Strangeness production around threshold region and a possibility with the new beam line and NKS2

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for the NKS2 collaboration

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金田雅司

Outlook of this talk

- Introduction of the experiment
  - Motivation
  - Collaboration list
  - Fruits of our study
- Physics topics
  - strangeness production
  - model and data
- Experiment with Neutral Kaon Spectrometer (NKS)
  - setup
  - results
- New spectrometer (NKS2)
- A possibility with new beam line and NKS2

Introduction

NKS experiment

- Focusing on strangeness production by Electromagnetic interaction
  - by $\gamma+p$ and $\gamma+n$ reaction
  - using photon beam at Laboratory of Nuclear Science (LNS)-Tohoku
    - 0.8-1.1 GeV (accuracy: 6MeV) γ beam from 1.2 GeV (2mA) electron
  - information for
    - meson-baryon interaction
    - hadron structure
- What are our characteristics?
  - measurement of neutral kaon
    - K^+ photo-/electro-production existed on markets in 1990's
      - Bonn-SAPHIR, Jlab-CLAS, SPring8-LEPS
    - however no K^0 data on the neutron target
    - Studied with γ+C and γ+d reaction
  - now under constructing a new spectrometer (NKS2)

Collaborators are:

- **Department of Physics, Tohoku University**
  - K. Tsukada, M. Ejima, Y. Fujii, O. Hashimoto, K. Hirose, K. Hutatsugawa, S. Kameoka, H. Kanda, M. Kaneta, D. Kawama, H. Katoh, S. Kinoshita, T. Kon, K. Maeda, N. Maruyama, A. Matsumura, Y. Miura, Y. Miyagi, H. Miyasei, S.N. Nakamura, H. Nomura, K. Nonaka, A. Ohtani, Y. Okayasu, M. Oyamada, K. Shirotori, T. Takahashi, H. Tamura, H. Tsubota, D. Uchida, M. Ukai, H. Yamauchi, K. Yawata, M. Wakamatsu, T. Watanabe
- **Laboratory of Nuclear Science, Tohoku University**
  - T. Ishikawa, T. Kinoshita, H. Miyahara, T. Nakabayashi, H. Shimizu, T. Tamae, T. Terasawa, H. Yamazaki
- **Department of Electrical and Electric Engineering, Akita University**
  - A. Sasaki
- **Department of Electrical Engineering, Ichinoseki National College of Technology**
  - O. Konno

Fruits of our study

- Thesis
  - 2 of Dr. Sci. (T. Watanabe, K. Tsukada),
    7 of M. Sci. and 4 of B. Sci. in 5 years
- Conference talk
  - PANIC02
    - Photoproduction of Neutral Kaons on C in the Threshold Region
  - LEPS03
    - K^0 and double pion photoproduction experiments at LNS
  - SENDAI03
    - Photoproduction of Neutral Kaons in the Threshold Region at LNS
  - HYP2003
    - K^0 photoproduction on ^{12}C in the threshold region
  - Hirschegg 2004
    - Photoproduction of neutral kaons on carbon and liquid deuterium targets in the threshold region
- JPS talk
  - 15 talks in 2001-2005
- Publication
  - now on going.....

Physics topics

Strangeness photo-production

Physics motivation

- Kaon production on nucleon by electromagnetic interaction
  - Strangeness production mechanism
  - Meson-baryon coupling constants
  - Structure of hadrons (form factor)

understood better than hadronic interactions

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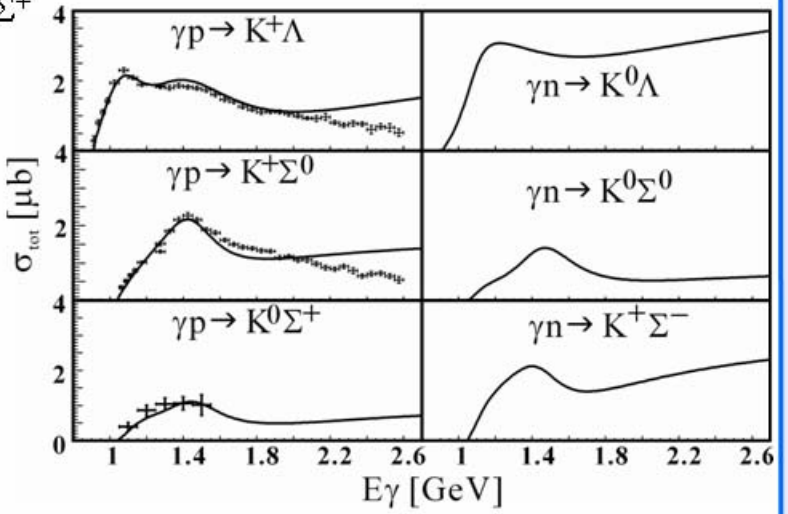
Strangeness photo-production

Previous studies

- High quality data for K^+ photo- or electro-production since 1990s.
  - Bonn-SAPHIR
    $p(\gamma,K^+)\Lambda$, $p(\gamma,K^+)\Sigma^0$, $p(\gamma,K^0)\Sigma^+$
  - JLAB
    $p(\gamma,K^+)\Lambda$, $p(\vec{e},e'K^+)\Lambda$
  - SPring8/LEPS
    $p(\vec{\gamma},K^+)\Lambda$, $p(\vec{\gamma},K^+)\Sigma^0$
  - $K^0\Sigma^+$ channel by SAPHIR with poor statistic
  - Almost no data for K^0 production



Solid lines: theoretical calculation by Kaon-MAID

- Key information from other three strangeness production channel

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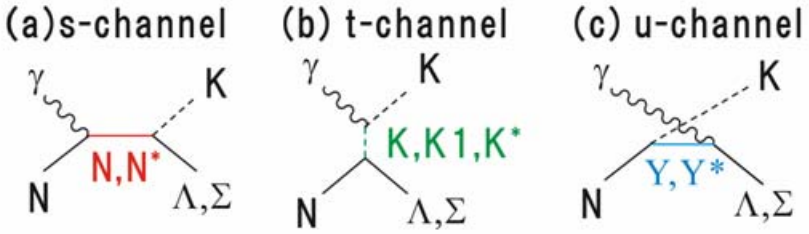
Strangeness photo-production

Isobar model - framework



- SU(3) flavor symmetry
  - $g_{\pi NN}$ to g_{KYN} ($-4.5<g_{K\Lambda p}<-3.0$, $0.9<g_{K\Sigma 0p}<1.3$)
- Duality hypothesis
  - extract resonances with higher spin in t-channel
- Crossing symmetry
  - radiative capture , $p(K^-,\gamma)\Lambda \leftrightarrow p(\gamma, K^+)\Lambda$

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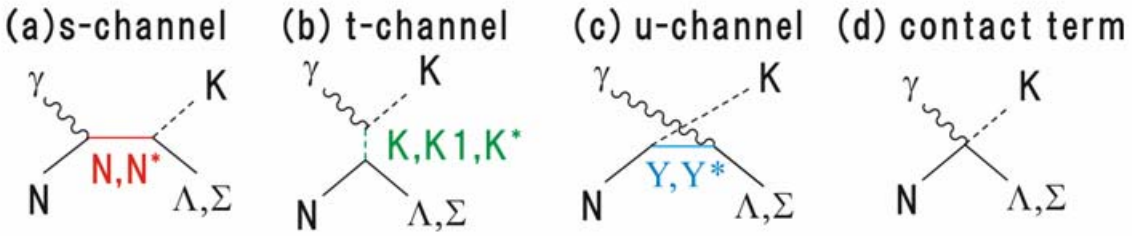
Strangeness photo-production

Isobar model - modification



- Only Born term (under SU(3) constraint)
  → produce higher cross section than data.
- To reduce Born strength
  - the hadronic form factor (+contact term)
  - the hyperon resonances in u-channel → SLA

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Strangeness photo-production

Improved Isobar model

- Kaon-MAID [T.Mart, C.Bennhold, Phys. Rev. C61 (2000) 012201(R)]
  - Resonances : $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$, $D_{13}(1895)$, $K^*(892)$, $K_1(1270)$
  - Reaction of input data : $K^+\Lambda$, $K^+\Sigma^0$, $K^0\Sigma^+$
  - Hadronic form factor , contact term
- Saclay-Lyon A [T.Mizutani et.al., Phys. Rev. C58 (1998) 75]
  - Resonances : $P_{13}(1720)$, $K^*(892)$, $K_1(1270)$, $\Lambda(1405)$, $\Lambda(1670)$, $\Lambda(1810)$,$\Sigma(1660)$
  - Reaction of input data : $K^+\Lambda$
  - No hadronic form factor

