Photoproduction of K^* for the study of Λ(1405)

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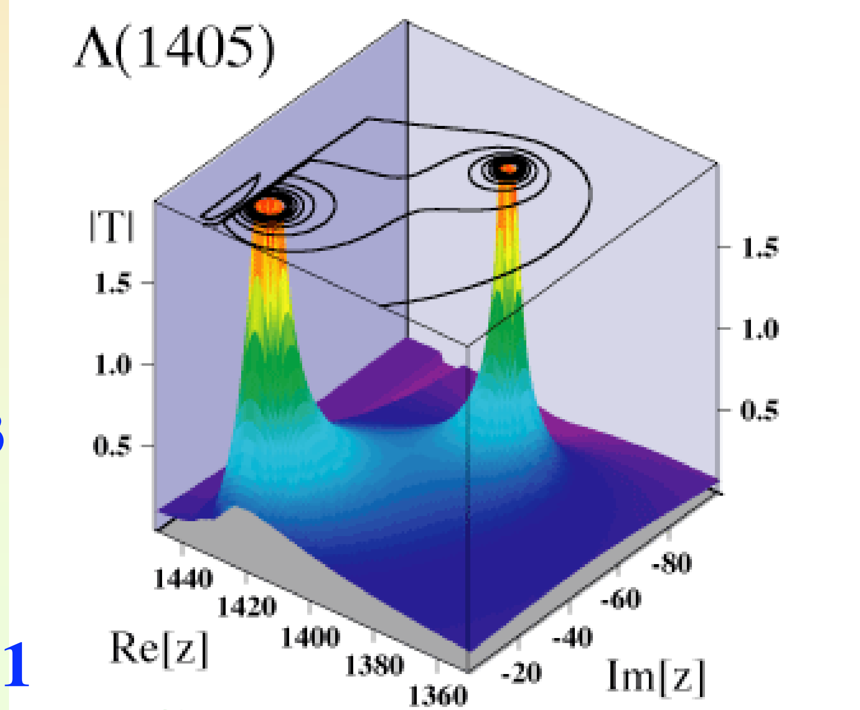
Motivation : Two poles?

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

- **<u>Cloudy bag model</u> (1990)**
  - J. Fink *et al.* PRC41, 2720
- **<u>Chiral unitary model</u> (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

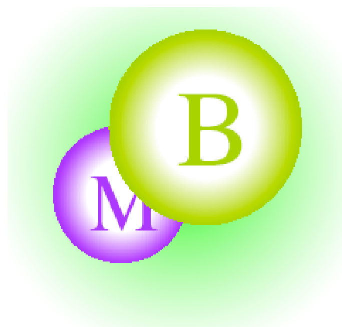
Non-perturbative resummation

Dynamical generation

$J^P = 1/2^-$

Resonances

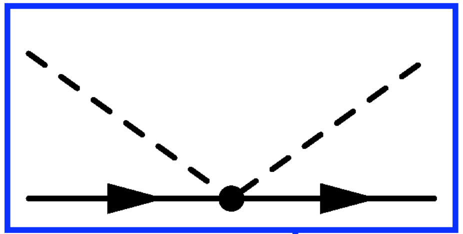
□(1405), □(1670), N(1535),
□(1620), □(1620)



