Recent result of LEPS and prospects of LEPS2

M. Miyabe
Tohoku University
LEPS collaboration

as substitute of Dr. Niiyama

Overview of LEPS

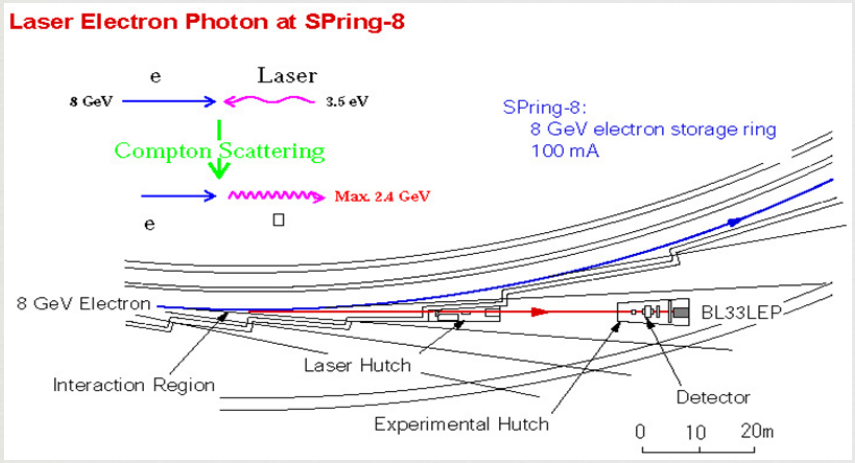
LEPS
2001~

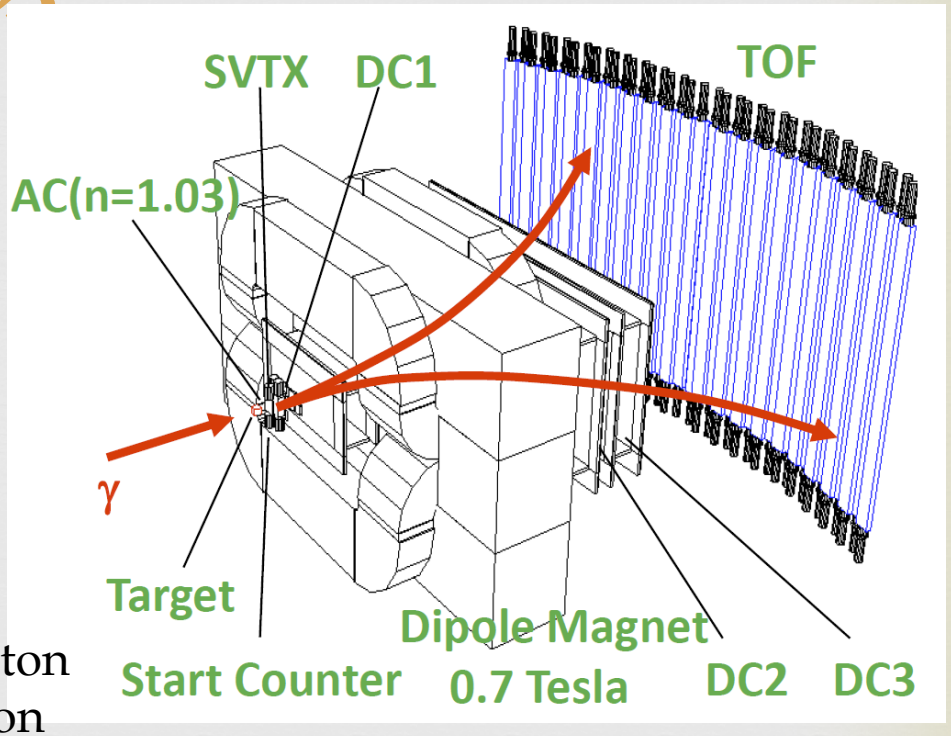
LEPS2
2013~

Physics at SPring-8/LEPS

- ϕ-meson production
  - Reaction mechanism, ϕ-nucleon interaction [T. Sawada]
- Evidence for a κ meson [S.H. Hwang]
  - Reaction mechanism
- Backward meson production
  - Baryon resonance study
- Exiotic baryons
  - Λ(1405) Photoproduction up to 3 GeV [Y. Nakatsugawa]
  - Θ+ Photoproduction
  - Search for KNN Bound State [A. Tokiyasu]

SPring-8 LEPS





LEPS forward spectrometers

LEPS backward compton scattering photon

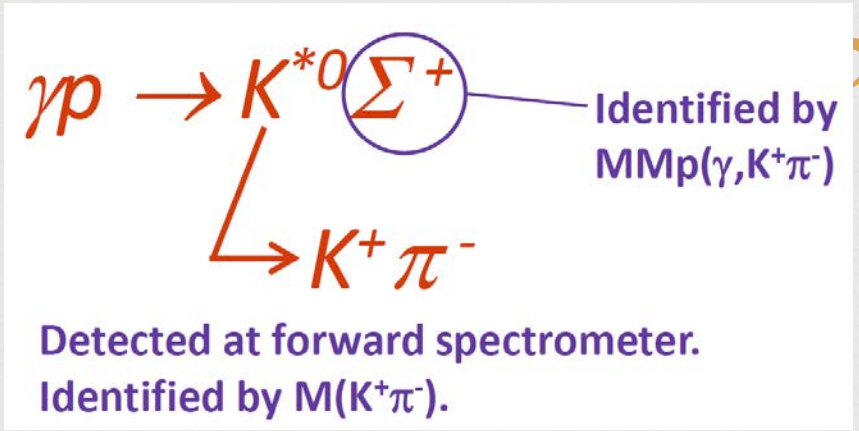
- Eγ~2.4GeV, Eγ~2.9GeV Tagged photon
- Polarization ~95%
- > 1 Mcps

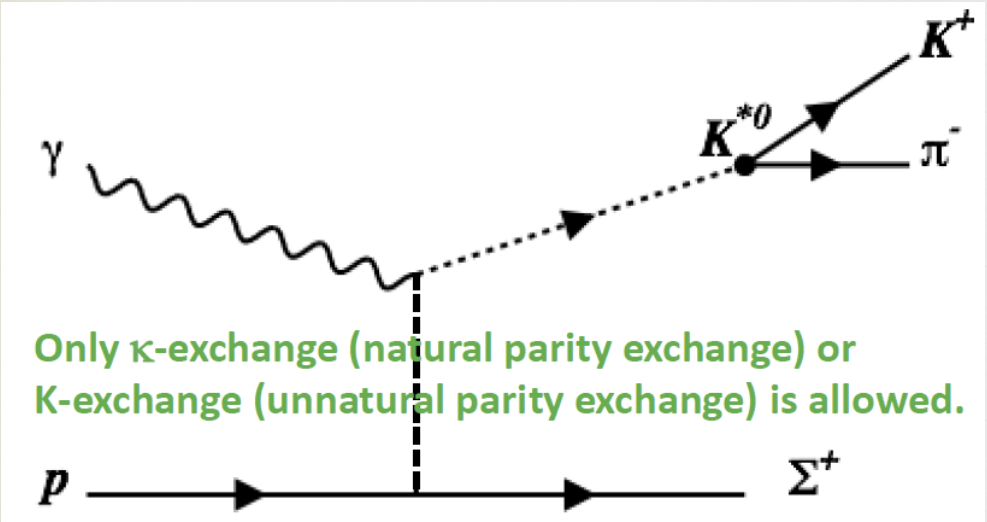
Physics run from 2001

Photo production experiment using charged particle spectrometer.

Pion, kaon, proton at forward angle.

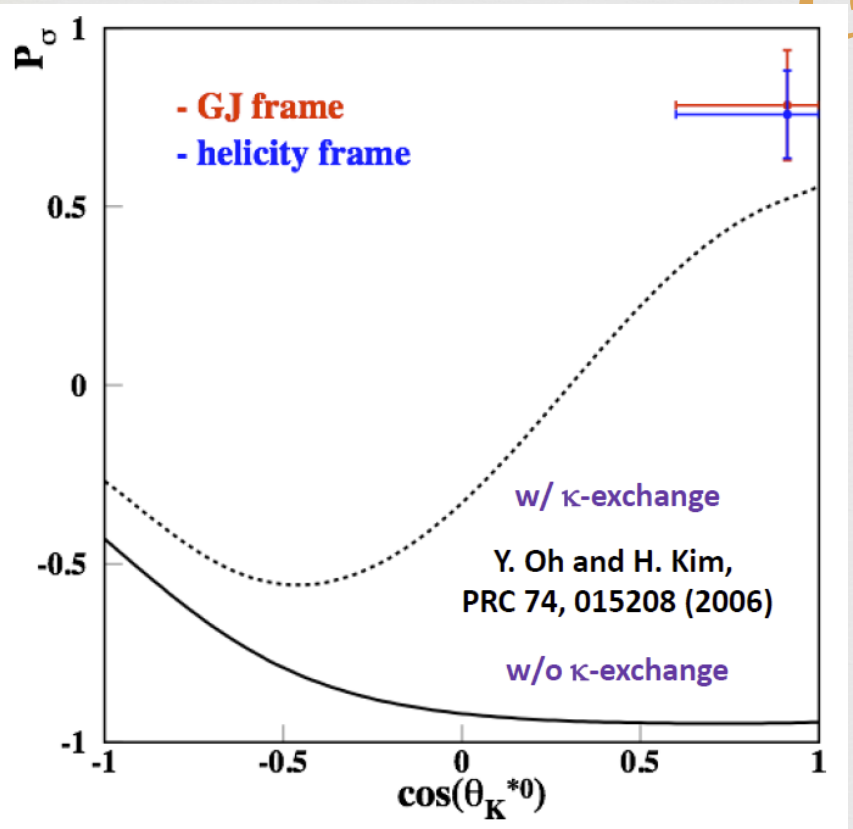
$K^{*0}\Sigma^{+}$ photoproduction





- t-channel exchange is dominant
- K-exchange is prohibit in K photoproduction
- Exchanged particle information from Decay asymmetory analysis

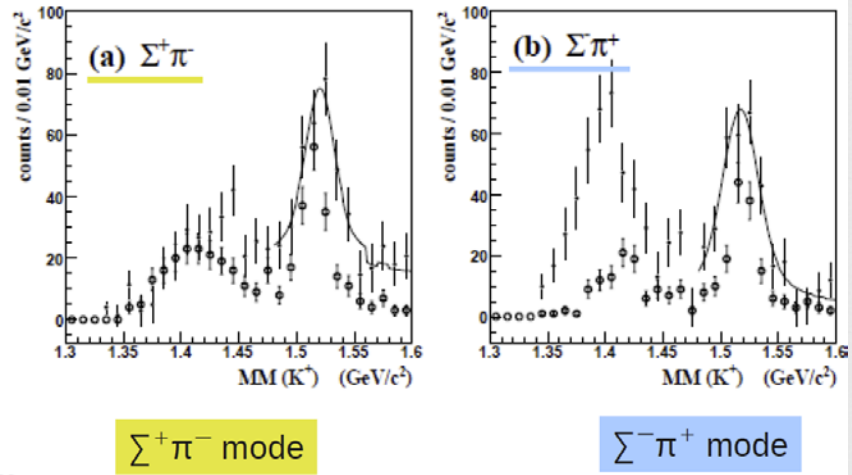
κ meson



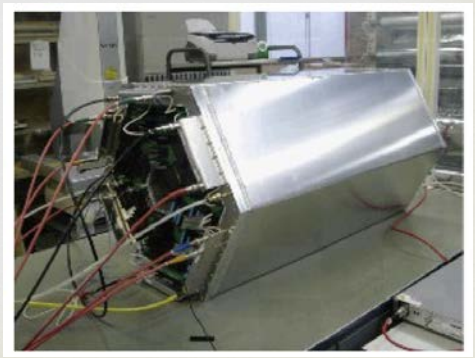
- Parity spin asymmetry :
  $P_\sigma = 2\,\rho^1_{1\text{-}1} - \rho^1_{00}$
  [Similar to photon beam asymmetry.]
  - GJ frame : 0.784 ± 0.154
  - Helicity frame : 0.758 ± 0.123
- Dominance of natural-parity exchange is indicated at forward angles.
  - Consistent with κ(800) meson exchange.

