Construction of $\bar{K}N$ potential based on chiral unitary approach

Kenta Miyahara , Tetsuo Hyodo

Kyoto Univ. YITP

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Motivation

Λ(1405) ⟺ quasi bound state of **$\bar{K}$N**

cf. Y. Akaishi and T. Yamazaki, Phys. Rev. C 65, 044005 (2002)
T. Hyodo and D. Jido, Prog. Part. Nucl. Phys. 67, 55 (2012)

⇓

$\bar{K}$N interaction is **strongly attractive**

⇒ interesting phenomena of **few body systems**

to calculate few body systems

we need $\bar{K}$N potential

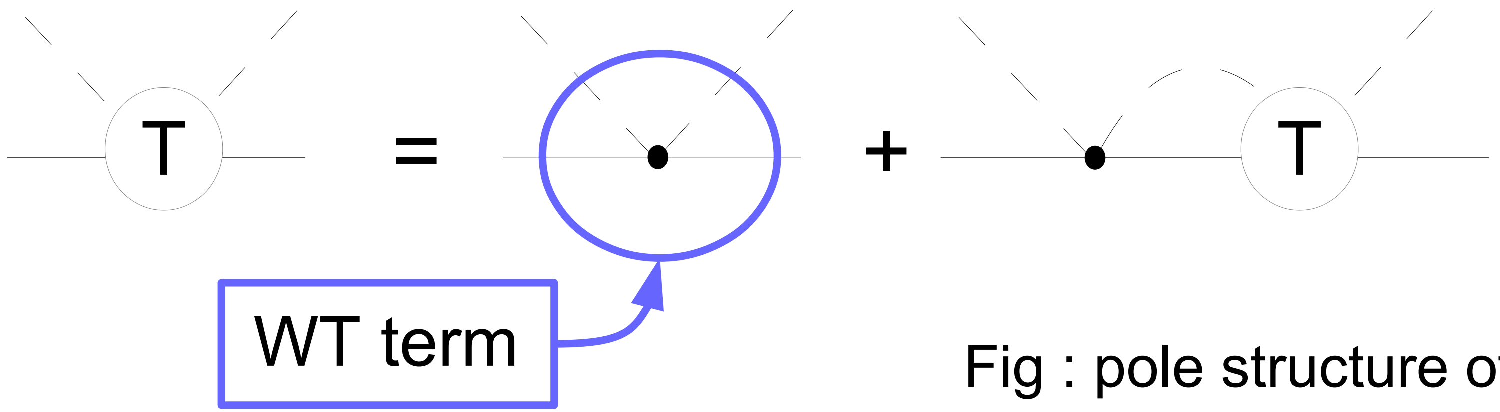
Previous work

T. Hyodo and W. Weise, Phys. Rev. C 77, 035204 (2008)

- calculated the $\bar{K}N$ amplitude
  - chiral unitary approach
  - channel coupling ($\pi\Sigma$, $\bar{K}N$, $\eta\Lambda$, $K\Xi$)

- made the equivalent local potential
  - $\bar{K}N$ single-channel
  - coordinate space representation

