All known particle reactions, whether they be strong, electromagnetic, or weak, are in accordance with CP Invariance, with the notable exception of the recent experimental results of Christenson, Cronin, Fitch, and Tur- lay on the apparent decay of $K^+_2$ mesons into two pions with a branching ratio of $2.3 \times 10^{-2}$. Several explanations of this effect may be proposed, which take account of the fact that this apparent CP nonconservation is “very small.” They include the following:

1. External fields not invariant under CP of TCP. Such a mechanism could make the long-lived component have a small admixture of $K^0_L$, thus leading to a small two-pion mode. The smallness of the apparent CP nonconservation is then due to the smallness of these external fields, say due to a very weak long-range coupling of hypercharges, or the local density of neutrinos.\(^4\)

2. “Maximal” CP nonconservation in a rare decay channel. Either the $\Delta f = \frac{1}{2}$ part of the nonleptonic decay amplitude\(^5\) or the $I = \frac{3}{2}$, $\Delta Q = -\Delta S$ leptonic decay amplitude\(^6\) could be chosen to fit the role.

3. The reinterpretation of the decay modes as decay into two particles, at least one of which differs in spin-parity assignment from the pion. Since Christenson et al. measured the masses of the two particles rather carefully, we must assume that such a particle (or particles) is degenerate with pions in mass.

In a recent investigation, two of us have found some evidence for a small but significant correlation between the direction of emission of the decay muon and the initial direction of emission of the pion produced in the $\tau$-decay mode of $K^+$ mesons. Elsewhere\(^6\) these two authors have announced this effect (the Baku- nine effect) and presented a brief analysis of the experimental data. If we believe in the existence of such a genuine correlation, at least some of these “pions” must possess spin, but have nearly the same mass as the usual pseudoscalar pion.

We therefore propose that a new particle, called the spinon (spinning pion), is involved in the “two-pion” mode of $K^+_2$ and (some of) the “three-pion” mode of $K^+$. CP nonconservation is no longer implied by the observation of Christenson et al.; and the observed $\pi-\mu$ decay correlations would be explained.

Such a decay mechanism would have several direct experimental tests:

1. The spinon would be expected to have more or less equal rates for decay into the electron and muon lepton modes.\(^6\) The $\pi-\mu$ decay asymmetry could be explained by an admixture of at least $5\%$ of spinons in $\tau$ decay; we therefore expect that at least $3\%$ of all the “pions” from $\tau$'s decay into electrons.\(^6\)

2. The muons (and electrons) from spinon decay would be polarized oppositely to those from pion decay. Hence, in particular, we would expect the muons from the two-meson decay of $K^+$ to exhibit a polarization different from the polarization of muons from pion decay.

3. Since at least one of the mesons in the Christenson experiment is a spinon, the electron decay mode would be expected to be quite frequent (between 25 and 50%).

4. If the spinon occurs only in the charged form, the $\Delta f = \frac{1}{2}$ rule would be violated by several percent in $\tau$ decay. If neutral spinons exist, they are forbidden to decay into two photons if their spin is 1; in such a case the preferred mode will be decay into an electron-positron pair plus a photon. There will thus be an anomalous number of Dalitz pairs.

---

\(^*\)Work supported by the Swiss National Foundation for Scientific Research and the U. S. Atomic Energy Commission.

\(^\dagger\)Permanent address: Physics Institute, University of Neuchâtel, Neuchâtel, Switzerland.

\(^\ddagger\)Permanent address: Syracuse University, Syracuse, New York.


\(^2\)J. S. Bell and J. K. Perring, Phys. Rev. Letters
DETERMINATION OF THE $\Delta_5^{++} - \Delta_5^0$ MASS DIFFERENCE

Martin G. Olsson

Department of Physics, University of Wisconsin, Madison, Wisconsin

(Received 7 December 1964)

The $\Delta_5^{++} - \Delta_5^0$ mass difference has been found to be $-0.45 \pm 0.85$ MeV. This measurement is compared to an SU(6) prediction and to various dynamical theories of SU(3) splitting.

It is well known that the particle masses of an isotopic spin multiplet are split by electromagnetic effects. Within an SU(3) supermultiplet general relationships may be derived between these electromagnetic mass differences. More specific predictions of these splittings may be made with dynamical models such as the “tadpole” model of Coleman and Glashow or the calculation of Socolow which uses only known particles. The agreement with experiment of these predicted mass differences has been quite satisfactory with the pseudoscalar and baryon octets; thus it would be of interest also to test the decuplet mass-splittings predictions.

Accurate measurements of the decuplet masses are difficult for the following reasons:

1. Rather large statistics are required since the $\Delta_5$, $\Sigma_5$, and $\Xi_5$ have level widths comparable to or larger than the electromagnetic mass differences.

2. $\Sigma_5$ and $\Xi_5$ are not seen experimentally in two-body reactions of the form

$$m + B^* \to m + B,$$

but must be studied in production reactions such as

$$m + B \to m + B^* \to m + m + B.$$

In production reactions the exact position of the $B^*$ on the Dalitz plot has no simple relation to its mass, but depends on the largely unknown details of the production mechanism. However, if charge-symmetric reactions are studied, mass differences may, in principle, be measured.

Although the width of the $\Delta_5$ is about two orders of magnitude larger than the accuracy to which we wish to determine its mass, we have the advantage that there already exists a large body of experimental data on $\Delta_5$ formation from low-energy pion-nucleon scattering experiments. The reactions which have been extensively studied are

$$\pi^+ + p \to \Delta_5^{++} \to \pi^+ + p;$$

$$\pi^- + p \to \Delta_5^0 \to \pi^- + p \to n^0 + n.$$

Thus by an analysis of these reactions we hope to determine, among other things, the $\Delta_5^{++} - \Delta_5^0$ mass difference.

For two reasons we have used only total cross-section measurements in our analysis. First, statistical accuracy is assured since the beam-attenuation measurement is the simplest and most often performed scattering experiment. Second, the nonresonant partial waves contribute incoherently to the total cross section, thus minimizing their effect upon the dominant resonant state.

The experimental data are taken from the compilation of Kleipikov, Meshcheryakov, and Socolov, with the addition of several later experiments. These data have been fitted to an expression of the following form:

$$\sigma_{\text{tot}}(\pi^+ p) = \sigma_{\gamma} + c_{3/2} \sigma_{b}(\frac{3}{2});$$

$$\sigma_{\text{tot}}(\pi^- p) = \frac{1}{2} \sigma_{\gamma} + \frac{1}{2} c_{3/2} \sigma_b(\frac{3}{2}) + \frac{3}{2} c_{1/2} \sigma_b(\frac{1}{2}).$$

The meanings of the individual terms are as follows:

$$\sigma_{\gamma} = \frac{8\pi\lambda^2}{(m-m_0)^2 + (\Gamma/2)^2},$$

where

$$\lambda = \frac{\sqrt{m^4 - m_0^4}}{m^2 + m_0^2 - \frac{\Gamma^2}{4}}.$$