

Study of the $d(\gamma, K^+)\Sigma^-\pi^+$ reaction at LEPS

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for LEPS collaboration

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Outline of my talk

1. Physics Motivation

2. LEPS experiment

3. Analysis procedure

4. Result and Discussion

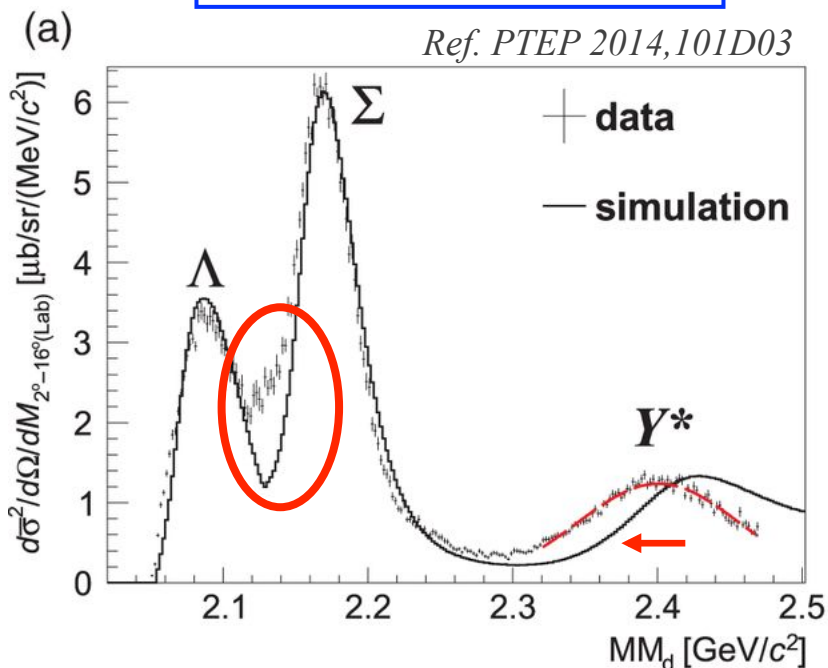
5. Future prospect

Physics Motivation

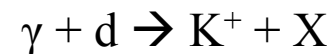


MM(K⁺) *J-PARC E27*

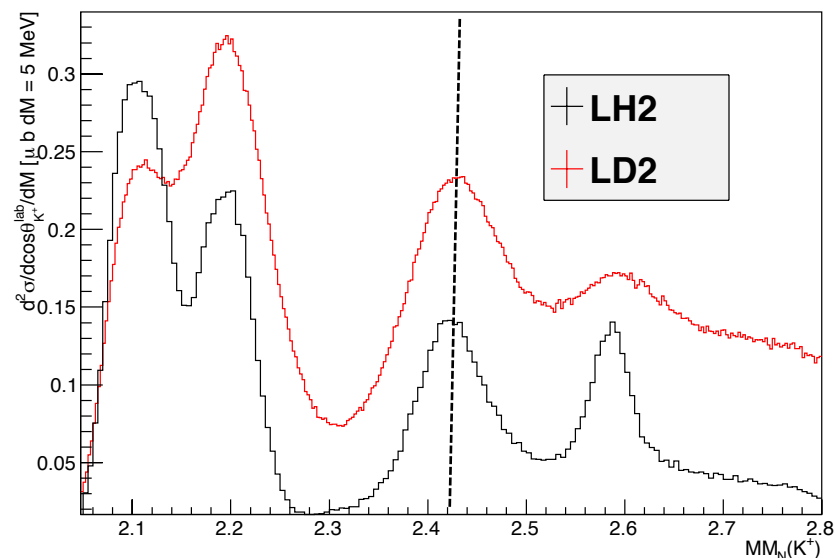
Ref. PTEP 2014,101D03



30 MeV shift was observed in Y* region
(caused by Y*N interaction?)



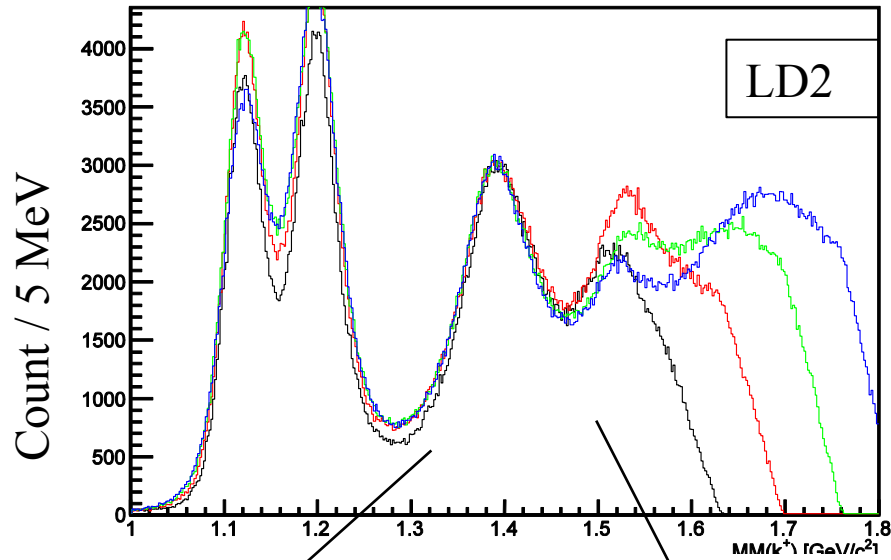
MM(K⁺) *LEPS*



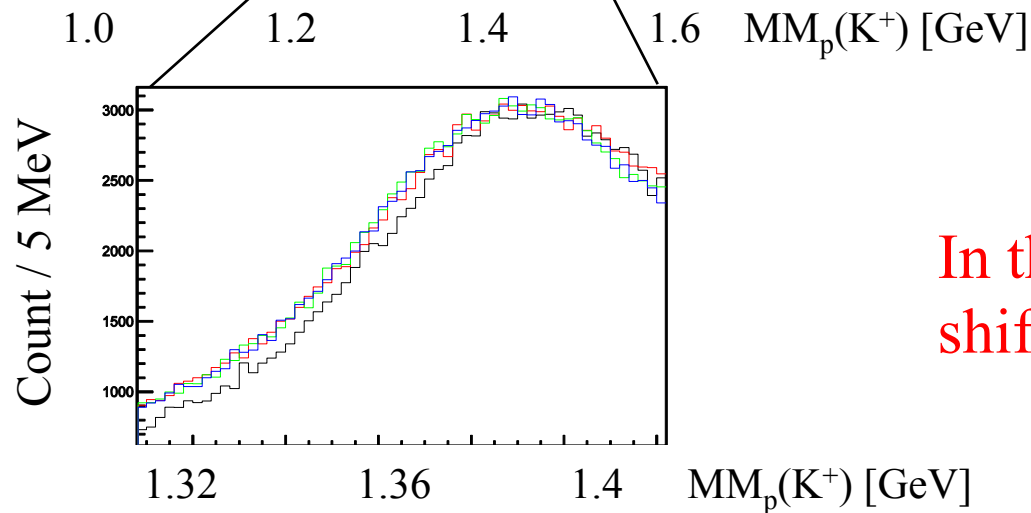
no shift was observed in Y* region

Why is the shift not observed in the γ -induced reaction?

