$\bar{K}N$ interaction based on chiral SU(3) dynamics


Tetsuo Hyodo[a,b]

and Wolfram Weise[a]

TU München[a]   YITP, Kyoto[b]

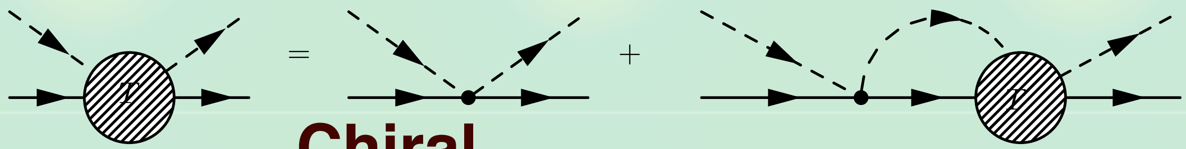
2008, Mar. 24th

Chiral unitary approach

S = -1, $\bar{K}N$ s-wave scattering : Λ(1405) in I=0

- ○ Interaction <-- chiral symmetry
- ○ Amplitude <-- unitarity (coupled channel)

$$T = \frac{1}{1 - VG} V$$



Chiral
(WT interaction)

cutoff
(subtraction
constant)

N. Kaiser, P. B. Siegel, W. Weise, Nucl. Phys. A594, 325 (1995)
E. Oset, A. Ramos, Nucl. Phys. A635, 99 (1998)
J. A. Oller, U. G. Meissner, Phys. Lett. B500, 263 (2001)
M.F.M. Lutz, E. E. Kolomeitsev, Nucl. Phys. A700, 193 (2002),
.... many others

strong attraction (<- chiral)
bound state below threshold

➡ **non-perturbative framework**

Effective interaction based on chiral SU(3) dynamics

Result of chiral dynamics --> single channel potential

Coupled-channel BS $T_{ij}(\sqrt{s})$
+ real interaction $V_{ij}(\sqrt{s})$

(exact)

Single-channel BS $T^{\text{eff}}(\sqrt{s}) = T_{ii}(\sqrt{s})$
+ complex interaction $V^{\text{eff}}(\sqrt{s})$

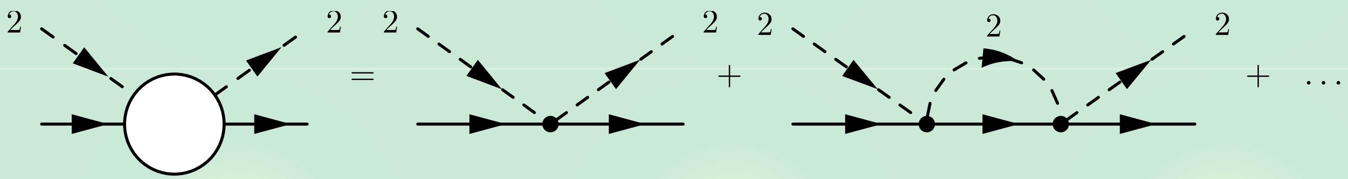
(approximate)

Schrödinger equation $f^{\text{eff}}(\sqrt{s}) \sim T^{\text{eff}}(\sqrt{s})$
+ local potential
complex, energy-dependent $U^{\text{eff}}(r, \sqrt{s})$

few-body kaonic nuclei

Construction of the single channel interaction

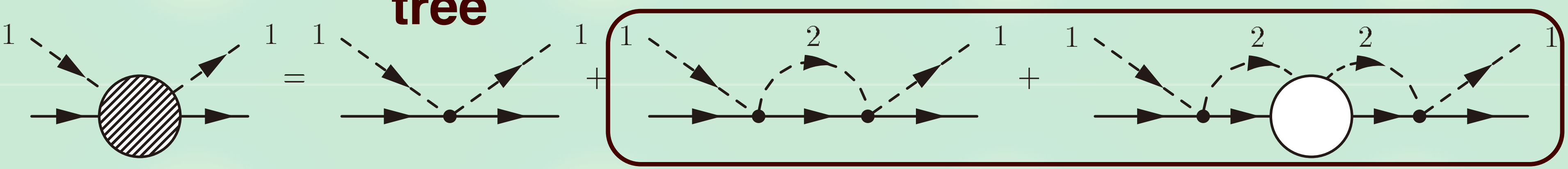
Channels 1 and 2 --> effective int. in 1



