Θ^+ production in the $K^+p \to \pi^+KN$ reaction

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Motivations

Results of (π^-,K^-) reaction at KEK

Upper limit of cross section ~ 2 μb

K. Miwa, talk given at PENTAQUARK04

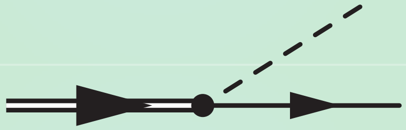
Why so small? What about (K^+,π^+) ?

Two meson coupling effects for Θ^+

Possibility of KπN bound state

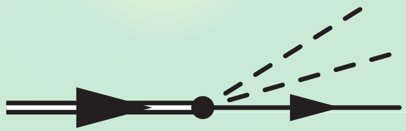
P. Bicudo, *et al.*, Phys. Rev. C69, 011503 (2004)
T. Kishimoto, *et al.*, hep-ex/0312003
F. J. Llanes-Estrada, *et al.*, Phys. Rev. C69, 055203 (2004)

Two-meson coupling



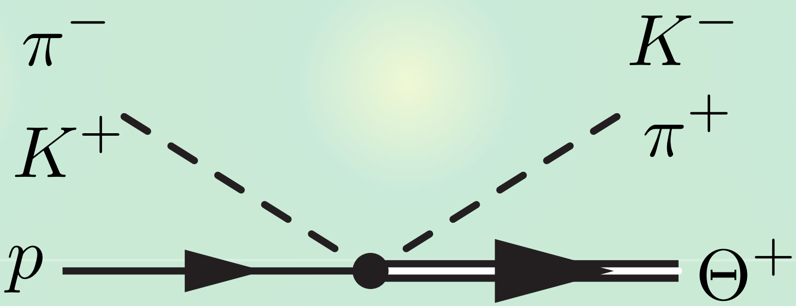
$\Theta^+ \to KN$ — **Very narrow**

$N(1710) \to \pi N$ — **10–20 %**



$\Theta^+ \to K\pi N$ — **Forbidden**

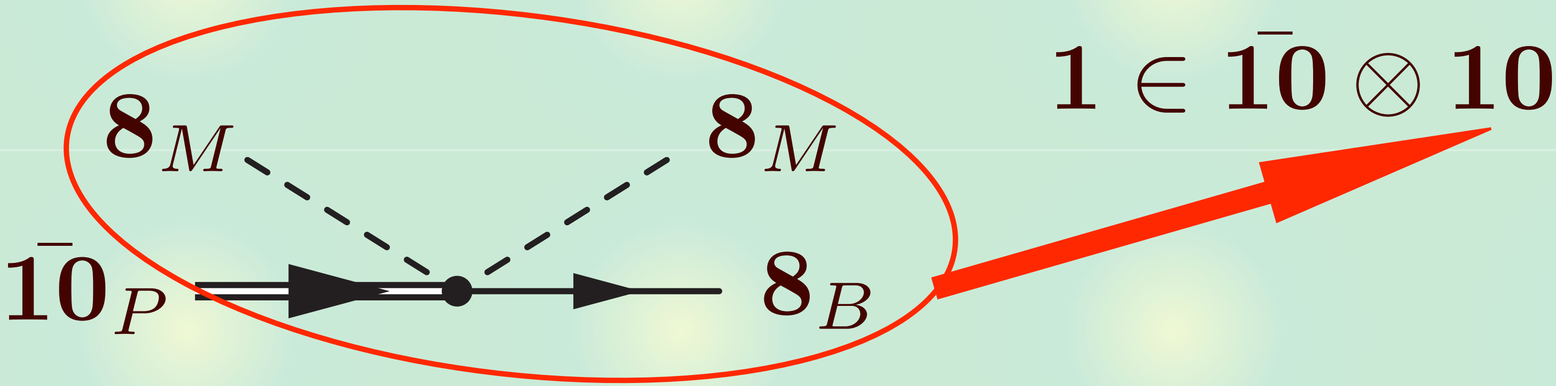
$N(1710) \to \pi\pi N$ — **40–90 %**



Large??

