Hyp-X, Tokai
Sept. 14, 2009

Single-pole Nature of $\Lambda(1405)$ and Structure of K^-pp

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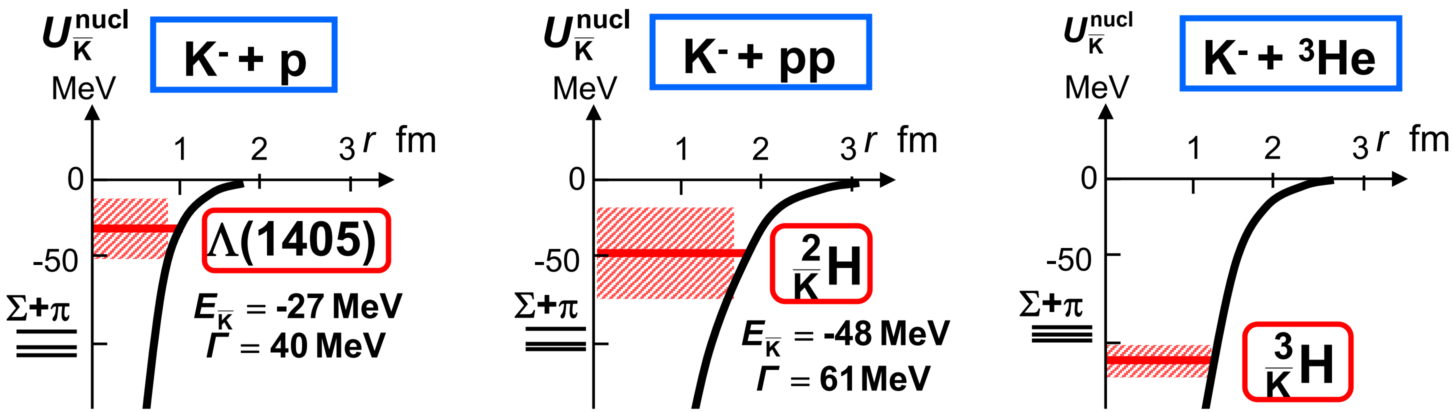
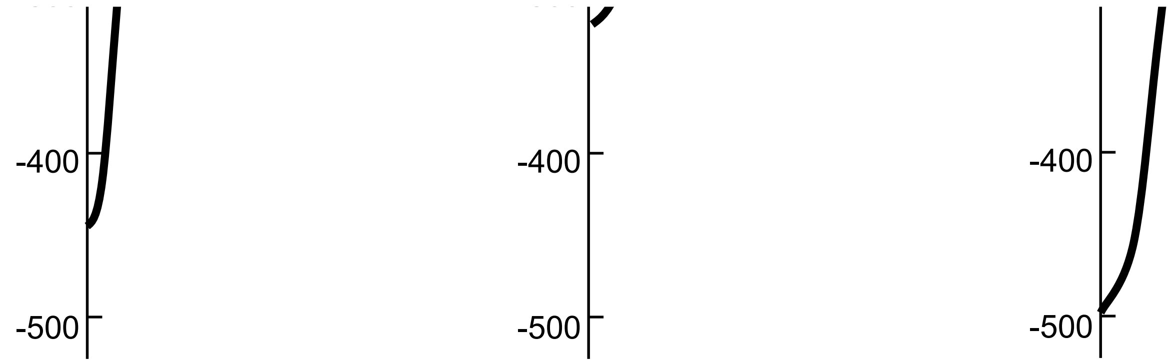
Mitsuaki OBU & Masanobu WADA

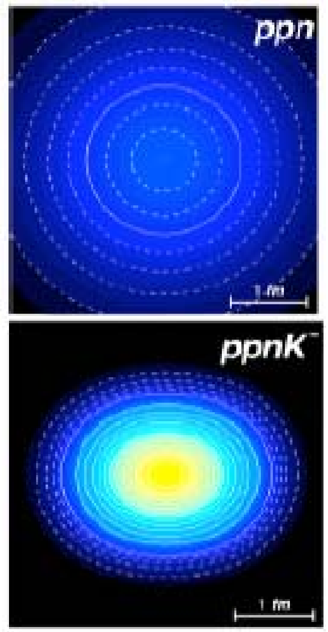
"Λ(1405) Ansatz"



N.V. Shevchenko, A. Gal & J. Mares, Phys. Rev. Lett. 98 (2007) 082301
E = -55~-70 MeV, Γ = 90~110 MeV
Y. Ikeda & T. Sato, Phys. Rev. C 76 (2007) 035203
E = -80 MeV, Γ = 73 MeV



A. Dote et al.



Shrinkage!

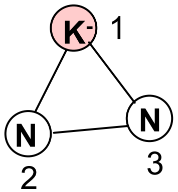
T. Yamazaki & Y. Akaishi, Phys. Lett. B 535 (2002) 70
Y. Akaishi & T. Yamazaki, Phys. Rev. C 65 (2002) 044005

Variational wave function of K⁻pp

ATMS

Amalgamation of **T**wo-body correlations into **M**ultiple **S**cattering process

$$\Psi = \left[\left\{ f^{I=0}(r_{12})\hat{P}_{12}^{I=0} + f^{I=1}(r_{12})\hat{P}_{12}^{I=1} \right\} f_{\mathrm{NN}}(r_{23}) f(r_{31}) + f(r_{12}) f_{\mathrm{NN}}(r_{23}) \left\{ f^{I=0}(r_{31})\hat{P}_{31}^{I=0} + f^{I=1}(r_{31})\hat{P}_{31}^{I=1} \right\} \right] \left| T = 1/2 \right\rangle$$



$$\hat{P}_{12}^{I=0} = \frac{1 - \vec{\tau}_{\mathrm{K}}\vec{\tau}_{\mathrm{N}}}{4}, \quad \hat{P}_{12}^{I=1} = \frac{3 + \vec{\tau}_{\mathrm{K}}\vec{\tau}_{\mathrm{N}}}{4}$$

$$\left| T = 1/2 \right\rangle = \sqrt{\frac{3}{4}} \left[\left(\bar{K}_1 N_2 \right)^{0,0} p_3 \right] + \sqrt{\frac{1}{4}} \left[-\sqrt{\frac{1}{3}} \left(\bar{K}_1 N_2 \right)^{1,0} p_3 + \sqrt{\frac{2}{3}} \left(\bar{K}_1 N_2 \right)^{1,1} n_3 \right]$$

$\Lambda^* p$

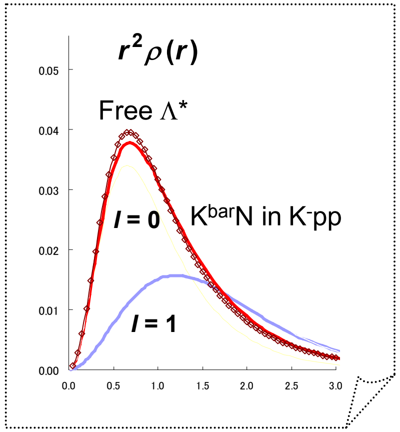
Euler-Lagrange equation

$$\delta_f \left\{ \left\langle \Psi \middle| H \middle| \Psi \right\rangle - \lambda \left\langle \Psi \middle| \Psi \right\rangle \right\} = 0$$

