Effective $\bar{K}N$ interaction in chiral SU(3) dynamics

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Introduction : Λ(1405) and $\bar{K}N$ dynamics

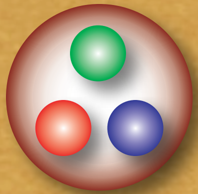
$\Lambda(1405) : J^P = 1/2^-, I = 0$

Mass : 1406.5 ± 4.0 MeV

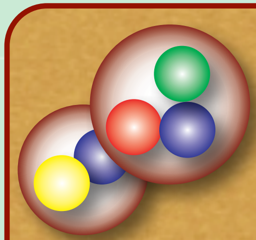
Width : 50 ± 2 MeV

Decay mode : $\Lambda(1405) \rightarrow (\pi\Sigma)_{I=0}$ **100%**

“naive” quark model
: p-wave
~1600 MeV?



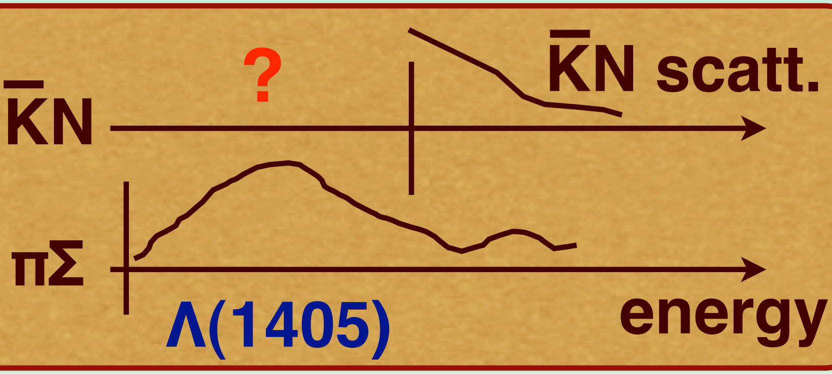
N. Isgur and G. Karl, PRD18, 4187 (1978)

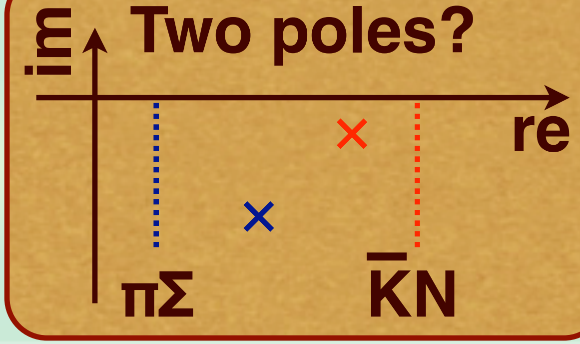


Coupled channel multi-scattering

R.H. Dalitz, T.C. Wong and
G. Rajasekaran, PR153, 1617 (1967)

$\bar{K}N$ int. below threshold





Two poles?

Chiral unitary approach

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

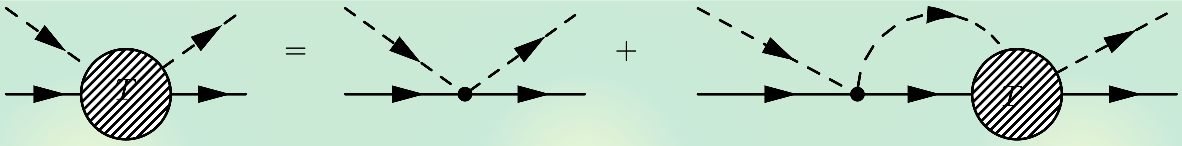
○ **Interaction <-- chiral symmetry**

Y. Tomozawa, Nuovo Cim. 46A, 707 (1966); S. Weinberg, Phys. Rev. Lett. 17, 616 (1966)

○ **Amplitude <-- unitarity (coupled channel)**

R.H. Dalitz, T.C. Wong and G. Rajasekaran, PR153, 1617 (1967)

