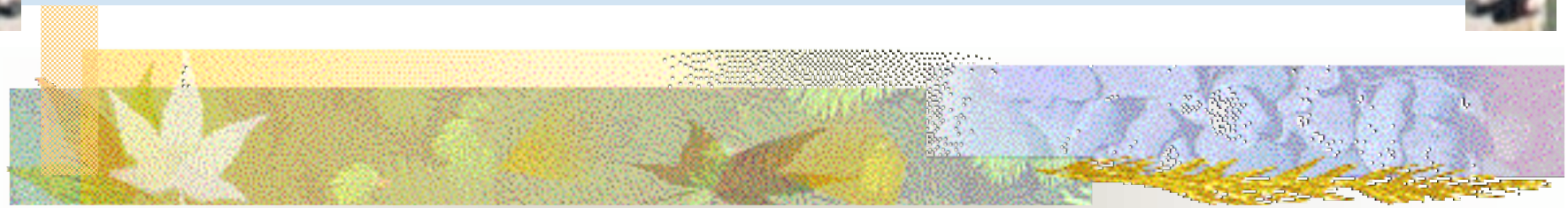
Photoproduction of K^* for the study of the structure of $\Lambda(1405)$



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Contents

1. Introduction

1. Motivation : Two poles?

2. Chiral unitary model

1. Framework of the chiral unitary model

2. Example : $K^- p$ scatterings

3. Pole structure of $\Lambda(1405)$

4. Example : $\pi^- p \to K^0 \pi\Sigma$

3. $K^* \Lambda(1405)$ production

1. Effective interactions

2. Numerical results

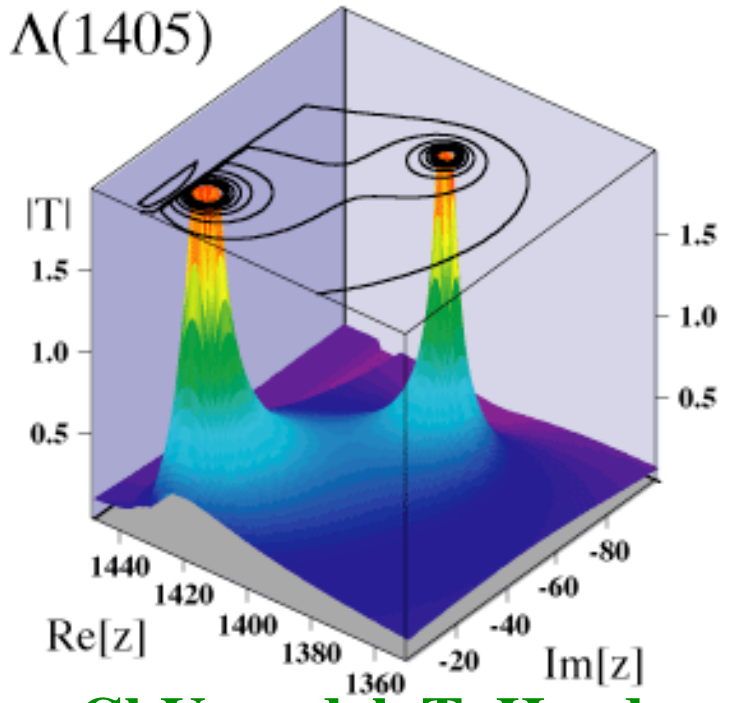
Motivations : Two poles?

There are two poles of the scattering amplitude around nominal Λ(1405) energy region.

- **Cloudy bag model (1990)**
  - J. Fink *et al.* PRC41, 2720

- **Chiral unitary model (2001~)**
  - J. A. Oller *et al.* PLB500, 263
  - E. Oset *et al.* PLB527, 99
  - D. Jido *et al.* PRC66, 025203
  - T. Hyodo *et al.* PRC68, 018201

Λ(1405) : $J^P=1/2^-$, I=0



ChU model, T. Hyodo

Chiral unitary model

Flavor SU(3) meson-baryon scatterings (s-wave)

Chiral symmetry

Low energy behavior

+

Unitarity of S-matrix

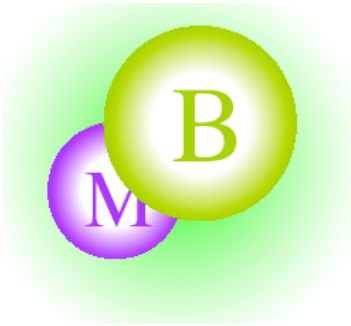
Non-perturbative resummation

Dynamical generation

$$J^P = 1/2^-$$

Resonances

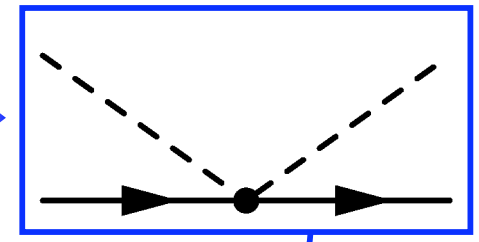
□(1405), □(1670), N(1535), □(1620), □(1620)



