Λ(1405)-*induced Non-mesoinc Decay in Kaonic Nuclei*

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Takayasu Sekihara （*D2, Kyoto Univ.*）

in collaboration with

Daisuke Jido（*YITP*）*and Yoshiko Kanada-En'yo*（*YITP*）

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1. *Introduction*
2. *Elementary* Λ(1405) *N* ─> **Y** *N non-mesonic transitions*
3. *Non-mesonic decay of kaonic nuclei* --- Λ(1405) *doorway processes*
4. *Discussions*
5. *Summary*

1. Introduction

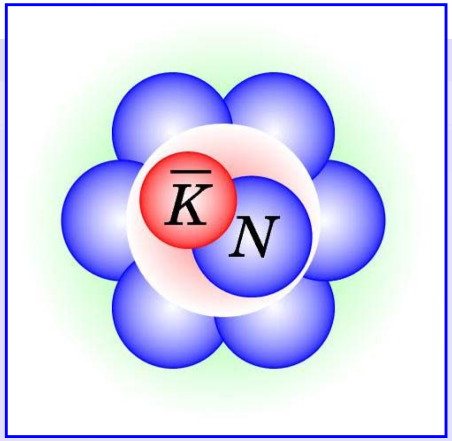
++ Hadrons in nuclei ++

- **The properties of hadrons in nuclei tell us some hints for understanding the dynamics of strong interactions.**

--- Extension of "nuclear force", dynamics in finite density,..

- **Kaonic nuclei**

--- "Strongly" attractive interaction between $\bar{K}N$ may make kaon bound in nuclei.



—> Dynamics of strong interactions including strangeness.

- **Systematic study of decay pattern for kaonic nuclei is desired, since its $\bar{K}$ absorption width is large.**

1. Introduction

++ Non-mesonic decay of kaonic nuclei ++

□ Consider **non-mesonic decay of kaonic nuclei.**

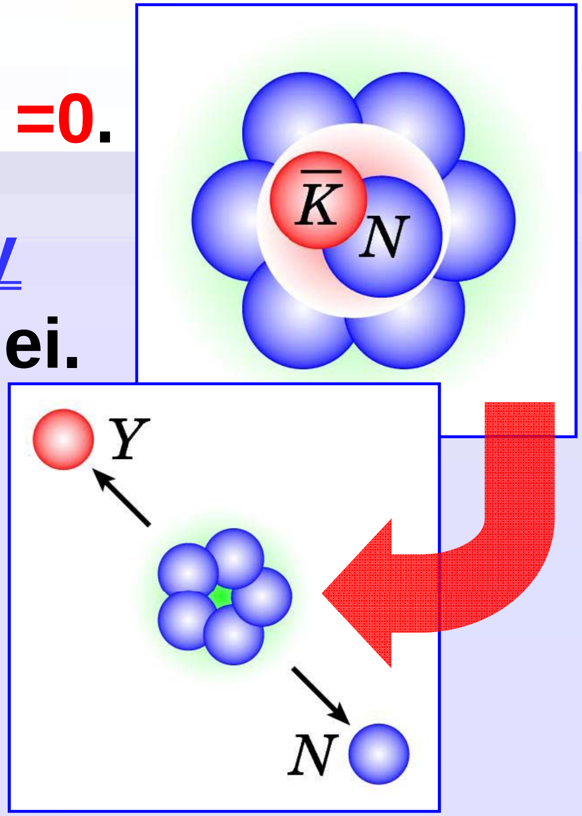
□ **$\Lambda(1405)$ doorway process ($\bar{K}N$ –> $\Lambda(1405)$ –> MB) may be the main one of non-mesonic decay.**

--- $\Lambda(1405)$ (= Λ^*) : $\bar{K}N$ resonant state with I =0.

□ **If $\Lambda^* = \bar{K}N$ quasi-bound state, Λ^* doorway will be more important in the kaonic nuclei.**

--- $\bar{K}N$ correlations in kaonic nuclei.

