Overview of the LEPS /SPring-8

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Outline

- LEPS facility
- Some recent results
- Status of Θ^+ study
- Summary

NSTAR2009@IHEP, Bejing, April 20th, 2009.

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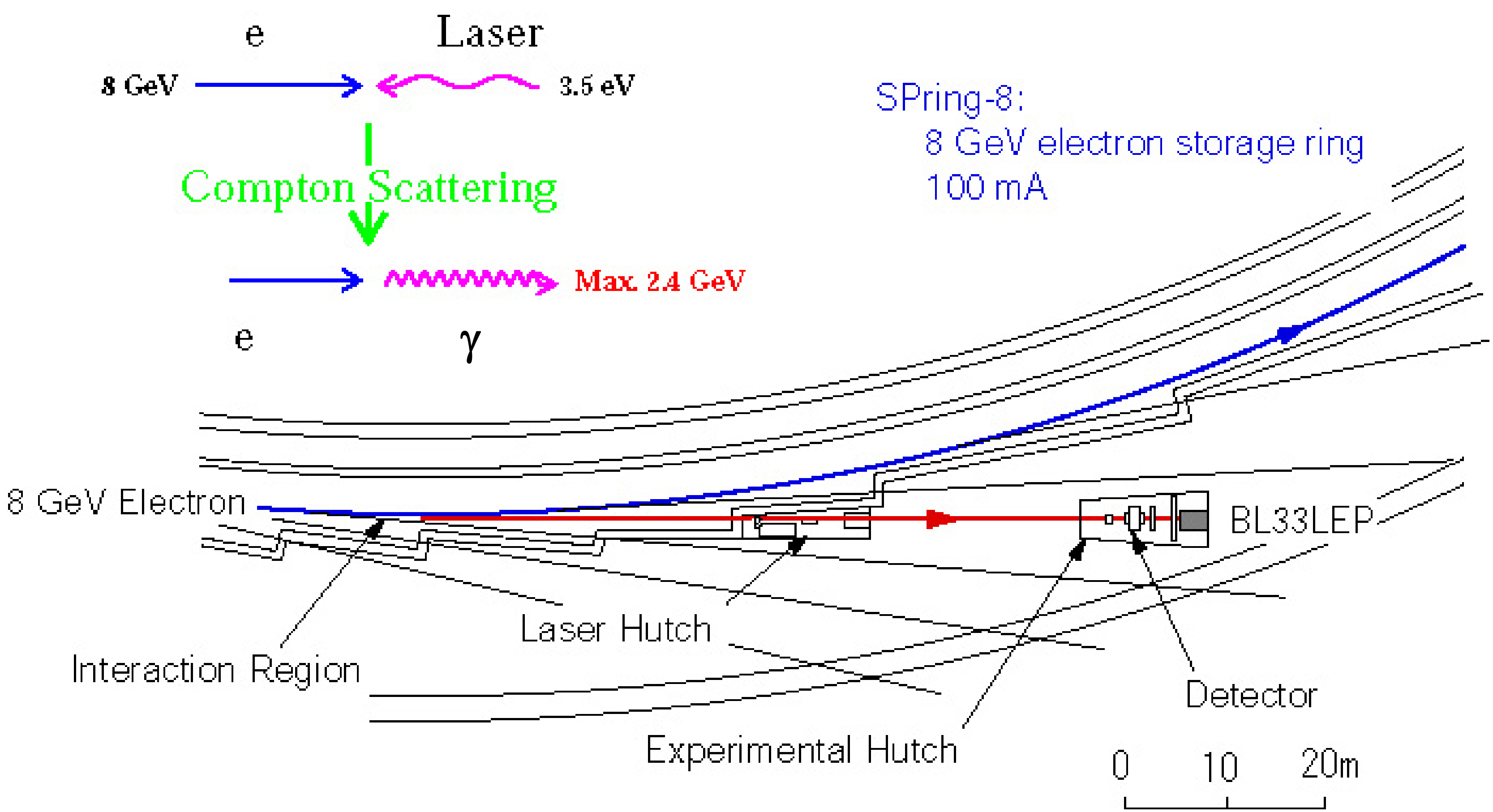
Super Photon ring-8 GeV SPring-8

- Third-generation synchrotron radiation facility
- Circumference: 1436 m
- 8 GeV
- 100 mA
- 62 beamlines