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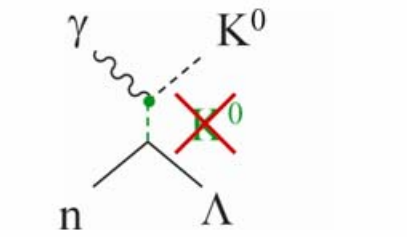
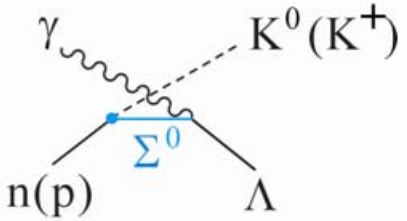
Strangeness photo-production

K^0 production near the threshold

- Interference among diagrams is quite different from K^+ production
  - no charge in the reaction
    → t-channel Born term does not contribute
  - Isospin symmetry
    → coupling constant of Σ^0 exchange term in u-channel,

$$g(K^0\Sigma^0 n) = -g(K^+\Sigma^0 p)$$





- In the threshold region, the influence from higher resonances is considered small.

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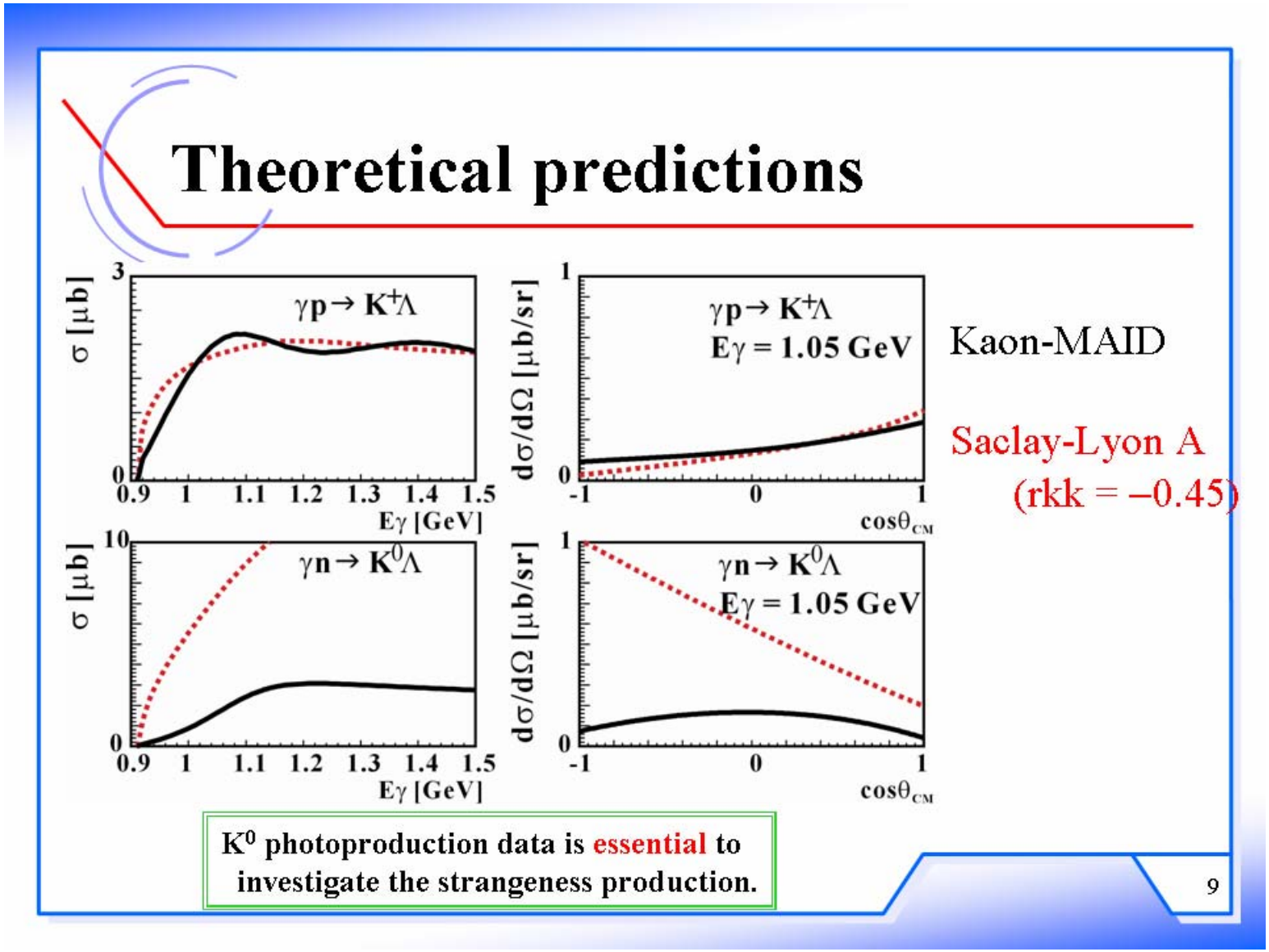
Strangeness photo-production



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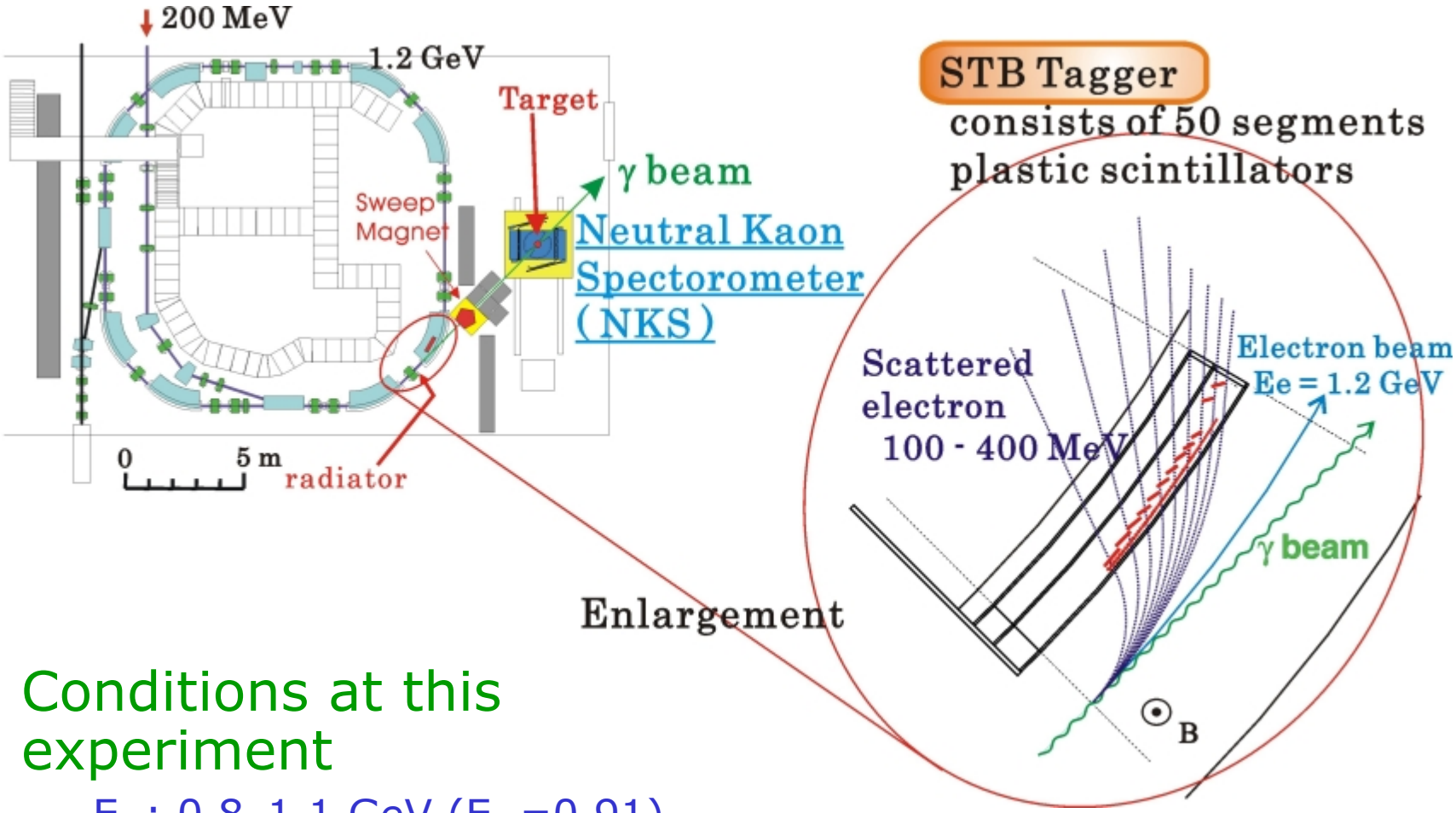
Experimental setup of NKS

