Phenomenology of spin 3/2 baryons with pentaquarks

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2005, Oct. 20th

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Introduction : Flavor SU(3) symmetry

Existence of Θ^+ + Flavor SU(3) symmetry

➡ **Existence of flavor partners of Θ^+**

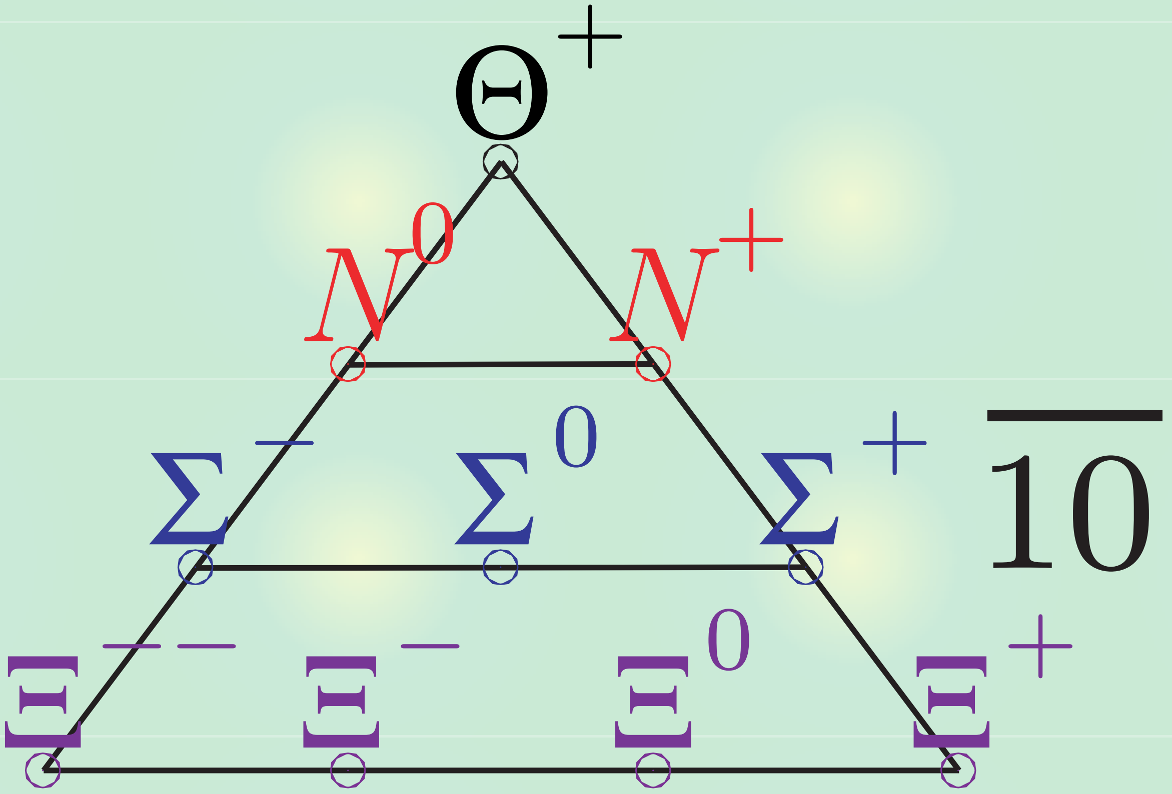
Assuming the flavor multiplet that Θ^+ belongs to, we examine its properties by symmetry relation, in connection with known baryon resonances.

➡ **to determine the J^P of Θ^+**

Phenomenological but model independent analysis up to $O(m_s)$

Pure antidecuplet case

Simplest assignment for Θ^+



Test the masses and widths of partners via flavor SU(3) symmetry relations

Pure antidecuplet case

Mass and decay width [MeV]

$$M(\overline{\mathbf{10}};Y) = M_{\overline{\mathbf{10}}} - aY \qquad g_{\Theta KN} = \sqrt{6}g_{N^*\pi N}$$

J^P	M_Θ	M_N	M_Σ	M_Ξ	Γ_Θ
$1/2^-$	1540	1647	1753	1860	156.1
exp.	Θ(1540)	N(1650)	Σ(1750)	Ξ(1860)	
$1/2^+$					
exp.					
$3/2^+$					
exp.					
$3/2^-$					
exp.					

