

# Search for Hidden-strangeness Pentaquark States near $\phi p$ Threshold

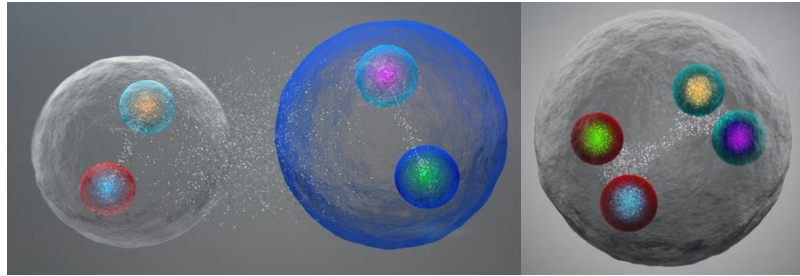
Sun Young Ryu  
( RCNP, Osaka University )

ハドロン分光に迫る反応と構造の物理

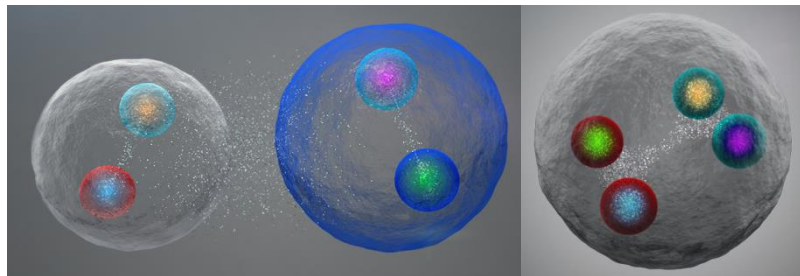
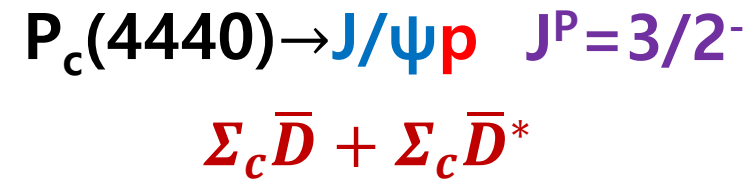
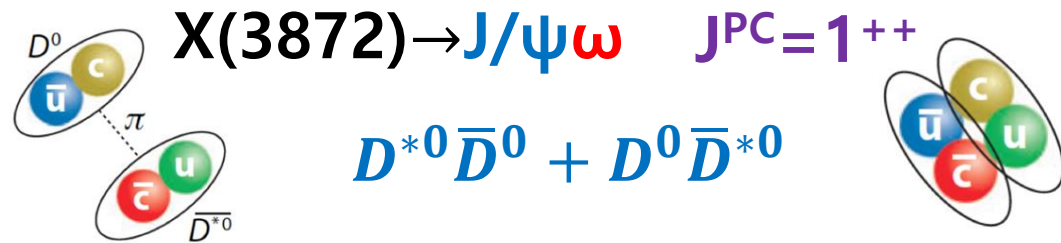
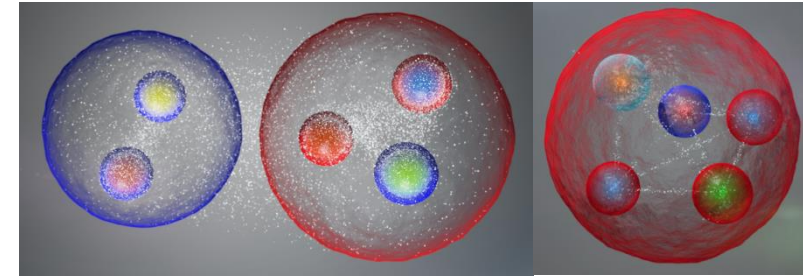
December 6~7, 2022

Research Center for Electron Photon Science

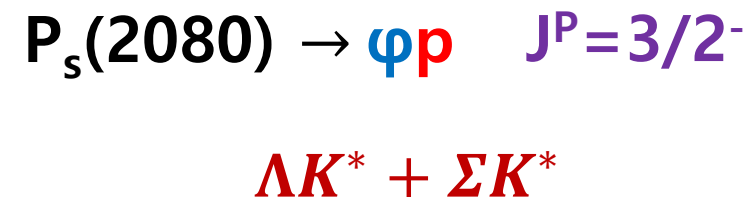
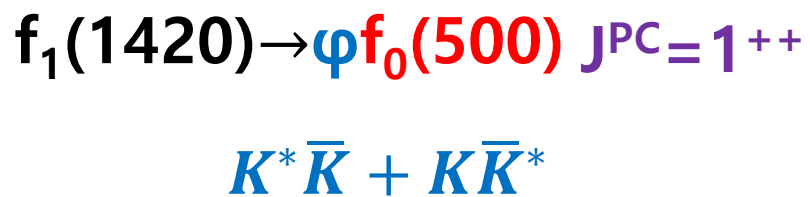
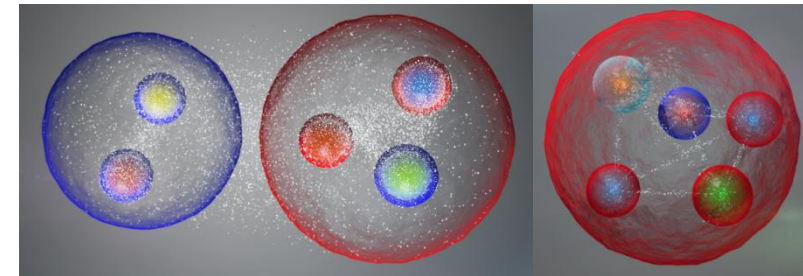
# Exotic Particles with Hidden Flavor



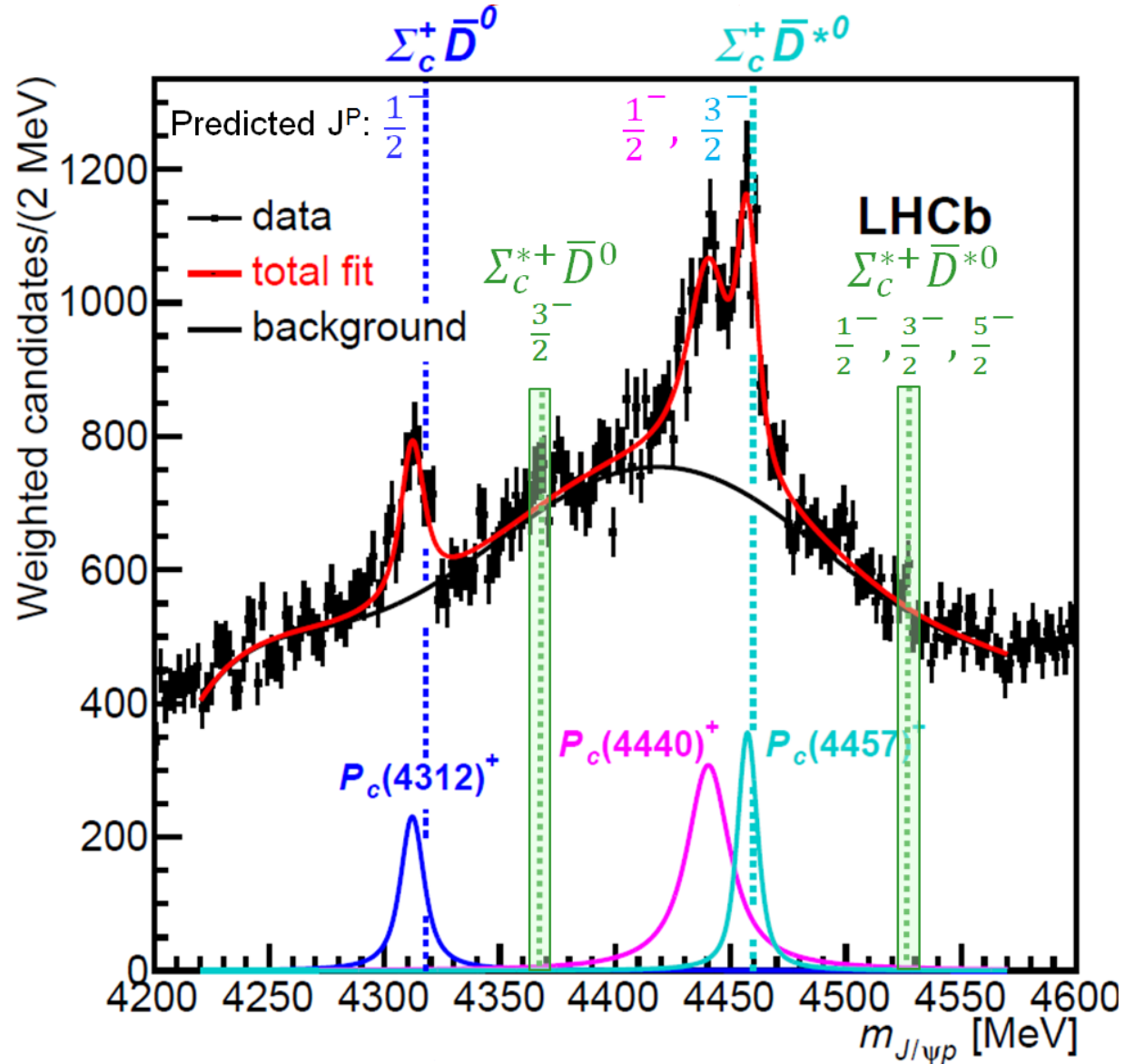
$\bar{c}c$



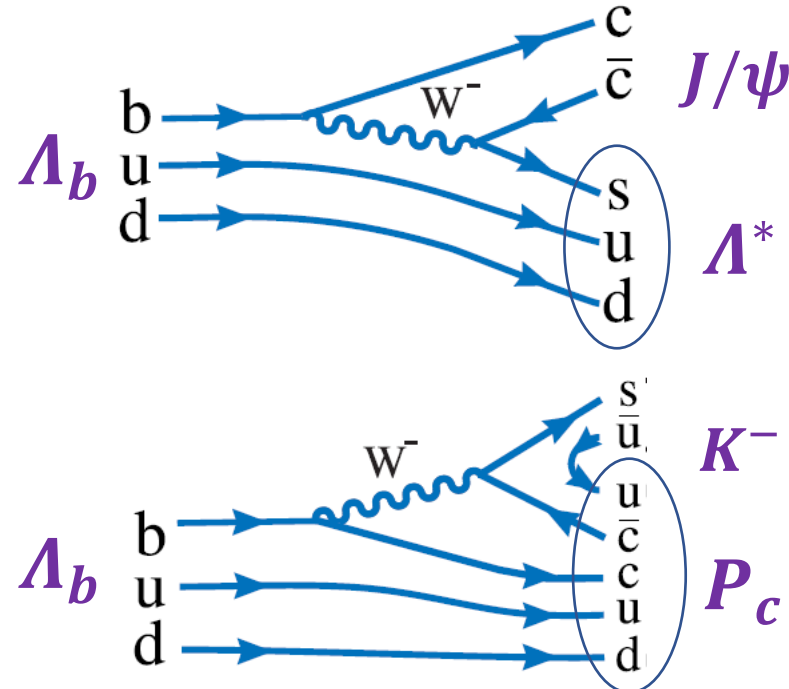
$\bar{s}s$



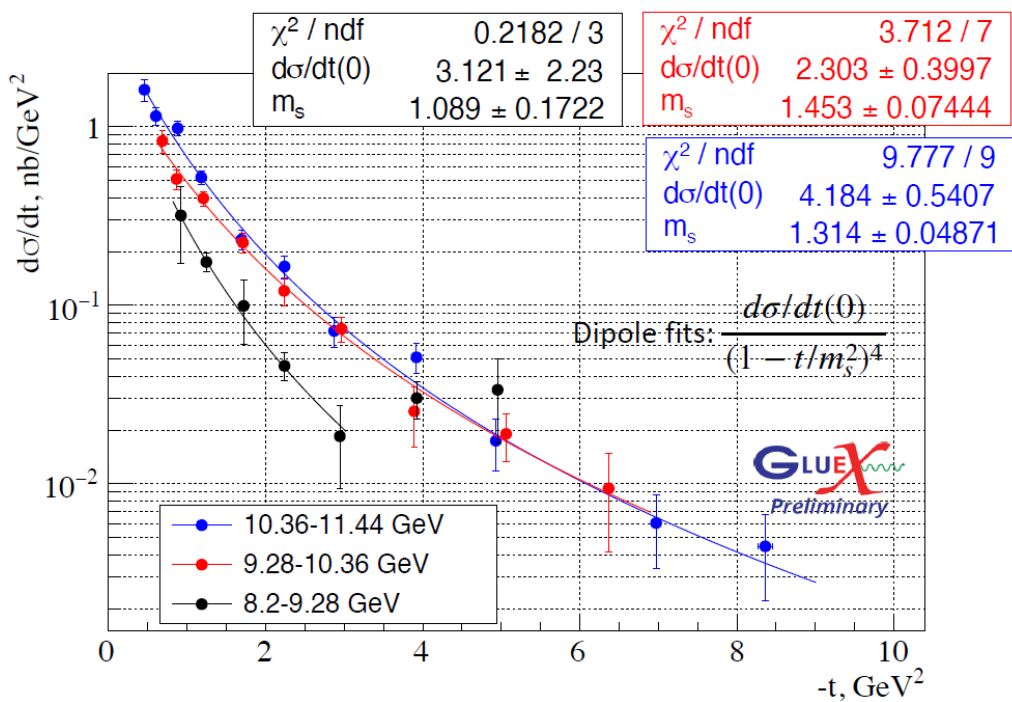
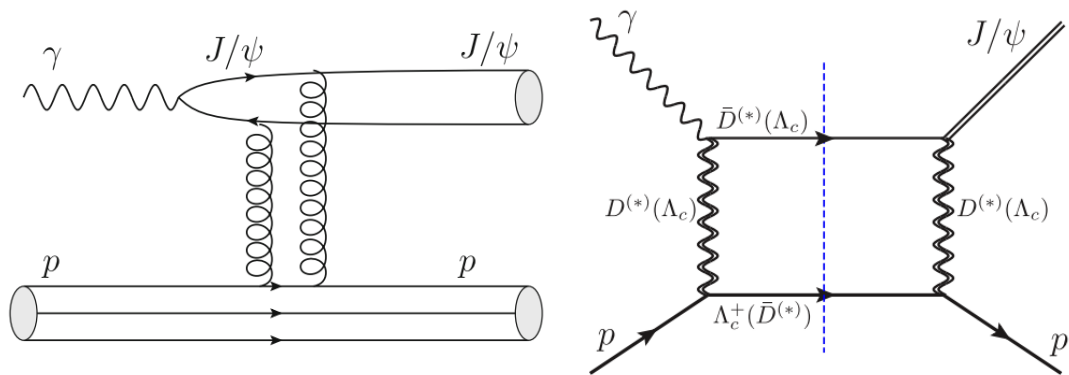
# Hidden Charm Pentaquarks



