Multi-GeV photon beam experiments at SPring 8 - laser - back scattering facility

Yoshikazu Maeda
Research Center Nuclear Physics
Osaka univ.
On behalf for LEPS collaboration

Contents

- Introduction
- LEPS facility
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- New experiment using TPC
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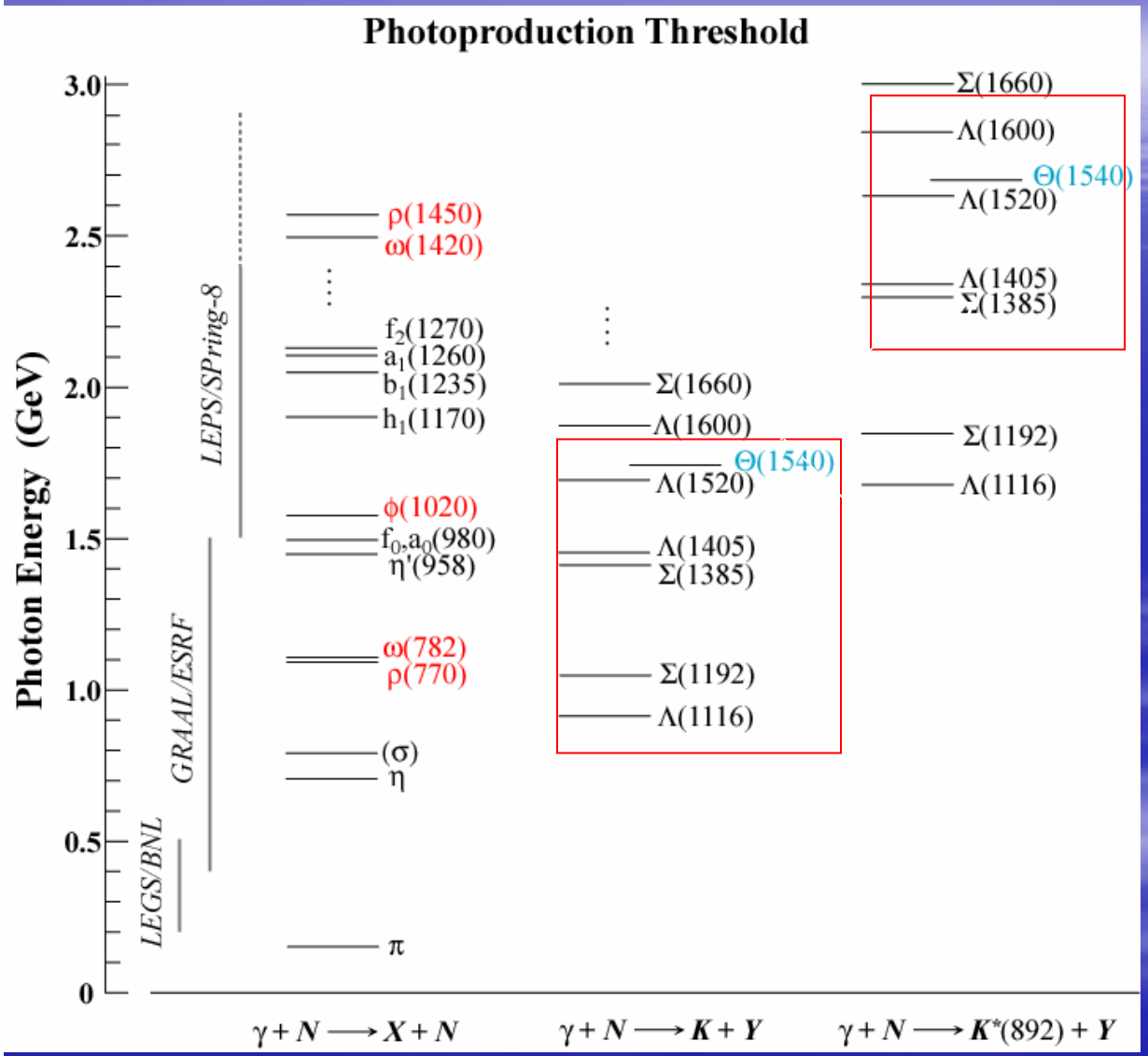
Introduction

- **How are quarks confined in Hadrons**
  Production mechanism of hadrons
  Decay property of hadrons
  Penta-quark exists?

- **Interaction between Hadrons**
  Role of Gluon
  Meson-baryon picture⇔Quark-Gluon picture?

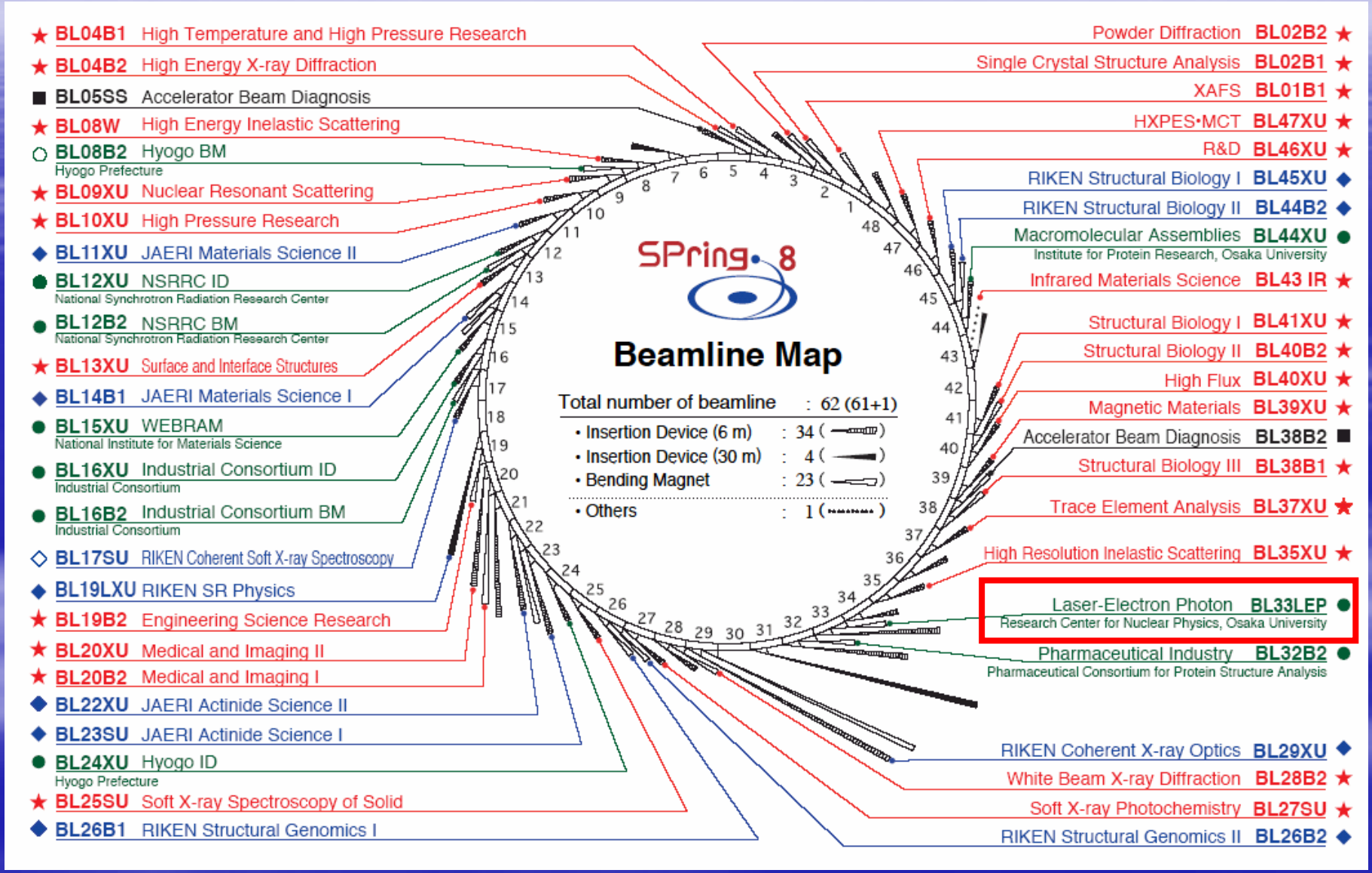


Key words :

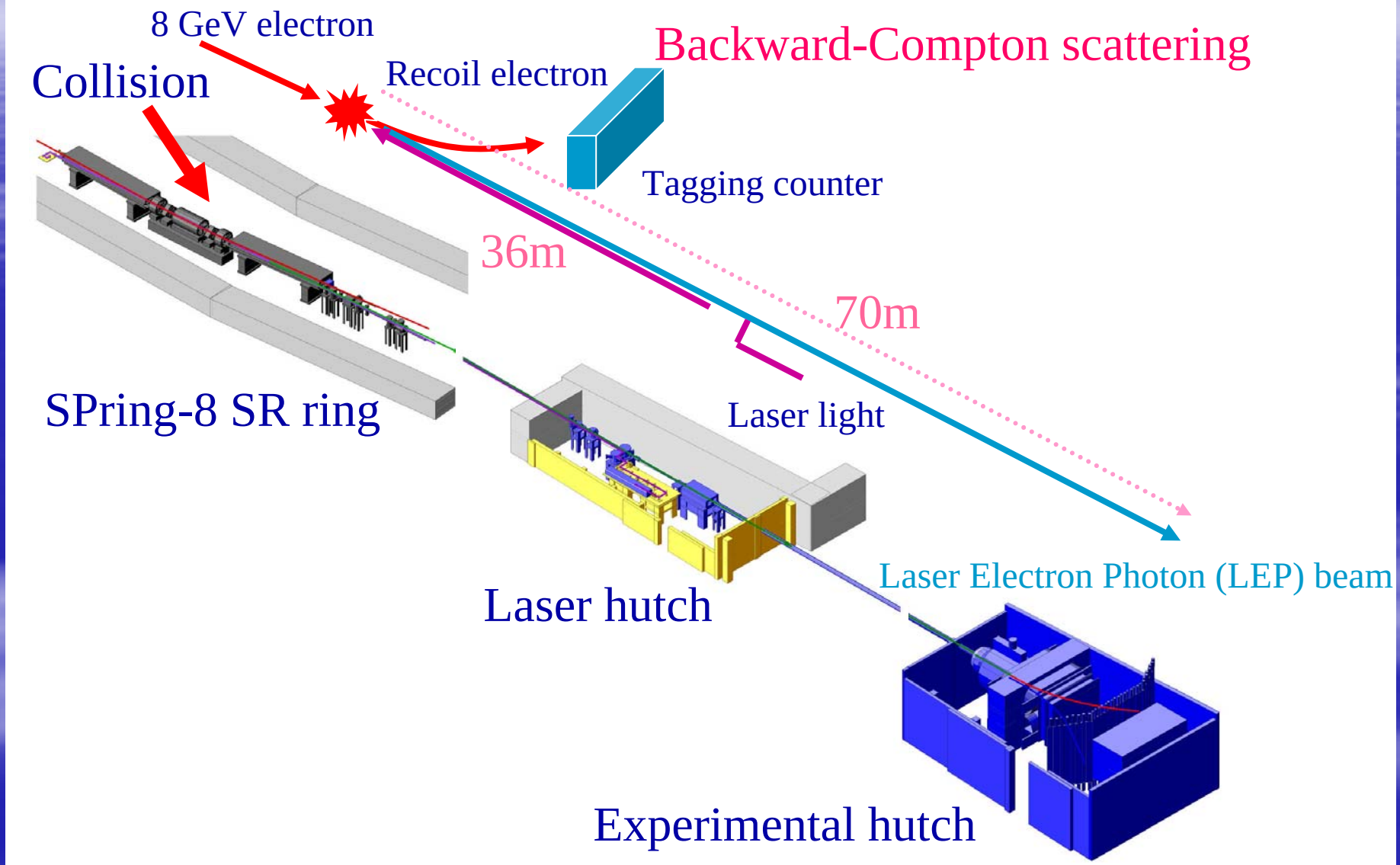
1. Forward angle measurement including 0 deg.
2. Polarized photon
3. Strangeness
4. Decay particles

→ Large acceptance

Beam line map of Spring-8



LEPS facility



Laser Electron Photon (LEP) Beam

8 GeV electrons in SPring-8 + 351nm (257nm) Ar laser

⇒ maximum photon energy 2.4 GeV (3.0 GeV)

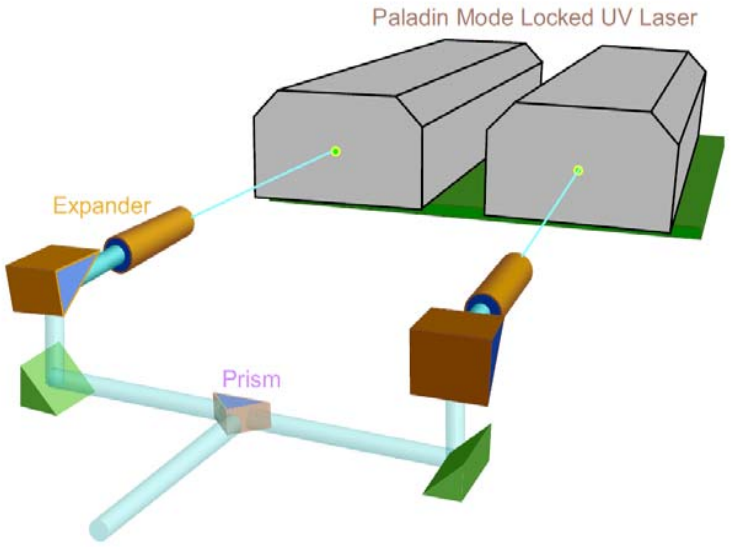
— E_γ measured by tagging a recoil electron ⇒ E_γ>1.5 GeV, ΔE_γ ~10 MeV

Laser Power ~6 W (UV)⇒ Photon Flux ~1 Mcps

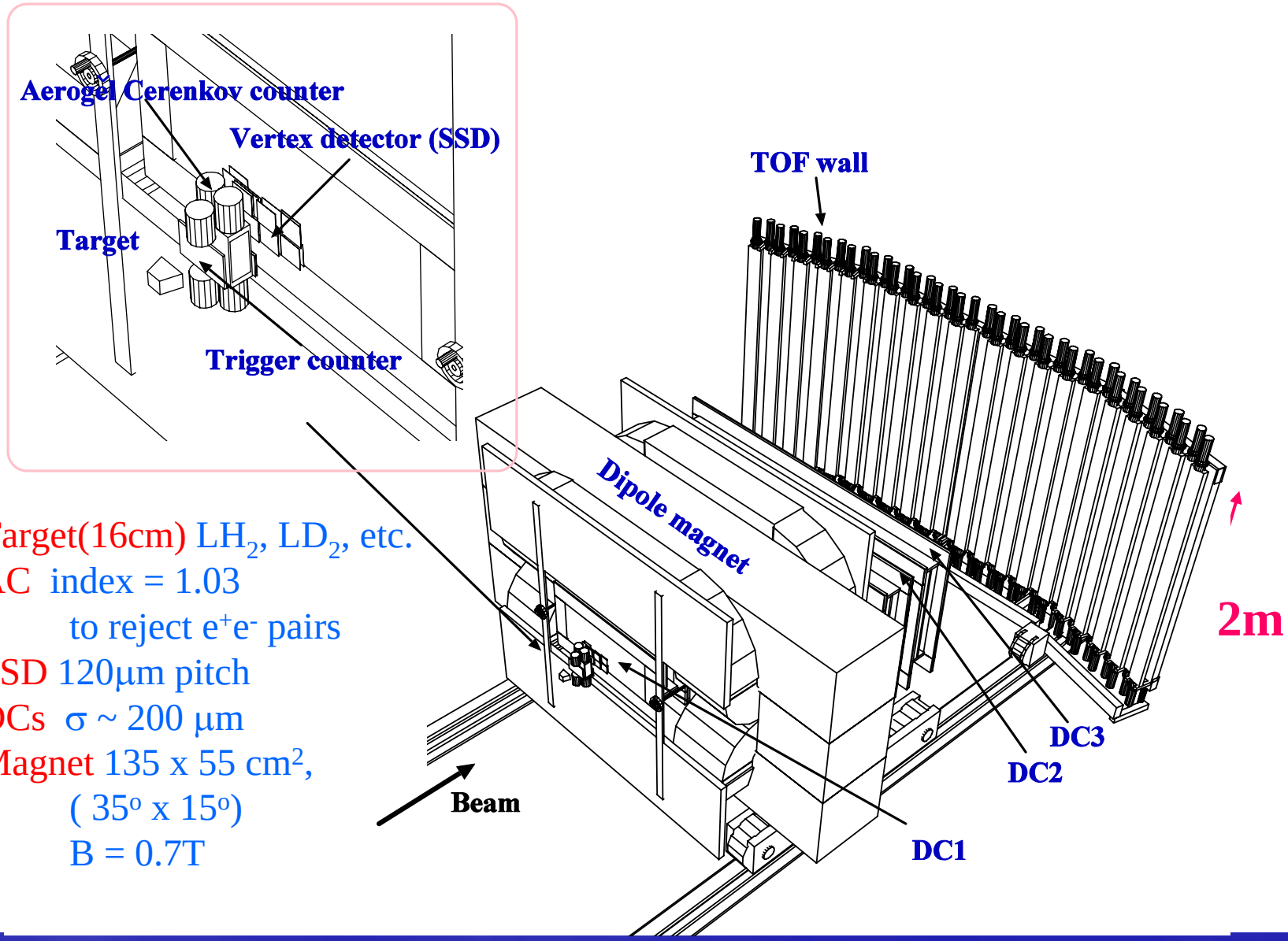
1.5W (Deep-UV) 200 kcps

2-laser injection at BL33LEP.