Pure antidecuplet case

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$1/2^+$ exp.	1540 Θ(1540)	1710 N(1710)	1880 Σ(1880)	2050 Ξ(2030)	7.2
$3/2^+$ exp.					
$3/2^-$ exp.					

Pure antidecuplet case

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$3/2^+$ exp.	1540 Θ(1540)	1720 N(1720)	1900	2080	10.6
$3/2^-$ exp.					

Pure antidecuplet case

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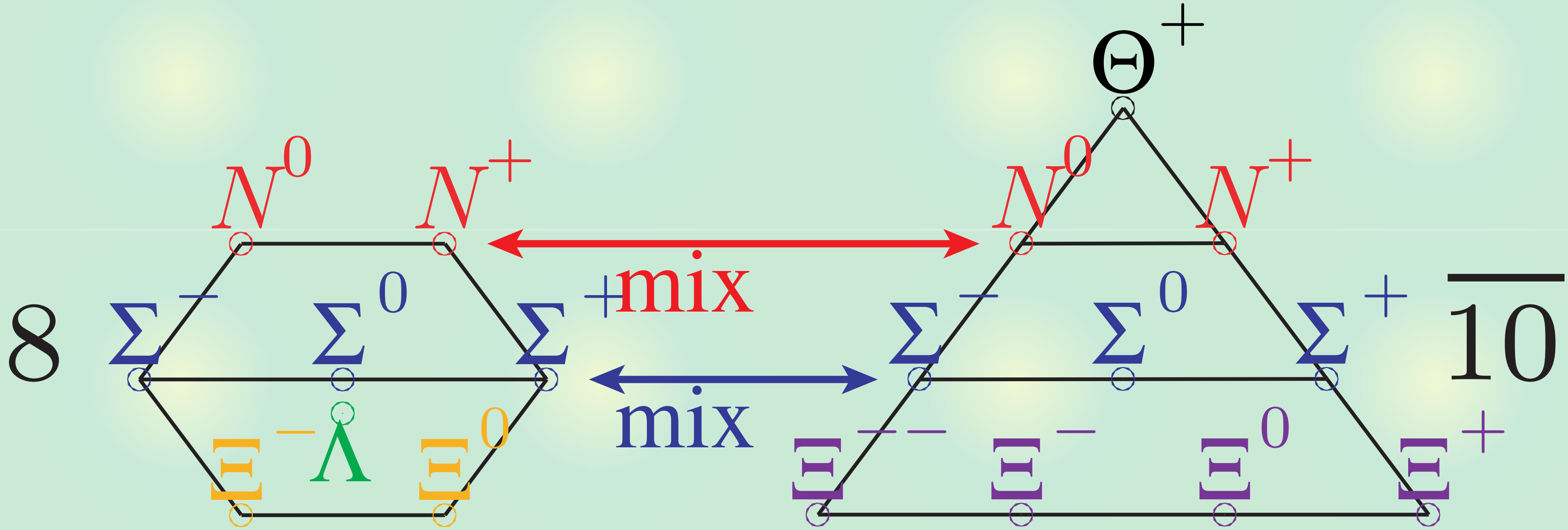
exp.	Θ(1540)	N(1710)	Σ(1880)	Ξ(2030)	
$3/2^+$	1540	1720	1900	2080	10.6
exp.	Θ(1540)	N(1720)			
$3/2^-$	1540	1700	1860	2020	1.3
exp.	Θ(1540)	N(1700)		Ξ(2030)	

are not reproduced simultaneously.

Octet-antidecuplet mixing

Second simplest assignment for Θ⁺



Mixing is induced by the SU(3) breaking in mass term.