E_γ cut



- 1.8 < E_γ < 1.95
- - - 1.95 < E_γ < 2.1
- - - 2.1 < E_γ < 2.25
- - - 2.25 < E_γ < 2.4



In the different E_γ condition,
shift was not observed.

E27 v.s. LEPS

J-PARC/E27
 $\pi^+ + d \rightarrow K^+ + X$

SPring-8/LEPS
 $\gamma + d \rightarrow K^+ + X$

momentum transfer

0.8 GeV/c

0.7 – 1.0 GeV/c

mass resolution

2 MeV/c²

10 MeV/c²

X (Λ^* / Σ^*)

1 / 3

1 / 10

Ref. Nucl. Phys. B56, 15(1973)

Ref. PRC.78,035202 (2008)

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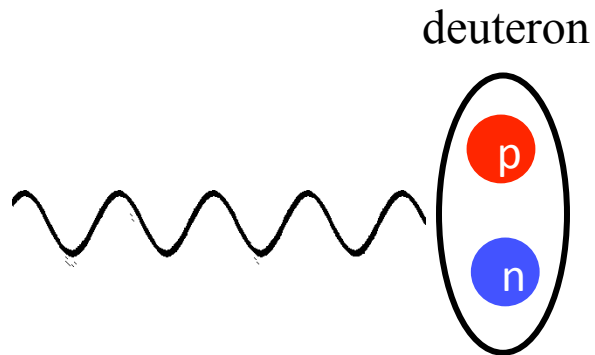
1 / 3

1 / 10

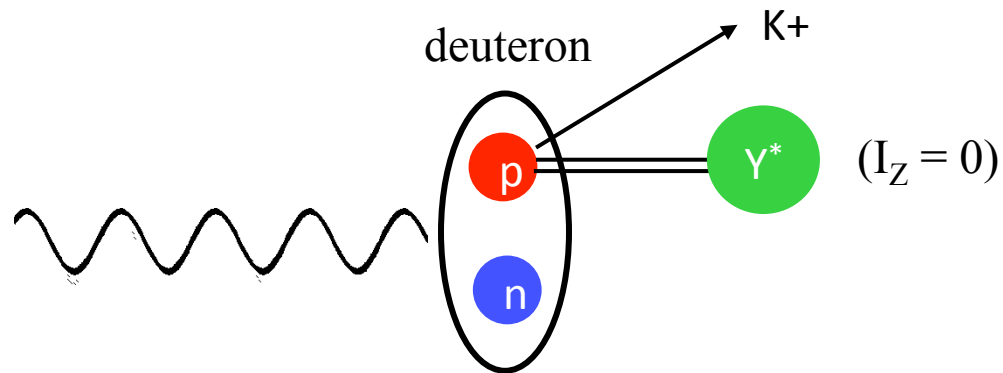
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Ref. PRC.78,035202 (2008)

- We need to disentangle Λ^*/Σ^* contribution.
- Especially Λ^*N final state is interesting.



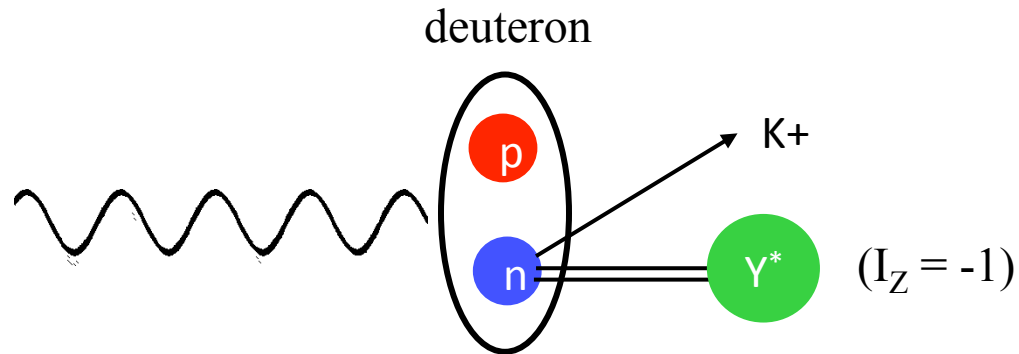
$$\gamma + N \rightarrow K^+ + Y^*$$



from proton target

$\Lambda(1405)$

$\Sigma(1385)^0$



from proton target

$\Lambda(1405)$

$\Sigma(1385)^0$

from neutron target

$\Sigma(1385)^-$



from proton target

$\Lambda(1405)$

$\rightarrow \Sigma^0 \pi^0$ (33 %)

$\rightarrow \Sigma^+ \pi^-$ (33 %)

$\rightarrow \Sigma^- \pi^+$ (33 %)

$\Sigma(1385)^0$

$\rightarrow \Lambda \pi^0$ (88 %)

$\rightarrow \Sigma^- \pi^+$ (6 %)

$\rightarrow \Sigma^+ \pi^-$ (6 %)

from neutron target

$\Sigma(1385)^-$

$\rightarrow \Lambda \pi^-$ (88%)

$\rightarrow \Sigma^0 \pi^-$ (6%)

$\rightarrow \Sigma^- \pi^0$ (6%)

1. If we detect π^+ as a decay particle,
 \rightarrow reactions from proton are selected.
 (directly comparable with LH₂ target data)
2. If we identify $\Sigma^- \pi^+$ final state,
 $\rightarrow \Lambda^*$ contribution is enhanced.
 ($\Lambda^*/\Sigma^* : 1/10 \rightarrow 2 - 3$)

