Experimental results of K^+ photoproduction at SPring-8/LEPS

Mizuki Sumihama

RCNP, Osaka Univ.

for the LEPS collaboration

1. Introduction
2. Experiment
3. Data analyses
4. Experimental results
5. Summary

Super Photon Ring 8GeV (SPring-8)

HYP2003 Oct. 16th 2003

LEPS collaboration

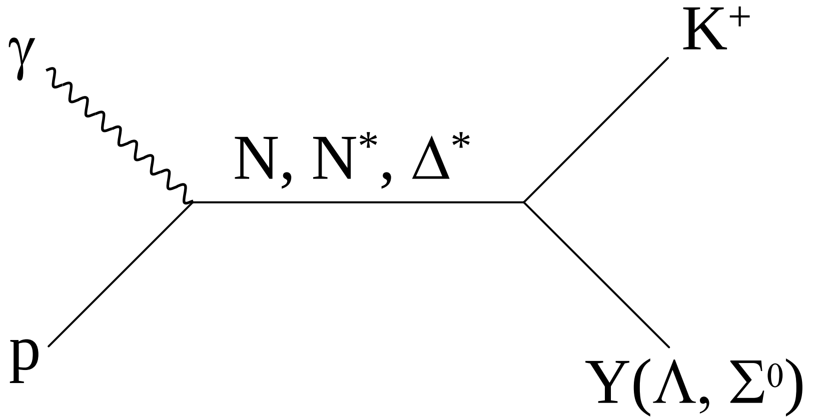
D.S. Ahn[a], J.K. Ahn[b], H. Akimune[c], Y. Asano[d], W.C. Chang[e], S. Date[f], H. Ejiri[a,f], H. Fujimura[h], M. Fujiwara[a,b], K. Hicks[i], T. Hotta[a], K. Imai[j], T. Ishikawa[k], T. Iwata[l], H. Kawai[m], Z.Y. Kim[h], K. Kino[a], H. Kohri[a], N. Kumagai[f], S. Makino[n], T. Matsumura[a], N. Matsuoka[a], T. Mibe[a], K. Miwa[j], M. Miyabe[j], Y. Miyachi[o], M. Morita[a], N. Muramatsu[d], T. Nakano[a], M. Niiyama[j], M. Nomachi[p], Y. Ohashi[f], T. Ooba[m], H. Ookuma[f], D. S. Oshuev[e], C. Rangacharyulu[q], A. Sakaguchi[p], T. Sasaki[j], P. M. Shagin[a], Y. Shiino[m], H. Shimizu[k], Y. Sugaya[p], M. Sumihama[a] H. Toyokawa[f], A. Wakai[o], C.W. Wang[e], S.C. Wang[e], K. Yonehara[c], T. Yorita[f], M. Yosoi[j] and R.G.T. Zegers[a],

a Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan
b Department of Physics, Pusan National University, Pusan 609-735, Korea
c Department of Physics, Konan University, Kobe, Hyogo 658-8501, Japan
d Japan Atomic Energy Research Institute, Mikazuki, Hyogo 679-5148, Japan
e Institute of Physics, Academia Sinica, Taipei 11529, Taiwan
f Japan Synchrotron Radiation Research Institute, Mikazuki, Hyogo 679-5198, Japan
h School of physics, Seoul National University, Seoul, 151-747 Korea
i Department of Physics, Ohio University, Athens, Ohio 45701, USA
j Department of Physics, Kyoto University, Kyoto, Kyoto 606-8502, Japan
k Laboratory of Nuclear Science, Tohoku University, Sendai 982-0826, Japan
l Department of Physics, Yamagata University, Yamagata, Yamagata 990-8560, Japan
m Department of Physics, Chiba University, Chiba, Chiba 263-8522, Japan
n Wakayama Medical College, Wakayama, Wakayama 641-0012, Japan
o Department of Physics, Nagoya University, Nagoya, Aichi 464-8602, Japan
p Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan
q Department of Physics, University of Saskatchewan, Saskatoon, S7N 5E2, Canada
r Department of Applied Physics, Miyazaki University, Miyazaki 889-2192, Japan

1. Introduction

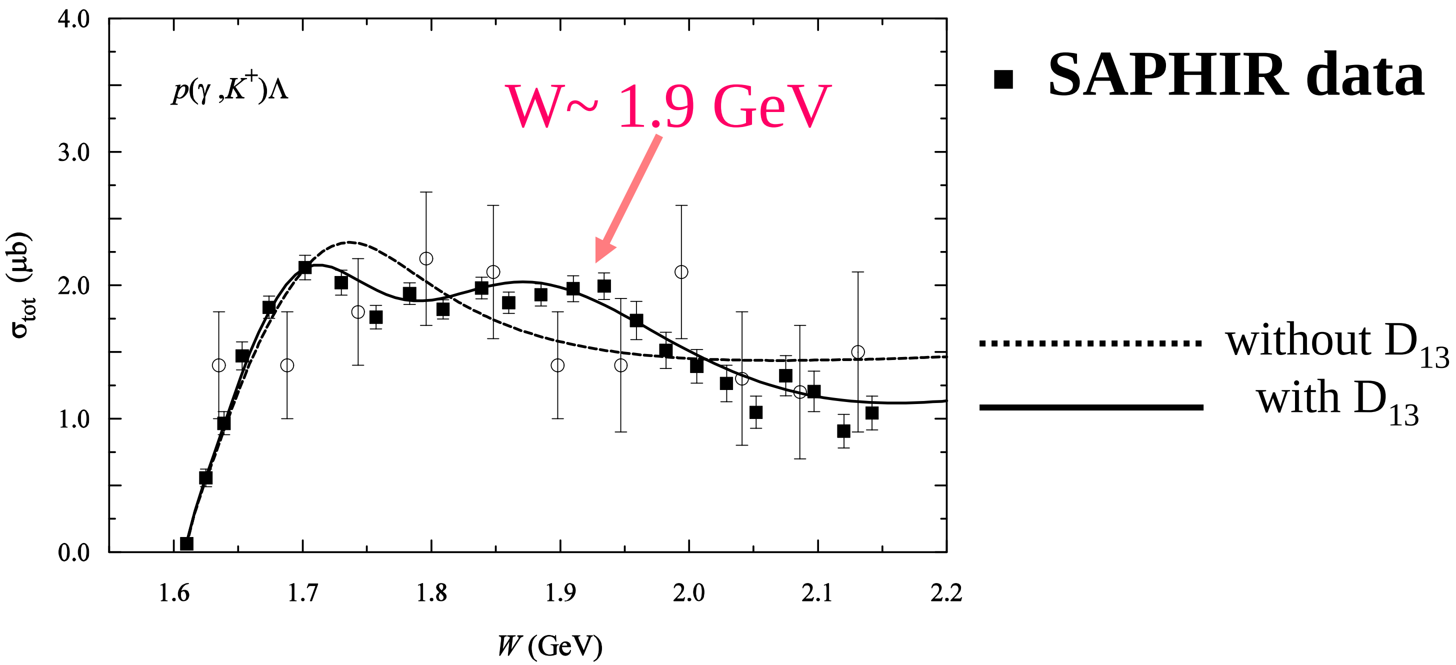
Missing resonances N^* and Δ^* in strangeness channels

- Information on nucleon resonances mainly comes from the πN channel.
- Many nucleon resonances predicted by quark model are still missing.
- It is essential to fully know N^* and Δ^* to understand the structure of baryons.