Octet-antidecuplet mixing

Mass formulae

$$M_\Theta = M_{\overline{\mathbf{10}}} - 2a \qquad M_{\Xi_{\overline{10}}} = M_{\overline{\mathbf{10}}} + a$$

$$M_\Lambda = M_{\mathbf{8}} \qquad M_{\Xi_8} = M_{\mathbf{8}} + b + \frac{1}{2}c$$

$$M_{N_1} = \left(M_{\mathbf{8}} - b + \frac{1}{2}c\right)\cos^2\theta_N + (M_{\overline{\mathbf{10}}} - a)\sin^2\theta_N - \delta\sin 2\theta_N$$

$$M_{N_2} = \left(M_{\mathbf{8}} - b + \frac{1}{2}c\right)\sin^2\theta_N + (M_{\overline{\mathbf{10}}} - a)\cos^2\theta_N + \delta\sin 2\theta_N$$

$$M_{\Sigma_1} = (M_{\mathbf{8}} + 2c)\cos^2\theta_\Sigma + M_{\overline{\mathbf{10}}}\sin^2\theta_\Sigma - \delta\sin 2\theta_\Sigma$$

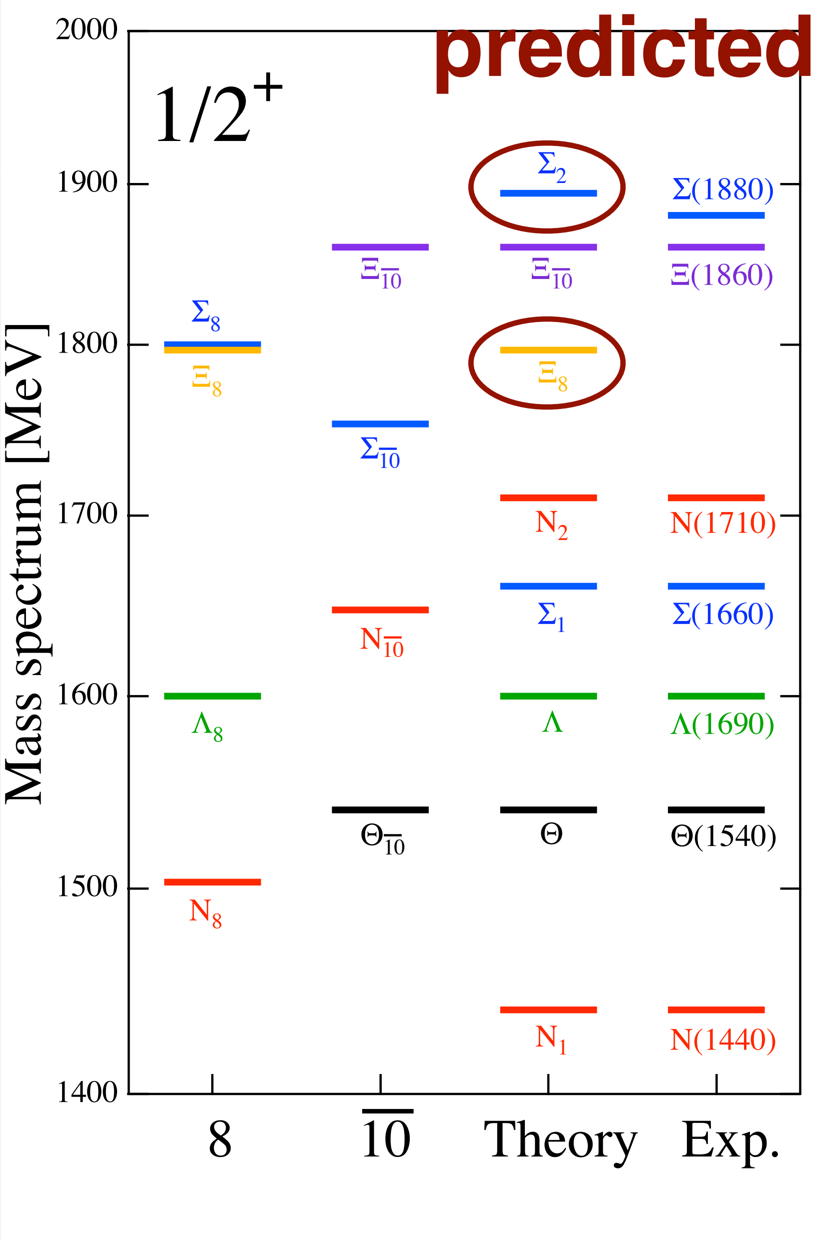
$$M_{\Sigma_2} = (M_{\mathbf{8}} + 2c)\sin^2\theta_\Sigma + M_{\overline{\mathbf{10}}}\cos^2\theta_\Sigma + \delta\sin 2\theta_\Sigma$$

