The 4th J-PARC symposium2024, 14-18 October, 2024, Mito

Study of Mesonic Decay Branches of $\bar{K}NN$

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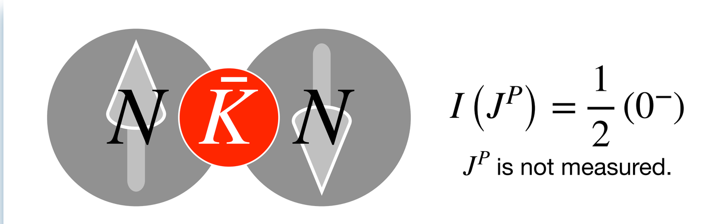
Related papers
Mesonic — PRC **110** 014002
Non-mesonic — PRC **102** 044002

– Abstract –

We studied mesonic decay branches of the $\bar{K}NN$ quasi-bound state to understand its large decay width $\Gamma_{\bar{K}NN} \sim 100$ MeV, which is twice as large as $\Gamma_{\Lambda(1405)}$. To understand the large $\Gamma_{\bar{K}NN}$, we measured differential cross sections of the $K^- + {}^3\mathrm{He} \to \pi^\pm\Sigma^\mp p + n'$, $\pi^+\Lambda n + n'$, and $\pi^-\Lambda p + p'$ reactions. We evaluated decay branches of the $\bar{K}NN$ from a spectral decomposition with a simple model. The result indicates that $\bar{K}NN$ is twice as unstable as $\Lambda(1405)$ due to the mesonic $\bar{K}$-absorption in the $I_{\bar{K}N} = 1$ channel. [*Published on* PRC **110** 014002]

– Introduction –

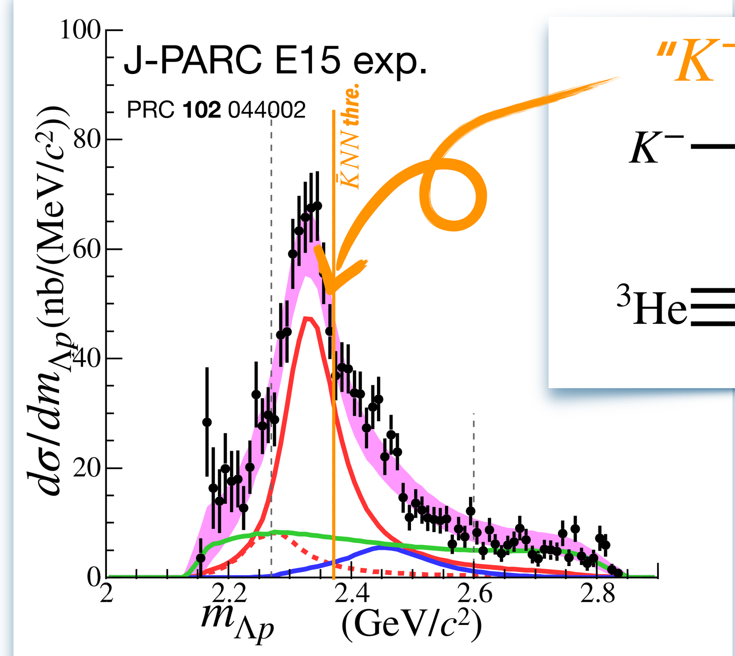
– The Lightest *Kaonic* Nucleus, $\bar{K}NN$ –

