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Overview of hadron photoproduction studies at LEPS/LEPS2

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1. Introduction of SPring-8/LEPS2 facility

2. Overview of the LEPS2-solenoid experiment

3. Physics motivation of LEPS2-solenoid experiment

☆ Photon beam is complementary to π beam for studying hadron.

- Polarization observables.
- Study of the excited hadrons with small πN coupling.



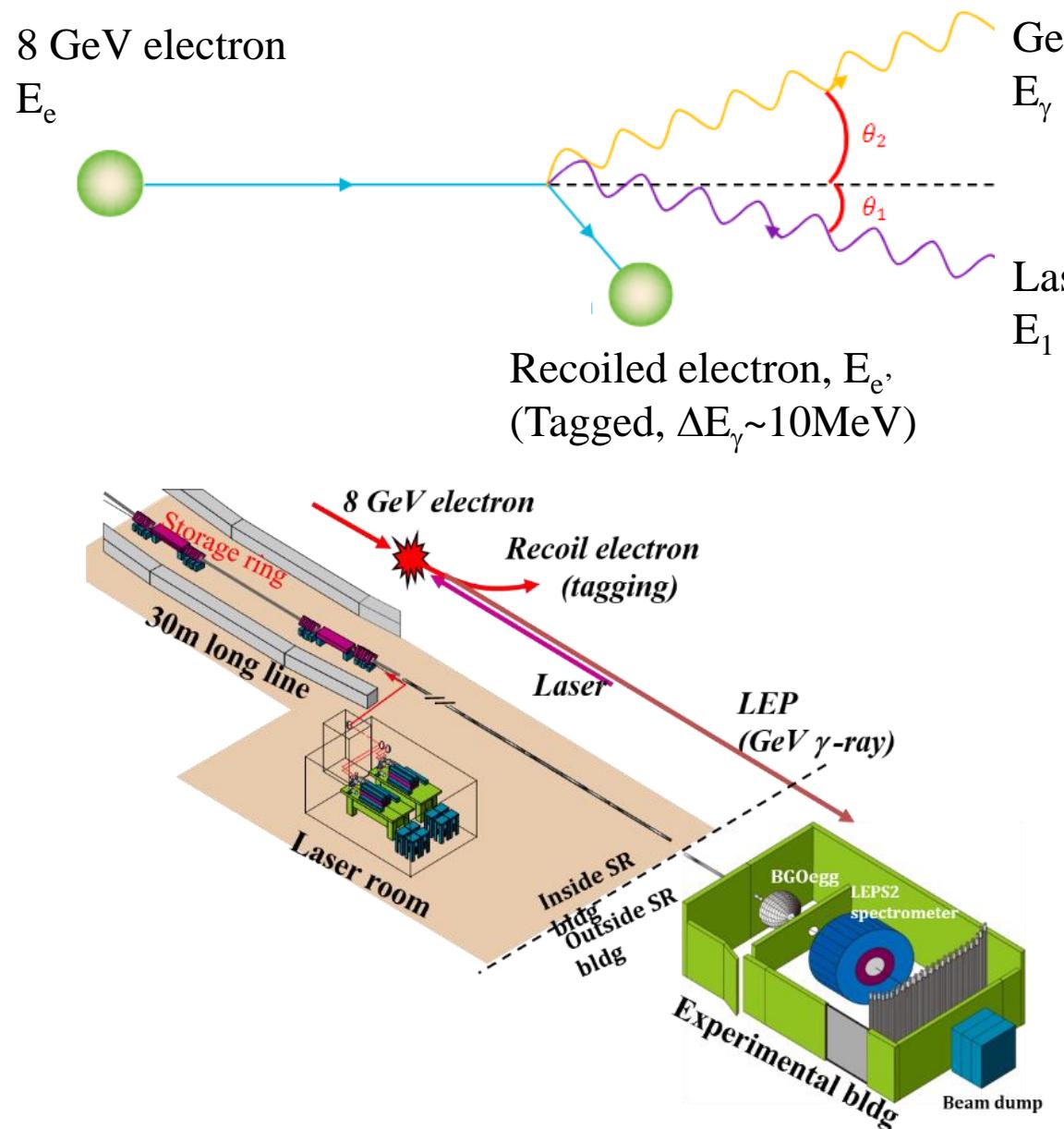
SPring-8

(Super Photon ring - 8GeV)
@ Hyogo, Japan

LEPS

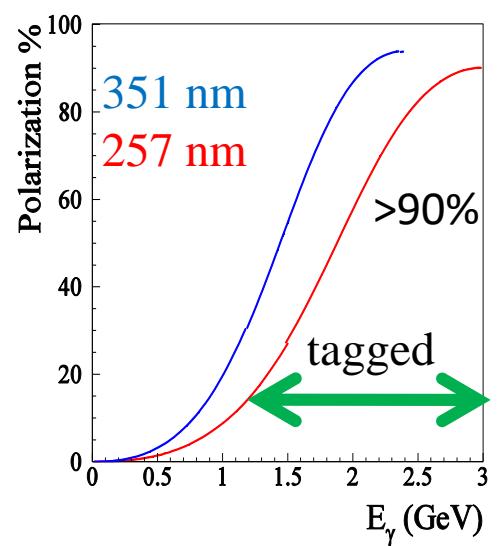
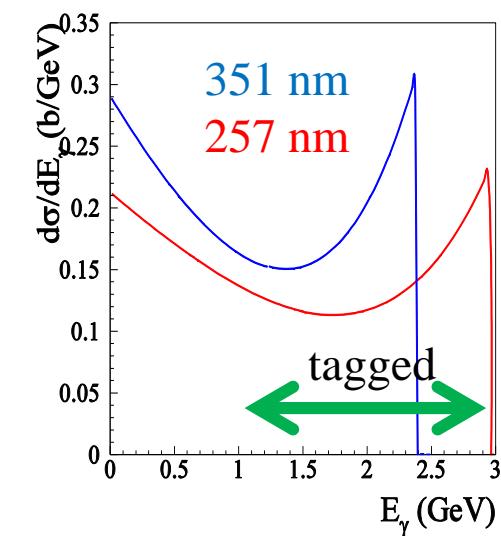
(Laser-Electron-Photon facility at SPring-8)
-Hadron photo-production
by Backward Compton scattering method
 $-E_\gamma = 1.3 - 2.9 \text{ GeV}$ ($W = 1.82 - 2.52 \text{ GeV}$)

