OBSERVATION OF $K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$ DECAYS

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Four decays of long-lived K^0 mesons with concomitant emission of four charged particles have been observed in a cloud chamber bombarded by a neutral-particle beam from the proton synchrotron of the Joint Institute of Nuclear Research. All four events are identified as decays proceeding according to Eq. (1). An estimate of the probability of the decay $K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$ relative to all K_2^0 decays involving secondary particles yields 0.08 ± 0.04.

THE presently available experimental data[1-3] on the decay $K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$ do not contain direct information on the nature of the neutral decay particle insofar as in these experiments the decay products of the π^0 meson were not recorded. Okonov et al[4] recorded one case of a four-prong decay among 600 two-prong decays; the most probable interpretation of this mode is the decay via the scheme $K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$ with the subsequent decay of the π^0 meson through a Dalitz pair. However, owing to the impossibility of measuring the momentum of one of the decay particles, the authors of that work were not able to carry out a complete kinematical analysis of the event in order to exclude decay via the scheme $K_2^0 \rightarrow \pi^+ + \pi^- + \gamma$.

In the present experiment, the four-prong events were uniquely identified as the decays

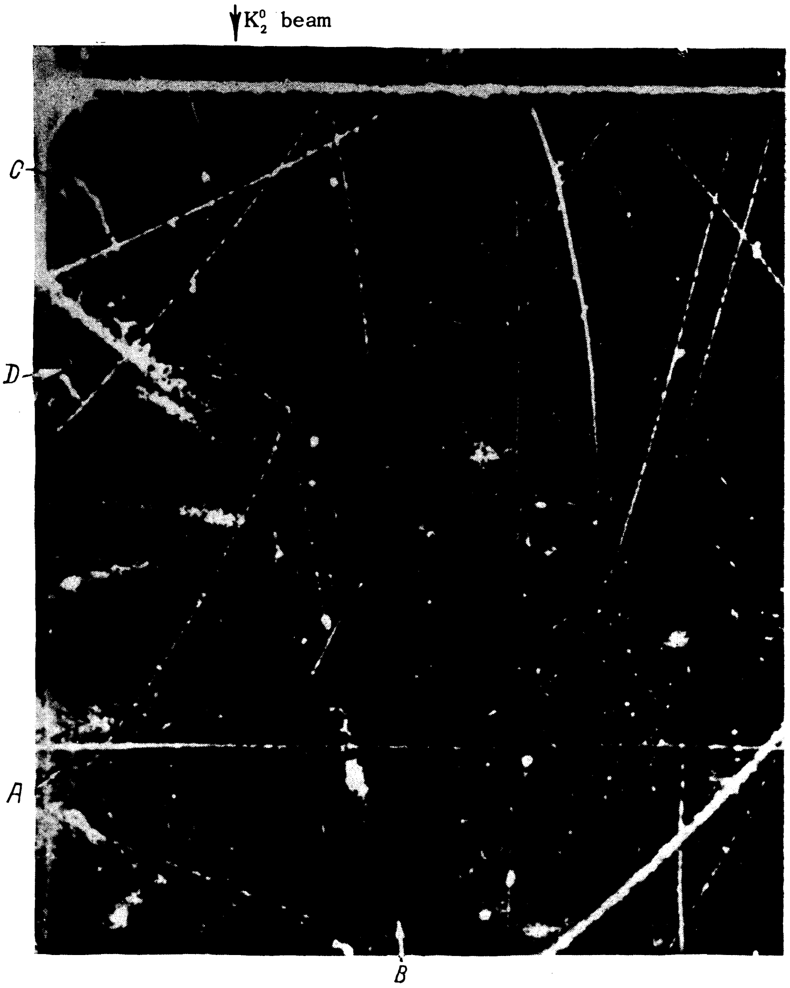
$$K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0 \begin{matrix} \nearrow \gamma \\ \searrow e^+ + e^- \end{matrix}, \quad (1)$$

which is direct evidence of the existence of this decay mode.

