Scanned with permission from the publisher:

A probable example of the production and decay of a neutral
 τ -meson / Cooper, W A, Filthuth, H, Newth, J A, Petrucci, G,
Salmeron, R A, Zichichi, Antonino
CERN-57-05

Published in Nuovo Cimento 4 (1956) pp 1433-1444

From Carmen Vasini <vasini@sif.it>
To Jens Vigen <Jens.Vigen@cern.ch>
Subject Re Request for permission to reproduce published material

Dear Jens Vigen,

we are glad to grant you permission to reproduce the material requested provided full credit is given to the source

Kindest regards

Carmen Vasini

A Probable Example of the Production and Decay of a Neutral Tau-Meson.

W A COOPER, H. FILTHUTH, J A NEWTH, G PETRUCCI,
R A SALMERON and A ZICHICHI

CERN Geneva

(ricevuto il 9 Settembre 1956)

Summary — A four pronged event observed in a magnet cloud chamber is described. It is interpreted as the decay in flight of a neutral τ meson according to the scheme $\tau^0 \rightarrow \pi^+ + \pi^- + \pi^0$ with the subsequent decay of the π^0 meson into an electron pair and a γ ray. The τ^0 meson is produced in carbon in a small nuclear interaction which may be a charge exchange reaction ($K^+ + n \rightarrow \tau^0 + p$). The lifetime of the τ^0 meson before decay is about $3 \cdot 10^{-10}$ s. Other possible interpretations of the event are discussed and shown to be improbable.

1 - Introduction

We have recently observed in a magnet cloud chamber at the Jungfraujoch an event of a type that has not previously been reported. The event consists of four tracks originating at a point in the gas of the cloud chamber. Two are the tracks of positive and negative electrons; the other two are tracks of fast particles and resemble a typical neutral V-event (See Plates 1 and 2).

After considering the possible interpretations of this event we have concluded that it is most readily explained as the decay of a neutral τ -meson with the subsequent decay of the secondary π^0 -meson into an electron pair and a γ -ray. The two decay processes can be written as

$$\tau^0 \rightarrow \pi^+ + \pi^- + \pi^0,$$

and

$$\pi^0 \rightarrow e^+ + e^- + \gamma$$

The four-pronged event is geometrically associated with a small nuclear interaction that occurs in a 2.5 cm graphite plate placed across the centre of the cloud chamber. This interaction can be interpreted most easily as a charge exchange reaction,

though it could also be an example of double production according to the scheme

in which the Σ^+ -particle decays inside the graphite plate into a proton and a π^0 -meson that escapes detection.

The existence of the τ^0 -meson has frequently been suggested ⁽¹⁾ as an explanation of some of the «anomalous» neutral V-events that have been observed ^(*). A τ^0 -decay in which only the two charged π -mesons are seen can never be definitely identified and, even for our event, there are other possible explanations that have to be considered. We present, in this paper, all the measurements that have been made on our event and the details of the reasoning that leads us to our interpretation.

2 - Measurements of the Event

A drawing of the complete event is given in the figure and all the relevant tracks are labelled. The measurements made on these tracks are recorded in Table I and in Table II the angles between the tracks are given.

The event is most easily visualized when it is realized that the three tracks *A*, *C* and *D* are very nearly coplanar and that their plane contains the nuclear interaction (*O*) in the gra-

Fig. 1 - A drawing of the complete photograph showing all the relevant tracks. The shaded area represents the 2.5 cm graphite plate placed across the centre of the cloud chamber.

⁽¹⁾ A full bibliography is given by R. W. THOMPSON in an article in *Progress in Cosmic Ray Physics*, **3** (1956).

^(*) The recent phenomenological theories that attempt to systematize our knowledge of the strange particles all predict the existence of the τ^0 meson.

