Abstract

Motivated by recent results by lattice analysis\cite{1}, we assume that the spin-1 mesons of \((\rho,\omega,\phi,\rho',\omega',\phi')\) make a rep. of 16 of (SU(4)\times U(1)) emergent symmetry in two-flavor QCD when the chiral symmetry is not broken. We study the decay properties of the spin-1 mesons by using a chiral model with an SU(4)\times U(1) hidden local symmetry (HLS). We first show that, since the SU(4)\times U(1) is spontaneously broken together with the chiral symmetry, each coupling of the interaction among one pion and two spin-1 mesons is proportional to the mass difference of the relevant spin-1 mesons similarly to the Goldberger-Treiman (GT) relation. In addition, some of one-pion couplings are related with each other by the SU(4)\times U(1). We further show that there is a relation among the mass of \(\rho\) meson, the \(\rho\) photon mixing strength as well as the Kawai-Okubo-Links-Rauch-Rho-Fayyazuddin (KSRF) relation for the \(\rho\) meson. From the relations, we give numerical predictions such as ratios of the spin-1 meson decay widths, which are compared with future experiments for testing the existence of the SU(4)\times U(1) emergent symmetry.

SU(4) symmetry

\begin{align*}
\psi^\dagger = \left( \begin{array}{c} v_1 \\ v_2 \\ v_3 \\ d_1 \\ d_2 \\ d_3 \\ u_1 \\ u_2 \\ u_3 \end{array} \right) \quad \begin{array}{c} \text{SU(4) flavor sym.} \\
\text{SU(3)}&\text{SU(3)}&\text{SU(3)}&\text{SU(3)}
\end{array}
\end{align*}

Chiral symmetry with SU(4)\times U(1) HLS

We construct a chiral model with an SU(4)\times U(1) hidden local symmetry (HLS). The model has the following symmetries.

\begin{align*}
\text{Chiral sym.} & \quad \text{HLS} & \quad \text{SU(2)}_{L} \times \text{SU(2)}_{R} & \quad \text{SU(4)} \times \text{U(1)} \\
\text{SU(2)}_{L} & \quad \text{SU(2)}_{R} & \quad \text{SU(4)} & \quad \text{U(1)}
\end{align*}

Extended GT Relations

The extended Goldberger-Treiman (GT) relation is obtained.

\begin{align*}
\frac{1}{2} g_1 \gamma_5 \psi \sigma_{\mu\nu} F_{\mu\nu} = \frac{m_1^2 - m_2^2}{2 f_2} g_1 (0)
\end{align*}

Other Relations

Due to a \(\alpha, \rho\) mixing, \(\frac{1}{2} g_1 \gamma_
u \psi \sigma_{\mu\nu} F_{\mu\nu}\) interactions among \(\nu'/\nu\) are obtained from \(g_{\nu'} = g_\nu (p^2 = 0)^2 f_2^2\) included in \(\mathcal{L}_k\).

\begin{align*}
\nu'/\nu\text{ int. are controlled by only three: } \alpha_1, \theta_\rho, \theta_\omega
\end{align*}

Summary

- We constructed a chiral model with SU(4)\times U(1) HLS.
- The following relations are obtained.
  1. Extended GT relation
  2. Relations among the VV\(\pi\) couplings
  3. KSRF-I relations for \(\rho\) and \(\rho'\)
- We gave some predictions.

Future work...

Clarifying the correspondence between the lattice QCD result and our calculation.

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