□ **Decay ratio $\Gamma_{\Lambda N} / \Gamma_{\Sigma N}$ will be independent from the production process.**



2. Elementary $\Lambda(1405)\,N \longrightarrow Y\,N$

++ $\Lambda^* N \longrightarrow Y\,N$ transitions ++

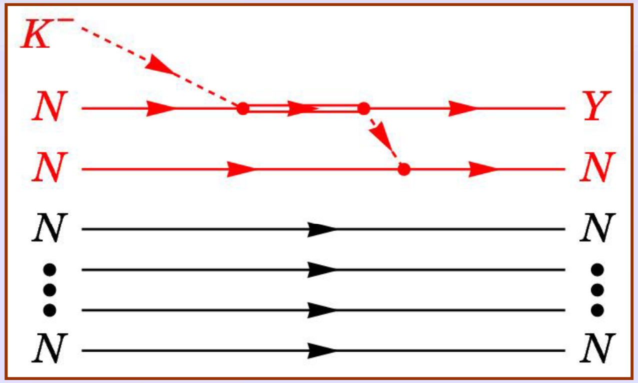
☐ Define **elementary $\Lambda^* N \longrightarrow Y\,N$ ($Y = \Lambda$ or Σ) transiton rate**:

$$\gamma_{YN} \equiv \frac{1}{4} \sum_{\text{spin}} \int d\Phi_2 |T_{YN}|^2 (2\pi)^4 \delta^4(P_{\text{tot}} - P_Y - P_N)$$

--- T_{YN} : $\Lambda^* N \longrightarrow Y\,N$ non-mesonic transition amplitudes,
$d\Phi_2$: phase space of final Y and N.

☐ Here we consider 2 N absorption of $\bar{K}$:
elementary $\Lambda^* N \longrightarrow \Lambda N$, $\Sigma^0 N$, $\Sigma^{\pm} N$
(Λ^* doorway processes).

--- Final N will NOT be affected by
Pauli blocking effects in nuclear medium,
since its momentum is about more than 500 MeV/c.

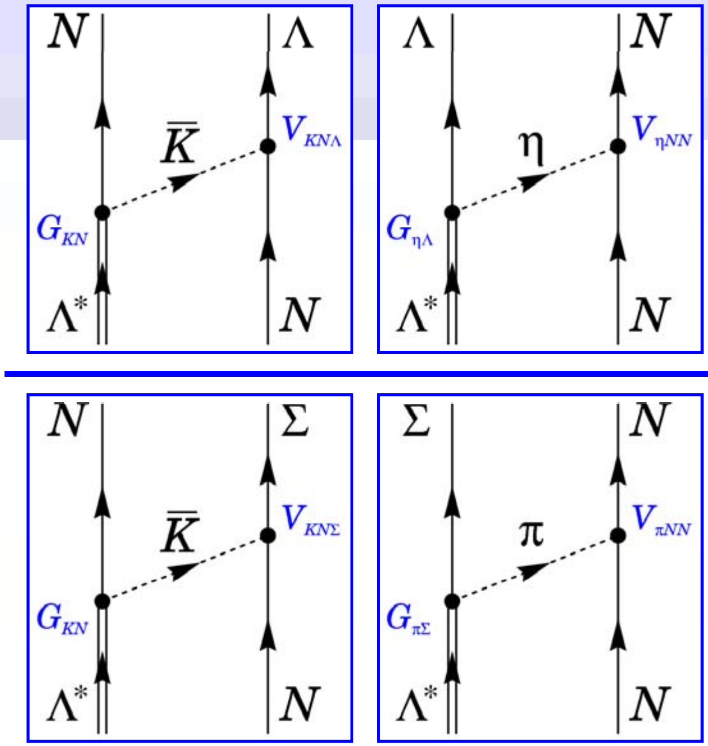


2. Elementary $\Lambda(1405)\,N \longrightarrow Y\,N$

++ $\Lambda^* N \longrightarrow Y\,N$ transitions ++

- We choose **one-meson exchange model** for the non-mesonic $\Lambda^* N \longrightarrow Y\,N$ transition Amp. T_{YN}. (cf. non-mesonic decay of Λ hyper nuclei).

Jido, Oset and Palomar, *Nucl. Phys.* A694 (2001) 525.



: ΛN

: ΣN

- There are 3 parts for the diagrams.

1. **$\Lambda^* MB$ couplings G_{MB} (parameter).**
2. Meson propagators including short-range correlations.
3. MBB three-point interaction V_{MBB} by flavor SU(3) symmetry.