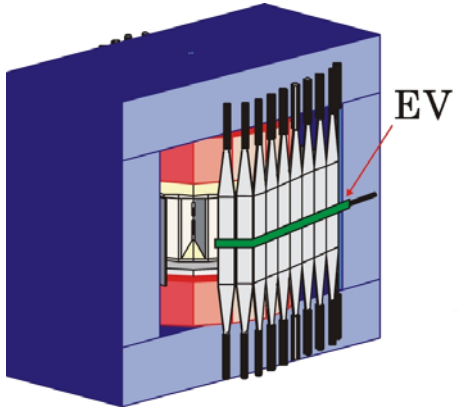
LNS STB ring and NKS

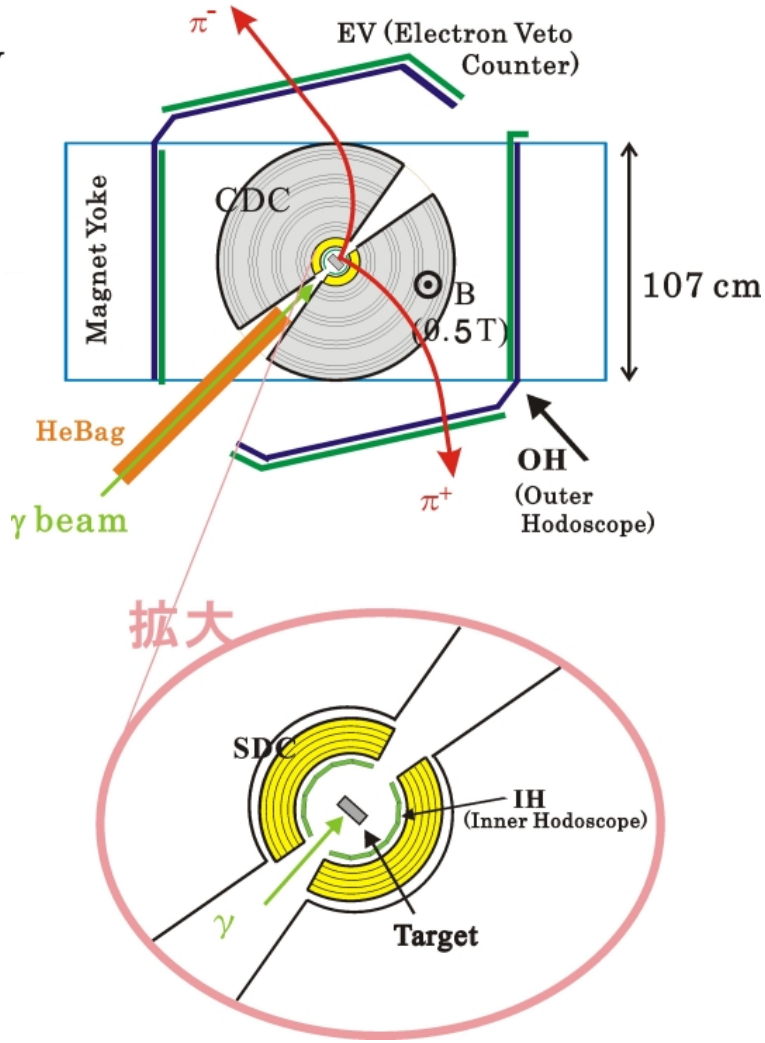


- Conditions at this experiment
  - E_γ : 0.8–1.1 GeV (E_{th}=0.91)
  - Duty factor : ~ 60 %
  - Beam current : ~ 2 mA

The spectrometer

$K^0_S \rightarrow \pi^+\pi^-$
B.R. ~ 68.6 %
ct ~ 2.67 cm





- TAGX magnet
  - Dipole magnet with 0.5 T
- Inner Hodoscope (IH) and Outer Hodoscope (OH)
  - Trigger counter
  - Time of flight measurement
- CDC (cylindrical drift chamber) and SDC (straw drift chamber)
  - Tracking
  - Momentum
- EV (electron veto counter)
  - e^+e^- background suppression

Results from NKS experiment

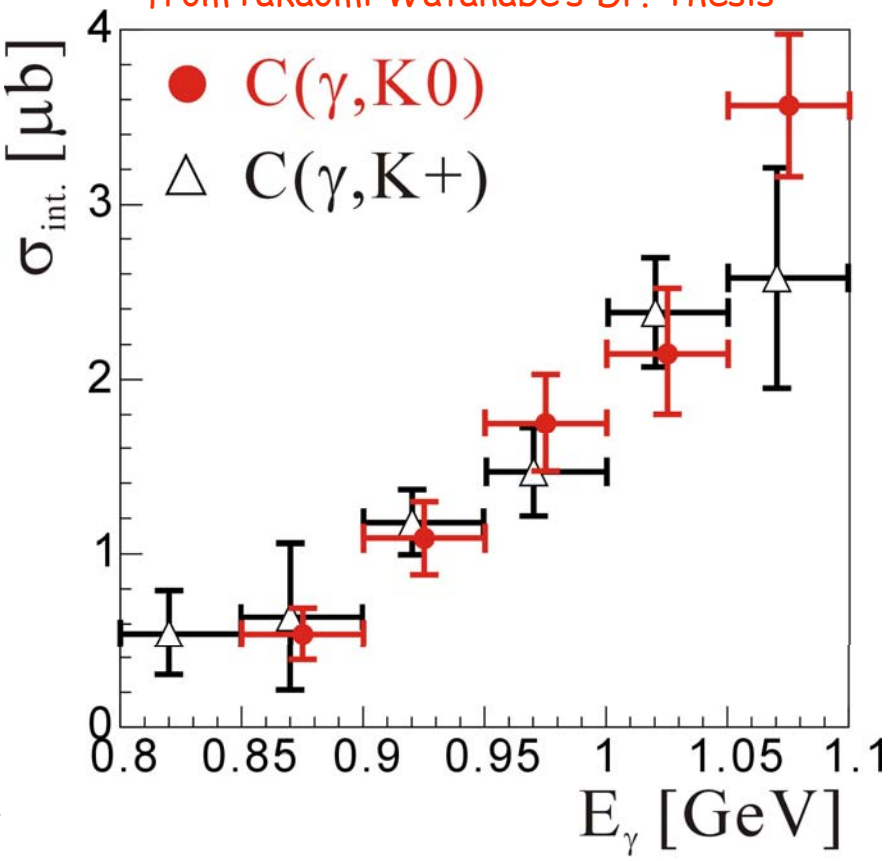
$$\gamma + C(n) \rightarrow K^0 + X(\Lambda)$$

$$\gamma + d(n) \rightarrow K^0 + X(\Lambda)$$

Results of NKS experiment

- γ+C(n) $\rightarrow$ K^0+X(Λ)

fromTakaomi Watanabe's Dr. Thesis



K^0: NKS $(0.800 < \cos\theta < 1.000)$

K^+: H.Yamazaki et al. $(0.766 < \cos\theta < 0.985)$

Phys. Rev. C51 (1995) R1074

Integrated region: almost same acceptance effect

K^0: uncorrected (<5%)

