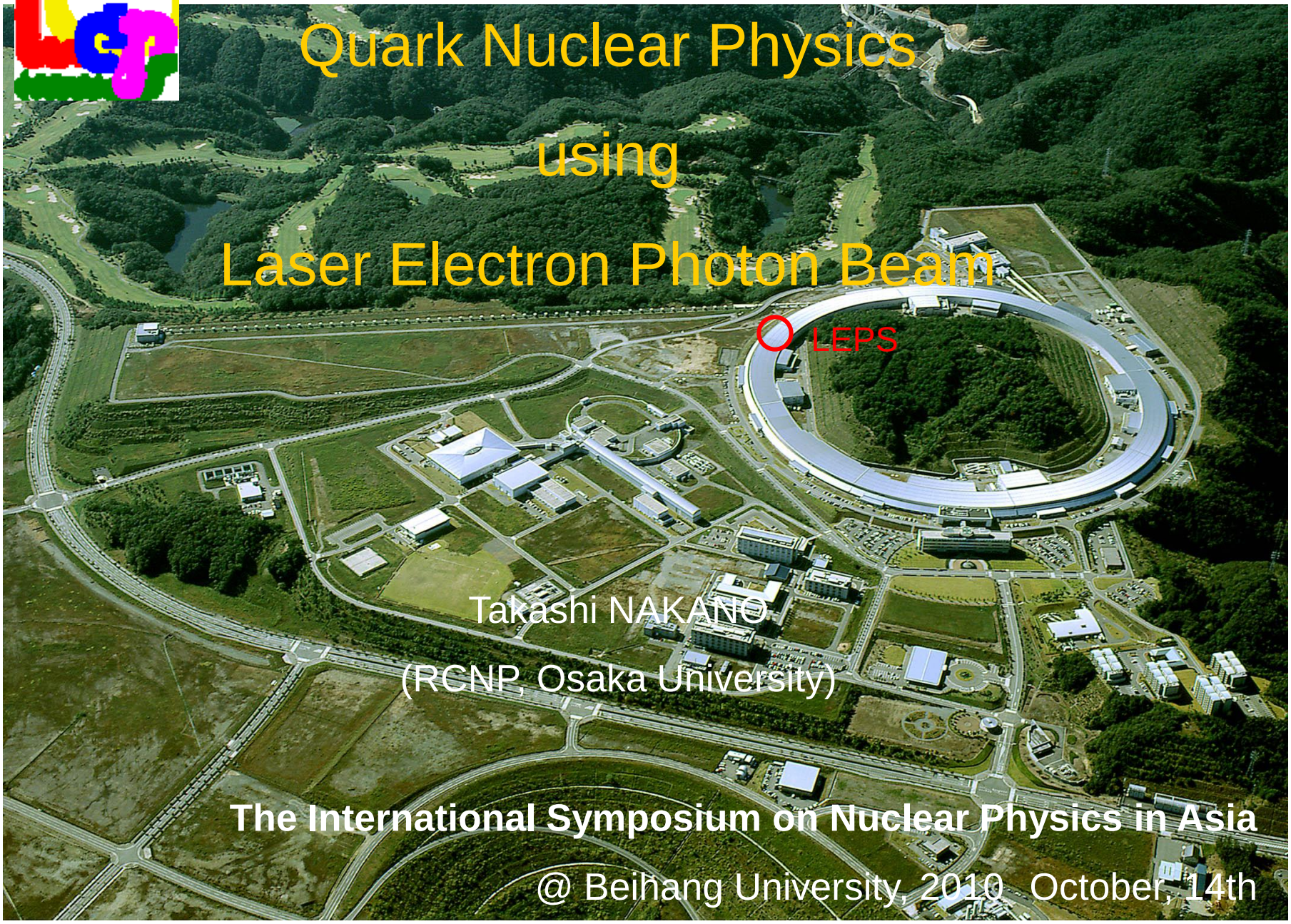

Quark Nuclear Physics using Laser Electron Photon Beam

Takashi NAKANO

(RCNP, Osaka University)

The International Symposium on Nuclear Physics in Asia

@ Beihang University, 2010 October, 14th

LEPS Collaboration

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RIKEN : Y. Nakatsugawa
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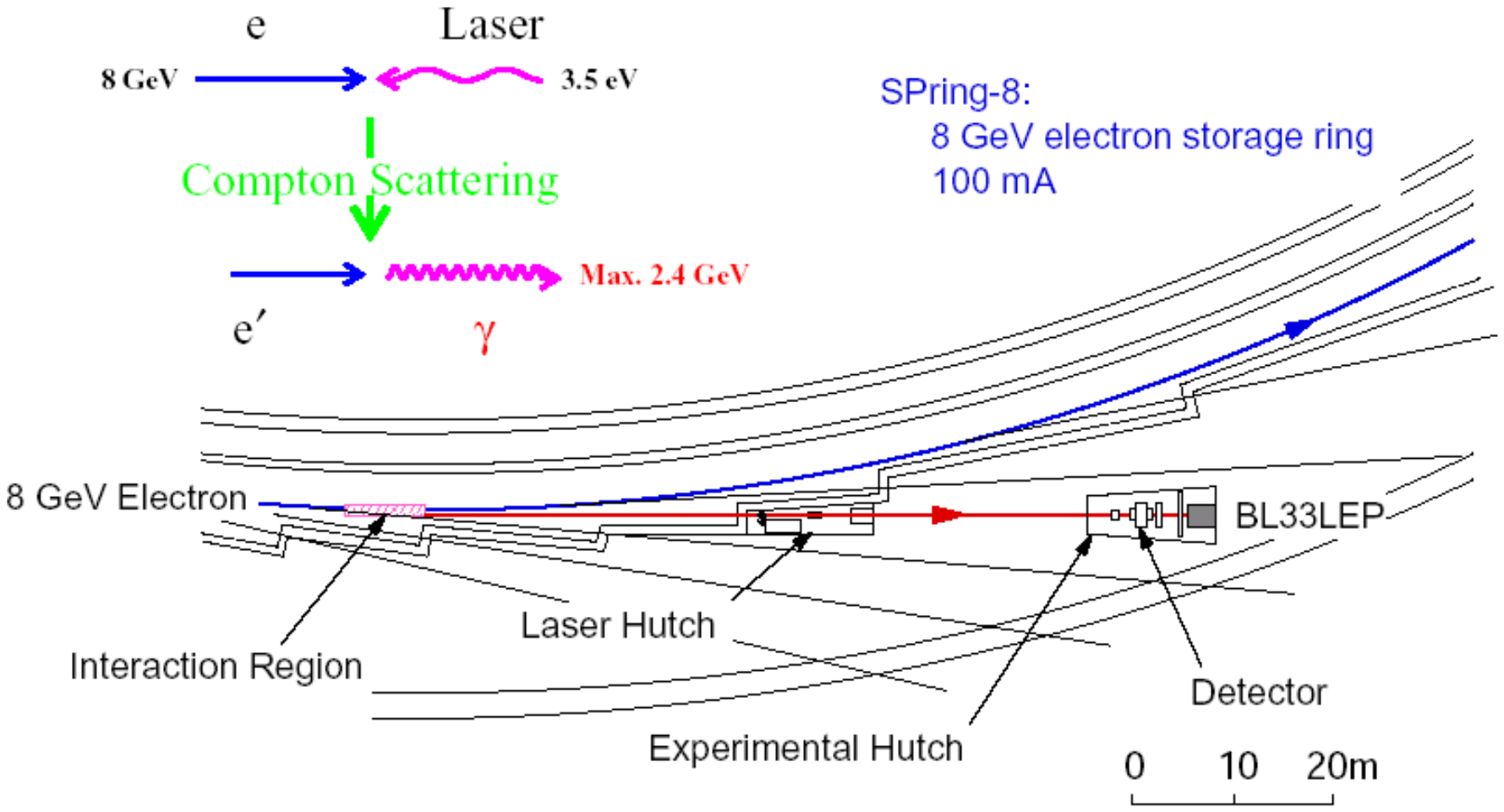
Laser Electron Photon beamline at SPring-8



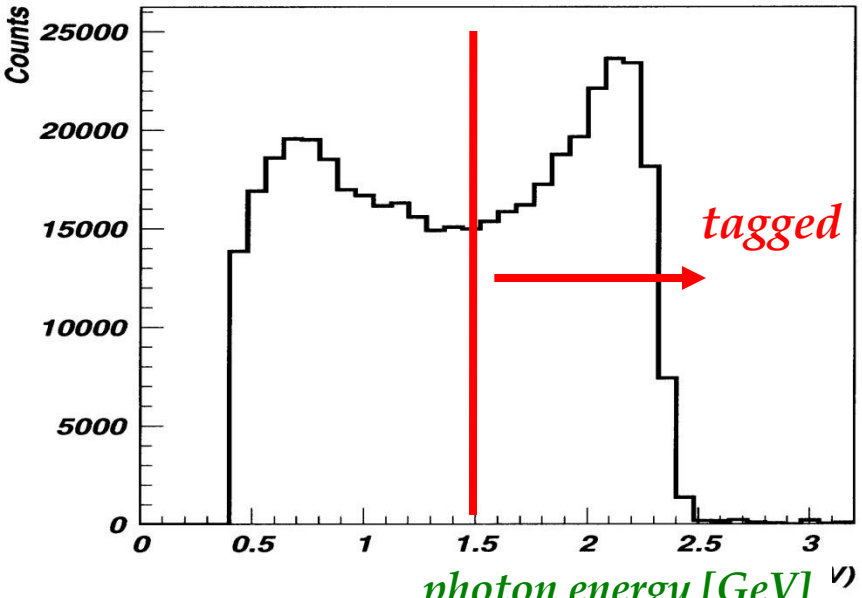
Questions to be answered

- **How are quarks confined in hadrons?**
- **Why does a constituent quark model work well? (and sometimes not?)**
- **What are effective degrees of freedom for hadrons?**
- **How can we learn about the structure of the hadrons from their production and decay?**