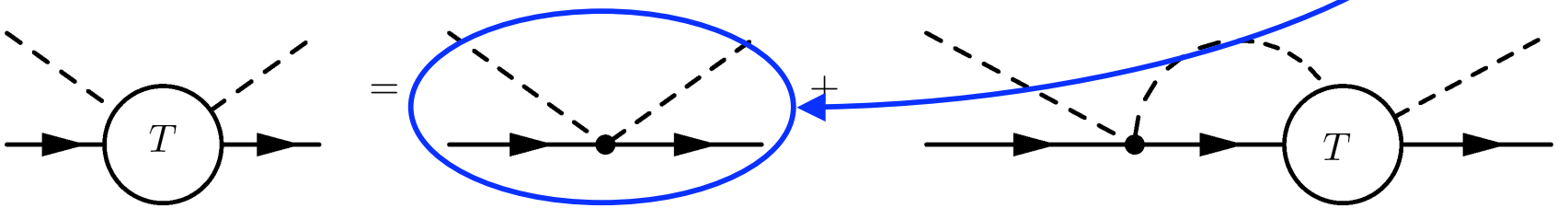
Framework of the chiral unitary model

Chiral perturbation theory

$$\mathcal{L}_{WT} = \frac{1}{4f^2}\mathrm{Tr}(\bar{B}i\gamma^\mu[(\Phi\partial_\mu\Phi - \partial_\mu\Phi\Phi), B])$$



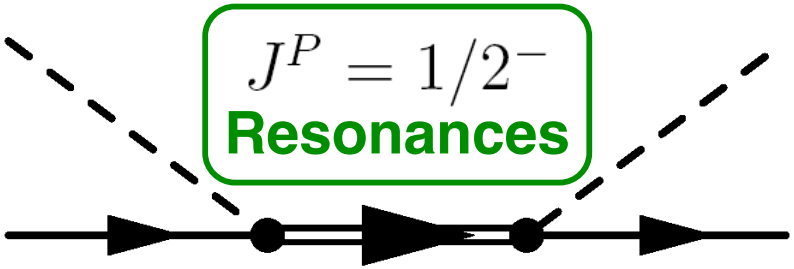
Unitarization



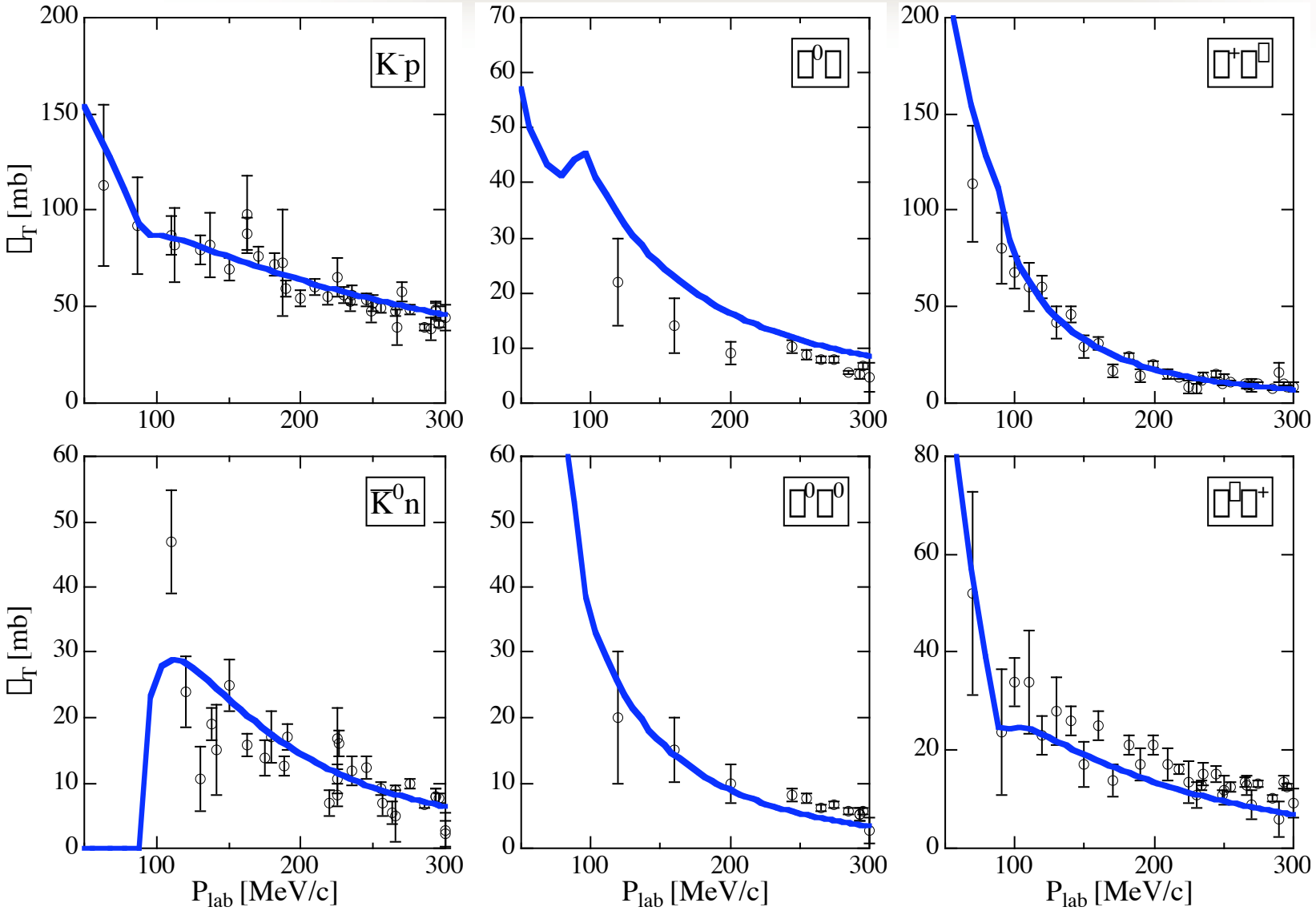
$$T_{ij}(\sqrt{s}) \sim \frac{g_i g_j}{\sqrt{s} - M_R + i\Gamma_R/2} + T_{ij}^{BG}$$

