The recent results of strangeness photoproduction in the threshold region at ELPH-Tohoku

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  - Strangeness photoproduction
  - Neutral Kaon Spectrometer (NKS2)

- Experiment
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- Previous results

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- New Tagger

- Summary

- New Project about Λn final state interaction was presented by M. Kaneta in the previous session: Parallel 2a

Kaon Photoproduction

- The investigation of the hypernuclear physics with electromagnetic production of the strangeness

• Ambiguity and Discrepancy between theoretical calculations
← Not all the isospin channels are covered by the experimental data

• **Measurement of the K^0 production process on the neutron with REAL PHOTON**

→ **Better understanding of the electromagnetic production of the strangeness**
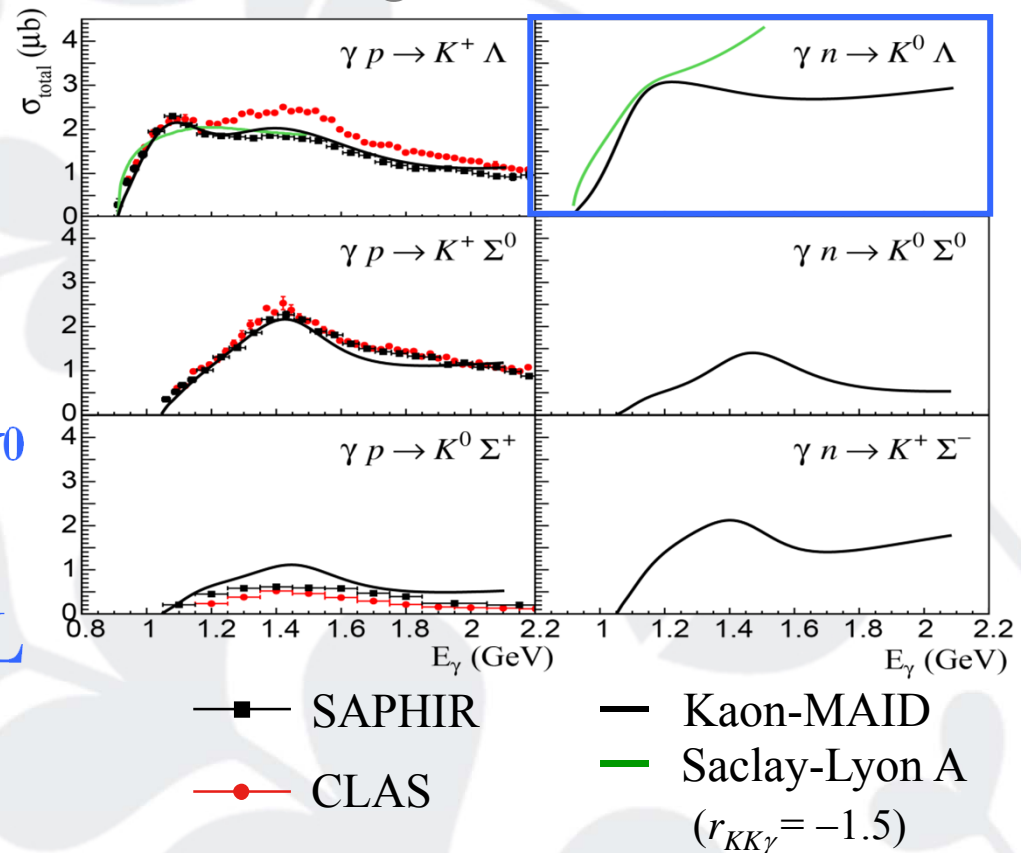
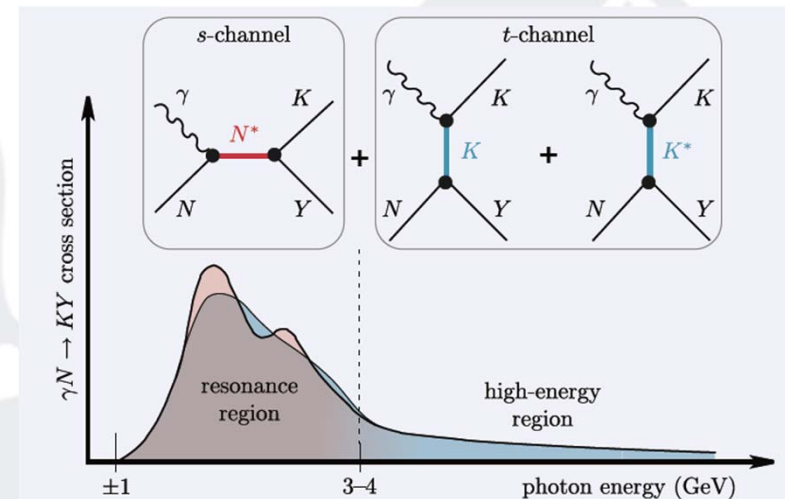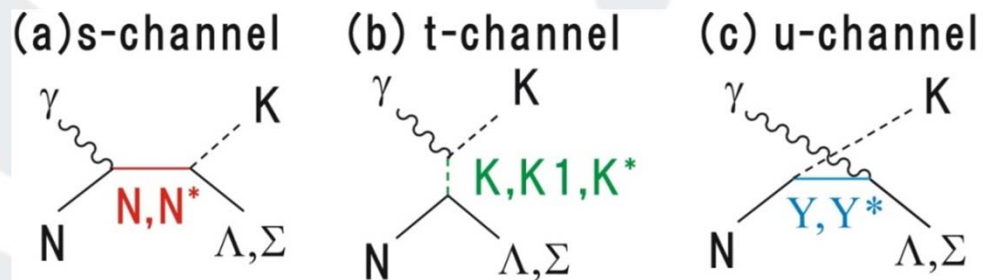$$\Gamma_{K_1^0 \to K^0 \gamma} / \Gamma_{K_1^+ \to K^+ \gamma} = r_{K_1 K \gamma}^2$$

Study of $\gamma d \to K^0 \Lambda$ in the threshold region

- Isospin mirror reaction of $\gamma p \to K^+ \Lambda$
- Suppression of the t-channel Born term
- $E_\gamma \sim 1$ GeV is just around the threshold
  → Small contributions from the higher resonances
- Well understood electromagnetic vertex

Theoretical models describing $\gamma d \to K^0 \Lambda$ reaction

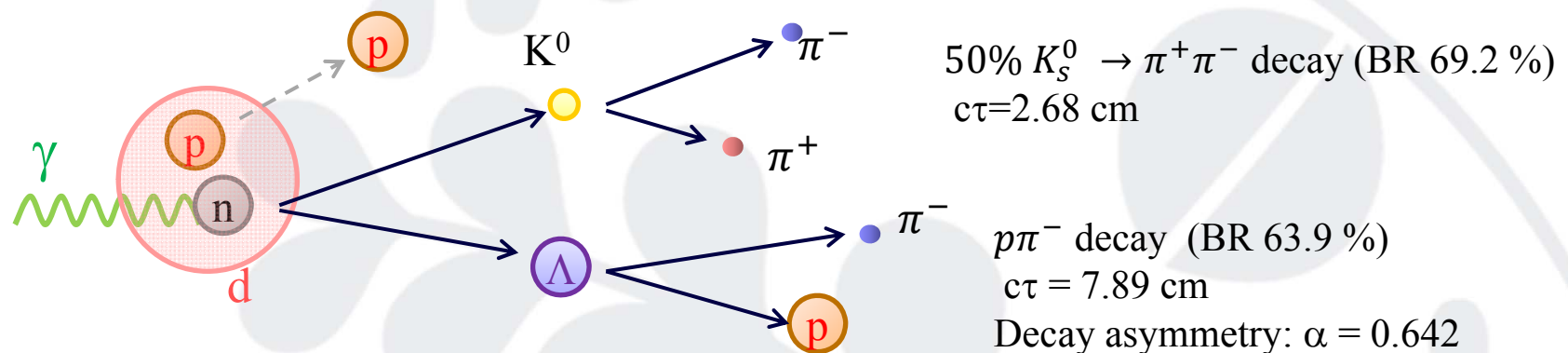Isobar models : K-MAID, Saclay-Lyon A

Regge Plus Resonance model

P. Vancraeyveld Ph. D Thesis

Study of $\gamma d \to K^0 \Lambda$ with the Neutral Kaon Spectrometer (NKS2)