Λ(1405) production

- Study for internal structure of Λ(1405)
  - qqq, NK, qqqqq
  - Spectrum shape
- Production mechanism
  - Photon beam symmetry
- Large acceptance detector
  - TPC

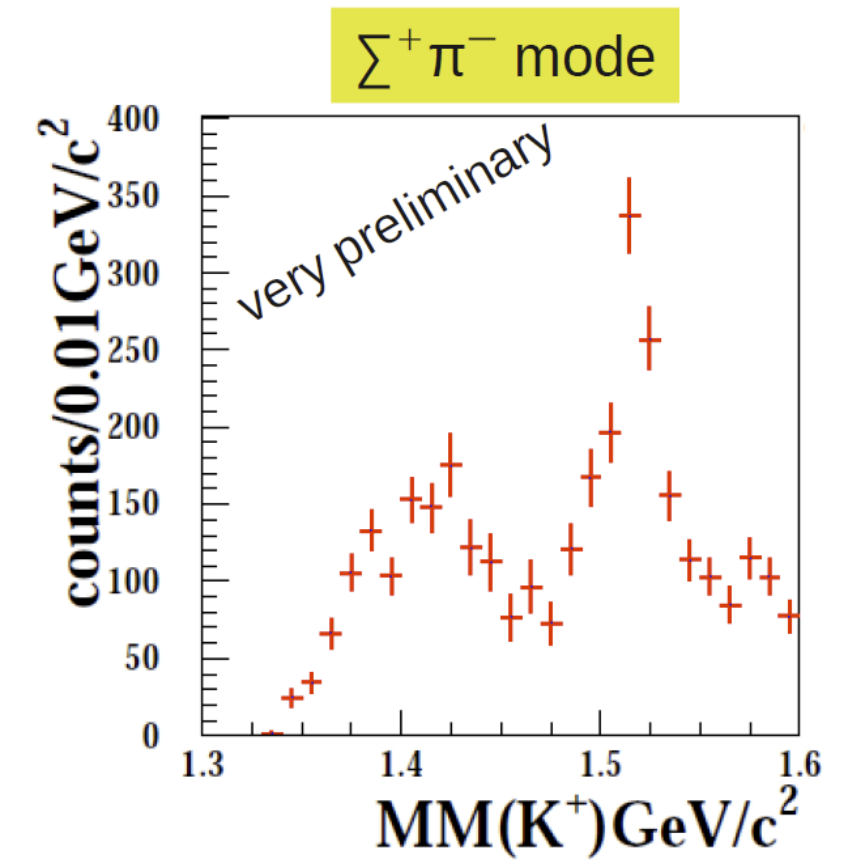


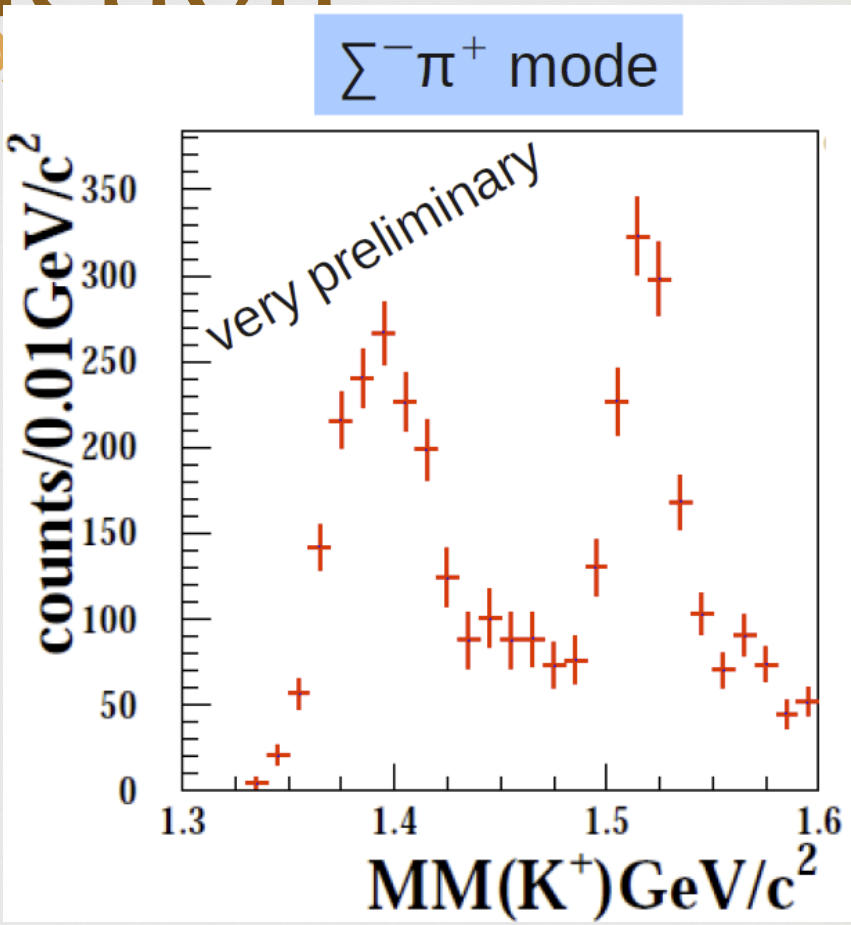
Previous result of LEPS (2008)
CH2 target



New result of Λ(1405) production

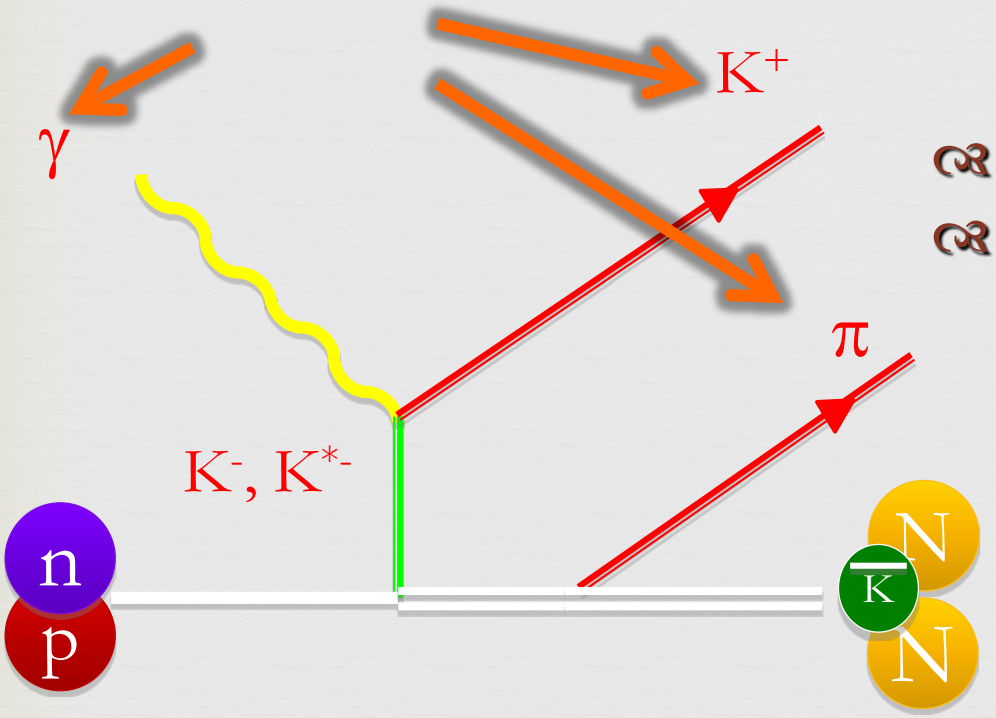
3 times higher statistic with LH2 target





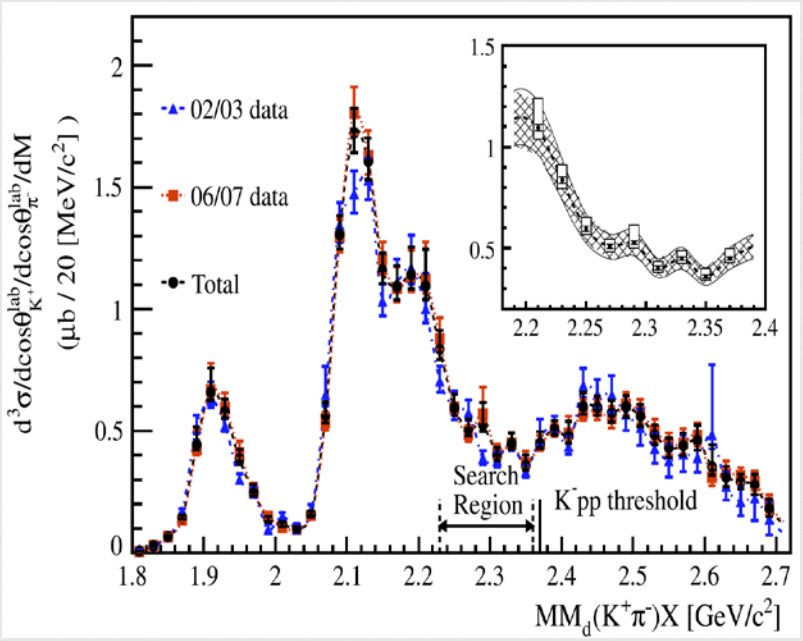
Spectrum shape is difference in each charge mode

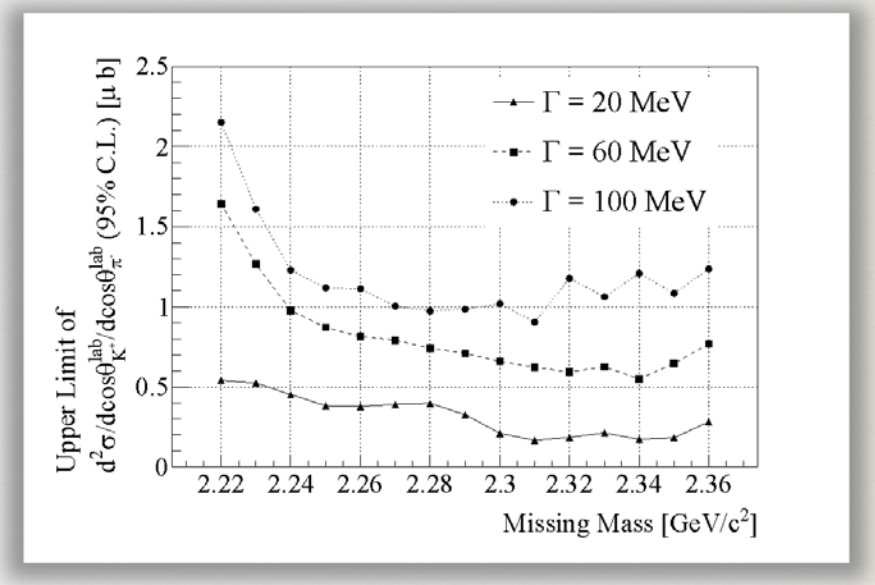
Search for the K^-pp bound state



- **Theoretical prediction : B.E.=10 – 80 MeV, Γ=30-110 MeV**
  - Phys.Lett.B712,132 etc…
- **d (γ, K^+ π^+) K^-pp**
- Unique feature of γ beam
  - direct coupling to K, K^* → virtual K, K^* beam
  - J=1 (spin flip)

Search for the $K^- pp$ bound state





No peak structure was observed

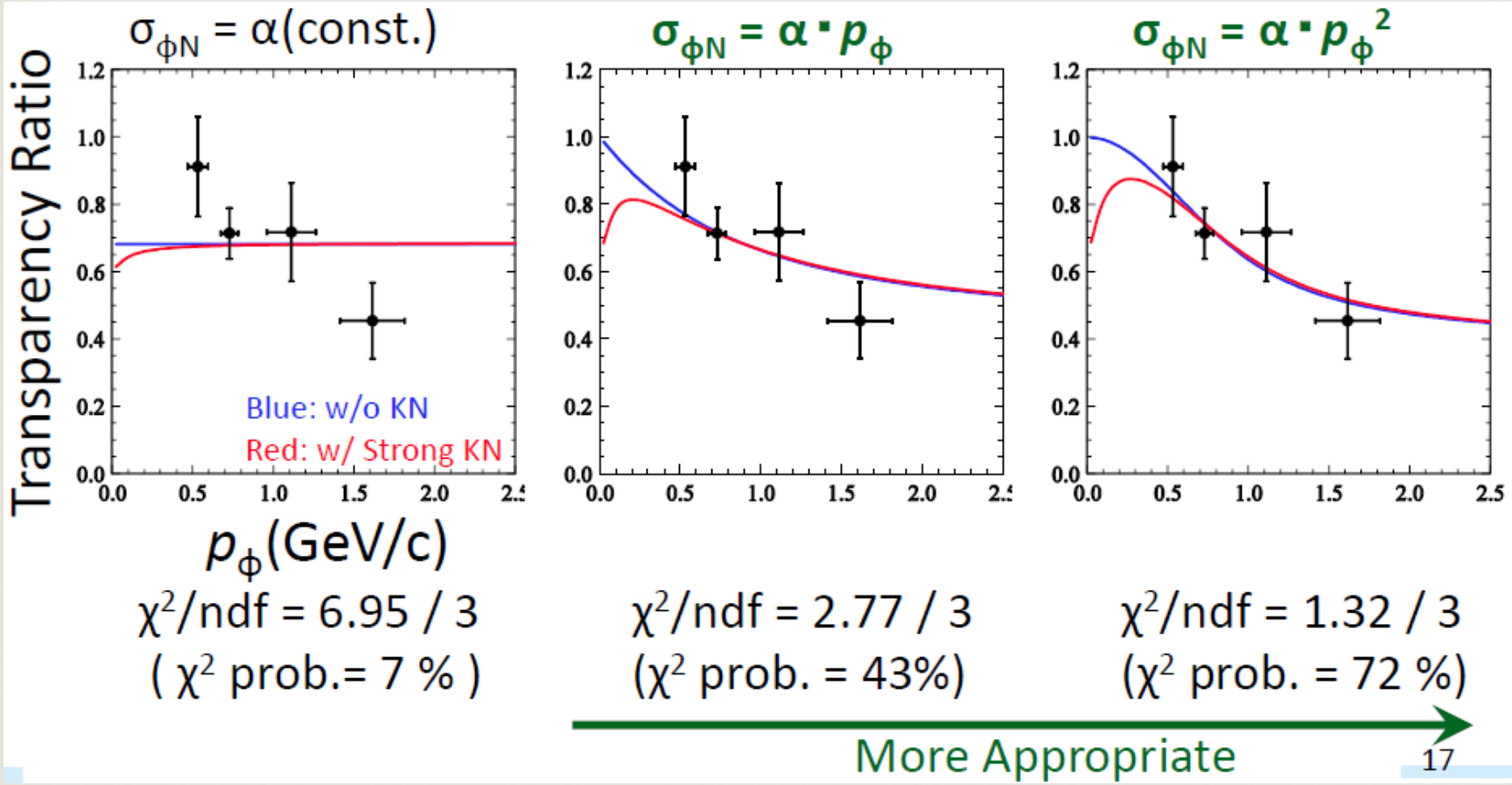
Upper Limit
(0.17–0.55), (0.55–1.7) (1.1–2.9) μb at 95% CL
for Γ = 20, 60 , 100 MeV