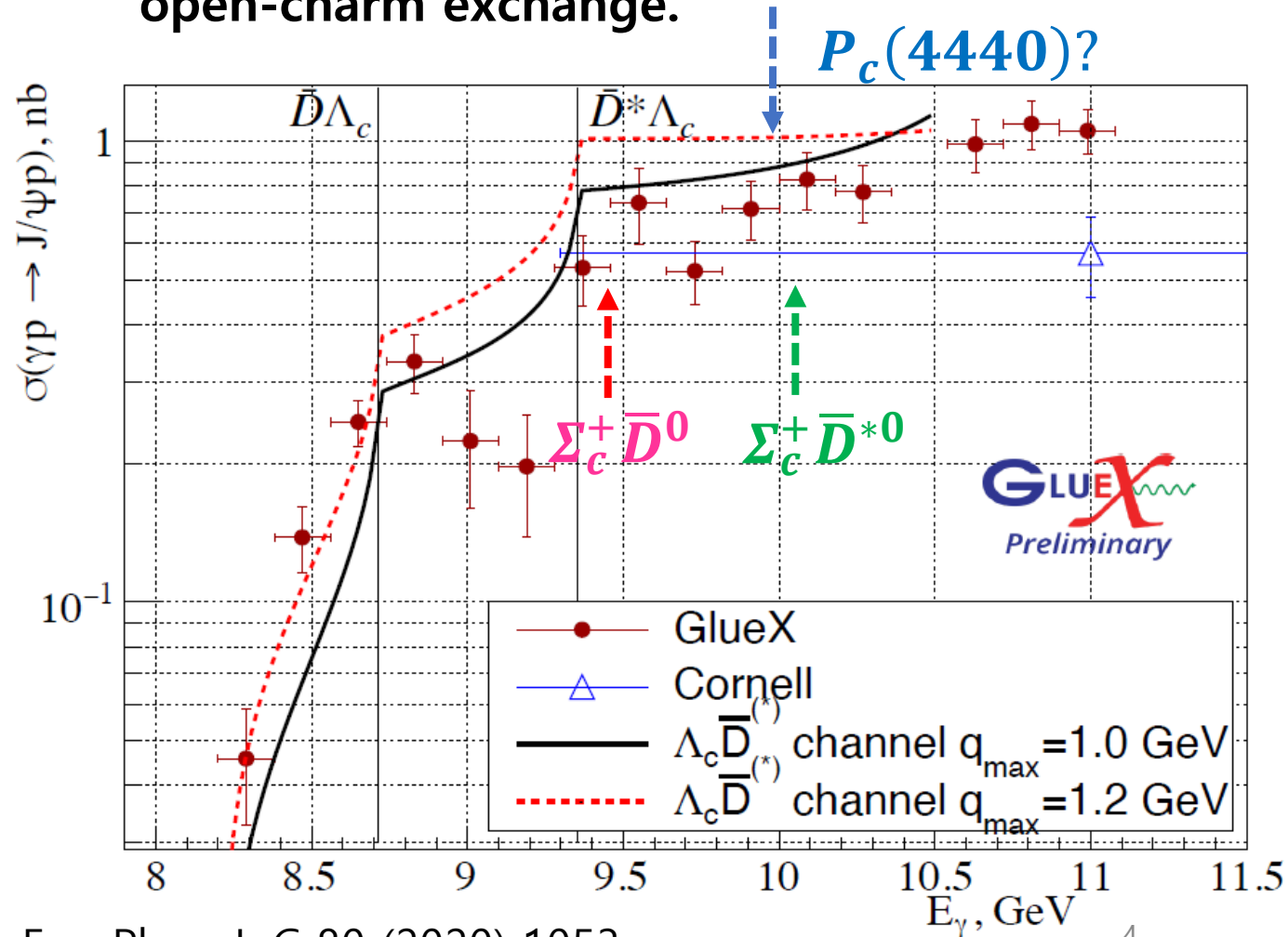
- LHCb claimed evidence for three hidden-charm pentaquark states near open-charm decay thresholds for  $\Sigma_c^+ \bar{D}^0$  and  $\Sigma_c^+ \bar{D}^{*0}$  in  $\Lambda_b \rightarrow J/\psi p K^-$  decays.



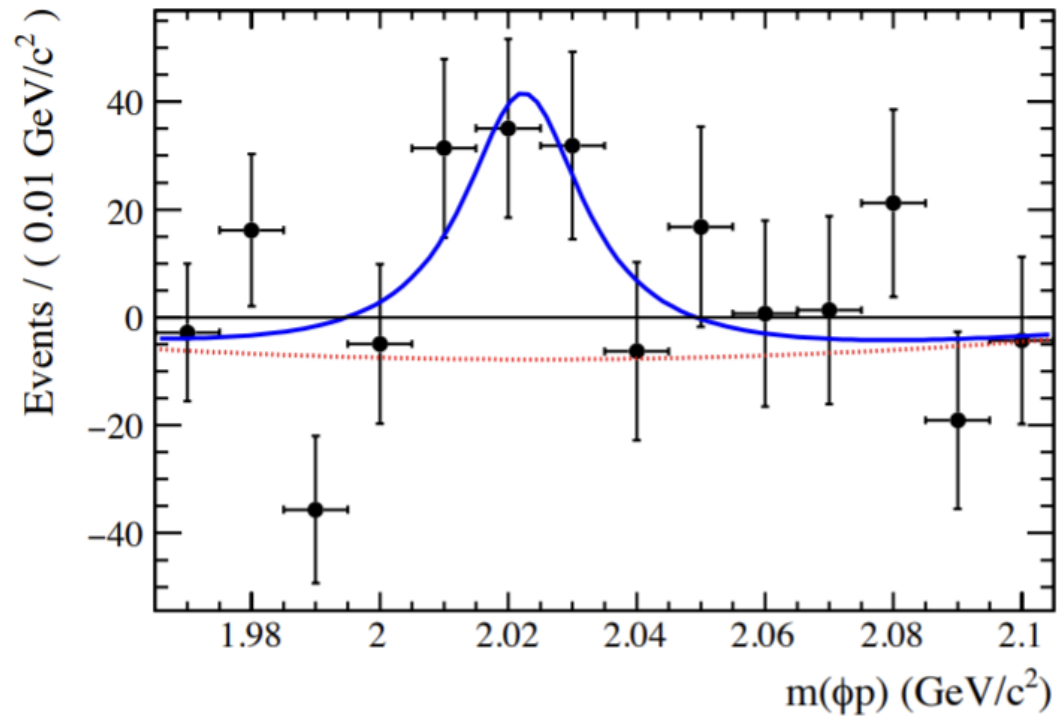
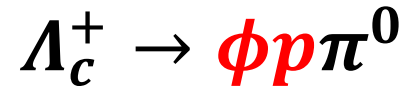
# J/ψ Photoproduction from GlueX



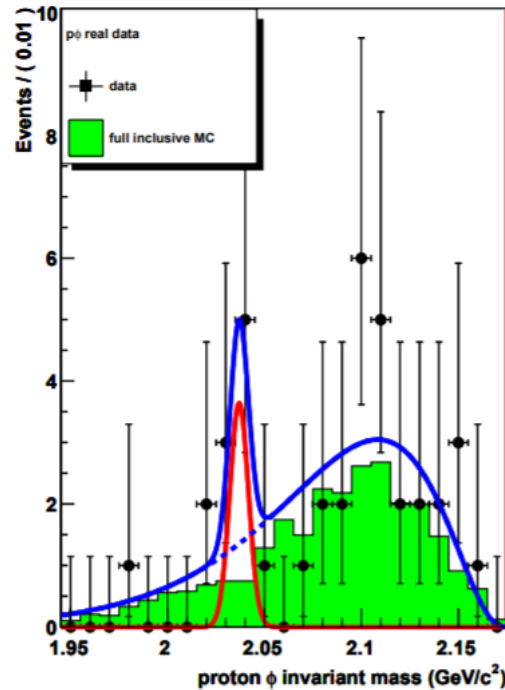
- Total cross sections are in agreement with open-charm exchange.



# Hidden-Strangeness Pentaquark(s) (Ps)



B. Pal *et al.* (Belle Collab), PRD 96, 051102 (2017).

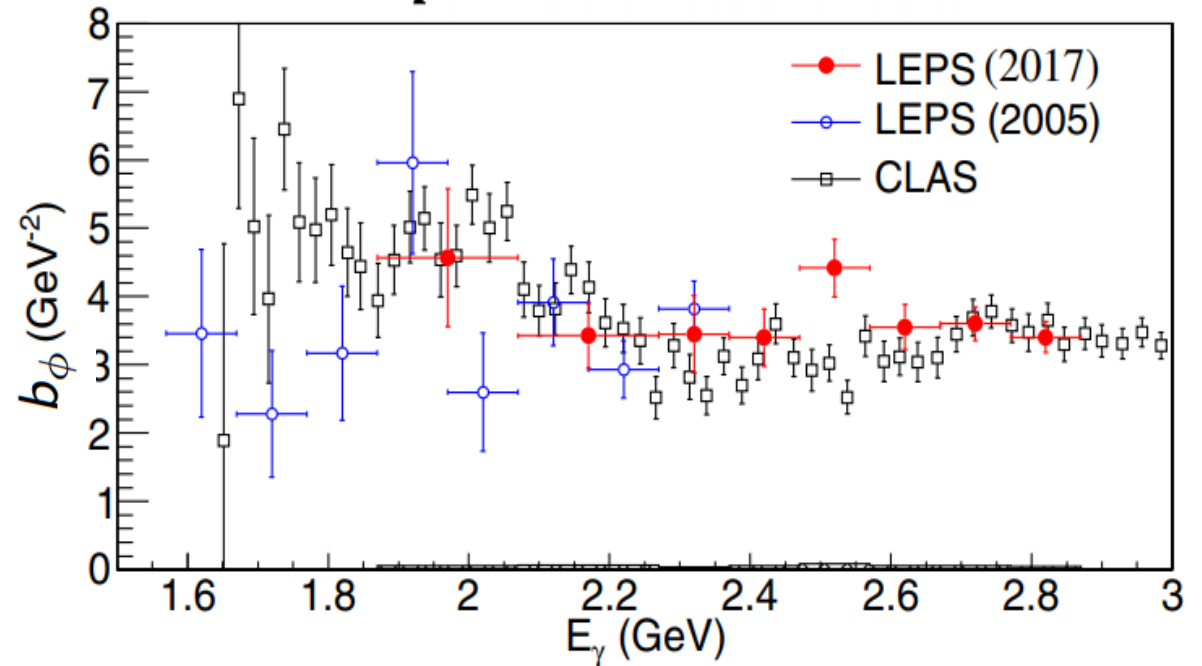
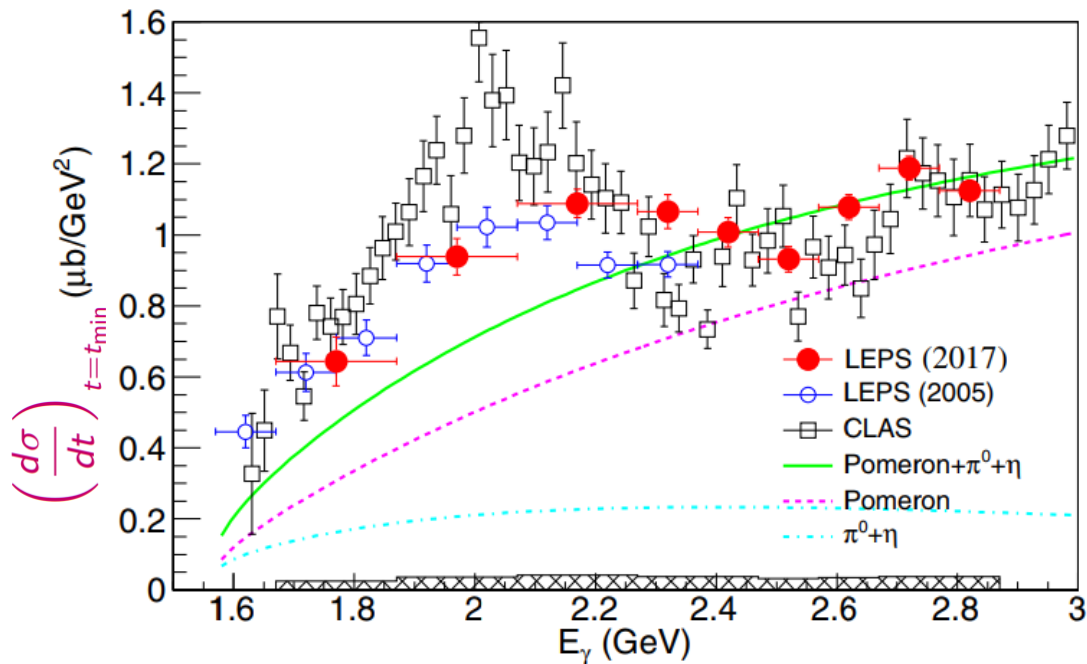
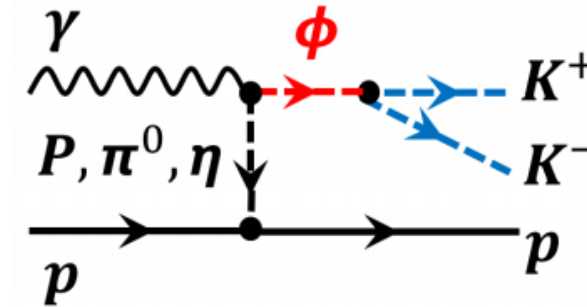