Backward Compton scattering



$$E_\gamma = E_1 - \frac{(1 - \beta \cos \theta_1)}{(1 - \beta \cos \theta_2) + \frac{E_1}{E_e}(1 - \cos(\theta_2 - \theta_1))}$$

E_γ (max)= 2.4 GeV ($\lambda=352\text{ nm}$)
 E_γ (max)= 2.9 GeV ($\lambda=257\text{ nm}$)



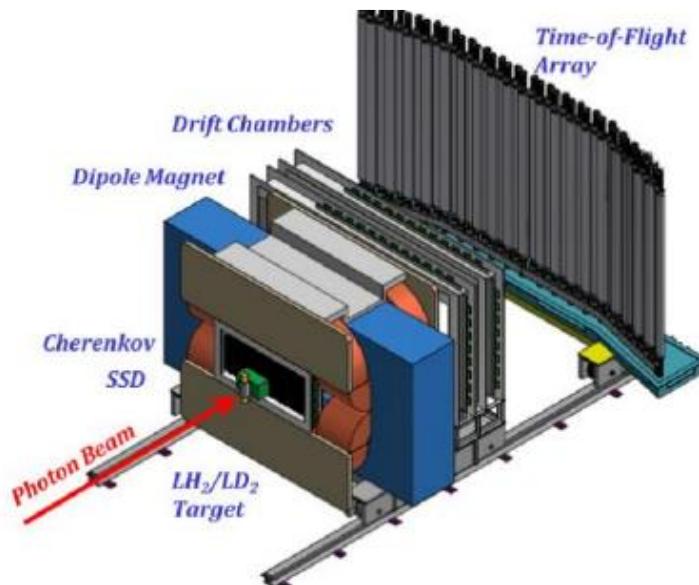
1. Maximum at highest photon energy.

2. highly linearly polarized beam

Experiments at SPring-8

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LEPS facility (1999 — 2021)



LEPS experiment

Spectrometer for the charged particle at forward angle(<15deg)

Extension of the tagged region:
 $E_\gamma = 1.5 - 2.9 \text{ GeV}$

$E_\gamma = 1.3 - 2.9 \text{ GeV}$

Intensity:

UV $2 \times 10^6 \text{ cps}$

DUV $2 \times 10^5 \text{ cps}$

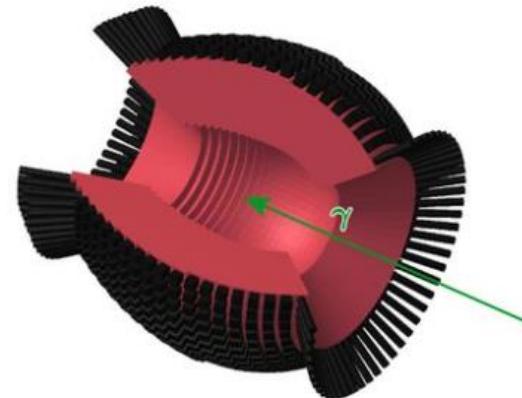
UV $< 10^7 \text{ cps}$

DUV $\sim 10^6 \text{ cps}$

(multi-Laser injection,
pulse laser system)

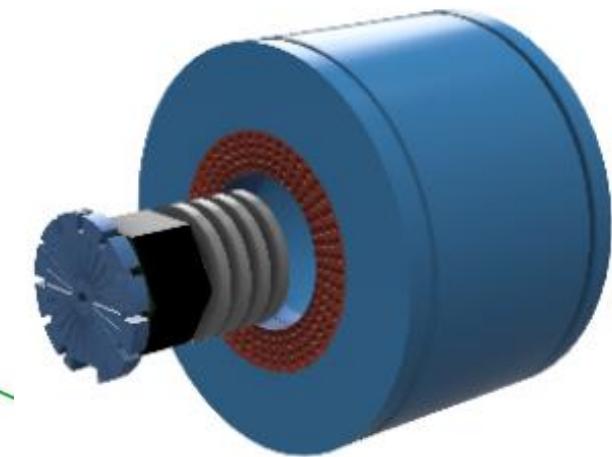
LEPS2 facility (2013 -)

Dr. T. Nam's talk
from 16:30



BGOegg experiment

EM Calorimeter composed
of 1320 BGO crystals.

