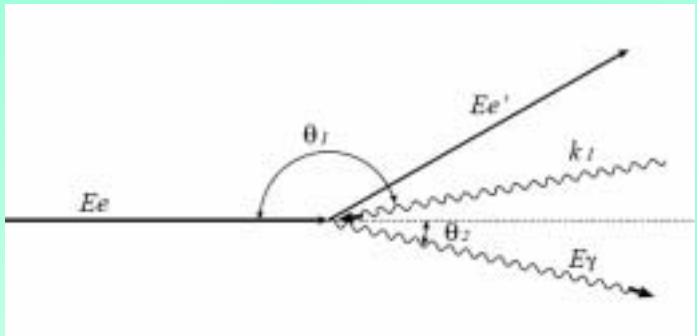
Workshop on LEPS/Spring-8 new beamline

M. Yosoi, RCNP ← Kyoto

- Present LEPS (Laser-Electron Photon at SPring-8) facility
- Some experimental results and the present status
  - photon beam asymmetry for the K^+ photoproduction
  - ϕ meson photoproduction
  - search for pentaquark Θ^+
  - $2\pi^0$, $\pi^0\eta$ photoproductions with a large EM calorimeter
  - Hyperon resonance, $\Lambda(1405)$ with a TPC
- New LEPS project

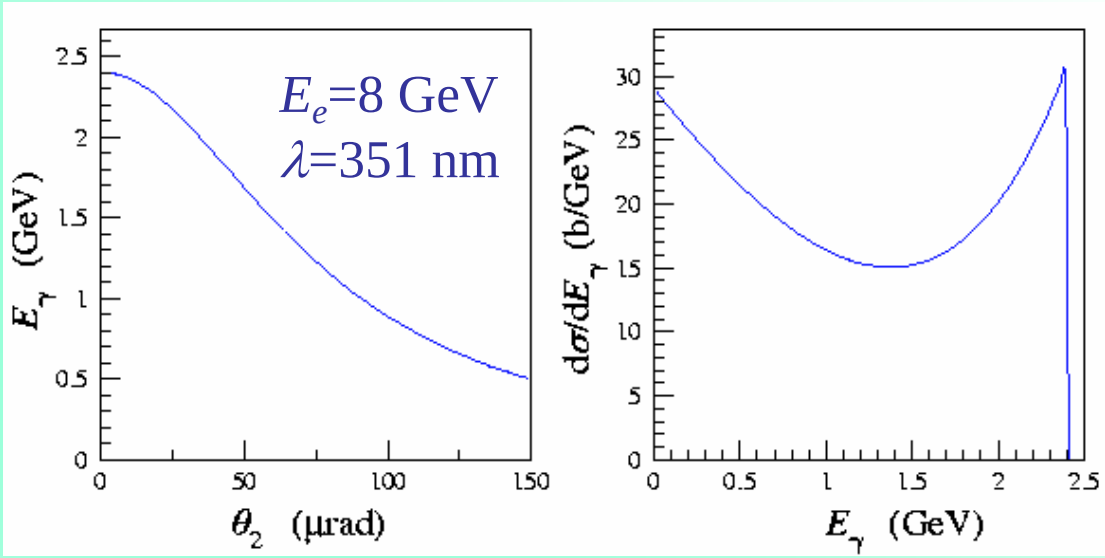
Characteristics of BCS photons

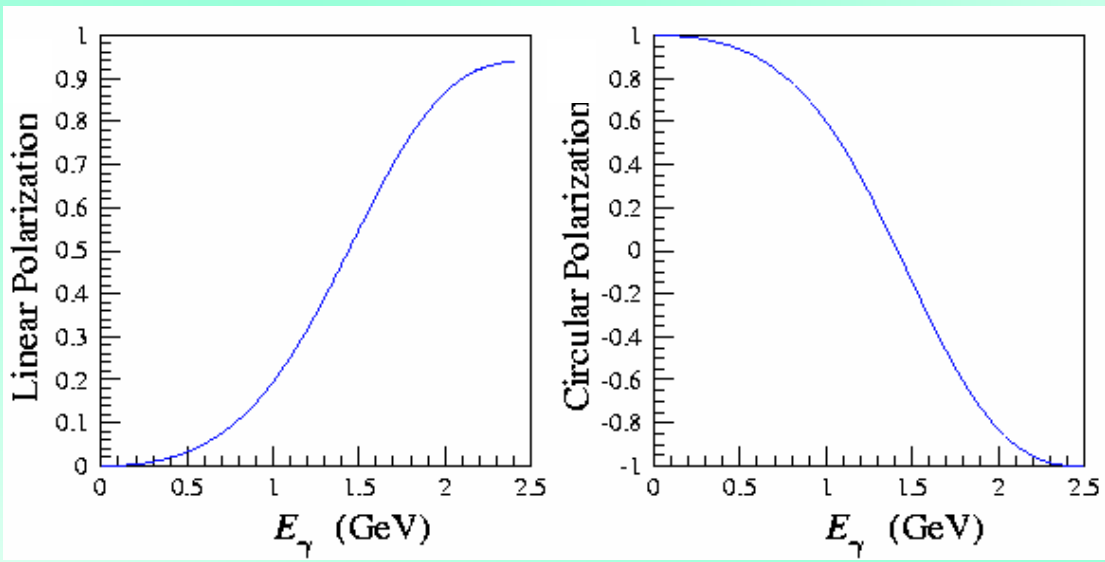
(BCS:Backward Compton Scattering)



- rather flat energy distribution with small spreading

  (Unlike the Bremsstrahlung, where low energy photons are dominated, ~1/E_γ)
- high linear- or circular-polarization
- photon energy can be tagged by recoil electron





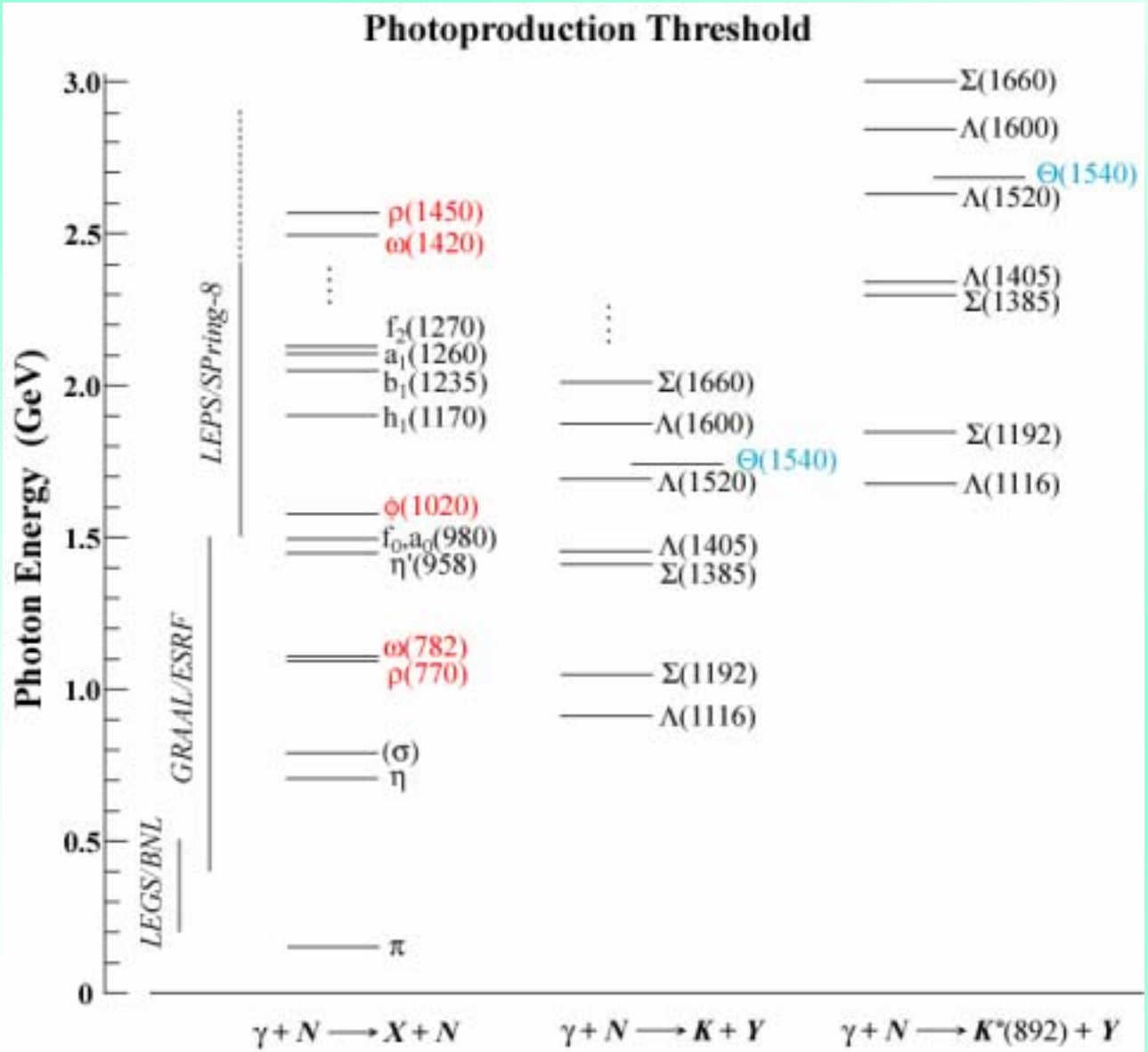
Synchrotron Radiation Rings with laser-backscattering facilities

LEGS@NSLS/BNL
2.8 GeV

GRAAL@ESRF 6 GeV

LEPS@SPring-8 8GeV ~100mA

With LEPS, what can be aimed at ?



Threshold region of $\phi(s\bar{s})$ meson and hyperon resonances

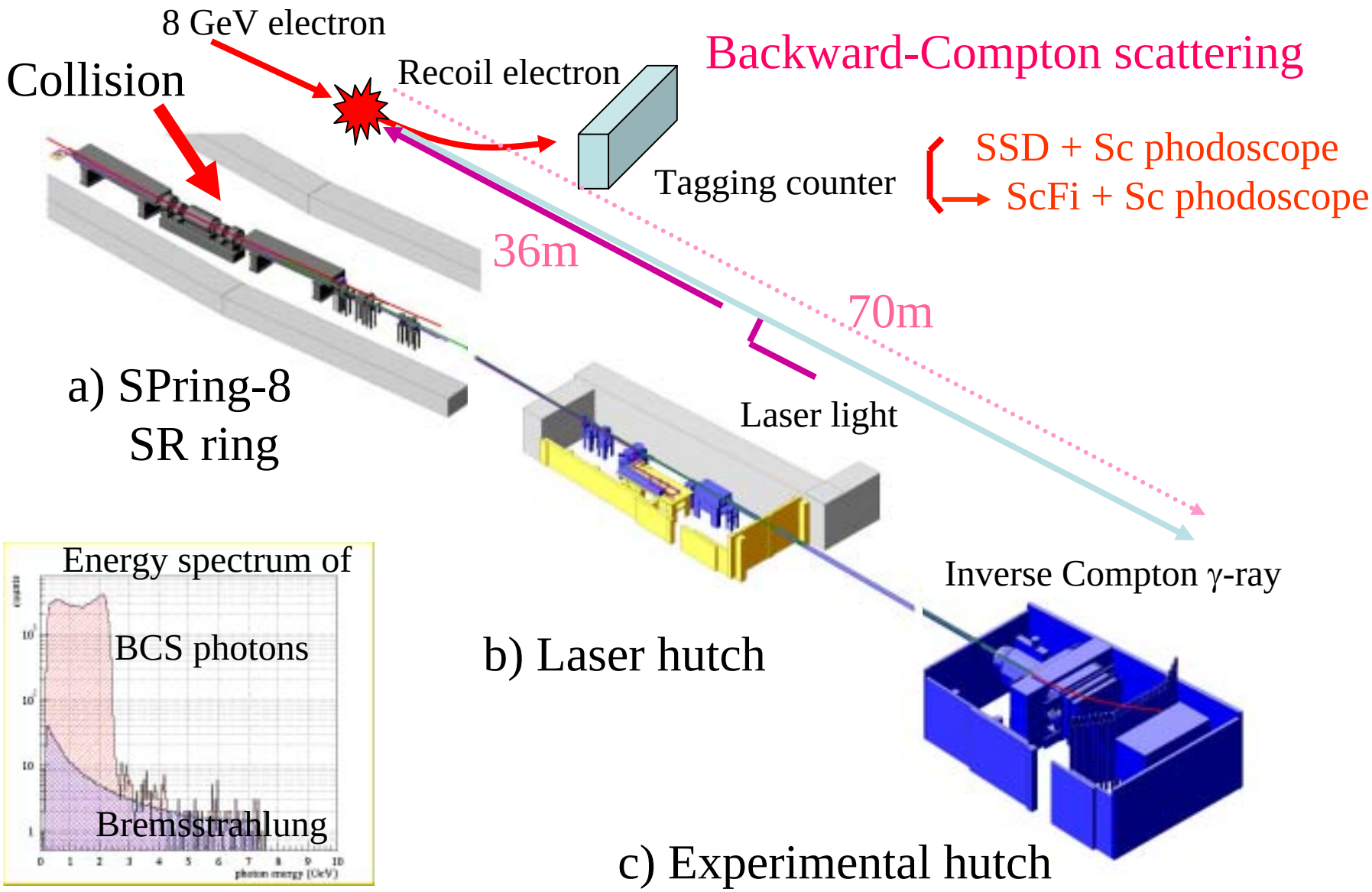
Key words :

