$K^0\Lambda$ photoproduction studied with electromagnetic calorimeter FOREST

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Outline

- Motivation and background
- Experiment
  - 4π electromagnetic calorimeter FOREST
- Analysis
  - Particle identification
  - K0 signal and Background
  - Acceptance and Yield counting
  - Differential and Total cross sections
- Summary

Motivation and background

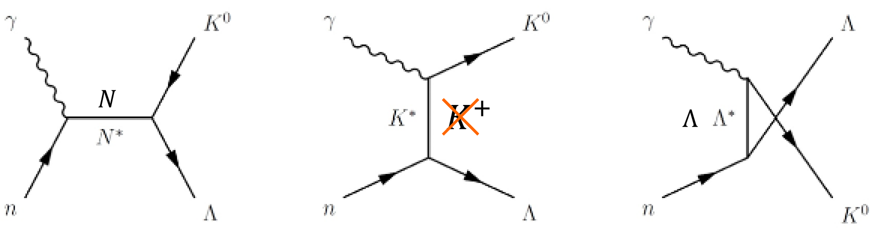
Baryon spectroscopy via KY *photoproduction*

one of the useful channels for studying baryon resonances:

highly excited baryons which hardly couple to πN, ηN

- $K^+\Lambda(\Sigma)$: recently well investigated
- K^0Y: still received few investigation

$\gamma n \rightarrow K^0\Lambda$ reaction



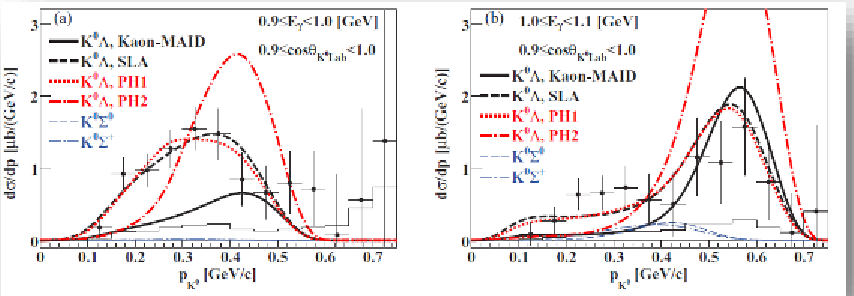
All of the participants are *NEUTRAL*

→ no charged particle can be exchanged

→ Born term contributions are smaller than that of the $K^+\Lambda$ case

The previous measurement was done for $E_\gamma = [0.9, 1.1)$GeV and $\cos\theta_K^{Lab} = [0.9, 1.0)$

K. Tsukada et al., Phys. Rev. C **83** 039904



Motivation and background - $N(1685)$

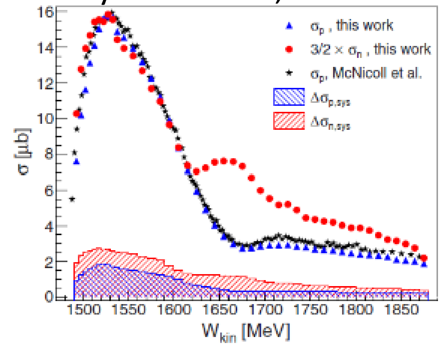
- The prominent structure observed in the $\gamma n \rightarrow \eta n$
  - Reported by **LNS, ELPH, GRAAL, MAINZ, CB-ELSA/TAPS**
  - Those results are consistent with each other:
    - The structure observed in the $n(\gamma, \eta)n$ reaction but not in $p(\gamma, \eta)p$
    - Narrow width (~ 25 MeV) and peak position ~ 1670 MeV

Many theoretical interpretations

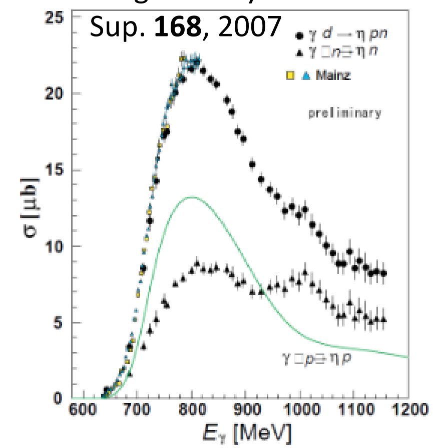
- Intrinsic narrow state
- Pentaquark state
- Coupled-channel effects
- Interference effects
- KY threshold effects, etc.