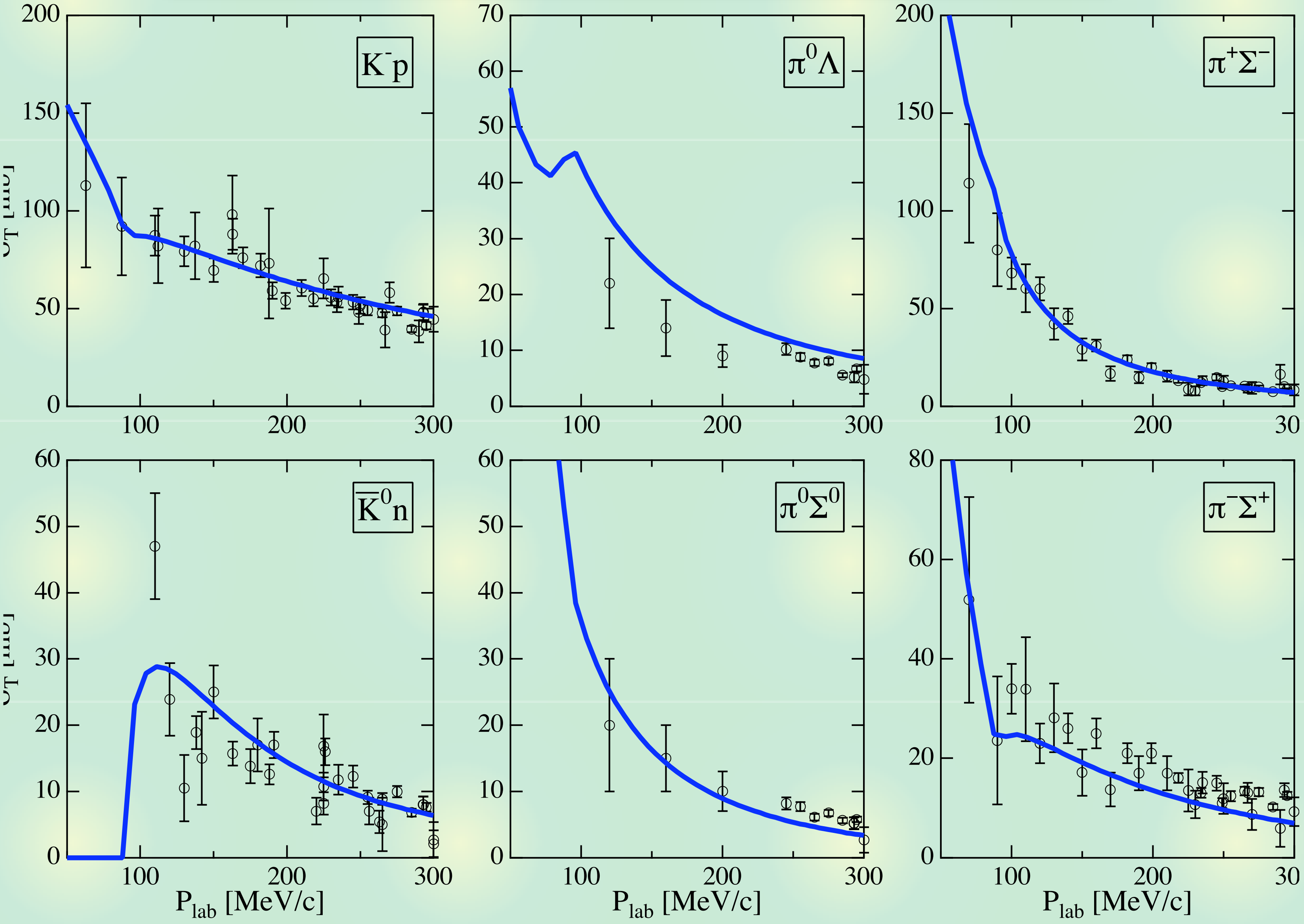
$$T = \frac{1}{1 - VG} V$$



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

works successfully, also in S=0, meson-meson scattering, heavy quark sectors, ...

Total cross sections of K$^-$p scattering



T. Hyodo, S.I. Nam, D. Jido, A. Hosaka, Phys. Rev. C68, 018201 (2003)

Effective interaction based on chiral SU(3) dynamics

Result of chiral dynamics --> single channel potential

few-body K-nuclei :

Doté-san's next Talk

Coupled-channel BS $T_{ij}(\sqrt{s})$

+ real interaction $V_{ij}(\sqrt{s})$

(exact)

Single-channel BS $T^{\rm eff}(\sqrt{s}) = T_{ii}(\sqrt{s})$

+ complex interaction $V^{\rm eff}(\sqrt{s})$

(approximate)

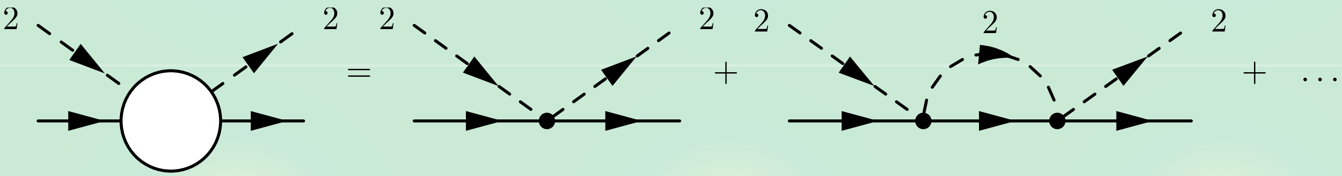
Schrödinger equation $f^{\rm eff}(\sqrt{s}) \sim T^{\rm eff}(\sqrt{s})$