1. **Forward angle measurement including 0 deg.**
2. **Polarization observables**
3. **Strangeness**

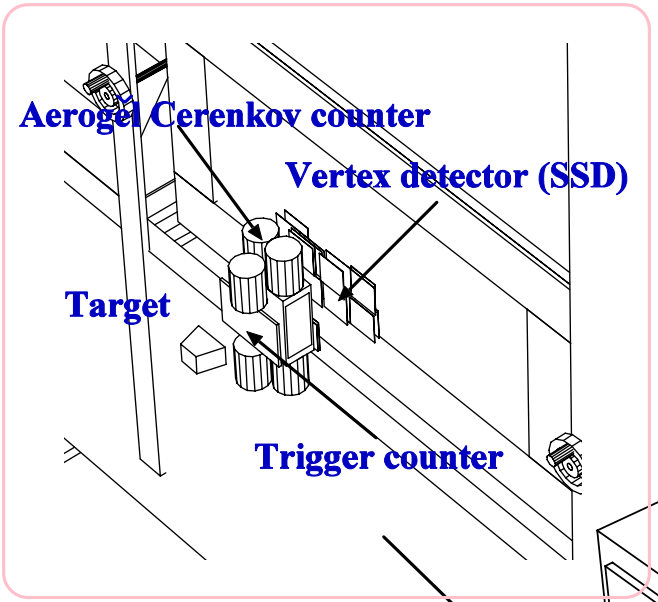
Milestones of Spring-8/LEPS

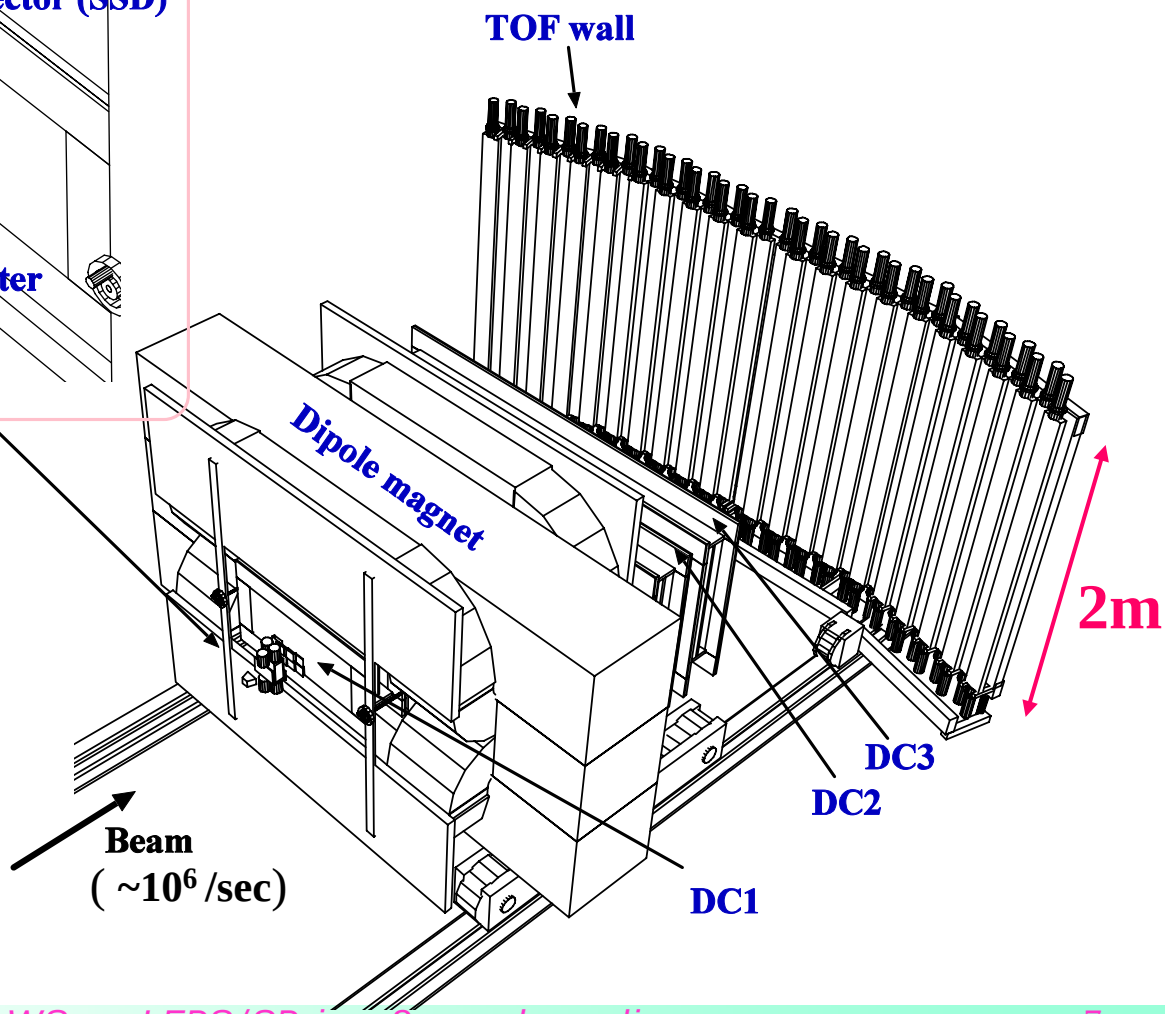
- 1995.7　1st Workshop「GeVレーザー電子光が拓くクォーク核物理」
- 1996.2　レーザー電子光クォーク核物理プロジェクト　(RCNP)
- 1997.3　First SR beam at Spring-8
- 1997.5　Workshop (Quark-Gluon Nuclear Physics with Multi-GeV Laser-Electron Photons)
- 1997.10 Spring-8 共同利用開始
- 1998.5　LEPSプロジェクト採択　(SP8/JASRI + JAERI + RCNP)
- 1999.4　RCNPに流動部門　(**山形大教授、京大助手→** RCNP)
- 1999.7　First laser-electron photon beam
- 2000.3　Complete the LEPS detector system
- 2000.5　Start commissioning
- 2000.10 International Workshop「LEPS2000」
- 2000.12 physics runs with Liq.H_2 target →nuclear target, Liq.D_2 development of EM calorimeter and TPC
- 2002.10 PANIC'02 Θ^+発見の報告　(2003.7 Phys.Rev.Lett.)
- 2004.7　International Workshop「PENTAQUARK 04」

Schematic view of the LEPS facility



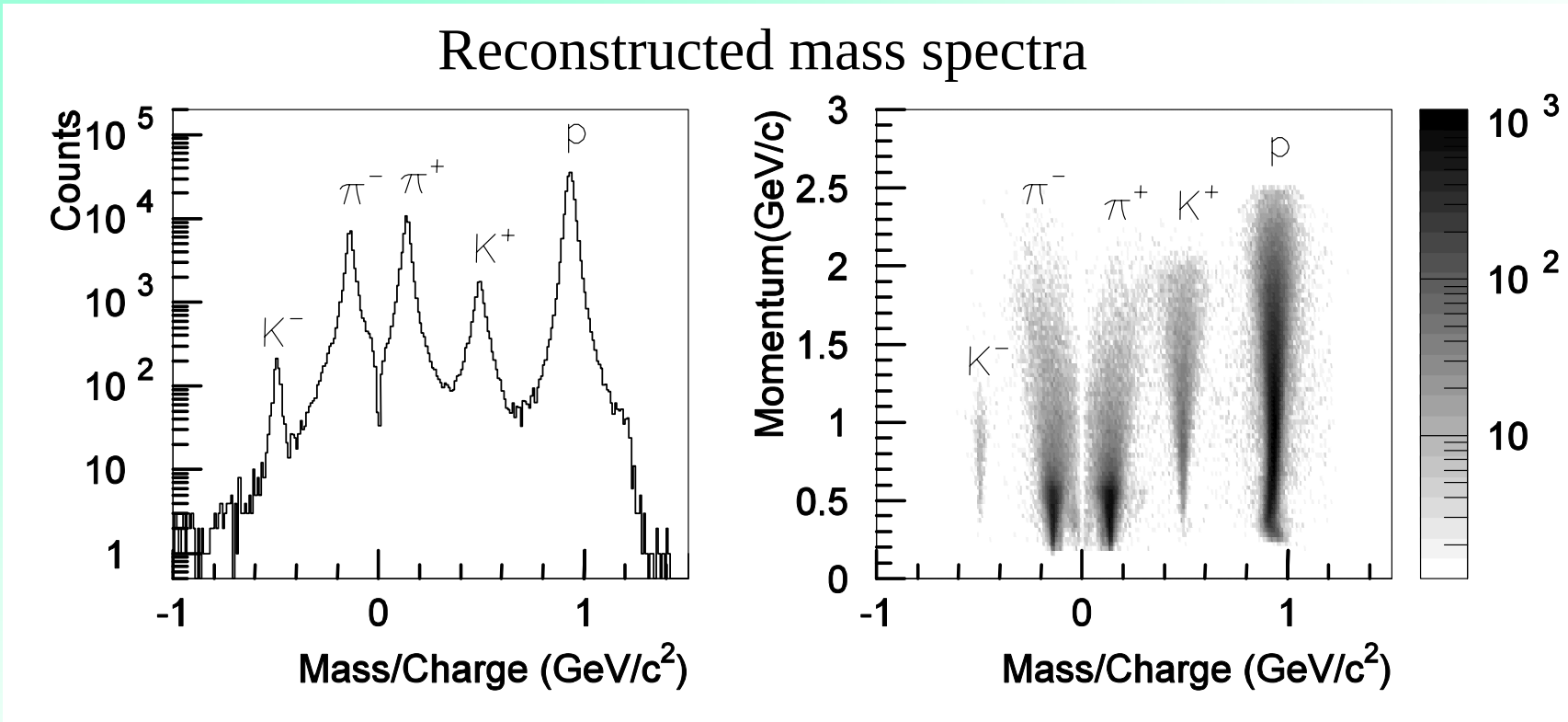
LEPS forward spectrometer





- Target LH_2, LD_2, etc.
- AC index = 1.03
  to reject e^+e^- pairs
- SSD 120μm pitch
- DCs $\sigma \sim 200$ μm
- Magnet 135 x 55 cm^2,
  (35^o x 15^o)
  B = 0.7T