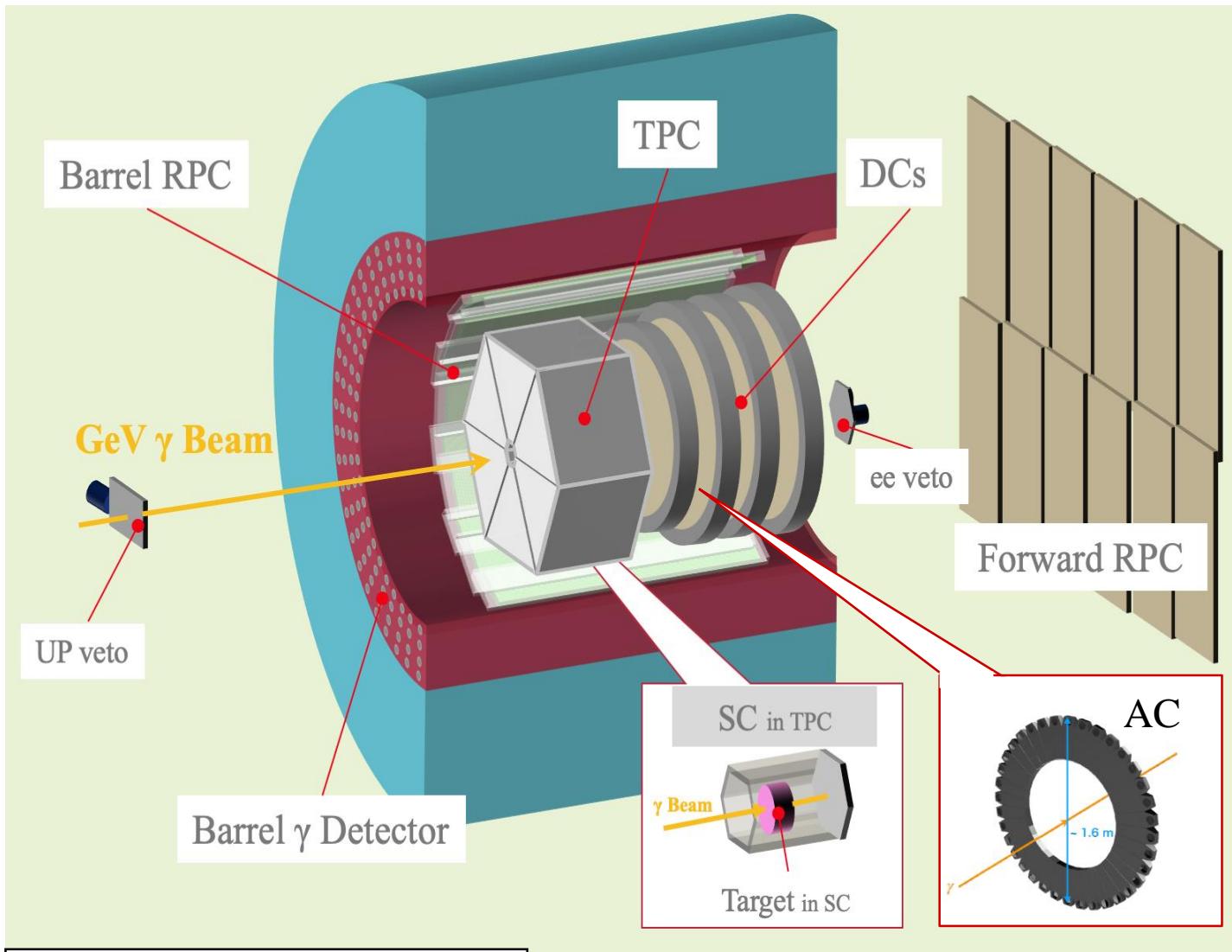


*LEPS2-solenoid
experiment*

Large spectrometer system
for charged/neutral particles.

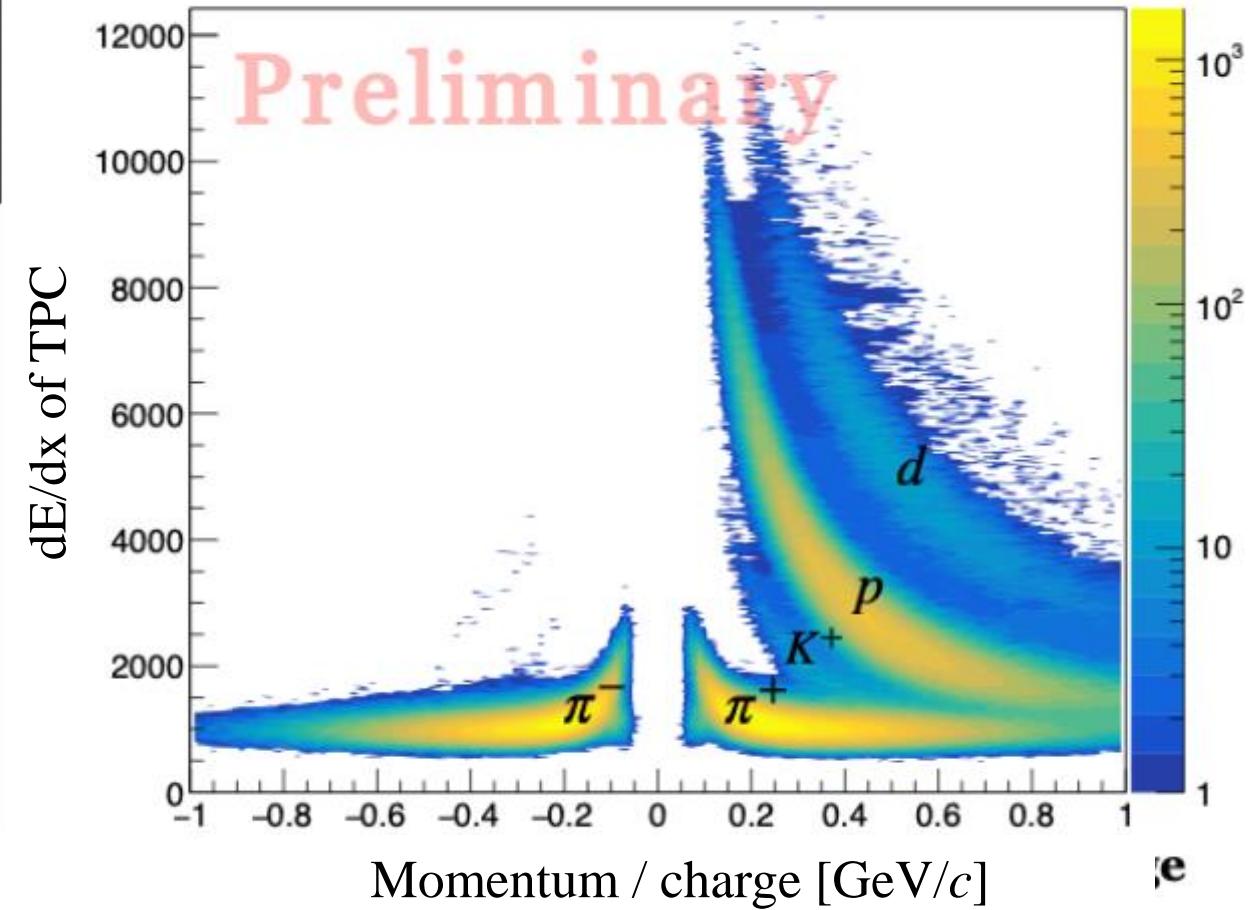
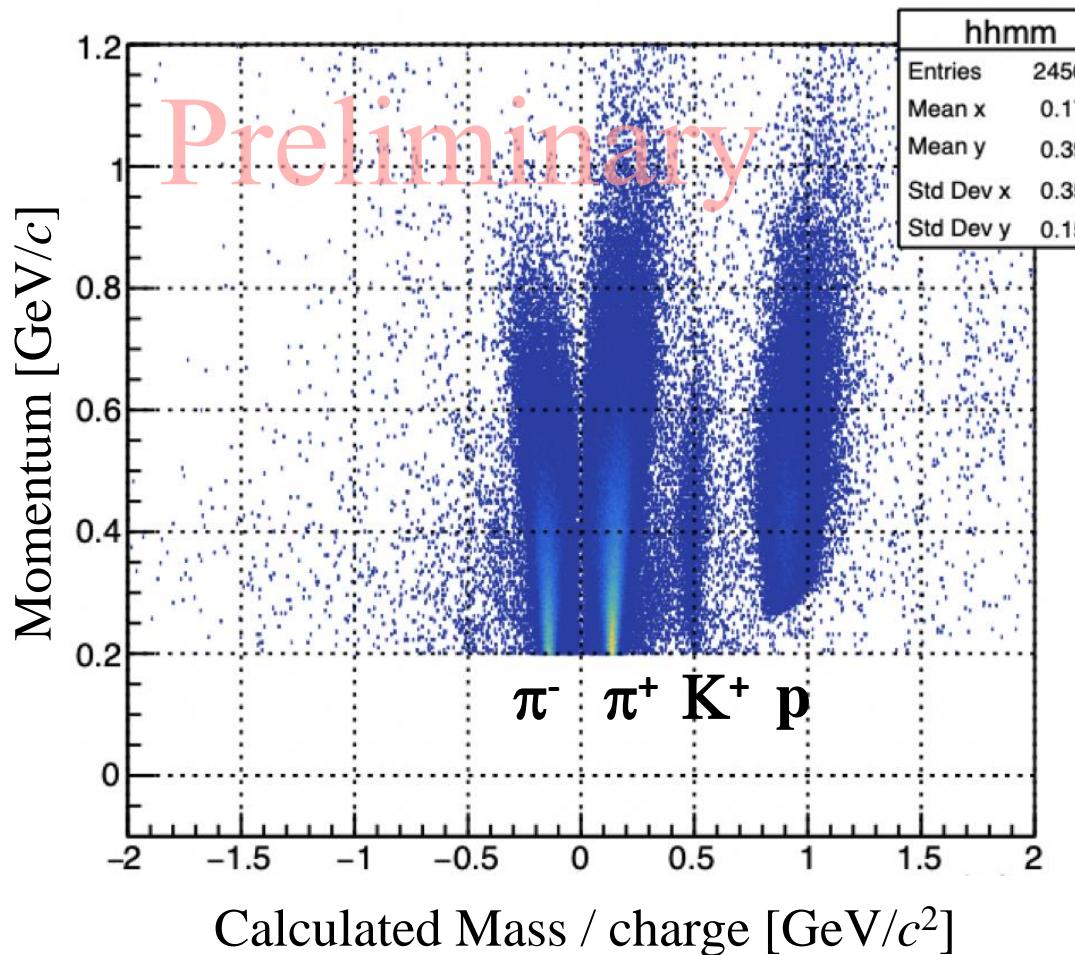
LEPS2 spectrometer