- **chiral unitary approach**

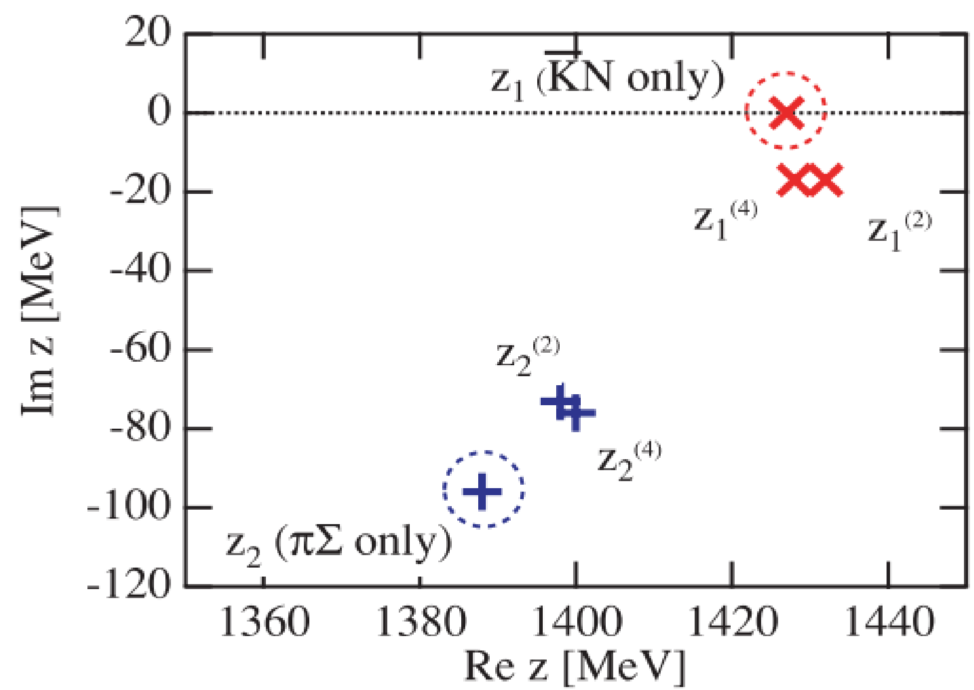


- **channel coupling**

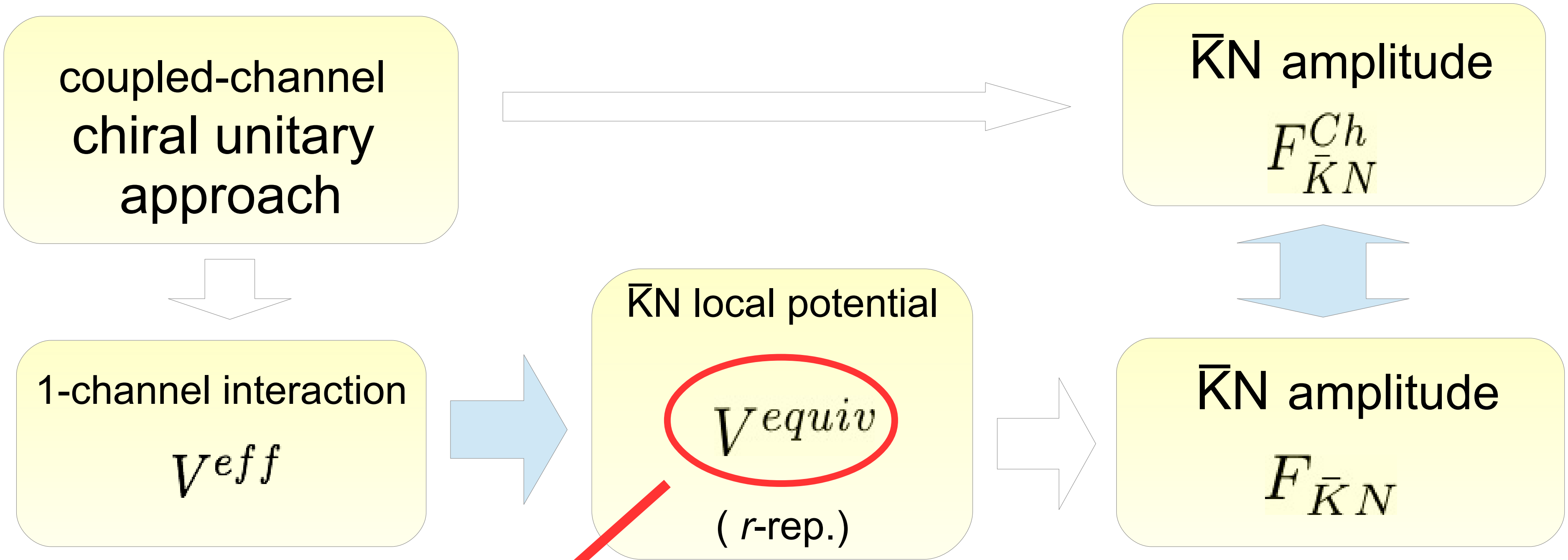
in S=-1 , I=0 sector

K̅N-πΣ coupling leads to **double pole** structure

Fig : pole structure of Λ(1405)



equivalent local potential



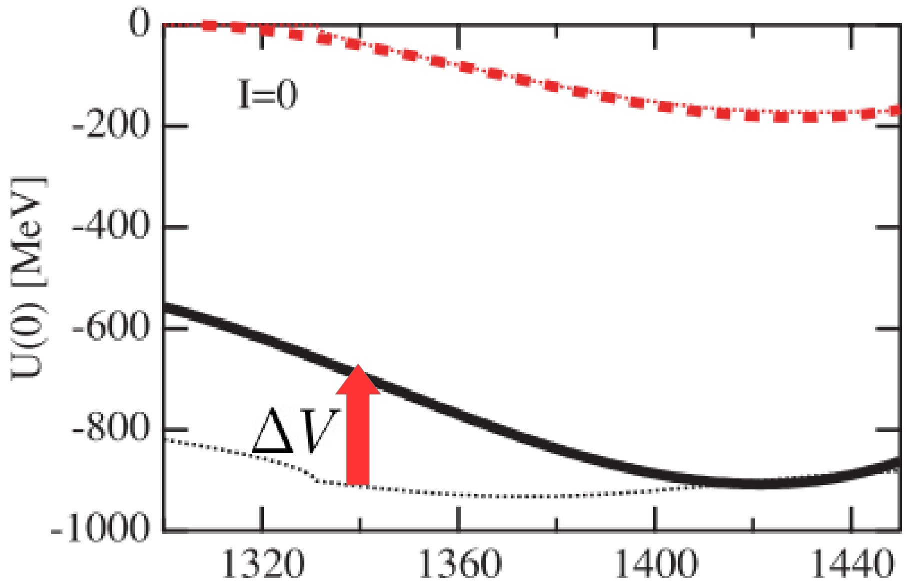
$$V^{equiv}(r,E) = g(r)N(E)\ \left(V^{eff}(E) + \underline{\Delta V(E)}\right)$$