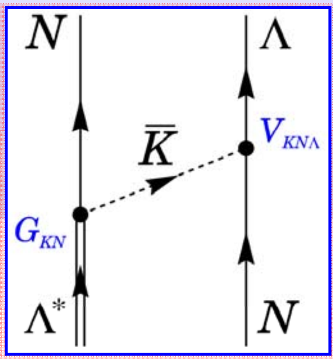
$\longrightarrow$ **Dynamics determined by G_{MB} !**

2. Elementary $\Lambda(1405)\,N \rightarrow Y\,N$

++ Properties of transition rate ++

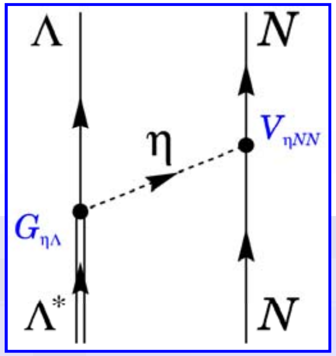
- *MBB* couplings V_{MBB} are determined by the flavor SU(3), with Exp. fits for parameters (*D* and *F*).

ΛN :



$$V_{\bar{K}N\Lambda} \propto \frac{D+3F}{2\sqrt{3}} \simeq 0.63$$

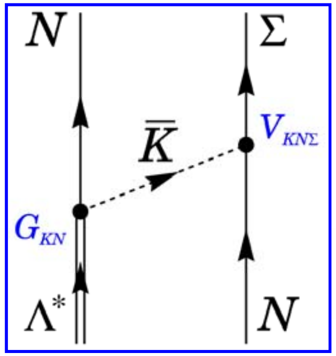
Large contribution.



$$V_{\eta NN} \propto \frac{D-3F}{2\sqrt{3}} \simeq -0.10$$

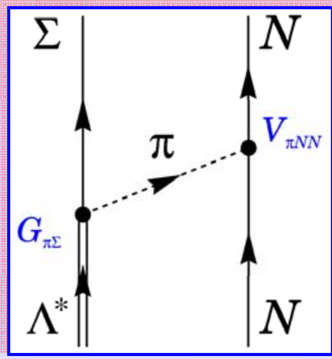
Small contribution.

ΣN :



$$V_{\bar{K}N\Sigma^0} \propto \frac{D-F}{2} \simeq 0.17$$

Small contribution.



$$V_{\pi^0 NN} \propto \frac{D+F}{2} \simeq 0.63$$

Large contribution.

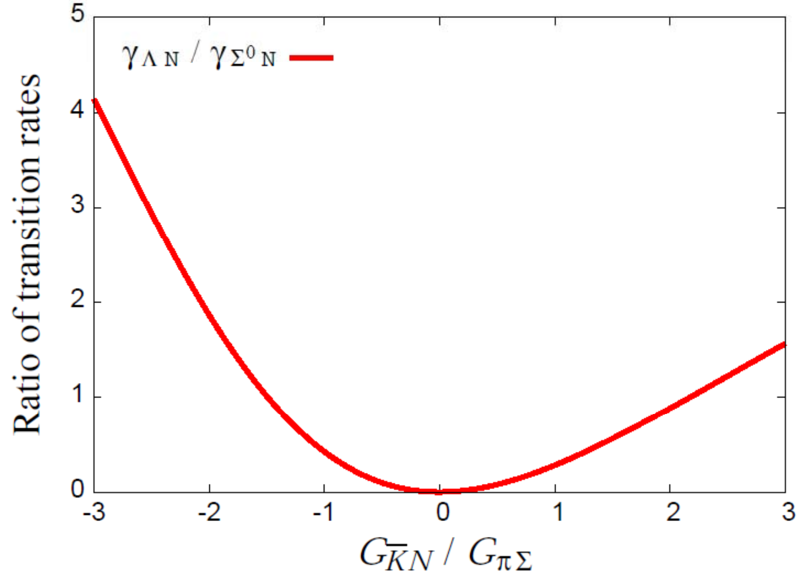
- We expect that **Λ^* couplings G_{KN} , $G_{\pi\Sigma}$ will be important.**

2. *Elementary* $\Lambda(1405)\ N \longrightarrow Y\ N$

++ Properties of transition rate ++

- ☐ What is the general properties of non-mesonic decay ?

  —> Regarding Λ^* coupling ratio G_{KN} / $G_{\pi\Sigma}$ as parameters, plot ratio of the transition rate $\gamma_{\Lambda N} / \gamma_{\Sigma^0 N}$.



- ☐ Both Λ^* and N at rest.
- ☐ M_{Λ^*}= 1420 MeV, $G_{\eta\Lambda}$=0.

--- Sensitive to Λ^* coupling ratio;

Larger G_{KN} / $G_{\pi\Sigma}$ leads to $\Gamma_{\Lambda N} / \Gamma_{\Sigma^0 N}$ ratio enhancement !