Generated resonances are expressed as poles of the scattering amplitude.

$\sim$



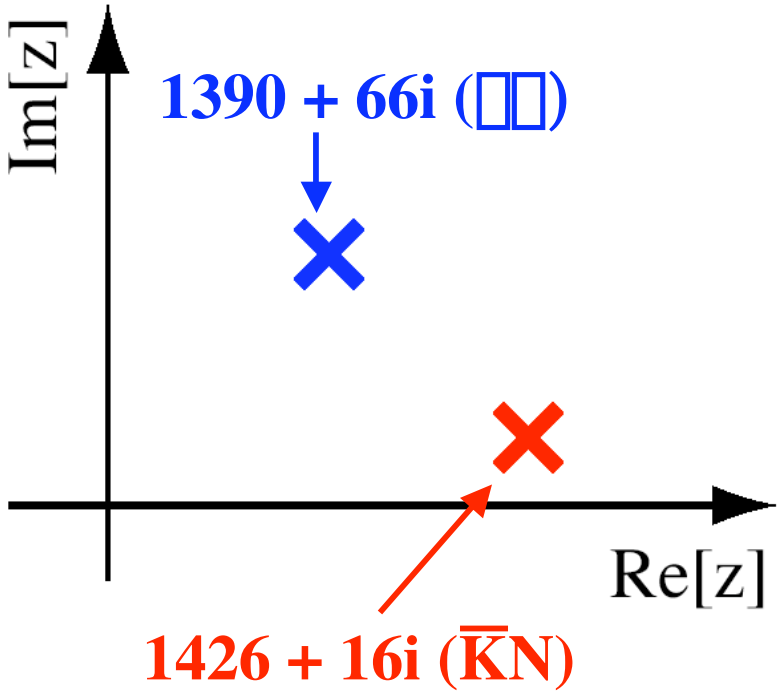
Total cross sections of K□p scatterings



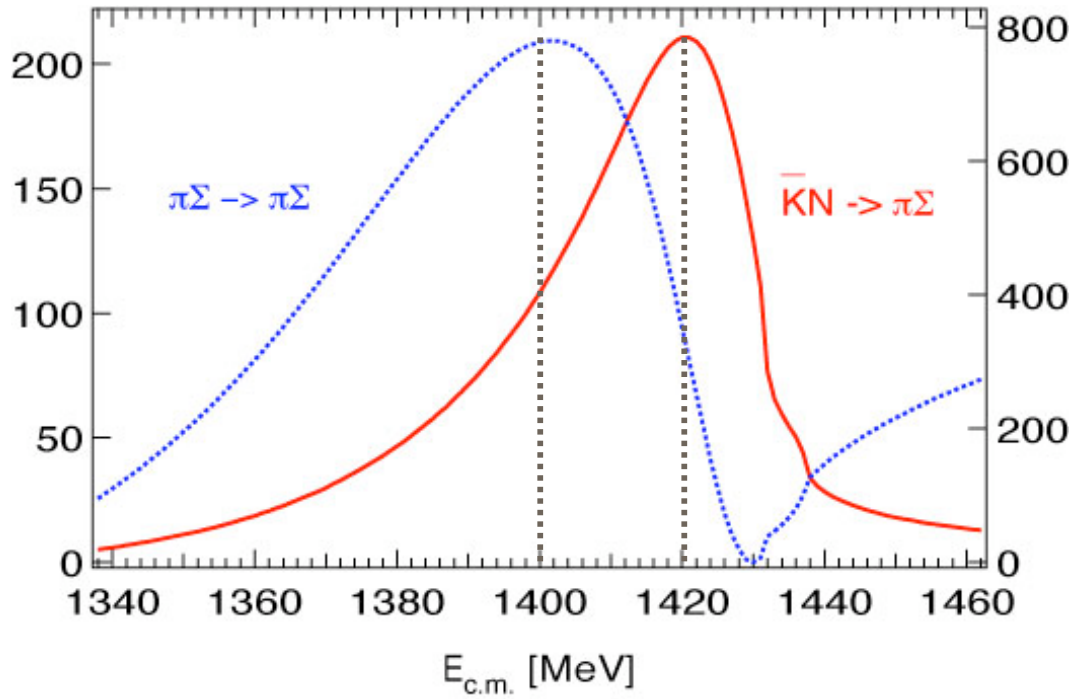
T. Hyodo, *et al.*, Phys. Rev. C 68, 018201 (2003)

□(1405) in the chiral unitary model

position of poles



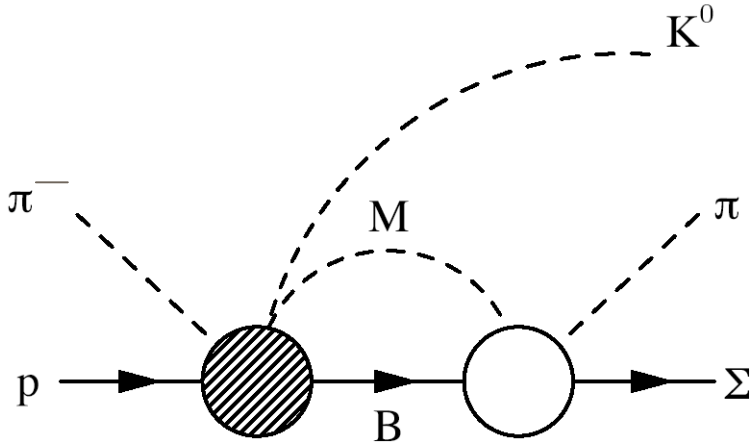
□□ mass distribution



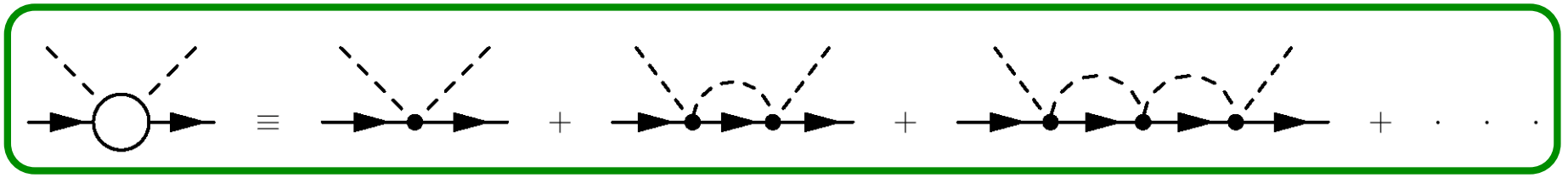
$$\frac{d\sigma}{dM_I} = C|t_{\pi\Sigma\to\pi\Sigma}|^2 p_{CM} \quad \Rightarrow \quad \frac{d\sigma}{dM_I} = |\sum_i C_i t_{i\to\pi\Sigma}|^2 p_{CM}$$