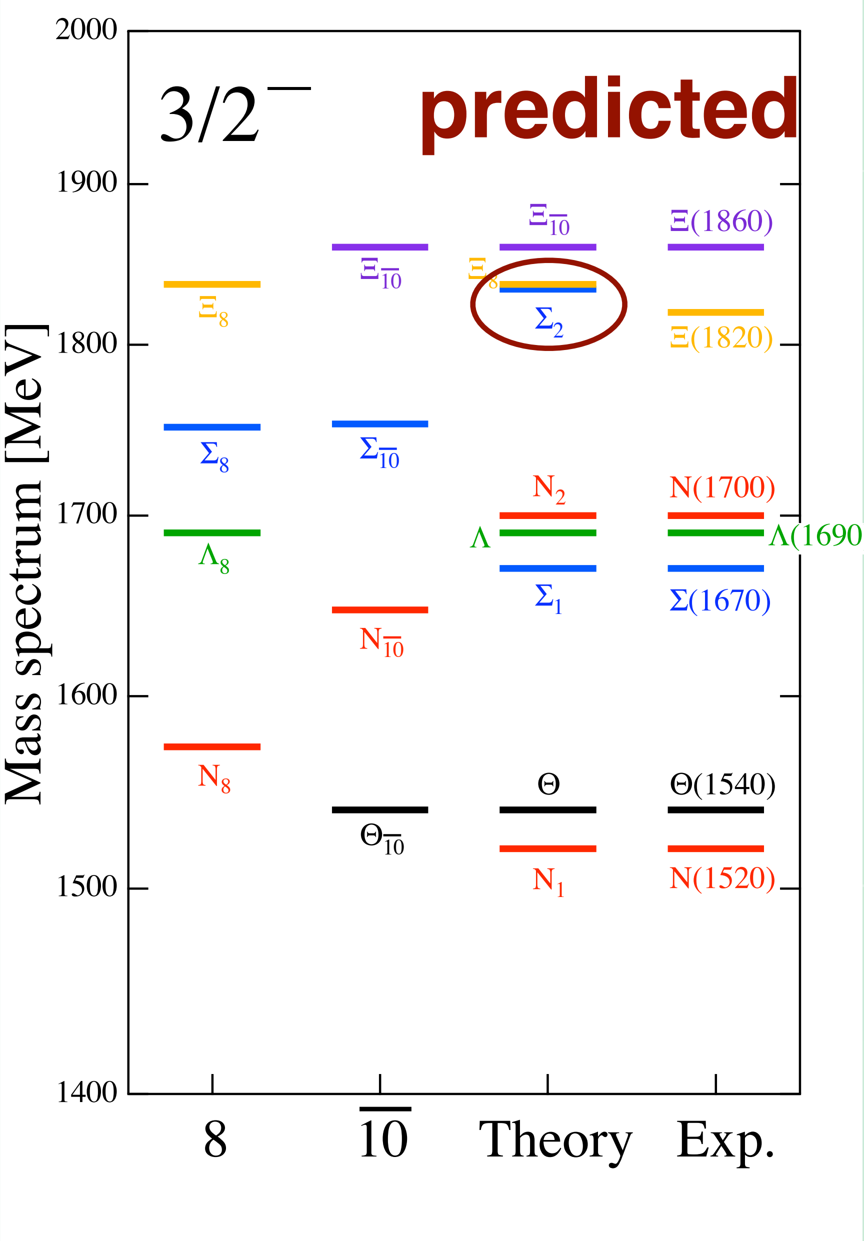
8 masses v.s. 6 parameters

$J^P = 1/2^-$: too wide width

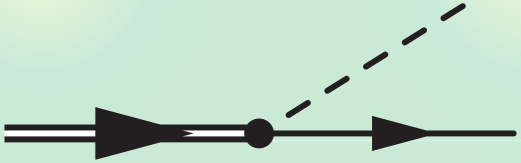
$J^P = 3/2^+$: states are not well established