Particle identification



- TOF : RF signal - TOF wall, Δt = 120 ps
- Momentum : SSD, DCs, Tracking

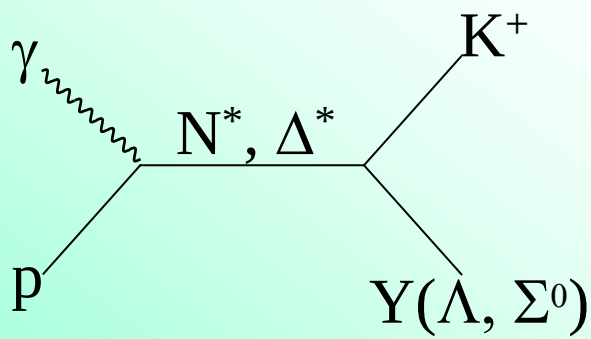
  Δp ~ 6 MeV/c for 1 GeV/c K

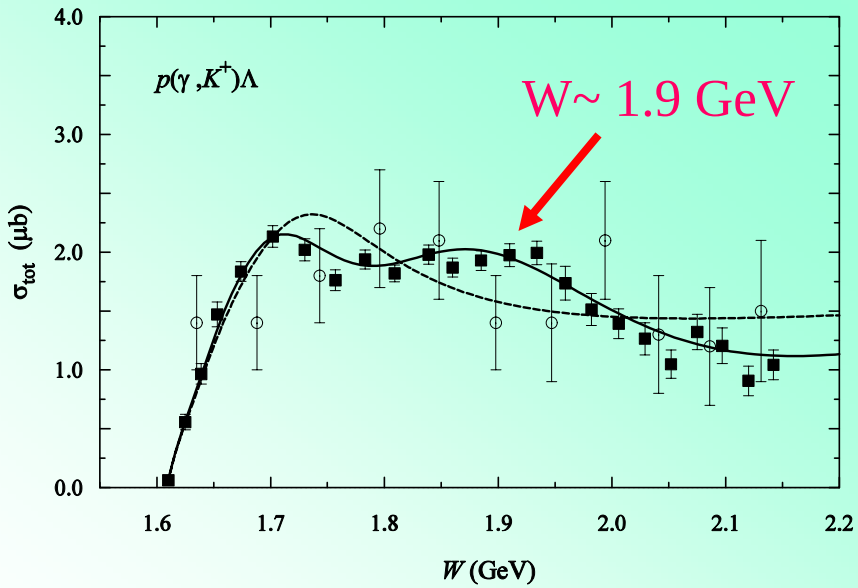
Photon beam asymmetry for the $p(\gamma,K^+)\Lambda$ and $p(\gamma,K^+)\Sigma^0$ reactions

R.G.T. Zegers et al. PRL29,092001

Missing resonances N^* and Δ^*

- Knowledge of N* and D* is essential to understand the internal structure of baryons.
- Many nucleon resonannces predicted by quark models are still missing.
- So far, πN channel → $K\Lambda$ or $K\Sigma$ channel





- **SAPHIR data**

→ **$D_{13}(1895)$ resonance ?**

..... without D_{13}

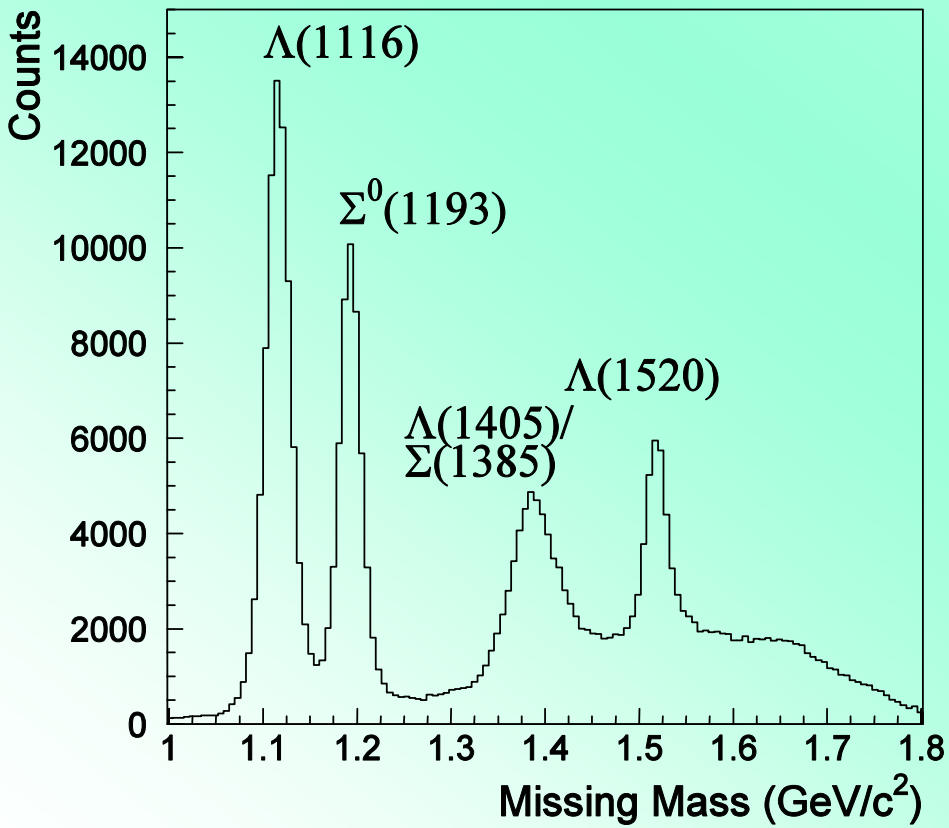
——— with D_{13}

Recent CLAS data show more than one resonance !

Missing mass spectrum and photon beam asymmetry Σ

Λ and Σ^0 events

2σ cuts : contamination < 2%

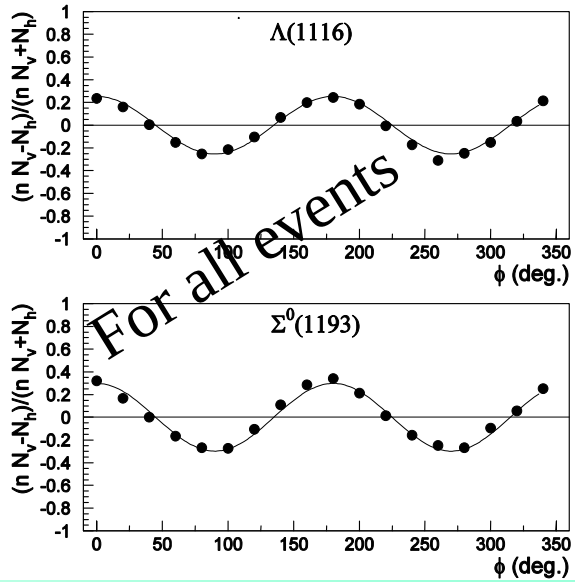


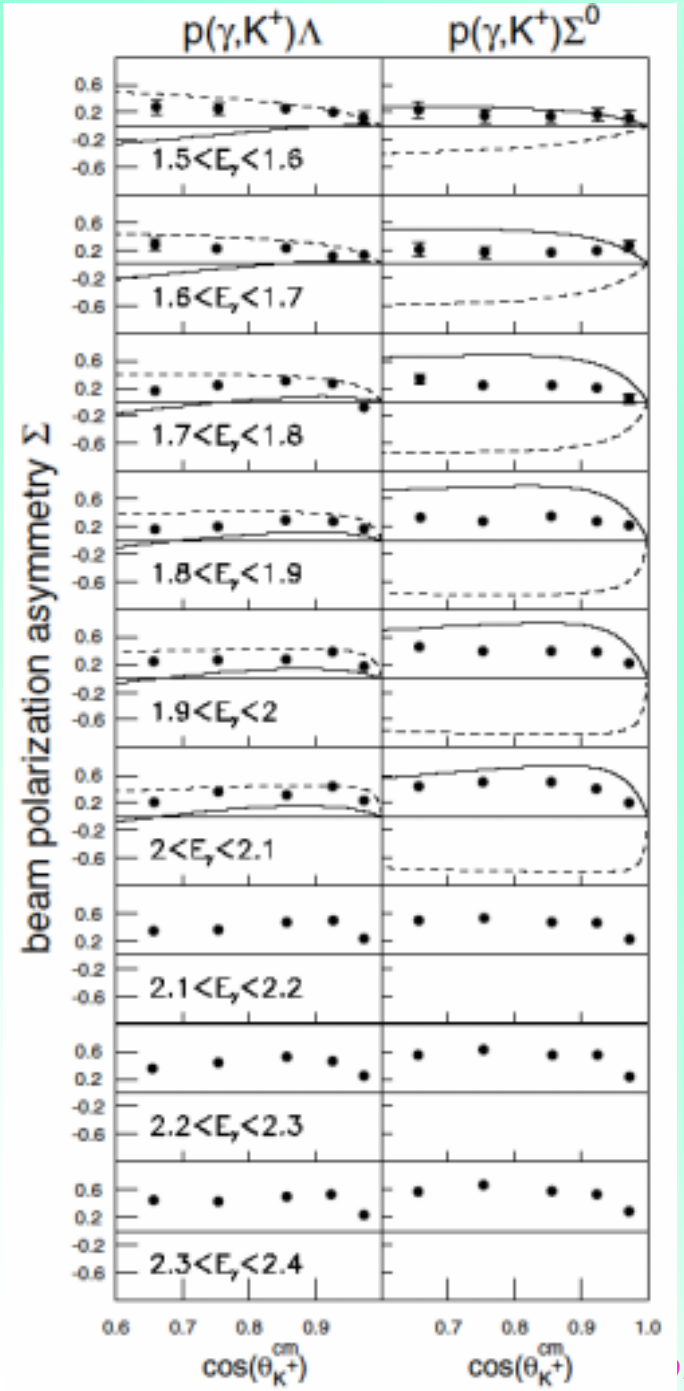
$$\frac{N_v - N_h}{N_v + N_h} = \Sigma\, P_\gamma \cos(2\phi)$$

$N_{v(h)}$: normalized yield of K^+ photoproduction for vertical (horizontal) pol.

ϕ : K^+ azimuthal angle

P_γ : Polarization of photon





Experimental Results and comparison with model calculations

Data : positive sign
become large as E_γ

—— Janssen et al.
PRC65, 015201, PRC66,035202

..... Mart & Bennhold
PRC61, 012201
(with D_{13})

Currently no models reproduce our data consistently.

