

Light Pentaquark Searches with Hadron Beams

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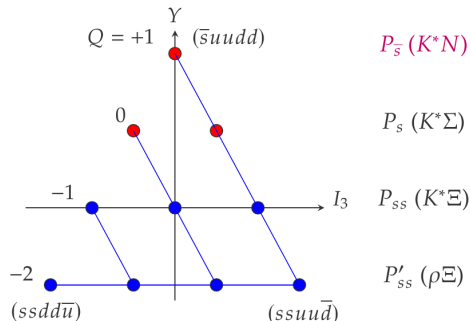
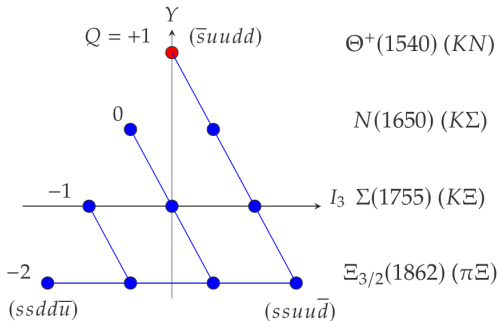


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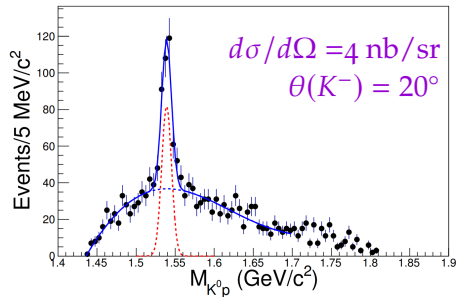
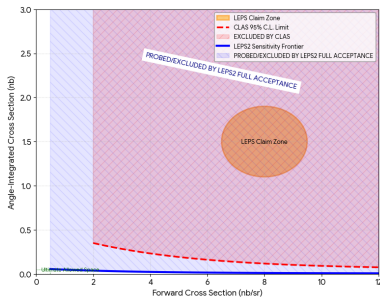
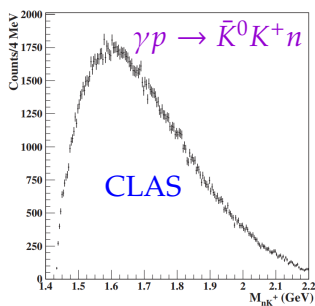
Light Pentaquark States

- Light pentaquark states (Θ^+ , $P_{s\bar{s}}$, $P_{\bar{s}}$, and P_s)



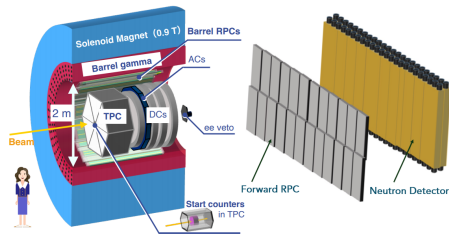
- Hidden-charm pentaquark states ($P_{c\bar{c}}$)
- Dibaryons with multi-strangeness (H -dibaryon and $d_{\Omega N}$)

Θ^+ Search with the LEPS2 Solenoid Detector



- The LEPS2/SPring-8 explores the $\gamma d \rightarrow K^- K^0 p p$ reaction. ^a
- The first run in 2025, and the next run is planned in 2026 for a total of 100 days.

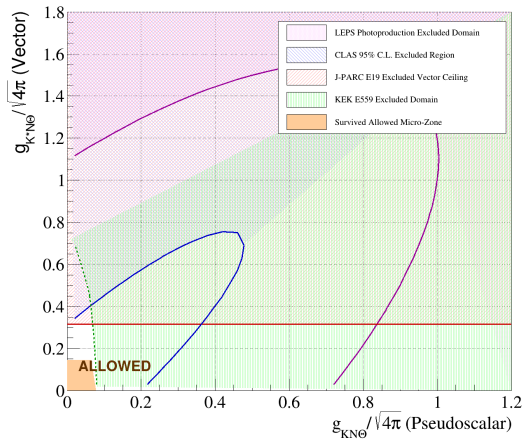
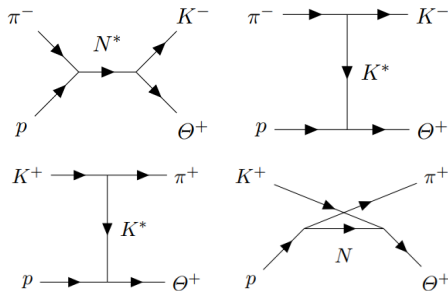
^a T. Nakano *et al.*, Acta. Phys. Pol. B 56, 3-A13 (2025).



