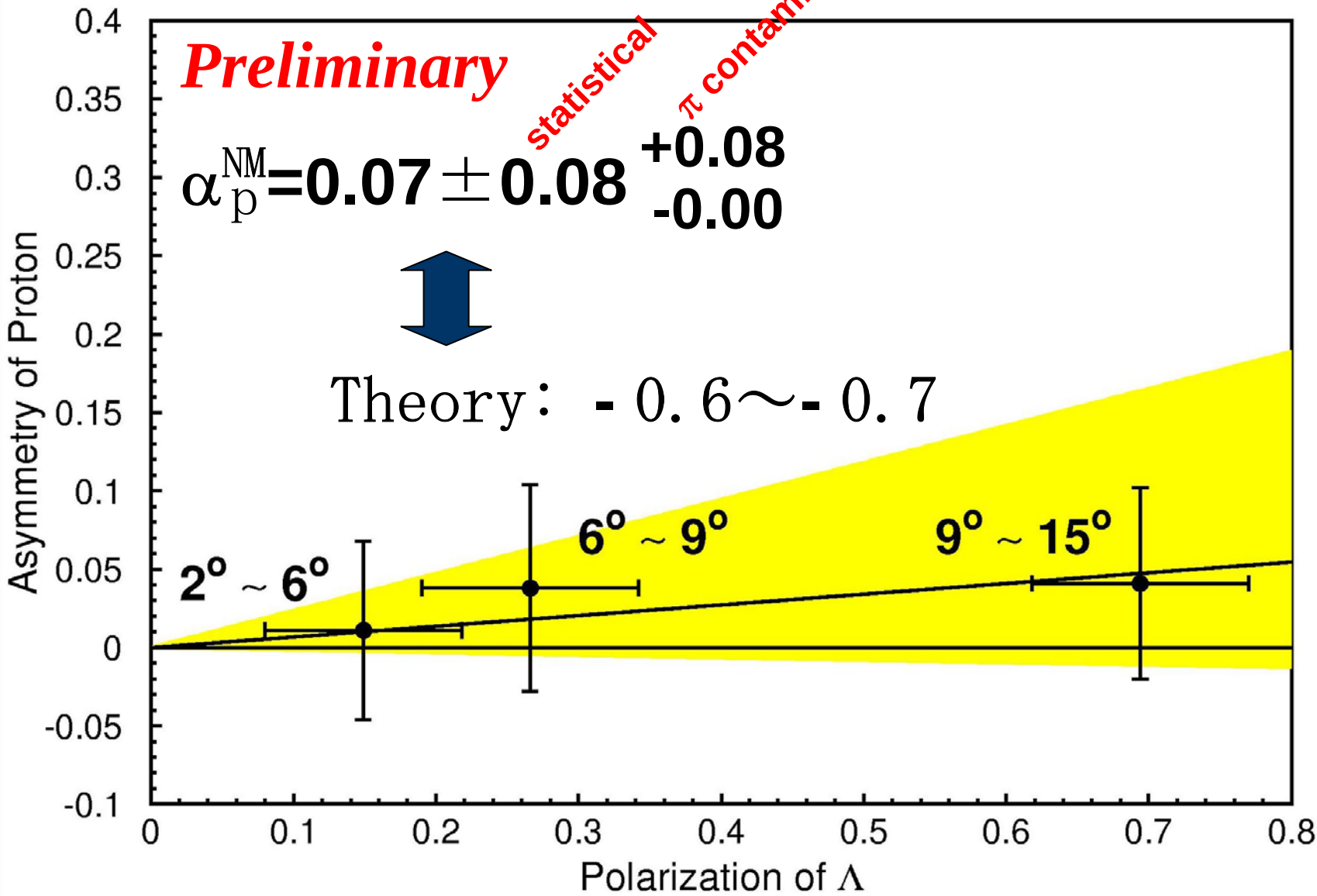
A_π: Asymmetry of π
α_π: Asymmetry Parameter of mesonic decay
$(=-0.642 \pm 0.013)$
P_Λ: Polarization of Lambda
ε : Attenuation factor

- Asymmetry Parameter of Proton

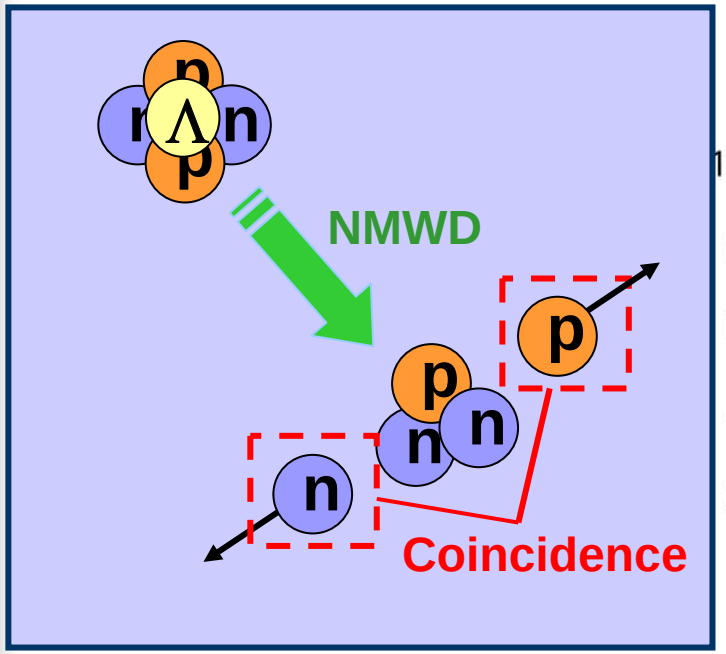
$$A_p = \alpha_p^{NM} P_\Lambda \varepsilon$$

We can calculate ${}_p\alpha^{NM}$ without theoretical hel

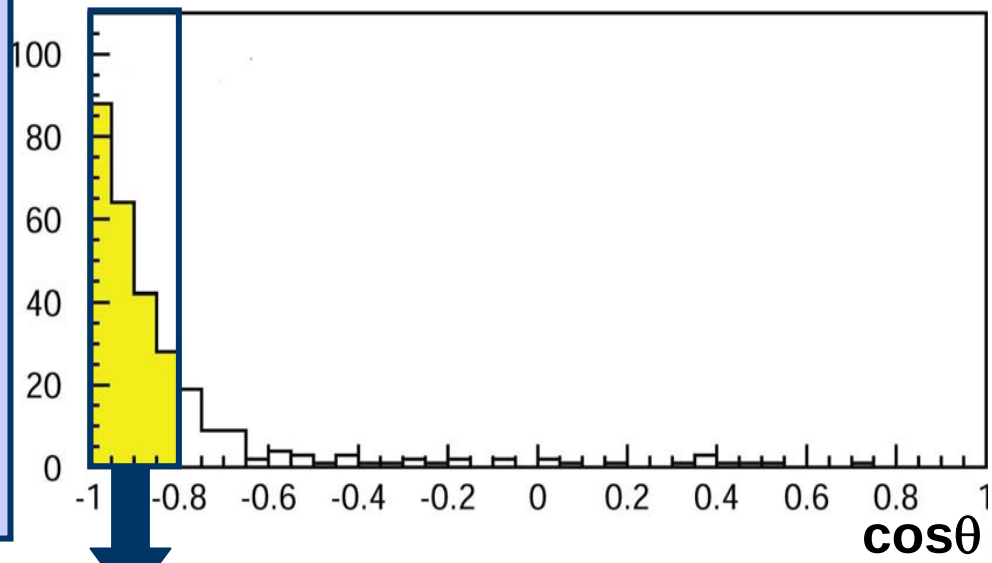
Asymmetry parameter of ${}^{5}_{\Lambda}He$