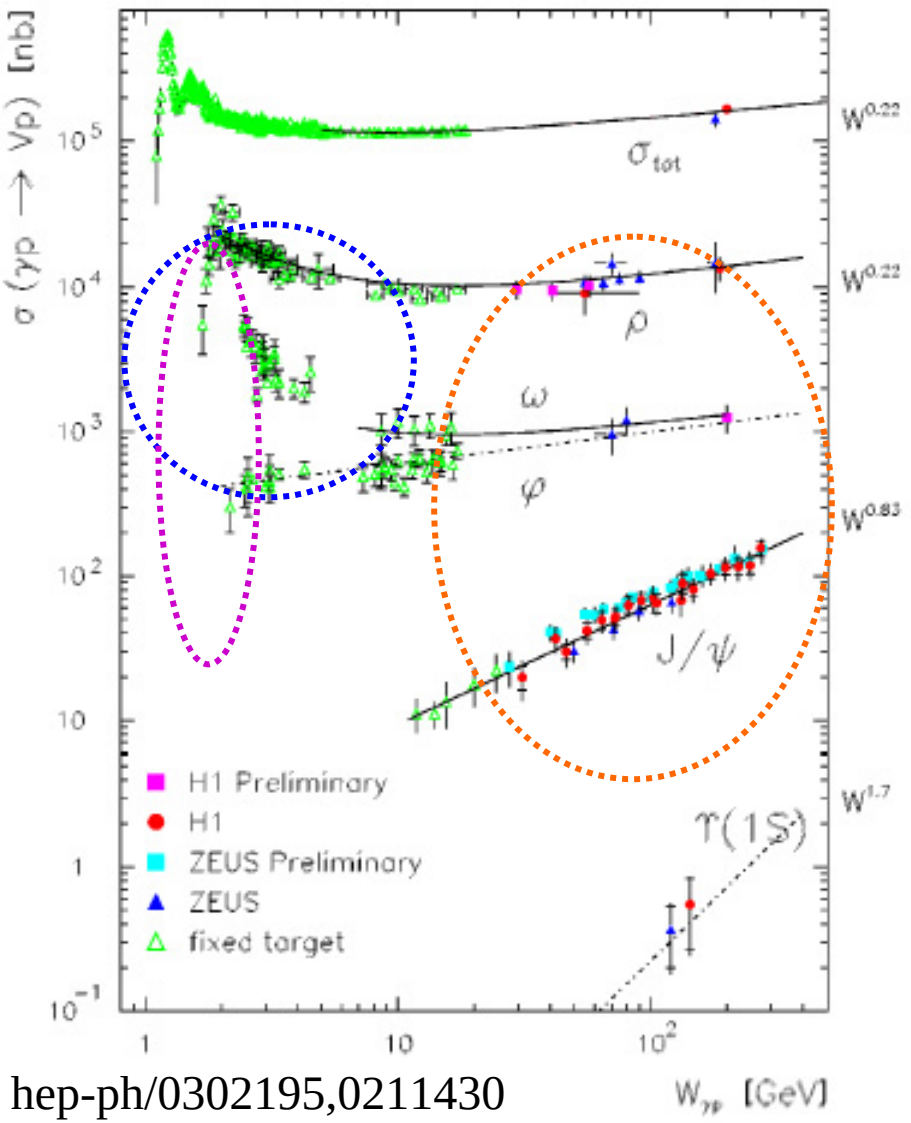
→ Strong conclusions for D_{13} etc., are very premature.

ϕ meson photoproduction on protons near threshold

cf.) ϕ photoproduction from Li, C, Al, and Cu has also been measured

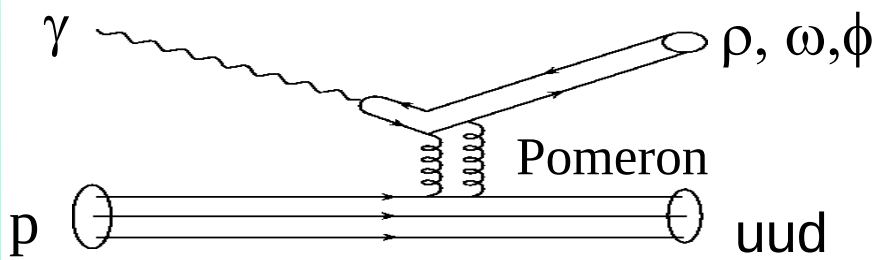
→ study modification of ϕ in the nuclear medium (T. Ishikawa et al. PLB608, 215)

Vector meson photoproduction

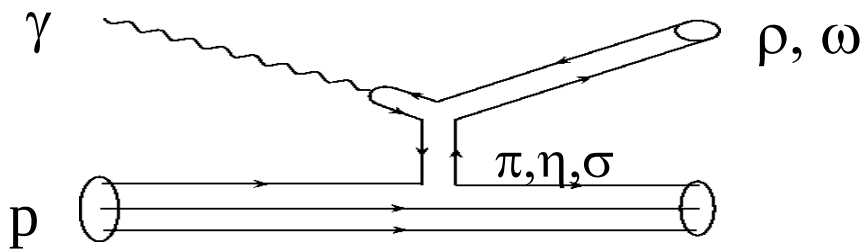


hep-ph/0302195,0211430

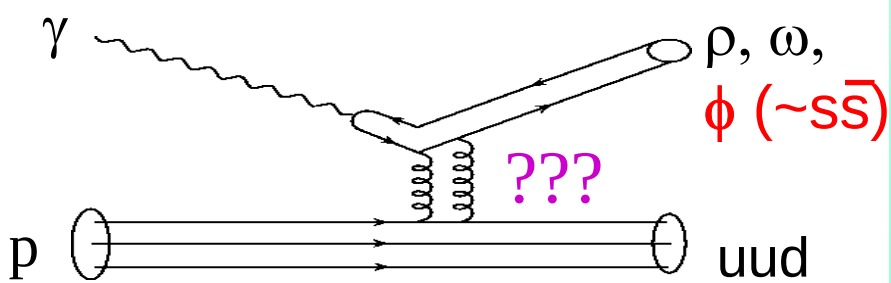
Pomeron exchange



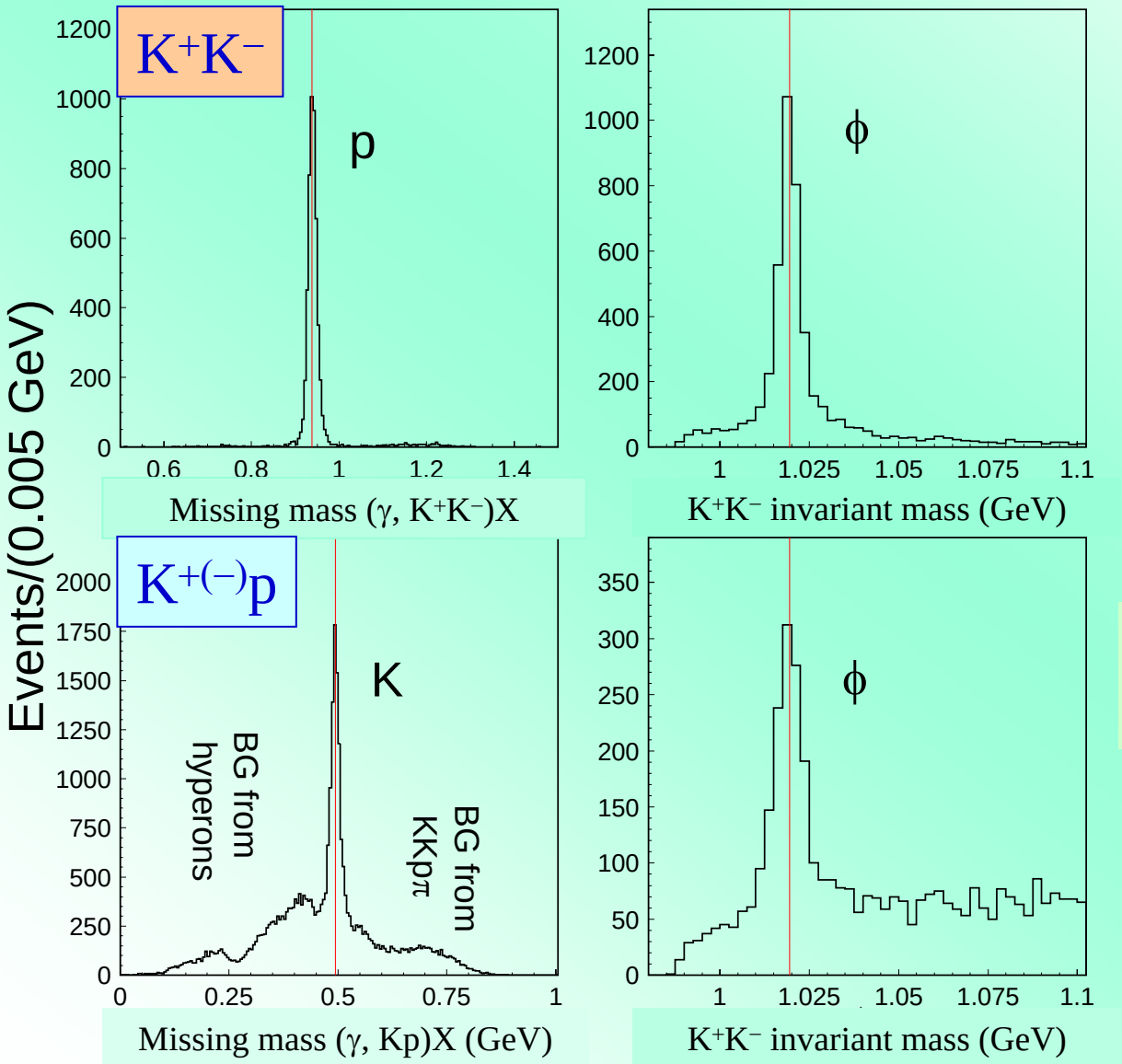
Meson exchange



Glueball exchange ??



K^+K^- invariant mass distributions



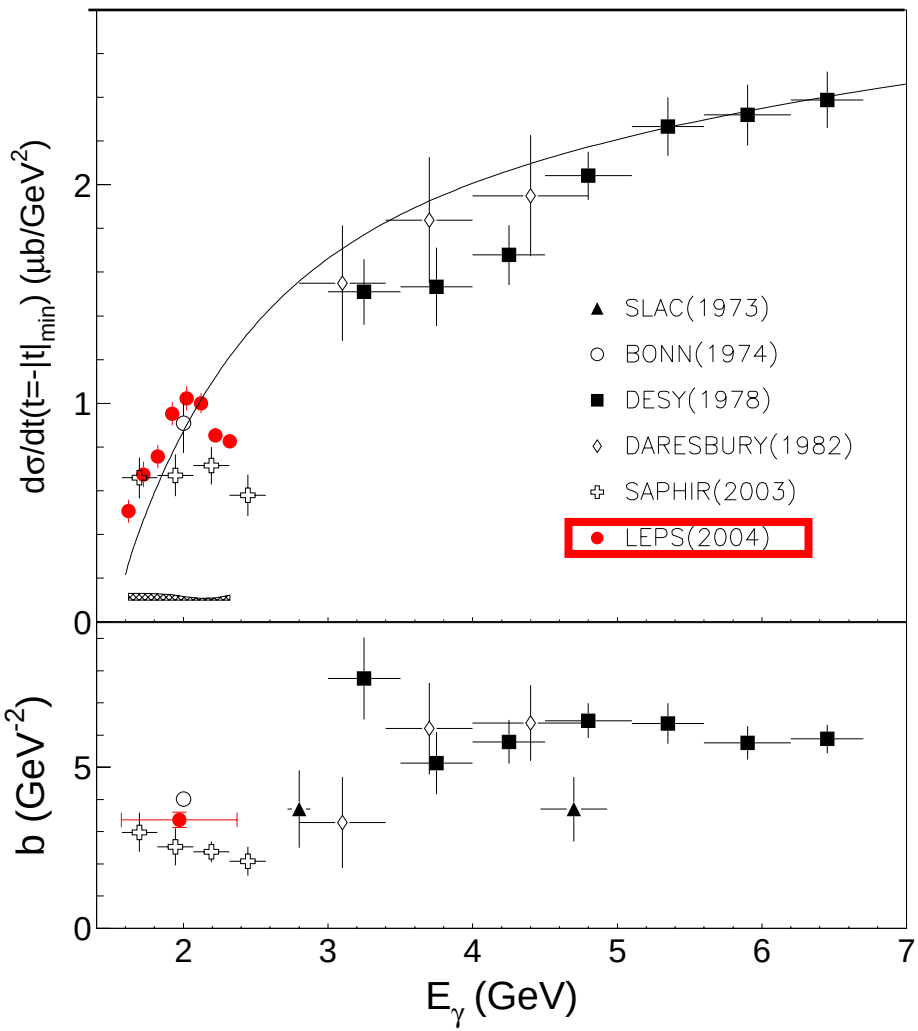
Missing mass resolution
σ=10 MeV
Invariant mass resolution
σ=2-3 MeV

Selection of K^+K^-p final state:
3 σ cut in missing mass

ϕ selection cut:
$|M_{KK}-1.019|< 10$ MeV

BG subtraction by using weighted MC which fits to the real data.