G. Mezzadri, Ph.D thesis, Ferrada U (2018).

- A strange partner Ps (uudss) was searched for in the Cabibbo-suppressed  $\Lambda_c^+ \rightarrow \phi p \pi^0$  decay at Belle and BESIII. ( $B(\Lambda_c^+ \rightarrow P_s \pi^0) \cdot B(P_s \rightarrow \phi p) < 8.3 \times 10^{-5}$  at 90% CL)
- Limited phase-space leads to a very small decay ratio.

# $\phi$ Photoproduction near Threshold

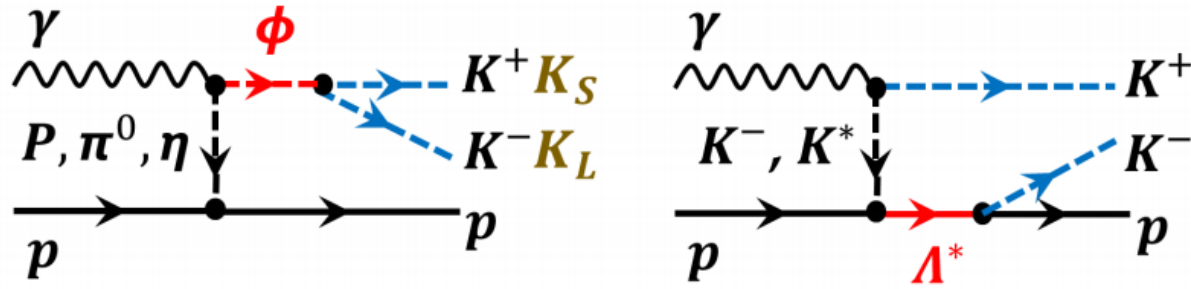
$$\frac{d\sigma}{dt}(\gamma p \rightarrow \phi p) = \left( \frac{d\sigma}{dt} \right)_{t=t_{\min}} \exp(-b_\phi |t - t_{\min}|)$$



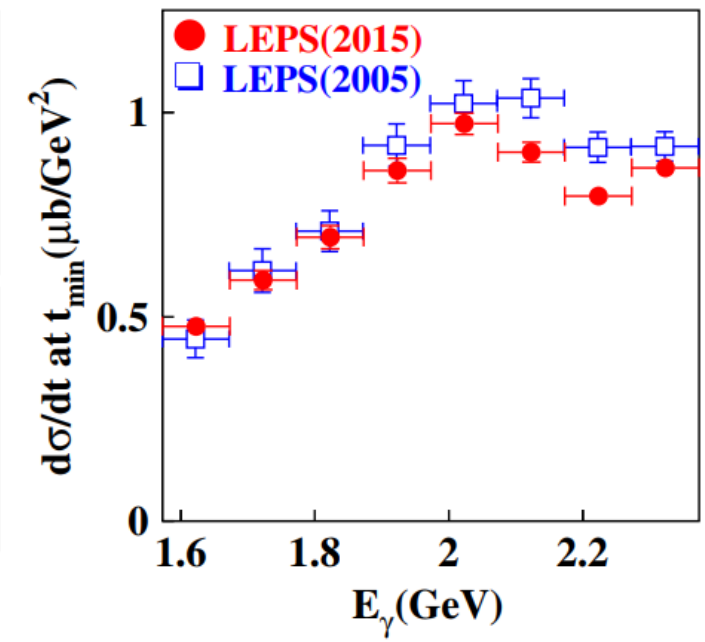
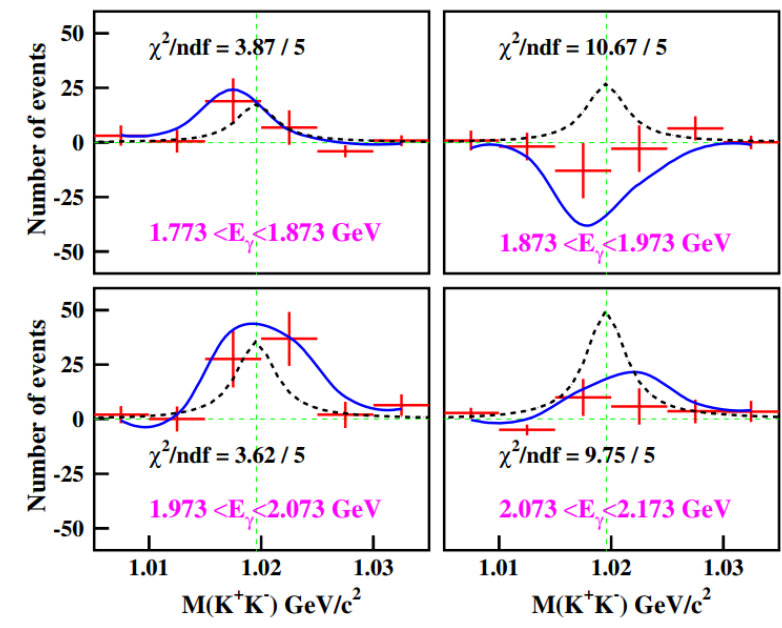
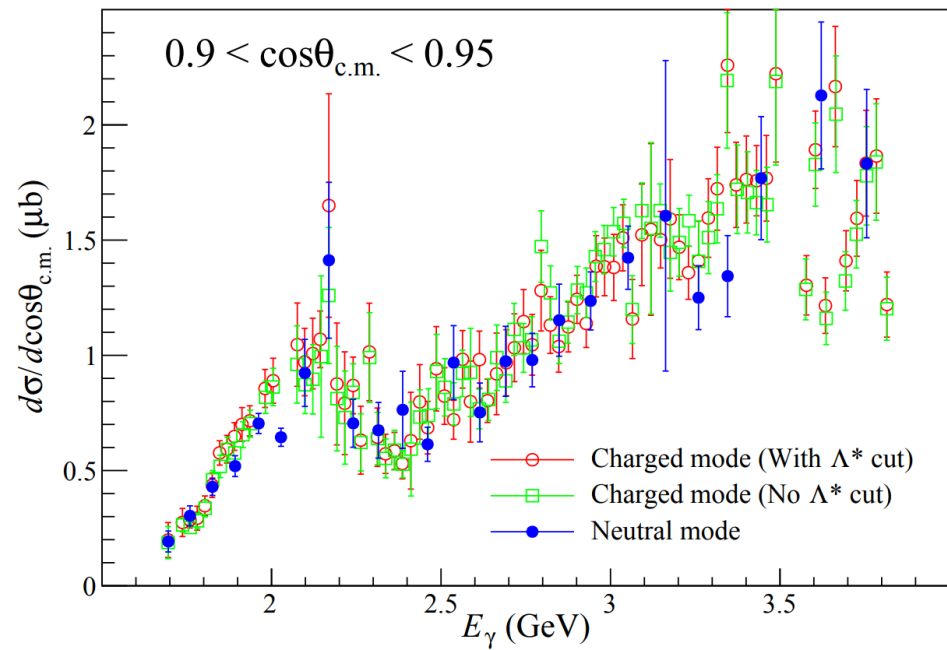
- Enhancement near 2.1 GeV in  $\gamma p \rightarrow \phi p$  draws considerable attention



# $\phi$ Photoproduction near Threshold

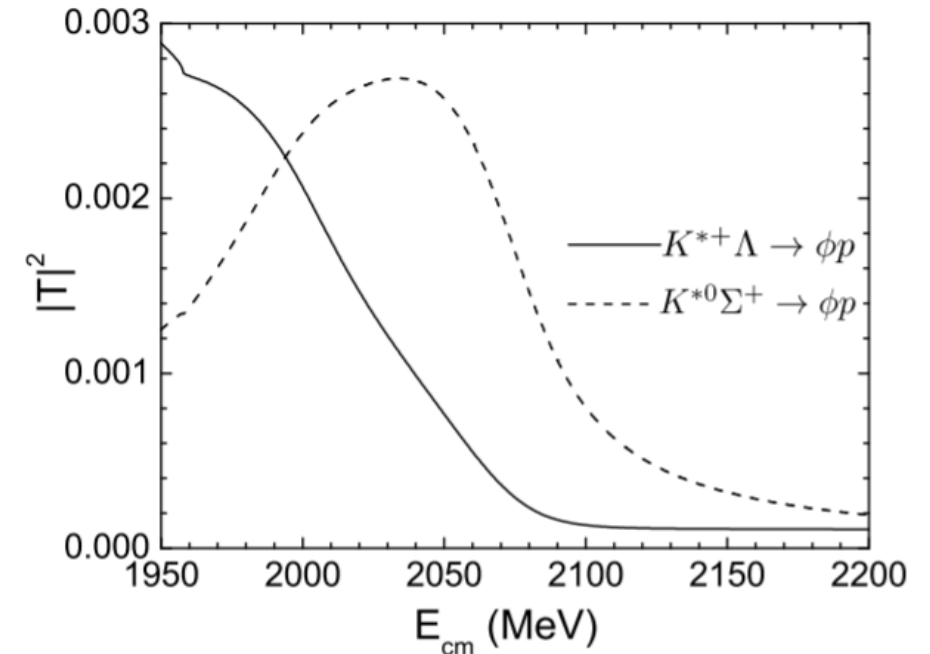
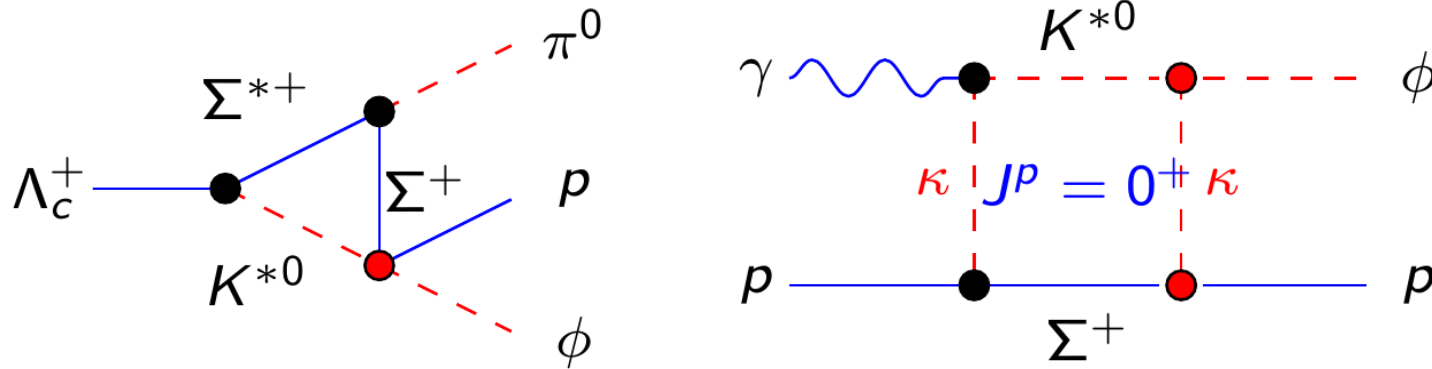


- $\Lambda(1520)$  channel does not contribute to the 2.1 GeV bump in  $\gamma p \rightarrow \phi p$ .
- The bump structure was reconfirmed without the Phi-L interference region.