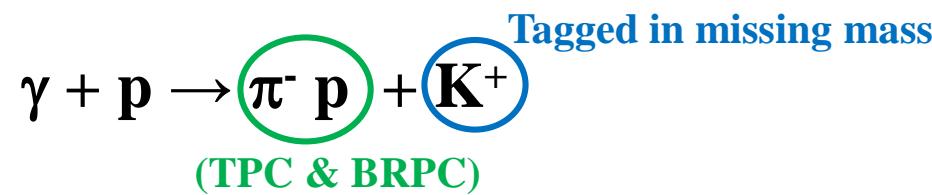
6/15



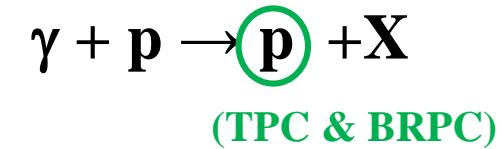
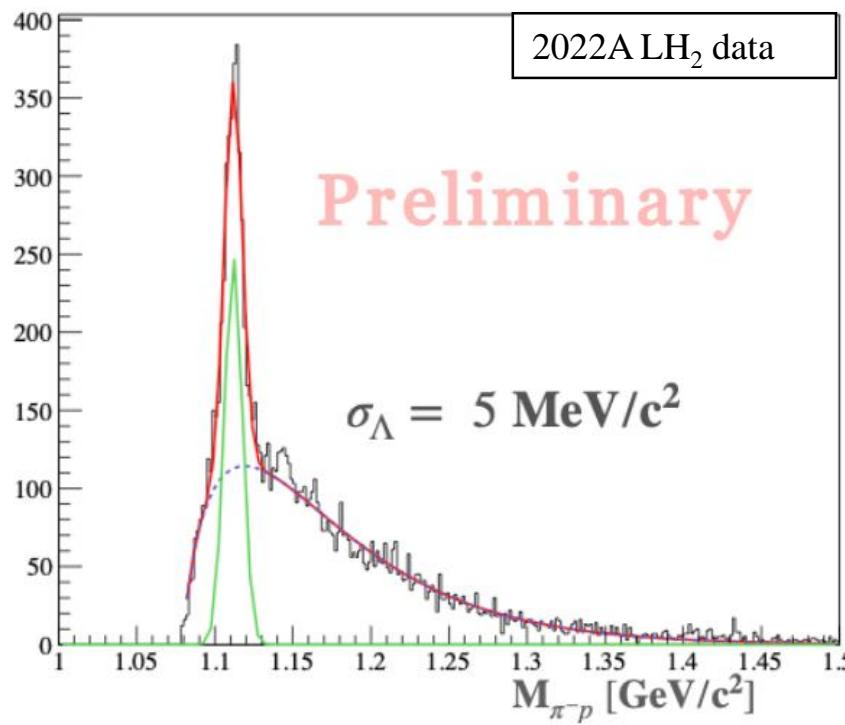
~80 collaborators in total
20 facilities from 5 countries.

- * Charged particles tracking:
Acceptance : 7 – 110 deg
Side: Time Projection Chamber (TPC)
Forward : Drift Chamber (DC x 4)
- * γ -rays
Acceptance : 40 – 110 deg
Barrel-g 1st – 3rd layer (Full : 4 layers)
- * Particle Identification (p/K/ π)
Side: Barrel Resistive Plate Chamber (RPC)
Middle : Aerogel Cherenkov Counter
Forward: Forward RPC
- * We started taking physics data from 2021.
2021 Oct. —
 $\text{LH}_2 : \sim 1.5 \times 10^{12}$ photon on target.
 $\text{LD}_2 : \sim 4.0 \times 10^{12}$ photon on target.