D. Jido, *et al.*, Nucl. Phys. A 723, 205 (2003)

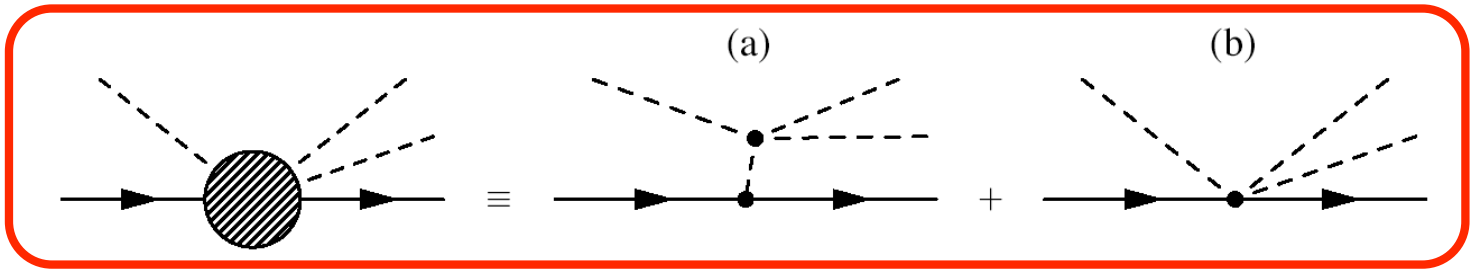
Example : the □□p -> K⁰□□ reaction



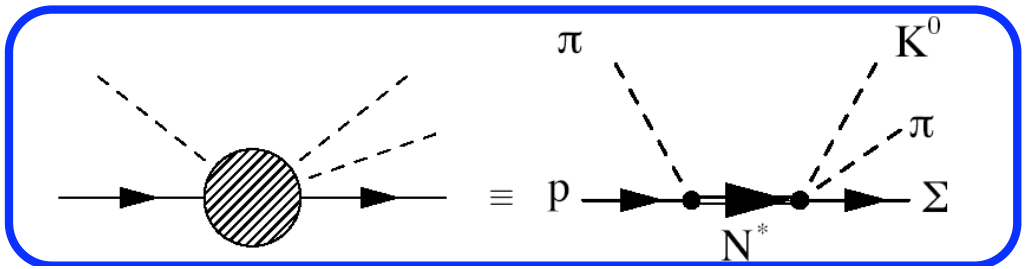
Chiral unitary model



Chiral term

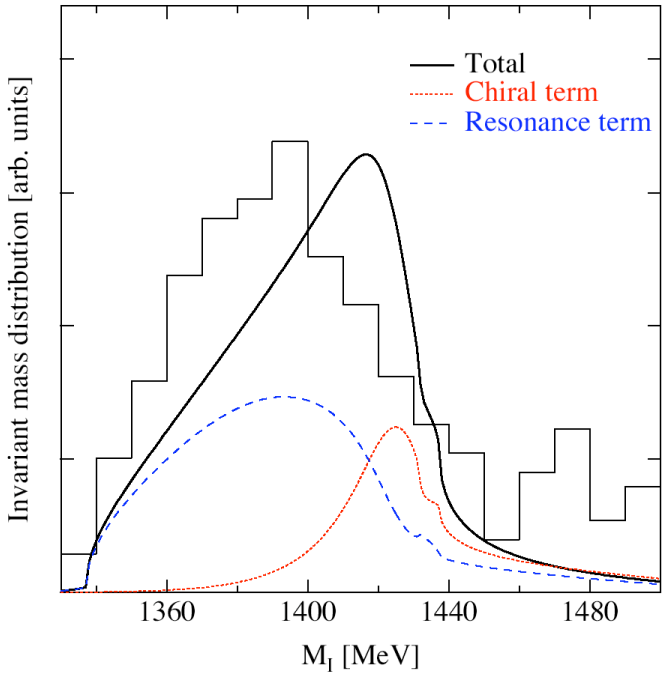


N(1710)



Results for □□p -> K⁰□□

Mass distribution



Total cross sections [mb]

final state	K^0K^-p	$K^0\bar{K}^0n$	$K^0\pi^0\Lambda$	$K^0\pi^+\Sigma^-$	$K^0\pi^-\Sigma^+$
Exp.	2.9	8.3	104.0	25.1	20.2
total	3.75	5.98	6.02	21.32	20.01
chiral	2.36	2.84	3.14	3.04	6.78
resonance	0.70	0.67	10.85	16.18	5.43

