nied by an increase in T_c. This fact supports the correlation, mentioned in reference 3, between the temperatures at which the superconducting transition occurs and the position in the Mendeleev table of the metal forming the compound with the bismuth.

It is probable that the other group of compounds BiK_3, $BiRb_3$, and $BiCs_3$ are also isomorphs and have a structure of the Na_3As type.[4] A series of compounds of arsenic, antimony, and bismuth with the alkali metals crystallizes in this type of structure: Li_3As, Na_3As, K_3As, α-Li_3Sb, Na_3Sb, K_3Sb, Na_3Bi, and K_3Bi.

According to one author,[6] the compound $BiCs_3$, obtained by the method of successive precipitation of layers of bismuth and cesium by vacuum sublimation, can serve as a photo-cathode like the compound $SbCs_3$, but among the group of compounds $SbCs_3$, $SbRb_3$, SbK_3, and $BiCs_3$ it is the one least sensitive to light.

CONCLUSIONS

1. A tentative melting diagram has been constructed for the bismuth — cesium system.
2. Three compounds crystallize in the bismuth — cesium system: Bi_2Cs, $BiCs_2$, and a compound which presumably consists of $BiCs_2$. The compounds Bi_2Cs and $BiCs_3$ correspond to maxima on the melting diagram; the third compound is formed in a peritectic reaction.
3. The superconducting compound Bi_2Cs crystallizes in a cubic lattice with $a = 9.726 \pm 0.005$ kX and has a structure of the Cu_2Mg type.
4. Crystallochemical analysis shows that for the isomorphic group Bi_2K, Bi_2Rb, and Bi_2Cs, an increase in the period of the unit cell is accompanied by an increase in T_c.

We take this opportunity to express our deep gratitude to Professor G. S. Zhdanov and to Professor N. E. Alekseevskii for valuable discussions and for guidance during the performance of the present research, and to V. A. Smirnov for assistance in conducting the experiments.

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SOVIET PHYSICS JETP VOLUME 34(7), NUMBER 4 OCTOBER, 1958

ANGULAR CORRELATIONS OF $\pi^+ - \mu^+ - e^+$ *-DECAYS IN A PROPANE BUBBLE CHAMBER*

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The result of projective treatment of 6760 $\pi^+ - \mu^+ - e^+$ -decay events photographed in a two liter propane bubble chamber is discussed. Assuming the angular distribution of decay positrons to be described by the formula $1 + a \cos\theta$, it is found that $a_{prop} = -0.19 \pm 0.03$. This result confirms the hypothesis of Lee and Yang of nonconservation of parity in weak interactions.

1. INTRODUCTION

THE hypothesis of Lee and Yang[1,2] of non-conservation of parity and charge conjugation in weak interactions has been confirmed by a series of experiments on β-decay and angular correlations in $\pi^+ - \mu^+ - e^+$ -decay. If parity is not conserved in the consecutive stages of the $\pi^+ - \mu^+ - e^+$ -decay, the angular distribution of the positrons will be given by the formula

$$dN = (1 + a\cos\theta)\,d\Omega/4\pi, \qquad (1)$$

where θ is the angle between the original direction of motion of the μ^+-meson and the positron.

The value of the factor of asymmetry a depends on the relation between the various types of interactions in the μ^+-decay. The experimental energy spectrum of decay positrons is in best agreement with the vector and pseudovector variants of the theory. The asymmetry factor can assume (over the whole spectrum) values from $-1/3$ to $+1/3$ depending on the type of interaction. An accurate determination of the factor a for the whole spectrum of decay positrons and measurements of the energy dependence of the asymmetry factor may provide information about other types of interaction present.

The use of a propane bubble chamber in such an investigation is especially advantageous since it combines the desirable characteristics of photographic emulsion (good angular definition, constant sensitivity for electrons of various energies) with higher statistical accuracy due to the lesser degree of μ^+-meson depolarization in propane and the possibility of fast reduction of a large number of $\pi^+ - \mu^+ - e^+$ decay events.

The present work is devoted to the study of angular distribution of positrons in $\pi^+ - \mu^+ - e^+$ decay and determination of the factor a in propane over the whole energy spectrum of positrons.