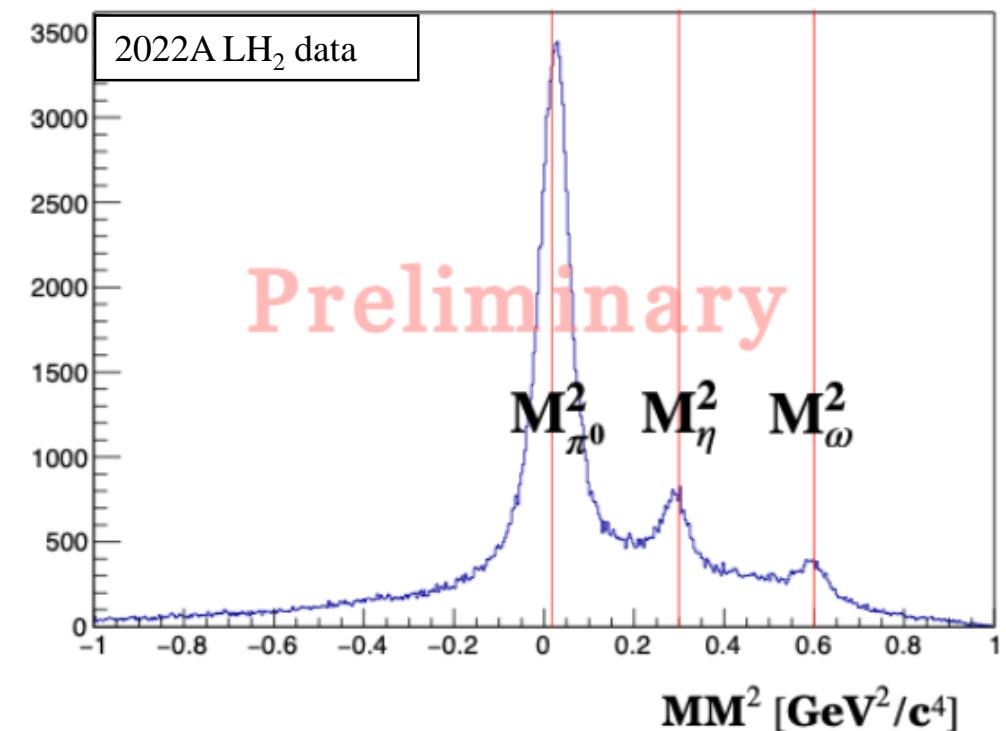




Invariant mass spectrum
 $M(\pi^- p)$



Missing mass spectrum
 $MM^2_H(\gamma, p)$



LH₂ target

* Study of property of $\Lambda(1405)$

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

* Search for Meson-Baryon bound state ($\rho\Delta$)

Ref) Phys.Rev.C 79 (2009) 025209

$$\gamma + p \rightarrow \Delta(1930) \rightarrow p \pi^+ \pi^- \pi^0$$

LD₂ target

* Search for penta-quark

$$\gamma + n \rightarrow K^- + \Theta^+, \Theta^+ \rightarrow K_s + p$$

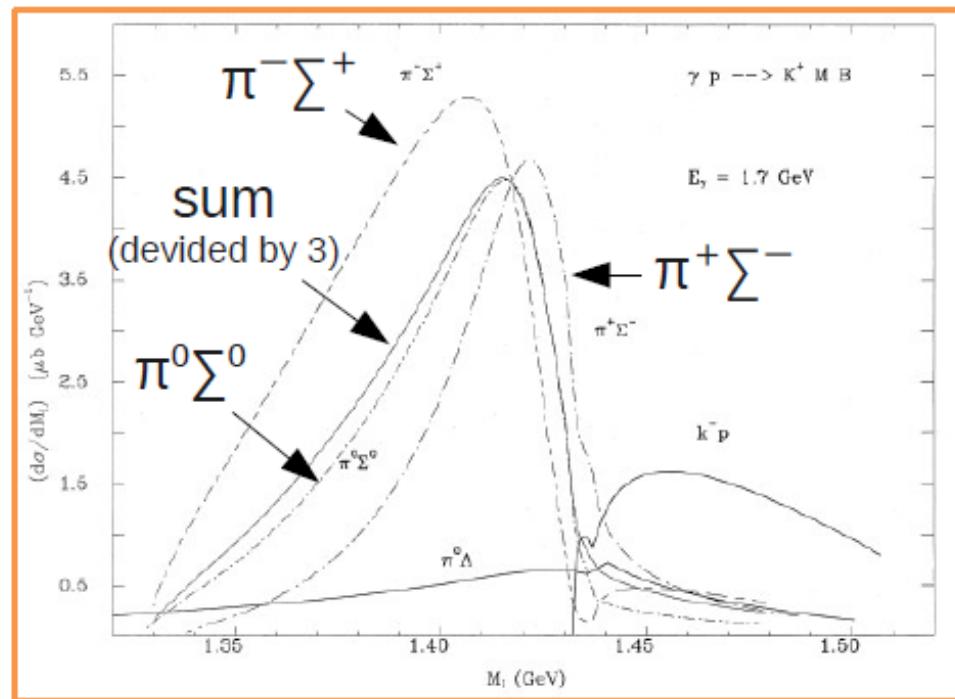
* Search for the Mesonic nuclei

$$\gamma + d \rightarrow K^- pp + K^0$$

$$\gamma + d \rightarrow \eta' n + p/n$$

$\Sigma(1385) : \text{qqq}$

$\Lambda(1405) : \text{qqq? meson-baryon molecular state? qqqq}\bar{q}?$



J.C.Nacher et.al., Phys. Lett. B455,55(1999)

Chiral Unitary model

1390-66i [$\pi\Sigma$], 1426-16i [$\bar{K}N$]