with $g(r) = \frac{1}{\pi^{3/2}b^3} e^{-r^2/b^2}$

correction so that $F_{\bar{K}N} \sim F^{Ch}_{\bar{K}N}$

$g(r)\ \left[\sum_n C_n E^n\right]$ fit with a polynomial

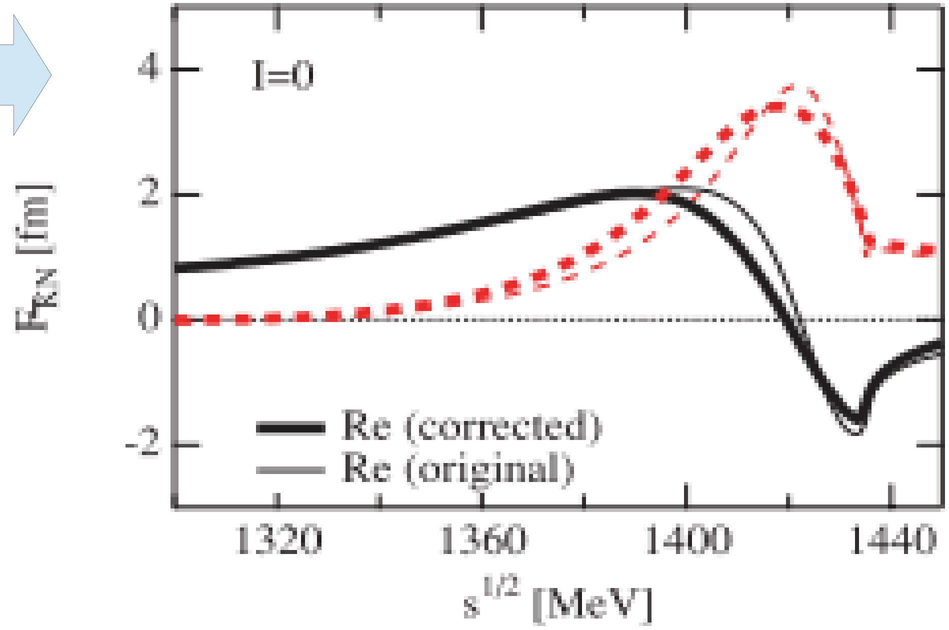
➢ Results



E dependence of $V^{equiv}(0, E)$

- real ΔV
- Im[ΔV]=0

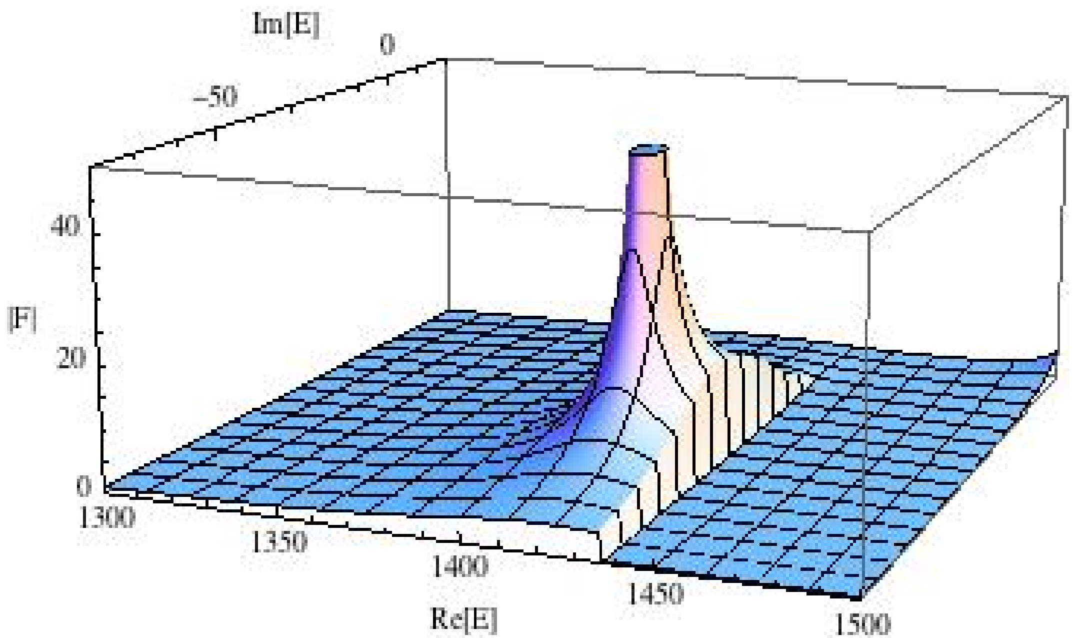
E-dep. of $F_{\bar{K}N}$ and $F^{Ch}_{\bar{K}N}$



