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

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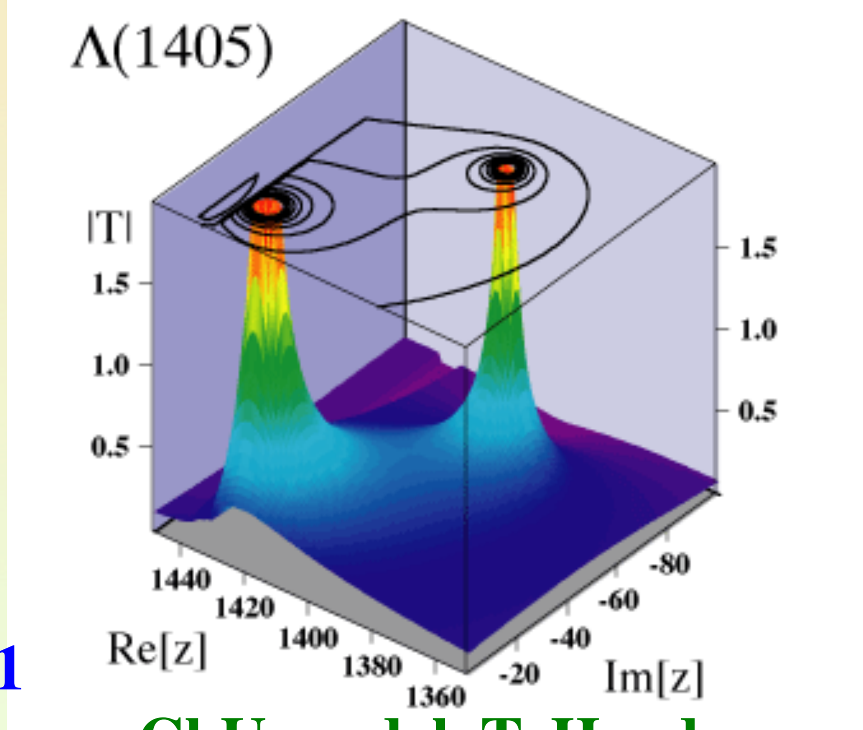
Motivations : Two poles?

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

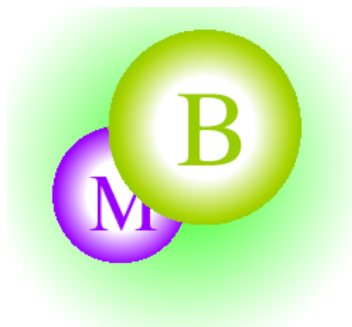
Non-perturbative resummation

Dynamical generation →

$J^P = 1/2^-$

Resonances

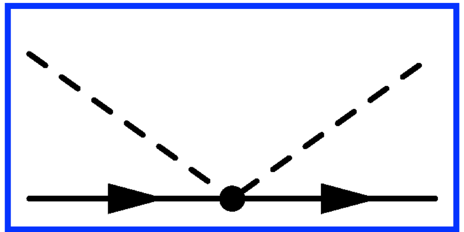
Λ(1405), Λ(1670), N(1535), Σ(1620), Ξ(1620)