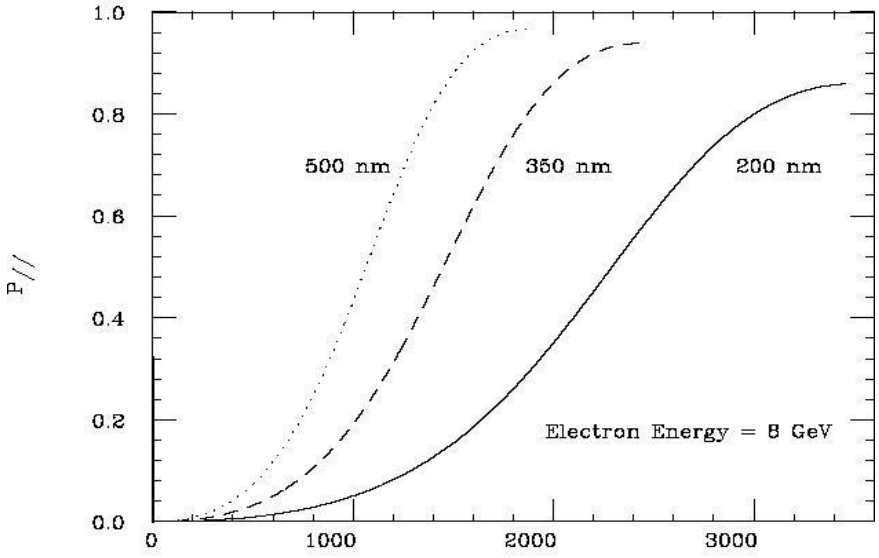
Backward-Compton Scattered Photon

- 8 GeV electrons in SPring-8 + 351nm Ar laser (3.5eV)
  ➔ maximum **2.4 GeV** photon
- Laser Power ~6 W ➔ Photon Flux ~1 Mcps
- Eγ measured by tagging a recoil electron ➔ Eγ>1.5 GeV, **ΔEγ ~10 MeV**
- Laser linear polarization 95-100% ⇒ **Highly polarized γ beam**

PWO measurement



Linear Polarization of γ beam

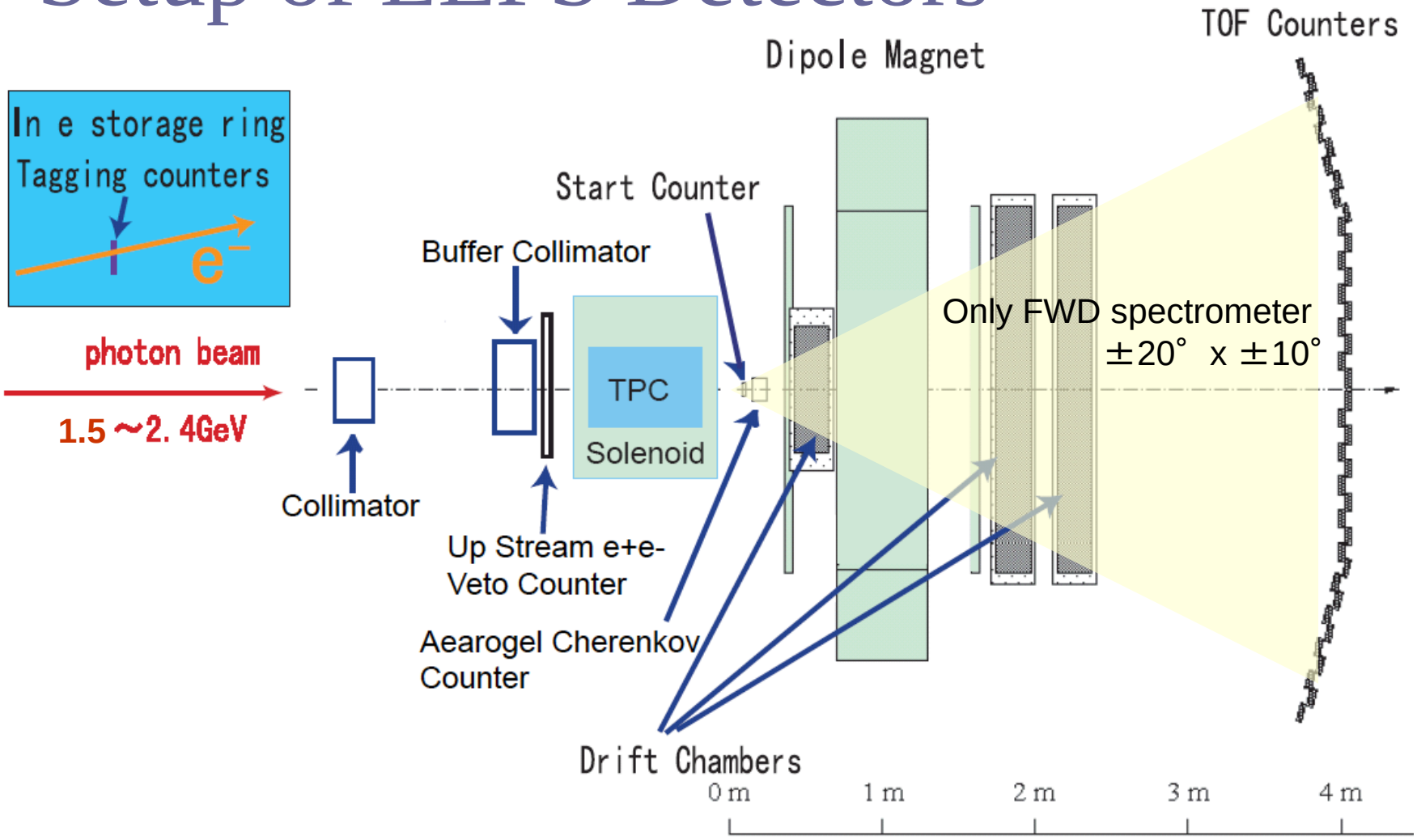


ADVANTAGE OF LASER-ELECTRON PHOTON BEAM FOR HADRON PHYSICS

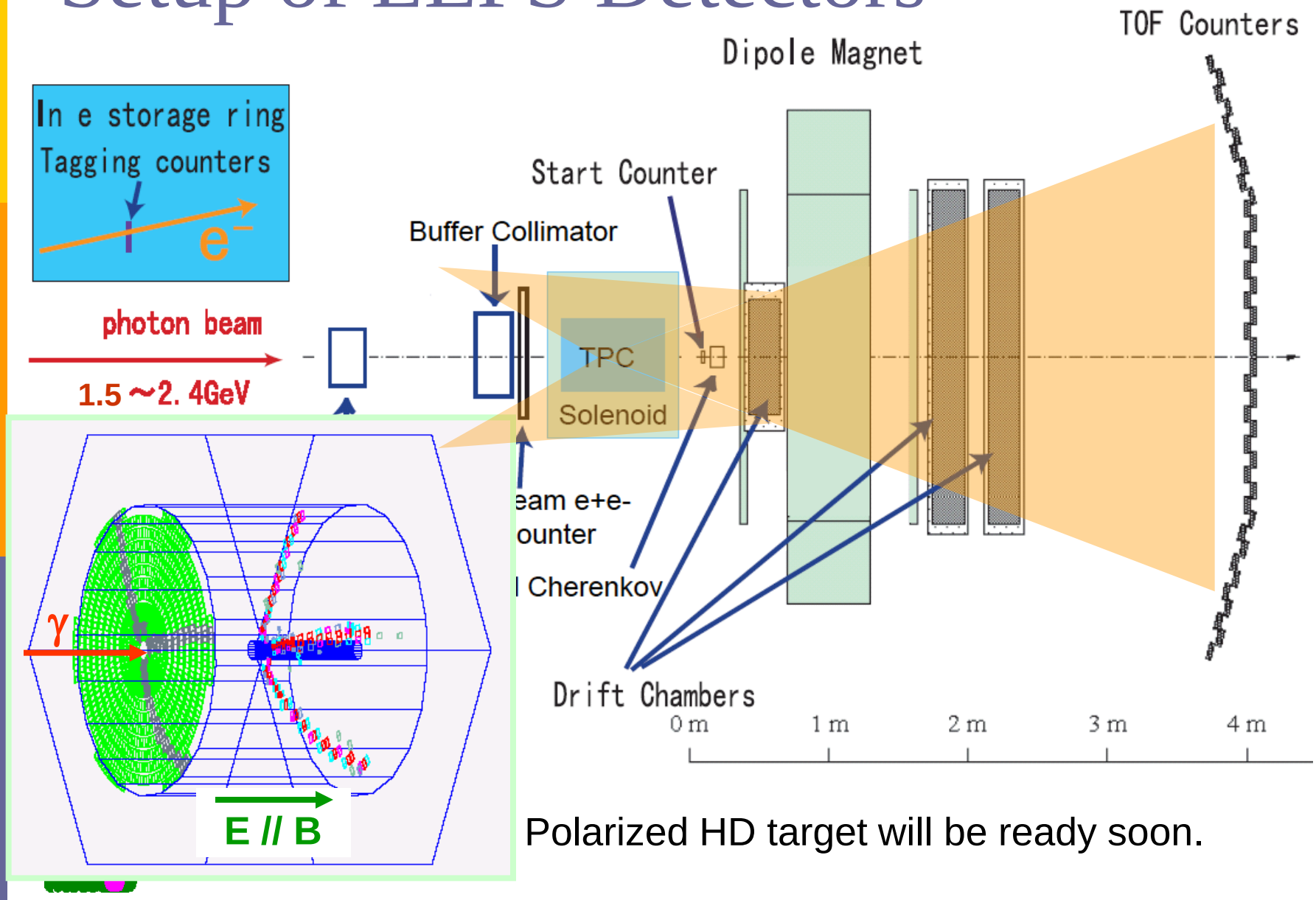
- **Hadronic component of a photon contains a large fraction of $s\bar{s}$.**
- **Isospin dependence is not trivial because a γ contains both I=0 and I=1 components.**
- **Linear polarization can be used as a parity filter.**
- **The polarization can be changed easily.**

Disadvantage is low interaction rates. → Require high beam intensity and large detector acceptance.