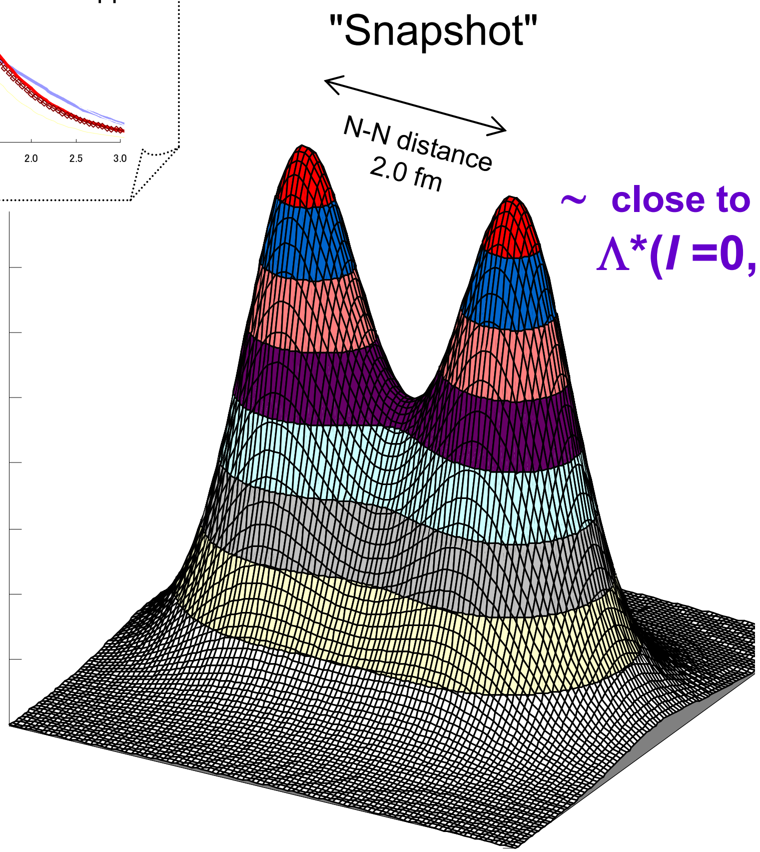
$$v_{\bar{\mathrm{K}}\mathrm{N}}^{T=0}(r) = \{-595 - i83\}_{\mathrm{MeV}} \exp\left\{-(r/0.66_{\mathrm{fm}})^2\right\}$$

$$v_{\bar{\mathrm{K}}\mathrm{N}}^{T=1}(r) = \{-175 - i105\}_{\mathrm{MeV}} \exp\left\{-(r/0.66_{\mathrm{fm}})^2\right\}$$

$$v_{\mathrm{NN}}(r) = 2000_{\mathrm{MeV}} \exp\left\{-(r/0.447_{\mathrm{fm}})^2\right\} - 270_{\mathrm{MeV}} \exp\left\{-(r/0.942_{\mathrm{fm}})^2\right\} - 5_{\mathrm{MeV}} \exp\left\{-(r/2.5_{\mathrm{fm}})^2\right\}$$



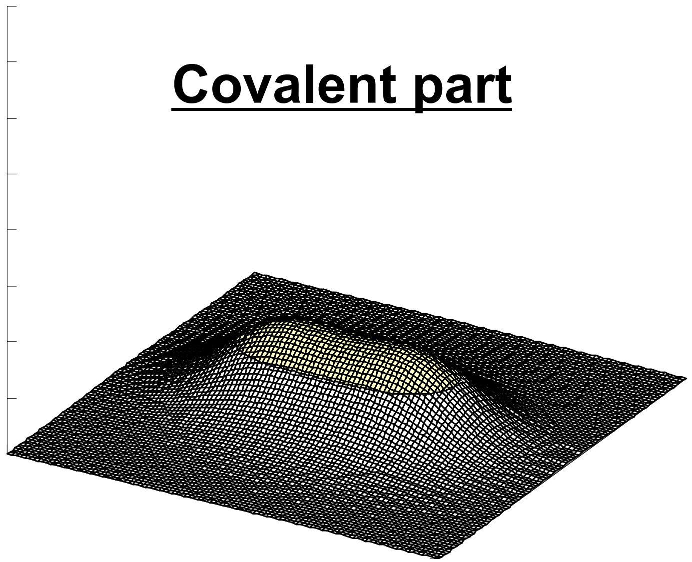
K^- distribution in K^-pp



~ close to free

$\Lambda^*(I=0, K^-p)$

Covalent part

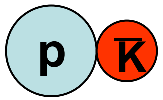


$$\Psi_\pm = \phi_a \pm \phi_b$$

Covalent bonding

$$\int d\vec{\tau}\,\left|\Psi_\pm\right|^2 = \int d\vec{r}_a\,\left|\phi_a(\vec{r}_a)\right|^2 + \int d\vec{r}_b\,\left|\phi_b(\vec{r}_b)\right|^2 \pm \int d\vec{\tau}\,\left|\phi_a^*(\vec{r}_a)\,\phi_b(\vec{r}_b) + \phi_b^*(\vec{r}_b)\,\phi_a(\vec{r}_a)\right|$$

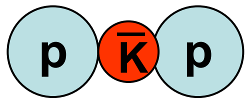
Heitler-London picture of K^-pp



Λ(1405)

[MeV]

E	$-27.8 \quad -20.0i$
KE	115.3
PE	$-143.1 \quad -20.0i$



K^-pp

[MeV]

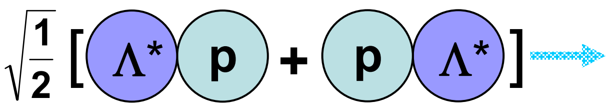
E	$-47.5 \quad -30.6i$
KE	167.0
PE	$-214.5 \quad -30.6i$
$\langle v_{NN} \rangle$	-19.0
$\langle 2v_{\bar{K}N} \rangle$	$-195.5 \quad -30.6i$
$\langle 2v_{\bar{K}N}^{I=0} \rangle$	$-188.2 \quad -26.2i$ (88%)
$\langle 2v_{\bar{K}N}^{I=1} \rangle$	$-7.3 \quad -4.4i$
$\langle 2v_{\bar{K}N}^{dir} \rangle$	$-143.0 \quad -23.3i$
$\langle 2v_{\bar{K}N}^{exc} \rangle$	$-52.6 \quad -7.3i$