np coincidence analysis



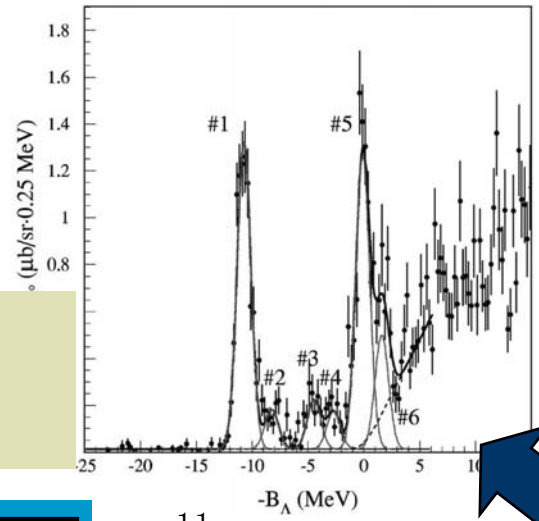
np angular correlation

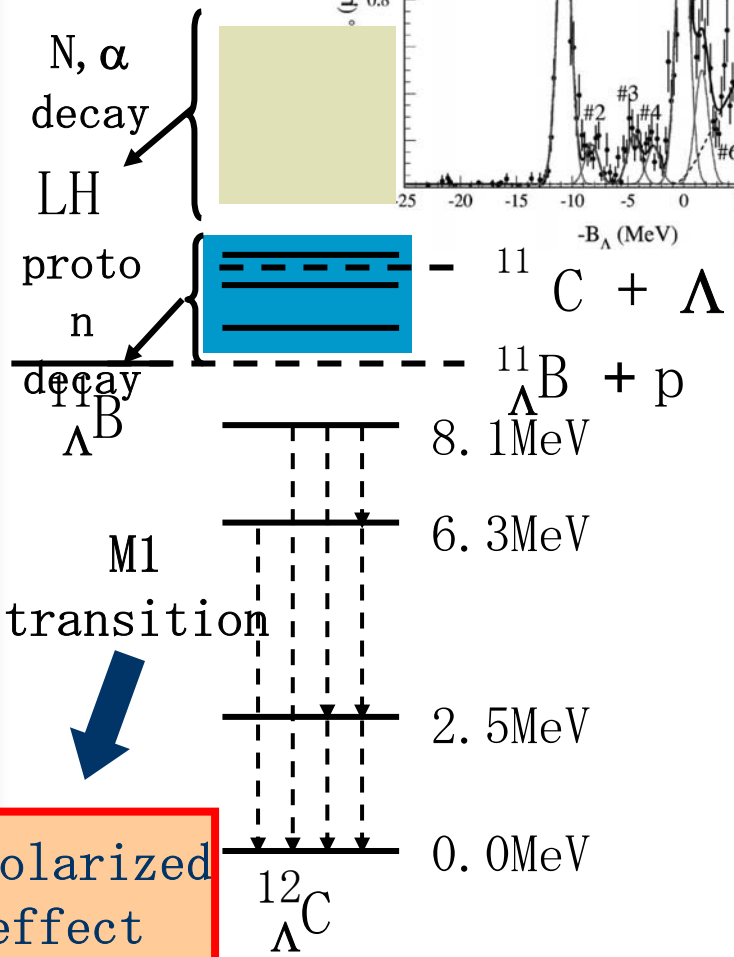


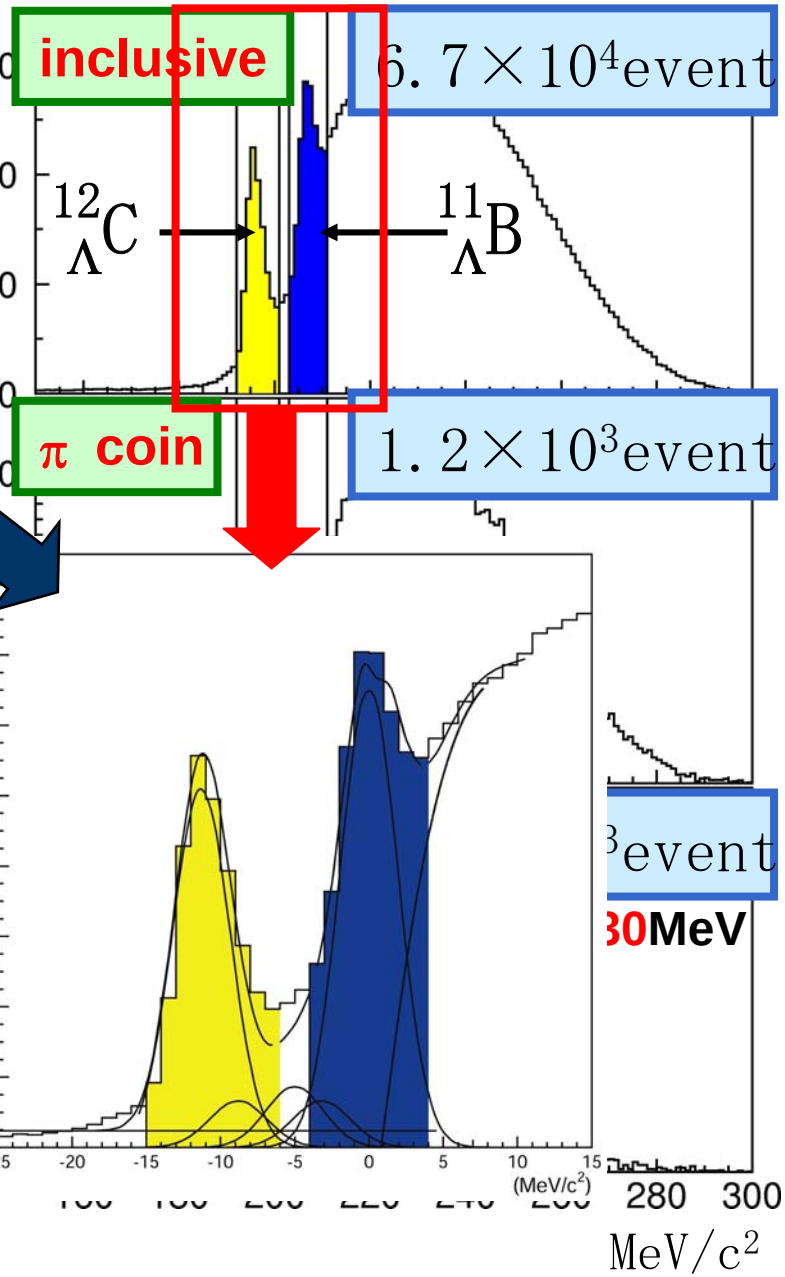
back-to-back events

Horizontal Scattering Angle	N_{upper}/ N_{bwer}		Asymmetry	Asymmetry Parameter
	θ <0	θ >0		
6<|θ |<15°	23/ 26	30/ 19	0.18± 0.12	0.31± 0.22

${}^{12}_{\Lambda}C$ Hypernuclear mass spectra



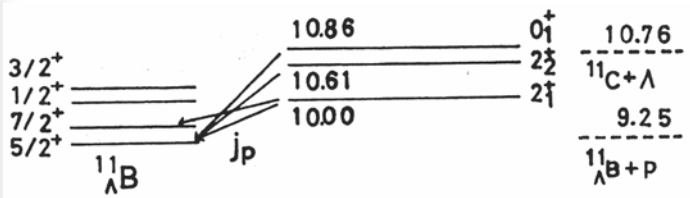


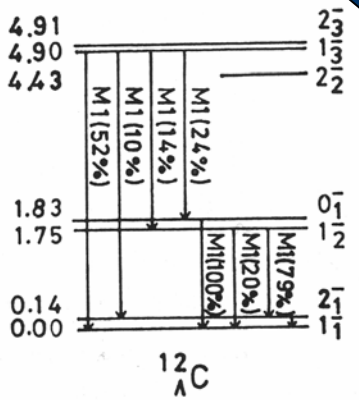


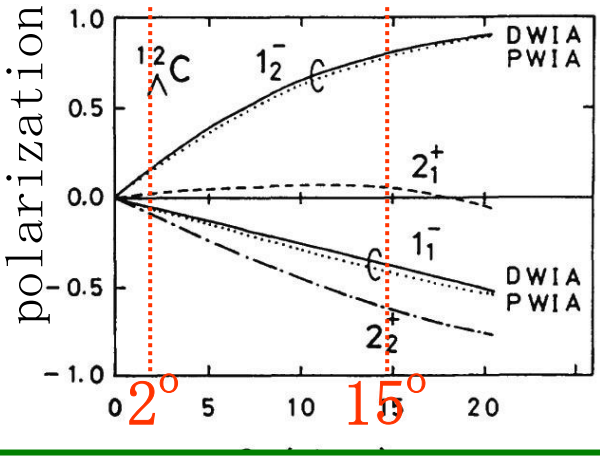
Polarization of Λ

Itonaga *et al.*
Prog. of Theo. Phys. Supp. 117(1994)14

M1 transition reduces Polarization of Λ







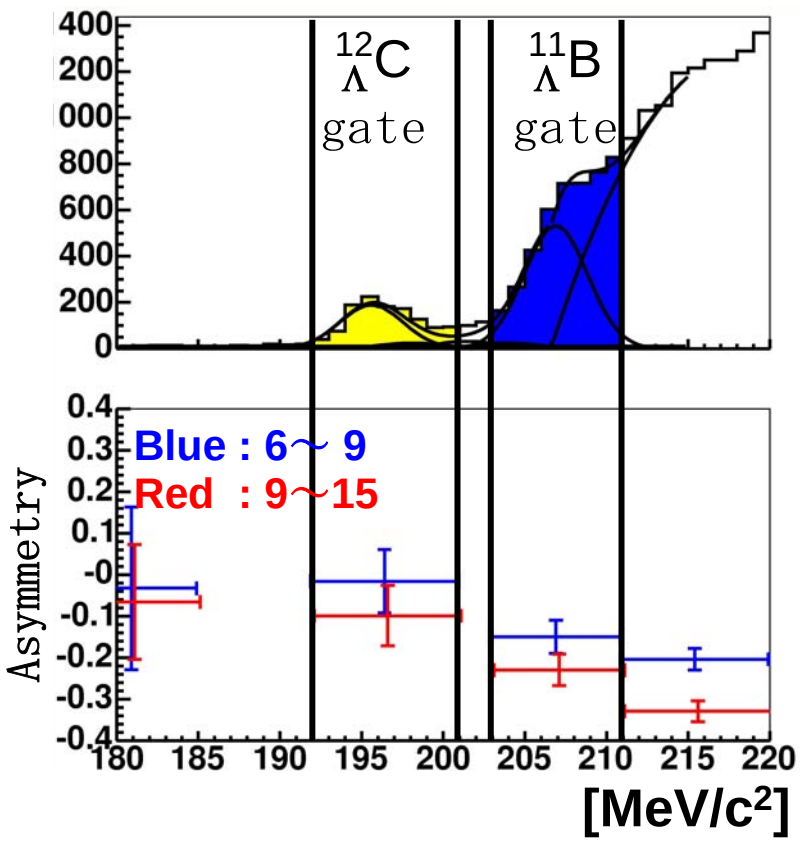
If assuming polarization is proportional to scattering angle.

P_Λ	Kaon Scattering angle		
	2°～6°	6°～9°	9°～15°
$^{12}_{\Lambda}C$	0.04	0.08	0.12
$^{11}_{\Lambda}B$	0.04	0.07	0.12

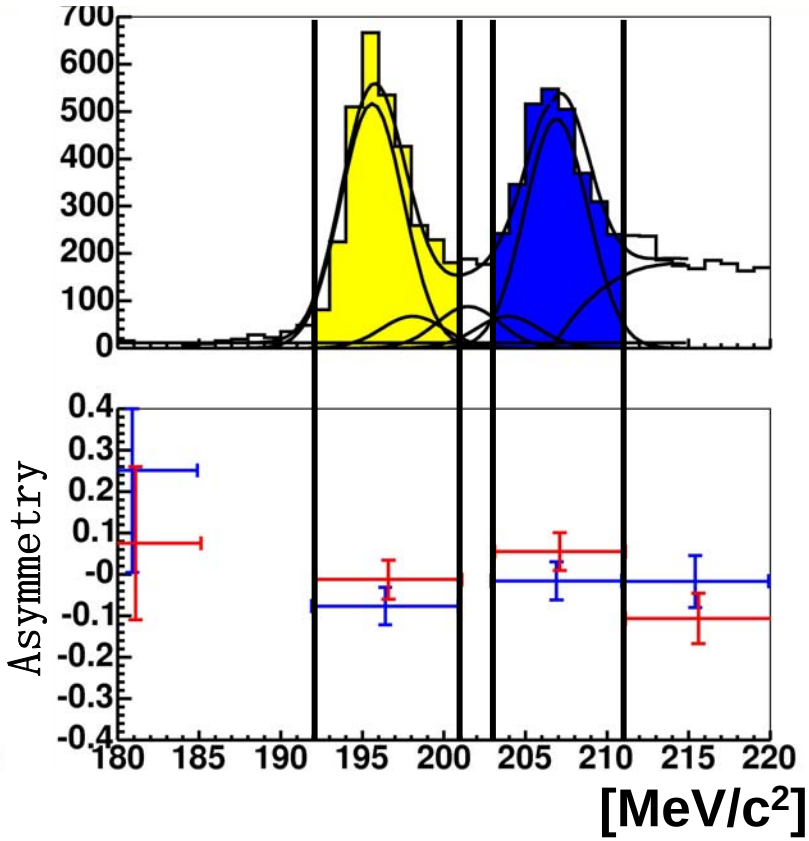
Asymmetry of p-shell hypernuclei

Estimation of the contamination from other energy levels .