+ local potential

complex, energy-dependent $U^{\rm eff}(r, \sqrt{s})$

Construction of the single channel interaction

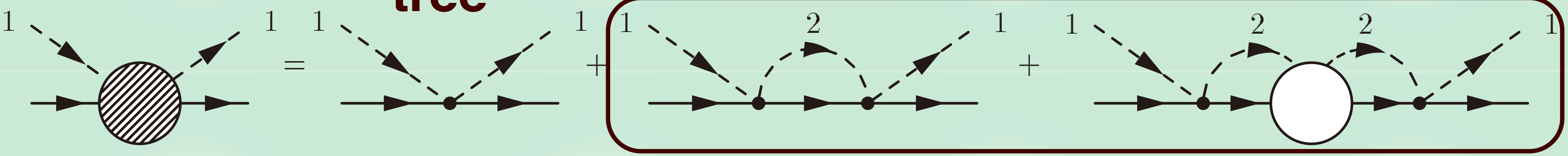
Channels 1 and 2 --> effective int. in 1



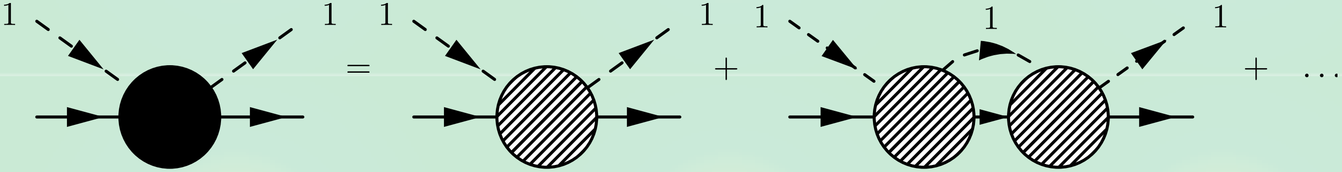
$$T_{22}^{\text{single}} = V_{22} + V_{22} G_2 T_{22}^{\text{single}}$$

effect of channel 2

tree



$$V^{\text{eff}} = V_{11} + V_{12} G_2 V_{21} + V_{12} G_2 T_{22}^{\text{single}} G_2 V_{21}$$