W A COOPER, H FILLIUTH, J A NEWTH, G PETRUCCI,
R A SALMERON and A ZICHICHI

Plate 1 A reproduction of the photograph showing the four pronged event near to the bottom of the cloud chamber

W. A. COOPER, H. FILTHUTH, J. A. NEWTH, G. PETRUCCI,
R. A. SALMERON and A. ZICHICH

Plate 2 Enlargement showing the details of the tracks of the four pronged event

TABLE I *Measurements of the tracks in the event*

The signs in the third column are found on the assumption that all the particles travel downwards in the chamber. For the short tracks (*A*, *B*, *C*, *D*) the error in the momentum has been derived from the noise due to ion diffusion, ignoring convective distortion. For the tracks *G* and *H* we have used the pessimistic procedure of assuming a distortion curvature that varies inversely as the square of the length of the track and corresponds to a momentum of 4 GeV/c for tracks 22 cm long. The ionization densities in the fifth column are visual estimates.

If track *H* is that of a proton, the estimated ionization corresponds to a momentum between 400 MeV/c and 700 MeV/c. The corresponding range for a K meson is from 220 MeV/c to 370 MeV/c.

Track	Length (cm)	Sign of Charge	Momentum (MeV/c)	Ionization Density (I_0)	Mass of Particle (m_0)
<i>A</i>	5.8	+	38 ± 2	< 2	< 120
<i>B</i>	4.2	—	26 ± 2	< 2	< 90
<i>C</i>	4.3	?	> 250	< 2	?
<i>D</i>	4.3	?	> 250	< 2	?
<i>G</i>	18.5	+	940^{+470}_{-240}	< 2	?
<i>H</i>	12.0	+	380^{+180}_{-90}	2 to 4	780 to 2600

TABLE II *Geometry of the event*

In (a) the plane angles between various pairs of tracks are given. In (b) the angle $\Delta(CD)$ is, for example, the angle between track Δ and its projection in the plane defined by *C* and *D*. The angle $(GT)(UD)$ is the angle between the normals to the two planes.

The errors attached to the measurements have been found in two ways. First, the uncertainty in the orientation of each track was estimated from its length and position. This led to a direct estimate of the error in each angle. Second, all the measurements and calculations were made four times independently and the results compared. The errors in the table are in accord with both estimates.

(a) Angles between Tracks		(b) Coplanarity of Tracks	
Tracks	Angle (Degrees)	Tracks	Angle (Degrees)
<i>A B</i>	23.0 ± 2	<i>A (CD)</i>	2.5 ± 3
<i>C D</i>	25.5 ± 1	<i>B (CD)</i>	13.5 ± 3
<i>A T</i>	56.0 ± 2	<i>T (CD)</i>	1.5 ± 1
<i>B T</i>	37.0 ± 2	<i>T (GH)</i>	2.0 ± 2
<i>C T</i>	13.5 ± 2	<i>G (HT)</i>	2.0 ± 2
<i>D T</i>	12.0 ± 2	—	—
<i>G H</i>	38.0 ± 1	$(GT)(UD)$	45.0 ± 3
<i>G T</i>	21.0 ± 1	—	—

Distance $OX = (16.2 \pm 0.3)$ cm

phite plate. The fourth track, B , makes an angle of 13.5° with this plane but, since B is the track of a low energy electron, the vector sum of the momenta of the four particles lies very nearly in the plane of A , C and D .

Similarly, the two tracks H and G that define the interaction in the plate lie in a plane which, within the errors of measurement, contains the apex (X) of the four pronged event. Thus the line T , joining O to X , is the intersection of the planes defined by H , G and by A , C , D . The angle between these two planes is 45° .

The identification of tracks A and B as due to an electron pair is certain. The tracks C and D are very short and show no detectable curvature. Their straightness is, in itself, evidence that there is no gross convective distortion in this region of the cloud chamber. For this reason we consider that the minimum magnetic curvature that we could detect in these tracks is set by the diffusion of the ions prior to condensation⁽²⁾. The mean «noise» curvature in tracks of this length in our chamber corresponds to a momentum of 500 MeV/c. In the following discussion we assume that both the particles C and D had momenta greater than 250 MeV/c.

Track H could be due either to a positive heavy meson or to a proton and, in interpreting the reaction at O , we consider both possibilities.