More experimental information is needed
-> How about the $K^0\Lambda$ case?

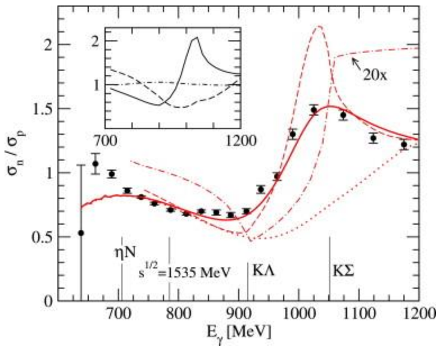
Phys. Rev. C **90**, 015205



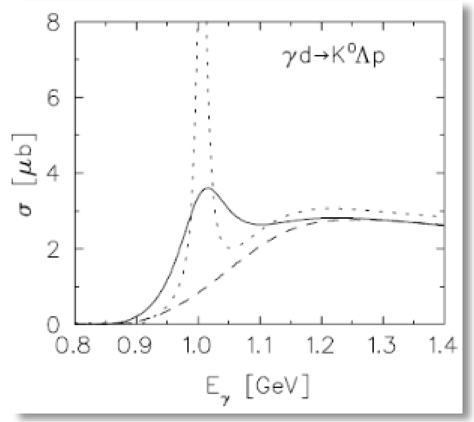
Prog. Th. Phys. Sup. **168**, 2007



M. Döring and K. Nakayama, Phys. Lett. B 683, 145 (2010).



A. Fix et al., Eur. Phys. J. A 32, 311–319 (2007).



Experiment

4 π electromagnetic calorimeter complex FOREST @ ELPH

192 Pure CsI
SCISSORS III

PS 24 × 3 layers
SPIDER

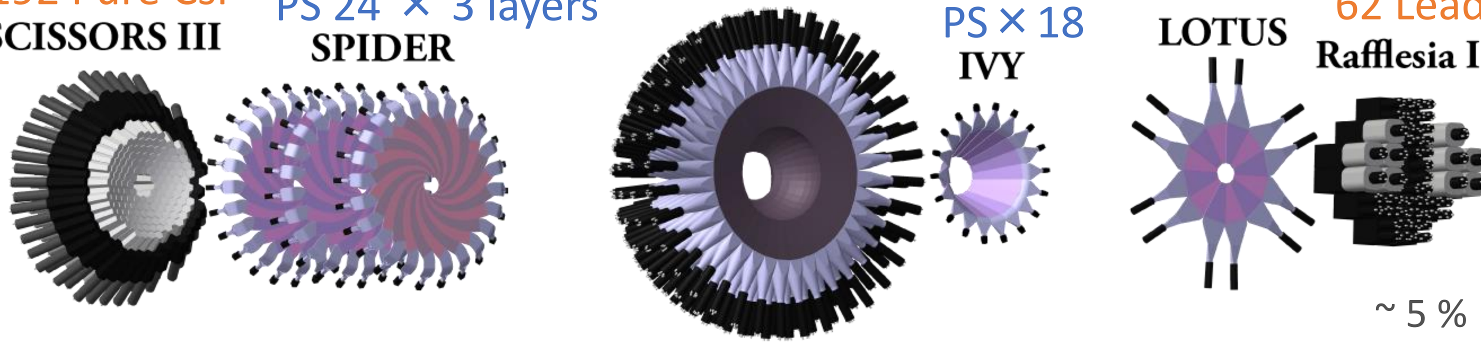
252 Lead/SciFi mod.s
LEPS Backward Gamma

PS × 18
IVY

PS × 12
LOTUS

62 Lead/Glass
Rafflesia II

(Forward)



