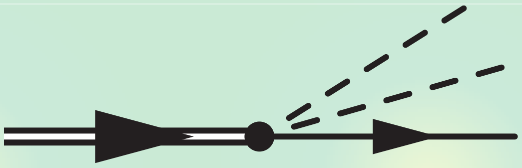
Θ^+ production and two-meson coupling of antidecuplet

Tetsuo Hyodo[a],

A. Hosaka[a], F. J. Llanes-Estrada[b], E. Oset[c],
J. R. Pelaez[b] and M. J. Vicente Vacas[c]

RCNP, Osaka[a] *Madrid[b]* *IFIC, Valencia[c]* 2004, Oct. 25th

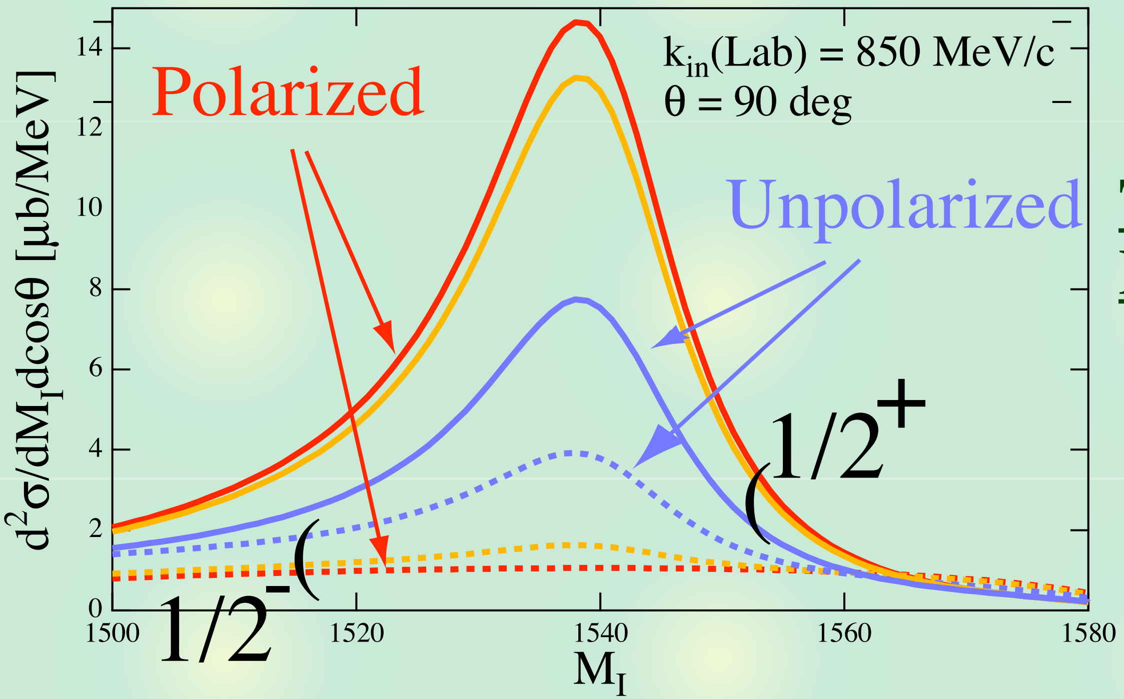
Contents



Introduction : determining the quantum numbers

We have proposed $K^+p \rightarrow \pi^+\Theta^+ \rightarrow \pi^+K^+n(K^0p)$

Polarization observable can be used to determine the quantum numbers



T. H., A. Hosaka, E. Oset, Phys. Lett. B579, 290 (2004)

➡ **Understanding of reaction mechanism**

Motivations

Results of (π^-,K^-) reaction at KEK