2. EXPERIMENTAL ARRANGEMENT AND METHOD OF DATA REDUCTION

A two liter propane bubble chamber[3] was used in conjunction with the π^+-beam of the United Institute of Nuclear Studies synchrocyclotron.

Positive pions were produced in a polyethylene target bombarded by 650 Mev protons. π^+-mesons of ~ 170 Mev were selected by means of a deflecting magnet, focussing devices, and a collimator. A Cu — Al absorber, with thickness so chosen that a maximum number of $\pi^+ - \mu^+ - e^+$-decays was observed in the chamber, was used for slowing the π^+-mesons. The chamber was shielded from the magnetic field of the synchrocyclotron by a laminated screen of soft sheet iron of Armco type and Permalloy. The complicated shape of the chamber made it difficult to shield it properly and in the first series of pictures the stray field amounted to 1.8 gausses. Addition of a second shield in the second series of pictures reduced the stray field to 0.35 gausses.

Tracks in the bubble chamber were photographed with a stereoscopic camera having an average reduction of 4.5 and distance between lenses equal to 70 mm. High-speed 35 mm motion picture film was used. Pictures of the $\pi^+ - \mu^+ - e^+$-decays were projected and the angle between the projections of the μ^+-meson and positron tracks on the film plane measured. The mean error of angle measurement was $\leq 5°$.

There are two ways of comparison of the measured angular distribution with Eq. (1) and of determination of the asymmetry factor a. The first method can be used for the case of $\pi^+ - \mu^+ - e^+$-decays when the μ^+-meson track is at a small angle to the film plane. Assuming then that the track lies in that plane, one can easily pass from the distribution of angle projections on a plane to the distribution in space.[4] This method was used by us as an independent check of the form of the angular distribution (Fig. 1).

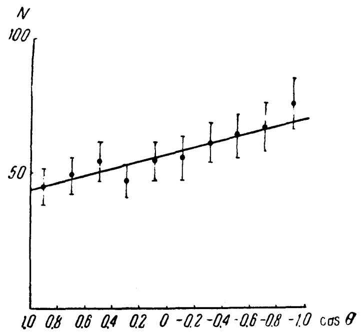

FIG. 1. Angular distribution of $\pi^+ - \mu^+ - e^+$-decay positrons calculated for space angles θ. Events with track projections of the μ^+-meson > 3 mm and perpendicular to the axis of π^+-meson beam were selected. n = 607, a = 0.20 ± 0.075.

The second method is based on an expression for the distribution of angle projections equivalent to Eq. (1). It can be shown that the expression is of the form

$$dN = (1/\pi)\,[1 + (a\pi/8)\,f(\alpha)\cos\varphi]\,d\varphi, \qquad (2)$$

where φ is the angle between the projections of the μ^+-meson and positron tracks, and α is the maximum angle between the μ^+-meson track and the plane of projection. The function $f(\alpha)$ is defined by the following relation:

$$f(\alpha) = \frac{\alpha}{\sin\alpha} + \frac{\sin 2\alpha}{2\sin\alpha}. \qquad (3)$$

It has been assumed in the derivation of Eq. (2) that the μ^+-mesons produced in π^+-decay are isotropic. The function $f(\alpha)$ varies from 2 to 1.57 for α varying from 0 to $\pi/2$. The values $\alpha = 0$ and $\alpha = \pi/2$ correspond to the two limiting cases: for $\alpha = 0$ the tracks of μ^+-mesons lying in the plane of projection are selected, while for $\alpha = \pi/2$ all decay events are taken into account.

It follows from Eq. (2) that the use of the projective method of treatment reduces the asymmetry. In fact, if a track is inclined at a large angle to the plane of projection, then positrons propagating both in the forward and backward directions with respect to the direction of motion of the μ^+-meson will fall into the angle interval $\Delta\varphi$ in the plane of projection and the distribution of the projections of positron tracks with respect to the projections of μ^+-mesons tracks will be almost isotropic.

Events with length of the projected μ^+-meson track < 1 mm were disregarded in view of the low accuracy of angle measurements. This corresponds to the angle $\alpha = 73°$. Such a selection causes the loss of 4.5% of the decay events.