- NKS2: Magnetic spectrometer for charged particles
- Trigger on two or more then two charged particles detected events (Minimum bias… Single charged particle? Huge background from $e^+ e^-$ pair production)
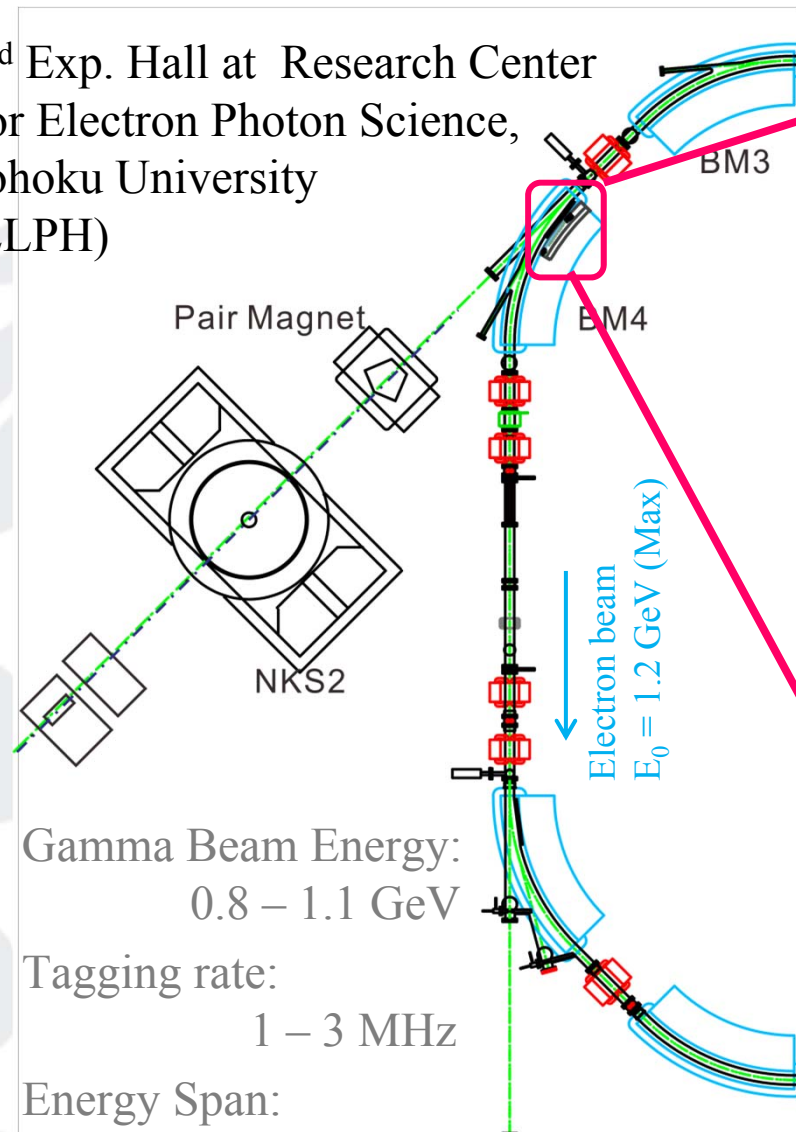

50% $K_s^0 \to \pi^+ \pi^-$ decay (BR 69.2 %)
 $c\tau = 2.68$ cm

$p\pi^-$ decay (BR 63.9 %)
 $c\tau = 7.89$ cm
Decay asymmetry: $\alpha = 0.642$

- $d(\gamma, K^0)$ → subsequent K_S decay into $\pi^+ \pi^-$
- $d(\gamma, \Lambda)$ → subsequent Λ decay into $p\, \pi^-$: Recoil polarization
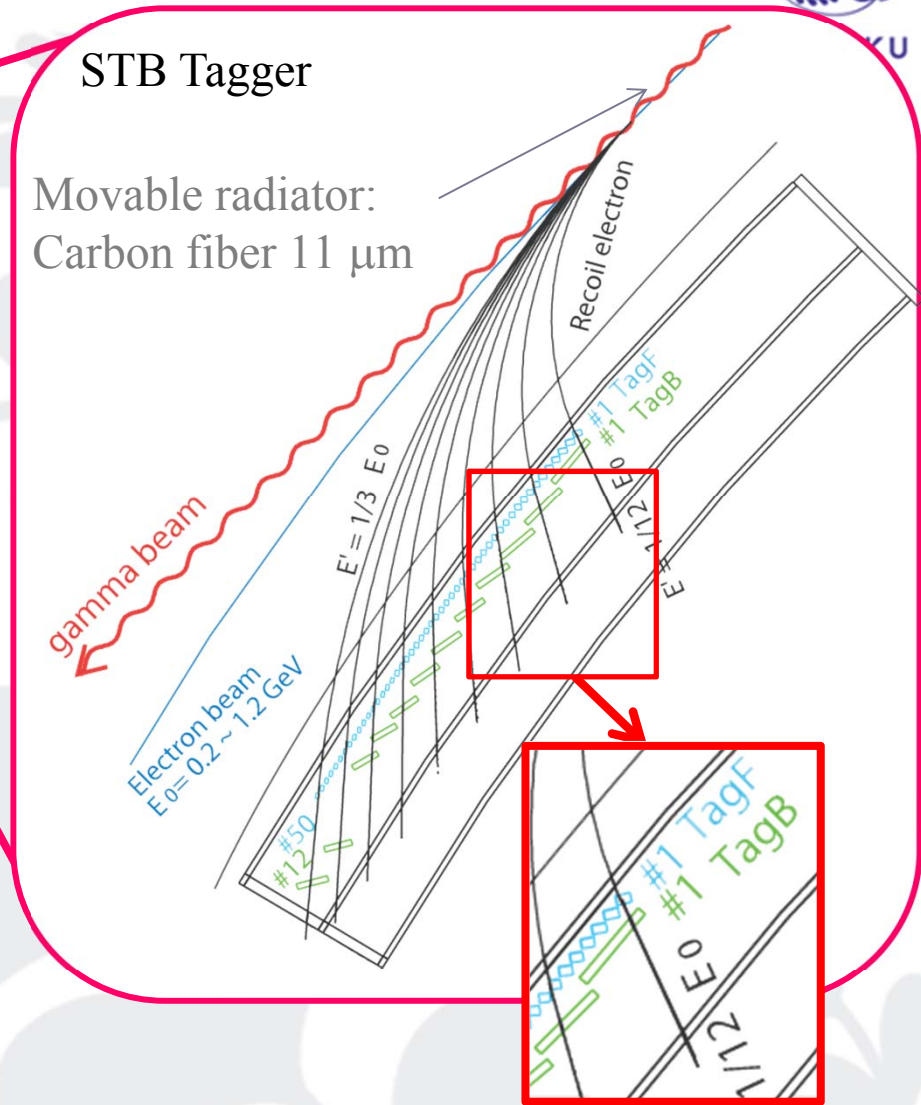
Tagged Photon Beam Line

2nd Exp. Hall at Research Center
For Electron Photon Science,
Tohoku University
(ELPH)