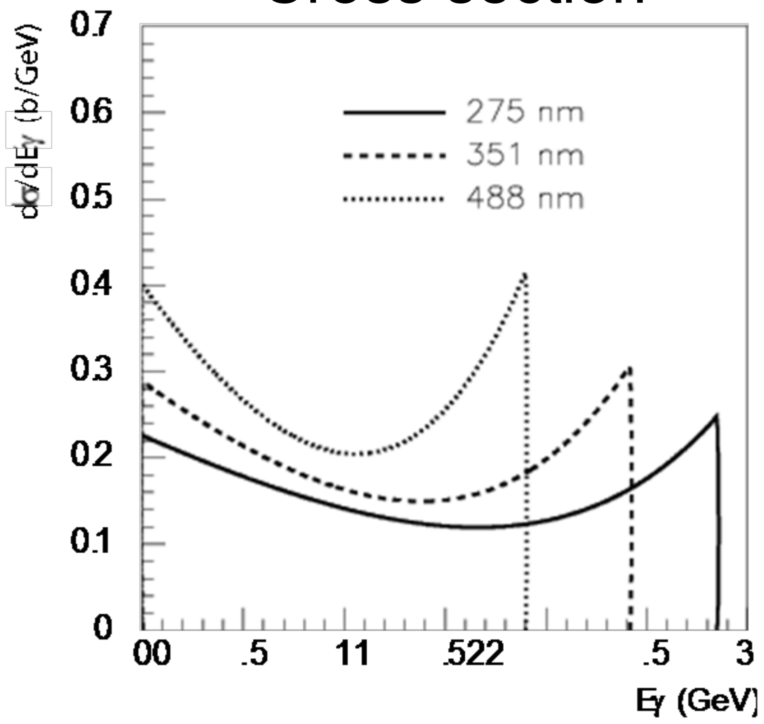
LEPS beamline

in operation since 2000

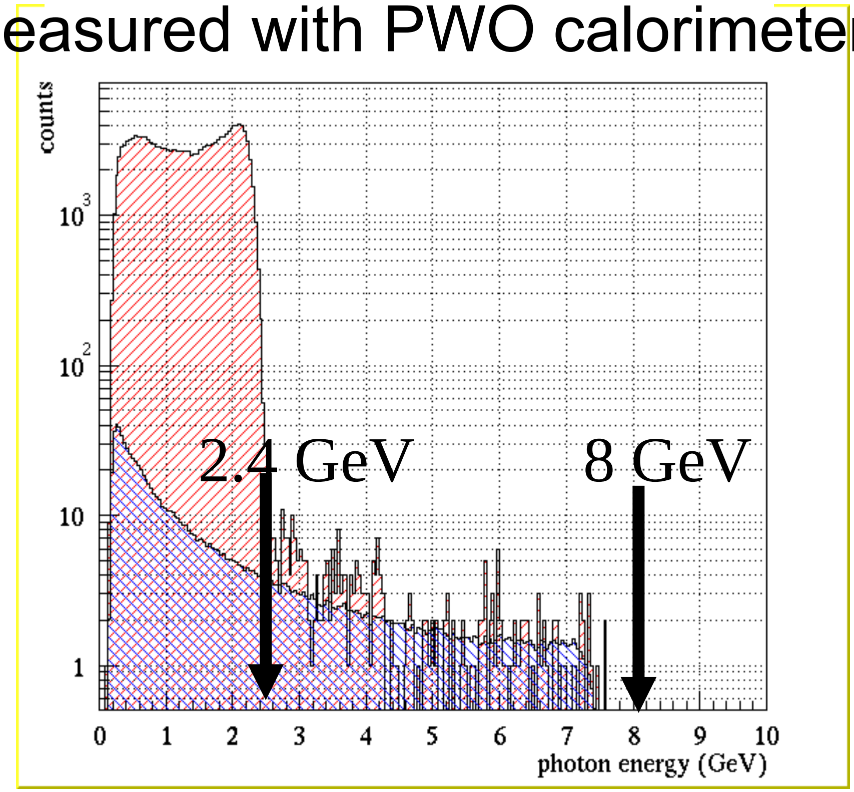


Energy Spectrum of the LEPS beam

Cross section



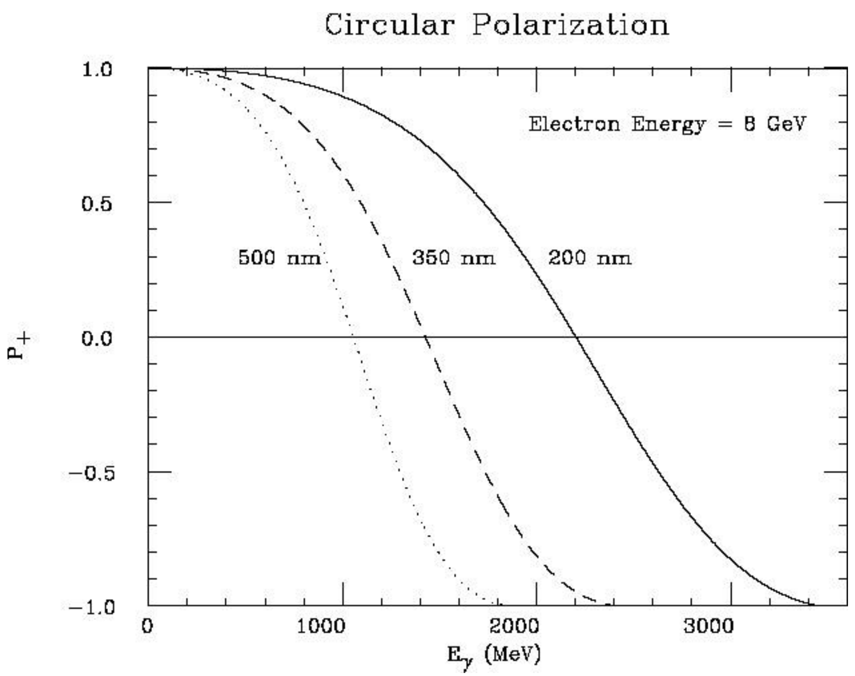
Measured with PWO calorimeter

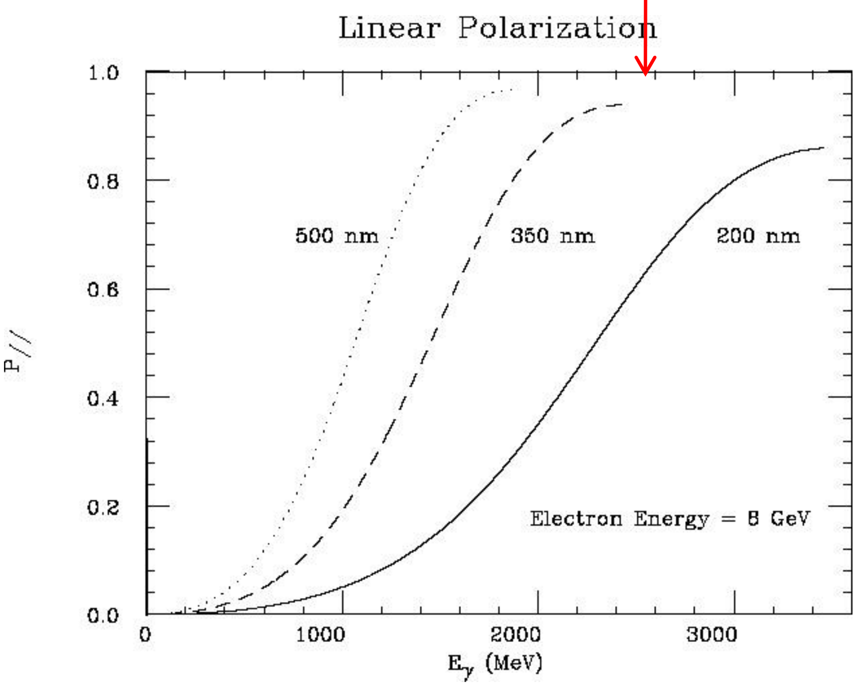


Tagged γ intensity (Typ.) : 1×10^{6} cps

Polarization of LEP Beam

Regular setting

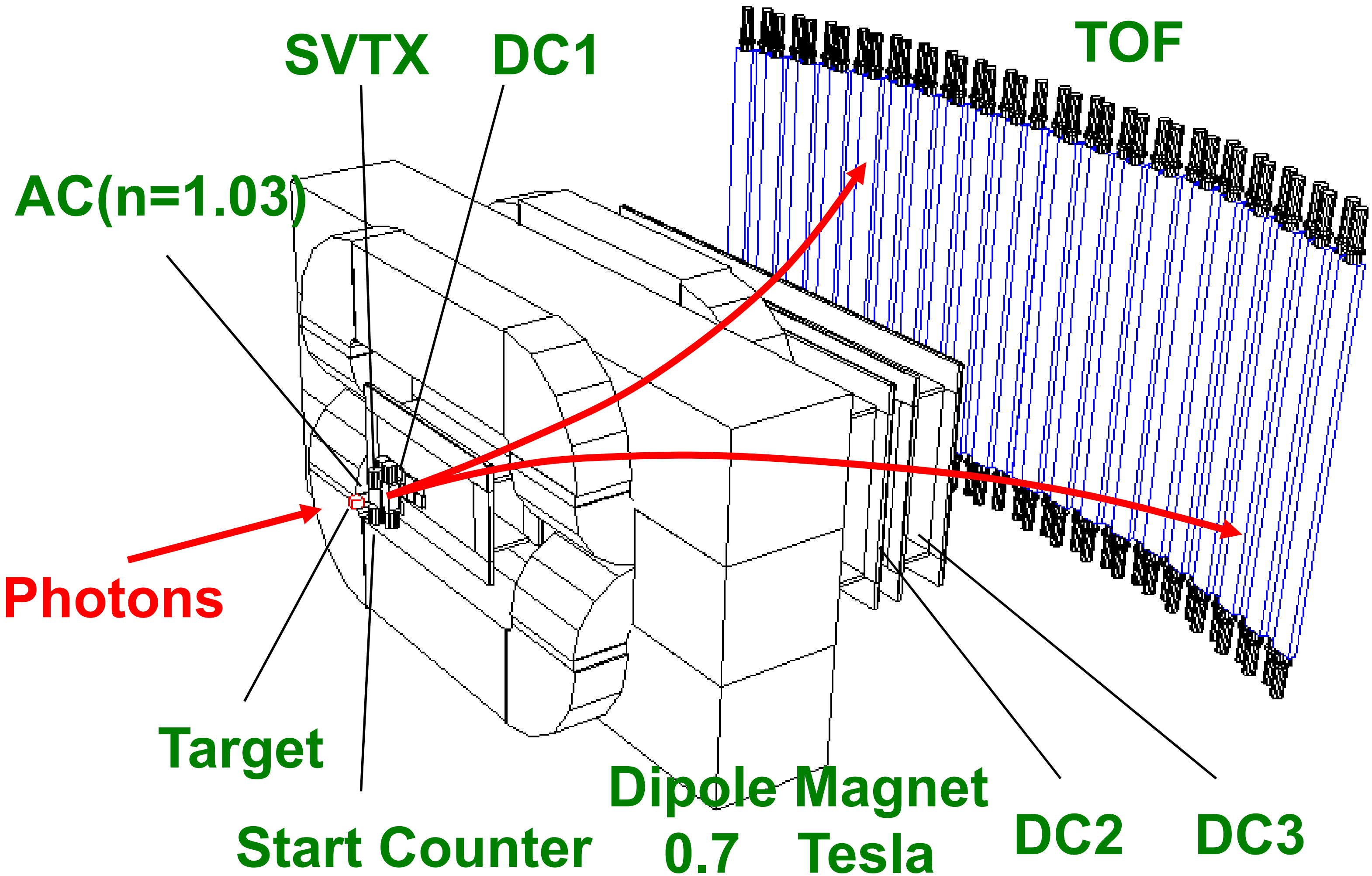




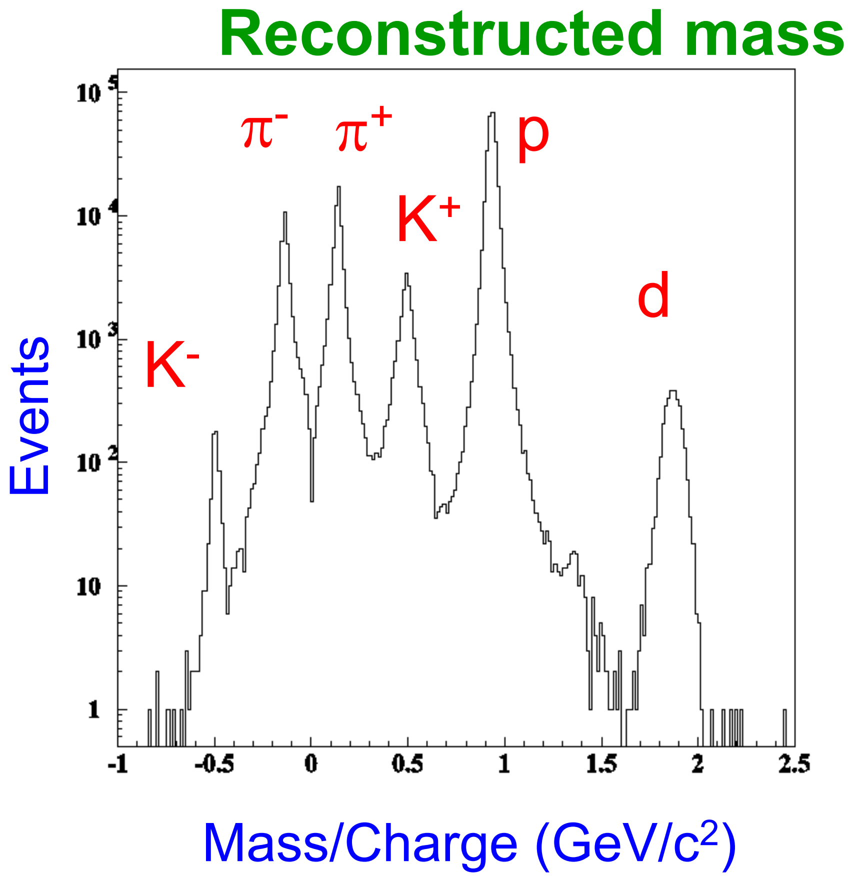
Linear Polarization : 95 % at 2.4 GeV

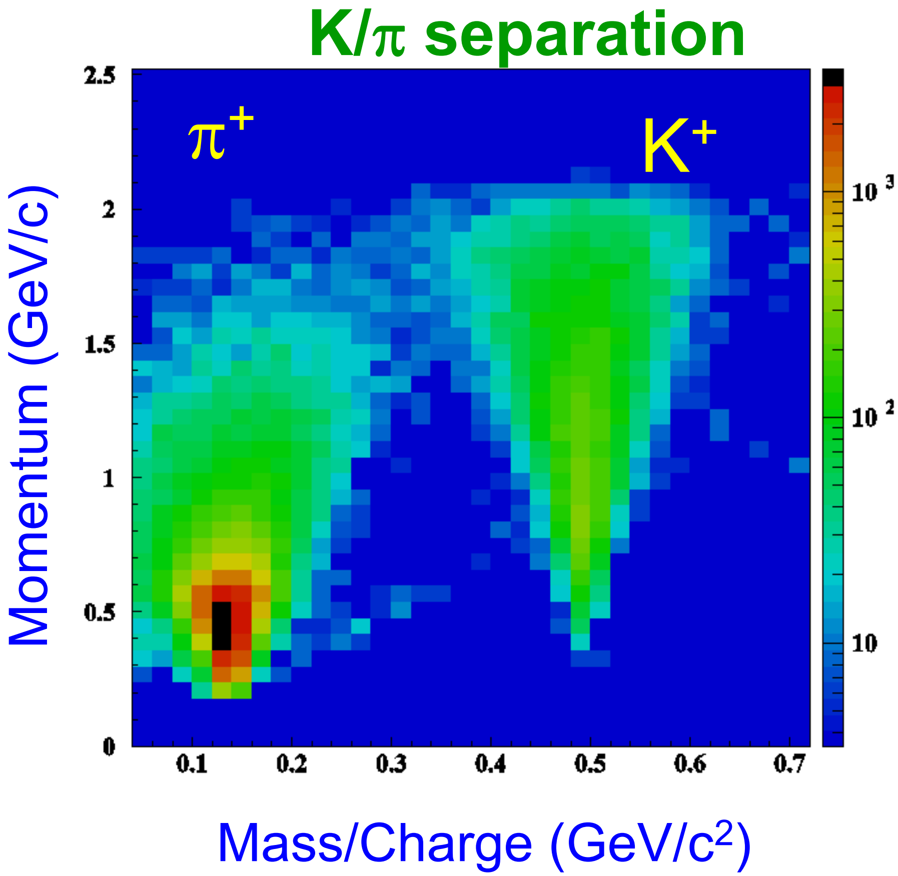
LEPS spectrometer

Charged particle spectrometer with forward acceptance
PID from momentum and time-of-flight measurements



Particle Identification

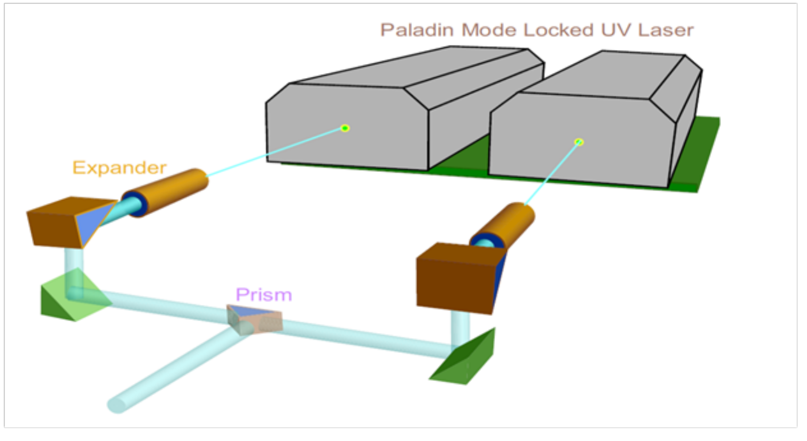


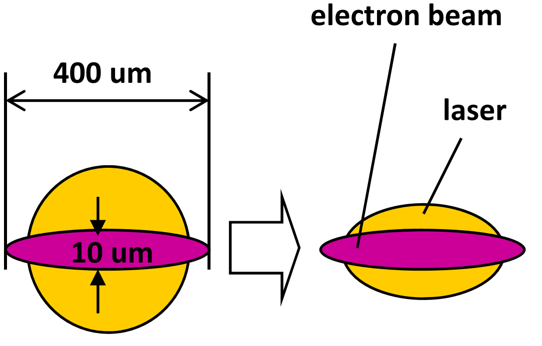


σ_P ~6 MeV/c for 1 GeV/c, σ_{TOF} ~150 ps,
σ_{MASS} ~30 MeV/c^2 for 1 GeV/c Kaon

Photon beam upgrades by new laser injection methods

- Two-laser injection ⇒ The intensity becomes nearly twice. [~2 Mcps]
  - Interference was avoided by using pulsed lasers and a prism.
  - In a future project, 4-laser injection is planned at a large aperture beamline.
- Laser power upgrade on a commercial base : 8 → 16 W
  ⇒ Nearly twice of the intensity was achieved.
- Laser beam shaping by a cylindrical expander to increase energy density.
  - A test with visible laser was successfully done, resulting in twice of the energy density. ⇒ We plan the application to UV laser.
- Deep-UV laser : 355 → 257 nm ⇒ Max. E_γ : 2.4 → 3.0 GeV
  - The intensity is 100~200 kcps, but it is useful depending on physics purpses.