- $F_{\bar{K}N}$ almost reproduced $F^{Ch}_{\bar{K}N}$

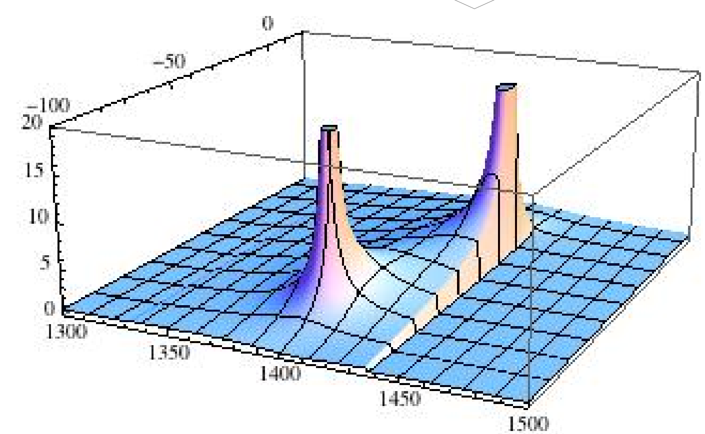
This work

- analytic continuation of $F_{\bar{K}N}$ with V^{equiv} to the complex energy plane



$F^{Ch}_{\bar{K}N}$ from

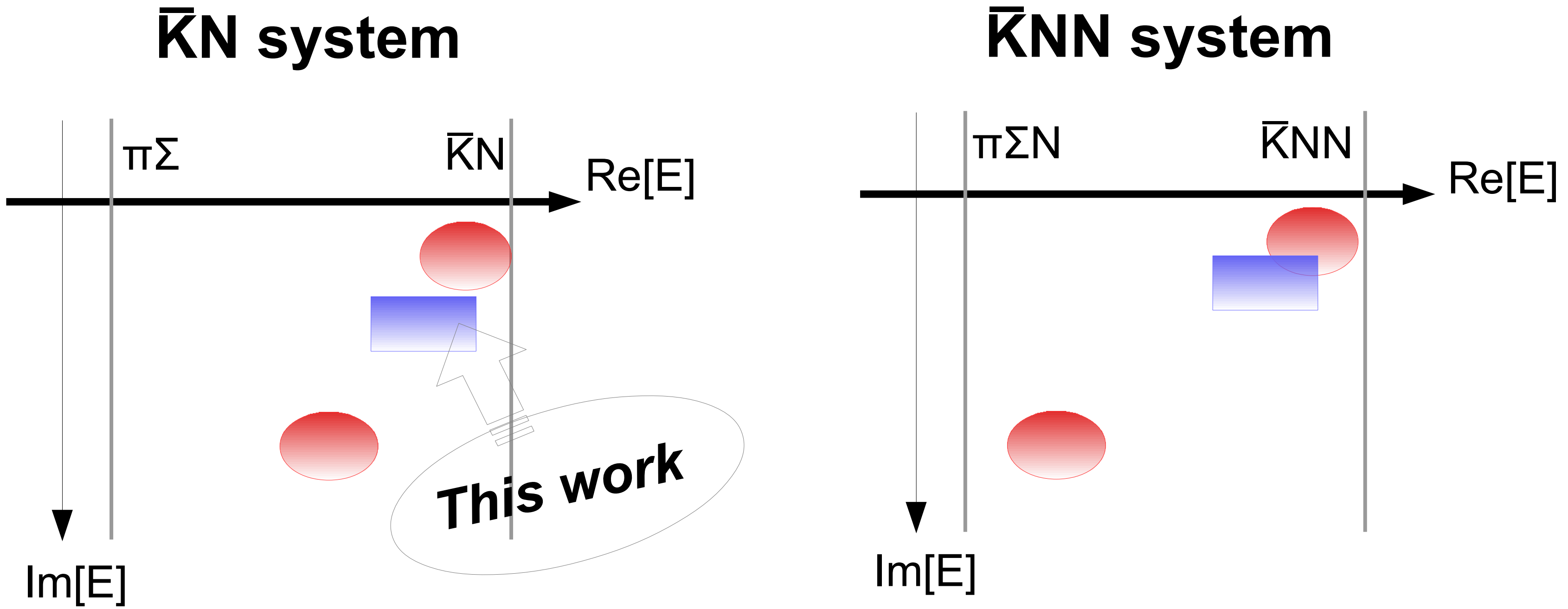
chiral unitary approach



V^{equiv} doesn't reproduce the pole structure of the original amplitude

➢ **problem**

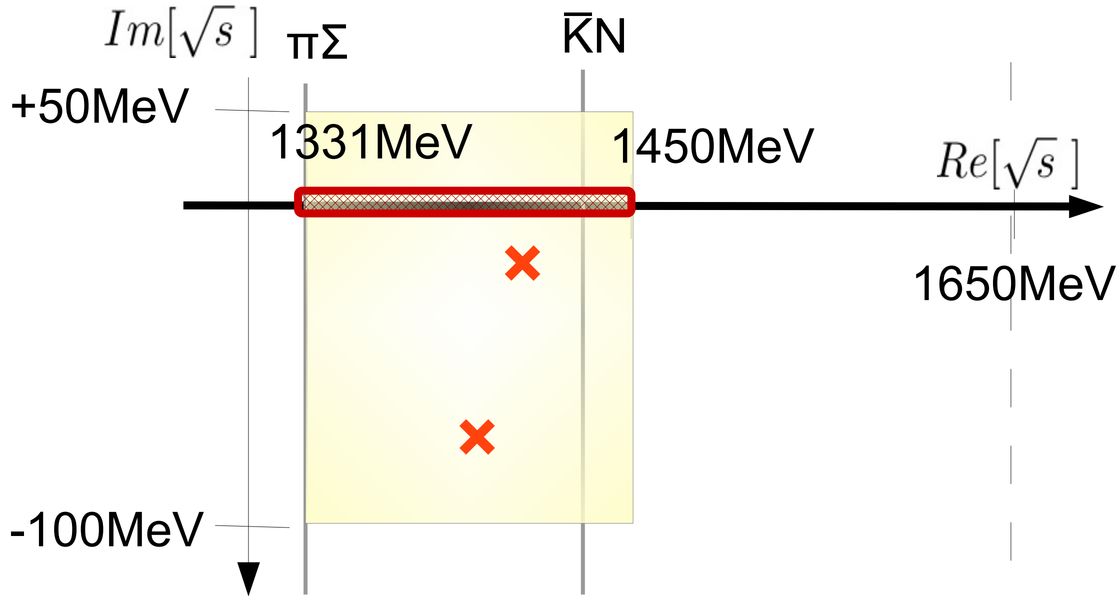
cf. A. Dote, T. Hyodo and W. Weise (2009) :
Y. Ikeda, H. Kamano and T. Sato (2010) :