3 - Interpretation of the Event

3.1 General - In the following sections we attempt, first of all, to explain the four-pronged event in terms of known particles and processes. The three different types of process that could be responsible for it are listed below.

a) A neutral particle (probably a neutron) is ejected from the interaction at O and produces, itself, a nuclear interaction in the gas of the cloud chamber at X . The tracks A , B , C , D are those of the charged secondary particles from the interaction. In this interpretation the electron pair A , B results from the decay of a π^0 meson ($\pi^0 \rightarrow e^+ + e^- + \gamma$).

b) A charged particle (C or D) travelling upwards in the cloud chamber decays at X giving rise to three charged secondaries. In this interpretation the apparent association with the interaction at O must be fortuitous.

c) An unstable neutral particle produced at O decays spontaneously at X producing the four charged secondary particles.

The possibility of the event being a casual coincidence in space between an electron pair and a neutral V-event can be ignored since a rough calculation shows that the expected number of such coincidences in our experiment is $\sim 10^{-5}$.

(2) P. M. S. BLACKETT; *Suppl. Nuovo Cimento*, **11**, 264 (1954).

3 2 A Nuclear Interaction in the Gas – There are strong arguments against interpretation *a*) The energy of the neutron producing the nuclear interaction would have to be at least 800 MeV and yet no charged evaporation particles are produced and there is no track due to a recoil nucleus Interpretation as a simple collision between a neutron and a hydrogen nucleus is excluded by the requirement of charge conservation and, in a heavier nucleus, a neutron-neutron collision at 800 MeV would almost certainly produce some slow charged particles

An additional difficulty in this interpretation arises from considering the interaction at *O* If we assume that the particle *G* causes the interaction, that *H* is a secondary proton and that *T* is the path of a neutron with an energy of more than 800 MeV (momentum 1450 MeV/c) it is necessary to postulate additional, unseen, secondary particles to balance the energy and momentum in the interaction If such particles were produced, the observed coplanarity of the line *T* with the tracks *G* and *H* is improbable

Taking these arguments together we consider that interpretation *a*) is unlikely to be correct but it is not possible to assign any numerical value to the probability of seeing a nuclear interaction of this type We have observed about 85 nuclear interactions with a visible energy greater than 800 MeV in the gas of our cloud chamber Of these, about 25 have neutral primary particles However, these «stars» are usually identified by the presence of slow, heavily-ionizing particles and we have no valuable information about interactions that lead to a small number of fast charged particles alone

3 3 Decay of a Charged Particle – Interpretation *b*) of the event as the decay in flight of a charged particle coming from the bottom of the cloud chamber can be excluded without difficulty Assuming either *C* or *D* to be the unstable primary particle and the other a product of the decay, the value of p^* , the secondary momentum in the centre of mass frame of reference, is found to be > 400 MeV/c This value is much larger than that found in the decay of any known charged particle

3 4 Decay of a Neutral Particle – There remains interpretation *c*) and we list below the decay processes of known, long lived, neutral particles that could result in a four pronged event similar to ours

$$(1) \quad \Lambda^0 \rightarrow n + \pi^0,$$

$$(2) \quad \Lambda^0 \rightarrow p + \pi^- + \gamma,$$

$$(3) \quad \theta^0 \rightarrow \pi^0 + \pi^0,$$

$$(4) \quad \theta^0 \rightarrow \pi^+ + \pi^- + \gamma$$

In process (1) the four tracks would be those of two pairs of electrons from the decay of the π^0 -meson. Apart from the improbability of this mode of π^0 -decay, process (1) can be excluded as an interpretation of the event using the measurements of dynamics given in Tables I and II. If the four tracks A, B, C, D are all due to positive and negative electrons from the decay of a single particle, calculation gives the mass of the particle as greater than $300 m_e$. This is more than the mass of the π^0 -meson.

In process (2) the electron pair A, B would result from the internal conversion of the γ -ray in the decay process. This interpretation of the event can also be completely excluded since it is easily shown that the energy of the pair A, B in the centre of mass system of the decaying particle is more than 42 MeV. This is greater than the energy released in Λ^0 decay.

Process (3) followed by the decay of both π^0 mesons into an electron pair and a γ -ray is a possible interpretation of the event. So, too, is process (4) where the γ -ray produces an electron pair by internal conversion. These two modes of θ^0 -decay are expected to arise with very different probabilities and it is valuable to estimate these probabilities.