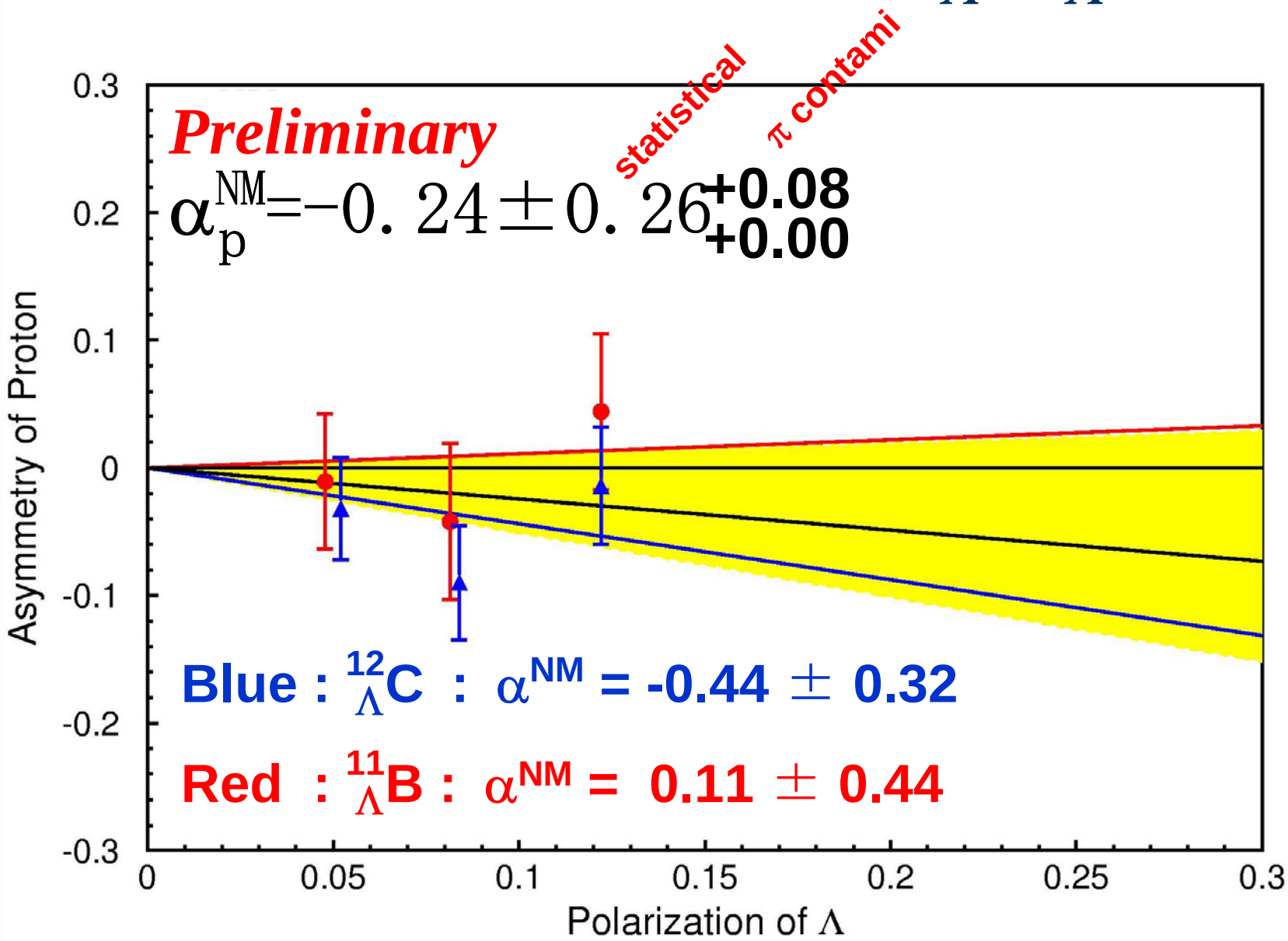
Pion coincidence



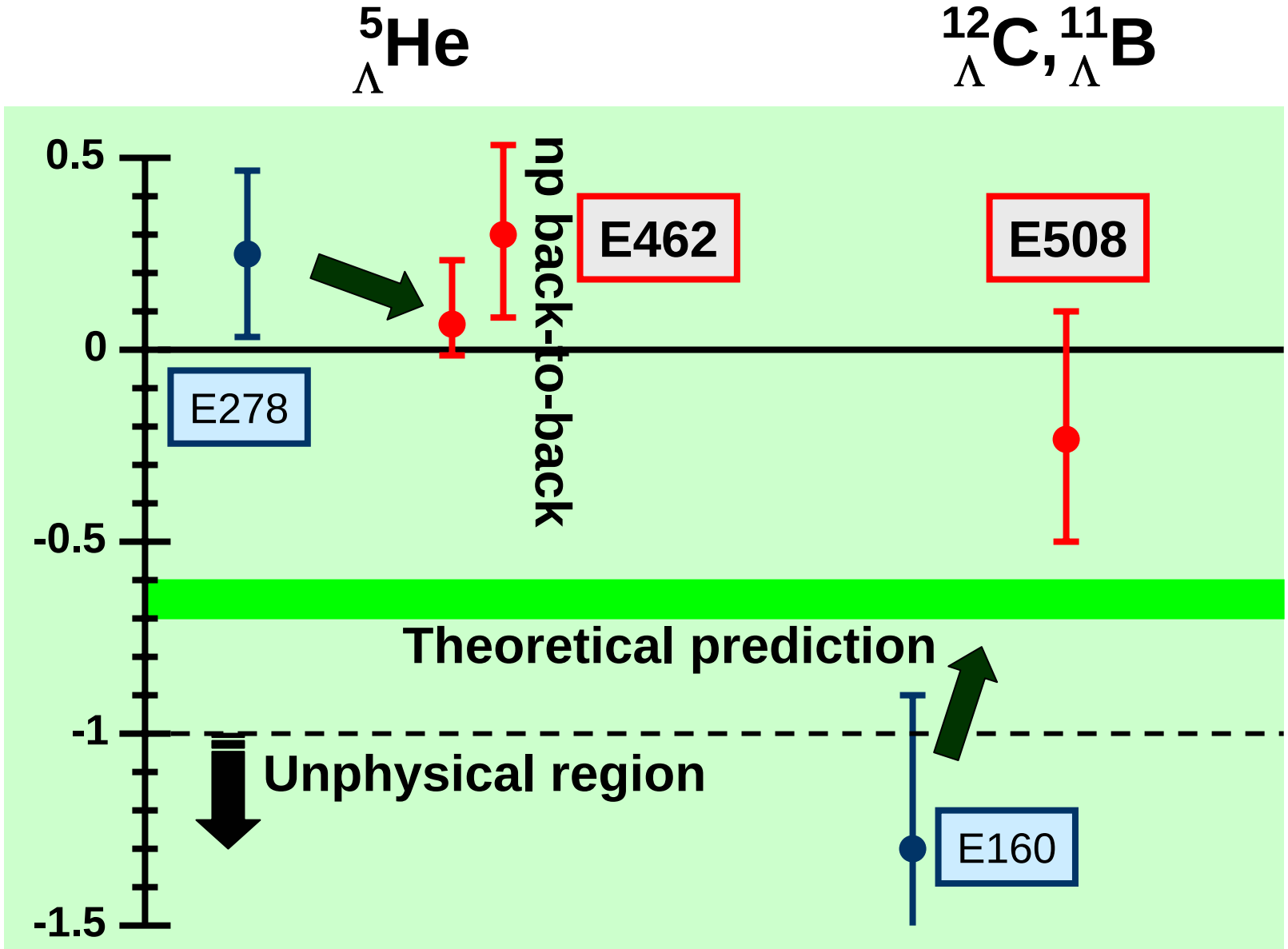
Proton coincidence



Asymmetry parameter of ${}^{12}_{\Lambda}C, {}^{11}_{\Lambda}B$



Comparison with recent results



Summary

- We performed precise α_p^{NM} measurements of ${}^{5}_{\Lambda}\mathrm{He}$(s-shell) and ${}^{12}_{\Lambda}\mathrm{C}$,${}^{11}_{\Lambda}\mathrm{B}$(p-shell) hypernuclei.
- Slightly positive α_p^{NM} ($\mathbf{0.07 \pm 0.08^{+0.08}_{-0.00}}$) of s-shell hypernuclei was confirmed and α_p^{NM} of np back-to-back event also supports this tendency(**0.31±0.22**).
- In the case of p-shell hypernuclei, our result ($\mathbf{-0.24 \pm 0.26^{+0.08}_{-0.00}}$) contradicts large negative α_p^{NM} which obtained previous experiment with several times higher statistics.
- Theoretical calculation is inconsistent with our results, it means new reaction mechanism are required.

Spare OHP

Summary

Asymmetry parameter of NMWD

- s-shell
  (${}^{5}_{\Lambda}$**He**: E462)

→ **- Total :**

$$0.07 \pm 0.08\ ^{+0.08}_{-0.00}$$ *(preliminary)*

- np back-to-back :

$$0.31 \pm 0.22$$ *(preliminary)*

- p-shell
  (${}^{12}_{\Lambda}$**C**,${}^{11}_{\Lambda}$**B**: E508)

→ $$-0.24 \pm 0.26\ ^{+0.08}_{-0.00}$$ *(preliminary)*

Large discrepancy

Theoretical prediction
(s/p-shell hypernuclei) → -0.6 ～-0.7

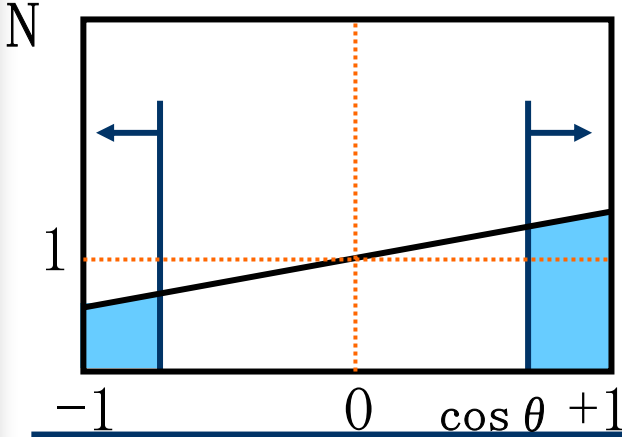
Asymmetry measurement of decay proton

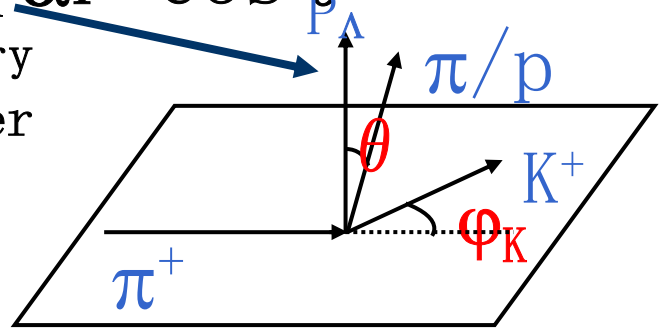
Asymmetry : Volume of the asymmetric emission from NM

$$N(\theta) = 1 \pm A\cos\theta = 1 +_{\Lambda} \alpha P \cos\theta$$

Asymmetry

Asymmetry Parameter





Decay counter Acceptance
$|\theta| > 0.7$

SKS Acceptance
$\varphi_K = +15^\circ \sim -15^\circ$

$$A = \frac{(r+1)}{(r-1)}, \quad r = \frac{N(\theta^+)}{N(\theta^-)}$$

$$r = \left\{ \frac{N(\theta^+(+\varphi)) \times N(\theta^-(-\varphi))}{N(\theta^+(-\varphi)) \times N(\theta^-(+\varphi))} \right\}^{1/2}$$