Setup of LEPS Detectors

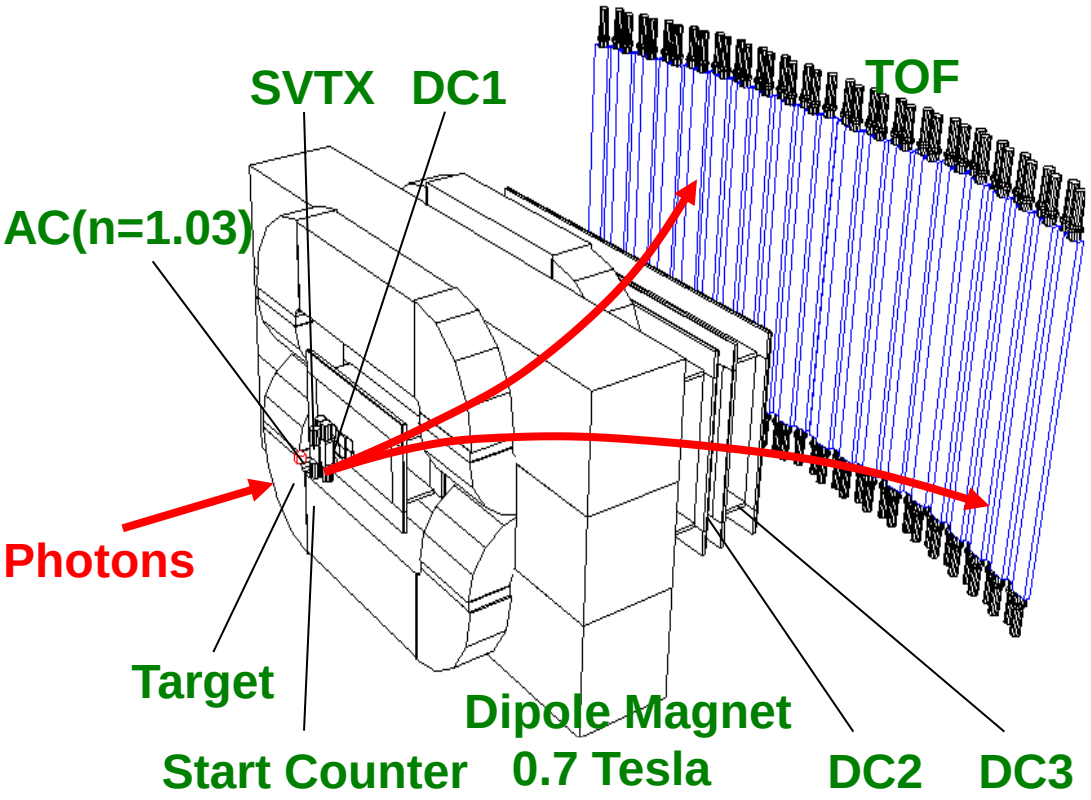


Setup of LEPS Detectors

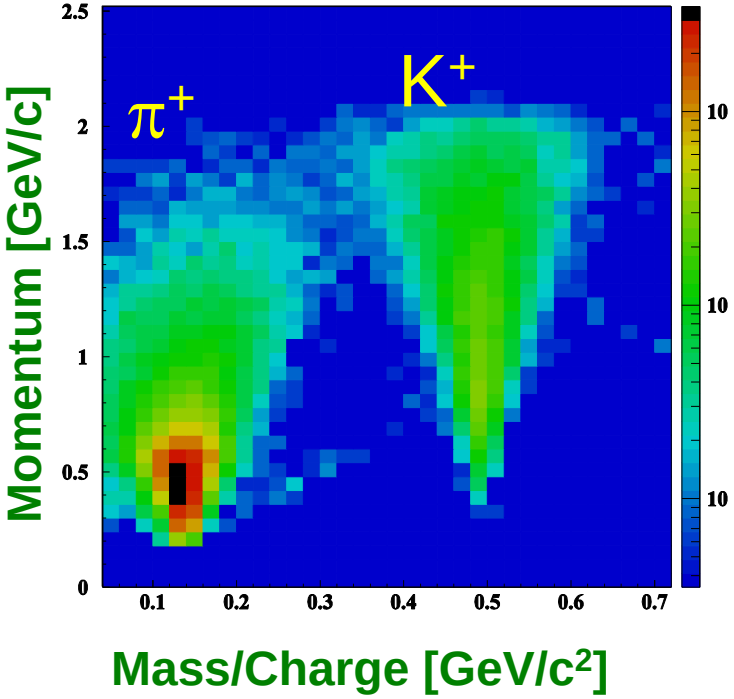


Polarized HD target will be ready soon.

PID in LEPS Spectrometer



K/π separation



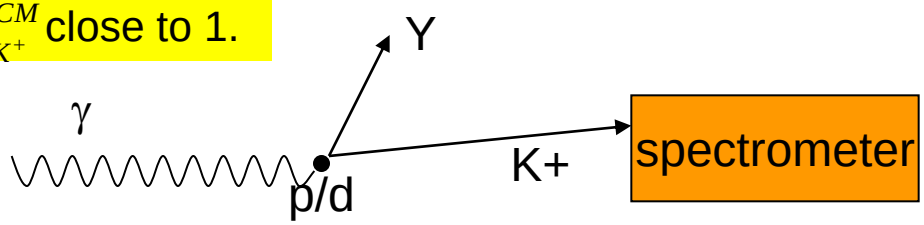
σ_P ~6 MeV/c for 1 GeV/c

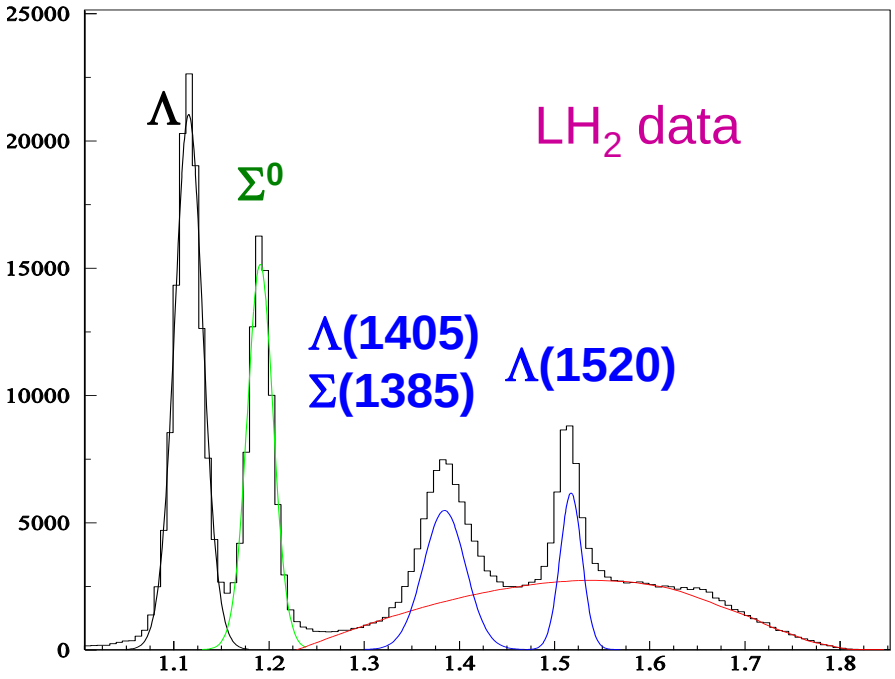
σ_{TOF} ~150 ps

σ_{MASS} ~30 MeV/c² for 1 GeV/c Kaon

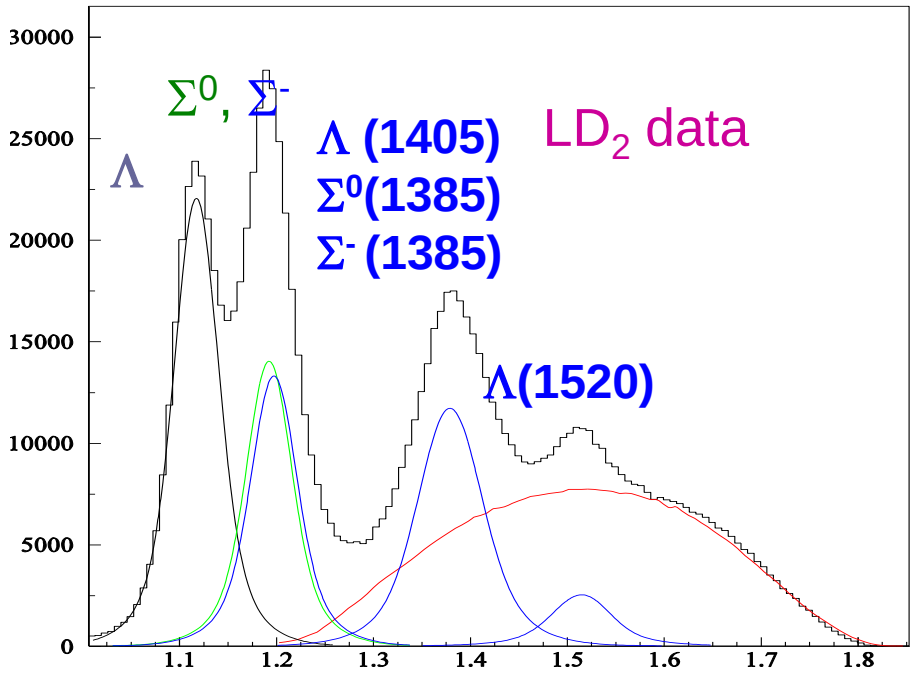
Identification of Hyperon From p/d in LEPS: Missing Mass of K^+

Acceptance of $\cos\theta^{CM}_{K^+}$ close to 1.