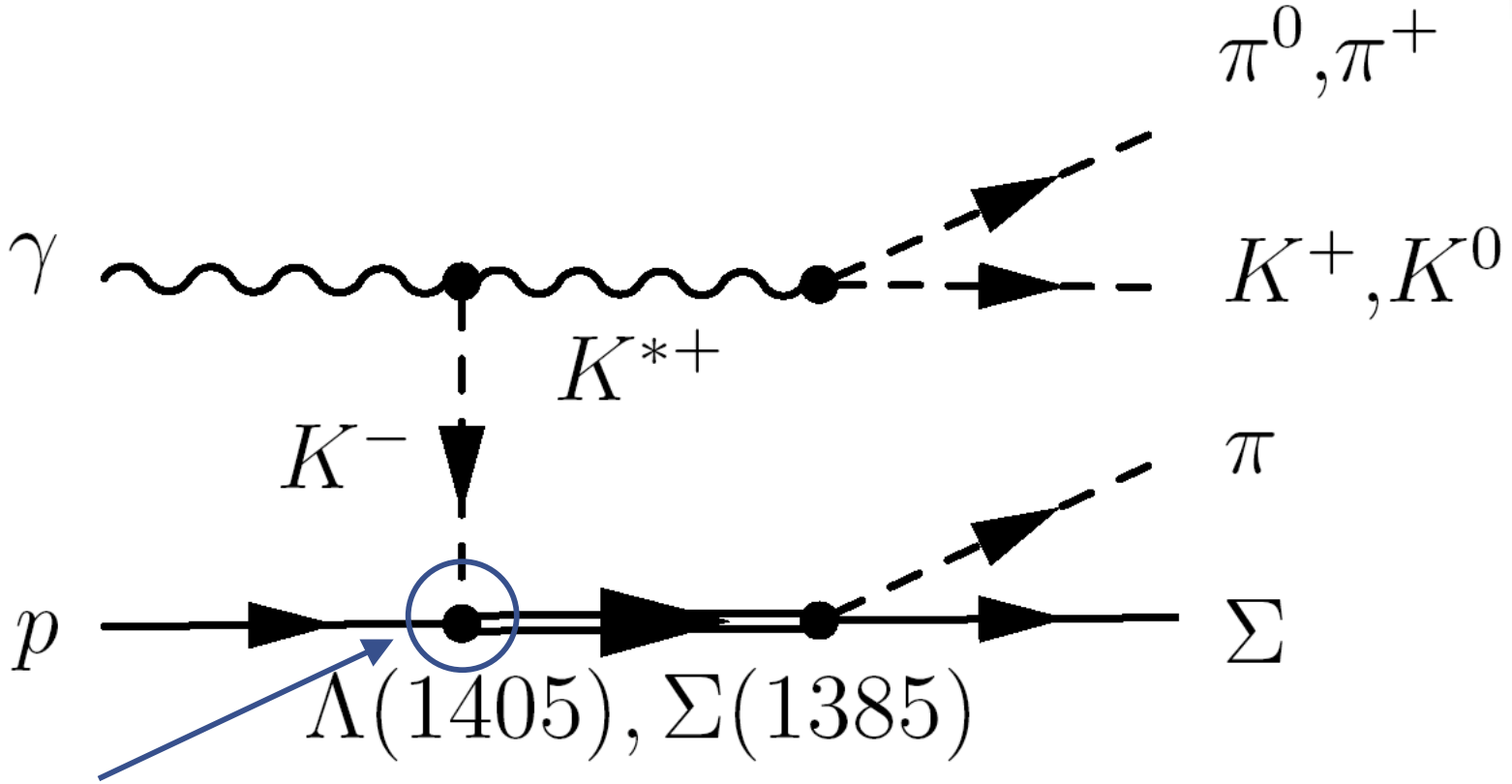
□(1385) effect

Good agreement

- There are two mechanisms in the initial stage interaction, which filter each one of the resonances.

T. Hyodo, *et al.*, nucl-th/0307005, Phys. Rev. C, in press

Photoproduction of K* Λ(1405)



Only K⁻p channel appears at the initial stage

Higher pole ??

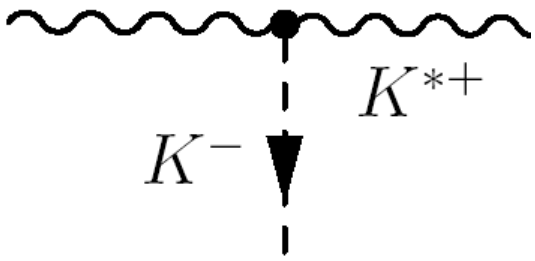
Effective interactions for meson part

1. □VP coupling

$$-it = ig_{\gamma K^* K}\epsilon^{\mu\nu\alpha\beta}P_\mu\epsilon_\nu(K^{*+})k_\alpha\epsilon_\beta(\gamma)\ ,$$