ΔE = -20

ΔKE = 52

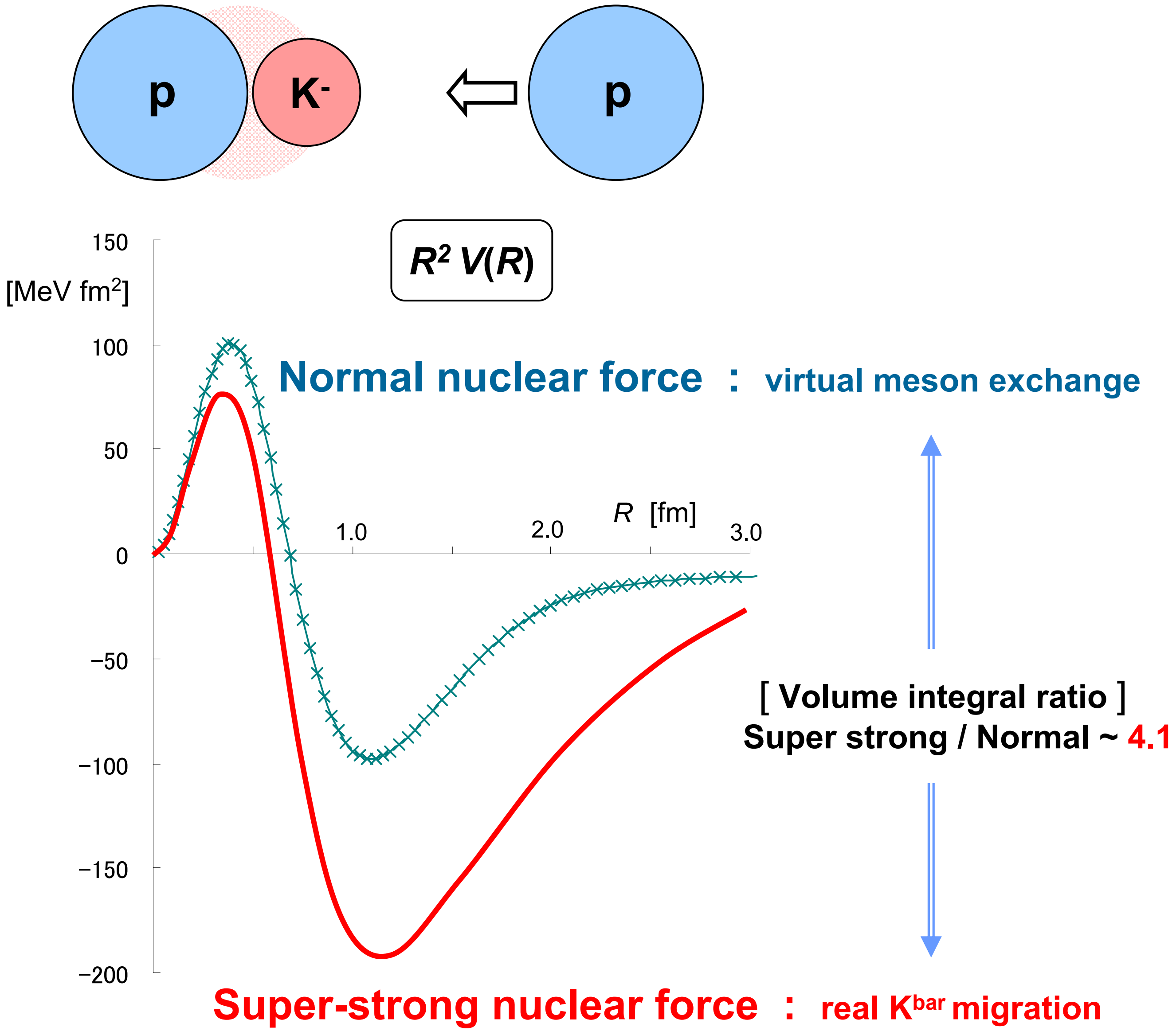
ΔV_{NN} = -19

ΔV^{exc} = -53

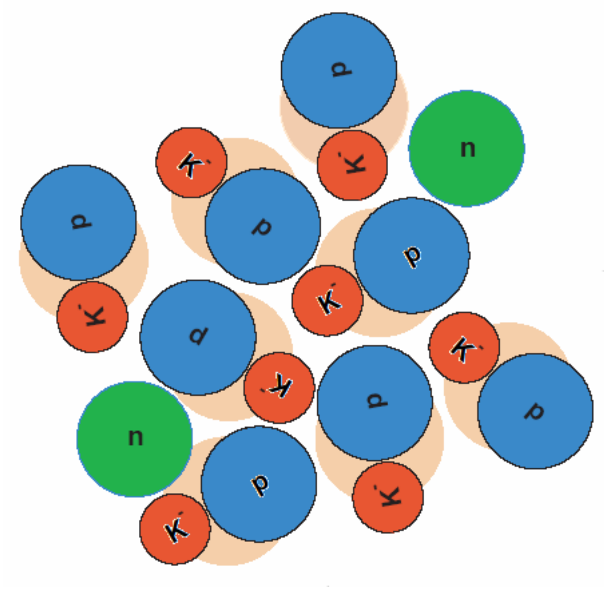


Real K^{bar} migrating attraction

Adiabatic p-p potential in $K^{-}pp$



$\Lambda^* = (K^- p)^{I=0}$ condensed matter



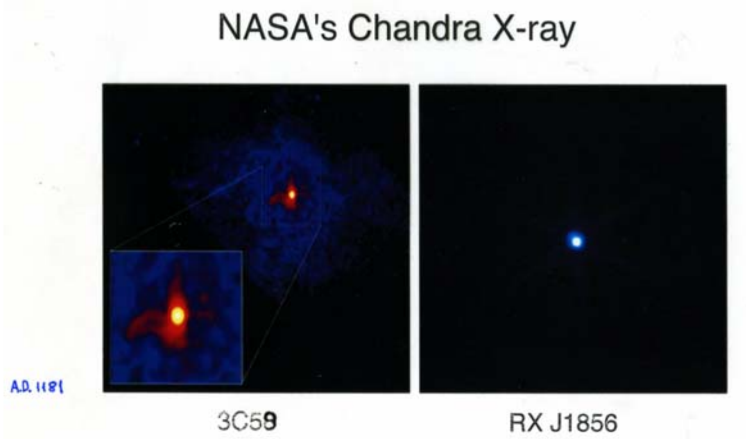
Real kaons are migrating!

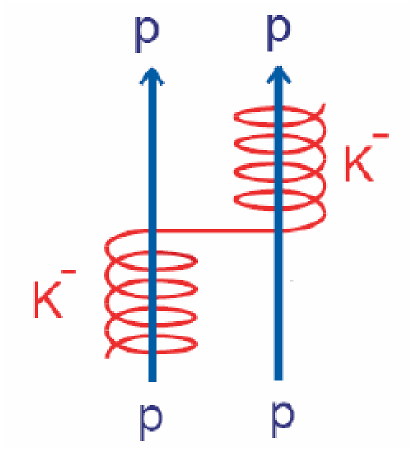
— a new paradigm —

New!

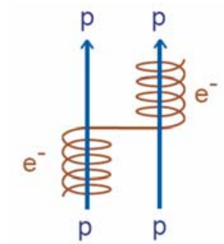
DISTO data on $K^- pp$

M. Maggiora et al.





Revival of Heitler-London-Heisenberg picture

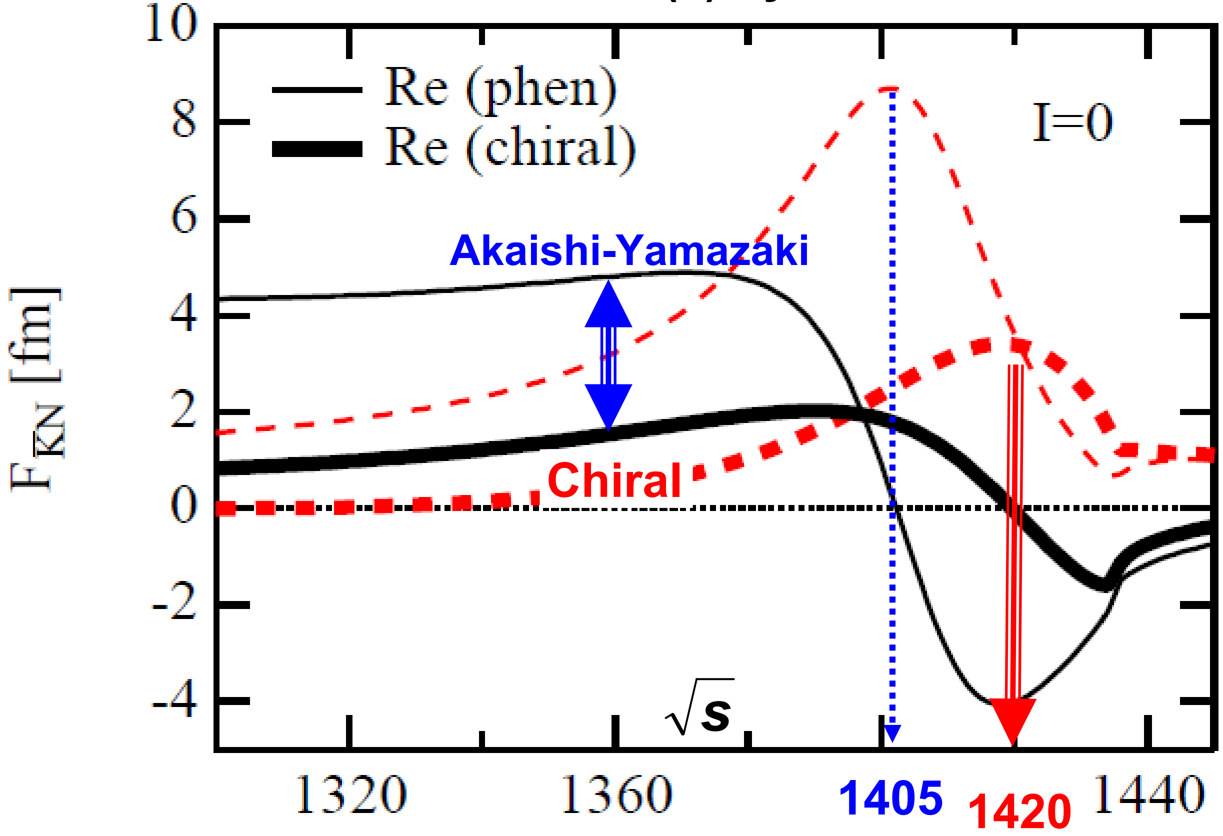


T. Yamazaki & Y. Akaishi,
Proc. Japan Academy, B 83 (2007) 144

$K^{bar}N$ scattering amplitude

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

Chiral SU(3) dynamics



"**ORB**": E. Oset, A. Ramos & C. Bennhold, Phys. Lett. B 527 (2002) 99

"**HNJH**": T. Hyodo, S.I. Nam, D. Jido & A. Hosaka, Phys. Rev. C 68 (2003) 018201