⇒ ~2 Mcps

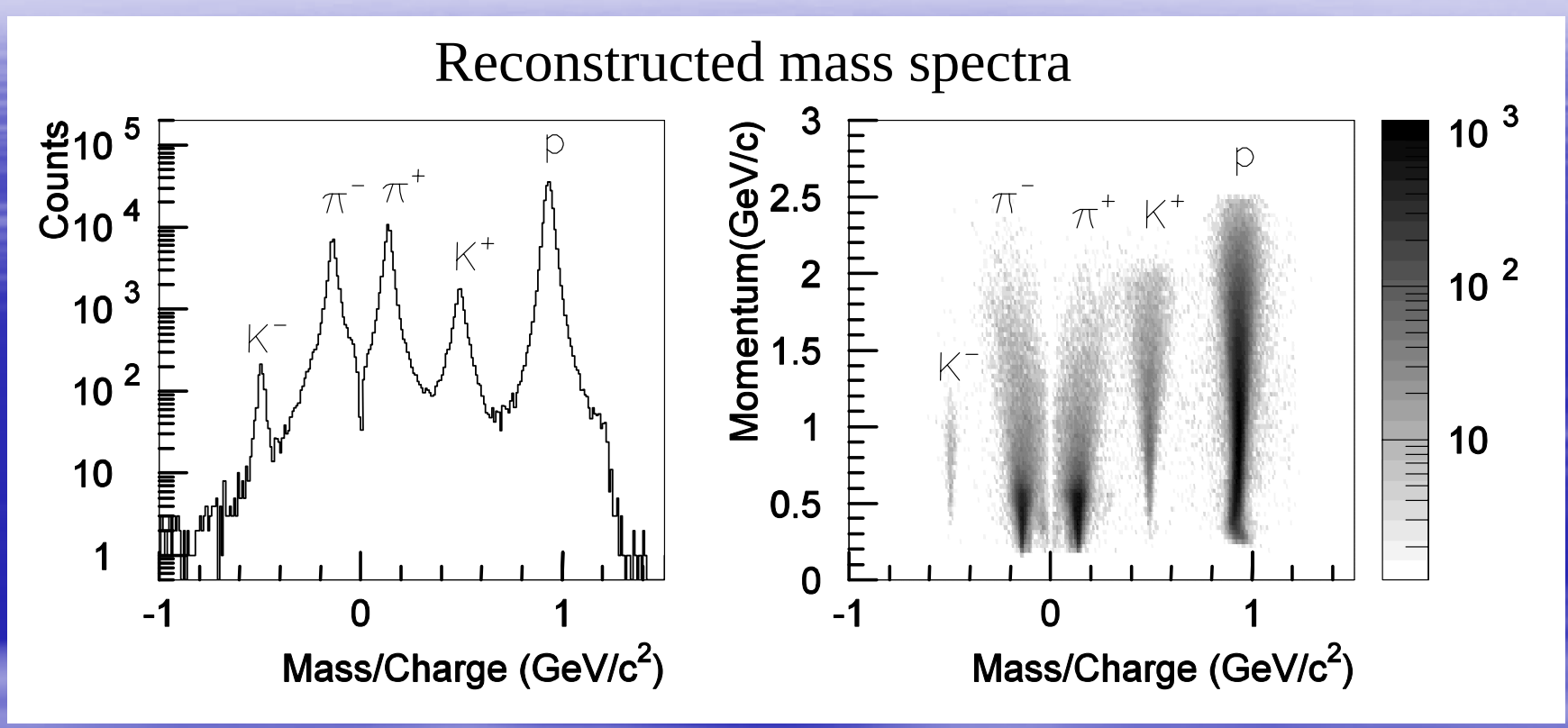


LEPS forward spectrometer



- Target(16cm) LH_2, LD_2, etc.
- 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

Particle identification



σ_P ~6 MeV/c for 1 GeV/c, σ_{TOF} ~150 ps

→K/π separation 10 σ_{MASS}

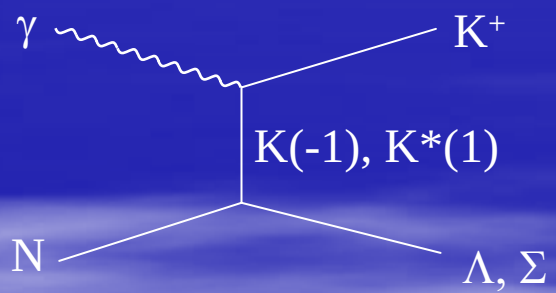
Results

- K^+ photo-production

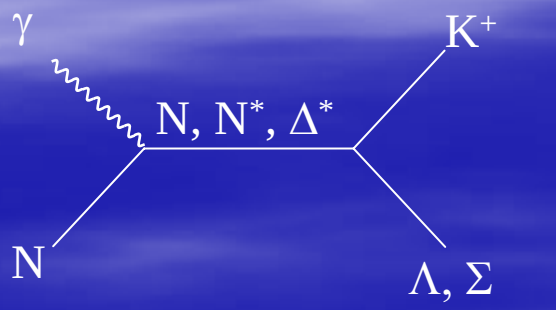
  $\gamma p \rightarrow K^+ \Lambda/\Sigma^0$,

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

T-channel



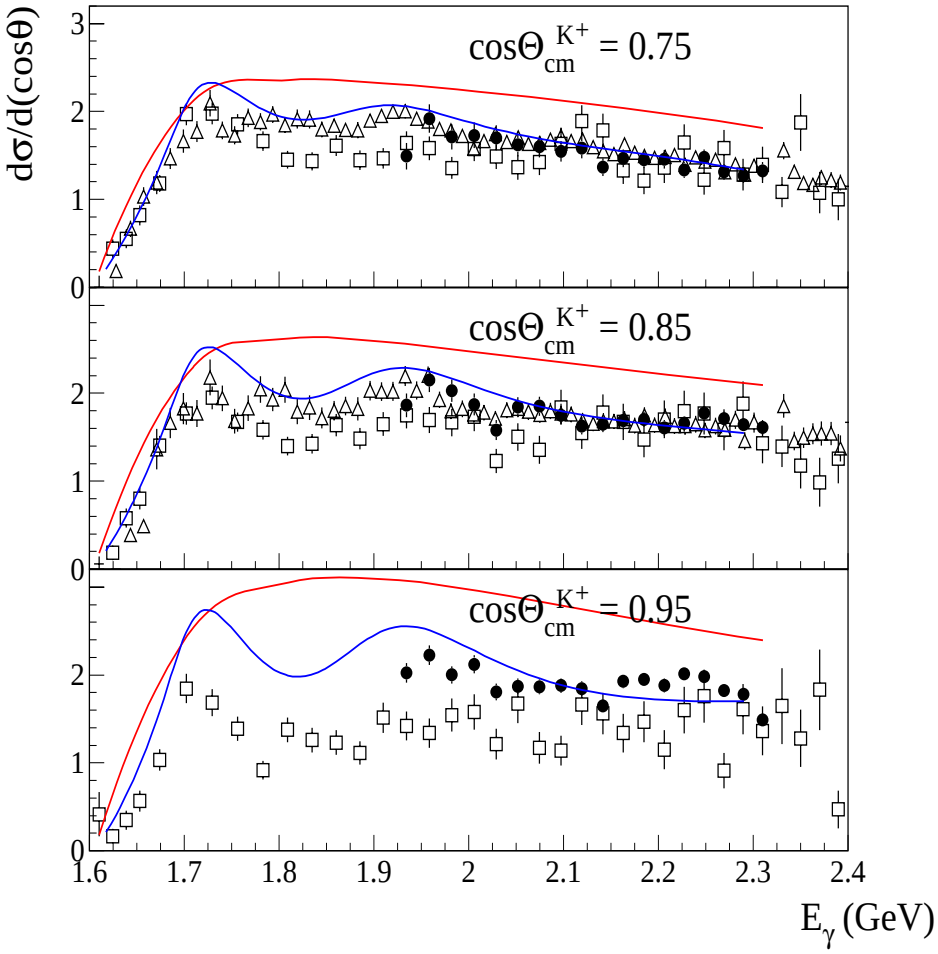
S-channel



● LEPS □ SAPHIR ▲ CLA

R.Zeger et al. PRL91,092001(2003)

M.Sumihama et al,PRC73,035214(2006)

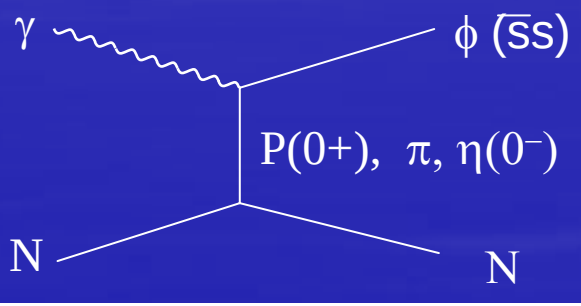


- $\phi(\bar{s}s)$ meson production

T.Mibe et al, PRL. 95, 182001 (2005)

W.C.Chang et al. PLB. 658(2008)

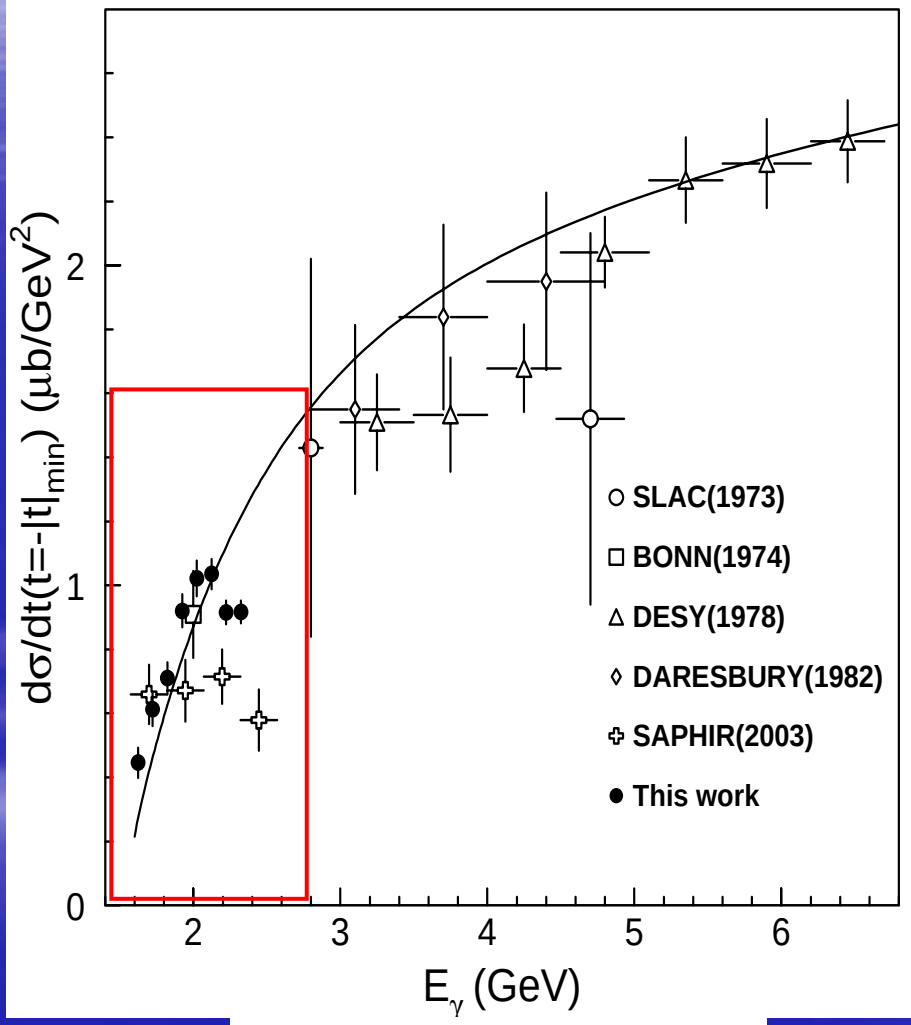
$\gamma p \rightarrow \phi p$, $\gamma d \rightarrow \phi d$



$$\Sigma_\phi = \frac{\sigma_{//} - \sigma}{\sigma_{//} + \sigma} \cong \frac{\sigma_n - \sigma_{un}}{\sigma_n + \sigma_{un}}$$

→**0.5 purely Natural Parity**

$\Sigma(\gamma d \rightarrow \phi d)$= 0.48 +-0.1(sys)



Bump structure!

θ^+ search

Phys.Rev.Lett. 91 (2003) 012002

hep-ex/0301020

D_2: $\gamma n \rightarrow \theta^+ K^- \rightarrow n(K^+K^-)$

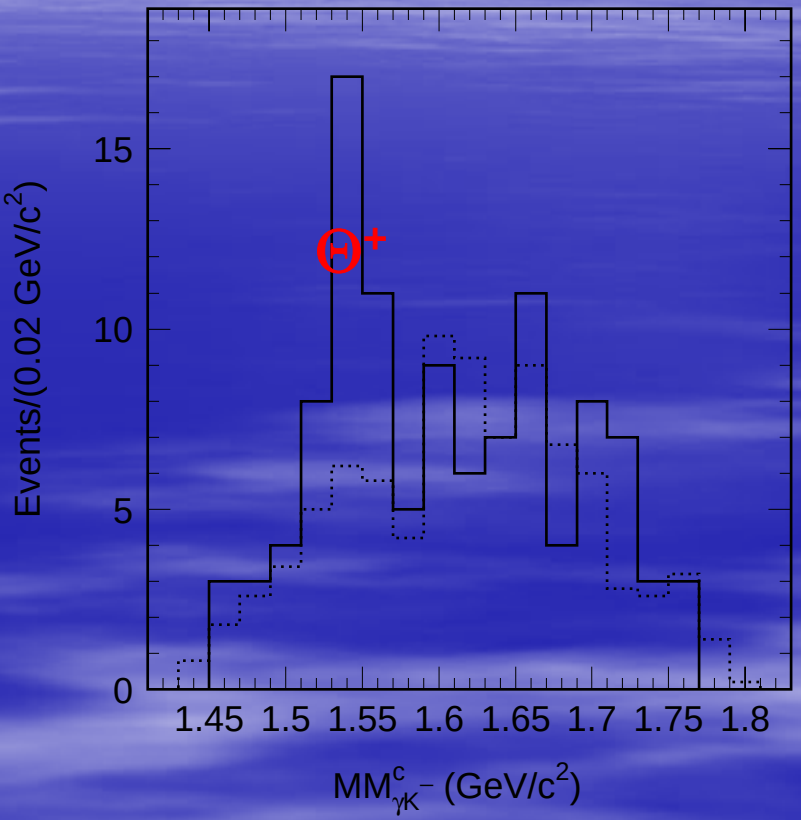
$\gamma d \rightarrow \theta^+ \Lambda(1520) \rightarrow nK^+(pK^-)$

2002/2003

Final result will be reported.

2006/2007

The same measurement was performed to confirm previous measurement and blind analyses are in progress.



Other results

- **Photoproduction of $\Lambda(1405)$ and $\Sigma^0(1385)$ on the proton at E(γ) = 1.5-2.4-GeV.**
  M.Niiyama, *et al.*, **arXiv:0805.4051**

- **Backward-angle photoproduction of π^0 mesons on the proton at E_γ =1.5-2.4 GeV,**
  M. Sumihama, *et al.*, Phys. Lett. B 657 32(2007)

- **Measurement of the $\gamma p \rightarrow K^+ \Lambda$ reaction at backward angles**,
  K. Hicks, *et al.*, Phys. Rev. C 76, 042201(R) (2007).

- **Differential Cross Section and Photon-Beam Asymmetry for the $\gamma n \rightarrow K^+ \Sigma^-$ Reaction at E_γ =1.5-2.4 GeV**,
  H. Kohri, *et al.*, Phys. Rev. Lett. 97, 082003 (2006).

- **ϕ photo-production from Li, C, Al and Cu nuclei at E_γ =1.5-2.4 GeV**,
  T. Ishikawa, *et al.* Phys. Lett. B 608, 215 (2005).

Deuteron Photodisintegration at 1.5-2.4 GeV photon energy

γd→pn at Eγ=1-4 GeV

- **Meson-nucleon ⇨ Quark-gluon (pQCD)**

  Which energy does the transition appear?

  How to develop model describing physics underlying here?

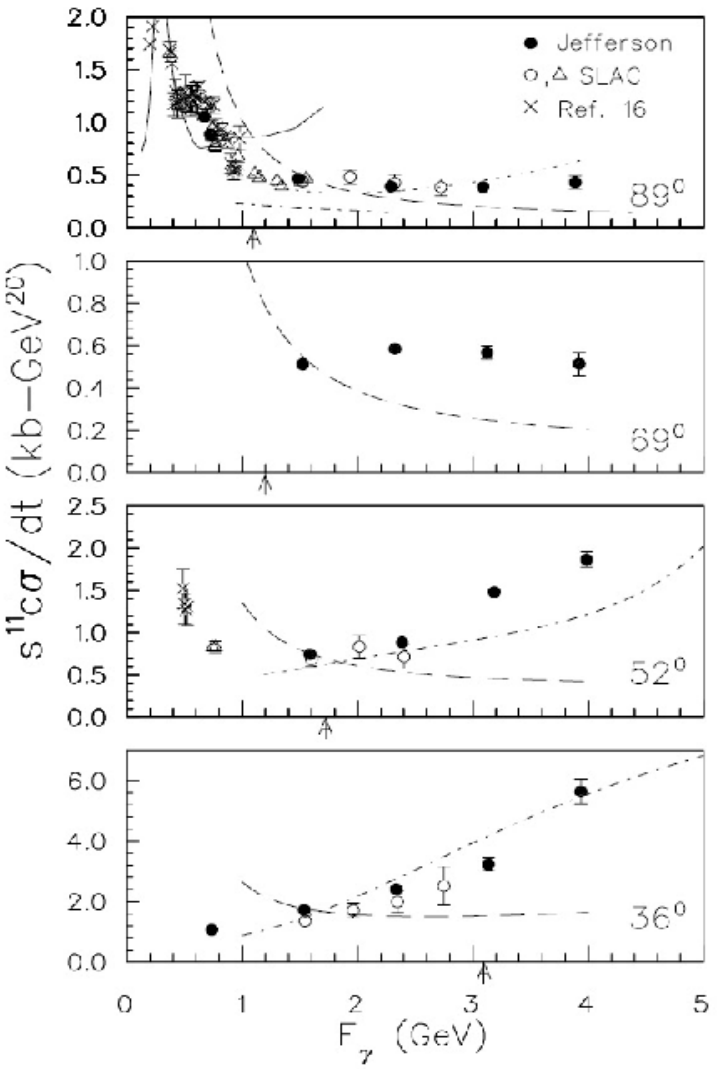
- **pQCD**
  - **Constituent-counting rules**

    $(ds/dt)_{AB\to CD} \sim s^{2-n} f(\theta_{cm})$,n=13

But at forward region

No scaling →Non-pQCD

JLAB HALL C(1998)



Non-pQCD model

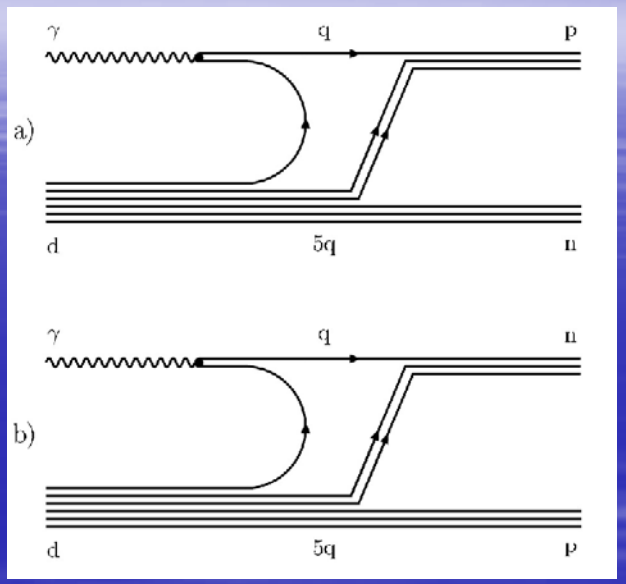
- **Quark-Gluon String model**

  Regge theory evaluated by

  3 quark exchange.