K^+: corrected

$$\frac{\sigma_{C(\gamma,K0)}}{\sigma_{C(\gamma,K+)}} = 1.1 \pm 0.1$$

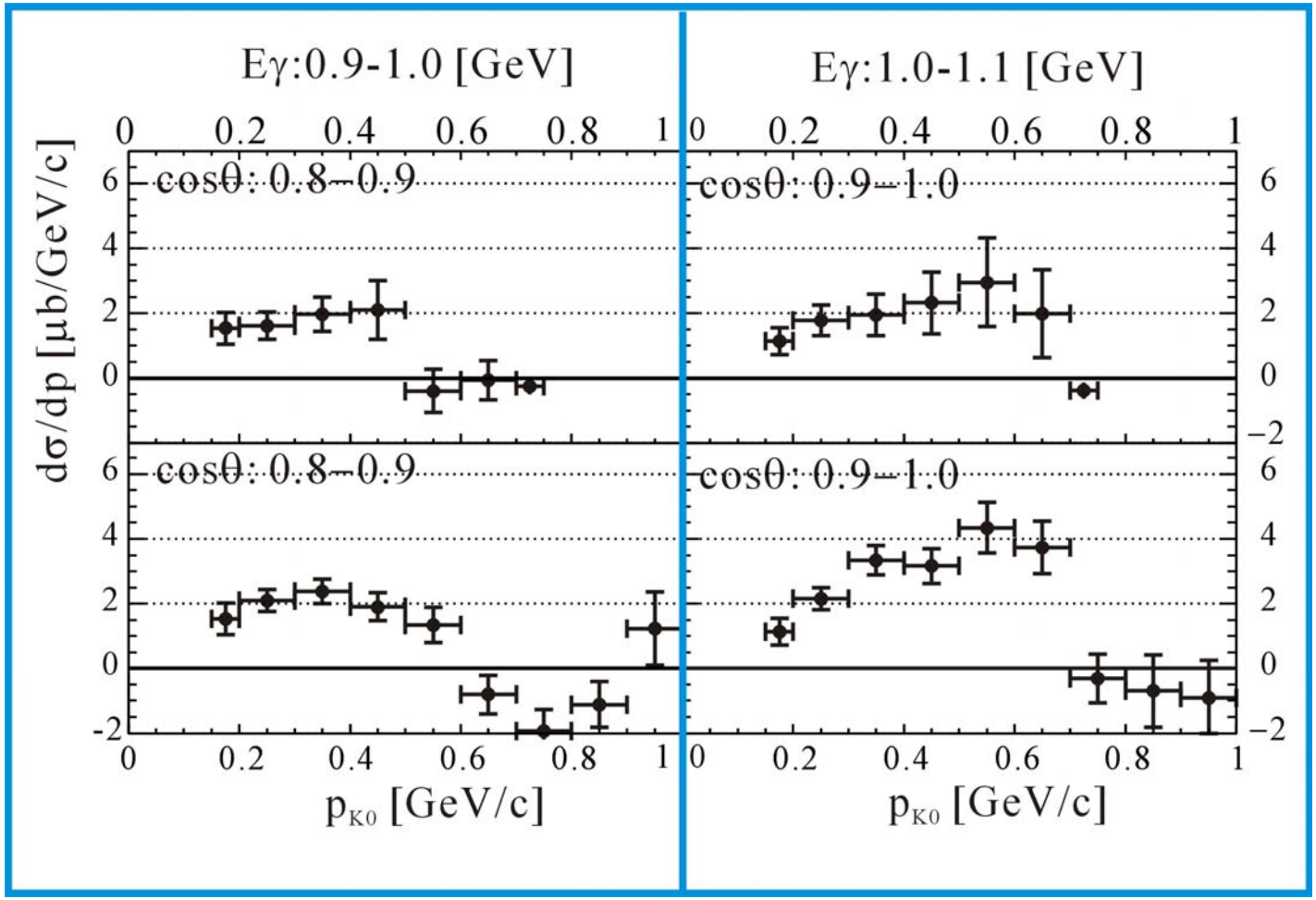
$\Downarrow$

K^0 cross section is close to K^+ one

Results of NKS experiment

- $\gamma + C(n) \rightarrow K^0 + X(\Lambda)$
  - K^0 Cross section as a function of momentum, cosθ (= p_Z/p), and E_γ

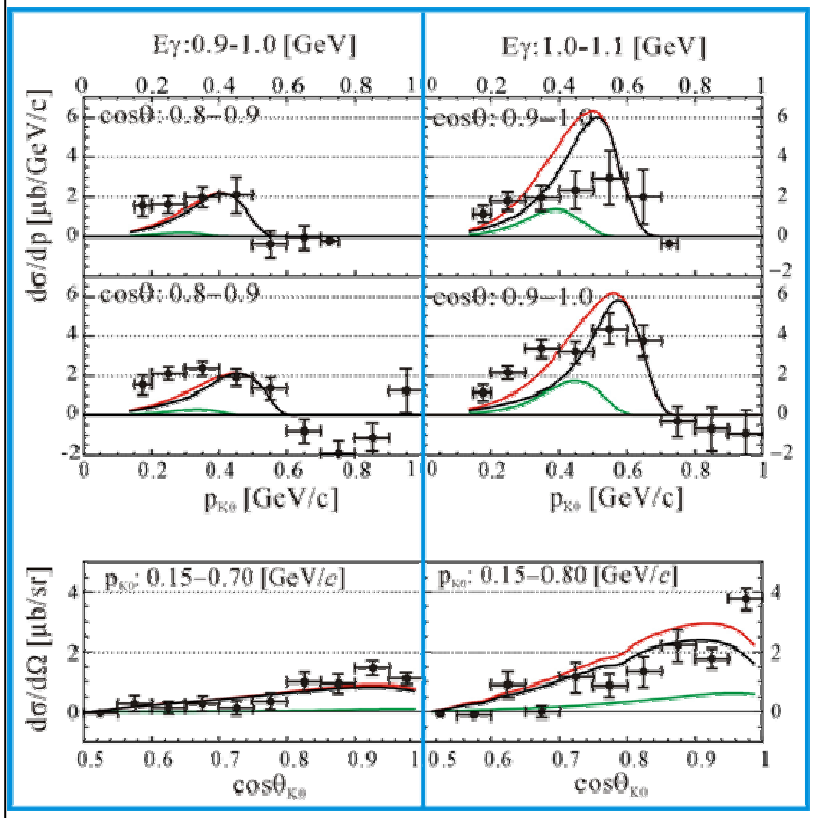
from Takaomi Watanabe's Dr. Thesis



Results of NKS experiment

$\gamma + C(n) \rightarrow K^0 + X(\Lambda)$

Comparison with Kaon-MAID



- The model has:
  - same order of magnitude for cross section
  - underestimate in low E_γ and p region
- need a correction of the model for K^0 Λ channel

γn→K⁰Λ

γn→K⁰Σ⁰ + γp→K⁰Σ⁺

All

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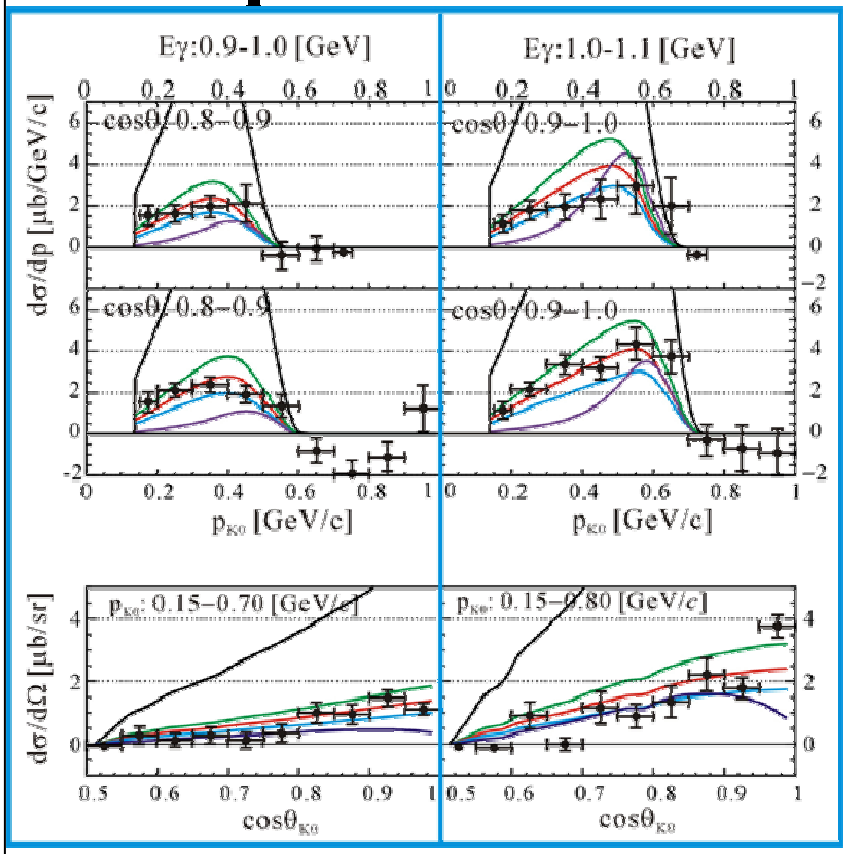
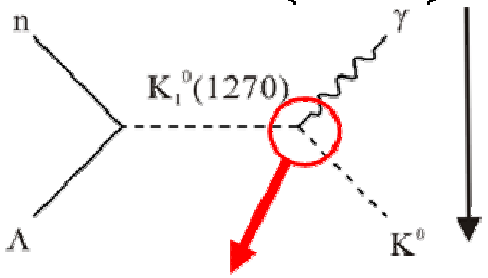
Results of NKS experiment