LEPS experiment



LEPS

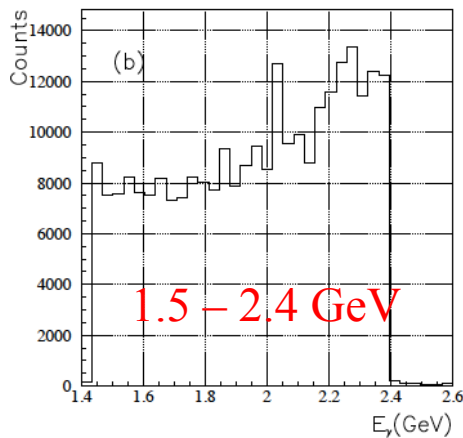
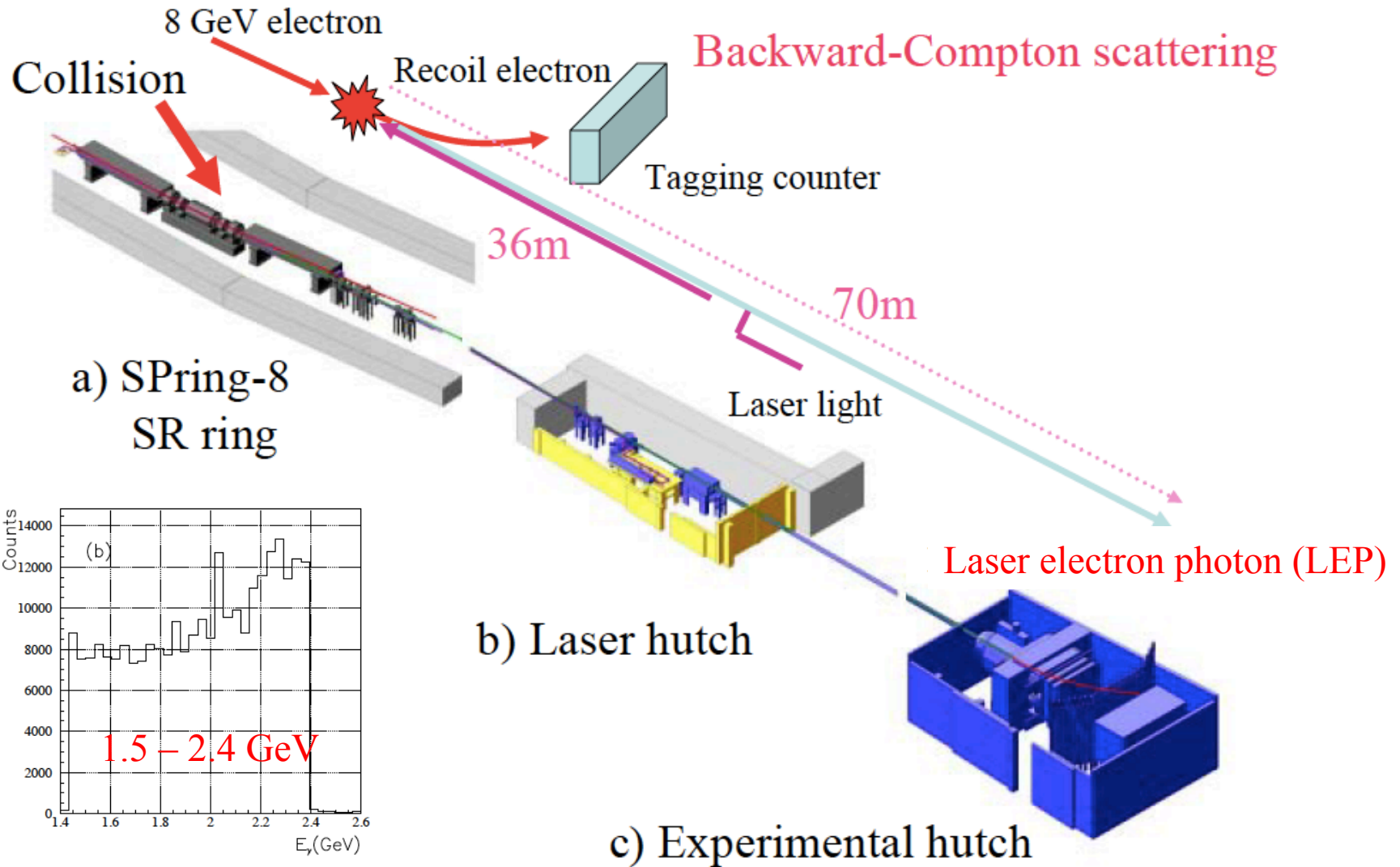


(Laser-Electron-Photon facility
at SPring-8)

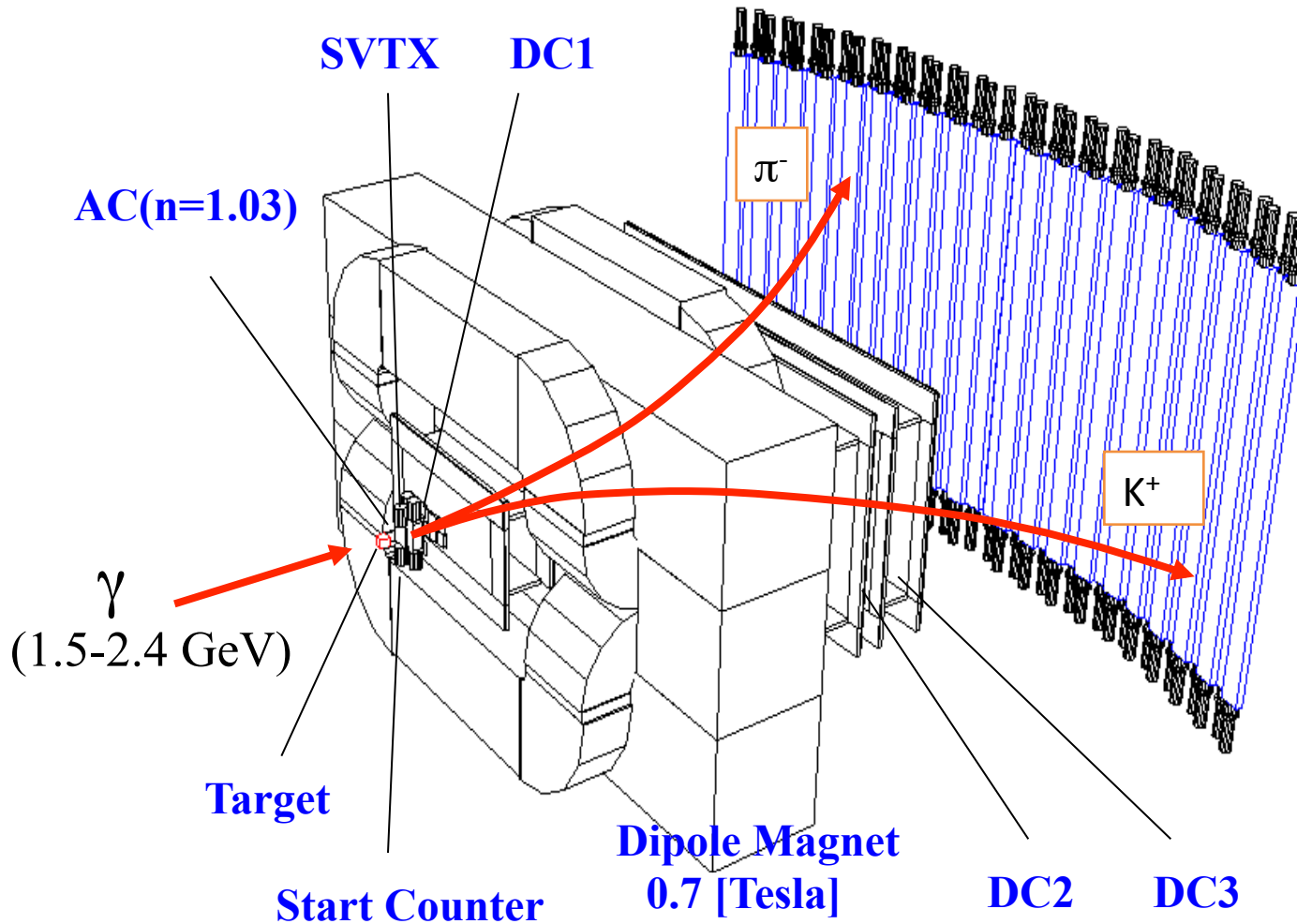
Spring-8
(Super Photon ring - 8GeV)
@ Hyogo, Japan

-Hadron photo-production
by backward Compton scattering
- $E_\gamma = 1.5 - 2.4 \text{ GeV}$