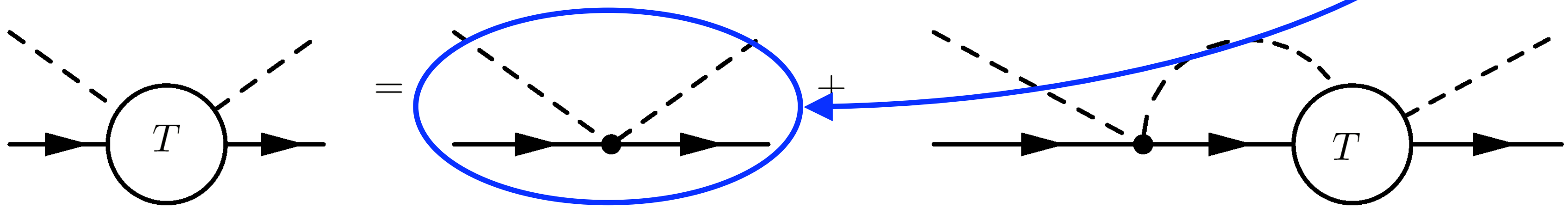
Framework of the chiral unitary model

Chiral perturbation theory

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



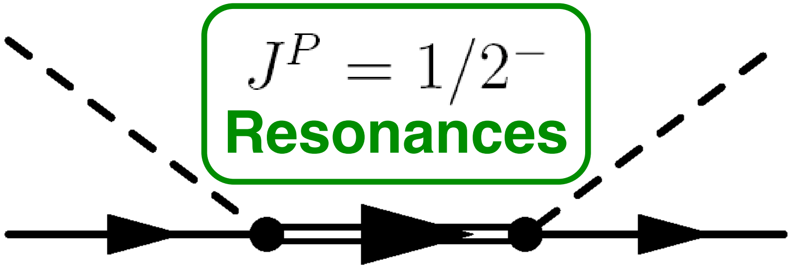
Unitarization



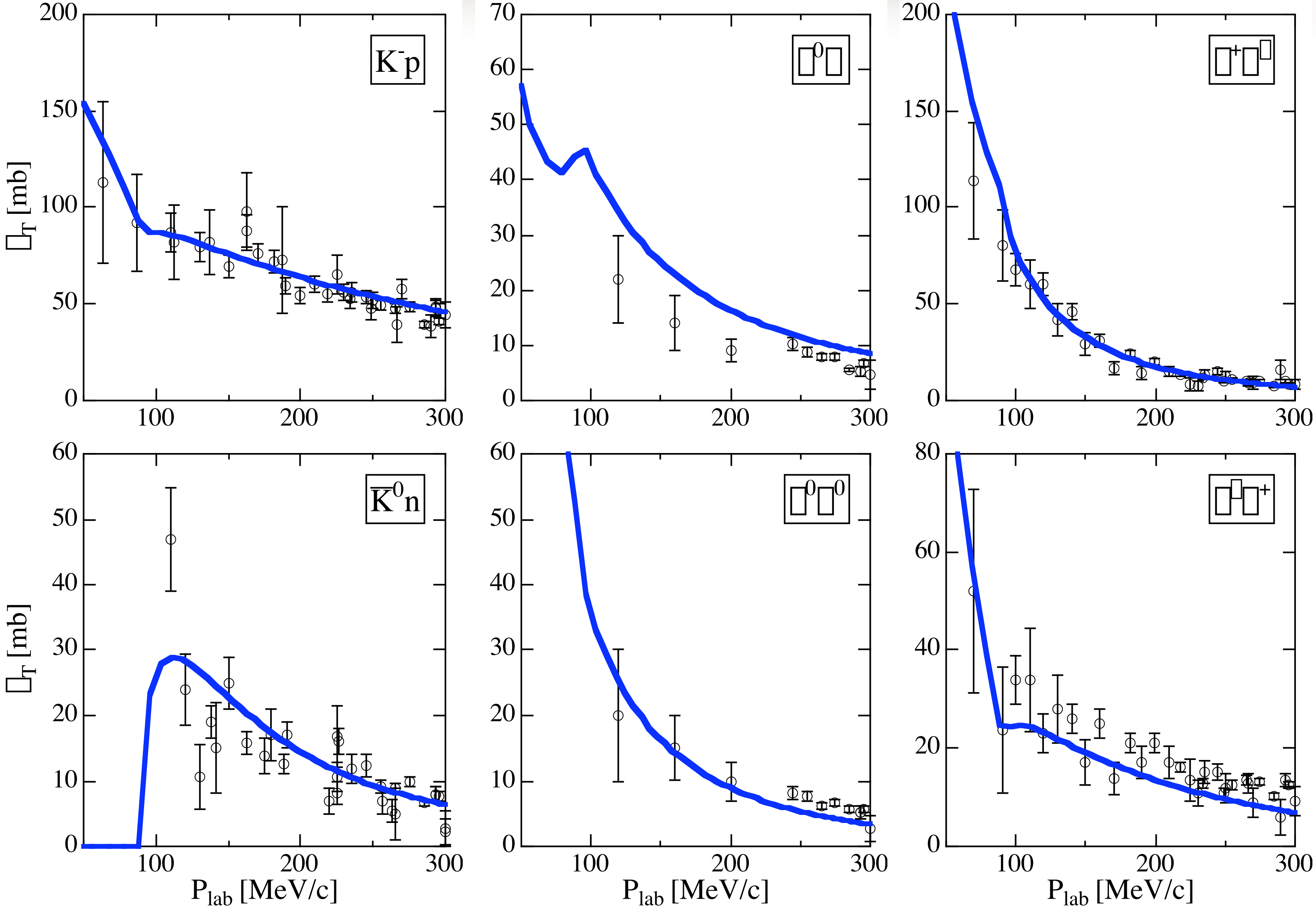
$$T_{ij}(\sqrt{s}) \sim \frac{g_i g_j}{\sqrt{s} - M_R + i\Gamma_R/2} + T_{ij}^{BG}$$

Generated resonances are expressed as poles of the scattering amplitude.