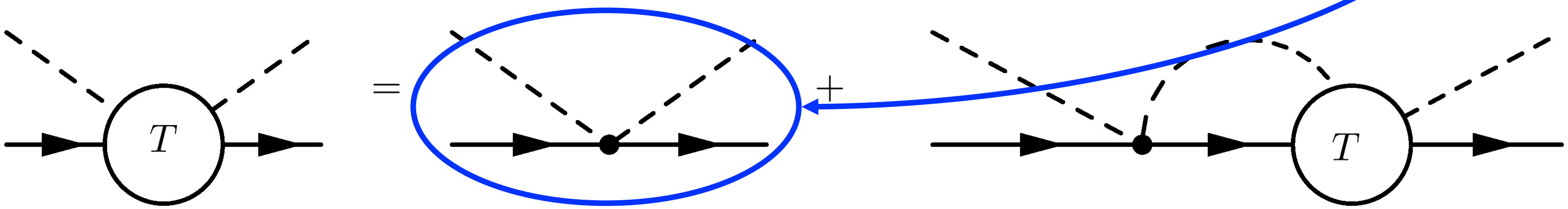
Framework of the chiral unitary model

Chiral perturbation theory

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



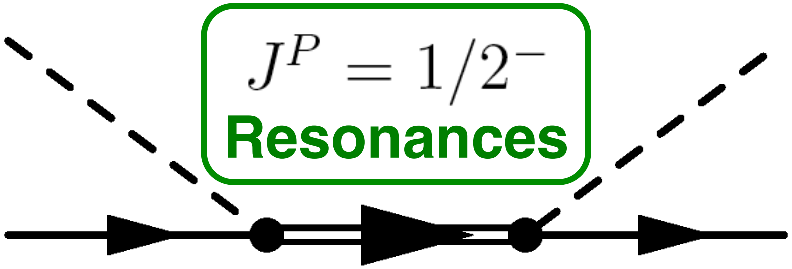
Unitarization



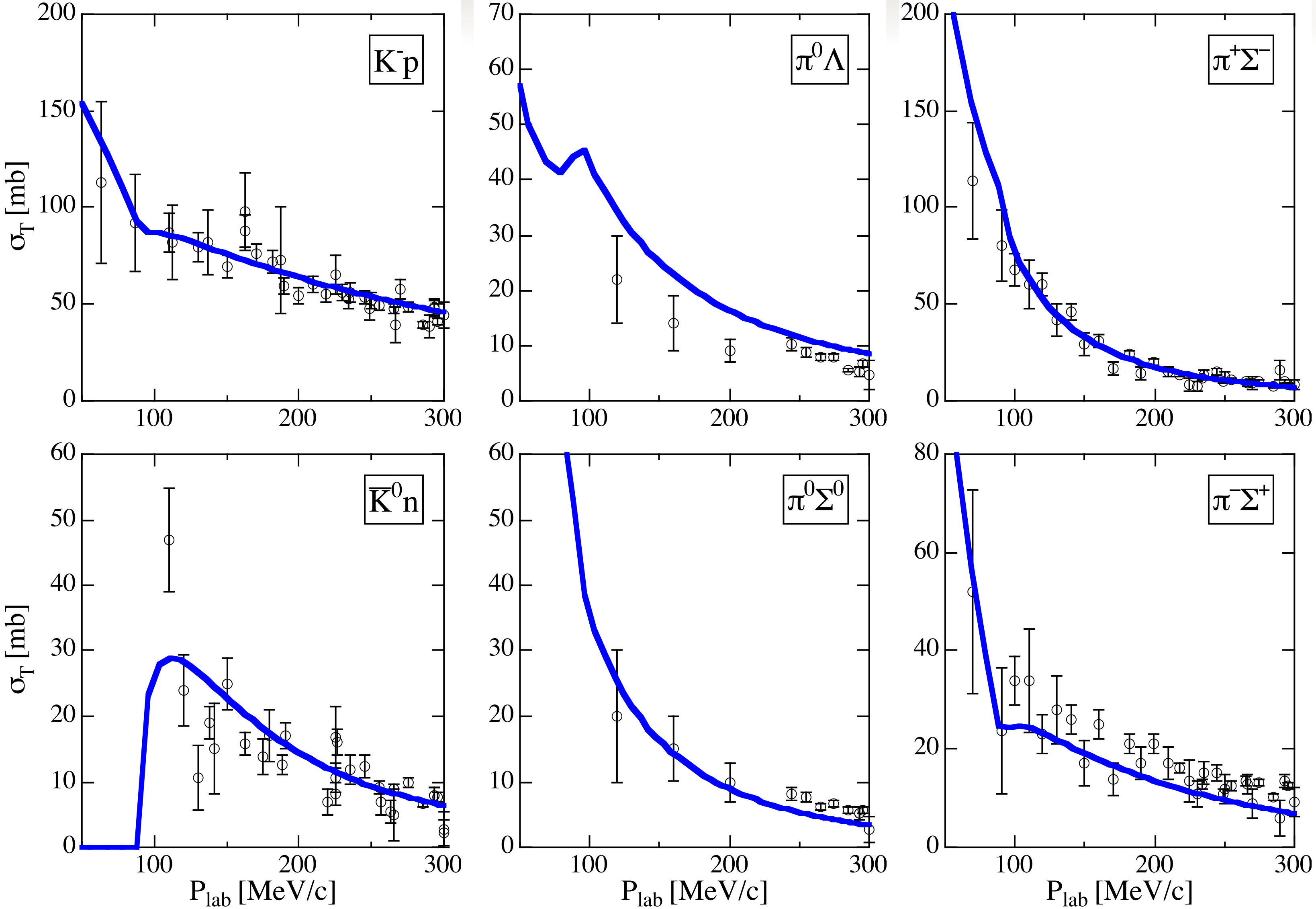
$$T_{ij}(\sqrt{s}) \sim \frac{g_i g_j}{\sqrt{s} - M_R + i\Gamma_R/2} + T_{ij}^{BG}$$