$\gamma + C(n) \rightarrow K^0 + X(\Lambda)$

Comparison with SLA model (KΛ)





$rKK_1 = g(K_1^0 K^0 \gamma) / g(K_1^+ K^+ \gamma)$

free parameter

when Kaon-MAID value is used for rKK_1, SLA model do not represent the data

With rKK_1= -1.4 – -1.8

good agreement with the data

rKK_1= –0.447 (Kaon-MAID)

= –1.4 or –1.6 or –1.8 or –3.4

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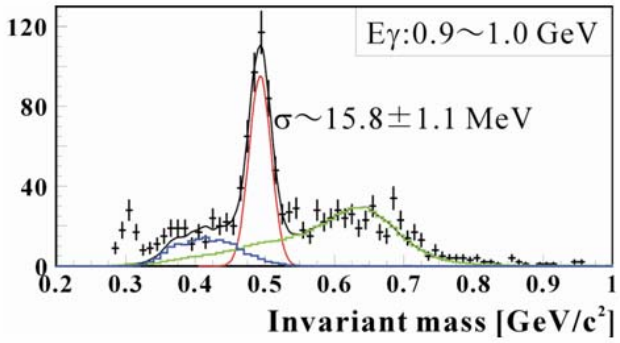
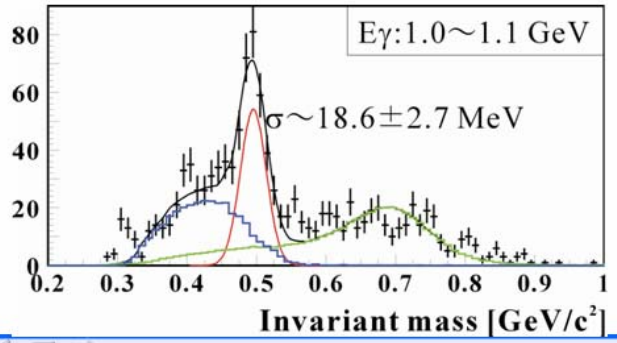
Results of NKS experiment

$\gamma + d(n) \rightarrow K^0 + X(\Lambda)$

Invariant mass spectrum





- black : decay volume
- Background
- green : case 1
  - leak from target region
- blue : case 2
  - π^+ from K^0 and π^- from Λ

Mass gate : 0.46 – 0.54 GeV/c²

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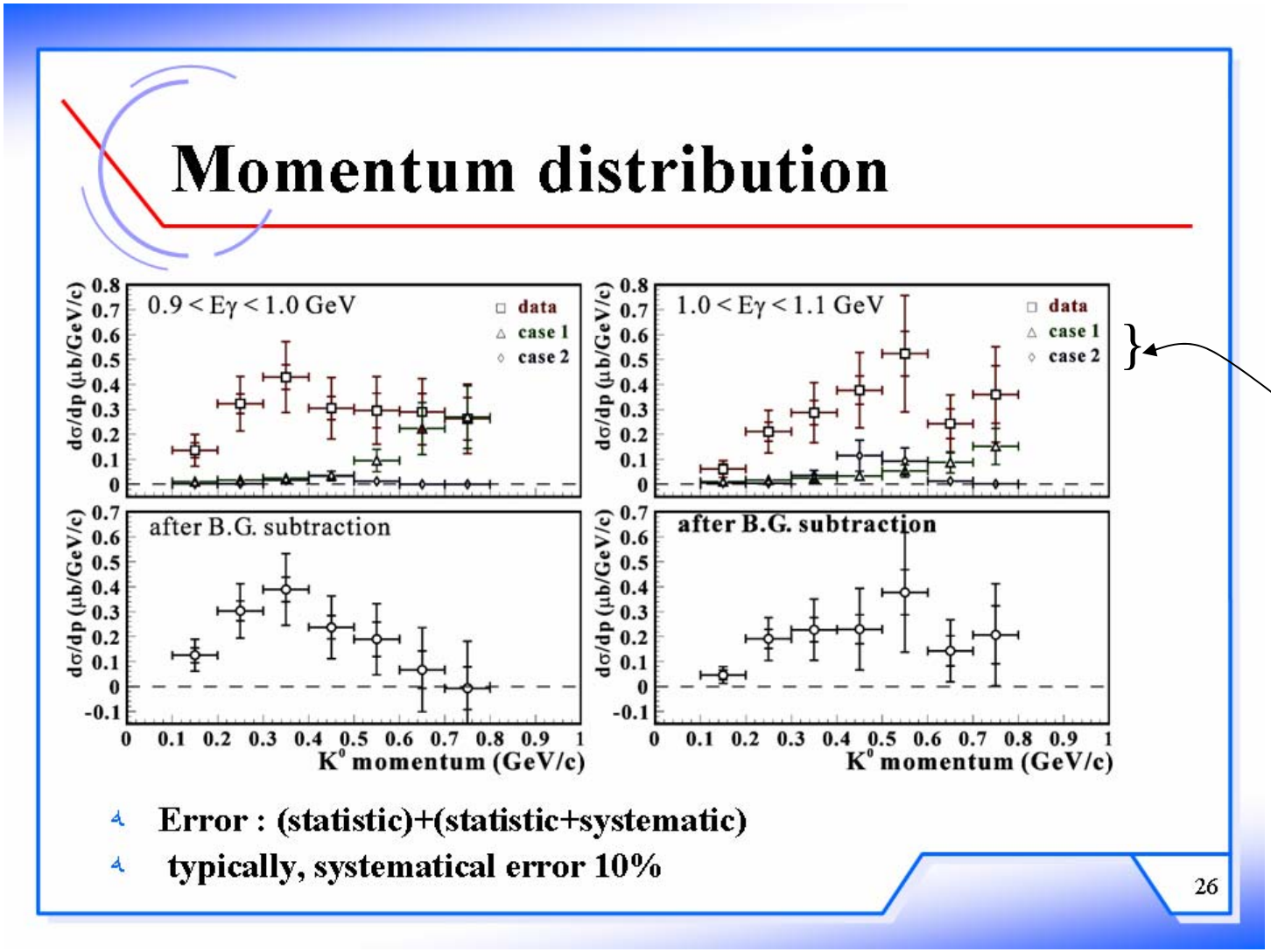
Results of NKS experiment

$\gamma + d(n) \rightarrow K^0 + X(\Lambda)$



background estimated

1: ππ pair from out of target (ρ, ω, etc)