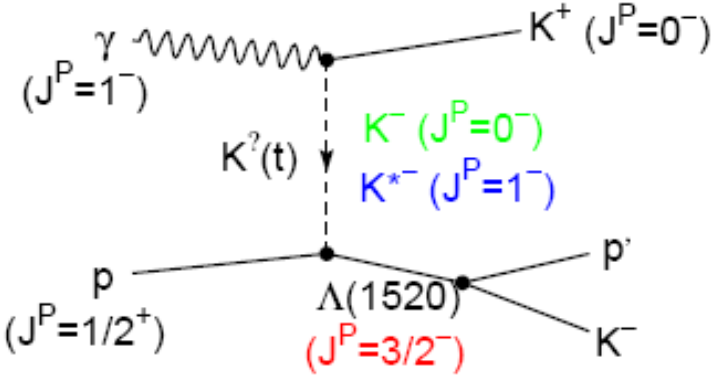
p(γ, K^+) GeV/c^2

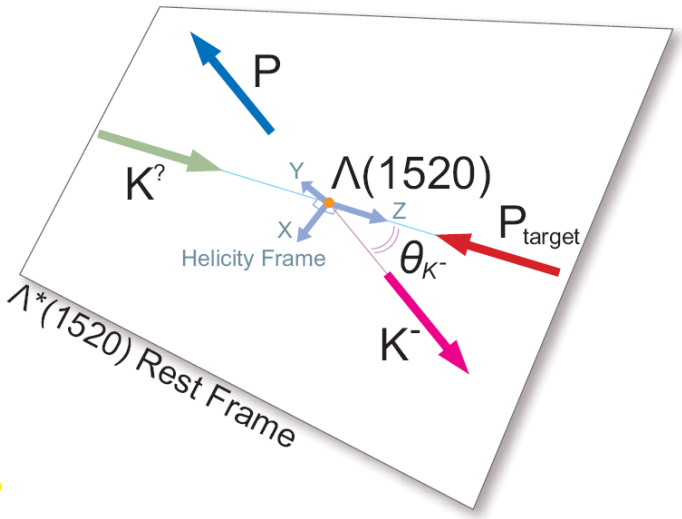


N(γ, K^+) GeV/c^2

$\Lambda(1520)$

K^- Decay Asymmetry



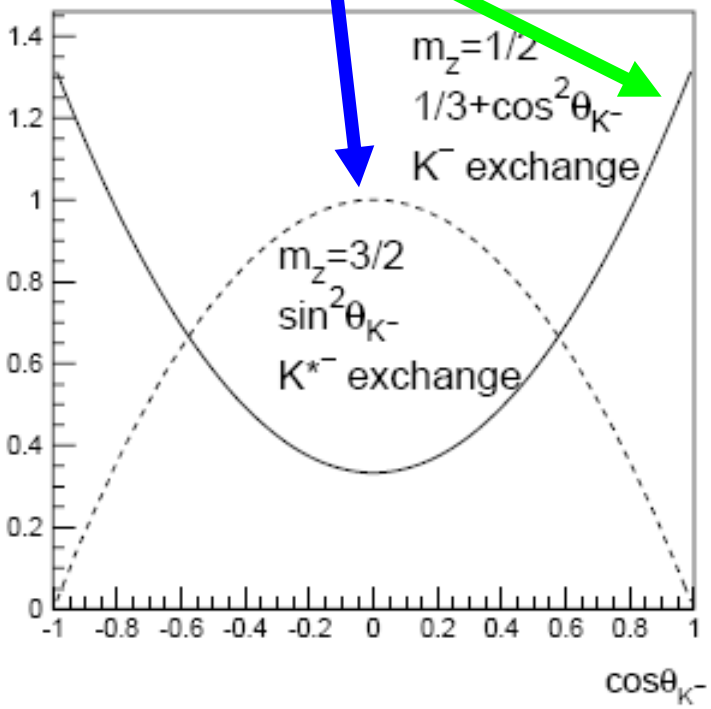


$$m_z = \pm\frac{3}{2}$$

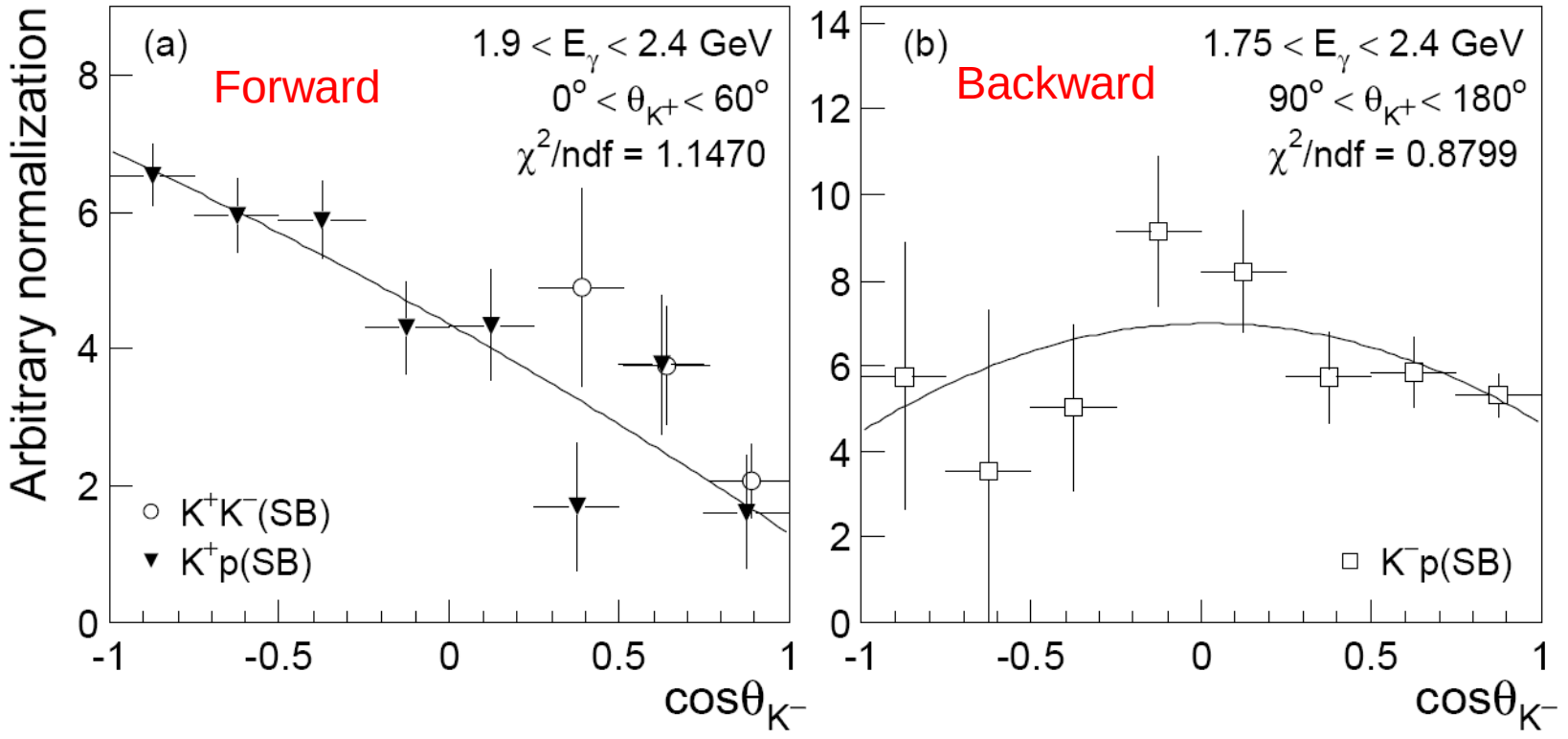
$$\Rightarrow K^{*-}\text{exchange}$$

$$m_z = \pm\frac{1}{2}$$

$$\Rightarrow K^{-}\text{exchange}$$



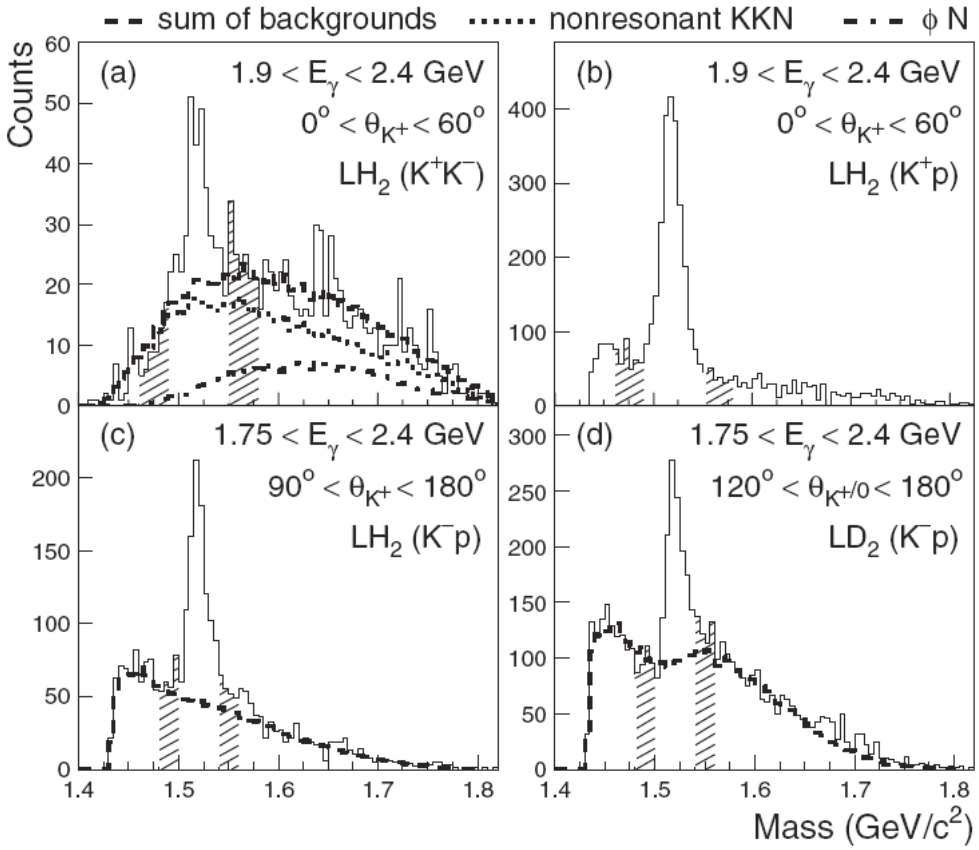
Decay Asymmetry



- In K^+p mode, an asymmetric distribution suggests an interference effect. The fraction of helicity-3/2 component was about 0.5.
- In K^-p mode, the helicity-3/2 fraction was around 0.6.

Photoproduction of Λ(1520) from p/d

$$\gamma + p \rightarrow K^+ + \Lambda(1520) \rightarrow K^+ + p + K^-$$