Polarized HD target

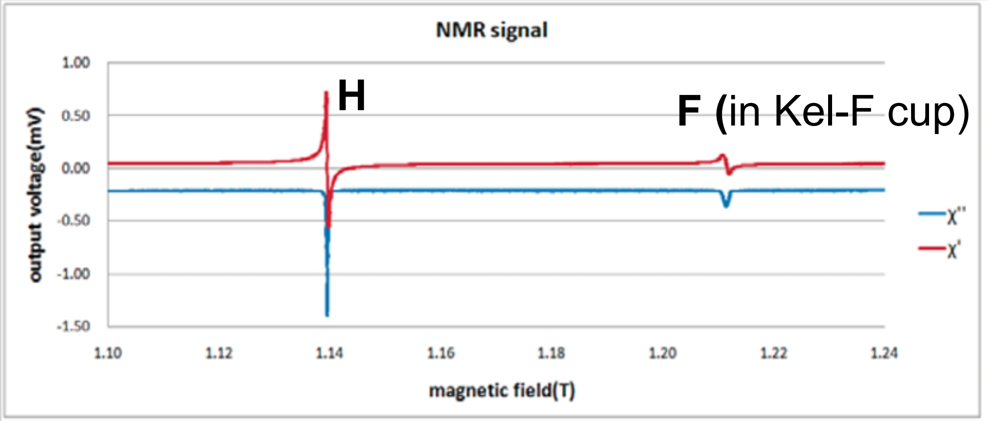
Present status:

- 1-mol HD has been successfully polarized with ‘brute-force’ method (14 mK, 17 T, and 50-days aging time)

  Polarization > 40%

  Relaxation time ~100 days

  (still have non-linearity problem in the NMR system)



Next steps

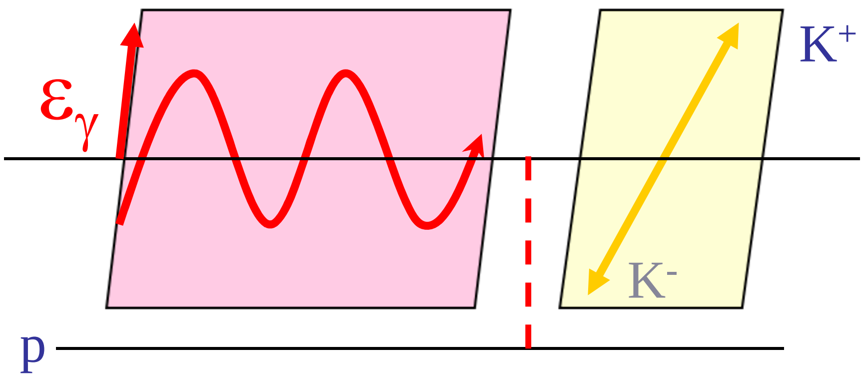
- Improve the NMR system (single coil → cross coil)
- Transportation test of the HD target from RCNP(Osaka) to SPring-8 (~130 km) [need to operate five cryostats !]
- In-beam check of the HD target → experiment using pol_H
- Convert polarization from H to D by means of AFP (adiabatic fast passage) → experiment using pol_D

LEPS Run Summary

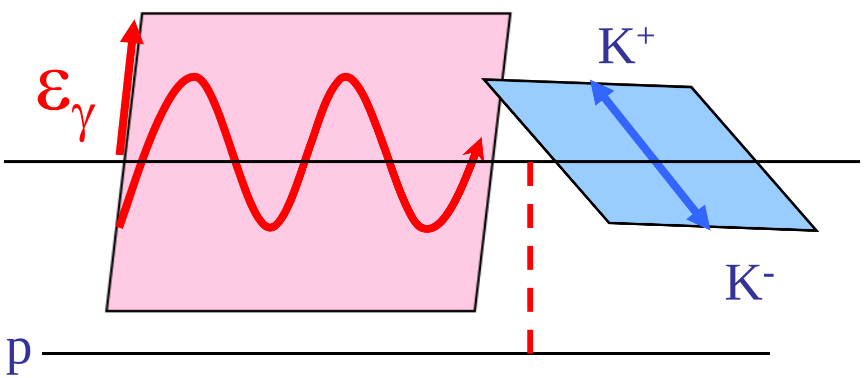
Period	Spectrometer	Target	Max. E_γ	Purpose
Jun.06 – Jul. 07	Forward	D_2, H_2	2.4 GeV	Confirmation of Θ^+
Sep.07 – Oct. 07	TPC+FWD	H_2	3.0 GeV	TPC Commissioning
Oct.07 – Dec. 07	Forward	H_2	3.0 GeV	$K^{*0}\,\Sigma^-$ production
Jan. 08 – Jul. 08	TPC+FWD	H_2	3.0 GeV	$K^{*0}\,\Theta^+$ production
Jul. 08 – Dec. 08	TPC+FWD	H_2, D_2	2.4 GeV	Θ^+, $\Lambda(1405)$ …etc
Feb. 09 –	TPC+FWD	He	2.4 GeV	Θ^+ -nuclei search, ϕ A-dep

Polarization observables with linearly polarized photon

ϕ meson rest frame



Decay Plane // $\vec{\gamma}$
natural parity exchange $(-1)^J$
(Pomeron, Scalar Glueball,
Scalar mesons)

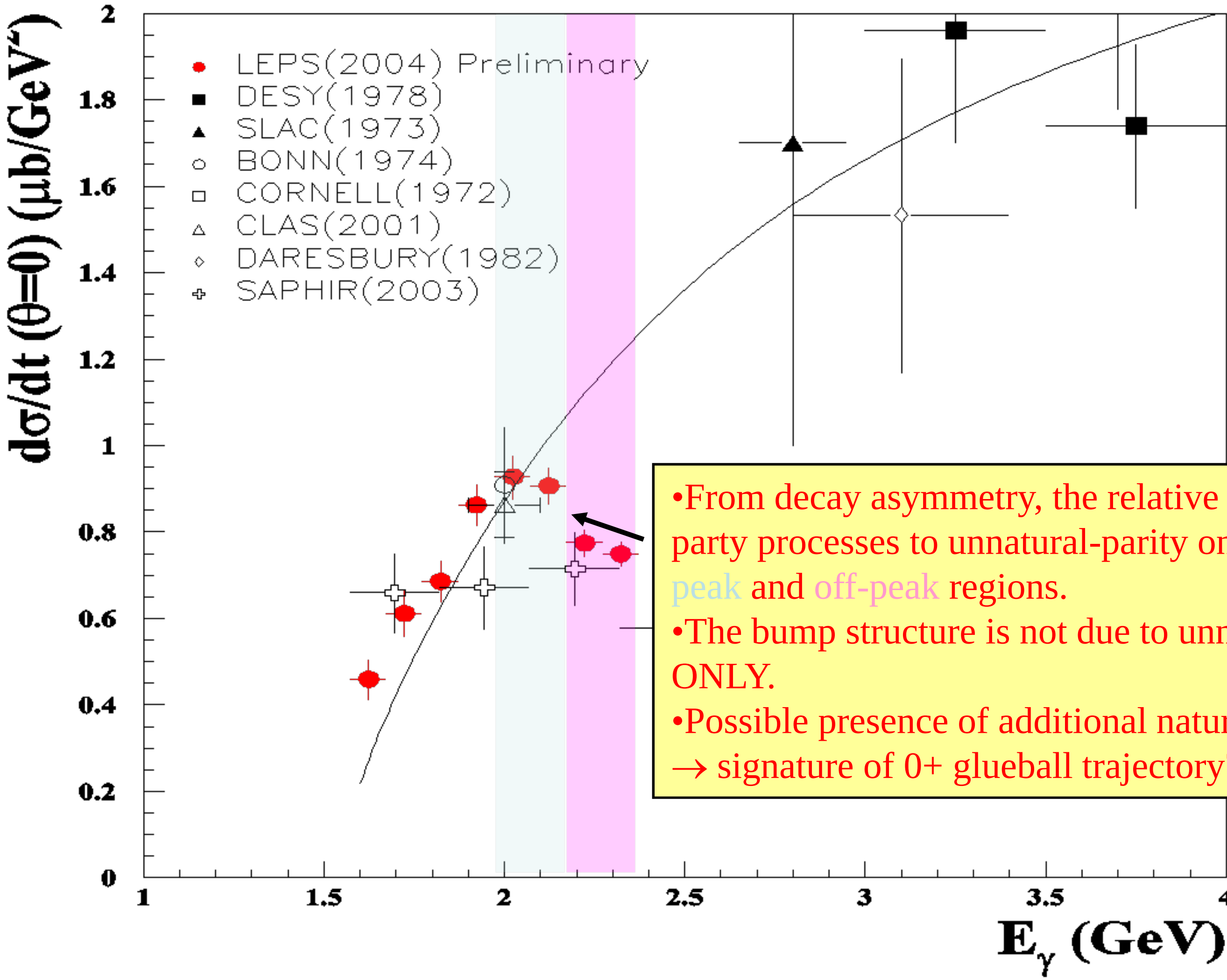


Decay Plane $\perp$ $\vec{\gamma}$
unnatural parity exchange $-(-1)^J$
(Pseudoscalar mesons π,η)

Decay angular distribution of ϕ → **Relative contributions from natural, unnatural parity exchanges**