$$|g_{\gamma K^{*\pm}K^\pm}| = 0.252\ \ [\mathrm{GeV}^{-1}]\ ,$$

$$|g_{\gamma K^{*0}K^0}| = 0.385\ \ [\mathrm{GeV}^{-1}]\ .$$

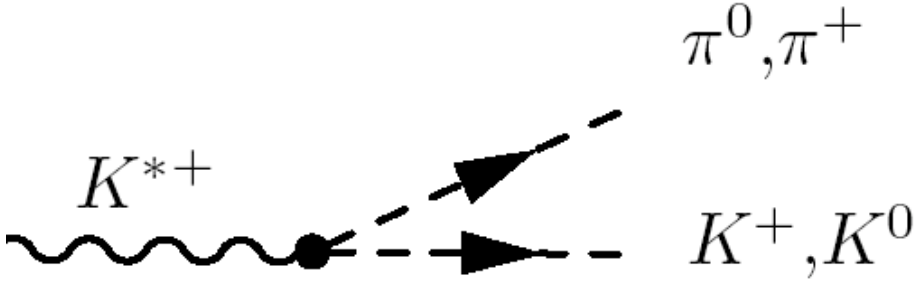


2. VPP coupling

$$-it(K^{*+} \to K^+\pi^0) = i\frac{g_{VPP}}{\sqrt{2}}\frac{1}{\sqrt{2}}[p_\mu(K^+) - p_\mu(\pi^0)]\epsilon^\mu(K^{*+})\ ,$$

$$-it(K^{*+} \to K^0\pi^+) = i\frac{g_{VPP}}{\sqrt{2}}[p_\mu(K^0) - p_\mu(\pi^+)]\epsilon^\mu(K^{*+})\ ,$$

$$g_{VPP} = -6.05$$



Effective interaction for □(1385)

3. □(1385)MB coupling

SU(6) symmetry

$$-it_{\Sigma^* i} = c_i \frac{12}{5} \frac{D+F}{2f} \boldsymbol{S} \cdot \boldsymbol{k}_i$$

channel i	$K^- p$	$\bar{K}^0 n$	$\pi^0 \Lambda$	$\pi^0 \Sigma^0$	$\eta \Lambda$	$\eta \Sigma^0$	$\pi^+ \Sigma^-$	$\pi^- \Sigma^+$	$K^+ \Xi^-$	$K^0 \Xi^0$
c_i	$-\sqrt{\frac{1}{12}}$	$\sqrt{\frac{1}{12}}$	$\sqrt{\frac{1}{4}}$	0	0	$-\sqrt{\frac{1}{4}}$	$-\sqrt{\frac{1}{12}}$	$\sqrt{\frac{1}{12}}$	$\sqrt{\frac{1}{12}}$	$-\sqrt{\frac{1}{12}}$