Differential cross section at $t=-|t|_{min}$



$$\frac{d\sigma}{dt} = \left(\frac{d\sigma}{dt}\right)_{t=-|t|_{min}} \exp\left(b\left(t+|t|_{min}\right)\right)$$

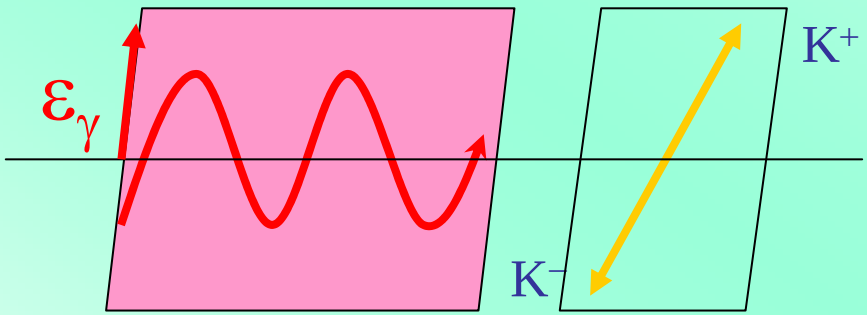
Curve : Pomeron + Pseudo scalar exchange model
(A. Titov et. al, PRC 67, 065205)

A peaking structure is seen in $d\sigma/dt$ near E_γ=2 GeV, which has not been explained by model calculation.

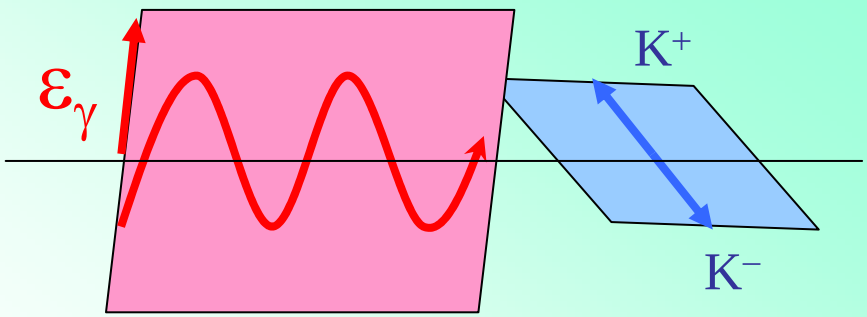
Smaller t-slope near threshold.

Decay polarization observables with linearly polarized photon

$\phi \rightarrow K^+K^-$



Photon Polarization



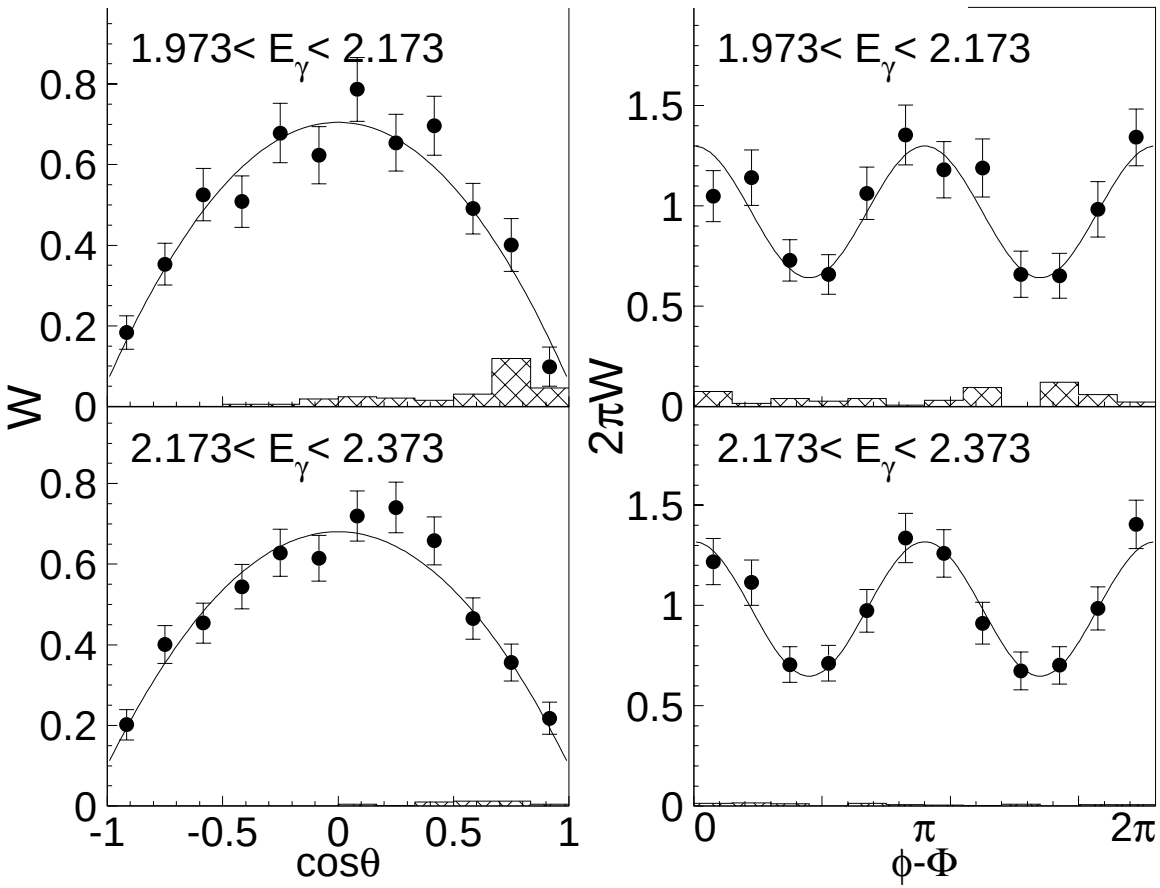
Decay Plane // $\vec{\gamma}$
natural parity exchange $(-1)^J$
(Pomeron, 0^+ glueball,
Scalar mesons)

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

Decay angular distribution of ϕ meson → **Relative contributions from natural, unnatural parity exchanges (U/UN)**

Decay angular distribution

Forward angles; $-0.2 < t+|t|_{min} < 0$ GeV^2



around the peak region of the cross section

above the peak region

~2 GeV peak :
mainly natural parity exchange
Need more data above 2.4 GeV

- W ~ $\sin^2\theta$: Helicity-conserving process is dominant.
- Natural parity exchange is dominant. (no energy dependence)

Search for pentaquark Θ^+

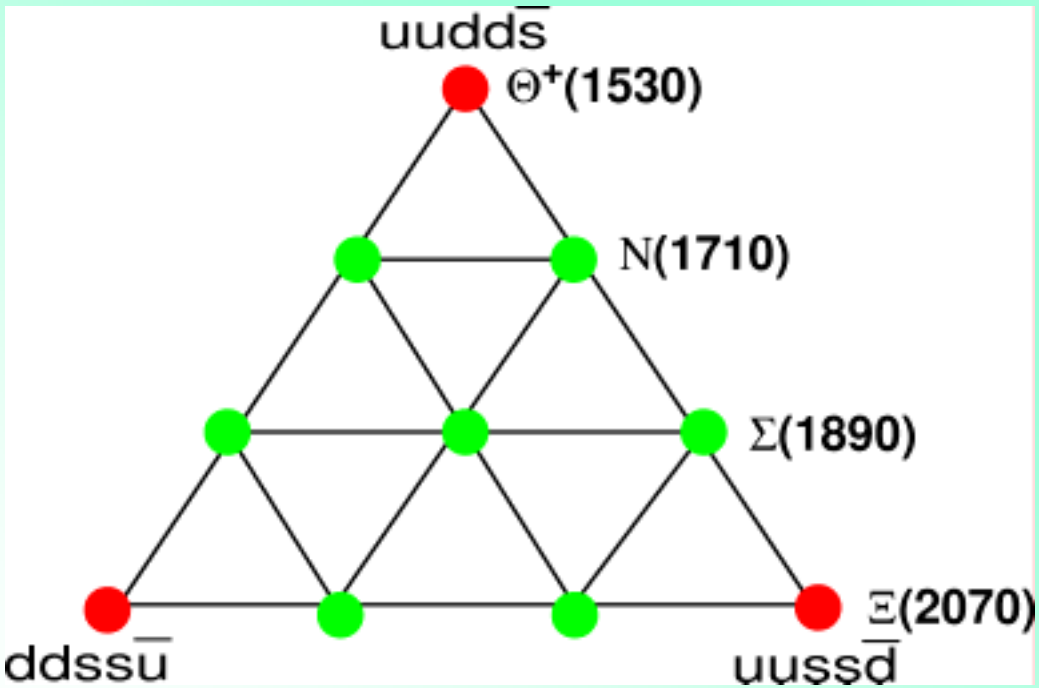
What are pentaquarks ?

- **Minimum quark content : 5 quarks** $qqqq\bar{q}$
- **Quantum numbers of "Exotic" pentaquarks : not 3-quark**

Theoretical Prediction of Θ^+

D. Diakonov, V. Petrov, and M. Polyakov, Z. Phys. A 359 (1997) 305

(Chiral Soliton Model)



M = [1890-180*Y] MeV

- **Exotic: S = +1**
- **Low mass: 1530 MeV**
- **Narrow width: ~ 15 MeV**
- **$J^\pi = 1/2^+$**

First evidence of Θ^+ from LEPS

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

M = 1.54±0.01 GeV
Γ < 25 MeV
Gaussian significance 4.6σ

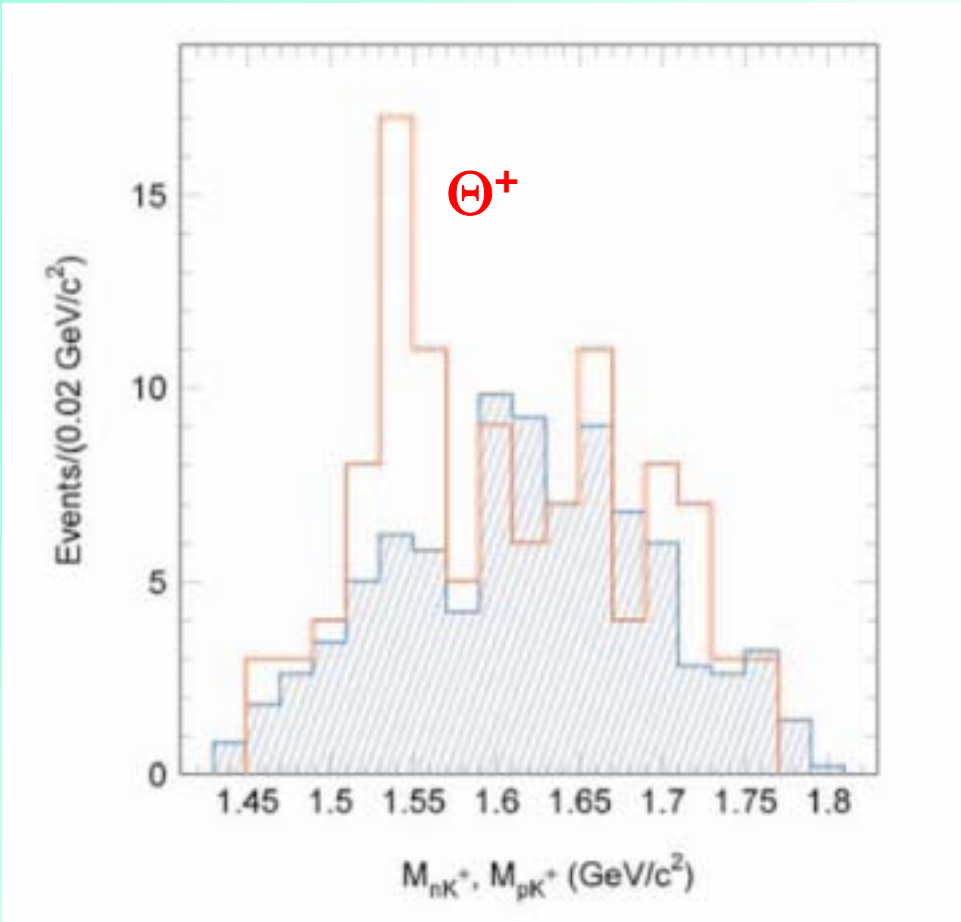
Target: neutron in Carbon nucleus

Background level is estimated by a fit in a mass region above 1.59 GeV.