2. *Elementary* $\Lambda(1405)\ N$ —> $Y\ N$

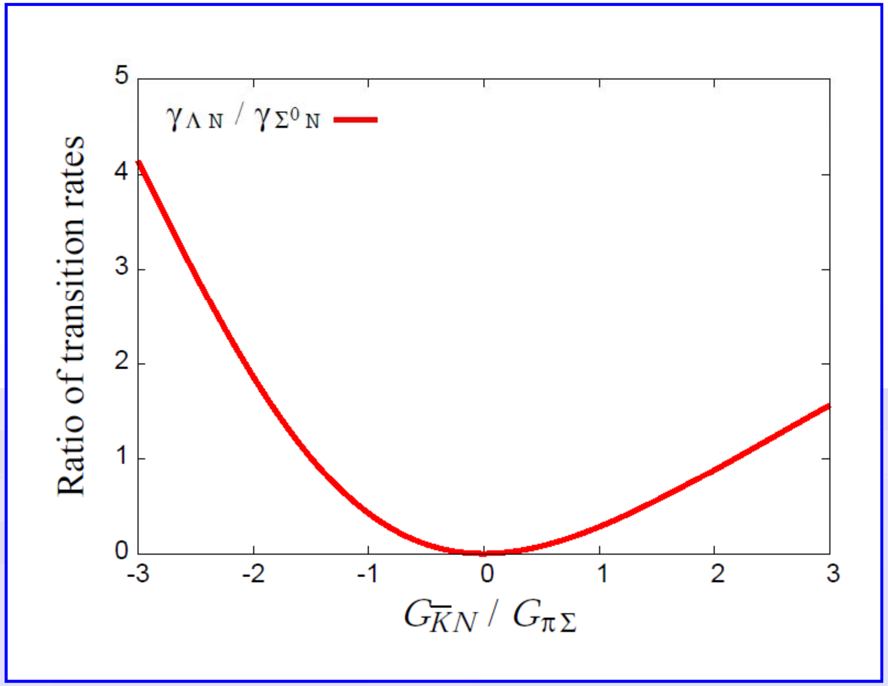
++ Properties of transition rate; Comments ++

- ☐ **Λ* mass dependence is small;** similar result in M_{Λ^*}= 1405 MeV.

- ☐ **Initial momentum (Λ* or N) dependence is also small.**

  <— Due to large phase space of final Y and N, compared with momentum scale ~100 MeV/c.

  —> Similar $\Gamma_{\Lambda N}$ / $\Gamma_{\Sigma^0 N}$ ratio enhancement occur for non-mesonic decay of kaons in finite nuclear density.

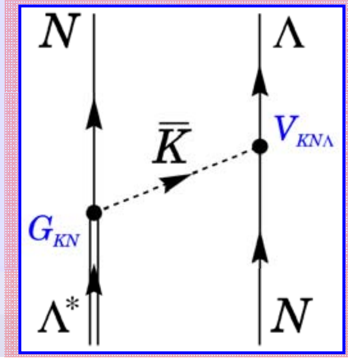


- ☐ **$G_{\eta\Lambda}$ dependence is also small due to small $V_{\eta NN}$.**

2. Elementary Λ(1405) N —> Y N

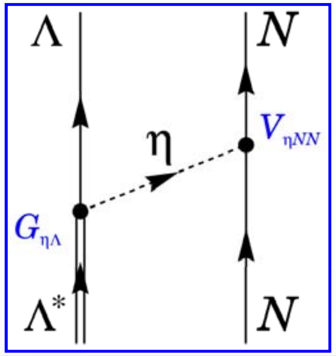
++ Short summary; $\Gamma_{\Lambda N} / \Gamma_{\Sigma^0 N}$ enhancement ++

ΛN :



$$V_{\bar{K}N\Lambda} \propto \frac{D+3F}{2\sqrt{3}} \simeq 0.63$$

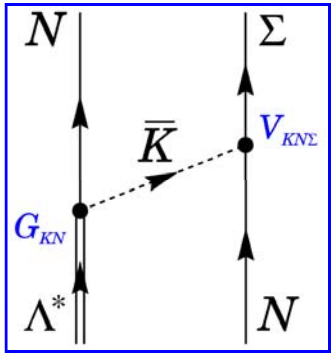
Largest Amp. for large G_{KN}.



$$V_{\eta NN} \propto \frac{D-3F}{2\sqrt{3}} \simeq -0.10$$

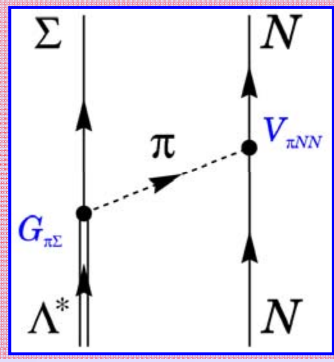
Small contribution.