Generated resonances are expressed as poles of the scattering amplitude.

$\sim$



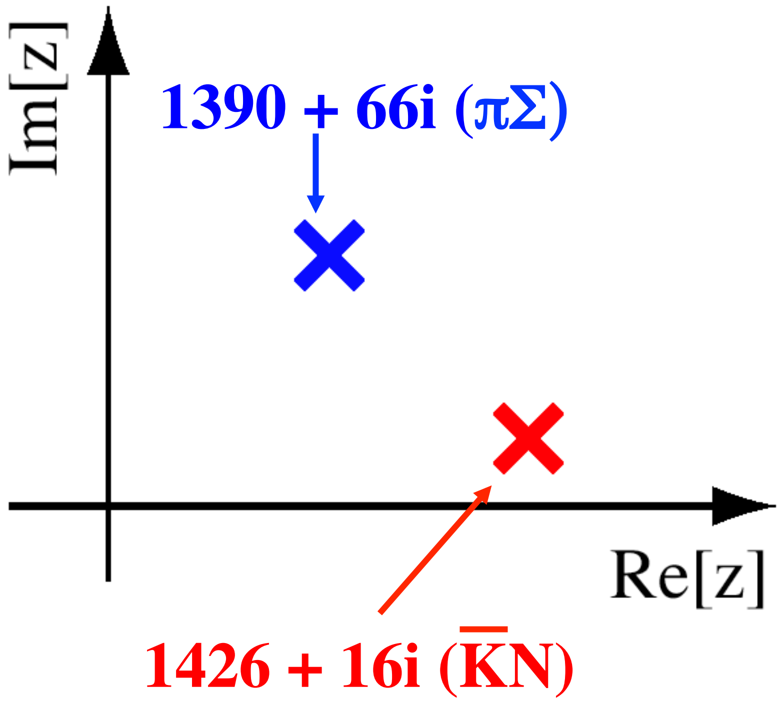
Total cross sections of K⁻p scatterings



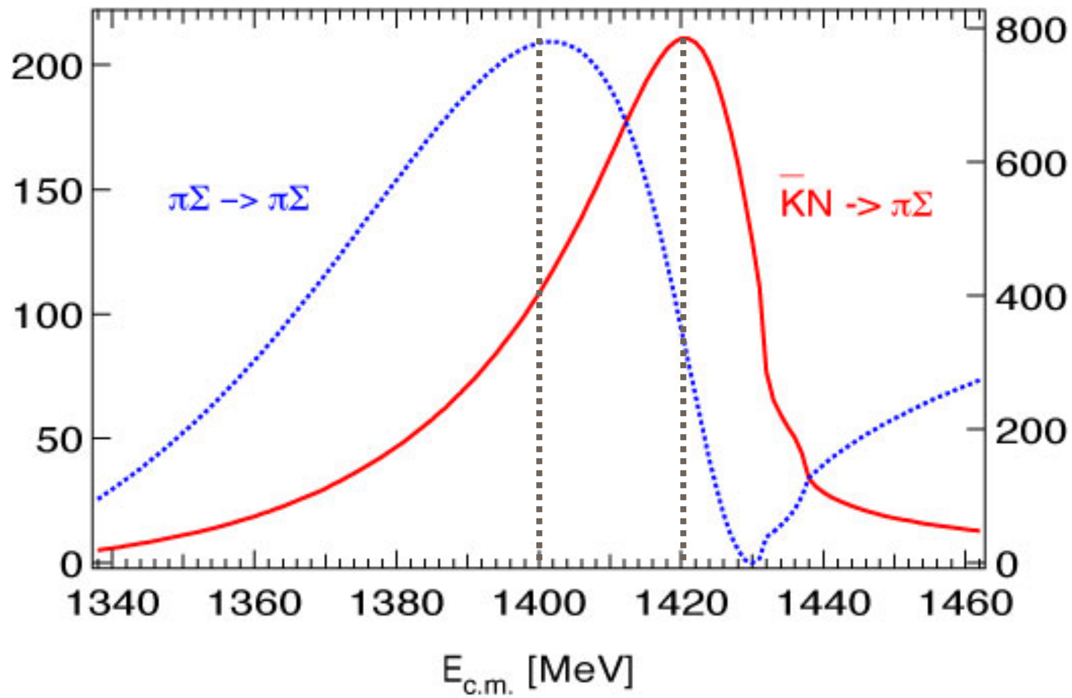
T. Hyodo, *et al.*, Phys. Rev. C 68, 018201 (2003)