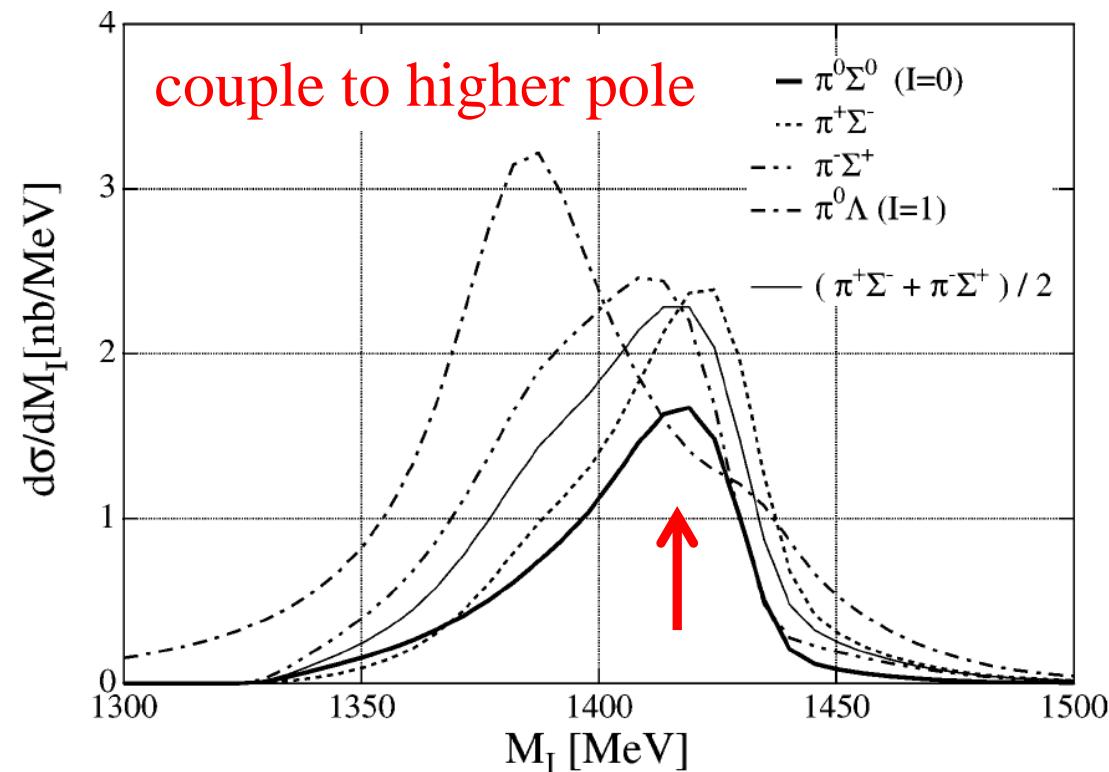
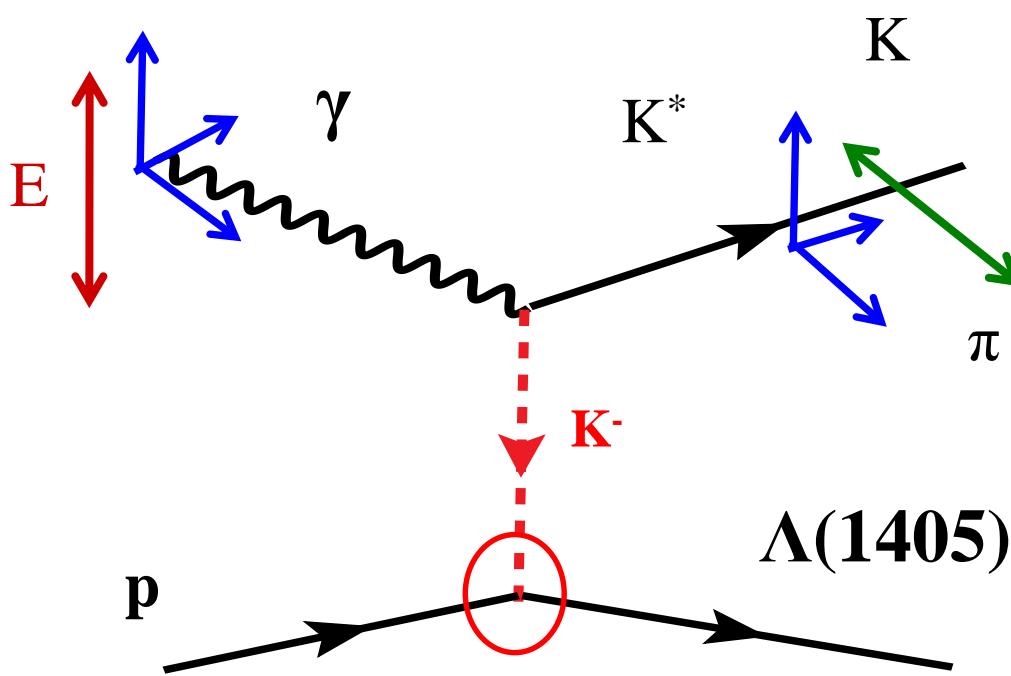
- Low energy $\bar{K}N$ interaction.
- Kaonic nuclei search.

$$\begin{aligned}\sigma_{\Sigma^+\pi^-} &= \frac{1}{2}|T^{(1)}|^2 + \frac{1}{3}|T^{(0)}|^2 + \frac{2}{\sqrt{6}}\text{Re}(T^{(0)}T^1) \\ \sigma_{\Sigma^-\pi^+} &= \frac{1}{2}|T^{(1)}|^2 + \frac{1}{3}|T^{(0)}|^2 - \frac{2}{\sqrt{6}}\text{Re}(T^{(0)}T^1)\end{aligned}$$

★ parity filter with linearly polarized photon

Pol. plane of $\gamma \perp$ decay plane ($K^* \rightarrow K\pi$)
 → unnatural parity ex (K)

Pol. plane of $\gamma \parallel$ decay plane ($K^* \rightarrow K\pi$)
 → natural parity ex(K^* , κ)

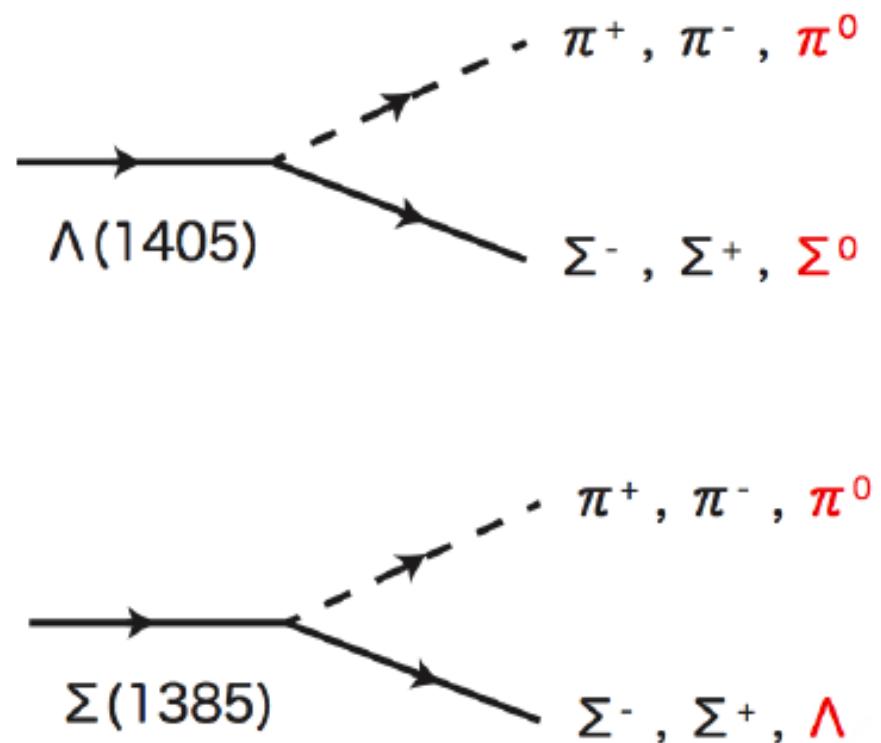


Phys. Lett. B593, 75 (2004)