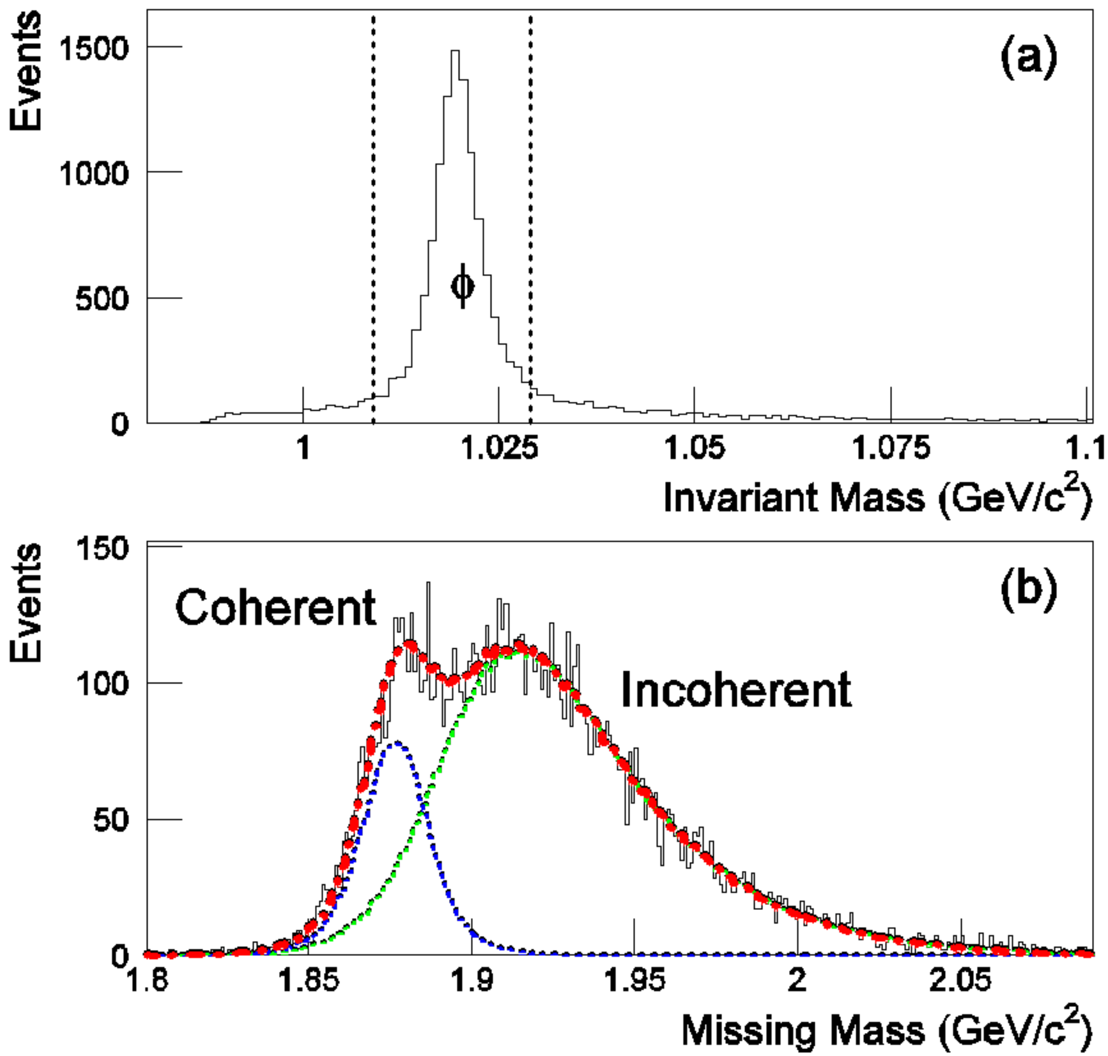
$\gamma N \rightarrow \phi N$

T. Mibe, et al., Phys. Rev. Lett. 95, 182001 (2005)



- From decay asymmetry, the relative strength of natural-party processes to unnatural-parity ones is the same in the peak and off-peak regions.
- The bump structure is not due to unnatural-parity processes ONLY.
- Possible presence of additional natural parity exchange $\rightarrow$ signature of 0+ glueball trajectory??

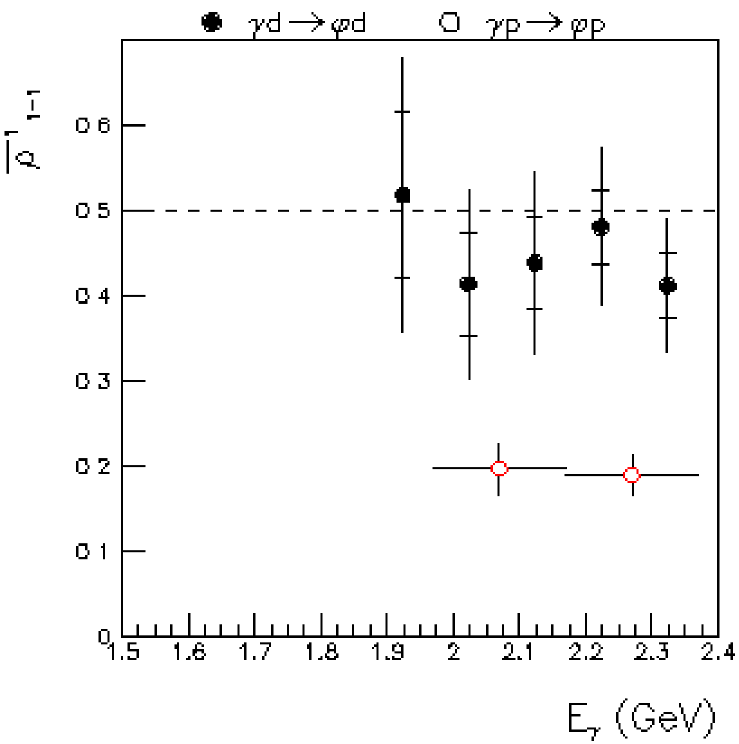
$\gamma D \to K^+K^- X$



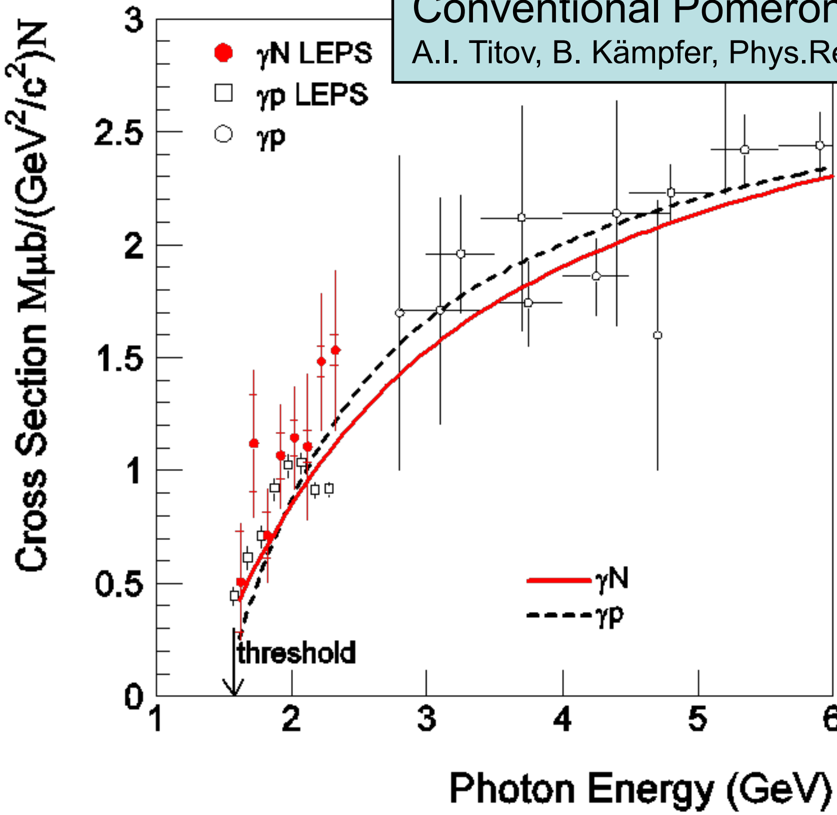
Coherent production $\gamma D \to \phi D$

W.C. Chang, et al. , Phys.Lett.B658:209-215, 2008

Coherent interaction $\gamma D \to \phi D$ is dominantly contributed by natural-parity exchanges.

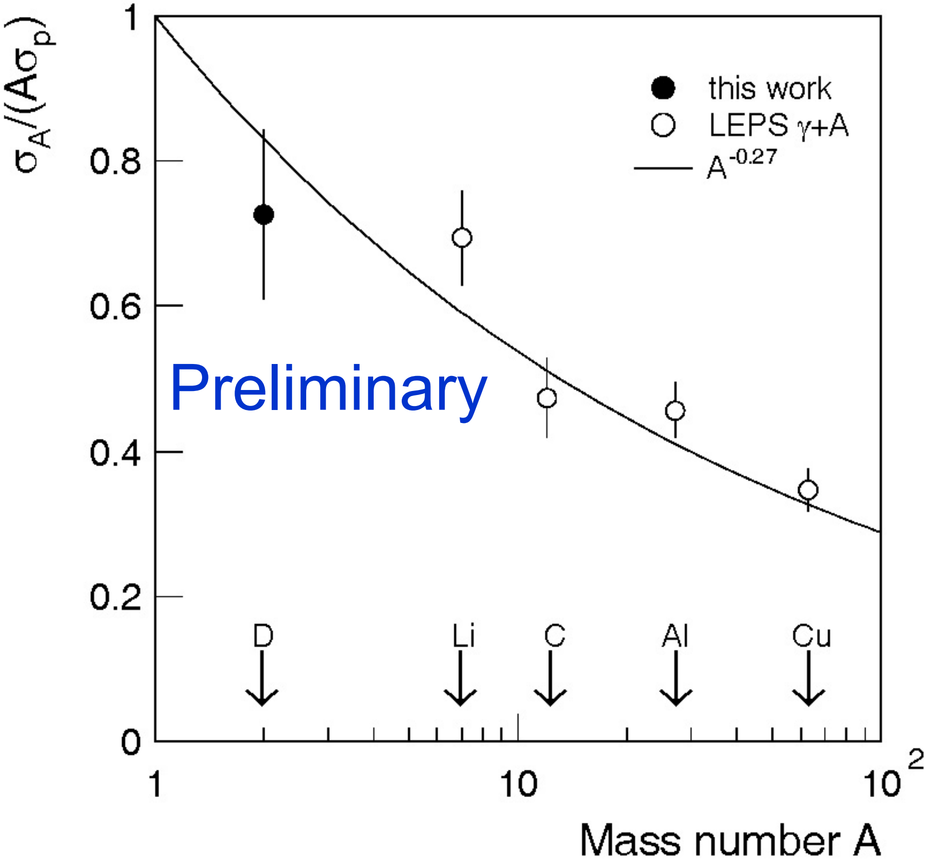


Conventional Pomeron exchange
A.I. Titov, B. Kämpfer, Phys.Rev.C76:035202,2007



Hints of either modified energy dependence of conventional Pomeron trajectory or the appearance of new natural-parity dynamics at low-energy regime.

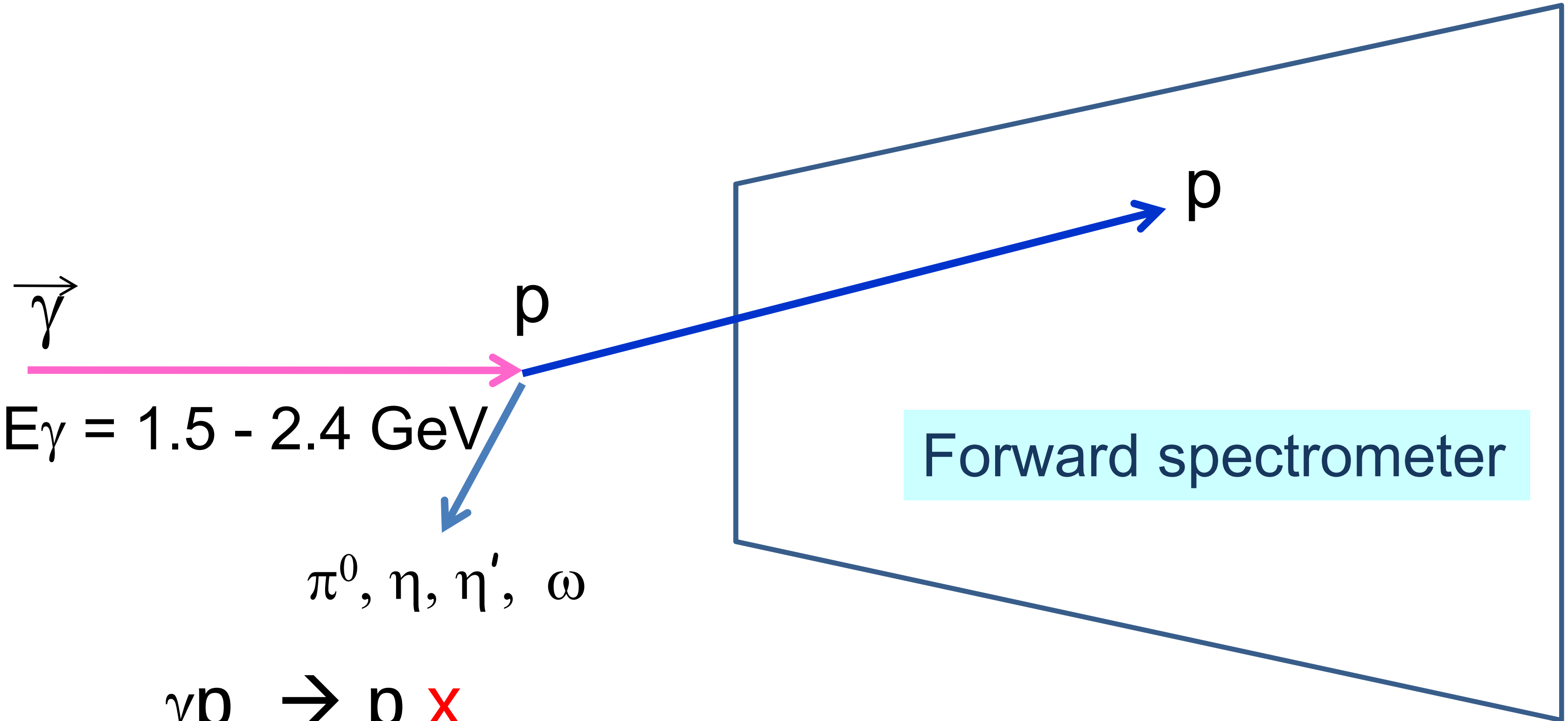
A-dependence of Nuclear Transparency ratio



- Strong suppression is seen in D target.
- Nuclear density effect is unlikely to be the main cause for the suppression.