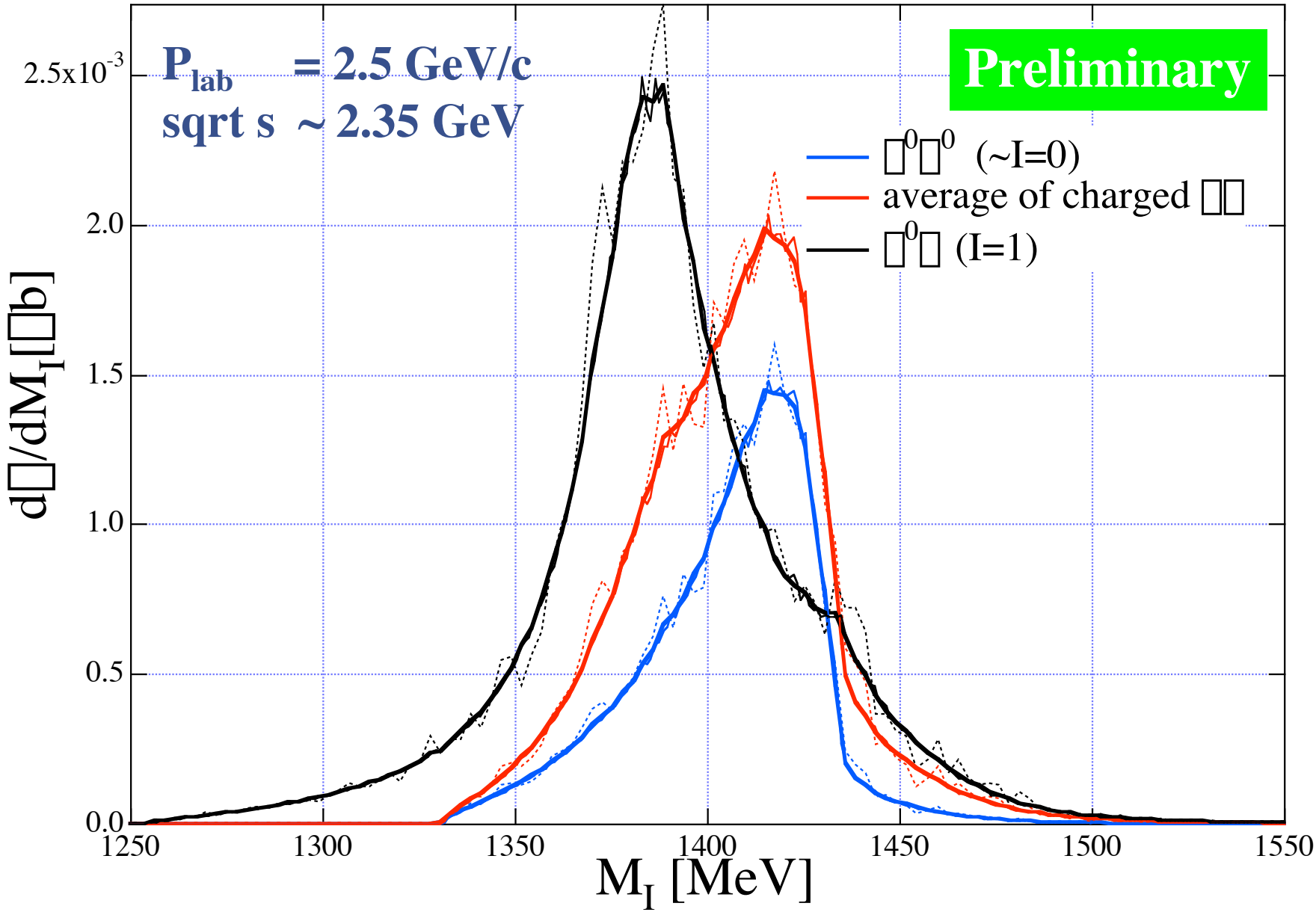
4. K□P -> □(1385) -> MB amplitude

$$-it_{1i} = c_1 c_i \left(\frac{12}{5} \frac{D+F}{2f} \right)^2 \boldsymbol{S} \cdot \boldsymbol{k}_1 \boldsymbol{S}^\dagger \cdot \boldsymbol{k}_i \frac{i}{M_I^{(b)} - M_{\Sigma^*} + i\Gamma_{\Sigma^*}/2} F_f(k_1)$$

$$= c_1 c_i \left(\frac{12}{5} \frac{D+F}{2f} \right)^2 (k_1)_l (k_i)_m \left(\frac{2}{3}\delta_{lm} - \frac{i}{3}\epsilon_{lmn}\sigma_n \right) \frac{i}{M_I^{(b)} - M_{\Sigma^*} + i\Gamma_{\Sigma^*}/2} F_f(k_1)$$

$$F_f(k_1) = \frac{\Lambda^2 - m_K^2}{\Lambda^2 - (k_1)^2}$$

Experiments : □□ mass distribution



Summary and conclusions

