Vector Meson Property in Covariant Classification Scheme

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1.Introduction

Existence of "extra" vector meson $\omega(1250)$, $\rho(1250)$ is pointed out by recent and several old works. e.g.;

M.N.Achasov et al.,hep-ex/0109035
M.N.Achasov et al.,PLB462(99) 365
V.Ivanchenko,hep-ph/0106041
A.Bertin et al.,PLB408(97) 476
A.Bertin et al.,PLB414(97) 220 ･･･ etc.

These stases are obviously out of the PDG classification scheme based on non relativistic quark model.

$N^{2s+1}L_J$	$(u\bar{u}-d\bar{d})/\sqrt{2}$	$(u\bar{u}+d\bar{d})/\sqrt{2}$	$s\bar{s}$
1^3S_1	ρ(770)	ω(783)	ϕ(1020)
2^3S_1	ρ(1450)	ω(1420)	ϕ(1680)
1^3D_1	ρ(1700)	ω(1650)	
3^3S_1	ρ(2150)		

(PDG assignments of vector mesons)

What is the nature of ω(1250) and ρ(1250)?

Experimental studies of ω(1250) and ρ(1250)

ω(1250)

1) It was observed trough $e^+e^- \to V \to \pi^+\pi^-\pi^0$ process. and found that $\rho\pi$ intermediate state dominates there.

2) It was also found that $\sigma(V \to \omega\pi\pi) = 0$

ρ (1250)

3) It was seen in $e^{+}e^{-} \to V \to \pi^{+}\pi^{-}$ process.

Although there is some wide enhancement in the cross section around 1.25[GeV],but peak is not clear.This indicates that $\rho(1250)$ has quite weak coupling to 2π channel and broad other decay channels.(i.e. $\Gamma_{tot}(\omega(1250) \to any)$ is large.)

We have proposed the covariant classification scheme of hadrons,leading to possible existence of **two ground state vector mesons.**
One is corresponding to ordinary ρ -nonets ($V^{(N)}$) , and the other is "extra" ρ -nonets ($V^{(E)}$).

Purpose of this talk

Extra vector mesons experimentally observed have the light mass to be assigned to our extra vector mesons predicted in covariant classification scheme.

$\omega(1250) = \omega^{(E)}$,and $\rho(1250) = \rho^{(E)}$

We investigate decay property of these mesons and point out this assignment is promising.

2.Wave Function of Light Quark Mesons

The hadron wave functions in the covariant classification scheme, are the tensors in $O(3,1) \otimes \tilde{U}(12)$ -space.

All $q\bar{q}$ -mesons are described by $\mathbf{144}$ -multiplet of $\tilde{U}(12)$;

$$\Phi_A^B$$

(where, $A=(a,\alpha)(B=(b,\beta))$ representing the flavor and Dirac spinor indices of quarks (anti-quarks).)

Representation and Structure of Composite Meson

Ordinary SU(6) meson

$$6 \otimes \bar{6} = 36 = (3_{\mathrm{F}}, 2_{\mathrm{S}}) \otimes (\bar{3}_{\mathrm{F}}, \bar{2}_{\mathrm{S}}) = (8 + 1_{\mathrm{F}}, 3 + 1_{\mathrm{S}}) \ : \mathbf{V}_\mu, \mathbf{P}_{\mathrm{s}}$$

Covariant extension

$\tilde{\mathrm{U}}(12)$ meson

$$12 \otimes \bar{12} = 144 = (3_{\mathrm{F}}, 4_{\mathrm{DS}}) \otimes (\bar{3}_{\mathrm{F}}, \bar{4}_{\mathrm{DS}}) = \begin{cases} (8 + 1_{\mathrm{F}}, 3 + 1_{\mathrm{S}}) = 36 : \mathbf{V}_\mu^{(\mathrm{N})}, \mathbf{P}_{\mathrm{s}}^{(\mathrm{N})} \\ (8 + 1_{\mathrm{F}}, 3 + 1_{\mathrm{S}}) = 36 : \mathbf{V}_\mu^{(\mathrm{E})}, \mathbf{P}_{\mathrm{s}}^{(\mathrm{E})} \\ (8 + 1_{\mathrm{F}}, 3 + 1_{\mathrm{S}}) = 36 : \mathbf{A}_\mu^{(\mathrm{N})}, \mathbf{S}^{(\mathrm{N})} \\ (8 + 1_{\mathrm{F}}, 3 + 1_{\mathrm{S}}) = 36 : \mathbf{A}_\mu^{(\mathrm{E})}, \mathbf{S}^{(\mathrm{E})} \end{cases}$$

Spin wave function

(definite C-parity and chiral symmetry)