Λ(1405) in the chiral unitary model

position of poles



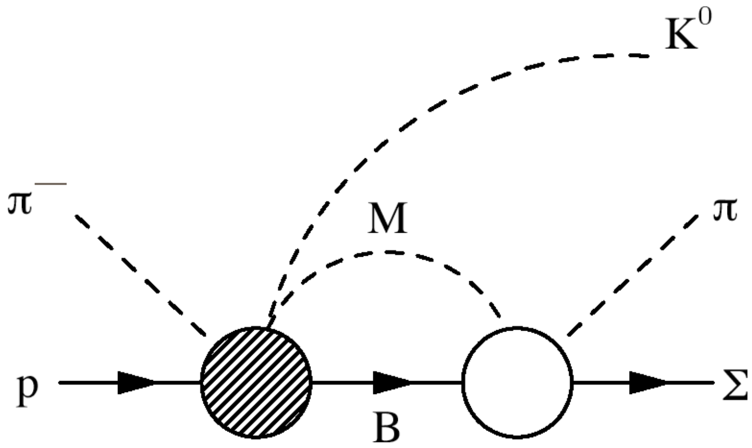
πΣ mass distribution



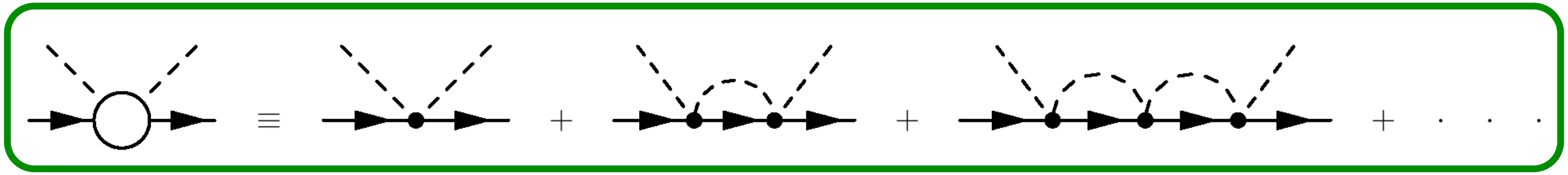
$$\frac{d\sigma}{dM_I} = C|t_{\pi\Sigma\to\pi\Sigma}|^2 p_{CM} \Rightarrow \frac{d\sigma}{dM_I} = |\sum_i C_i t_{i\to\pi\Sigma}|^2 p_{CM}$$