We study the structure of Λ(1405) using the chiral unitary model.

- There are two poles of the scattering amplitude around nominal Λ(1405).

Pole 1 (1426+16i) : strongly couples to KN state
Pole 2 (1390+66i) : strongly couples to ΣΠ state

- By observing the ΣΠ mass distribution in the γp -> K*Λ(1405) reaction, it could be possible to isolate higher energy pole.

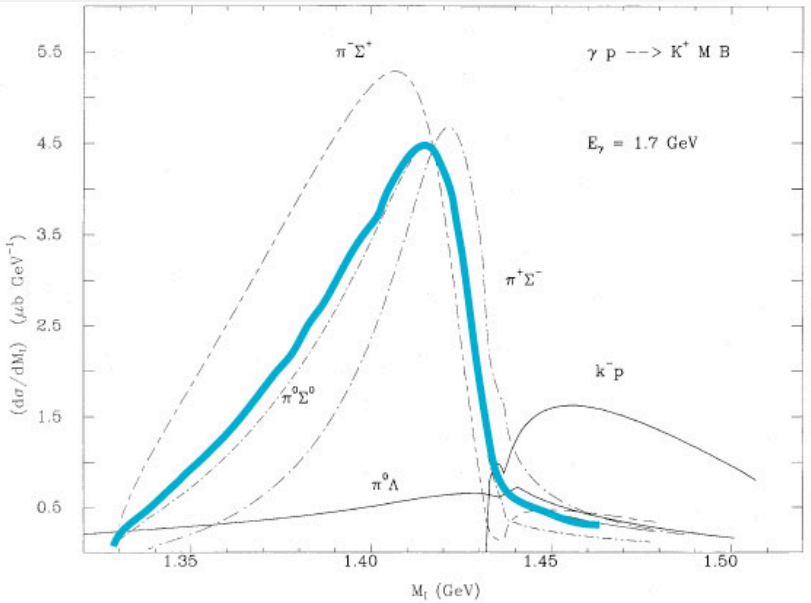
http://www.rcnp.osaka-u.ac.jp/~hyodo/index_e.html

Appendix : other processes

□p -> K□□

J.C. Nacher, *et al.*, PLB445, 55(1999)

Spring-8



□□p -> □□□

J.C. Nacher, *et al.*, PLB461, 299(1999)

J-PARC?