$\sim$

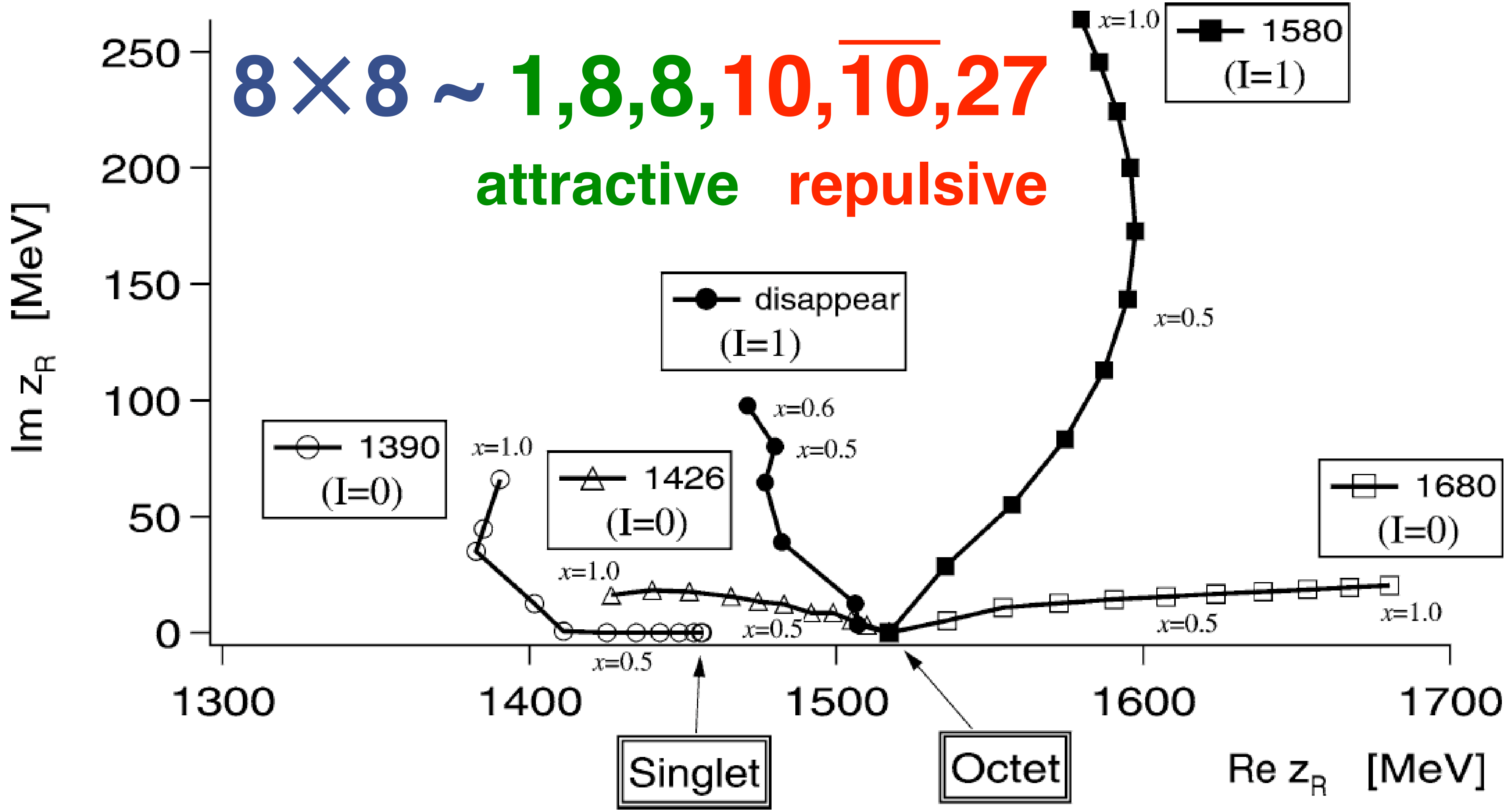


Total cross sections of K^-p scatterings



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

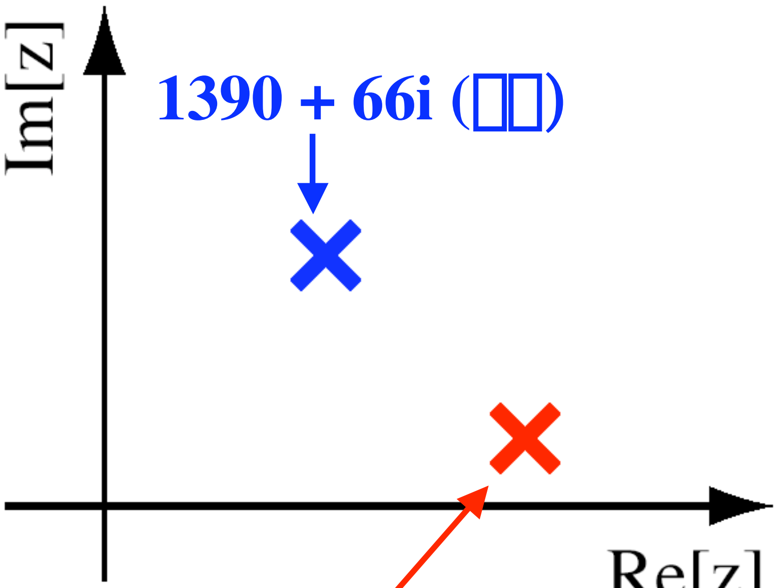
Poles of amplitude in S=−1 channel



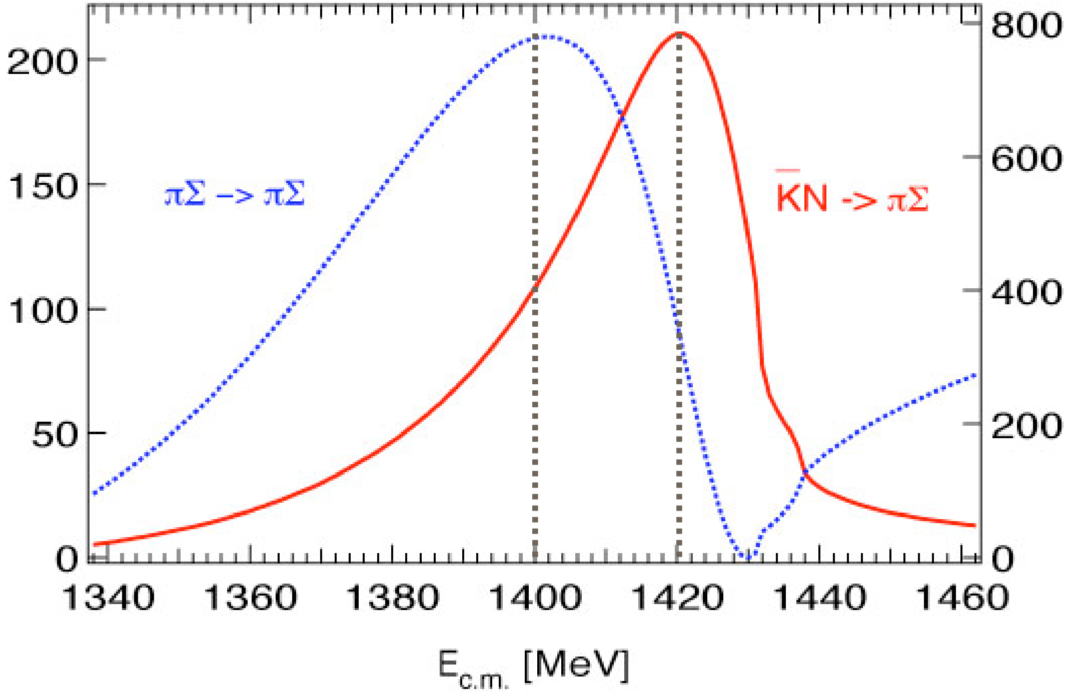
D. Jido, *et al.*, Nucl. Phys. A 723, 205 (2003)