  Isovector-Isoscalar photon coupling.

  V. Yu. Grishina et al., EPJ A19, 117 (2004)



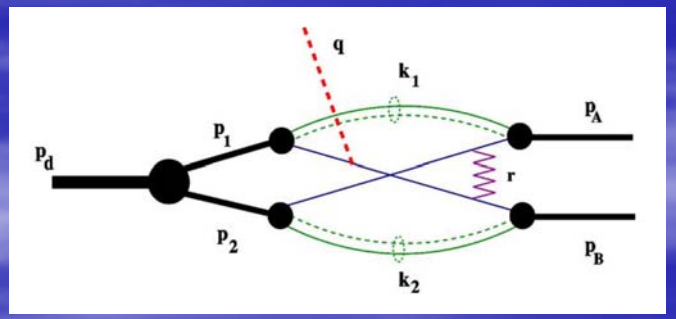
- **Hard Quark Rescattering model**

  Quark exchange between nucleons.

  Empirical NN scattering amplitude.

  L. L. Frankfurt et al., PRL. 84, 3045 (2000)

  M. M. Sargsian et al., PL. B587, 41 (2004)

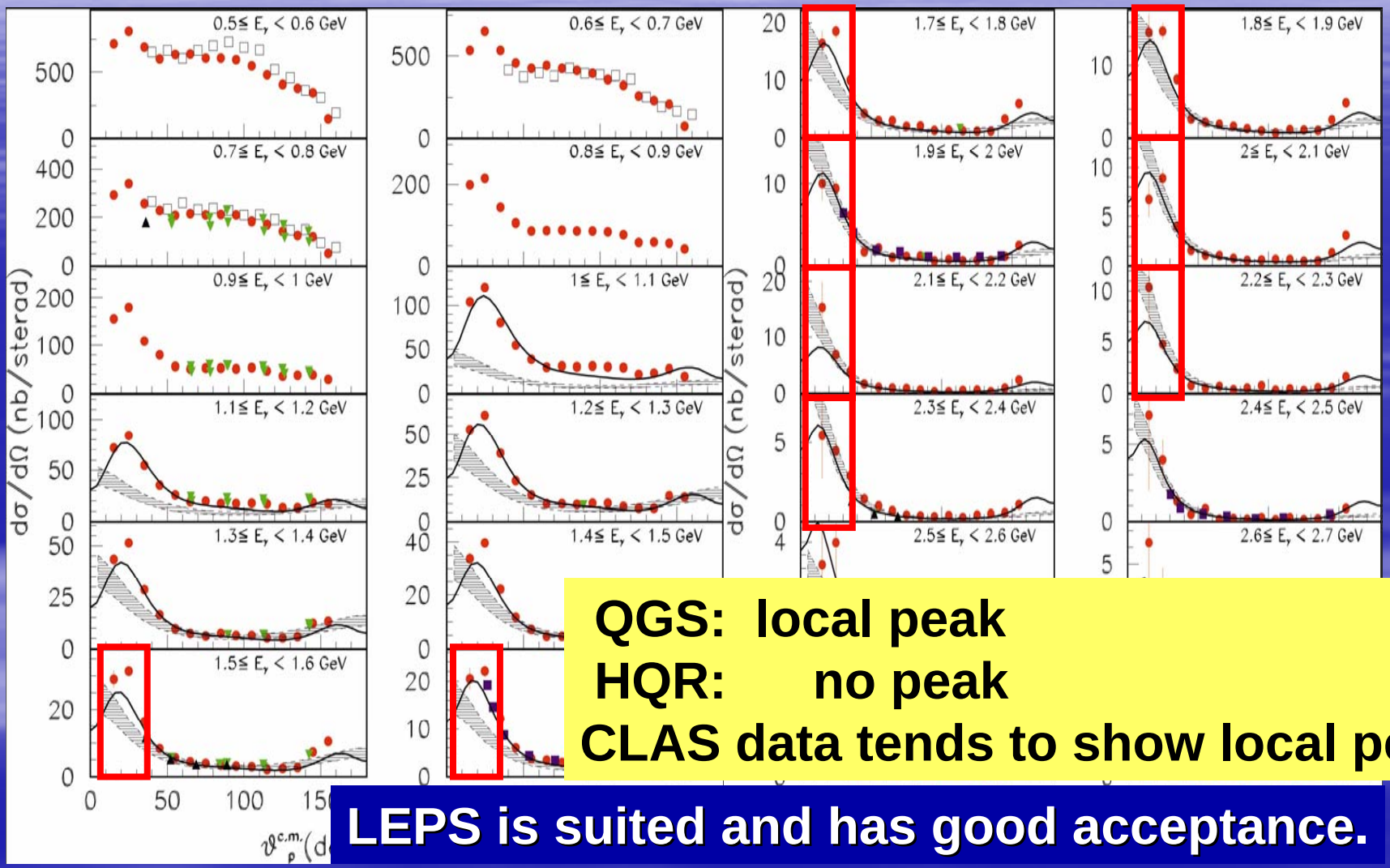


- **Model based on Meson-Baryon theory** (at Eγ<1 GeV)

A. E. L. Dieperink and S. I. Nagormy, PL. B456, 9 (1999)

CLAS data

M.Mirazita et al., PRC 70, 014005 (2004)



QGS: local peak
HQR: no peak
CLAS data tends to show local peak

LEPS is suited and has good acceptance.

Polarization observables

- **pQCD**
  - **Hadron Helicity consevation**

    $\theta_{cm} \sim 90^{o}$

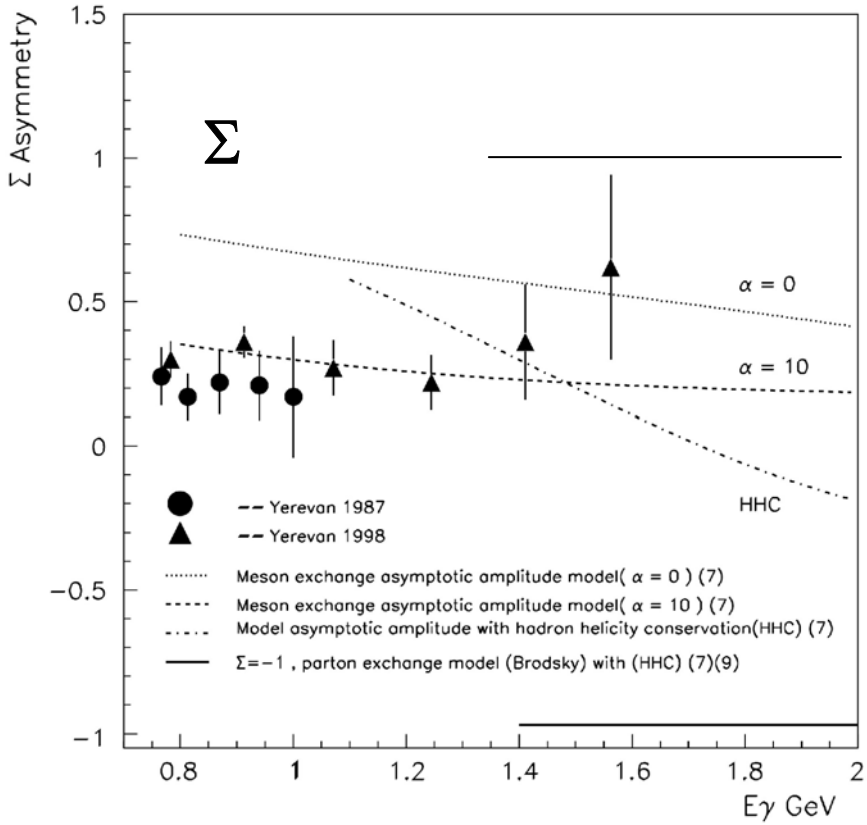
    $\Sigma \rightarrow +1$ **(Isovector)**

    $\rightarrow -1$ **(Isoscalar)**
- **Non-pQCD**

  Σ **(QGS) = 0.4-0.5 at 2 GeV**

  →Isovector and Isoscalar photon coupling

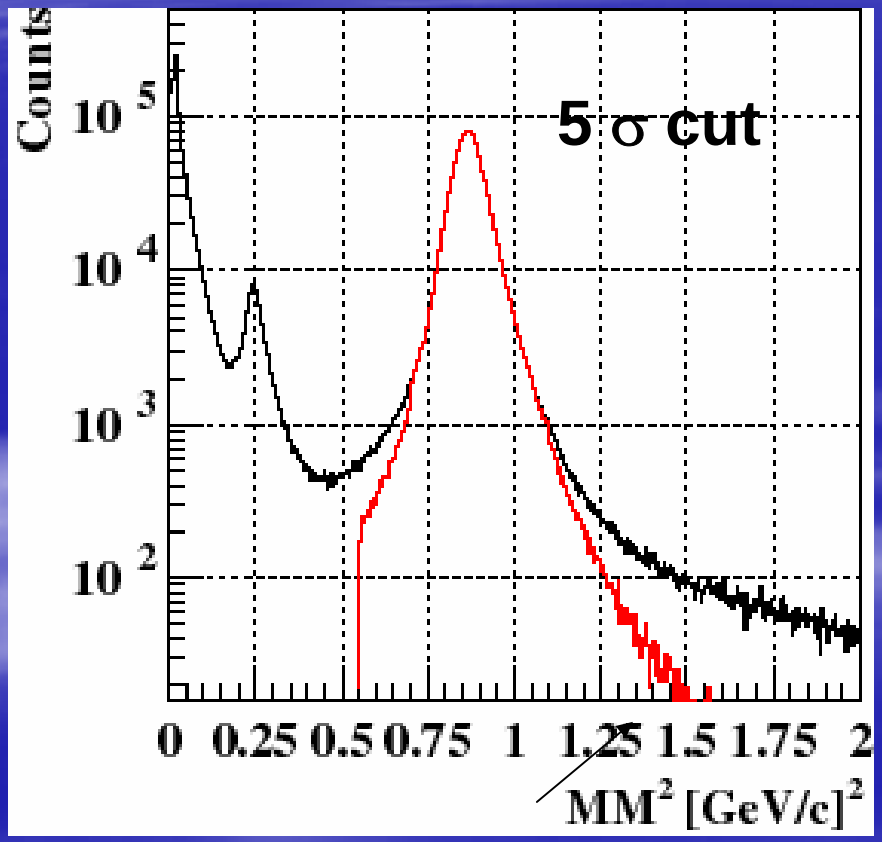
F.Adamian et al EPJ A8,423(2000)

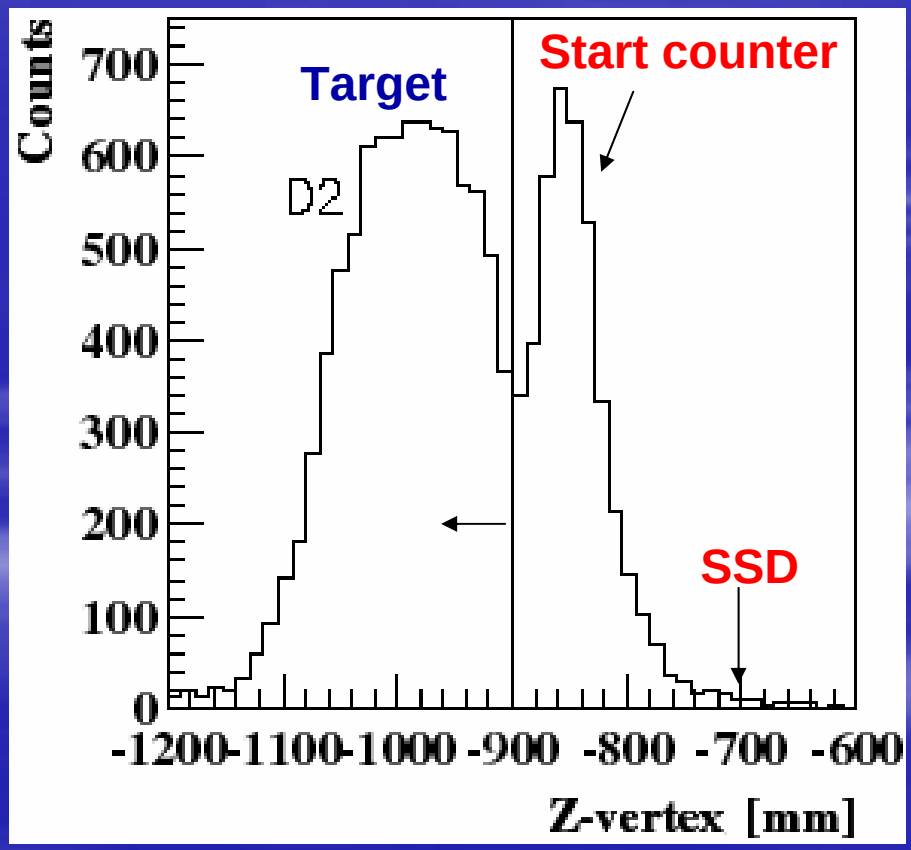


Analysis

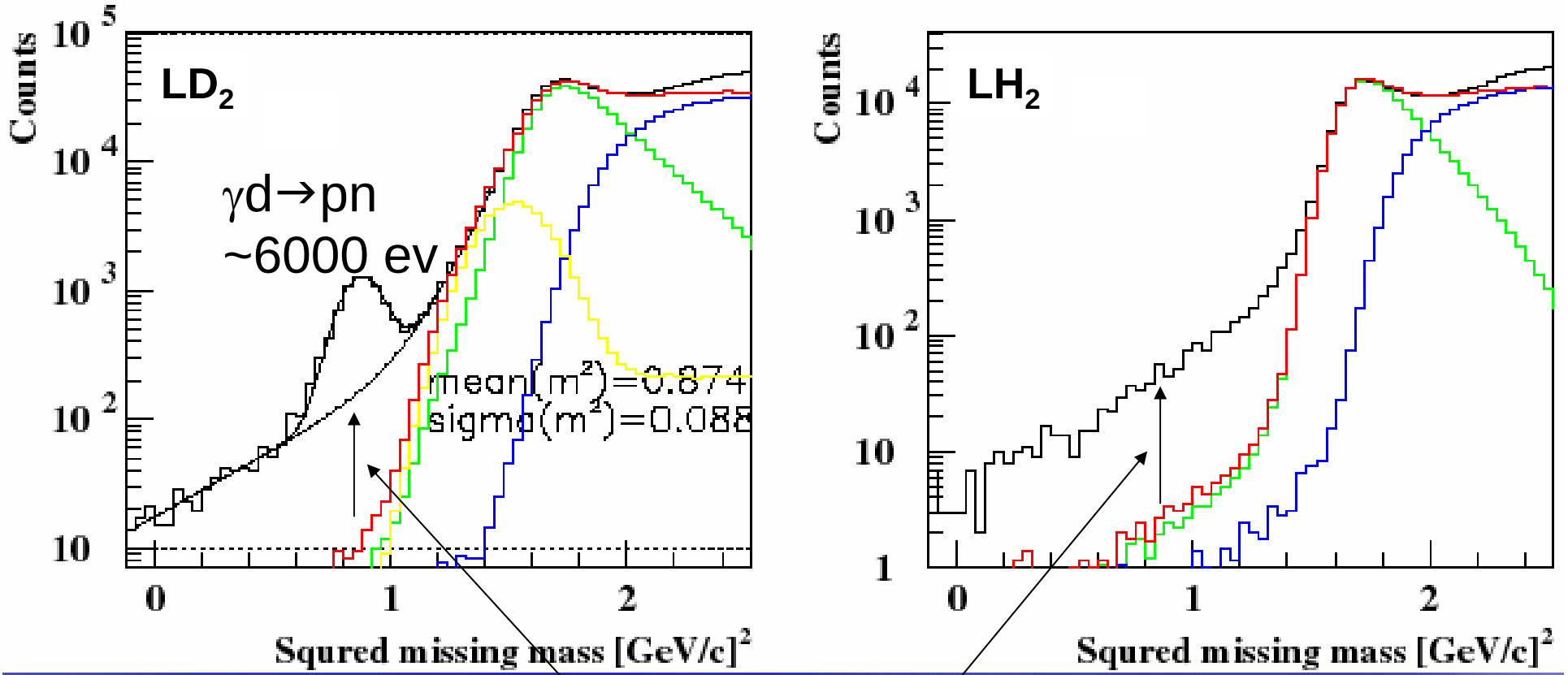
- LD_2/LH_2 at 2002/2003 experimental period
- Single proton in LEPS spectrometer

$\theta_{lab} < 20^o$, $p>2.0$ GeV/c $\rightarrow$ $\theta_{cm}<40^o$



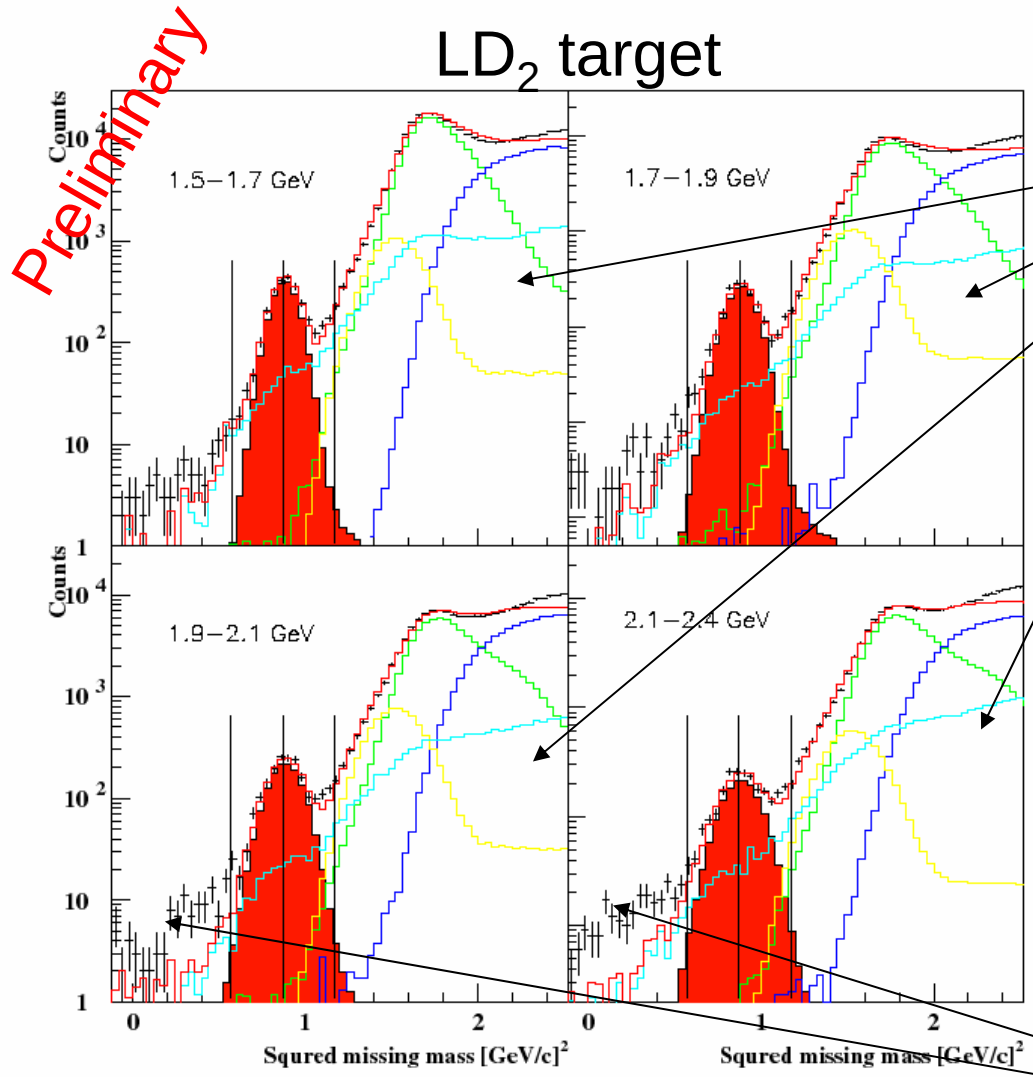


Squared Missing Mass



Inelastic process coming from target windows (Kapton foil).