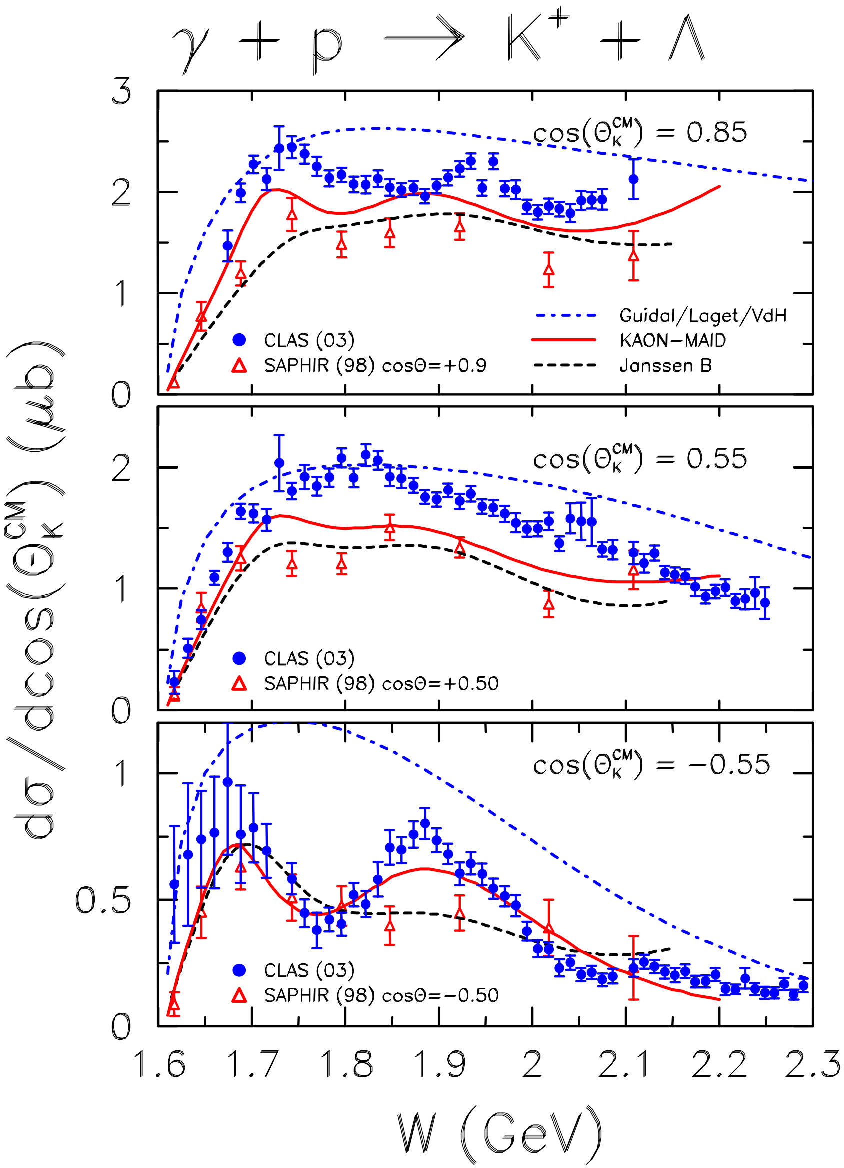
Some resonances may couple to $K\Lambda$ or $K\Sigma$ channel.
K^+ photoproduction is good means to search missing resonances.

Resonance structure?



- Resonancelike structure in the cross section for p(γ,K$^+$)Λ from SAPHIR was seen at ~1900 MeV.
- Missing resonance D_{13}(1895) is predicted by Mart and Bennhold. PRC vol.61 012201

CLAS data



More than one resonance is seen in the CLAS data.

- More precise studies are needed to confirm the existence of resonances.

- Need caution to define conclusions with cross sections only

Description of Kaon photoproduction

tree-level effective-Lagrangian approach

Ambiguities

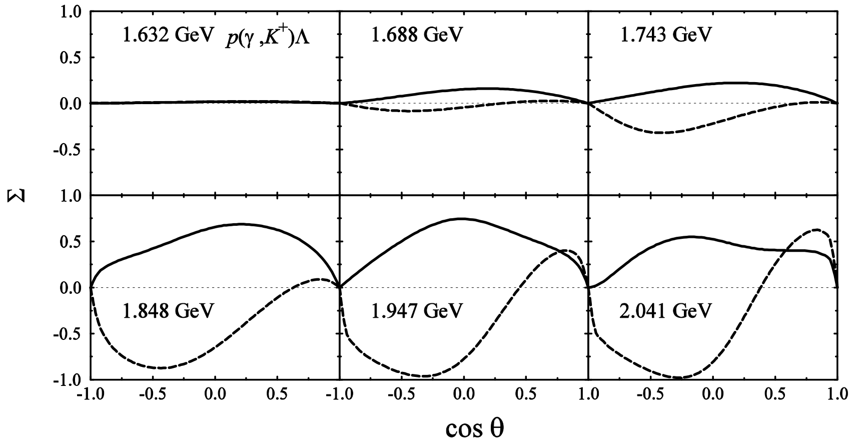
- Choice of included resonances
- Coupling constant
- Hadronic form factors
- Treatment of background terms

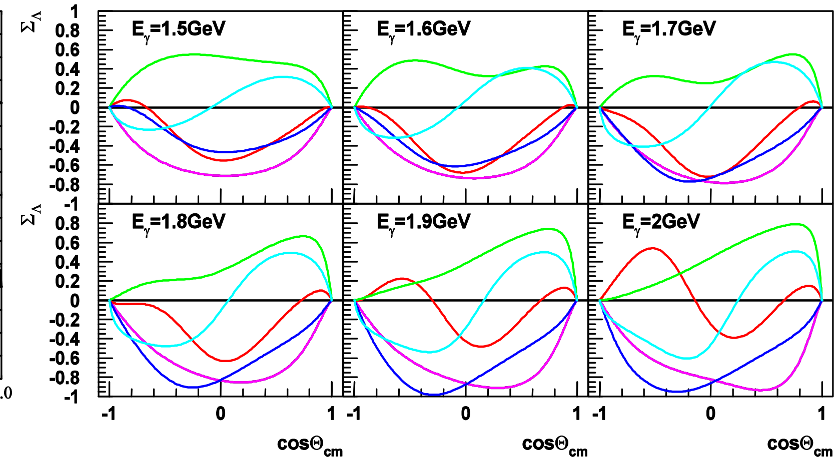
Need more study to fix parameters.

- Need caution to define conclusions with cross sections only

- Additional observables are useful for further studies.
- There are the data of cross sections and recoil polarizations from SAPHIR and CLAS collaborations.
- Photon beam asymmetry is one of the good candidates.
- **LEPS** facility has a linearly - polarized photon beam.

Theoretical predictions of photon asymmetry





By Mart & Bennhold
PRC 61 012201 (1999)

By Janssen *et al*
PRC 65 015201 (2002)

- - - - - without $D_{13}(1895)$

——— with $D_{13}(1895)$

Hadronic form factor	A	B	C
Davidson&Workman	[magenta]	[red]	[cyan]
Haberzettl	[green]	[blue]	

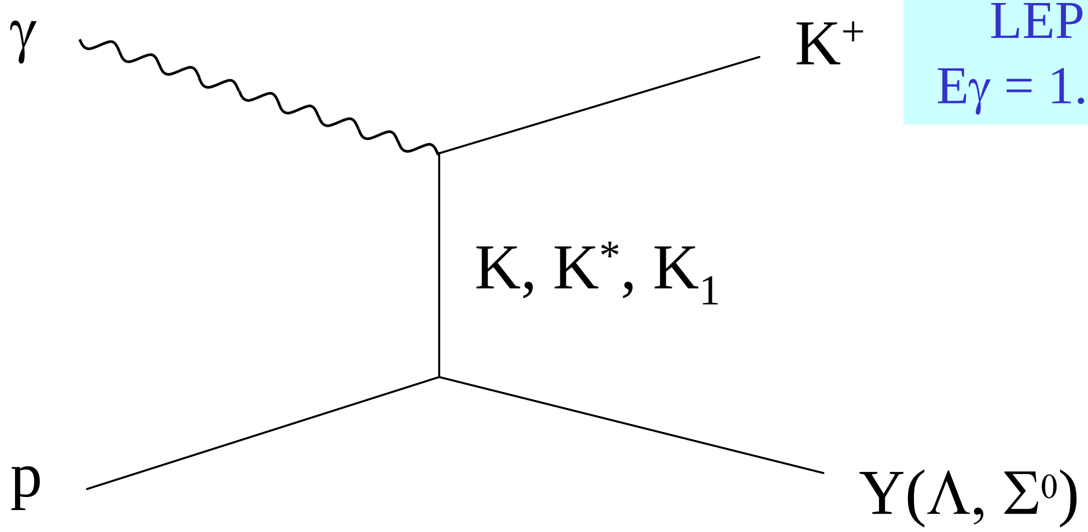
With $D_{13}(1895)$
A) Small cut-off mass
B) Λ^* in u-channel
C) No restriction on g_{KYp}

Need more study to fix parameters.