□(1405) in the chiral unitary model

position of poles



□□ mass distribution



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

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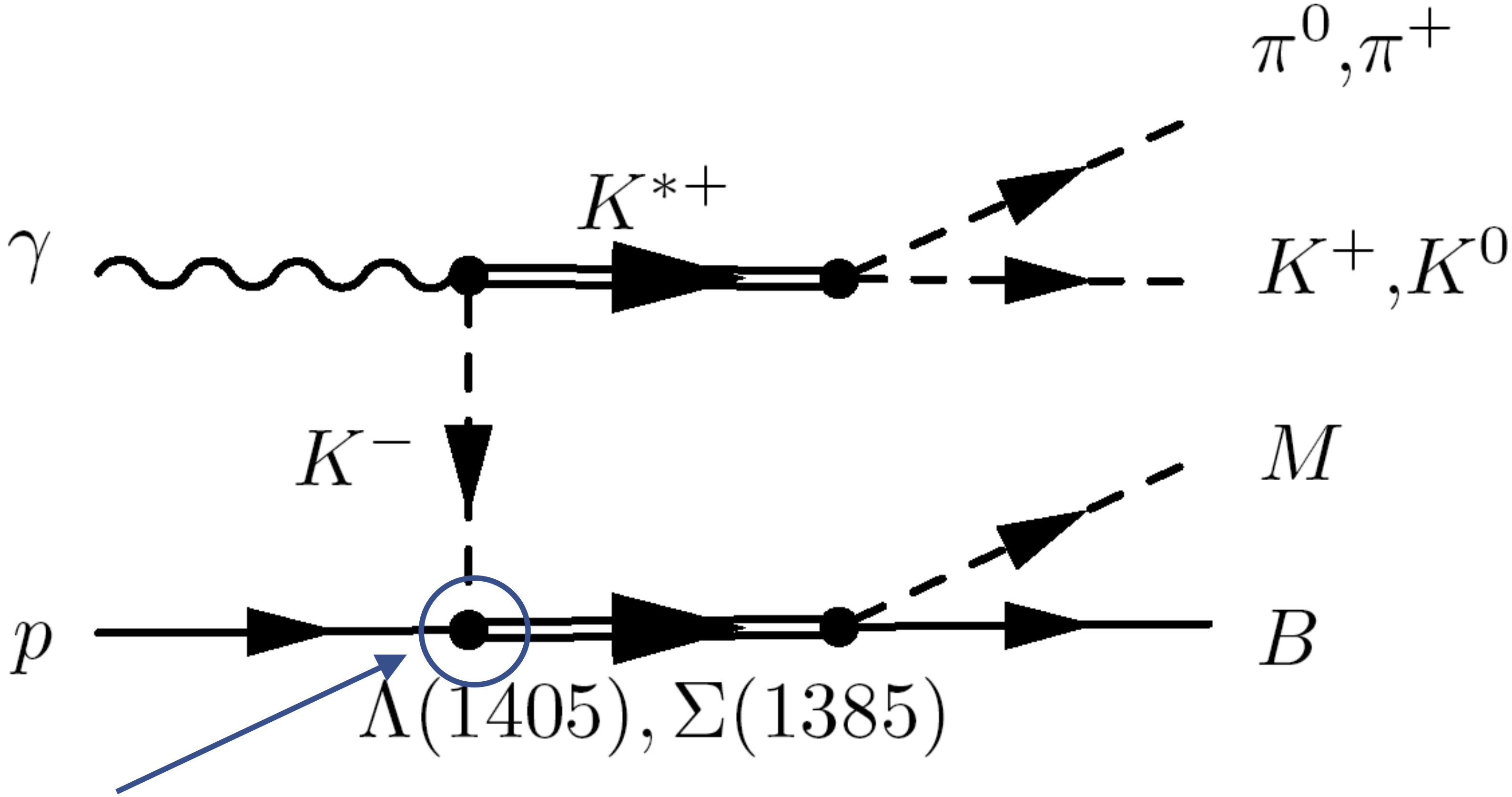
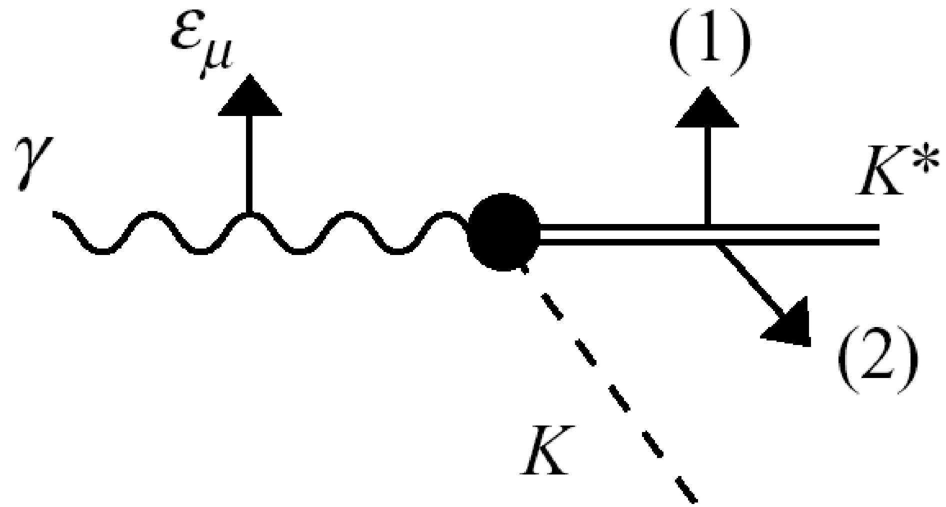
Photoproduction of K* Λ(1405)



Only K^-p channel appears at the initial stage

Higher pole ??