Upper limit of cross section ~ 2 μb

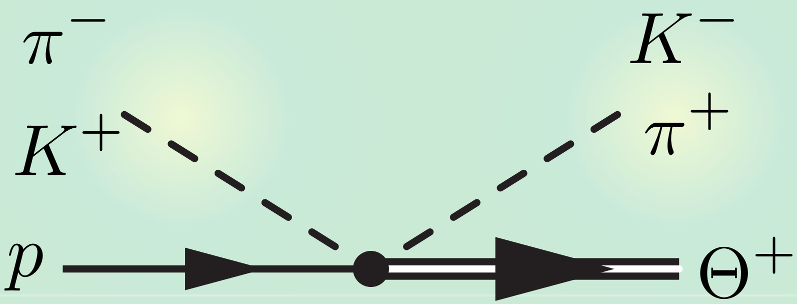
K. Miwa, talk given at PENTAQUARK04

Why so small? What about (K^+,π^+) ?

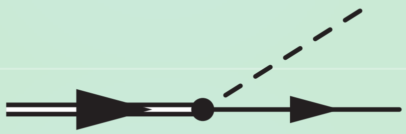
Two-meson coupling effects for Θ^+

Possibility of KπN bound state

P. Bicudo, *et al.*, Phys. Rev. C69, 011503 (2004)
T. Kishimoto, *et al.*, hep-ex/0312003
F. J. Llanes-Estrada, *et al.*, Phys. Rev. C69, 055203 (2004)

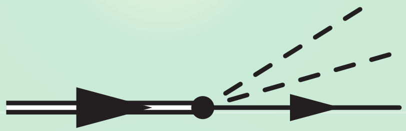


Two-meson coupling



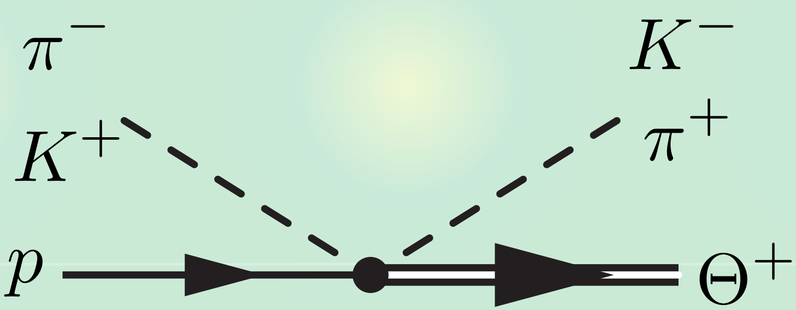
$\Theta^+ \to KN$ **Very narrow**

$N(1710) \to \pi N$ **10–20 %**



$\Theta^+ \to K\pi N$ **Forbidden**

$N(1710) \to \pi\pi N$ **40–90 %**



Large??