ΣN :



$$V_{\bar{K}N\Sigma^0} \propto \frac{D-F}{2} \simeq 0.17$$

Small contribution.



$$V_{\pi^0 NN} \propto \frac{D+F}{2} \simeq 0.63$$

Largest Amp. For large $G_{\pi\Sigma}$.

□ **Larger Λ* coupling $G_{KN} / G_{\pi\Sigma}$ <—> $\Gamma_{\Lambda N} / \Gamma_{\Sigma^0 N}$ enhancement !**

3. Non-mesonic decay of kaonic nuclei

++ $\bar{K}N$ system in finite nuclear density ++

□ **Non-mesonic decay width of kaonic nuclei:**

$$\Gamma_{YN}(k_F) = \int^{k_F} \gamma_{YN}(k_i)$$

--- γ_{YN} : non-mesonic transition rate ($\Lambda^* N$ —> $Y N$),
Fermi gas approximation for the initial N (nuclear matter).

□ **Chiral unitary approach gives Λ^*-induced $\bar{K}N$ —> MB Amp.**

$T^{\chi}_{\bar{K}N \to MB}$: $\bar{K}N$ —> Λ^* —> MB process.

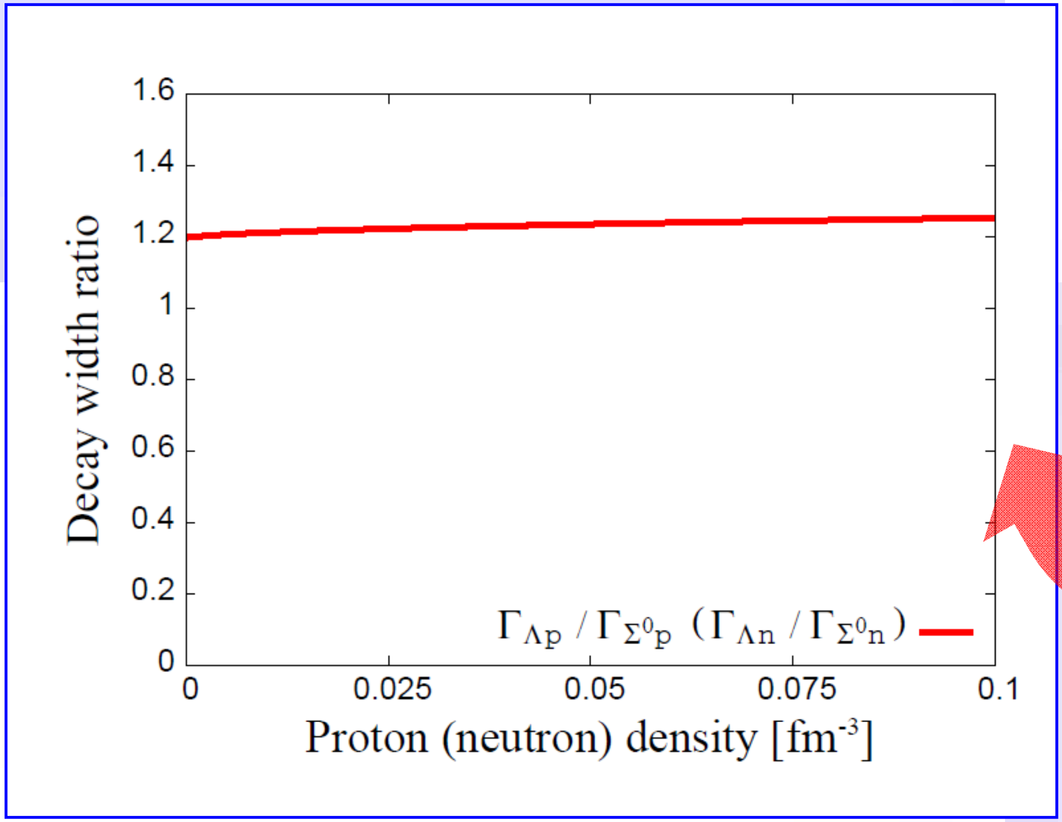
—> **Ratio of transition $T^{\chi}_{\bar{K}N \to MB}$ at Λ^* peak (=1420 MeV) is equal to $\Lambda^* MB$ coupling ratio**, as a good approximation:

$$\frac{G_{\bar{K}N}}{G_{\pi\Sigma}} = \left. \frac{T^{\chi}_{\bar{K}N\to\bar{K}N}(W)}{T^{\chi}_{\bar{K}N\to\pi\Sigma}(W)} \right|_{W=1420\,\mathrm{MeV}}, \quad \frac{G_{\bar{K}N}}{G_{\eta\Lambda}} = \left. \frac{T^{\chi}_{\bar{K}N\to\bar{K}N}(W)}{T^{\chi}_{\bar{K}N\to\eta\Lambda}(W)} \right|_{W=1420\,\mathrm{MeV}}$$