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

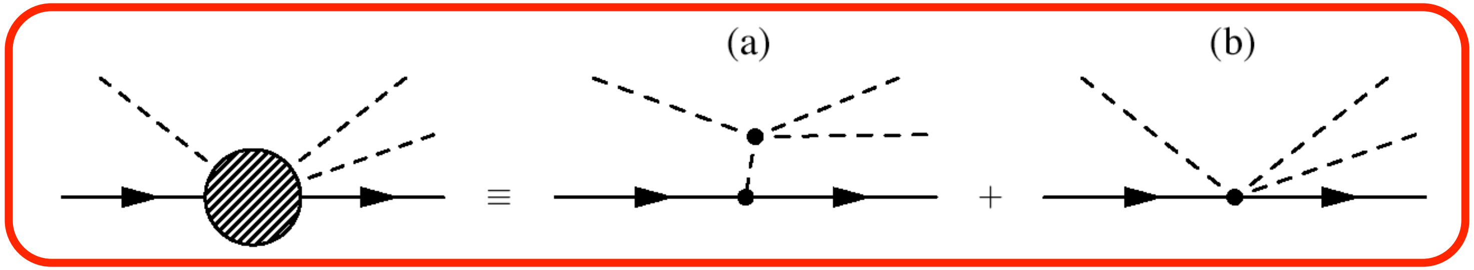
Example : the $\pi^- p \rightarrow K^0 \pi \Sigma$ reaction



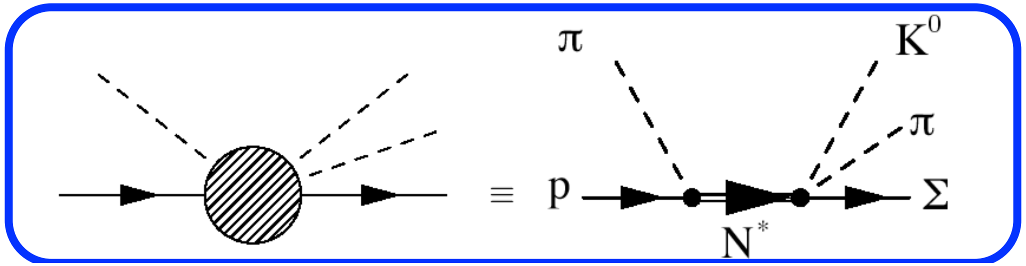
Chiral unitary model



Chiral term

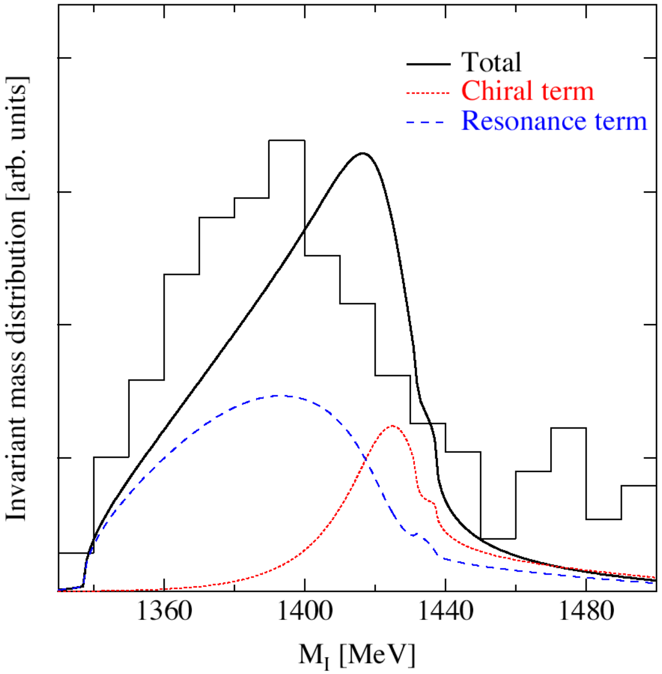


N(1710)