2: accidental coincidence of π from K^0 and π from Λ

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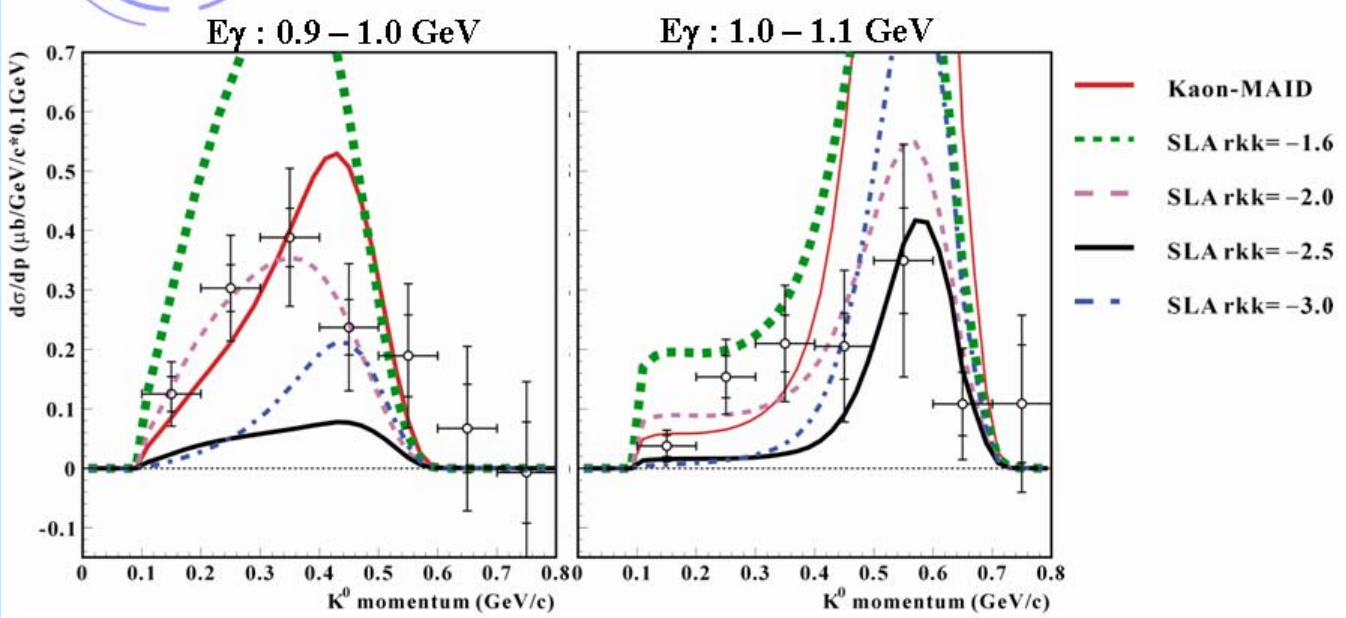
Results of NKS experiment

$\gamma + d(n) \rightarrow K^0 + X(\Lambda)$

Momentum dependences



- Kaon-MAID : too large at 1.0～1.1 GeV
- SLA rkk= –2.0 : good agreement

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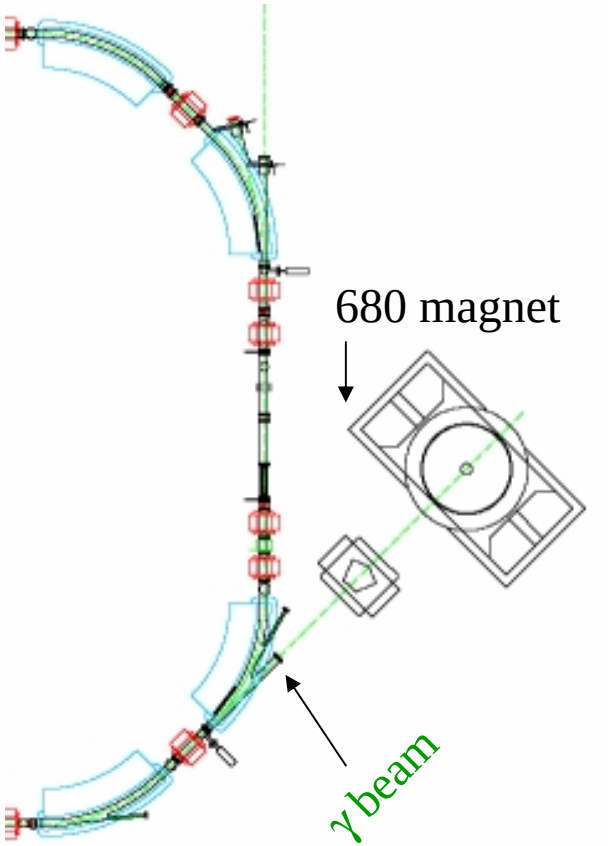
Summary of the NKS experiment

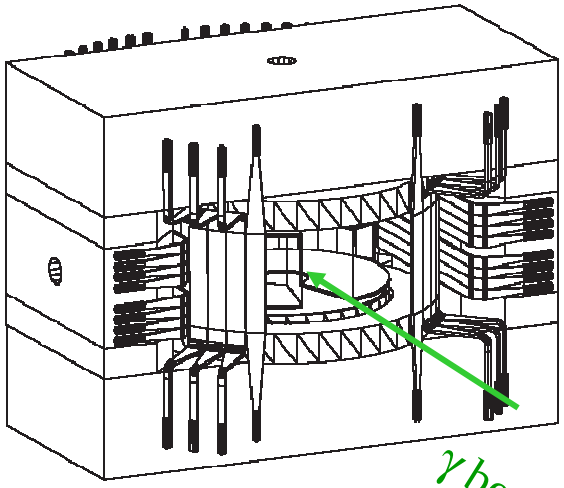
- Neutral kaon production by $\gamma+n \rightarrow K^0+\Lambda$ is studied via
  - $\gamma+C \rightarrow K^0+X(\Lambda)$ and $\gamma+d \rightarrow K^0+X(\Lambda)$ reaction
    - First time measurement of K^0 cross section in $\gamma+d$
- Comparison of data with two models
  - Kaon-MAID
    - in $\gamma+C$
      - seems to underestimate in low momentum (backward direction)
    - in both $\gamma+d$ and $\gamma+C$
      - over estimate in $p>0.7$GeV/c and $E_\gamma = 1.0 - 1.1$ GeV
  - SLA
    - with tuning of the free parameter rKK_1
      - $rKK_1 = -1.4$ to -1.8 for $\gamma+C$ data
      - $rKK_1 \simeq -2.0$ for $\gamma+d$ data
    - Need more statistics to conclude rKK_1
      - additionally, need to consider a nucleus effect in C
- We expect more statistics with NKS2
  - 2 times of K^0 and 10 times of Λ compared with NKS

The new spectrometer NKS2

The new spectrometer (NKS2)

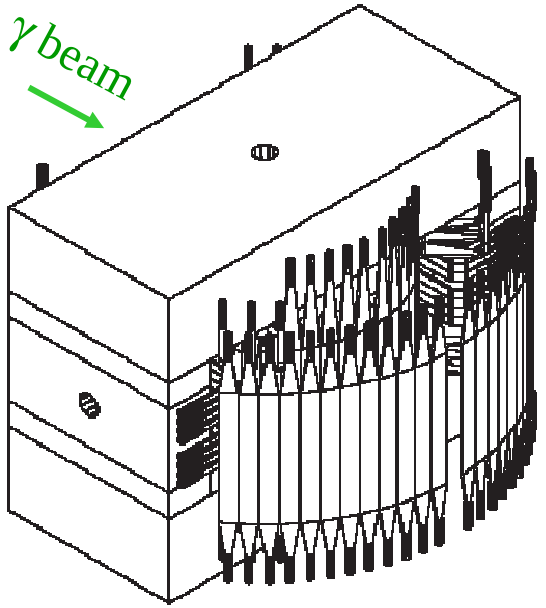
- New magnet (so called 680 magnet)
  - used for cyclotron in CYRIC-Tohoku
  - 0.42T (1000A, 110V)
- New cylindrical drift chamber
  - covered forward region