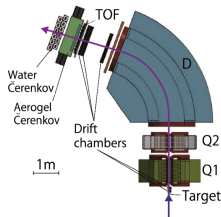
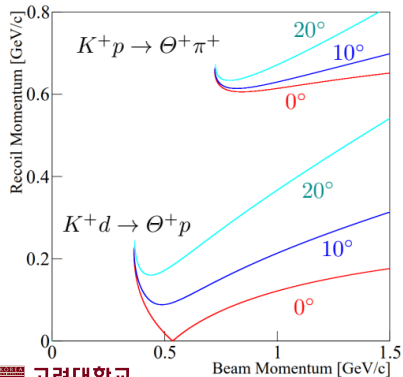
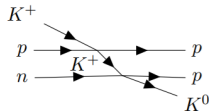
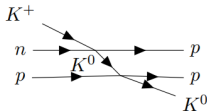
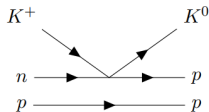
Coupling Constants $g_{KN\Theta}$ and $g_{K^*N\Theta}$

- The $\pi^- p \rightarrow \Theta^+ K^-$ reaction (J-PARC E19) in the forward direction provides a clean isolation of $g_{K^*N\Theta}^2/4\pi$, while the $K^+ p \rightarrow \pi^+ \Theta^+$ reaction (KEK E559), in u -channel exchanges, directly maps $g_{KN\Theta}^2/4\pi^a$

^a J.K. Ahn, in preparation (2026).

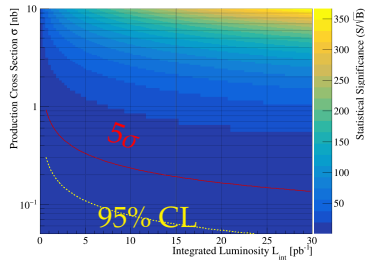
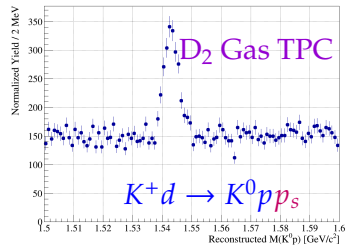


$K^+d \rightarrow \Theta^+p$ and $K^+d \rightarrow \Theta^+p_s$ Reactions

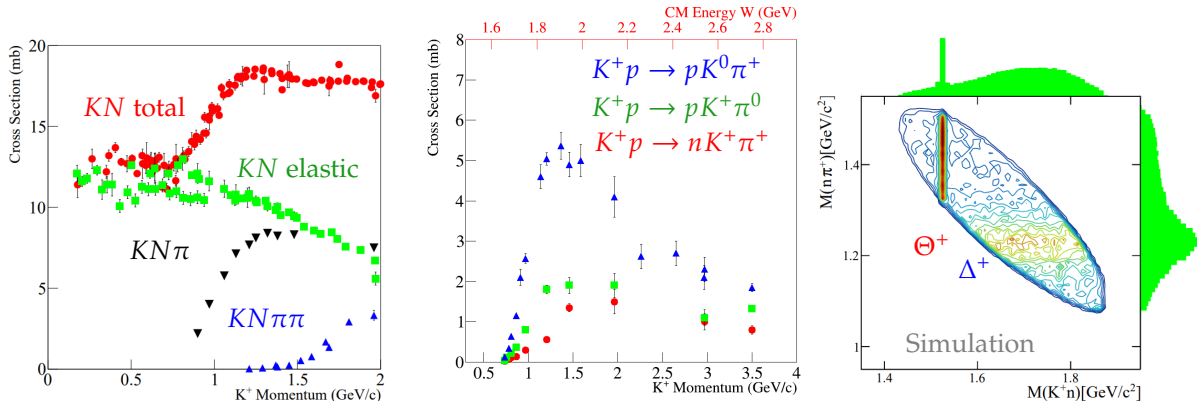


○ A new experiment for $d(K^+, p)$ reaction is now under consideration.