3. Non-mesonic decay of kaonic nuclei

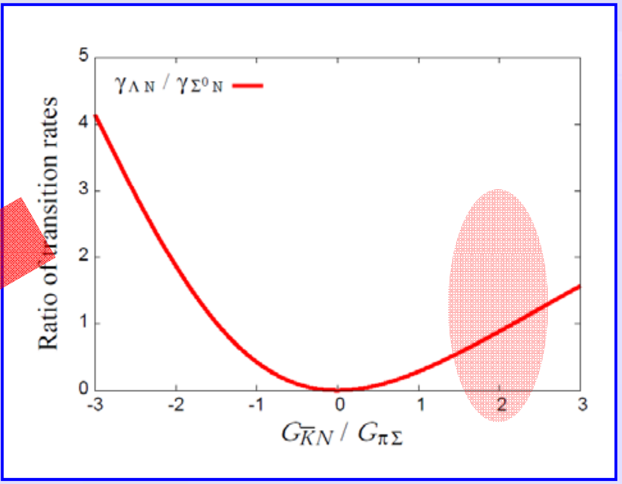
++ Branching ratio vs. baryon density ++

- **Plot branching ratio $\Gamma_{\Lambda N}$ / $\Gamma_{\Sigma^0 N}$ vs. nucleon density.**



- **$\Gamma_{\Lambda N}$ / $\Gamma_{\Sigma^0 N}$ ~ 1.2 in chiral unitary approach.**

  --- Large G_{KN} / $G_{\pi\Sigma}$.



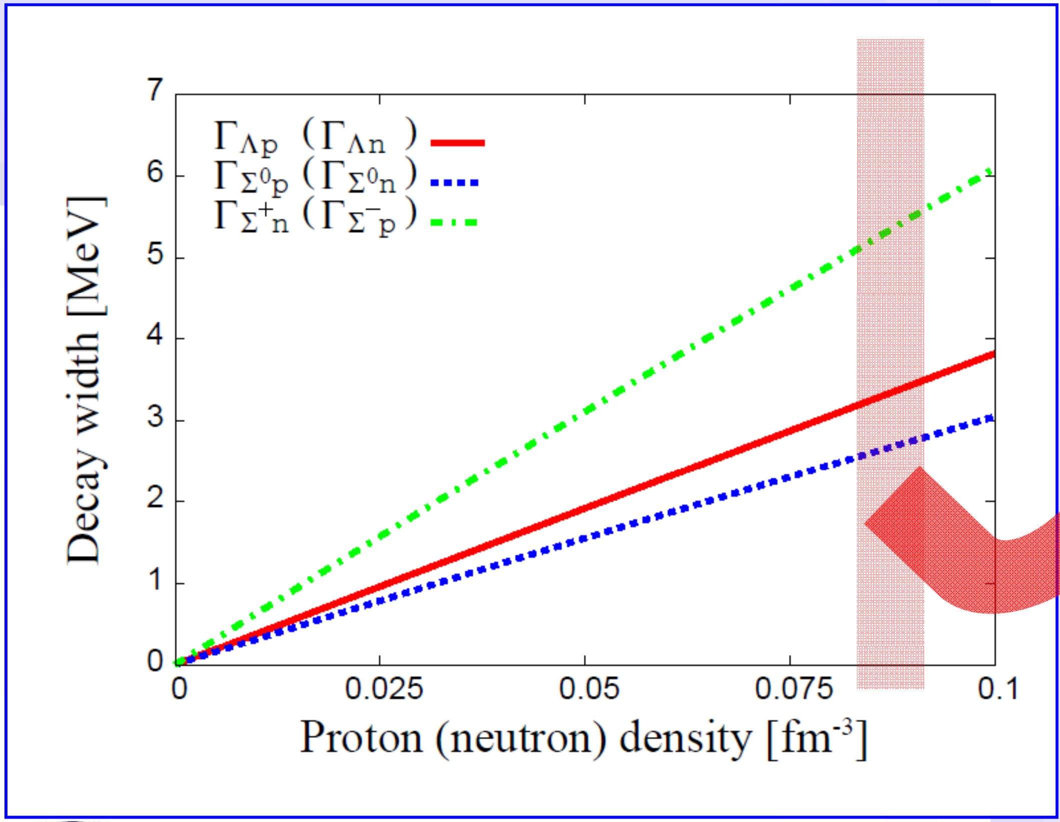
- **Large phase space**

  —> Independence from ρ.