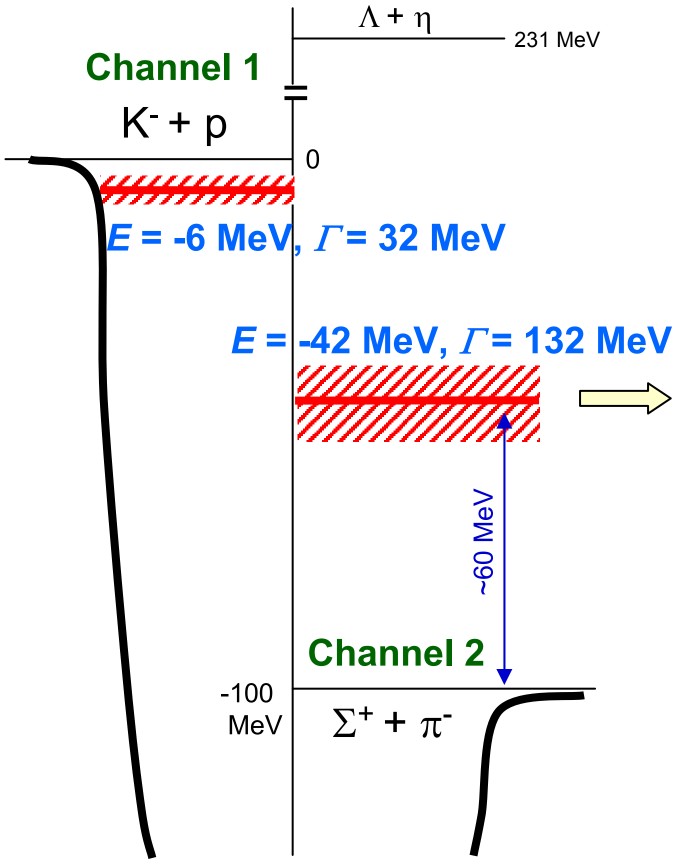
"**BNW**": B. Borasoy, R. Nissler & W. Weise, Eur. Phys. J. A 25 (2005) 79

"**BMN**": B. Borasoy, U.G. Meissner & R. Nissler, Phys. Rev. C 74 (2006) 055201

"**JOORM**": D. Jido, J.A. Oller, E. Oset, A. Ramos & U.G. Meissner, Nucl. Phys. A 725 (2003) 181

Double pole structure of Λ(1405)

D. Jido, J.A. Oller, E. Oset, A. Ramos & U.G. Meissner, Nucl. Phys. A 725 (2003) 181



Λ(1405) consists of two poles, one of which is not K^-p but Σπ pole.

⇨ **What effects on experimental observables?**

Chiral SU(3) dynamics

Weinberg-Tomozawa term

$$-c_{ij}\frac{\omega_i+\omega_j}{4f^2}$$

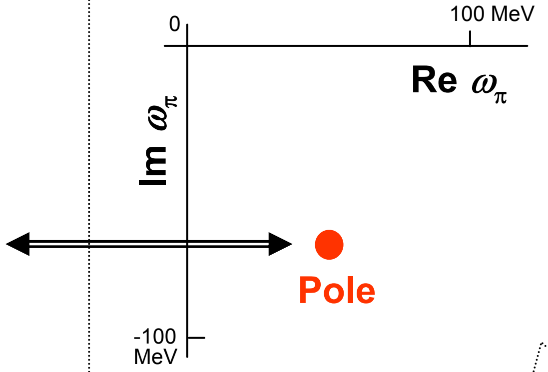
$$c_{ij}^{I=0}=\begin{bmatrix} 3 & -\sqrt{\frac{3}{2}} \\ -\sqrt{\frac{3}{2}} & 4 \end{bmatrix} \begin{matrix} \bar{K}N \\ \pi\Sigma \end{matrix}$$