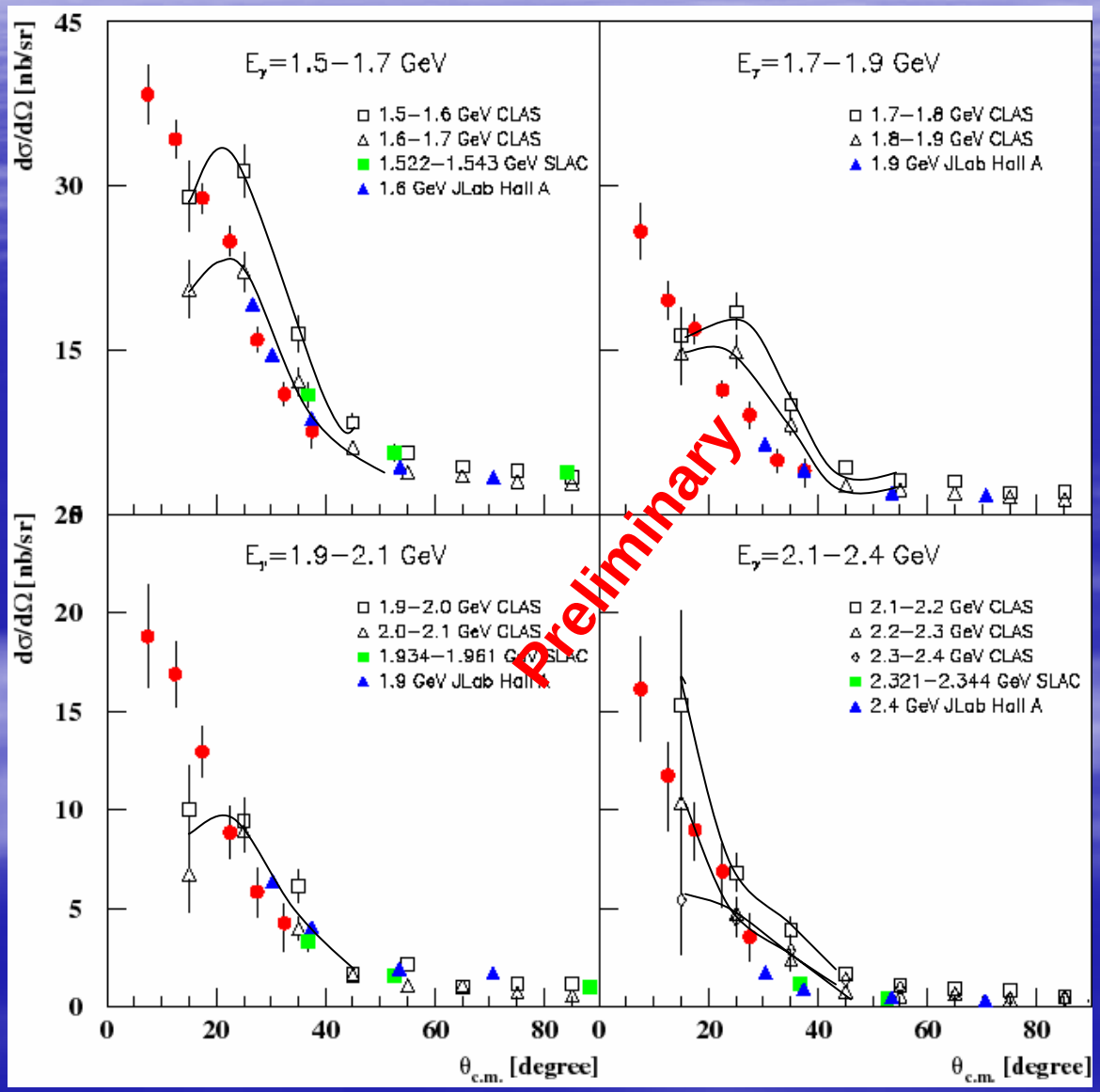
Yield estimate of γd→pn



Contamination of BG~20% in $3M_{\sigma}$ region

Excess from the fit is 1.2-1.4 times larger that LH2 case
→Sys error(10-30%)

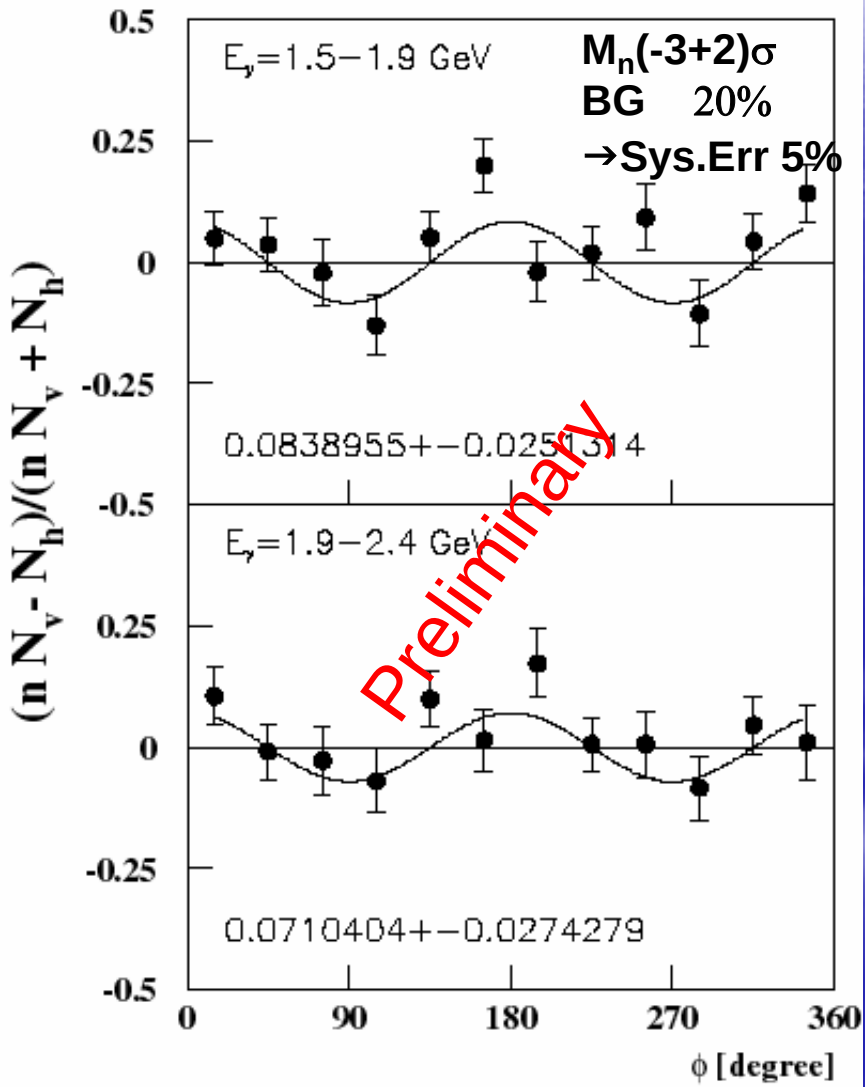
Differential cross section



- LEPS data points is increased toward smallest angle
  → **No local peak**

- QGS model X
- HQR model OK

Photon beam asymmetry



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

$N_{v(h)}$:Yield of vertical (horizontal) pol.
ϕ : Azimuthal angle
P_γ : Polarization of photon

Eγ [GeV]	Pγ	Σ
1.5-1.9	0.63	0.13(0.05)
1.9-2.4	0.83	0.09(0.04)

Σ(all)=0.11(0.03)

Σ(pQCD) = 1.

Σ(QGS) = 0.4-0.5 → Too strong Isovector?

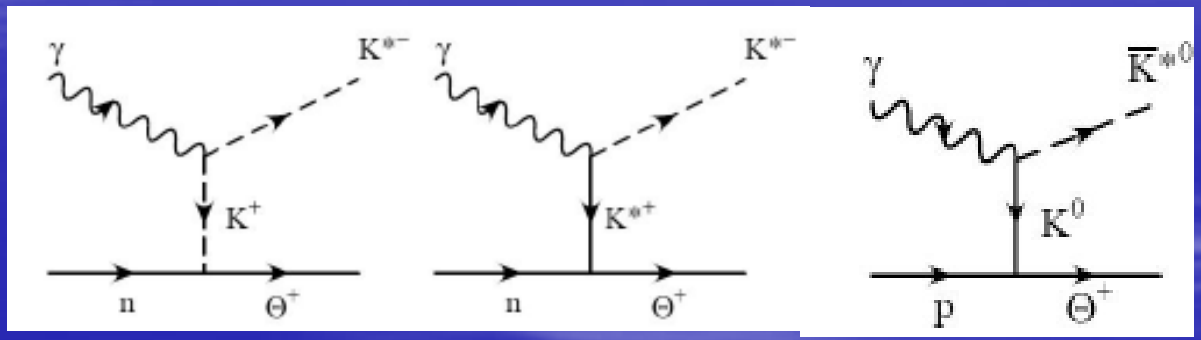
Recent Experimental Setup
Forward + TPC

$\gamma + N \rightarrow \overline{K^*} + \Theta^+$

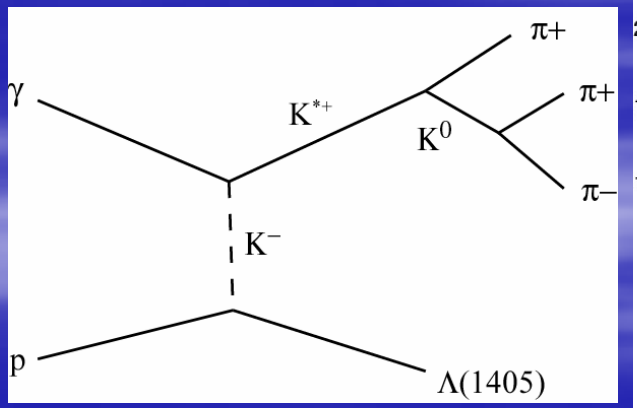
$\hookrightarrow K^0\, p$

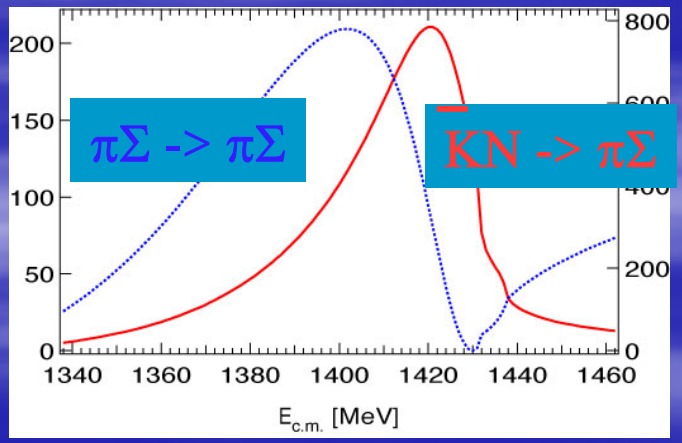
$\hookrightarrow K^+\, n$

$\hookrightarrow K\ \pi$



$\gamma p \rightarrow K^* \Lambda(1405)$

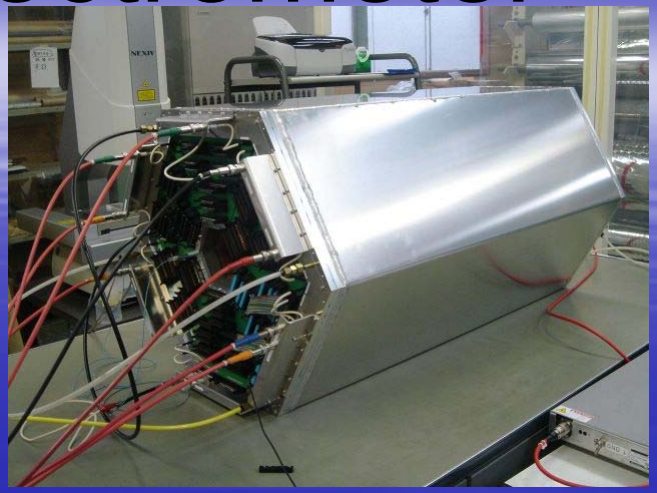


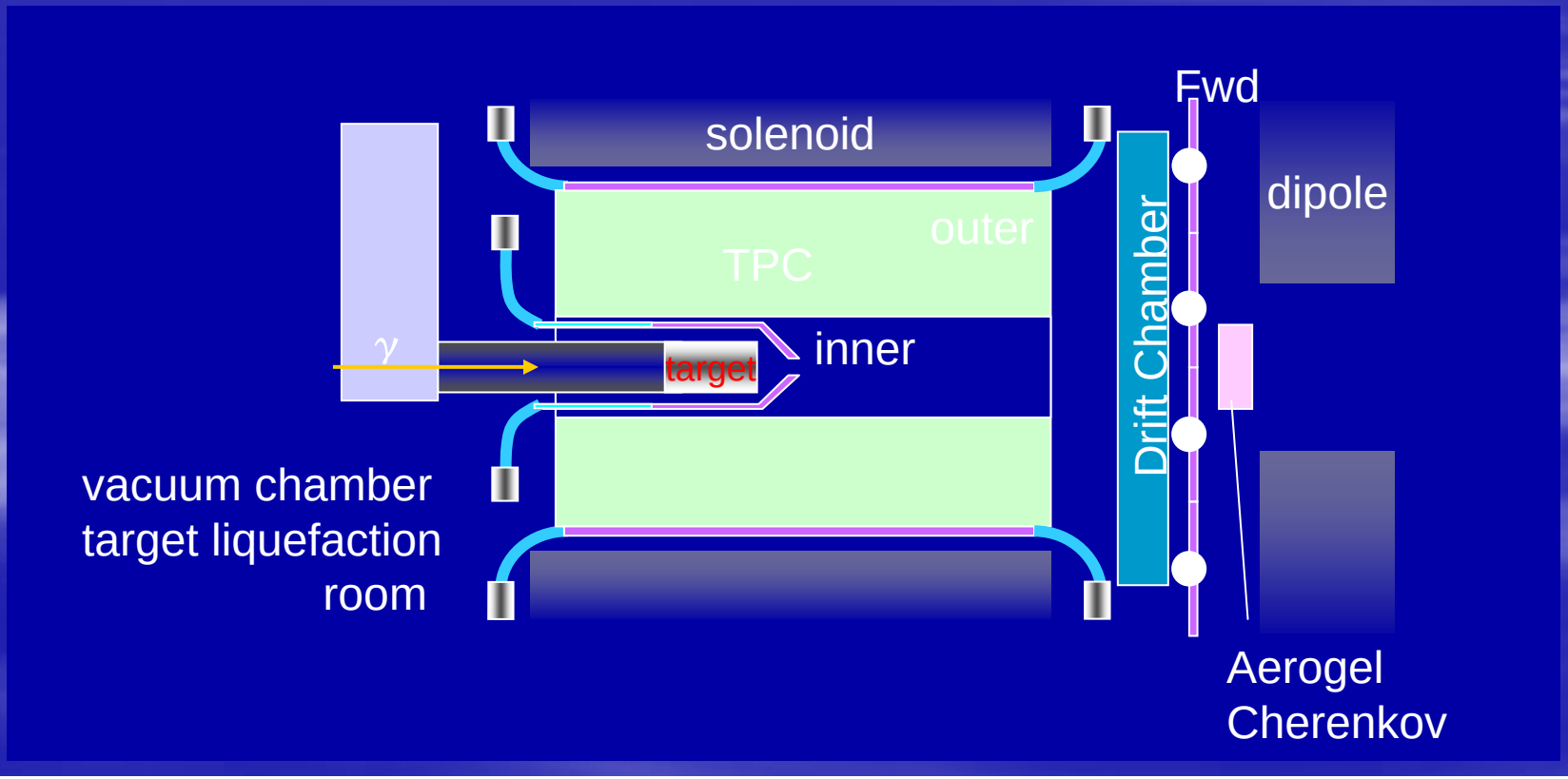


Jido-Oller-Oset-Ramos-Meissner,
Nucl.Phys.A725:181-200,2003: nucl-th/0303062

TPC + Forward spectrometer

A TPC(Time Projection Chamber) is installed with a superconducting solenoidal Magnet (~ 2 T) and Liquid target





Time Projection Chamber

Field cage

Drift voltage = **12.1kV/75cm**
P10 gas(Ar90% CH4 10%)