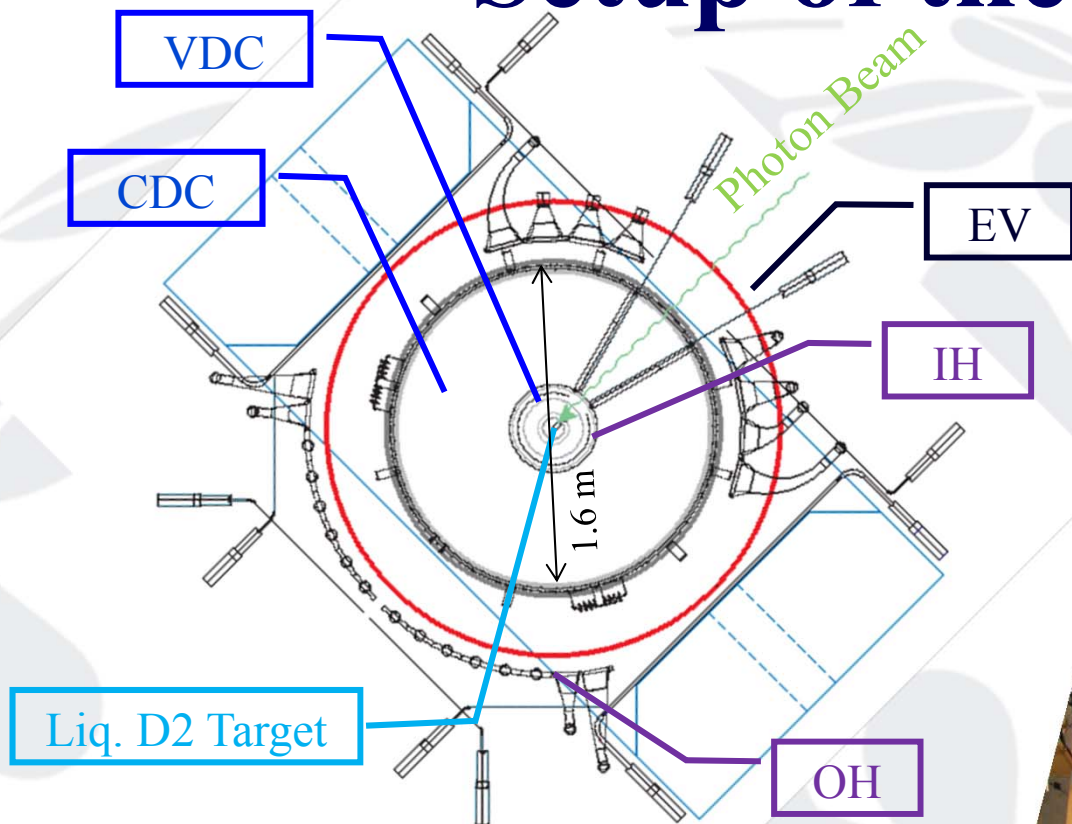STB Tagger

Movable radiator:
Carbon fiber 11 μm

- Gamma Beam Energy:
  0.8 – 1.1 GeV

- Tagging rate:
  1 – 3 MHz

- Energy Span:
  6 MeV(TagF: 48 ch)

Setup of the NKS2

VDC

CDC

Photon Beam

EV

IH

1.6 m

Liq. D2 Target

OH

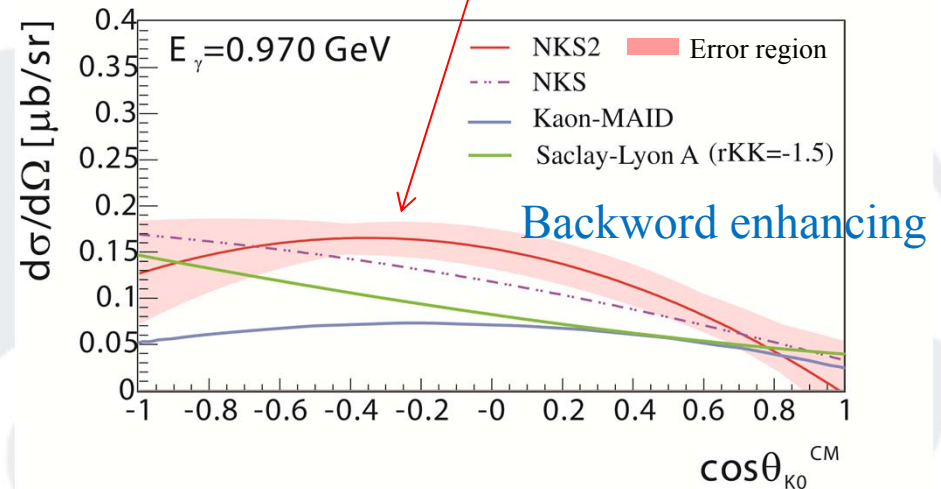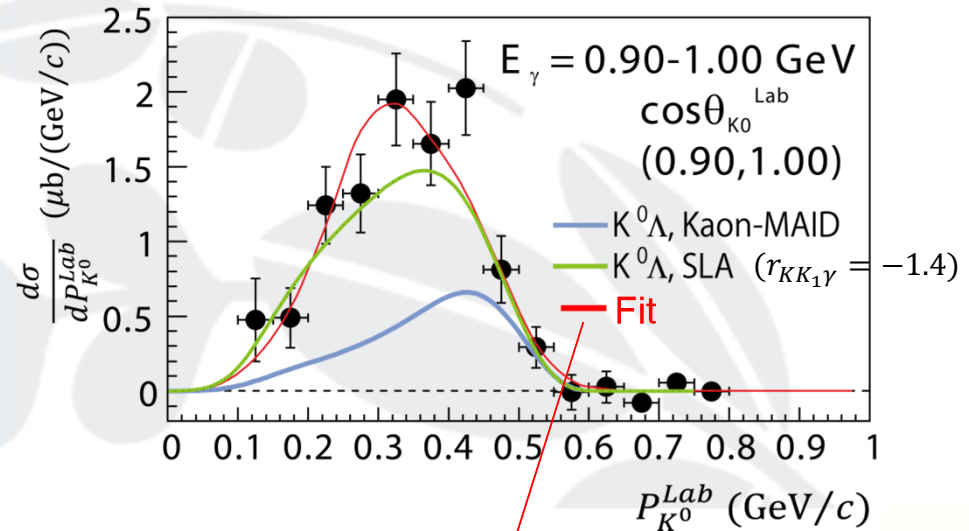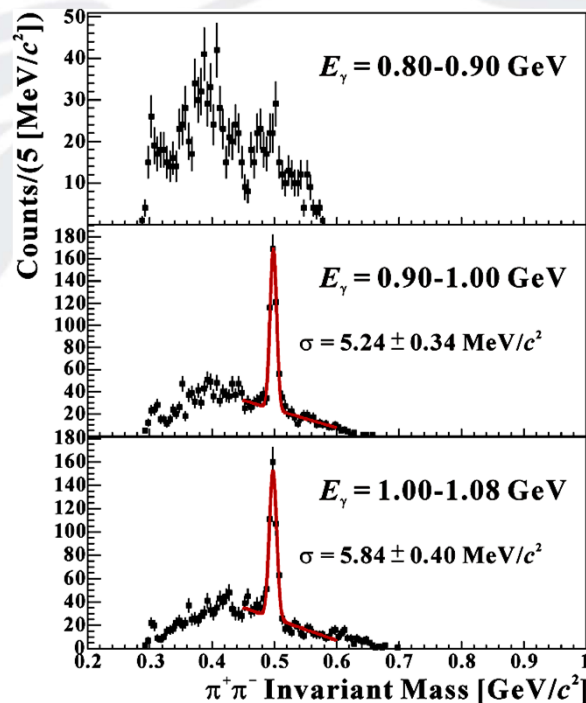- Dipole magnet : B ~ 0.42 T, R = 0.8 m
- Hodoscopes (IH and OH): TOF measurement
- MWDC's (CDC and VDC) : Tracking for momentum and vertex finding
- EV: Reduction of QED background
- Geometrical acceptance: ~ 1 π sr

Previous results from the NKS2

Inclusive K^0 detection

- Sufficient invariant mass reconstruction quality
- Fitting of a parametrized angular distribution to obtained K0 momentum distribution
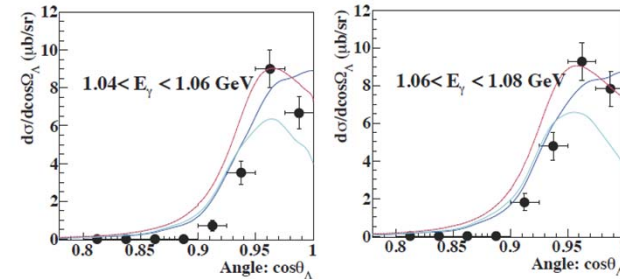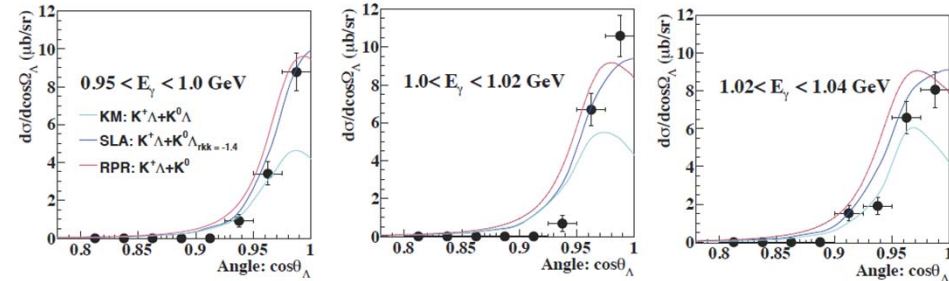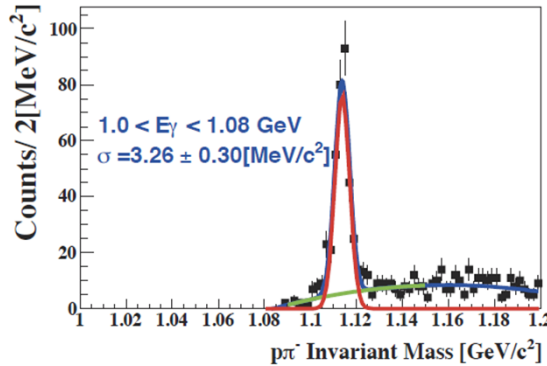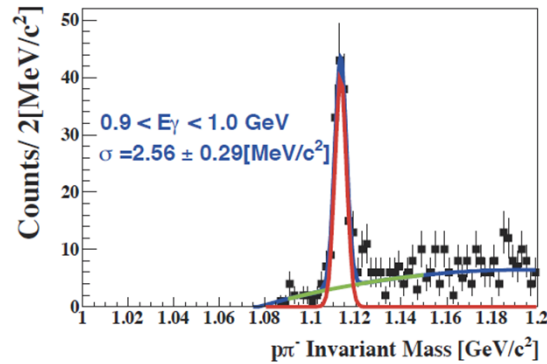
$$\frac{d\sigma}{d\Omega^{CM}} = \sqrt{s - s_0}\,[1 + e_0(s - s_0)] \cdot (a_0 + a_1 \cos\theta_{K^0}^{CM} + a_2 \cos^2\theta_{K^0}^{CM})$$