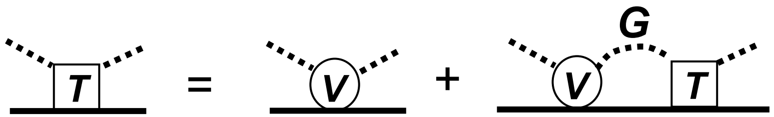
$$\omega_i \Leftarrow \sqrt{s}-M_i$$

Energy dependent interaction

with a large positive imaginary part

$\Sigma\pi$ channel

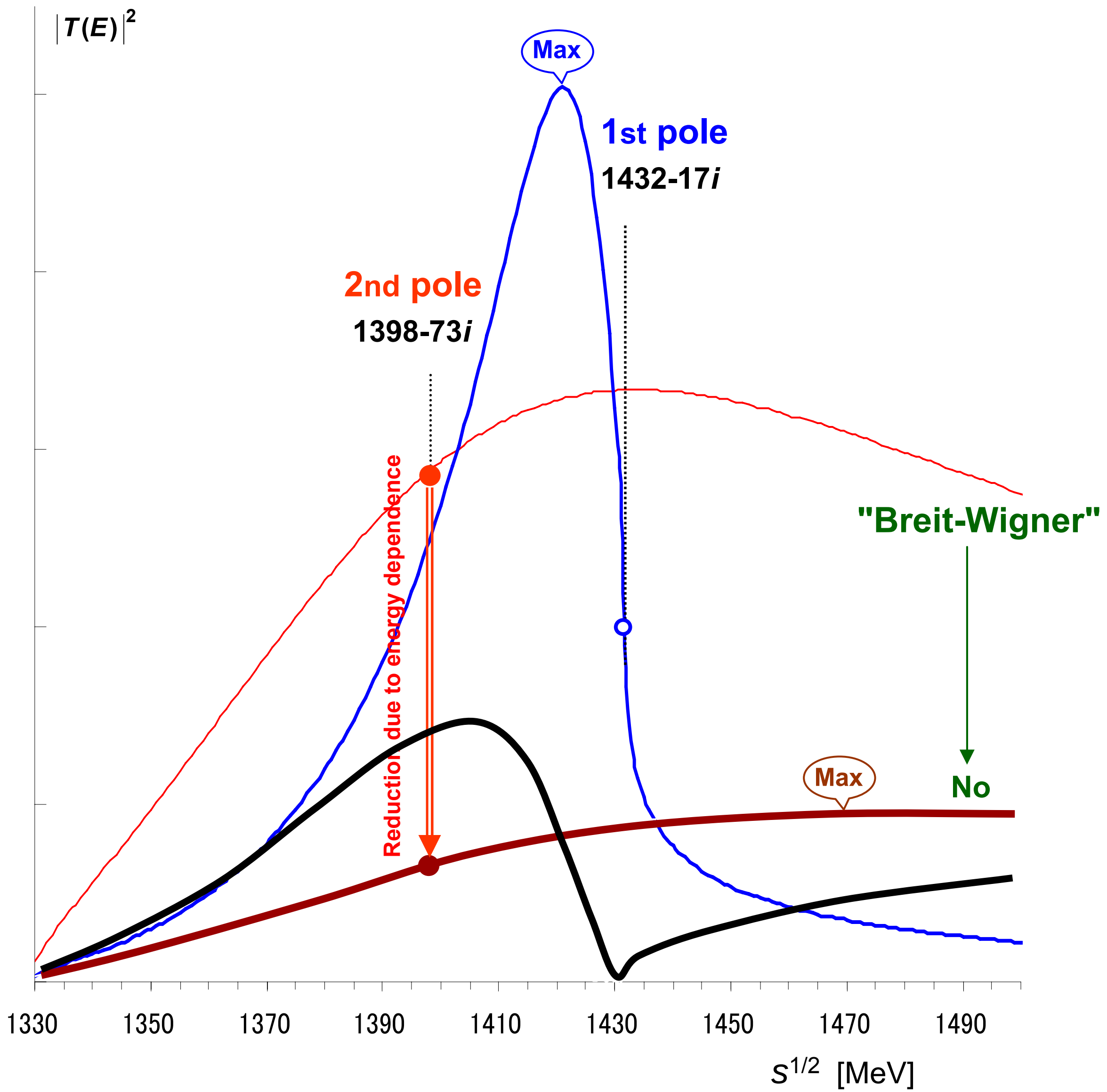


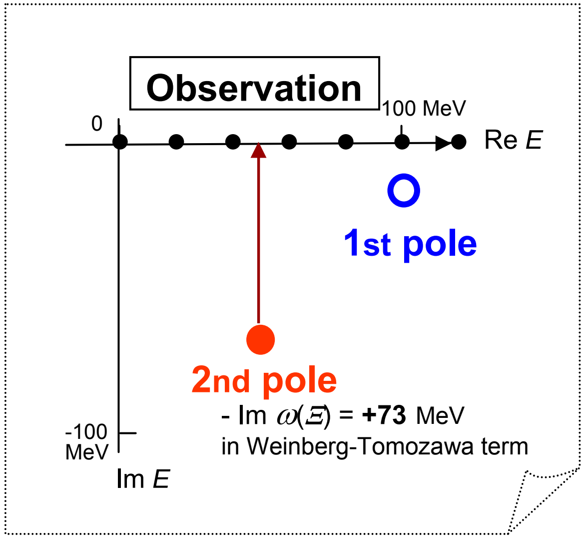


$$T=\frac{1}{1-VG}V \quad ; \quad V=\left\{V_{ij}^{WT}\right\}$$ Total 10 channels

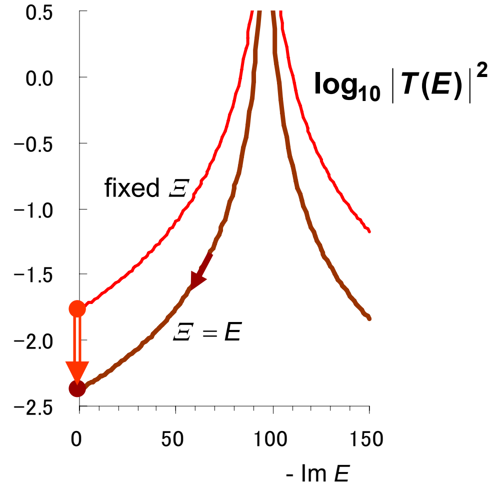
$$1-VG=0$$ ⇨ **Resonance (bound) states**

$\Sigma\pi$ invariant mass spectrum of $\bar{K}N$-$\Sigma\pi$ coupled system





$$|T(E)|^2 \approx \frac{\Gamma(\Xi)^2/4}{(E-E_R(\Xi))^2+\Gamma(\Xi)^2/4}$$

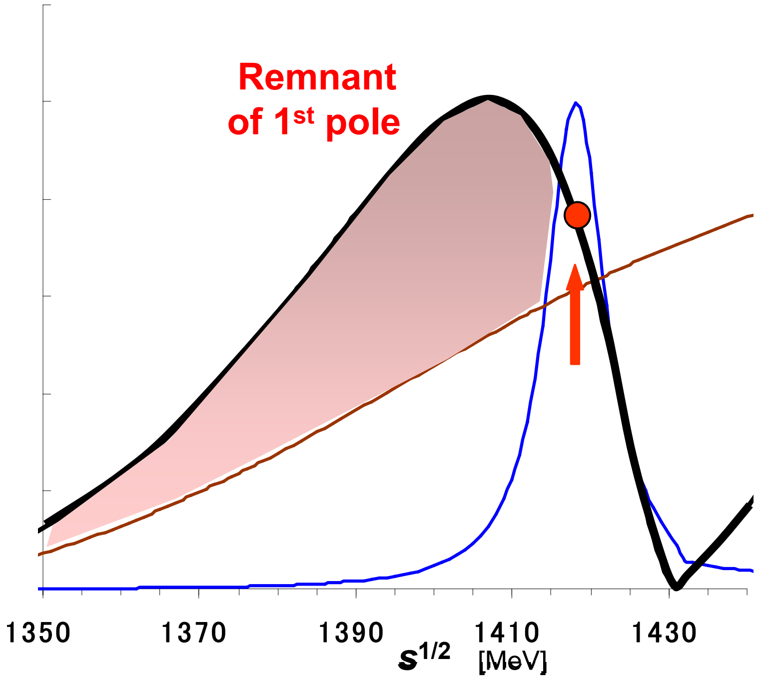


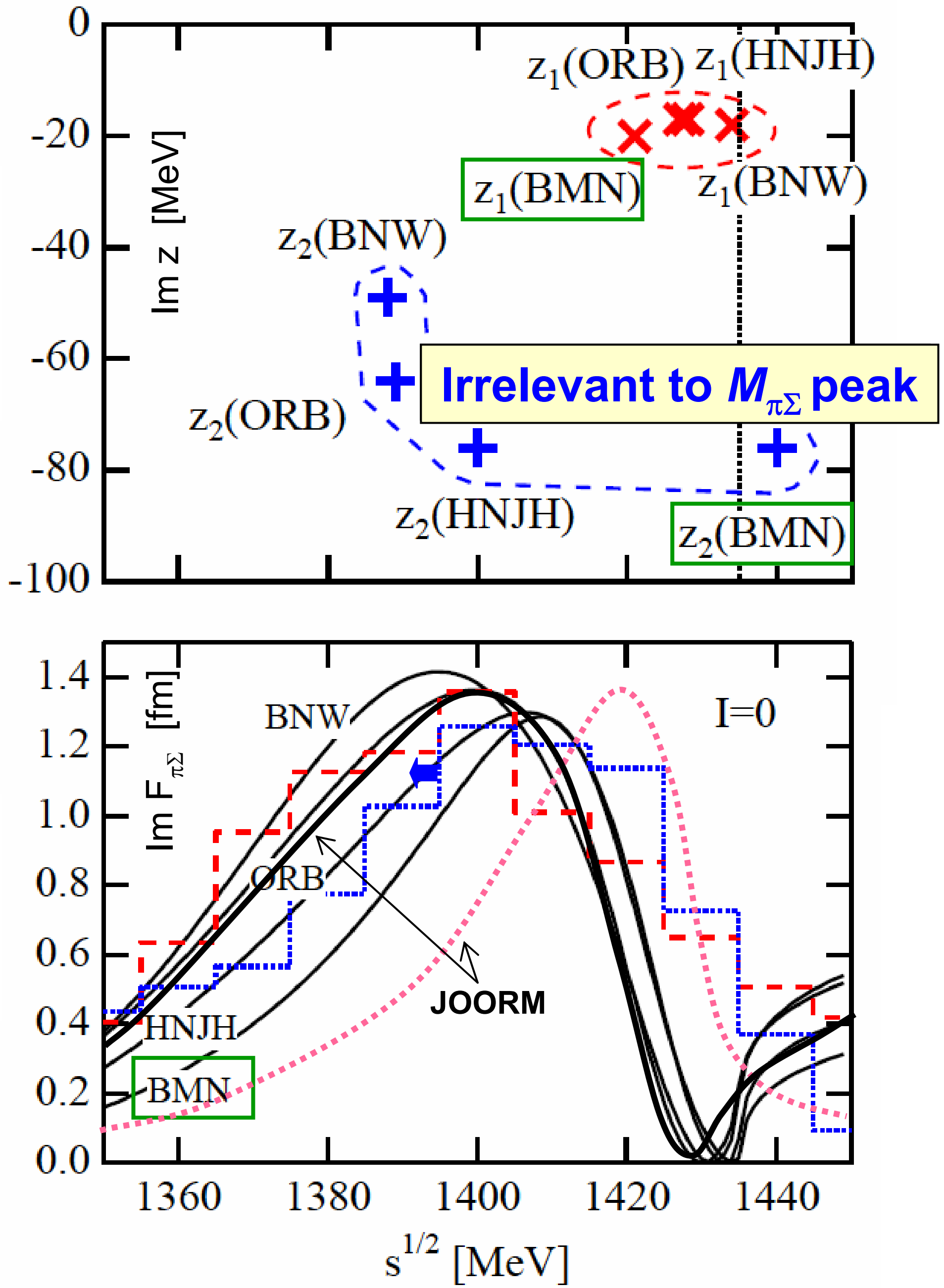
Feshbach theory

1 ; $\bar{K}N$
2 ; $\Sigma\pi$

Interference

$$|T_{22}(E)|^2 = \left| e^{i\delta_c} \sin\delta_c + \frac{\Gamma/2}{E - E_R + i\Gamma/2} \right|^2$$