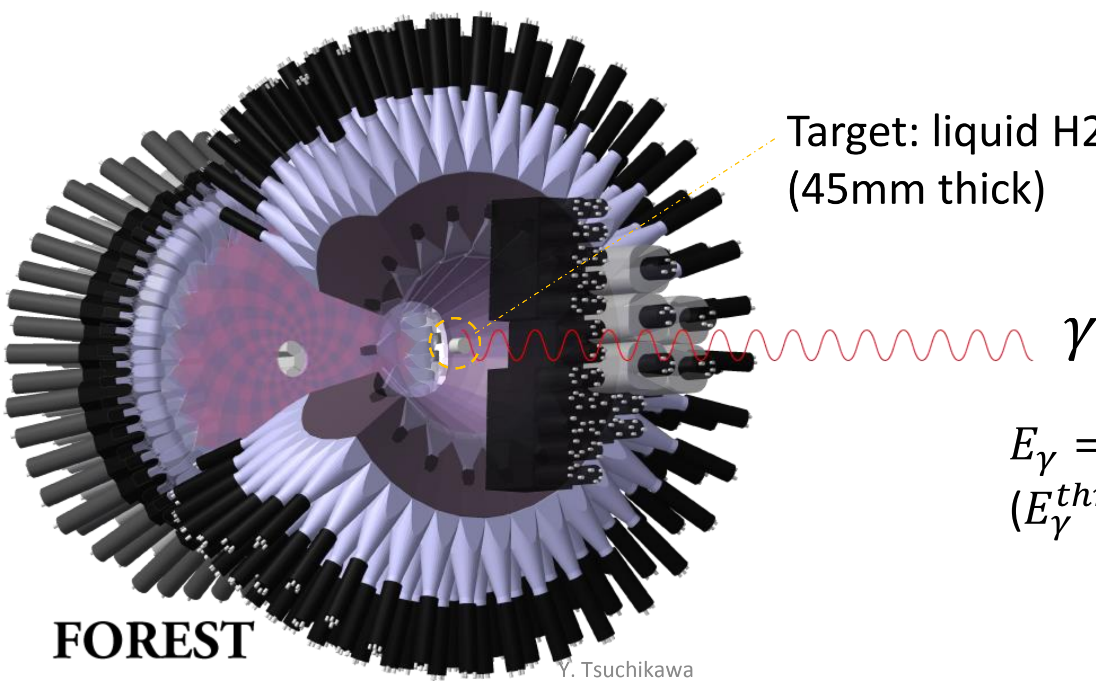
(Backward)

Energy resolution (for 1 GeV γ)

~3 %

~ 7 %

~ 5 %

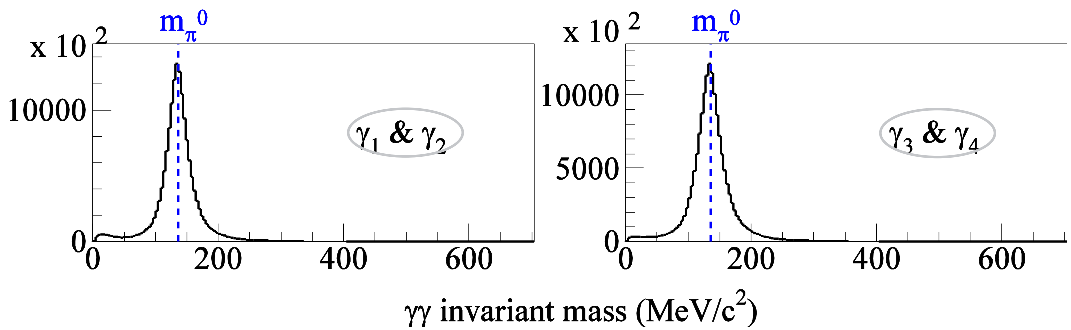


Target: liquid H2/D2 target
(45mm thick)