Photon beam asymmetry is quite sensitive to model differences.

Meson exchange in t-channel

Contribution of t-channel meson exchange becomes large at $E\gamma$ > 2GeV.



LEPS beam :
$E\gamma$ = 1.5 ~ 2.4 GeV

Photon beam asymmetry Σ

natural parity exchange (K^*) ⟶ Σ = + 1

unnatural parity exchange (K, K_1) ⟶ Σ = −1

SLAC data at E_γ=16GeV

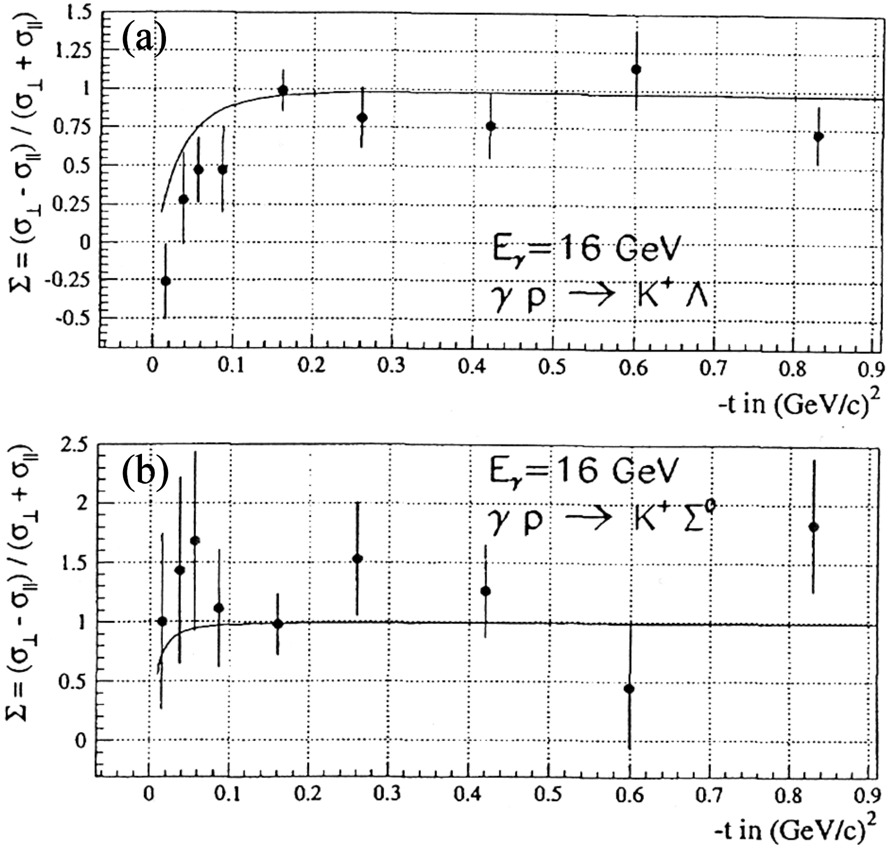
Photon beam asymmetry Σ

PRD vol.20 1553 (1979)

natural exchange (K^*)
---> Σ = + 1
unnatural exchange (K, K_1)
---> Σ = − 1

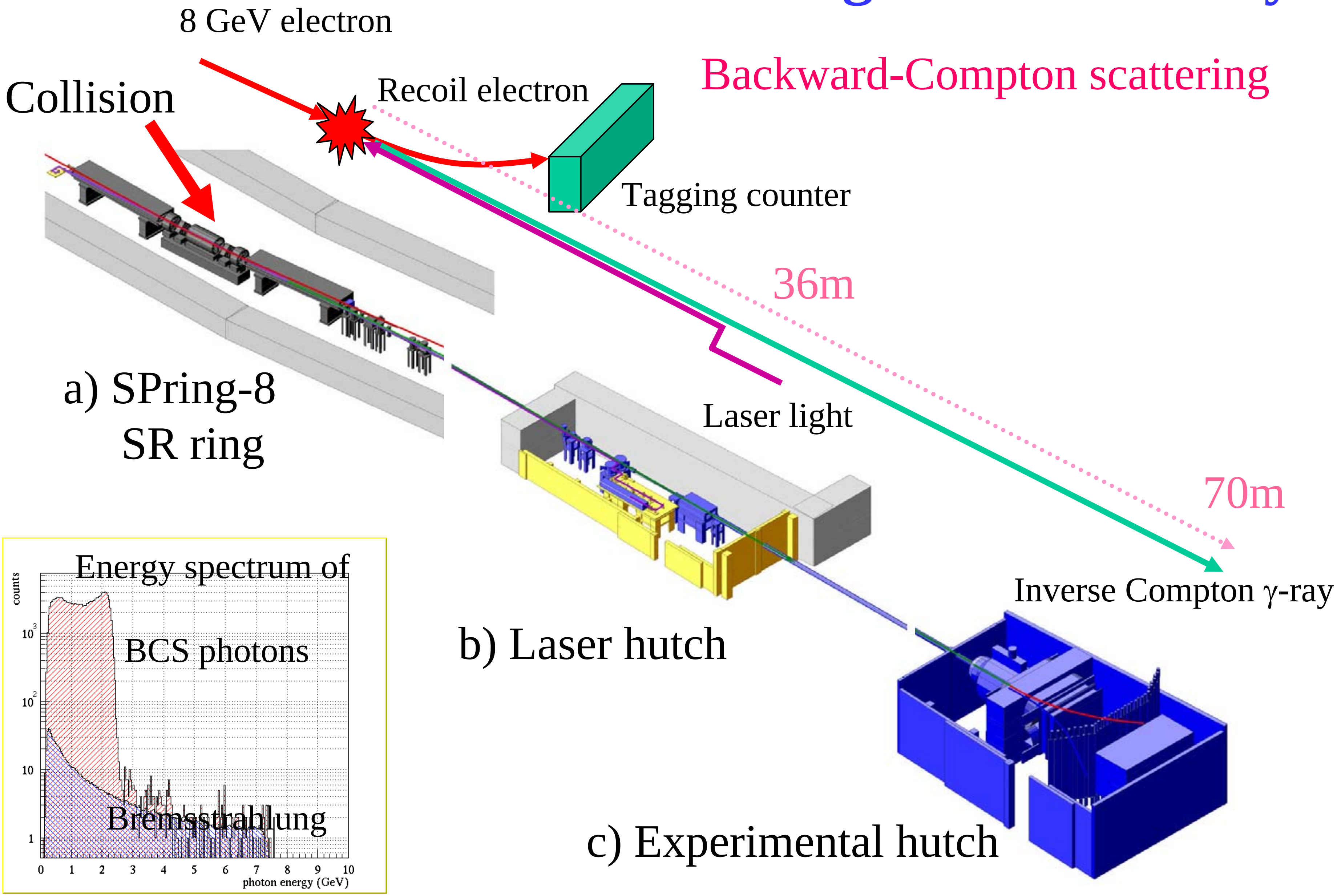
unnatural exchange
at very forward angles
(small t)

