The Possible Existence of a Neutral Meson

with Isotopic Spin 0

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The possible existence of a neutral meson \( \pi' \), with isospin 0 and strangeness 0, which has strong interaction with baryons, pions and kaons, has been discussed some time ago by the present author \(^1\) and by Baldin-Kabir \(^2\). Later on, experimental checks \(^3\) of its existence have been carried out. From this, and together with other information on pion physics at low energies, one can rule out the existence of \( \pi' \) with mass range

\[
m' \leq 2m_{\pi}
\]

where \( m' \) and \( m_{\pi} \) are the masses of \( \pi' \) and usual pions. If \( m' > 3m_{\pi} \), then \( \pi' \) would decay immediately into several pions via strong interactions, whatever the spin-parity of \( \pi' \) might be. Then we do not naturally call such \( \pi' \) a "particle", but we simply call it a resonance level in scattering (or reactions) processes. Hence we must require for \( \pi' \) as a particle:

\[
m' \leq 3m_{\pi}
\]

In fact what we can call a "particle" must have long enough lifetime so that the "particle" created by some production process must be able to escape outside the strongly interaction region. Since the collision time of pion-nucleon or nucleon-nucleon collision is shorter than (or of the order of) \( 10^{-22} \) sec, the criterion for the validity of "particle concept" should be given by the statement: "the lifetime \( \tau \) of the "particle" must be longer than the collision time", say

\[
\tau > 10^{-21} \text{ sec.}
\]

Extremely short-lived — but that can still be called — "particles" known to us are \( \Sigma^0 \) and \( \pi^0 \), and their decay mechanisms involve the electromagnetic interactions:

\[
\Sigma^0 \rightarrow \Lambda^0 + \gamma
\]

\[
\pi^0 \rightarrow 2\gamma
\]
If there exists a decay process of a particle which involves only strongly interacting particles but no photons, and whose lifetime is longer than \( \sim 10^{-21} \) sec, it would surprise us. Fortunately we have not found such a case.

Therefore, if \( \pi' \) ever existed as a particle, its decay must be caused by the presence of the electromagnetic interactions, unless it is caused by the weak interactions. We have assumed "non-strange" \( \pi' \) to be strongly coupled to baryons and mesons. Hence the \( \pi' \) with \( m' > 2m_\pi \) and decaying solely via weak interactions is impossible. Thus the "particle" \( \pi' \) must have the dominate decay mode:

\[
\pi' \rightarrow 2\pi + \gamma \quad \text{or} \quad \pi^0 + \gamma \quad (4)
\]

since

\[
\pi' \rightarrow 2\gamma \quad \text{or} \quad 3\gamma \quad \text{etc.}
\]

are supposed to occur less frequently than (4). If we compare \( \Sigma^0 \rightarrow \Lambda^0 + \gamma \) with (4) and recall our mass value for \( \pi' \):

\[
3m_\pi \geq m' \geq 2m_\pi \quad (5)
\]

we may say that \( \pi' \) and \( \Sigma^0 \) must have more or less the same lifetime. Since we know \( \Sigma^0 \) as a "particle", we can also call \( \pi' \) a particle. Here we must forbid the \( 2\pi \) decay of \( \pi' \):

\[
\pi' \rightarrow \pi^+ + \pi^- \quad \text{or} \quad 2\pi^0 .
\]

This imposes a very strong limitation on the spin-parity of \( \pi' \). Among low spin values (smaller than 2) allowed combination of spin-parity will be given by:

\[
\text{Spin-parity of } \pi' : \quad 0^- \text{ or } 1^+ \quad (6)
\]

Let us discuss these two possibilities a little bit further.

\(^*)\) decay process with strangeness conservation,
The $\gamma$-rays coming from $\pi'$-decay (4) are assumed to be of the lowest multipole. Then the $\gamma$ of the decay process $2\pi + \gamma$ must be M.D. for both cases $0^-$ or $1^+$ for $\pi'$. $2\pi$-state will be a p-state or s-state depending on pseudoscalar or axial vector $\pi'$. Hence $2\pi$ must have total isospin 1 or 0. By charge independence,

$$\frac{\omega(\pi' \rightarrow 2\pi^0 + \gamma)}{\omega(\pi' \rightarrow \pi^0 + \pi^- + \gamma)} = \begin{cases} 0 & \text{for pseudoscalar } \pi' \\ \frac{1}{2} & \text{for axial vector } \pi' \end{cases}$$

Of course the axial vector $\pi'$ can have another decay mode $\pi' \rightarrow \pi^0 + \gamma$. In either case, the experimental test of such a $\pi'$ must be relatively easy. Also the kinematics of the reaction

$$\pi^- + p \rightarrow n + \pi'$$

or the cusp behaviour $^4$) of $\pi^-$-p cross-section will serve to test the existence of $\pi'$. 

Recently, the present author has shown $^5$) that a composite theory of mesons (Sakata model) predicts the existence of pseudoscalar $\pi'$. 

**Summary:**

If a strongly interacting meson with isospin 0 and strangeness 0 does exist as a "particle", its mass must lie between $2m_{\pi}$ and $3m_{\pi}$, its lifetime is nearly the same as that of $\Sigma^0$ and its main decay mode is given by

$$\pi' \rightarrow \pi^+ + \pi^- + \gamma \text{ or } \pi^0 + \gamma$$

and could be either pseudoscalar or axial vector.
REFERENCES

1) Y. Yamaguchi, Prog. Theor. Phys. 12, 622 (1958). In this paper a careless statement has been made. (p. 627, just above Eq. (16)). A pseudoscalar \( \pi' \) can be produced by the reaction

\[
\text{d} + \text{d} \rightarrow \pi + \pi'.
\]


3) T. Yamagata, G. Stoppini and A.C. Odian (to be published). J.M. Cassels, P.G. Murphy and others (to be published).