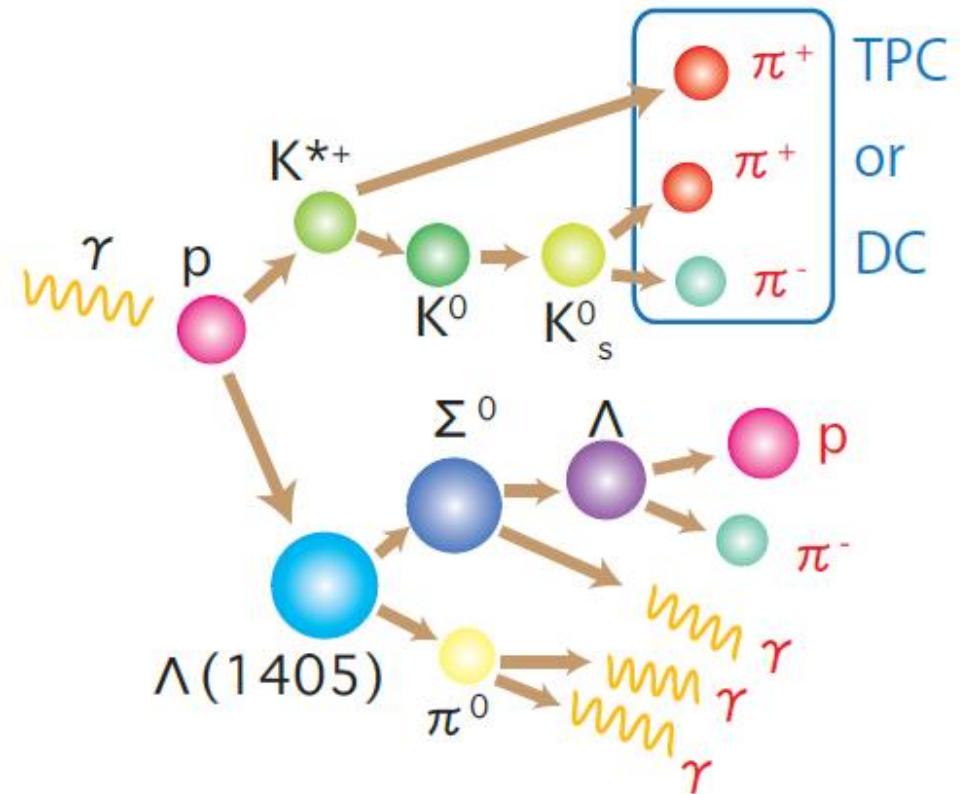
Information of
transition form
factor



Information of size
of $\Lambda(1405)$???

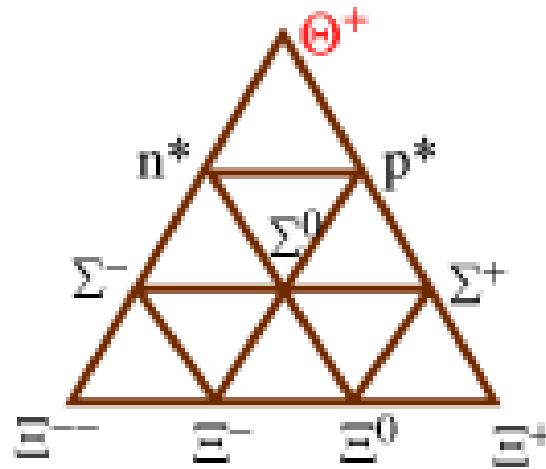


$\Sigma^0 \pi^0$ mode can be used to identify $\Lambda(1405)$



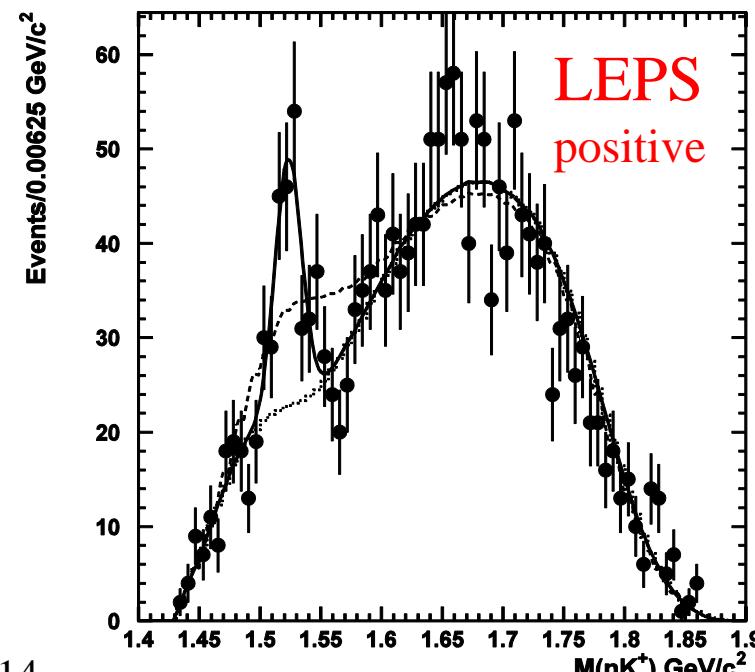
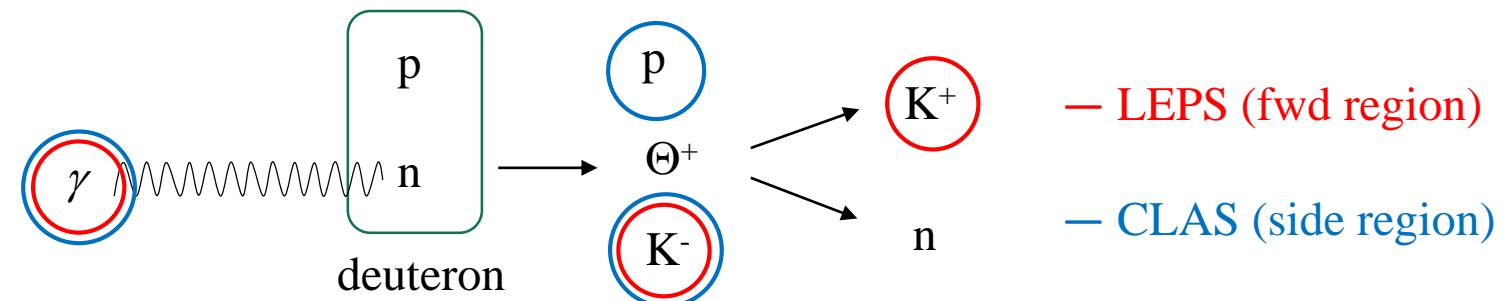
★ 4 π detector system for charged/neutral particles.
→ LEPS2 spectrometer