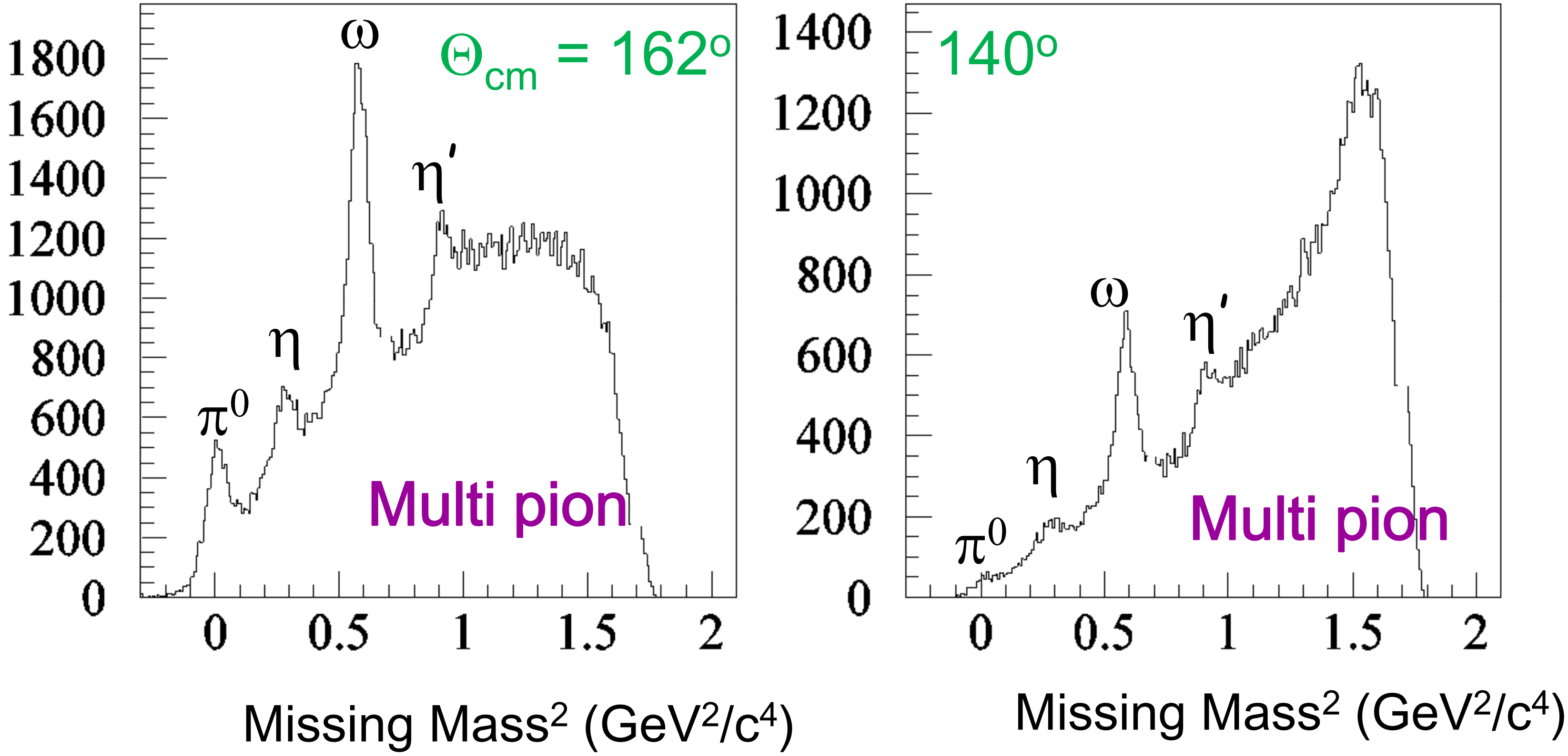
Backward meson photo-production

Detect protons and identify mesons in missing mass.



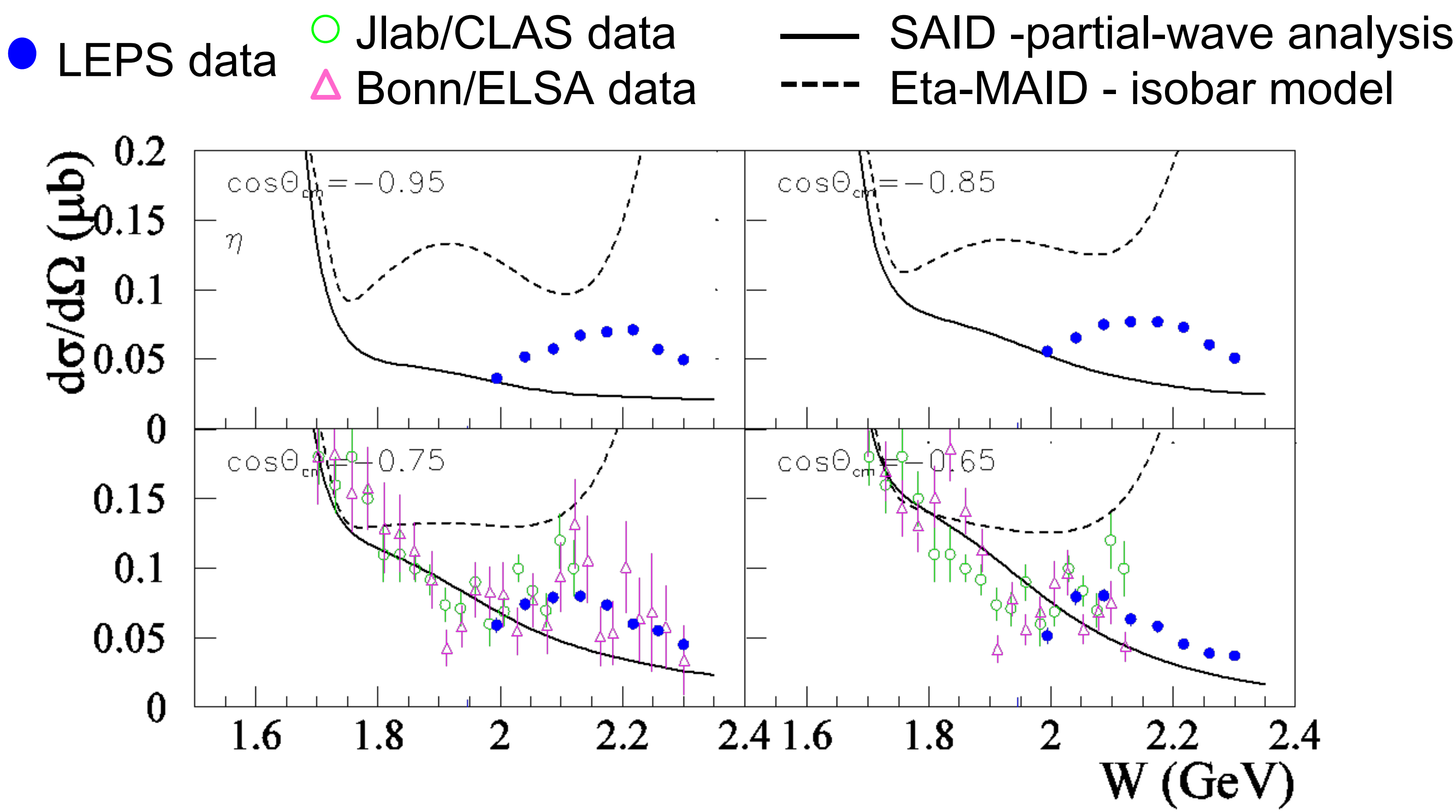
$\gamma p \rightarrow p \; \underline{x}$ Missing mass

Missing mass spectrum $\gamma p \rightarrow pX$



S/N is better at backward angles.

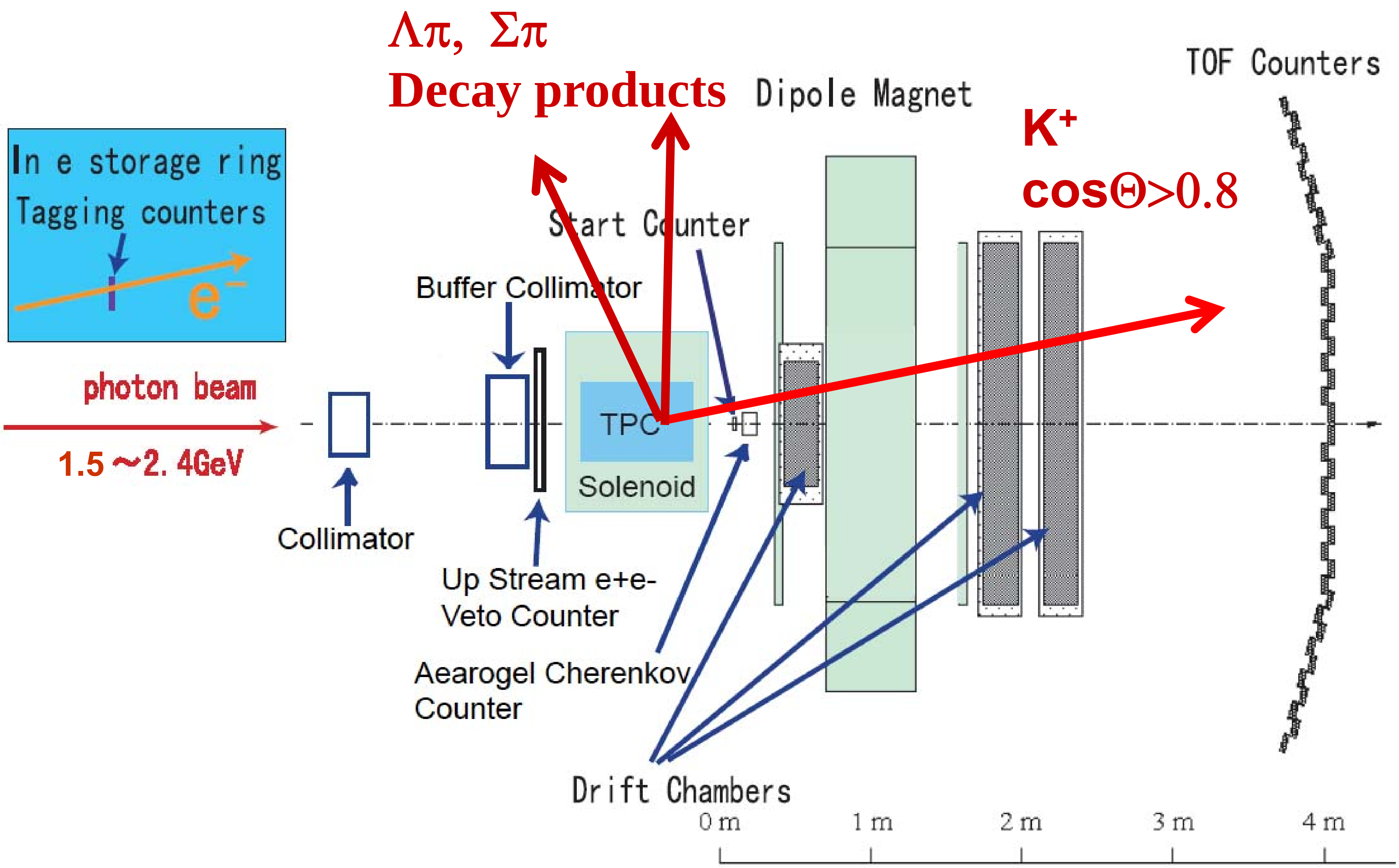
η : Differential cross sections



Wide enhancement is seen above W=2.0 GeV

LEPS result is consistent with ELSA & CLAS results.