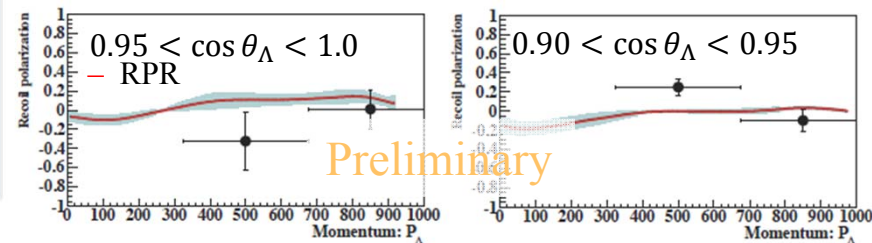K. Futatsukawa Doctor Thesis

Previous results from the NKS2

- ## Inclusive Λ detection

Angular distribution of Λ in lab. system

Recoil polarization with respect to Λ momentum in lab. system

Preliminary

$$\hat{n} = -\frac{P_\gamma \times P_\Lambda}{|P_\gamma \times P_\Lambda|}$$

$E_\gamma = 1.0 - 1.1$ GeV

- Sufficient invariant mass reconstruction quality
- Comparison of angular distribution with theoretical calculations
- Comparison of recoil polarization with theoretical calculations

B. Beckford Doctor Thesis

New data points added on the excitation function

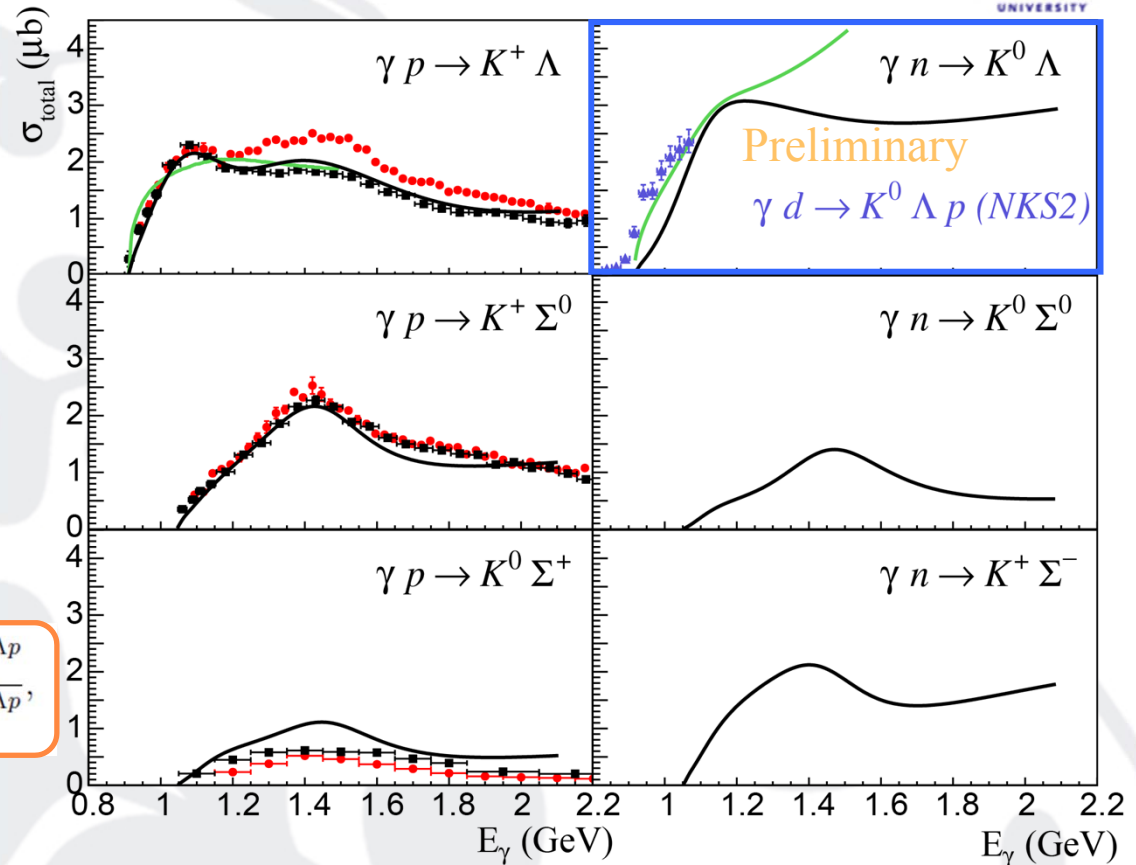- Derivation of $\gamma d \rightarrow K^0 \Lambda p$ cross section:

  - $K^+\Lambda$ contribution was subtracted from the inclusive cross section cross section

  - Scaling: $\gamma n \rightarrow K^0 \Lambda$ integrated cross section over the NKS2 acceptance / $\gamma n \rightarrow K^0 \Lambda$ total cross section

$$\sigma_{Total}^{K^0\Lambda} = \left(\sigma_{Integral}^{\gamma d \rightarrow \Lambda X} - \sigma_{Integral}^{* \, \gamma d \rightarrow K^+ \Lambda n} \right) \cdot \frac{\sigma_{Total}^{* \, \gamma d \rightarrow K^0 \Lambda p}}{\sigma_{Integral}^{* \, \gamma d \rightarrow K^0 \Lambda p}},$$
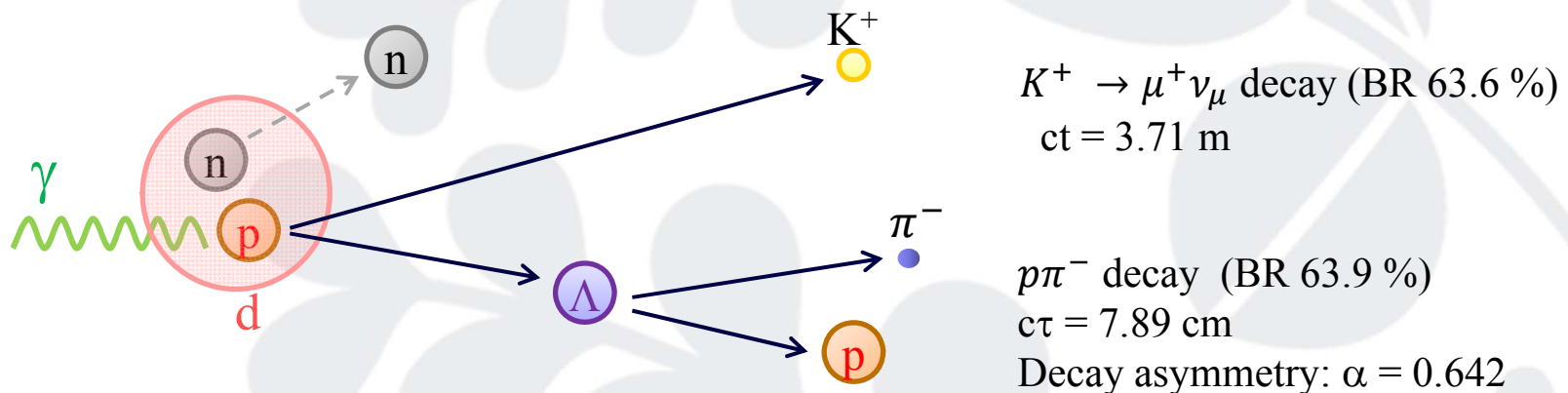
Measured