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

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

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

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

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

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

Construction of 8s Lagrangian

$$D^{i}{}_{j}[\mathbf{8}^{s}_{MM}] = 2\phi^{i}{}_{k}\phi^{k}{}_{j} - \frac{2}{3}\delta^{i}{}_{j}\phi^{a}{}_{b}\phi^{b}{}_{a}$$

$$T^{ijk}[\bar{\mathbf{10}}_{MM(8s)B}] = \epsilon^{abk} D^{i}{}_{a} B^{j}{}_{b} + (\text{symmetrized})$$

$$\Rightarrow \quad \mathcal{L}^{8s} = \frac{g^{8s}}{2f}\bar{P}_{ijk}\epsilon^{abk}\phi^{i}{}_{c}\phi^{c}{}_{a}B^{j}{}_{b} + h.c.$$

Interaction Lagrangians 2

$$\mathcal{L}^{8s} = \frac{g^{8s}}{2f} \bar{P}_{ijk} \epsilon^{abk} \phi^i{}_c \phi^c{}_a B^j{}_b + h.c.$$

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

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

<- symmetry under exchange of mesons

$$\mathcal{L}^{27} = \frac{g^{27}}{2f} \left[4\bar{P}_{ijk} \epsilon^{ibc} \phi^j{}_b \phi^k{}_a B^a{}_c - \frac{4}{5} \bar{P}_{ijk} \epsilon^{abk} \phi^i{}_c \phi^c{}_a B^j{}_b \right] + h.c.$$

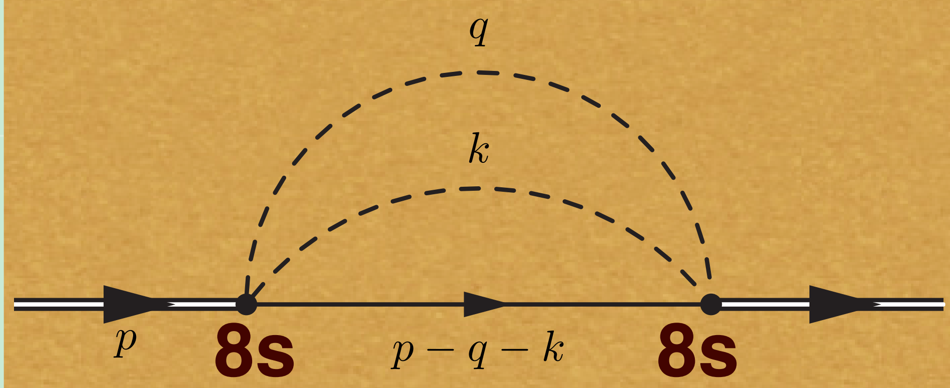
Experimental information

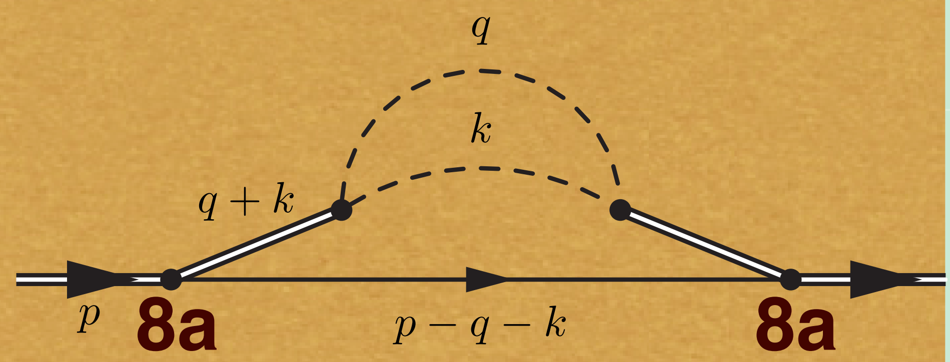
$$N(1710) \to \pi\pi(s\text{-wave}, \ I = 0)N$$

