ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

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Just at the time when the first experiments proved the non-conservation of the spatial parity in the β-decay, Landau[1], Lee and Yang[2] suggested that in weak interactions there is no conservation of the parity (P) and the charge conjugation (C) separately, but exists only the invariance with respect to combined operations (CP). Only a few investigations have so far been made which would be devoted to a verification of this hypothesis, and the experimental indications in its favour have been mainly obtained for the decay interactions without strange particles being involved.

Therefore, a further research on the check of the CP-invariance consequences is of great importance for the theory of weak interactions.

If applied to the K^0 meson decays the CP- invariance leads to some consequences which can be most easily studied experimentally

1) The decay of the long-lived K^0-meson into two mesons is forbidden.

2) For the three-particle leptonic decays the ratio of the probabilities of negative and positive π-meson emission (in the following referred to as "charge ratio"

$$R = \frac{w[K_2^0 \to \pi^+ + e^-(\mu^-) + \nu]}{w[K_2^0 \to \pi^- + e^+(\mu^+) + \nu]}$$

is equal to unity.

3) The decay into $3\pi^0$ mesons may occur only for K_2^0 mesons, while the decay $K_2^0 \to \pi^+ + \pi^- + \pi^0$ is at least 100 times more probable than an analogous decay of the short-lived K^0-meson *

The first experimental data concerning the consequence (1) have been obtained by Bardon et al[4] who have found no decay into 2 charged π-mesons among 150 detected decays of the K_2^0 particles.

At the Rochester Conference (1957). Lederman presented the data on 54 identified K_2^0 decays: 16 – with a π^- emitted, and 38 – with a π^+meson *. However, the author of the report did not consider it possible to draw the conclusion whether or not these data are in agreement with the CP-invariance.

In this work performed by using the cloud chamber in the magnetic field with the Joint Institute for Nuclear Research synchrophasotron, the consequences (1), (2), and (3) have been studied by analysing

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* Strictly speaking, the consequences (1) and (2) are not independent since, as it was shown by Weinberg[3] , the forbideness of the $K_2^0 \to \pi^- + \pi^+$ decay restricts the magnitude of the possible "charge asymmetry".

* The mentioned number of the identified events includes 8 K_2^0 -decay identified by the Berkeley group.

649 decays of the long-lived K_2^0-mesons. The experimental arrangement is described in detail in our previous paper [6].

1. The first stage of the search for two-particle decays was the visual analysis of all recorded K_2^0-mesons. It was believed that the K_2^0 decay is not a two-body one, if both decay charged particles are emitted at one side from the direction of the K_2^0-meson motion or both tracks are directed upwards or downwards with respect to the horisontal plane(which is coinciding in our case with the photographing plane). 399 events of the three-body decay have been selected visually. For other K_2^0 decays the measurements have been made of the momenta (P) of the decay particles, of the emission angles (θ), of the azimuthal angles ϕ and of the opening angles γ. In the measurements those K^0 decays have been excluded from the consideration in which one or both tracks had the length less than 40 mm or the azimuthal angle more than 60°. For these reasons 52 K_2^0 decays were excluded from the further consideration. Then, each of the measured events was analysed by means of the following kinematic criteria of the two-body decay:

a) coplanarity of the decay particle tracks with the direction of the motion of the decaying K^0 meson

$$\phi_+ = \phi_- + 180^\circ \quad ^*;$$

b) the balance of the transverse momenta P_t of the decay particles

$$P_+ \sin\theta_+ = P_- \sin\theta_-;$$

c) the consistence of the measured momenta of the decay particles with their opening angles γ :

$$E_+ E_- + p_+ p_- \cos\gamma = \frac{m_{K^0}^2 - m_+^2 - m_-^2}{2}$$

where E_+, E_- are the total energies, and m_+, m_-, m_k are the particle masses.

As a measure for the deviation of the analysed event from the $K^0 \to \pi^- + \pi^+$ decay there was taken the ratio of the difference between the measured and calculated magnitudes of ϕ, P_t, γ to the magnitude of the root-mean-square error in the determination of this difference. The root-mean-square errors in the measurement had the following values: for the momentum – not more than 15%, for the azimuthal angle – 3 - 4°, for the opening angle – 3-4°. The direction of the incident beam of the K_2^0 mesons was set by the geometry of the experiment with an accuracy of ± 1°. Practically it was determined by using flexible wire stretched from the internal target of the synchrophasotron through the collimator and the middle of the

* The signs + and – are referred to the positive and negative decay particles.

working volume of the cloud chamber. Additionally this direction was checked by measuring the angular distribution of the electron-positron pairs, produced by the quanta of the beam in the chamber gas.

The results of the analysis are listed in Table 1. In Column 1 of this Table the distribution for all the analysed events is presented while in Column 11 – only for those to which not less than two selection criteria can be applied at a time.

Table 1.

Deviation (in terms of root-mean-square errors)	The number of events	
	1	11
0 – 1	0	0
1 – 2	2	1
2 – 3	15	7
3 – 4	37	23
4 – 5	51	38
> 5	96	83
Total	201	152

To check the reliability of the visual selection the measurements of the tracks for 60 K_2^0 decays selected earlier visually were made. It was found that the deviation for them from the two-body decay mode is more than 5 root-mean-square errors. At the same time among 597 K_2^0 decays we have analysed there was found not a single event which would follow the decay mode $K^0 \to \pi^- + \pi^+$ within one root-mean-square error.