Theoretically calculated

σ_{total} (µb)

$\gamma p \rightarrow K^+ \Lambda$

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

Preliminary

$\gamma d \rightarrow K^0 \Lambda p$ (NKS2)

$\gamma p \rightarrow K^+ \Sigma^0$

$\gamma n \rightarrow K^0 \Sigma^0$

$\gamma p \rightarrow K^0 \Sigma^+$

$\gamma n \rightarrow K^+ \Sigma^-$

E_γ (GeV)

E_γ (GeV)

- ■ SAPHIR
- ● CLAS
- ━ Kaon-MAID
- ━ SLA ($r_{K1K\gamma} = -1.5$)

Study of K⁺ production on the deuteron

- Detection of three charged particles
- Comparison with data taken with hydrogen target
  - Estimation of systematics of the analysis
- Kinematically complete measurement
  - Reconstruction of center-of-mass kinematics → Determination of the scattering plane for Λ polarization measurement

$K^+ \to \mu^+ \nu_\mu$ decay (BR 63.6 %)
  ct = 3.71 m

$p\pi^-$ decay (BR 63.9 %)
cτ = 7.89 cm
Decay asymmetry: α = 0.642

• $d(\gamma, K^+ \Lambda)$ ← detection of K⁺
   subsequent Λ decay into $p \, \pi^-$: Recoil polarization

Track selection

- Three particles detected events (p, π^-, X^+)

  1. Proton and π^- vertex found
     → momentum of a parent particle

  2. X^+ found

  3. Vertex of X+ and the parent particle found in the target region

Missing

n

2

X^+

γ
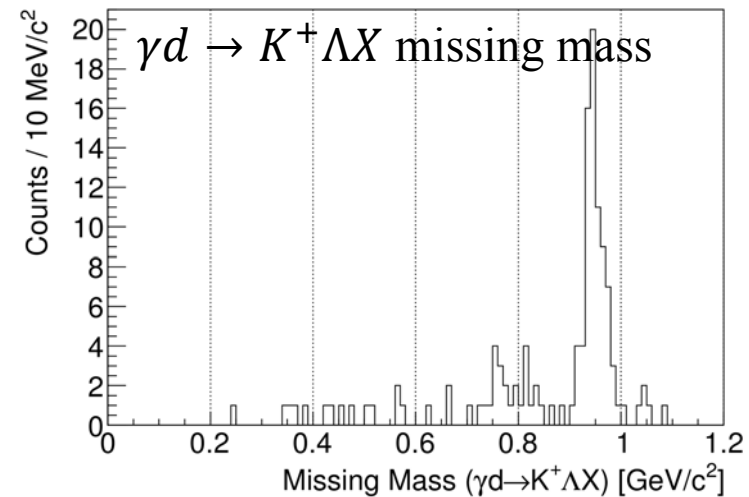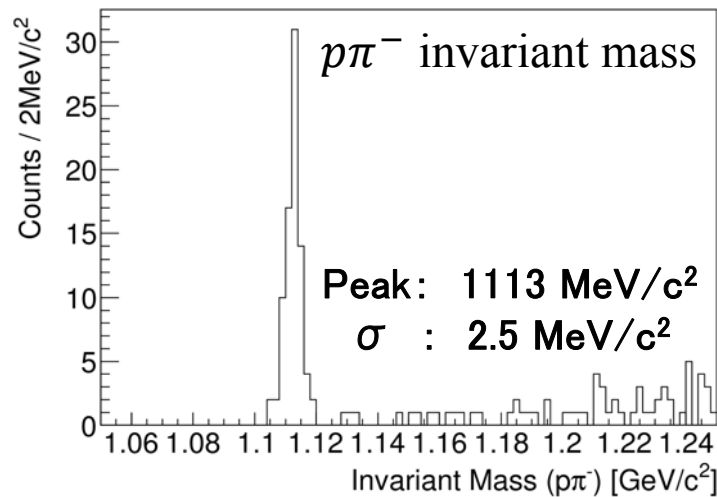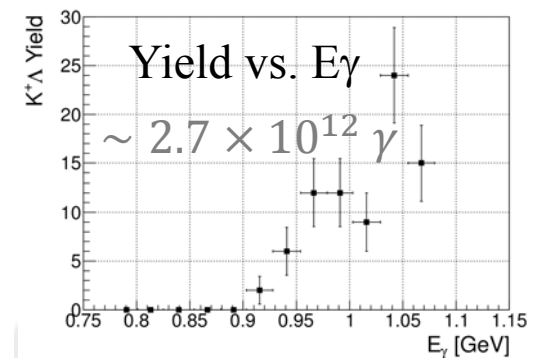
n

p

d

3

Λ

1

π^-

p
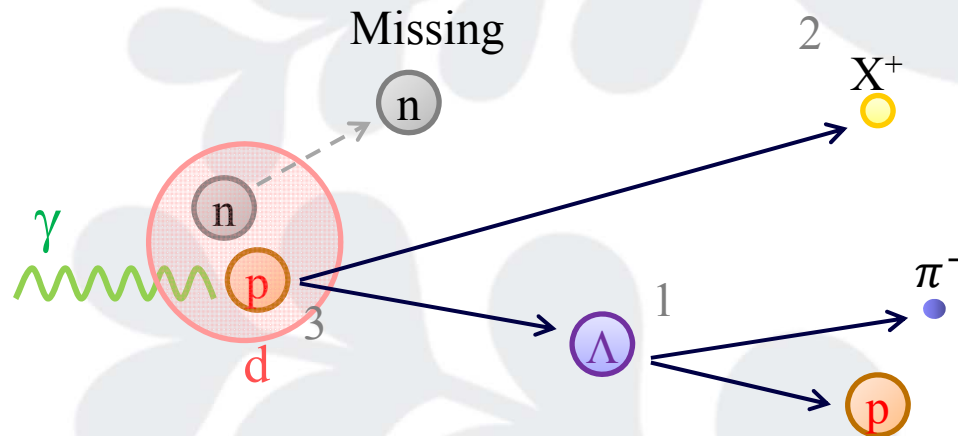
→ Step further to kinematic analyses

Current status of data analysis

- Three particles detected events (p, π^-, X^+)

$p\pi^-$ invariant mass

Peak: 1113 MeV/c^2

σ : 2.5 MeV/c^2
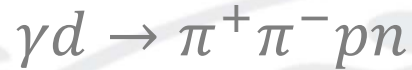
$\gamma d \rightarrow K^+ \Lambda X$ missing mass

Selection with invariant mass
And missing mass
→ K^+ found in X^+
  in a mass reconstructed from
  measured momentum and velocity
Further analysis is ongoing

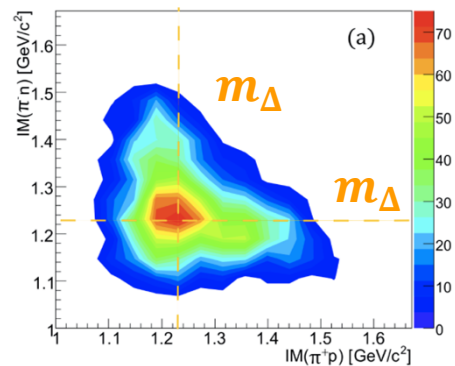Yield vs. Eγ

$\sim 2.7 \times 10^{12}\ \gamma$
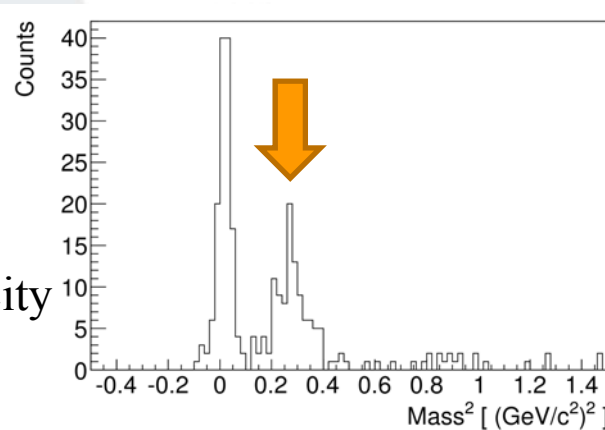
Work by T. Fujii