Mass spectra





Decay width of Θ



Relation between coupling constants

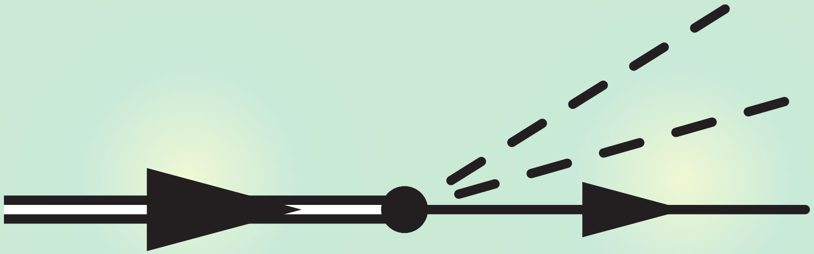
$$g_\Theta = \sqrt{6}(g_{N_2}\cos\theta_N - g_{N_1}\sin\theta_N)$$

C.G. Coeff. **N* decay** **from masses**

J^P	θ_N [deg]	Γ_Θ [MeV]
$1/2^+$	29	29.1
$3/2^-$	33	3.1

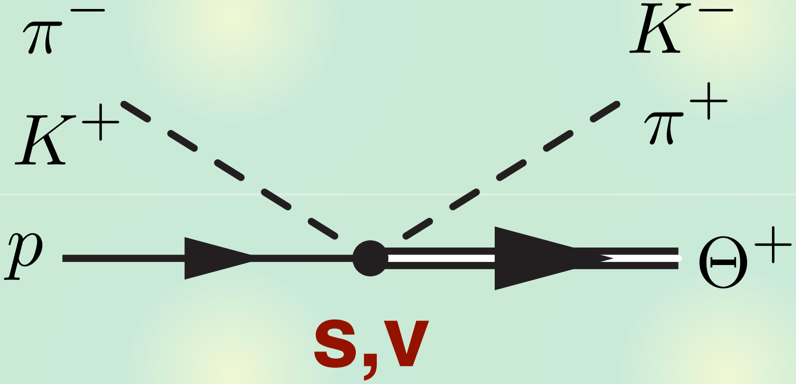
Two-meson coupling

Then, what about two-meson coupling?