There are two circumstances which make the determination of the real number of the long-lived K^0-meson decays into two π mesons rather difficult. First, this is K_1^0-meson regeneration in the chamber wall and the lead plate accompanied by $K_1^0 \to \pi^- + \pi^+$ decay and, second, the immitation of the two-body decays by the three-body ones. To estimate the number of the regenerated K^0 mesons in the unscattered beam of the K_2^0 we made use of the data obtained from Miller's et al experiment[7] who studied the regeneration of the K_2^0-particles with the momentum of 670 MeV/c on the iron nucleus using a bubble chamber.

According to these data, we could observe about one decay of the K_1^0 meson. Therefore, in our case the decays of the regenerated K_1^0 mesons could not contribute to the noticeable number of possible decays via the mode $K^0 \to \pi^- + \pi^+$ *.

The two-particle decays can be immitated only by those three-body decays in which the neutrinos are emitted in the forward direction and have a small energy. If one assumes that energy spectra of electrons and neutrinos are the same, then from the data of the measurements of the decay particle momentum, it is possible to estimate the expected number of the "pseudo two-particle" decays.

Among all the decay electrons there is only one electron with an energy of less than 20 MeV, and in the emission angle interval 0°-30° only one electron with an energy of 21 MeV has been found, the energy of other decaying electrons in this emission angle interval is more than 100 MeV.

According to these data we could detect within the measurement error approximately two three-particle decays which are close to the two-particle decay $K_2^0 \to \pi^- + \pi^+$ by their kinematics what does not contradict the results of the analysis made above (see Table 1).

Thus, within the statistical material obtained in this experiment both circumstances create no obsta - cles for determining the relative probability of the two-particle decay $K_2^0 \to \pi^- + \pi^+$.

2. To determine the "charge ratio" $R = \frac{w(K_2^0 \to \pi^- \ldots)}{w(K_2^0 \to \pi^+ \ldots)}$ the data on the identification of the K-decays we have obtained in studying the passage of the decay particles through the lead plate and in ionization measuring of the decay products with the momentum of less than 120 MeV/c. Using another method the decay particles with the minimum ionization were sele cted. Such a particle was identified as an electron if its measured momentum did not exceed 100 MeV/c or, the decay particle was considered not to be a π meson, if its momentum was lying between 100 MeV/c and 120 MeV/c.

As a result of this analysis the charge ratio has been determined. It turned out to be

$$R = \frac{K_2^0 \to \pi^- \ldots}{K_2^0 \to \pi^+ \ldots} = \frac{46}{51} = 0.90 \pm 0.18$$

As is seen, the found ratio is not different from unity within the error ***.

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* It should be also taken into account that the mean free path of the regenerated K_1^0 meson is ~2.5 cm, while the recording efficiency of an event near the front wall of the chamber and the lead plate is less than in other regions of the chamber due to the background conditions.

** This method has been described in more detail in our previous paper /6/.

*** This result published in a previous report is being made now more accurate.

Thus, both results we have obtained: the absence of the $K_2^0 \to \pi^- + \pi^+$ decays and the magnitude of the "charge ratio" / $R \sim 1$ /, point out to the CP-invariance in the decay interaction of K^0-mesons.

The earlier obtained /6/,/10/ experimental data pertaining to the decays of a long-lived K_2^0 meson into 3π mesons are also in qualitative agreement with the CP-invariance hypothesis. Indeed, the recorded decay $K_2^0 \to \pi^+ \pi^- \pi^0$ accompanied by the decay of a π^0 meson via the Dalitz pair indicates that this decay constitutes an appreciable part of all K_2^0 mesons. On the other hand, as the analysis, made in /6/, has shown 4 Dalitz pairs found should be treated as a direct experimental indication to the existence of the decay $K_2^0 \to 3\pi^0$.

At the same time , for the K_1^0 meson there has been so far recorded no reliable event of the decay $K_1^0 \to \pi^- + \pi^+ + \pi^0$. As far as the forbideness of the decay $K_1^0 \to 3\pi^0$ is concerned, its experimental verification is much more difficult. However, according to the isotopic invariance and the selection rule $(\Delta I) = 1/2$ one can state that this decay is at least forbidden as well as $K_2^0 \to \pi^- + \pi^+ + \pi^0$. These experimental data indicated in favour of the CP-invariance.

Note, that among 59% analyzed K_2^0 decays we found no event of the two-lepton decay via the modes

1) $K_2^0 \to e^- + e^+$

2) $K_2^0 \to \mu^- + \mu^+$

3) $K_2^0 \to \mu^\pm + e^\mp$ *

The experimental fact we have obtained points to the absence of the neutral lepton "current" in the decay interaction of the K_2^0 mesons. This circumstance makes more difficult the introduction of the neutral intermediate bosons to the theory of weak interactions /11/.

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* It should be emphasizes that the decays (1) – (2) are permitted from the point of view of CP-invariance (in contrast to the analogous decays of the K_1^0-meson).

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