$$\gamma + n \rightarrow K^0 + \Lambda(1520) \rightarrow \pi^+ + \pi^- + p + K^-$$

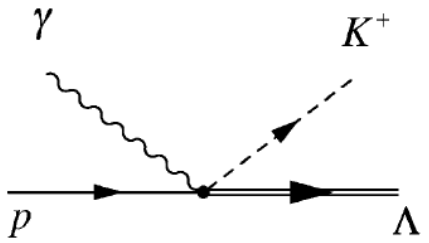


$$\sigma(d) \simeq \sigma(p)$$
$$\sigma(n) \ll \sigma(p)$$

N. Muramatsu et al. (LEPS Collaboration), PRL 103, 012001 (2009)

A Large Isospin Asymmetry in Λ^* Production

$\Lambda(1520)\ J^P = 3/2^-$



Reactions	$\gamma p \to K^+\Lambda^*$	$\gamma n \to K^0\Lambda^*$
σ	$\sim 900\,nb$	$\sim 30\,nb$
$d\sigma/d(\cos\theta)$	Forward peak	Peak at $\sim 45°$

Contact term

- $\sigma(p) >> \sigma(n)$
- Strong forward peak

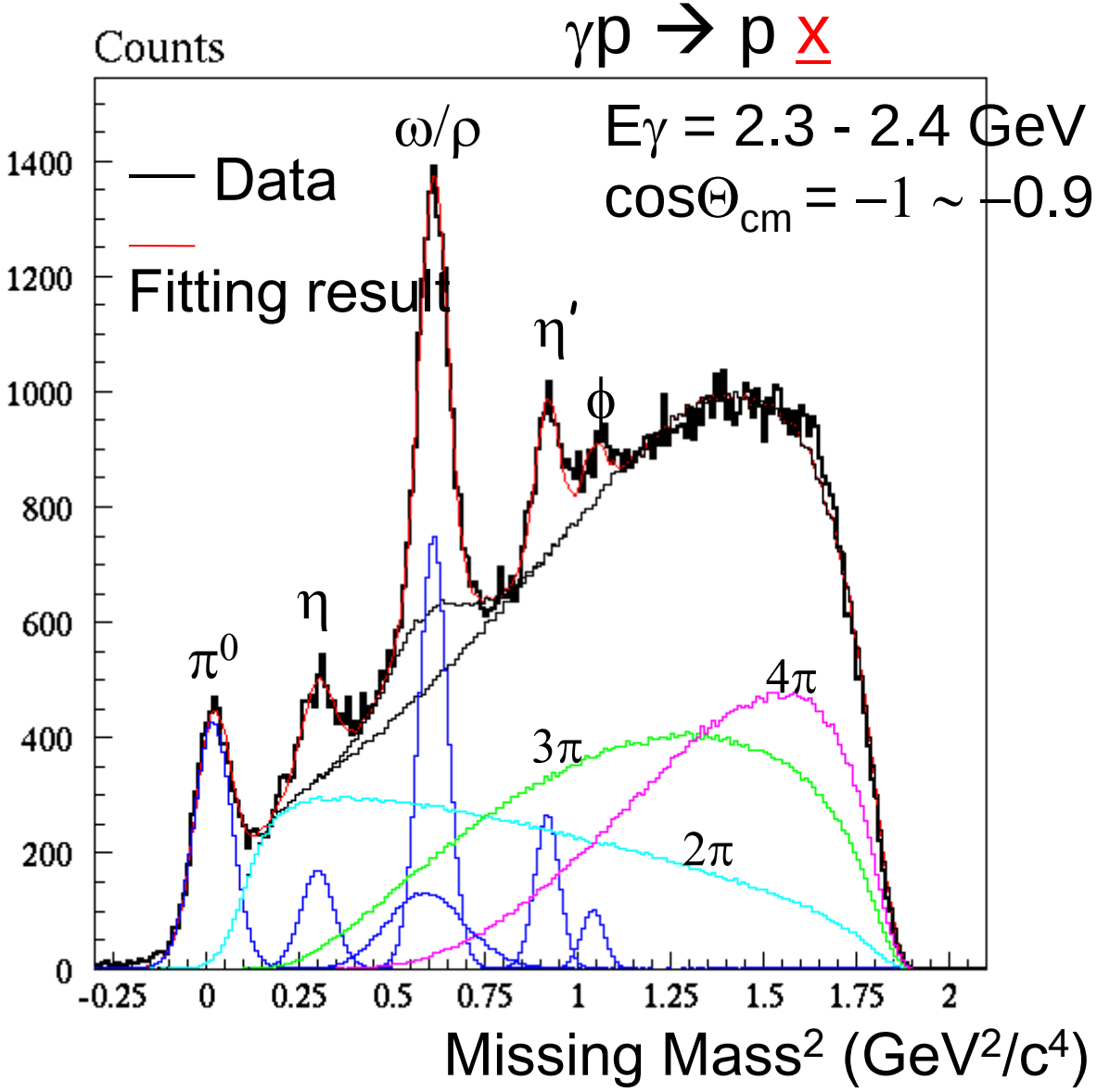
⇨ To be checked by experiments

For Θ: we expect $\sigma(p) << \sigma(n)$

S.i. Nam, A. Hosaka, and H.-Ch. Kim, Phys. Rev. D, 71, 114012 (2005)