ϕ-nucleon interaction

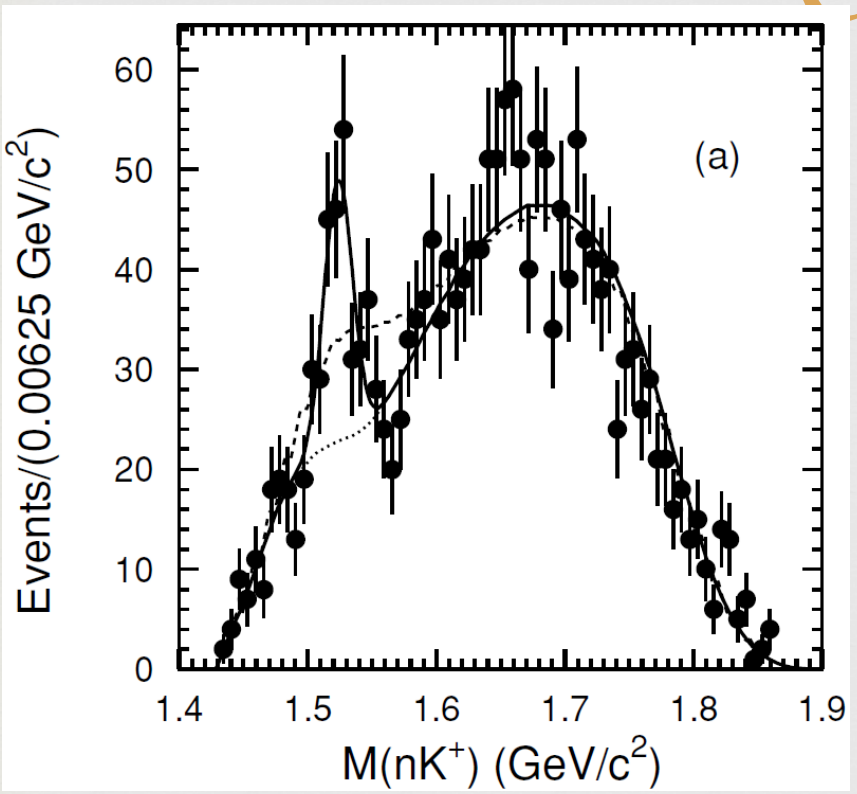
$$T = \frac{R^{\phi}_{Cu}/A_{Cu}}{R^{\phi}_{C}/A_{C}}$$

Here, the production rate of ϕ mesons

$$R^{\phi}_{A} = \frac{N^{\phi}_{A}}{N^{beam}_{A}\, N^{nuclei}_{A}\, \eta^{att}_{A}\, \eta^{geo}_{A}\, BR}$$



Result of the Θ^+ from LEPS



- Data from 2002-03
  - Significance 5.1σ
    - Shape analysis
  - M(Θ)=1524 MeV

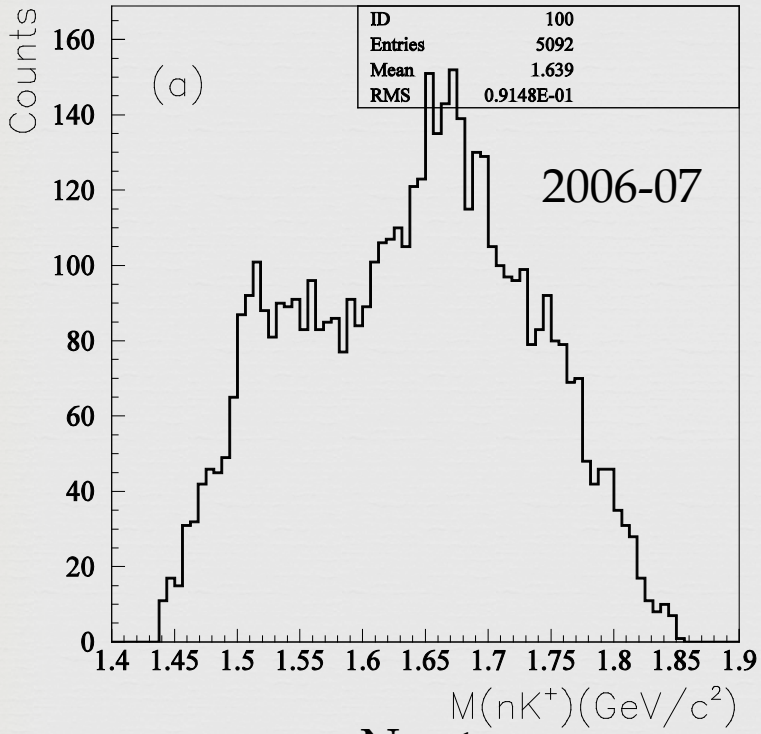
- To clarify the existence of Θ^+ ….
  - Higher statistic
  - Blind analysis

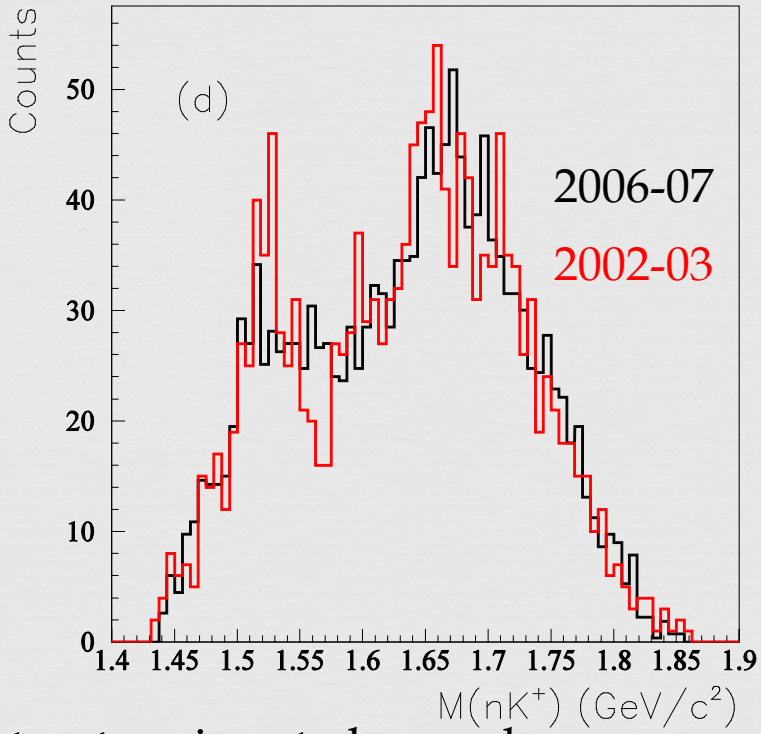
  ->

  2006-07, 2.6 times higher statistic experiment

New Result of Θ^+ (blind analysis)

Same cut condition (2002-03) and better calibration in blind analysis



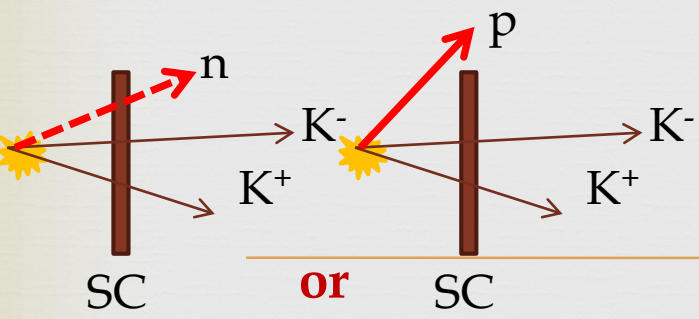


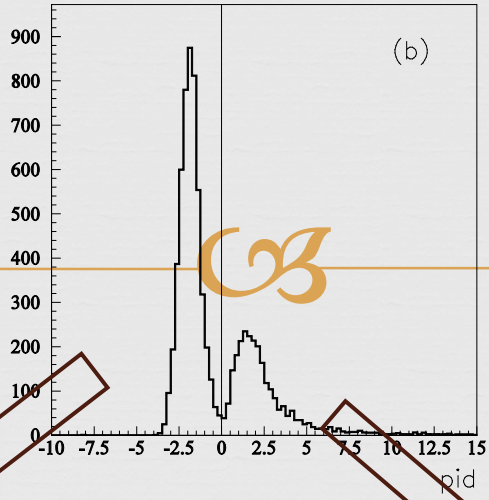
No strong narrow peak structure is not observed.

To understand the discrepancy between two result…

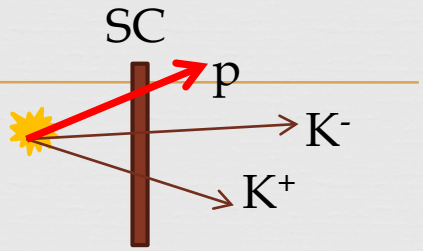
-> Exclusive analysis (proton/neutron identification)

Proton detection by using dE/dx in Start Counter





Pid = (Measured energy loss in SC)
– (Expectation of KK)
– (Half of expectation of proton)

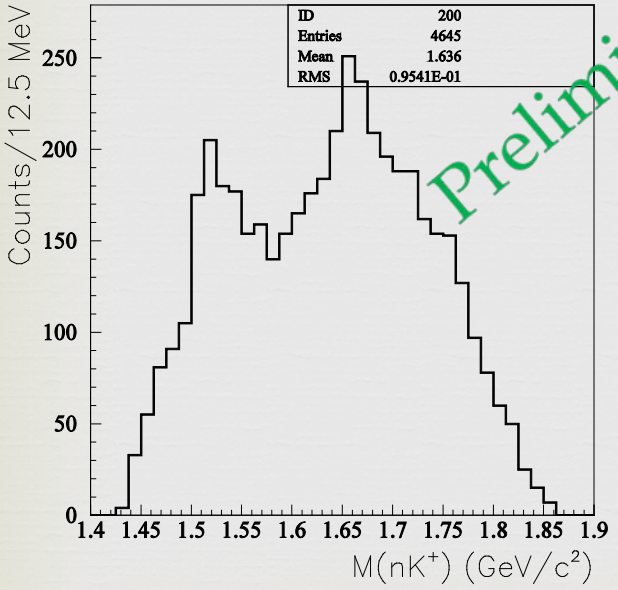


Proton not tagged (Proton rejected)

KKn and part of KKp

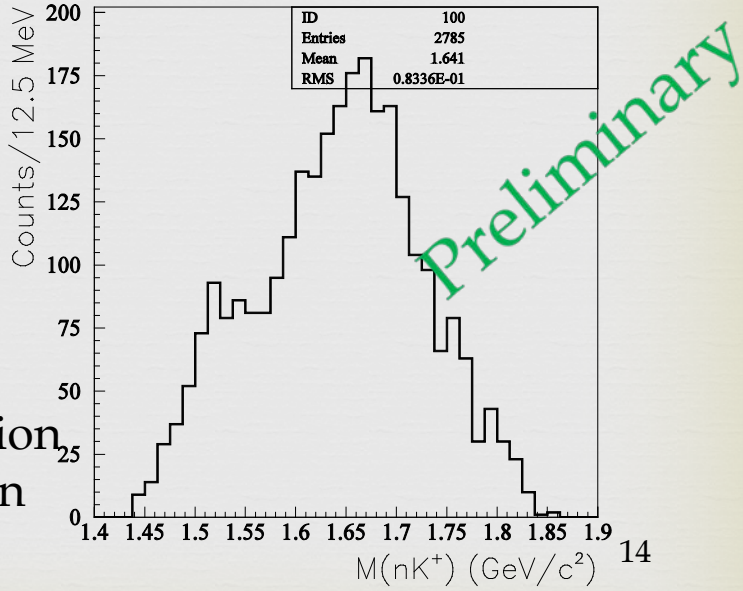
Proton tagged (ε ~60%)

KKp only

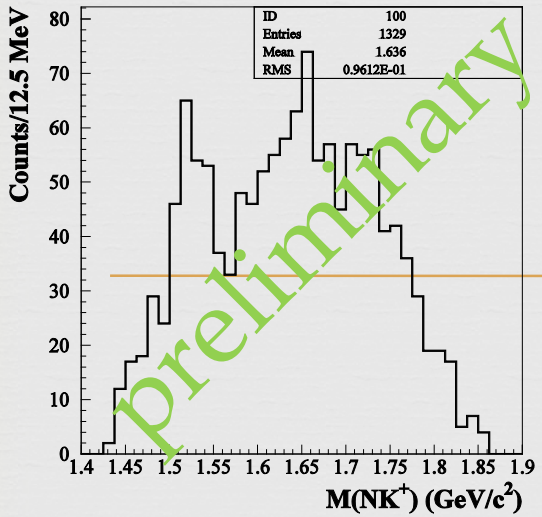


Signal enhancement is seen in proton rejected events.
→ should be associated with γn reaction.