LEPS beam :
Eγ = 1.5 ~ 2.4 GeV



Line K + K* : M. Guidal *et al*. Nucl. Phys. A627 645(1997)

SPring-8/LEPS facility



2. Experimental method

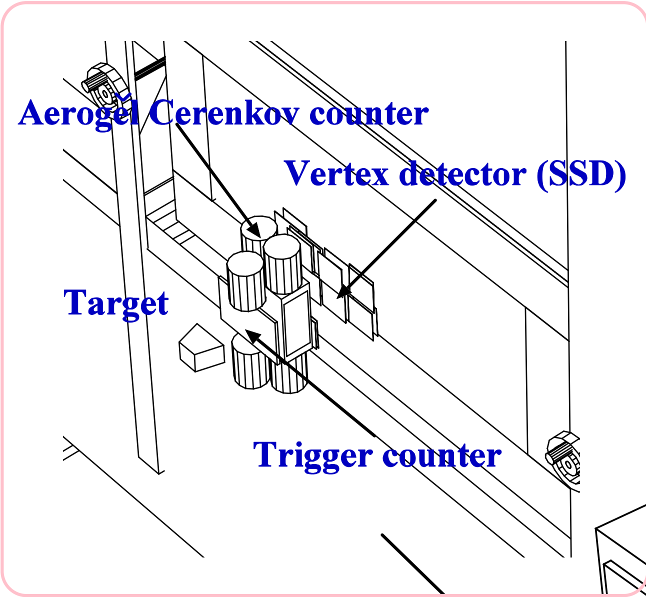
Photon beam

Linearly - polarized photons
produced by backward-Compton scattering

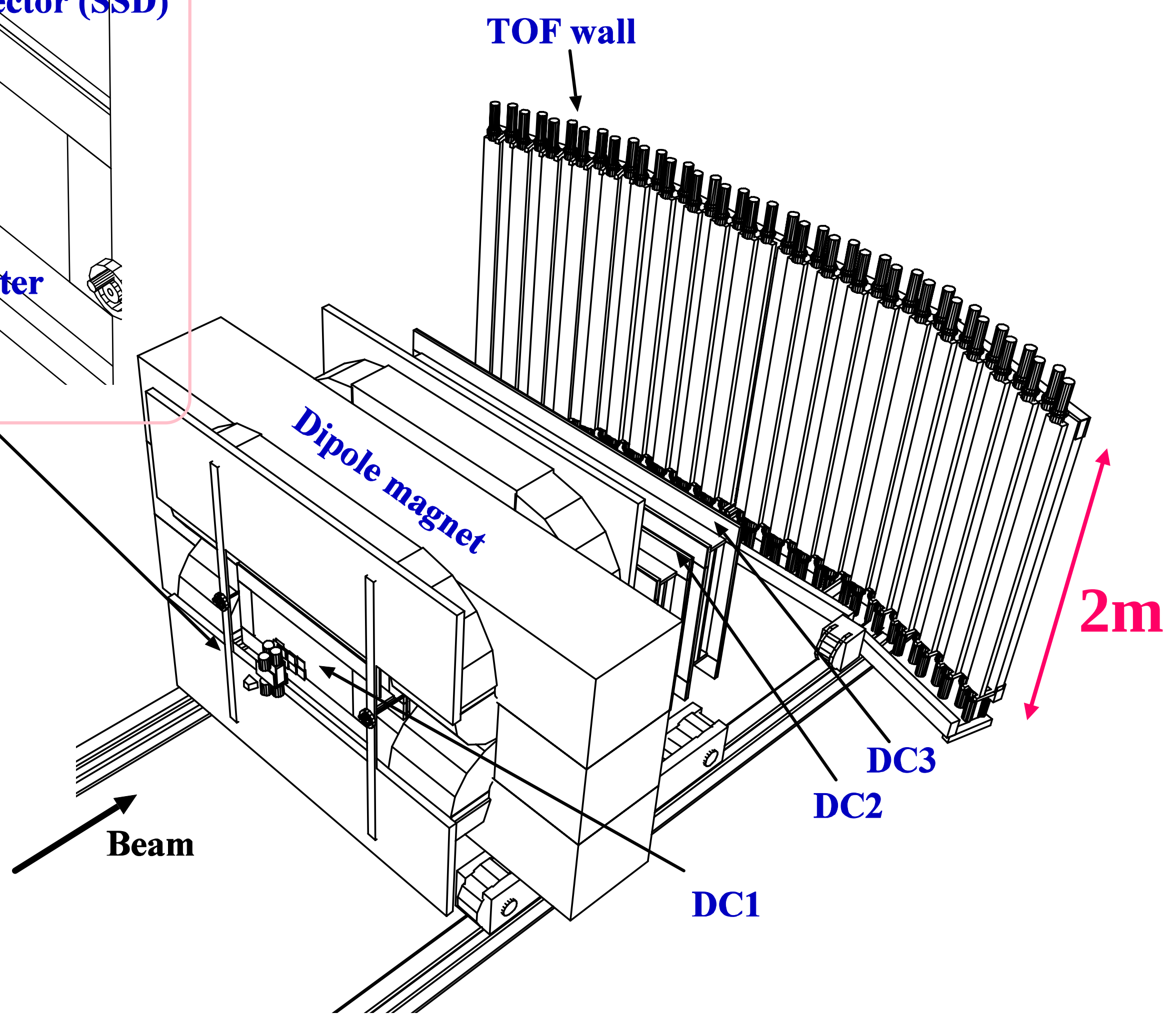
- Photon energy $E\gamma$ = 1.5 ~ 2.4 GeV
  - tagged by tagging counter (SSD and hodoscope)
- Energy Resolution 15 MeV
  (due to beam conditions ..)
- Intensity 5×10^5 cps → Now 1×10^6 cps
- Polarization ~92% at 2.4 GeV
  ~55% at 1.5 GeV