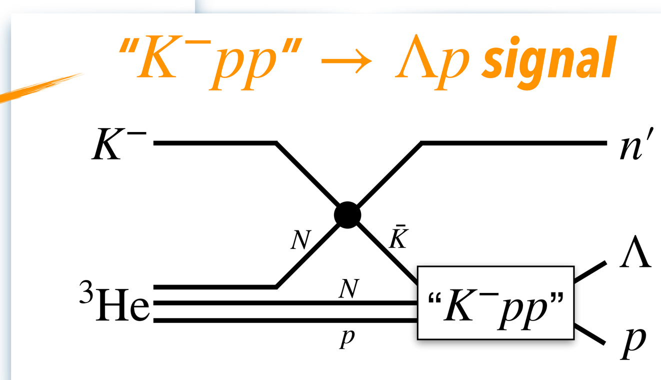


Properties

- Containing a $\bar{K}$-meson (*Not only baryons!*)
- Formed by $\bar{K}N$-int. in $I_{\bar{K}N} = 0$ (*Stronger attractive than NN int.!*)
- Deeply bound, so perhaps dense (*Beyond normal nuclei!*)

– Observation of the $\bar{K}NN_{I_3=+1/2}$ ("K^-pp") –





B.E. & Width obtained

- $E_{\bar{K}} \sim 40$ MeV
- $\Gamma_{\bar{K}NN} \sim 100$ MeV (*So large!* c.f.) $\Gamma_{\Lambda(1405)} \sim 50$ MeV)

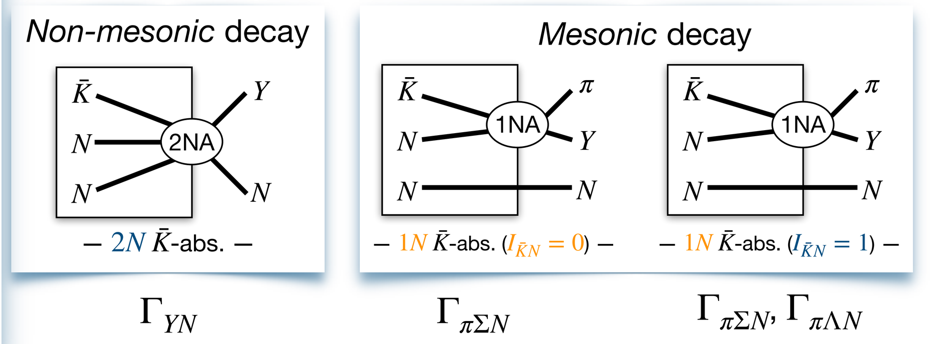
– Objective of the Study –

Open Question

Why is $\bar{K}NN$ ~ twice as unstable as $\Lambda(1405)$? ($\equiv \bar{K}N$)

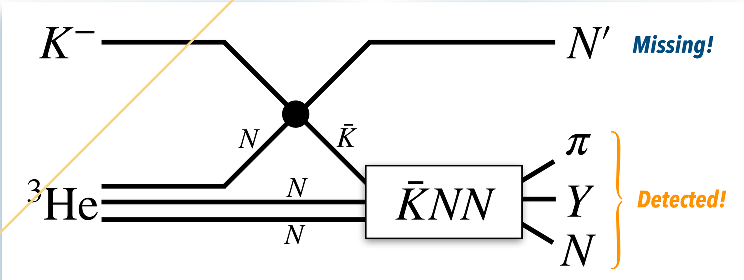
Objective

Measureing decay branching ratios of $\bar{K}NN$ to understand the large $\Gamma_{\bar{K}NN}$



– Experiment –

– Measured Reactions –



Measured channels

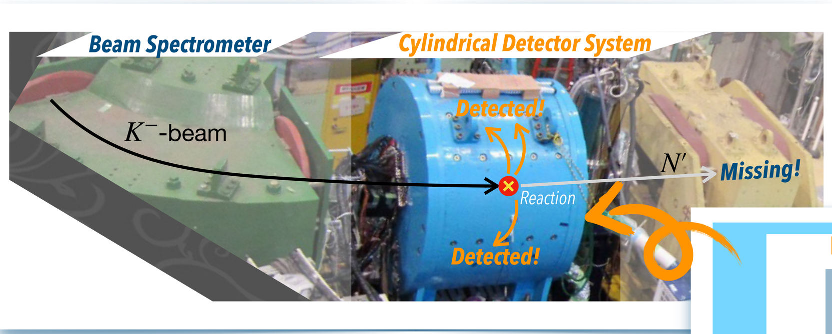
- $\pi^+\Sigma^-p + n'$ ("K^-pp")
- $\pi^-\Sigma^+p + n'$ ("K^-pp")