Results for $\pi^- p \to K^0 \pi \Sigma$

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

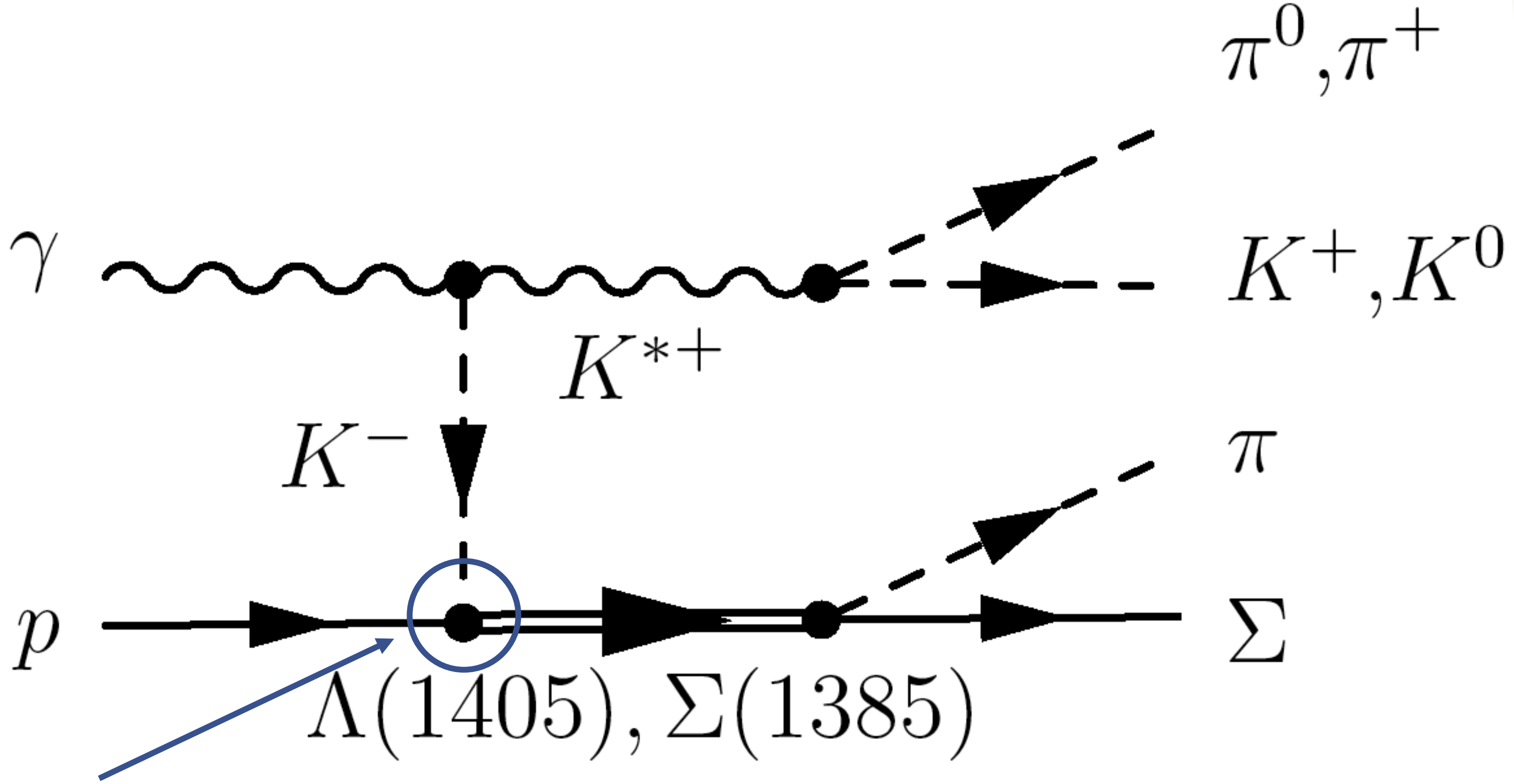
Σ(1385) effect

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 ??