Setup with TPC



Photoproduction of Σ(1385) and Λ(1405)

2004 Apr – Jul、Sep – Dec   Forward spectrometer + TPC

CH_2 9×10^{11} photons   C 5×10^{11} photons

Production ratio of Λ(1405)/Σ(1385)

- K^+ detection at the forward angles $0.8 < \cos\theta_{kCM} < 1$

$$\gamma\, p \to K^+\, \Sigma(1385) \to K^+ \Lambda\, \pi^0 \to K^+\, p\pi^-\, \pi^0$$

$$\gamma\, p \to K^+\, \Lambda(1405) \to K^+ \Sigma^\pm\, \pi^\mp \to K^+\, \pi^+\, \pi^-\, n$$

2000 Dec-Jun   Forward spectrometer

Liquid H_2 2×10^{12} photons

Production cross section of Λ(1405)+Σ(1385)

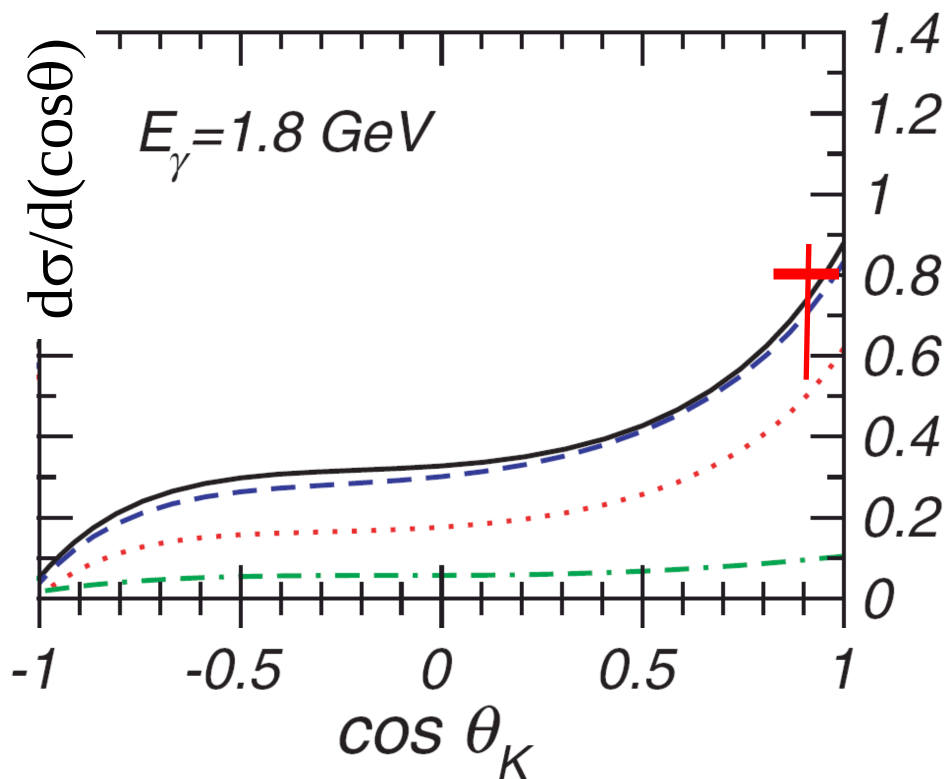
Niiyama et. al. PRC 78, 035202 (2008)

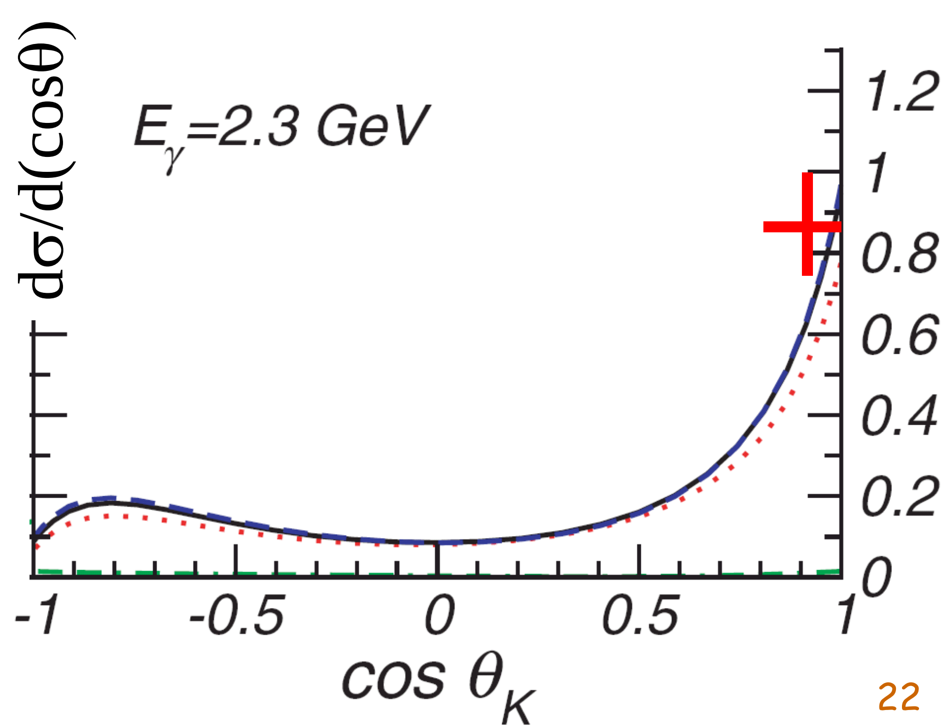
Differential cross section of Σ(1385) production

1.5<Eg<2 GeV $0.80 \pm 0.092 \, ^{+0.062}_{-0.27}$ μb

2.0<Eg<2.4 GeV $0.87 \pm 0.064 \, ^{+0.13}_{-0.067}$ μb

Consistent with theoretical calculation using effective Lagrangian (∼0.8μb, 0.8<cosθ<1) by Oh et al.

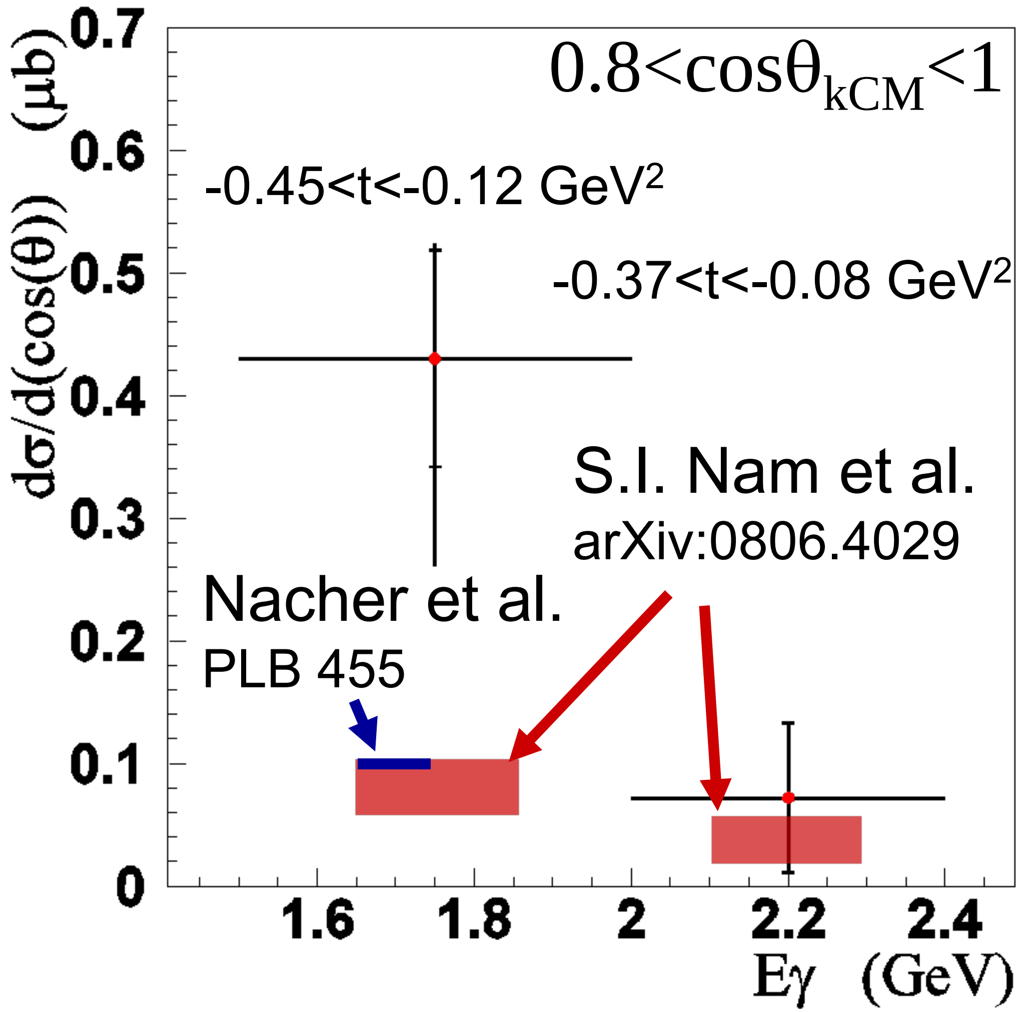




Differential cross section of Λ(1405) production

1.5<Eg<2 GeV $0.43 \pm 0.088^{+0.034}_{-0.14}$ μb

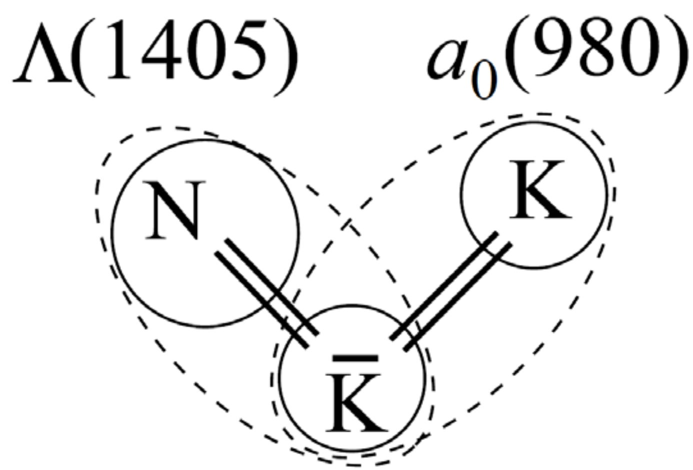
2.0<Eg<2.4 GeV $0.072 \pm 0.061^{+0.011}_{-0.0056}$ μb



K̄KN bound state proposed by D.Jido and Y.En'yo PRC 78, 035203(2008)

M ~ below KKN threshold (1930 MeV)

Γ ~ 90 MeV



We need more data

Near-threshold Photoproduction of $\Lambda(1520)$

nucl-ex/0904.2034 (submitted to PRL) :

New measurement at low energies and with a neutron target.