LEPS experiment



LEPS spectrometer



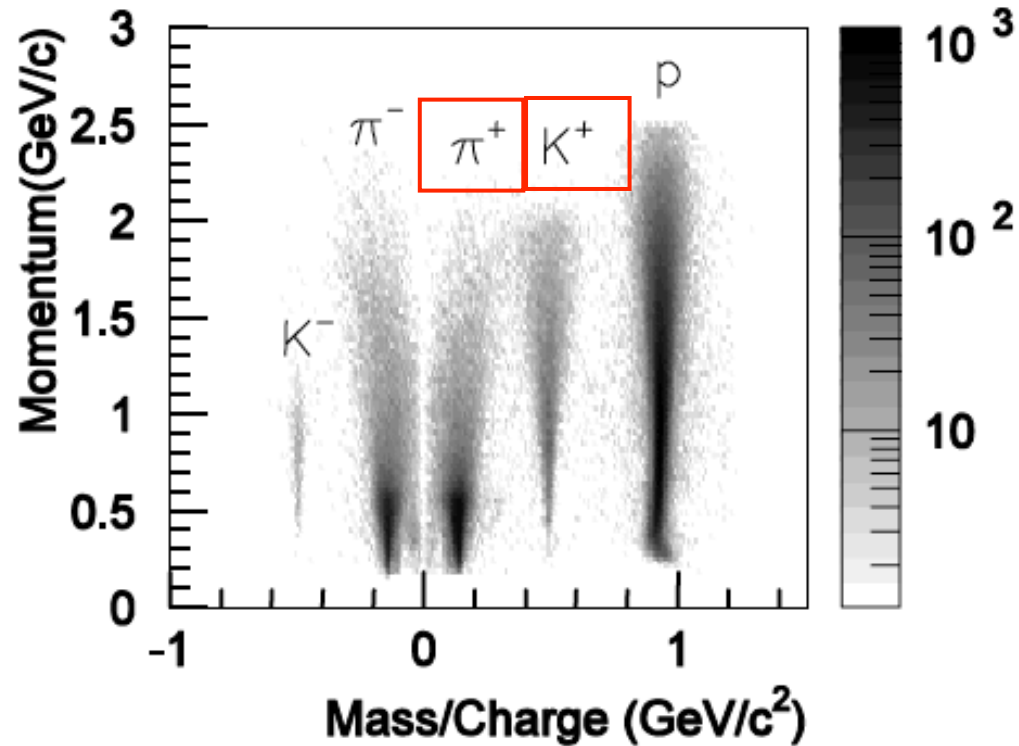
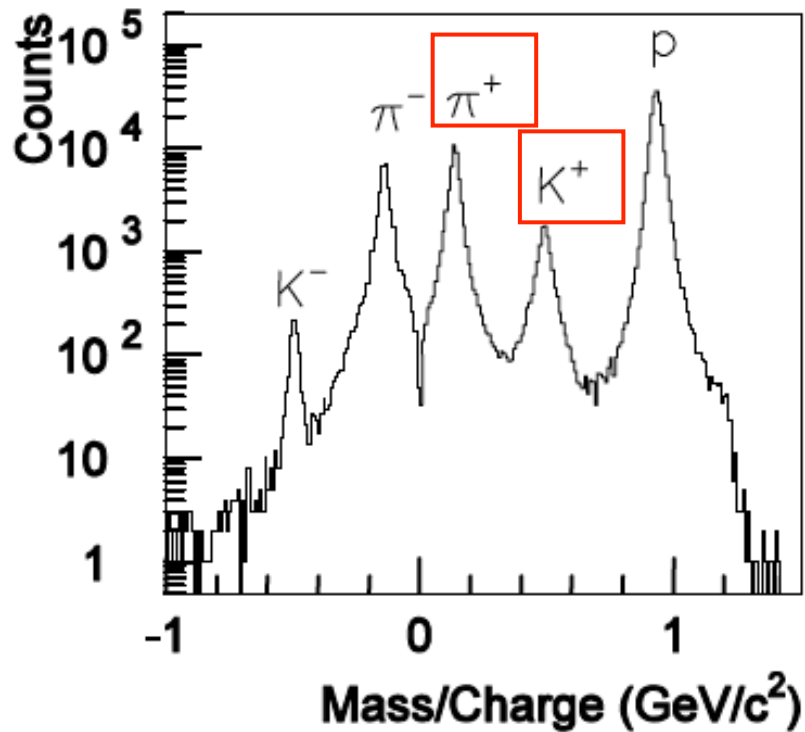
- $\Delta p \sim 6 \text{ MeV}/c$
@ $1 \text{ GeV}/c$

- PID (π, K, p)
at forward angle
(< 15 degree)

- Data-set
2006/2007
 10^{12} photon
on LD_2 target

Particle Identification

Reconstructed mass spectra



K^+/π^+ miss-identification $\sim 3\%$

K^+ and π^+ were selected and used for the analysis.

Analysis procedure

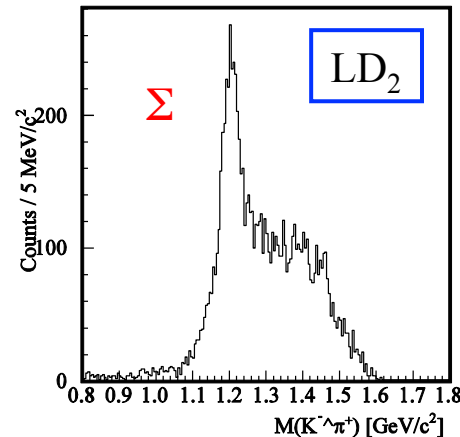
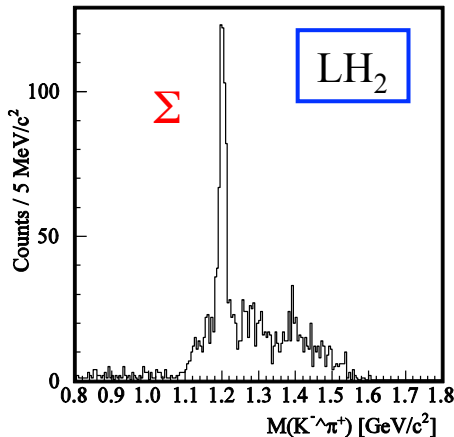
☆ *Purpose:*

