Recent results from LEPS

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for the LEPS&LEPS2 collaboration

MENU2016, July 28th, 2016

Outline

LEPS

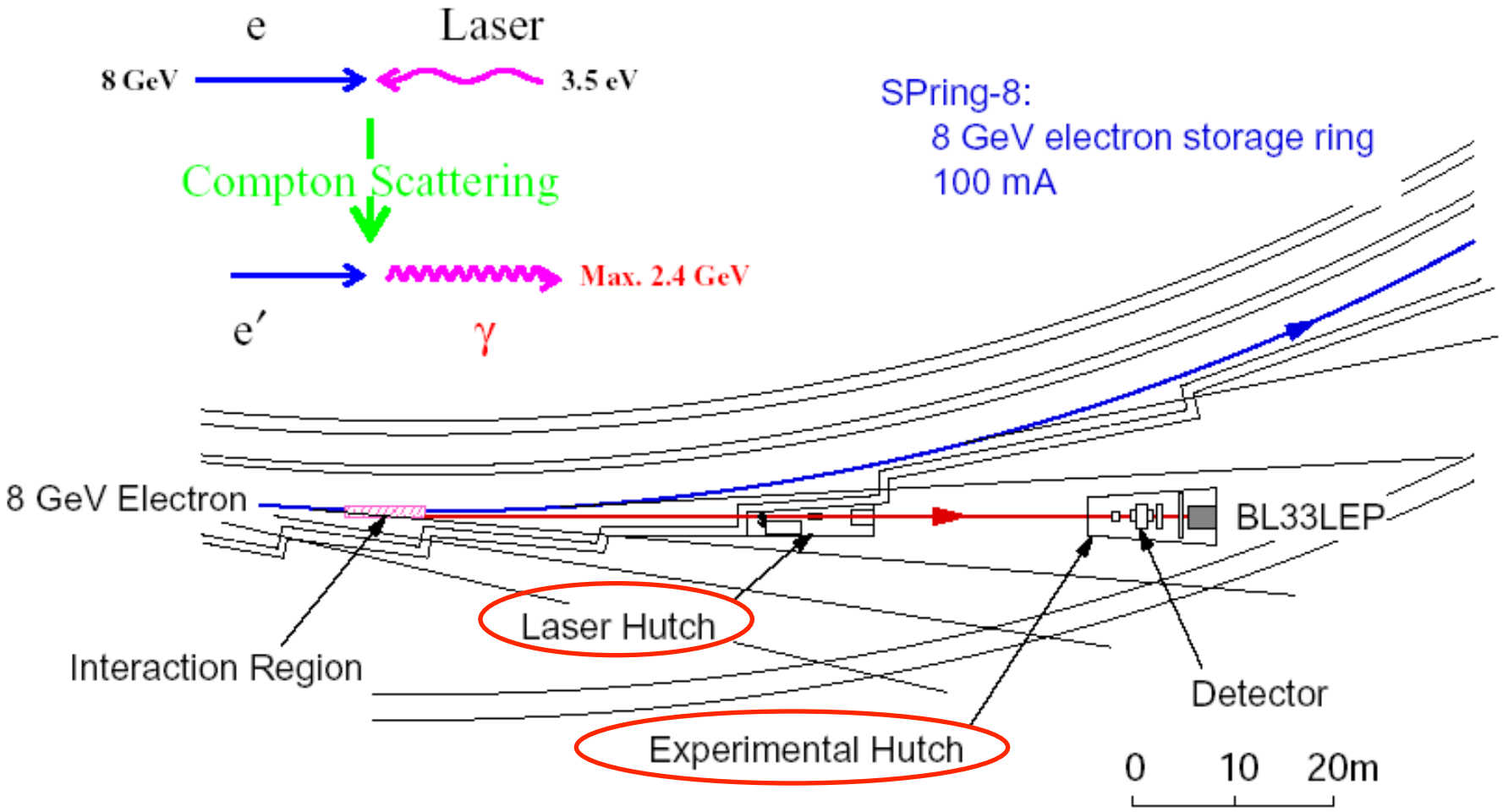
- Overview
- Status and recent results
- HD target

LEPS2

- Overview
- First experiment

Summary

Laser Electron Photon beamline at SPring-8



Operated since 2000.

Backward-Compton Scattered Photon

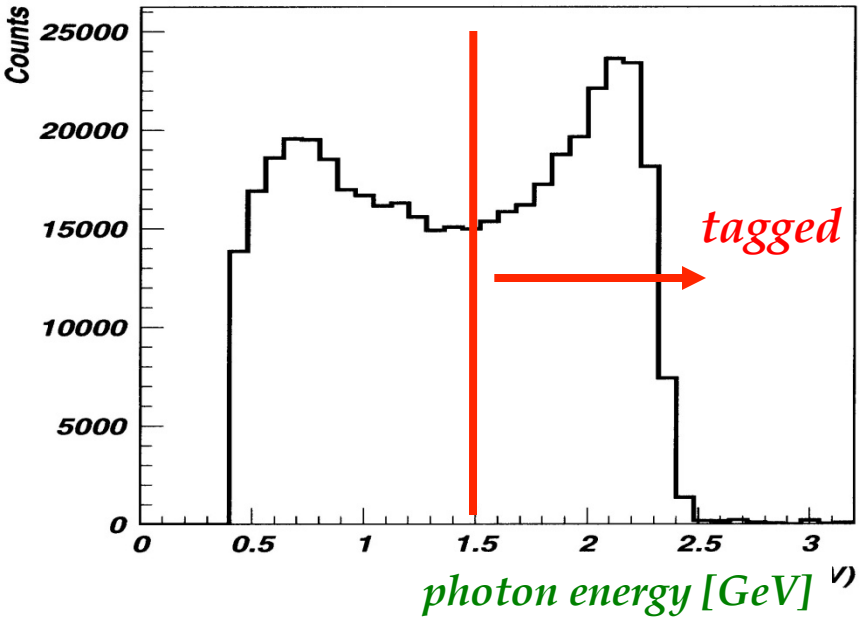
8 GeV electrons in SPring-8 + 350nm(260nm) laser ➔ maximum 2.4 GeV(2.9 GeV) photon

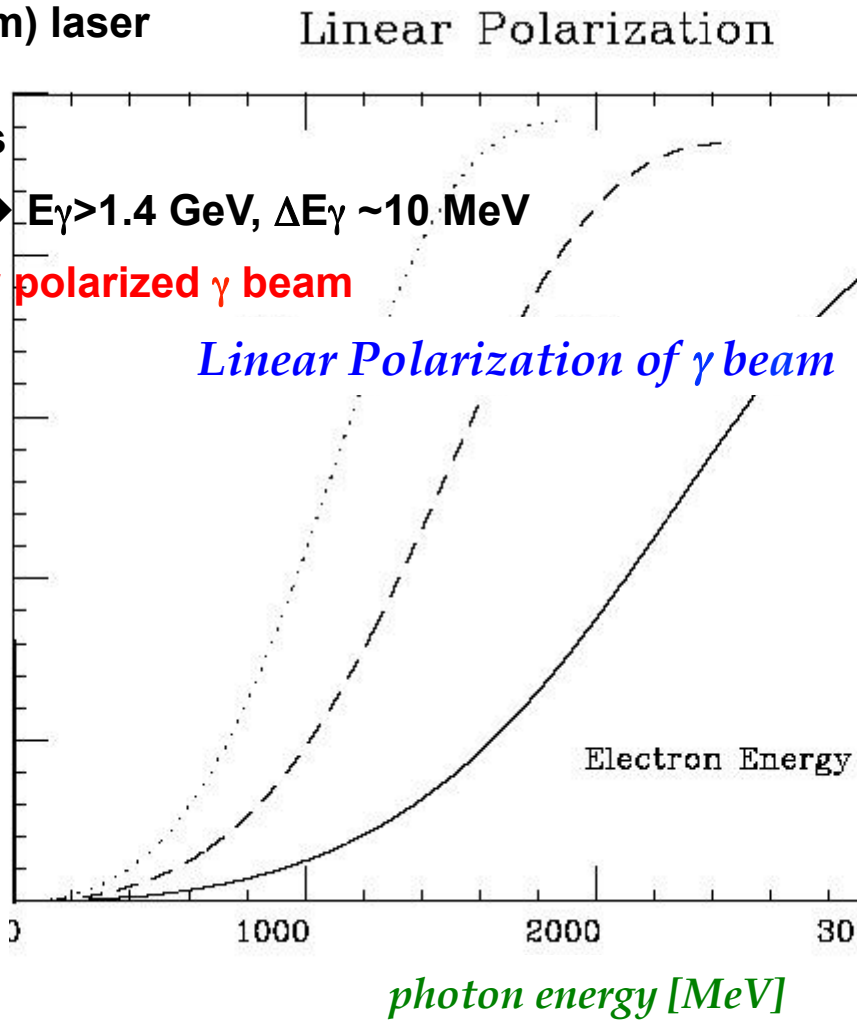
Laser Power ~6 W ➔ Photon Flux ~1 Mcps

Eγ measured by tagging a recoil electron ➔ Eγ>1.4 GeV, ΔEγ ~10 MeV

Laser linear polarization 95-100% ⇒ Highly polarized γ beam

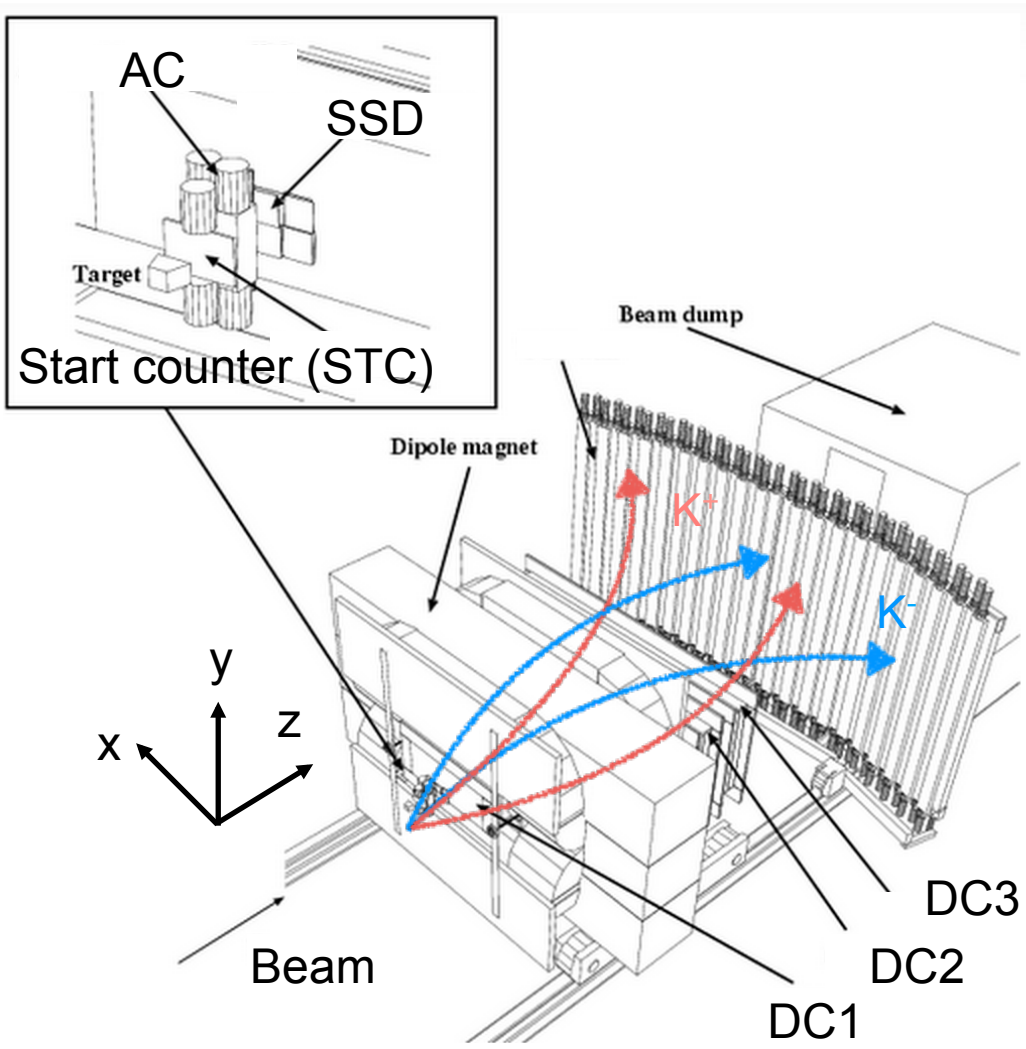
PWO measurement





Linear Polarization of γ beam

LEPS spectrometer

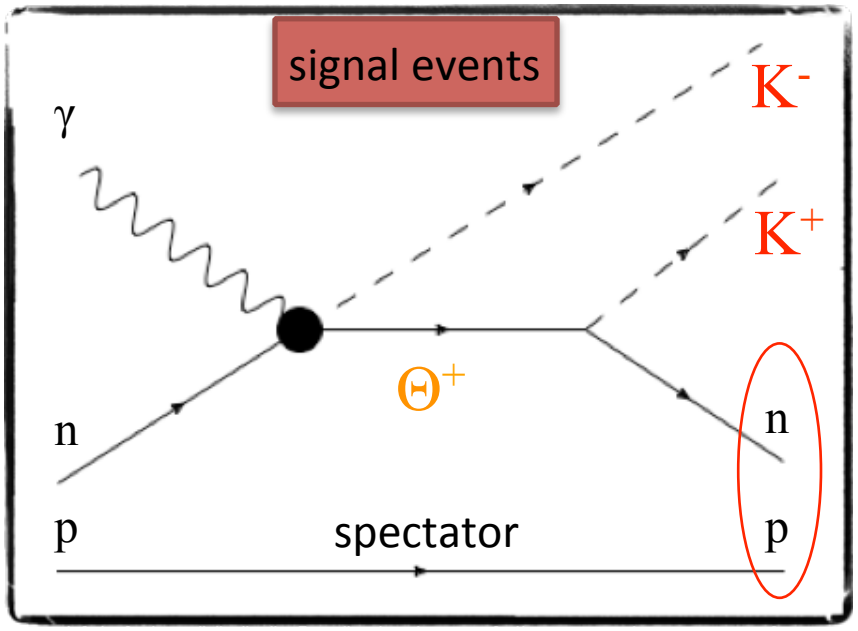


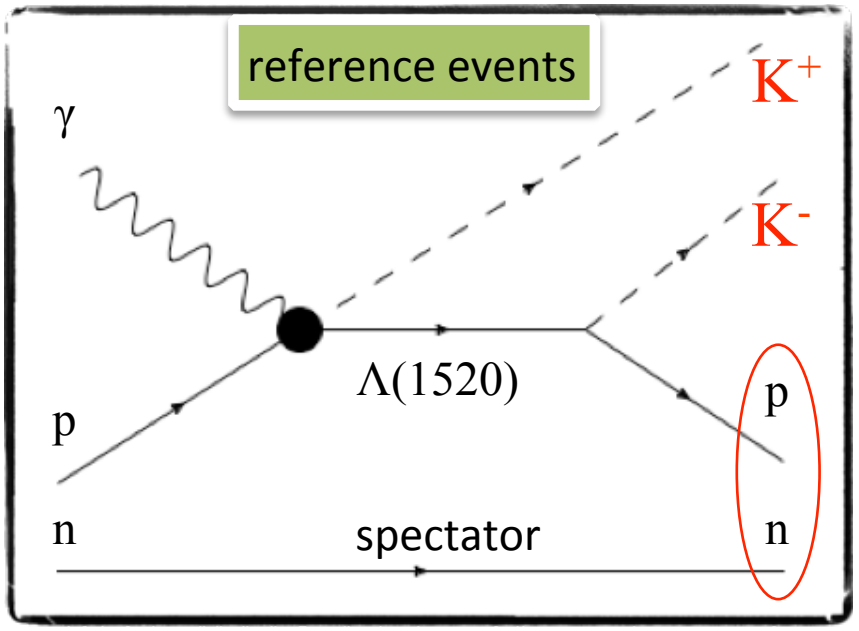
- Dipole magnet : 0.7 Tesla
- Acceptance :
  Hori : ± 20°
  Vert : ± 10°
- AC index : 1.03
  (reject 0.6 GeV/c π)

- E_γ = 1.5 ~ 2.4 GeV
- tagger rate : ~10^6 cps
- trigger rate : ~ 100 cps

Θ^+ study at LEPS

Θ^+ production via $\gamma d \rightarrow K^-\Theta^+ \rightarrow K^-K^+pn$





signal events : $\gamma n \rightarrow K^-K^+n$

reference events : $\gamma p \rightarrow K^-K^+p$

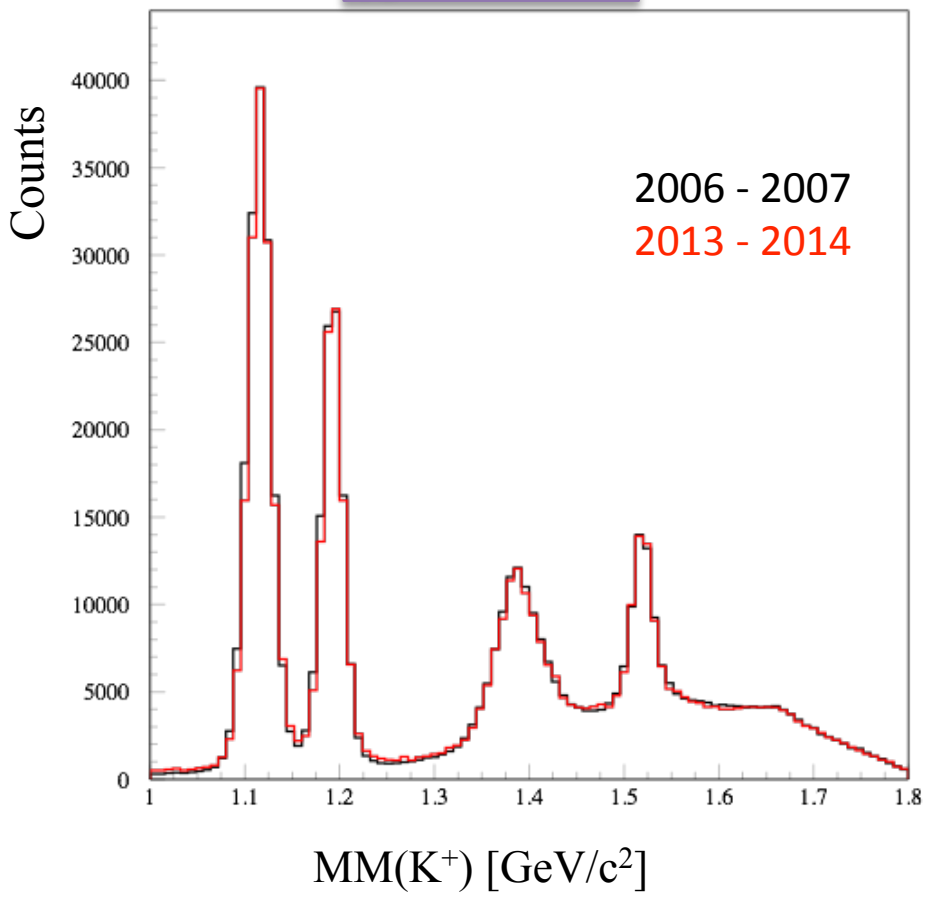
Spectator can not escape from the target.

n/p separation is possible by improving the proton detection efficiency.

