DN interaction and DNN bound state

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Conventions for heavy mesons

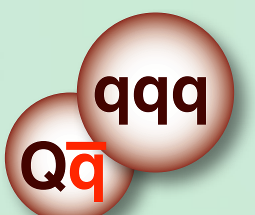
Convention of quantum number of quarks

strange	charm	bottom
S = -1	C = +1	B = -1

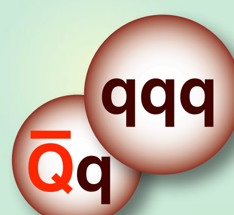
Heavy-light mesons: bar for negative flavor-ness (q~u,d)

with $\bar{q}$	$\bar{K}$ ($s\bar{q}$)	D ($c\bar{q}$)	$\bar{B}$ ($b\bar{q}$)
with q	K ($\bar{s}q$)	$\bar{D}$ ($\bar{c}q$)	B ($\bar{b}q$)

DN <--> $\bar{K}$N : non-exotic
light quark annihilation

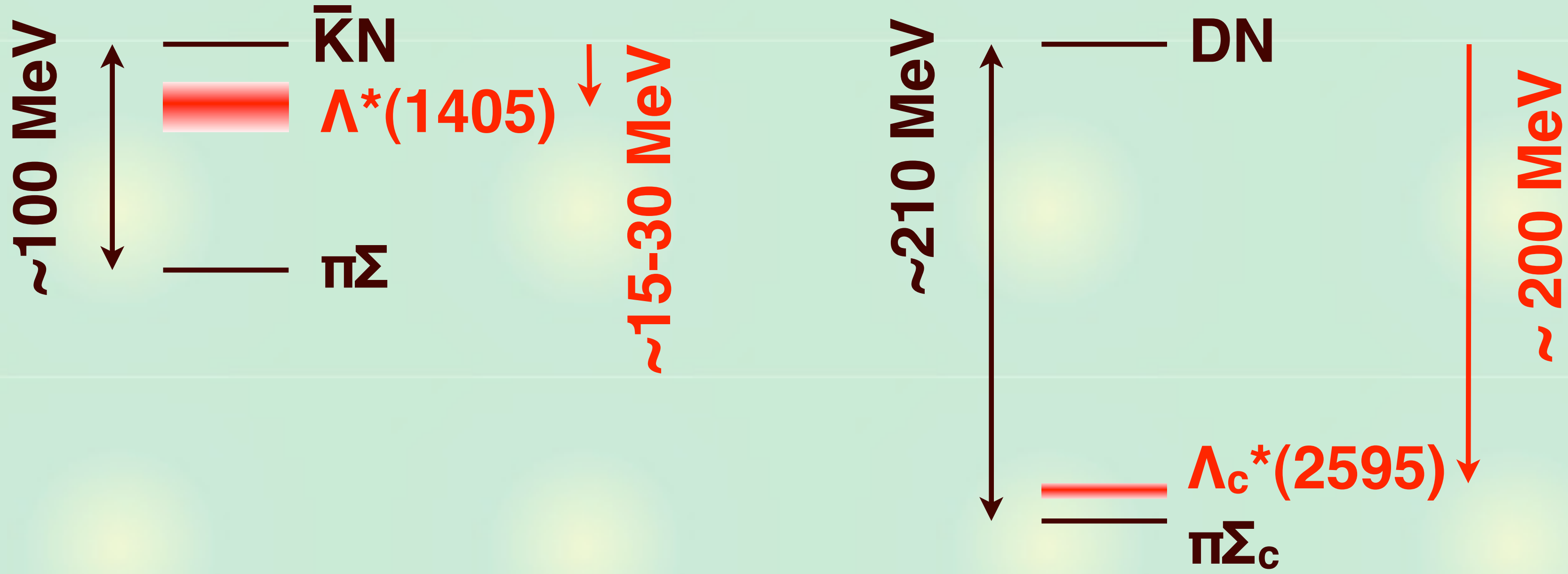


$\bar{D}$N <--> KN : exotic
Θ+, Yasui-Sudoh



Why DN and DNN?

Comparison with $\bar{K}N$ system in I=0 channel



- large mass splitting between DN and $\pi\Sigma_c$
- negative parity Λ_c^*, analogously with Λ(1405)
- small phase space --> narrow width of Λ_c^*

Λ*: a $\bar{K}N$ bound state in the πΣ continuum --> $\bar{K}$ nuclei

Λ_c^*: a DN bound state in the $\pi\Sigma_c$ continuum --> D nuclei?