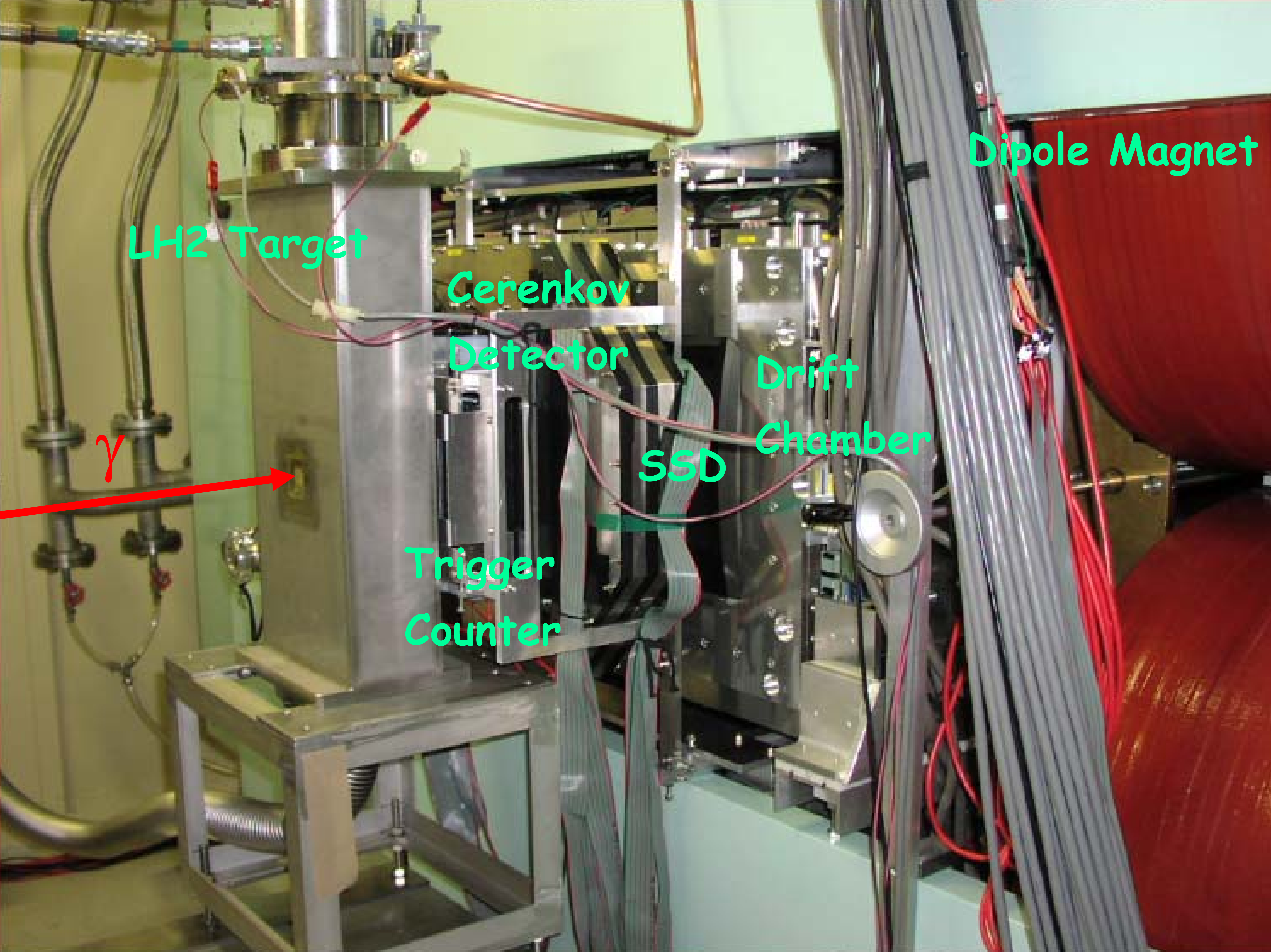
laser photons 98%

Experimental setup



- Target LH_2, 5cm
- AC index = 1.03
  to reject e^+e^- pairs
- SSD 120μm pitch
- DCs σ ~ 200 μm
- Magnet 135 x 55 cm^2,
  (35^o x 15^o)
  B = 0.7T

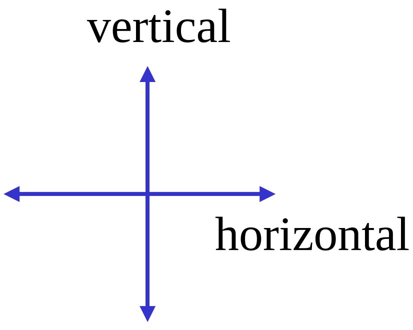



Dipole Magnet
LH2 Target
Cerenkov
Detector
Drift
Chamber
γ
SSD
Trigger
Counter

Summary of data taking

- **December, 2000 to June, 2001**

- Trigger : more than one charged particle
  20 Hz for 500 kHz@tagger
- Total number of photons at the target
  2 x 10^{12} photons
- 52% data with vertical polarization
  48% data with horizontal polarization
- Target : liquid hydrogen target, 5cm

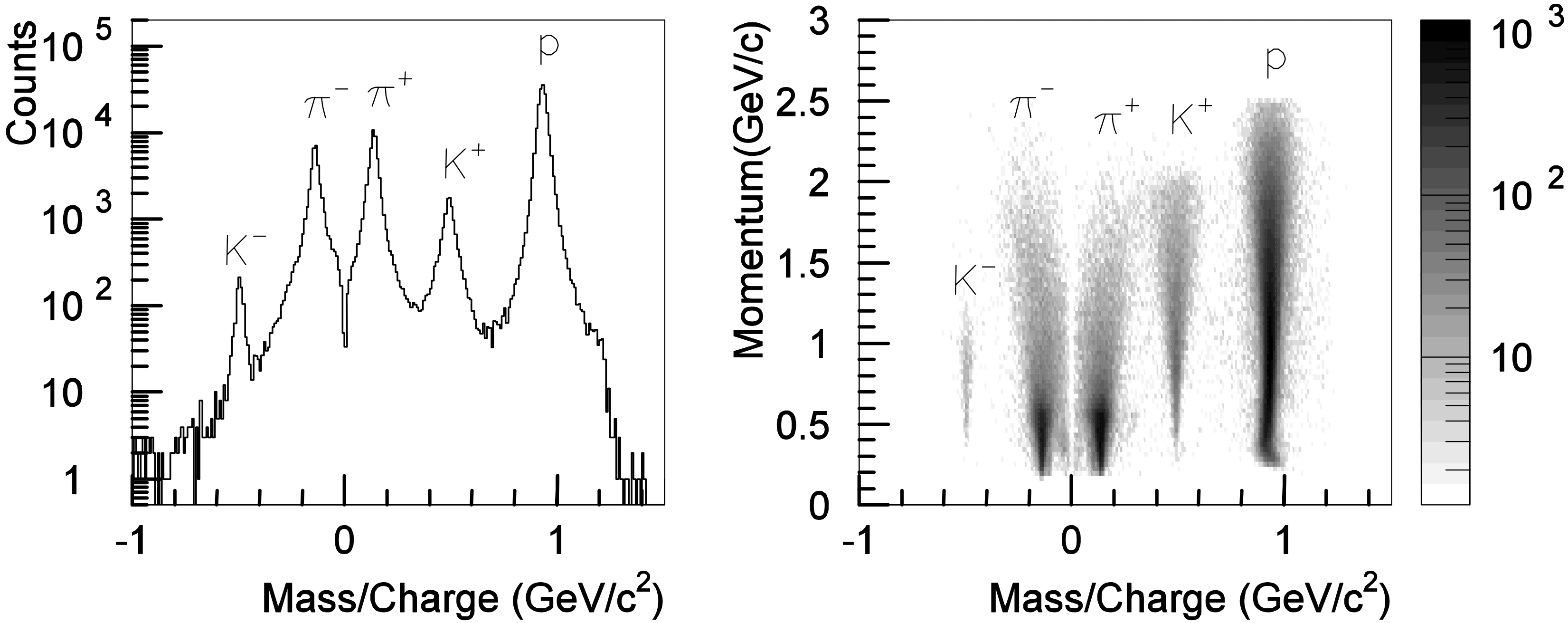


→ Θ^+, K^+, ϕ photoproduction…..