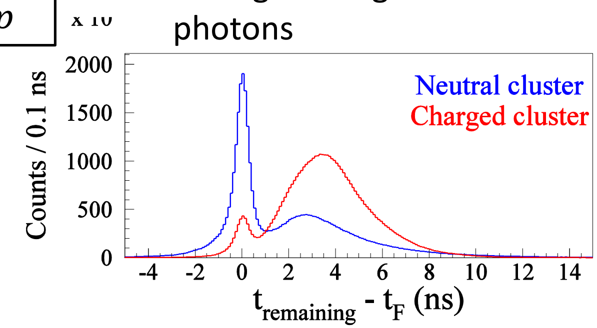
$E_\gamma = 750 - 1150$ MeV
$(E_\gamma^{thr}(K^0\Lambda) = 915$ MeV$)$

Particle identification

$$\gamma d \rightarrow K^0 \Lambda p_{sp} \rightarrow K_S^0 \Lambda p_{sp} \rightarrow (\pi^0\pi^0)(p\pi^-)p_{sp} \rightarrow (4\gamma)(p\pi^-)p_{sp}$$



The event timing criterion: average timing of 4 photons



No other neutral particles but more 2 charged particles are required both of hodoscope and calorimeter

Kinematic fit with 4 constraints

"$\gamma\gamma$ invariant mass $= m_{\pi^0}$"

1. $M^2(\gamma_1,\gamma_2) \equiv 2E_1E_2(1 - \sin\theta_1 \sin\theta_2 \cos(\phi_1 - \phi_2) - \cos\theta_1 \cos\theta_2) = m_{\pi^0}^2$
2. $M^2(\gamma_3,\gamma_4) \equiv 2E_3E_4(1 - \sin\theta_3 \sin\theta_4 \cos(\phi_3 - \phi_4) - \cos\theta_3 \cos\theta_4) = m_{\pi^0}^2$

"4γ missing mass $= m_\Lambda$"

3. $M_X^2(\gamma_1,\gamma_2,\gamma_3,\gamma_4) \equiv E_X^2 - P_X^2 = \left(E_\gamma + m_n - \sum_{i=1}^{4} E_i\right)^2 - P_X^2(E_i,\theta_i,\phi_i,E_\gamma) = m_\Lambda^2$

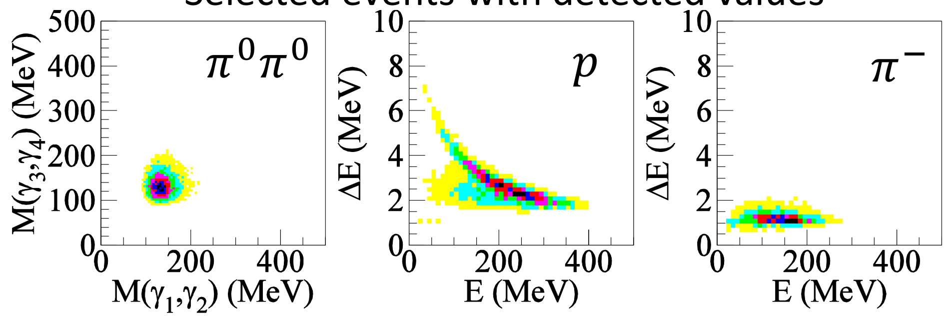
"$4\gamma p$ missing mass = m_π"

4. $M_X^2(\gamma_1,\gamma_2,\gamma_3,\gamma_4,p) = m_\pi^2$

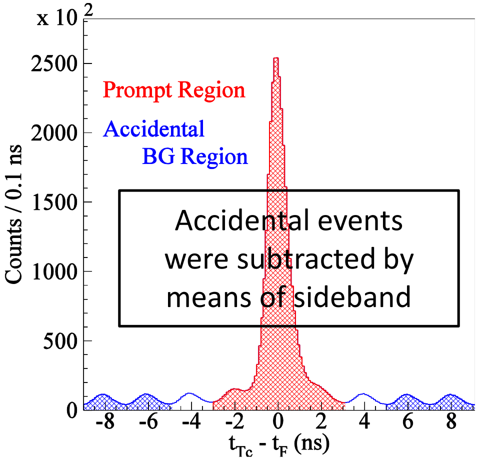
16 variables:
γ_i energy, polar, and azimuthal angles: E_i, θ_i, ϕ_i $(i = 1, \ldots, 4)$, same for proton: E_p, θ_p, ϕ_p,
and Photon beam energy: E_γ