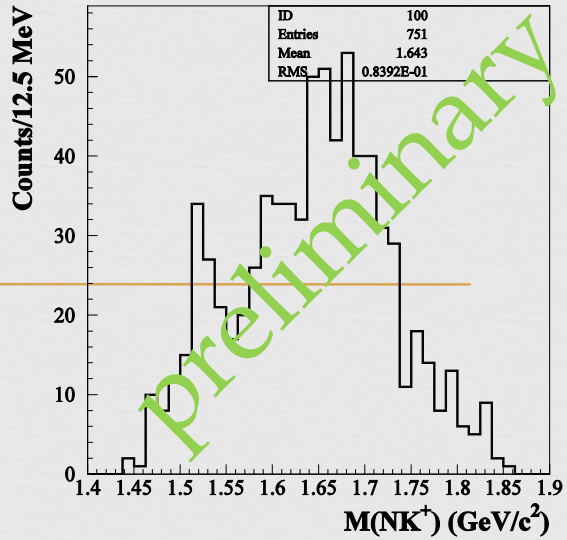
p/n ratio:
1.6 before proton rejection
0.6 after proton rejection



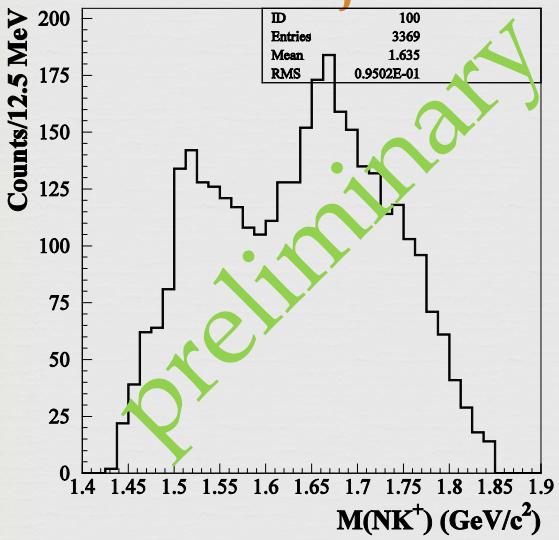
M(NK$^+$) for exclusive samples for each data



previous

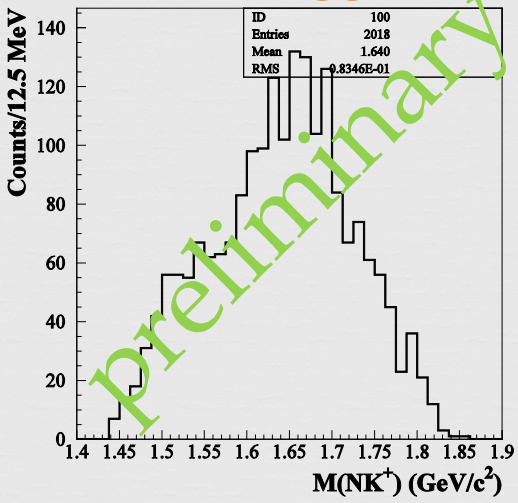


Proton rejected



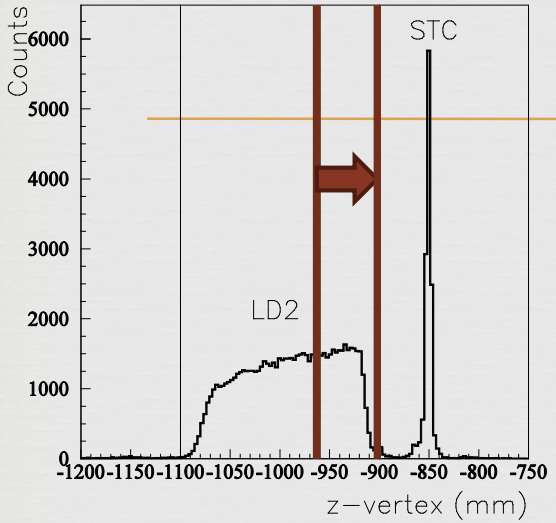
new

Proton tagged



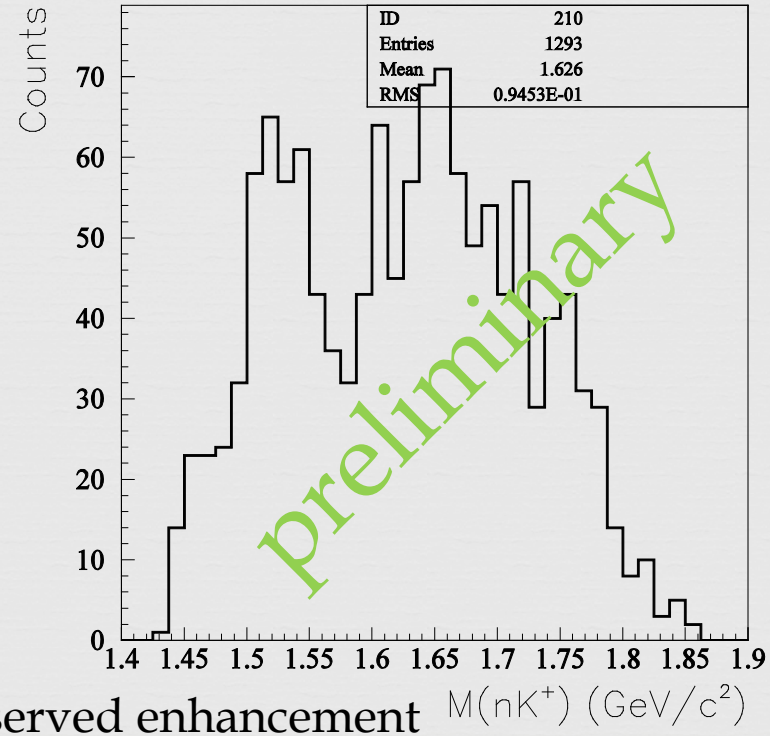
- Peak is seen in tagged events for the previous data while not seen in the new data.
- An enhancement is seen in proton rejected events in the both data.

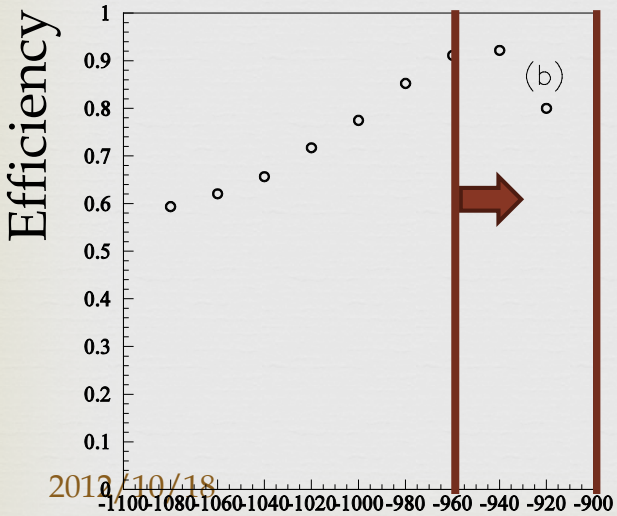
Z-Vertex cut



Proton rejection efficiency becomes large by selecting downstream

Enhance the Neutron event





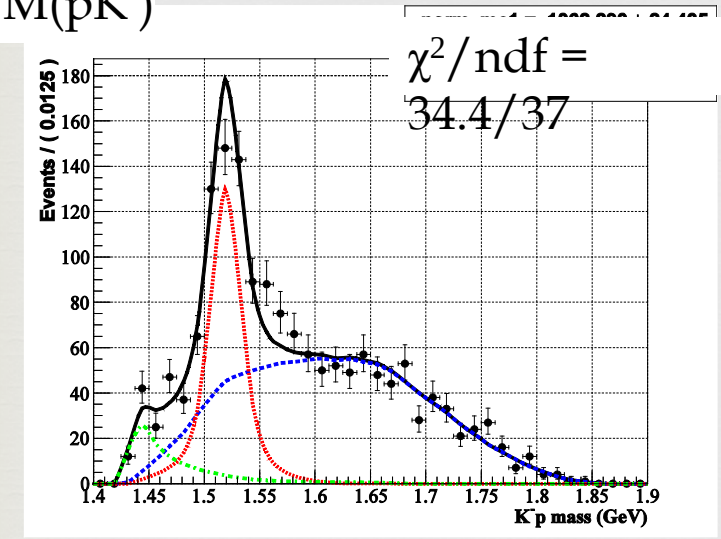
Clearly observed enhancement

MC based exclusive analysis

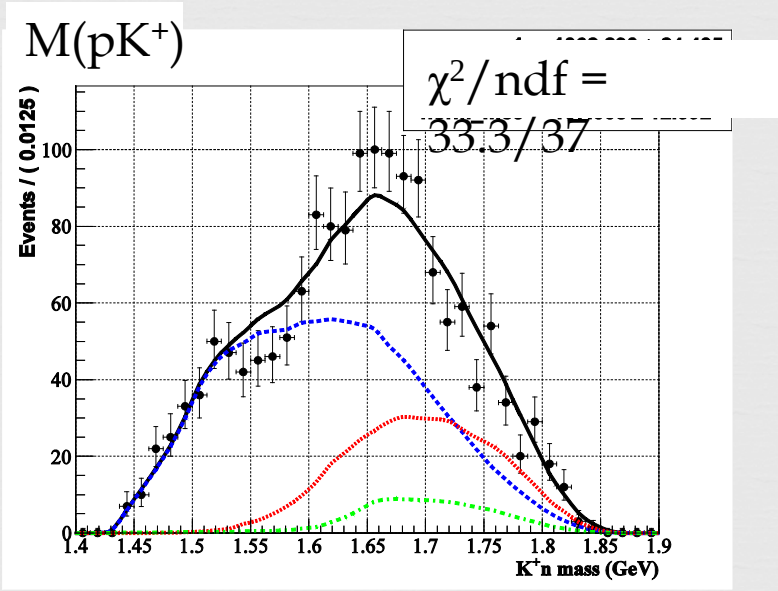
- Important to estimate the proton contribution
- The estimated proton contributions are subtracted from full data sample (without z-vertex and proton tagging cut) using MC.

Unbined fit for M(pK$^-$) with MC simulation

M(pK$^-$)



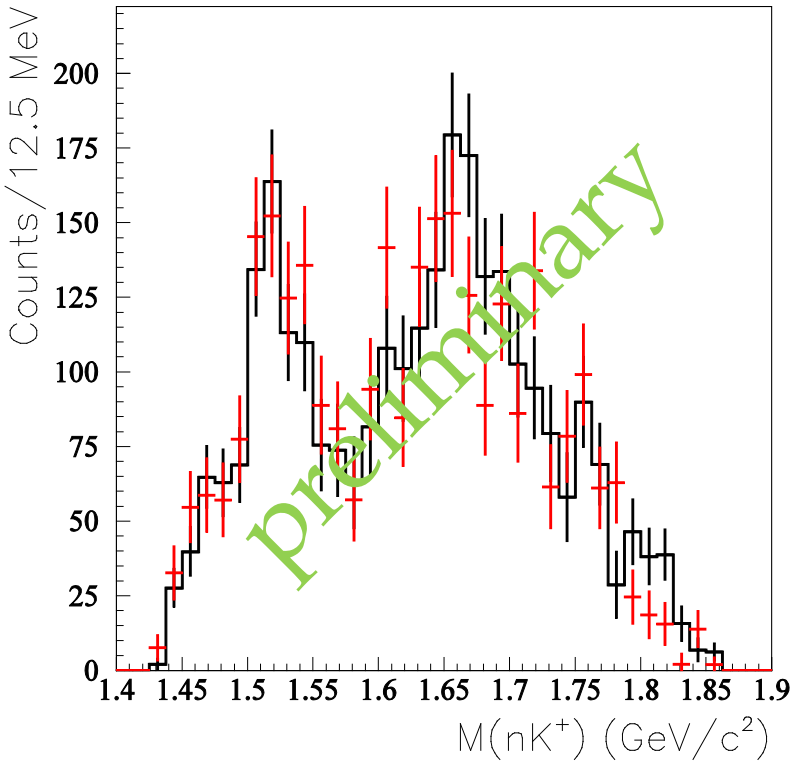
M(pK$^+$)



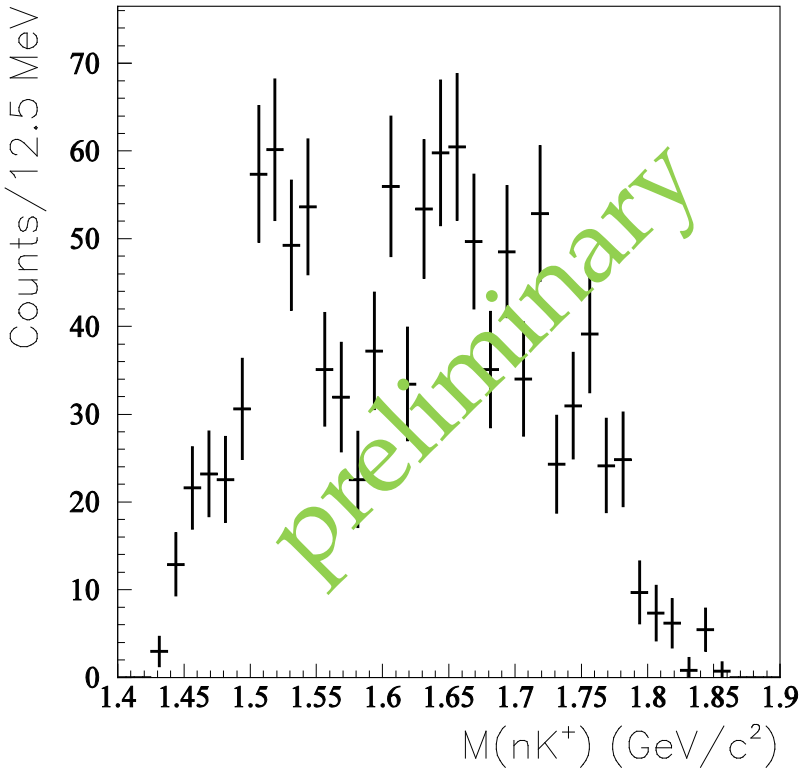
φ and non-resonant KK , Λ(1520), Λ(1405)

