Flavor symmetry and the pentaquark Θ(1540)

We study the properties of the exotic Θ(1540) baryon from the viewpoint of flavor SU(3) symmetry. The role of two-meson cloud in the baryon antidecuplet are investigated based on the effective interactions, assuming $J^P = 1/2^+$. Then we study the possibilities of having $J^P = 1/2^\pm, 3/2^\pm$ in connection with the known baryon resonances.

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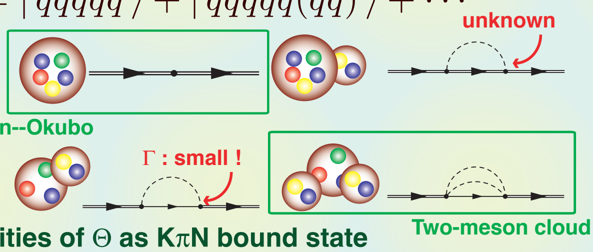
Motivation : Two-meson cloud

In general, an exotic state can be represented as linear combination of infinite number of Fock components

$$|\,P\,\rangle = |\,qqqq\bar{q}\,\rangle + |\,qqqq\bar{q}(q\bar{q})\,\rangle + \cdots$$



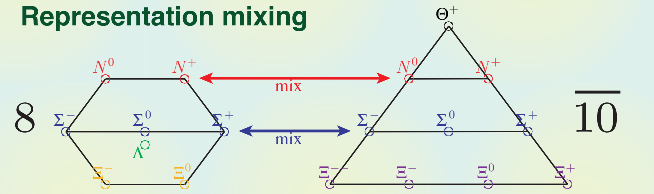
Possibilities of Θ as KπN bound state

P. Bicudo, *et al.* Phys. Rev. C 69, 011503 (2004)
T. Kishimoto, *et al.* hep-ex/0312003
F. J. Llanes-Esrada, *et al.* Phys. Rev. C 69, 055203 (2004)

What about other JP?

Properties of SU(3) multiplet in general framework

Representation mixing



We assign several baryon resonances in this framework together with Θ(1540) and Ξ(1860).

Self-energy results

Interaction Lagrangians

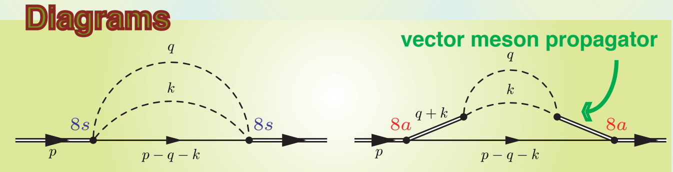
Lagangian should be SU(3) symmetric.

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

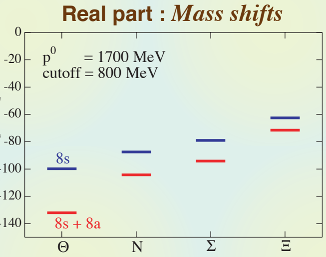
$$\mathcal{L}^{8a} = i\frac{g^{8a}}{4f^2}\bar{P}_{ijk}\epsilon^{lmk}\gamma^\mu(\partial_\mu\phi_l{}^a\phi_a{}^i - \phi_l{}^a\partial_\mu\phi_a{}^i)B_m{}^j + \text{h.c.}$$

Coupling constants are determined from the experimental data of the decay width of N(1710) -> Nππ. Since the Lagrangians are SU(3) symmetric, self-energies of all the members of antidecuplet can be calculated.

Diagrams



Real part : ***Mass shifts***



Imaginary part : ***Decay widths***

Decay widths (MeV)	$\Gamma^{(8s)}$	$\Gamma^{(8a)}$	Γ^{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	

(in MeV)

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

Mass and width

Mass spectrum

$$M_\Theta = M_{\mathbf{10}} \qquad M_{\Xi_{\mathbf{10}}}$$

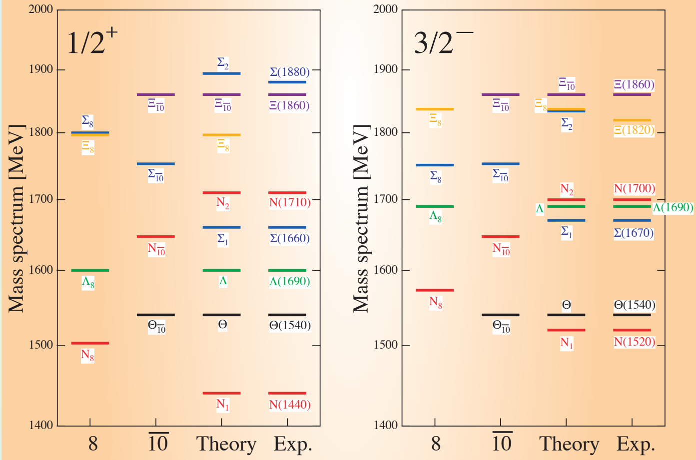
$$M_\Lambda = M_{\mathbf{8}} \qquad M_{\Xi_8} = M_{\mathbf{8}} + b + \frac{1}{2}c$$

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

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

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

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



Decay width of Θ

Exp. N* -> Nπ   mass spectrum

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

J^P	θ_N	Phase 1	Phase 2
$1/2^+$	29° (Mass)	29.1	103.3
$3/2^-$	33° (Mass)	3.1	20.0

(in MeV)

Conclusions 1

We study the two-meson vertial 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%**.
- Decay widths to the three body channel are relatively **small**.

A. Hosaka, T. H., F. J. Llanes-Estrada, E. Oset, J. R. Pelaez, and M. J. Vicente Vacas, Phys. Rev. C 71, 045205 (2005)

Conclusions 2

We examine 8-10 mixing scheme for the Θ(1540) and known resonances of $J^P = 1/2^\pm, 3/2^\pm$.

- The experimental mass spectrum of $1/2^+$ and $3/2^-$ are well repoduced.
- By obseving the decay widths of N* -> Nπ with the mixing angle obtained from the masses, $J^P = 3/2^-$ assignment seems plausible.

T. H. and A. Hosaka, Phys. Rev. D 71, 054017 (2005)