H. Seraydaryan *et al.* (CLAS Collab), PRC 89, 055206(2014) 'S.Y. Ryu *et al.* (LEPS Collab), PRL 116, 232001(2016)

# Possible Candidates for Enhanced $\phi p$ Production



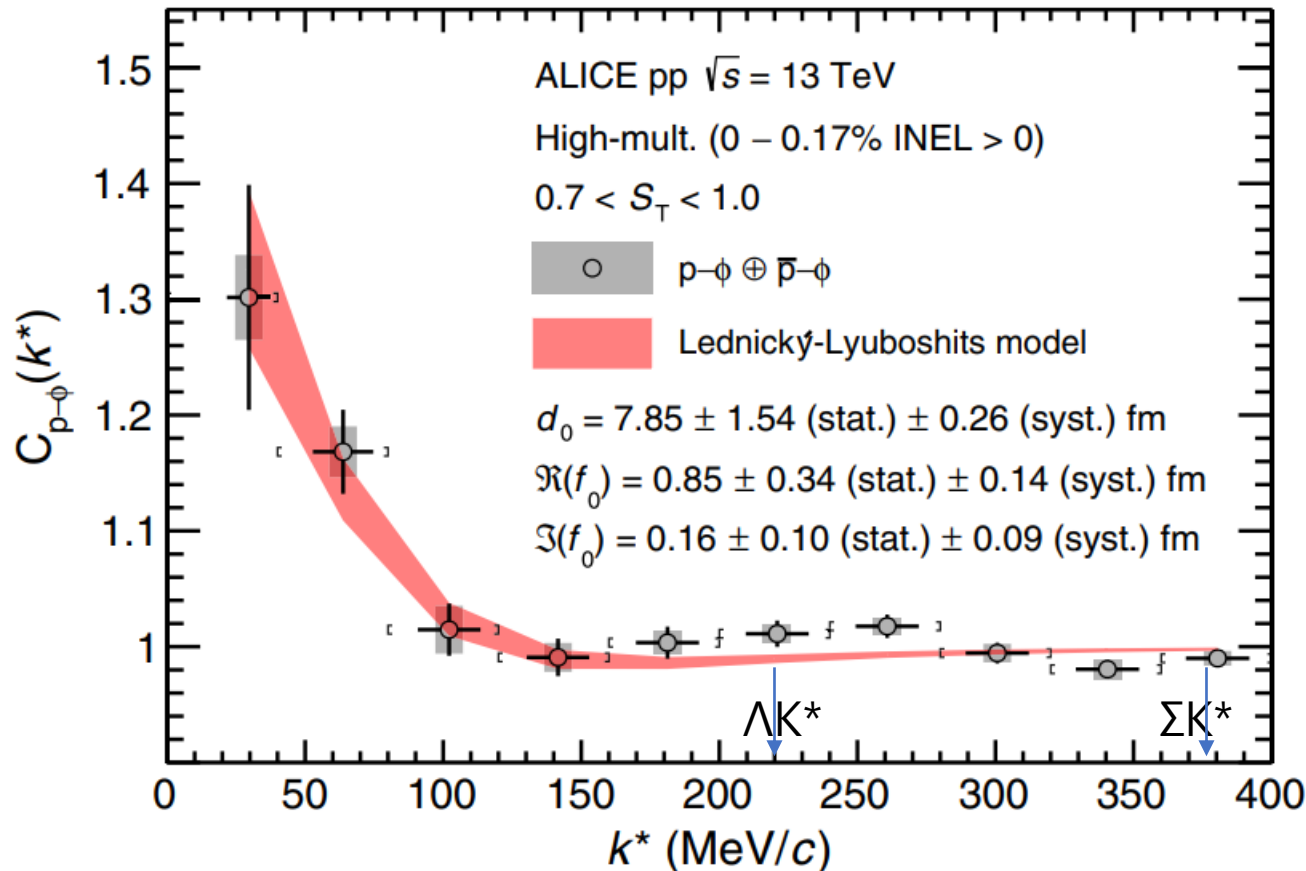
- The  $\phi p$  bump structure observed could be regarded as a  $\Sigma K^*$  molecular state ( $J = 3/2^-$ ). Triangular singularity could also explain the bump structure with  $\Sigma K^* \rightarrow \phi p$ .
- The measured parity spin asymmetry shows that natural-parity exchange is dominant in  $\gamma p \rightarrow K^{*0} \Sigma^+$  reaction.
- The nature of the bump structure should be further investigated using circularly polarized photon beam and a polarized (HD) target.

J.-J. Xie and F.-K. Guo, PLB 774, 108 (2017);

J. He, PRD 95, 074031(2017). S.H. Hwang *et al.* (LEPS Collab.), PRL 108, 092001(2012).

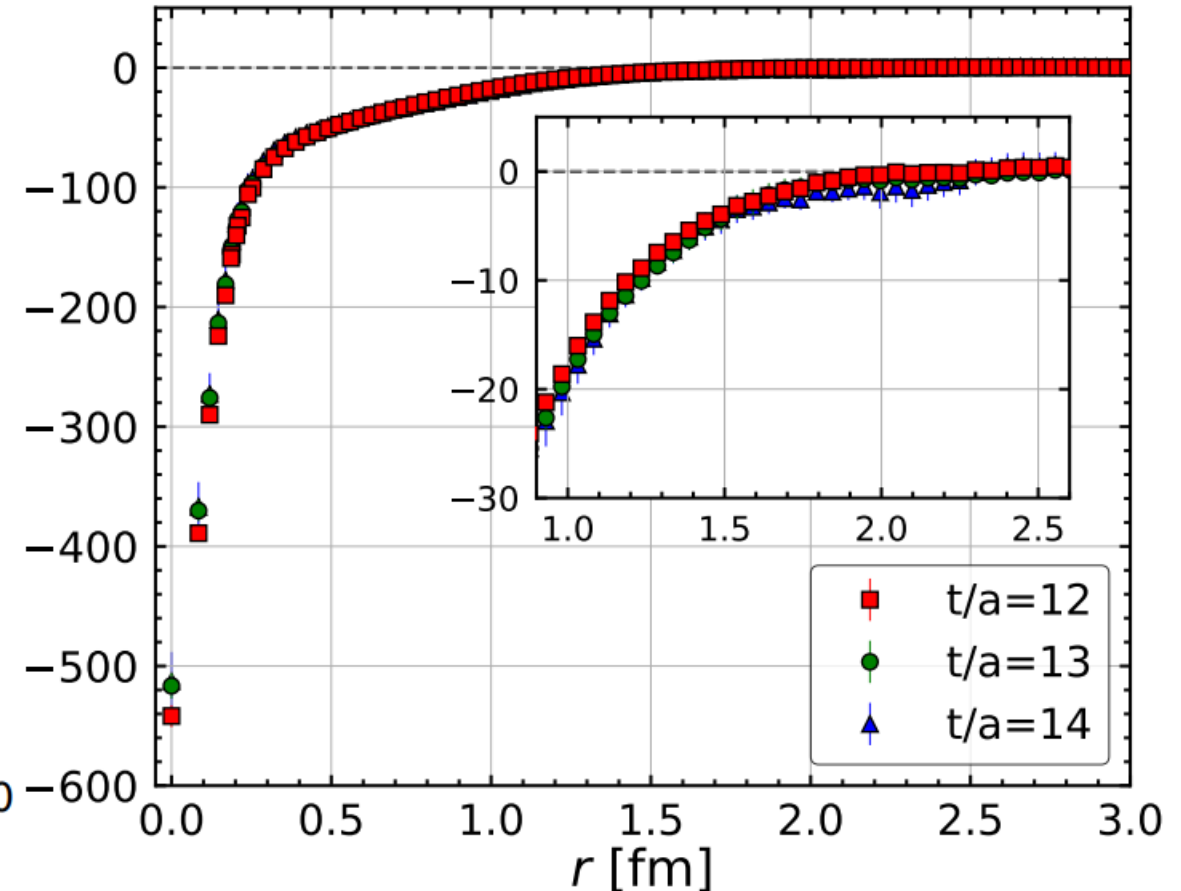


# Indication to Strong $\phi p$ Interaction



- $a_{\phi p} = 0.85 \pm 0.34 \pm 0.14 + i(0.16 \pm 0.10 \pm 0.09)$  fm
- Vanishing imaginary contribution indicates Elastic  $\phi p$  dynamics dominates.

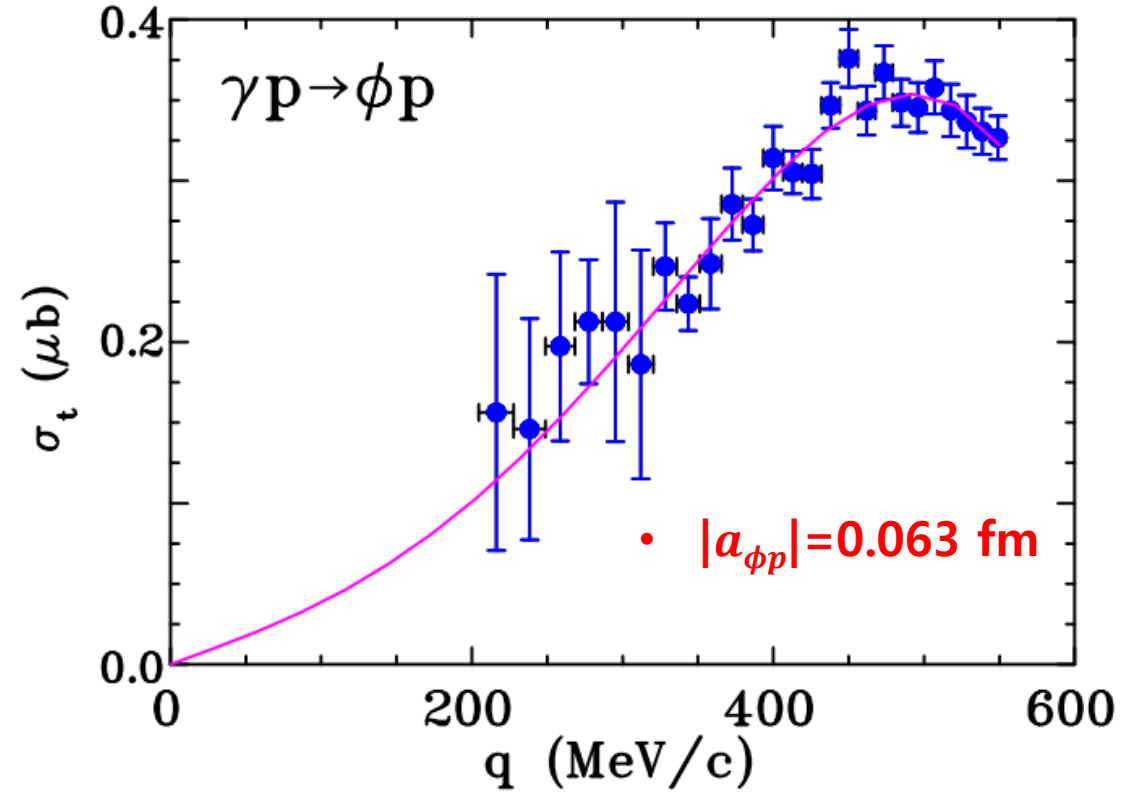
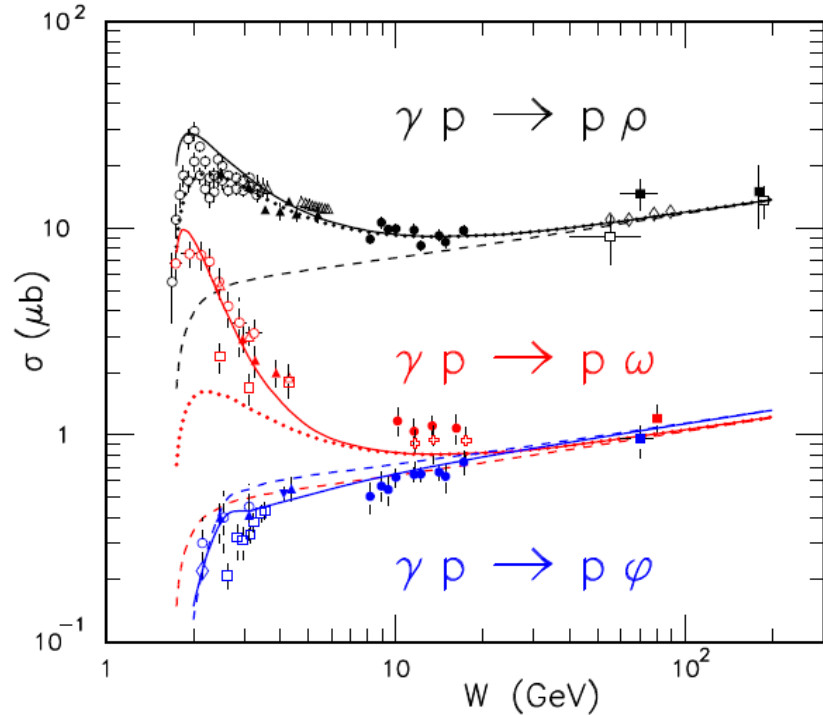
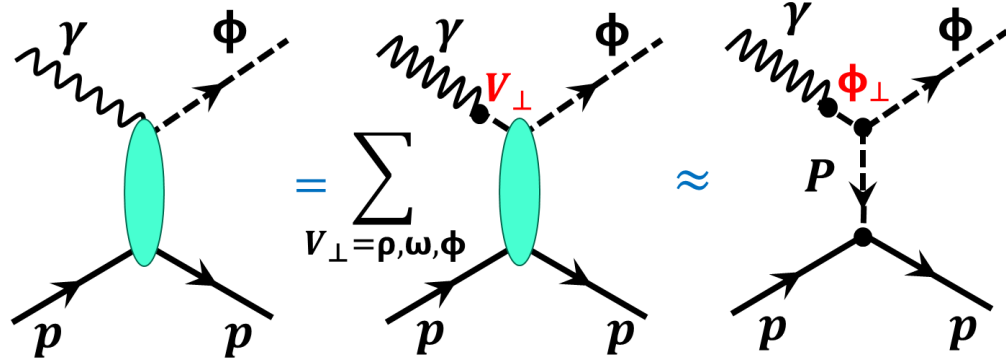
ALICE, Phys. Rev. Lett. 127, 172301 (2021)