3. Non-mesonic decay of kaonic nuclei

++ Value of non-mesonic decay width ++

- $\Gamma_{\Lambda^* \to \pi\Sigma}$ = 40 MeV (obtained from chiral unitary approach) <—> $|G_{\pi\Sigma}|$ =0.78 at Λ^* peak position (=1420 MeV).

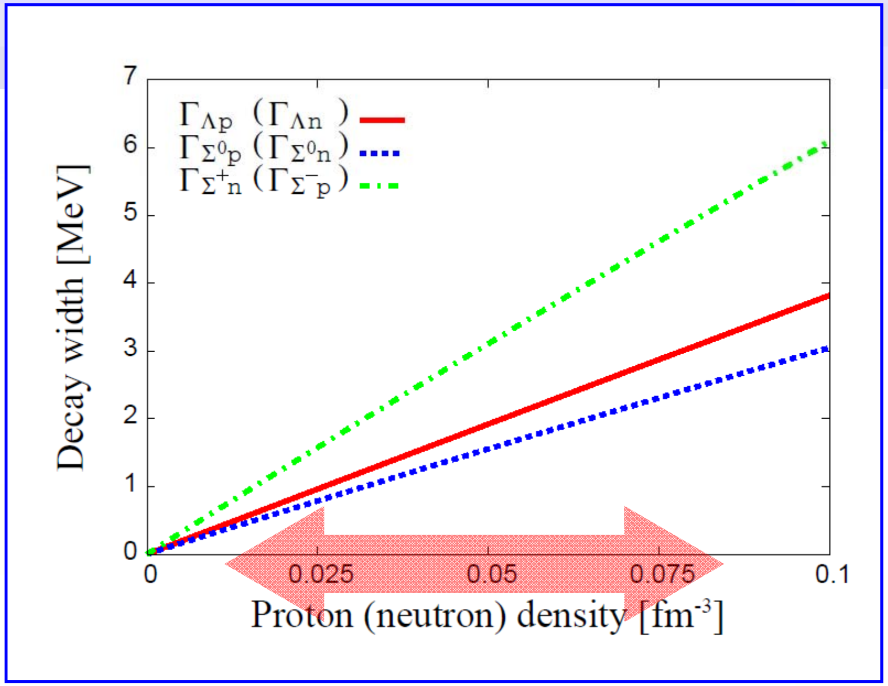


- Estimate **absolute value of non-mesonic decay**.
- **Total non-mesonic decay width = 22 MeV at the saturation density**
  ($\Gamma_{\Lambda N}$ = 7 MeV, $\Gamma_{\Sigma^0 N}$ = 5 MeV, $\Gamma_{\Sigma^\pm N}$ = 10 MeV).
  --- About half of $\Lambda^* \to \pi\Sigma$.

4. Discussions

++ Non-mesonic decay width of $\bar{K}NN$ ++

- **In our approach the non-mesonic decay width of $\bar{K}NN$ can roughly be estimated if density between NN is known (in the Ansatz that $\bar{K}N$ is Λ^* in the $\bar{K}NN$).**



--- Density between NN relates to non-mesonic decay width.