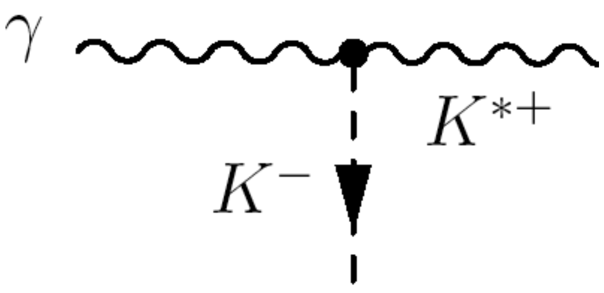
Effective interactions for meson part

1. γVP coupling

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

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

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

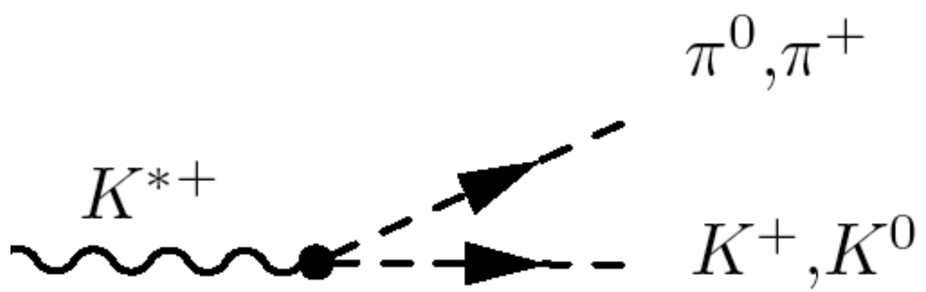


2. VPP coupling

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

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

$$g_{VPP} = -6.05$$



Effective interaction for Σ(1385)

3. Σ(1385)MB coupling

SU(6) symmetry

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

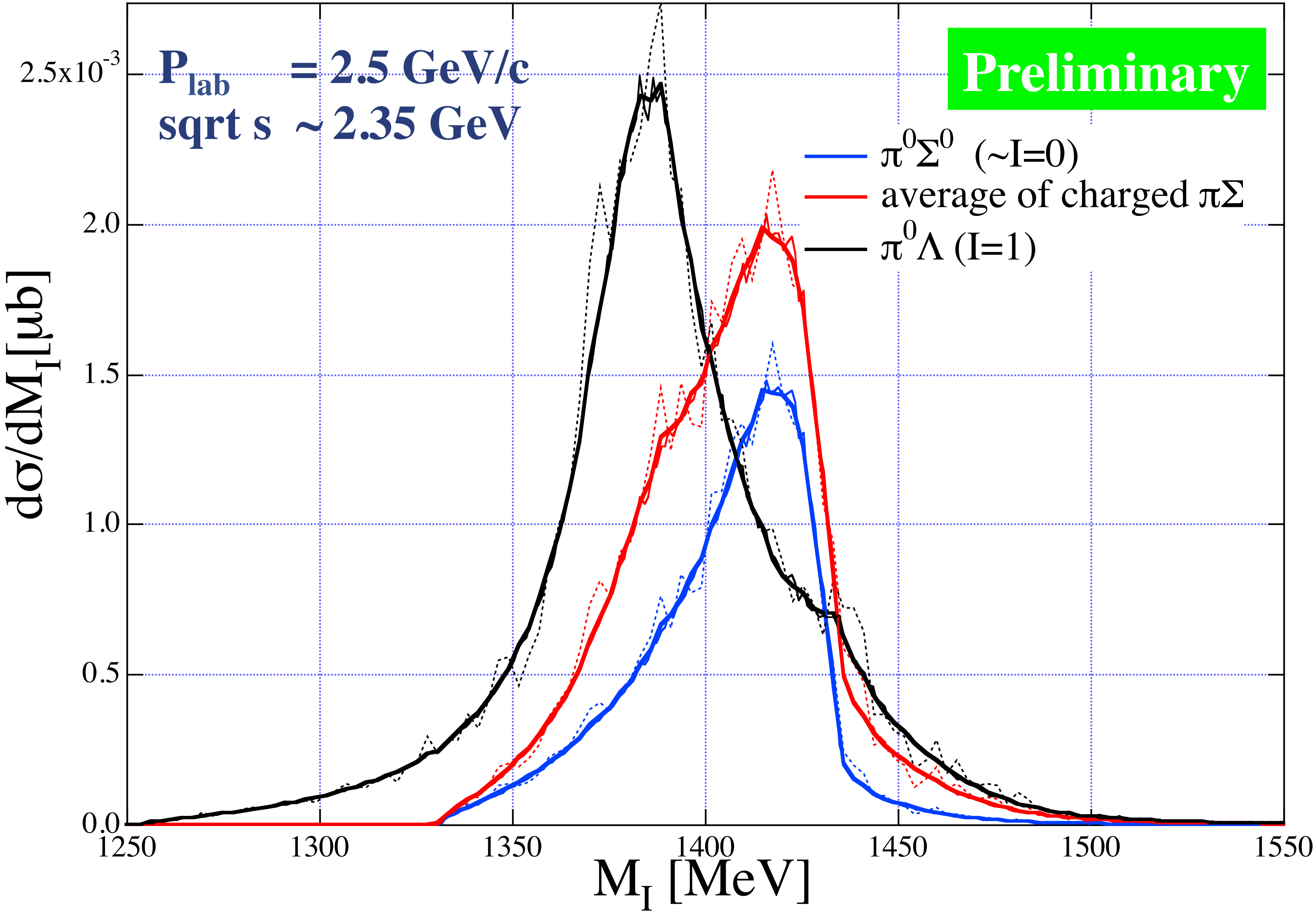
channel i	K^-p	$\bar{K}^0 n$	$\pi^0\Lambda$	$\pi^0\Sigma^0$	$\eta\Lambda$	$\eta\Sigma^0$	$\pi^+\Sigma^-$	$\pi^-\Sigma^+$	$K^+\Xi^-$	$K^0\Xi^0$
c_i	$-\sqrt{\frac{1}{12}}$	$\sqrt{\frac{1}{12}}$	$\sqrt{\frac{1}{4}}$	0	0	$-\sqrt{\frac{1}{4}}$	$-\sqrt{\frac{1}{12}}$	$\sqrt{\frac{1}{12}}$	$\sqrt{\frac{1}{12}}$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