A cloud chamber (with an illuminated region of size $100 \times 60 \times 17$ cm) placed in a magnetic field with a mean intensity of 9000 Oe was exposed to a neutral beam at a distance of 6 m from the internal target of the Joint Institute of Nuclear Research proton synchrotron. The beam was at an angle of 90° relative to the direction of motion of the accelerated protons. The general layout of the experiment was the same as that described by Neagu et al.[5] The charged particles produced in the target were prevented from entering the chamber by the magnetic field of the accelerator and also by a special sweeping field located in the middle of the collimator. A lead convertor 10 cm thick was placed in the front part of the collimator. The magnet with the chamber was placed in a concrete shield. Owing to the good shielding and the sweeping of the beam, there was no background of charged particles entering the chamber from the target and the convertor; the background from γ radiation in the beam direction was also very small. The main background contamination consisted of recoil protons knocked out by neutrons from the front wall of the chamber and from the plates located inside the chamber.

The exposure of the chamber yielded 15,000 pictures. As a result of a triple scanning, we recorded 3900 K_2^0 decays in these pictures; we found four events in which four charged particles were emitted. A photograph of one such case (event 14.62) is shown in the figure. The results of the measurements of the momenta and angles and the estimates of the track densities of the decay products are shown in Table I. If we compare the measured track densities of the particles with the measured momenta, then it is obvious that we have to do with light particles, where particles A and B are most likely π or μ mesons and C and D were uniquely identified as a positron and an electron. None of the particles could be interpreted as K mesons or protons.

Among other processes which could resemble the analyzed events, the most likely is the production of two charged pions and one neutral pion in a single interaction with the subsequent decay of the π^0 meson through an electron-positron Dalitz pair. In our case, however, the probability of such an event is extremely small, owing to the compar-



atively low energy of the neutrons (E_{av} = 75—100 MeV) in the beam of incident particles. In fact, we recorded in the gas of the chamber a total of about 50 stars in which one π^- meson was produced, but we did not observe a single case in which a π^+ and π^- pair was produced (not to mention the production of three pions). We also did not find any stars with an electron-positron pair which could have arisen from the decay of a π^0 meson through a Dalitz pair after having been produced in a star. Hence the recorded four-prong events should be considered as decays of a neutral particle.

These events cannot be regarded as the decays of regenerated K_1^0 mesons (for example, $K_1^0 \rightarrow \pi^+ + \pi^- + e^+ + e^-$), since they were observed far from the walls of the chamber and the plates (see Table II).

If it is assumed that the decaying particles were moving in the direction of the beam, then the absence of a balance of the transverse momenta of the charged particles (see Table II) makes it necessary to assume that at least one more neutral particle was emitted in the decay. It would be most natural to assume that these cases represent the decay (1). We have calculated the mass of the decaying particle under this assumption.[1] In all three fully calculable cases one of the solutions proved to correspond, within the limits of error, to the mass of a K^0 meson. The agreement cannot be explained by chance circumstances and should be considered to be confirmation of the correctness of this interpretation. The mean value of the resultant momentum of the electron and the positron (particles C and D) was $p_{e^+e^-}$ = 92 MeV and their mean opening angle was $\gamma_m \sim 20°$, which is in good agreement with the corresponding mean quantities[2] expected in the decay (1):

$$p_{e^+e^-} = 110\text{MeV}, \quad \gamma_m = 16°.$$

In order to attempt to force agreement with the decay scheme

$$K_2^0 \rightarrow \pi^+ + \pi^- + \gamma, \tag{2}$$

it is necessary to assume that the K_2^0 meson, be-

[1]For scheme (1) the same measurement data yield two values of the particle mass.

[2]The mean energy of the K_2^0 mesons in our experiment was 180 MeV.