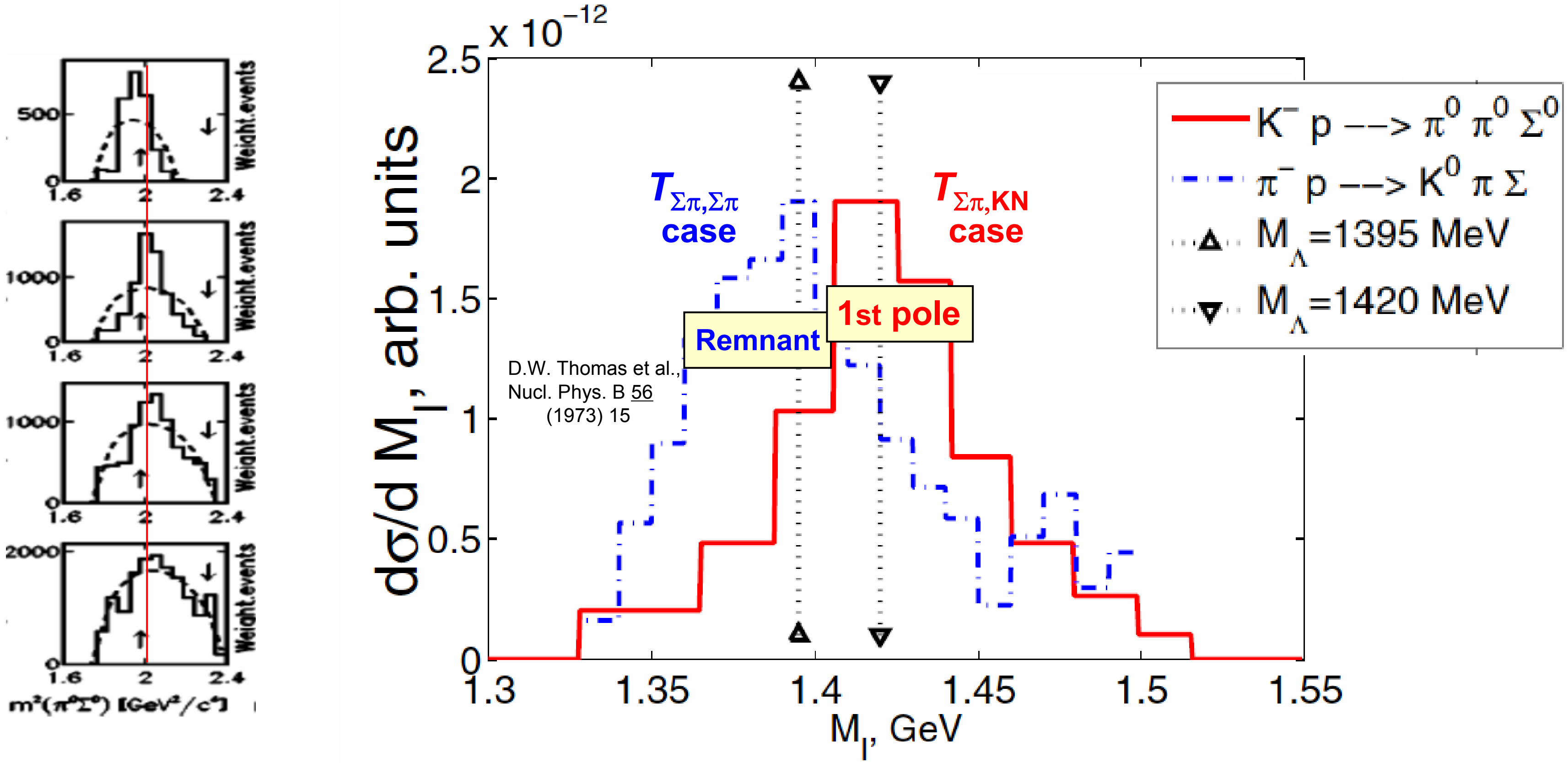


O. Morimatsu & K. Yazaki, Prog. Part. Nucl. Phys. 33 (1994) 679

Logically impossible !

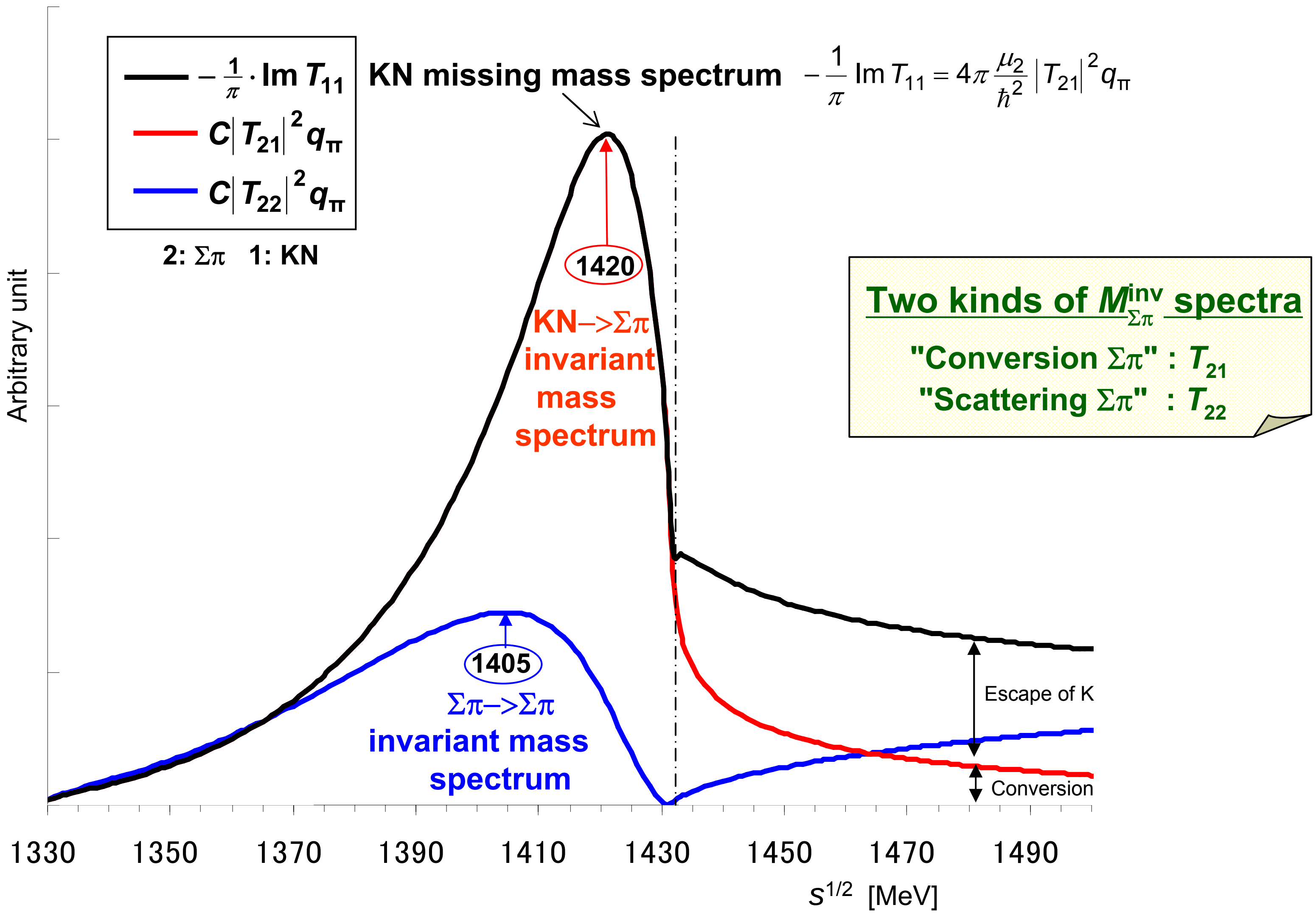
Evidence for two-pole structure of Λ(1405)