PRL vol.91 092001-1

PRL vol.91 012002

Particle identification
by time-of-flight and momentum measurements

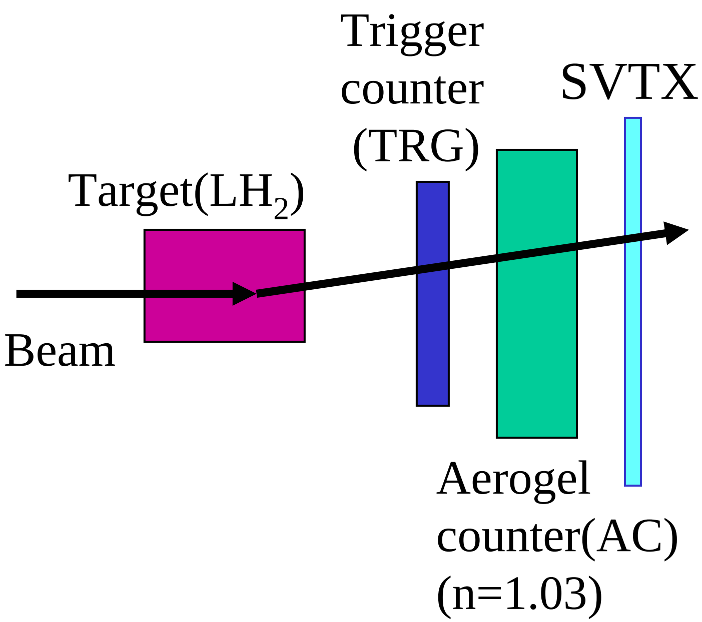


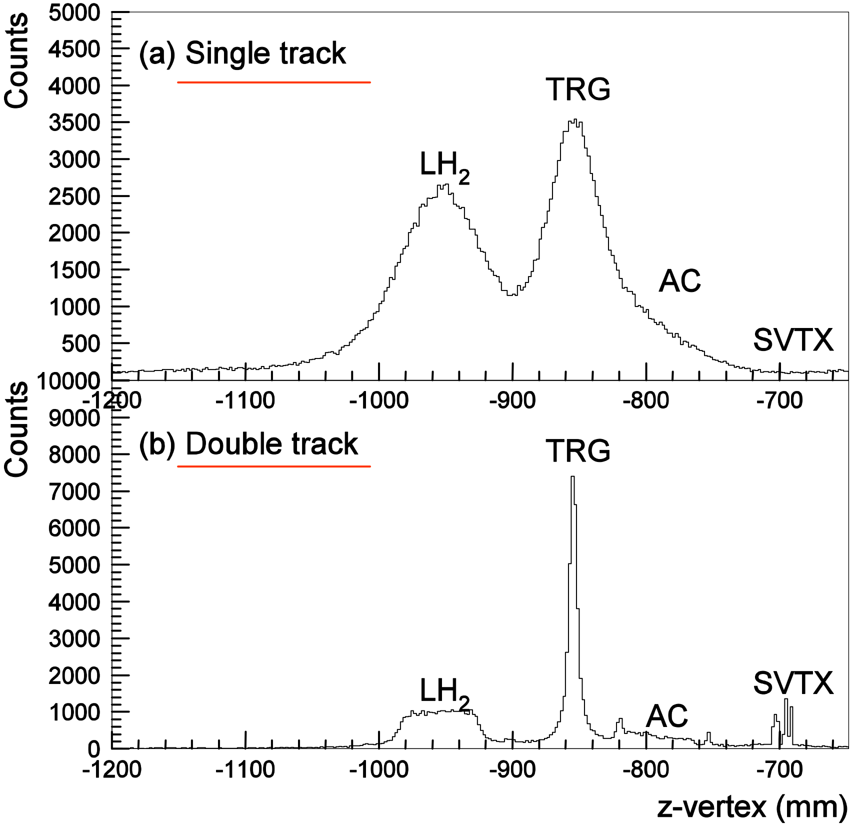
TOF : RF signal - TOF wall, $\Delta t = 120$ps

Momentum : SSD, DCs, Tracking with Kalman filter,

Δp ~6MeV for 1GeV/c Kaon

Vertex position





Single track :
closest distance between a track
and the beam axis

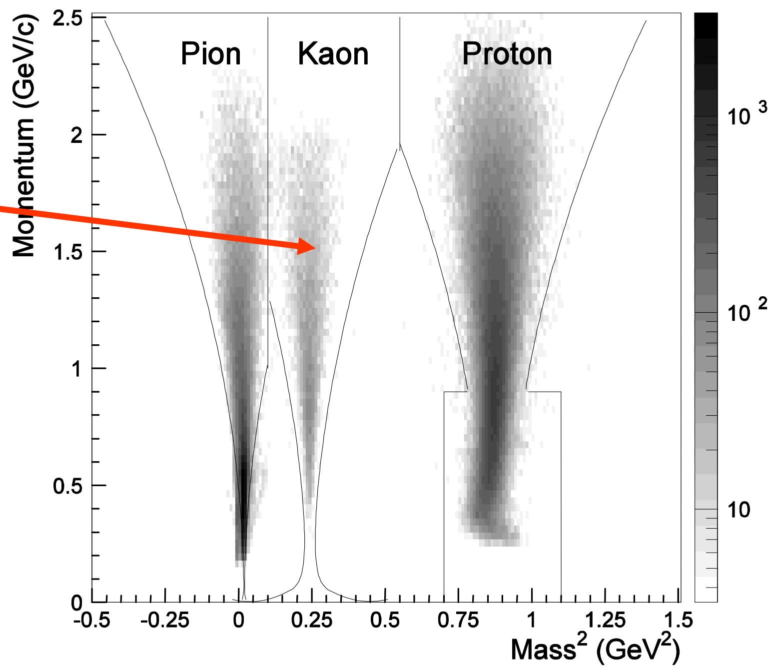
3. Data analyses

Event selections for $p(\gamma,K^+)\Lambda$ and $p(\gamma,K^+)\Sigma^0$

1. Tagged photons

   recoil electron reconstructed by Tagging counter

2. K^+ events
   - a) charge = +1
   - b) mass distribution
   - c) χ^2 probability cut of tracking
     - confidence level 98%



Contaminations

π ~ 3% (5%) for $K^+\Lambda(K^+\Sigma^0)$

proton ~ 3% (6%) for $K^+\Lambda(K^+\Sigma^0)$

at 2GeV/c momentum.

Event selections for $p(\gamma,K^+)\Lambda$ and $p(\gamma,K^+)\Sigma^0$

3. Events from the proton target (LH_2)

z-vertex point of K^+

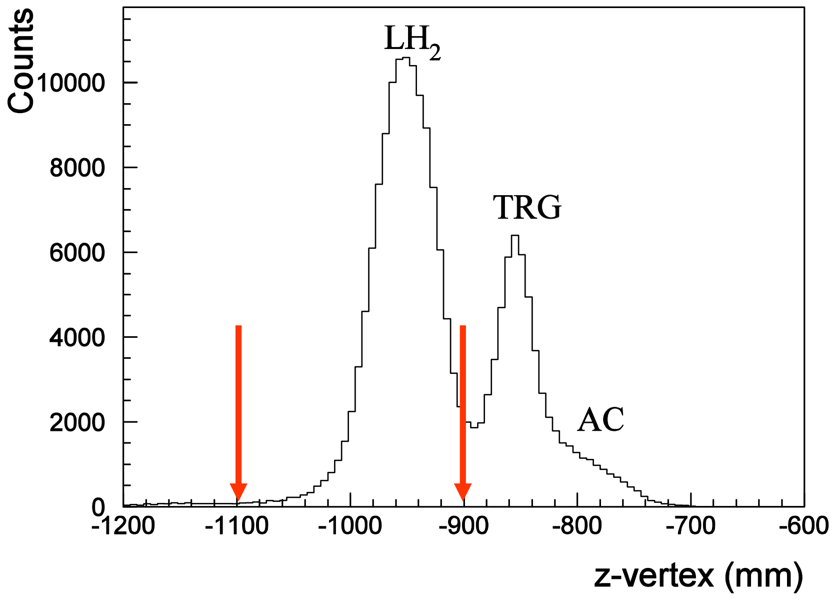
(closest point between K^+ track and beam axis)

Contamination from
the trigger counter (TRG)
- plastic scintillator (CH)