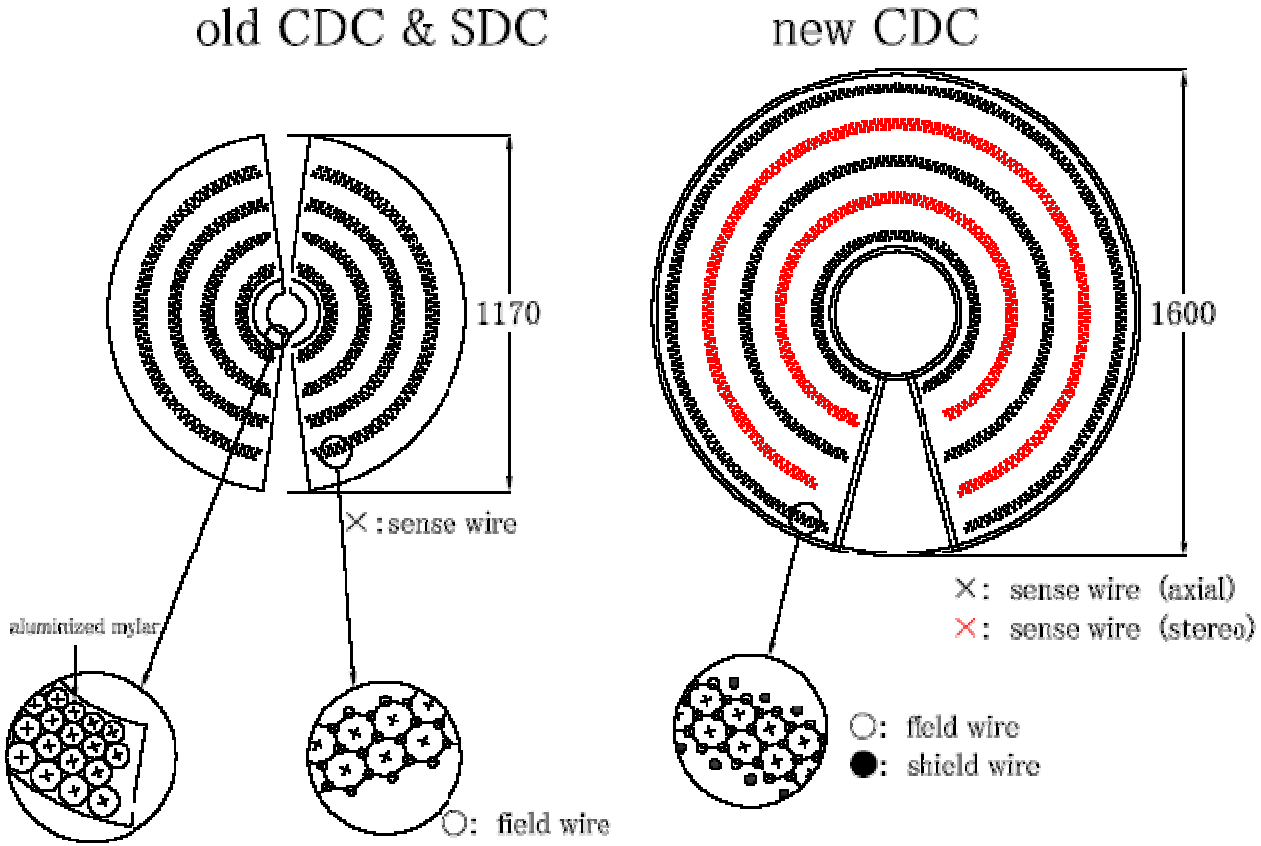


view from upstream

view from downstream



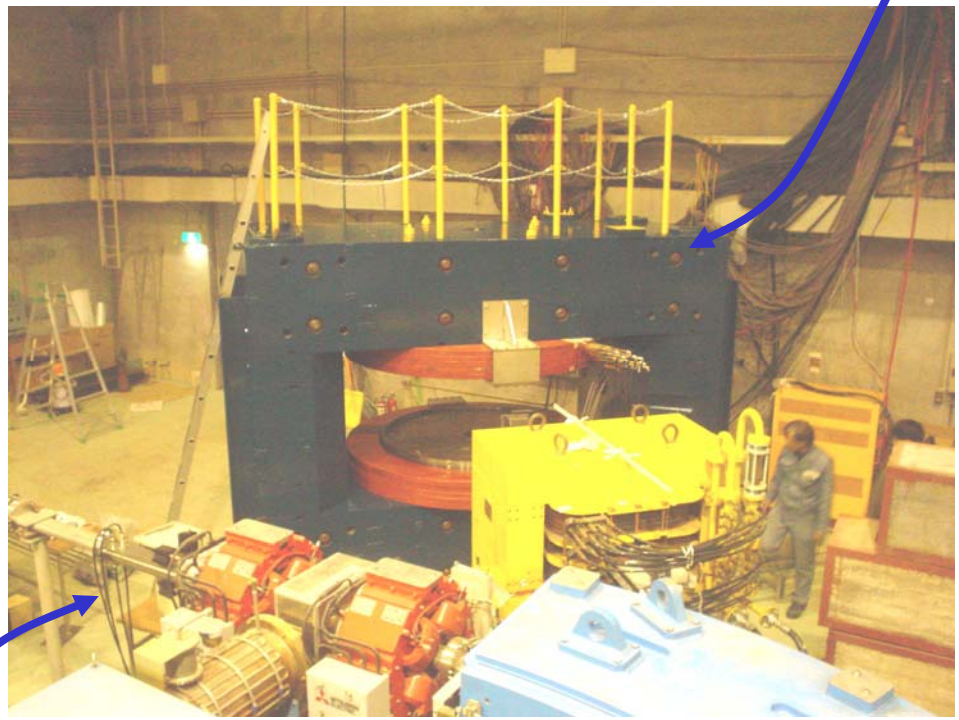
Comparison of new CDC with old one



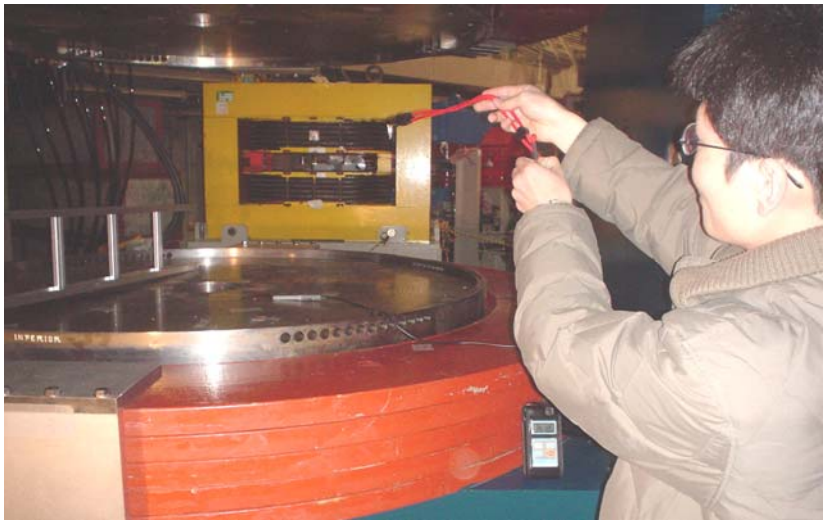
- New CDC
  - covered forward region
  - 3D tracking by x,u,v wire read-out
  - acceptance
    - 20–80 cm radius
    - ±165 deg in zx plane along the beam
    - ±165cm height
    - 1.127 π Sr (28.18% of total solid angle)

Some pictures of NKS2

680 magnet



STB ring



Detectors will be installed from this autumn

A possibility with the new beam line and NKS2

A possibility(-ies)

- It is just rough idea which MK hit upon....
  - that is, might be "Picture of Rice cakes (= "Pie in the sky")

A possibility(-ies)

- With large acceptance of 680 Magnet + CDC + α
  - Strangeness production study
    - Λ, Λ^*,.. (also polarization measurement)
      - many resonances will be backgrounds
    - multi-strangeness baryons are interesting
      - need inner tracker (Mini TPC, Si detector, etc.)
    - charmonium??
      - cross section/polarization measurement
      - with several E_γ, if possible
  - Sea quark ($s\bar{s}$) contribution in spin structure of nucleons
    - an asymmetry of ϕ production with polarized γ beam

Summary

Summary

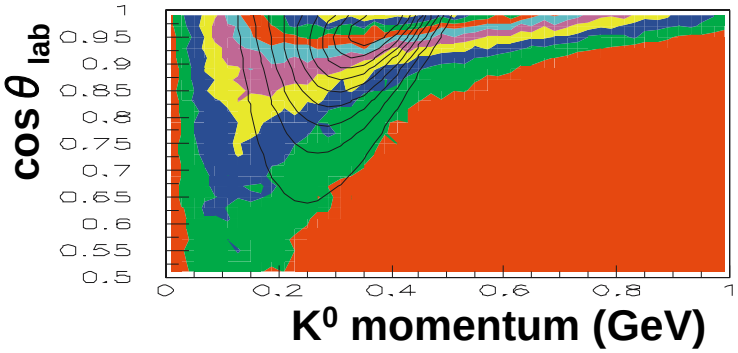
- Neutral kaon production by $\gamma+n \rightarrow K^0+\Lambda$ is studied via
  - $\gamma+C \rightarrow K^0+\Lambda$ and $\gamma+d \rightarrow K^0+\Lambda$ reaction
    - First time measurement of K^0 cross section in $\gamma+d$
- Comparison of data with two models
  - SLA show better agreement than Kaon-MAID
    - however, it is not perfect
    - to fix a free parameter rKK_1, need more statistics
- We expect more statistics with NKS2
  - 2 times of K^0 and 10 times of Λ compared with NKS
- Some rough ideas for new beam line with NKS2 are presented