— $I_{\pi Y} = 0$ & 1 —

- $\pi^-\Lambda p + p'$ ("$\bar{K}^0nn$")
- $\pi^+\Lambda n + n'$ ("K^-pp")

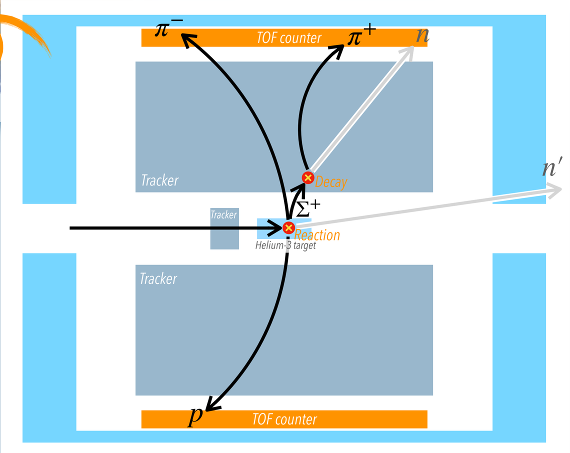
— $I_{\pi Y} = 1$ —

– Detector Systems –



Measurement

- Charged: **Momentum** by Curvature, **PID** by TOF
- Neutrons: **Momentum** by TOF, **Charge-veto** by Tracker



Measured particles (Detected! / Missing!)

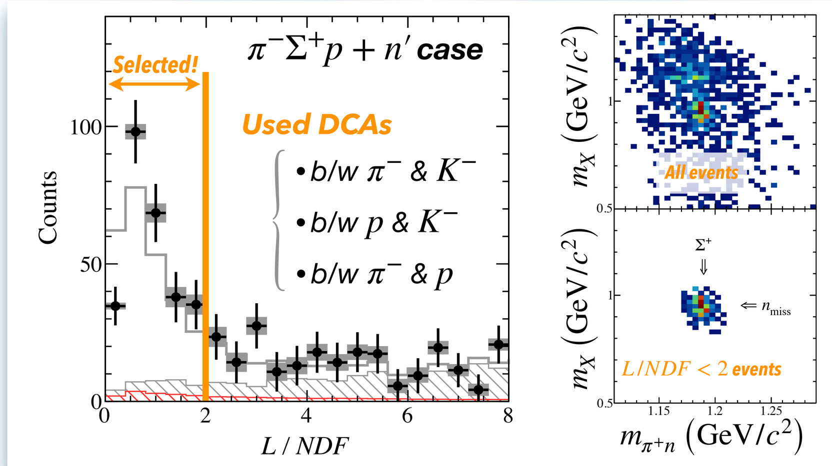
$\pi^\pm\Sigma^\mp p + n' \to [\pi^\pm(\pi^\mp n)\,p] + n'$
$\pi^+\Lambda n + n' \to [\pi^+(\pi^-p)\,n] + n'$
$\pi^-\Lambda p + p' \to [\pi^-(\pi^-p)\,p] + p'$

– Event Selection –

Likelihood for selection

$$L = -\ln\left(p\left(\chi^2_{kfit}\right) \times \prod_i^{N_{DCA}} p(DCA_i)\right)$$