→ Drift Velocity ～**52mm/μs**

Pad xy postion

size : **5.1mm x 14.5mm**

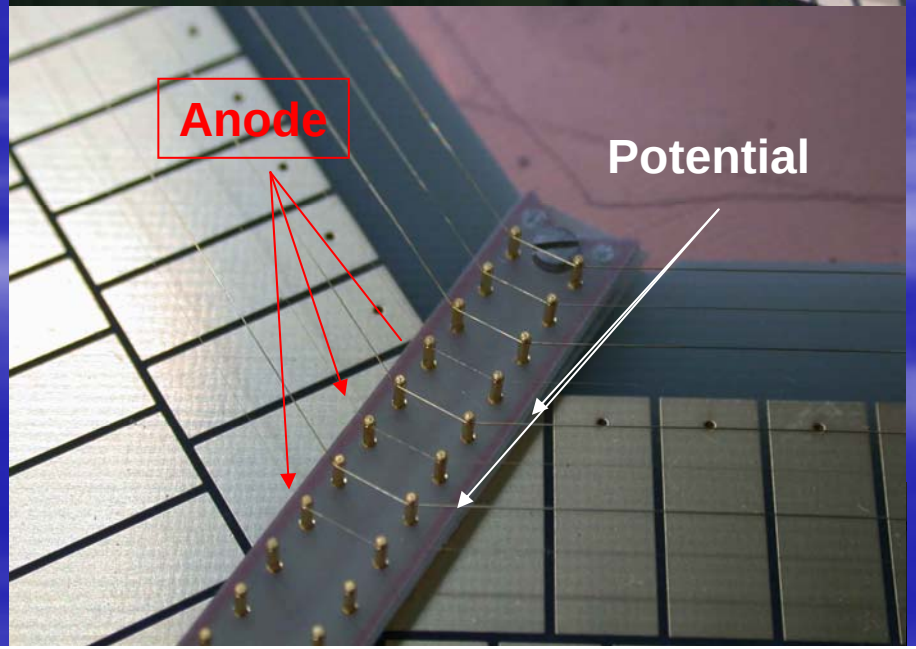
225pads/ 1sector

gate wire

shield

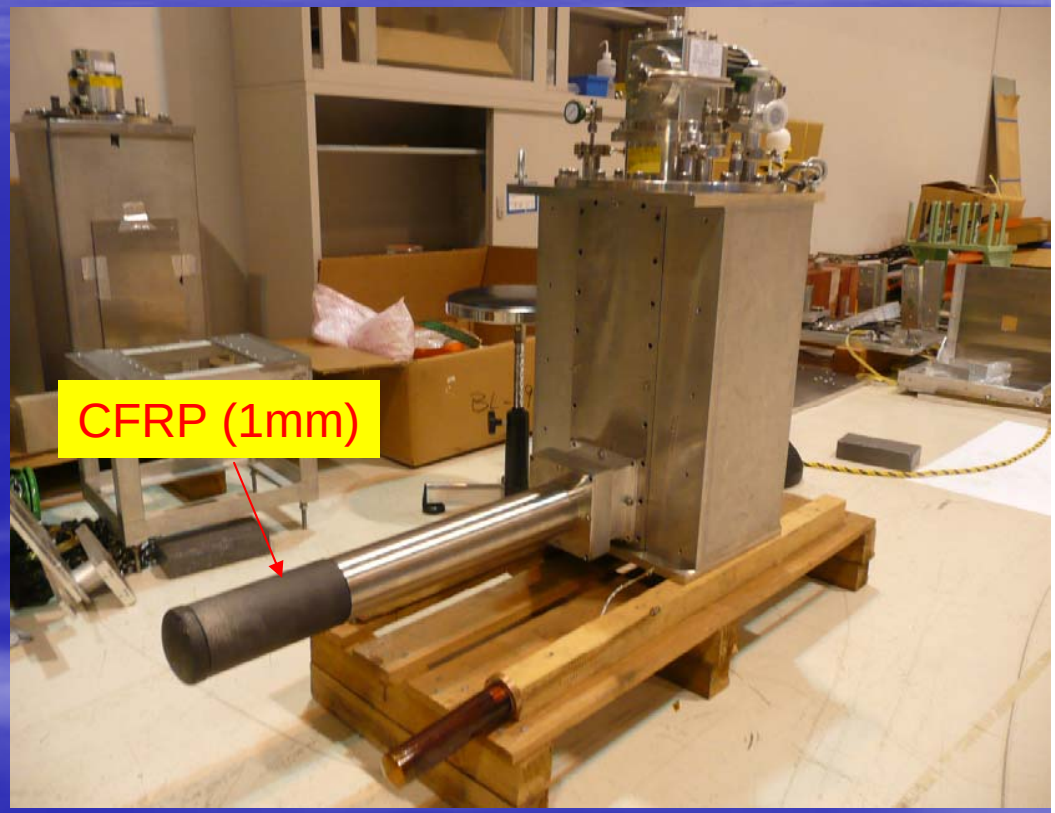
anode/potential

Position resolution **200μm**

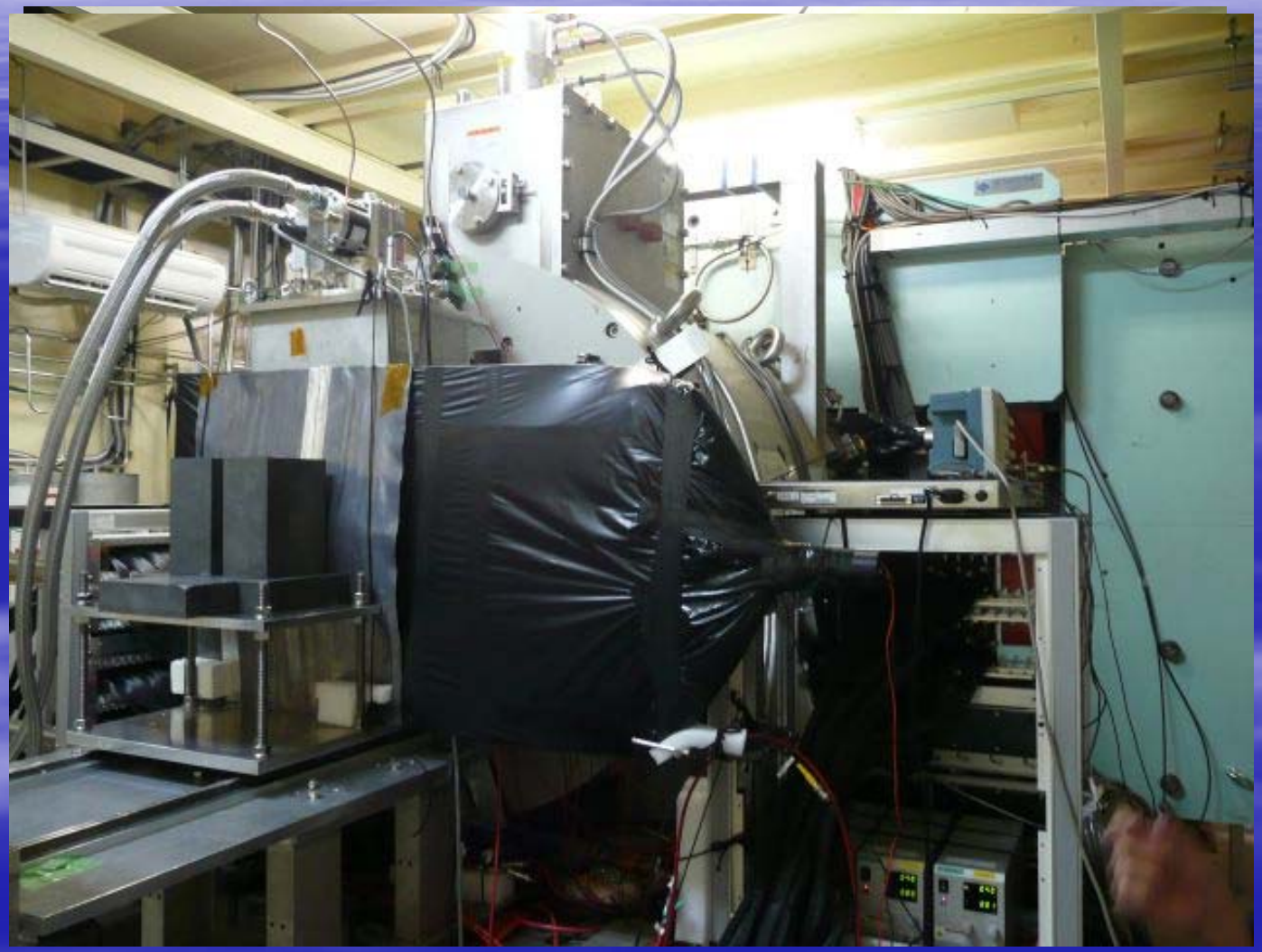


Liquid Target System

- **4 K Cryogenic refrigerator**
  H_2, D_2, ^4He
- **Target cell**
  Kapton foil (125μm thick)
- **Chamber**
  CFRP (1mm thick)



Setup



Set up

Upstream veto counter was replaced with larger one.

Preliminary Analysis

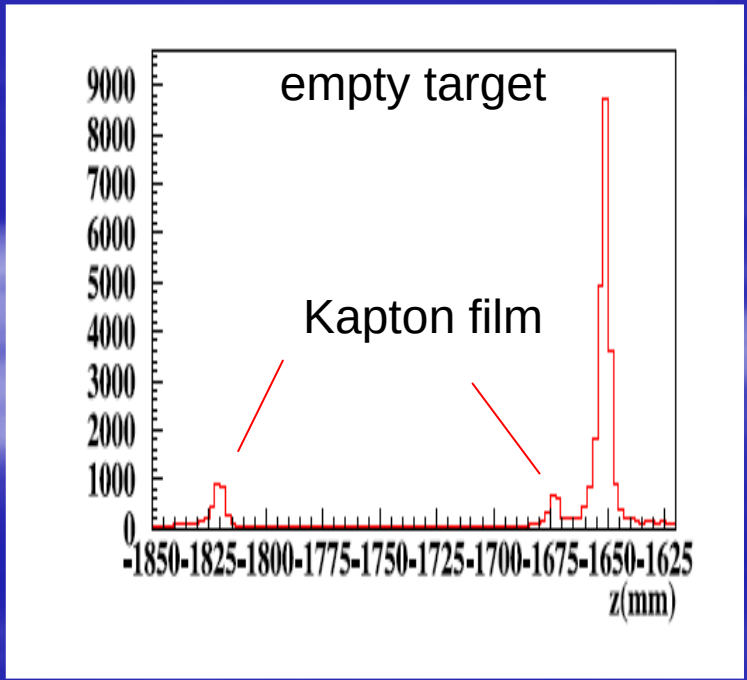
Vertex distribution

Clear shape of LH2 target & CFRP cap

Empty target ➔ peak of Kapton films

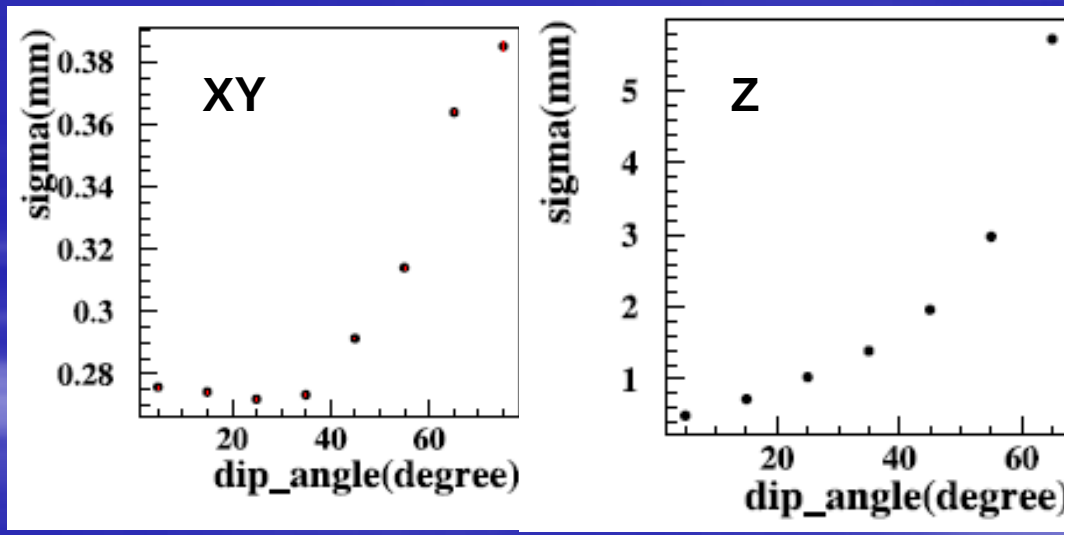
Drift velocity determination

51.53 mm/ μ s



Position Resolution

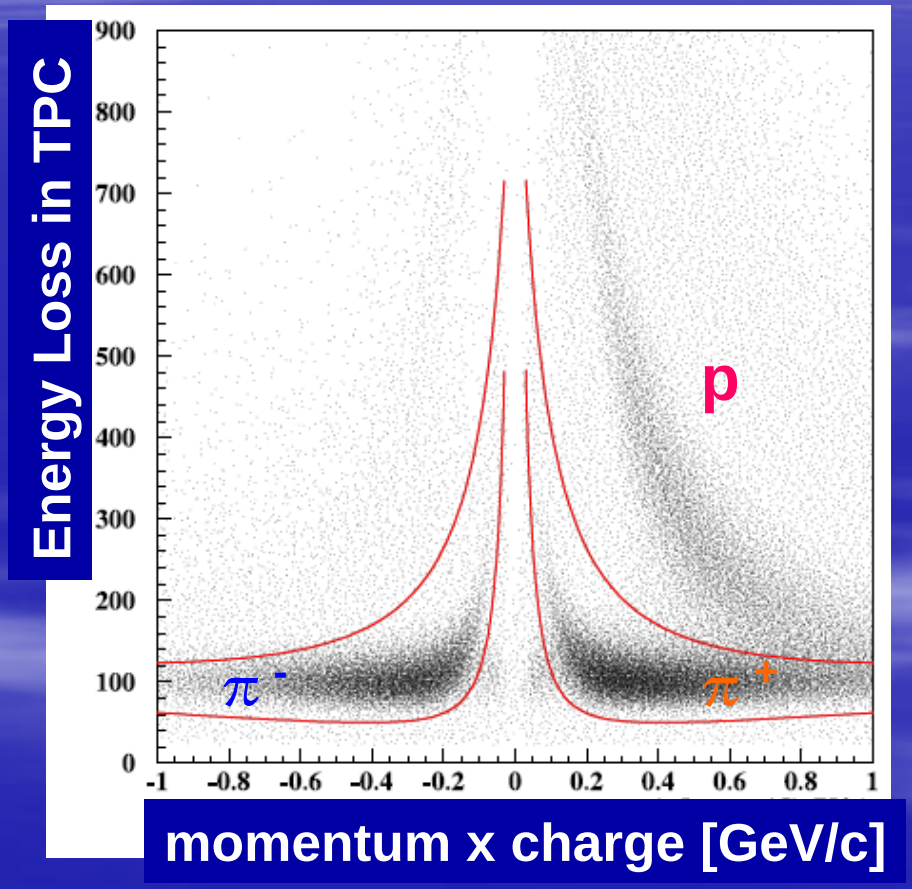
Y position is determined by wire position only and ADC information is not included yet.



Particle identification

- **PID**
  Energy loss, Momentum, charge
  Kaon is not still visible.

Further analysis is in progress



Plans

2008Jan~2008July

Deep UV laser →Maximum Photon energy 3.0 GeV because of K* production
Photon intensity 100kcps

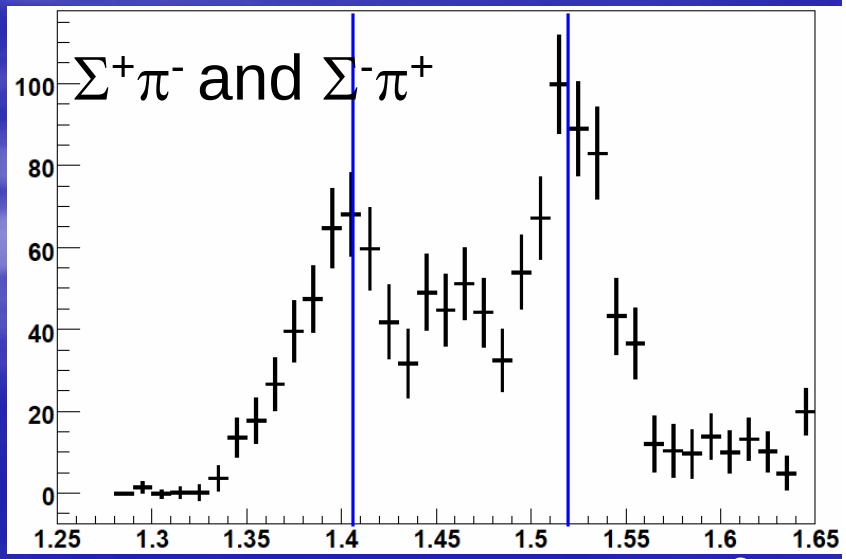
estimated number of $\overline{K^*}$ (γ p→$\overline{K^*}\Theta^+$) detected by NTPC ~ **400**

(assuming σ (γ p→K*Θ+) =**10nb**)

From 2008July

UV Laser → 1Mcps But maximum

- H_2
  $\gamma p \rightarrow K^+\Lambda(1405) \rightarrow K+ (\Sigma\pi)$
- D_2
  $\gamma n \rightarrow K^+\theta^+$



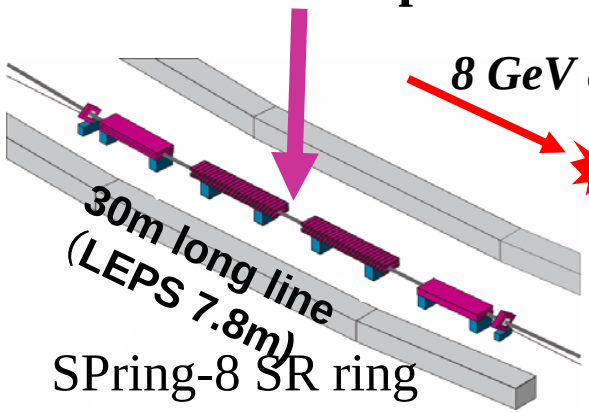
Missing mass *p* (γ, K^+) (GeV/c^2)

New beam line project (LEPS2)

- **Higher intensity and energy photon beam**
- **General purposed detector**
  - **Large acceptance**
  - **Detection for neutral particles**

New Beamline Project at SPring-8

Backward Compton Scattering

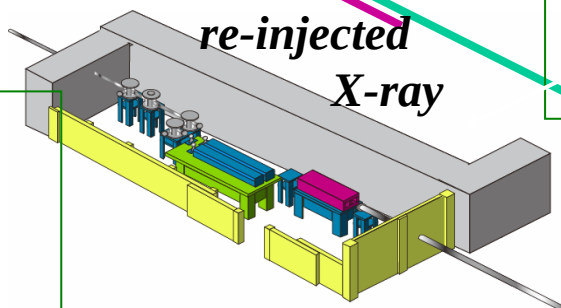


SPring-8 SR ring

8 GeV electron

Recoil electron (Tagging)