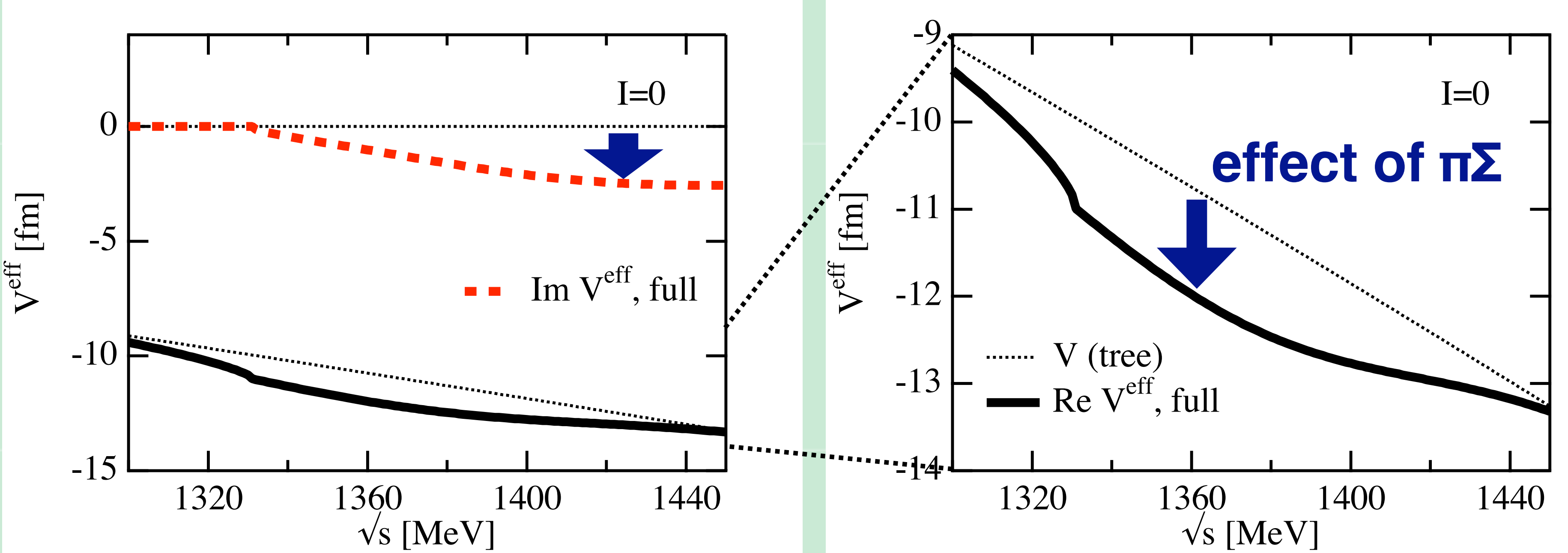


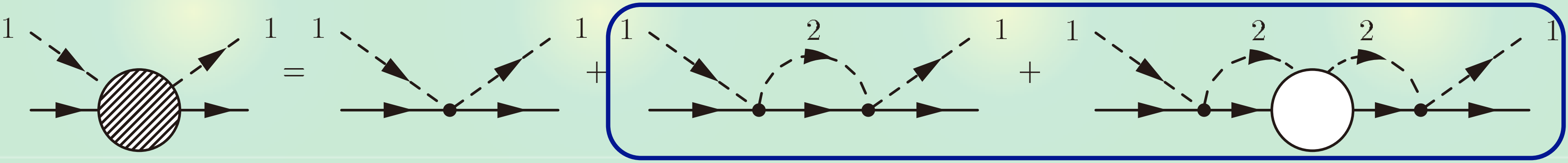
single channel

$$T_{11} = T^{\text{eff}} = V^{\text{eff}} + V^{\text{eff}} G_1 T^{\text{eff}}$$

Equivalent to the coupled-channel equations

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

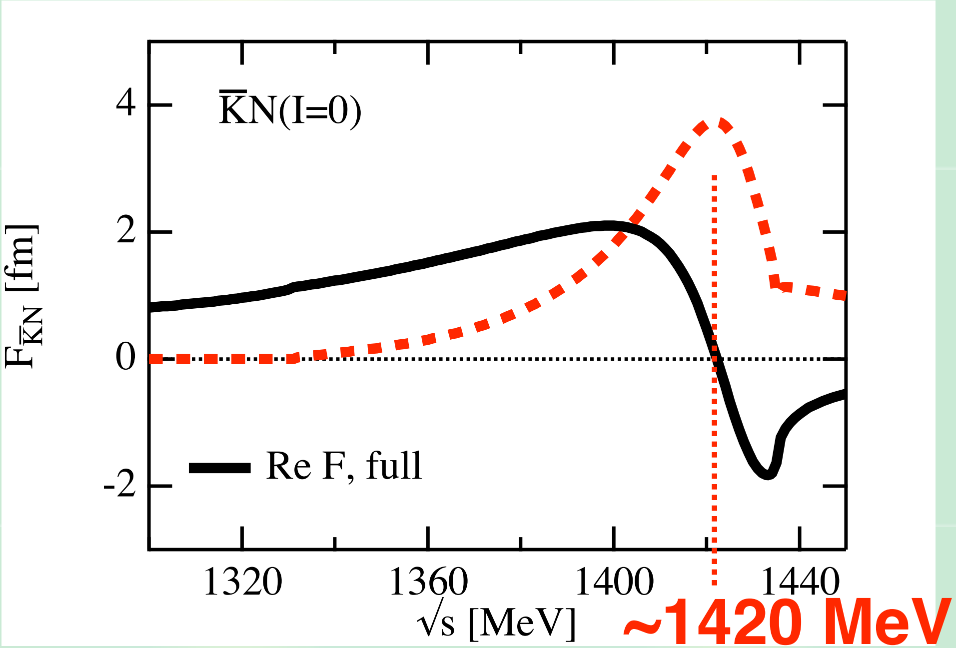




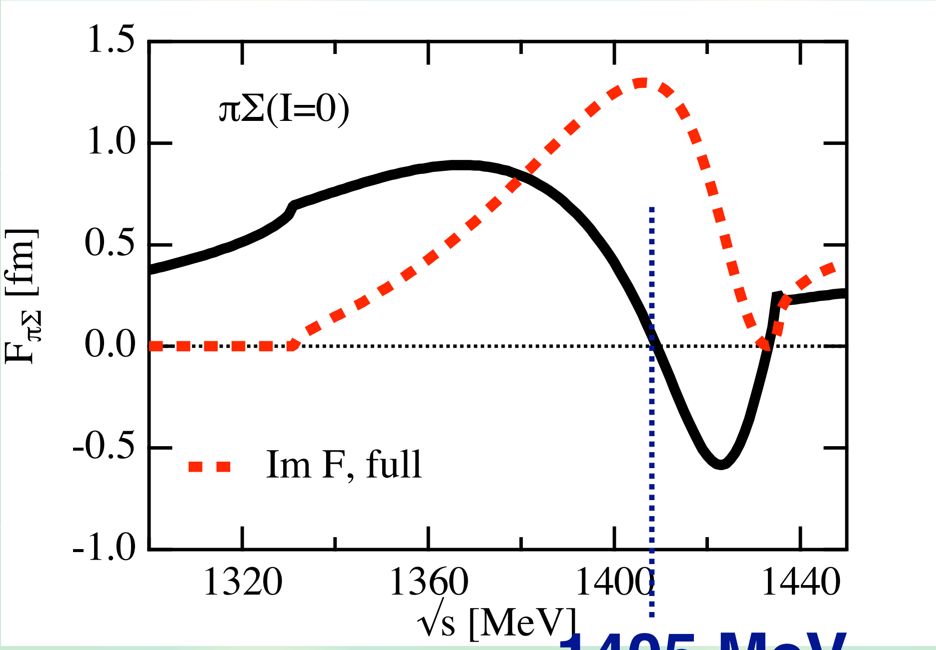
Strength : comparable with the WT term

~1/2 of phenomenological (AY) potential

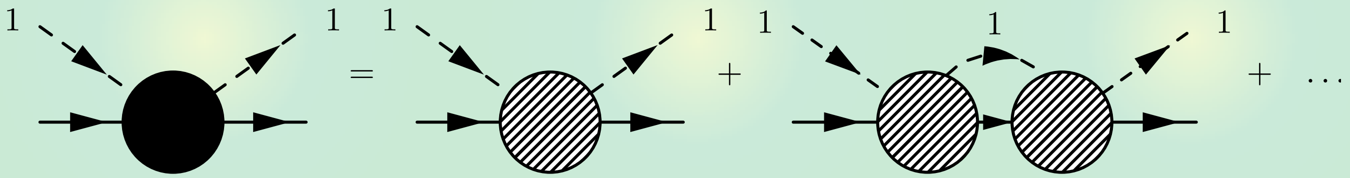
Scattering amplitude in $\bar{K}N$ and $\pi\Sigma$



~1420 MeV



~1405 MeV
(Experiment)



Resonance in $\bar{K}N$: around 1420 MeV
<-- strong πΣ dynamics (coupled-channel)

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

Why two poles? What is the difference?