- **the difference of pole structure may affect the binding energy of the few body system**

- **We want to improve** V^{equiv} **to reproduce** $F^{Ch}_{\bar{K}N}$ **in the complex E plane**

➢ definition ⟸ to discuss the "good" V^{equiv}



$$\Delta F_{real} = \frac{1}{N}\sum_i \left| \frac{F^{Ch}_{\bar{K}N} - F_{\bar{K}N}}{F^{Ch}_{\bar{K}N}} \right| \times 100$$
: average deviation of the amplitude on the real axis

P_{comp} : the percentage of the area in the complex plane which satisfies
$$\left| \frac{F^{Ch}_{\bar{K}N} - F_{\bar{K}N}}{F^{Ch}_{\bar{K}N}} \right| \times 100 \; < \; 20\%$$

➢ improvement

1) deviation of the amplitude on the real axis

change ΔV and fitting range

	Hyodo-Weise	Potential1 (This work)	Chiral unitary
ΔV	real	complex	
fit rang [MeV]	1300~1410	1331~1450	
ΔFreal [%]	13	0.45	
Pole [MeV]	1421-35i	1427-17i	1428-17i 1400-76i

→ ΔF_{real} **and pole position are greatly improved**

2) precise area in the complex plane

second pole doesn't appear → we add other improvements

Hyodo-Weise (2008)

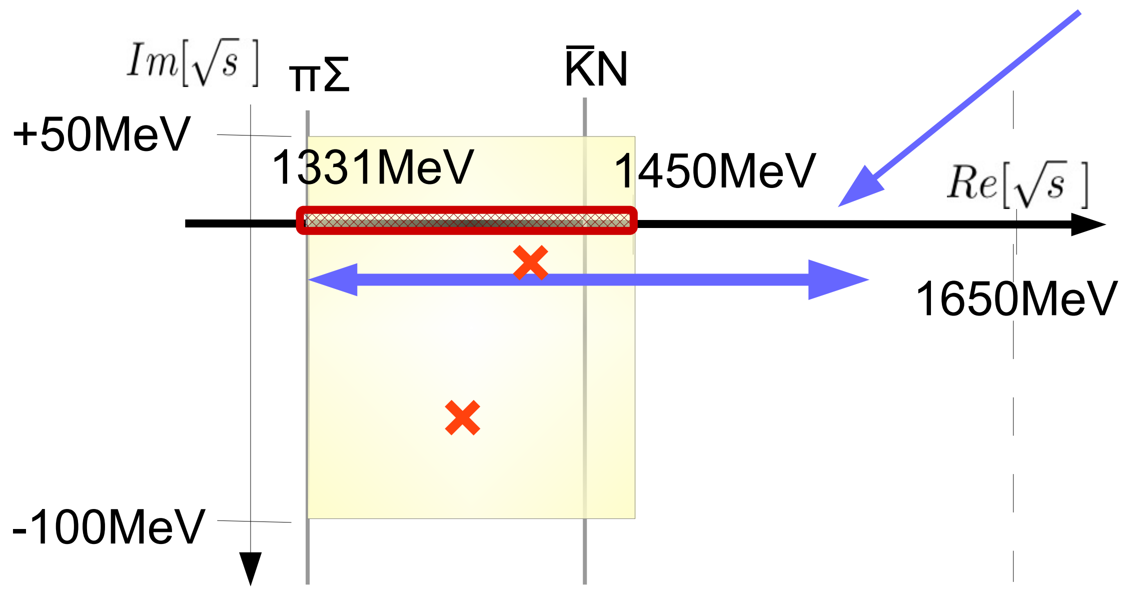
- third-order polynomial in $\sqrt{s}$
- fitting range :

$$1300 < \mathrm{Re}[\sqrt{s}\,] < 1410 \text{ MeV}$$

potential2 (This work)