SU(3) relation enable us to calculate

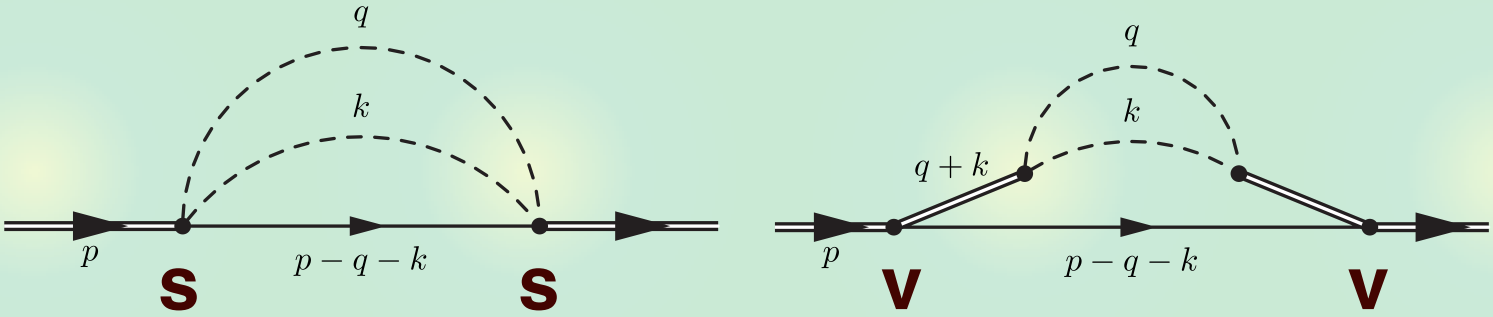
the cross section of

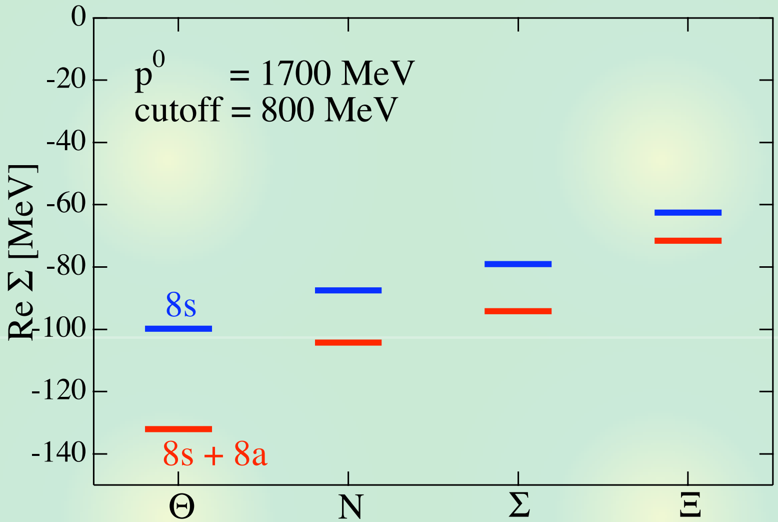


from the decay of nucleons into two pions.

Two-meson coupling

Contact interaction :





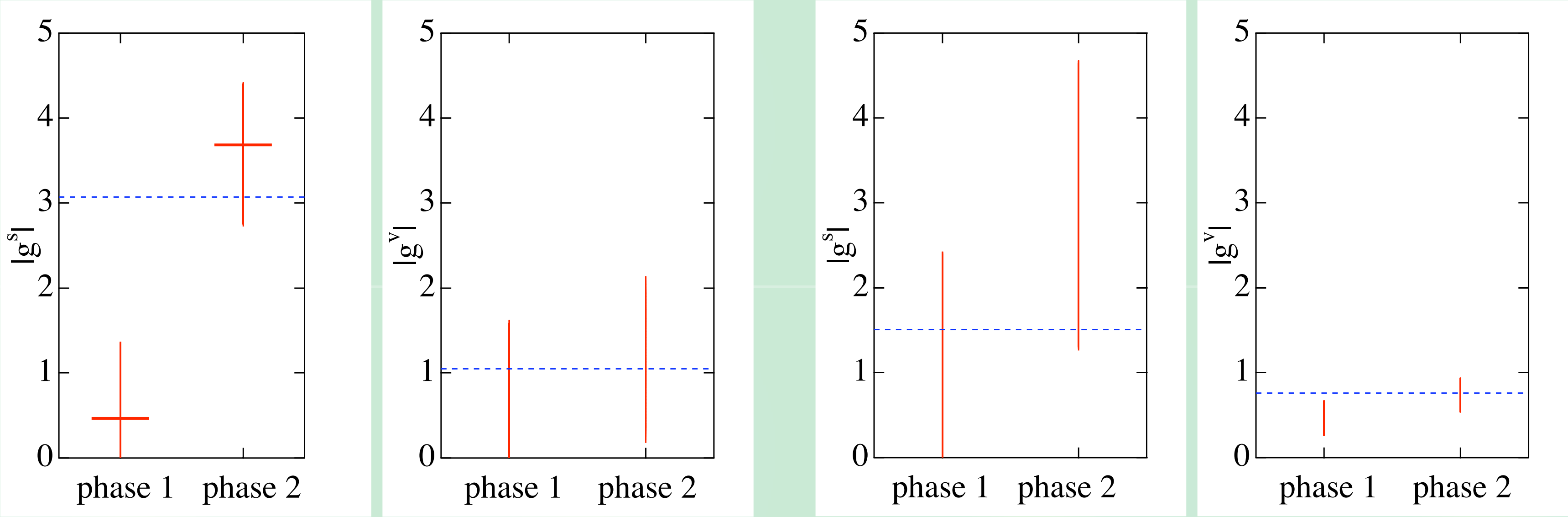
A. Hosaka, et al., Phys. Rev. C71 045205 (2005)

Talk by Llanes-Estrada

Two-meson coupling

Branching fraction [%]

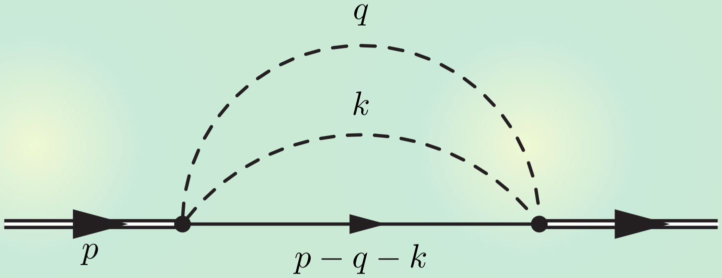
J^P	state	πN	ππN(s)	ππN(v)
$1/2^+$	N(1440)	65	7.5	<8
	N(1710)	15	25	15
$3/2^-$	N(1520)	55	25	20
	N(1700)	10	<85-95	<35