Laser or re-injected X-ray



Laser hutch

High intensity :

Multi (ex. 4) laser injection w/ large aperture beam-line & Laser beam shaping

~10 ^{7} photons/s (LEPS ~10 ^{6})

High energy :

Re-injection of X-ray from undulator

Eγ < 7.5GeV (LEPS < 3GeV)

BL31ID:

Better divergence beam

⇒better tagger resolution

⇒collimated photon beam

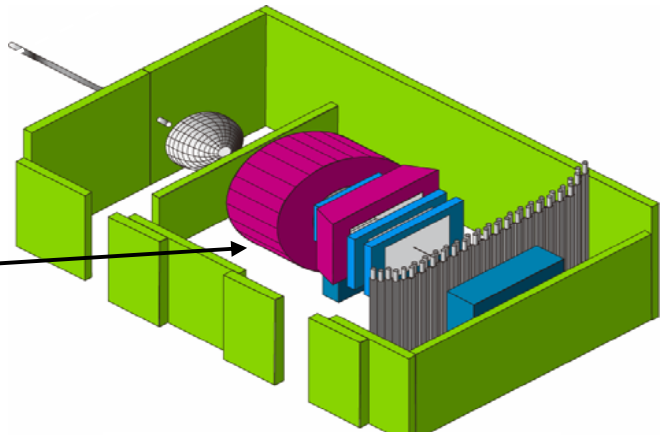
Inside building

Outside building

Large 4π spectrometer

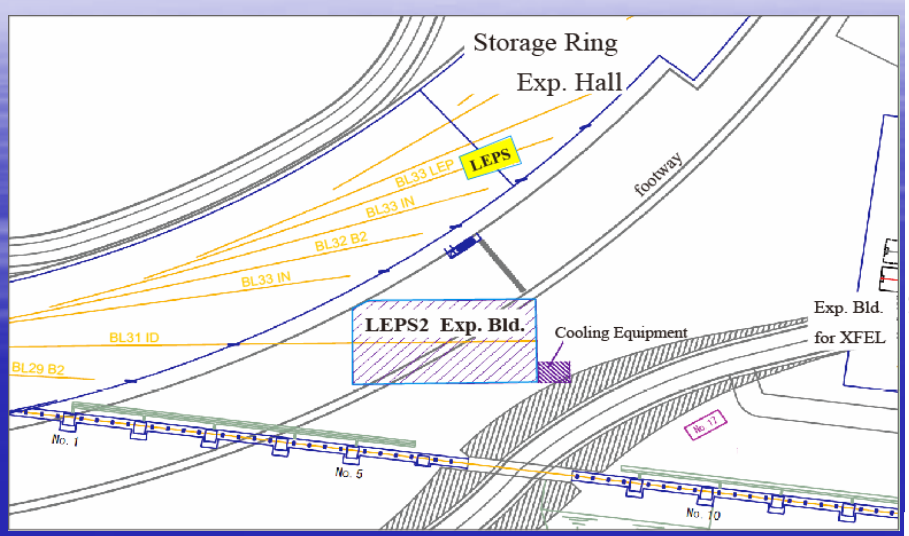
Better resolutions in θ^{lab}>10°.

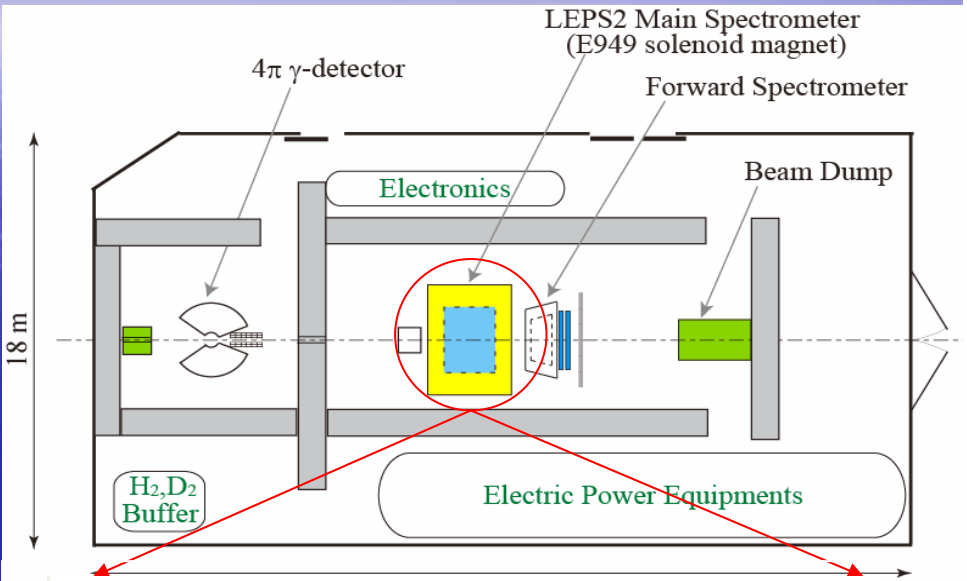
Simultaneous photon detection.

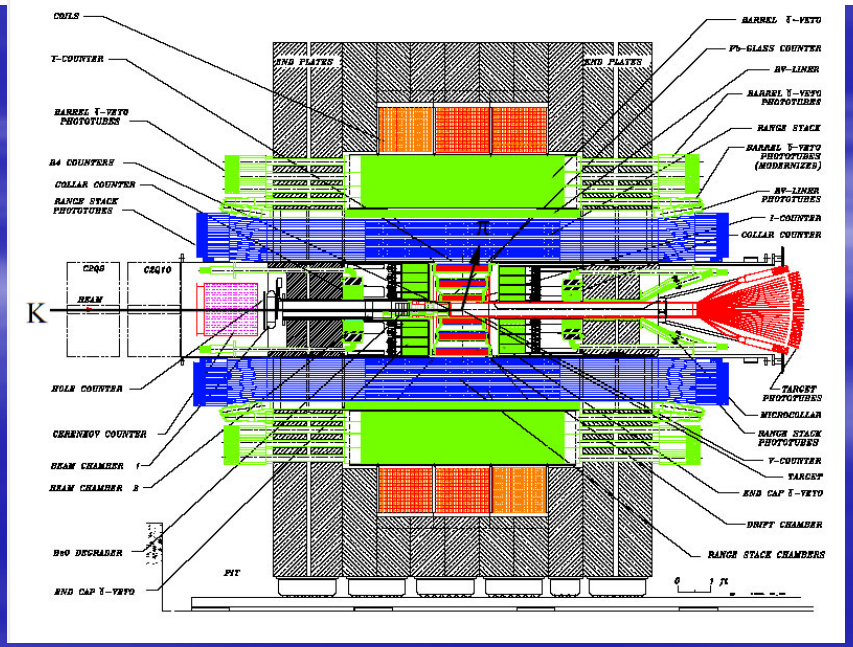


Experimental hutch

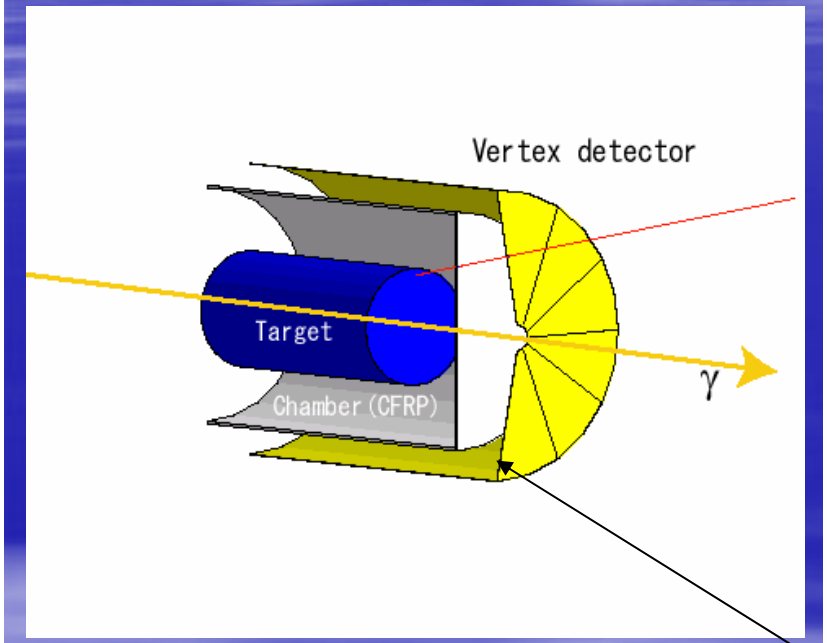
Experimental building for LEPS2

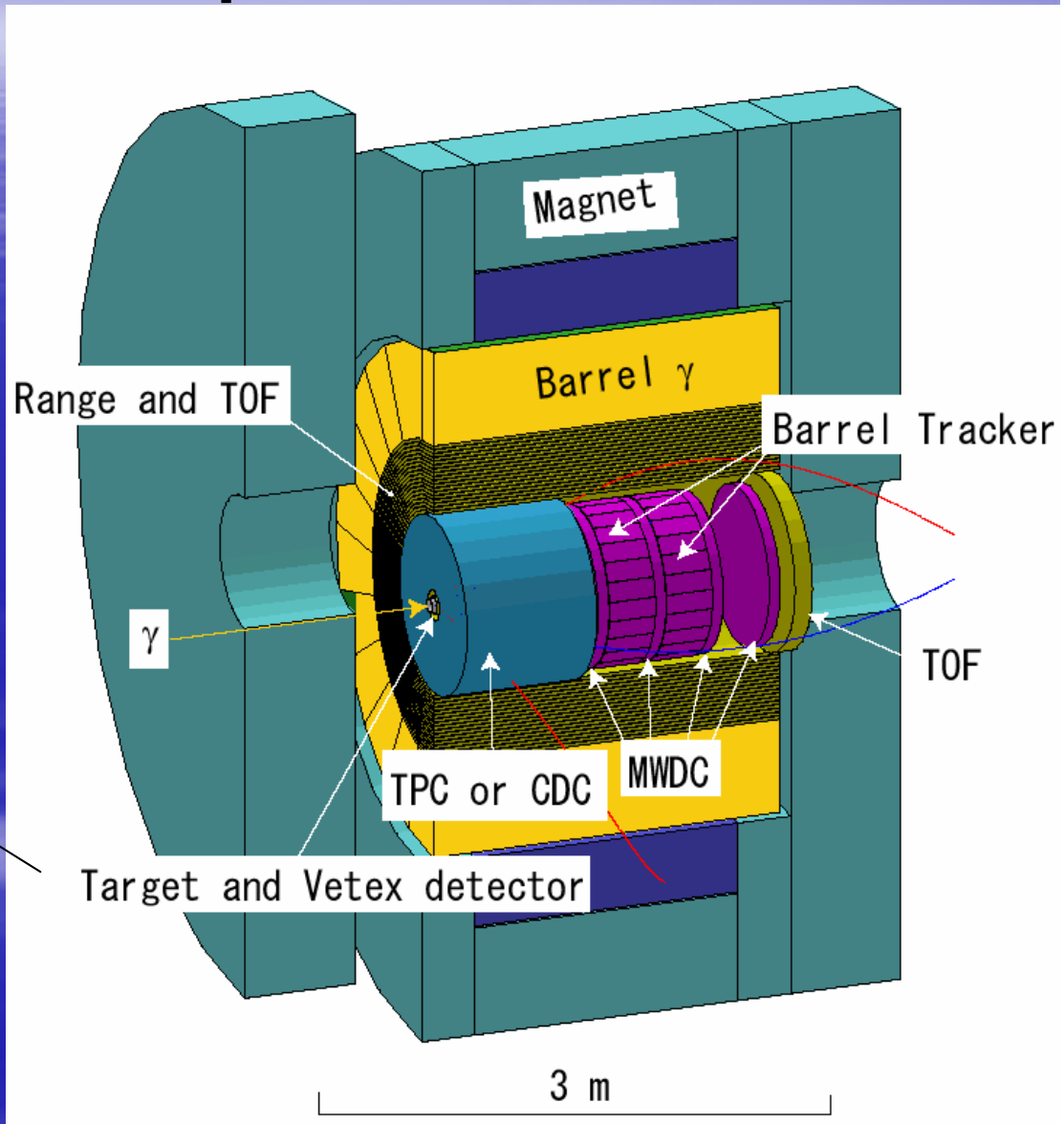






Setup





Virtual laboratory http://www.hadron.jp

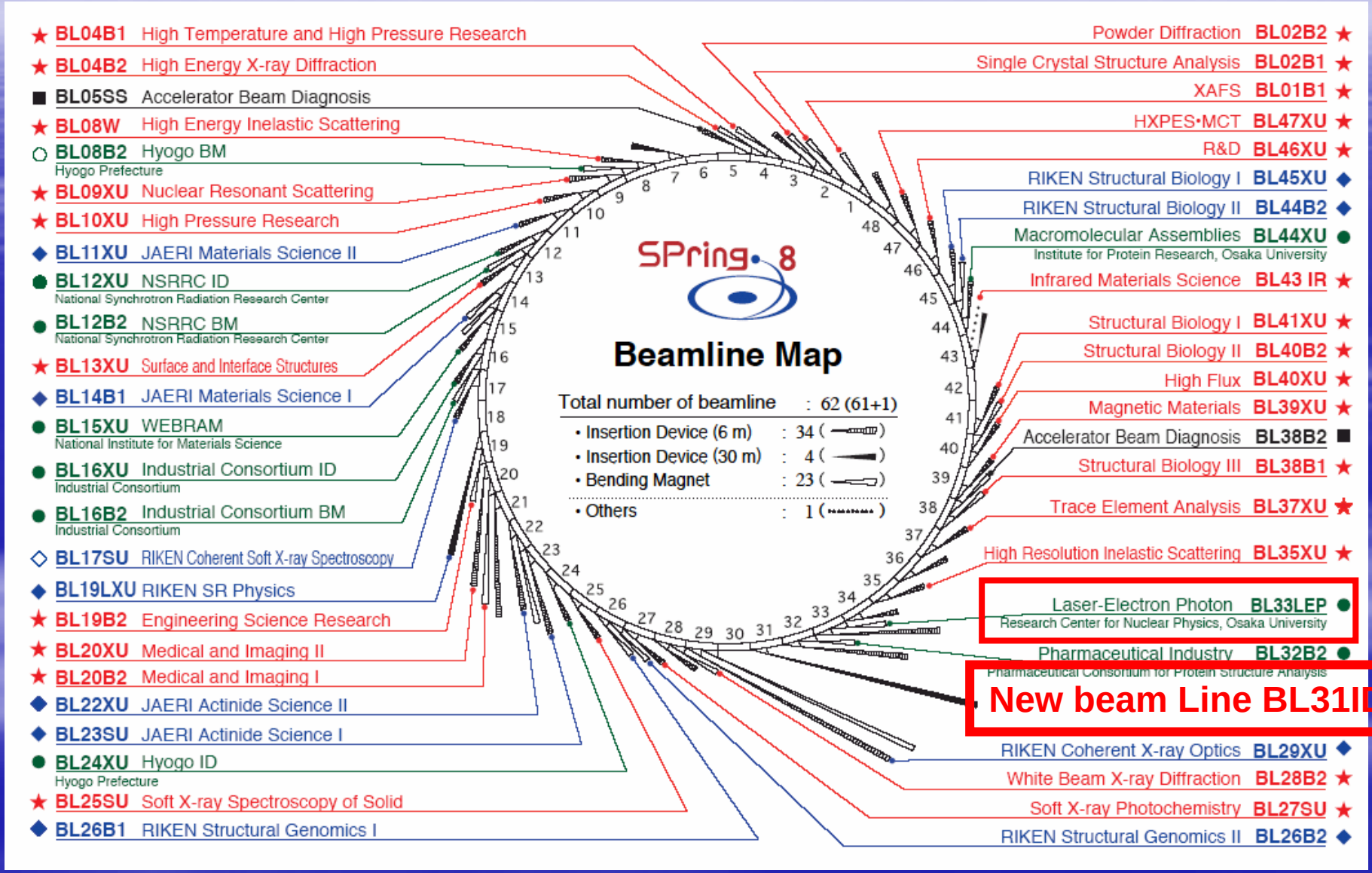
Summary

- Since 2001 LEPS experiment has been operated and is unique tool to study hadron structure and interaction using polarized photon beam.
- Several analyses are in progress and the results will appear soon.
- TPC and new Liquid target system enable one to detect charged particle at larger angle. Simultaneous measurements of forward particles and decayed particle become possible and give more clear insight to study the production mechanism and structure of hadrons.
- We hope that the new beam line project is approved.