1. Identify the $\gamma + p \rightarrow K^+ + \pi^+ + \Sigma^-$ reaction.

detect

identify in MM

MM($K^+\pi^+$)
spectrum

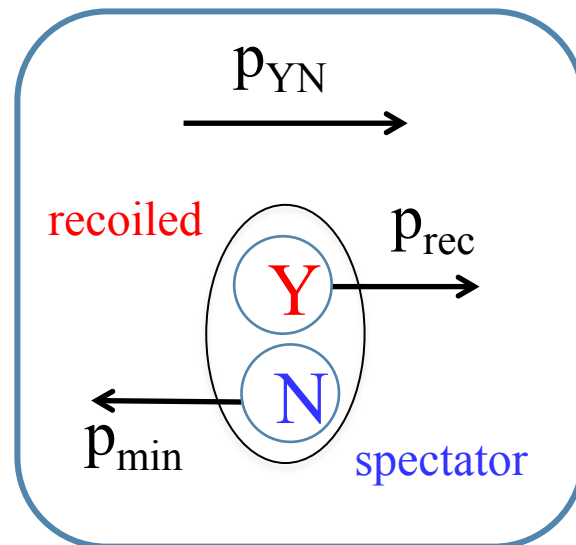
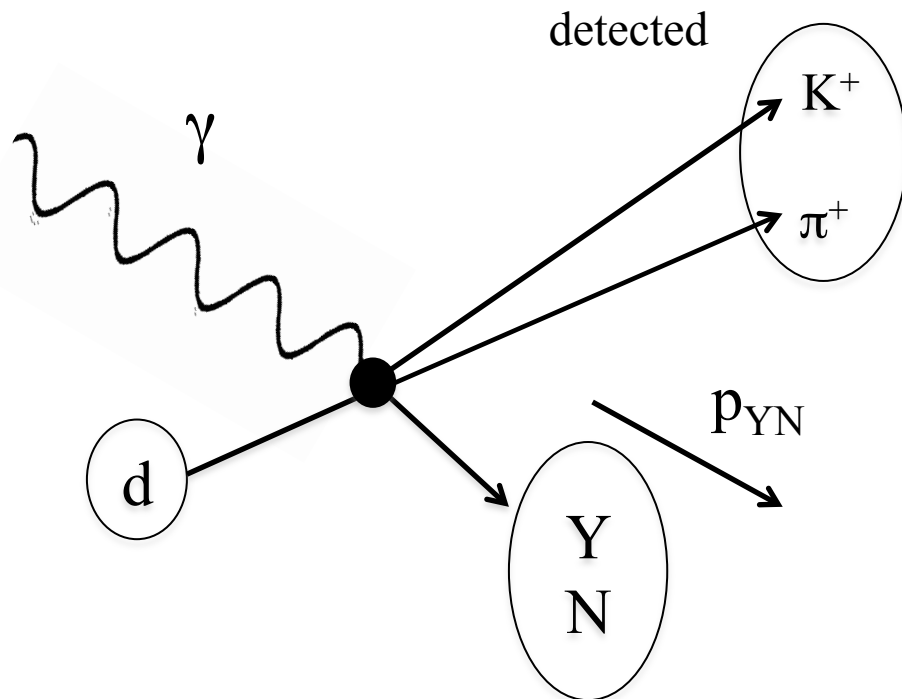


2. Compare the IM($\Sigma^-\pi^+$) between LH₂ and LD₂.
Fermi- motion correction is necessary.

→ Minimum Momentum Spectator Approximation
(MMSA)

Minimum Momentum Spectator Approximation

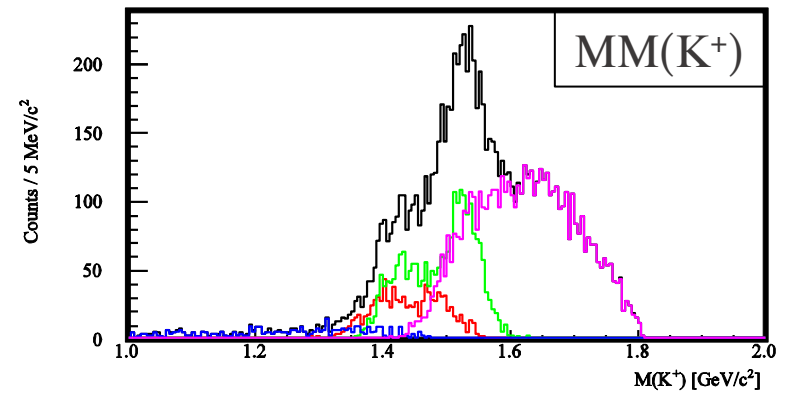
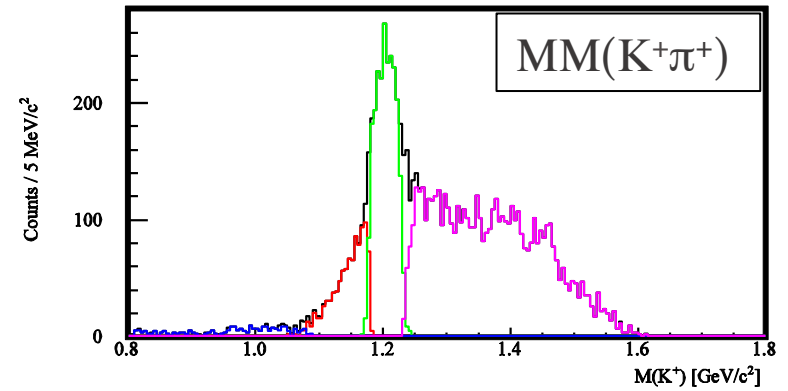
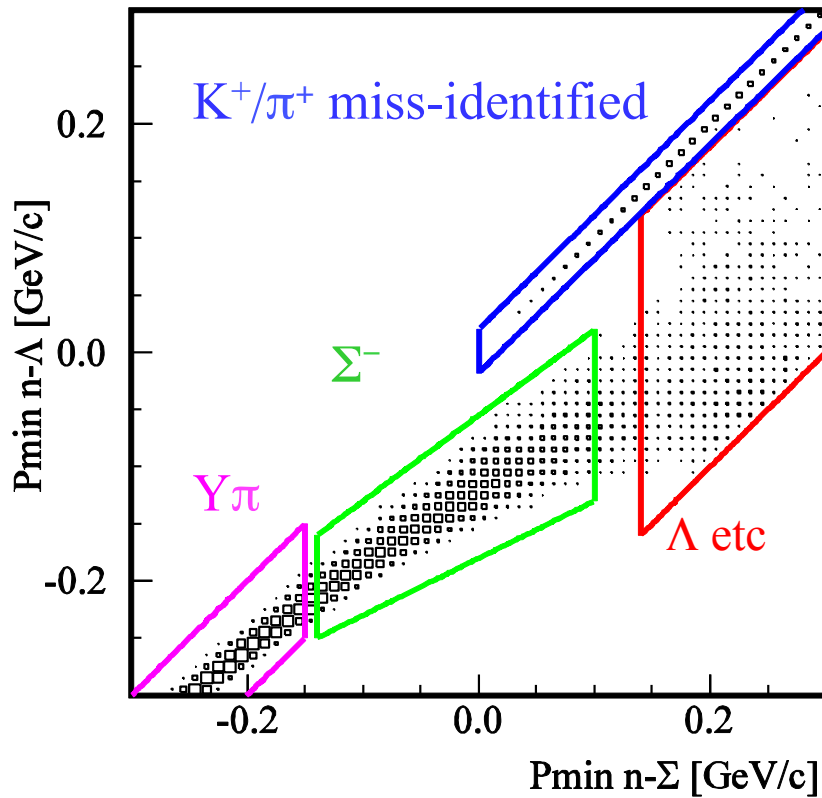
Ref) T.Nakano, PRC79, 025210



Assume possible minimum momentum (p_{min}) configuration for the spectator.
 If the assumption is good, $p_{min} \sim 0$.

$p_{min}(\Sigma N)$ vs $p_{min}(\Lambda N)$ plot $\rightarrow \Sigma N$ final state selection.
 usage of p_{rec} to calculate $IM(\Sigma\pi)$ \rightarrow Fermi motion correction.