Still large uncertainty

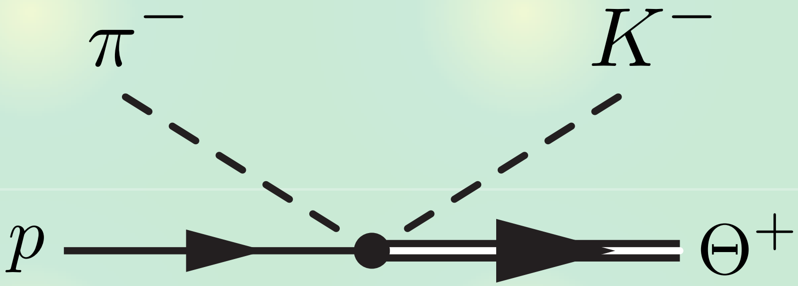
Constraints on the coupling

Self-enefgy : not too large, but not too small



~ 100 MeV

π^-p -> K$^-\Theta^+$ at KEK : upper limit is ~ 4.1 μb

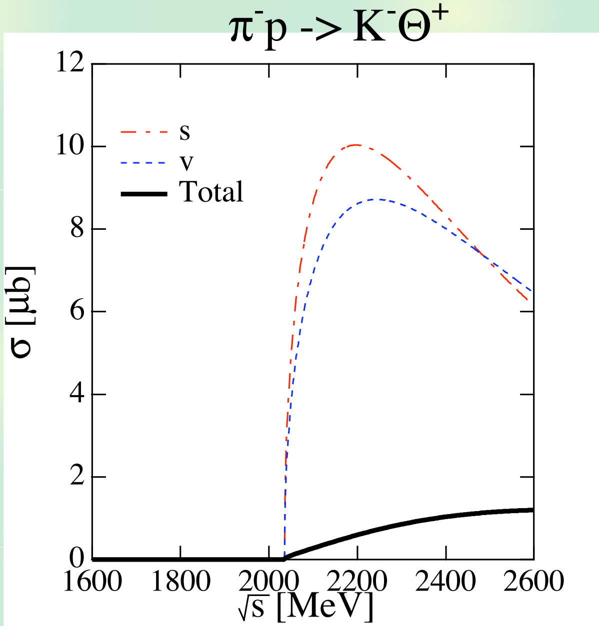


< 4.1 μb

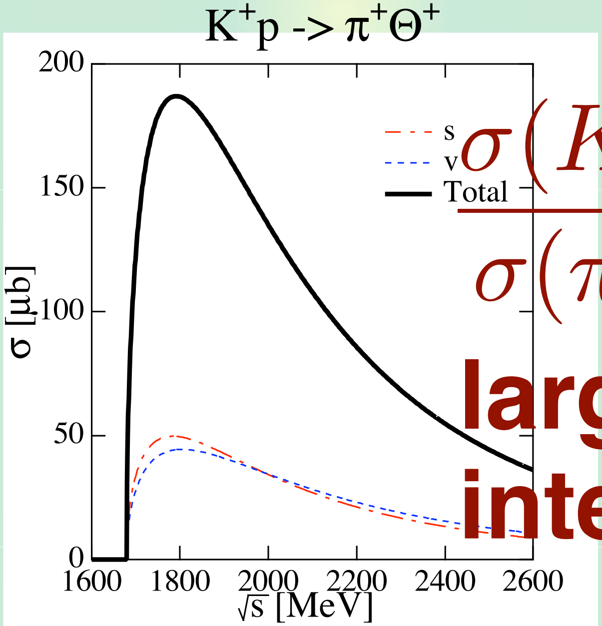
It is necessary to use the interference effect among two terms, s and v.