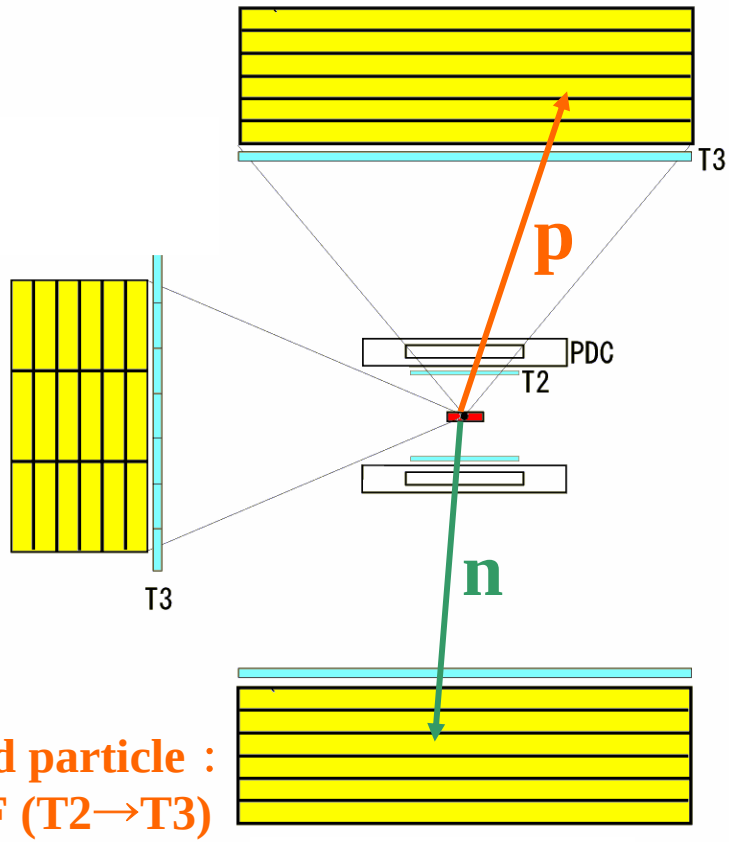
Difference of acceptance & efficiency is canceled out !

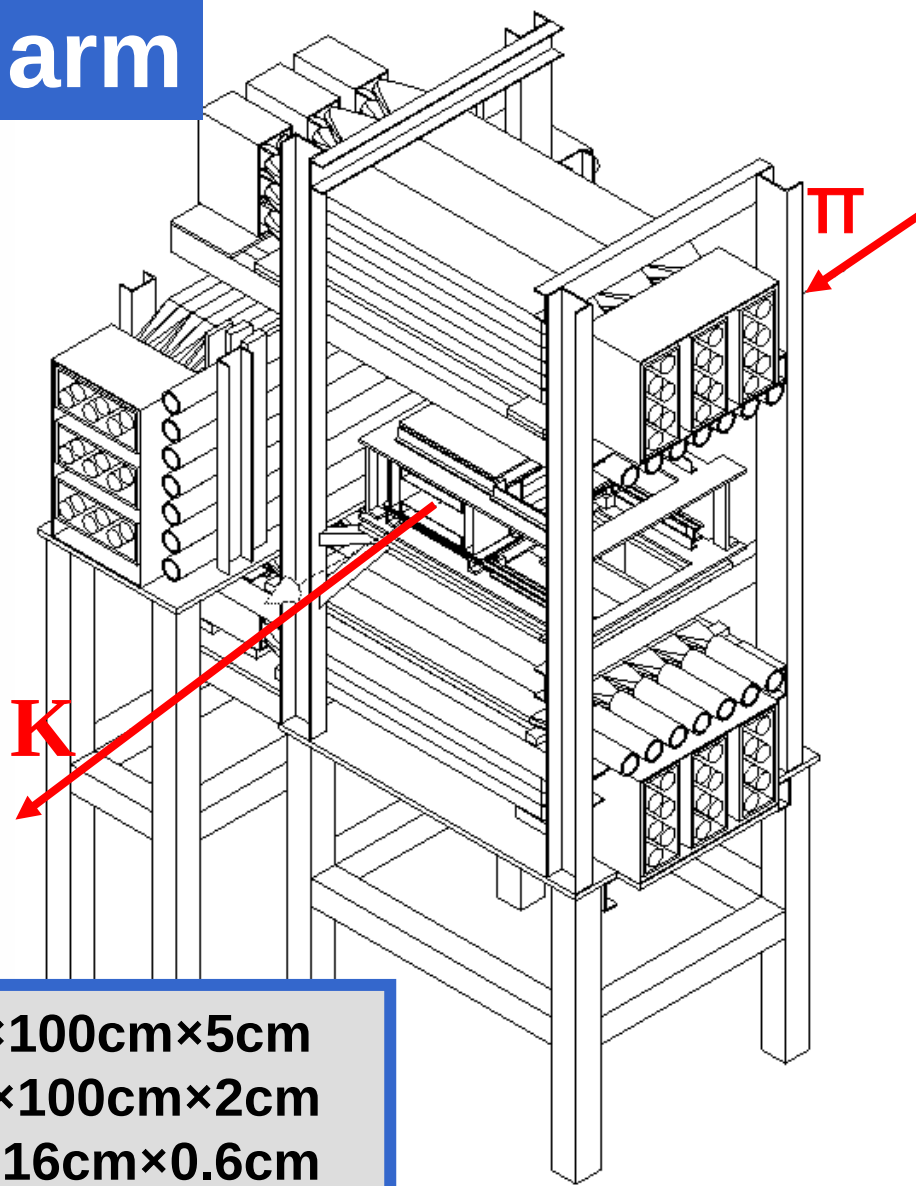
Setup

(KEK-PS K6 beamline & SKS)

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

Decay arm



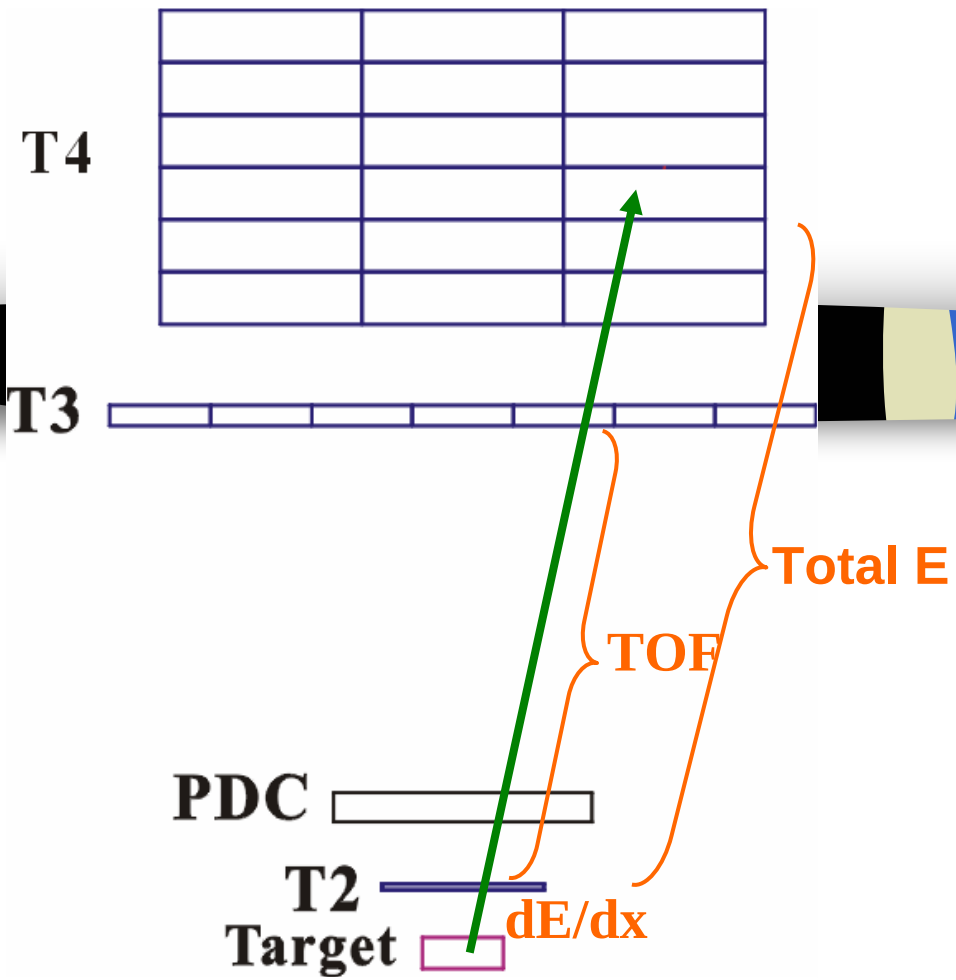


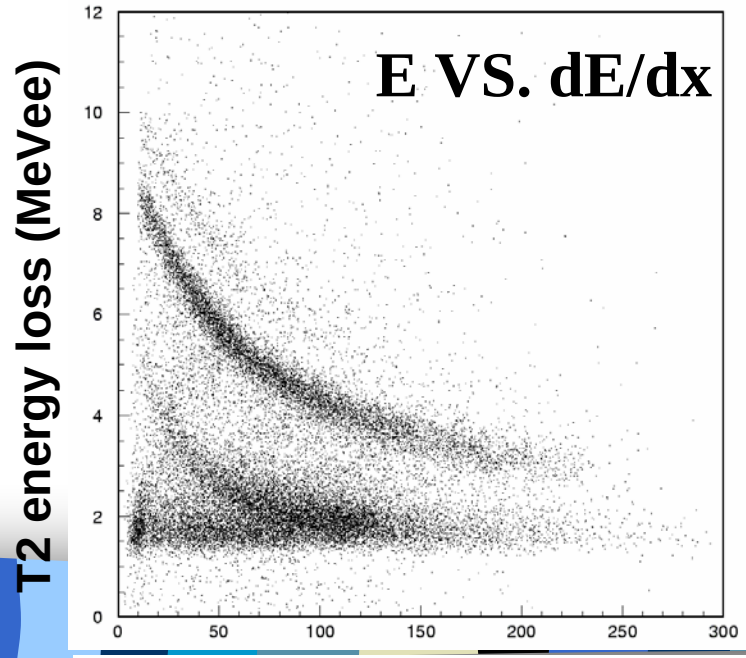
Charged particle：
- **TOF (T2→T3)**
- **tracking（PDC）**