Experimental Study of the $S = +1$ Bar...
Shin Hyung Kim



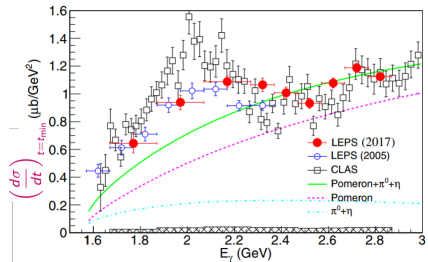
$K^+p \rightarrow K^+\pi^+n$ Reaction at 1.5 GeV/c



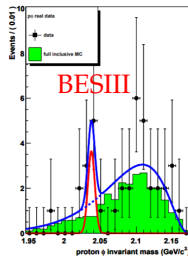
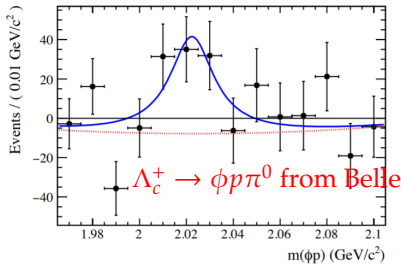
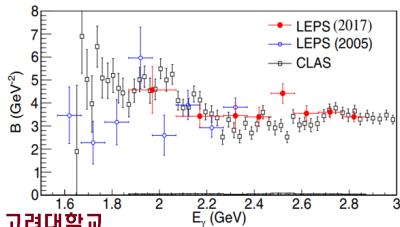
○ Dalitz plots of the K^+n vs $n\pi^+$ masses and the $K^+\pi^+$ vs K^+n masses for the reaction $K^+p \rightarrow K^+n\pi^+$ at 1.5 GeV/c. ^a

^a J.K. Ahn, Acta. Phys. Pol. B 56, 3-A15 (2025).

Strange Partner $P_{s\bar{s}}$ of $P_{c\bar{c}}$ Pentaquark States



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

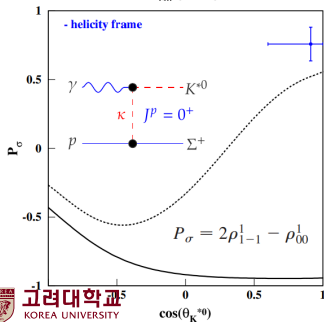
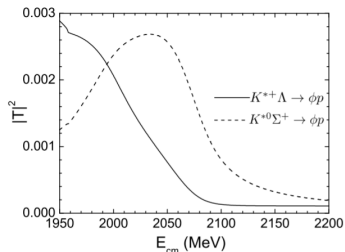


- A strange partner $P_s(uuds\bar{s})$ was searched for in the Cabibbo-suppressed $\Lambda_c^+ \rightarrow \phi p \pi^0$ decay at Belle^a and BESIII.^b $\mathcal{B}(\Lambda_c^+ \rightarrow P_s \pi^0) \cdot \mathcal{B}(P_s \rightarrow \phi p) < 8.3 \times 10^{-5}$ at 90% CL)

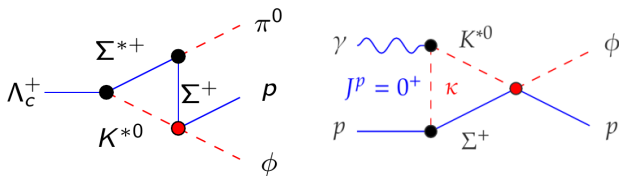
^a B. Pal *et al.* (Belle Collab), PRD 96, 051102 (2017).