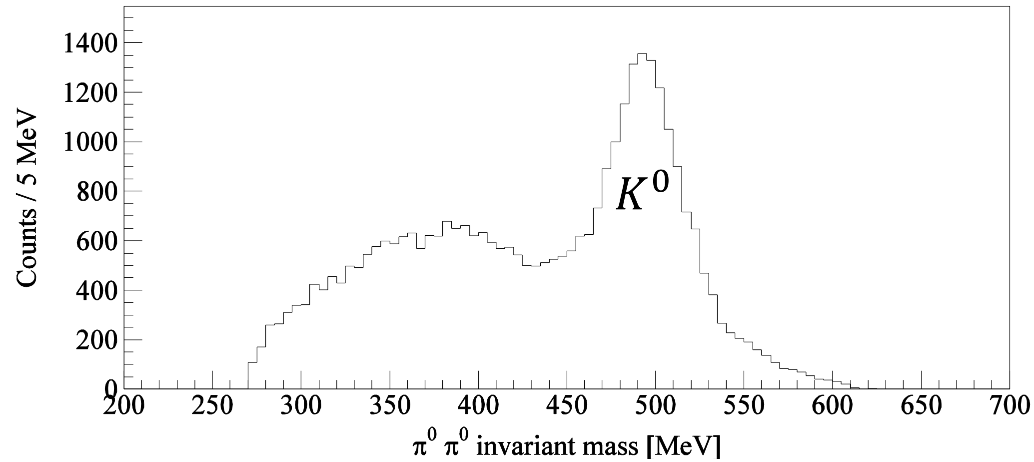
Two charged particles were distinguished by TOF based kinematic cut conditions
Finally, $2\pi^0, p$ and π^- were well identified

Selected events with detected values



K^0 signal and background



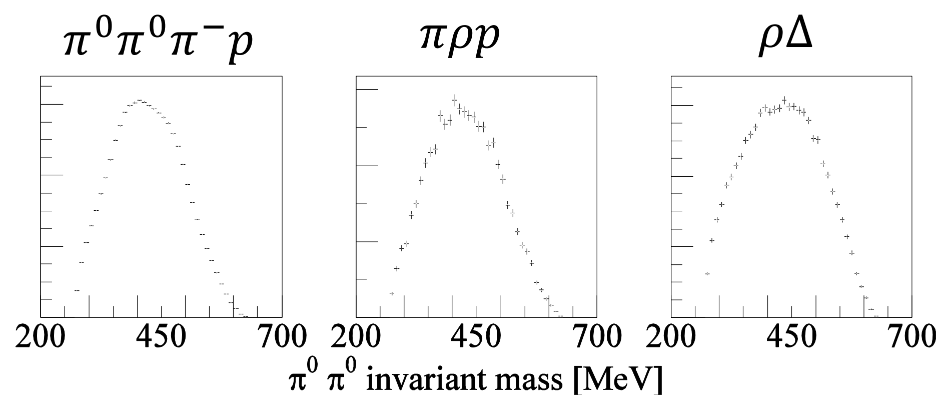


K^0 peak is clearly shown in $\pi^0\pi^0$ invariant mass distribution

Reactions as background sources have been investigated via GEANT4-based simulations.
Candidates of the reactions:

$$\gamma n \to \pi X(\Delta, N^*, \rho N) \to \pi^-\pi^0\pi^0 p,$$
$$\gamma n \to \pi^0\pi^0\pi^- p.$$

Those candidates do not show significant differences on 2 pi invariant mass distributions with each other