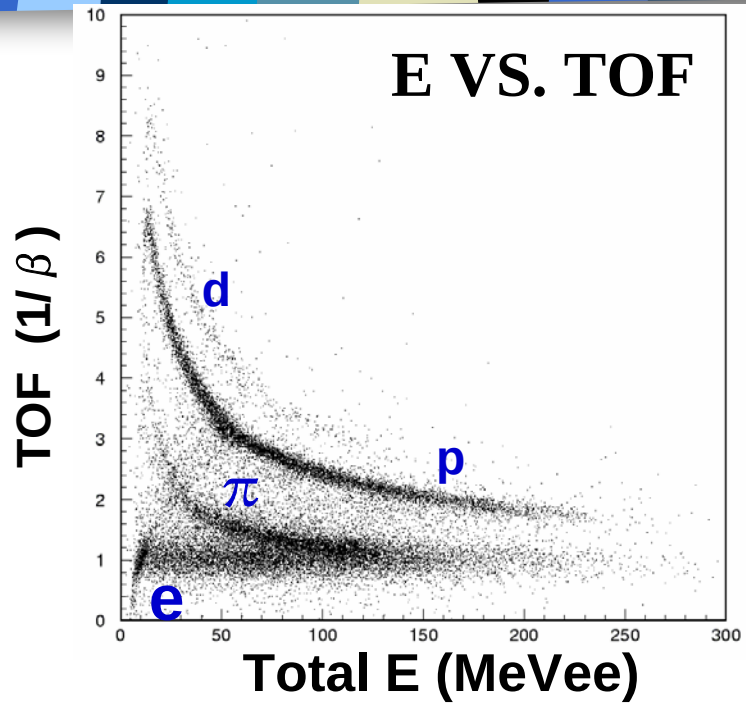
Neutral particle： 20cm
- **TOF (target→NT)**
- **T2/T3 VETO**

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

Charged particle ID

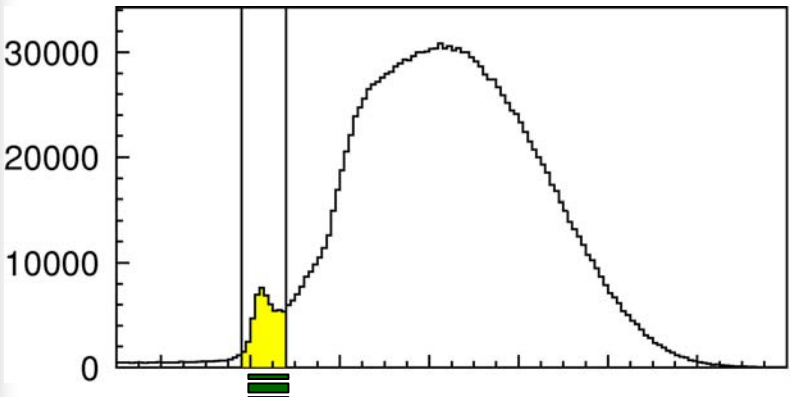




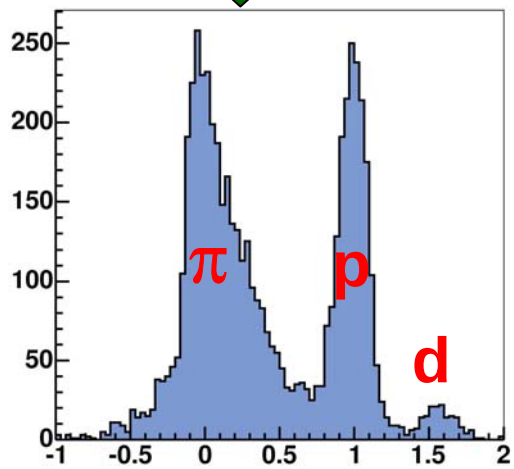


PID distribution

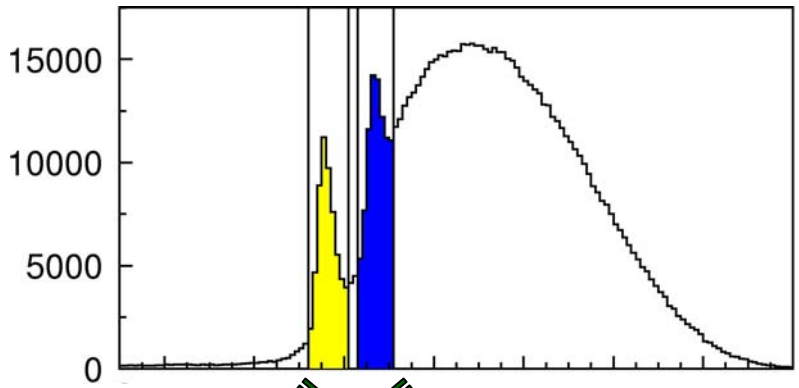
$^{5}_{\Lambda}$He spectrum(E462)



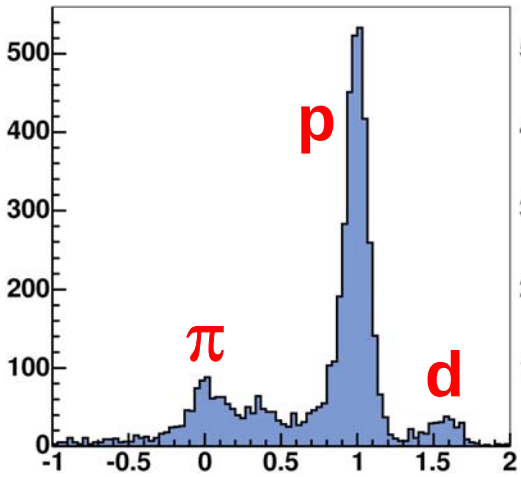
$^{5}_{\Lambda}$He gate



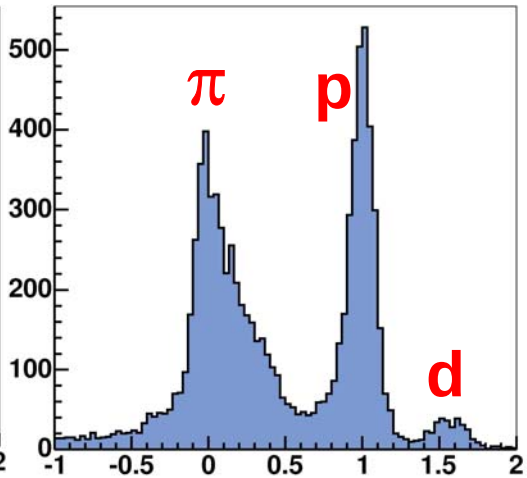
$^{12}_{\Lambda}$C spectrum(E508)



$^{12}_{\Lambda}$C gate



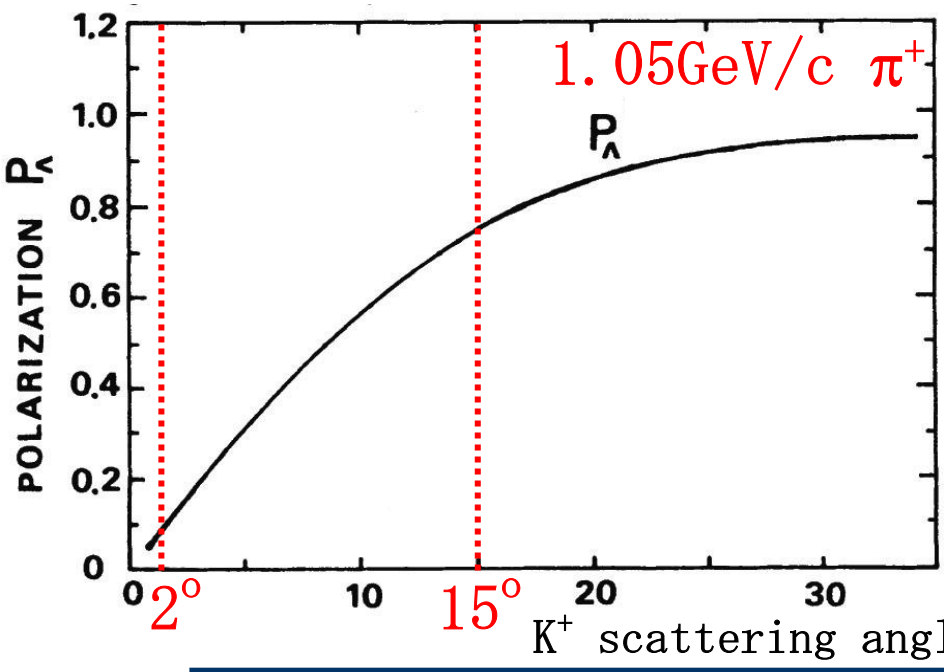
$^{11}_{\Lambda}$B gate

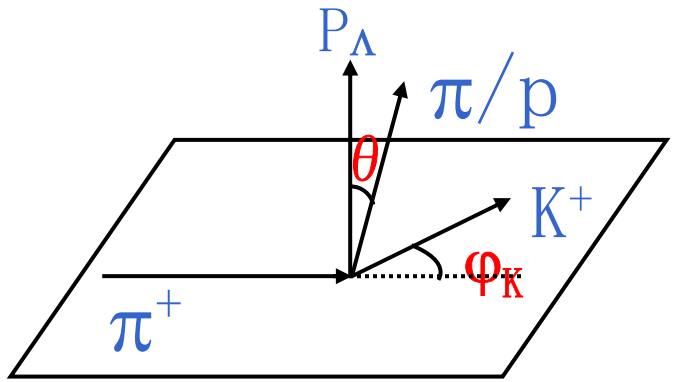


Production of Polarized hypernuclei

E462/E508 experiment → 1.05GeV/c π^+ beam is injected.

Distribution of Λ polarization in the n(π^+,K^+)Λ reaction.