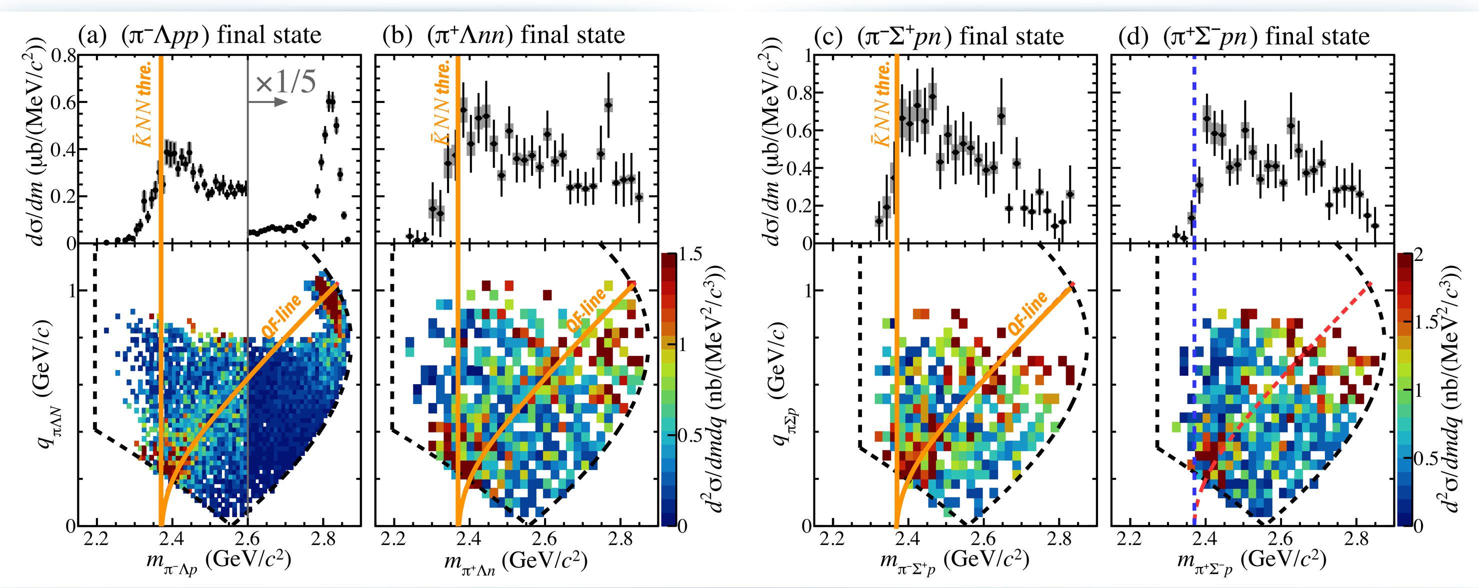
Chi-squared of Kinematic Fit; Distance of Closest Approach b/w. Two Charged



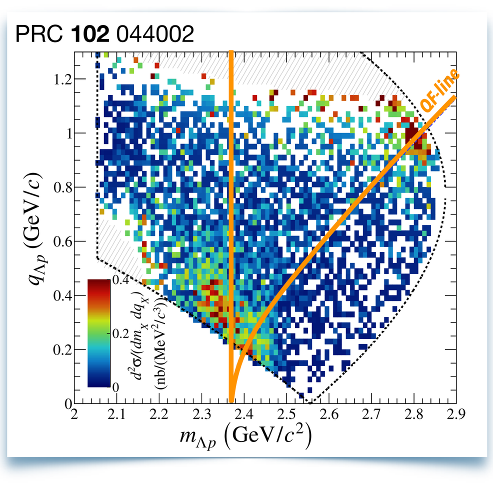
– Results & Discussions –

– Obtained Distributions –

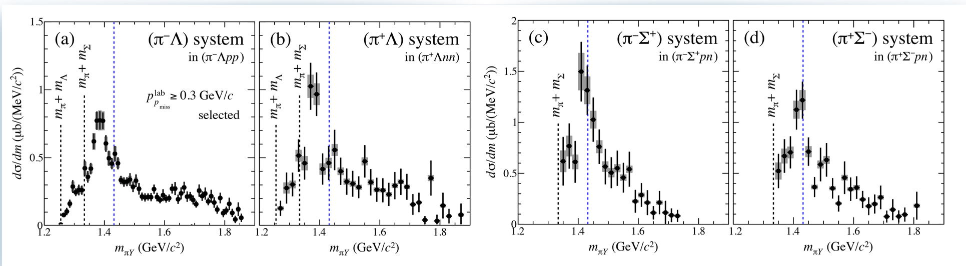
Invariant mass vs. Momentum transfer of πYN