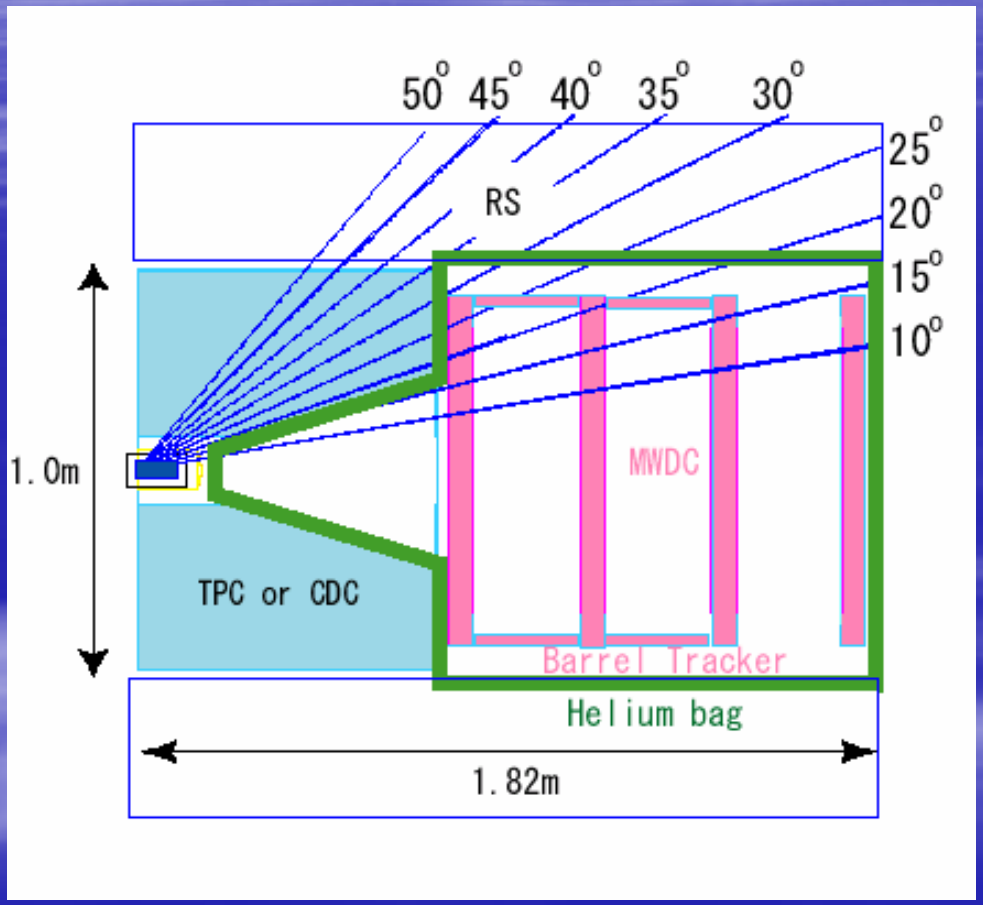
LEPS collaboration

D.S. Ahn, J.K. Ahn, H. Akimune, Y. Asano, W.C. Chang, S. Date, H. Ejiri, H. Fujimura, M. Fujiwara, K. Hicks, K. Horie, T. Hotta, K. Imai, T. Ishikawa, T. Iwata, Y.Kato, H. Kawai, Z.Y. Kim, K. Kino, H. Kohri, N. Kumagai, Y.Maeda, S. Makino, T. Matsumura, N. Matsuoka, T. Mibe, M. Miyabe, Y. Miyachi, M. Morita, N. Muramatsu, T. Nakano, Y. Nakatsugawa, M. Niiyama, M. Nomachi, Y. Ohashi, T. Ooba, H. Ookuma, D. S. Oshuev, C. Rangacharyulu, A. Sakaguchi, T. Sasaki, T. Sawada, P. M. Shagin, Y. Shiino, H. Shimizu, S. Shimizu, Y. Sugaya, M. Sumihama H. Toyokawa, A. Wakai, C.W. Wang, S.C. Wang, K. Yonehara, T. Yorita, M. Yosoi and R.G.T. Zegers,

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


SPring-8
Beamline Map
Total number of beamline : 62 (61+1)
• Insertion Device (6 m) : 34
• Insertion Device (30 m) : 4
• Bending Magnet : 23
• Others : 1
BL04B1 High Temperature and High Pressure Research
BL04B2 High Energy X-ray Diffraction
BL05SS Accelerator Beam Diagnosis
BL08W High Energy Inelastic Scattering
BL08B2 Hyogo BM
Hyogo Prefecture
BL09XU Nuclear Resonant Scattering
BL10XU High Pressure Research
BL11XU JAERI Materials Science II
BL12XU NSRRC ID
National Synchrotron Radiation Research Center
BL12B2 NSRRC BM
National Synchrotron Radiation Research Center
BL13XU Surface and Interface Structures
BL14B1 JAERI Materials Science I
BL15XU WEBRAM
National Institute for Materials Science
BL16XU Industrial Consortium ID
Industrial Consortium
BL16B2 Industrial Consortium BM
Industrial Consortium
BL17SU RIKEN Coherent Soft X-ray Spectroscopy
BL19LXU RIKEN SR Physics
BL19B2 Engineering Science Research
BL20XU Medical and Imaging II
BL20B2 Medical and Imaging I
BL22XU JAERI Actinide Science II
BL23SU JAERI Actinide Science I
BL24XU Hyogo ID
Hyogo Prefecture
BL25SU Soft X-ray Spectroscopy of Solid
BL26B1 RIKEN Structural Genomics I
Powder Diffraction BL02B2
Single Crystal Structure Analysis BL02B1
XAFS BL01B1
HXPES•MCT BL47XU
R&D BL46XU
RIKEN Structural Biology I BL45XU
RIKEN Structural Biology II BL44B2
Macromolecular Assemblies BL44XU
Institute for Protein Research, Osaka University
Infrared Materials Science BL43 IR
Structural Biology I BL41XU
Structural Biology II BL40B2
High Flux BL40XU
Magnetic Materials BL39XU
Accelerator Beam Diagnosis BL38B2
Structural Biology III BL38B1
Trace Element Analysis BL37XU
High Resolution Inelastic Scattering BL35XU
Laser-Electron Photon BL33LEP
Research Center for Nuclear Physics, Osaka University
Pharmaceutical Industry BL32B2
Pharmaceutical Consortium for Protein Structure Analysis
New beam Line BL31ID
RIKEN Coherent X-ray Optics BL29XU
White Beam X-ray Diffraction BL28B2
Soft X-ray Photochemistry BL27SU
RIKEN Structural Genomics II BL26B2

Tracking system



- SSD (Cylindrical+ Corn disk)
  Double side strip or Pixel type
  σ=35um,

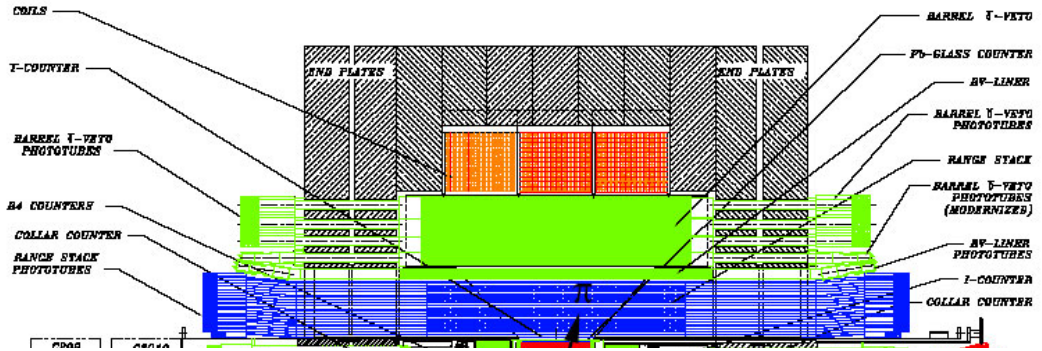
- Forward MWDC chamber
  He4+Ethane,
  R = 450 mm,
  6 wire plane,
  σ_{xy} =150um,
  $X/X_0 = 1.1 \times 10^{-3}$,

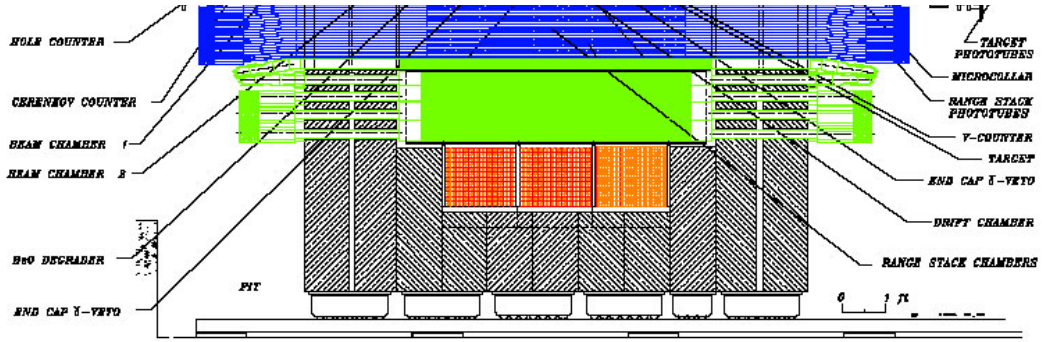
- Barrel tracker
  Cathode strip + Anode wire
  $\sigma_{r\phi}$ = 250um, σ_z = 2-3 mm

- Side way tracker
  TPC or CDC
  R = 500 mm (24-26 layer),
  $\sigma_{r\phi}$ =150um, σ_z =2mm,

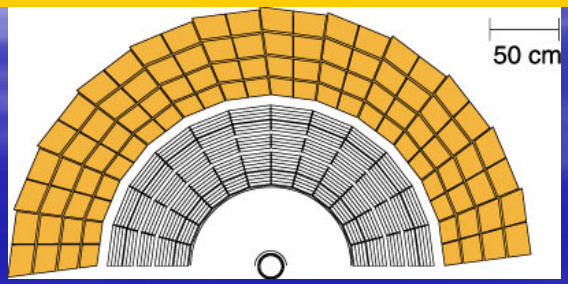
BNL-E949 detector

Designed for $K^+ \rightarrow \pi^+ \nu\nu$



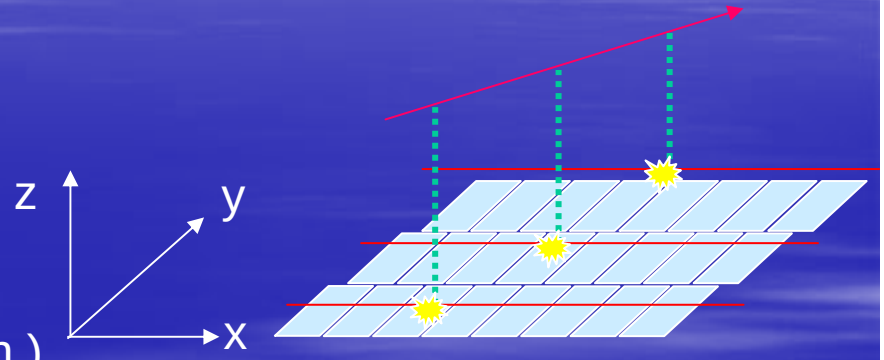


- Solenoid
  1 T
- Inner volume
  2.22x2.96 m
- Barrel Photon detector
  Plastic & lead sandwich detector
  $14.3X_0$
  Energy and position
- Range counter
  Plastic scintillators 19 layers
  Energy and Range

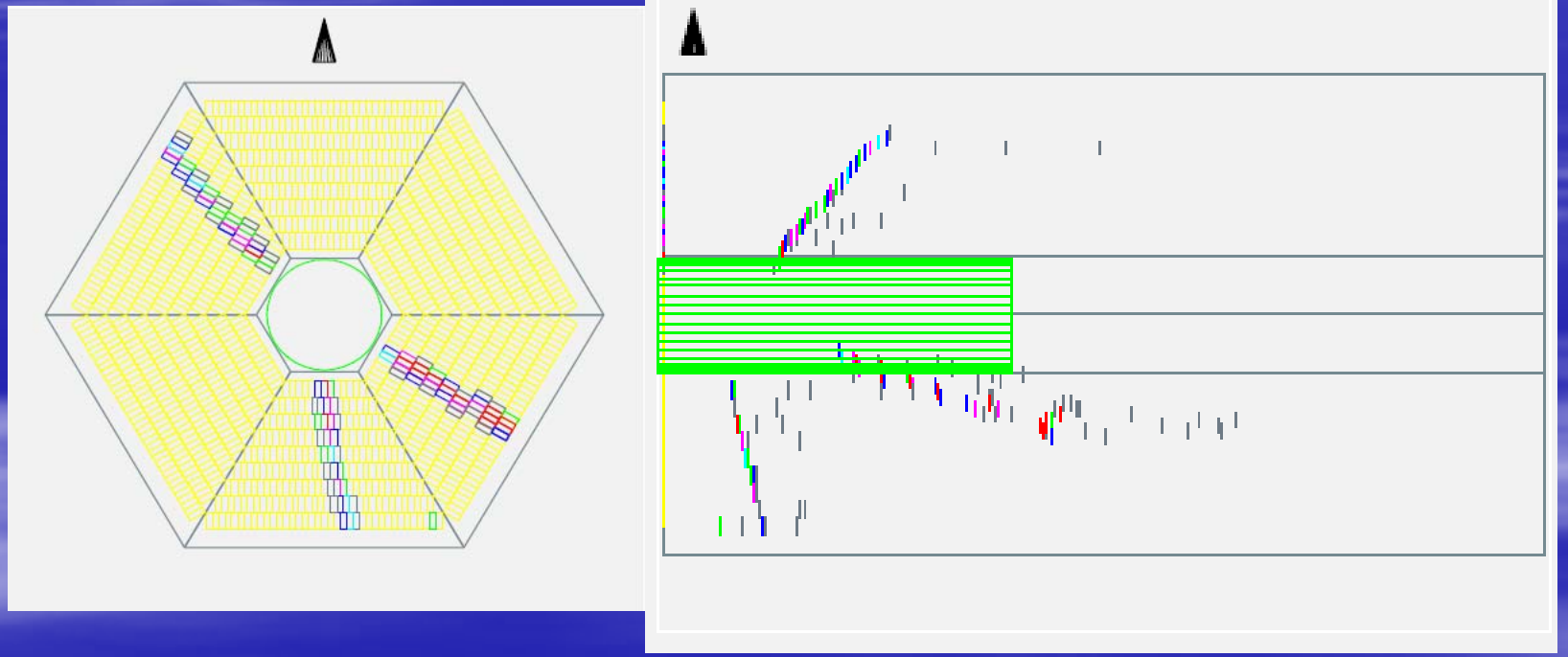


Time Projection Chamber

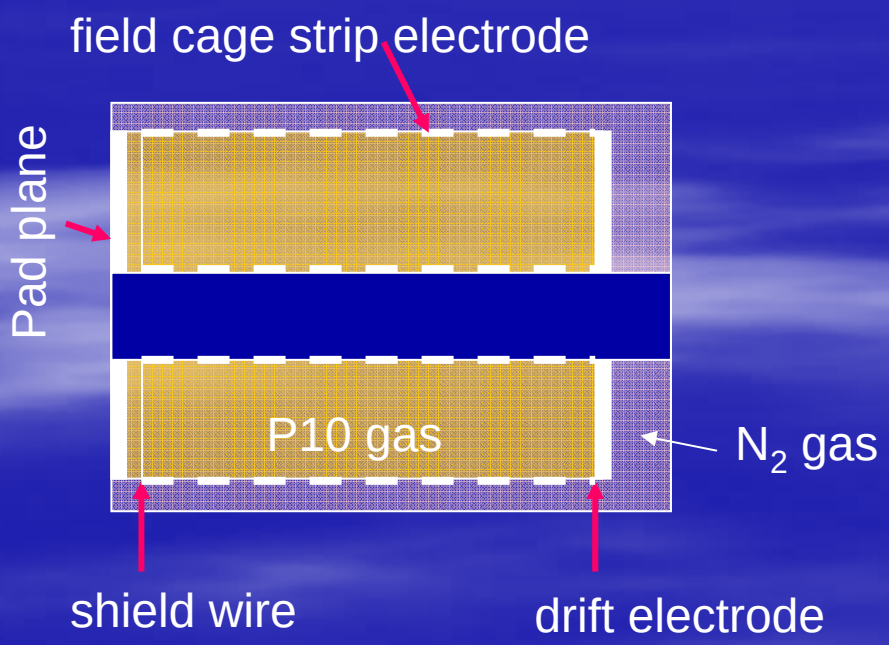
- Operating principle
  - anode wire & cathode pad
  - parallel electric & magnetic field(z direction)
  - induced charge distribution on cathod plane ➔ xy position
  - drift time of ionization electrons ➔ z position

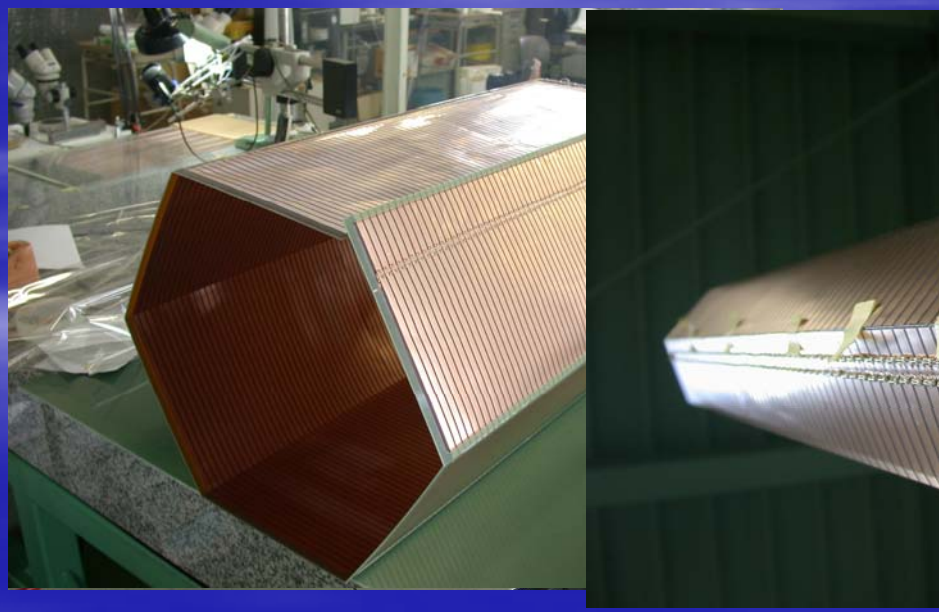


Event Display



- drift region : drift electrode～shield wire= **752mm**
- P10 gas　Ar90% CH_4 10%
- drift velocity　calculation with GARFIELD--- maximum at **160V/cm** (～**52mm/μs**)
  ➔ drift voltage = **12.1kV**
- electric field definition with field cage (strip electrodes)
- Nitrogen gas is used to electrically isolate the field cage from the outer of the TPC.