Θ production

$1/2^{+}$



$\pi^{-}p \to K^{-}\Theta^{+}$

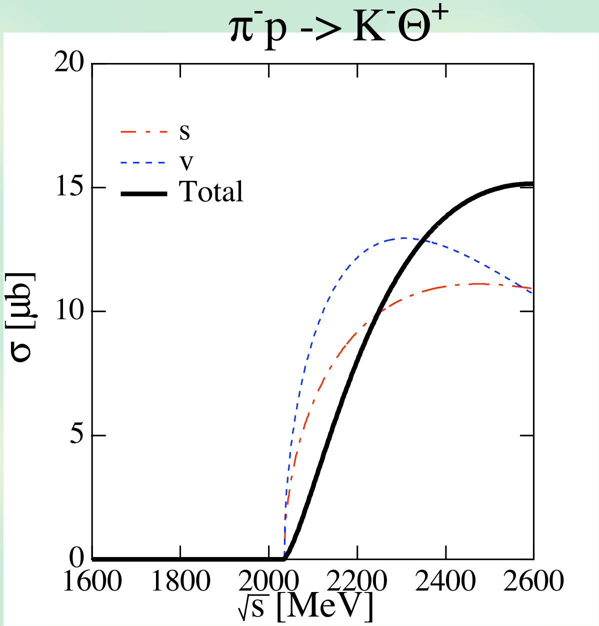


$K^{+}p \to \pi^{+}\Theta^{+}$

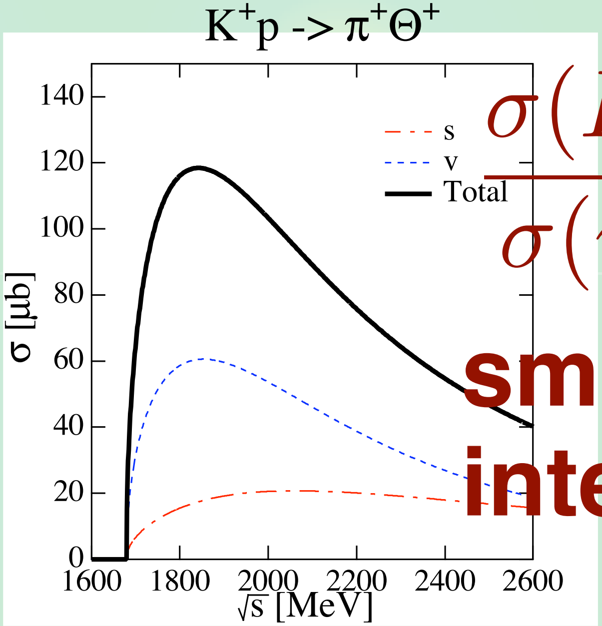
$$\frac{\sigma(K^{+})}{\sigma(\pi^{-})} \sim 50$$

large interference

$3/2^{-}$



$\pi^{-}p \to K^{-}\Theta^{+}$



$K^{+}p \to \pi^{+}\Theta^{+}$

$$\frac{\sigma(K^{+})}{\sigma(\pi^{-})} \sim 3$$

small interference

Summary 1 : mixing scheme

We examine $8\text{–}\overline{10}$ mixing scheme for the exotic and non-exotic baryon resonances.

- Masses of Θ(1540) and Ξ(1860) are well fitted in the $8\text{–}\overline{10}$ mixing scheme with $J^P = 1/2^+$ or $3/2^-$ baryons.
- The width of Θ is very narrow for the $J^P = 3/2^-$ case.
- For both cases, the mixing angle is close to the ideal angle.

T. H. and A. Hosaka, Phys. Rev. D71, 054017 (2005)

Summary 2 : Two-meson coupling and Θ producion

Based on the mixing scheme, we evaluate the two-meson coupling of Θ, and calculate the reaction process for Θ production

- There is an interference effect between two amplitudes, which is prominent for 1/2+ case and rather moderate for 3/2- case

J^P	g^s	g^v	σ_{π^-}	σ_{K^+}	$\mathrm{Re}\Sigma_\Theta$
$1/2^+$	1.59	-0.27	4.1 μb	<1928 μb	-78 MeV
$3/2^-$	0.104	0.209	4.1 μb	<113 μb	-23 MeV

T. H. and A. Hosaka, hep-ph/0509104, Phys. Rev. C, in press.