Effective interactions which account for the $N(1710) \to \pi\pi N$ decay

Criteria to construct the Lagrangian

Interaction is SU(3) symmetric

Small numbers of derivative

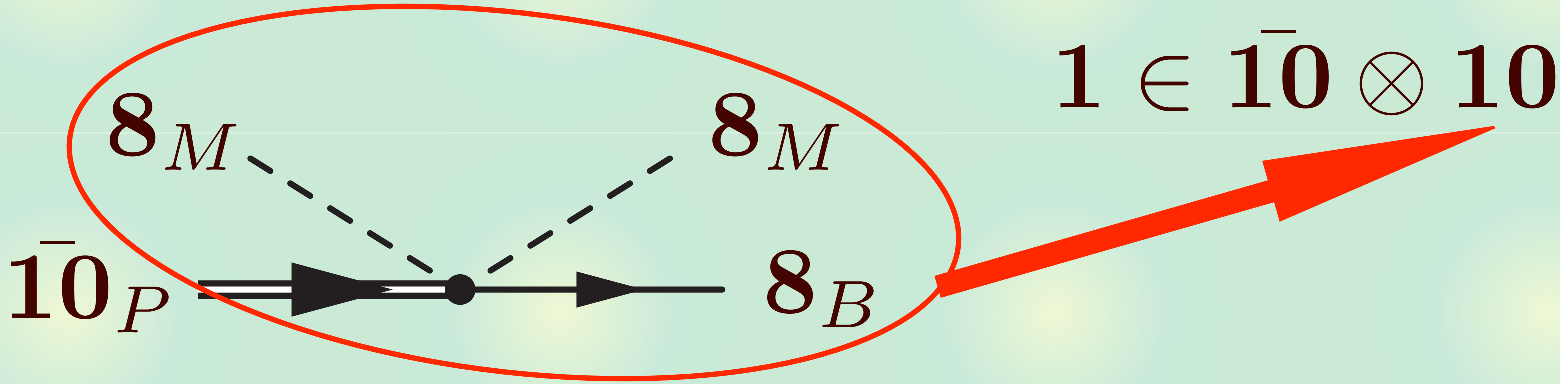
Assumptions for Θ^+

N(1710) is the S=0 partner of antidecuplet -> $J^P = 1/2^+$

No mixing with 8, 27,...

T.D. Cohen, Phys. Rev. D70, 074023 (2004)
S. Pakvasa and M. Suzuki, Phys. Rev. D70, 036002 (2004)
S. Ceci, *et al.*, nucl-th/0406055

SU(3) structure of effective Lagrangian



$$\mathbf{8}_M \otimes \mathbf{8}_M \otimes \mathbf{8}_B = (\mathbf{1} \oplus \mathbf{8}^s \oplus \mathbf{8}^a \oplus \mathbf{10} \oplus \overline{\mathbf{10}} \oplus \mathbf{27})_{MM} \otimes \mathbf{8}_B$$

$$= \mathbf{8} \quad \leftarrow \text{from } \mathbf{1}_{MM} \otimes \mathbf{8}_B$$

$$\oplus (\mathbf{1} \oplus \mathbf{8} \oplus \mathbf{8} \oplus \mathbf{10} \oplus \overline{\mathbf{10}} \oplus \mathbf{27}) \quad \leftarrow \text{from } \mathbf{8}^s_{MM} \otimes \mathbf{8}_B$$

$$\oplus (\mathbf{1} \oplus \mathbf{8} \oplus \mathbf{8} \oplus \mathbf{10} \oplus \overline{\mathbf{10}} \oplus \mathbf{27}) \quad \leftarrow \text{from } \mathbf{8}^a_{MM} \otimes \mathbf{8}_B$$

$$\oplus (\mathbf{8} \oplus \mathbf{10} \oplus \mathbf{27} \oplus \mathbf{35}) \quad \leftarrow \text{from } \mathbf{10}_{MM} \otimes \mathbf{8}_B$$

$$\oplus (\mathbf{8} \oplus \overline{\mathbf{10}} \oplus \mathbf{27} \oplus \mathbf{35}') \quad \leftarrow \text{from } \overline{\mathbf{10}}_{MM} \otimes \mathbf{8}_B$$

$$\oplus (\mathbf{8} \oplus \mathbf{10} \oplus \overline{\mathbf{10}} \oplus \mathbf{27} \oplus \mathbf{27} \oplus \mathbf{35} \oplus \mathbf{35}'' \oplus \mathbf{64}) \quad \leftarrow \text{from } \mathbf{27}_{MM} \otimes \mathbf{8}_B$$

Interaction Lagrangians 1

Antidecuplet field

$$P^{333} = \sqrt{6}\Theta^{+}_{\bar{10}}$$

$$P^{133} = \sqrt{2}\, N^{0}_{\bar{10}} \qquad P^{233} = -\sqrt{2}\, N^{+}_{\bar{10}}$$

$$P^{113} = \sqrt{2}\, \Sigma^{-}_{\bar{10}} \qquad P^{123} = -\Sigma^{0}_{\bar{10}} \qquad P^{223} = -\sqrt{2}\, \Sigma^{+}_{\bar{10}}$$

$$P^{111} = \sqrt{6}\Xi^{--}_{\bar{10}} \qquad P^{112} = -\sqrt{2}\, \Xi^{-}_{\bar{10}} \qquad P^{122} = \sqrt{2}\, \Xi^{0}_{\bar{10}} \qquad P^{222} = -\sqrt{6}\Xi^{+}_{\bar{10}}$$