Result of exclusive ly

MC-based

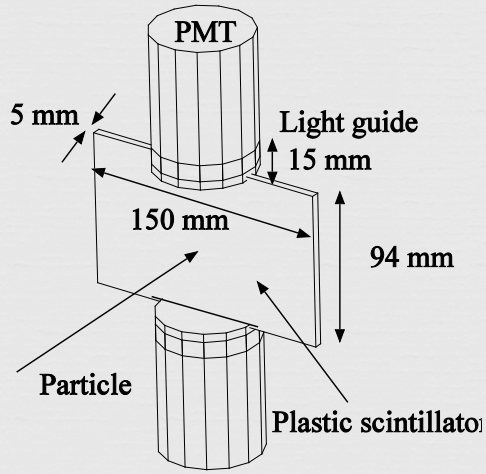


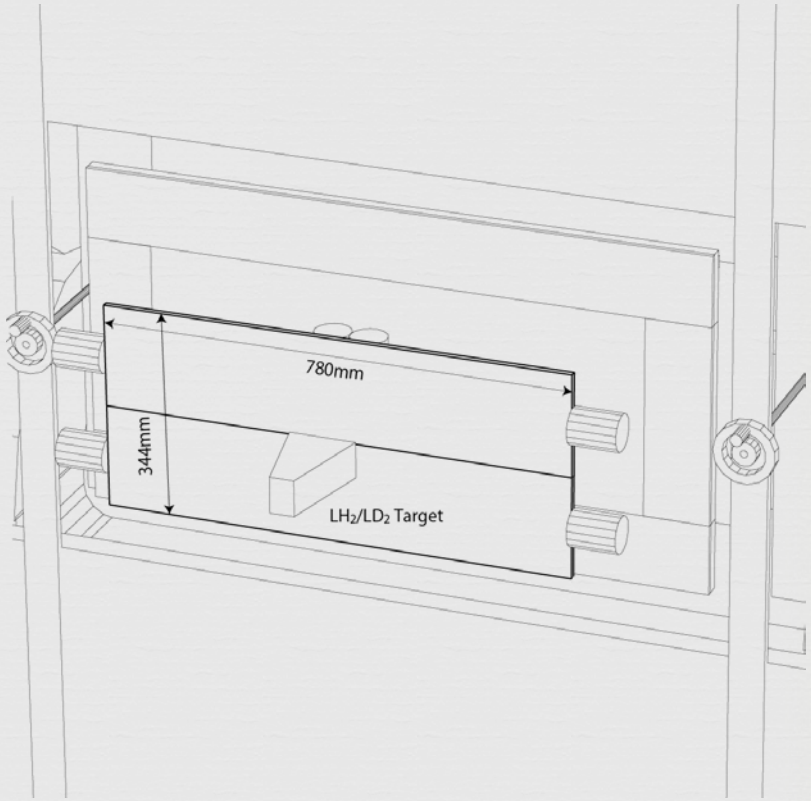
dE/dX-based



- An enhancement is seen both the exclusive analysis.
- Mass and significance estimation is underway.
  -> New experiment with large SC from this October.

New experiment setup

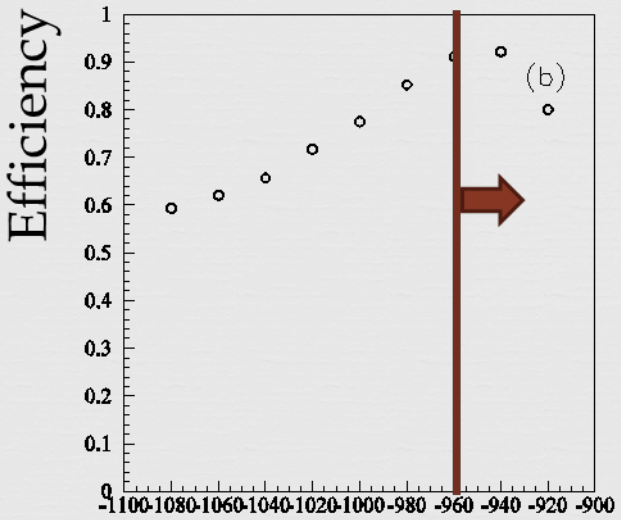


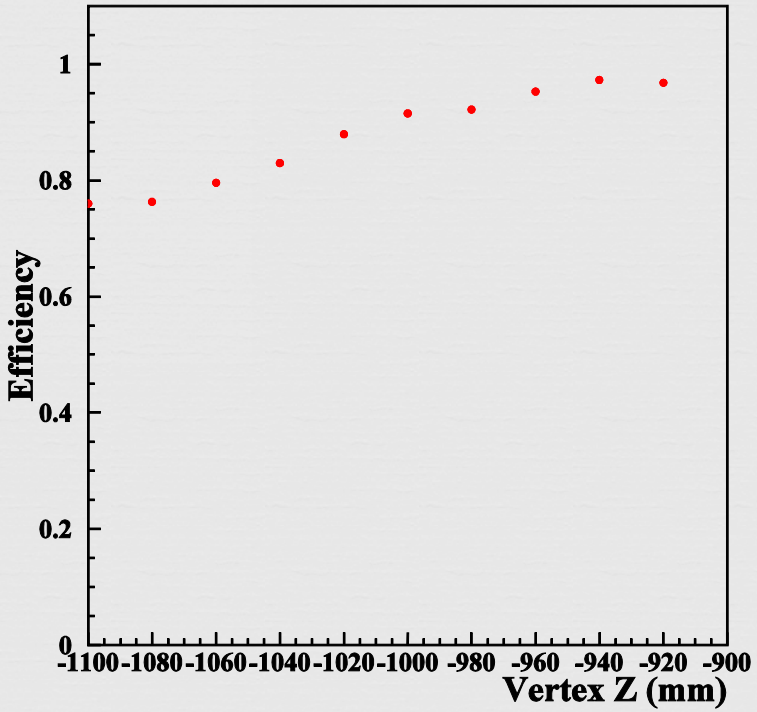


Start counter (~ 2007)

New Start counter (2012~)

Improvement of proton tagging





Start counter (~ 2007)

New Start counter (2012~)

Future prospect LEPS2

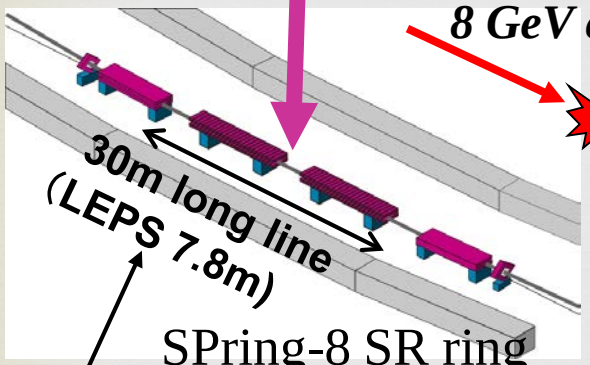
BGOEGG EM-calorimeter
(neutral meson detection experiment)

BNL-E949 base detector
Θ+ search,Λ(1405)
Expansion of LEPS experiment


LEPS2 Laser-Room
LEPS Experimental Hutch
LEPS2 Experimental Building
SPring-8
8GeV e⁻ 100mA
457 m
Booster Synchrotron
XFEL SACLA
Linac: 1 GeV
New SUBARU

LEPS2 Project at SPring-8

Backward Compton Scattering



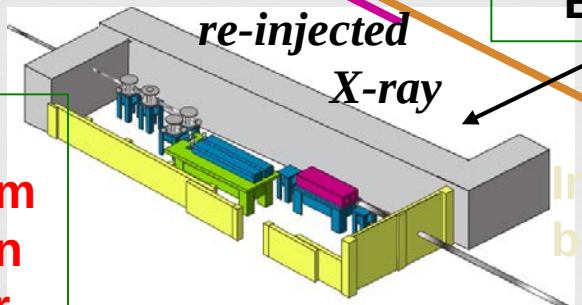
8 GeV electron

Recoil electron (Tagging)

SPring-8 SR ring

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)

Laser or re-injected X-ray



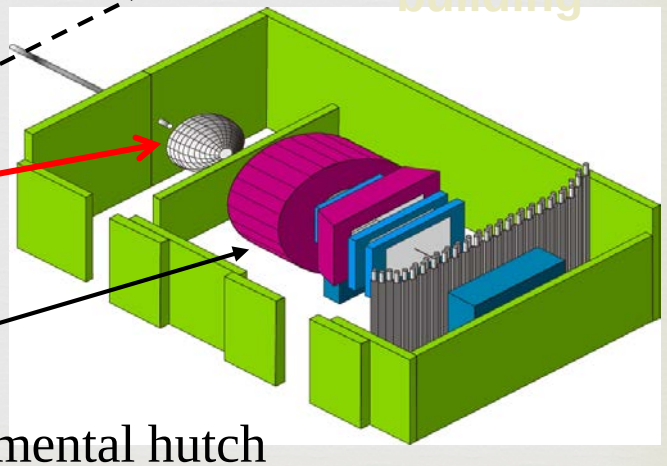
Laser hutch

GeV γ-ray

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

Inside building

Outside building



Large acceptance EM calorimeter BGOEGG.

Large 4π spectrometer based on BNL-E949 detector system.

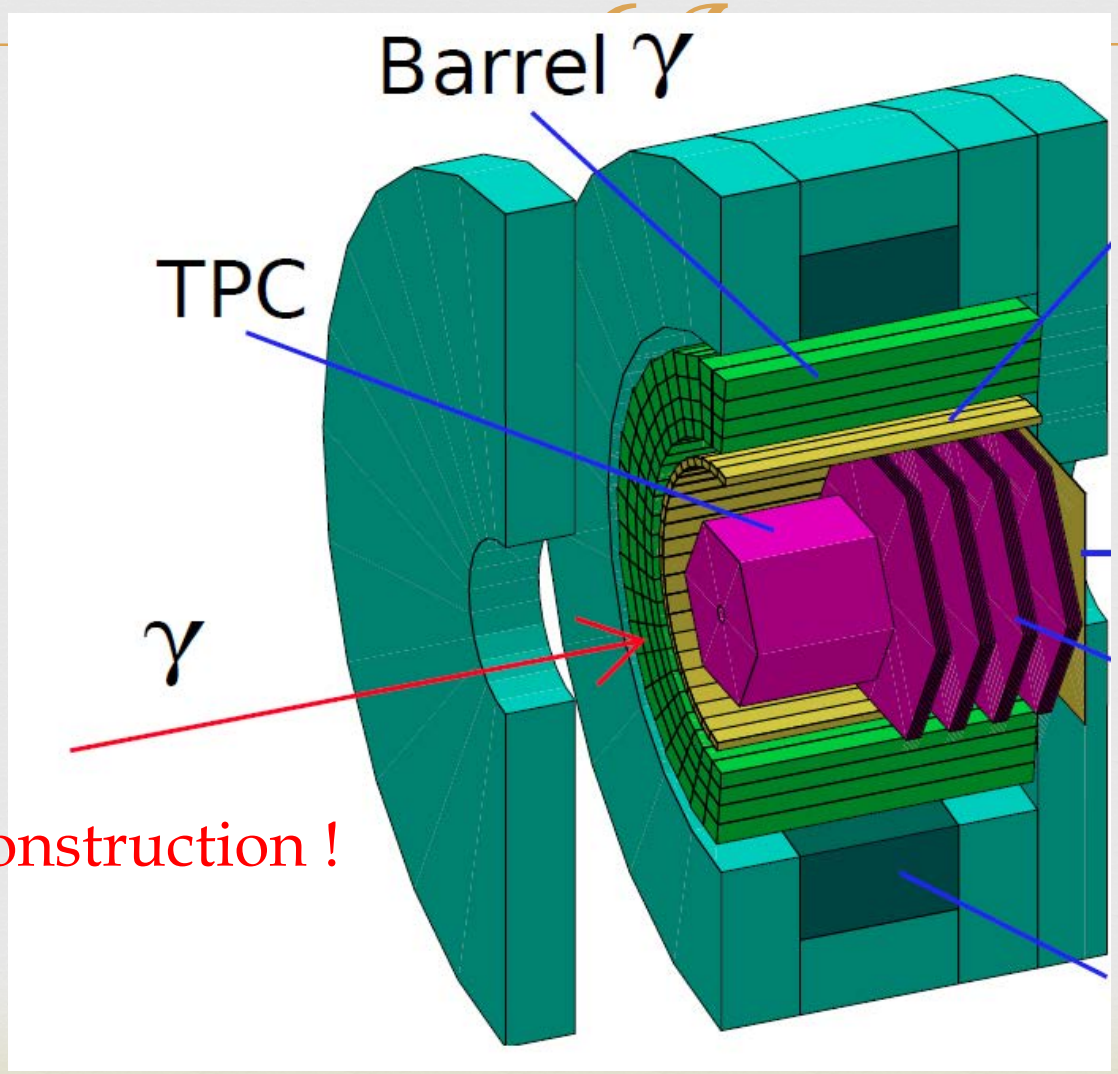
Experimental hutch

Physics at LEPS2

- BNL-E949 base detector
  - Θ^+, $\Lambda(1405)$

  Expansion of LEPS experiment
- BGOEGG detector
  - η' mesic nulei
  - Baryon resonance study with multi meson production

E949 based spectormeter

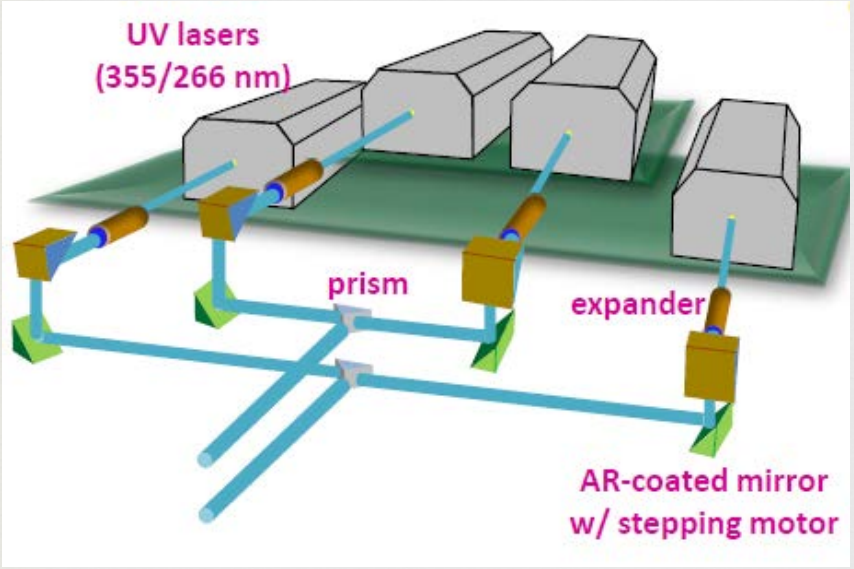


Under construction !
(2014)