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

$$\mathcal{L}^{8a} = i\frac{g^{8a}}{4f^2} \bar{P}_{ijk} \epsilon^{abk} \gamma^\mu \left(\Phi \partial_\mu \Phi - \partial_\mu \Phi \Phi \right)^i{}_a B^j{}_b + h.c.$$

Diagrams for self-energy





Real part : mass shift

Imaginary part : decay width

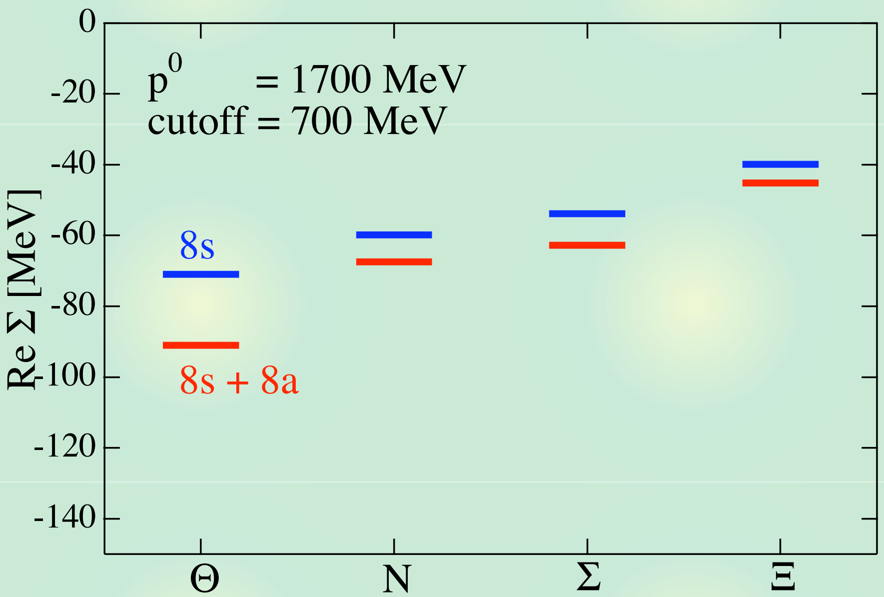
SU(3) breaking : masses of particles

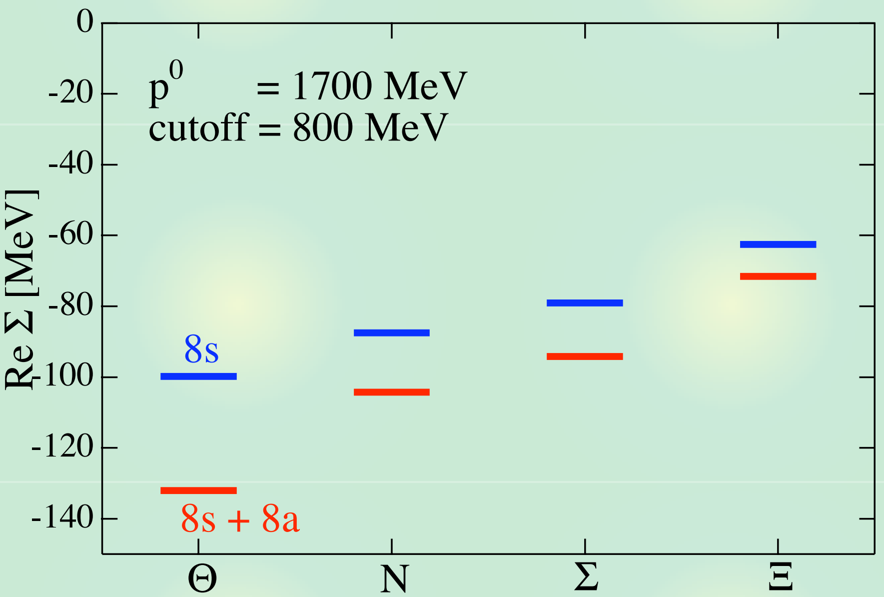
$N(1710) \to \pi\pi(s\text{-wave}, I=0)N$ **25 MeV**

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

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

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





All mass shifts are attractive.