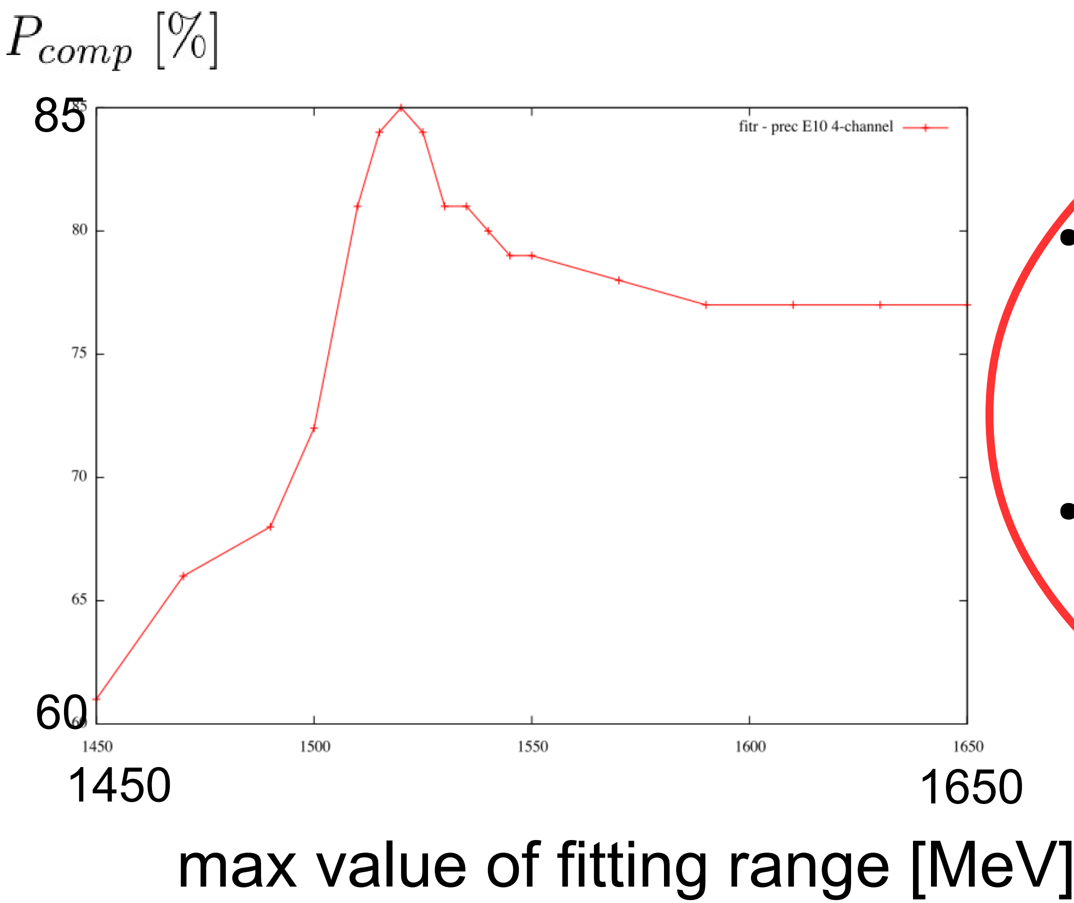
- 10th-order
- fitting range :

$$1331 < \mathrm{Re}[\sqrt{s}\,] < 1450 \sim 1650$$



Results

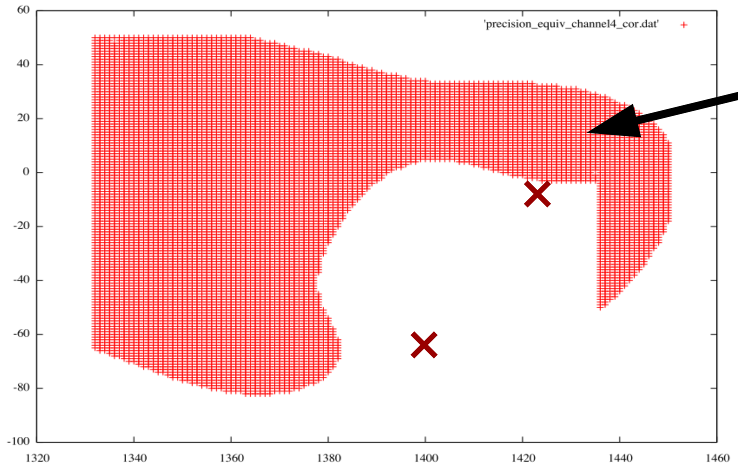
- the first pole reproduces the original one against the change of fitting range
- We get second pole
- P_{comp} changes depending on fitting range



- P_{comp} tends to increase as fitting range is broadened
- P_{comp} reaches a maximum at $\sqrt{s}_{max} = 1520\ \mathrm{MeV}$