LEPS2 laser system

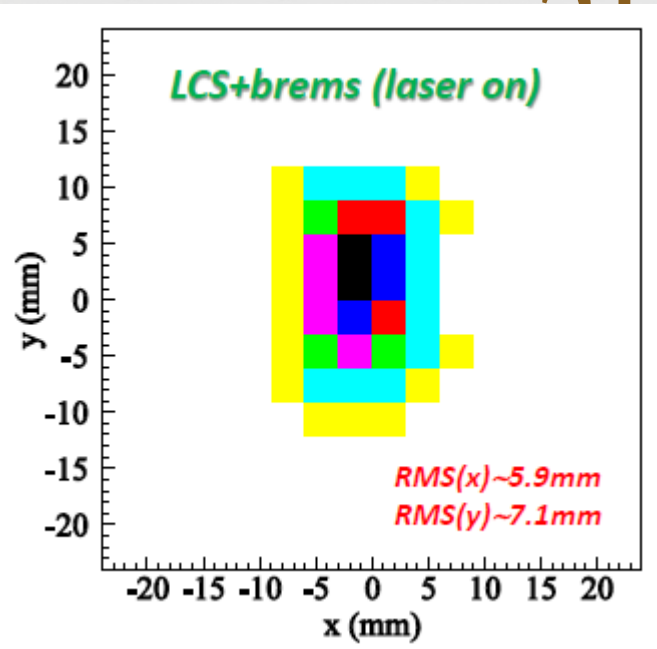
- simultaneous 4-laser injection
- Increase the laser power
  - 8 W -> 16 W or 24W
- Smaller beam size
  - Lower e^- divergence

    $<\sigma_{x'}>$=58 μm -> 14 μm



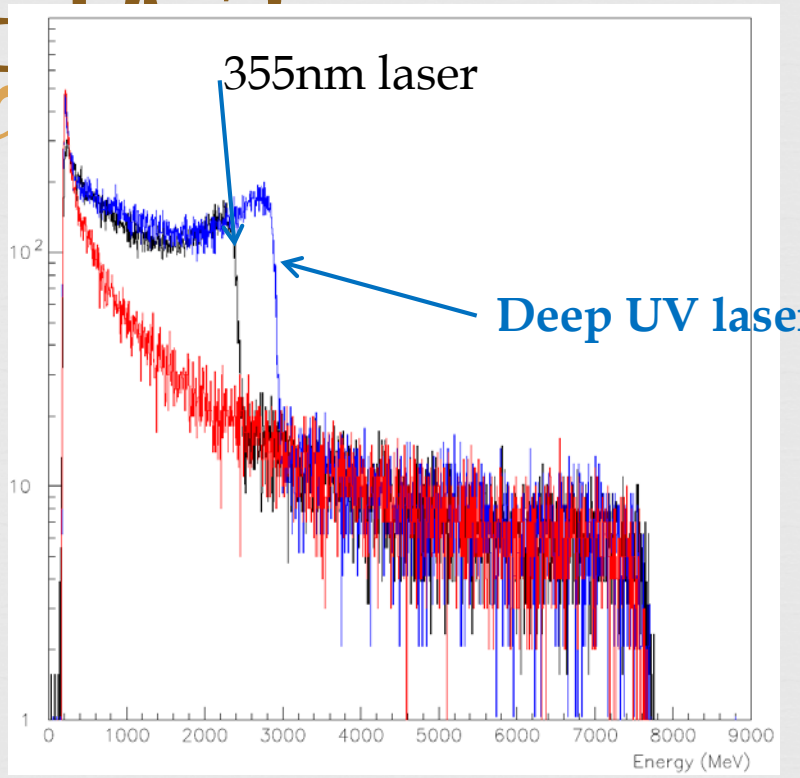
Multi laser injection system

First beam observation at LEPS2



beam profile is well collimated

consistent with the expectation

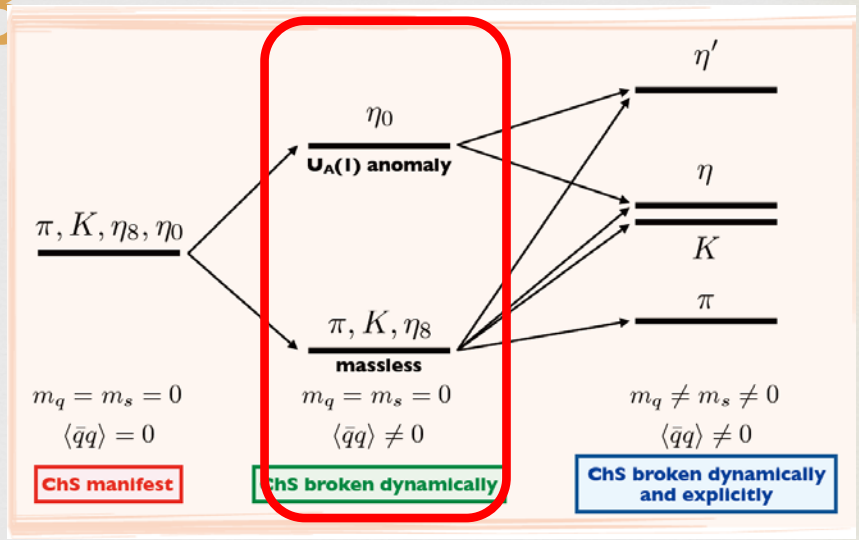


Energy spectrum with
large BGO crystal (ϕ 8 cm x L 30cm)

Photon beam intensity ~ **7 MHz** (for 0<Eγ<2.4 GeV)
@ 3-(355nm) laser

η′(958) and $U_A(1)$ anomaly

- The experimental mass of η′ is more than 2 times larger expected value.
  - $U_A(1)$ anomaly effect.
- Origin of large η′ mass
  - Chiral symmetry breaking
  - $U_A(1)$ anomaly

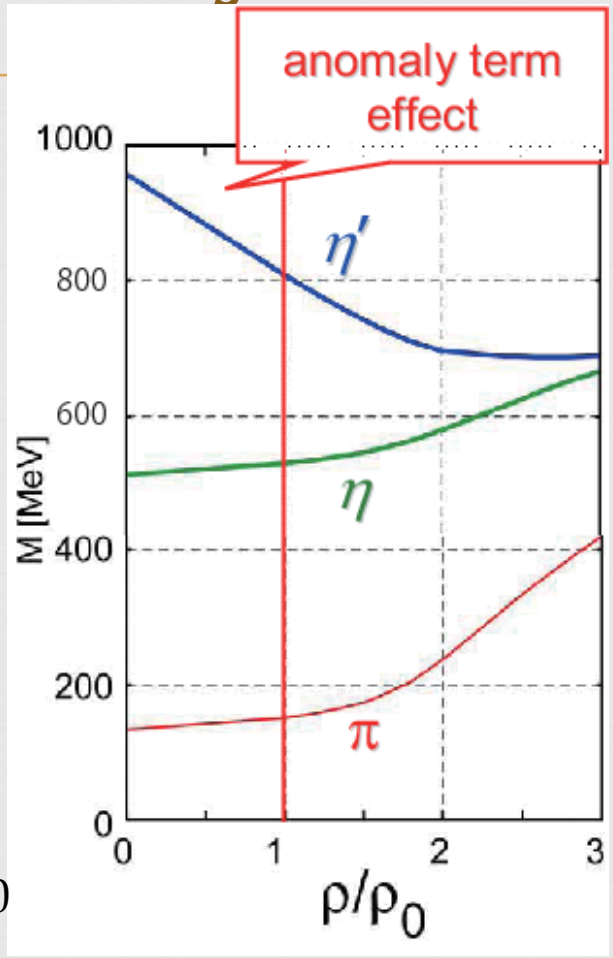


Daisuke Jido, Hideko Nagahiro, and Satoru Hirer
Phys. Rev. C 85 (2012) 032201(R).

No experimental information for $U_A(1)$ anomaly effect

Mass modification in finite density

- Mass of η′ is possibly modified under the finite density compared with the vacuum
  - $\Delta m_{\eta'} \sim$ -150MeV @ρ_0
  - $\Delta m_{\eta} \sim$ + 20MeV @ρ_0



- P. Rehberg, et al. Phys. Rev. C53(1996) p410
- H. Nagahiro, M Takizawa, S. Hirenzaki Phys. Rev. C 74, 045203 (2006)

Measurement of η‘ in finite density

- Large mass reduction(150 MeV) of the η′ meson in the normal nuclear density

- existence of a bound state with a nucleus (η′-mesic nuclei)
  - H. Nagahiro, M. Takizawa, and S. Hirenzaki, Phys. Rev. C 74, 045203 (2006).

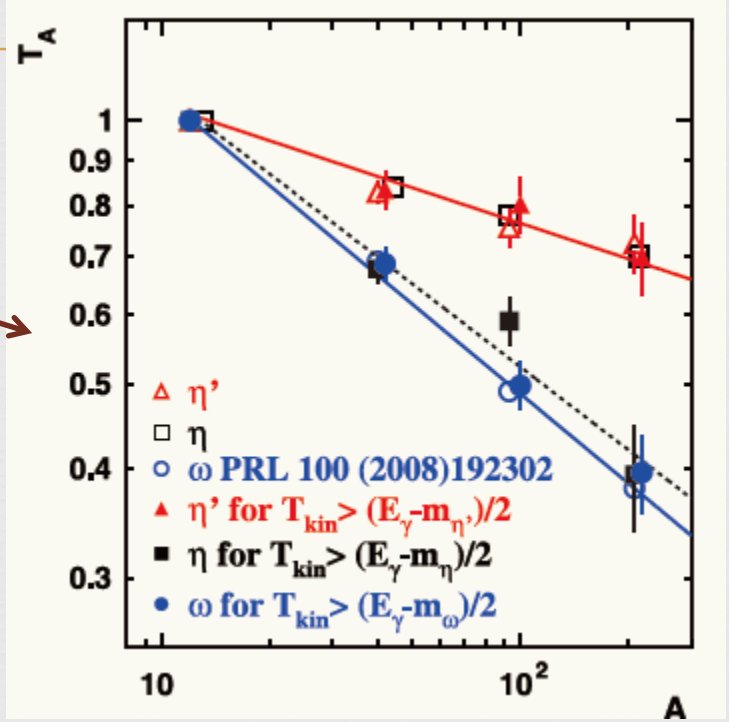
- If we observe the η′ bound state, we achieve the information for UA(1) anomaly effect.

η′-mesic nuclei

- Strong attractive force and small absorption
  - Attractive force
    - $U_A(1)$ anomaly effect
  - Absorption
    - $ReW_0 \sim 7.5$-12.5MeV (CB-ELSA)

      M. Nanova et al., PLB 710, 600 (2012)
- Experimental results
  - Re $a_{\eta' N}$<0.8fm
    - Phys. Lett. B474(2000)p416
  - $|a_{\eta' N}|$ <0.1fm
    - Phys. Lett. B482(2000)p356
- Optical potential with Chiral unitary model
  - ReV >> ImV (possible)

→ more detailed experiment!



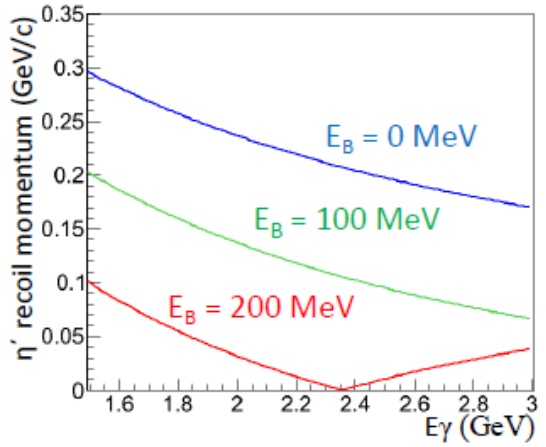
Transparency ratio

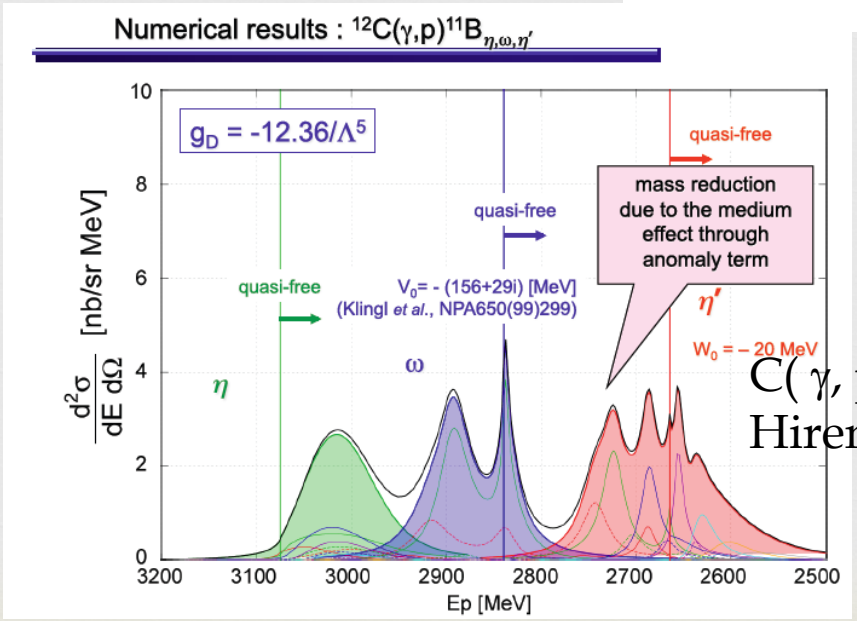
Search the η′ mesic nuclei using nuclear target.