Validity of the DN bound state picture

Can Λ_c^* (with strong binding) be a DN bound state?

- **D (1867 MeV) is heavier than $\bar{K}$ (496 MeV)**
  Kinetic energy is suppressed.
  If the $\bar{K}N$ system develops a quasi-bound state Λ(1405), with the same interaction, DN bounds more strongly.

- **vector meson exchange picture leads to the stronger DN interaction than $\bar{K}N$**

$$\frac{V_D}{V_K} = \frac{m_D}{m_K} \sim 3.8$$ **(next slide)**

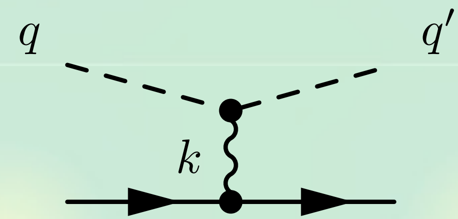
DN system should generate a strongly bound state: Λ_c^*.

Vector meson exchange for DN

DN ($\bar{K}$N) interaction in vector meson exchange

$$
\begin{aligned}
V \sim & g\bar{u}\gamma^{\mu}u \times \frac{1}{k^2 - m_v^2}\left[g_{\mu\nu} - \frac{k_\mu k_\nu}{m_v^2}\right] \times g(q+q')^{\nu} \\
\to & -\bar{u}\gamma^{\mu}u\frac{g^2}{m_v^2}g_{\mu\nu}(q+q')^{\nu} \quad (k \ll m_v) \\
= & -\frac{1}{2f^2}\bar{u}(\not{q} + \not{q}')u \quad \text{(KSRF relation)} \\
\to & -\frac{1}{2f^2}(\omega + \omega') \quad \text{(nonrel. leading)} \\
= & -\frac{m}{f^2} \quad \text{(at threshold)}
\end{aligned}
$$

<-- (Weinberg-Tomozawa term)



Interaction is proportional to the meson mass at threshold.

$$\frac{V_D}{V_K} = \frac{m_D}{m_K} \sim 3.8$$

DN interaction is about four times stronger than $\bar{K}$N

Application to DNN system

We construct the DN effective potential in the DN bound picture for Λ_c^*, and apply the potential to the DNN system

Pro

- Potential is strongly attractive.
  --> easy to produce a bound state in nuclei
- Imaginary part of the DN potential is smaller than $\bar{K}N$.
  --> good feature for the variational three-body calculation