^b G. Mezzadri, Ph.D thesis, Ferrara U (2018).

Strange Partner of P_c Pentaquark States



- The bump structure observed in ϕ photoproduction could be regarded as a ΣK^* molecular state ($J = 3/2^-$). Triangular singularity could also explain the bump structure with $\Sigma K^* \rightarrow \phi n$.^a



- The measured parity spin asymmetry shows that natural-parity exchange is dominant in $\gamma p \rightarrow K^{*0} \Sigma^+$ reaction.^b
- The nature of the bump structure should be further investigated using circularly polarized photon beam and a polarized (HD) target.
- The SPring-8/LEPS is currently studying both ϕn and ϕp systems using the

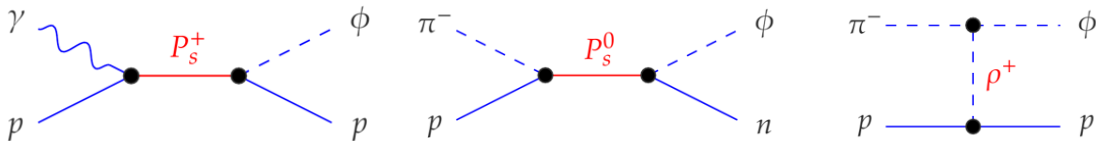
Search for Hidden-Strangeness Pent...
Shintaro TANAKA

$\gamma d \rightarrow \phi p n$ reaction:

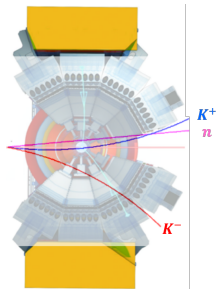
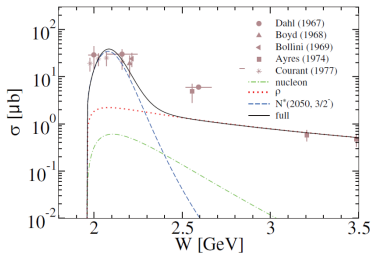
^a J.-J. Xie and F.-K. Guo, PLB 774, 108(2017); J. He, PRD 95, 074031(2017).

^b S.H. Hwang *et al.* (LEPS Collab.), PRL 108, 092001(2012).

$P_{s\bar{s}}$ Search via Pion-induced Reactions



- While t -channel dominates in $\gamma p \rightarrow \phi p$, s channel dominates in $\pi^- p \rightarrow \phi n$.
- The $\pi^- p$ reaction probes a $P_{s\bar{s}}^0$, an isospin-doublet member with $P_{s\bar{s}}^+$.
- The **J-PARC E95** will measure cross sections for $\pi^- p \rightarrow \phi n$ at momenta from 1.6 to 2.4 GeV/c to explore N^* and possible $P_{s\bar{s}}$ coupled to ϕN .^a



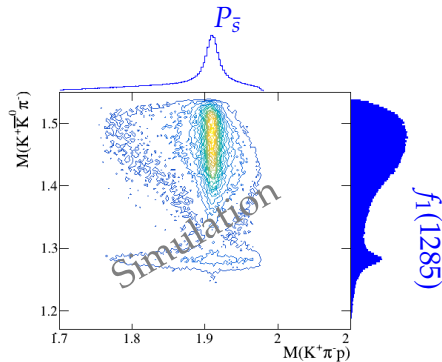
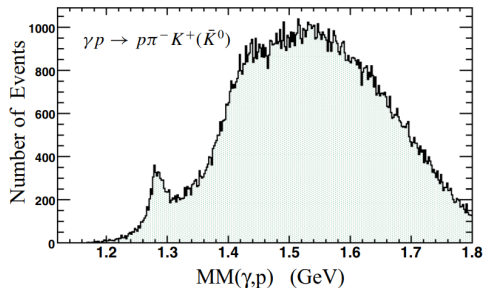
- Theoretical calculation supports an s -channel dominance below 2.2 GeV/c (Sangho Kim).