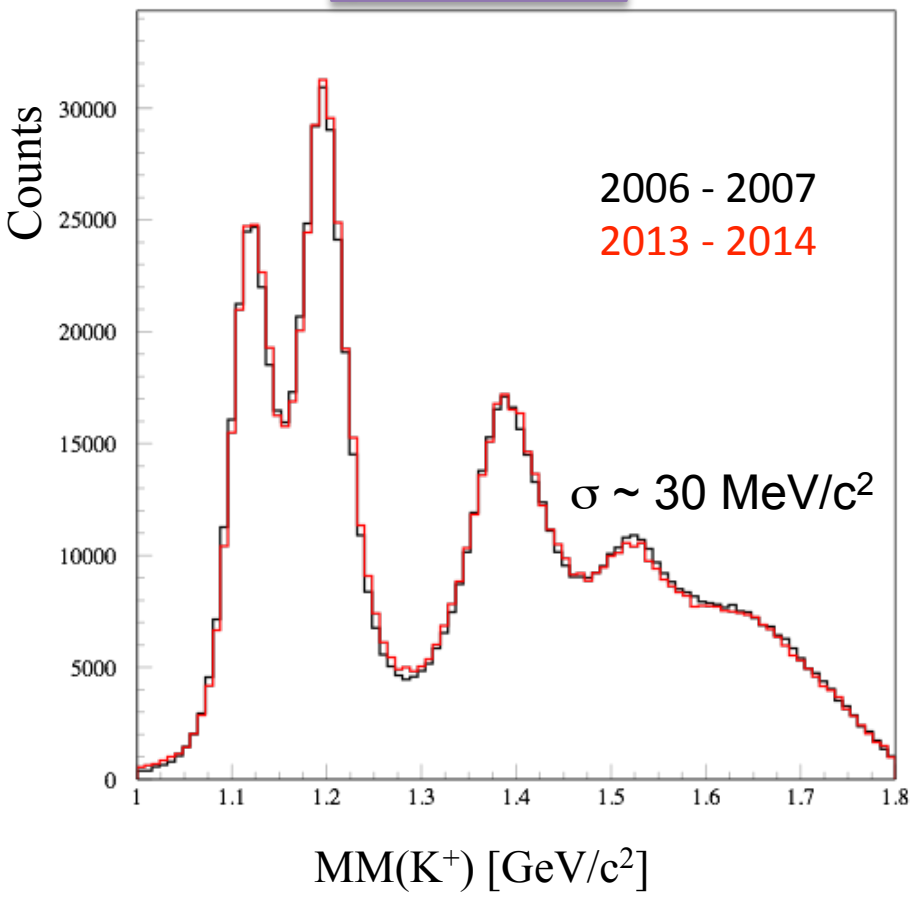
K^+ missing mass spectra

assuming proton mass for missing mass calculation

$\gamma p \rightarrow K^+X$



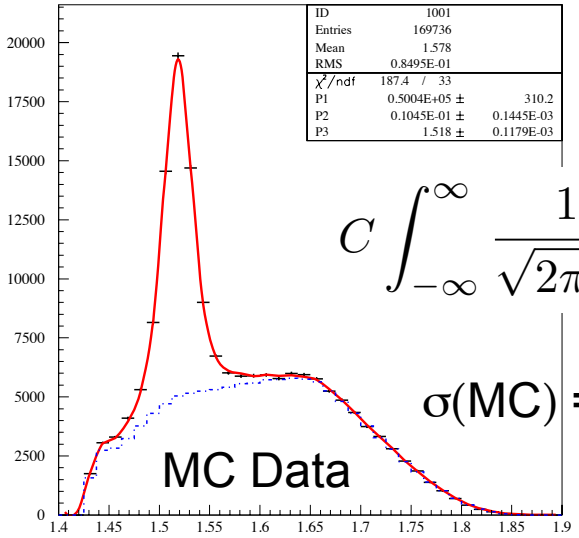
$\gamma d \rightarrow K^+X$



Quality of K^+ missing mass spectra is the almost same.

Detailed calibrations were done by Y. Nozawa.

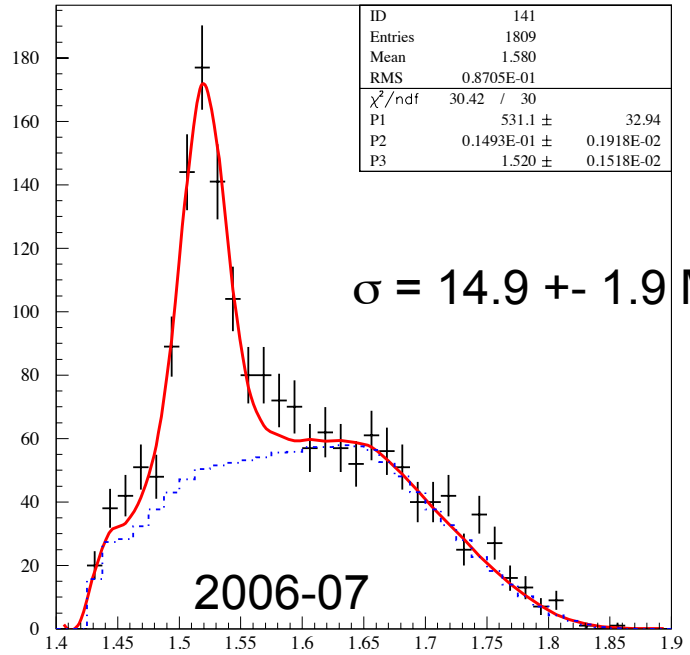
Estimation of Mass Resolution by MMSA



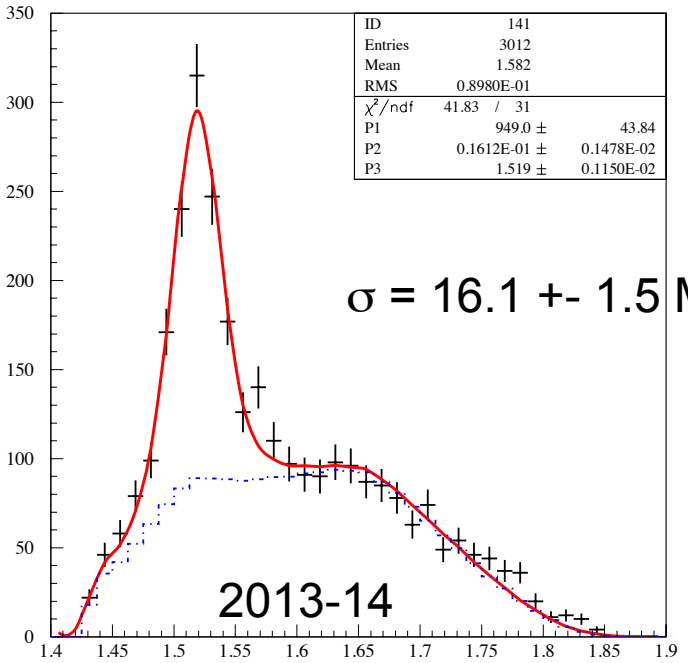
Λ(1520) peak fit with Voigt function

$$C\int_{-\infty}^{\infty}\frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{(y-M_0)^2}{2\sigma^2}\right)\cdot\frac{1}{\pi}\frac{\Gamma/2}{(x-y-M_0)^2+(\Gamma/2)^2}\mathrm{d}y$$

σ(MC) = 10.5 MeV/c²

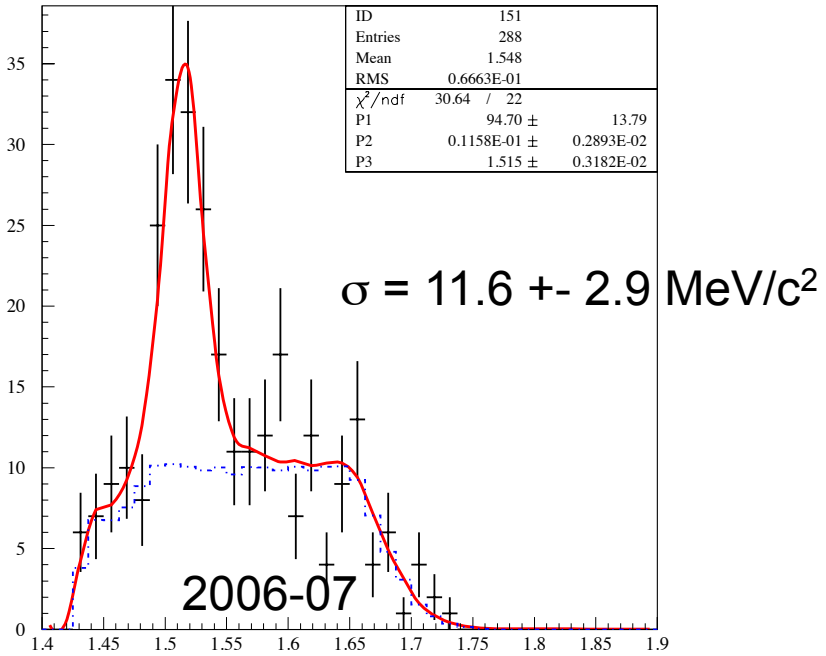


σ = 14.9 +- 1.9 MeV/c²

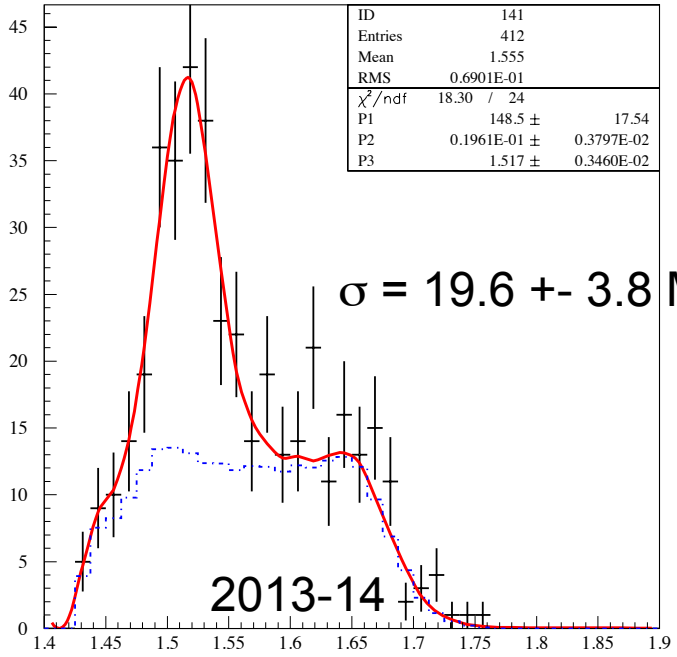


σ = 16.1 +- 1.5 MeV/c²

Mass Resolution in the low energy region



σ = 11.6 +- 2.9 MeV/c^2

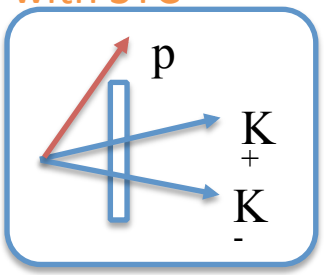


σ = 19.6 +- 3.8 MeV/c^2

- Currently checking the reason for the bad mass resolution of the new data in the low beam energy region (below 2.1 GeV).

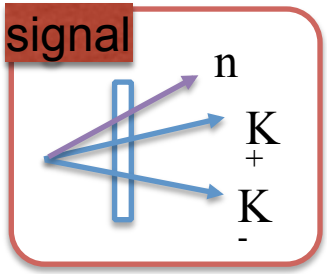
Proton detection with STC

proton untagged with STC

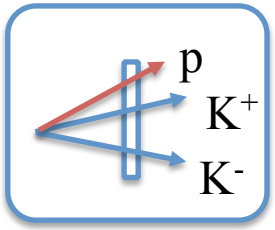


or

signal



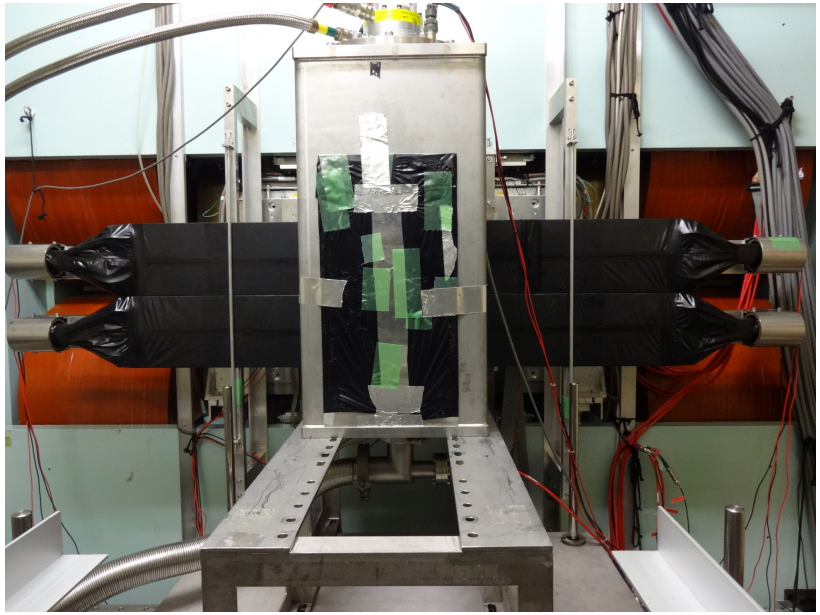
proton tagged with STC



2002 - 2007

Small STC
x : 150 mm
y : 94 mm
z : 5 mm

2013 - 2014

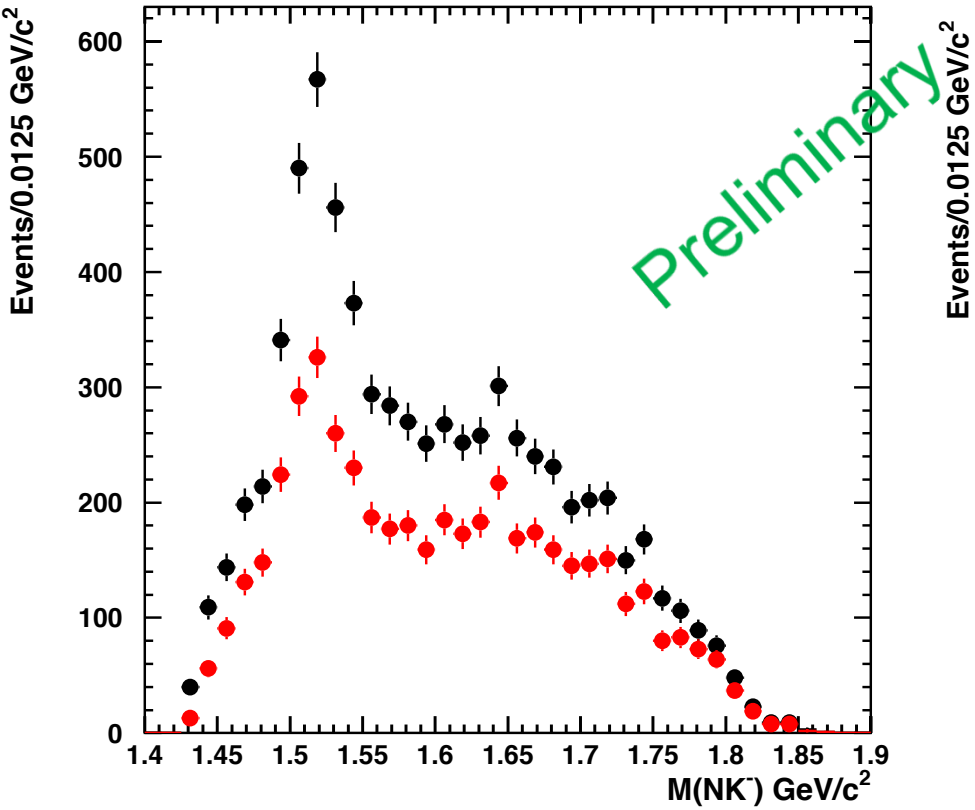


Large STC (LSTC)
x : 780 mm
y : 340 mm
z : 10 mm

Proton detection efficiency is improved by using large-area start counter (STC) in 2013-2014 run.

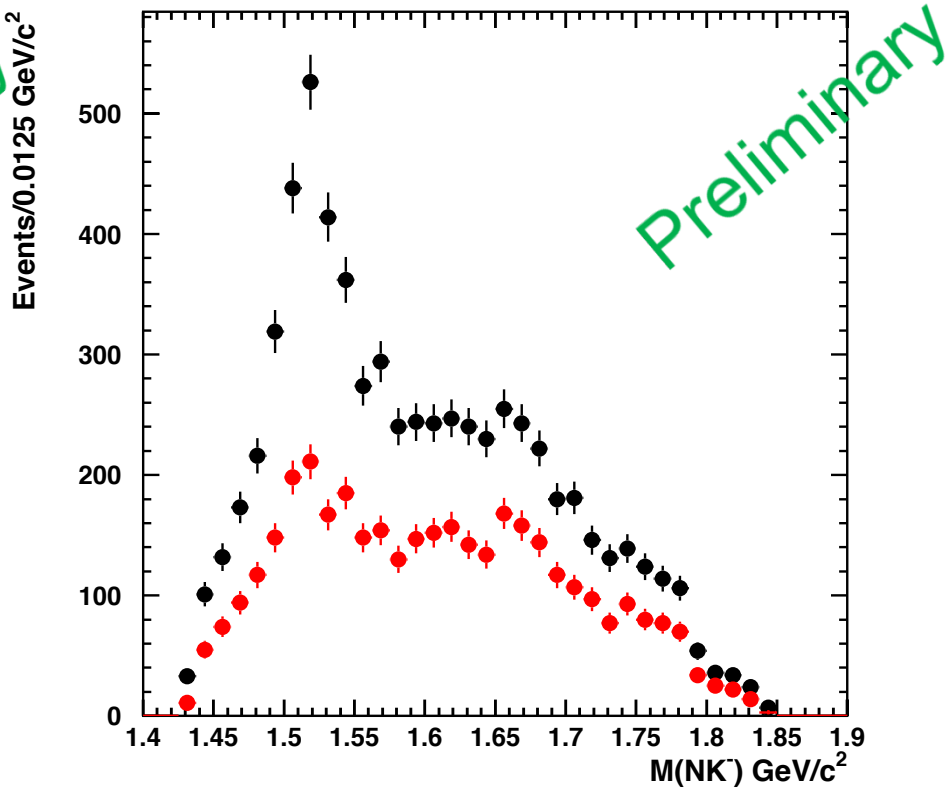
Improvement in Proton-event rejection

Previous data
(2002-03, 2006-07)



Proton detection efficiency: 59%

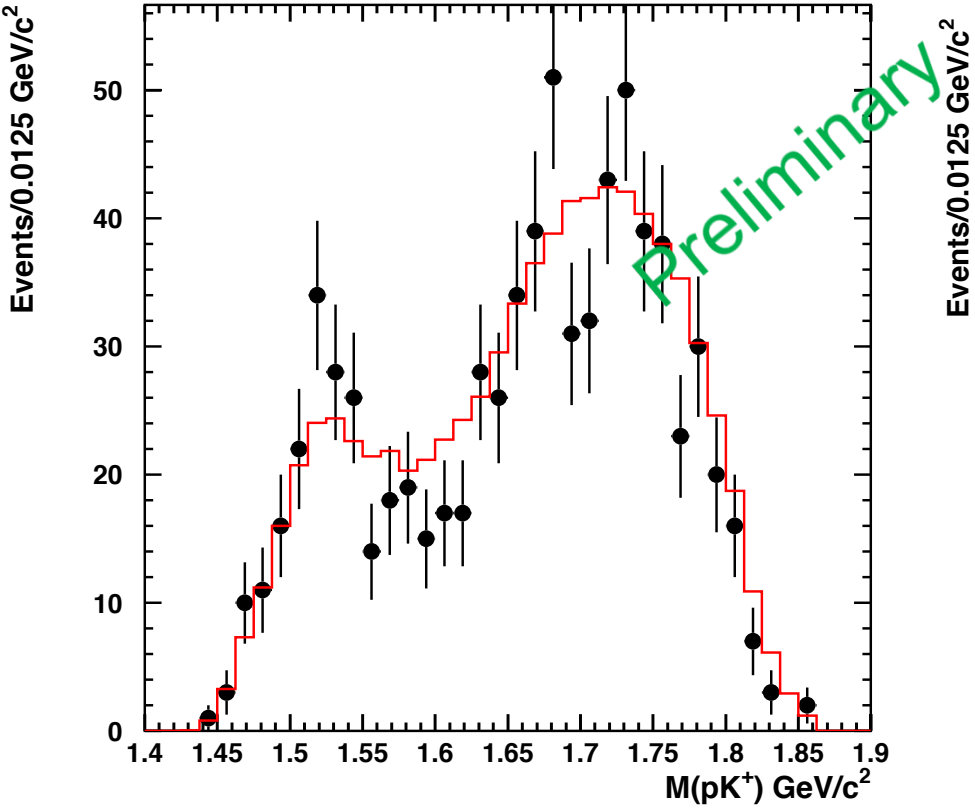
New data
(2013-14)

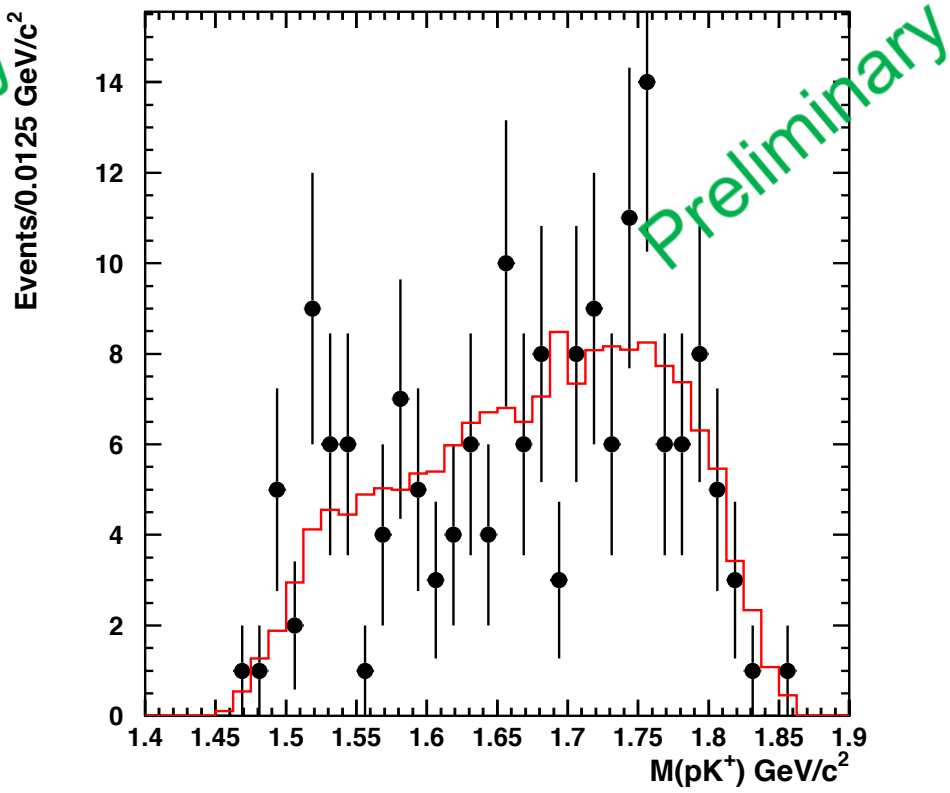


Proton detection efficiency: 84%

Effect of Proton-event leakage

- Unidentified proton event may introduce non-uniform BG.
- Proton detection efficiency is improved by selecting events with VTX point near the STC (2/3 of the target volume).
- Events with a large-angle proton are also to be rejected.