significant at very forward angles

~ 8% for $\theta_{lab} < 5^o$

< 2% for $\theta_{lab} > 5^o$



Missing mass spectrum

4. Λ and Σ^0 events

2σ cut

contamination

Λ in Σ^0 and Σ^0 in Λ < 1%

- $p(\gamma,K^+)\Lambda(1116)$

  72,500 events

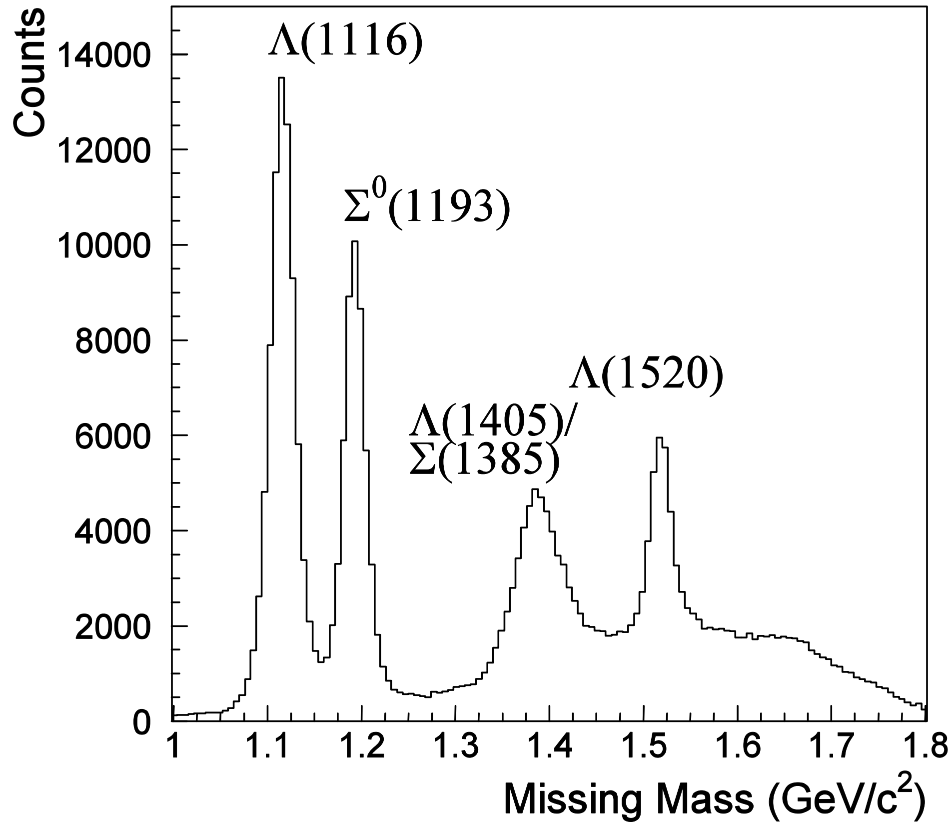
- $p(\gamma,K^+)\Sigma^0(1193)$

  48,900 events

1.5 GeV < Eγ < 2.4 GeV

(1.9 GeV < W < 2.3 GeV)

$0.6 < \cos\theta_{cm}^{K^+} < 1$

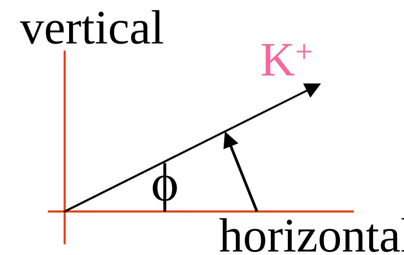


Photon beam asymmetry Σ

- Vertical $$\frac{d\sigma}{d\Omega_v} = \frac{d\sigma}{d\Omega_{unpol}}[\,1 + P_\gamma \Sigma \cos(2\phi)\,]$$
- Horizontal $$\frac{d\sigma}{d\Omega_h} = \frac{d\sigma}{d\Omega_{unpol}}[\,1 - P_\gamma \Sigma \cos(2\phi)\,]$$

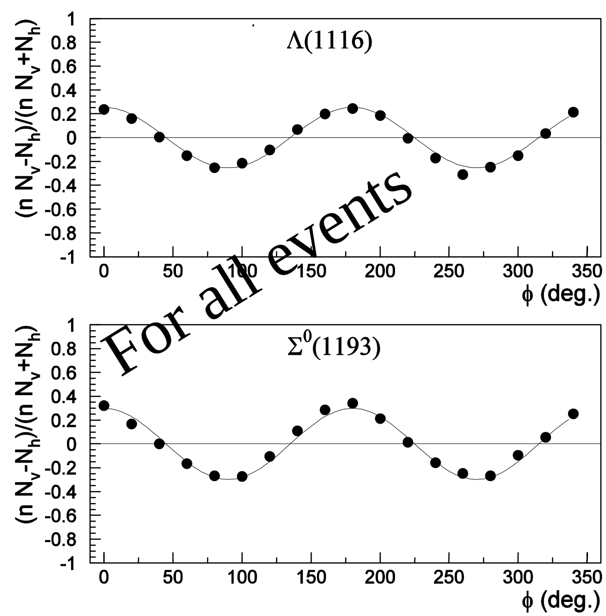
$$N = F_{acc}\,\frac{d\sigma}{d\Omega}$$

Acceptance effect is canceled in first order



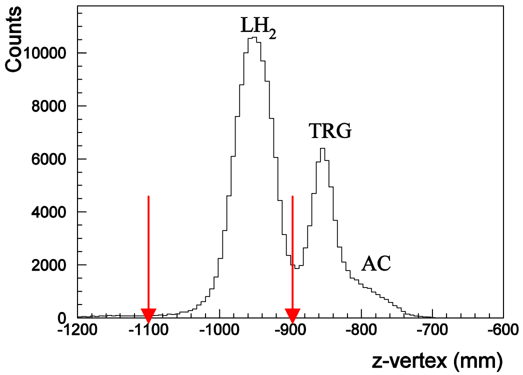
$$\frac{nN_v - N_h}{nN_v + N_h} = P_\gamma \Sigma \cos(2\phi)$$

- N : K^+ photoproduction yield
- ϕ : K^+ azimuthal angle
- P_γ : Polarization of photon
- n : Normalization factor for N_v



Correction and systematic errors I

1. Contamination of π and proton in the K^+ sample
2. Contamination from the trigger counter(TRG) in vertex cut



Correction for these contaminations is done by using the contamination rate and beam asymmetries of those BG events. $\Delta\Sigma = 0 \sim 0.03$

3. Normalization(n) of photon yields

$n = n_h/n_v$: number of photons with horizontal/vertical polarization

systematic error of n

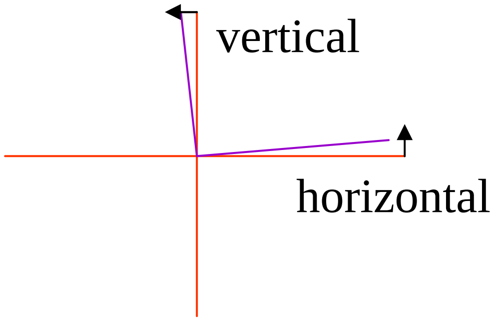
→ $\Delta\Sigma = -0.02 \sim 0.06$ << statistical error

Correction and systematic errors II

4. Polarization degree and angle

- monitor the polarization run by run (~ 3hours) with polarimeter
- measurement error of polarization degree = 1.5%
- shift from the horizontal/vertical plane < 4^{o}

→ systematic error = 0.4%



5. Difference of acceptance

between horizontally and vertically polarized photon beam

By Monte Carlo simulation,

the effect of acceptance difference is $\Delta\Sigma < 0.01$

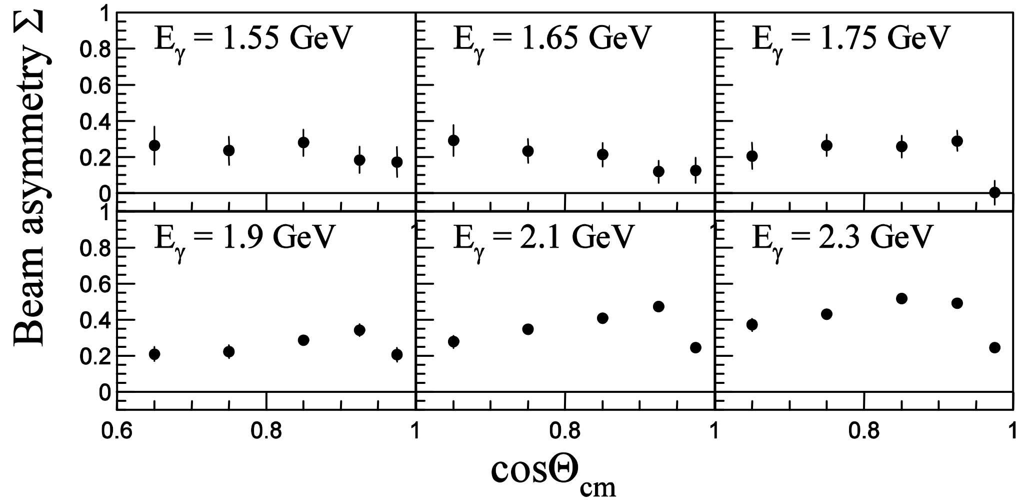
Total systematic error 2% << statistical error