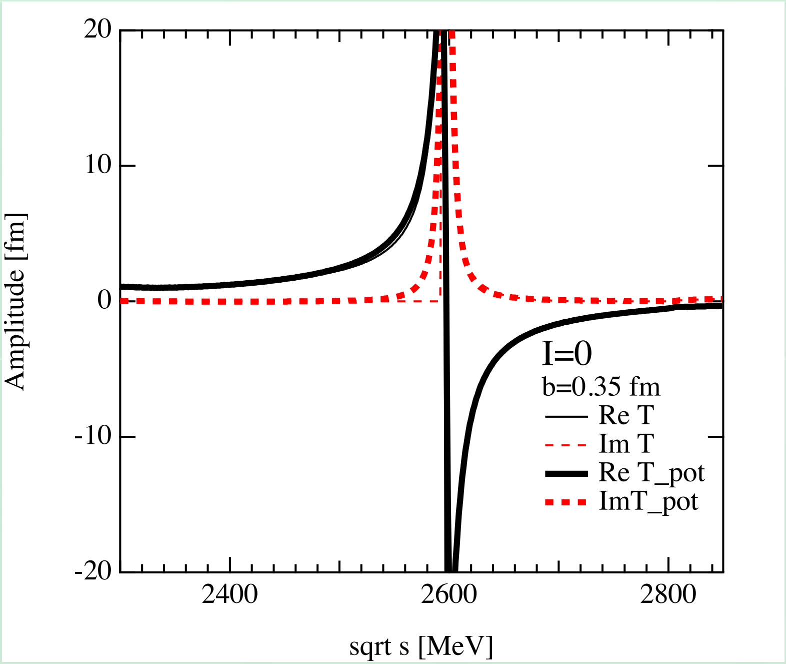
Contra

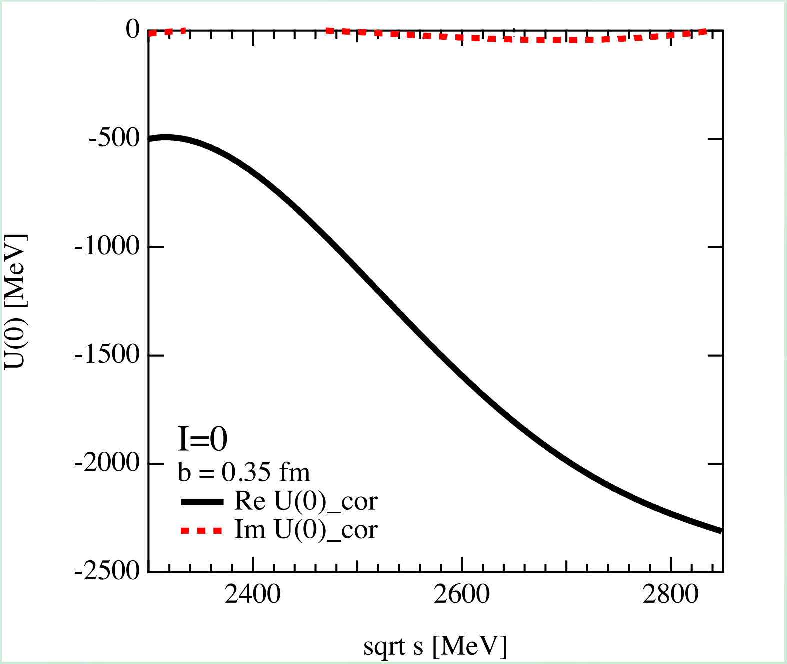
- DN binding energy may be too large.
  --> potential picture valid?
- Experimental information is poorer than $\bar{K}N$
  --> only the mass of Λ_c^* is known

DN local potential

Coupled-channel DN scattering amplitude

T. Mizutani, A. Ramos, Phys. Rev. C74, 065201 (2006)





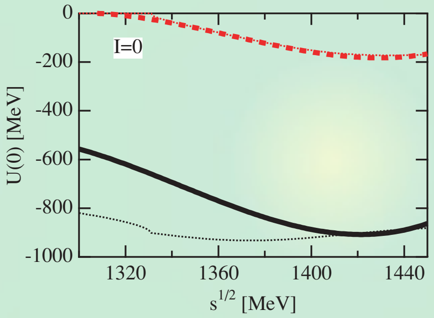
Equivalent local potential

T. Hyodo, W. Weise, Phys. Rev. C77, 035204 (2008)

$$U(r,E) = \frac{1}{2\tilde{\omega}}\frac{M_N}{\sqrt{s}}V^{\rm eff}(\sqrt{s})\frac{1}{\pi^{3/2}b^3}e^{-r^2/b^2}$$