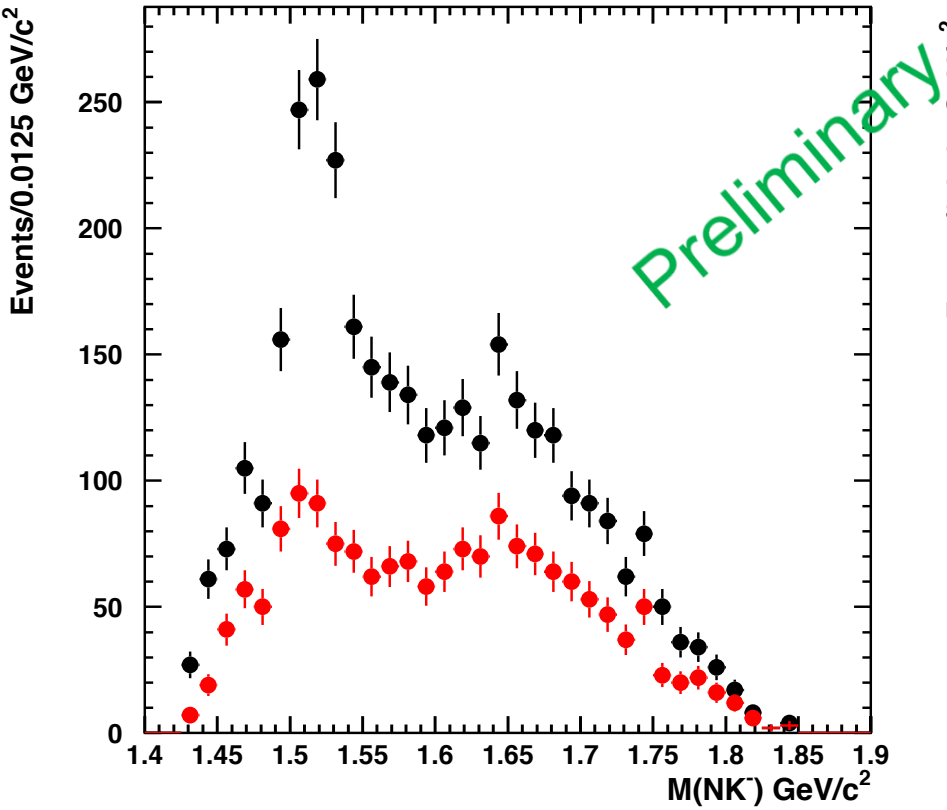




Leakage of proton events are reduced by a factor of 4.

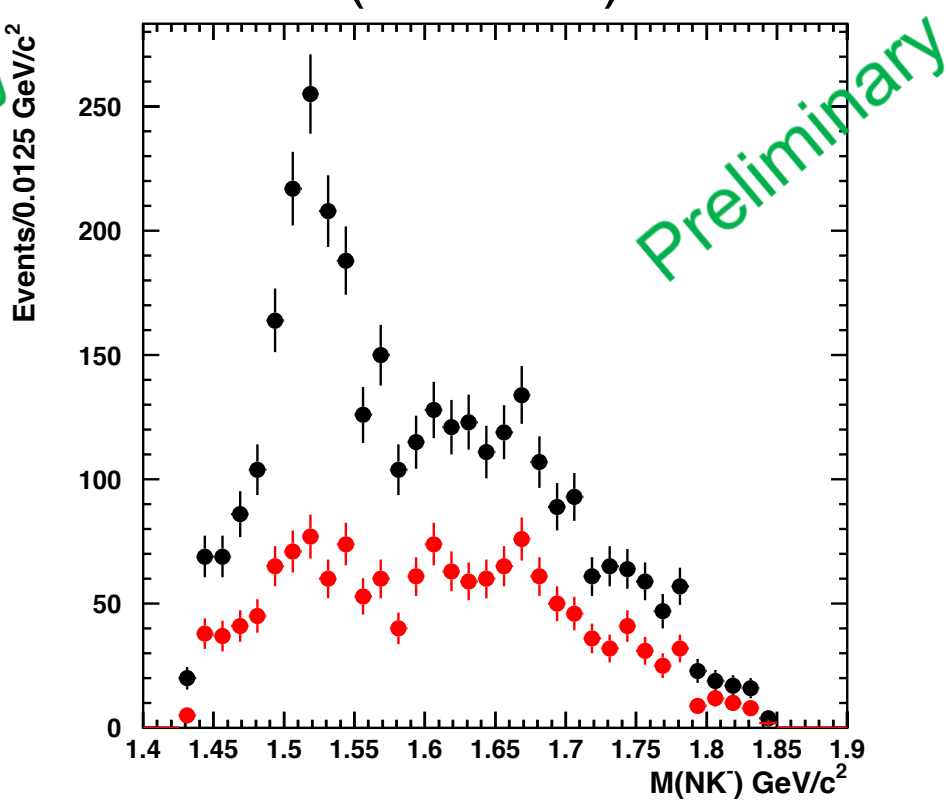
Proton-event rejection after tighter condition

Previous data
(2002-03, 2006-07)



Proton detection efficiency: 88%

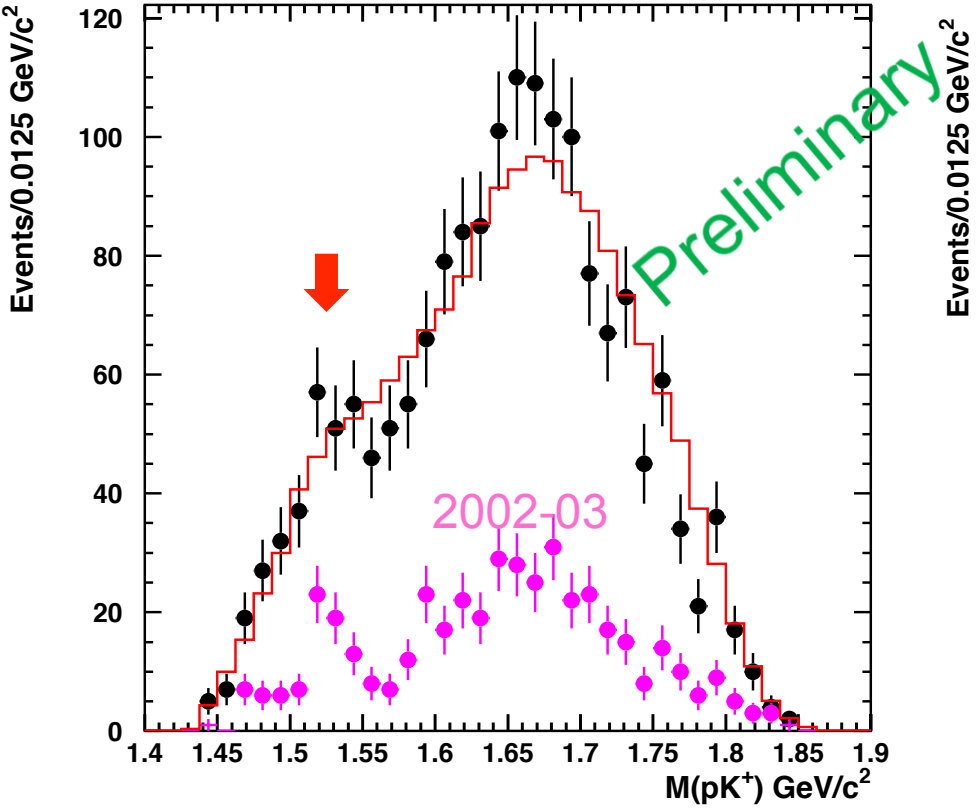
New data
(2013-14)



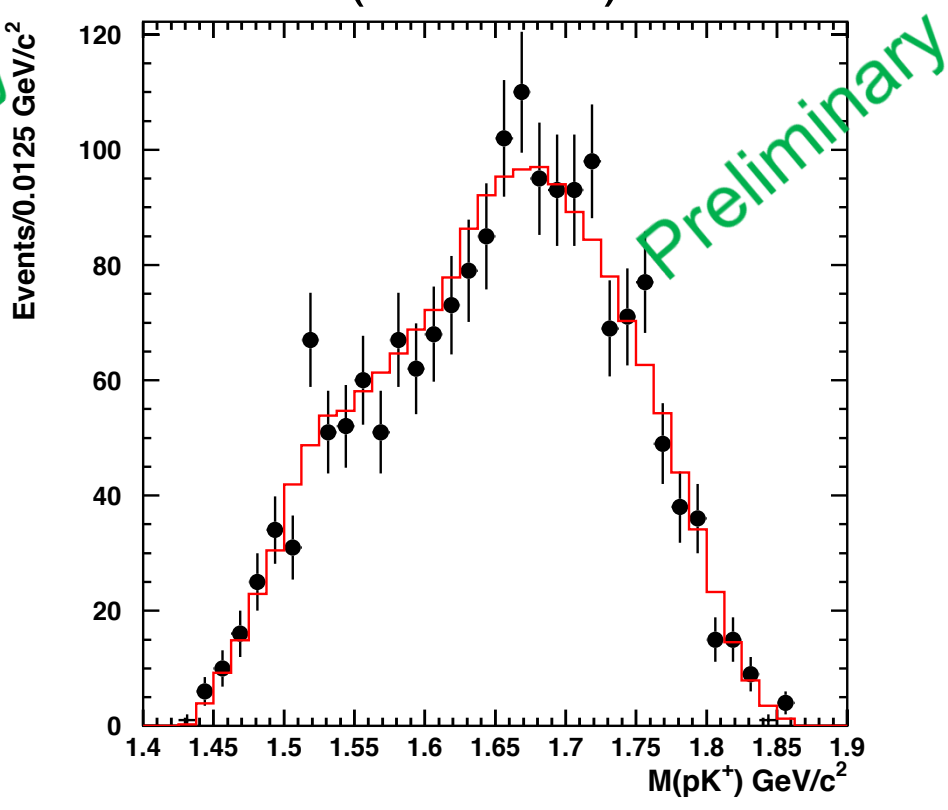
Proton detection efficiency: 98%

No peak around 1.53 GeV/c^2 in pK^+ mass distribution

Previous data
(2002-03, 2006-07)



New data
(2013-14)

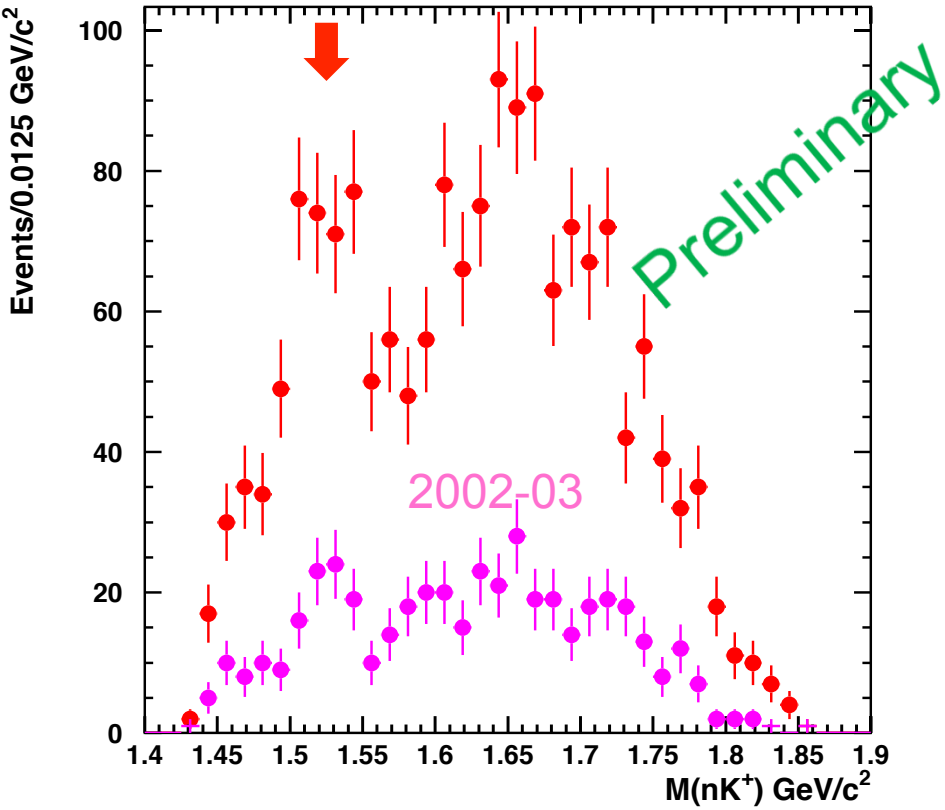


Large fluctuation was seen in 2002-03 data.

The fluctuation was not seen in 2006-07 data.

Enhancement in nK^+ mass distribution (Previous data)

Previous data
(2002-03, 2006-07)



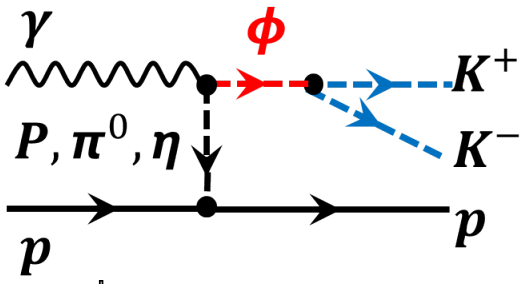
New data
(2013-14)

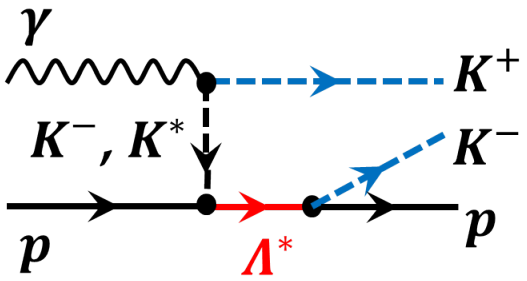
The "box" will be open soon after:

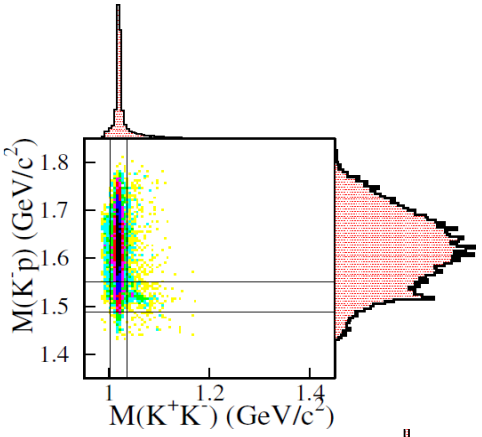
- The reason for a bad missing mass resolution in the low energy region is understood.
- The event selection was optimized in terms of proton tagging efficiency and signal sensitivity.

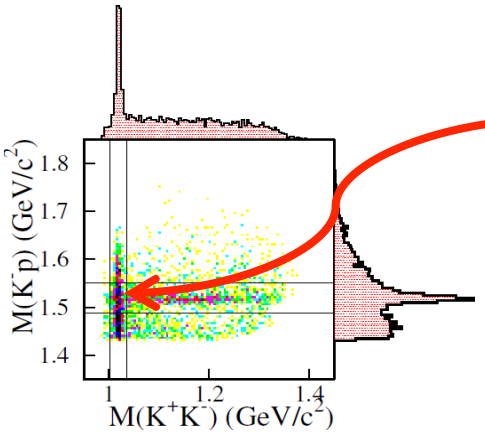
Interference effect between φ and Λ(1520) production channels in the γ p → K^+K^-p near threshold.