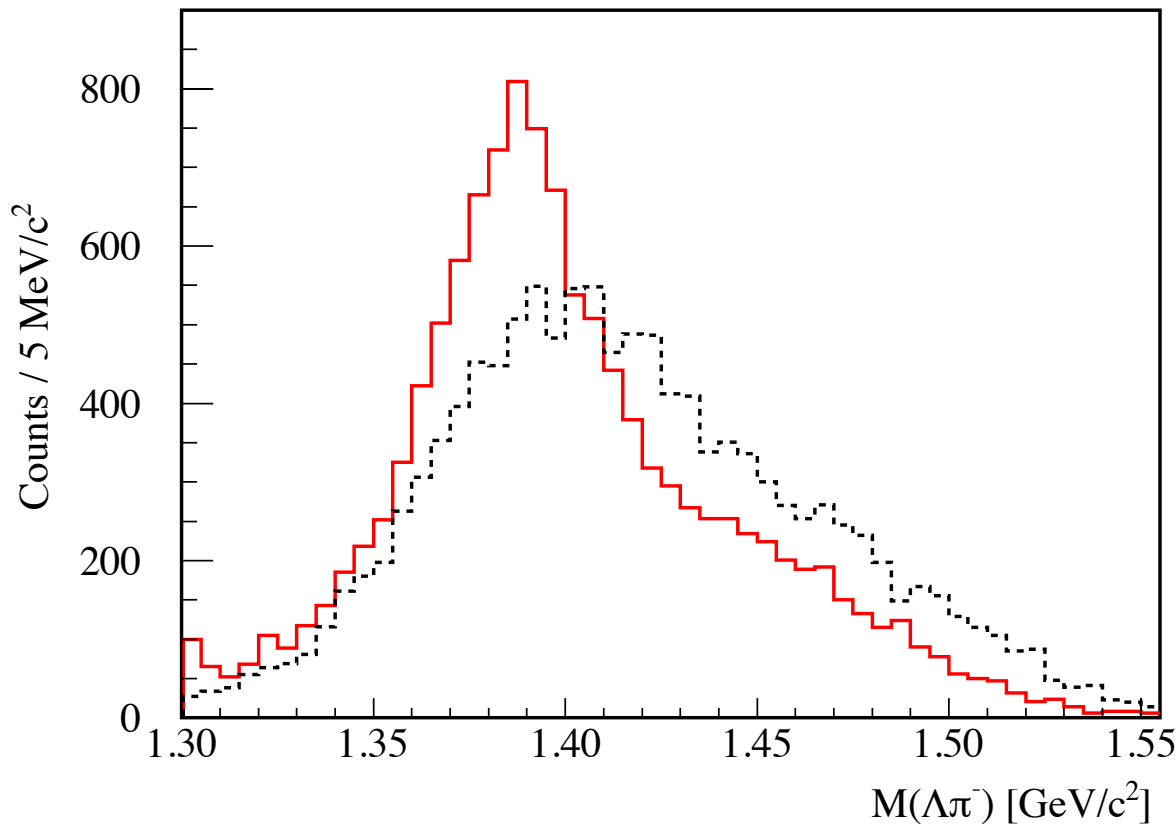
pmin plot



$$\text{cf. } \gamma + n \rightarrow K^+ + \pi^- + \Lambda$$

$\Sigma(1385)^-$ can be selected uniquely.

c.f. LEPS collaboration, PRL 102,012501 (2009)



Voigt Function Fit

Mass : 1386 ± 4 MeV

Width: 45 ± 1 MeV

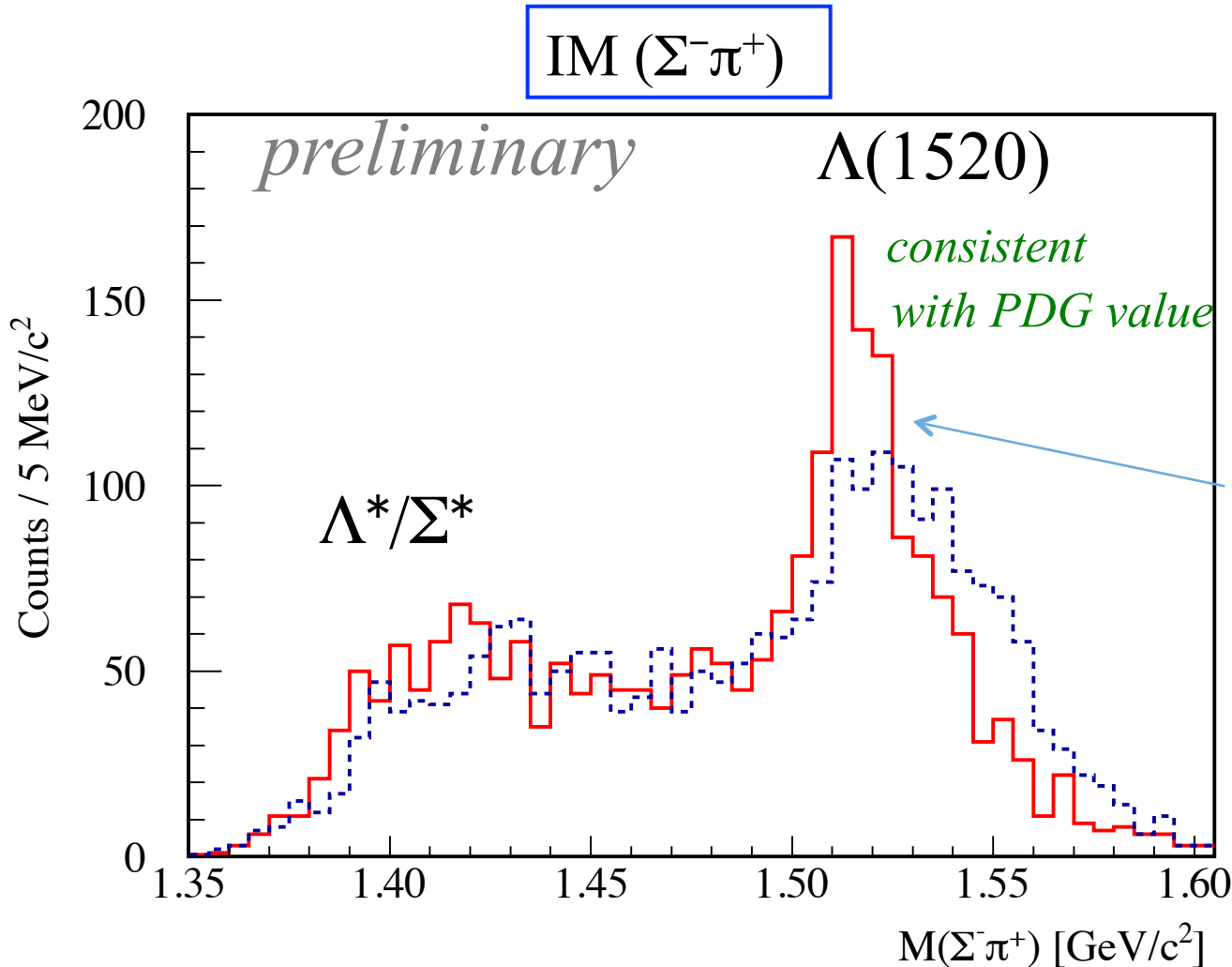
PDG-Value

Mass : 1387.2 ± 0.5 MeV

Width : 39.4 ± 2 MeV

$\Sigma(1385)^-$ peak position
is consistent with
PDG-value.