1) $P_S^{(N)}(0^{-+}) : U_{P_S}^{(N)} = (i/2)\gamma_5$

$V_\mu^{(N)}(1^{--}) : U_{V_\mu}^{(N)} = (i/2)\gamma_\mu$

2) $S^{(N)}(0^{++}) : C_S^{(N)} = (1/2)$

$A_\mu^{(N)}(1^{++}) : C_{A_\mu}^{(N)} = (i/2)\gamma_5\gamma_\mu$

3) $P_S^{(E)}(0^{-+}) : U_{P_S}^{(E)} = (-1/2)\gamma_5(v\gamma)$

$V_\mu^{(E)}(1^{--}) : U_{V_\mu}^{(E)} = (-1/2)\gamma_\mu(v\gamma)$

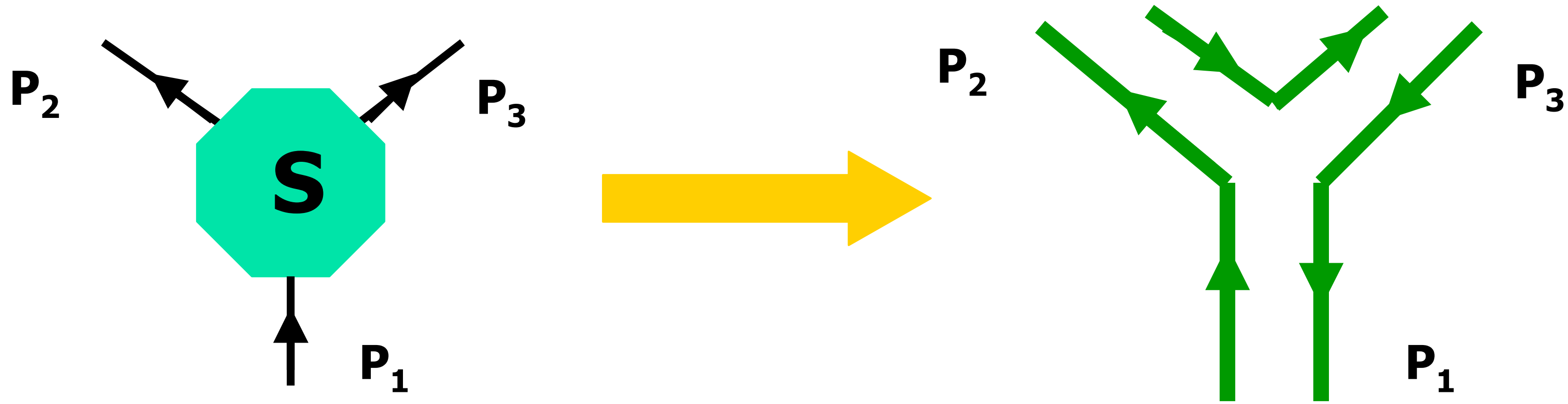
4) $S^{(E)}(0^{+-}) : C_S^{(E)} = (-1/2)(v\gamma)$

$A_\mu^{(E)}(1^{+-}) : C_{A_\mu}^{(E)} = (-i/2)\gamma_5\gamma_\mu(v\gamma)$

3.Description of Strong Interaction vertex

In our scheme,effective strong interactions (,corresponding to OZI allowed graph,) is obtained directly through the overlapping of relevant “constituent quark”line.

For instance,3-meson vertex is represented by;



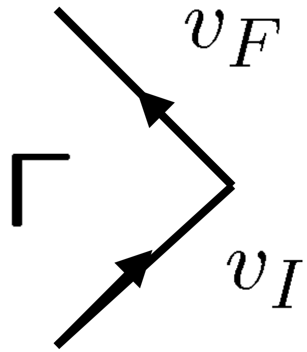
The overlapping of qurarks in the transition matrix elements must be chiral symmetric, consistently with fundamental QCD.

But, their form “ $\bar{\psi}\psi$ ” violates chiral symmetry.

To avoid this difficulty , we introduce the vetex factor to be called “connector”;

$$\Gamma = \frac{(-i\hat{v}_I\gamma)+(-i\hat{v}_F\gamma)}{2}$$

Where; $\hat{v} = \begin{cases} v \text{ for } q \\ -v \text{ for } \bar{q} \end{cases}$



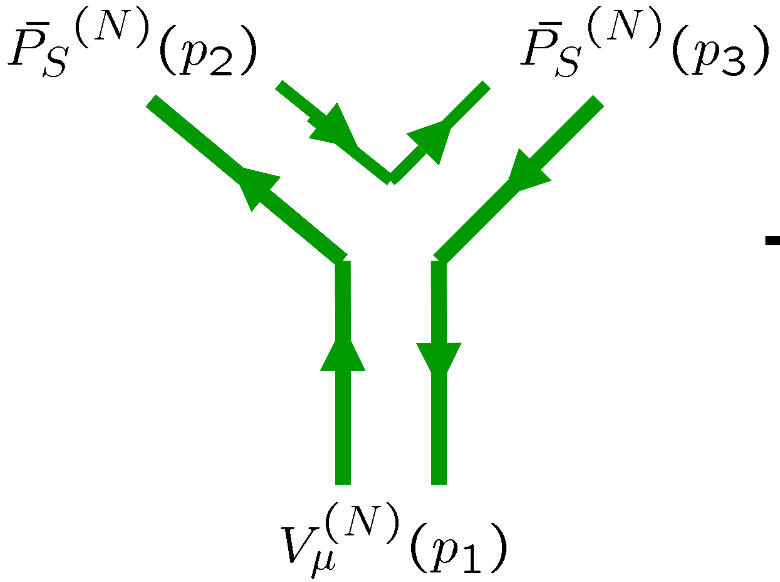
which is inserted between the Dirac spinors of initial and final quarks.