- $a_0^{(3/2)} \sim 1.25$  fm,  $r_{eff} \sim 2.49$  fm ( $^4S_{3/2}$ )

Lyu et al, Phys. Rev. D 106, 074507 (2022)

# Indication to Weak $\phi p$ Interaction

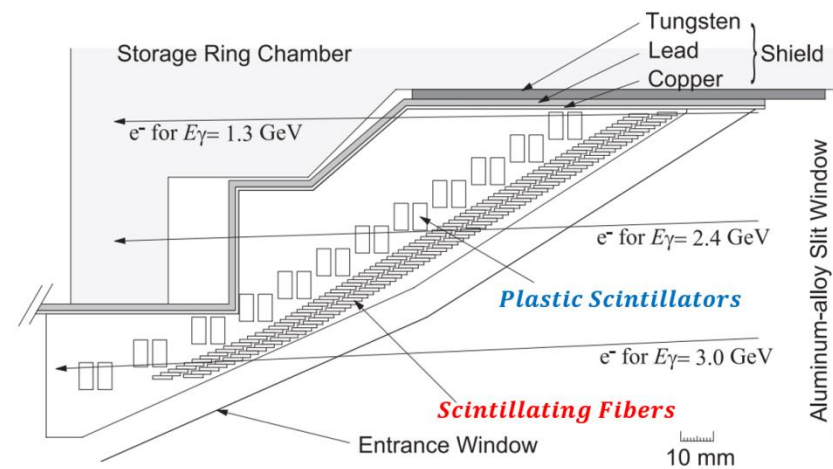
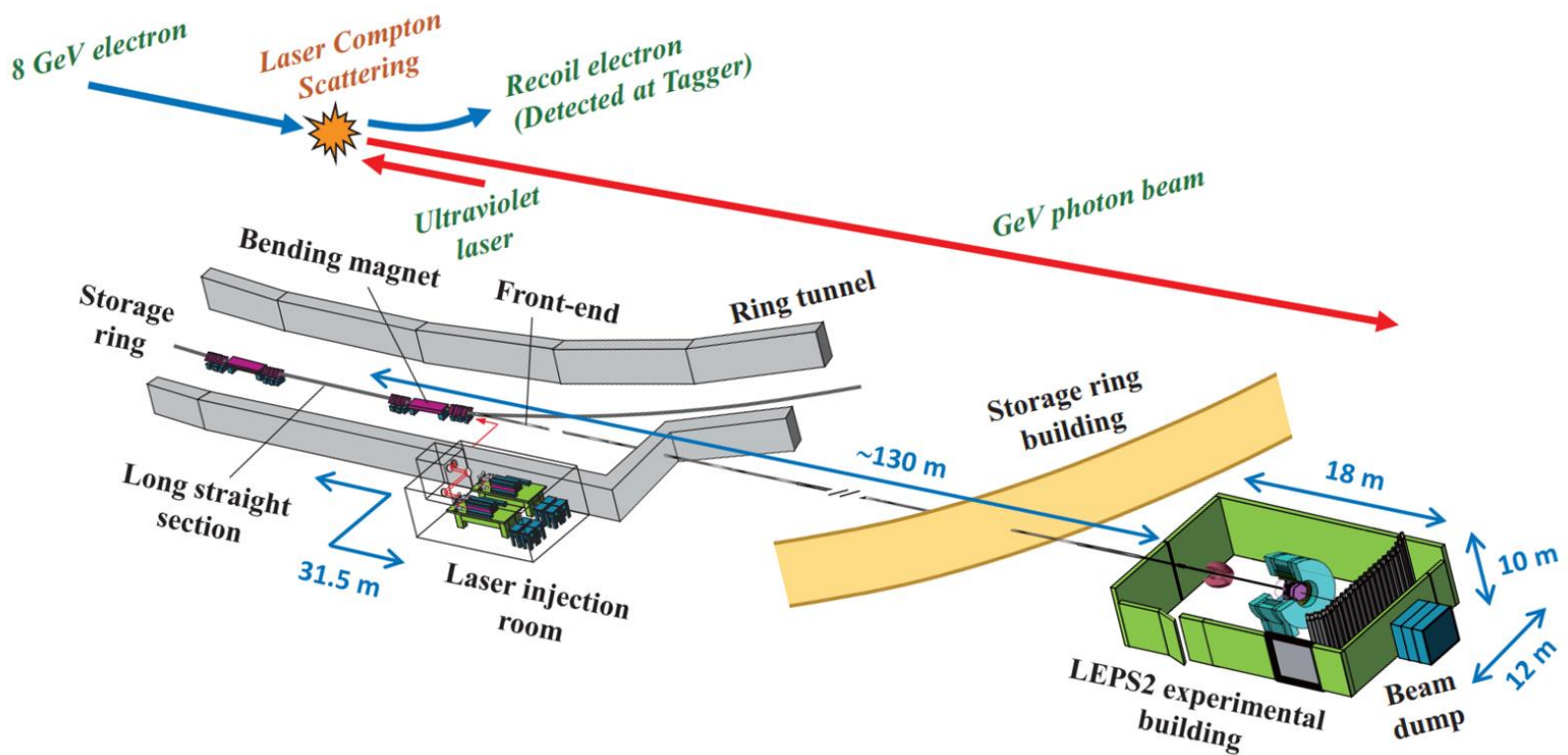
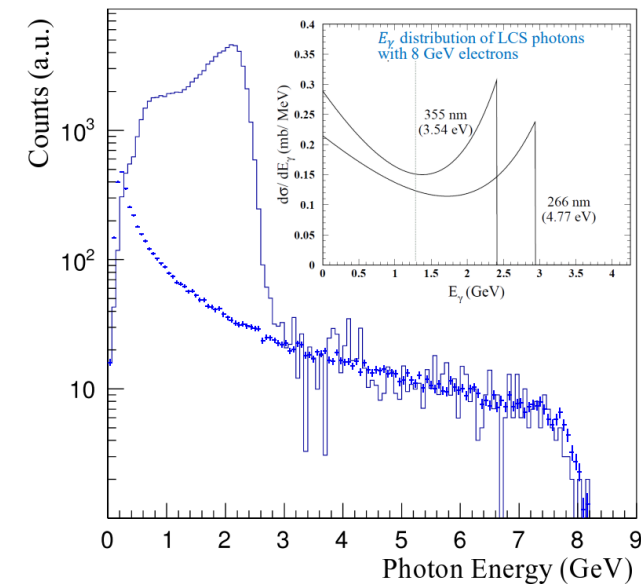
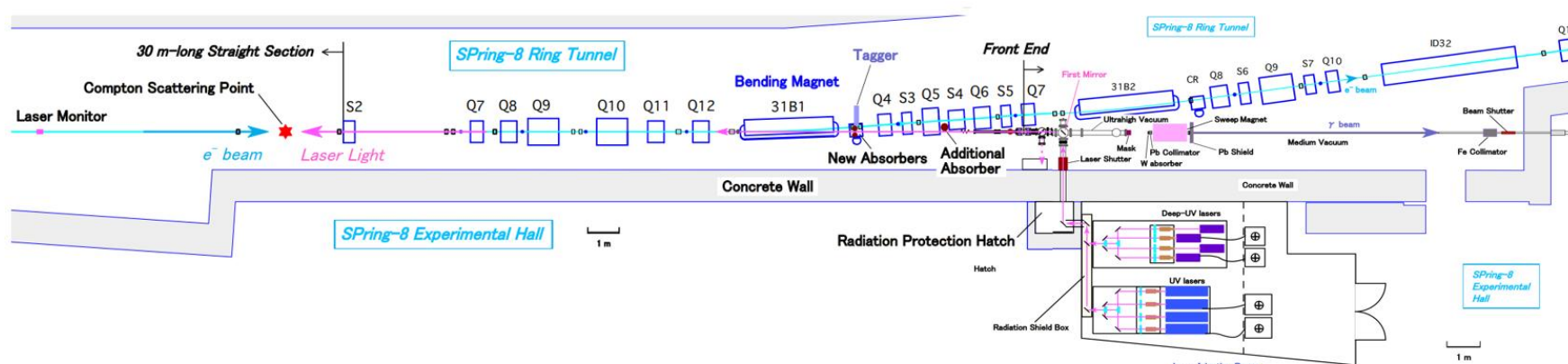


$$\sigma_t(q) = b_1 q + b_3 q^3 + b_5 q^5$$

$$|a_{\phi p}| = (343.0 \pm 5.4) \sqrt{b_1} \text{ fm}$$

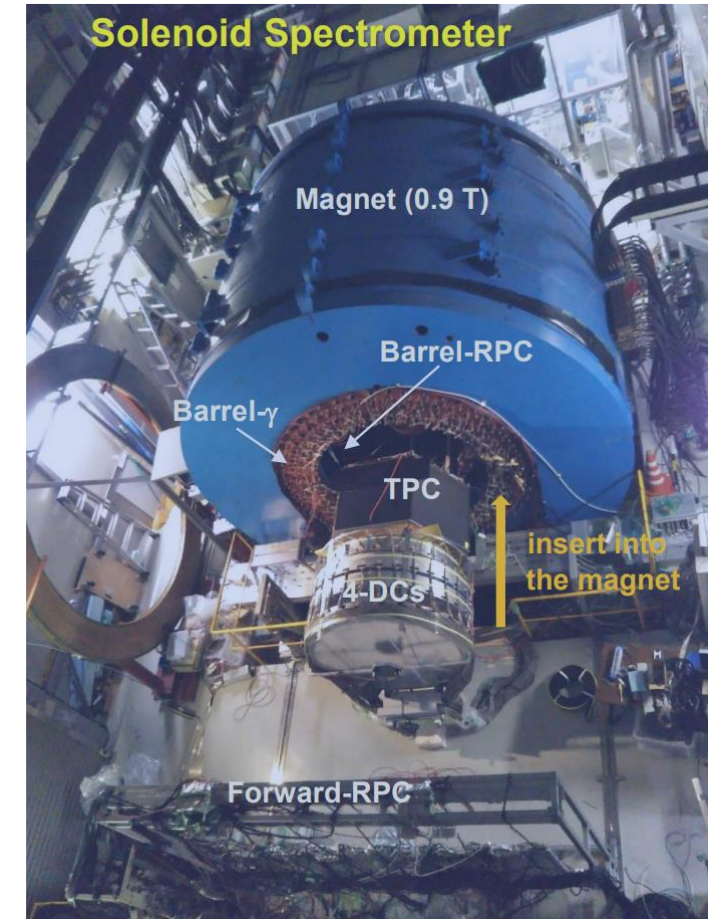
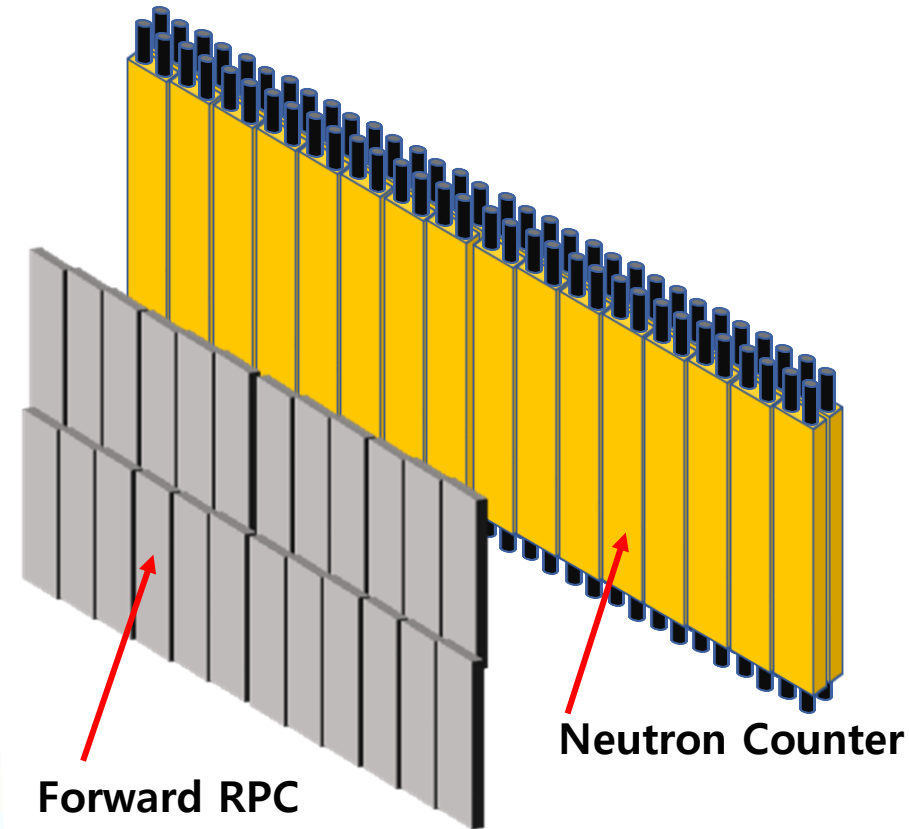
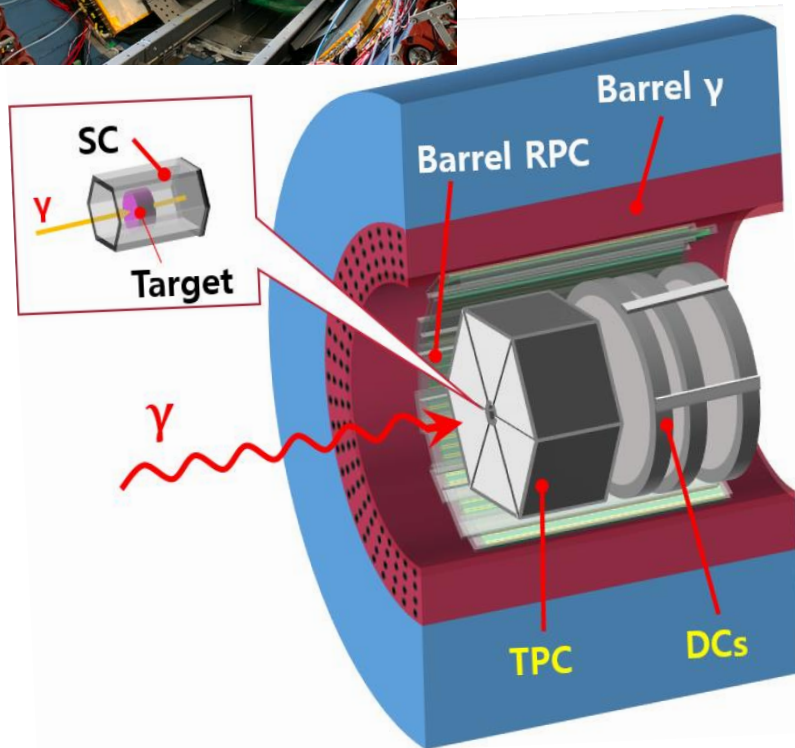
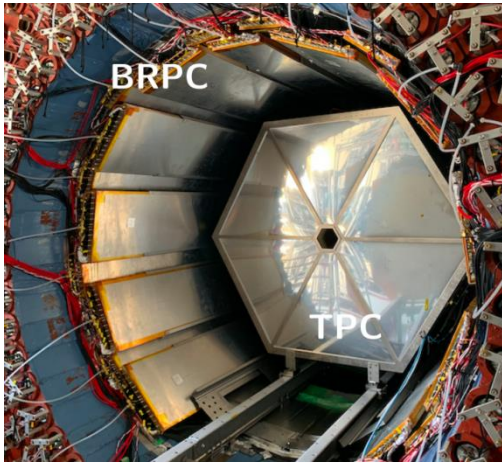
Strakovsky Pentchev, Titov Phys. Rev. C 101, 045201 (2020)