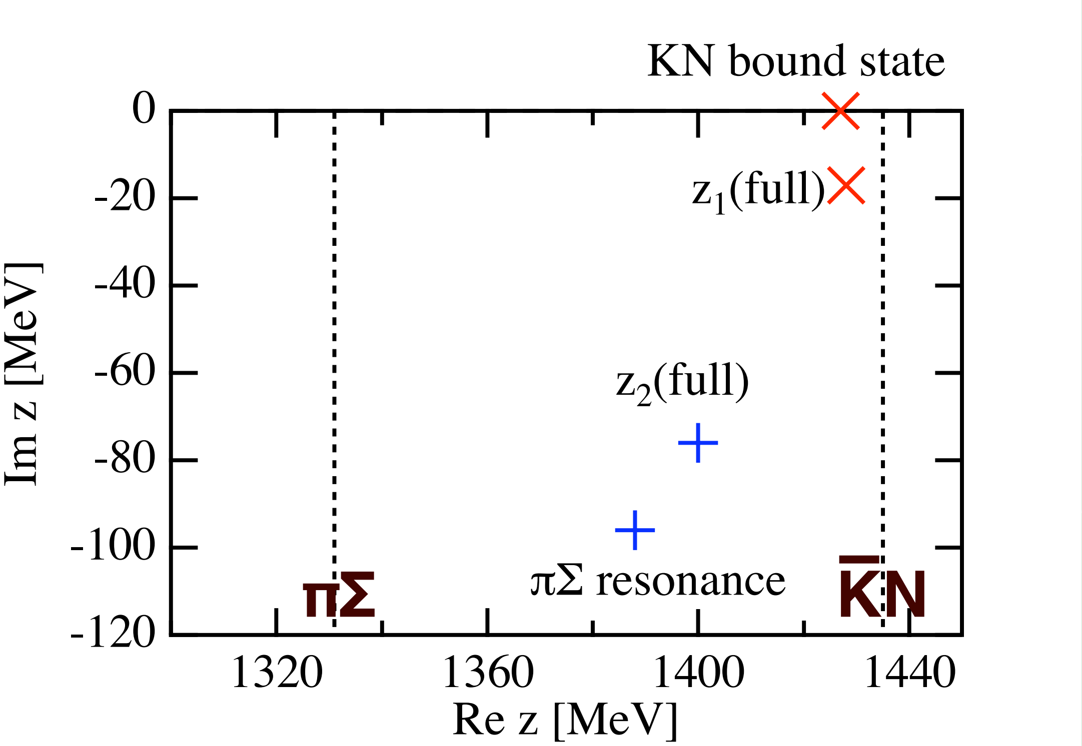
Origin of the two-pole structure

Chiral interaction

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

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

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



Very strong attraction in K̄N (higher energy) --> bound state

Strong attraction in πΣ (lower energy) --> resonance

(model dependent)

Two poles : natural consequence of chiral interaction

Comparison with phenomenological potential

Chiral interaction

Y. Tomozawa, Nuovo Cim. 46A, 707 (1966);
S. Weinberg, Phys. Rev. Lett. 17, 616 (1966)

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

$$C_{ij} = \begin{array}{cc} \bar{K}N & \pi\Sigma \\ \end{array}$$

$$C_{ij} = \left(\begin{array}{cc} 3 & -\sqrt{\frac{3}{2}} \\ -\sqrt{\frac{3}{2}} & \boxed{4} \end{array}\right)$$

phenomenological

Y. Akaishi, T. Yamazaki
Phys. Rev. C65, 044005 (2002)

$$\begin{array}{cc} \bar{K}N & \pi\Sigma \end{array}$$

$$v_{ij}(r) \sim -\begin{pmatrix} 436 & 412 \\ 412 & \boxed{0} \end{pmatrix} g(r)$$

Absence of πΣ diagonal coupling

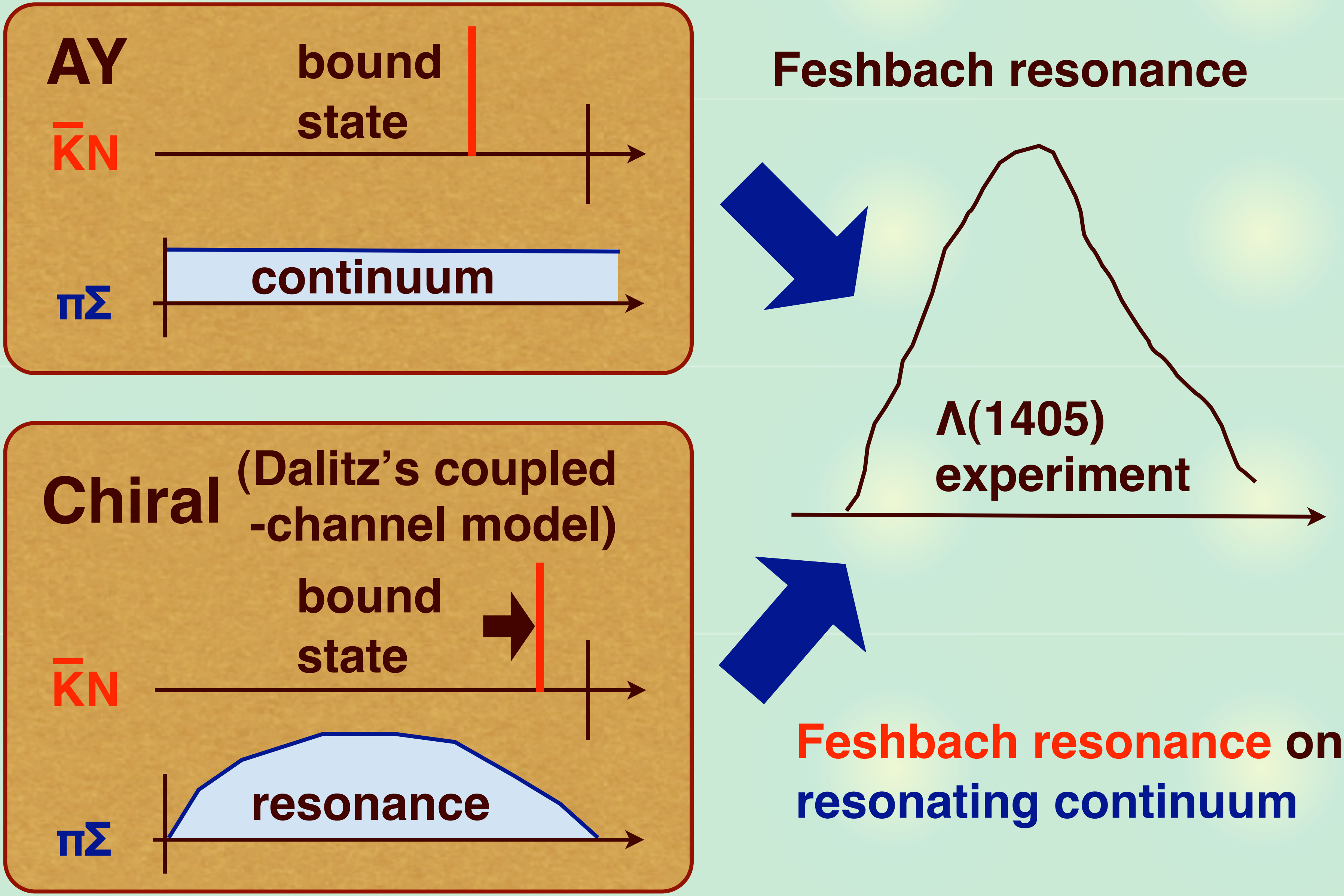
--> strong (×2) attractive interaction in $\bar{K}N$