Backup

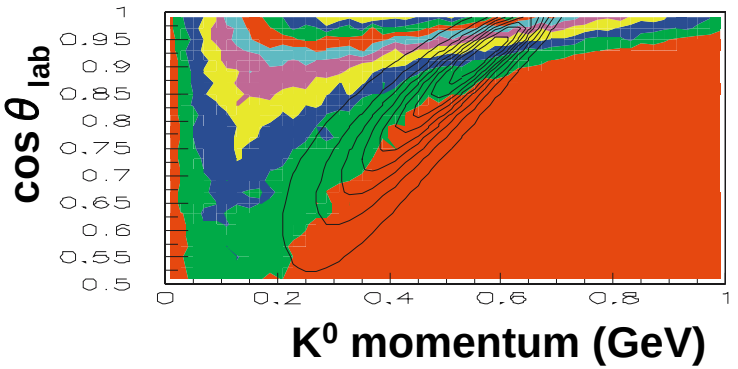
新旧スペクトロメータの比較　アクセプタンス

NKS

0.90 GeV < Eγ < 0.95 GeV

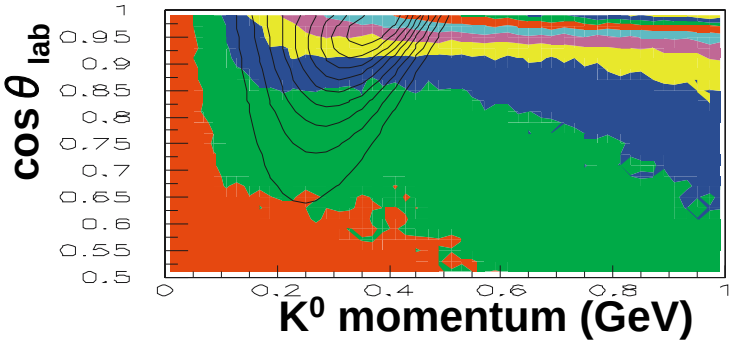


1.05 GeV < Eγ < 1.10 GeV

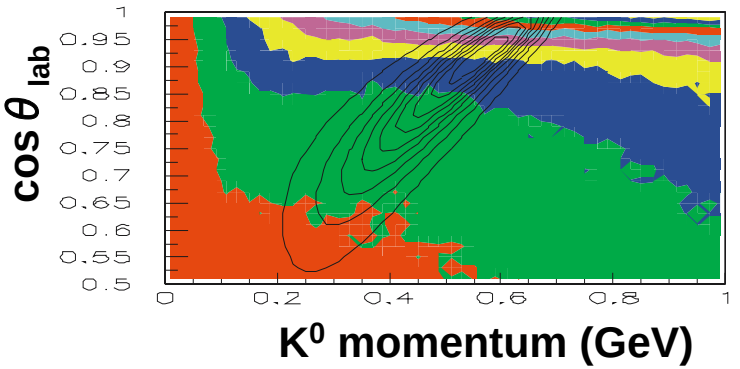


新スペクトロメータ

0.90 GeV < Eγ < 0.95 GeV



1.05 GeV < Eγ < 1.10 GeV



Color : Acceptance

Solid line :

Kaon-MAID

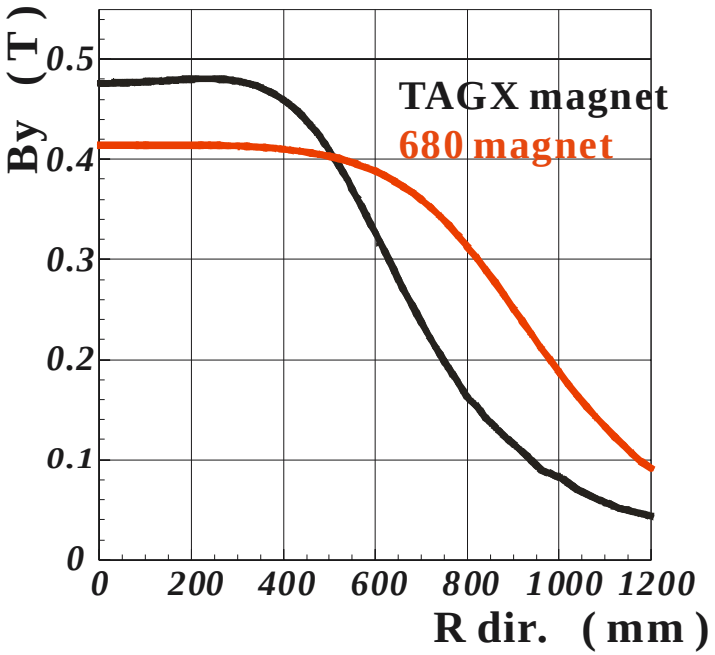
D_2

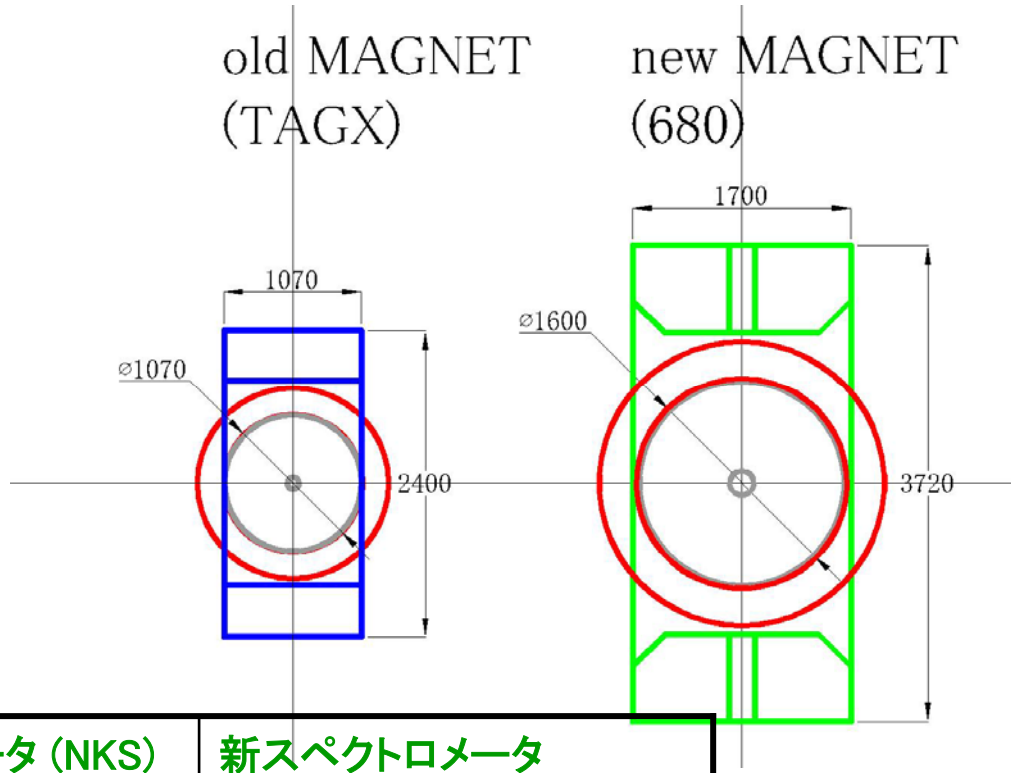
K^0 生成断面積

ほぼ全運動学的領域を覆っている。

K^0で2倍、Λで10倍の収量が期待できる。

新旧スペクトロメータの比較　電磁石





	旧スペクトロメータ (NKS) TAGX magnet	新スペクトロメータ 680 magnet
磁極半径	535 mm	800 mm
ギャップ	600 mm	680 mm
重量	30 t	120 t
電流	500 A	1000 A
最大平均磁場	0.5 T	0.4 T (TOSCA simulation)