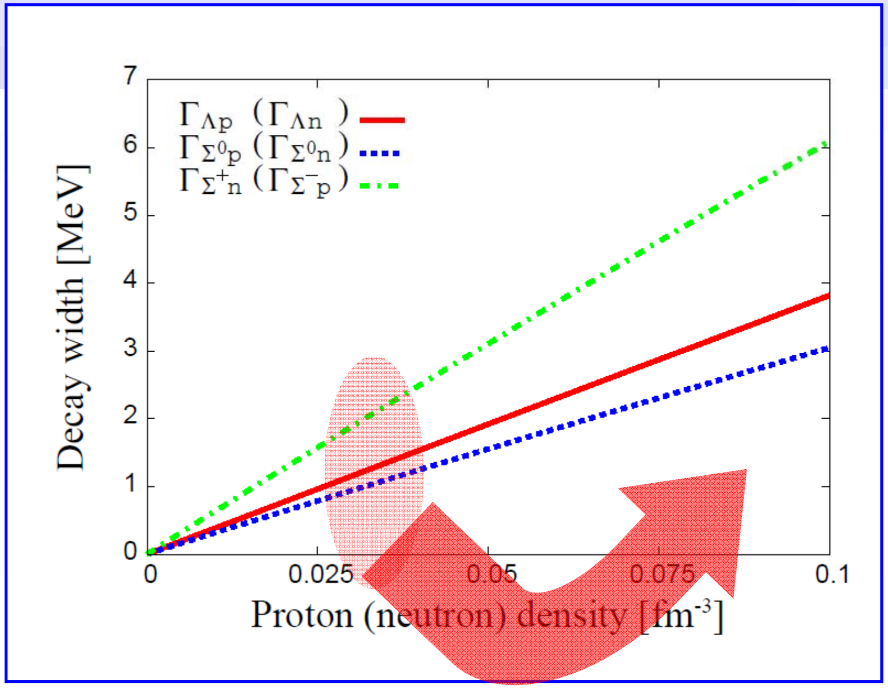
4. Discussions

++ Non-mesonic decay width of $\bar{K}NN$ ++

- ☐ **Examine our results in comparison with non-mesonic decay width of $\bar{K}NN$ in other approach.**

--- Dote-Hyodo-Weise estimates non-mesonic decay width = 4 ~ 12 MeV for $K^{-}pp$ system, with prediction of 0.03 fm^{-3} as the maximum NN density.

Dote, Hyodo, Weise, *Phys. Rev.* C79 (2009) 014003.



- ☐ **Our approach indicates total width ~ 5 MeV at 0.03 fm^{-3}.**

—> Consistent results!

5. Summary

++ Summary ++

- We investigate **non-mesonic decay of kaonic nuclei** with one-meson exchange **under the $\Lambda(1405)$ doorway process**.

- Branching ratio $\Gamma_{\Lambda N} / \Gamma_{\Sigma 0 N}$ is sensitive to Λ^* couplings.
  --- **Larger $G_{KN} / G_{\pi\Sigma}$ $\longleftrightarrow$ $\Gamma_{\Lambda N} / \Gamma_{\Sigma 0 N}$ enhancement.**

- Using chiral unitary approach we obtain branching ratio **$\Gamma_{\Lambda N} / \Gamma_{\Sigma 0 N} \sim 1.2$** for non-mesonic decay of kaonic nuclei.

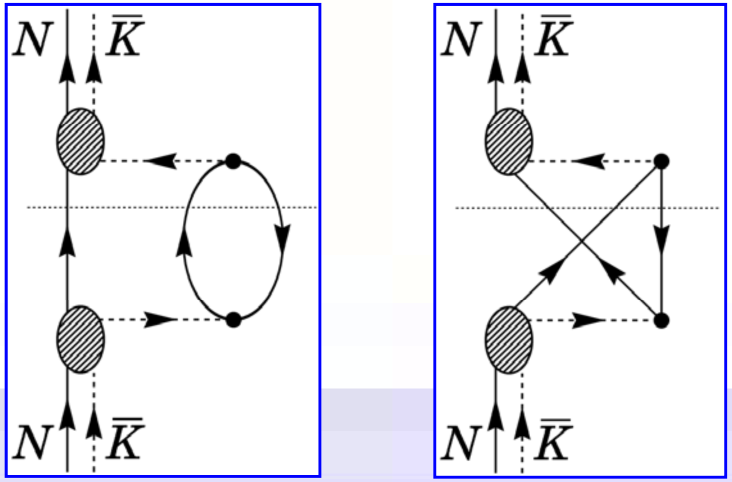
- **Total non-mesonic decay width is about 22 MeV** at saturation density. --- About half of $\Lambda^* \to \pi\Sigma$ decay width.

- Consistent width for $\bar{K}NN$ system with Dote-Hyodo-Weise.

5. Summary

++ Future plan ++

- ☐ 2 N absorption potential for $\bar{K}$
  --- We can evaluate (imaginary) potential in the same approach.
  - ^{3}He (K^{-}, n) $K^{-}pp$ reaction. (poster by Yamagata-Sekihara).



- ☐ In-medium effects on hadrons, such as by RPA Approx.
- ☐ $\bar{K}$ absorption by deuteron —> We can see Λ^* properties?

Thank you very much
for your kind attention.

Λ(1405)-*induced Non-mesoinc Decay in Kaonic Nuclei*