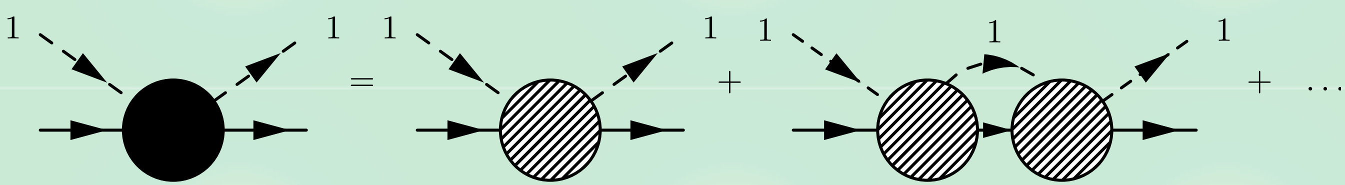
$$T_{22}^{\text{single}} = V_{22} + V_{22}G_2T_{22}^{\text{single}}$$

effect of channel 2

tree



$$V^{\text{eff}} = V_{11} + V_{12}G_2V_{21} + V_{12}G_2T_{22}^{\text{single}}G_2V_{21}$$

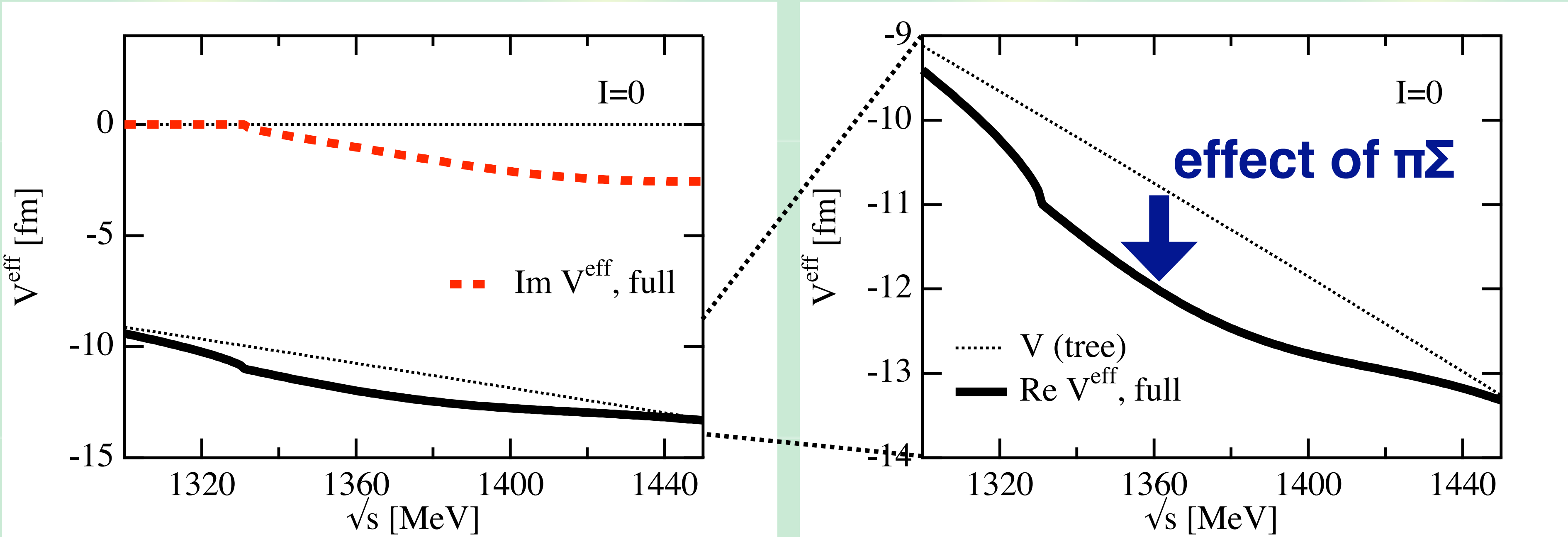


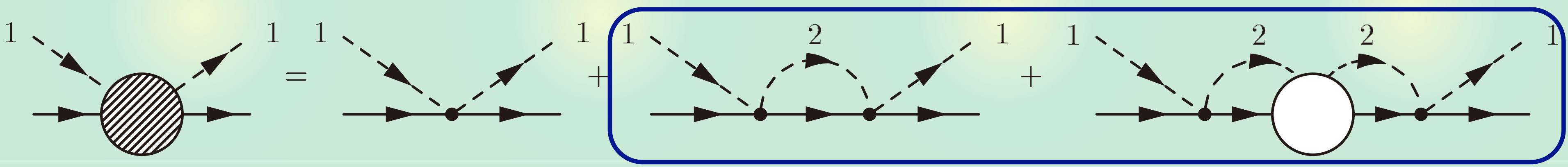
single channel

$$T_{11} = T^{\text{eff}} = V^{\text{eff}} + V^{\text{eff}}G_1T^{\text{eff}}$$