Meson and baryon fields

$$\Phi = \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & \pi^+ & K^+ \\ \pi^- & -\frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & K^0 \\ K^- & \bar{K}^0 & -\frac{2}{\sqrt{6}}\eta \end{pmatrix}$$

$$B = \begin{pmatrix} \frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & \Sigma^+ & p \\ \Sigma^- & -\frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & n \\ \Xi^- & \Xi^0 & -\frac{2}{\sqrt{6}}\Lambda \end{pmatrix}$$

Interaction Lagrangians 2

Terms without derivative

$$\mathcal{L}^{8s} = \frac{g^{8s}}{2f}\bar{P}_{ijk}\epsilon^{lmk}\phi_l{}^a\phi_a{}^i B_m{}^j + h.c.$$

8s

$$\mathcal{L}^{8a} = 0$$
$$\mathcal{L}^{10} = 0$$

<- symmetry under exchange of mesons

$$\mathcal{L}^{27} = \frac{g^{27}}{2f}\left[4\bar{P}_{ijk}\epsilon^{lbk}\phi_l{}^i\phi_a{}^j B_b{}^a - \frac{4}{5}\bar{P}_{ijk}\epsilon^{lbk}\phi_l{}^a\phi_a{}^j B_b{}^i\right] + h.c.$$

Experimental information

$$N(1710) \to \pi\pi(s\text{-wave},\ I=0)N$$
$$N(1710) \to \pi\pi(p\text{-wave},\ I=1)N$$

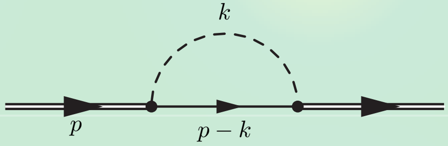
With one derivative

8a

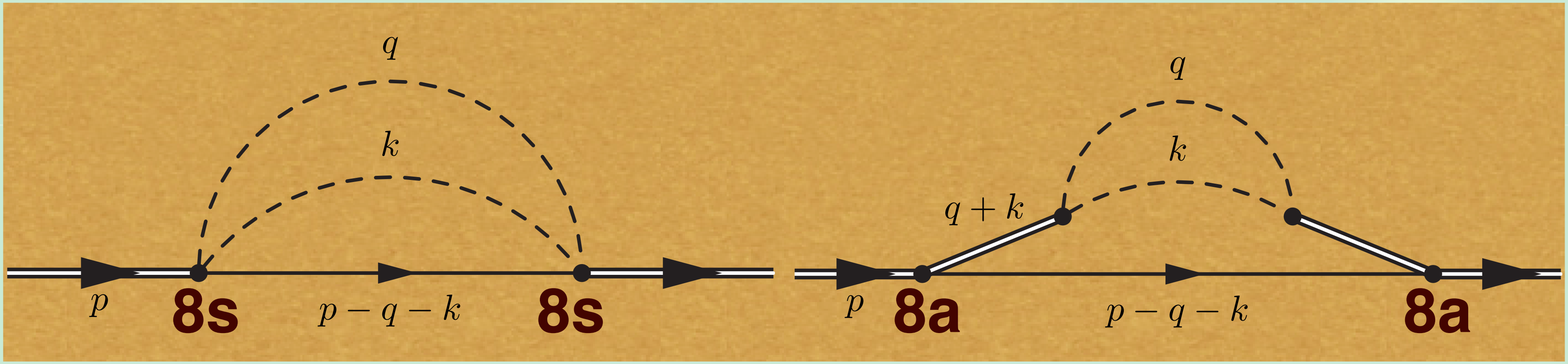
$$\mathcal{L}^{8a} = i\frac{g^{8a}}{4f^2}\bar{P}_{ijk}\epsilon^{lmk}\gamma^\mu(\partial_\mu\phi_l{}^a\phi_a{}^i - \phi_l{}^a\partial_\mu\phi_a{}^i)B_m{}^j + h.c.$$