→ In large scattering angle, Λ is much

Significance of asymmetry measurement

If assuming initial S state

Initial state	Final state	Amplitude	Isospin	Parity
$^1S_0$	$^1S_0$	a	1	No
	$^3P_0$	b	1	Yes
$^3S_1$	$^1S_1$	c	0	No
	$^3D_1$	d	0	No
	$^1P_1$	e	0	Yes
	$^3P_1$	f	1	Yes

$$\alpha_p^{NM} = \frac{\sqrt{3}/2[-ae + b(c - \sqrt{2}d)/\sqrt{3} + (\sqrt{2}c + d)f]}{1/4\{a^2 + b^2 + 3(c^2 + d^2 + e^2 + f^2)\}}$$

We can know the Interference between states with different **Isospin** and **Parity** .

$$\Gamma_n/\Gamma_p = \frac{2(a^2 + b^2 + f^2)}{a^2 + b^2 + c^2 + d^2 + e^2 + f^2}$$

(Applying $\Delta I = 1/2$ rule)

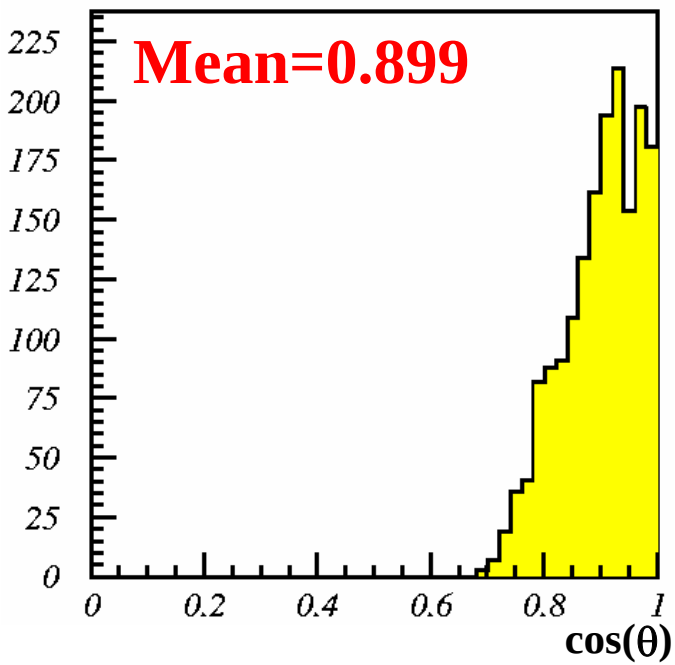
Theoretical and Experimental data

	s-shell $_{\Lambda}$(^{5}He)		p-shell $_{\Lambda}$(^{12}C, ^{11}B)	
	Γ_n/Γ_p	α^{NM}	Γ_n/Γ_p	α^{NM}
Theoretical calculation				
Sasaki *et al.*[2]				
OPE	0.133	-0.441		
π+K	0.450	-0.362		
π+K+DQ	0.701	-0.678		
Parreño *et al.*[3]				
OPE	0.086	-0.252	0.078∼0.079	-0.340
π+K	0.288∼0.498	-0.572∼-0.606	0.205∼0.343	-0.626∼-0.640
OME	0.343∼0.457	-0.675∼-0.682	0.288∼0.341	-0.716∼-0.734
Experimental data				
BNL 1991[4]	0.93±0.55		$1.33^{+1.12}_{-0.81}$	
KEK-E160[5][6]			$1.87^{+0.67}_{-1.16}$	-1.3±0.4
KEK-E278[7][8]	1.97±0.67	0.24±0.22		
KEK-E307[9]			$1.17^{+0.22}_{-0.20}$	

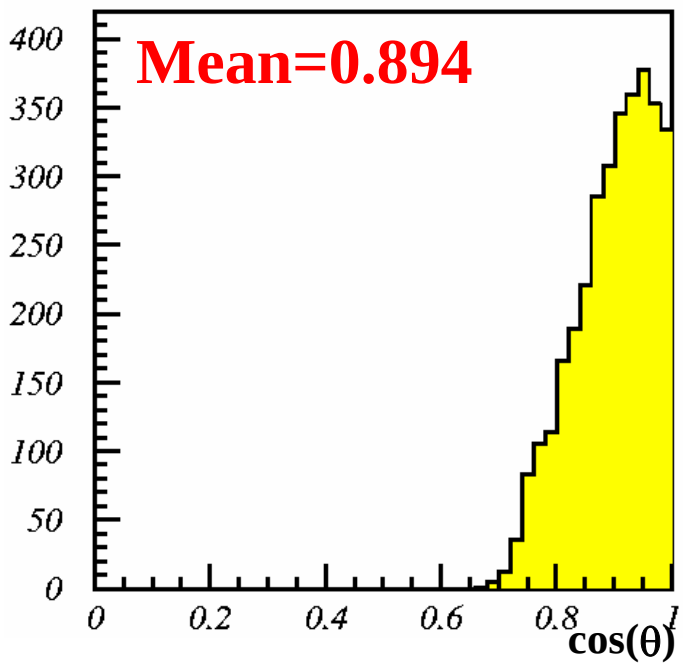
Estimation of Attenuation Factor

To estimate the attenuation factors(ε) ,
I checked angle distribution of decay particles.

Decay Proton



Decay Pion



Attenuation Factor (ε)=~0.9

Summary

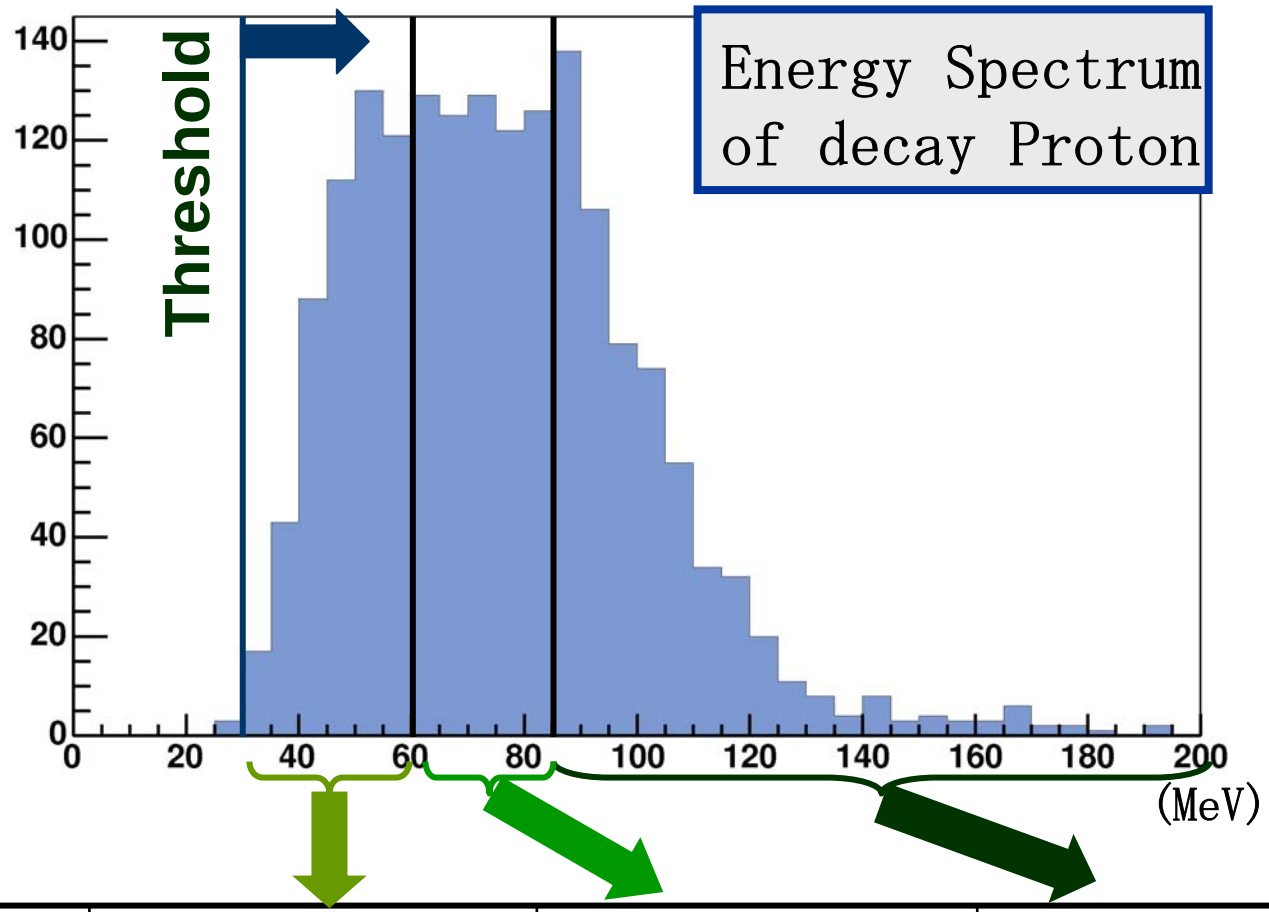
- We performed precise α_p^{NM} measurements of ${}^{5}_{\Lambda}\mathrm{He}$(s-shell)/${}^{12}_{\Lambda}\mathrm{C}$, ${}^{11}_{\Lambda}\mathrm{B}$(p-shell) hypernuclei.

- Slightly positive α_p^{NM} ($\mathbf{0.07 \pm 0.08^{+0.08}_{-0.00}}$) of s-shell hypernuclei was confirmed and α_p^{NM} of np back-to-back event also supports this tendency ($\mathbf{0.31 \pm 0.22}$).

- In the case of p-shell hypernuclei, our result ($\mathbf{-0.24 \pm 0.26^{+0.08}_{-0.00}}$) contradicts large negative α_p^{NM} which obtained previous experiment with several times higher statistics.

Spare OHP
(for E462 experiment)

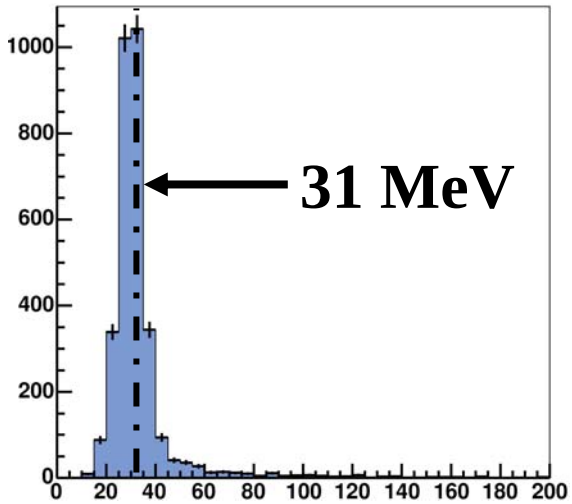
Proton Energy Dependence



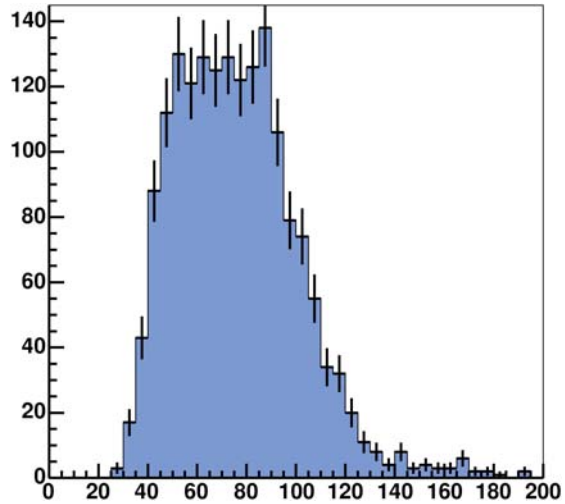
	30～60MeV	60～85MeV	85MeV～
6< $\lvert\theta_K\rvert$<15°	$-0.07 \pm 0.15^{+0.04}_{-0.00}$	$0.17 \pm 0.14^{+0.09}_{-0.00}$	$0.11 \pm 0.15^{+0.09}_{-0.00}$

