FOUR-PRONGED DECAY OF THE LONG LIVED K^0 MESON

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Among 140 decays of long-lived K_2^0 mesons observed in a cloud chamber, one case of a four-pronged star was observed, which most probably can be interpreted as a $K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$ decay with a subsequent $\pi^0 \rightarrow \gamma + e^+ + e^-$ decay.

In an exposure of a cloud chamber (see reference 1) to a beam of neutral particles from the proton synchrotron of the Joint Institute for Nuclear Research, at a distance of 8 m from the internal target, there were registered 140 K_2^0 decays* and among them one four-prong event, a photograph of which is shown in the figure. Tracks A, B, and D are directed upward relative to the plane of the photograph and track C downward. For tracks A, B, and D the radii of magnetic curvature were measured; for the short track C it was possible to determine only the angle and sign of the magnetic curvature. The results of the measurements are shown in the table. All tracks, including the positive particle tracks A and D, have an ionization close to minimum.

From the data of the measurements, it follows that the positive particles cannot be protons, and tracks A and B are probably an electron — positron pair. Therefore it is quite natural to consider the observed star to be the result of the decay of a neutral particle.

In fact, of the possible reactions of the interaction of neutrons (in the beam) with the gas of the chamber, the only events of this kind which may occur are those involving the production, in the same act, of two neutral π mesons or two charged π mesons and a neutral one in the absence of protons associated with the disintegration of a nucleus. In both cases we can observe a four-pronged star if each π^0 meson decays into γ quanta and an e^+, e^- pair (Dalitz pair). Under our conditions, however, such an event is extremely improbable, since the neutrons have a low energy. As a matter of fact, the mean energy of protons knocked out from the walls of the chamber by neutrons is 75 Mev, while among 10,000 recoil protons none were found to have an energy greater than 400 Mev. Moreover, among 15,000 stars recorded in the chamber gas, only 15 were observed to involve the production of one π^- meson; no reliable cases of pair production of π mesons (not to mention acts of triple production) were found. An estimate of the probability of observing one four-pronged star with the production, in one act, of two or three π mesons can be made on the basis of the experimental facts and investigations[2-4] of the meson production process in the interaction of nucleons. This estimate, in both cases, gives the value $\approx 10^{-7}$. The probability of a chance observation of two V^0 decays which might resemble a four-pronged star is also very small.

At the present time there is known only one type of decay which gives rise to four charged particles: This is the decay of a neutral π meson into two electron — positron pairs. In our case this extremely rare decay is practically excluded both from the magnitude of the probability of its observation, and from the kinematic relations. In particular, the divergence angle of the electrons in one of the pairs (tracks C and D) is very large (66°); moreover, the divergence angle is not in agreement with the energy of the γ quanta. It would be most natural to ascribe the event to a decay, not observed thus far, of a long-lived K^0 meson. There are two possible decays of this type allowed from the viewpoint of CP invariance:

$$K_2^0 \rightarrow \pi^+ + \pi^- + \gamma \rightarrow e^+ + e \quad (1)$$

$$K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0, \quad \pi^0 \nearrow e^+ + e^-, \quad \pi^0 \searrow \gamma \quad (2)$$

According to the theoretical estimate of Dalitz,[5] the probability of a decay of the first type is only 4% of the probability of the decay of the second type; therefore it is more probable to interpret the

*The direction of the beam of neutral particles was at an angle of 97° to the direction of the protons incident on the target.

Track	Momentum (Mev/c)	Sign of charge	Angle of flight (deg)	Dip angle (deg)	Divergence angle (deg)
A	89±5	+	43.5±1.5	13.5±0.5	3
B	31.5±2	—	43.0±1.5	11.0±0.5	
C	?	—	33±5	33±5	66
D	160±16	+	32.0±1.5	16.5±0.5	

four-pronged event observed by us as the decay of a K_2^0 meson into three π mesons with a subsequent decay of the π^0 meson through a Dalitz pair.

For the decay in accordance with scheme (1), we can determine the mass of the decaying particle; it proved to be equal to (400 ± 40) Mev. In the case of the more probable scheme (2), we found the kinetic energy of the K_2^0 particle to be 80 Mev, where it was assumed that the K^0 mass was 496 Mev.

It should be noted that among the previously reported[6-8] decays of long-lived K^0 mesons there are three V^0 events in agreement with the assumption that the unobserved neutral decaying particle is a π^0 meson. The discovery of a four-pronged decay of the K_2^0 meson is direct evidence of the correctness of this assumption, and consequently is evidence of the existence of the decay of the long-lived K^0 meson in accordance with scheme (2). A few years ago a four-pronged decay[7] was observed in cosmic radiation* similar to that observed by us. The authors interpreted it as the decay of a τ^0 meson with a lifetime of 3×10^{-10} sec. Along with this, they recorded 43 decays of short-lived K^0 mesons. It is difficult, however, to bring these facts into agreement with the subsequent theoretical and experimental data, which indicate that the decay of the short-lived K^0 meson into three π mesons is strongly forbidden. At the same time, the probability of observing a similar decay of a long-lived K^0 meson under the conditions of their experiment, was small ($\approx 10^{-3}$). In our case, we were definitely dealing with the decay of a long-lived K^0 meson, since the internal target, which was the source of the neutral particles, was at a distance of 8 m from the point of observation. Even if we make the improbable assumption that the production of the decaying particle took place in the chamber wall, then its lifetime would exceed the value of the mean lifetime of the K_1^0 meson by one order of magnitude. As regards the expected probability of observation of a decay of a K_2^0 meson in accordance with scheme (2), it is 0.1 — 0.2, in agreement with the available experimental data.

We also observed two electron — positron pairs whose direction of flight was at a large angle ($\approx 90°$) with the collimator axis, so that it could not be caused by γ quanta present in the incident beam. There are grounds for considering these electron — positron pairs as Dalitz pairs arising from the decay $K_2^0 \rightarrow 3\pi^0$, the probability of which, apparently is not too different from the probability of the decay $K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$.*

To arrive at a final conclusion, however, it is necessary to accumulate further data and study the background conditions more carefully.

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*For this case the signs of the charges of two decay products were not determined.

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*If it is assumed that the $K_{3\pi}^0$ decay results in a "symmetrical" state with an isospin I = 1 (as is the case for $K_{3\pi}^+$ decay), then, in good agreement with experiment, the selection rule $|\Delta I| = \frac{1}{2}$ leads in this case to the relation $w(K_2^0 \rightarrow 3\pi^0)/w(K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0) = 3/2$.