Diagrams for self-energy

Real part : mass shift
Imaginary part : decay width
SU(3) breaking : masses of particles



Small!!

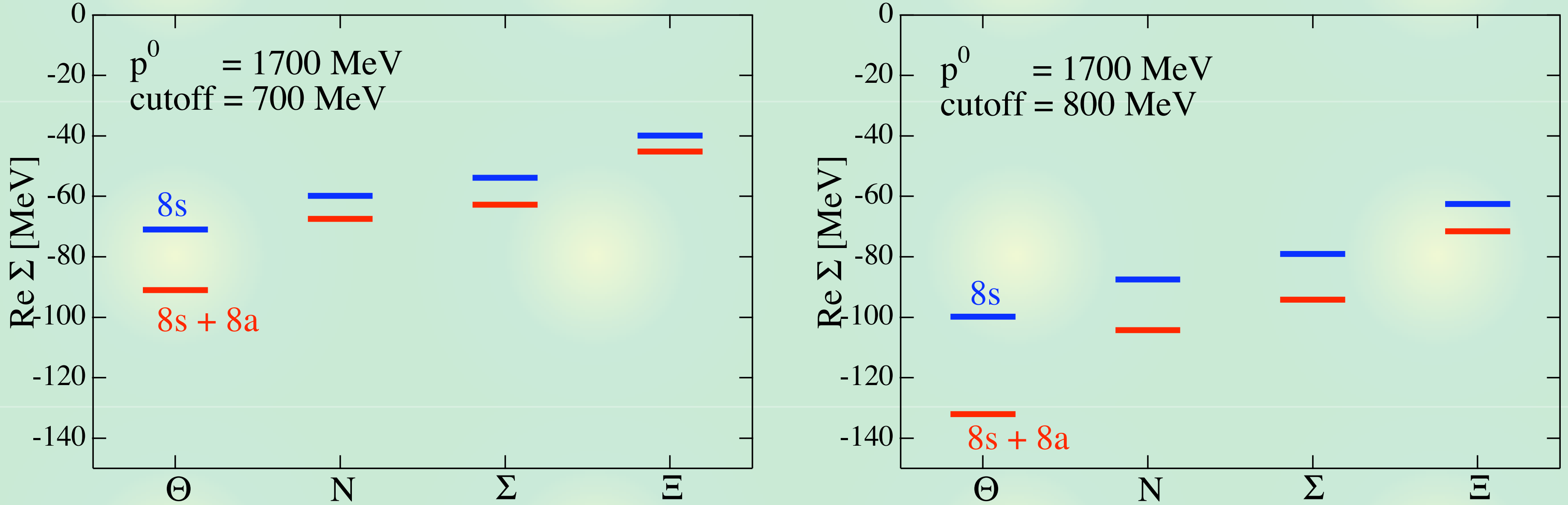


$$N(1710) \to \pi\pi(s\text{-wave},\ I=0)N \quad \textbf{25 MeV}$$

$$N(1710) \to \pi\pi(p\text{-wave},\ I=1)N \quad \textbf{15 MeV}$$

$$\Rightarrow \quad g^{8s} = 1.88\ , \qquad g^{8a} = 0.315$$

Results of self-energy : Real part (mass shift)



All mass shifts are attractive.

More bound for larger strangeness.