Advantage of this reaction



(1) $\varepsilon_\mu(K^*) \,//\, \varepsilon_\mu(\gamma)$: J^P = natural

(2) $\varepsilon_\mu(K^*) \perp \varepsilon_\mu(\gamma)$: J^P = unnatural

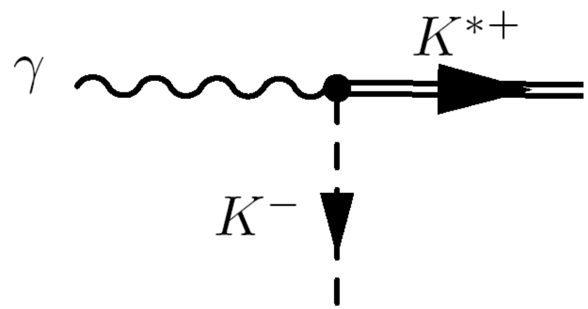
With polarized photon beam, the exchanged particle can be identified.

Clear mechanism

Effective interactions for vector meson

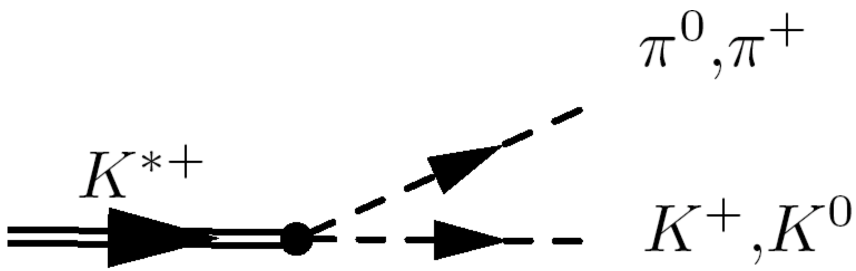
1. □VP coupling

$$\mathcal{L}_{K^*K\gamma} = g_{K^*K\gamma}\epsilon^{\mu\nu\alpha\beta}\partial_\mu A_\nu(\partial_\alpha K^{*-}_\beta K^+ + \partial_\alpha \bar{K}^{*0}_\beta K^0) + \text{h.c.}$$

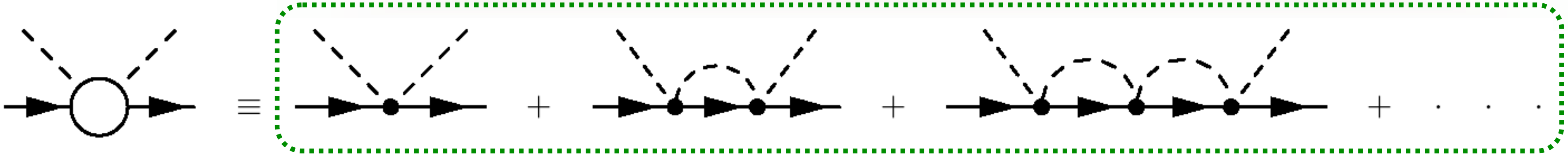


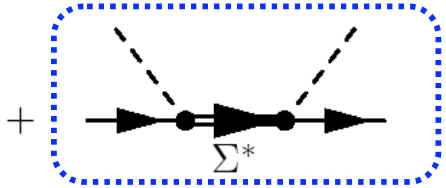
2. VPP coupling

$$\mathcal{L}_{VPP} = -\frac{ig_{VPP}}{\sqrt{2}}\mathrm{Tr}\left(V^\mu[\partial_\mu P, P]\right)$$