More bound for larger strangeness.

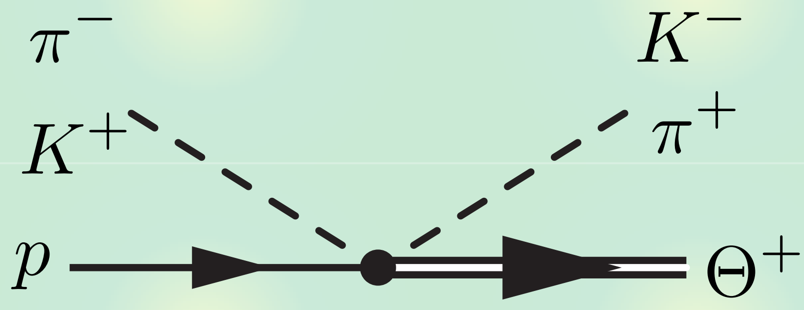
Mass difference between Θ and Ξ
-> 60 MeV : ~20 % of 320 = 1860–1540

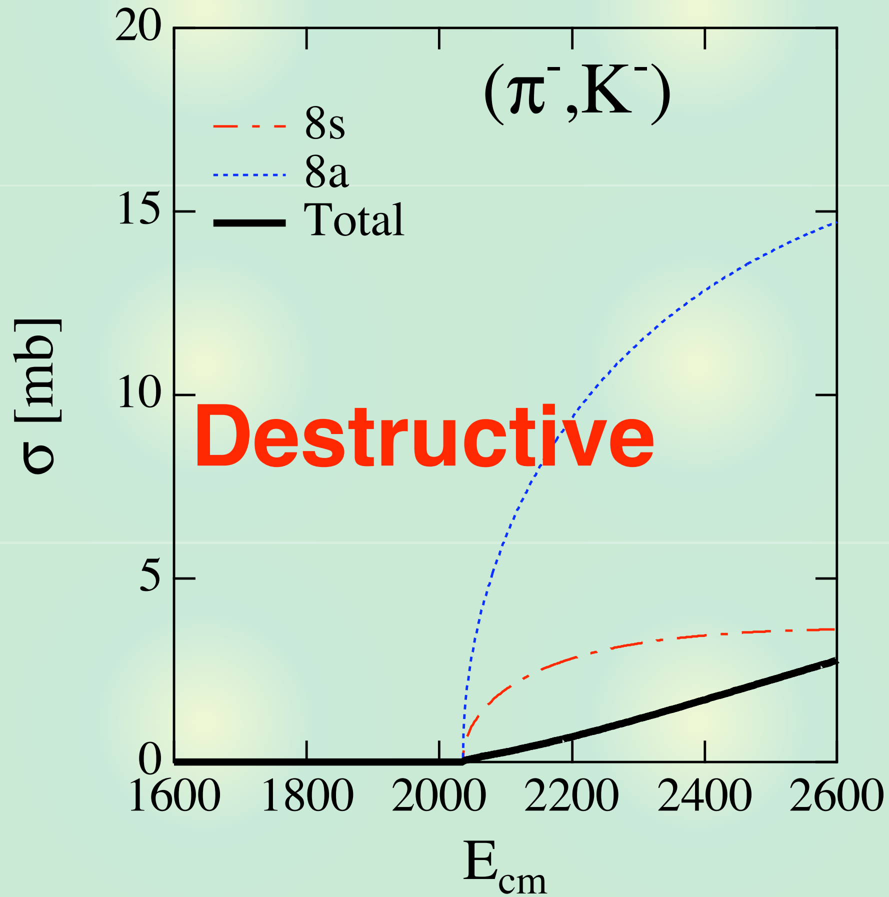
Results of self-energy : Imaginary part (decay width)