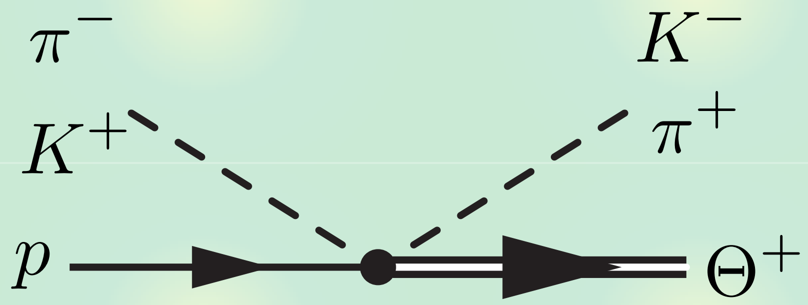
Mass difference between Θ and Ξ
-> 60 MeV : ~20 % of 320 = 1860–1540

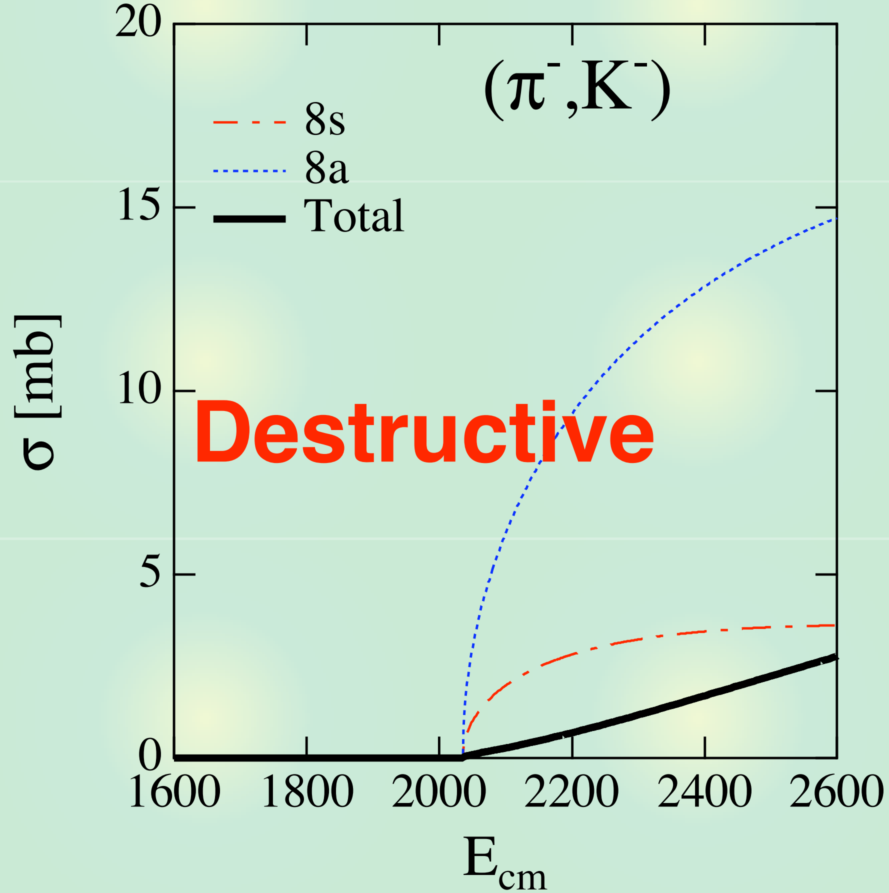
Results of self-energy : Imaginary part (decay width)