This prescription leads to a useful selection rule of which example will be shortly.

(cf. S.Ishida's talk)

Example:Effective Interactions of the process ; $\rho^{(\mathrm{N})} \to 2\pi^{(\mathrm{N})}$

H =



+ c.c.

$$= \quad tr[\Gamma_{31}\bar{U}_{P_S}(p_3)\Gamma_{23}\bar{U}_{P_S}(p_2)\Gamma_{12}U_{V_\mu}(p_1)]tr[(\bar{P}_s\bar{P}_s)_F V_\mu]$$

$$= \underbrace{g\frac{\sqrt{2}}{16m_2}(2+\frac{m_1}{m_2})}_{g_{\rho\pi\pi}}(p_3-p_2)_\mu \pi^{(N)-}(p_3)\pi^{(N)+}(p_2)\rho_\mu^{(N)0}(p_1)$$

g is determined as ; g= 1.27 [GeV]

from experimental value ;

$$\Gamma(\rho \to \pi\pi) = 150 \ \text{[MeV]}$$

$$m_\rho = 770\text{[MeV]},\ m_\pi = 140\ \text{[MeV]}$$

In the following,we apply this value

commonly for tri-liner interactions

among all $\tilde{U}(12)$ multiplets.

4.Extra Vector Meson Properties

$\omega^{(E)}$

1) $$H = -\underbrace{g\frac{\sqrt{2}i(m_1+m_2+m_3)}{8m_1m_2m_3}}_{f}\epsilon_{\mu\nu\alpha\beta}p_{2\alpha}p_{3\beta}\pi^{(N)}(p_3)\rho_\nu^{(N)}(p_2)\omega_\mu^{(E)}(p_1)$$

$$\Gamma(\omega^{(E)} \to \rho\pi) = \frac{f^2}{4\pi}|\mathbf{p_2}|^3 = 52.0[\mathrm{MeV}]$$

Not inconsistent with ω(1250) data.

2) $\omega^{(E)} \rightarrow \omega\pi\pi$

$$H = tr[\Gamma_{41}\bar{U}_{P_S}^{(N)}\Gamma_{34}\bar{U}_{P_S}^{(N)}\Gamma_{23}\bar{U}_{V\nu}^{(N)}\Gamma_{12}U_{V_\mu}^{(E)}]$$

$$\times\{tr[\bar{P}_S{}^{(N)}\bar{P}_S{}^{(N)}\bar{V}_\nu{}^{(N)}V_\mu^{(E)}] + c.c.\}$$

$$= 0$$!!

This process is forbidden by effect of Chiral symmetric Connector.

ρ (1250)

3) $\rho^{(E)} \to \pi\pi$

$$H = tr[\Gamma_{31}\bar{U}_{P_S}^{(N)}\Gamma_{23}\bar{U}_{P_S}^{(N)}\Gamma_{12}U_{V_\mu}^{(E)}]$$

$$\times\{tr[\bar{P}_S{}^{(N)}\bar{P}_S{}^{(N)}V_\mu^{(E)}] + c.c.\}$$

$$= 0$$ **!!**

This process is also forbidden in chiral limit. It seems that this is the reason why $\rho(1250)\pi\pi$ coupling is quite small. This process may occur trough the mixing of $\rho^{(N)} - \rho^{(E)}$,of which origin should be clarified.

Possible origins of large $\Gamma_{tot}(\rho^{(E)})$

$$\rho^{(E)} \to \omega\pi \ ,\eta\rho \ ,a_1\pi, h_1\pi \ ,4\pi\text{etc}$$

From the symmetry consideration,

$$\Gamma(\rho^{(E)} \to \omega\pi) = \tfrac{1}{3}\Gamma(\omega^{(E)} \to \rho\pi)$$

$$= 17.3[\text{Mev}]$$

(Other channel to be calculated)

Summary and Remarks

- We have studied the decay properties of $V^{(E)}$ meson by covariant classification scheme and obtained the results which are consistent with our assignment.
- Future problems ;

1. Phenomenological estimation of the numerical value $\Gamma_{tot}(\rho^{(E)})$
2. In this work ,we considered only chiral symmetric limit. So next ,we should consider the process in the order of spontaneous chiral symmetry breaking.
3. Phenomenological search for $\phi^{(E)} = (s\bar{s})$