Assumption:

- **Background is from non-resonant K^+K^- production off the neutron/nucleus**
- **… is nearly identical to non-resonant K^+K^- production off the proton**

T. Nakano et al., PRL91, 012002

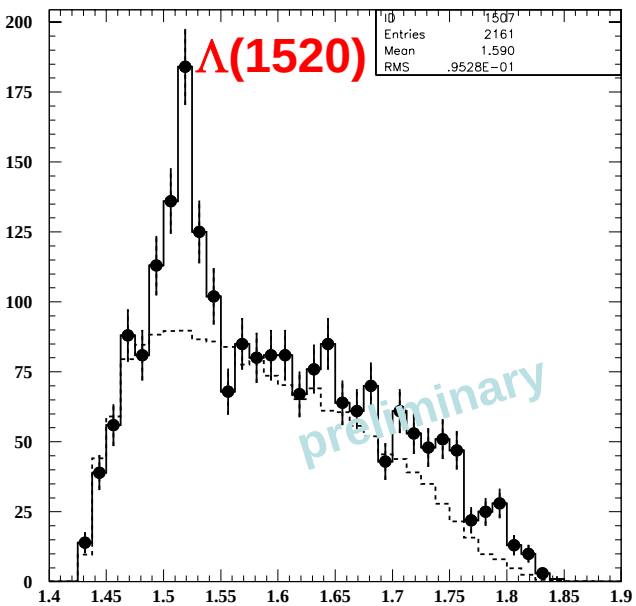


LEPS new search for Θ^+
1. $\gamma n \rightarrow \Theta^+ K^- \rightarrow K^+ K^- n$ in deuteron

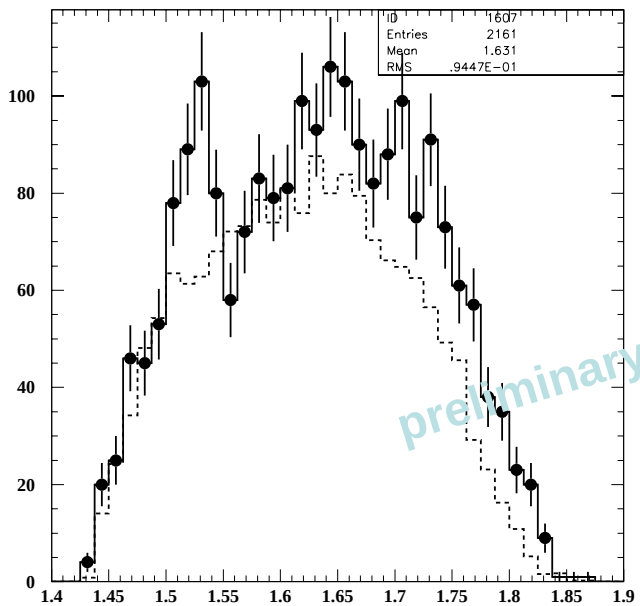
LEPS new LH_2/LD_2 data (Oct. 2002 – Jun, 2003)

- **Fermi motion is corrected to get the missing mass spectra**
- **ϕ exclusion cut is essential**
- **Background is estimated by mixed events**

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



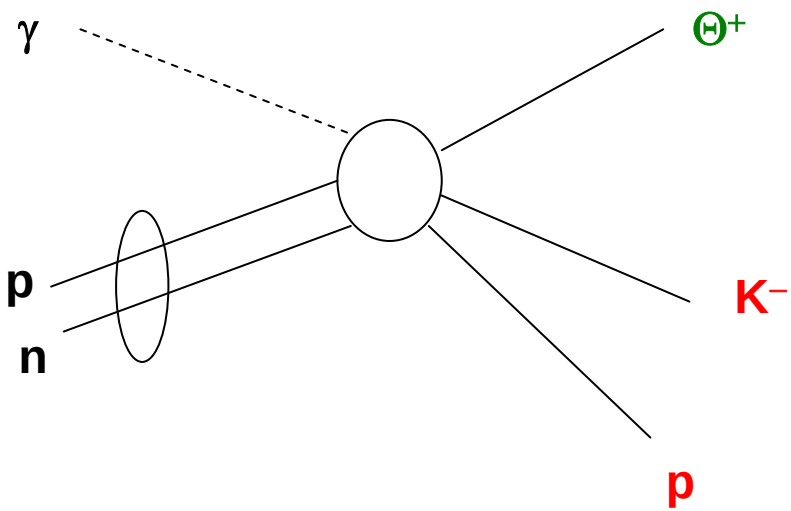
$\gamma n \rightarrow K^+ K^- n$

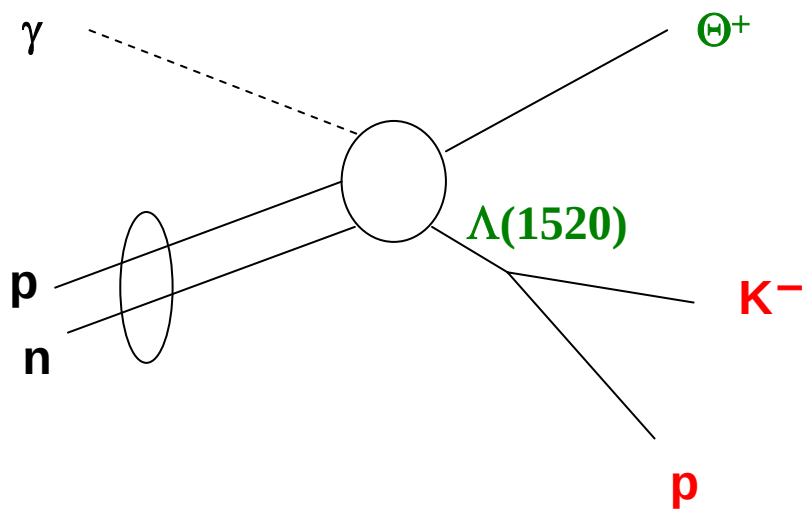


LEPS new search for Θ^+
2. $\gamma d \rightarrow \Lambda(1520)\Theta^+ \rightarrow K^- p\ \Theta^+$

Θ^+ is identified by $K^- p$ missing mass from deuteron.

→ No Fermi correction is needed.

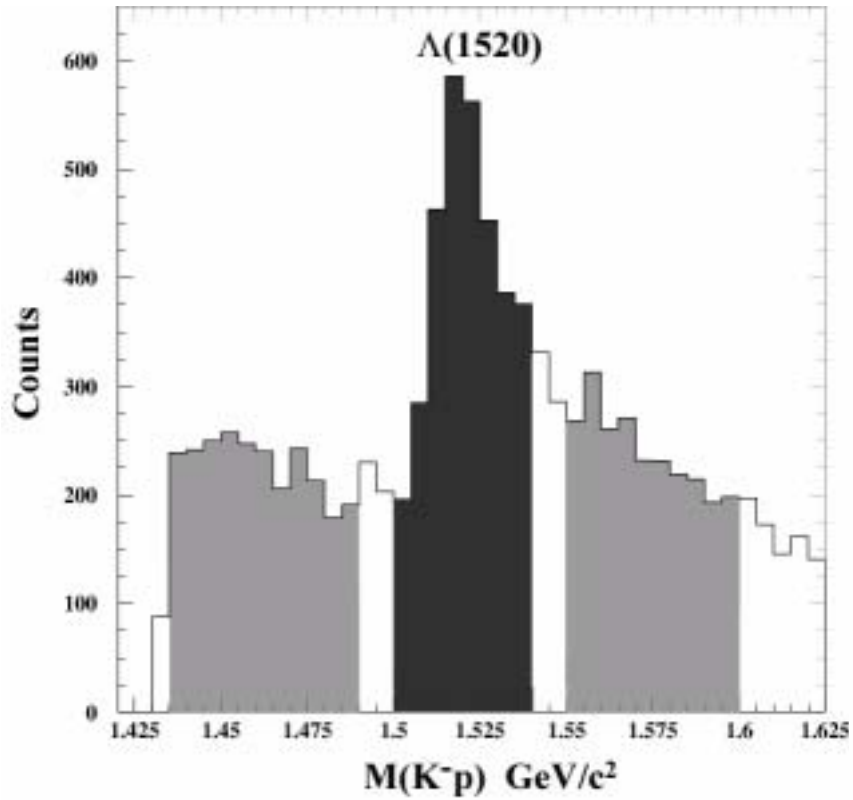


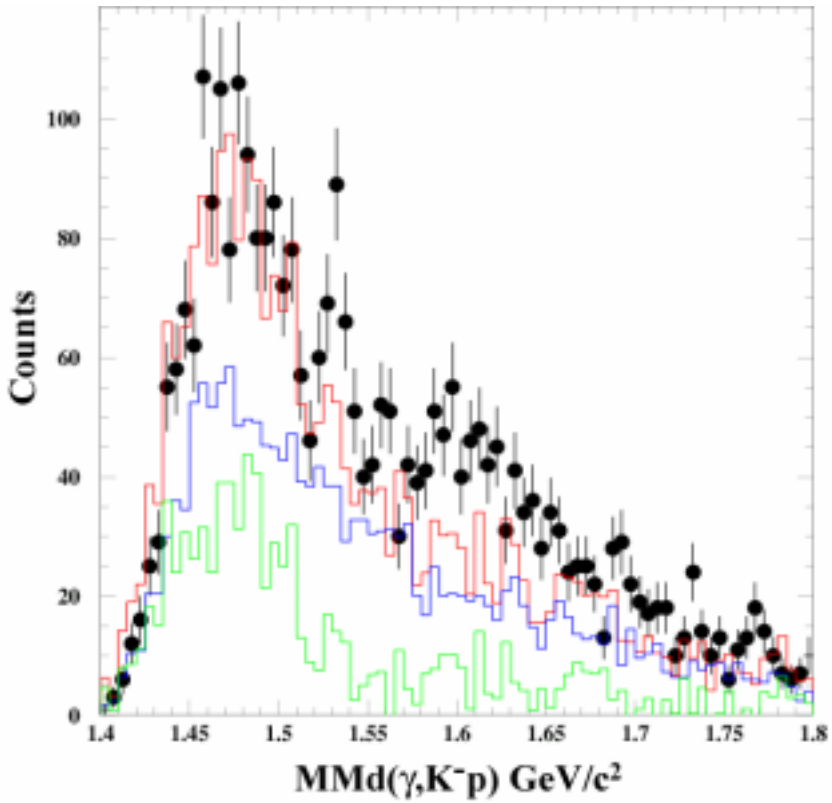


K^-p missing mass for $\Lambda(1520)$ production from deuteron

K^-p invariant mass

BG: quasifree $\Lambda(1520)$
+ non-resonant K^-p (side-band)