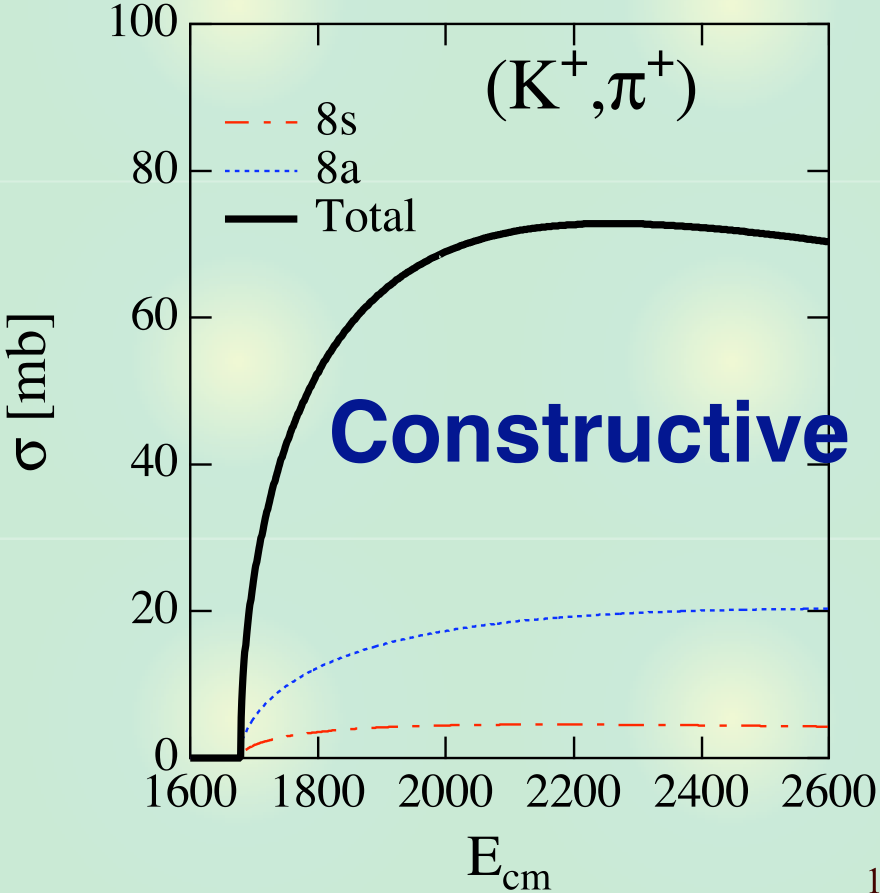
Decay [MeV]	$\Gamma^{(8s)}$	$\Gamma^{(8a)}$	$\Gamma^{(tot)}_{BMM}$
$N(1710) \to N\pi\pi$ (inputs)	25	15	40
$N(1710) \to N\eta\pi$	0.58	-	
$\Sigma(1770) \to N\bar{K}\pi$	4.7	6.0	24
$\Sigma(1770) \to \Sigma\pi\pi$	10	0.62	
$\Sigma(1770) \to \Lambda\pi\pi$	-	2.9	
$\Xi(1860) \to \Sigma\bar{K}\pi$	0.57	0.46	2.1
$\Xi(1860) \to \Xi\pi\pi$	-	1.1	

Results of reaction : cross sections

Total cross section of







Conclusion 1 : self-energy

We study the two-meson virtual cloud effect to the self-energy of baryon antidecuplet.

- **Two-meson cloud effects are always attractive, and contribute to the antidecuplet mass splitting, of the order of 20%.**
- **Antidecuplet members have relatively small decay widths to MMB channel.**

A. Hosaka, T. H., F. J. Llanes-Estrada, E. Oset, J. R. Pelaez, M. J. Vicente Vacas, *in preparation*

Conclusion 2 : reactions

We investigate the Θ production in (π^-,K^-) and (K^+,π^+) reactions, with the vertices obtained from the self-energy study.

- The small cross section of the order of a few micro barn in (π^-,K^-) reaction may require some special mechanisms, such as **interference of two amplitudes.**

T. H., A. Hosaka, E. Oset, M. J. Vicente Vacas, *in preparation*

Future works

Self-energy

Chiral symmetric Lagrangian,
Possible mixing with the other flavor multiplets (8, 27, ...),

Reaction

Quantitative analysis (Form factor),
background cross section