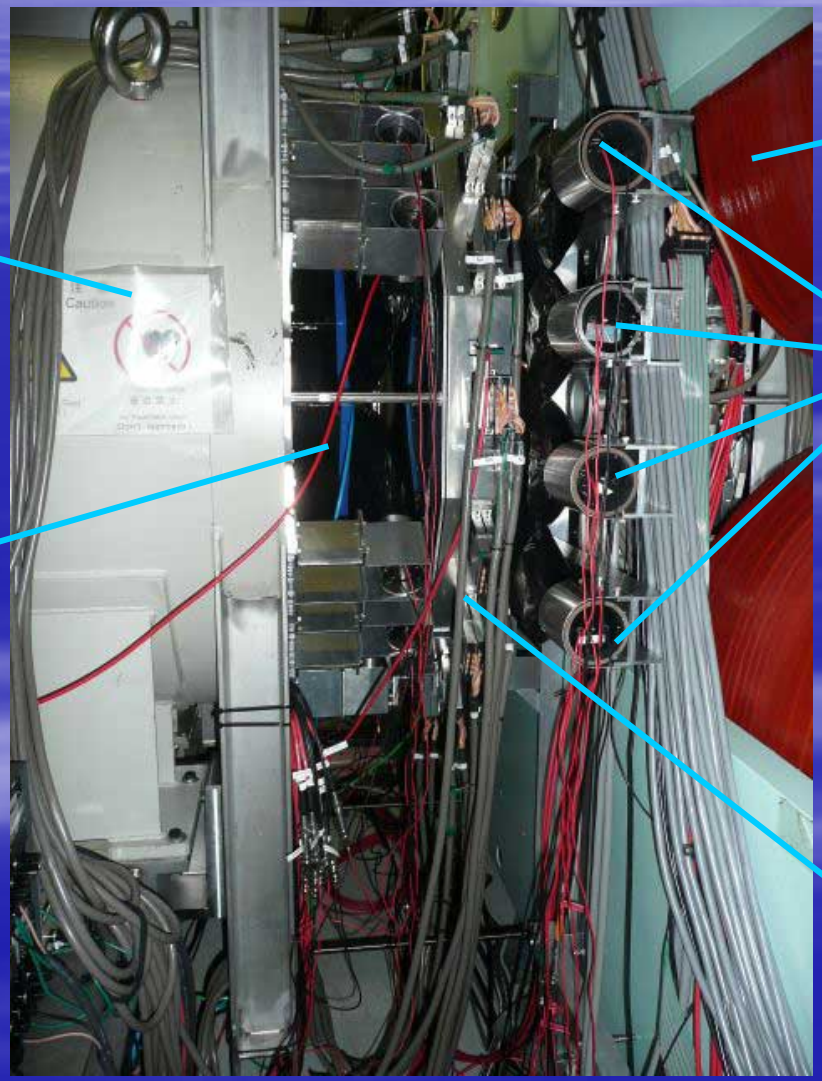


Set up

Upstream veto counter was replaced with larger one.

up

downstream



dipole

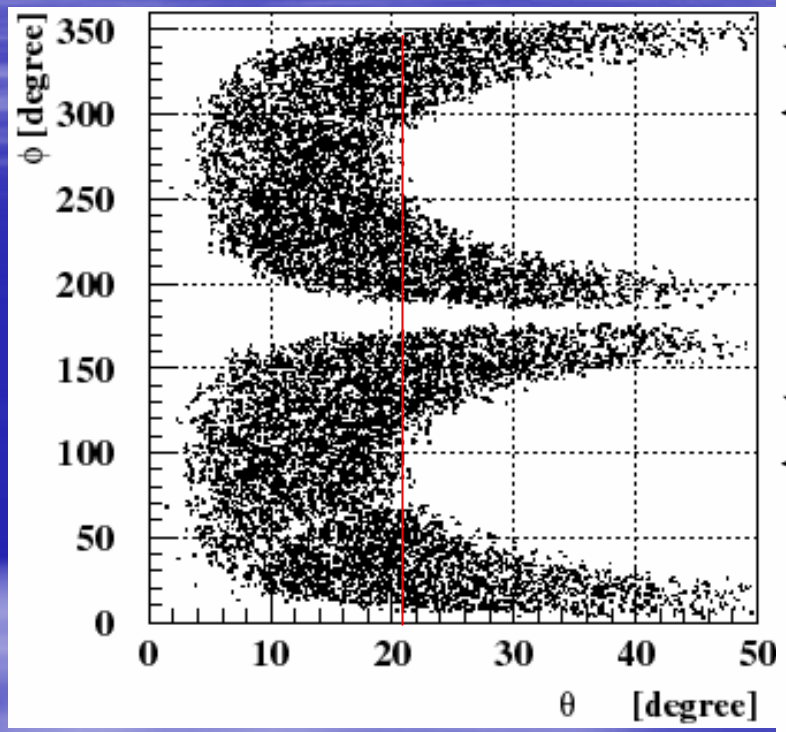
solenoid

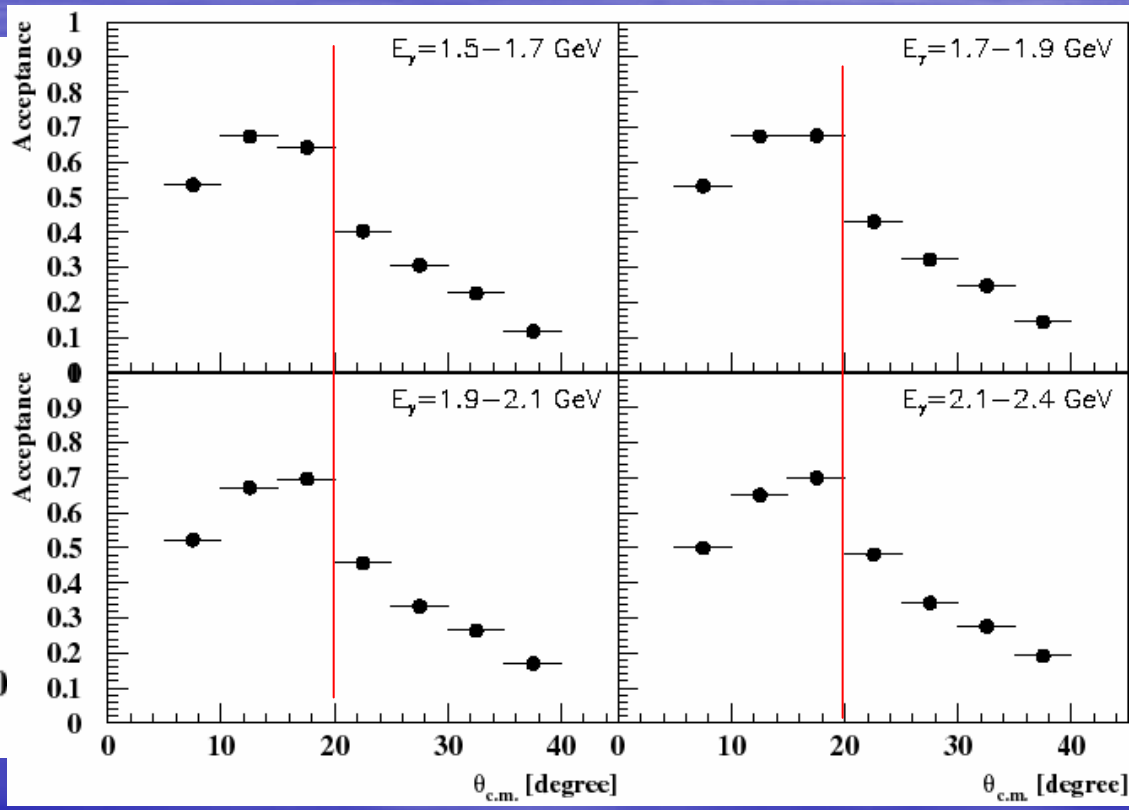
forward scintillator

outer scintillator

drift chamber

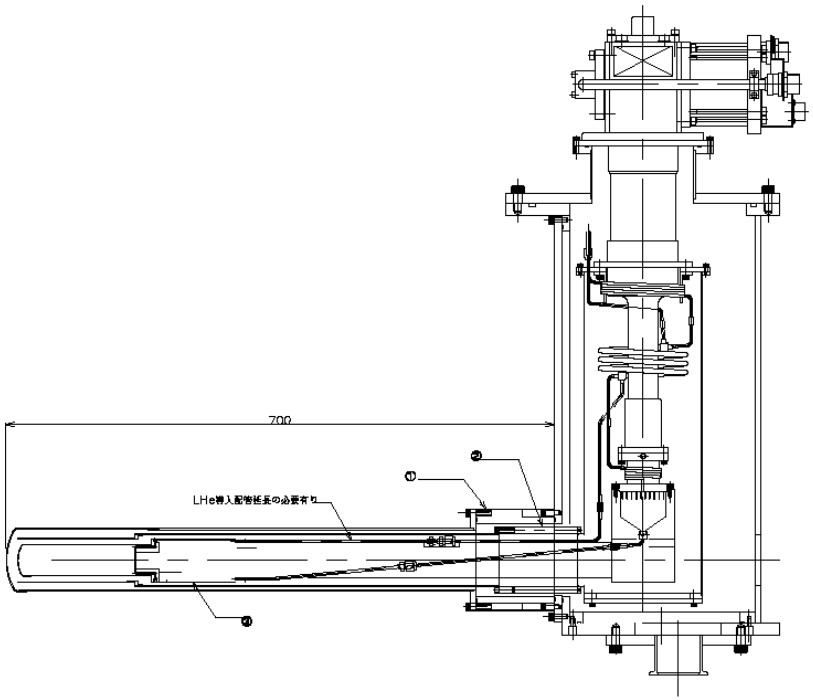
Angular acceptance





Acceptance is mainly determined by ee-blocker and coverage of azimulatual angle

→ well controlled by Monte-Carlo.

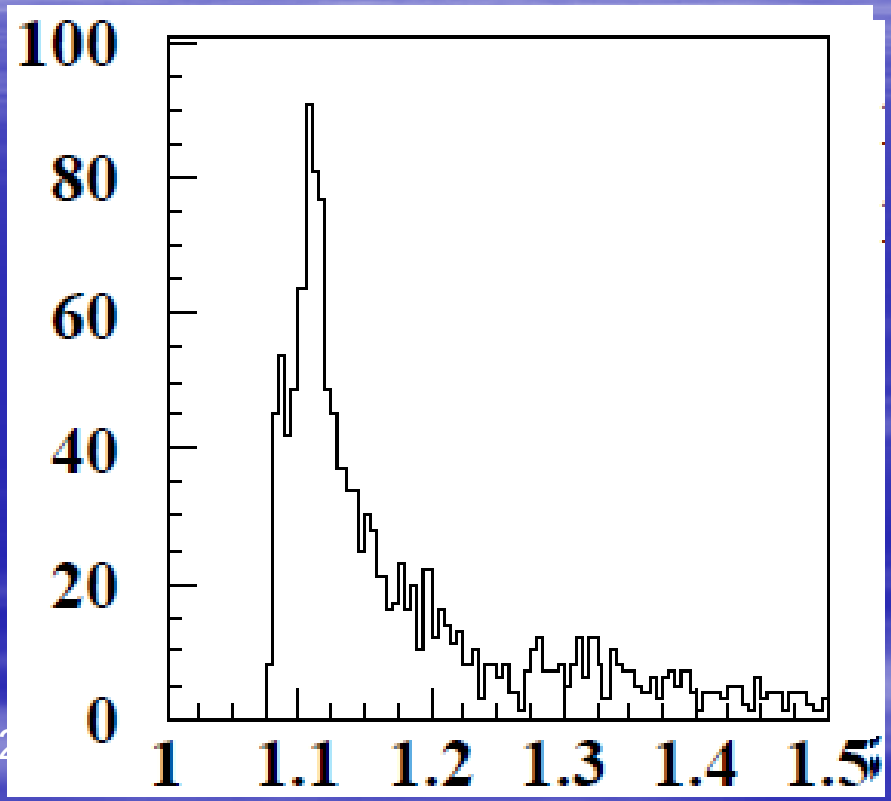

700
LHe導入配管延長の必要有り

Invariant Mass of $p\pi^-$

- M($p\pi^-$) distribution for various cuts of radial distance of vertex

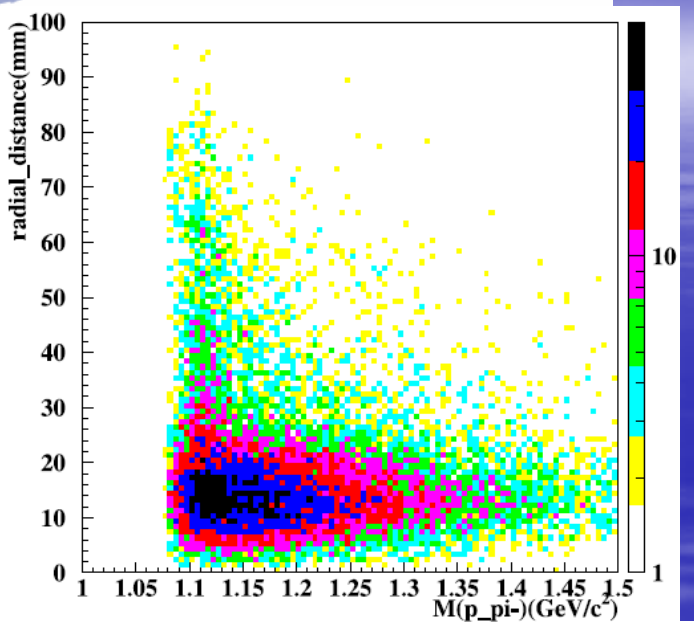
radial distance > **40** mm

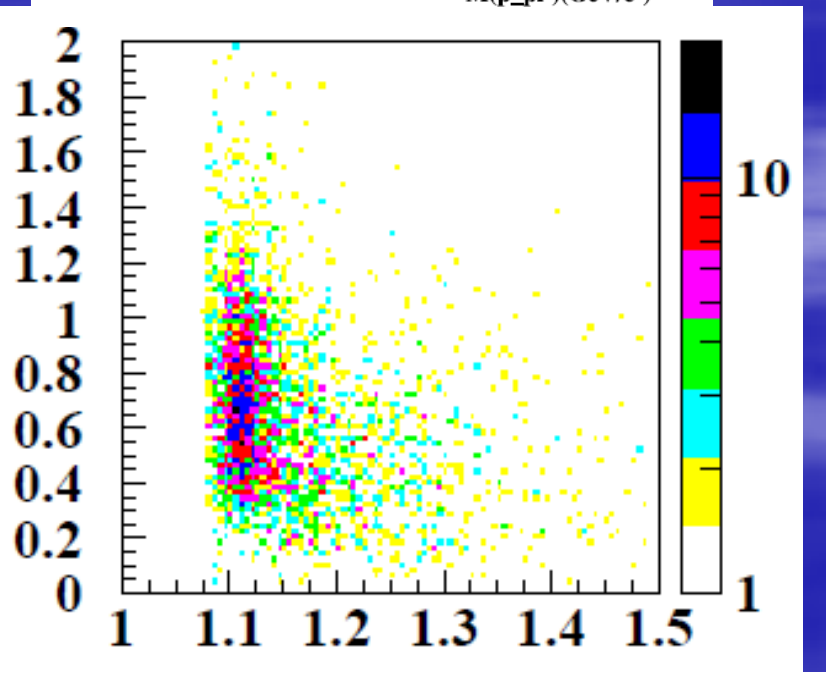
- center of peak = **1.111** $\pm$ 0.001 [GeV/c



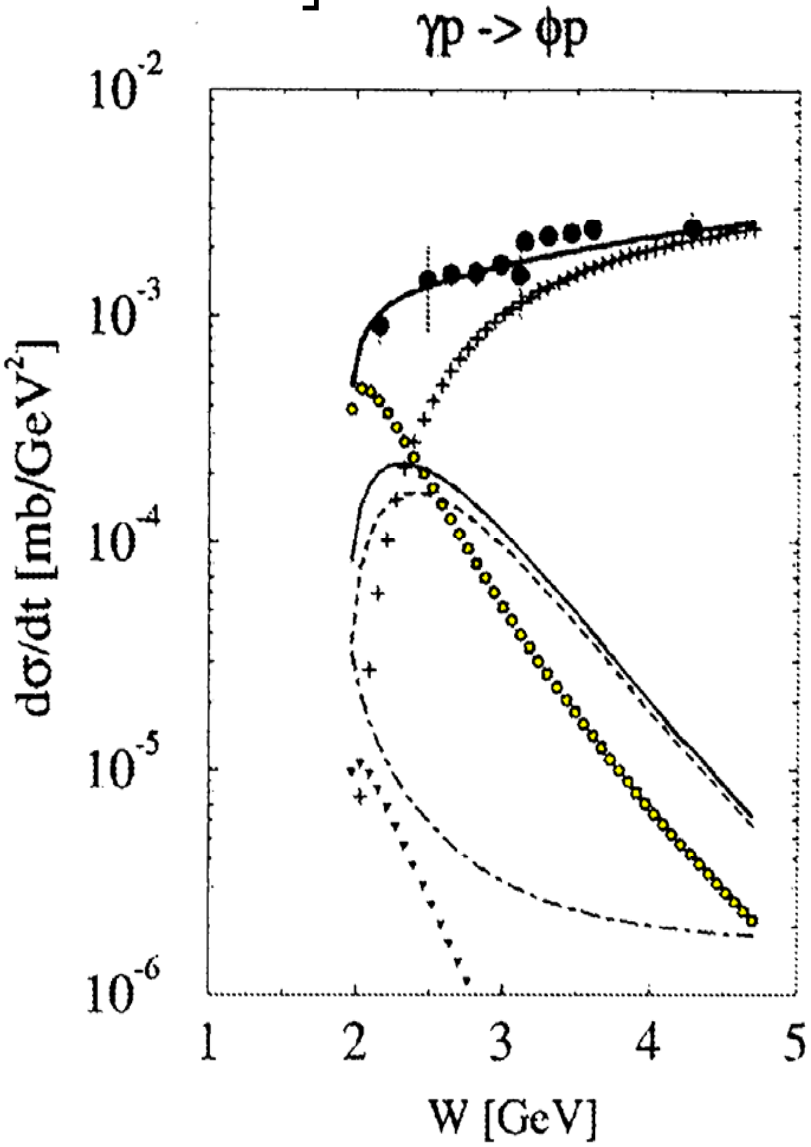
Invariant Mass of $p\pi^-$

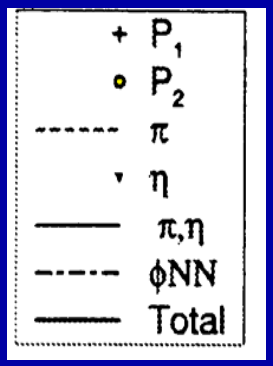
- Can NTPC reconstruct $\Lambda(1116)$?
- Correlation between $M(p\pi^-)$ and radial distance of vertex from the center of the target was checked.
- ・dip angle <65°
- ・closest distance of 2track < 5mm
- radial distance >25mm
  ➔ Locus can be seen around $M(p\pi^-)$~1.11GeV/c²
- various cut of radial distance of vertex (>20mm)





ϕ photoproduction near production threshold





Titov, Lee, Toki
Phys. Rev C59(1999)
2993

Data from: SLAC('73), Bonn('74),DESY('78)

P_2 : 2nd pomeron ~ 0^+ glueball (Nakano, Toki (1998))

Decay asymmetry

$$\Sigma_\phi = \frac{\sigma_{//} - \sigma_\perp}{\sigma_{//} + \sigma_\perp} \cong \frac{\sigma_n - \sigma_{un}}{\sigma_n + \sigma_{un}}$$

helps to disentangle relative contributions

Polarization observables

- **pQCD**
  - **Hadron Helicity consevation**

    $\theta_{cm} \sim 90^{o}$

    Py→0, Cx→0, Cz→1

    Σ→+1 (Isovector)

    →-1 (Isoscalar)
- **Non-pQCD**

  Σ (QGS) = 0.4-0.5 at 2 GeV

  →Isovector and Isoscalar photon coupling

F.Adamian et al EPJ A8,423(2000)