Effective interaction for baryon resonance





ChU amplitude

Σ(1385) pole term

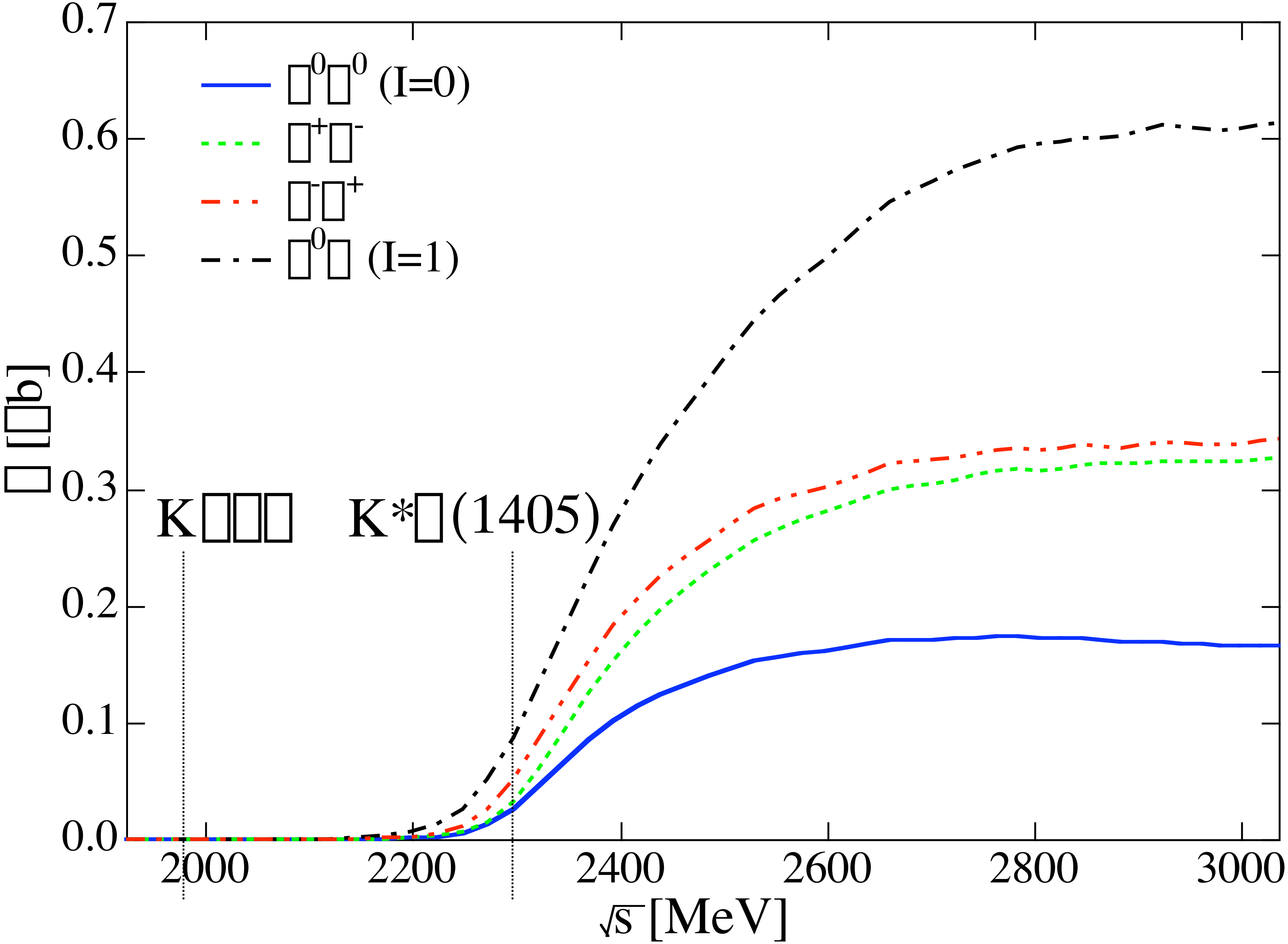
3. Σ(1385)MB coupling

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

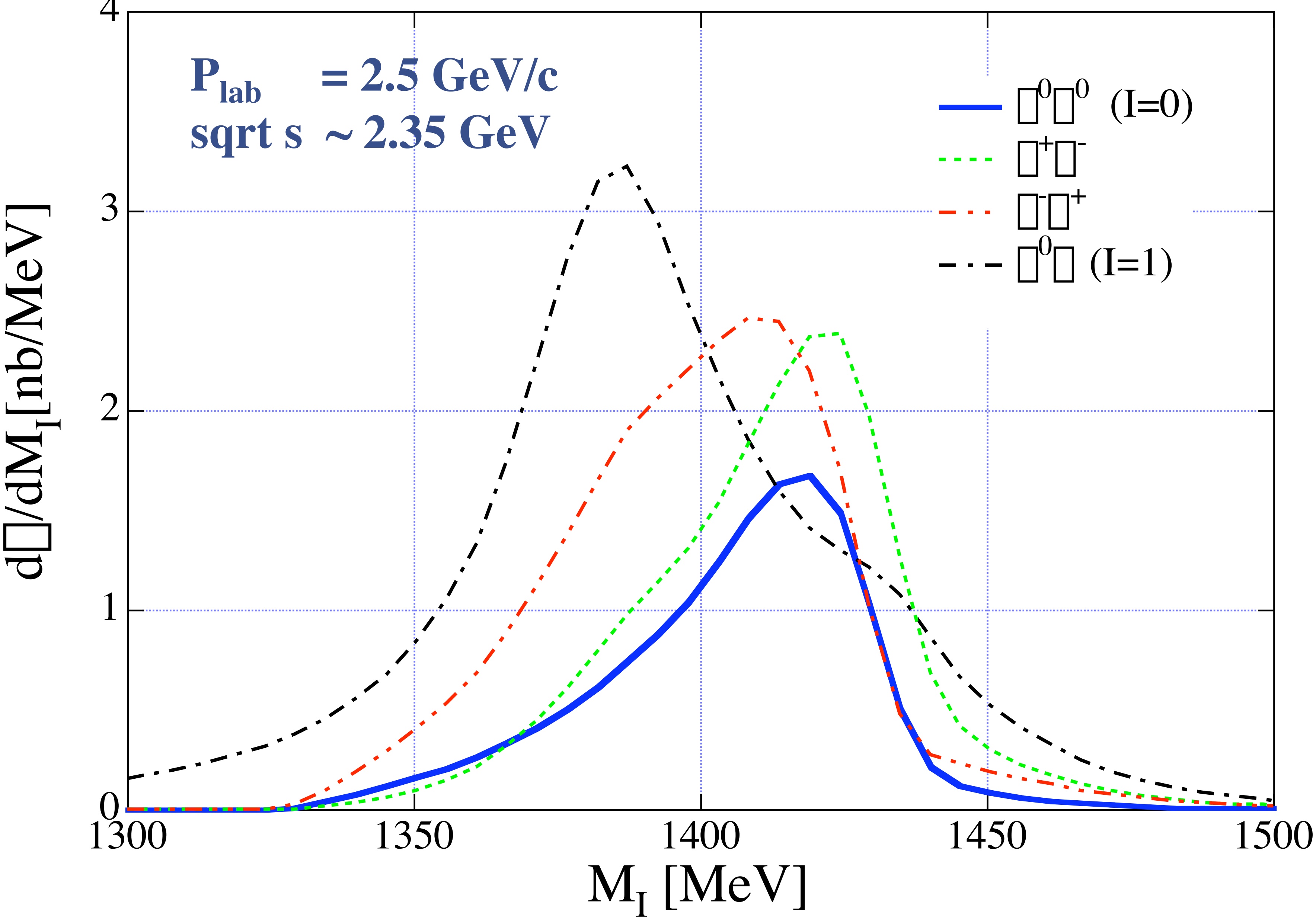
4. Form factor

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

Total cross section



Invariant mass distribution