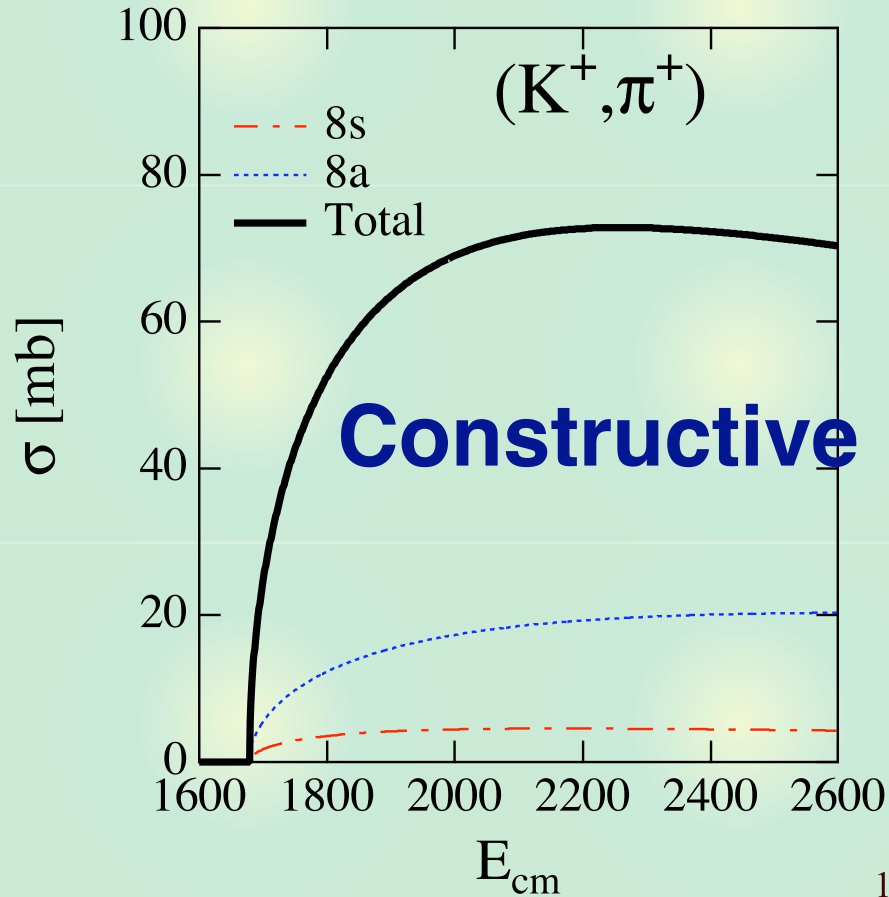
Decay [MeV]	$\Gamma^{(8s)}$	$\Gamma^{(8a)}$	$\Gamma^{(tot)}_{BMM}$
$N(1710) \to N\pi\pi$ (inputs)	25	15	40
$N(1710) \to N\eta\pi$	0.58	-	
$\Sigma(1770) \to N\bar{K}\pi$	4.7	6.0	24
$\Sigma(1770) \to \Sigma\pi\pi$	10	0.62	
$\Sigma(1770) \to \Lambda\pi\pi$	-	2.9	
$\Xi(1860) \to \Sigma\bar{K}\pi$	0.57	0.46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

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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 in (π^-, K^-) reaction could be qualitatively explained by the interference of two amplitudes.**

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

Future works

Self-energy

Possible mixing with the other flavor multiplets (8, 27, ...), other types of interactions (chiral?), ...

Reaction

Quantitative analysis (From factor), background cross section