4. K⁻P -> Σ(1385) -> MB amplitude

$$\begin{aligned} -it_{1i} =& c_1 c_i \left(\frac{12}{5}\frac{D+F}{2f}\right)^2 \boldsymbol{S}\cdot\boldsymbol{k}_1 \boldsymbol{S}^\dagger \cdot \boldsymbol{k}_i \frac{i}{M_I^{(b)} - M_{\Sigma^*} + i\Gamma_{\Sigma^*}/2} F_f(k_1) \\ =& c_1 c_i \left(\frac{12}{5}\frac{D+F}{2f}\right)^2 (k_1)_l (k_i)_m \left(\frac{2}{3}\delta_{lm} - \frac{i}{3}\epsilon_{lmn}\sigma_n\right) \frac{i}{M_I^{(b)} - M_{\Sigma^*} + i\Gamma_{\Sigma^*}/2} F_f(k_1) \end{aligned}$$

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

Experiments : $\pi\Sigma$ 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 πΣ state

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

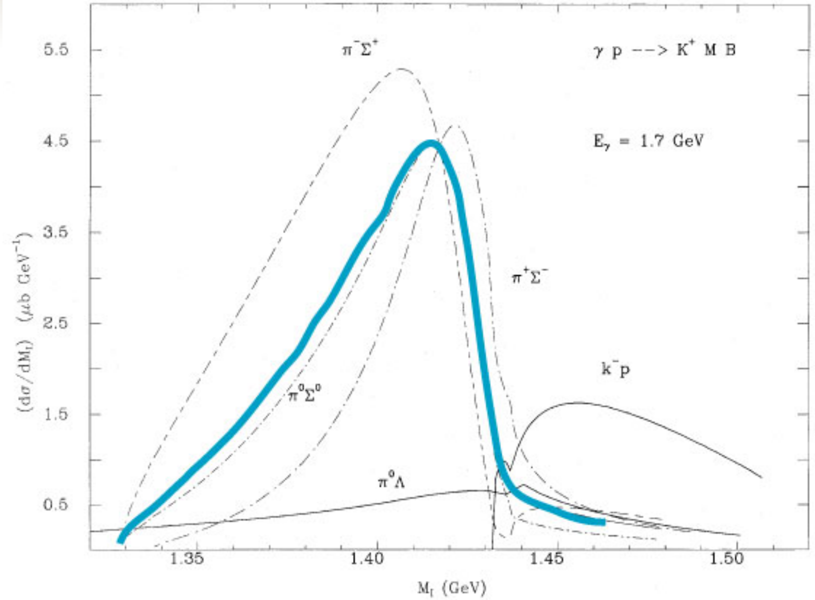
http://www.rcnp.osaka-u.ac.jp/~hyodo/index_e.html

Appendix : other processes

$\gamma p \to K^- \pi\Sigma$

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

Spring-8



$K^- p \to \gamma\pi\Sigma$

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

J-PARC?