Analysis status of pion detected events
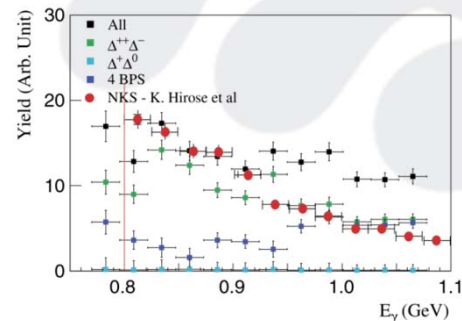
$$\gamma d \to \pi^+ \pi^- pn$$

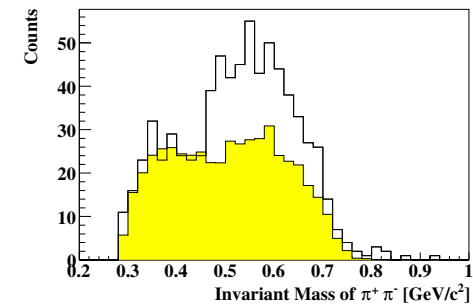Double delta excitation was found in the intermediate state
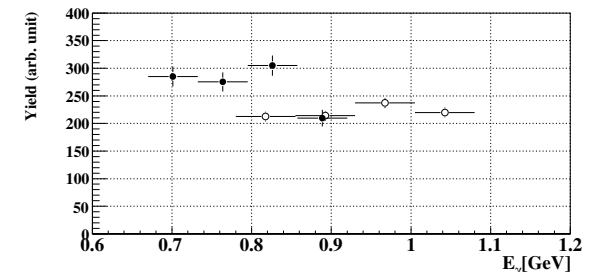
4 body Dalitz Plot

$$\gamma d \to \pi^+ \pi^- d$$

Two nucleon absorption or final state interaction?

Invariant mass of $\pi^+ \pi^-$

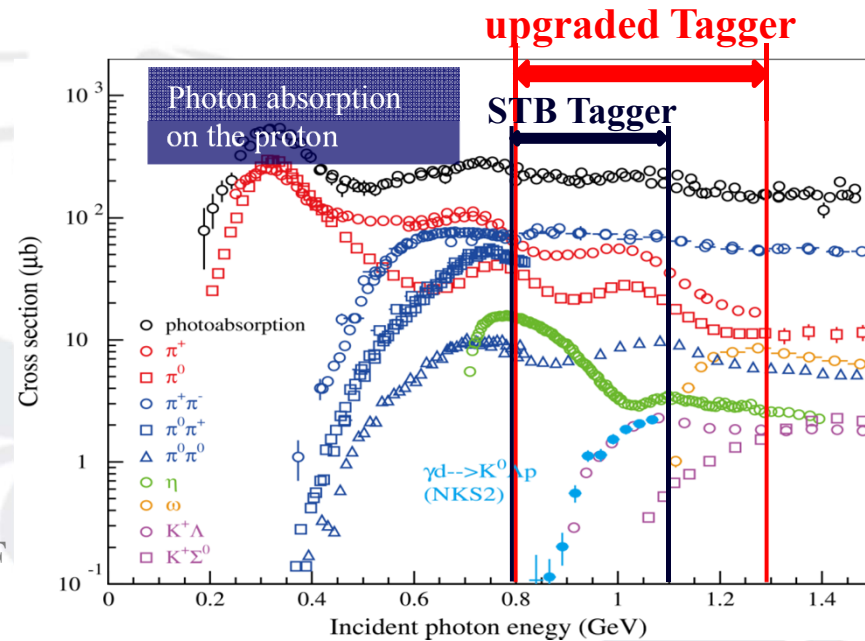

Energy dependence of yields
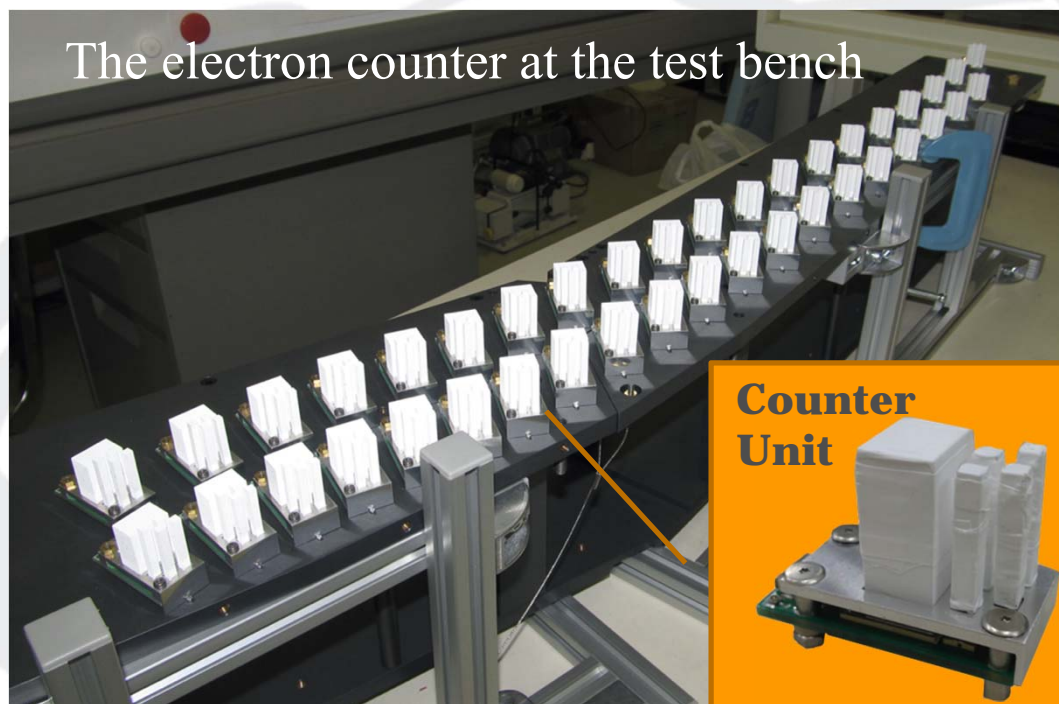

Energy dependence of yields

Upgrade of the tagger

- Upgrade of the electron synchrotron at ELPH
  - → Upgrade of the photon Tagger
    - Broader photon energy range
    - Finer granularity
- Compact form
- Magnetic field tolerance
- Rate tolerance
- Time resolution comparable to the TOF counters in the NKS2

	STB Tagger	Tagger III (design)
Electron beam energy [GeV]	1.2	1.3
Tagged photon energy [GeV]	0.8 – 1.1	0.8— sub 1.3
Energy span [MeV/ ch]	6	< 6
Number of detector channels	50	> 100
Count rate @ 2 MHz photon beam [kHz/ch]	250	200
Time resolution [ps (FWHM)]	820	< 500

The new tagger is being installed

The electron counter at the test bench

Counter Unit

The electron counter installed in the bending magnet

- In full operation in half a year (further development, commissioning and an energy calibration are planned)