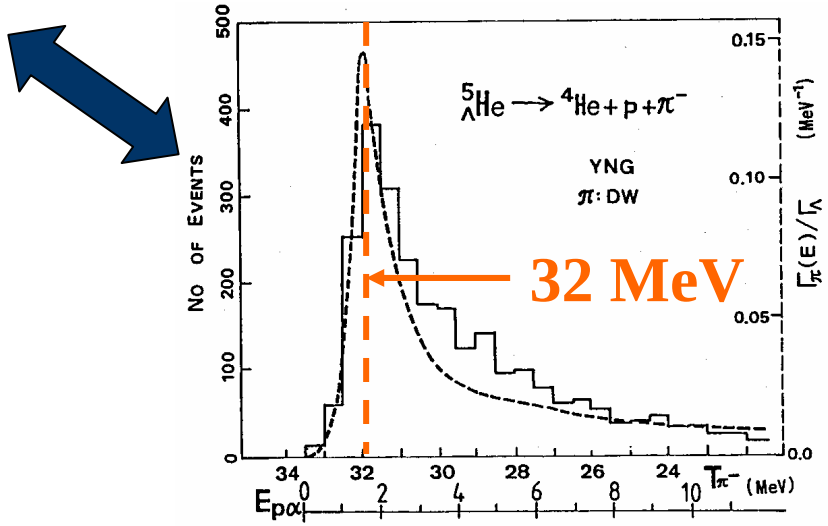
Energy of decay Particle ${}^{5}_{\Lambda}$He gate

π^- Energy

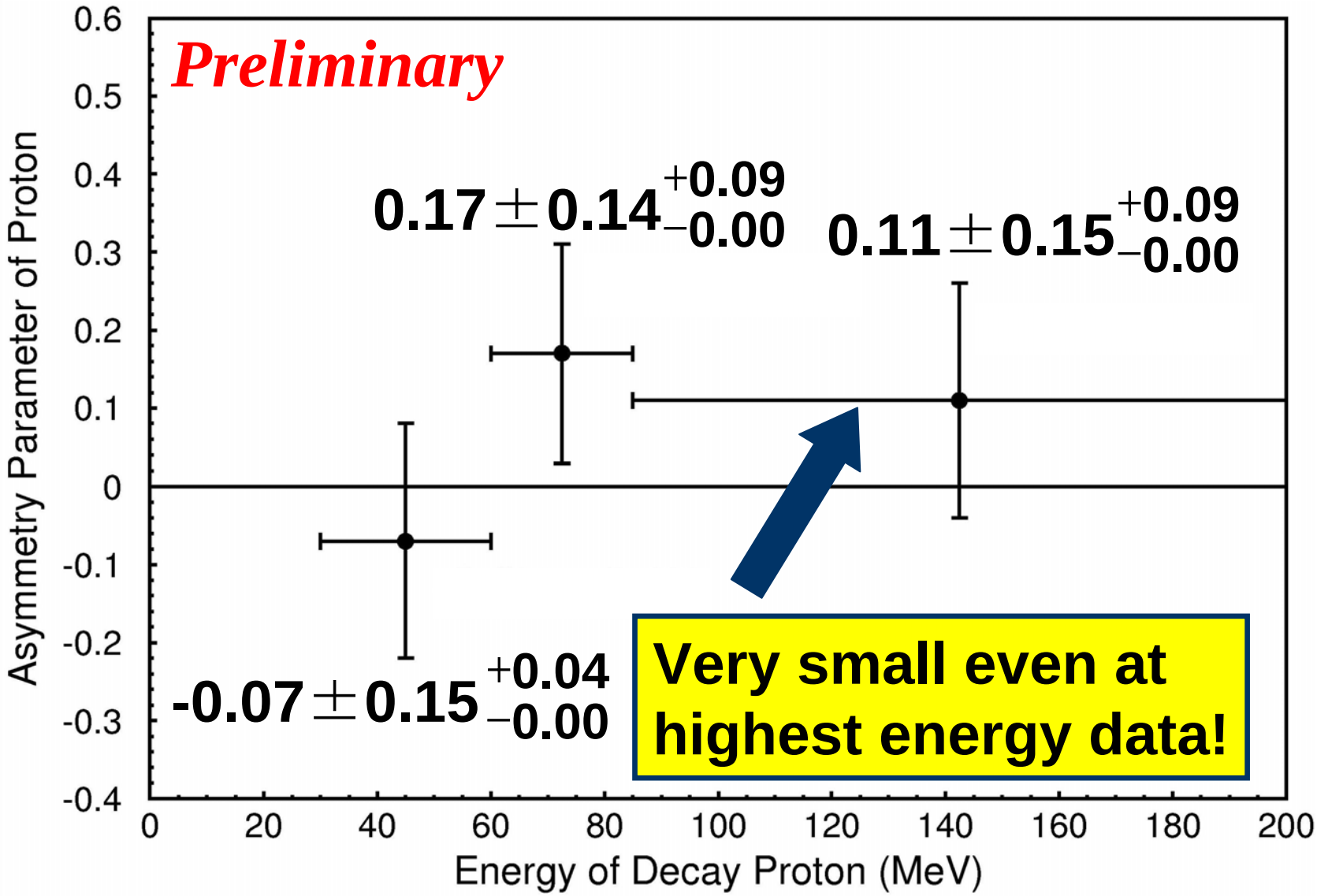


p Energy





Proton energy dependence



Spare OHPs
(for E508 experment)

Asymmetry of p-shell hypernuclei

	Horizontal Scattering Angle	Asymmetry (after correction) $^{12}_{\Lambda}C$	Asymmetry (after correction) $^{11}_{\Lambda}B$
Pion	2<|θ |<6°	-0.040± 0.071	0.060± 0.059
	6<|θ |<9°	0.017+ 0.080	-0.084+ 0.069
	9<|θ |<15°	-0.094+ 0.076	-0.158+ 0.065
Proton	2<|θ |<6°	-0.032+ 0.040	-0.011+ 0.053
	6<|θ |<9°	-0.090+ 0.045	-0.042+ 0.061
	9<|θ |<15°	-0.014+ 0.046	0.044+ 0.061

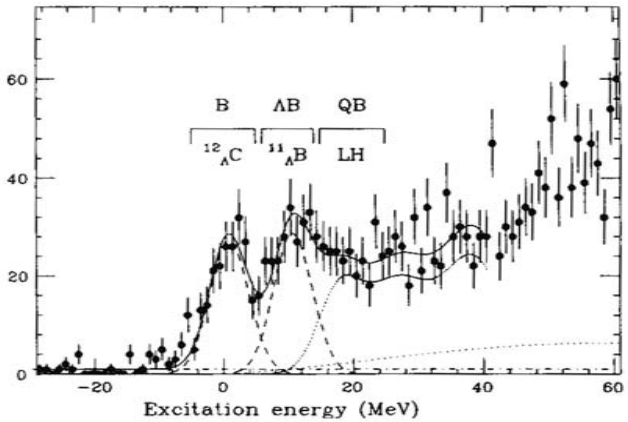
All the regions, Asymmetry is very sm

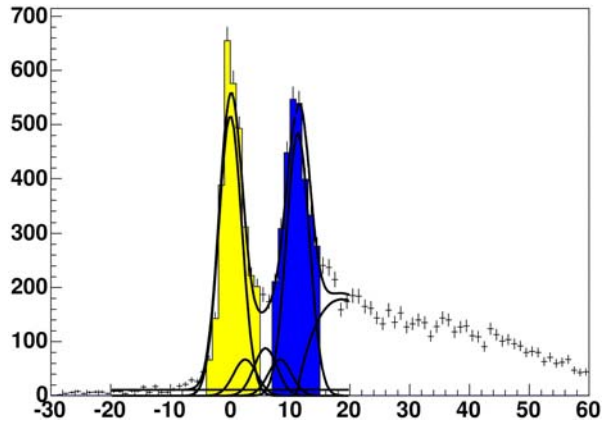
Statistical comparison with E160

E160

E508

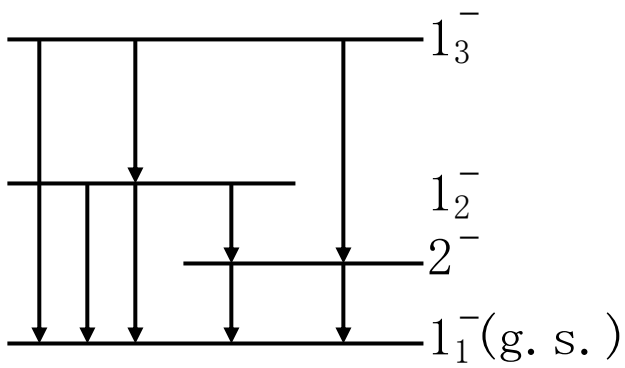
p-coin spectrum





$^{12}_{\Lambda}$C event	246 events	×11 →	2779 events
$^{11}_{\Lambda}$B event	393 events	×5 →	2122 events
Total	639 events	×8 →	4901 events

Polarization of Λ (E160)



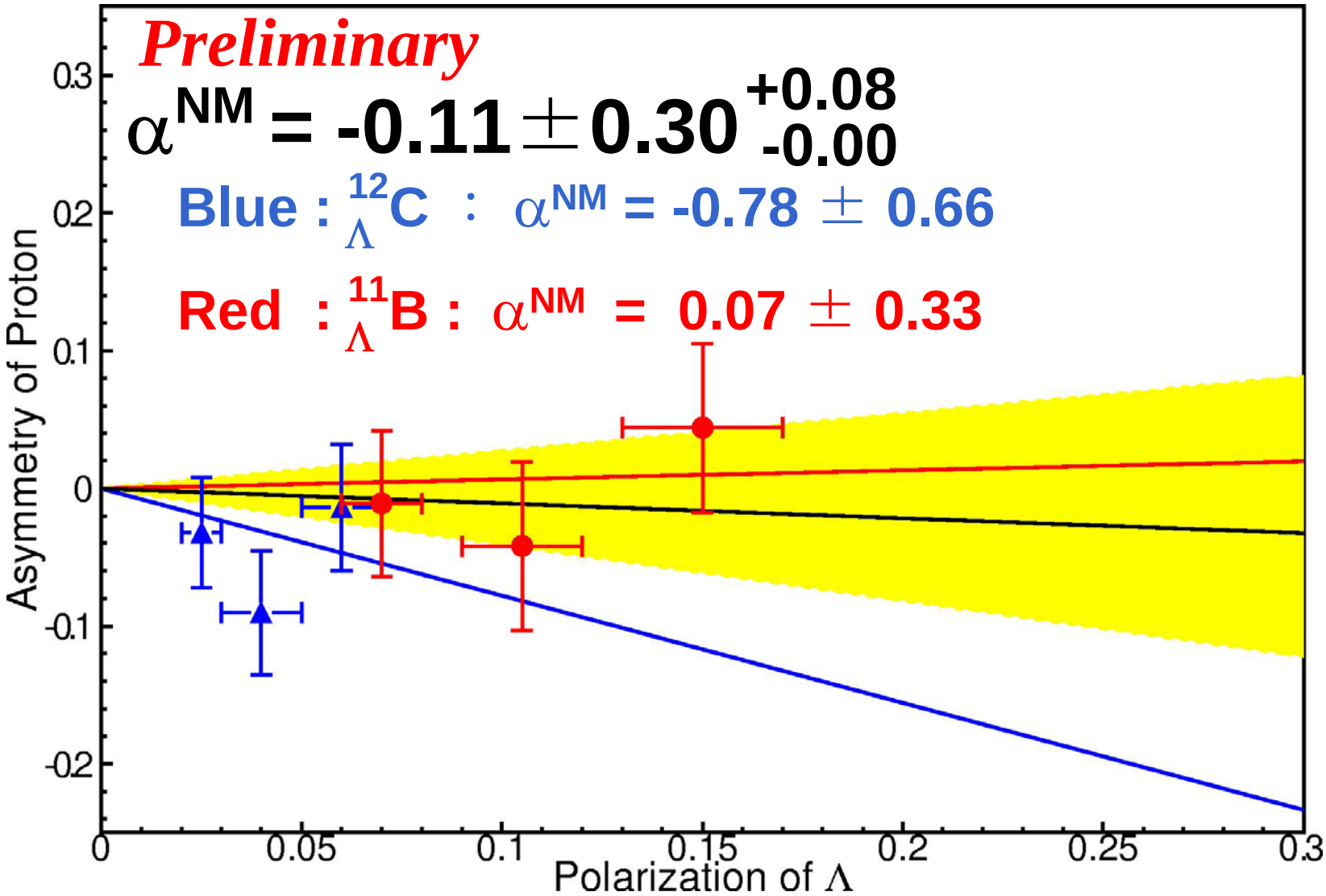
E160 result

	$P_\Lambda(\theta_K=14^\circ)$	Asymmetry
$^{12}_{\Lambda}C$	0.06 ~ 0.09	- 0.01± 0.11
$^{11}_{\Lambda}B$	0.16 ~ 0.21	- 0.19± 0.10
LH	0.15 ~ 0.26	- 0.24± 0.09