In the decay of θ^0 -mesons the branching ratio between decay into two charged or two neutral π -mesons is of the order of unity⁽³⁾. The probability that both the π^0 mesons should decay into an electron pair and a γ -ray is $\sim (1/80)^2$ ^(4,5). Moreover, the tracks C and D are unlike those of a normal electron pair from π^0 -decay. Following the suggestion of Peyrou⁽⁶⁾ we can calculate the energy of the particles C and D in their common centre of mass system on the assumption that they are an electron pair. This quantity (Q_{ee}) turns out to be > 110 MeV. For an electron pair arising from π^0 -decay Q_{ee} cannot be greater than the mass of the π^0 meson ($135 \text{ MeV}/c^2$) and the probability of its lying in the range from 110 MeV to 135 MeV is only 1/1000. Thus the overall probability that a θ^0 -meson should decay into two π^0 -mesons both of which give electron pairs and that one electron pair should have a value of Q_{ee} as high as 110 MeV is

$$P_3 \sim \frac{1}{2} (1/80)^2 \cdot 1/1000 \sim 8 \cdot 10^{-8}$$

The corresponding probability for process (4) can be estimated from the calculations of TREIMAN⁽⁷⁾ who has considered in some detail the radiative

⁽³⁾ J. OSHER and B. J. MOYER (reported by L. W. ALVAREZ): *Proc. of the Rochester Conference*, 5, 32 (1956)

⁽⁴⁾ R. H. DALITZ: *Proc. Phys. Soc.*, A **64**, 667 (1951)

⁽⁵⁾ N. H. KROPP and W. WADA: *Phys. Rev.*, **98**, 1355 (1955)

⁽⁶⁾ C. PEYROU: *Proc. of the Rochester Conference*, 6, 36 (1956)

⁽⁷⁾ S. B. TREIMAN: *Phys. Rev.*, **95**, 1360 (1954)

decay of the θ^0 -meson as a possible explanation of some of the « anomalous » V^0 -events. TREIMAN calculates the probability that the radiated γ ray should have an energy greater than E_γ . In our event $E_\gamma = 50$ MeV and the corresponding calculated probability is $7/1000$. Further, the probability that the γ ray should undergo internal conversion in the decay process is $\sim 1/160$ (*). Therefore the probability that a θ^0 -meson should decay by process (4) into four particles giving an event like ours is

$$P_4 \sim \frac{1}{2} \cdot \frac{7}{1000} \cdot \frac{1}{160} \sim 2 \cdot 10^{-5}$$

The total number of θ^0 mesons that have decayed in our cloud chamber during the sensitive time is about 1000 (allowing for unobserved decays into two neutral π -mesons). Multiplying this number by the probabilities P_3 and P_4 it is clear that process (3) can be neglected by comparison with (4) from which the expected number of events of our type is 0.02.

3.5 Decay of a Neutral τ -Meson — If we restrict our discussion to the decays of known particles, we find that process (4) is the most plausible interpretation of our event. However, the expected number of four-pronged events due to process (4) is very small, and there is also a difficulty in this interpretation that is discussed in § 5 below.

For these reasons it is worth considering an alternative explanation in terms of a particle whose existence has been suggested but not detected. We are led very directly to the neutral τ -meson since the electron pair A, B could readily arise from π^0 decay. The process

$$(5) \quad \tau^0 \rightarrow \pi^+ + \pi^- + \pi^0 + \sim 80 \text{ MeV},$$

can, in fact, account for all the features of our event. Moreover, the probability of the π^0 meson decaying into an electron pair is $1/80$ so that, if τ^0 mesons exist and decay according to (5), one in eighty decays should give a four-pronged event.

The normal decay (5) of the τ^0 -meson would appear as a neutral V event with an apparent Q value less than 80 MeV. The number of such events observed is difficult to estimate accurately; from the surveys of THOMPSON ⁽⁸⁾ and of BALLAM *et al.* ⁽⁹⁾ it is likely that between 2% and 5% of all neutral V events *could* be τ^0 -decays. In our experiment we have seen some 1500 V^0 events; the number of τ^0 -decays is probably less than, say, 75. The expected number

(*) There is experimental evidence that the conversion coefficient has this value in π^0 decay and in π capture. The coefficient is expected to be independent of the source of the γ ray at high energies. This is discussed by KROH and WADA ⁽⁵⁾.