Equivalent to the coupled-channel equations

Single channel $\bar{K}N$ interaction with $\pi\Sigma$ dynamics

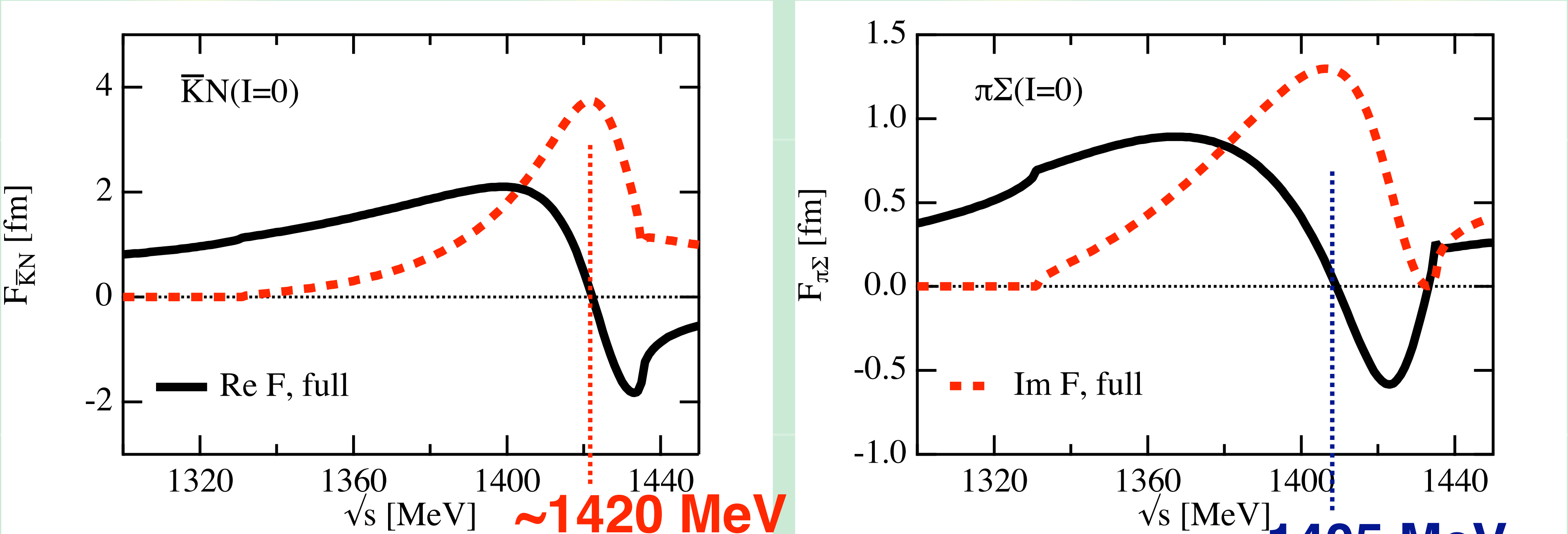




Strength : comparable with the WT term

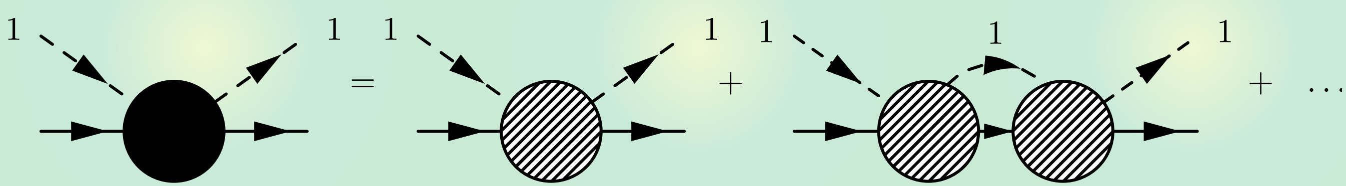
~1/2 of phenomenological (AY) potential

Scattering amplitude in $\bar{K}N$ and $\pi\Sigma$



~1420 MeV

~1405 MeV
Experiment



Resonance in $\bar{K}N$: around 1420 MeV

<-- two-pole structure (coupled-channel)