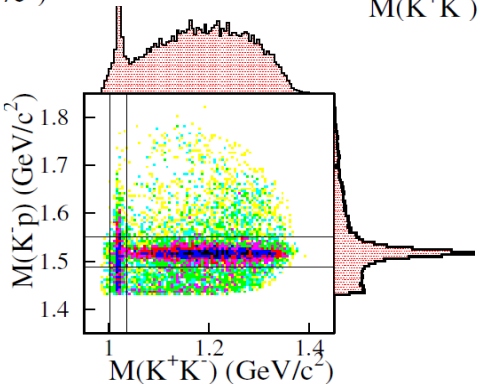
Jul.26th /26-mini-3 /S.Y. Ryu



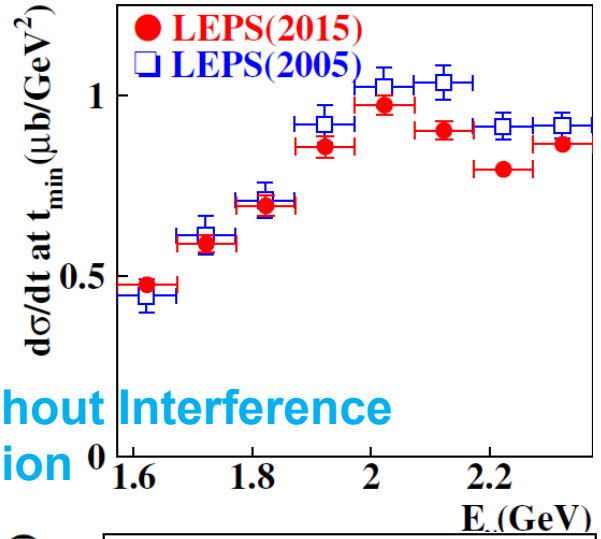


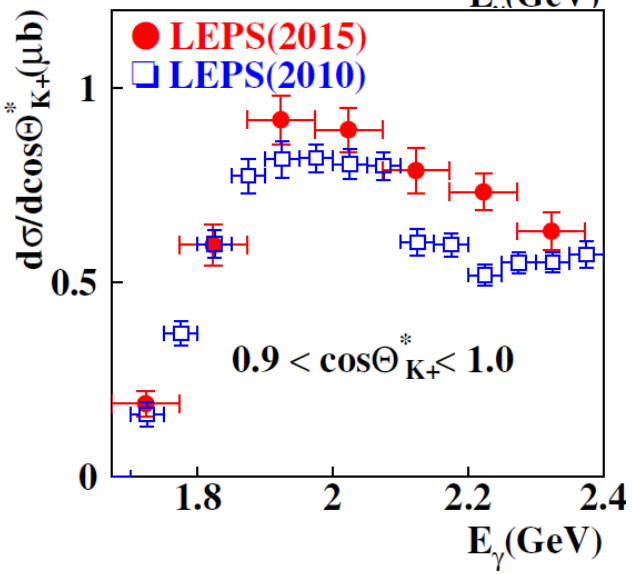




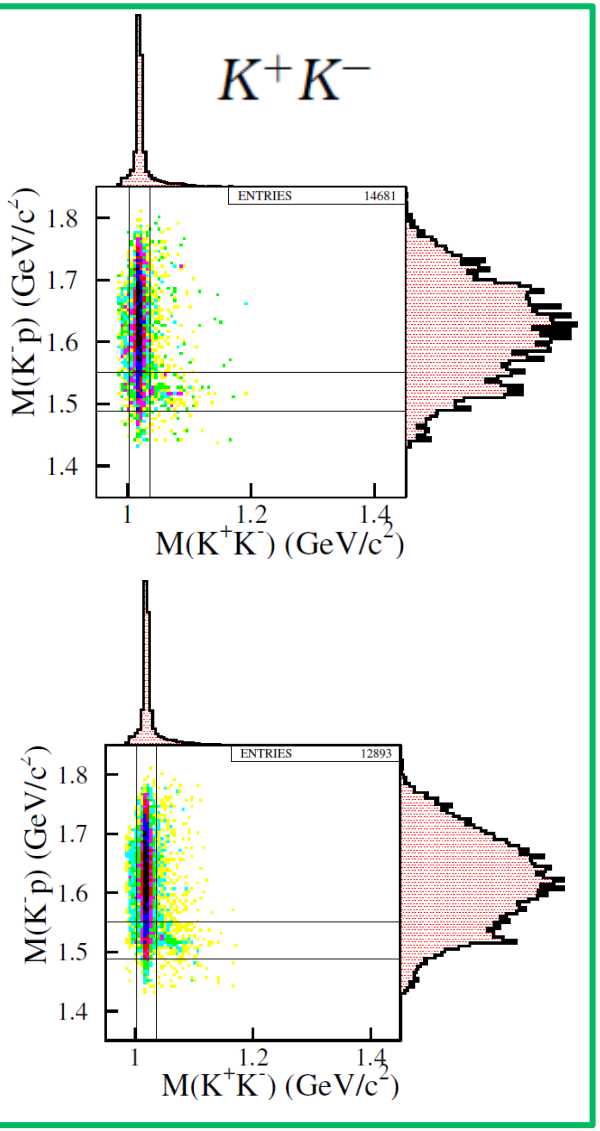


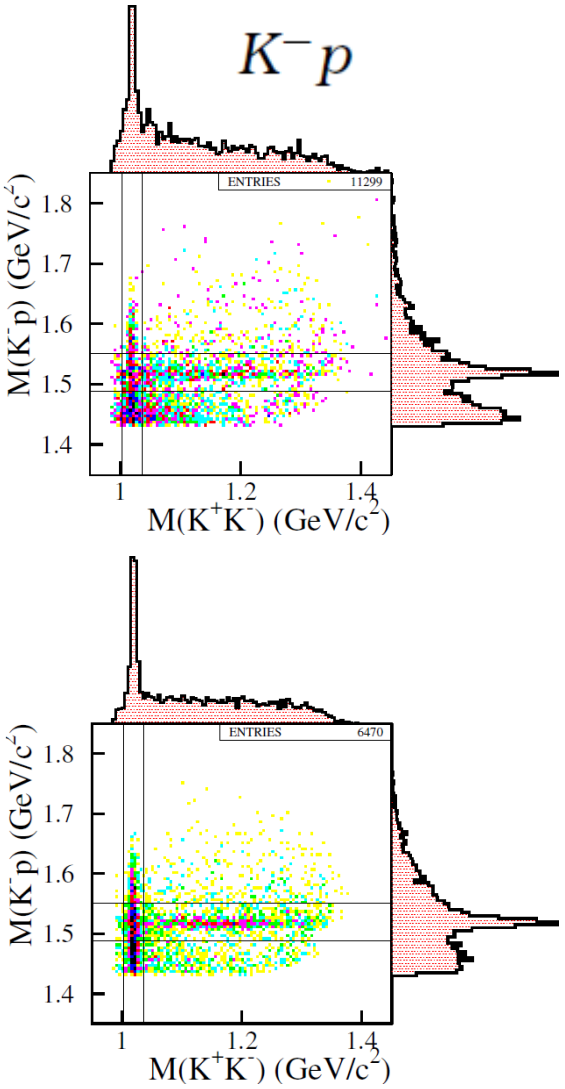
Without Interference region

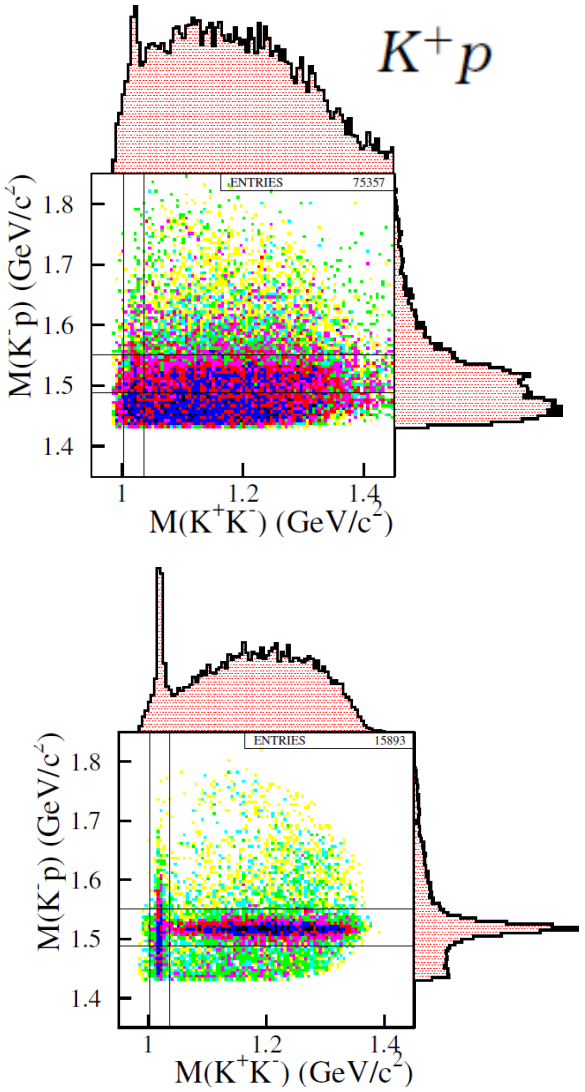




Event Selection with Kinematic Fit



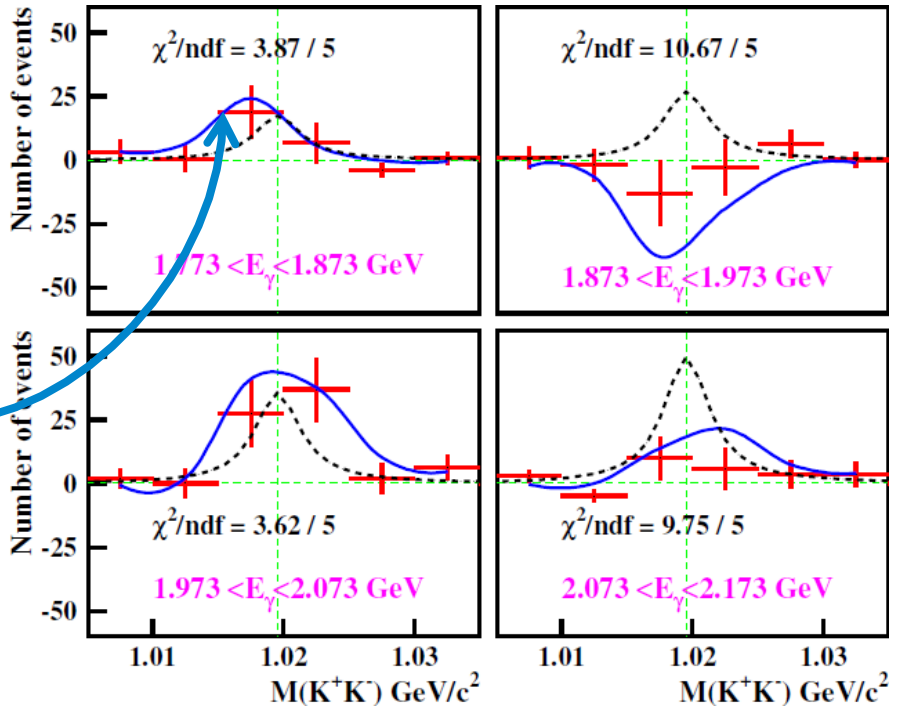




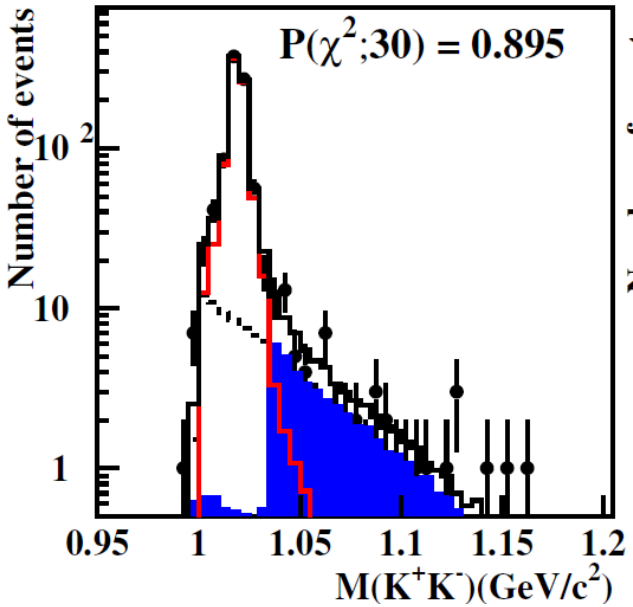
$$\frac{d\sigma}{dm_{K^+K^-}} \propto \left| \frac{ae^{i\psi_a}}{m_\phi^2 - m^2_{K^+K^-} + im_\phi\Gamma_\phi} + B(m_{K^+K^-})e^{i\psi_b} \right|^2$$

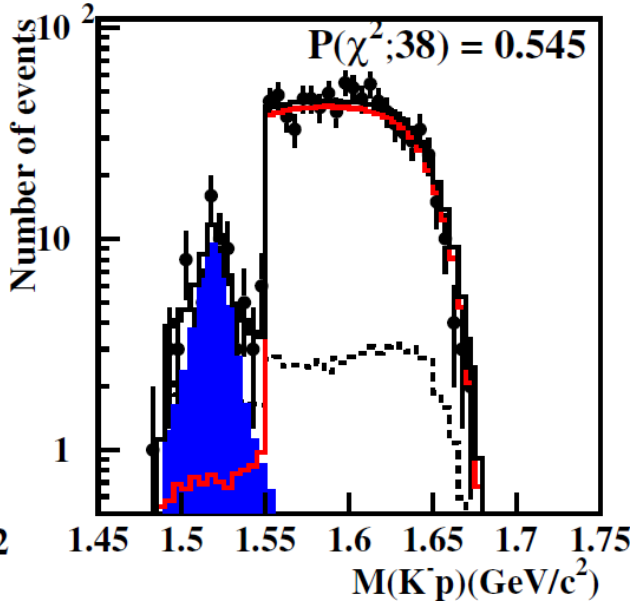
$$\frac{|a|^2}{(m_\phi^2 - m^2)^2 + m_\phi^2\Gamma_\phi^2} + |B(m)|^2 +$$

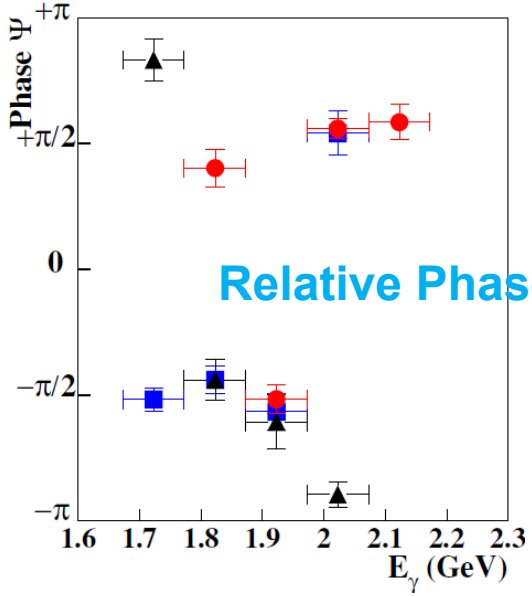
$$\frac{2(m_\phi^2 - m^2)|aB|\cos\psi + 2\Gamma_\phi m_\phi |aB|\sin\psi}{(m_\phi^2 - m^2)^2 + m_\phi^2\Gamma_\phi^2}$$



1.973 GeV< E_γ <2.073 GeV







Yield extraction for φ and Λ(1520)

Phys. Rev. Lett. 116, 232001 (2016).

Jul.29th E-1 /29-mini-6-16:50

Study of the d(γ, K^+)X reaction at LEPS

A.O. Tokiyasu

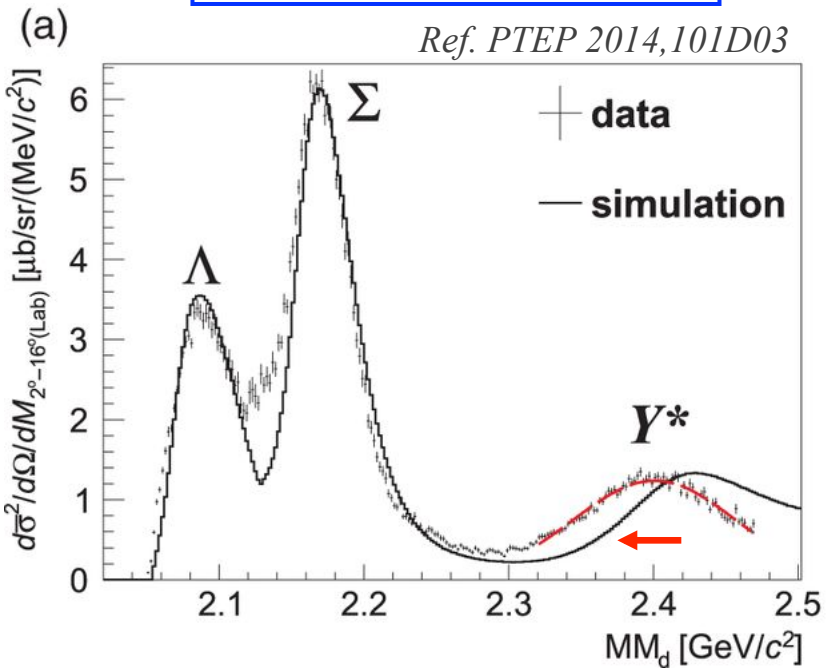
ELPH

Physics motivation

$\pi^+ + d \rightarrow K^+ + X$

MM(K^+) *J-PARC E27*

Ref. PTEP 2014,101D03

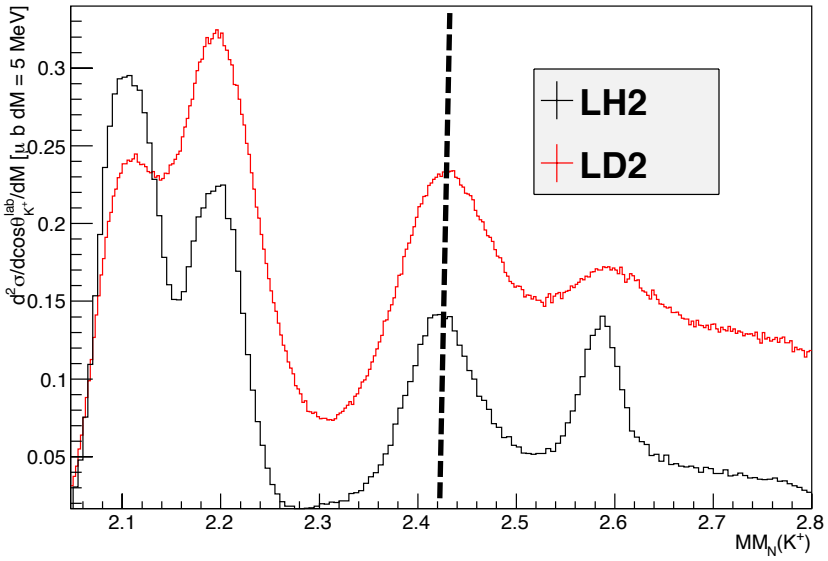


30 MeV shift was observed in Y* region

(caused by Y*N interaction?)

$\gamma + d \rightarrow K^+ + X$

MM(K^+) *LEPS*

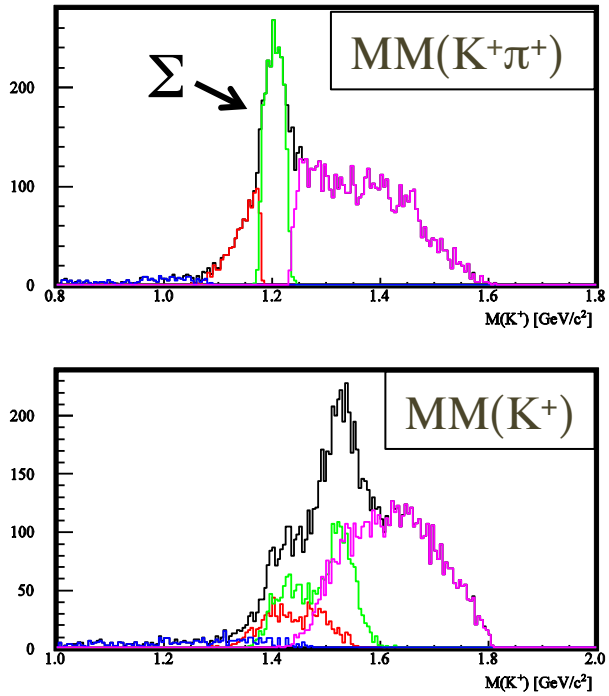


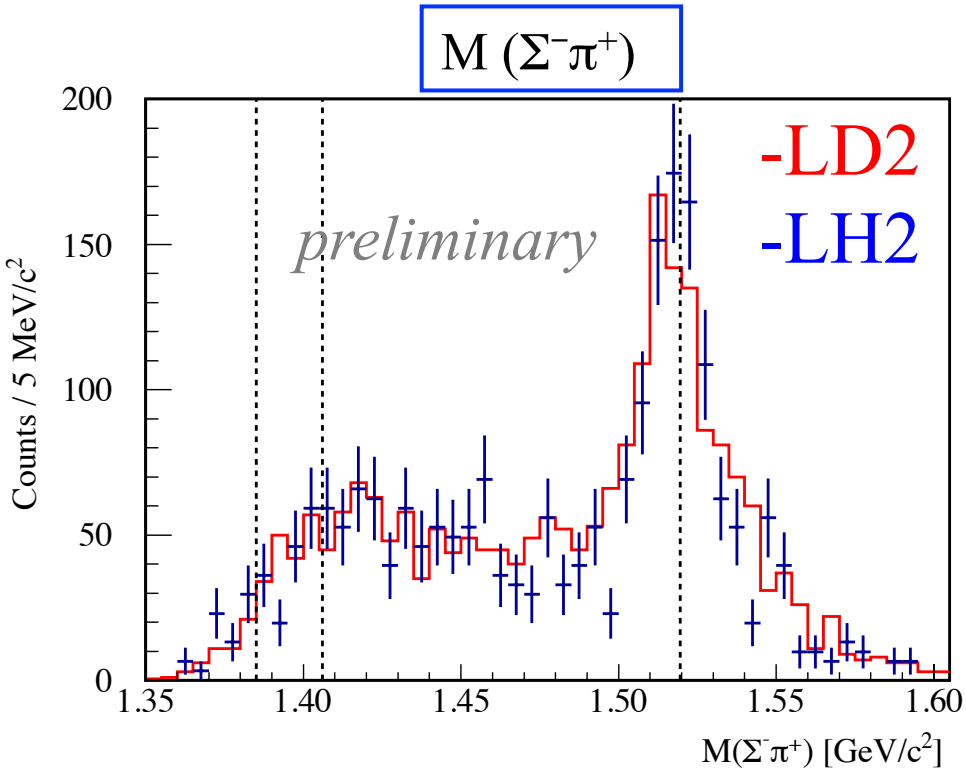
no shift was observed in Y* region

Why is the shift not observed in photo-production case?