# Polarized Photon Beam at LEPS2/SPring-8



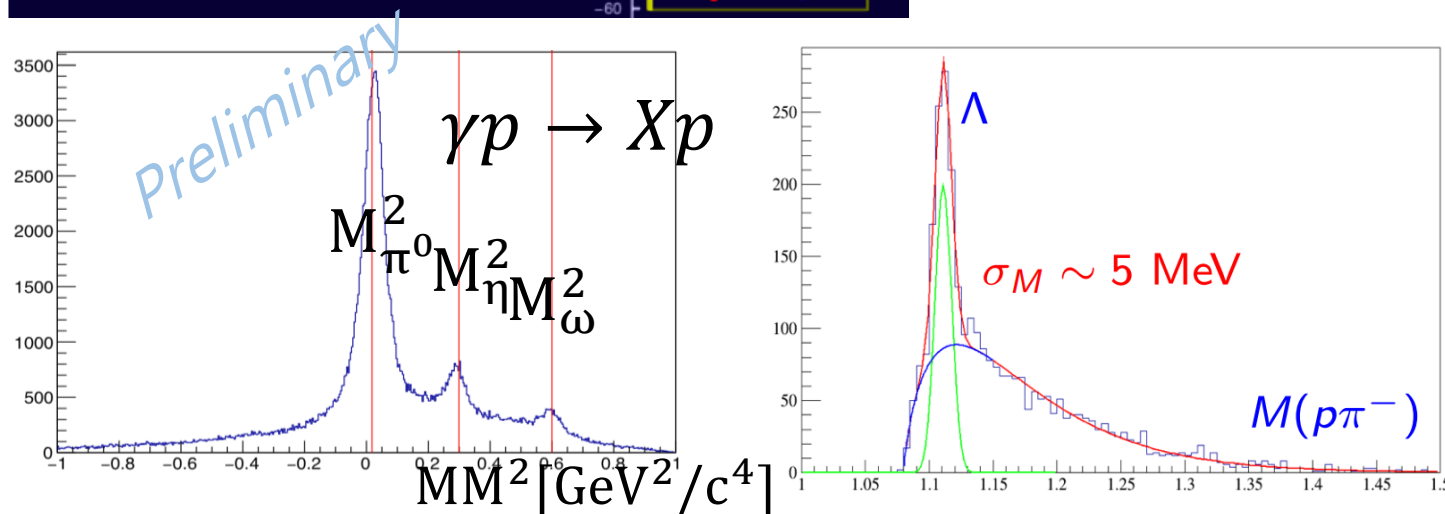
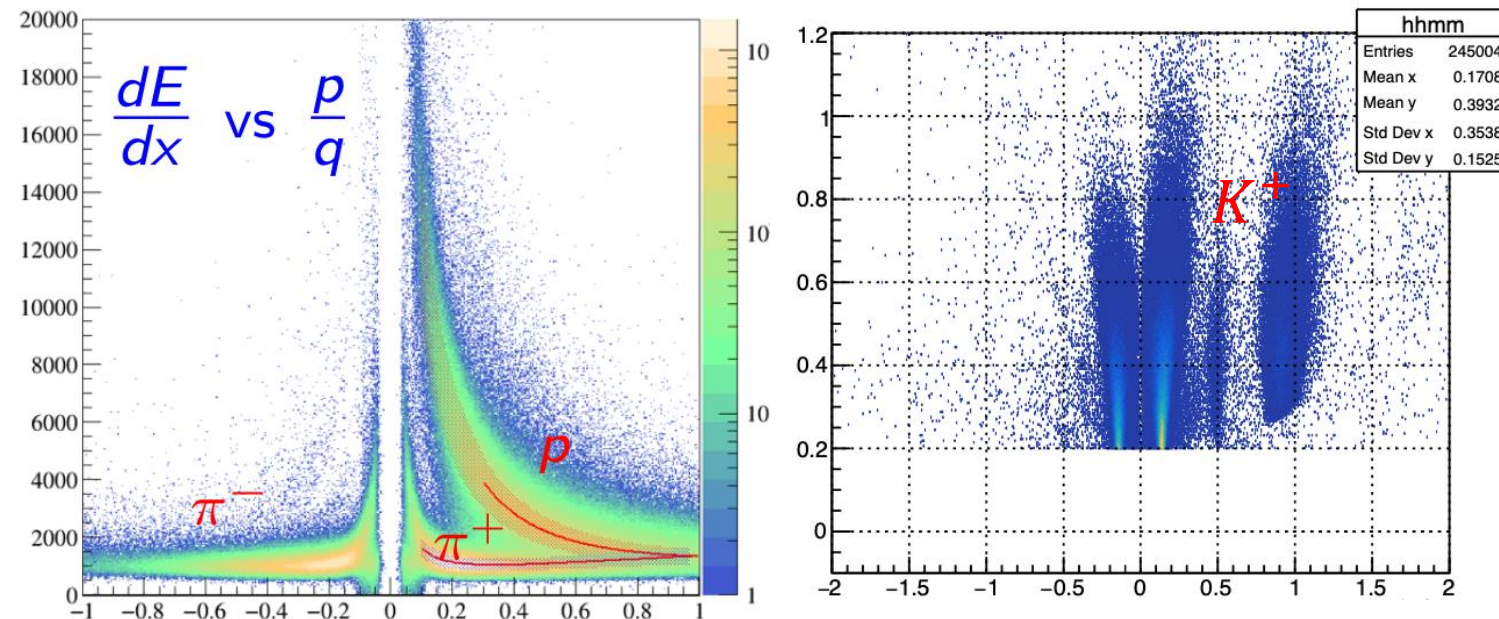
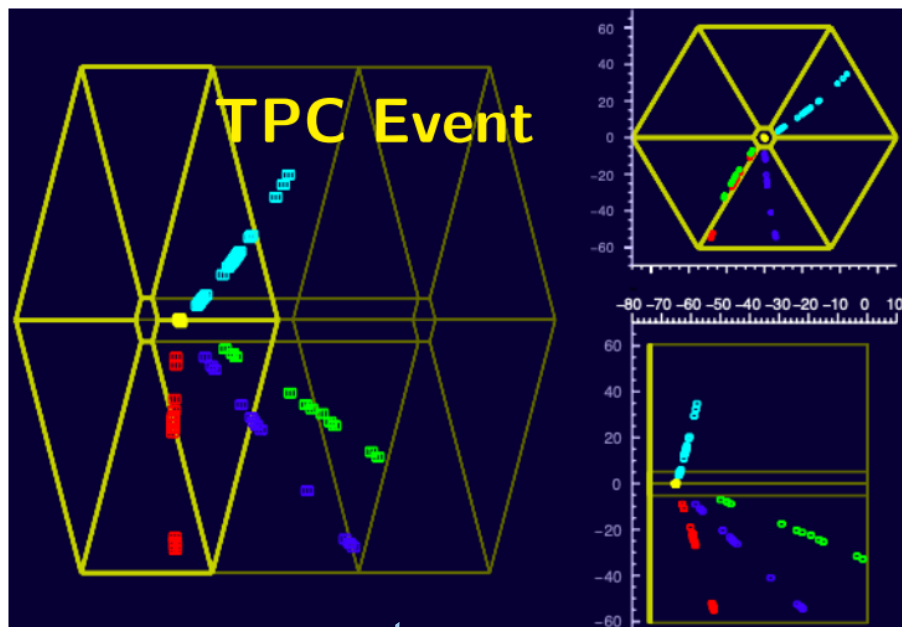


# LEPS2 Detector



- The LEPS2 solenoid detector comprises TPC, SC, DCs, forward and barrel RPCs, Barrel Pb/Scint calorimeter (14.3 X0), and neutron counters as well as a photon tagger placed approximately 150 m upstream from the detector.

# Preliminary Results from LEPS2



$\Lambda$  decays are successfully reconstructed with p and  $\pi^-$  tracks in the first dataset.

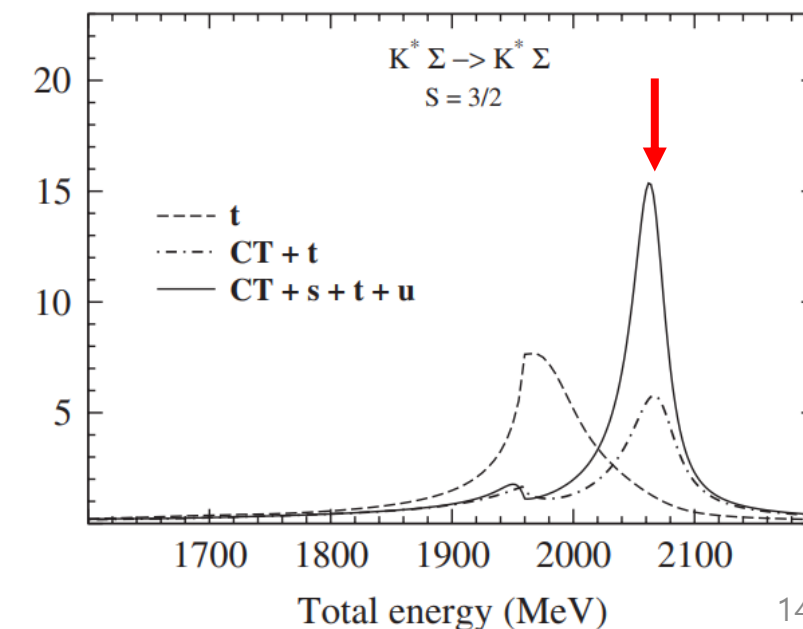
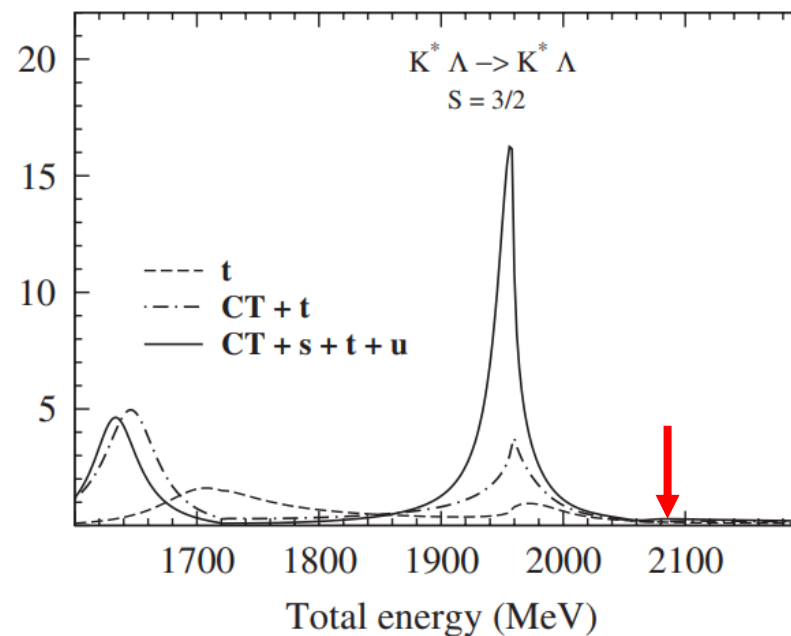
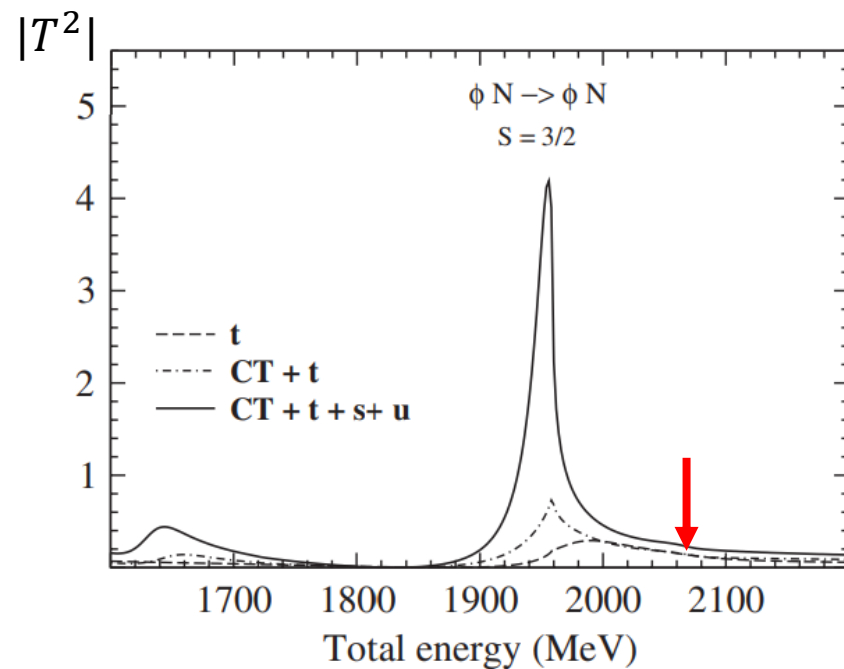
# Ps from Photoproduction with LEPS2