c.f.) $\Lambda p + n'$ channel



Invariant mass of πY

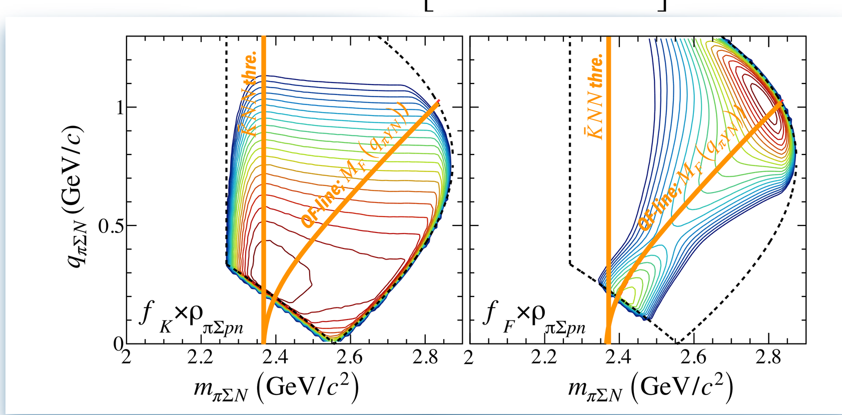


- *2D distributions are quite similar to the $\Lambda p + n'$ channel.*
- *C.S. are ~10 times larger than the $\Lambda p + n'$ channel.*
- *$\pi^\mp\Sigma^\pm$ & $\pi^\pm\Lambda$ are couples to $\Lambda(1405)$ & $\Sigma(1385)$.*

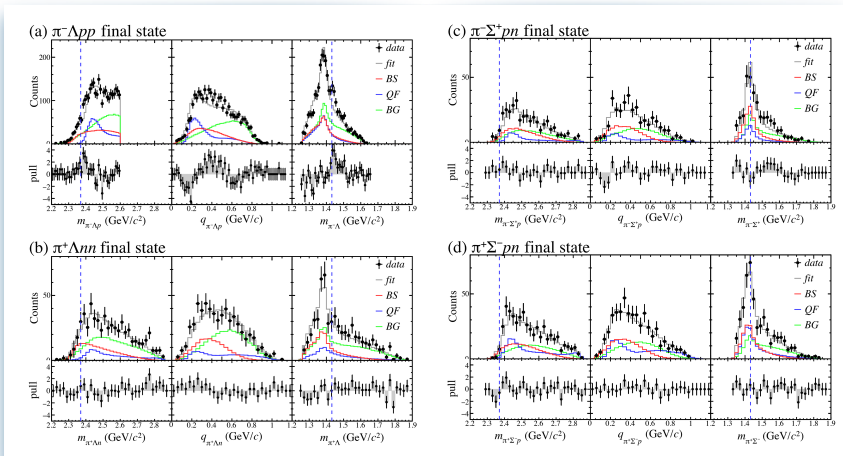
– Spectral Decomposition –

Model functions

- $\bar{K}NN$: $\dfrac{(\Gamma_{\bar{K}NN}/2)^2}{(m_{\pi YN} - M_{\bar{K}NN})^2 + (\Gamma_{\bar{K}NN}/2)^2} \times \exp\left(-\dfrac{q^2_{\pi YN}}{Q^2_{\bar{K}NN}}\right)$
- Quasi-Free: $\exp\left[-\dfrac{\left(m_{\pi YN} - M_F(q_{\pi YN})\right)^2}{\sigma_0 + \sigma_2 q^2_{\pi YN}}\right] \times F(q_{\pi YN})$