$M(\Sigma^-\pi^+)$ spectra of LH2/LD2

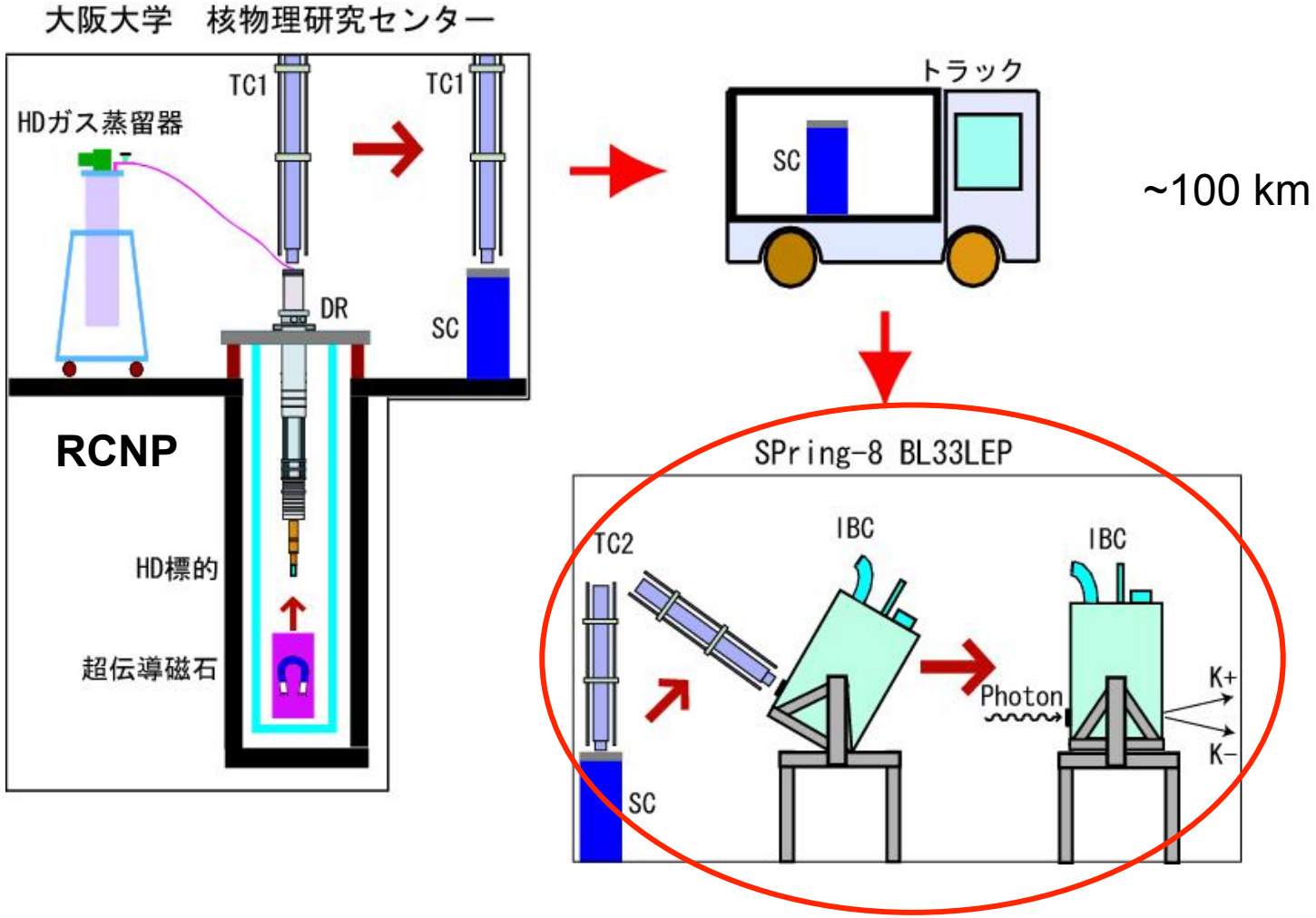
- $\gamma + p \rightarrow K^+ + \Sigma^- + \pi^+$ reaction was identified by MMSA.
  → increase Λ^*/Σ^* ratio (1/10 → 2-3)
- Compare the invariant mass spectra between LH2 and LD2.



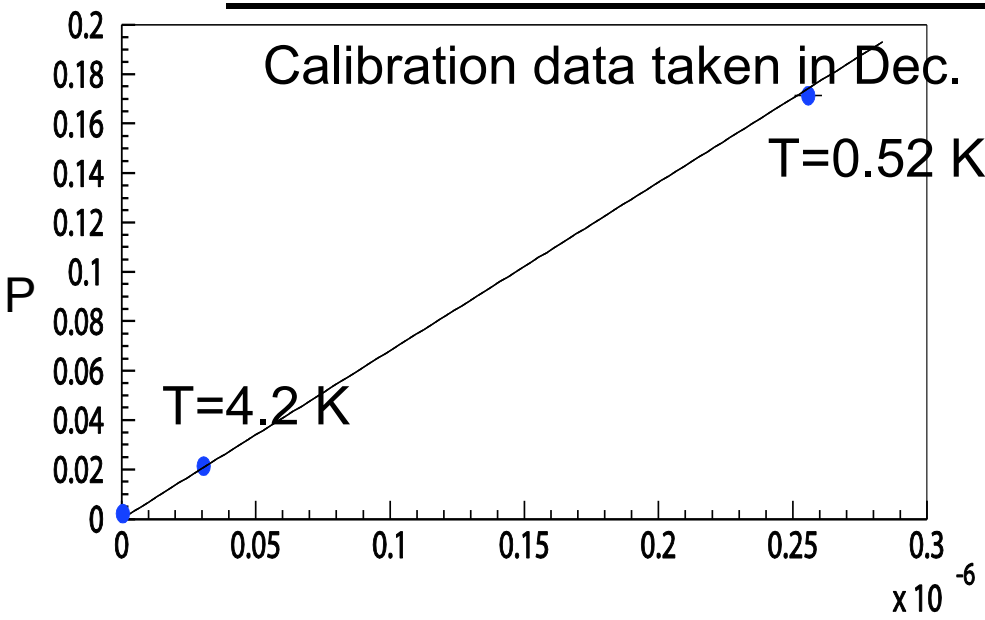


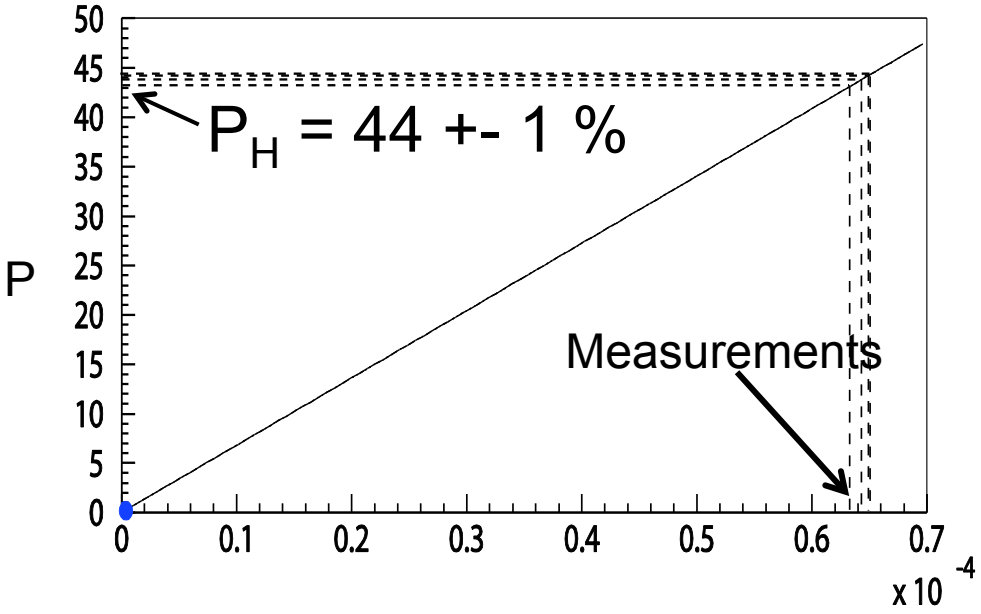
consistent within the error.

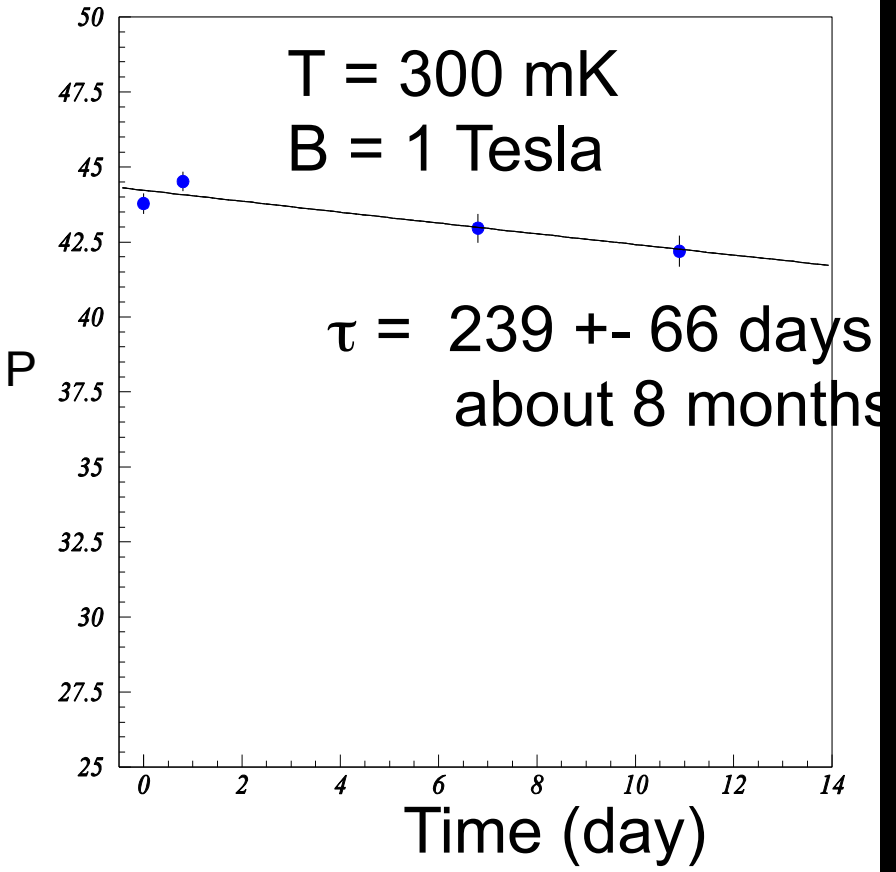
Development of HD polarized target



H Polarization & Relaxation time in HD







Refrigerators used for polarized HD target

RCNP
DRS
Stable

RCNP
TC1
Stable

RCNP -> SPring-8 SC Stable

TC2 ???

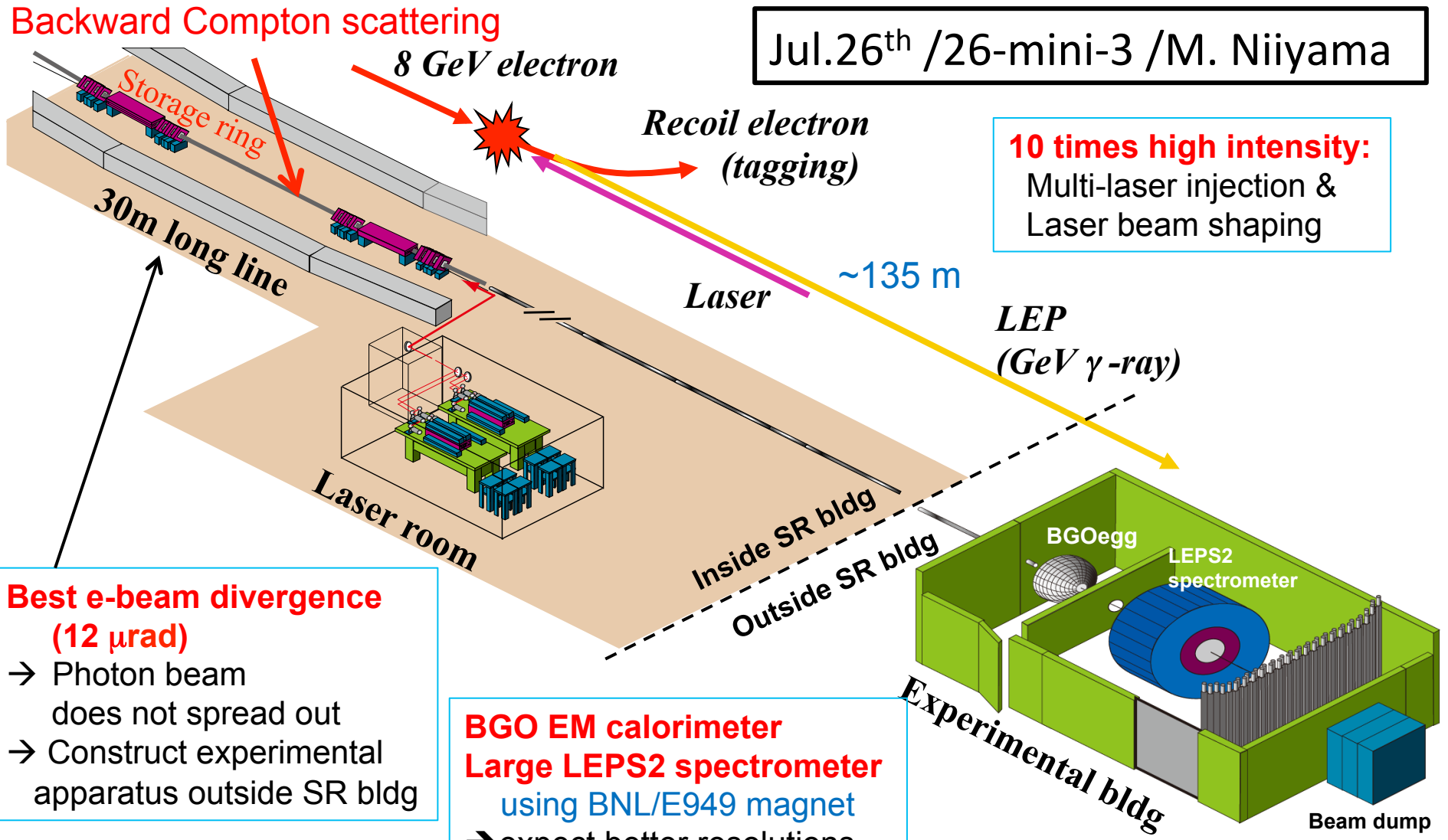
SPring-8

IBC
Stable

SPring-8

Outline of the LEPS2 facility

Jul.26th /26-mini-3 /M. Niiyama



10 times high intensity:
Multi-laser injection &
Laser beam shaping

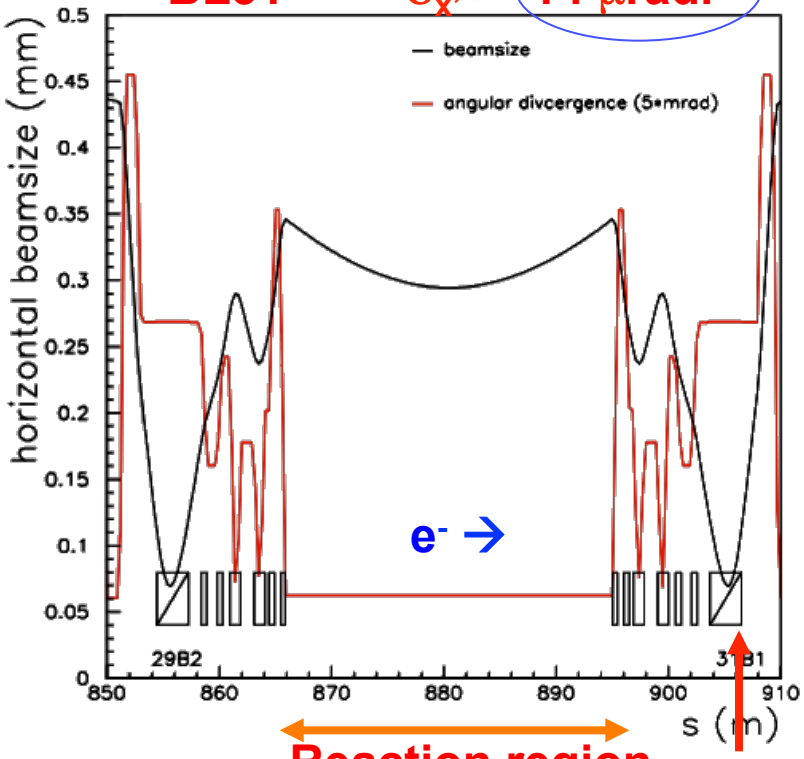
Best e-beam divergence
(12 μrad)
→ Photon beam
does not spread out
→ Construct experimental
apparatus outside SR bldg

BGO EM calorimeter
Large LEPS2 spectrometer
using BNL/E949 magnet
➔expect better resolutions

Divergence of LEP beam

LEPS2

BL31 **$<\sigma_x'>$=14 μrad.**

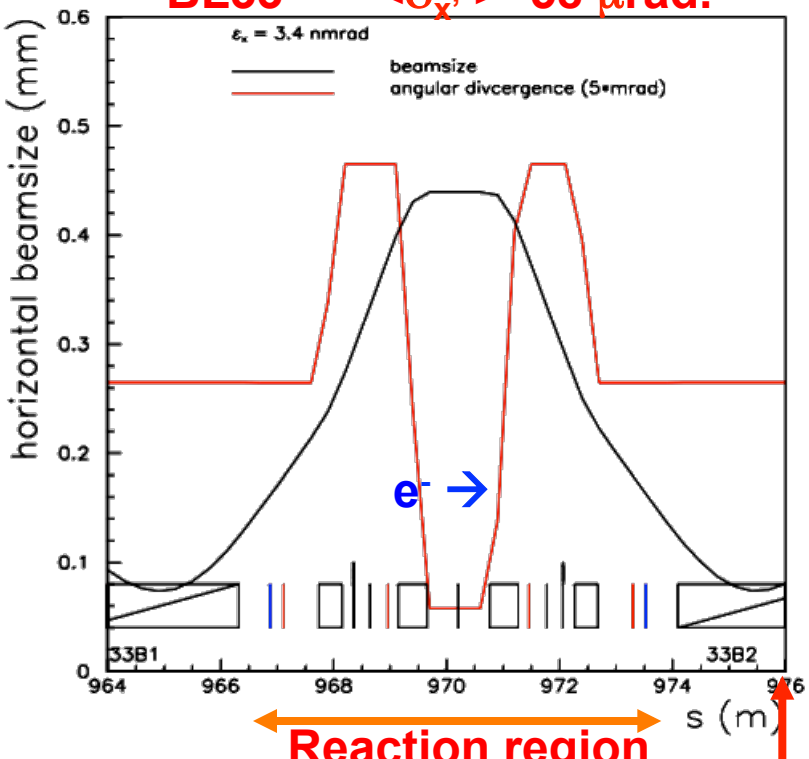


Reaction region (30m)

Tagging point

LEPS

BL33 **$<\sigma_x'>$=58 μrad.**



Reaction region (7.8m)

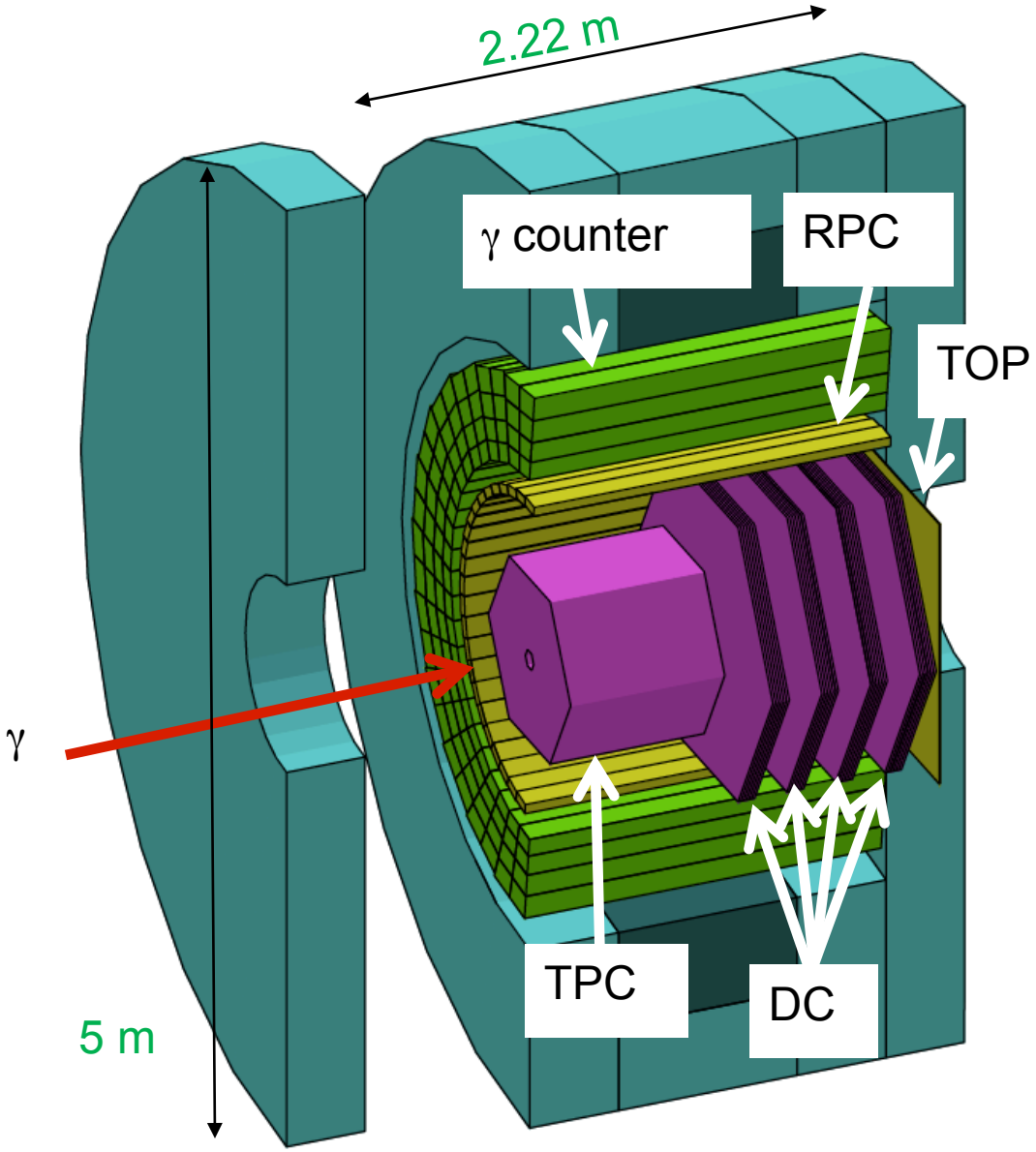
Tagging point

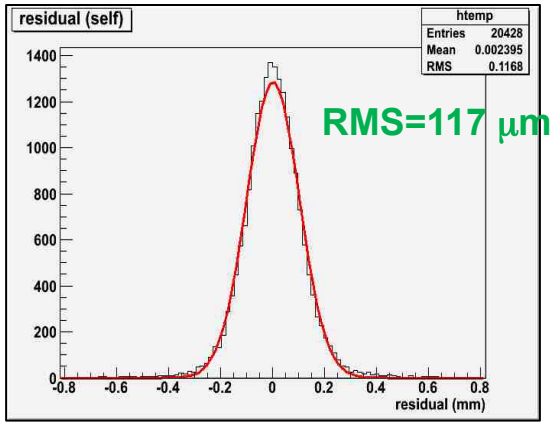
Better divergence → Better tagging resolution