➢ Results

Hyodo-Weise (2008)



the area which satisfies

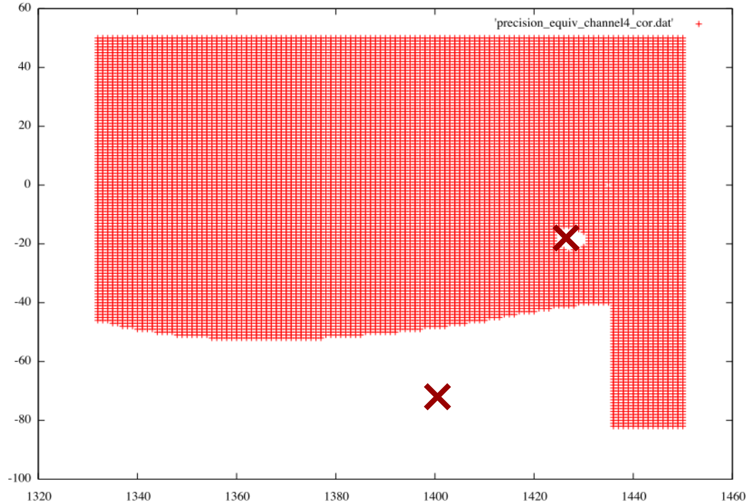
$$\left| \frac{F^{Ch}_{\bar{K}N} - F_{\bar{K}N}}{F^{Ch}_{\bar{K}N}} \right| \times 100 \ < \ 20\%$$

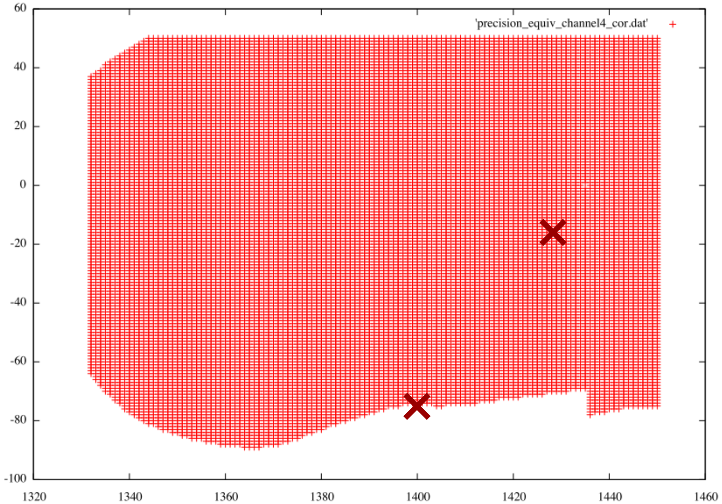
Potential1

- complex ΔV
- third-order
- $\sqrt{s}_{max} = 1450$ MeV

Potential2

- complex ΔV
- 10th-order
- $\sqrt{s}_{max} = 1520$ MeV





Summary

- In the previous work, $F_{\bar{K}N}$ does not reproduce $F_{\bar{K}N}^{Ch}$ well in the complex energy plane

- We improved the equivalent potential

  1) changed ΔV to complex value

  ⇒ ΔF_{real} becomes much better

  2) improved the fitting function, and broaden fitting range

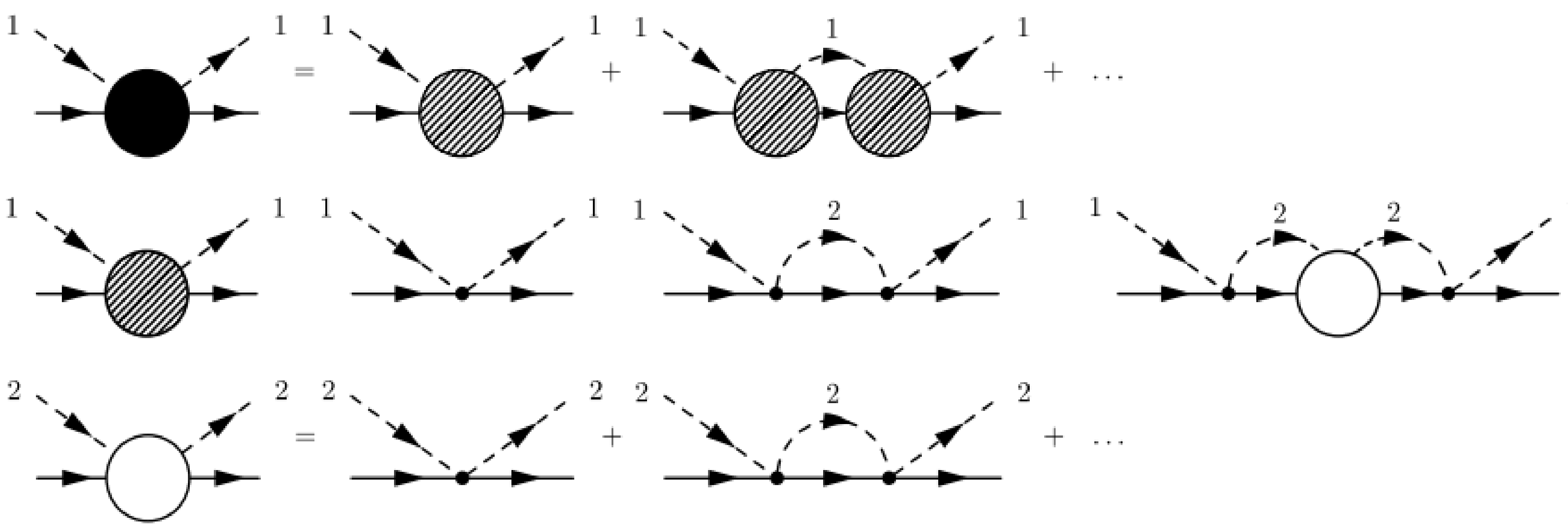
  ⇒ second pole appears and P_{comp} becomes better