⁽⁸⁾ R. W. THOMPSON: *Report of the Pisa Conference, 1955* (to be published).

of four-pronged events similar to the one we have seen is thus, on this hypothesis, less than $(1/80) \cdot 75 \simeq 1$.

We should emphasize that there is no evidence that *any* anomalous V^0 events are, in fact, τ^0 decays. The above argument only shows that the expected number of four-pronged events from τ^0 decay could be as high as 1. It could also, of course, be zero.

In making these rough statistical estimates we have used as a basis our own observations. The observations in other similar experiments are probably 10 or 20 times more numerous. The expected numbers of events produced by the various processes we have discussed should therefore be increased by a factor of 10 or 20 if we assume that a four pronged event like ours would have been reported wherever it was observed.

3.6 Summary — From the foregoing discussion of the four-pronged event we conclude that the two processes that could best explain it are the radiative decay of the θ^0 -meson (4) and the decay of the τ^0 -meson (5).

In the following sections we consider these two interpretations of the event in more detail and ignore the other possibilities that have been discussed above. The dynamics of the interaction at O are shown to provide evidence against the interpretation as radiative θ^0 decay.

4 — The Momentum and Lifetime of the Unstable Particle

The two different interpretations of the event lead to very different results when the momentum of the neutral heavy meson is calculated. If radiative θ^0 -decay is assumed, the momentum of the θ^0 meson can be very accurately calculated from the well measured angles given in Table II and the energy of the electron pair A, B . The result is 1400 ± 40 MeV/c. A θ^0 meson with this momentum requires $1.9 \cdot 10^{-10}$ s to travel the distance from O to X .

The alternative interpretation of τ^0 decay does not lead to a unique momentum for the τ^0 -meson since the direction of the secondary π^0 meson cannot be deduced only from measurements of the electron pair A, B . Rather involved calculations show that the momentum of the τ^0 -meson must be between 800 MeV/c and 1400 MeV/c. The times of flight corresponding to these two momenta are $3.3 \cdot 10^{-10}$ s and $1.9 \cdot 10^{-10}$ s (*).

(*) J. BARTAM, M. GRISARU and S. B. TREIMAN: *Phys. Rev.*, **101**, 1438 (1956).

(*) If the interpretation of the event as a τ^0 decay is correct, the lifetime provides strong evidence against the theory of Salam and Polkinghorne⁽¹⁰⁾ which predicts a mean lifetime of 10^{-13} s for τ^0 decay into three π mesons. For this reason, in the following discussion of production reactions we do not consider the reactions that are allowed in the theory of Salam and Polkinghorne such as $\pi^+ + n \rightarrow \tau^0 + p$.

(10) A. SALAM and J. C. POLKINGHORNE; *Nuovo Cimento*, **2**, 685 (1955).

In Table III the complete description of the decay is given on the assumption that it is due to a τ^0 meson with a momentum of 930 MeV/c. This value, well inside the allowed range, is the best value found for production by the process of charge exchange.

TABLE III — *Interpretation as τ^0 decay*

If the four pronged event is interpreted as the decay of a neutral τ meson of given momentum it is possible to calculate the parameters of the decay in the laboratory and centre of mass systems using only the well measured quantities (the angles between tracks and the momenta of the electrons A and B). The table shows the results calculated when the momentum of the τ^0 meson is taken as 930 MeV/c. The mass of the τ^0 meson was assumed to be $965 m_e$.

The calculation is made easier by the experimental observation that the line of flight (T) is coplanar with (CD).

Quantity	Laboratory System	Centre of Mass System
Momentum of neutral τ meson	930 (assumed)	0
Momentum of particle C ($\pi^\pm$)	467	120
Momentum of particle D ($\pi^\pm$)	292	61
Momentum of neutral π meson	196	66
Angle $T C$	+ 13.5° (measured)	+ 65°
Angle $T D$	- 12.0° (measured)	- 91°
Angle $T \pi^0$	14.5°	132°

All momenta are given in MeV/c

5 — The Parent Interaction

The nuclear interaction that occurs in the graphite plate is very important for the interpretation of the decay event. It is a simple interaction and the positive particle (G) whose momentum is only ~ 1 GeV/c is apparently the primary responsible for it. The only two secondary particles for which there is evidence are the positive heavy particle H and the unstable neutral particle T . The coplanarity of the three trajectories is a striking feature of the interaction that has to be explained.