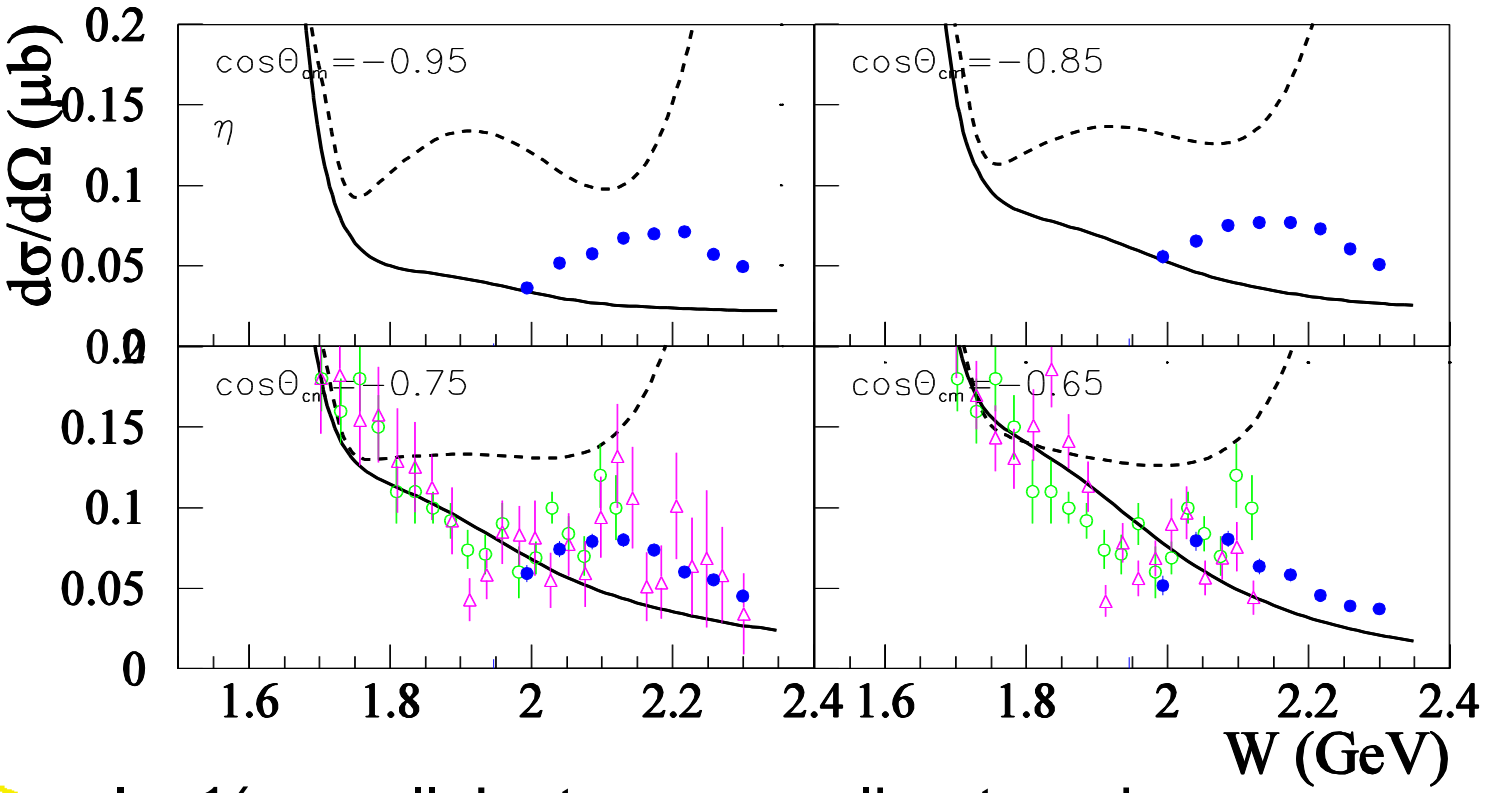
Backward η productions

Missing mass spectra



Differential cross sections for η photoproduction

- LEPS data
- Jlab/CLAS data
- Bonn/ELSA data
- SAID -partial-wave analysis
- Eta-MAID - isobar model

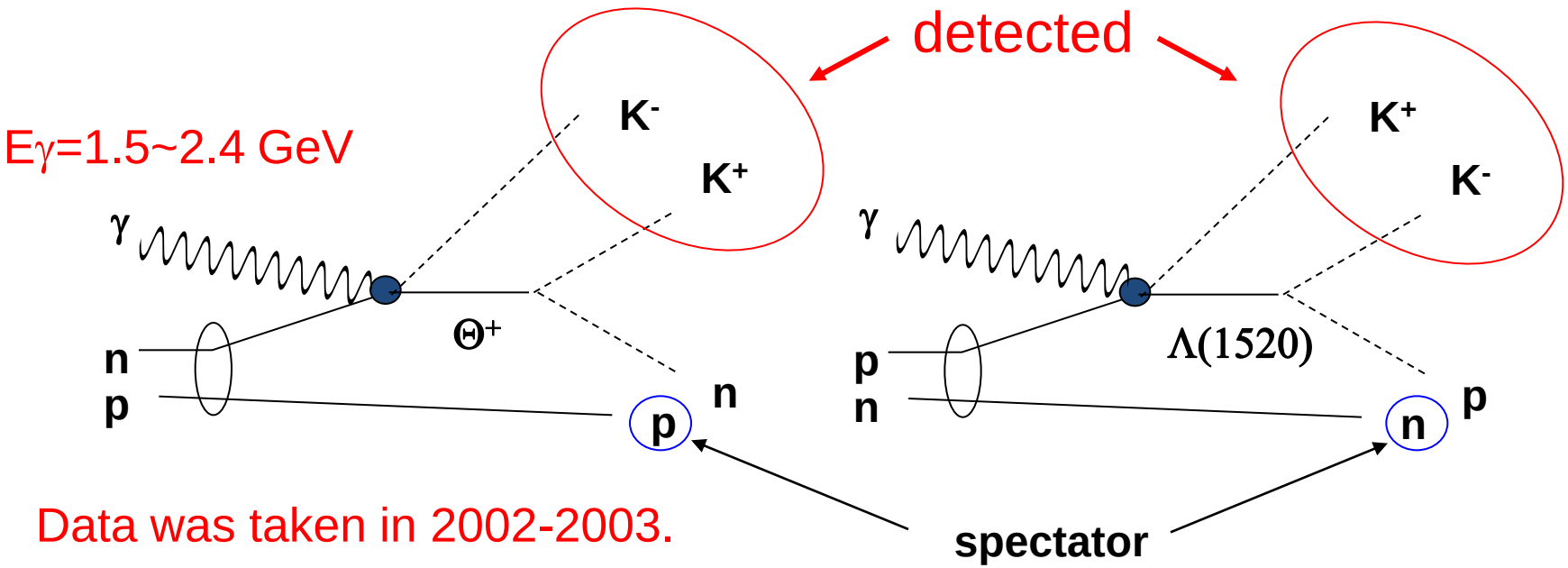


I = ½, small J, strong coupling to η, heavy
→ may contain large $s\bar{s}$ component

$\Theta^+(1530)$

$uudd\bar{s}$

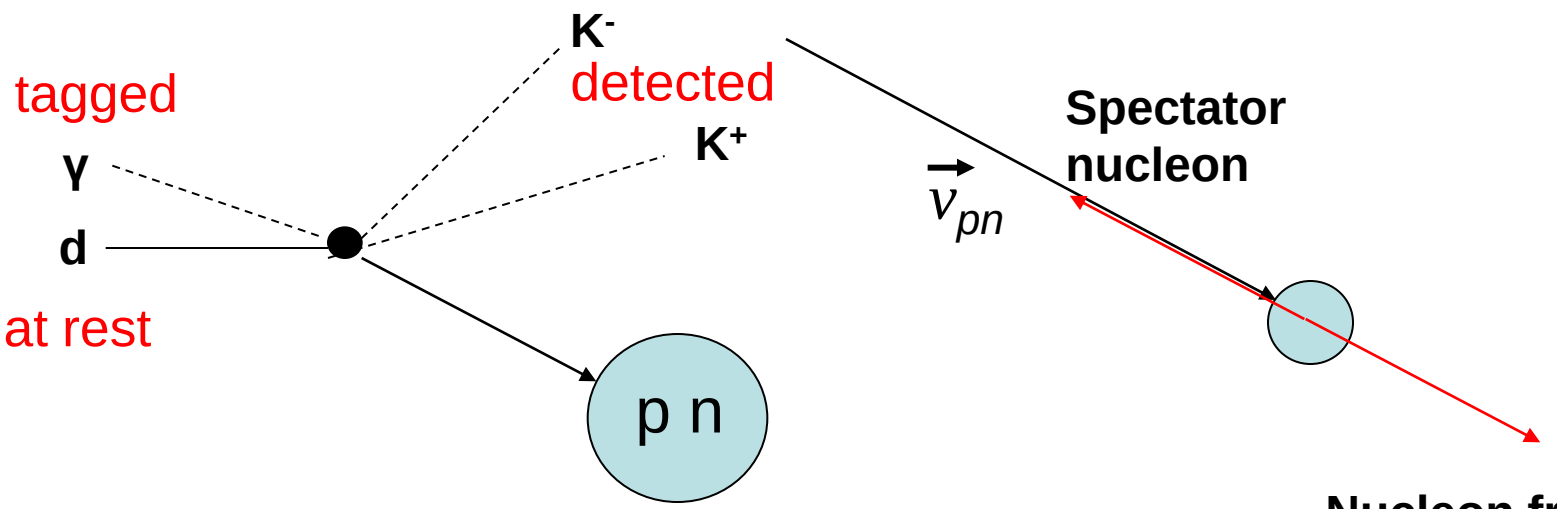
Quasi-free production of Θ^+ and $\Lambda(1520)$



Data was taken in 2002-2003.