At the time of E160, transition probability to 2^- wasn't known. So they calculated by changing it from 0% to 100%.

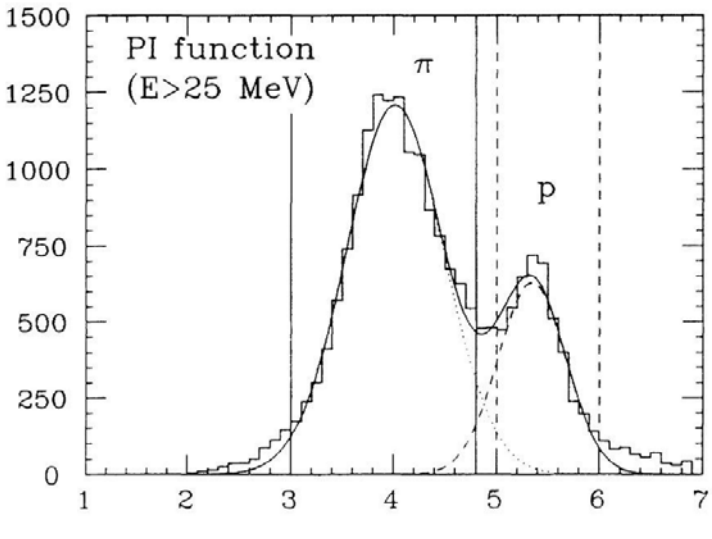
P_Λ	Kaon Scattering angle		
	$2^\circ \sim 6^\circ$	$6^\circ \sim 9^\circ$	$9^\circ \sim 15^\circ$
$^{12}_{\Lambda}C$	0.02 ~ 0.03	0.03 ~ 0.05	0.05 ~ 0.07
$^{11}_{\Lambda}B$	0.06 ~ 0.08	0.09 ~ 0.12	0.13 ~ 0.17

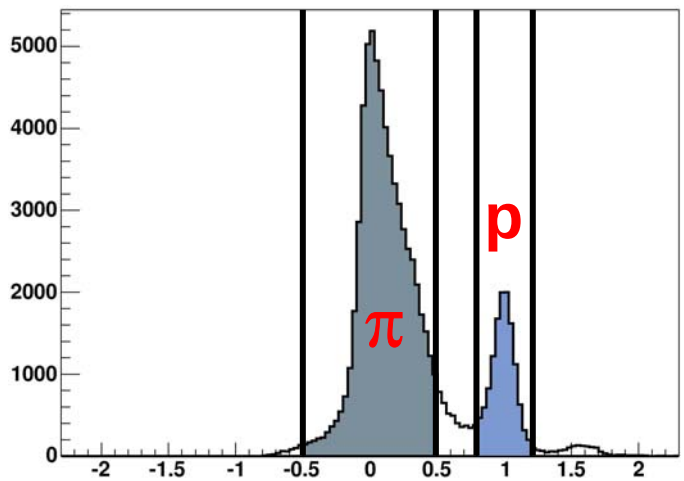
Asymmetry Parameter @ E160 P_Λ



Comparison with E160

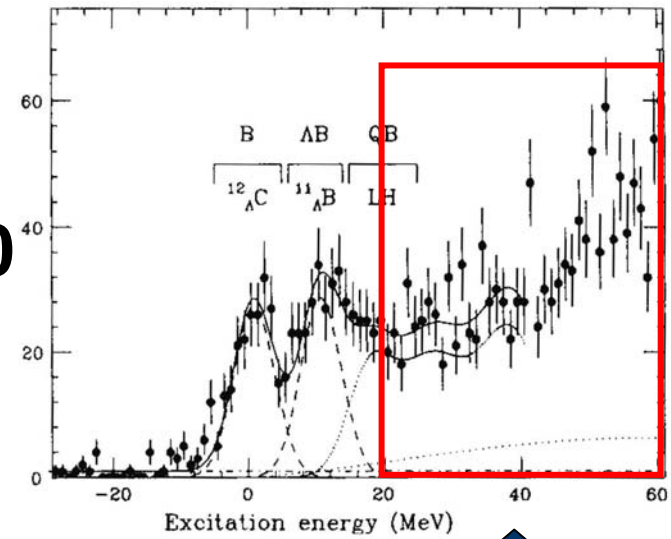
PID function

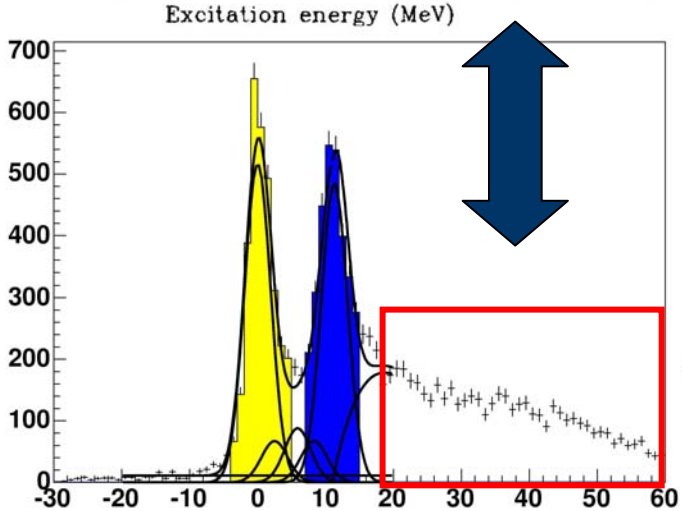




Energy spectrum

E160





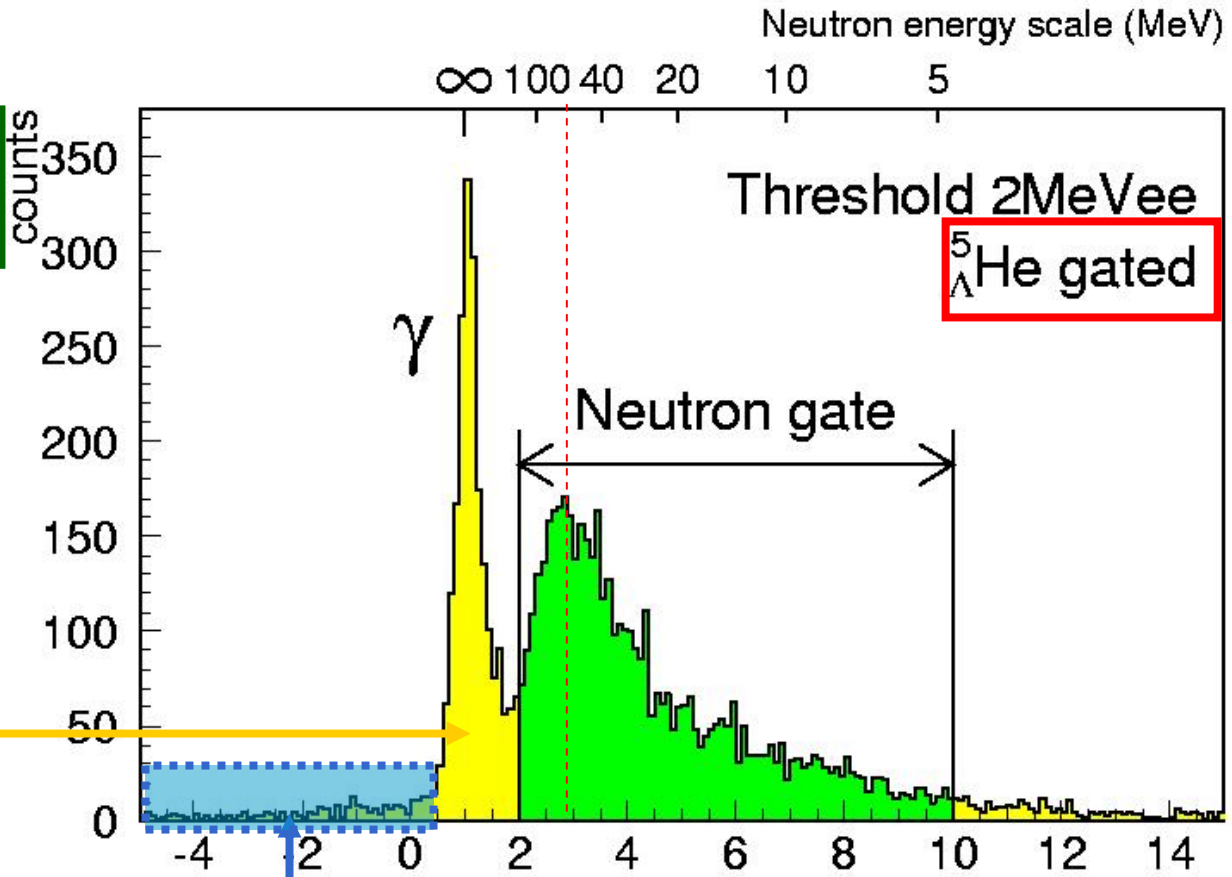
Spare OHPs (others)

Neutral particle analysis

- ✓ Good γ n separation
- ✓ Good S/N ratio (~ 15)

decay mode

$\Lambda \rightarrow n\,\pi^0$ (2γ) $\Lambda \rightarrow p\pi^-$	$\Lambda n \rightarrow n\,n$ $\Lambda p \rightarrow p\,n$



Resolution
for neutron counter
σ ~ 11MeV
(around 80MeV)
width of γpeak

1 / β spectra ($^{5}_{\Lambda}$He gate)

Constant back ground → very small