Isospin decomposition of □□ states

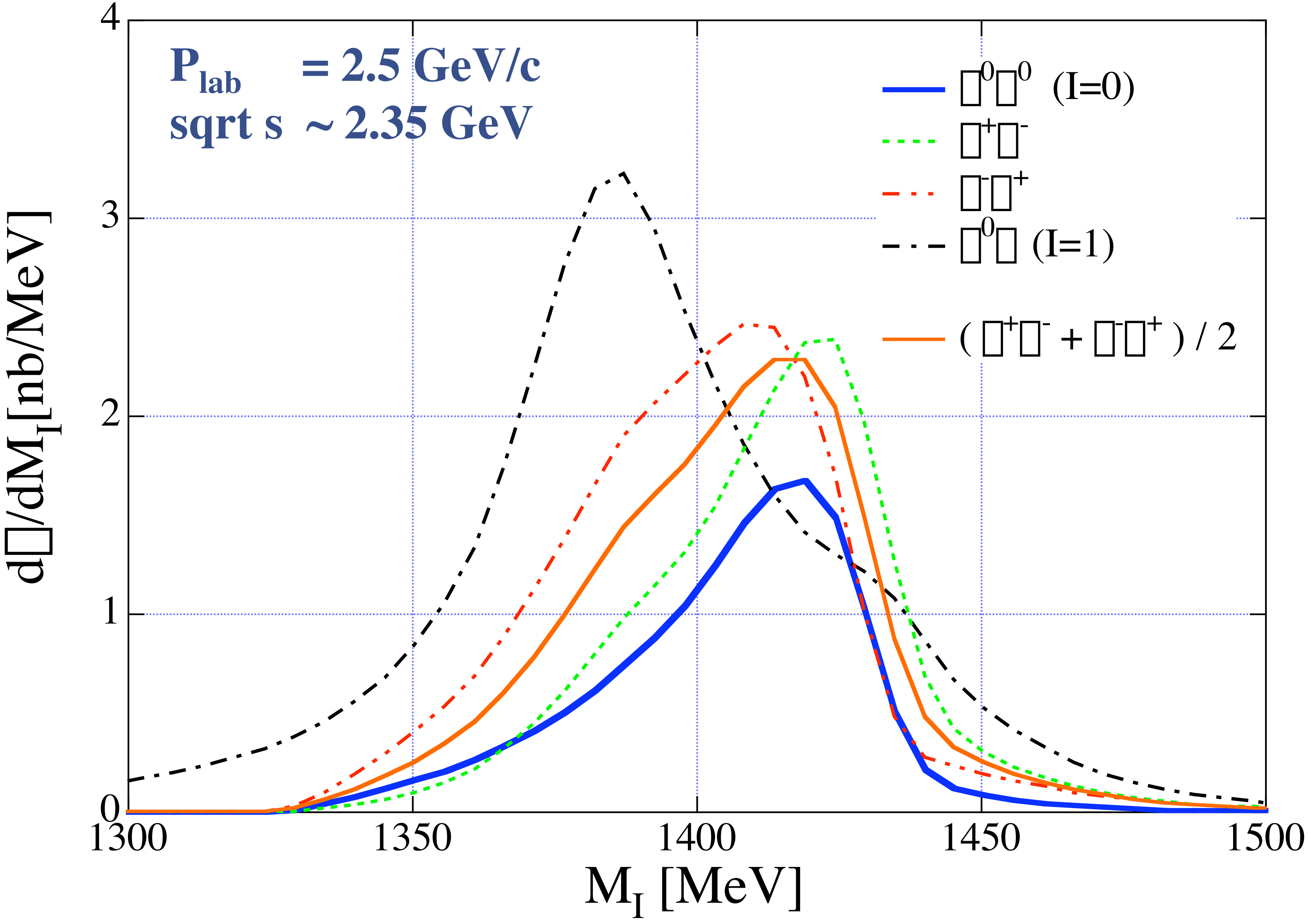
$$\frac{d\sigma(\pi^{\pm}\Sigma^{\mp})}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2 + \frac{1}{2}|T^{(1)}|^2 \pm \frac{2}{\sqrt{6}}\mathrm{Re}(T^{(0)}T^{(1)*})$$

$$\frac{d\sigma(\pi^{0}\Sigma^{0})}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2$$