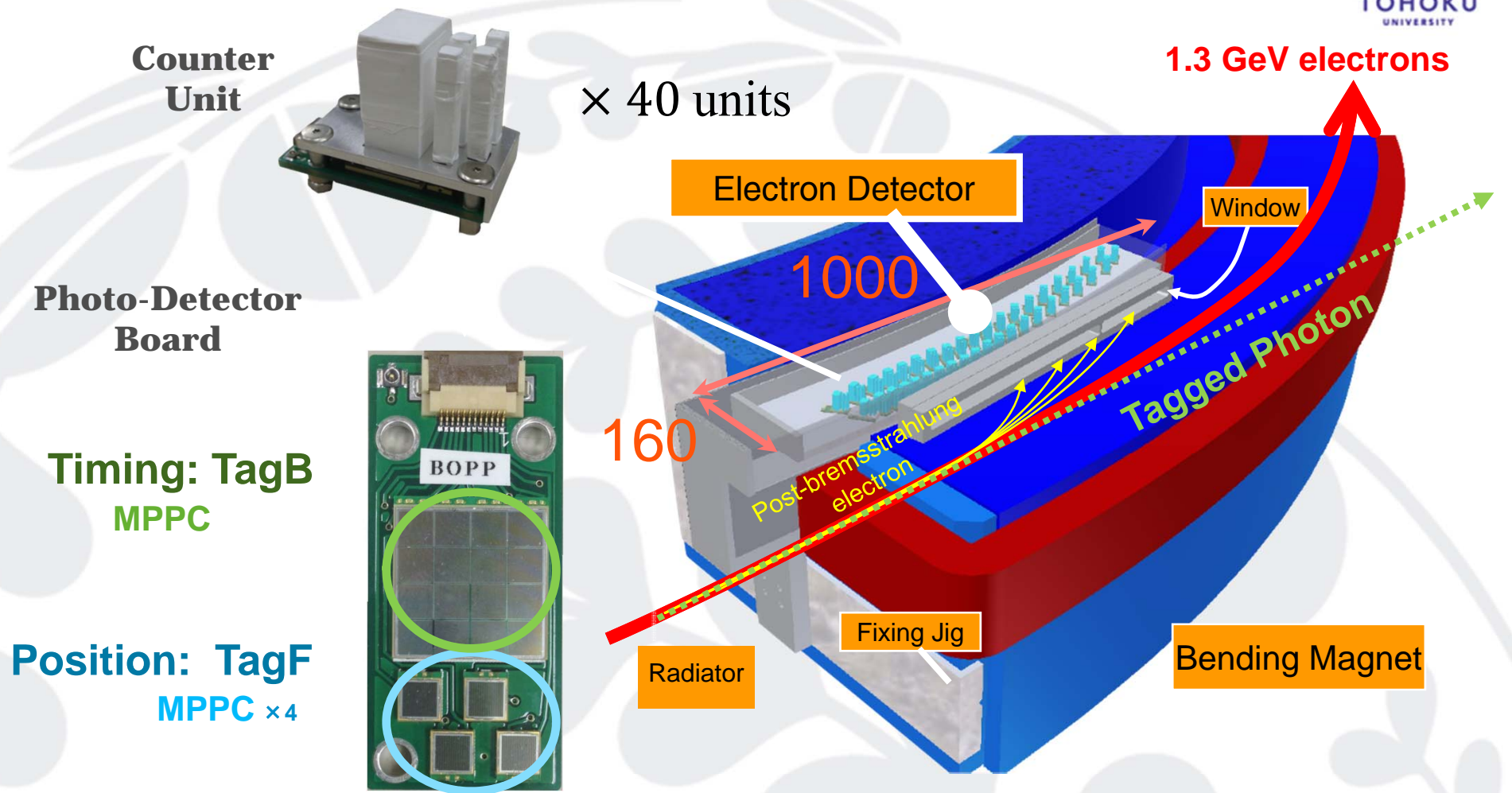- Physics data taking for new projects is planned in the next year

Summary

- Strangeness photoproduction has been explored at ELPH with the NKS2

- The NKS2: a magnetic spectrometer, was designed for the simultaneous measurement of two or more charged particles

- Analyses of the two particle detected events for K^0 or Λ inclusive measurements were almost finalized

- Analyses of the three particle detected events for K^+ Λ exclusive measurements are underway

- New Tagger system with an upgraded energy range will be ready in the near future

- Physics data taking for new projects is planned in the next year
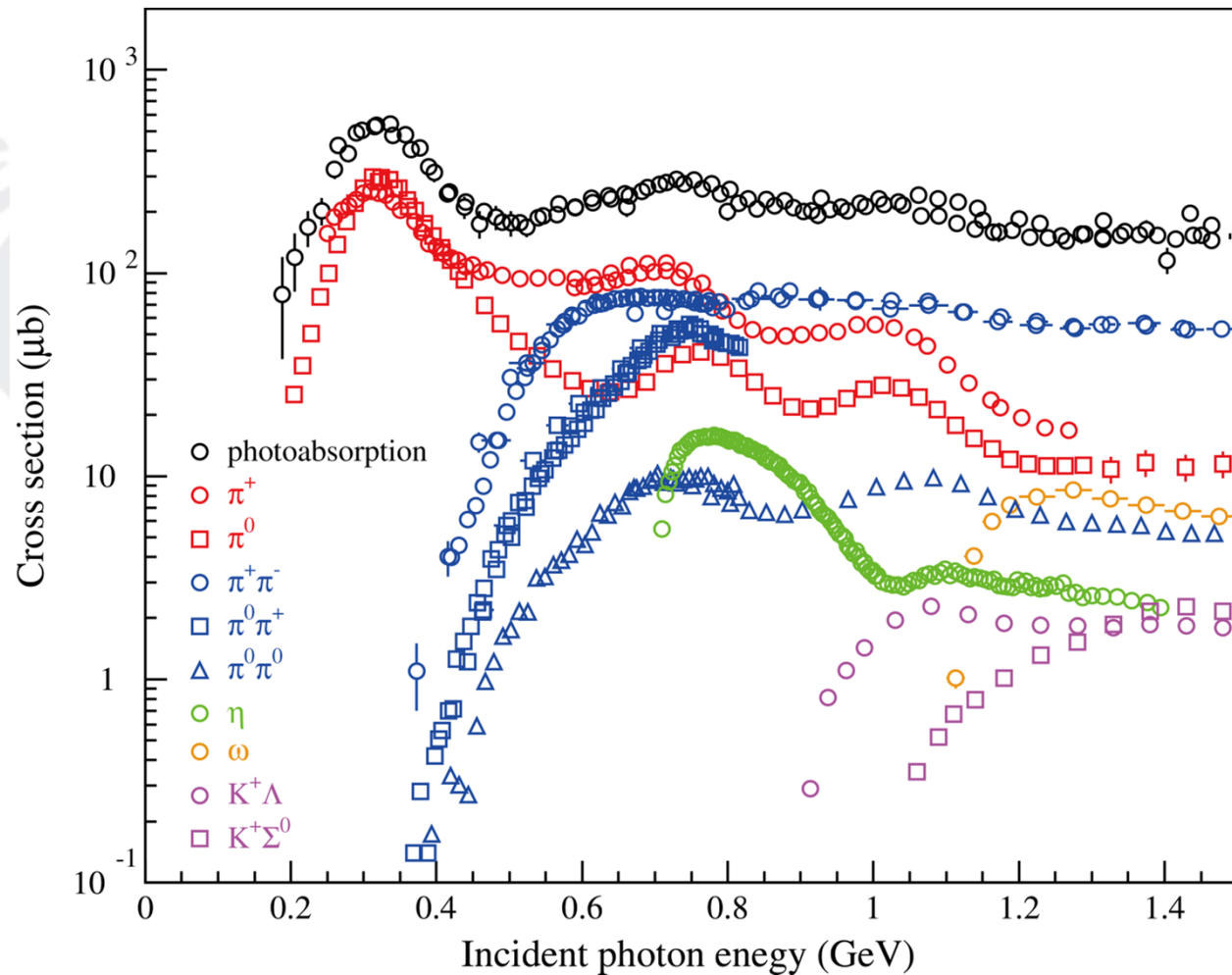
The NKS2 collaboration

- *Department of Physics, Tohoku University, Japan*
  - B. Beckford, T. Fujii, Y. Fujii, T.Fujibayashi, T. Gogami, K. Futatsukawa, O. Hashimoto, K. Honda, R. Honda, K. Hosomi, A. Iguchi, H. Kanda, Y. Kaneko, M. Kaneta, Y. Kasai, D. Kawama, T. Kawasaki, C. Kimura, S. Kiyokawa, T. Koike, Y. Ma, K. Maeda, N. Maruyama, A. Matsumura, M. Mimori, Y. Miura, Y. Miyagi, K. Miwa, S. Nagao, S.N. Nakamura, Y. Okayasu, A. Okuyama, K. Shirotori, H. Tamura, N. Terada, H. Tsubota, K. Tsukada, M. Ukai, F. Yamamoto, T.O. Yamamoto

- *Research Center for Electron Photon Science, Tohoku University (ELPH-Tohoku)*
  - K. Hirose, T. Ishikawa, K. Suzuki, T. Tamae, H. Yamazaki

- *Department of Nuclear Science, Lanzhou University, China*
  - Y.C. Han , T.S. Wang