- Circularly polarized photon beam + polarized HD target ( $J = \frac{1}{2} \rightarrow \leftarrow$ ;  $J = 3/2 \leftarrow \leftarrow$ )
- Cross-section measurements for  $\gamma p \rightarrow K^{*0} \Sigma^+$ ,  $\gamma p \rightarrow K^{*+} \Sigma^0$ ,  $\gamma p \rightarrow K^{*+} \Lambda$ ,  $\gamma p \rightarrow \phi p$  reactions near 2 GeV.

Ps

$M_R - i\Gamma/2 \rightarrow (J^\pi)$	2071 - i7 MeV ( $3/2^-$ )
Channels ↓	Couplings ( $g^i$ )
$\rho N$	0.02 - i0.4
$\omega N$	-0.1 - i0.1
$\phi N$	0.14 + i0.2
$K^* \Lambda$	-0.3 + i0.35
$K^* \Sigma$	2.4 + i0.3

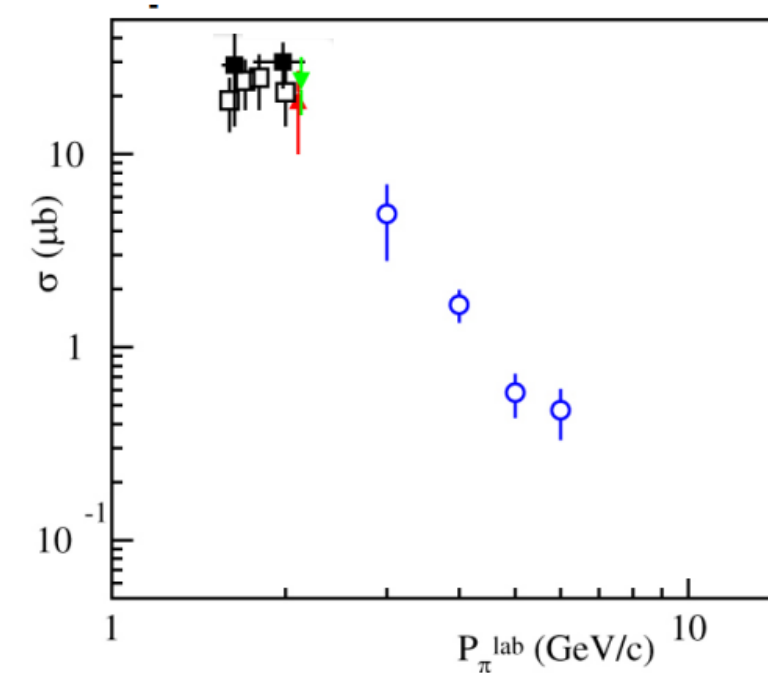
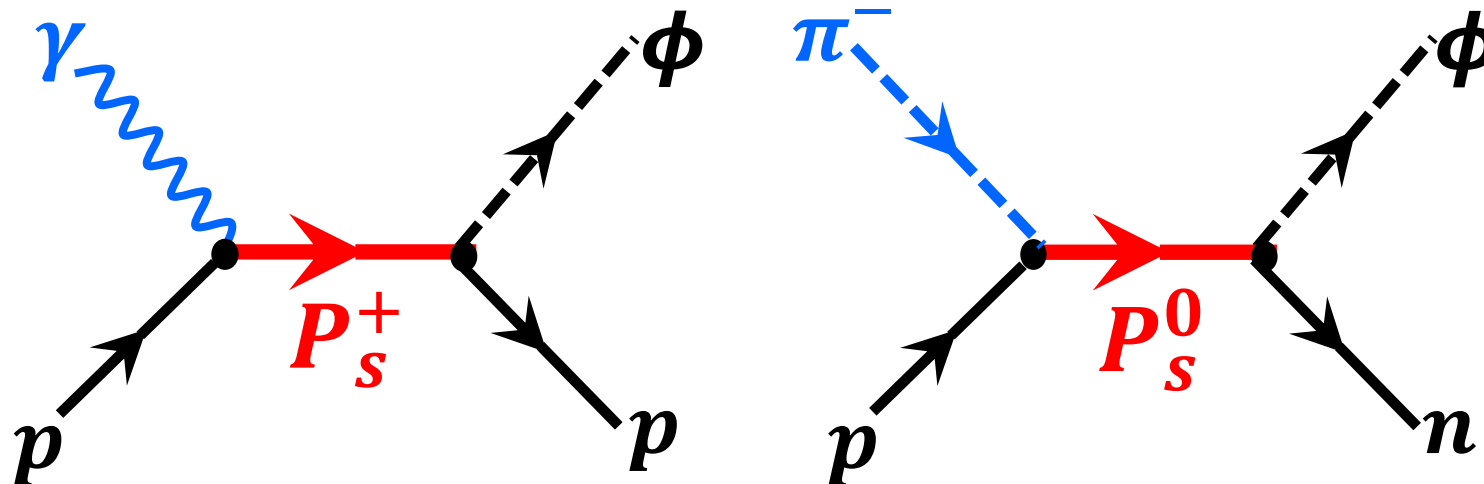
P. Khemchandani et al., Phys. Rev. D 83, 114041 (2011).



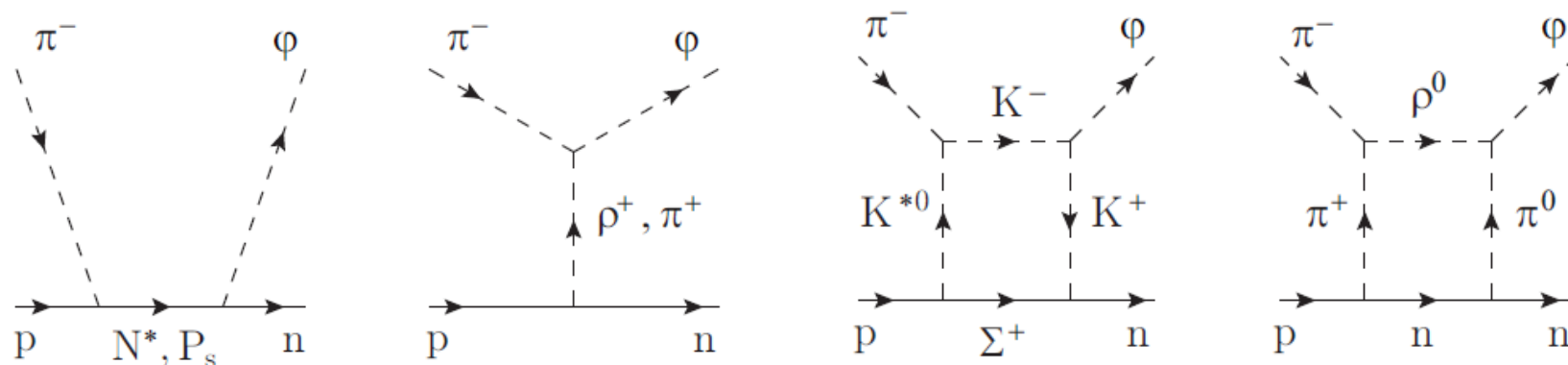


# Ps Photoproduction and Pion-induced Reactions

- While t-channel dominates in  $\gamma p \rightarrow \phi p$ , s-channel dominates in  $\pi^- p \rightarrow \phi n$ .
- Each reaction probes Ps with a different electric charge.
- Pion-induced reactions have larger production cross sections.

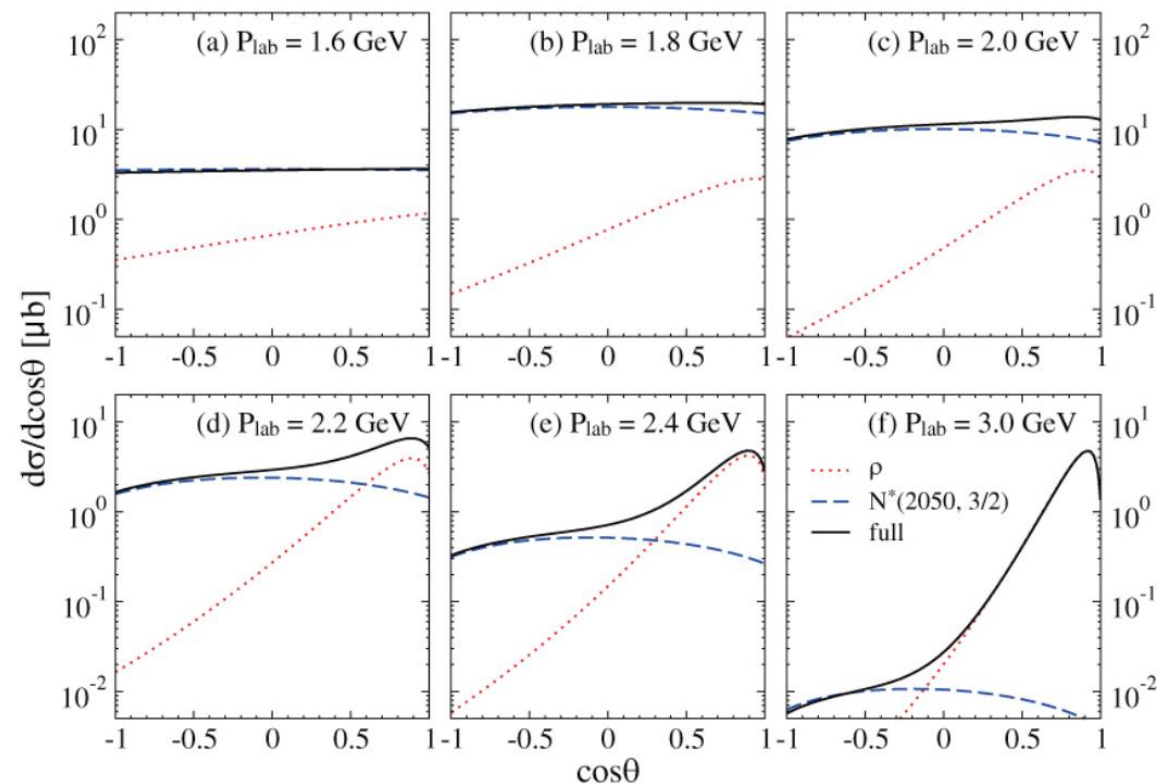
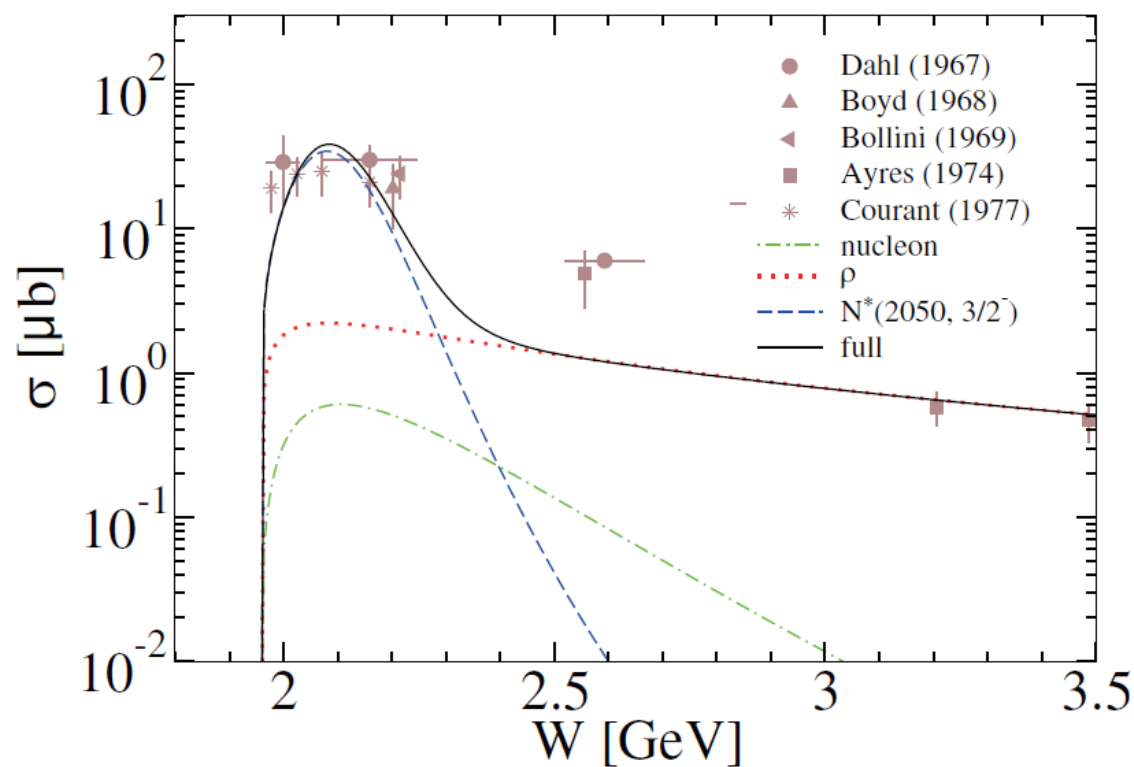