IM($\Sigma^-\pi^+$) spectrum



-w. correction
-w.o. correction

$\Lambda(1520)$ peak

Fit with

Voigt Function + pol2

Mass : 1517 ± 0.8 MeV

Width: 25 ± 3.0 MeV

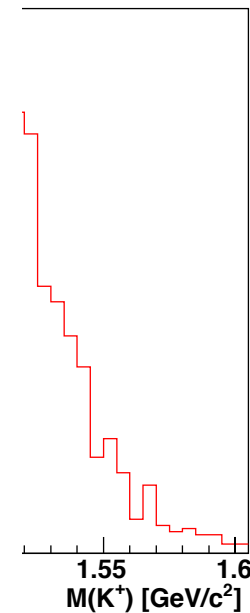
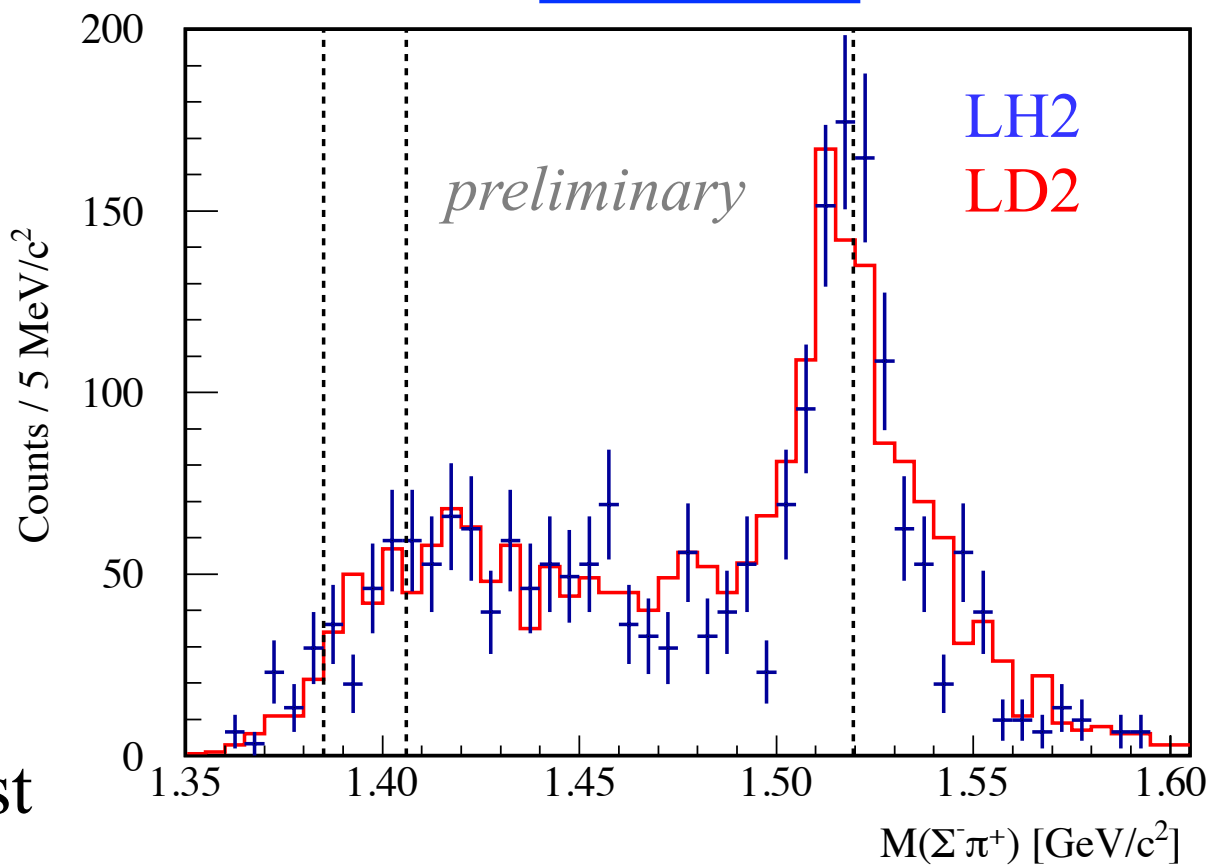
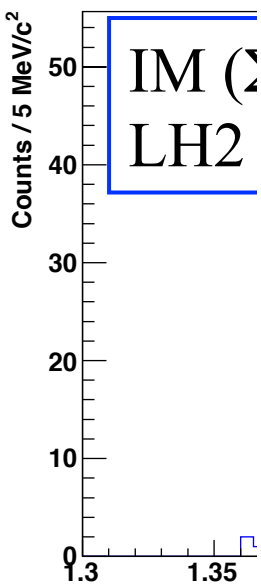
PDG-Value

Mass : 1519.5 ± 1 MeV

Width : 15.6 ± 1.0 MeV

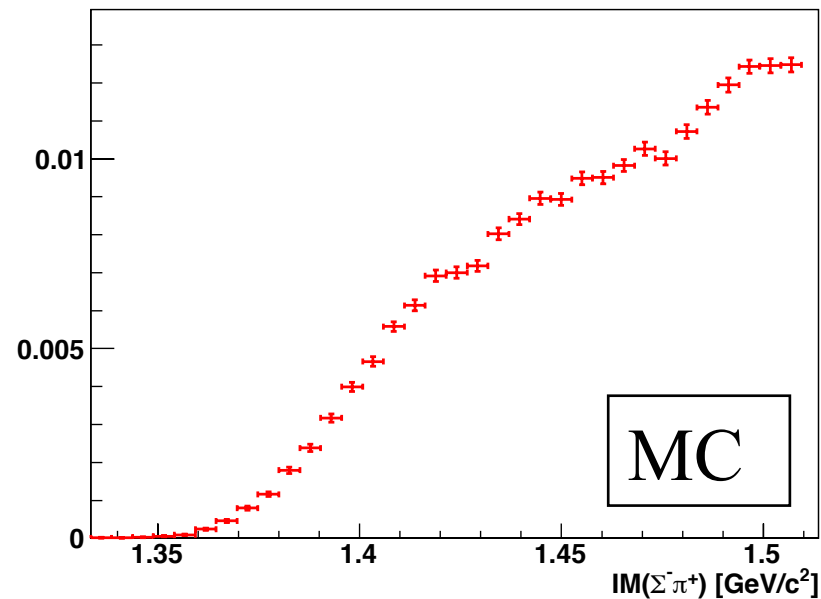
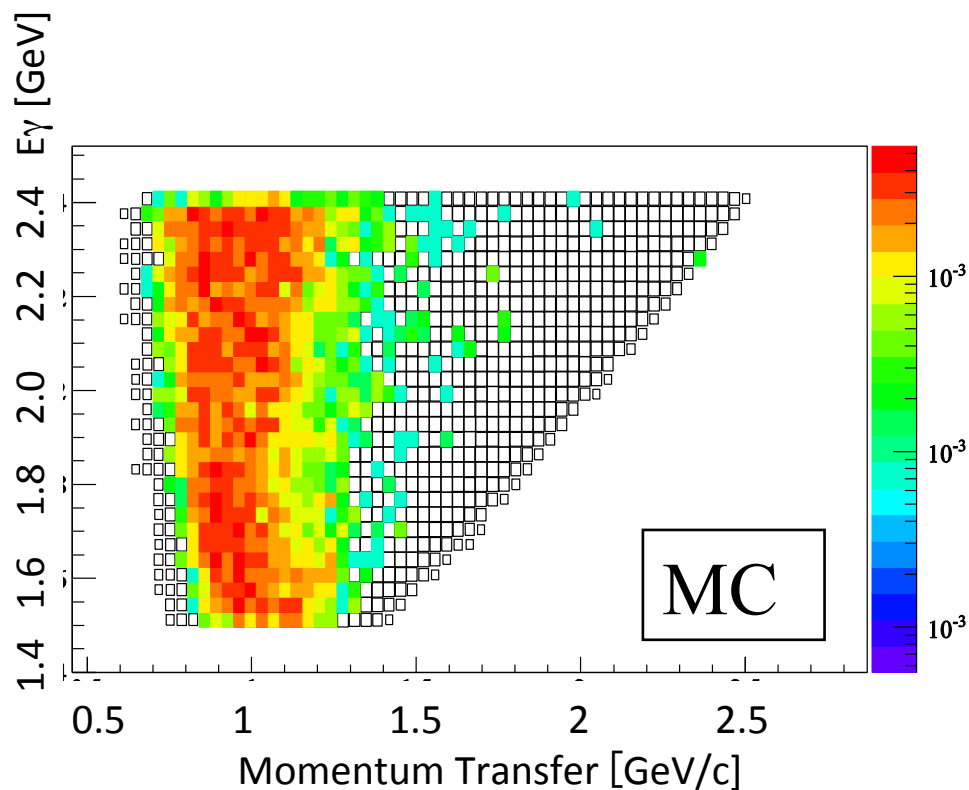
Comparison with LH2 target