^a T. Ishikawa *et al.*, J-PARC E95 proposal.

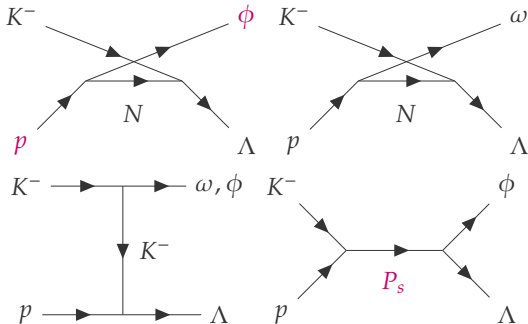
Search for $P_{\bar{s}}$ in $\gamma p \rightarrow p K^{*0} \bar{K}^0$

- The $P_{\bar{s}}$ (1910) state can be investigated in $\gamma p \rightarrow p K^+ \pi^- \bar{K}^0$ reaction above 2.65 GeV.
- CLAS has already measured the $\gamma p \rightarrow p K^+ \pi^- \bar{K}^0$ reaction, and reported an observation of $f_1(1285)1^+$ mesons in the $\pi K K$ channel. ^a.
- Simulated spectra indicate a correlation between the invariant mass $K^+ \bar{K}^0 \pi^-$ and the mass $K^+ \pi^- p$ for $E_\gamma = 2.8$ GeV.

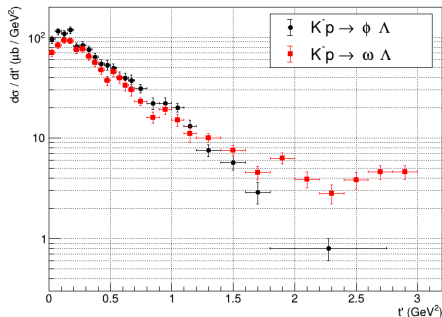
^a R. Dickson *et al.* (CLAS), Phys. Rev. C93, 065202(2016)



P_s Search in $K^-p \rightarrow \phi\Lambda$



$$\begin{aligned} \frac{g_{\phi\rho\pi}^2}{g_{\omega\rho\pi}^2} &= \frac{g_{N\bar{N}\phi}^2}{g_{N\bar{N}\omega}^2} = \frac{\sigma(\pi N \rightarrow \phi X)}{\sigma(\pi N \rightarrow \omega X)} \\ &= \frac{\sigma(K^-p \rightarrow \phi Y)}{\sigma(K^-p \rightarrow \omega Y)} \bigg|_{\text{back } \phi} = \tan^2 \theta_V \end{aligned}$$

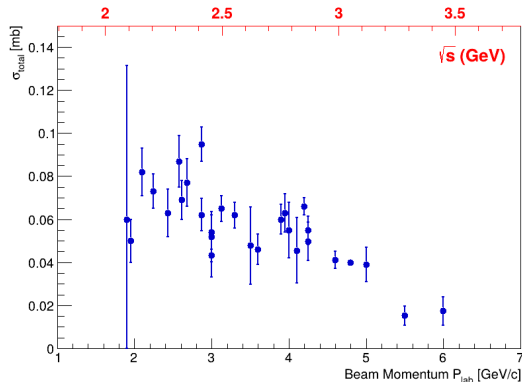
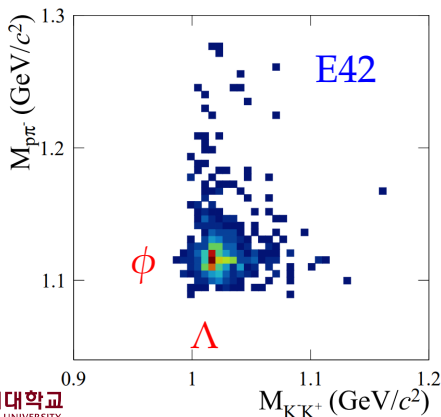


- An old bubble chamber experiment reported cross sections and polarization observables for $K^-p \rightarrow (\rho, \omega, \phi)(\Lambda, \Sigma)$ reactions at $4.2 \text{ GeV}/c$.^a

^a M.J. Losty et al., Nucl. Phys. B133, 38 (1978).