Table I

Event No.	Particle A: p_+, MeV/c	Particle A: θ_+, φ_+, deg	Particle A: I_+/I_e	Particle B: p_-, MeV/c	Particle B: θ_-, φ_-, deg	Particle B: I_-/I_e
06.32	109±8	82±1 145±1	1,7±0,3	68±5	123±1 44±1	3,4±0,5
14.62	144±16	15,5±1 28±1	0,89±0,15	226±23	70±2 265±2	0,7±0,1
47.78	80±9	27±1 201±2	over-estimated	120±13	160±1 79±3	over-estimated
53.85	191±18	35±1 116±2	~1	201±62	42±1 7±1	~1

Event No.	$\gamma_{\pi^+\pi^-}$, deg	Particle C: p_{e^+}, MeV/c	Particle C: θ_{e^+}, φ_{e^+}, deg	Particle D: p_{e^-}, MeV/c	Particle D: θ_{e^-}, φ_{e^-}, deg	$\gamma_{e^+e^-}$, deg
06.32	103±1	64±4	58±1 39±1	18±1	64±1 37±1	7±1
14.62	43±1	44±3	111±2 23±1	52±8	96±2 23±2	15±1
47.78	156±2	35±4	36±1 47±2	60±6	31±1 36±1	9±1
53.85	72±3	34±2	32±1 170±1	67±3	10±1 12±5	26±1

Note. p is the momentum; φ, θ, and γ are the azimuthal, emission, and opening angles; I/I_e is the ratio of ionization of the track to the ionization of an electron of energy >60 MeV.

Table II. Calculated values of the parameter of four-prong events

Event No.	$K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$: M_1, MeV	$K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$: p_1, MeV/c	$K_2^0 \rightarrow \pi^+ + \pi^- + \gamma$: M_2, MeV	$K_2^0 \rightarrow \pi^+ + \pi^- + \gamma$: p_2, MeV/c	$K_2^0 \rightarrow \pi^+ + \pi^- + \gamma$: θ, deg	$K_2^0 \rightarrow \pi^+ + \pi^- + \gamma$: p^t, MeV/c	L, cm
06.32			388±9	144±7	82±1	143±7	14
14.62	470±43 (670)	484±39 (145)	452±12	334±25	17±1.5	98±16	9
47.78	500±13 (841)	29±19 (400)	435±10	71±6	59±3	61±24	15,7
53.85	514±77 (872)	400±60 (2020)	411±22	412±53	9±1	64±9	16,2

Note. M is the mass, p is the momentum, θ is the scattering angle, p^t is the resultant transverse momentum of the secondary particles, L is the distance from the plate to the vertex of the event (along the beam). The second solution for the scheme $K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0$ is given in the parentheses.

fore decaying, underwent scattering, the probability of which for all three cases, under our conditions, did not exceed 10^{-4}. Even under this unlikely assumption, the calculated masses differ appreciably from the K_2^0 mass (see Table II).

In the case of event 06.32 we obtain a complex quantity for the mass. It is real if we assume that in this case a K_2^0, before decaying, scatters by an angle of 30—40°. Since event 06.32 (as well as event 14.62) was recorded in the run in which a 3-cm lead plate was placed inside the chamber, the probability of such scattering is not very small (~ 0.1). In order that this decay agree with scheme (2), it is necessary that the scattering angle be 82°. It turns out, however, that the point of the assumed scattering lies outside the K_2^0 beam, and the calculated value of the primary particle mass 388 ± 10 MeV differs from the K^0 mass.

Hence, the analysis of the four-prong events convinces us that they represent decays of long-lived neutral K^0 meson via the scheme

$$K_2^0 \rightarrow \pi^+ + \pi^- + \pi^0.$$

On the basis of the observed four-prong events, we estimated the probability of this decay relative to all decays with charged secondary particles. This probability proved to be 0.08 ± 0.04.

If in the estimates we also take into account the four-prong decay recorded by Okonov et al[4], then we obtain for the probability the value 0.09 ± 0.04. Both estimates are in agreement, within the limits of error, with similar data obtained by a more indirect approach (but on larger statistical material) by Luers et al[2] and Astier et al.[3] It should be mentioned that in view of the small number of four-prong events we could not determine the value of the efficiency for their registration. The estimate of the probability was therefore made under the assumption that the recording efficiency for two-prong and four-prong decays was the same. Here the possible systematic error in the result does not exceed 10%, which is much smaller than the statistical error given above.

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