IM ($\Sigma^- \pi^+$)



KS test
0.471

Detector Acceptance



Acceptance correction should be treated carefully.

Discussion

Result:

Even if we select the $\Sigma^-\pi^+$ final state,

(Λ^* contribution is increased)

LH2 and LD2 dataset seems consistent.

possible interpretation:

1. Λ^* - N interaction is different between p and n?

$$d(\pi^+, K^+) X : X = \Lambda^* - p$$

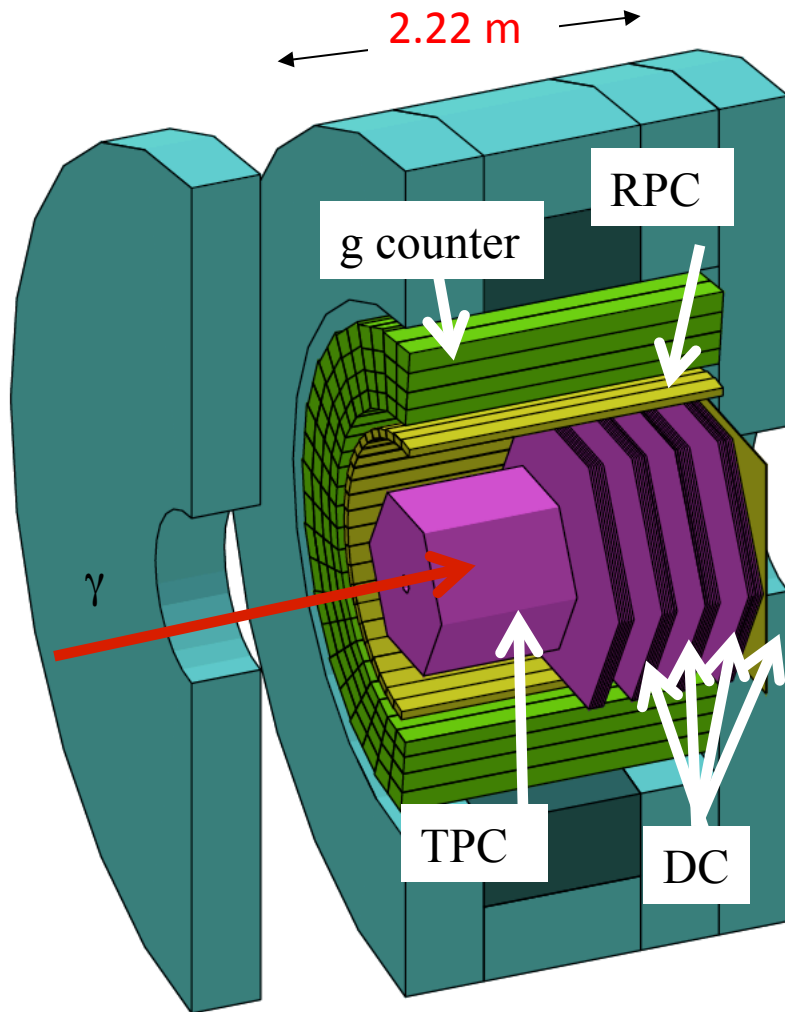
$$d(\gamma, K^+) X : X = \Lambda^* - n$$

2. Final state is not $\Sigma\pi$? (YN or $\Lambda\pi n\dots$)

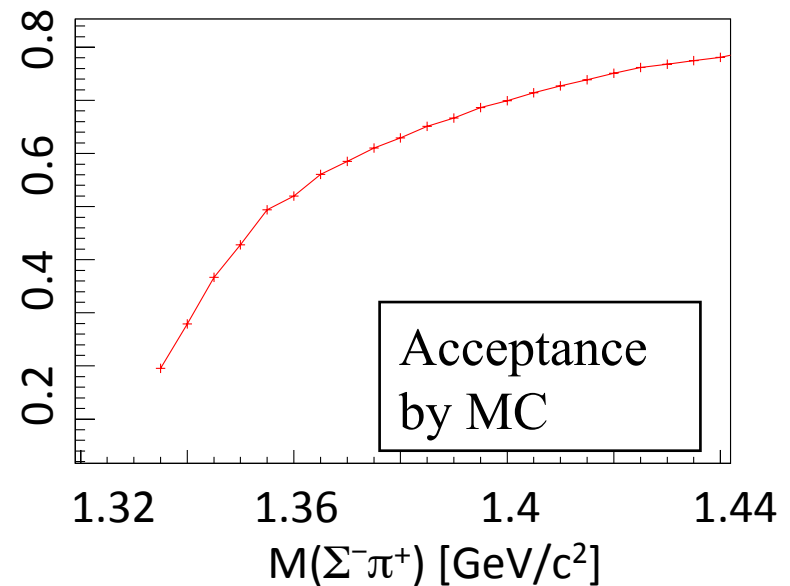
For more precise study:

$d(\gamma, K_s)X$ reactions, $\Sigma^0\pi^0$ detection

→ LEPS2 experiment



- ❖ 10 times higher intensity beam
→ Precise investigation of line shape.
- ❖ 4π acceptance spectrometer for charged/non-charged particles
→ sensitive for large shift.
→ unique identification of Λ^* in $\Sigma^0\pi^0$ decay.



Summary

- J-PARC E27 experiment studied $d(\pi^+, K^+)X$ reaction, and observed a 30 MeV shift in Y^* region in the inclusive missing mass spectrum.
- We studied $d(\gamma, K^+)X$ reaction, but a significant shift was not observed in the inclusive missing mass spectrum.
- We selected the final state $\Sigma^-\pi^+$ by using MMSA.
- $M(\Sigma^-\pi^+)$ spectra of LH2 and LD2 were compared, and they are consistent to each other.
- LEPS2 is one of the facility where we can perform more precise investigation.