V.K. Magas, E. Oset and A. Ramos, Phys. Rev. Lett. 95 (2005) 052301

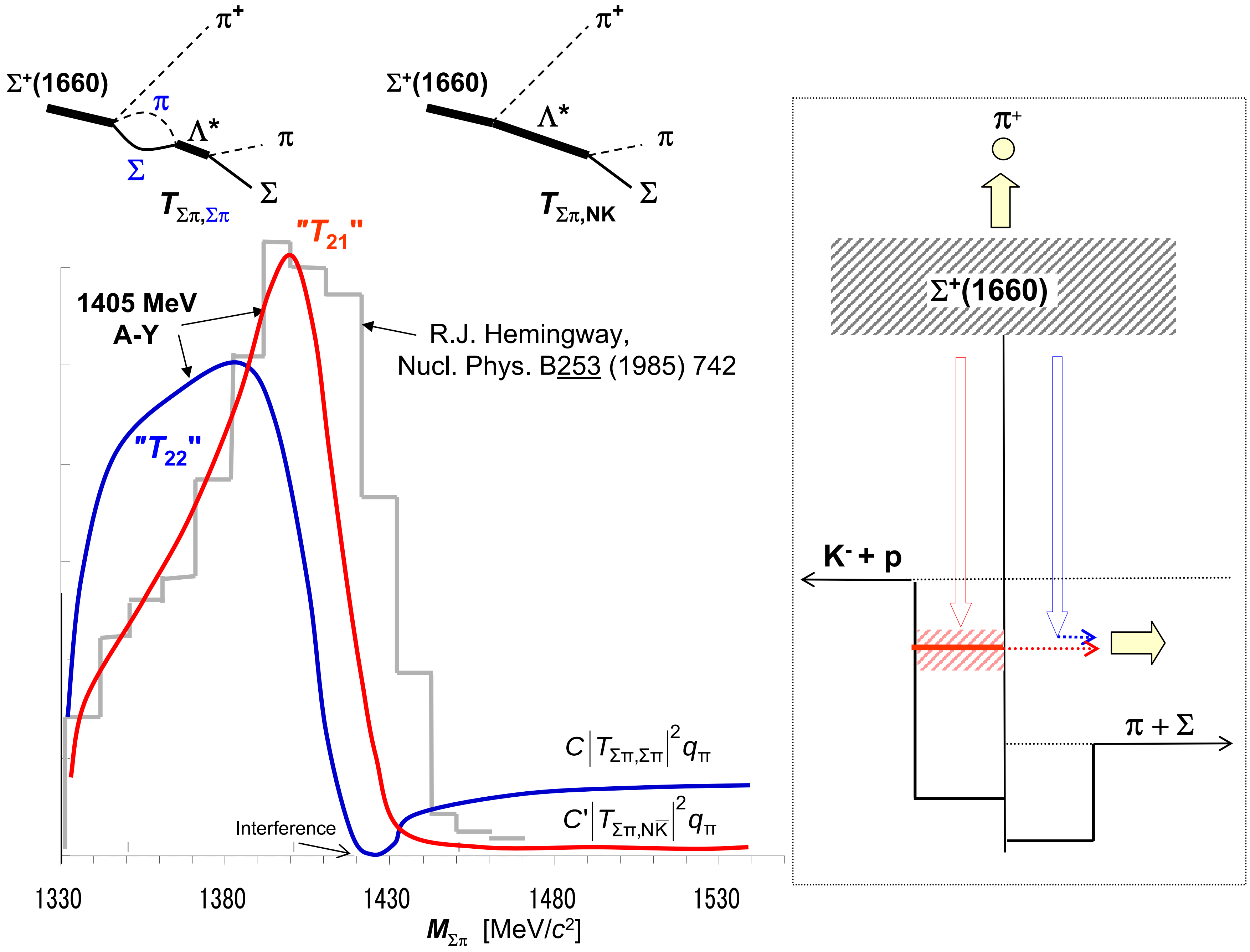


Observables of $\bar{K}$N-Σπ coupled system

Hyodo-Weise's chiral SU(3) dynamics

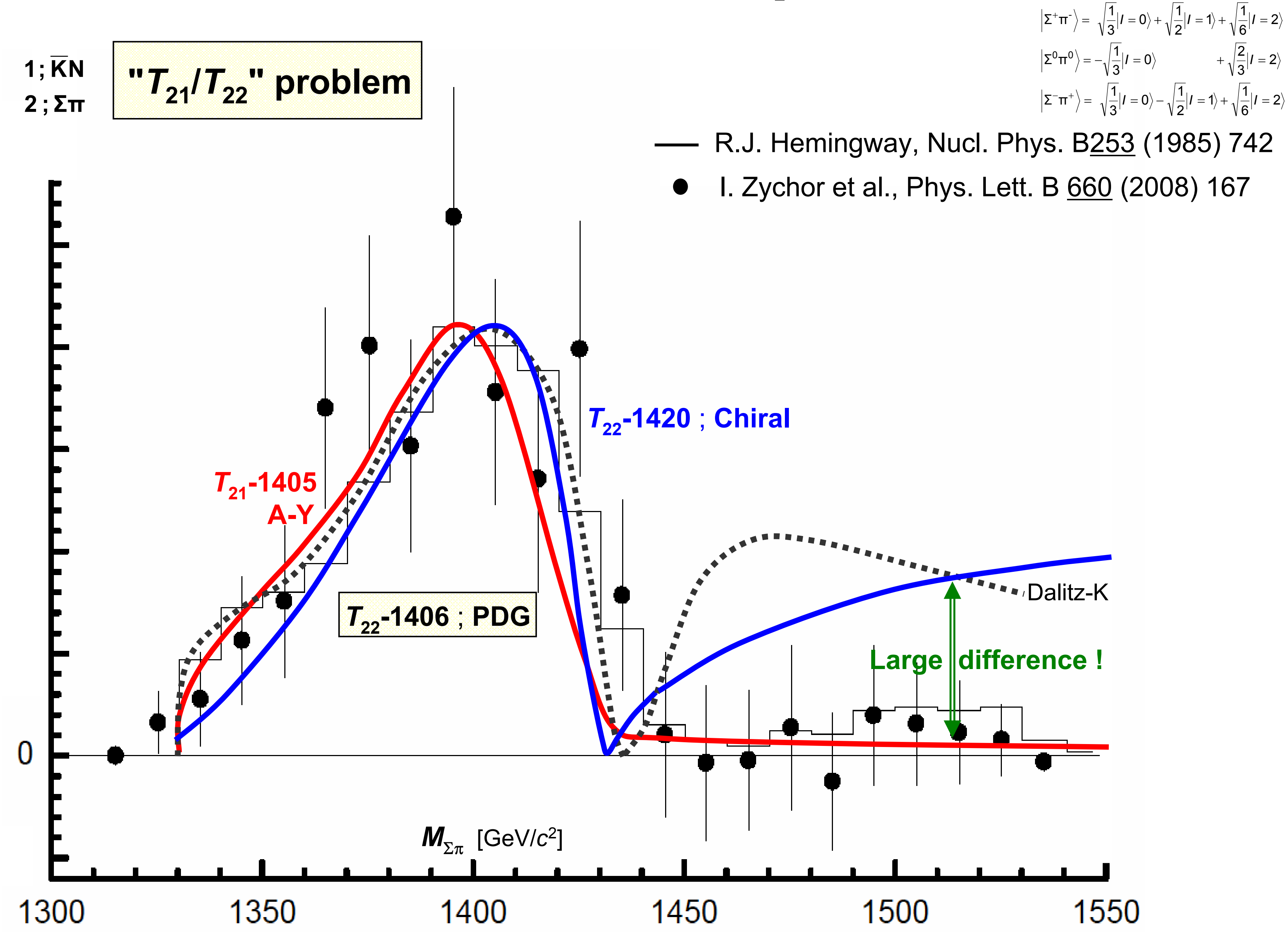


Weise/ChiralTm.f



Wpole/SpiInv1.f

Σπ invariant-mass spectrum



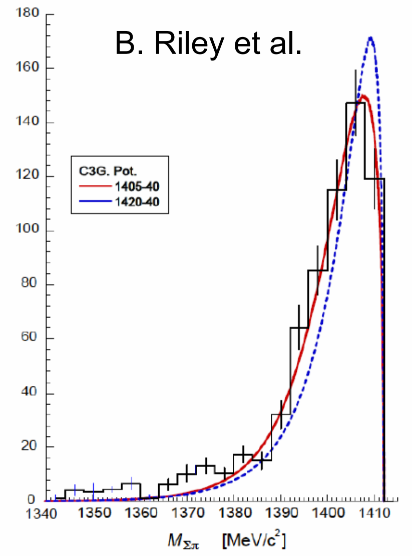
Concluding remarks

The Λ* resonance forms the basic structure of K^-pp.

The Λ(1405) is regarded to be of single-pole nature, since the 2nd pole is irrelevant to any experimental peak.

It is virtually important to distinguish the mass of Λ(1405), 1405 MeV or 1420 MeV, by considering "T_{21}/T_{22}" problem.