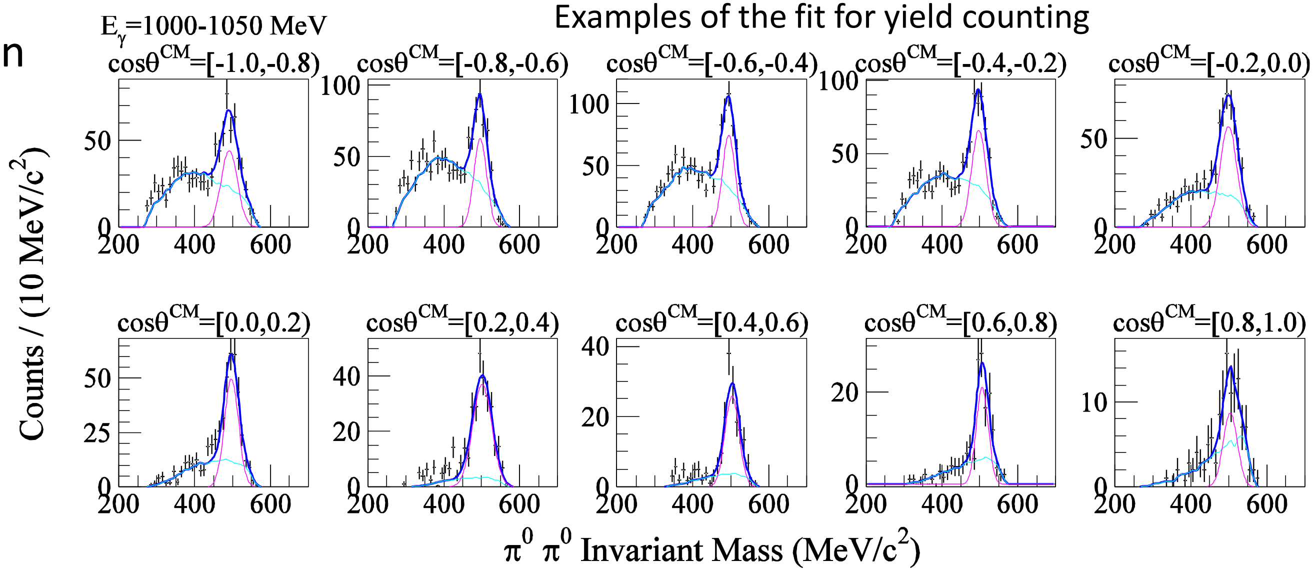


Yield counting

The simulated distribution ($\gamma p \rightarrow \pi^0 \pi^0 \pi^- p$) well describes the BG distribution for each $\cos\theta_K^{CM}$

Fit for yield counting:
Gaussian (magenta)
+ BG dist. (cyan)