Knowing that the energy of the positive primary particle is small there are only three simple reactions in which a neutral « strange » particle can be produced without violating the rule that such particles should be produced in association (see previous footnote). These are the charge exchange reaction

$$K^+ + n \rightarrow K^0 + p,$$

and the double production reactions

$$\begin{aligned}\pi^+ + n &\rightarrow K^0 + \Sigma^+, \\ \pi^+ + n &\rightarrow \bar{K}^0 + K^+ + n\end{aligned}$$

We have attempted to fit the dynamics of these three processes to the measurements made on the particles G , H and T . The results are shown in Table IV.

TABLE IV - Possible production processes

The table shows to what extent a number of possible production processes fit the experimental measurements made on the nuclear interaction at O . In each reaction the variables have been chosen to preserve the measured angles and to give the best fit with the measured momenta of G and H . In reactions (2) and (5) the particle H is assumed to be the proton secondary from Σ^+ decay.

In all the reactions except (3) and (6) we assumed that the target neutron had a Fermi energy of 20 MeV. In reaction (5) the direction of the neutron's Fermi momentum was chosen to reduce the momentum of the particle G as far as possible. In reactions (3) and (6) the target neutron was assumed to be at rest.

The last column gives, for each reaction, the probability that the line T should be as nearly coplanar with G and H as it is found to be.

Process	Momentum of Neutral Particle (MeV/c)	Momentum of Primary (G) (MeV/c)	Momentum of Secondary (H) (MeV/c)	Probability of Coplanarity
1) $K^+ + n \rightarrow \tau^0 + p$	930	1000	400	35%
2) $\pi^+ + n \rightarrow \tau^0 + \Sigma^+$	800	1200	500	5%
3) $\pi^+ + n \rightarrow \bar{\tau}^0 + K^+ + n$	800	1850	370 (*)	5%
4) $K^+ + n \rightarrow \theta^0 + p$	1400	1650	700	55%
5) $\pi^+ + n \rightarrow \theta^0 + \Sigma^+$	1400	1600	400	10%
6) $\pi^+ + n \rightarrow \bar{\theta}^0 + K^+ + n$	1400	2100	370 (**)	5%
Measured Values $\left\{ \begin{array}{l} 1400 \text{ for } \theta^0 \\ 800 \text{ to } 1400 \text{ for } \tau^0 \end{array} \right\} \quad 940^{+470}_{-240} \text{ (**) } \quad 380^{+180}_{-90}$				
(*) These values could be chosen to agree with the measurements				
(**) This error is discussed in the text				

In the first three rows of the table the momentum of the neutral K-meson has been restricted to the range from 800 MeV/c to 1400 MeV/c and chosen to give the best fit with the other measurements. In the remaining three rows the momentum was fixed at 1400 MeV/c — corresponding to the interpretation of the event as radiative θ^0 decay.

The charge exchange reaction satisfies the dynamical conservation laws if the target neutron has a Fermi energy of about 20 MeV (a momentum of 200 MeV/c). This momentum could affect significantly the coplanarity of the three trajectories and we have calculated the probability that they should be,

by chance, as nearly coplanar as they are. The last column in Table IV shows this probability.

In the reactions leading to the production of the short lived Σ^+ -particle it has been assumed that track H is that of the proton arising from Σ^+ -decay (*). This leads to a further possible departure from coplanarity of the trajectories and the probability in the last column of Table IV is correspondingly smaller.

Concerning the three body reaction, little need be said. In this reaction the primary momentum has to be much higher than the measured value and the probability that the observed coplanarity should arise by chance is small.

The results given in Table IV provide the evidence in favour of the event being a τ^0 -decay. It is clear that the best fit with the measurements is obtained by assuming the charge exchange reaction leading to the production of a τ^0 -meson with a momentum of about 900 MeV/c. In this case the primary has a momentum of 1 000 MeV/c and the proton secondary a momentum of 400 MeV/c, in excellent agreement with the measured values.