P_s Search in $K^-p \rightarrow \phi\Lambda$

- The J-PARC E42 collected the near-threshold quasifree ϕ production in $^{12}\text{C}(K^-, K^+)$ reaction from threshold to $\sqrt{s} = 2.3$ GeV.
- Recently, CLAS12 observed the $\phi\Lambda$ system in the $ep \rightarrow e'K^+\phi\Lambda$ reaction at energies exceeding (3 GeV).

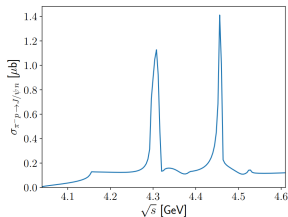
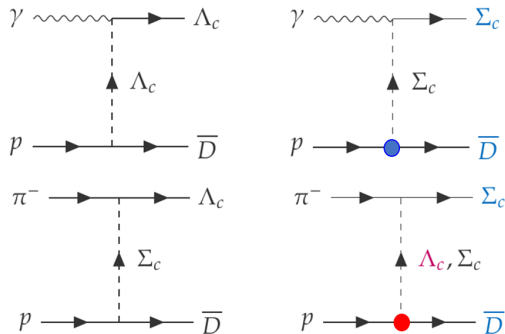


$P_{\bar{c}c}$ Search with Hadron Beams

- $P_{c\bar{c}}$ states **strongly couple** to $\Sigma_c^{(*)}\bar{D}^{(*)}$ channels, but only **weakly** to $\Lambda_c^{(*)}\bar{D}^{(*)}$ channels.
- Due to $g_{\Lambda_c N \bar{D}} \gg g_{\Sigma_c N \bar{D}}$, the $P_{c\bar{c}}$ may be suppressed in photoproduction but produced in $\pi^- p$ reactions ^a

^a S.Y. Ryu *et al*, J-PARC-P111 Proposal (2025); S. Clymton, S.Y. Ryu, J.K. Ahn, and H.-Ch. Kim, arXiv:2605.28285.; I. Strakovsky, J.K. Ahn, W.J. Briscoe, M.G. Ryskin, and A. Schmit, arXiv:2603.09622.

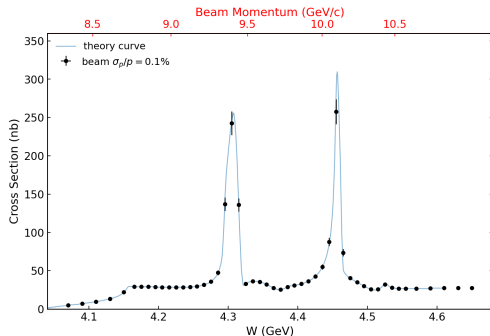
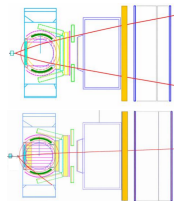
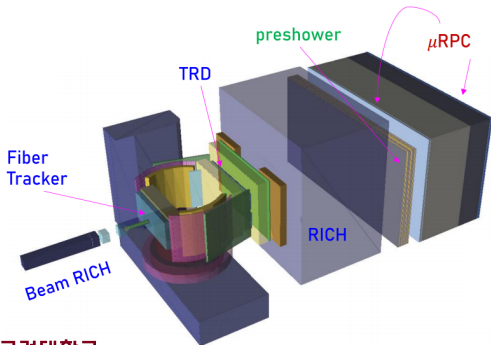
Reaction	Threshold (GeV/c)
$\pi^- p \rightarrow J/\psi n$	8.20
$\pi^\pm p \rightarrow J/\psi p \pi^\pm$	8.81
$K^\pm p \rightarrow J/\psi p K^\pm$	10.32
$\bar{p} p \rightarrow J/\psi p \bar{p}$	12.21