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

==> Dalitz's coupled-channel model

R.H. Dalitz, T.C. Wong and G. Rajasekaran, PR153, 1617 (1967)

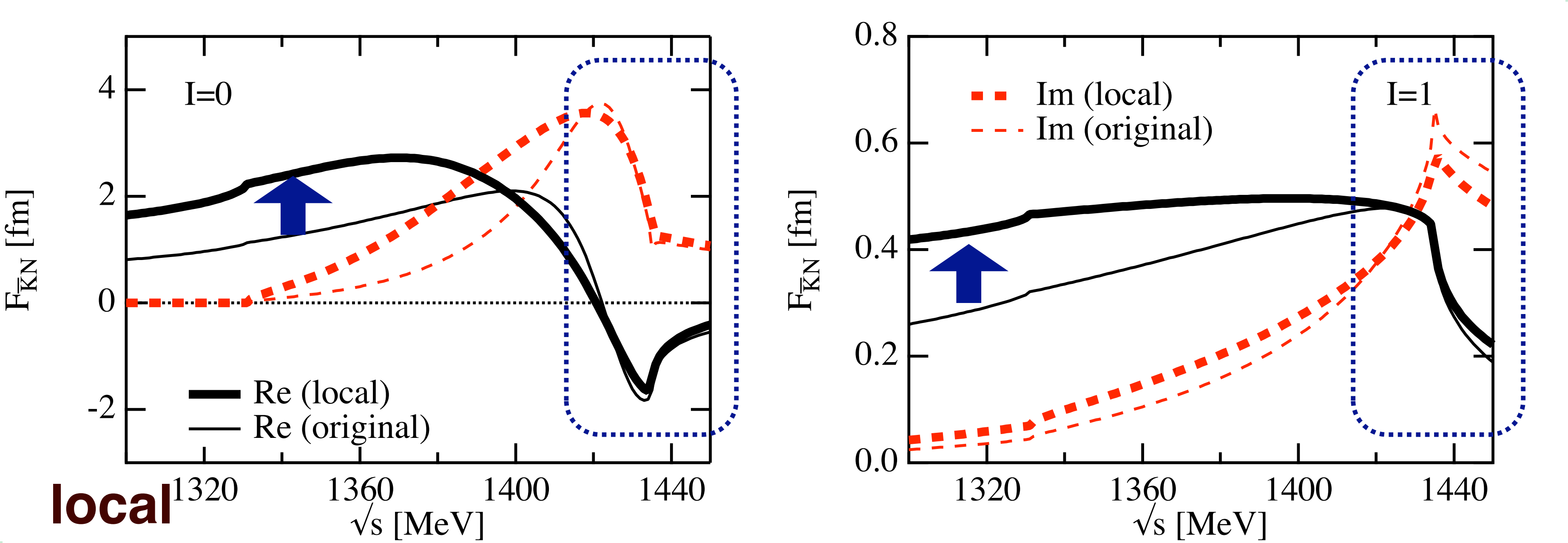
Schematic illustration : AY vs Chiral



Feshbach resonance

Feshbach resonance on resonating continuum

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



local potential **in BS**

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

gaussian

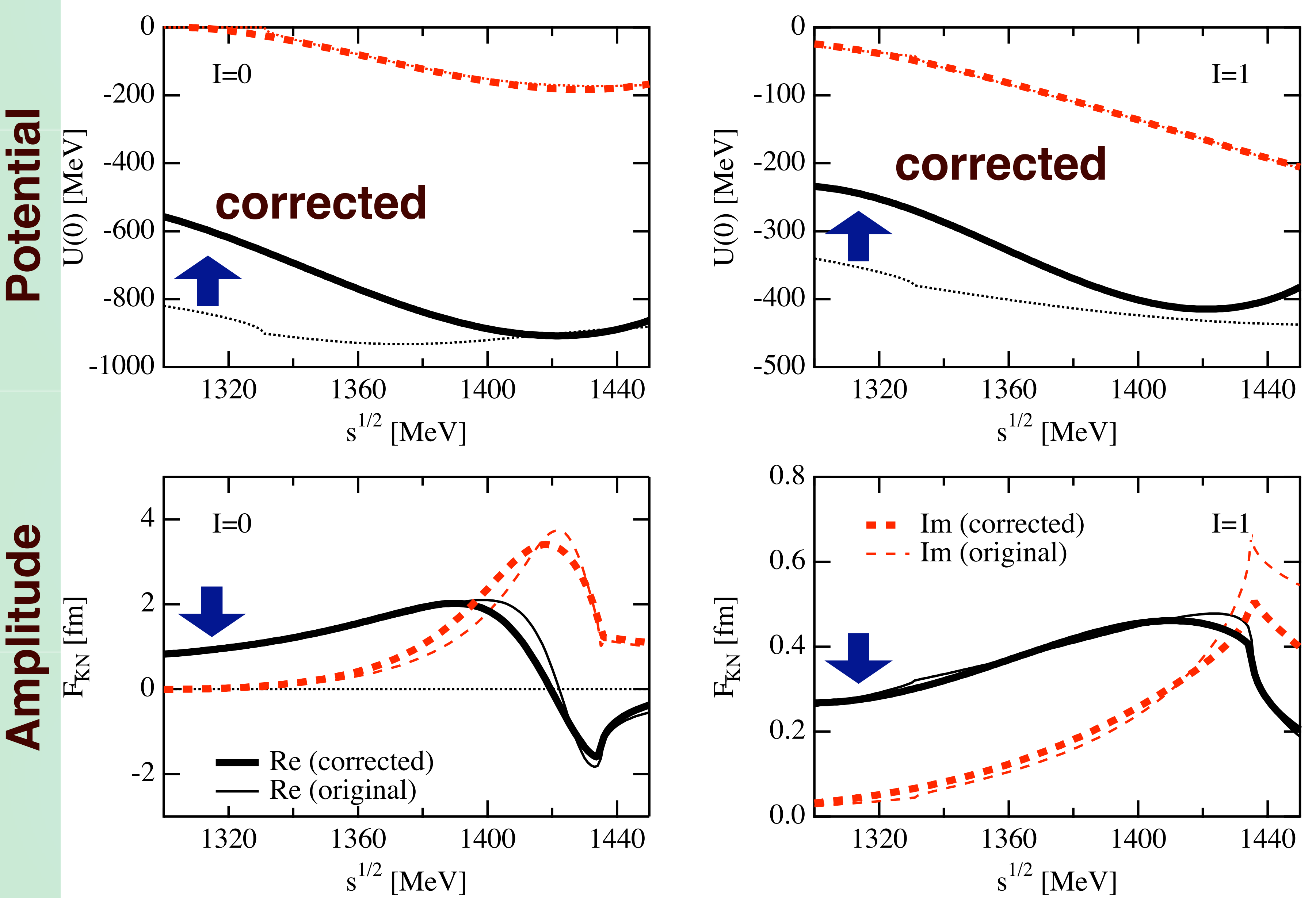
$b = 0.47$ fm **: to reproduce the resonance**

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** <-- **strong πΣ dynamics**
- Two attractive interactions in $\bar{K}N$ and πΣ

  Feshbach resonance on
  resonating continuum

  T. Hyodo and W. Weise, Phys. Rev. C 77, 035204 (2008)
- Application to K-pp system

  -> Doté-san's Talk

  A. Doté, T. Hyodo and W. Weise, Nucl. Phys. A 804, 197 (2008),
  arXiv: 0806.4917 [nucl-th]

Conservative conclusion

- Both AY/chiral potentials reproduce existing experimental data, but have different subthreshold behavior.
  => Present experimental database is not sufficient to constrain the $\bar{K}N$ interaction at (far) below threshold.
- So we need accurate data of
  $\bar{K}N$ scattering lengths,
  Spectrum of $\pi\Sigma$ (in different reactions, different channels, ...),
  K-pp system (energy, width, ...), ...