Binding energy : B = 15 MeV <--> 30 MeV

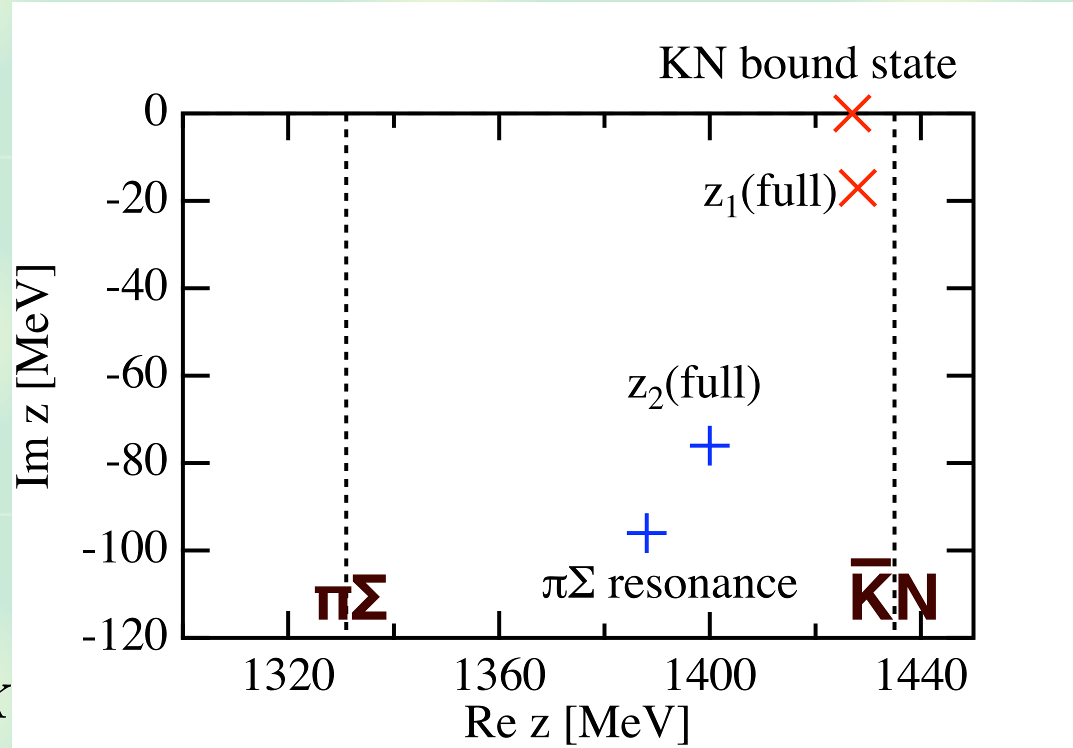
Origin of the two-pole structure

Chiral interaction

$$V_{ij} = -C_{ij}\frac{\omega_i + \omega_j}{4f^2}$$

$$C_{ij} = \begin{array}{cc} \bar{K}N & \pi\Sigma \\ \end{array}$$
$$C_{ij} = \begin{pmatrix} 3 & -\sqrt{\frac{3}{2}} \\ -\sqrt{\frac{3}{2}} & 4 \end{pmatrix}$$

$$\omega_i \sim m_i, \quad 3.3 m_\pi \sim m_K$$



Very strong attraction in $\bar{K}$N (**higher energy**) --> **bound state**
Strong attraction in πΣ (**lower energy**) --> **resonance**