New Detectors

1. EM calorimeter for $\pi^0 \rightarrow 2\gamma$, $\eta \rightarrow 2\gamma$

- **Main detector**

  Lead scintillating fiber

  252 modules

- Covered solid angle

  2.08π (str)

  θ : 30° ~ 100°

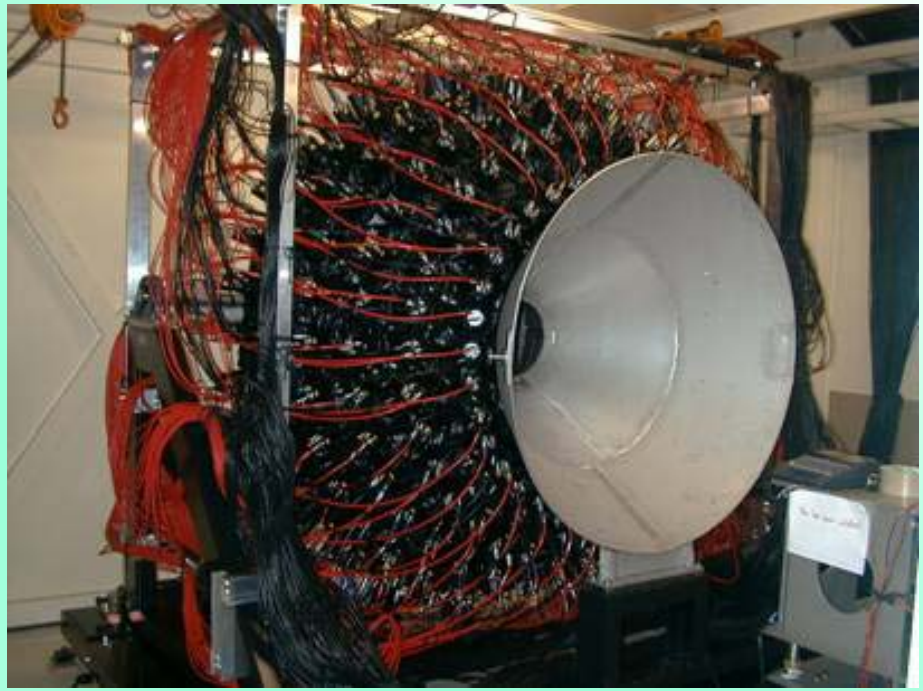
  ϕ : 0° ~ 360°

- Length of each module

  22cm (13.7 X_0)

- Angular interval (segment)

  10 degree

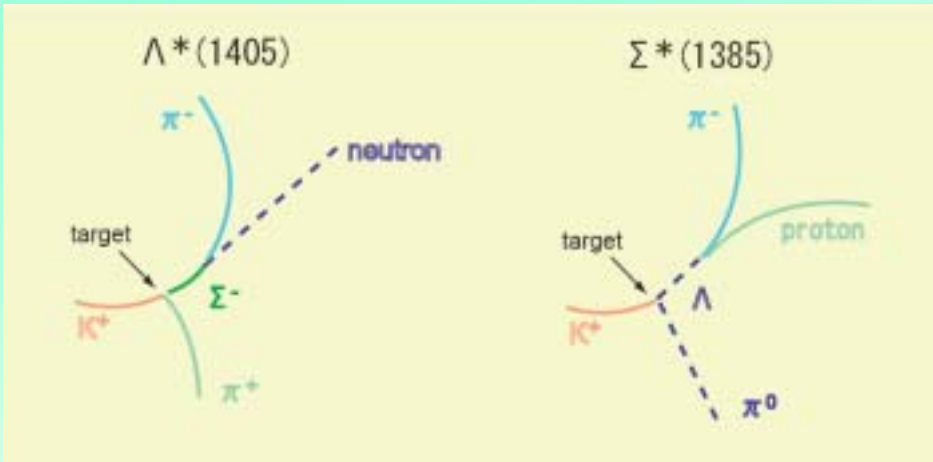


- Energy resolution

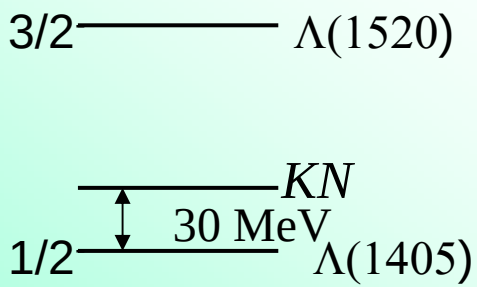
$$\frac{\sigma_E}{E} = \sqrt{\left(\frac{5.2 \pm 0.1\%}{\sqrt{E}}\right)^2 + (4.4 \pm 0.2\%)^2}$$

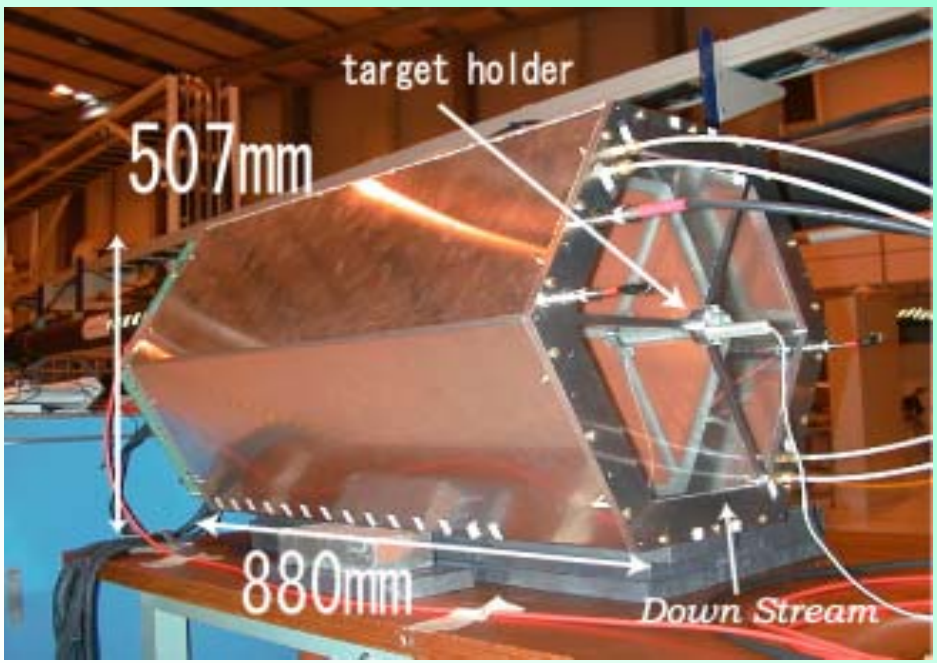
(6.8% for 1 GeV photon)

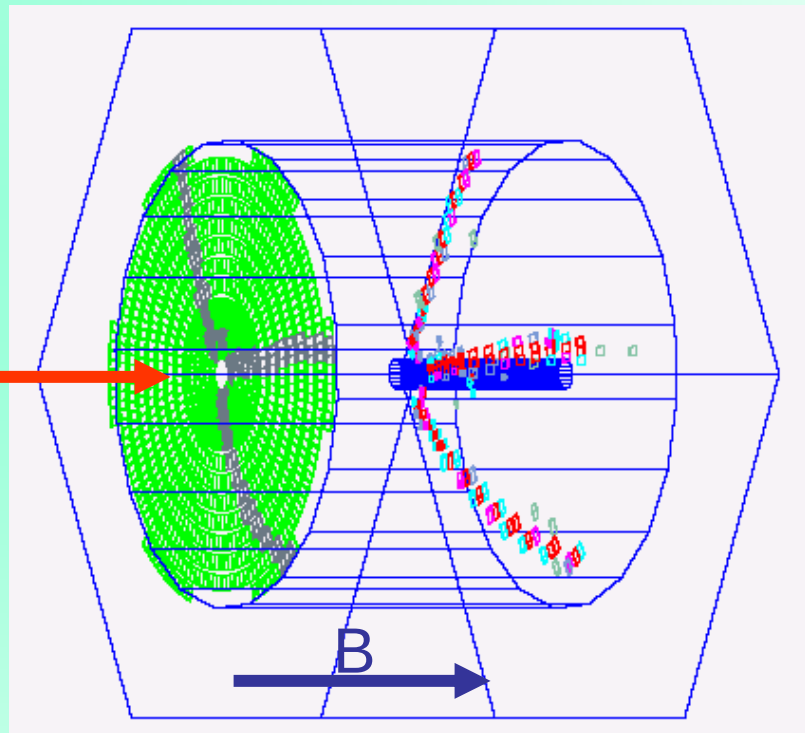
2. TPC for Hyperon Resonances



Λ(1405) :
3-quark state
or
KN bound state ?