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

Minimum Momentum Spectator Approximation



We know 4 momentum of *pn* system

$\downarrow$

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

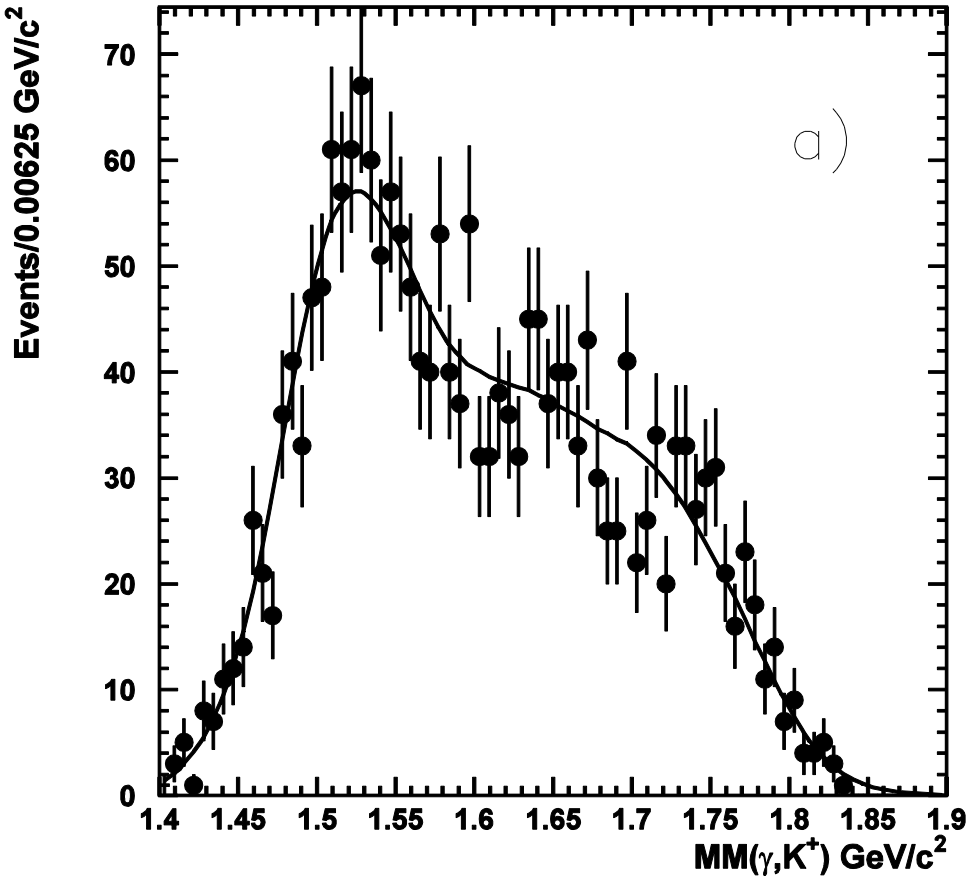
$\downarrow$

$|\vec{p}_{CM}|$ 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 $\vec{v}_{CM}$.

Results of $\Lambda(1520)$ analysis

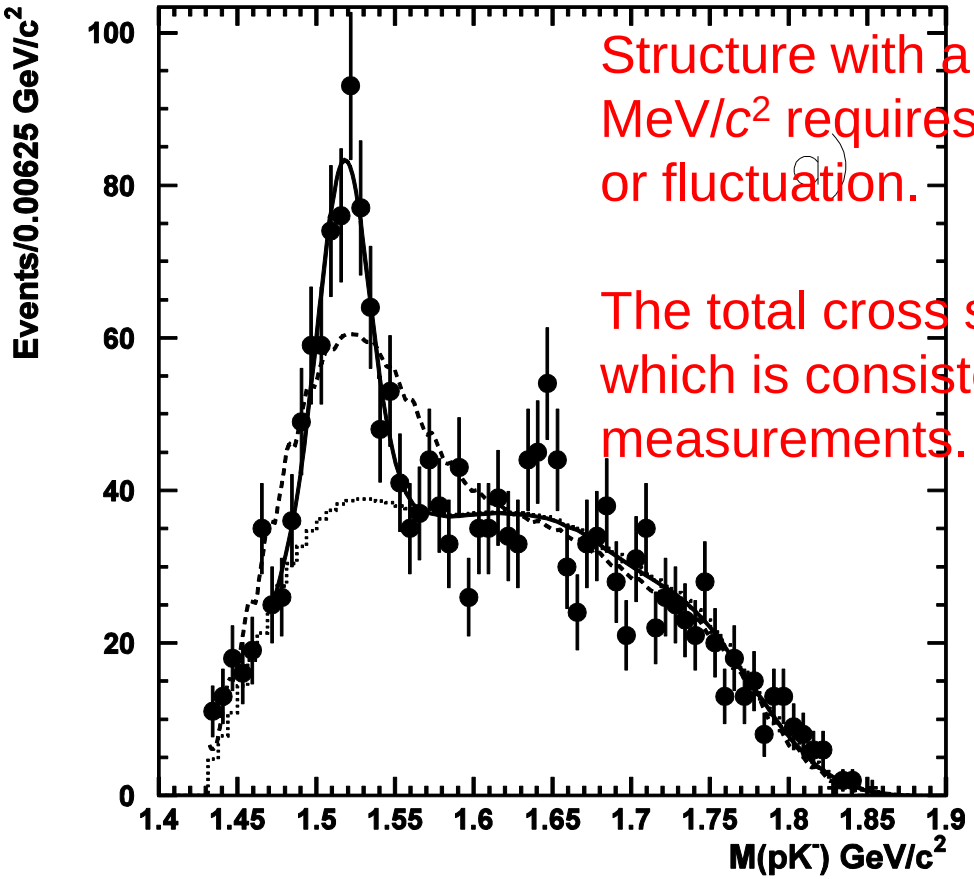
Simple (γ,K^+) missing mass: No correction on Fermi motion effect.



Proton is assumed to be stopped in the Lab system.

Results of $\Lambda(1520)$ 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.

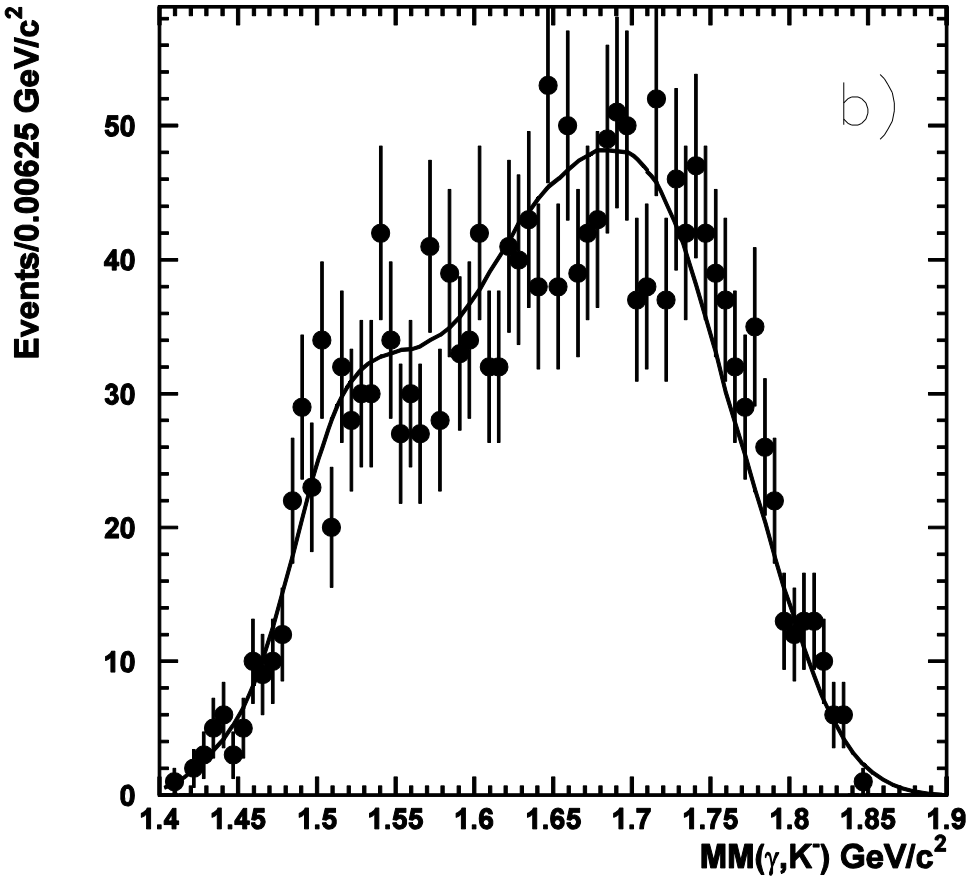
The total cross section is ~1 μb, which is consistent with the LAMP2 measurements.

$\Delta(-2\ln L) = 55.1$ for $\Delta ndf = 2 \longrightarrow 7.1\sigma$

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

Results of Θ^+ analysis

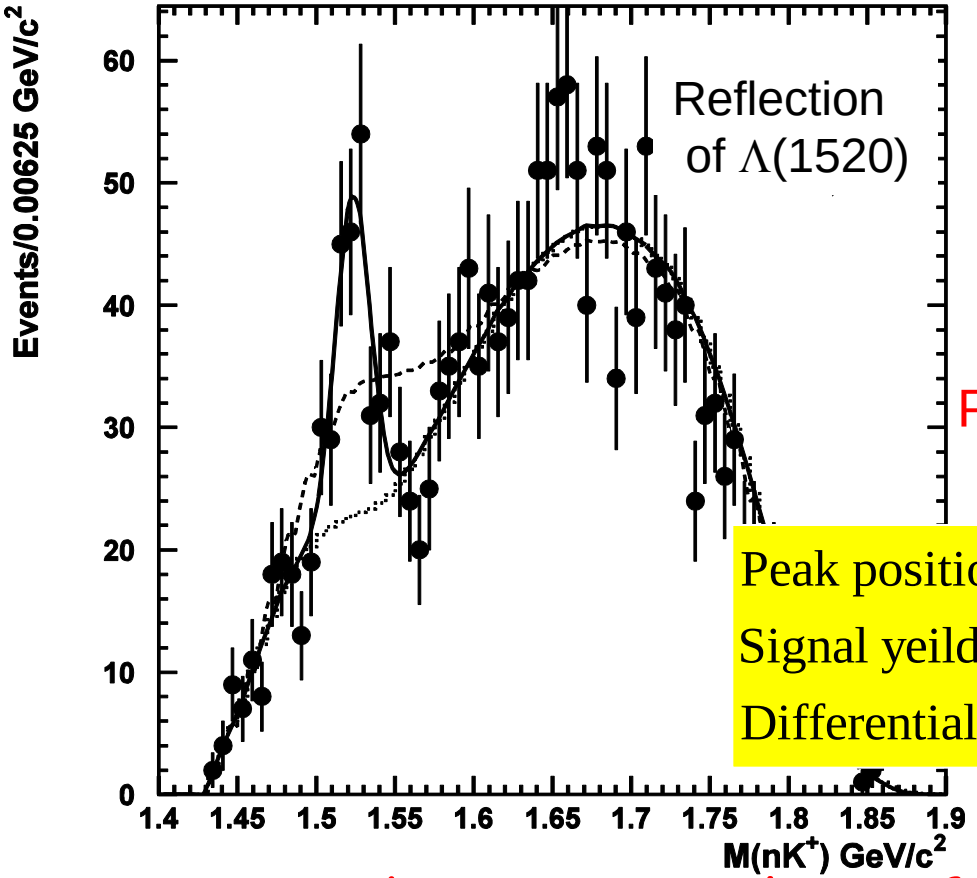
Simple (γ,K^-) missing mass: No correction on Fermi motion effect.