Fit result — *Distributions can be explained in common.*



– Branching Ratios of $\bar{K}NN$ –

Decay channel	$\sigma^{tot}_{\bar{K}NN}\,Br$ (μb) All regions	$\sigma^{tot}_{\bar{K}NN}\,Br$ (μb) Below the $\bar{K}$ binding threshold
$\bar{K}NN_{I_3=+1/2}$		
Λp	$9.3 \pm 0.8^{+1.4}_{-1.0}$ [2]	$5.5 \pm 0.5^{+0.8}_{-0.6}$
$\Sigma^0 p$	$5.3 \pm 0.4^{+0.8}_{-0.6}$ [2]	$3.1 \pm 0.2^{+0.5}_{-0.4}$
$\Sigma^+ n^{(*)}$ $(= \Sigma^0 p \times 2)$ *Assuming IsospinSymmetry*	$10.6 \pm 0.8^{+1.6}_{-1.2}$	$6.2 \pm 0.4^{+1.0}_{-0.8}$
total non-mesonic	$25.2 \pm 2.0^{+3.8}_{-2.8}$	$14.8 \pm 1.1^{+2.3}_{-1.8}$
$\pi^0\Lambda p^{(*)}$ $(= \pi^+\Lambda n \times 1/2)$ *Assuming IsospinSymmetry*	$31 \pm 5.5 \pm 4.5$	$7.8 \pm 1.4 \pm 1.1$
$\pi^0\Sigma^0 p$	NA	NA
$\pi^-\Sigma^+ p$	$110 \pm 8 \pm 8$	$9.4 \pm 0.4 \pm 0.7$
$\pi^+\Sigma^- p$	$38 \pm 3 \pm 3$	$3.2 \pm 0.2 \pm 0.2$
$\pi^+\Lambda n$	$62 \pm 11 \pm 9$	$15.5 \pm 2.7 \pm 2.1$
$\pi^+\Sigma^0 n$	NA	NA
$\pi^0\Sigma^+ n$	NA	NA
total mesonic	$> 241 \pm 20 \pm 17$	$> 37.9 \pm 4.1 \pm 3.3$
$\bar{K}NN_{I_3=-1/2}$		
$\pi^-\Lambda p$	$29 \pm 3 \pm 3$	$7.2 \pm 0.6 \pm 0.7$

- $\Gamma_{\pi YN} \sim 10 \times \Gamma_{YN}$
  — *Mesonic branches are dominant.* (*As expected*)
- $\Gamma_{\pi\Sigma N} \sim \Gamma_{\pi\Lambda N}$
  — *Both $I_{\bar{K}N} = 0$ & 1 are significant.* ($I_{\bar{K}N} = 1$ *contributions is larger than expected.*)

The large $\Gamma_{\bar{K}NN}$ would caused by $\Gamma_{\pi\Lambda N}$.

– Summary & Outlook –

Summary We measured differential cross sections of four $K^- + {}^3\mathrm{He} \to \pi YN + N'$ reactions. The $(m_{\pi YN}, q_{\pi YN})$ distributions are quite similar to the $\Lambda p + n'$ channel. The $m_{\pi Y}$ distribution shows πY system couples to the $\Lambda(1405)$ & $\Sigma(1385)$ resonances. The mesonic and non-mesonic distributions can be consistently explained by $\bar{K}NN$ production & QF processes. We evaluated branching ratios of $\bar{K}NN$ by integrating the model distribution. The result indicates that $\bar{K}NN$ is twice as unstable as $\Lambda(1405)$ due to the mesonic $\bar{K}$-absorption in the $I_{\bar{K}N} = 1$ channel.

Outlook We have planned new experiments at the J-PARC Hadron Experimental Facility. The ***J-PARC E80*** aims to search for the next lightest kaonic nucleus $\bar{K}NNN$. The ***J-PARC P89*** aims to search for the "$\bar{K}^0nn$", and to determine J^P of $\bar{K}NN$. A new cylindrical detector system is under construction.