Two poles
: natural consequence of chiral interaction

Comparison with phenomenological potential

Chiral interaction

$$V_{ij} = -C_{ij}\frac{\omega_i + \omega_j}{4f^2}$$

$$C_{ij} = \begin{array}{cc} \bar{K}N & \pi\Sigma \end{array}$$
$$C_{ij} = \begin{pmatrix} 3 & -\sqrt{\frac{3}{2}} \\ -\sqrt{\frac{3}{2}} & 4 \end{pmatrix}$$

phenomenological

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

$$\begin{array}{cc} \bar{K}N & \pi\Sigma \end{array}$$
$$v_{ij}(r) \sim -\begin{pmatrix} 436 & 412 \\ 412 & 0 \end{pmatrix} g(r)$$

Absence of πΣ diagonal coupling

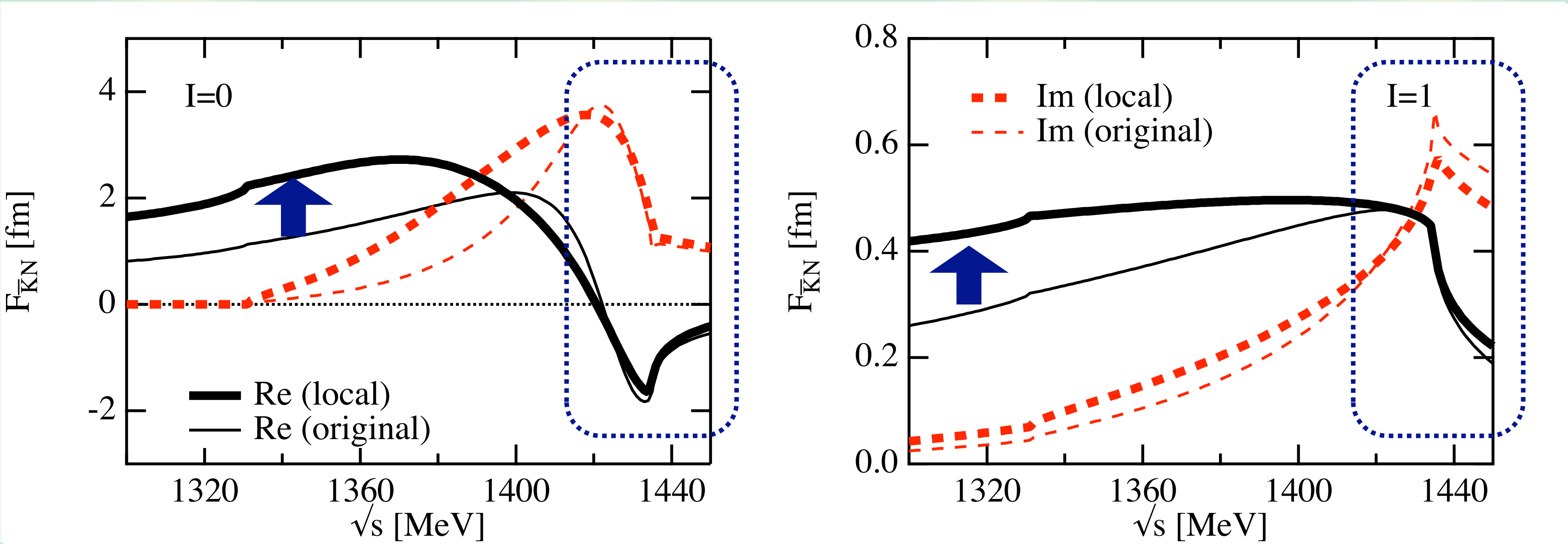
--> absence of πΣ dynamics, resonance

--> strong (×2) attractive interaction in $\bar{K}$N

πΣ -> πΣ attraction : flavor SU(3) symmetry

energy dependence : derivative coupling

$\bar{\mathrm{K}}$N amplitude with local potential



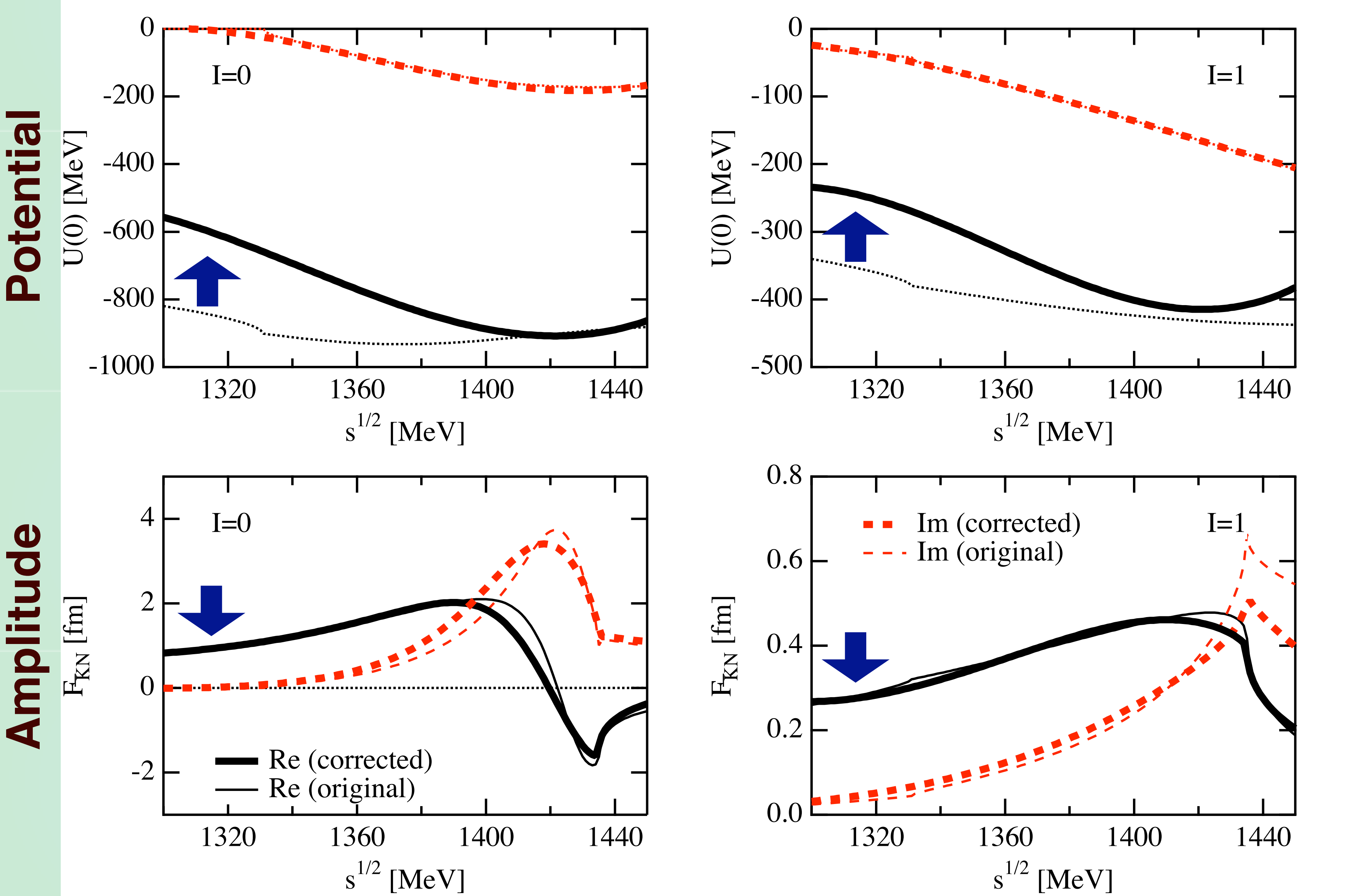
$$U(r,\sqrt{s}) = \frac{M_N V^{\mathrm{eff}}(\sqrt{s})}{2\sqrt{s}\tilde{\omega}(\sqrt{s})} g(r) \qquad g(r) = \frac{e^{-r^2/b^2}}{\pi^{3/2}b^3}$$

$b = 0.47$ fm **: to reproduce the resonance**

agreement around threshold : OK

Deviation at lower energy :
BS eq. <--> local potential + Schrödinger eq.

Correction of the strength of the potential



Summary : $\bar{K}N$ interaction

We derive the single-channel local potential based on chiral SU(3) dynamics.

- Resonance structure in $\bar{K}N$ appears at around **1420 MeV** <-- two-pole Λ(1405). The strength of the $\bar{K}N$ interaction is **comparable with the WT term**.
- Two poles are the consequence of **two attractive interactions in $\bar{K}N$ and πΣ**.
- Local (non-rel) potential **overestimates** amplitude at lower energy.

T. Hyodo, W. Weise, 0712,1613 [nucl-th], Phys. Rev. C, in press.