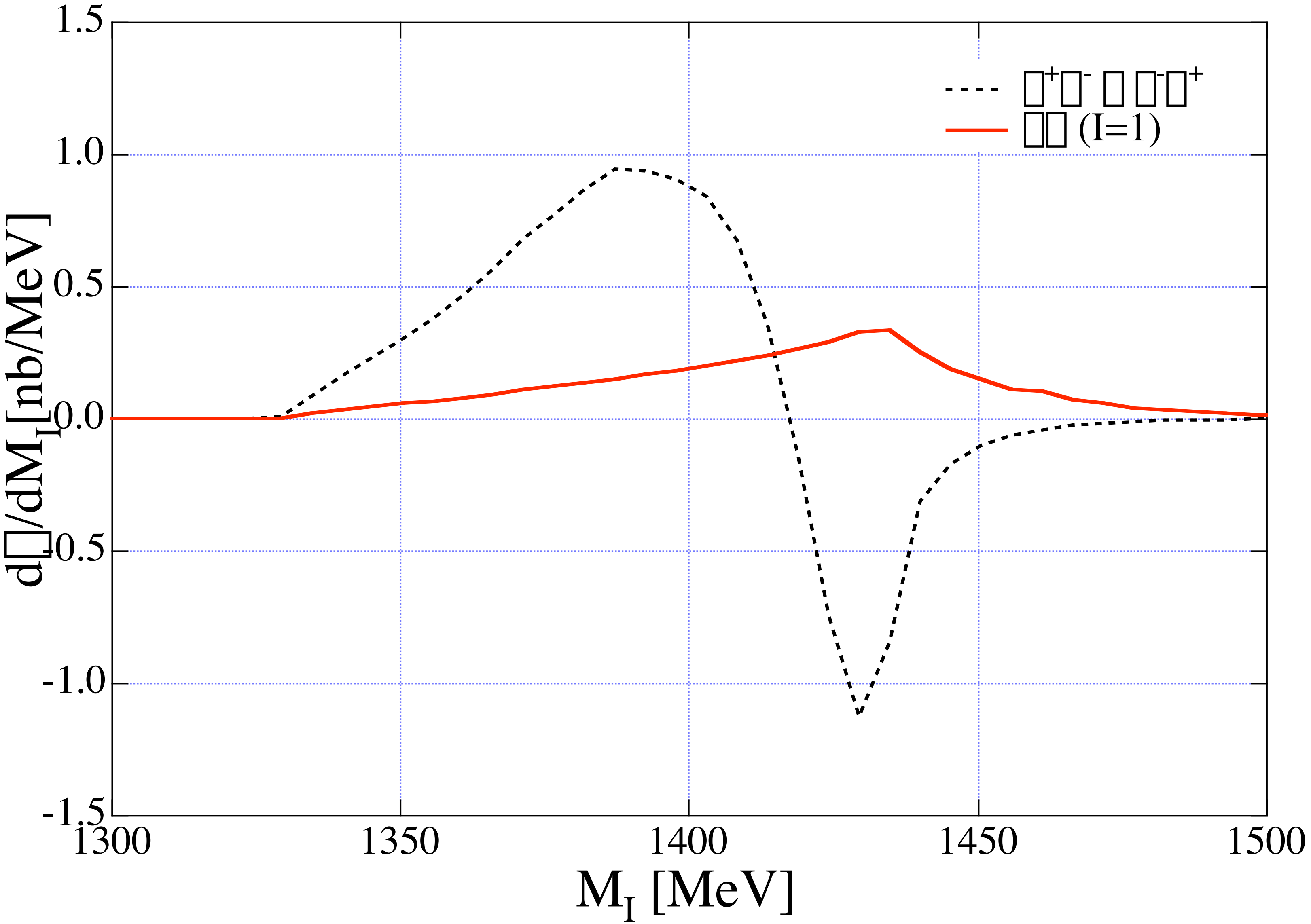
- **Difference among charged states**
  -> when summed up, this term vanishes

- **No p-wave contribution**
  -> I=1 s-wave amplitude

□nvariant mass distribution 2



I=1, s-wave amplitdue



Summary and conclusions 1

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

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

Pole 1 (1426+16i) : strongly couples to $\bar{K}N$ state

Pole 2 (1390+66i) : strongly couples to □□ state

- By observing the charged □□ states in the □p -> K*□(1405) reaction, it is possible to isolate higher energy pole.

Summary and conclusions 2

- If we observe **neutral □□ state**, clear **I=0 distribution** is obtained.
- Combining three **□□ states**, we can also study the **s-wave I=1 amplitude**, where the existence of another pole is argued.

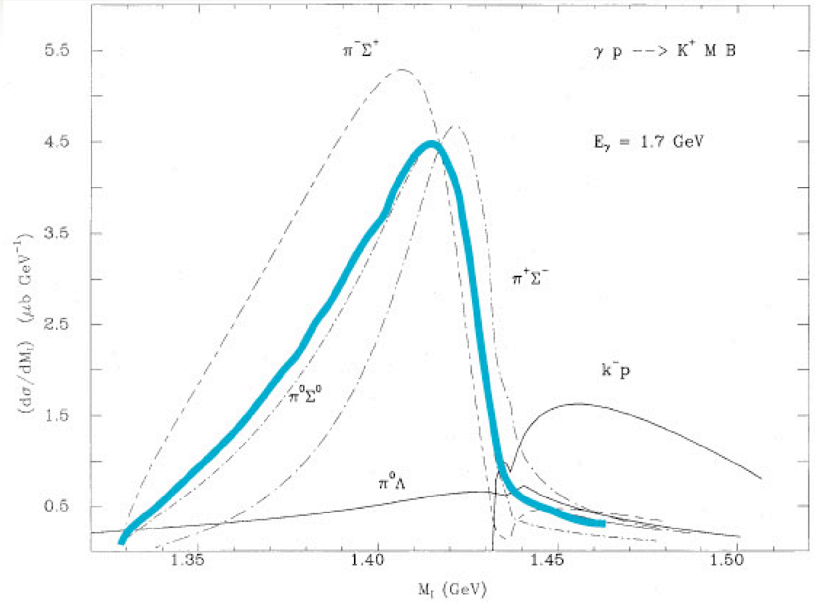
T. Hyodo, *et al*, nucl-th/0401051

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

Appendix : other processes

□p -> K□□□

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



□ □p -> □□□

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