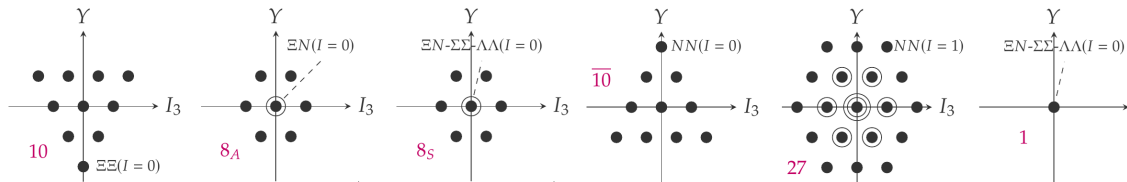
$P_{\bar{c}c}$ Search in Near-Threshold J/ψ Production in π^-p Reaction

- The **J-PARC P111** proposes to measure J/ψ production in π^-p reaction near threshold at the $\pi 20$ beam line. ^a
- The **dilepton detectors** plus the J-PARC MARQ detector will reconstruct $J/\psi \rightarrow ee$ and $\mu\mu$ decays.

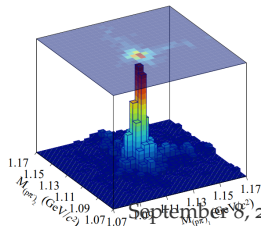
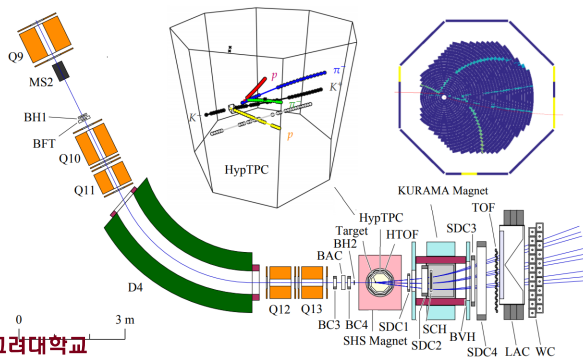
^a S.Y. Ryu *et al*, J-PARC-P111 Proposal (2025)



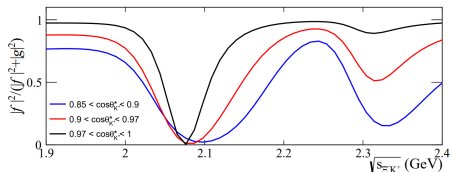
J-PARC E42 Search for the Hexaquark State: the H -Dibaryon



- The J-PARC E42 experiment is preparing to announce new results from the H -dibaryon search using $^{12}\text{C}(K^-, K^+)$ reaction at 1.8 GeV/c.

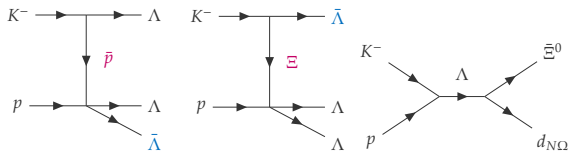


Strange Dibaryon Search via $d(K^-, K^0)$ and $(K^-, \bar{Y})$ Reactions



- The ratio of the **non-spin-flip** to **spin-flip** amplitudes squared was extracted from the Ξ^- polarization measurement results.^a
- The $\Xi^- p$ (1S_0) pair will be effectively produced in the $K^- d \rightarrow K^+ \Xi^- p$ reaction within a specific energy range where the spin-flip amplitude dominates.