Penta-quark Θ^+

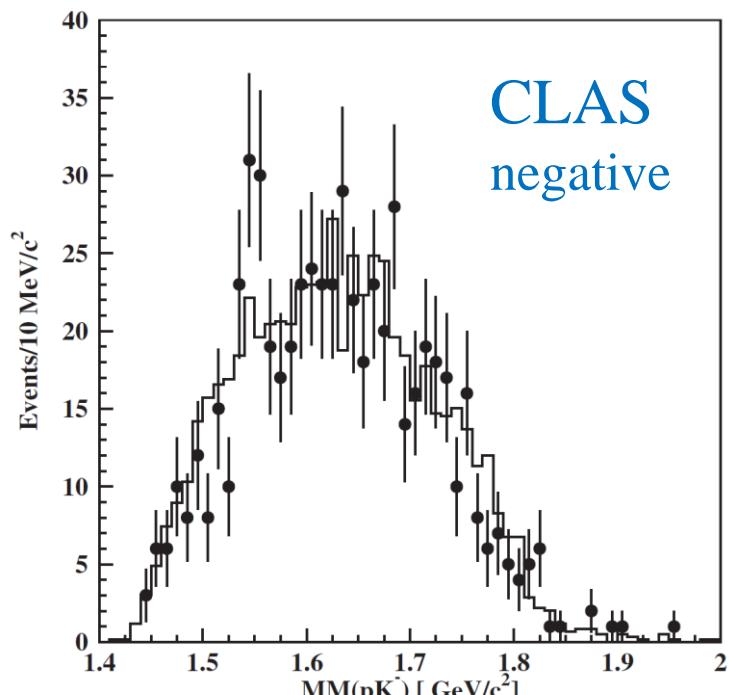


The existence was predicted in the chiral quark soliton model.

Ref) Diakonov et al. Z.Phys.A 359 (1997) 305-314



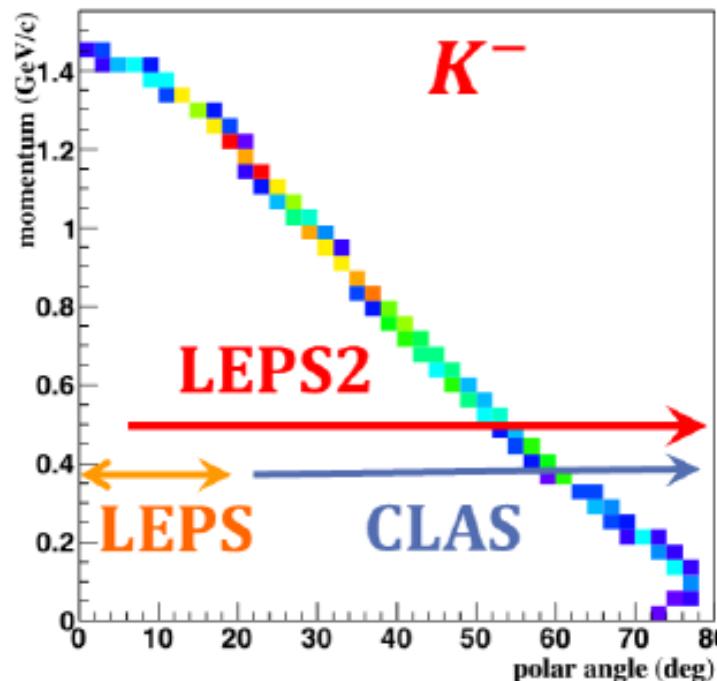
PRC 79, 025210 (2009)



PRL 96, 212001(2006)

☆ The observation of the penta-quark state in charm sector
 was reported by LHCb group. Ref) Phys. Rev. Lett. 122 (2019) 222001
 $P_c(4312)^+$, $P_c(4440)^+$, $P_c(4457)^+$ in invariant mass spectrum of $J/\Psi + p$

In the strangeness sector, the situation is still controversial.
 → Clarification at LEPS2.

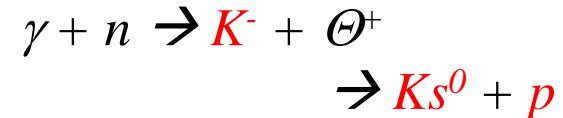


LEPS:



- * Fermi correction technique (MMSA)
- * Search in the $M(nK^+) \sim MM(\gamma, K^-)$
- * Large background from $\phi \rightarrow K^+K^-$

LEPS2:



- * Search in the $M(K_s^0 p)$
- * 4 π detector system
- * σ (Mass) ~ 6 MeV

- In the LEPS2 at SPring-8, a highly polarized photon beam ($E_\gamma = 1.3 - 2.9 \text{ GeV}$) is available via backward Compton scattering.
- LEPS2-solenoid detector system is sensitive for both charged and neutral particles with a large acceptance.
- LEPS2-solenoid experiment started taking data from 2021.
- Physics motivation of LEPS2-solenoid experiment:
 - $\Lambda(1405)$
 - Pentaquark Θ^+
- LEPS2-solenoid gives us many opportunity studying excited hadrons.
Any ideas are welcome!