- *Nuclear Physics Institute, Czech Republic*
  - M. Sotona, P. Bydžovský

Design of Tagger III

Counter Unit

× 40 units

Photo-Detector Board

Timing: TagB
MPPC

Position: TagF
MPPC ×4

BOPP

1.3 GeV electrons

Electron Detector

Window

1000

160

Post-bremsstrahlung electron

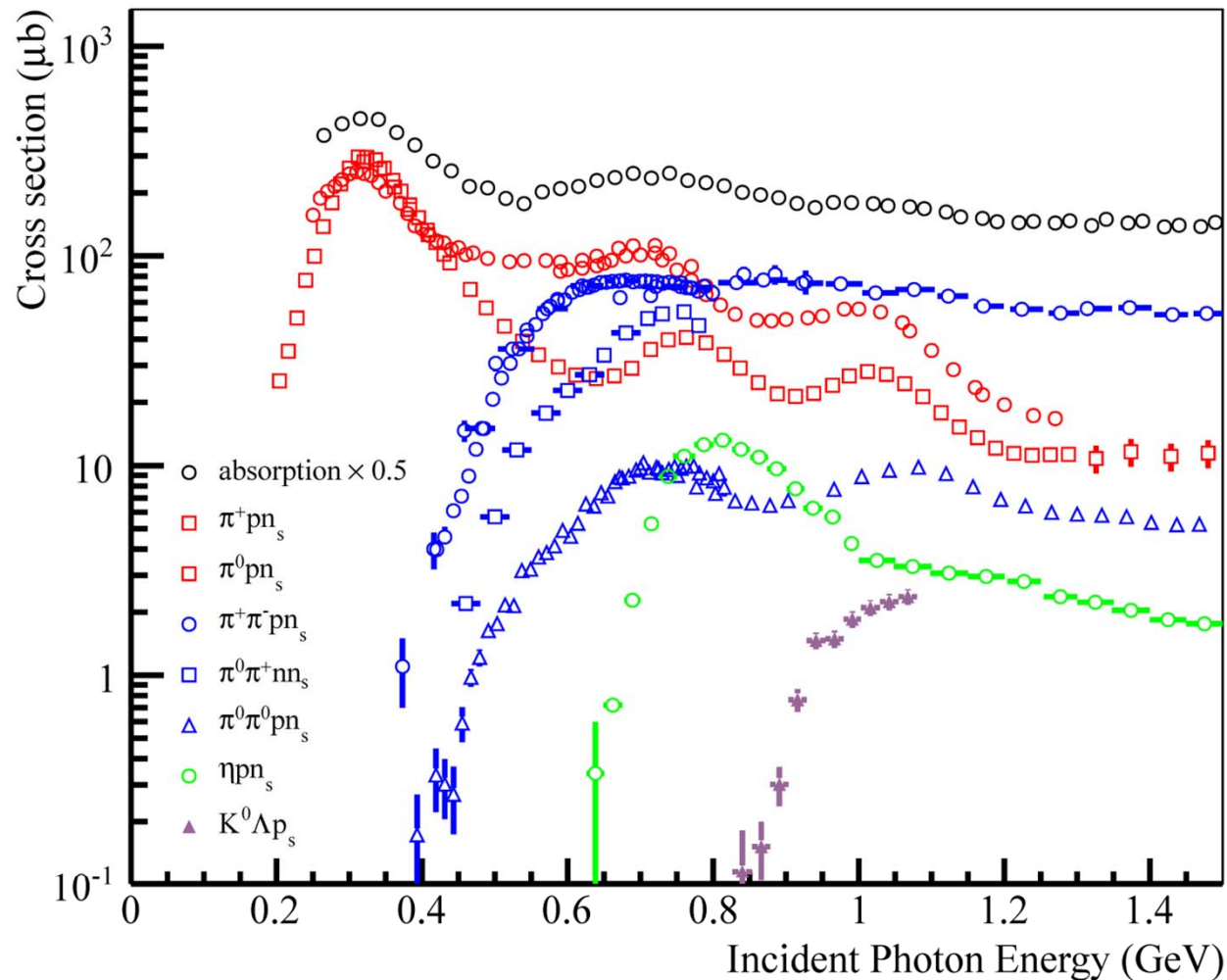Tagged Photon

Radiator

Fixing Jig

Bending Magnet

Meson Photoproduction

- Meson – Nucleon dynamics
- Search for Missing resonances

Meson Photoproduction

- On Deuteron (bound proton)
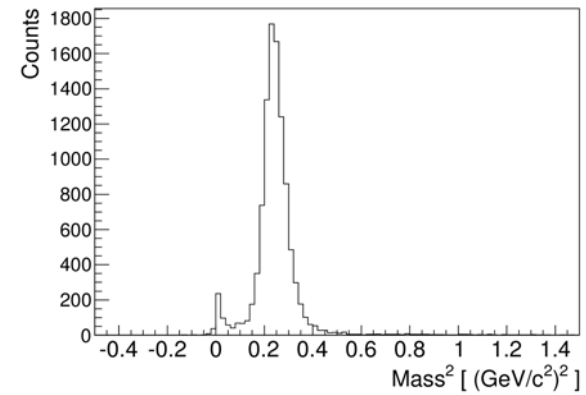- Similar cross section to proton target?

Mass Square Distribution
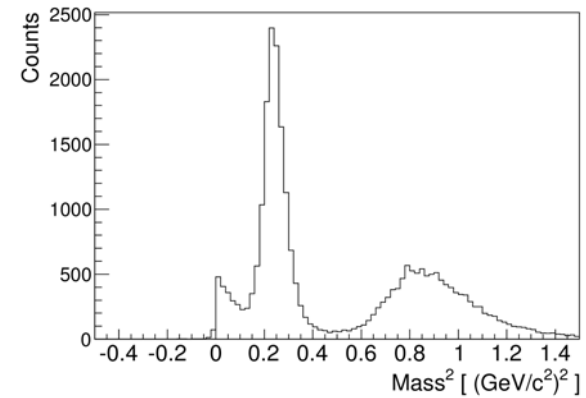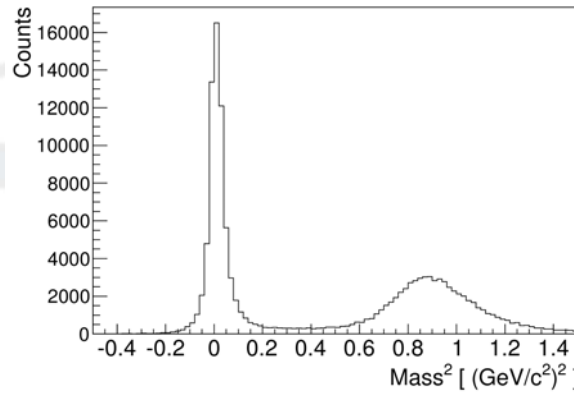
Charge ： ＋
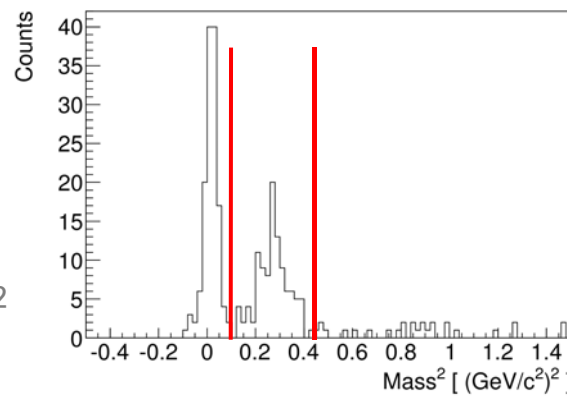
IM cut
Charge ： ＋
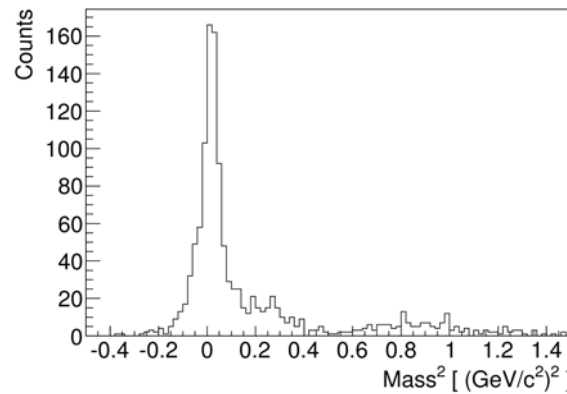
IM + MM cut
Charge ： ＋
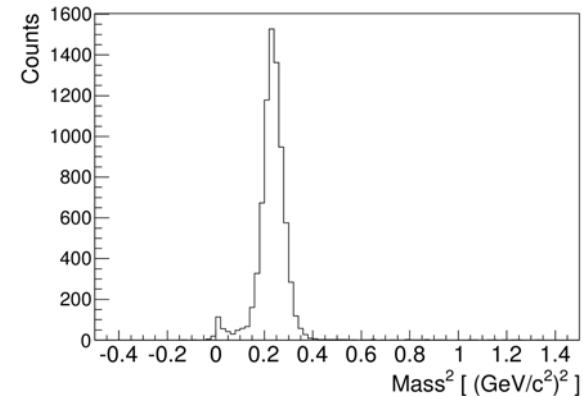
Cut region ：
  0.1 ＜ msqr ＜ 0.45 (GeV/c²)²

Energy Deposit at OH vs Momentum

青 : IM, MM Cut

緑 : IM, msqr Cut

赤 : IM, MM, msqr Cut