4. Experimental results

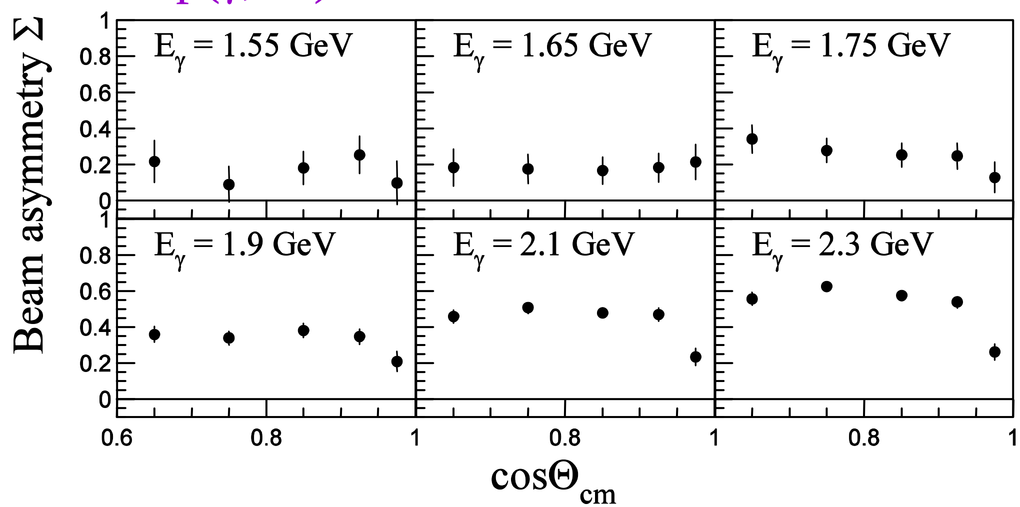
- **LEPS data**

- Positive sign
- Increase as the Eγ increases (t-channel?)
- Different angular distribution between Λ and Σ^0

$p(\gamma,K^+)\Lambda$

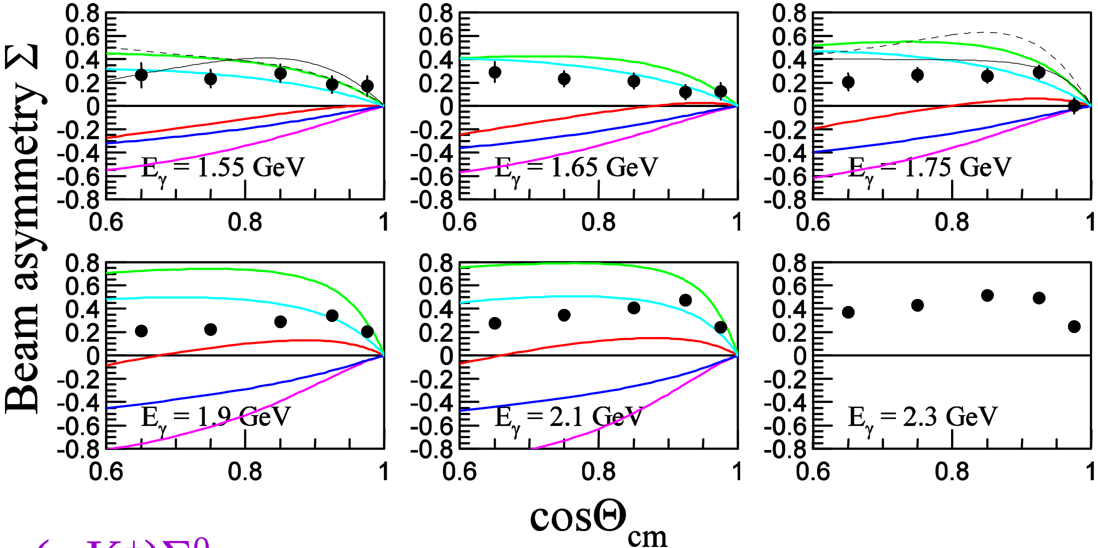


$p(\gamma,K^+)\Sigma^0$

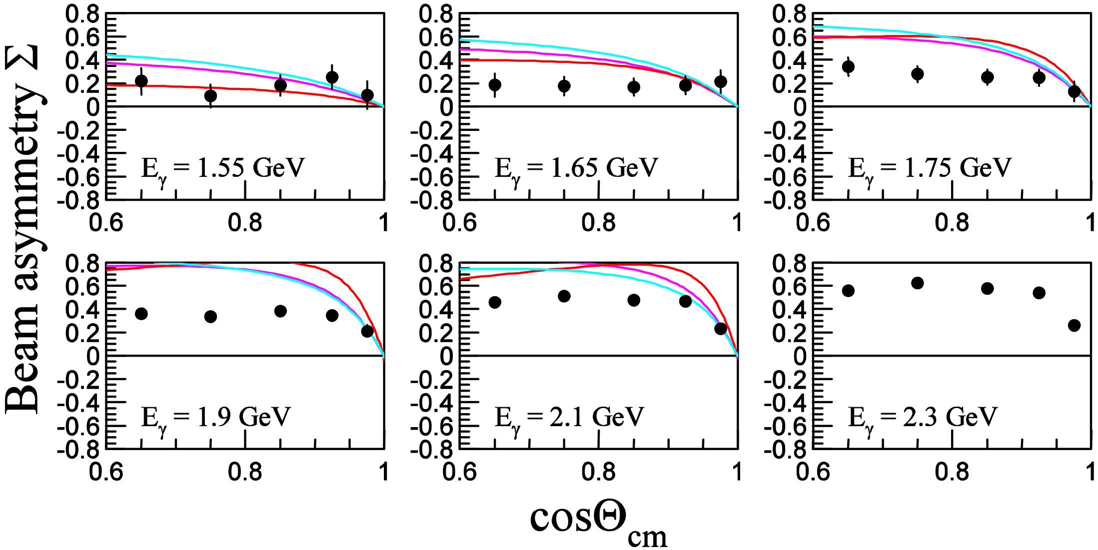


Comparison with models

p(γ,K^+)Λ



p(γ,K^+)Σ^0



by Mart & Bennhold
PRC 61 012201

.... without D_{13}(1960)

——— with D_{13}(1960)

by Janssen *et al*
PRC 65 015201

Hadronic form factor	A	B	C
Davidson&Workman			
Haberzettl			

A) Small cut-off mass
B) Λ^* in u-channel
C) No restriction on g_{KYp}
with D_{13}(1960)

Currently, no models reproduce our data, perfectly.

Experiment with Deuterium target

- Data taking was finished
- Oct. 2002 ~ June 2003
- Same trigger condition
- Target thickness 15cm
- By horizontal/vertical polarization of photons

Now, analyzing the data.
Photon beam asymmetry and cross section for the $n(\gamma,K^+)\Sigma^-$
etc. ……………

5. Summary

- K^+ photoproduction is useful to search for missing resonances. Photon beam asymmetry is good tool to define models.
- Photon beam asymmetries were obtained for the $p(\gamma,K^+)\,\Lambda$ and $p(\gamma,K^+)\Sigma^0$ reactions for the first time at $E\gamma$ = 1.5 ~ 2.4 GeV at SPring-8/LEPS. Positive sign
- None of current models can reproduce our data, perfectly.
- Our data will stimulate the further development of the theoretical models and extend our knowledge of this reaction including missing resonances.
- Differential cross sections at very forward angles ($\cos\theta_{cm}$~ 0.95) will be obtained near future.