η′ mesic nuclei in (γ,p) reaction

- Lower Recoil momentum of η′ than hadron beam
- Experimental parameters
  - Eγ 1.6~2.9 GeV
  - Target C
  - Forward proton detection

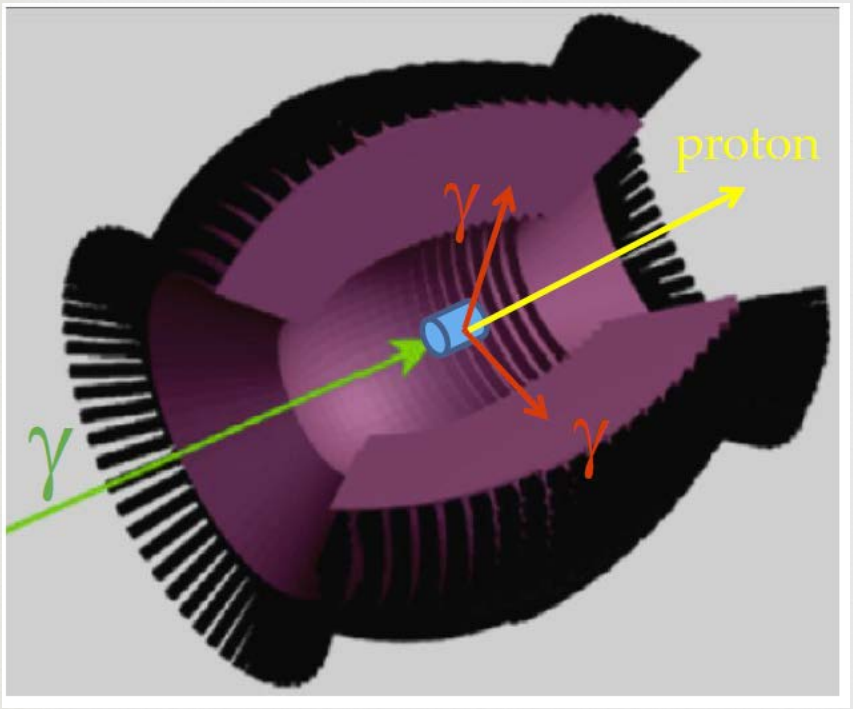
- momentum transfer (0 degree)





C(γ, p)X missing m
Hirenzaki@ELPH 201

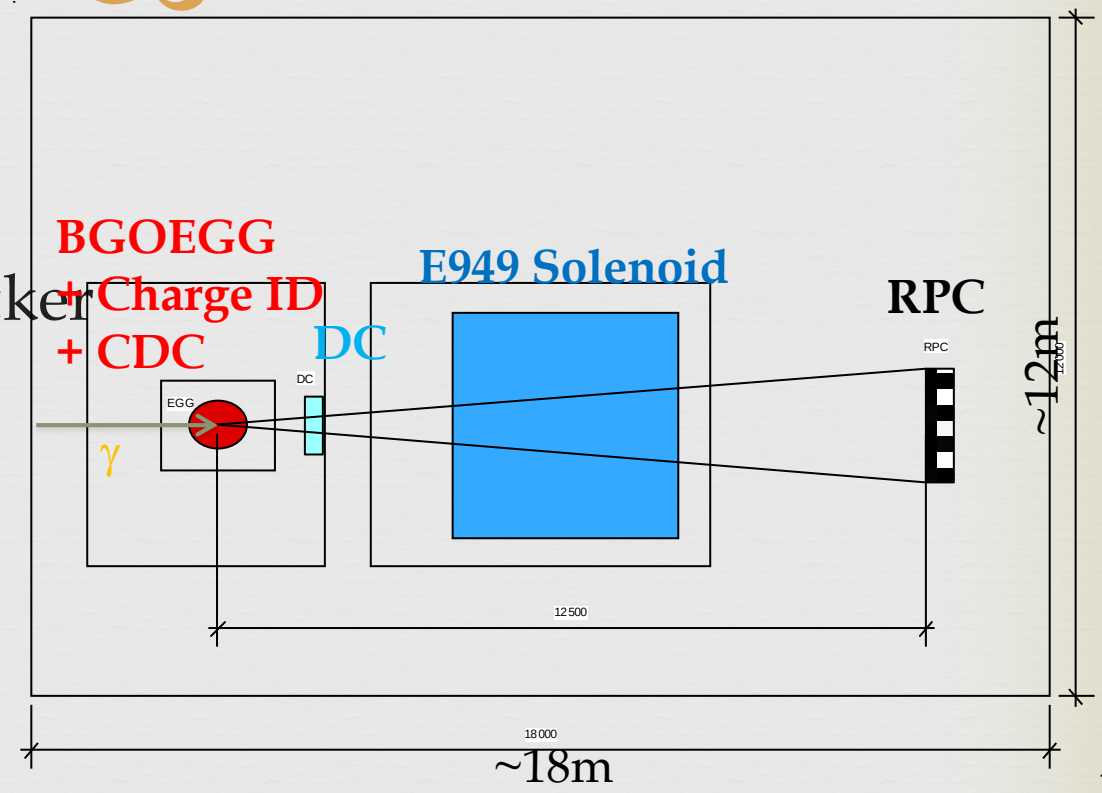
LEPS2 BGOEGG project



- Egg shape EM detector
- Total volume 264L
- Total weight 1.9t(crystal)
- 2-type PMT
  - H11334 (Metal package)
  - H6524 (head-on type)
- Very few Insensitive regeon
  - Without housing material
  - Only reflector 3M-ESR film (200μm)
- Energy resolution
  - 1.3 % for 1GeV e^+
- Position resolution
  - 3mm

Peripheral detectors

- Time of flight counter
  - RPC
- Charge identification detector
- Caharged particle tracker chambers
  - CDC, DC

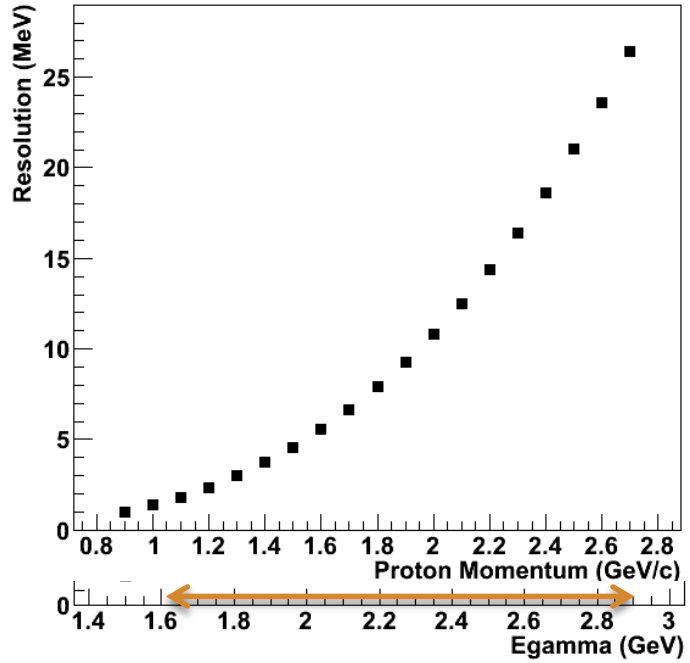


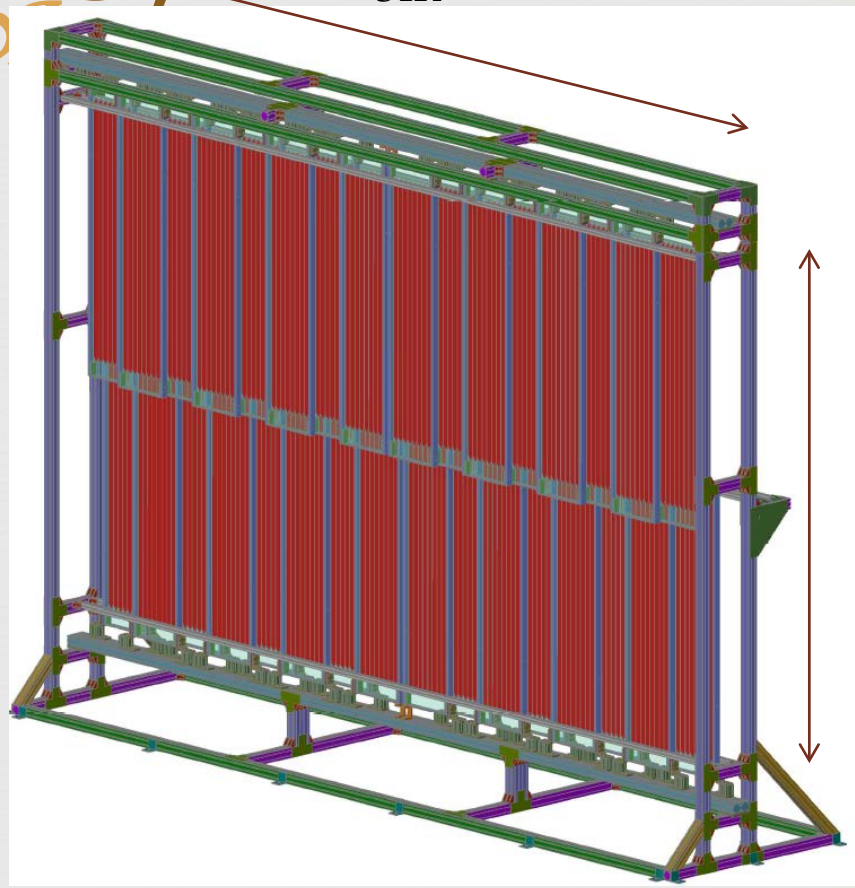
LEPS2 experiment hatch

Resistive Plate Chamber (RPC)

- Focus on mesic nuclei search
  - 12 MeV forward proton momentum resolution

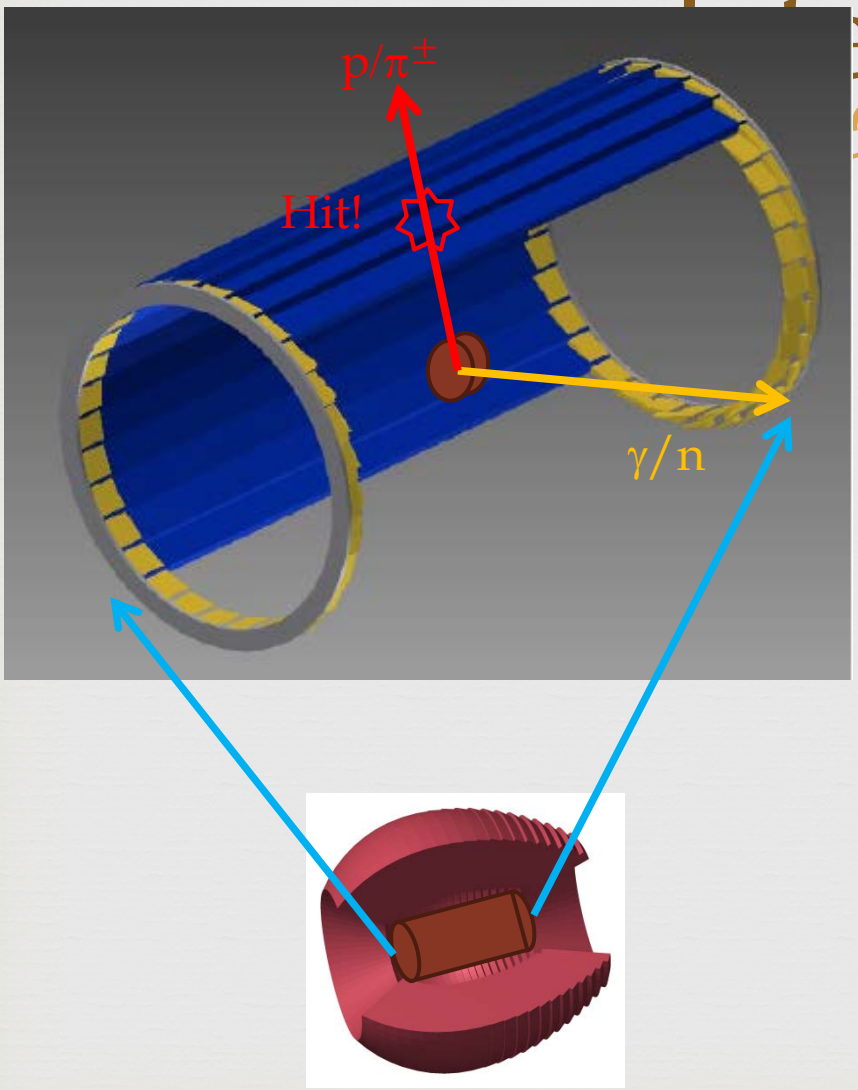
-> 50 psec time resolution at 12 m flight length