Smaller beam size at long distance

LEPS2 Detector

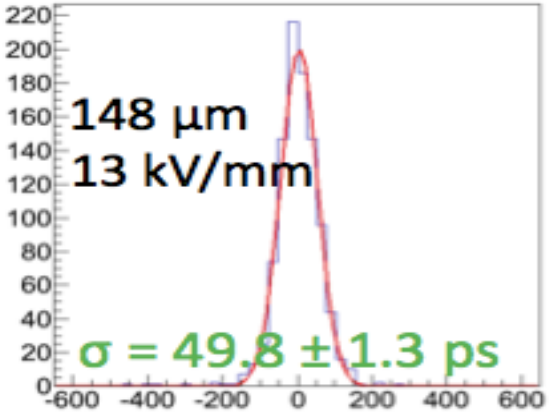
B=1 T : $\Delta p/p \sim 1\%$ for $\theta > 7°$





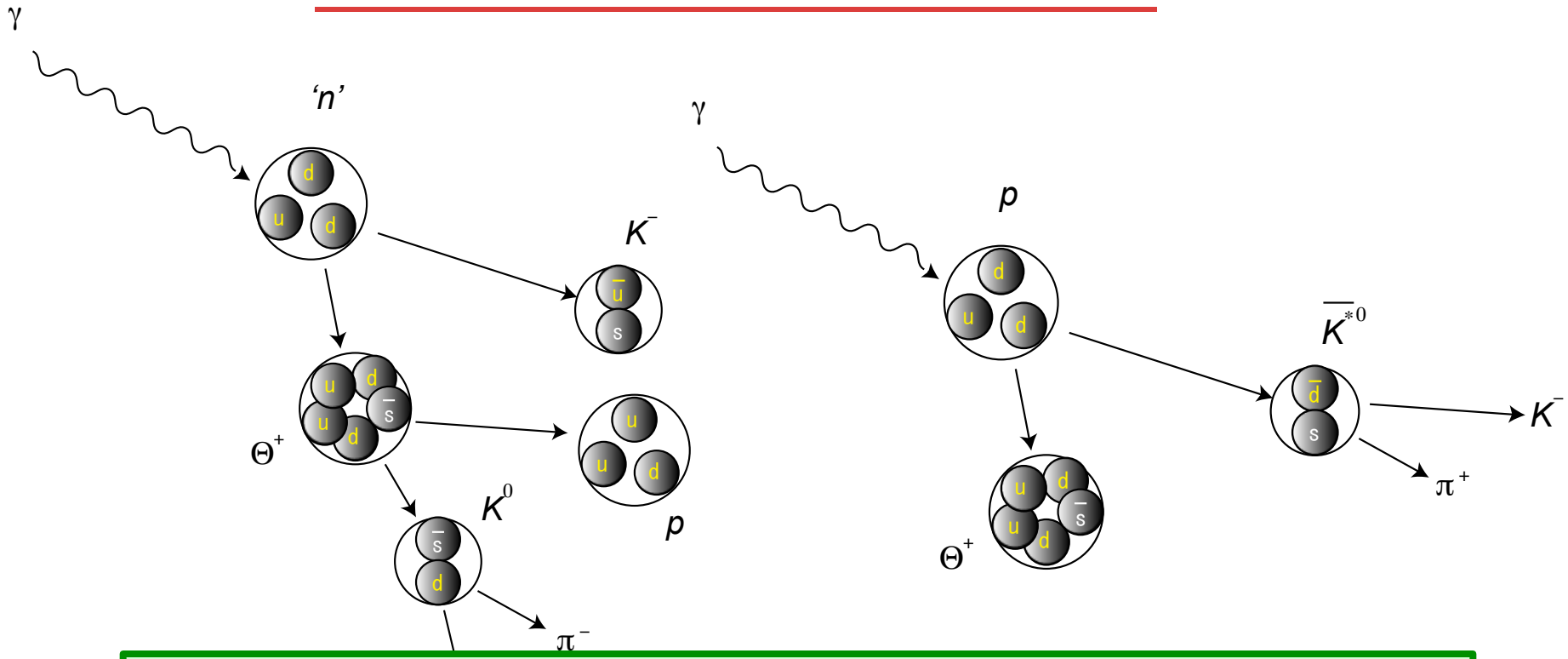
TPC Prototype Residual

RPC ToF time distribution



>3σ K/π separation @1.1 GeV/c^2

Θ^+ Search at LEPS2

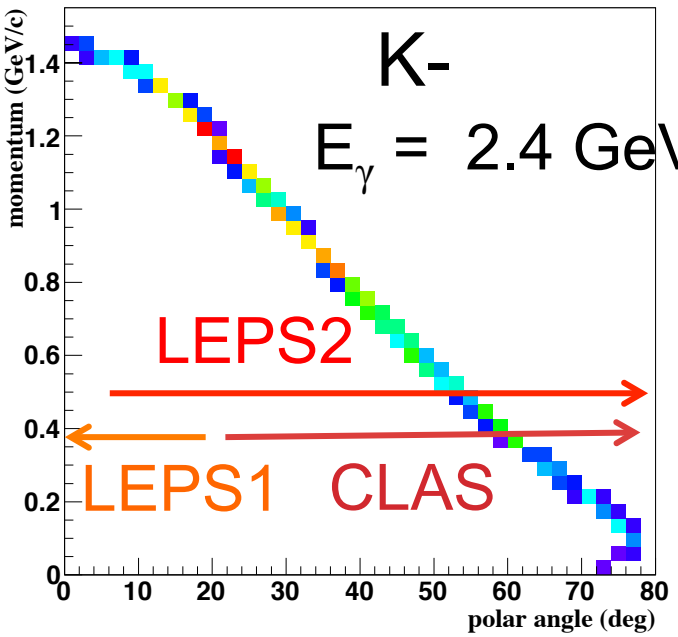


No Fermi motion correction.
No φ background.

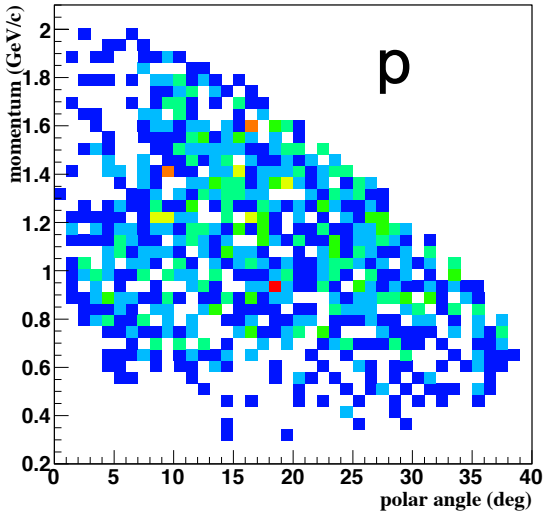
To measure angular dependence of production rate in large angle region, up to CLAS acceptance.

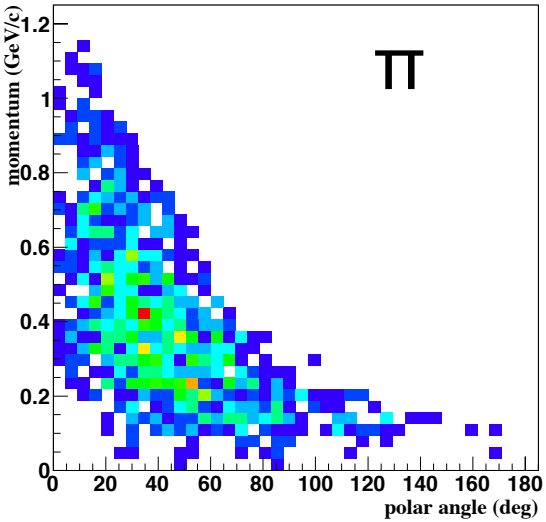
A large acceptance and better resolution detector is necessary.

γ 'n' $\rightarrow K^- \Theta^+ \rightarrow K^- K^0_s p \rightarrow K^- \pi^+\pi^- p$

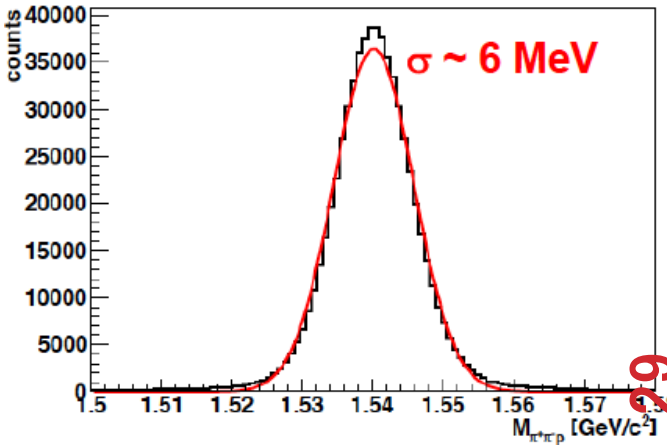


- Wide acceptance for K^-. Covers CLAS acceptance.
- K^- ID in p < 1.4 GeV/c.
- Large acceptance for multi-particle productions.
- Search for Θ^+ in the invm(K^0_sp). No need for Fermi-motion correction. No ϕ background。

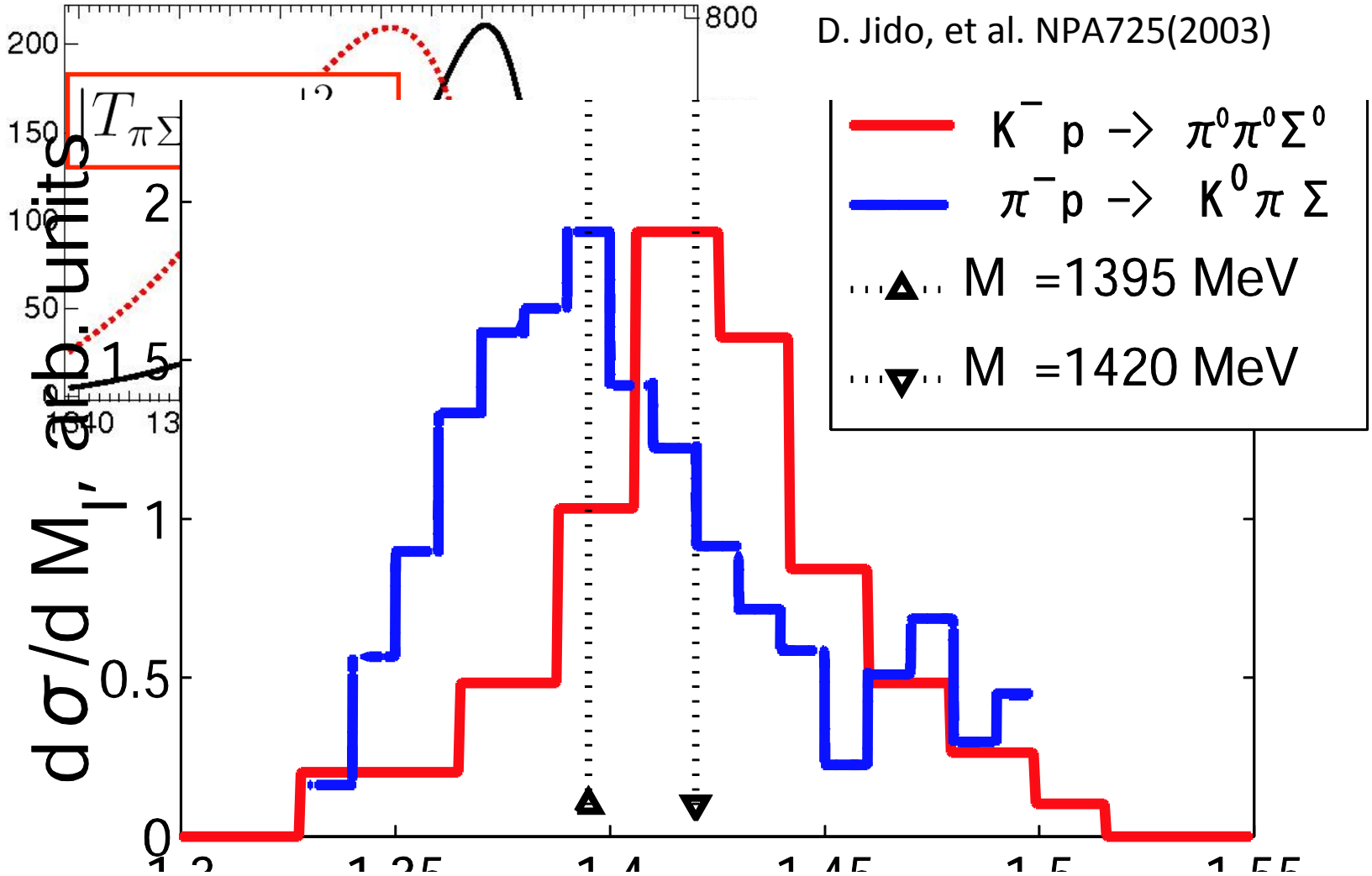




Expected invariant mass resolution



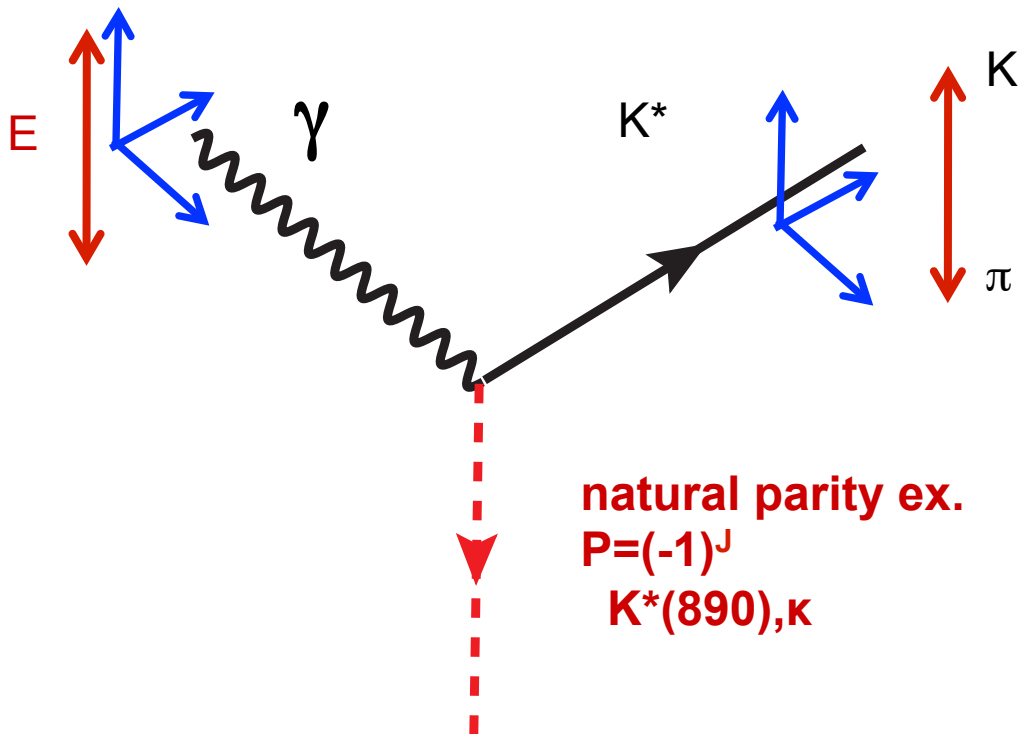
Two pole structure of Λ(1405)



V.K. Magas, E. Oset and A. Ramos, PRL 95

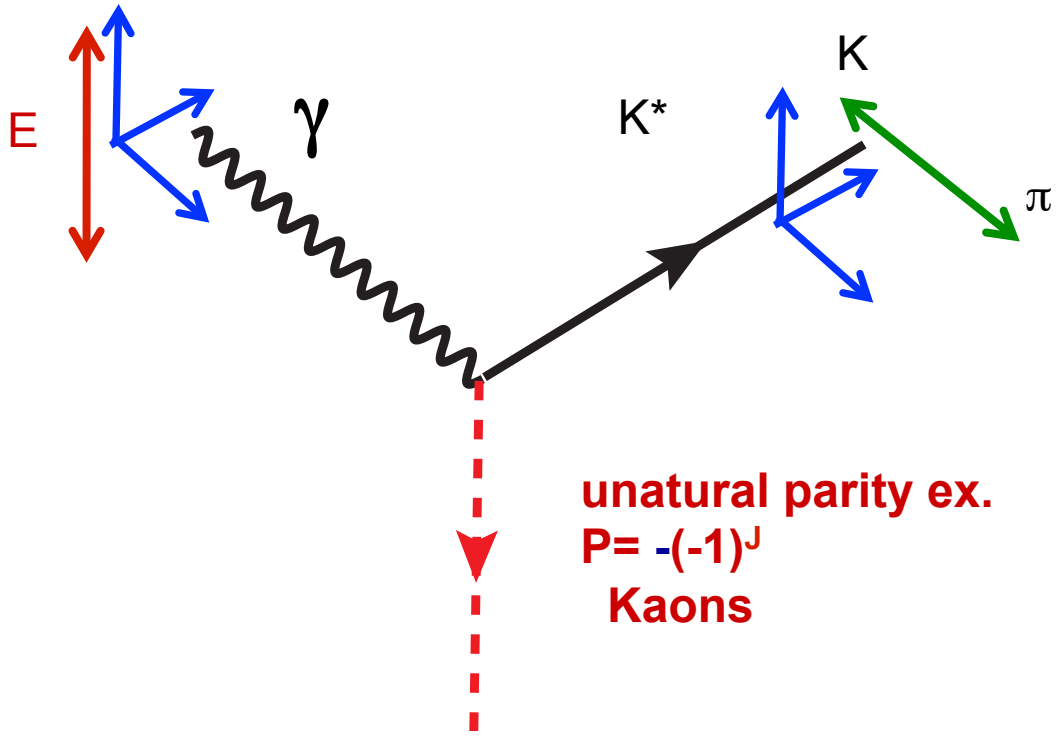
Hyperon production with K*(892)

- **Parity filter with linearly polarized photon**

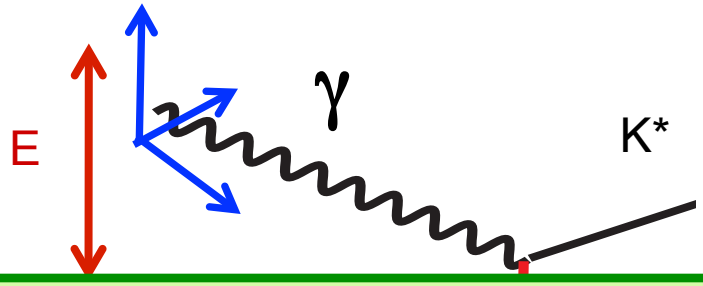


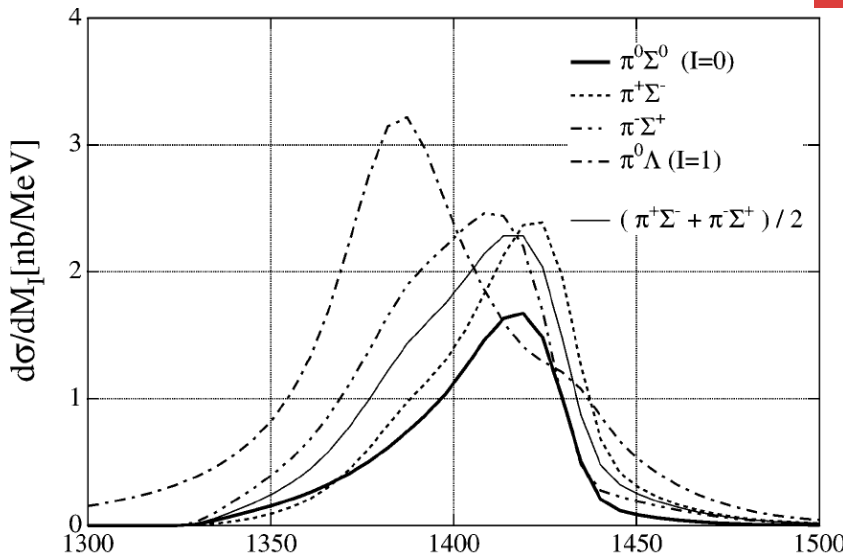
Hyperon production with K*(892)

- **Parity filter with linearly polarized photon**



K*(890) Λ(1405) photoproduction with linearly polar





High luminosity photon beam with Eγ>2.4 GeV.