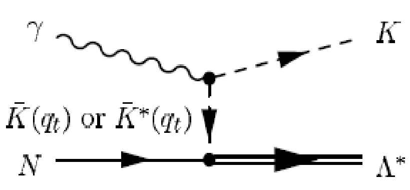
$[d\sigma/d\cos\theta(\gamma d \to K^{+/0}\Lambda^*)]/[d\sigma/d\cos\theta(\gamma p \to K^+\Lambda^*)] = 1.02 \pm 0.11$

at $120^\circ < \theta_{K+/0} < 180^\circ$ and $1.75 < E_\gamma < 2.4$ GeV

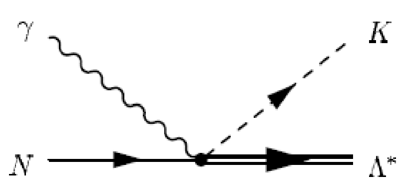
$\Rightarrow$ **A strong suppression of $\gamma n \to K^0\Lambda^*$, which indicates a dominance of a contact-term contribution or a small contribution from K* exchange.**

Differential cross sections, decay asymmetry, and photon beam asymmetry measured by $\gamma p \to K^+\Lambda^*$ at forward K^+ angles are compatible with this.

The dominance of the contact-term contribution may explain a possible suppression of $\gamma p \to \overline{K^0}\Theta^+$ relative to $\gamma n \to K^-\Theta^+$.



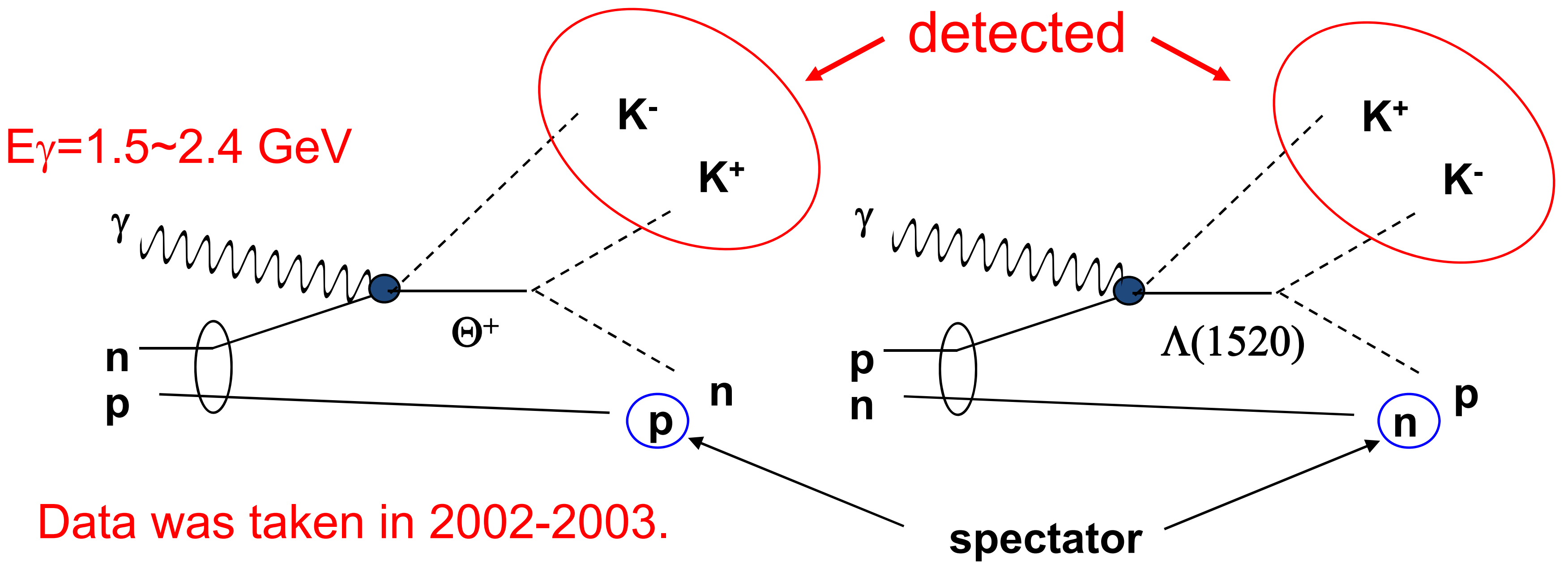
t or u–channel



c–channel

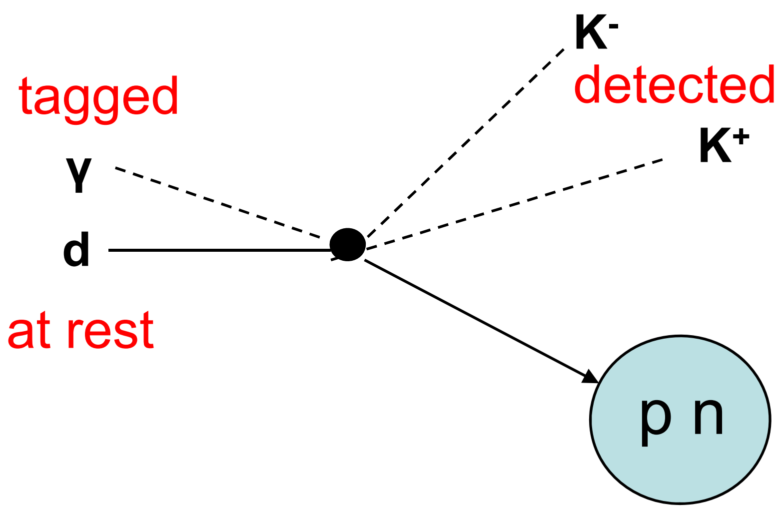
- The c-channel is necessary to conserve gauge invariance along with t-channel K exchange.
- K^* exchange is independently gauge invariant.
- The c-channel couples only with charge-exchange reactions.

Quasi-free production of Θ^+ and $\Lambda(1520)$



- Both reactions are quasi-free processes.
- Fermi-motion should be corrected.
- Existence of a spectator nucleon characterize both reactions.

Minimum Momentum Spectator Approximation (MMSA)



Nucleon from decay or scattering

We know 4 momentum of *pn* system

↓

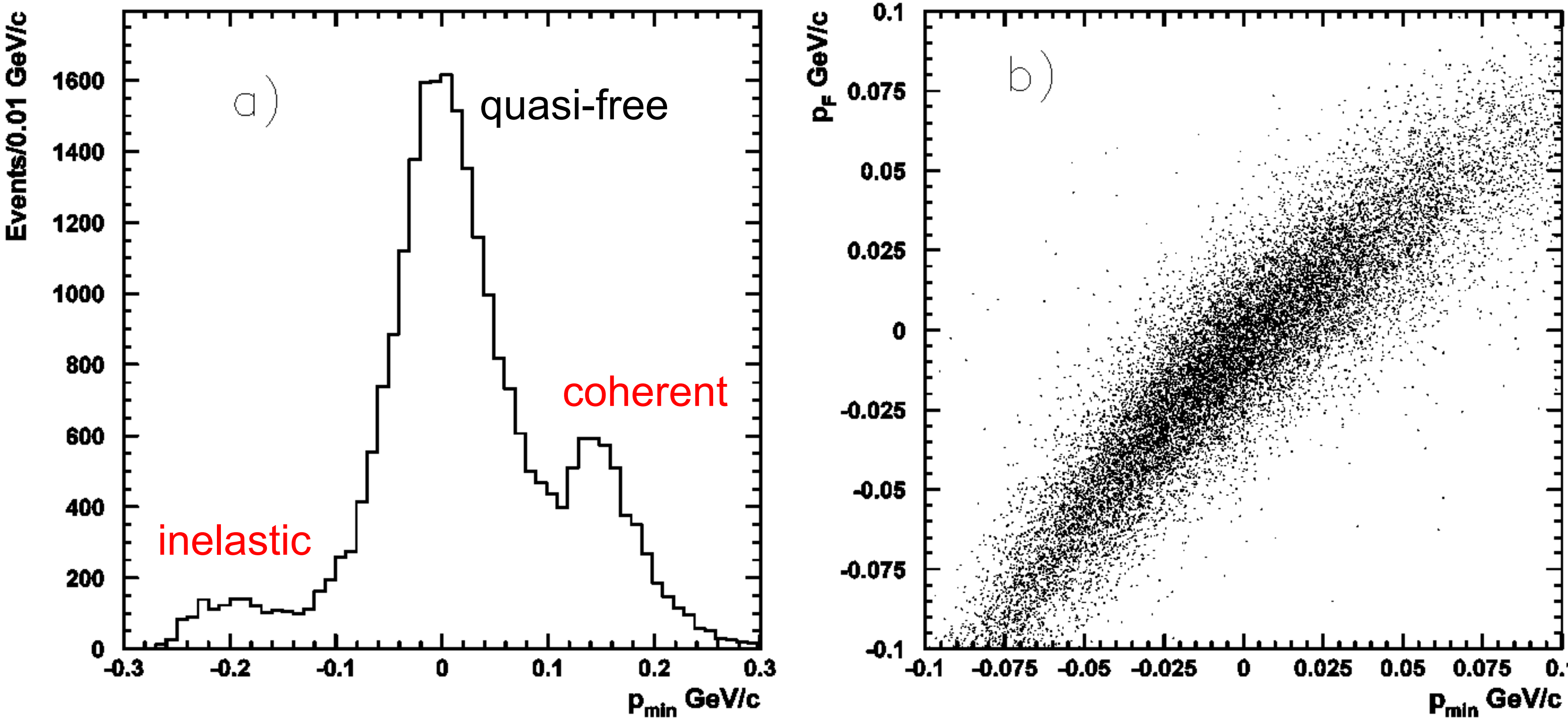
M_{pn} and $\vec{p}_{tot}$

↓

$|\vec{p}_{CM}|$ and $\vec{v}_{pn}$

Direction of $\vec{p}_{CM}$ is assumed so that the spectator can have the minimum momentum for given $|\vec{p}_{CM}|$ and $\vec{v}_{CM}$.

2-fold roles of p_{min}

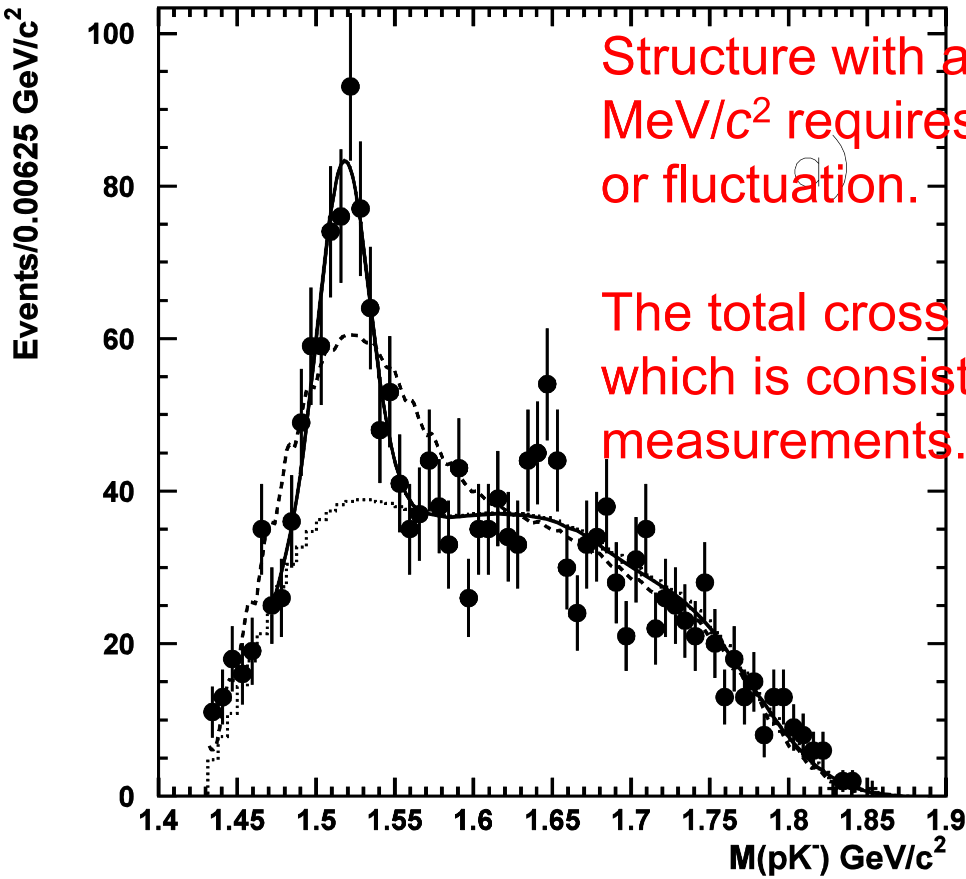


Clean-up

Estimation of p_F

Results of Λ(1520) analysis

pK^- invariant mass with MMSA: Fermi motion effect corrected.