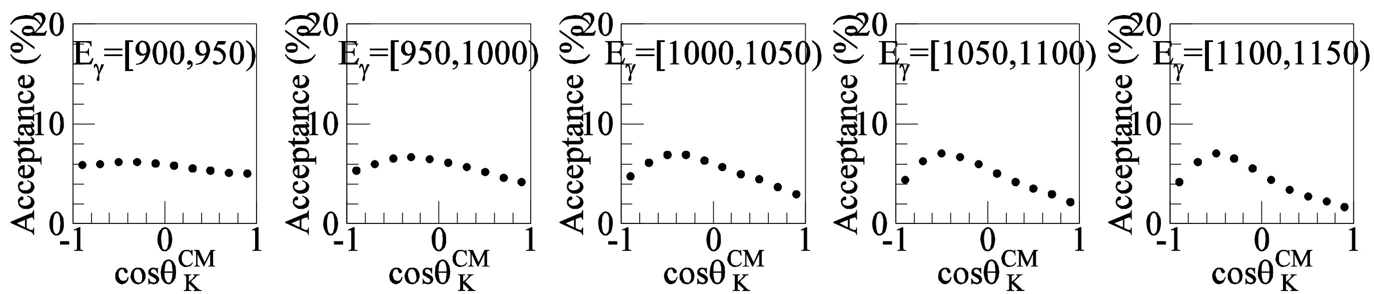
Examples of the fit for yield counting



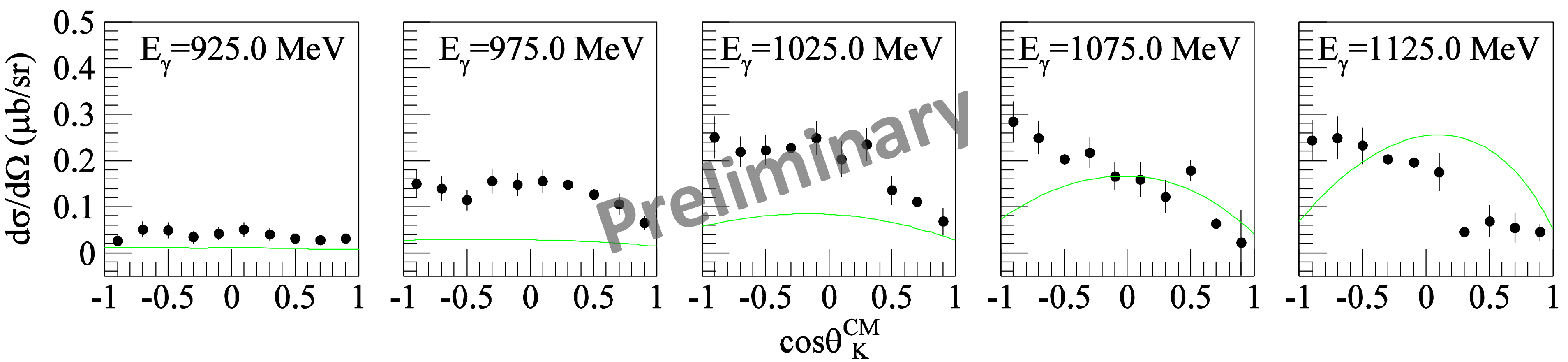
Acceptance

FOREST covers all of the $\cos\theta_K^{CM}$

Full coverage for $\cos\theta_K^{CM}$ to the whole range of E_γ

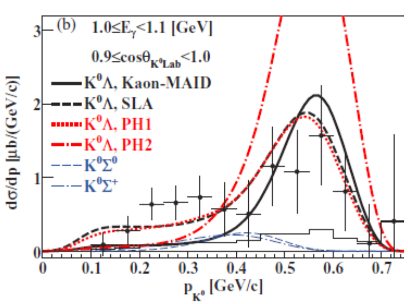


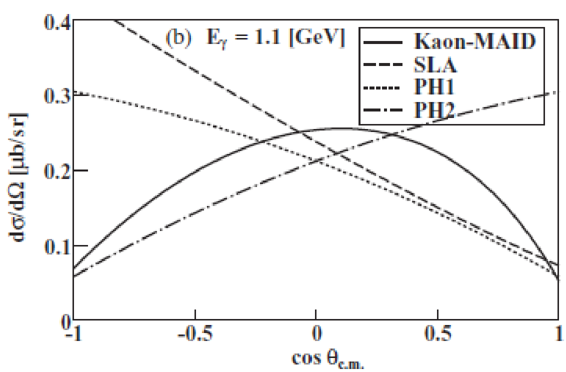
Differential and Total Cross Sections



Theoretical curves are given by Kaon-MAID

This result supports the experimental remark in the previous measurement for the $\gamma n \rightarrow K^0\Lambda$ reaction reported by K. Tsukada et al.





K. Tsukada et al., Phys. Rev. C **83** 039904

Summary

- The $\gamma d \to K^0 \Lambda p$ photoproduction reaction is studied with electromagnetic calorimeter complex FOREST at ELPH, Sendai
- K^0 signals are well confirmed by $\gamma d \to K_S^0 \Lambda p \to (\pi^0 \pi^0)(p\pi^-)p \to (4\gamma)(p\pi^-)p$ reaction chains with an exclusive analysis
- Shape of the background shown in the $\pi^0\pi^0$ invariant mass distribution can be well reproduced by the simulated distribution of $\gamma n \to \pi^0\pi^0\pi^- p$ non-resonant reaction
- Differential cross sections show backward enhancement as E_γ increases

  (This result supports the remark of the previous measurement)
- Total cross section shows bump like structure around 1.02 GeV

Future Plan

- Estimation of systematic errors
- Partial Wave Analysis

This work will also be presented in the poster session on Sept. 10 (Thu)
Board number: **A17**