$$= U(r=0,E)e^{-r^2/b^2}$$

c.f. $\bar{K}N$ case

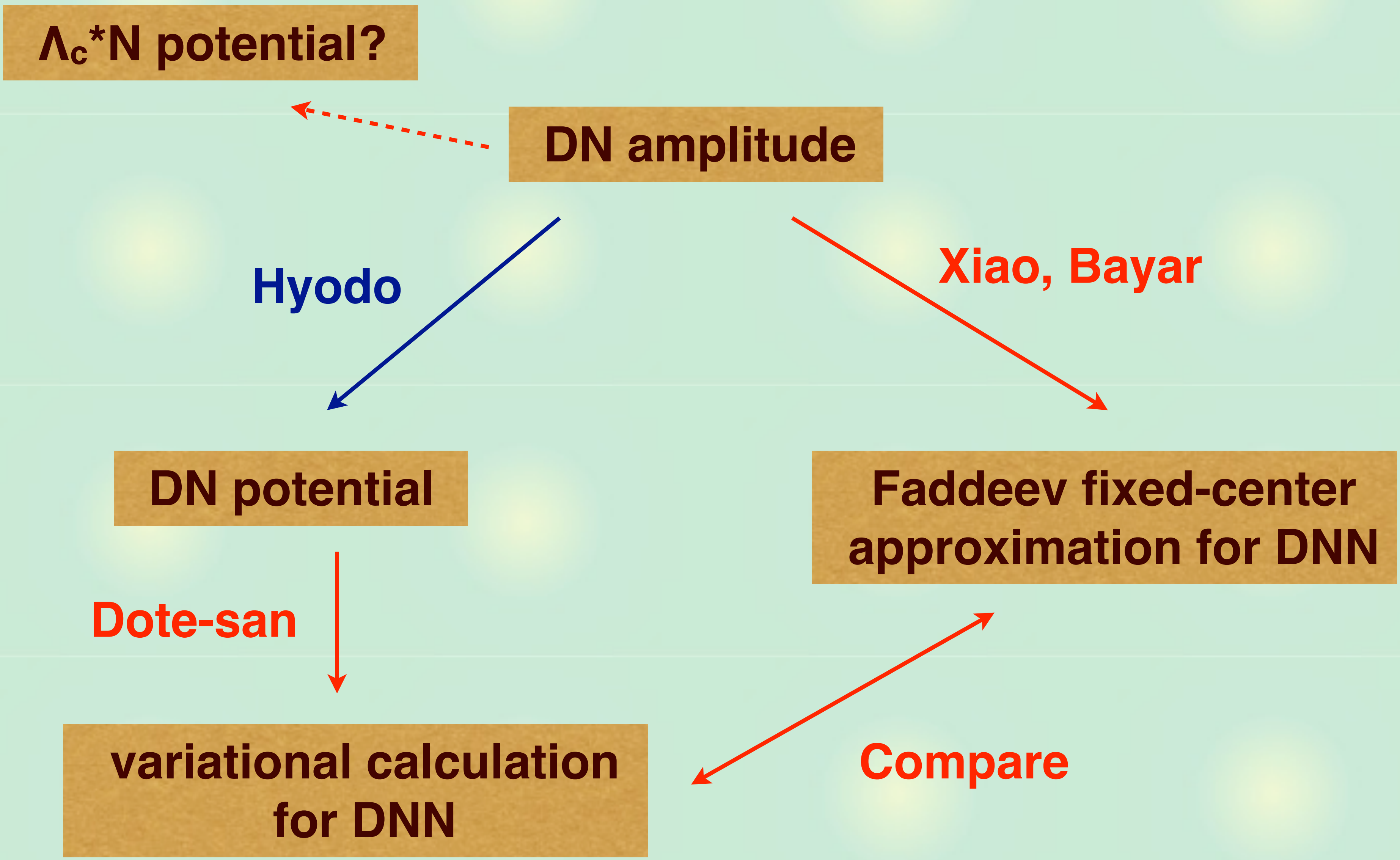


Summary

We study the DN interaction and DNN system

- Regarding Λ_c^* as a DN quasi-bound state, we construct a DN potential.
- D is heavy; we expect stronger binding with nucleon(nuclei) than $\bar{K}$ case.
- From the coupled-channel amplitude, equivalent DN potential is constructed.
- Potential has strong energy dependence.

Strategy


Λ_c*N potential?
DN amplitude
Hyodo
Xiao, Bayar
DN potential
Faddeev fixed-center approximation for DNN
Dote-san
variational calculation for DNN
Compare

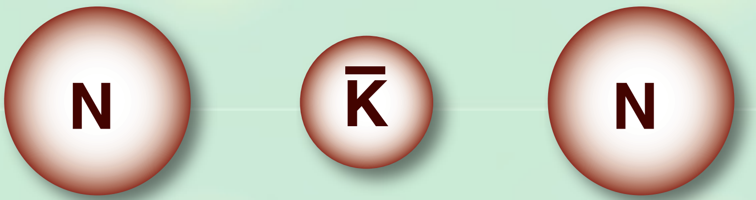
Expected structure of DNN

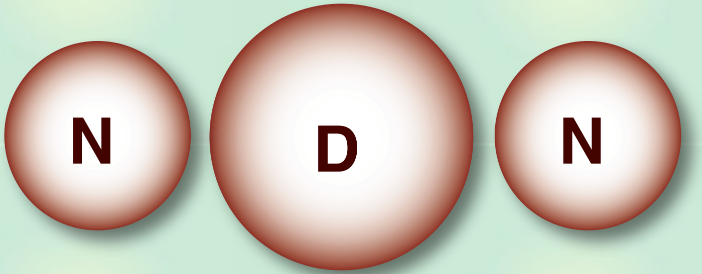
Binding energy of the DN system is 200 MeV.
Do we have DNN with 400 MeV binding?

- **No, because of the NN repulsion at short distance and strong energy dependence of the DN potential strength.**

KNN: K-migration picture

T. Yamazaki, Y. Akaishi, Phys. Rev. C76, 045201 (2007)





Interesting structure?