- Improving the amplitude on the real axis is important for the amplitude in the complex plane, including pole structure

- $\bar{K}N$ single-channel effective interaction

  situation : nonrelativistic and S-wave

→ **WT term** is LO



$$T^{eff} = V^{eff} + V^{eff} G_1 T^{eff}$$

$$= T^{11}$$

➢ improvement

We focus on these points

1) deviation of the amplitude on the real axis

Hyodo-Weise (2008)

- ΔV was real
- fitting range :

$1300 < Re[\sqrt{s}\,] < 1410$ MeV

This work

- ΔV is complex
- fitting range :

$1331 < Re[\sqrt{s}\,] < 1450$

	Hyodo-Weise (2008)	This work
ΔF_{real}	13 %	0.45%
P_{comp}	50 %	68%
pole	$1421 - 35i$ MeV	$1427 - 17i$ MeV

pole of $F^{Ch}_{\bar{K}N}$

$1428 - 17i$ MeV

Second pole position

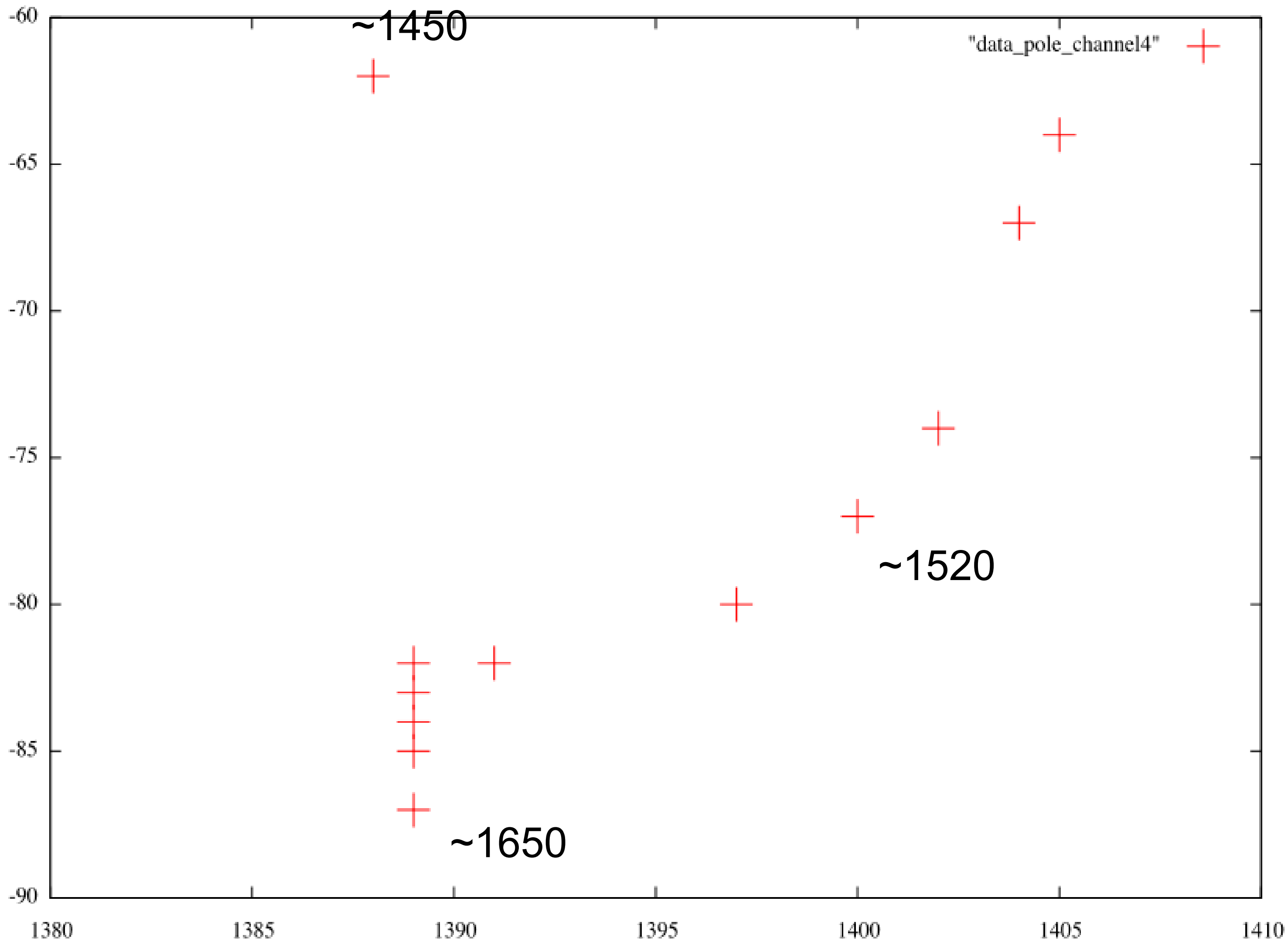


Figure of ΔF-Pcomp