Chiral $SU_3 \times SU_3$ Breaking and $K_{t3}$ Decay (*) (**).

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Summary. — $K_{t3}$ decay is discussed in connection with the GOR model. The constant $c$ is evaluated without assuming PCAC for $K$-mesons in the usual sense. The analysis done on the $K_{t3}$ form factors indicates agreement with $\xi(t) \simeq -1$ in the physical region.

In this note we use the GOR model (*) for the current divergences in connection with $K_{t3}$ decay in order to evaluate the relative strength of $SU_3$ and $SU_3 \otimes SU_3$ breaking, and also to suggest implications on the behaviour of the $K_{t8}$ form factors.

To this end, we consider the matrix elements of the strangeness-changing current relevant to the $K_{t3}$ decay, i.e.

\begin{equation}
\langle \sigma^0(q)|j_{\mu}^{K^+}(0)|K^+(p)\rangle = -\frac{1}{2} \{F^+(t)(p + q)_{\mu} + F^-(t)(p - q)_{\mu}\},
\end{equation}

where $j_{\mu}^{K^+}(0) = (1/\sqrt{2})(j_{\mu}^s - i\gamma_{\mu})$ and $F^+(0) = 1$.

By means of the relation

\begin{equation}
- i(p - q)_{\mu} \langle \sigma^0(q)|j_{\mu}^{K^+}(0)|K^+(p)\rangle = \langle \sigma^0(q)|\gamma_{\mu} j_{\mu}^{K^+}(0)|K^+(p)\rangle,
\end{equation}

where $0 < t = (p - q)^2 < (m_K - m_{\pi})^2$ the left-hand side can be written in the

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failing way:

\begin{equation}
\frac{i}{2} F^+(t) \left\{ 1 + \frac{t}{m_K^2 - m_{\pi}^2} \xi(t) \right\} \left( m_K^2 - m_{\pi}^2 \right),
\end{equation}

where $\xi(t) = F^-(t)/F^+(t)$. On the other hand, using the GOR model, the right-hand side reduces to

\begin{equation}
\langle \pi(q) | \bar{\epsilon}_\mu j_{\mu}^{\pi*}(0) | K^+(p) \rangle = -i \frac{\sqrt{3}}{\sqrt{2}} \langle \pi(q) | \bar{u} - i u | K^+(p) \rangle = -i \frac{\sqrt{3}}{4} \beta(t).
\end{equation}

We shall use $SU_3$ for the matrix elements of the $u$'s so that $\beta(t)$ is the reduced matrix element of the pseudoscalar octet. $c$ is the relative strength of $SU_3 \otimes SU_3$ and $SU_3$ breaking, which appears in the definition of the energy density $\delta = \mathcal{H}_0 - u_0 - cu_3$, where $\mathcal{H}_0$ is $SU_3 \otimes SU_3$ invariant and $u_0$ and $u_3$ belong to a $(3 \otimes 3^*) + (3^* \otimes 3)$ representation of $SU_3 \otimes SU_3$.

Assuming PCAC for pions and using the transformation properties of $\mathcal{H}_0$, $u_0$ and $u_3$ under $SU_3 \otimes SU_3$, we have

\begin{equation}
\lim_{q \to 0} \langle \pi(q) | - u_0 - cu_3 | \pi(p) \rangle = 2 \zeta_{\pi} \langle 0 | \bar{\epsilon}_\mu j_{\mu}^{\pi*} | \pi(p) \rangle = m_{\pi}^2 = \\
= \alpha(m_{\pi}^2) + \frac{c}{\sqrt{3}} \beta(m_{\pi}^2) \simeq \alpha(0) + \frac{c}{\sqrt{3}} \beta(0).
\end{equation}

In the $SU_2 \otimes SU_2$ limit $\bar{\epsilon}_\mu j_{\mu}^{\pi*}$ is conserved and the pion is massless so that $\alpha(0) = \sqrt{3} \beta(0)$. Therefore we can write

\begin{equation}
\left( \sqrt{\frac{2}{3}} + \frac{c}{\sqrt{3}} \right) \beta(0) \simeq m_{\pi}^2.
\end{equation}

Considering eq. (2) at $t = 0$, we obtain by using eqs. (6), (4) and (3),

\begin{equation}
F^+(0)(m_K^2 - m_{\pi}^2) = -\frac{3}{2} \frac{cm_{\pi}^2}{\sqrt{2} + c}.
\end{equation}

By virtue of Ademollo-Gatto theorem (\textsuperscript{2}) $F^+(0) = 1$ up to second order in $SU_3$ breaking, so that eq. (7) yields

\begin{equation}
e = -\sqrt{2} \frac{(m_K^2 - m_{\pi}^2)}{m_K^2 + \frac{1}{2} m_{\pi}^2} \simeq -1.25.
\end{equation}

The above expression for $e$ is the same as the one obtained by GOR. However in the present derivation there is no need to assume $\beta(0) \simeq \beta(m_{\pi}^2)$. In