Detect $K^{*+} \rightarrow K^0 s\ \pi^+ \rightarrow \pi\pi\pi$

$\Lambda(1405) \rightarrow \Sigma^0\pi^0 \rightarrow \Lambda\gamma\ \gamma\gamma$

$\Sigma(1385) \rightarrow \Lambda\pi^0$

Large acceptance charged / photon detector

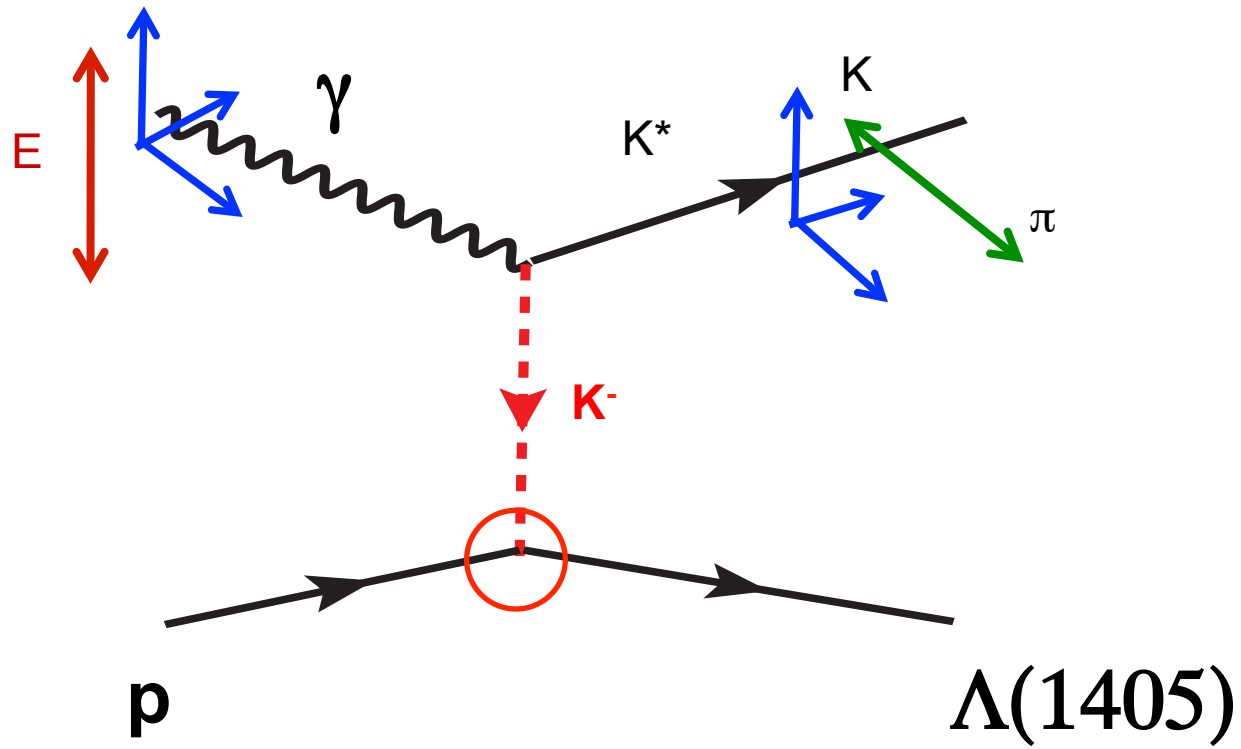
PLB593

p

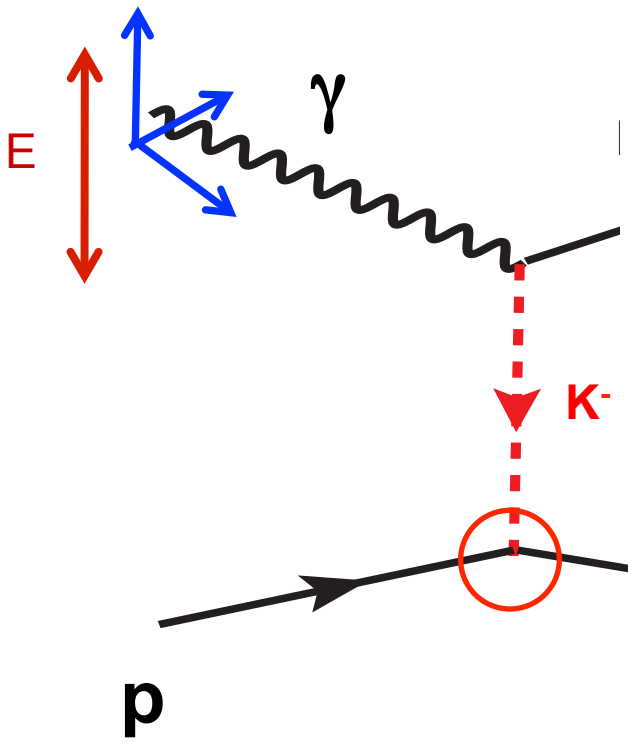
Λ(1405)

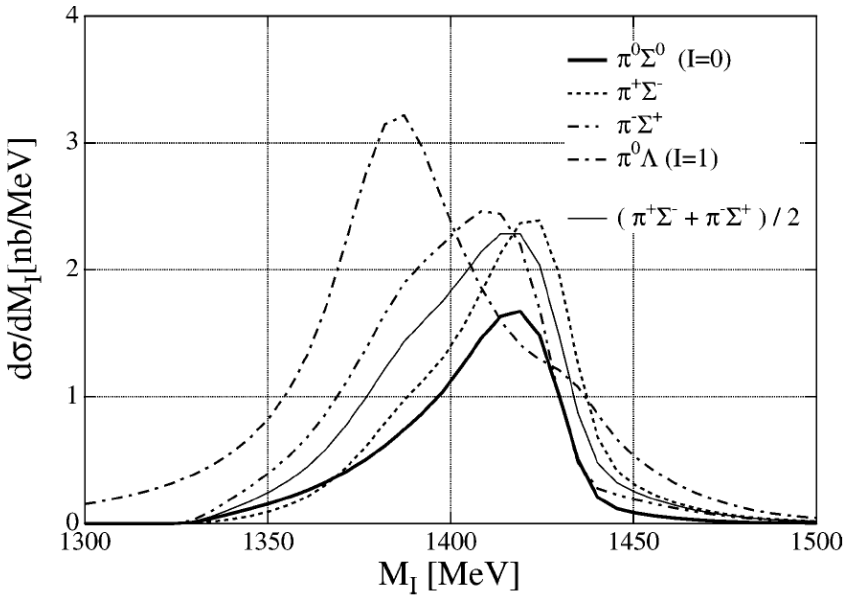
Σ(1385)

K*(890) Λ(1405) photoproduction with linearly polarized photon



K*(890) Λ(1405) photoproduction with linearly polarized photon



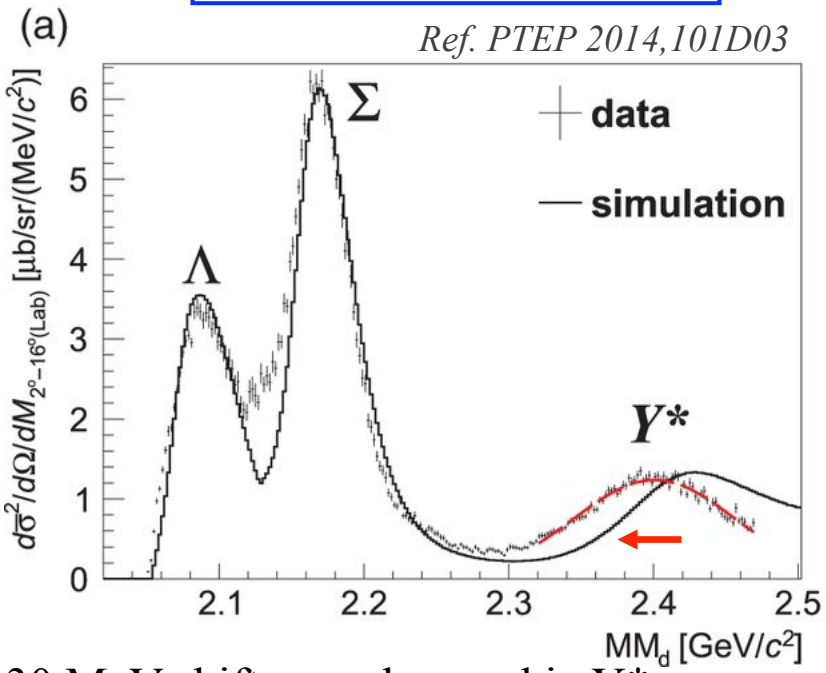


T.Hyodo et. al, PLB593

Kaonic nuclei search

If Λ(1405) is K^{bar} N molecule, $K^{-}pp$ system can be strongly bound state.

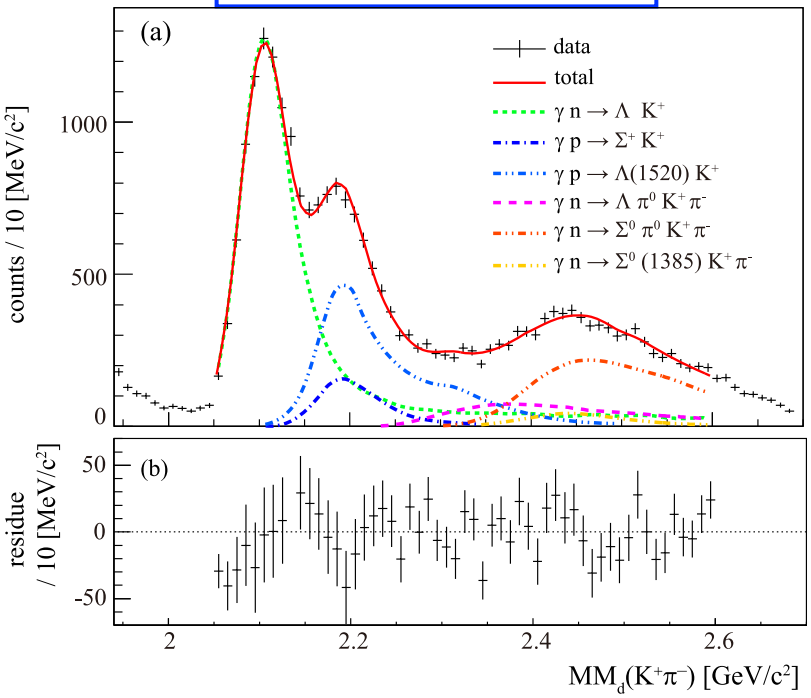
MM(K^+) *J-PARC E27*



30 MeV shift was observed in Y* region

(caused by Y*N interaction?)

MM($K^+\pi^-$) *LEPS*

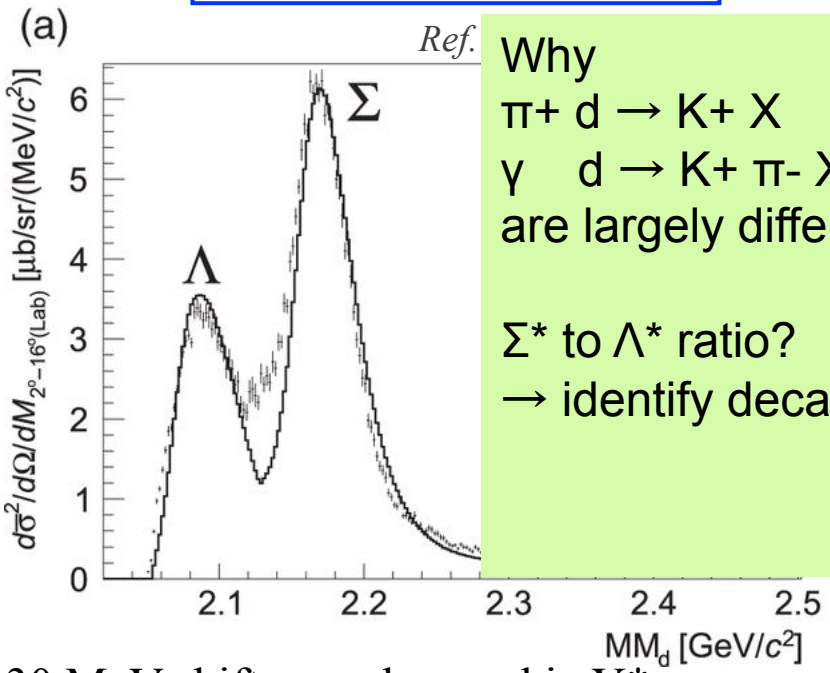


no shift was observed in Y* region

Kaonic nuclei search

If Λ(1405) is K^{bar} N molecule, K^-pp system can be strongly bound state.

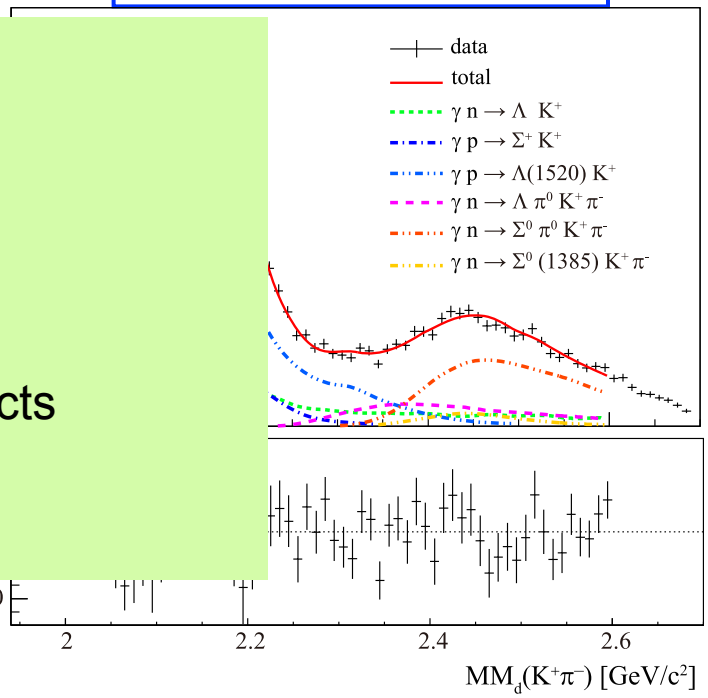
MM(K^+) *J-PARC E27*



Why
π+ d → K+ X
γ d → K+ π- X
are largely different?

Σ* to Λ* ratio?
→ identify decay products

MM($K^+\pi^-$) *LEPS*



30 MeV shift was observed in Y* region

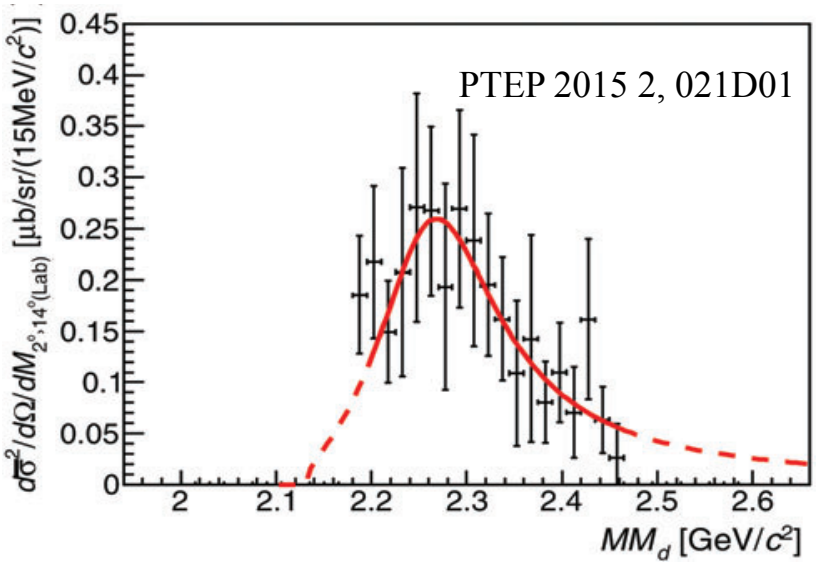
(caused by Y*N interaction?)

no shift was observed in Y* region

Kaonic nuclei search

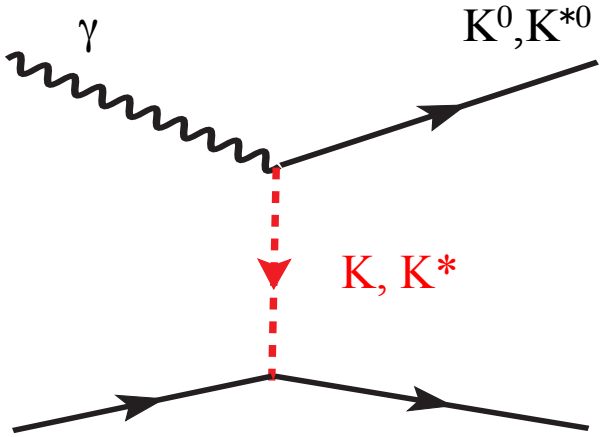
J-PARC E27

$d(\pi^+, K^+)X$
decay proton-tagged
$\Sigma^0 p$ ID using missing mass.



B.E. $= 95^{+18}_{-17}{}^{+30}_{-21}$ MeV
$\Gamma = 162^{+87}_{-45}{}^{+66}_{-78}$ MeV

LEPS2



- $\gamma + d \rightarrow K^+ + \pi^- + X$
- $\gamma + d \rightarrow K_s^0 + X$
- $\gamma + d \rightarrow K^{*0} + X$

☆detect decay products
X= Λp , $\Sigma^0 p$

Results from LEPS1 by
Dr. Tokiyasu at E-1 on 29th.