Neutron is assumed to be stopped in the Lab system.

Results of Θ^+ analysis

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



PRC **79,** 025210 (2009)

Peak position: 1.527 ± 0.002 GeV/c^2

Signal yeild: 116 ± 21 events

Differential cross-section: 12 ± 2 nb/sr

"We DO NOT estimate the statistical significance by counting the number of events above background level"

$\Delta(-2\ln L) = 31.1$ for $\Delta ndf = 2 \longrightarrow 5.2\sigma$ $\quad \mathrm{Prob}(5.2\sigma) = 2\times10^{-7}$

Next step

LARGE fluctuations are required if the peak is not real.

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

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

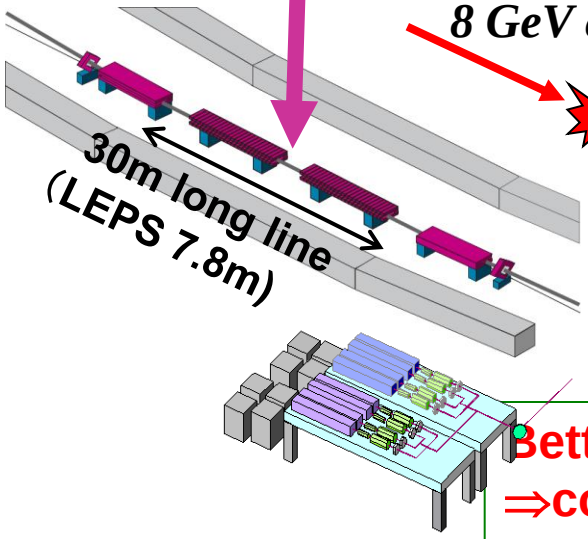
The result will tell us if the peak structure is due to statistical fluctuations or not unambiguously.

LEPS2

LEPS2 Project at SPring-8

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)

Backward Compton Scattering



8 GeV electron

Recoil electron (Tagging)

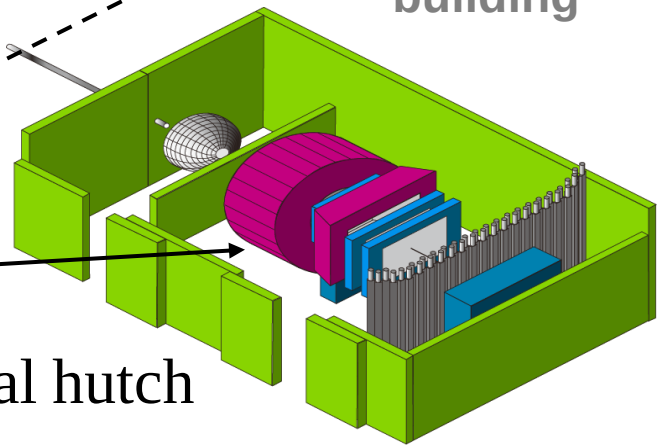
Laser or re-injected X-ray

GeV γ-ray

Better divergence beam
⇒collimated photon beam
Different focus points for multi CW laser injection

Inside building

Outside building

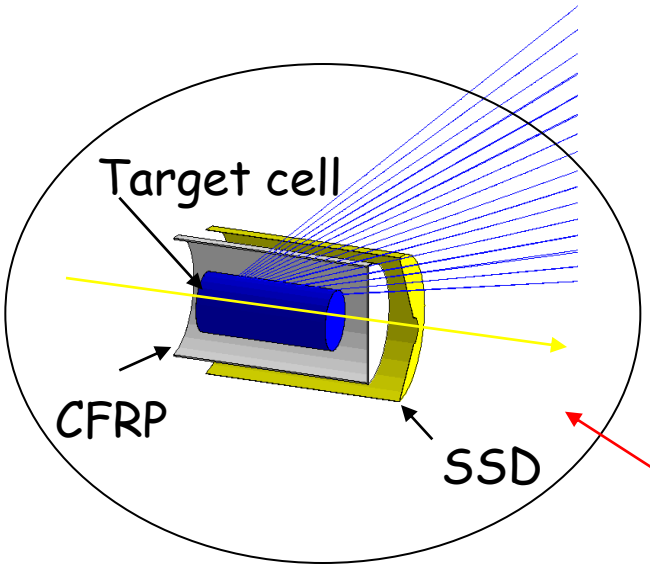


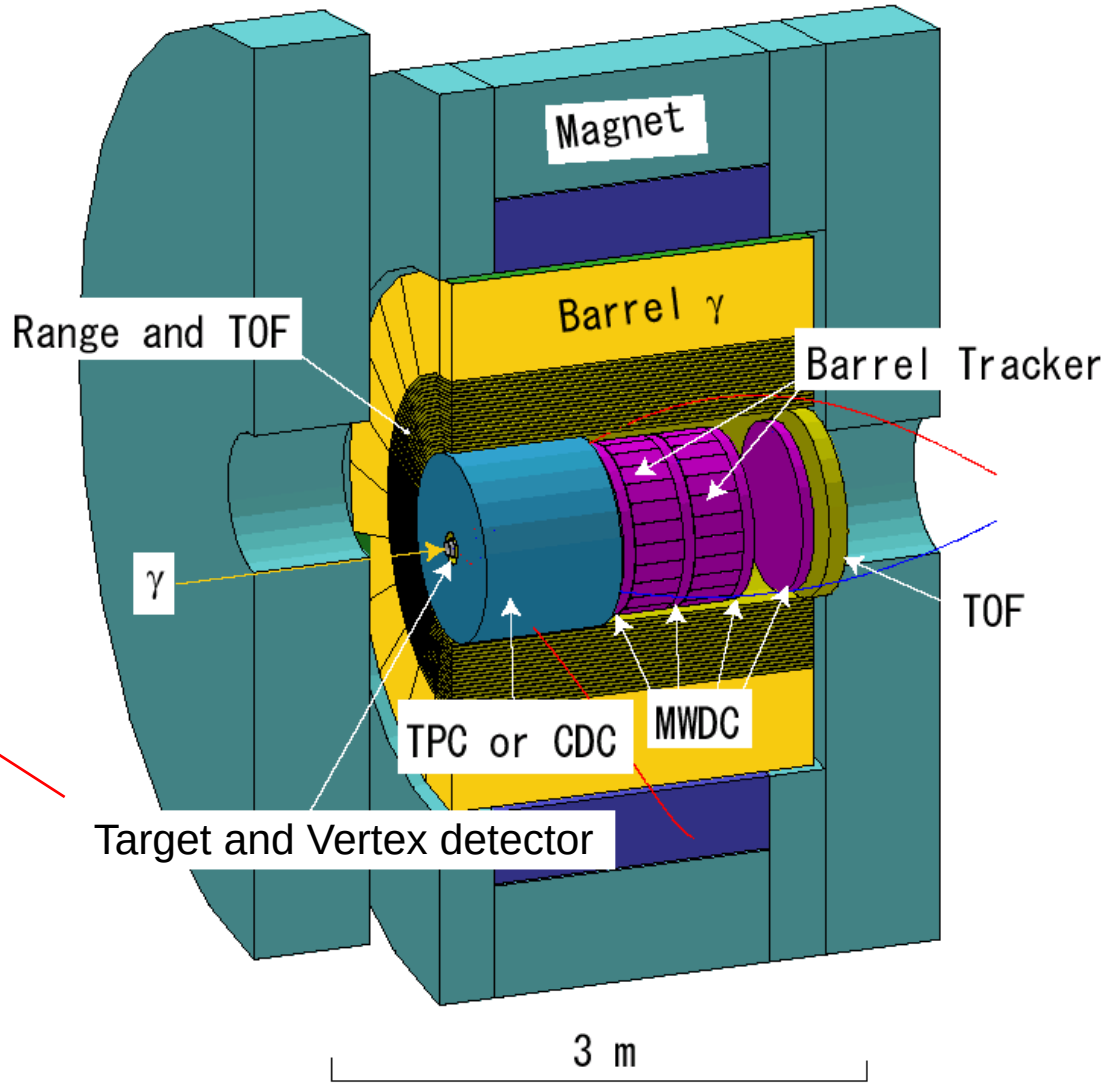
Experimental hutch

Large 4π spectrometer based on BNL-E949 detector system.
Better resolutions are expected.
New DAQ system will be adopted.

Main Detector Setup

E949 Solenoid Magnet
size: Φ5m × 3.5m
weight: ~400 t
Field: 1.0 T
(1.1 MW at 4400 A)





Construction of LEPS2 has been started!
Please join us!!