- The $\bar{Y}$ production in the $K^- p$ reaction opens up new windows for investigating multistrange dibaryons.
- The $d_{N\Omega}$ dibaryon with $J^P = 2^+$ can be produced in the $K^- p \rightarrow d_{N\Omega} \bar{\Xi}^0$ reaction.^a



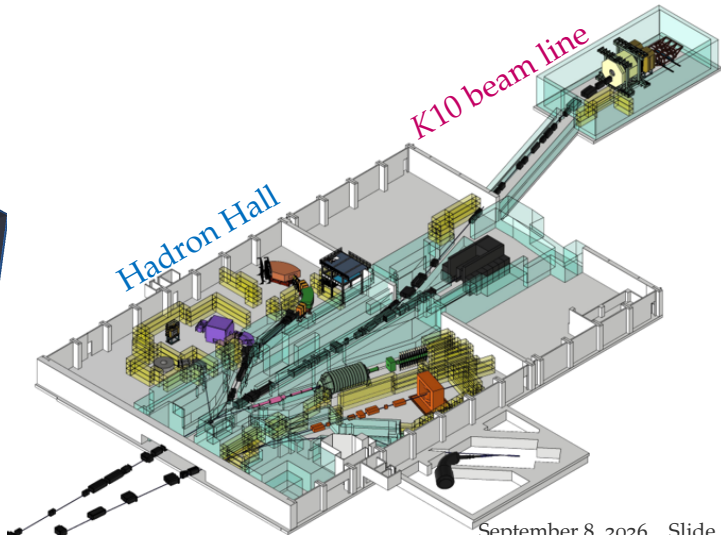
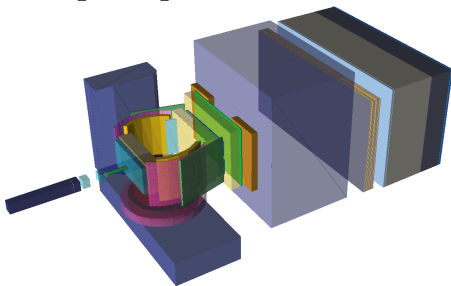
^a J. Lui *et al*, Chin. Phys. C 47, 053107 (2023).

^a B.M. Kang *et al.* (E42 Collab.), in preparation (2026).

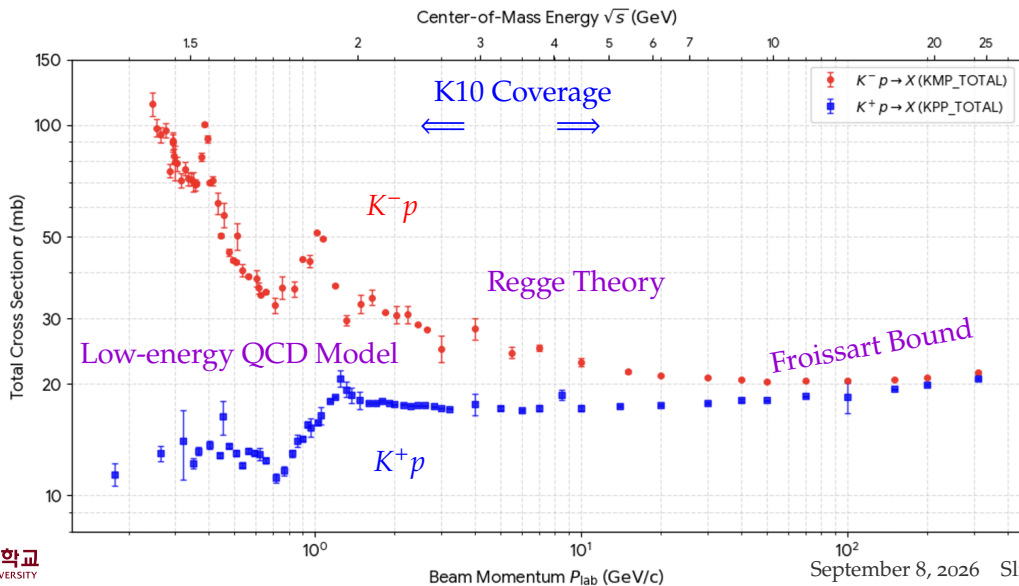
K10 Beamline at J-PARC

○ RF-separated $K^\pm$ beams in 3–10(15) GeV/ c , as well as $\pi^\pm$, p and $\bar{p}$ beams.

○ Large superconducting dipole spectrometer.



Total Cross Sections for K^-p and K^+p Reactions



Summary