The three reactions that lead to a θ^0 -meson with a momentum of 1 400 MeV/c all demand a primary momentum greater than 1 600 MeV/c and assuming any more complex production reaction only increases this figure. This is significantly above the measured value of 940^{+390}_{-240} MeV/c. The error in this measurement has been very pessimistically assessed; it corresponds to a maximum detectable momentum of 2.8 GeV/c for a vertical track 18.5 cm long. If we assume a maximum detectable momentum of 4 GeV/c (the measured value for tracks 22 cm long) we should quote the momentum of particle G as 940^{+390}_{-200} MeV/c. The internal consistency in the measurements of the track is good and there is no evidence of distortion on neighbouring photographs.

If we consider further the reactions leading to a θ^0 -meson we see that, apart from the high primary momentum, the charge exchange reaction demands also a high momentum for particle H . On the other hand, the double production reaction (5 in Table IV) with the lowest possible value of the primary momentum (1 600 MeV/c) demands very improbable parameters for the $\Sigma^\pm$ -decay if any fit is to be obtained.

It may be argued that since the τ^0 -mesons's momentum is not exactly defined there is inherently greater freedom for adjustment of the parameters of the reaction with this interpretation and a better fit with the measurements must necessarily be obtained. This is true but not of very great importance since the charge exchange reaction, for example, fits all the observations very well for any assumed momentum of the K^0 -meson between 700 MeV/c and 1 100 MeV/c — including half of the range allowed by the dynamics of τ^0 -decay. When the momentum of the neutral particle is raised above about 1 200 MeV/c the difficulty of fitting the observations increases rapidly.

(*) If H were the track of a Σ^+ particle, the time of flight of the particle would have to be $\sim 10^{-9}$ s which is an order of magnitude greater than the mean lifetime.

It is this difficulty that leads us to interpret the event as an example of τ^0 -decay

6 - Conclusions

The measurements made on the four pronged event allow its interpretation either as the radiative decay of a θ^0 meson or as the decay of a τ^0 meson. Either interpretation involves an element of novelty since the radiative θ^0 -decay has not been detected experimentally and the τ^0 meson is a particle whose existence has been predicted but not established.

If the event is interpreted as a θ^0 -decay the momentum of the θ^0 -meson must be 1400 MeV/c; if it is a τ^0 decay the momentum of the τ^0 -meson must be between 800 MeV/c and 1400 MeV/c.

The interaction that produces the neutral meson is of a very simple type and there is considerable difficulty in reconciling the measurements made on it with any process that leads to a K^0 meson with a momentum of 1400 MeV/c. This difficulty does not arise if the neutral meson has a lower momentum (~ 900 MeV/c).

For this reason the event is interpreted as an example of τ^0 -decay, the momentum of the τ^0 meson being about 900 MeV/c and its lifetime about $3 \cdot 10^{-10}$ s.

The production process is probably a charge exchange reaction involving a K^+ -meson and a neutron but a double production reaction is not excluded.

* * *

In our work at the Jungfraujoch Research Station we have received great help from the Administration and from the manager, Mr. HANS WIEDERKEHR.

Mr. S. O. LARSON has constructed a great deal of our apparatus and has helped to run it. Mlle. E. JOVET has assisted in making many of the measurements reported here.

We are very grateful to Dr. B. D'ESPAGNAT and to Dr. J. PRENTKI for valuable and informative discussions.

RIASSUNTO (*)

Si descrive un evento a quattro rami osservato in una camera a nebbia magnetica. Lo si interpreta come il decadimento in volo di un mesone τ neutro secondo lo schema $\tau^0 \rightarrow \pi^+ + \pi^- + \pi^0$ col successivo decadimento del π^0 in una coppia di elettroni e un γ . Il τ^0 è prodotto nel carbonio in una piccola interazione nucleare che può essere una reazione di scambio di carica ($K^+ + n \rightarrow \tau^0 + p$). La vita del τ^0 prima del decadimento è di circa $3 \cdot 10^{-10}$ s. Si discutono e si dimostra la scarsa probabilità di altre possibili interpretazioni dell'evento.

(*) Traduzione a cura della Redazione.