Stopped K^- on ^{4}He

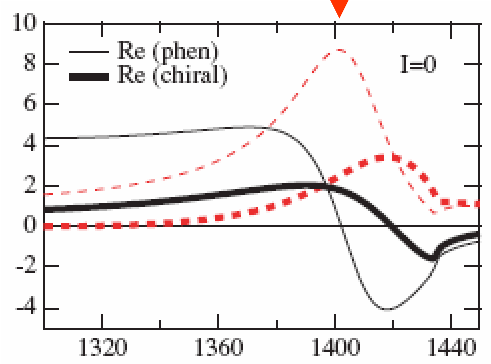


This T_{21} datum supports the "1405 Ansatz".

$$Mc^2 = 1405.5^{+1.4}_{-1.0} \text{ MeV and } \Gamma = 25.6^{+4}_{-3} \text{ MeV}$$

J. Esmaili et al.; arXiv:0906.0505

$$|T_{21}|^2 \, \mathrm{Im}\, G_2 = \mathrm{Im}\, T_{11}$$



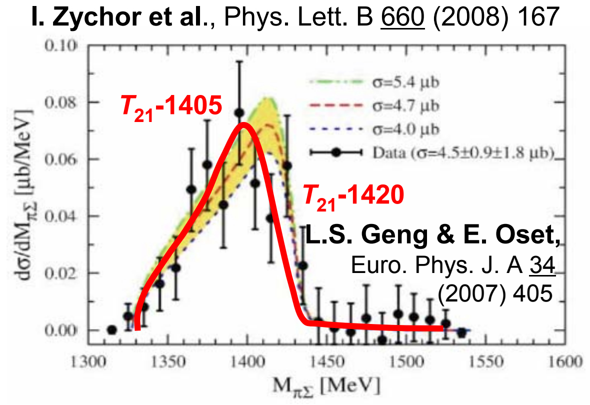
Stopped K^- on D T. Suzuki et al.

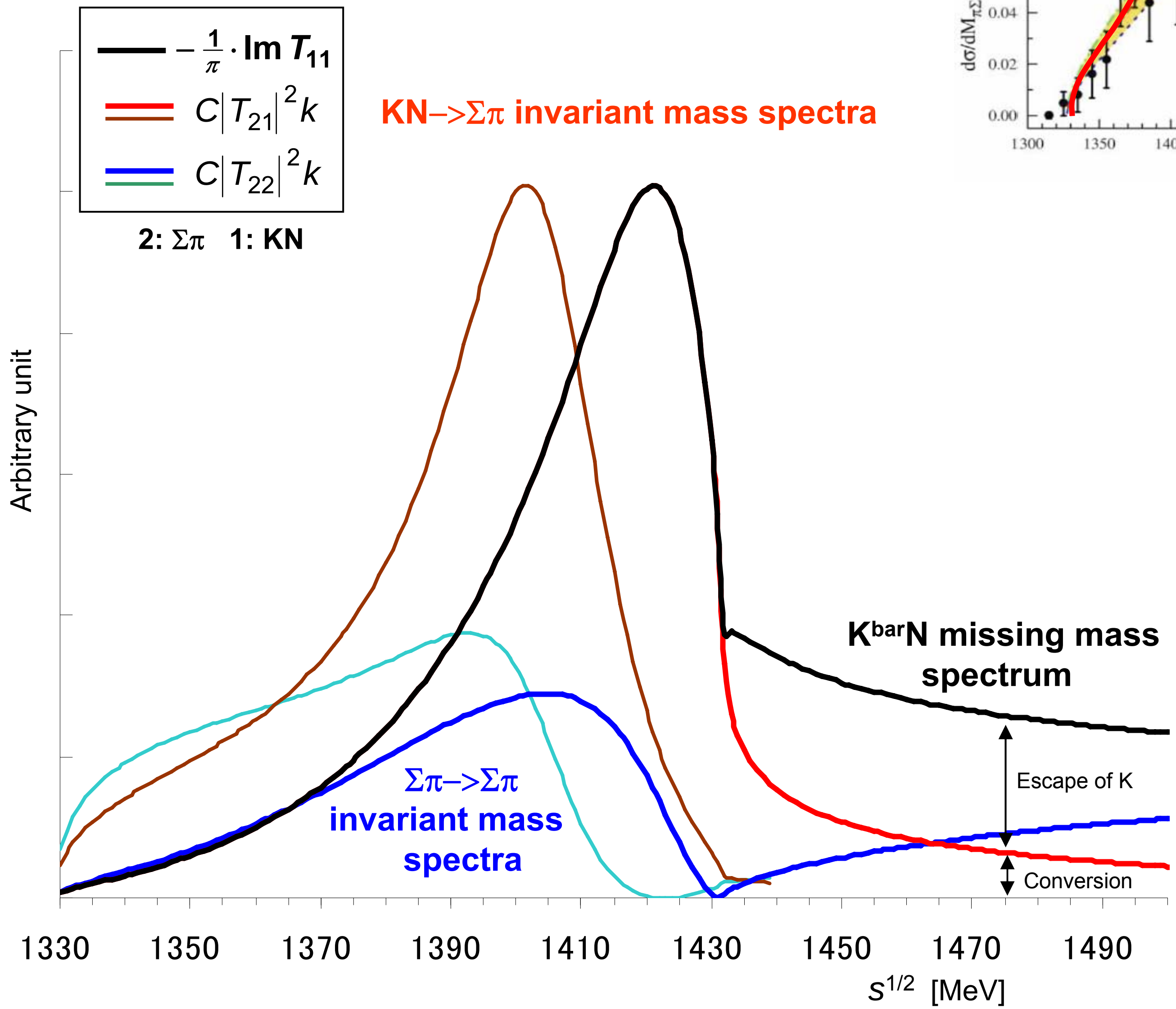
would provide a decisive datum.

Acknowledgments

J. Esmaili, K.S. Myint
M. Kawai, O. Morimatsu

Thank you very much!





Weise/ChiralTm.f
Weise/AMYsTm.f

$K^{-}d \rightarrow \Sigma^{-}\pi^{+}n$

P_K= **760** MeV/*c*

O. Braun et al.,
Nucl. Phys. B129 (1977) 1