32 modules in wall

Charge identification detector

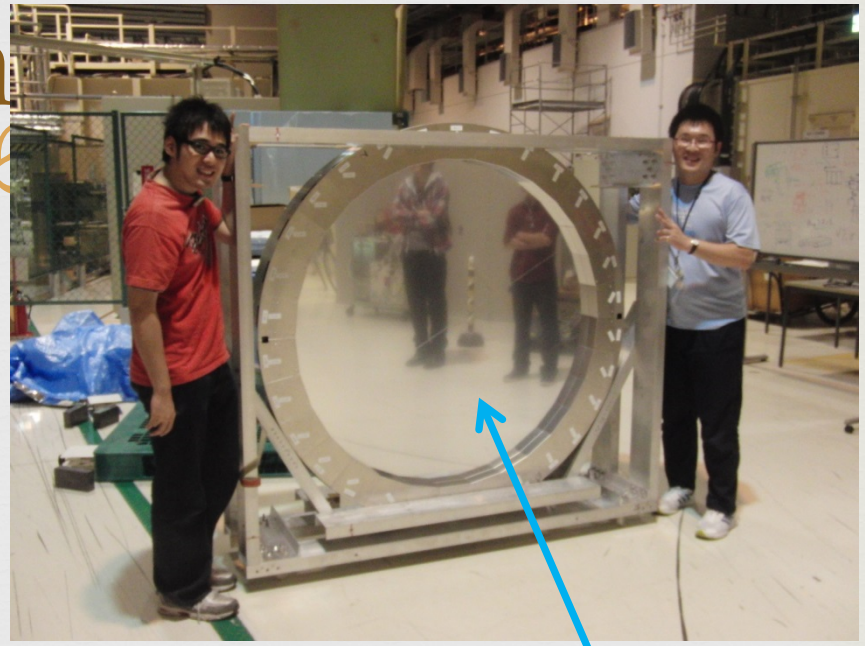


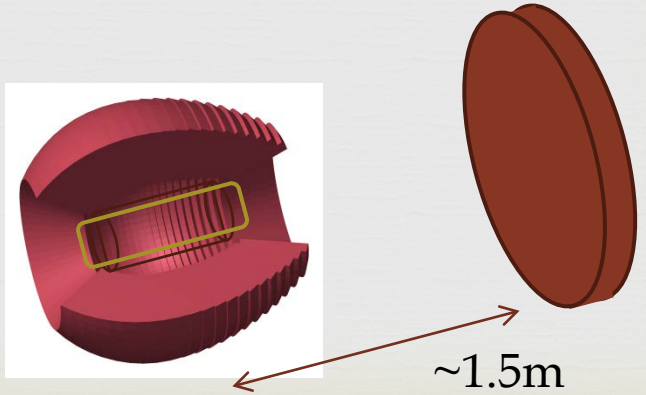
- Place at inside of BGOEGG
- 30 scintillators with overlap.
- Scintillator size
  - 5 x 26 x 413

    -> covering the inner face of BGOEGG
- Multi Pixel Photon Counter (MPPC) readout
  - Effective area 3mm×3mm
  - Pixel size 50um×50um

Charged particle tracker cham

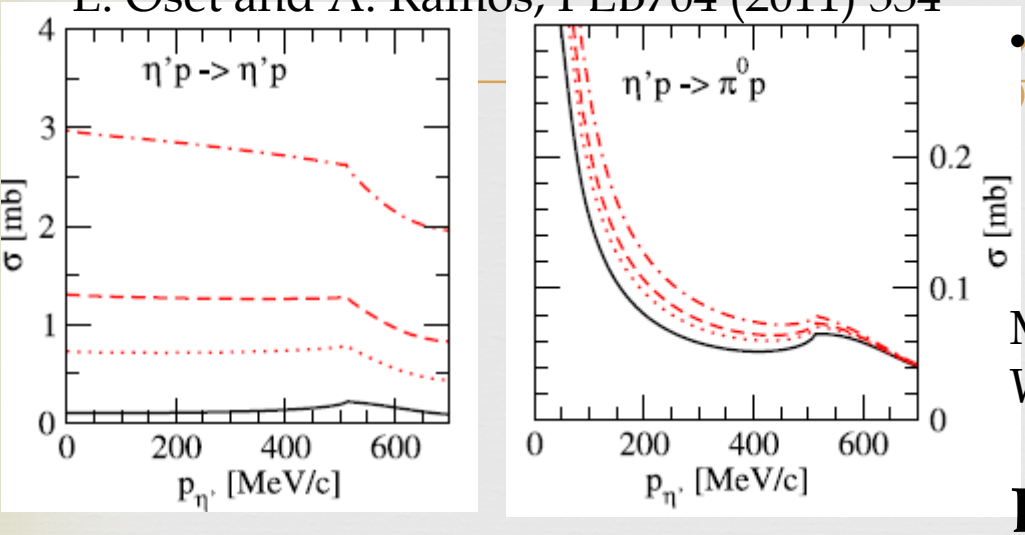
- Charged particle Positions/angles at forward angle(θ<24°)
- 6 planes (XX'UU'VV')
- 80 sense wires / plane
- effective area: ϕ1280mm
- 16 mm square cell
  - σ=130 μm

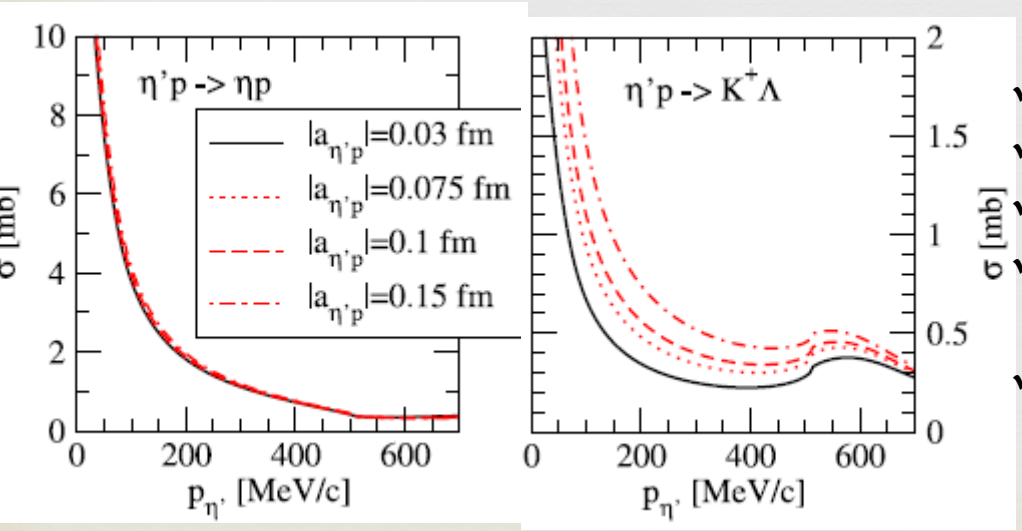




Yield estimation η′ mesic nuclei by η tagging at BGOEGG

E. Oset and A. Ramos, PLB704 (2011) 334





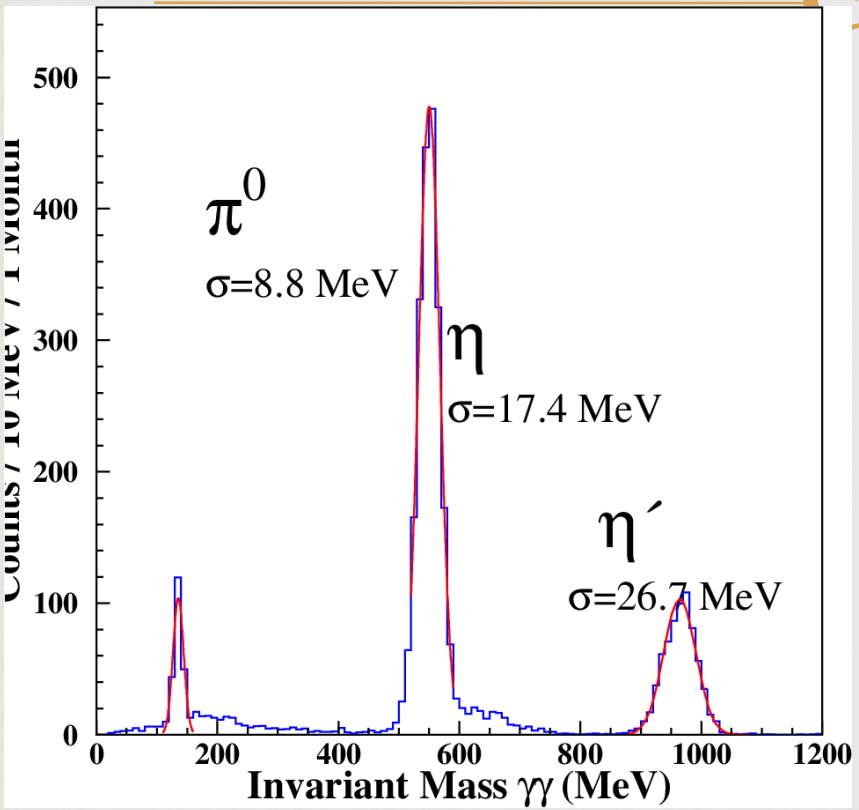
- Dominant conversion from η′
  ~ η′p->ηp
  - η -> γγ (39.3%)
  - η -> $\pi^0\pi^0\pi^0$ -> 6γ (33%)

Multi meson production background
Will be suppressed by η tag at BGOEGG!

Expected yield

- ✓ $d^2\sigma/dEd\Omega$ ~2nb/sr/MeV
- ✓ Target ~ Carbon 20mm
- ✓ Beam intensity ~ 2Mcps (Tag. Eff~50%)
- ✓ Forward proton with RPC(2x4m)
  -> 70000 event / month
- ✓ With η tag at BGOEGG
  -> 2~3000 event / month
  (η′N->ηN : 50% from bound state)

η′ meson production

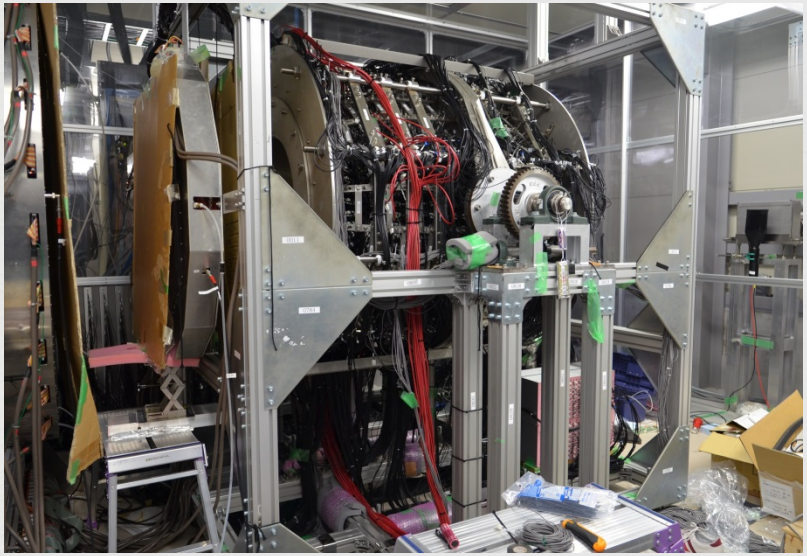


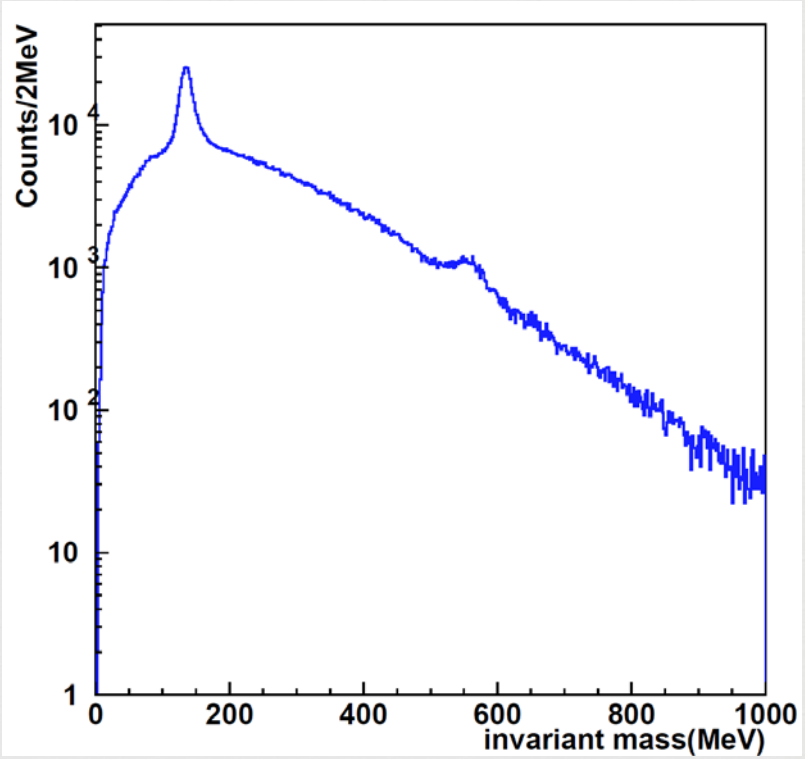
- Geant4 simulation
  - 44.3% $\eta' \rightarrow \pi^+\pi^-\eta$
  - 29.5% $\eta' \rightarrow \rho\gamma$
  - 20.9% $\eta' \rightarrow \pi^0\pi^0\eta \rightarrow 6\gamma$
  - 2.1% $\eta' \rightarrow \gamma\gamma$

  @ proton target (40mm)
- η′ mass resolution

  ~2.8 %
- 1,1000 η′ event @ LEPS2 per 1-month

First experiment in 2013





Summary

LEPS project are collaborating toward next generation experiments LEPS2 at SPring-8 with RIKEN and KEK.

LEPS

- $K^*\Sigma^+$ photoproduction with evidence for κ meson exchange.(PRL108,092001)
- Λ(1520) mass spectrum shape shows different in each charge mode.
- KNN bound state search (will be publish soon [PLB, **arXiv.1306.5320**])
- The Θ^+ is studied via $\gamma d \rightarrow K^+K^-pn$ reaction with high statistics data.
  - 2.6 times higher statistics compared with previous data are collected.
  - The inclusive M(nK+) spectrum for new data does not show a strong narrow peak.
  - The significance of the peak in new data is ~2σ by shape analysis.
  - The exclusive analysis

LEPS2

- SPring-8 LEPS2 facility just started
- LEPS2 has one order of magnitude higher intensity beam and large acceptance coverage.
  - BGOEGG, E949 based detectors.
- BGOEGG calorimeter experiments started in this winter.
  - η' mesic nuclei, baryon resonance, etc
- Thanks!

Thanks!