# Pion-induced Ps Production



Theoretical calculation supports a  $s$ -channel dominance below  $p_\pi \leq 2.2$  GeV/c

by S.H. Kim



# $\pi^- p \rightarrow \phi n$ at J-PARC P95

LGCs (PbGI Calorimeters)

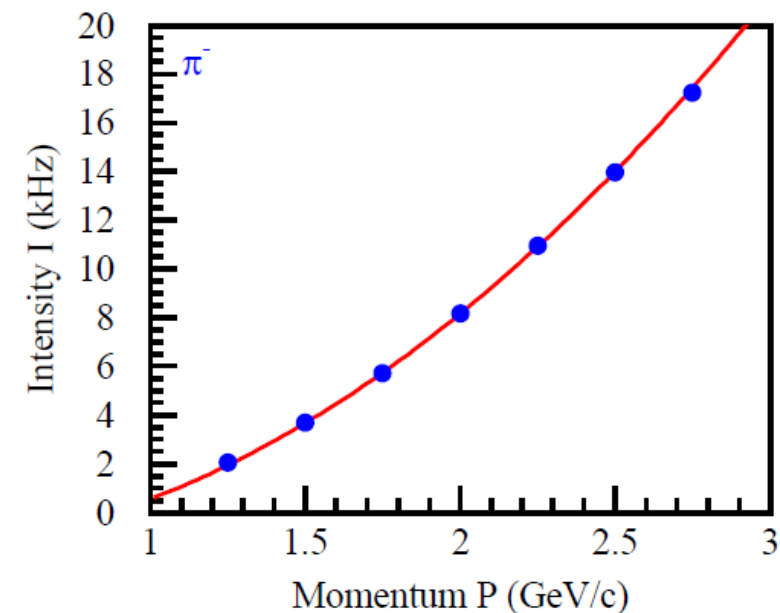
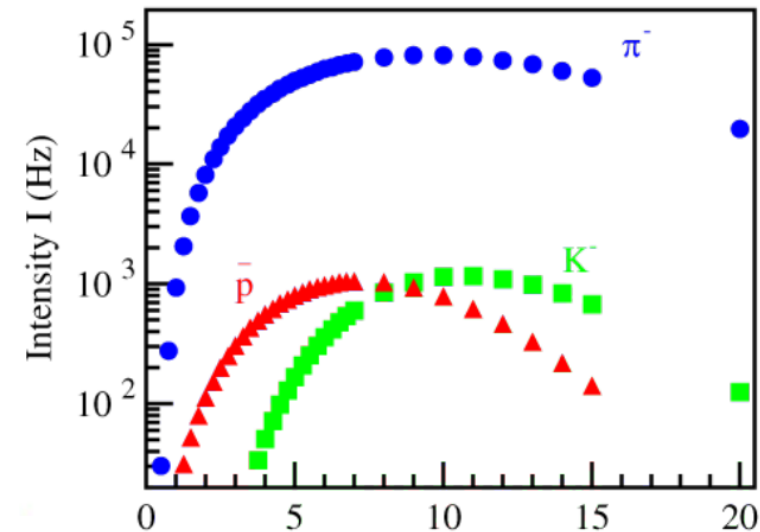
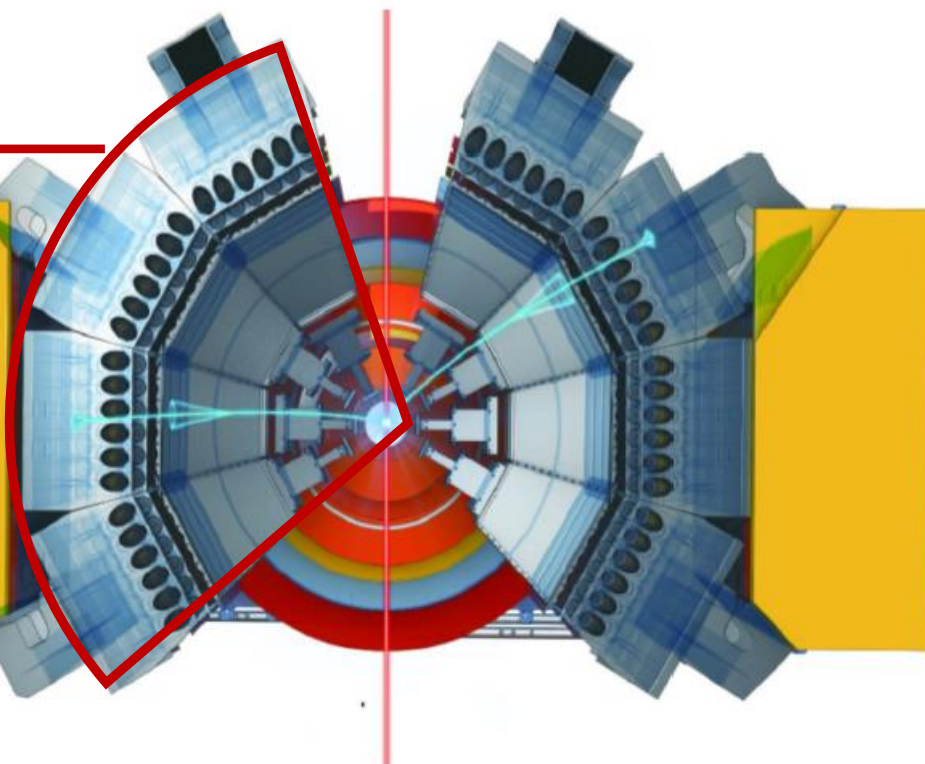
HBDs (Cherenkov Radiator)

GTRs (GEM Tracker)

SSDs

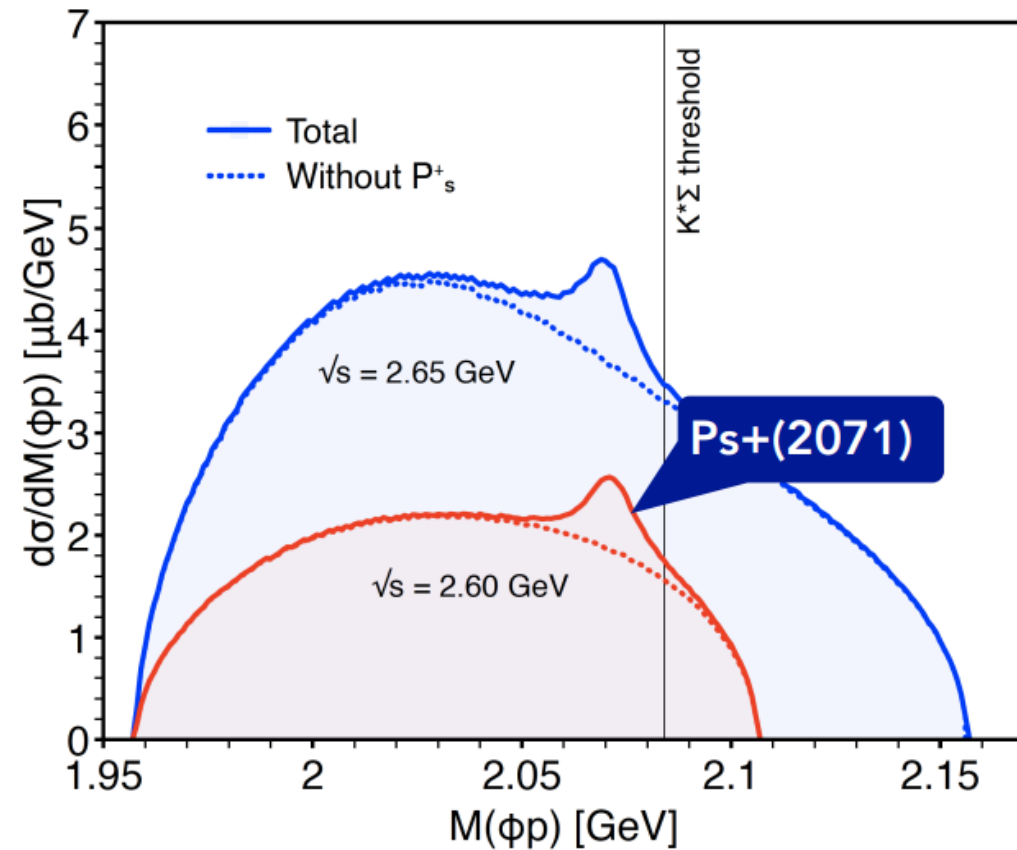
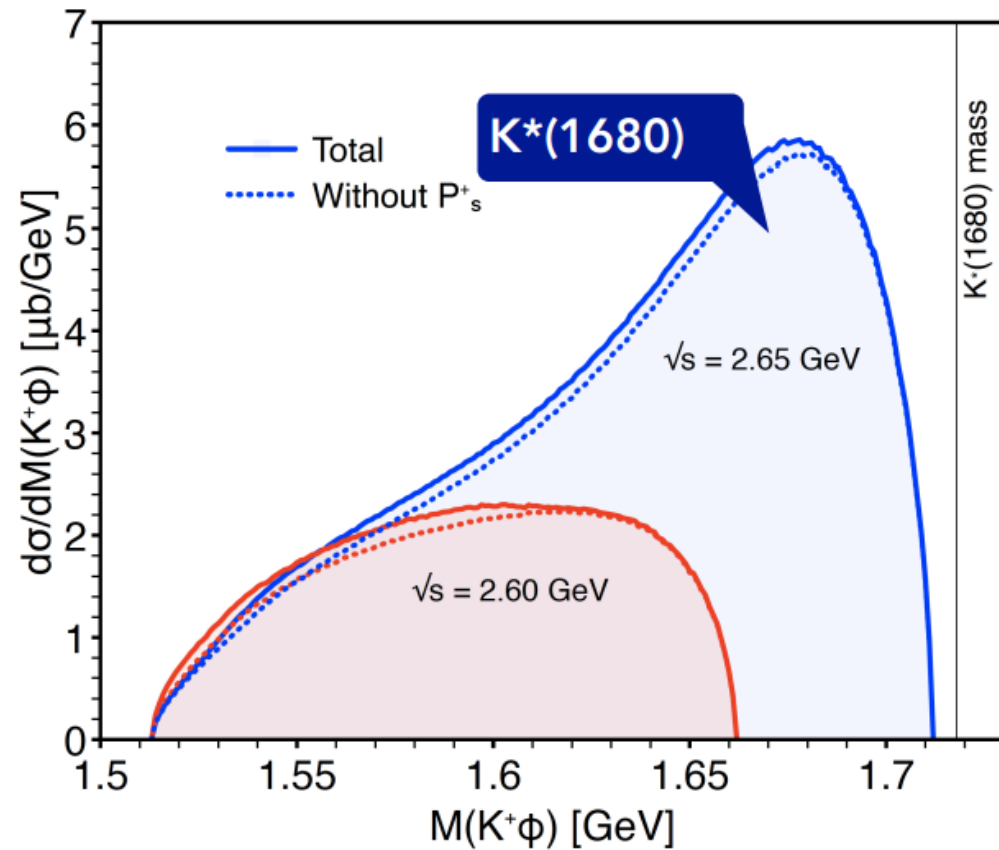
$$+15^\circ \leq \Psi_H \leq +112^\circ$$

$$-15^\circ \leq \Psi_V \leq +15^\circ$$



# $K^+ p \rightarrow K^+ \phi p$ at J-PARC

- No other background but  $K^*(1680)$  in  $K^+ p \rightarrow K^+ \phi p$ .



# Summary

- Observation of hidden charm pentaquark states (Pc) poses a question on the existence of their strange partner (Ps).
- A 2.1 GeV bump in forward cross sections for  $\gamma p \rightarrow \phi p$  indicates a possible existence of Ps decaying to  $\phi p$ .
- Formation of Ps via  $\pi^- p \rightarrow \phi n$  is critical to the Ps search without serious contributions from other resonances.
- LEPS2 will search for a Ps in total cross sections for  $\gamma p \rightarrow \phi p, K^{*0} \Sigma^+, K^{*+} \Sigma^0, K^{*+} \Lambda$  near 2.1 GeV.