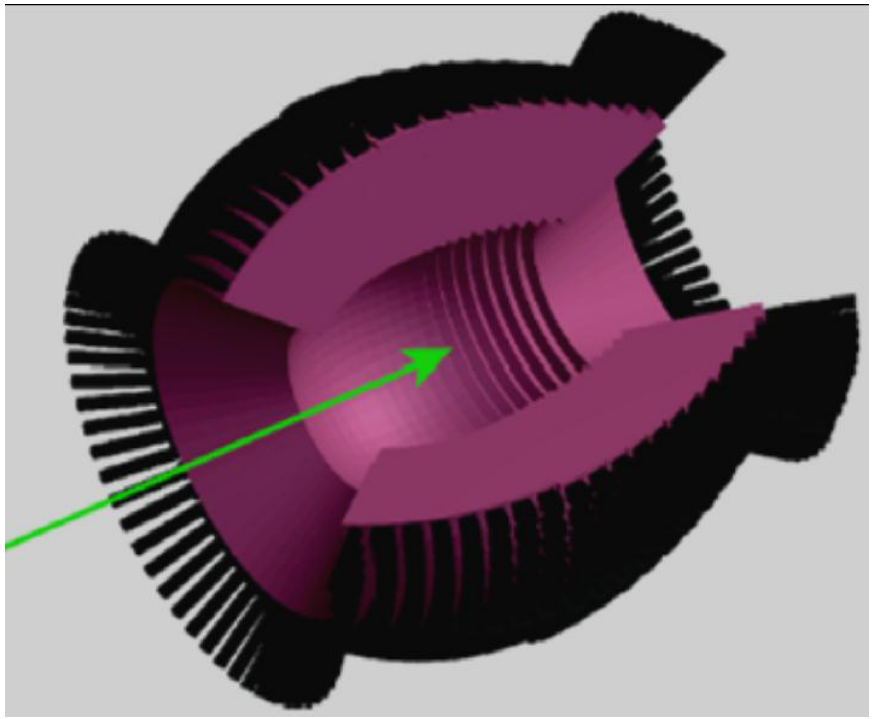

Exp. hall was constructed. (2010.Oct-2012Jan)

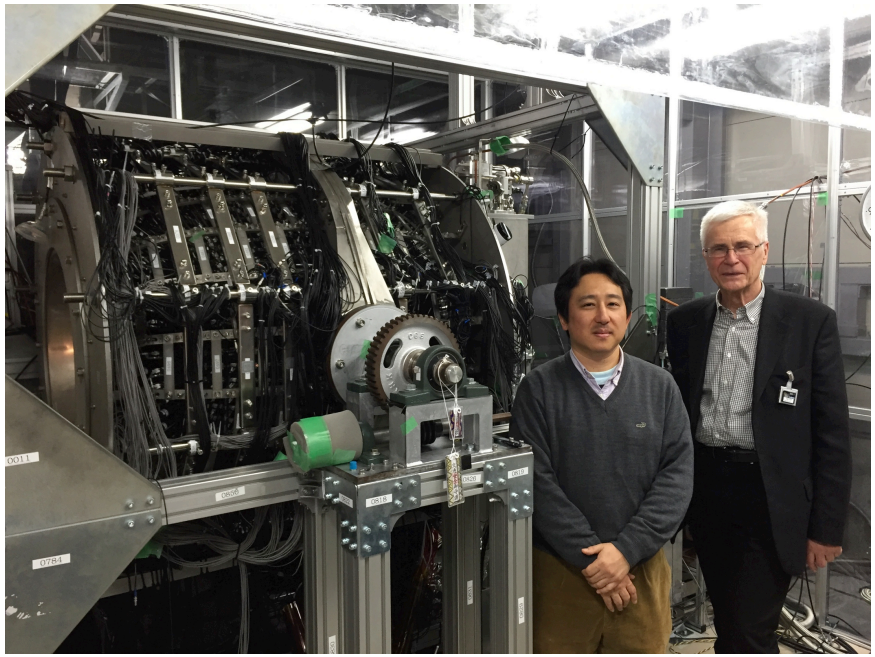

Installation of the E949 magnet (2011.Nev-Dec)


γ counters were installed. (2012.June)


Beam pipe (2012.May)

BGO-Egg : constructed @ ELPH, Tohoku U.



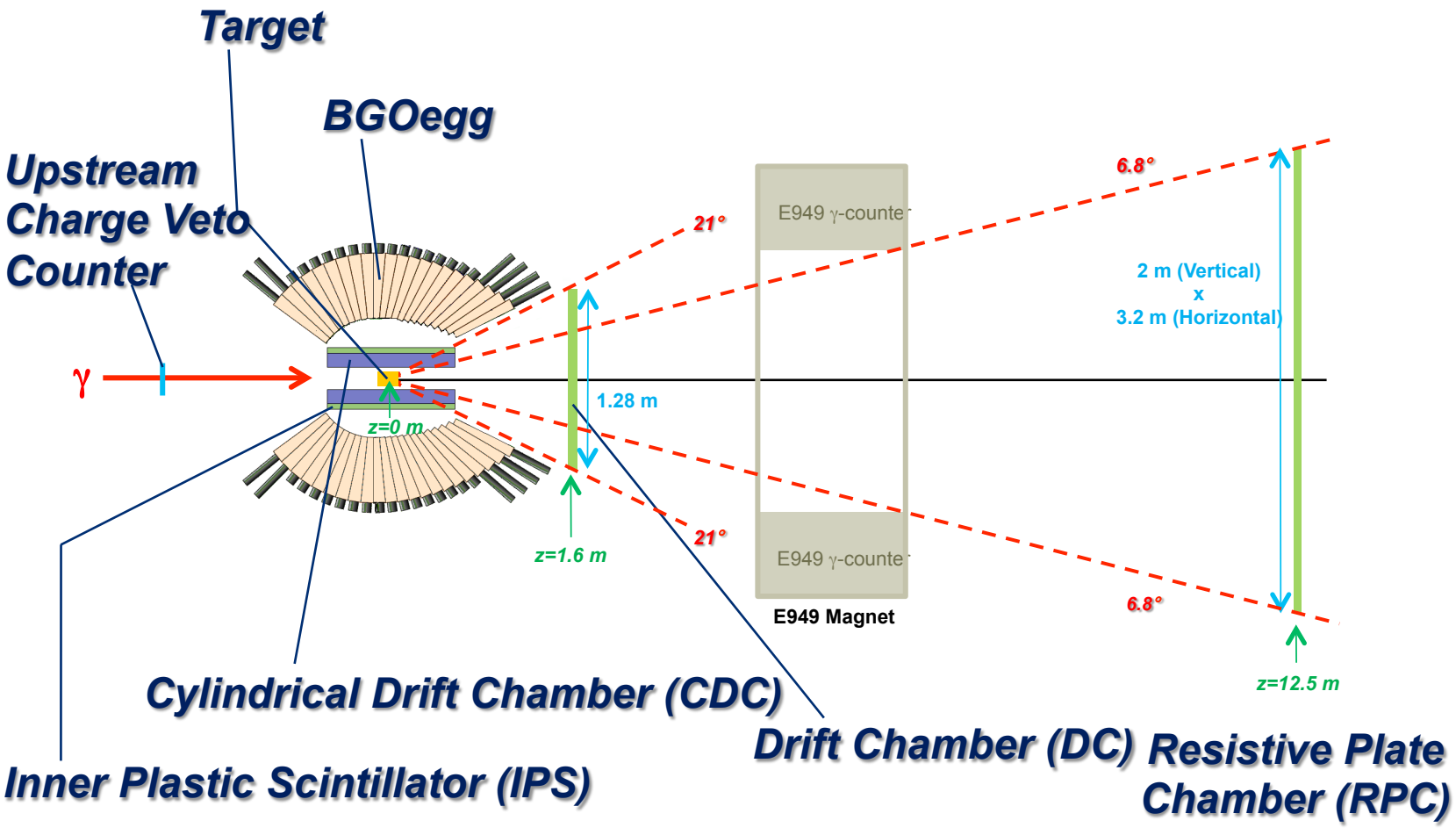


Large acceptance photon detector (BGO-Egg)

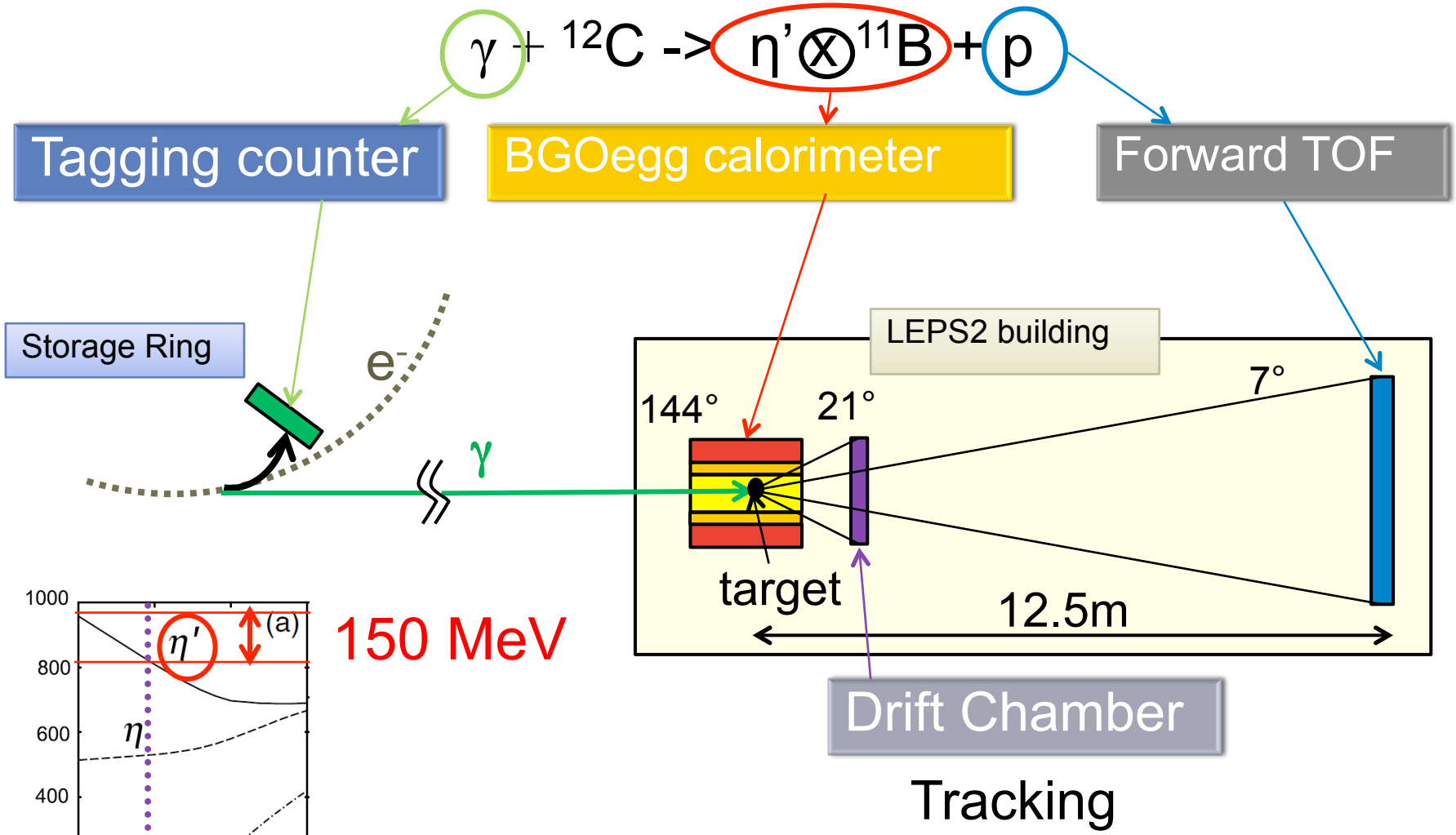
- 1320 BGO crystals
- Covering 24° ~144° polar angle
- 1.3% energy resolution for 1 GeV

Experimental Setup

Tagged Photon Energy : 1.3 – 2.4 GeV (355 nm UV laser)
Tagged Photon Intensity : 1.4 – 1.8 Mcps (3 or 4 laser injection)



Experimental setup



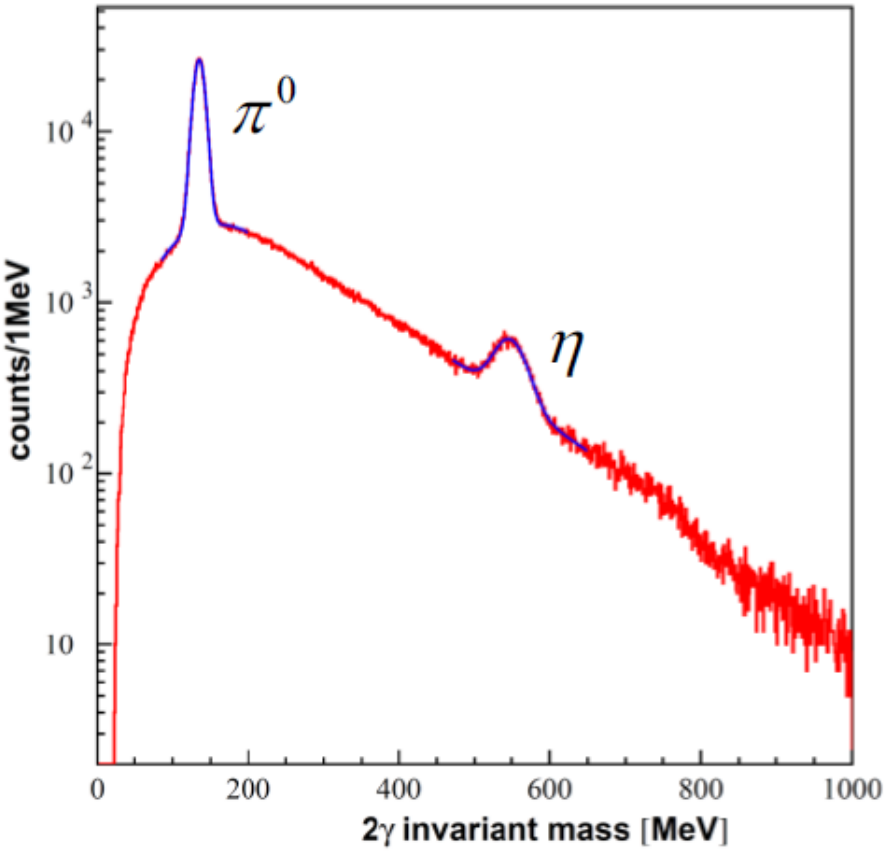
150 MeV

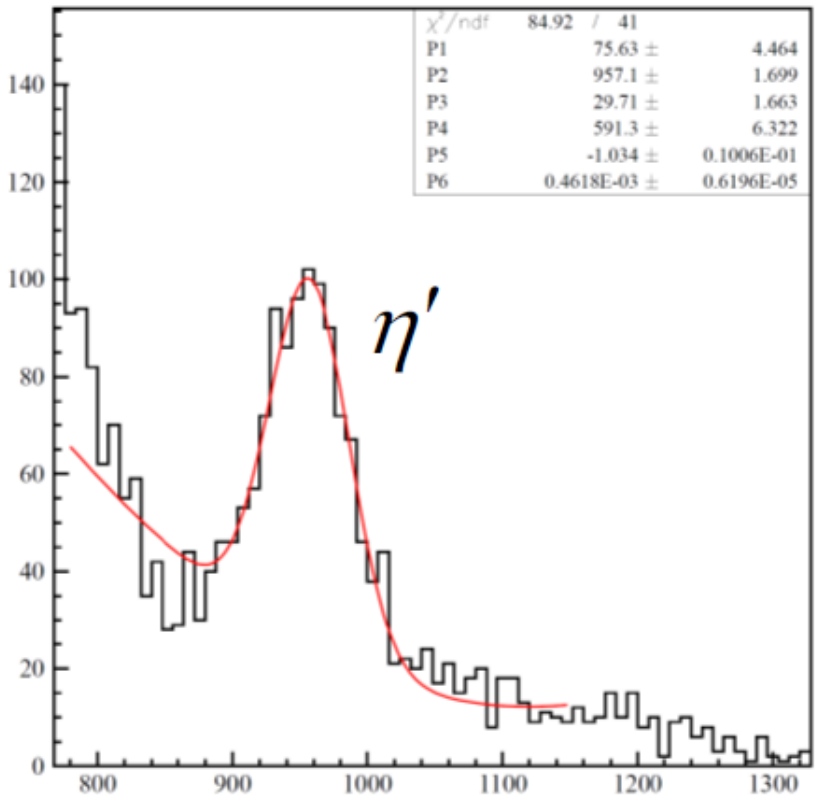
H.Nagahiro et al.
PRC74(2006)45203

Summary of Data Collection

Period	Target	Integrated # of γ's (tagged E_γ region) = tagger counts × dead time corr. × DAQ eff. corr.
2014A (Apr.~July)	**Carbon/CH_2** [20 mm]	**C: 1.31×10^{12}, CH_2: 1.58×10^{12} with RPC** (In total, C: 4.29×10^{12}, CH_2: 2.56×10^{12}) ***Test sample for η'-mesic nuclei search***
2014B (Nov.~Feb.)	**LH_2** [40 mm]	**Hori: 2.24×10^{12} , Vert: 2.01×10^{12}** ***N^* physics, etc (with spin observable)***
2015A (Apr.~July)	**Carbon** [20 mm]	**9.77×10^{12} (Vert: 8.97×10^{12})** ***η'-mesic nuclei search***
2015B (Sep.~Dec.)	**LH_2** [40 mm]	**Hori: 2.87×10^{12} , Vert: 2.92×10^{12}** ***More data for γp reactions***
2016A (Apr.~July)	**LH_2** [40 mm] **Carbon** [20 mm]	**C: comparable to 2015A (LH_2: one month)** ***More data for η' mesic nuclei search***

γγ invariant mass distribution

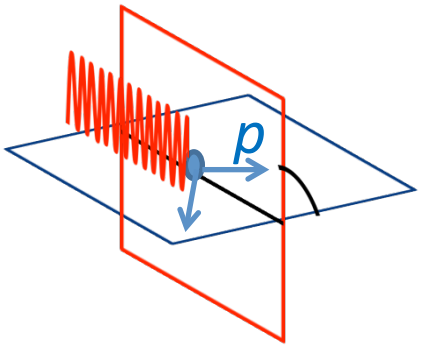




- π^0 Peak : Mean : **134.9(1) MeV**
  σ : **7.7(1) MeV**
- η Peak : Mean : **547.5(3) MeV**
  σ : **21.1(3) MeV**
- η' Peak : Mean : **957.1(17) MeV**
  σ : **29.7(17) MeV**

PDG mass : π^0 : 134.98 MeV
η : 547.86 MeV
η' : 957.78 MeV

Beam asymmetry in $\omega(\rightarrow\pi^0\gamma)$ photoproduction

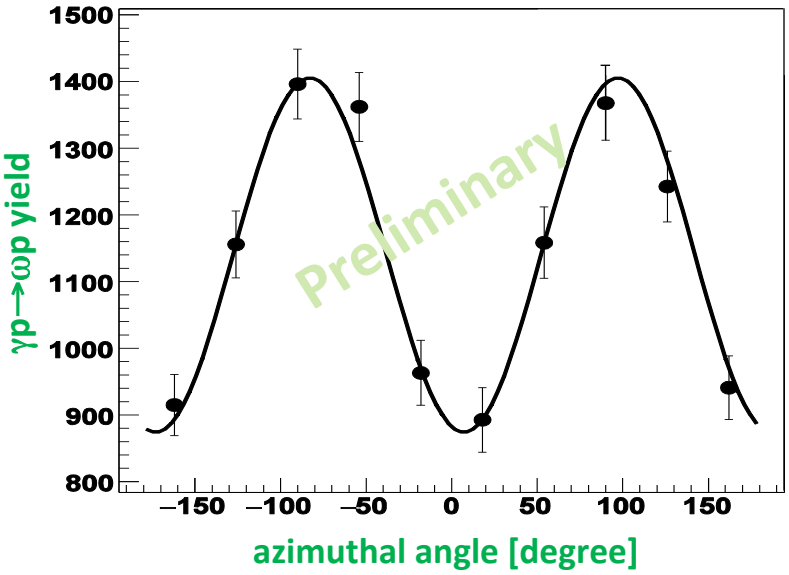


: beam polarization
: beam asymmetry

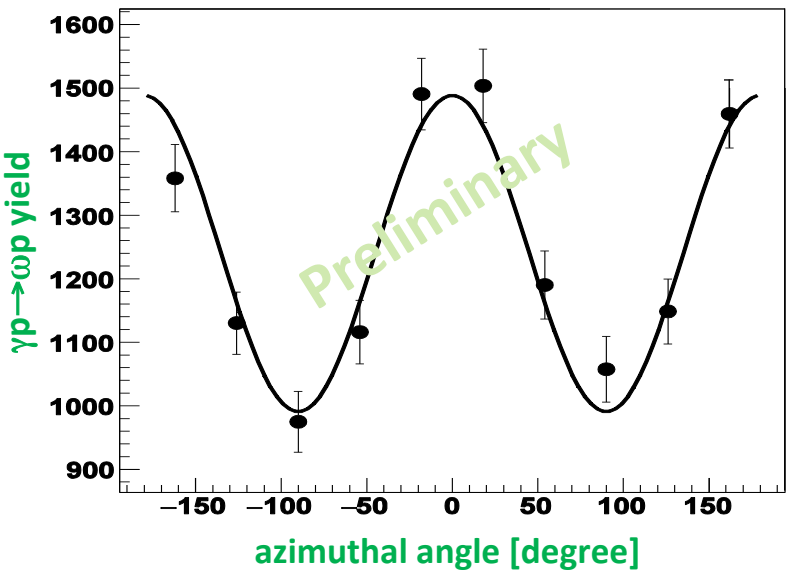
: the angle between reaction plane
and polarization direction

Polarization degree has not been taken into account. No division by E_γ & θ_ω^{CM}.

Vertical Pol.



Horizontal Pol.



LEPS2-BGOegg Status

- Precise calibration methods have been developed.
  Analysis programs are mostly finalized.
- Calibration for the η'-mesic nuclei search is in progress.
- Beam asymmetries for η and ω using 2014B will be measured first.

Summary

- LEPS
  - Updates on Θ^+, $\phi\Lambda*$ interference, kaonic nuclei search.
  - Development of the HD target
- LEPS2
  - x10 luminosity. ~10Mcps.
  - Two different experimental setups.
    - Solenoid spectrometer
    - Θ^+, $\Lambda(1405)$
    - BGOegg + TOF(RPC)
    - Backward meson production from proton and nuclei
- BGOegg experiment was started in 2014.