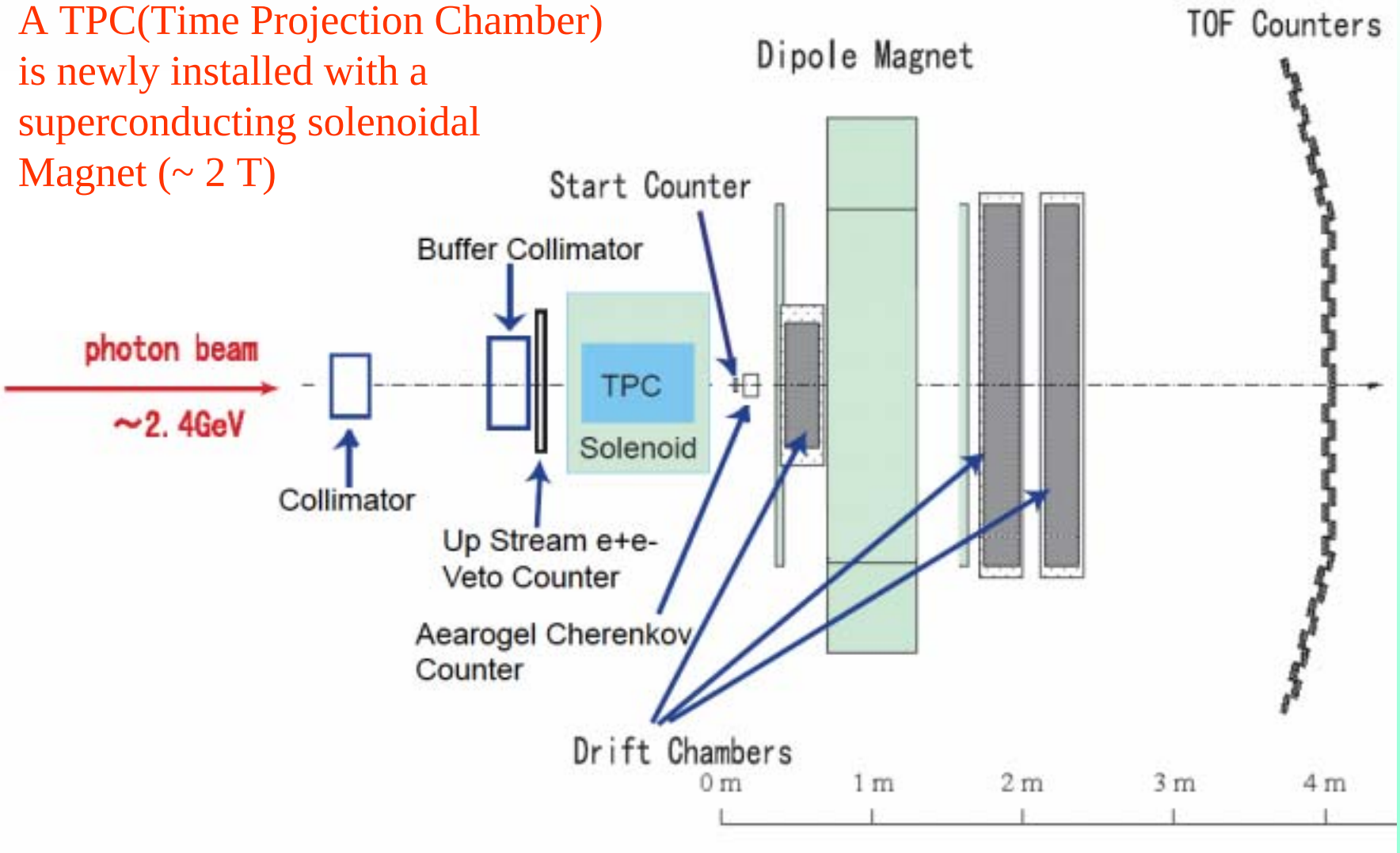






Recent experimental setup with TPC

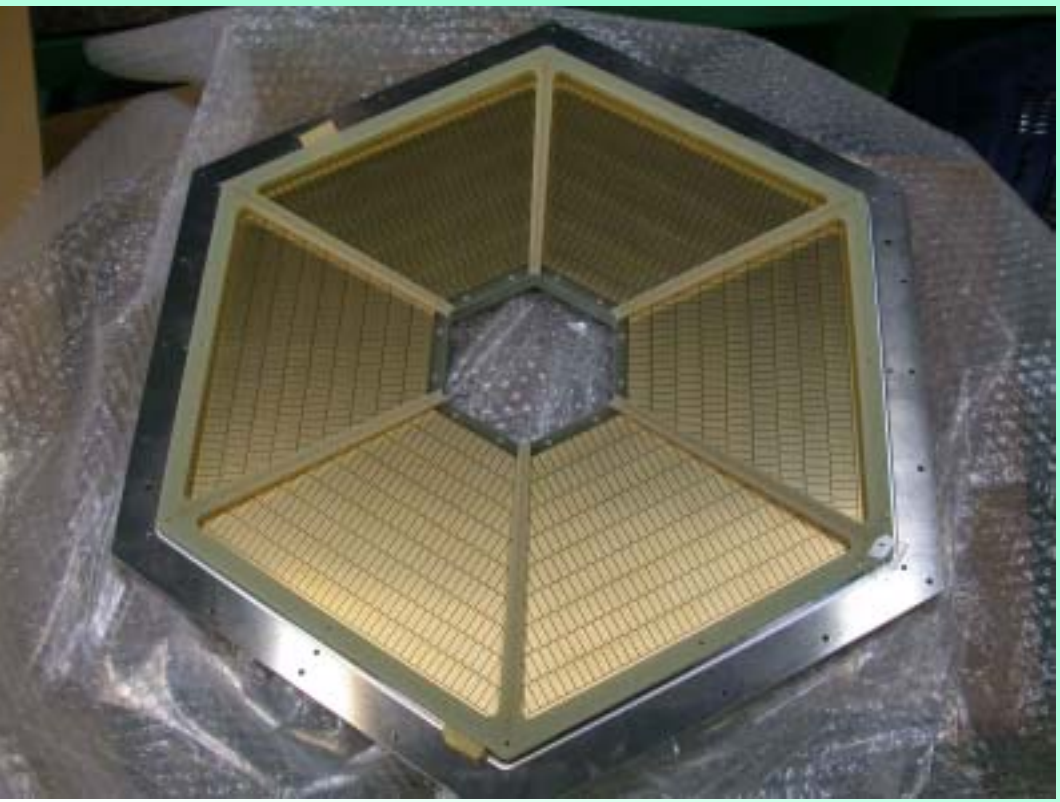
A TPC(Time Projection Chamber) is newly installed with a superconducting solenoidal Magnet (~ 2 T)

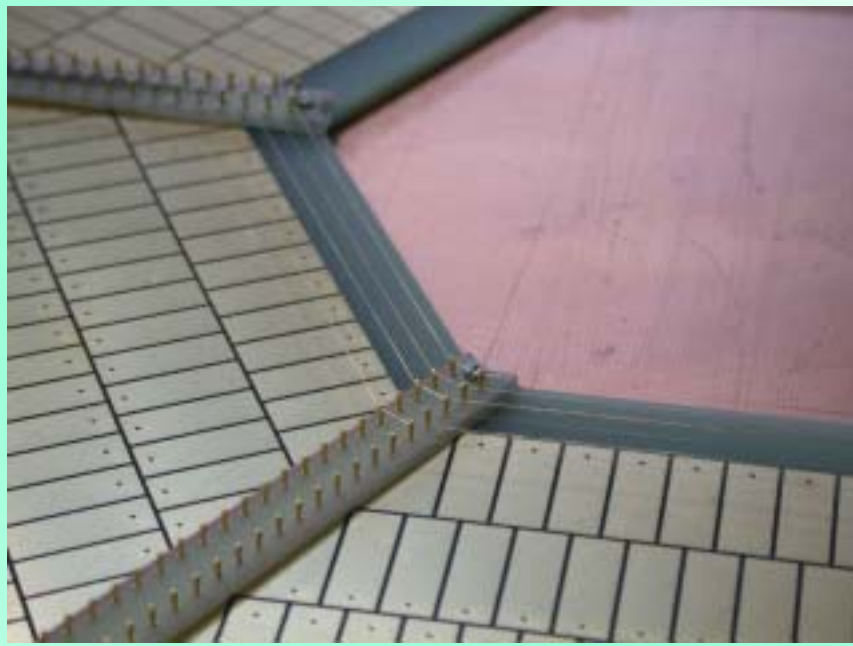


Present status and prospect

- Short LH_2 run (2000-2001), Long LD_2/LH_2 (2002-2003)
- ϕ photoproduction from nuclear target (Li,C,Al,Cu)
  data taking completed in 2001, already published
- $p(\gamma,K_s)$ experiment with gas Cherenkov counter
  data taking completed in 2002
- Experiment using the EM calorimeter with nuclear target (CH_2,C,etc)
  data taking completed in 2003
- Hyperon resonance study with TPC and spectrometer for nuclear target (CH_2,C,Cu)
  data taking completed in 2004
- Energy upgraded : 2.4 GeV → 2.9 GeV
  now going on for the nuclear target
- LH_2/LD_2 + newTPC + 2.9 GeV γ will start this autumn

New TPC with 100mmϕ bore for LH_2,LD_2 run



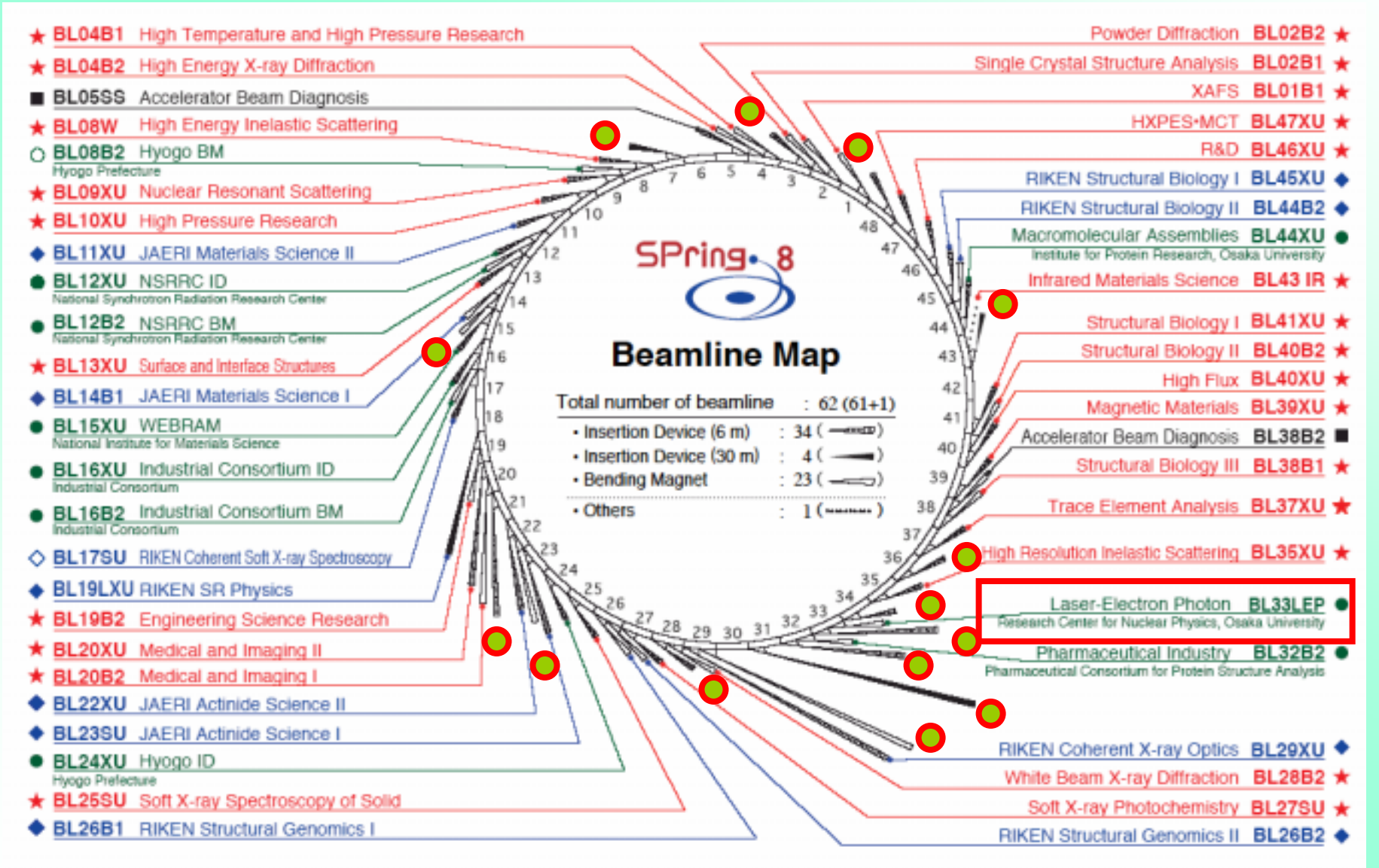


LEPS 2nd beam line に向けて: kickoff meeting

2005. 6. 8

SPring-8 におけるレーザー電子光 (LEPS) プロジェクトもその立案から約10年、データ収集開始から5年が経ちました。その間、ハドロン物理学の世界に一大センセーションを巻き起こし、且つ未だにその存在の有無が問題となっているΘ^+ 粒子の発見に始まり、φ中間子光生成等着実に成果を挙げてきており、その後、大立体角の電磁カロリメータやタイムプロジェクション・チェンバーといった新たな測定器も開発され、更に興味深い研究が進められてきています。しかし、一方で異なる検出器で同時に測定が行えないとか、ビーム強度や実験ハッチの制限のために実験を拡張しようと思っても容易でない、といった問題も生じてきています。従って、今はまさに2本目の LEPS ビームラインの建設を真剣に考える良い時期に来ています。そこで、この機にJASRI加速器グループ、LEPSのRCNPグループ及び主要ユーザーが一同に会しての、2ndビームラインに向けて旗揚げを行ないたいと思います。

Beam line map of Spring-8



LEPS/Spring-8 new beam line

- Beam upgrade
  - Energy
  - Intensity
  - Quality
- Detector upgrade
  - Scale
  - Flexibility
  - DAQ speed
- New physics

Virtual laboratory
http://www.hadron.jp (http://www.hadron.jp/member/
user: newleps
password: DearNewleps)