Structure with a width less than 30 MeV/c^2 requires a physics process or fluctuation.

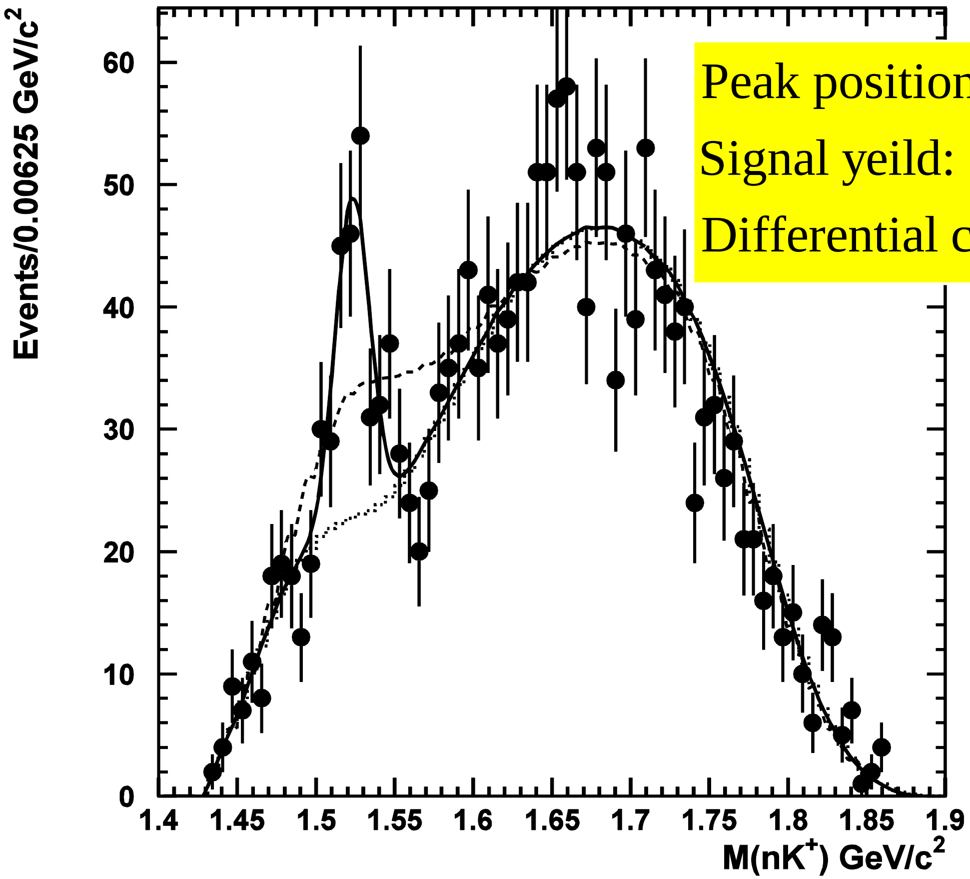
The total cross section is ~1 μb, which is consistent with the LAMP2 measurements.

$\Delta(-2\ln L)$ =55.1 for Δndf=2 ⟶ 7.1σ

$$\mathrm{Prob}(7.1\sigma) = 1.2 \times 10^{-10}$$

Results of Θ^+ analysis

nK^+ invariant mass with MMSA: Fermi motion effect corrected.



Peak position: 1.527 ± 0.002 GeV/c^2

Signal yeild: 116 ± 21 events

Differential cross-section: 12 ± 2 nb/sr

"The narrow peak appears only after Fermi motion correction."

$\Delta(-2\ln L) = 31.1$ for $\Delta ndf = 2$ $\longrightarrow$ 5.2σ $\quad \mathrm{Prob}(5.2\sigma) = 2 \times 10^{-7}$

Next step

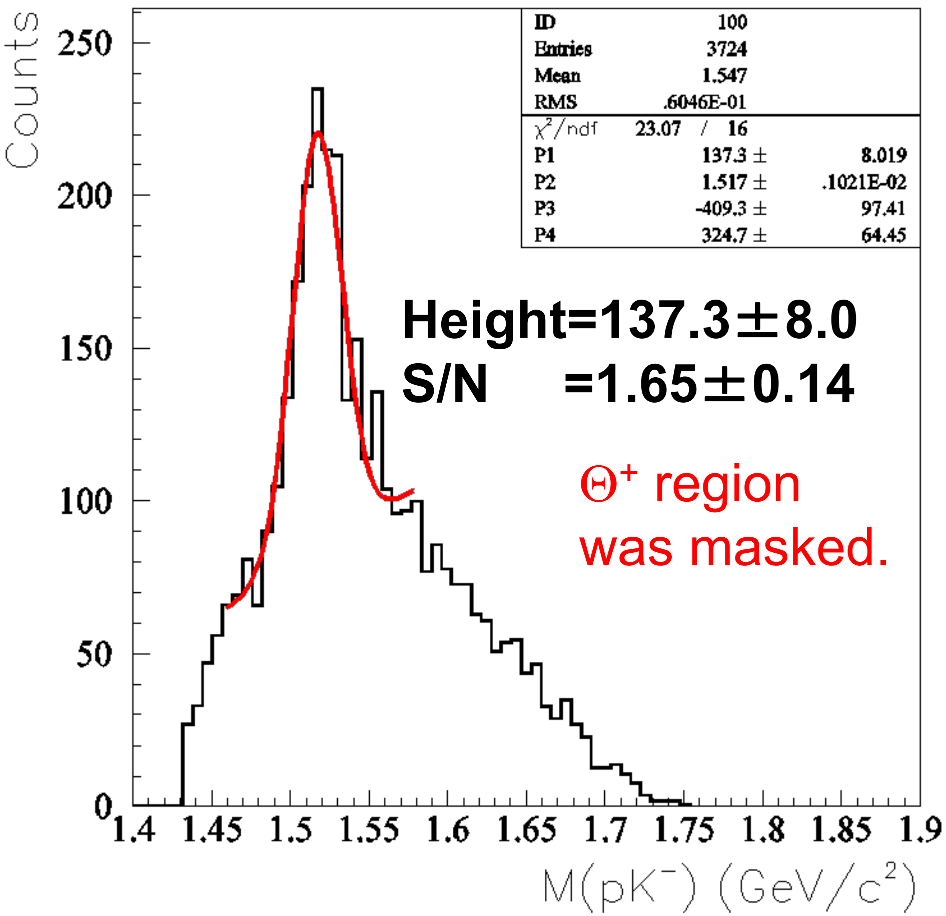
Probability of 1/5000000 may not be low enough.
"Extraordinary claim requires an extraordinary evidence."

High statistics data was collected in 2006-2007 with the same experimental setup.

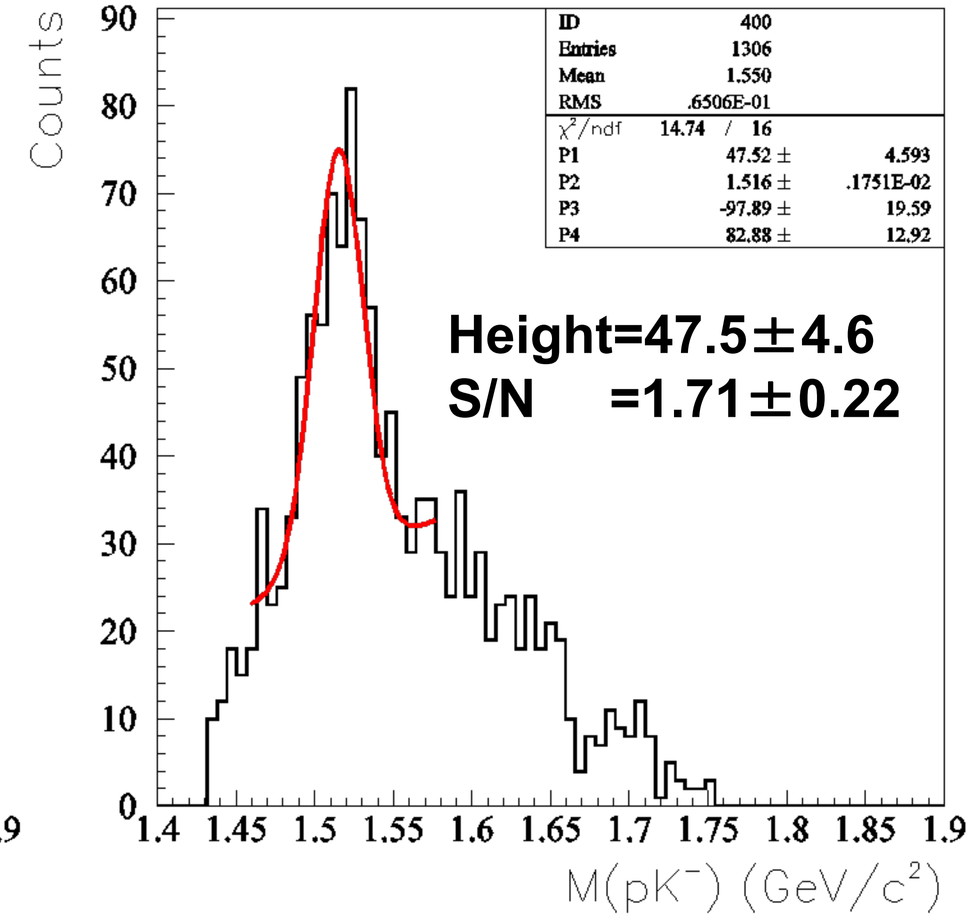
Blind analysis is under way to check the Θ^+ peak

Check of high-stat data with Λ(1520)

2006-2007 data



2002-2003 data



Fitting was carried out with fixed width(16MeV/c^2)

Ratio of height = 2.89±0.32 ← consistent with the luminosities

Θ^+ study: Status and Prospects

1. We obtained and reported a positive result from 2002-2003 data analysis. Phys. Rev. C 79, 025210 (2009)
2. Data with 3 times more statistics has been already taken.
3. Blind analysis is in under way out to check the peak (in a month).
4. New experiments with a Time Projection Chamber has been carried out since Jan 2008. → wider angle coverage and Θ^+ reconstruction in pK_s decay mode.
5. If the peak is confirmed, we will submit a proposal to carry out a conclusive experiment by using a low energy K^+ beam at J-PARC.

Production of unmasked ntuples will be finished in this week.

Summary

•Backward Compton sattered photons and forward spectrometer at LEPS provide us with unique capability to study hadrons through its production and decay.

• Linear polarization can be used as a parity filter.

• Photo-productions of the ϕ, η, $\Lambda(1405)$ show unexpected energy dependences in ~2 GeV region.

• For Θ^{+}pentaquark, an intensive study is in progress. The results from the high-statistics dedicated runs will be finalized and open soon.