The asymmetry factor a was determined from the "backward-forward" ratio, i.e., the ratio of the number of positrons with track projection between $\pi/2$ to π to the number of positrons with track projection in the interval 0 to $\pi/2$, according to the formula

$$a = 4(1-R)/f(\alpha)(1+R), \quad (4)$$

where R is the backward-forward ratio. For α = 73°, $4/f(\alpha) = 2.465$ and we have, therefore,

$$a = 2.465(1-R)/(1+R). \quad (4a)$$

It should be noted that the standard deviation of the asymmetry factor a is, in the method used, larger by 23% than that of spatial angle measurement. However, the ease and simplicity of the above method compensate fully for that disadvantage.

3. ANALYSIS OF RESULTS

Angular distribution of positrons for the first and second series of pictures is shown in Fig. 2a

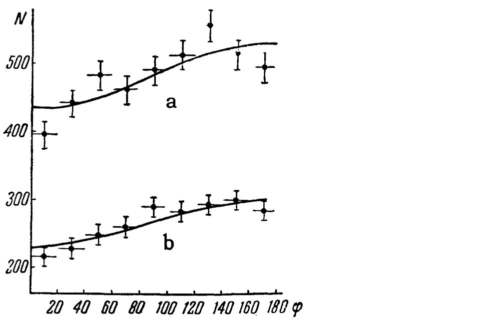

FIG. 2. Angular distribution of $\pi^+-\mu^+-e^+$-decay positrons in the plane of projection. a – first series of measurements, n = 4353, a = −0.175 ± 0.04. b – second series, n = 2408, a = −0.214 ± 0.05.

and b for 4353 and 2408 cases, respectively. The asymmetry factor was determined according to Eq. (4).

For the first series it was found that a = − 0.163 + 0.037. The stray magnetic field of 1.8 gausses caused a slight depolarization of μ^+-mesons due to precession of their magnetic moment. Calculations showed that for an isotropic distribution of μ^+-mesons the decrease in the value of a amounted to 7. After introducing a correction it was found that a = − 0.175 + 0.04. In the second series it was found that a = − 0.214 + 0.03. The average of the two series is a = − 0.19 + 0.03.

Experimental errors in reading the film are basically due to conical projection in photography and to the loss of a small fraction of $\pi^+-\mu^+-e^+$-decays, either because of the absence of the positron track or poor identification due to the general background. Equation (2) was obtained under the assumption that the projection is perpendicular. In the fact, conical projection takes place in photography. It can be shown, however, that if the inspected region of the chamber forms a cone with axis coinciding with the optical axis of the camera, and if the angle between track projections equals φ in the perpendicular projection, then, in conical projection, the number of cases when the angle is found to be $\varphi + \Delta\varphi$ will be equal to the number of cases with $\varphi - \Delta\varphi$.

Conical projection is therefore equivalent to perpendicular projection with certain symmetrical error of angle measurements and does not change the angular distribution. The error $\Delta\varphi$ can be minimized by selecting cases with small photographic angle. For the events analyzed, this angle was $\leq 5°$. Absence of distortion of the angular distribution due to conical projection or imperfections of the optical system is illustrated by the histograms of the angular distribution of μ^+-mesons about the axis of the π^+-meson beam (Fig. 3a) and the direction of π^+-meson tracks (Fig. 3b).

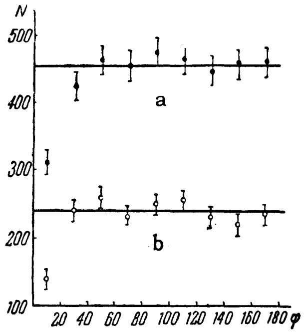

FIG. 3. Angular distribution of μ^+-mesons in the plane of projection: a – about the π^+ beam axis, n = 3953, R = −1.01 ± 0.032; b – about the direction of π^+-meson tracks, n = 2078, R = 1.01 ± 0.045.

Both distributions are in a good agreement with the assumption of isotropic distribution of μ^+-

mesons in $\pi^+ - \mu^+$ -decay. Deficiency of particles in the interval $0° - 20°$ can be easily explained by the difficulty in separating evnnts with small angles of emission of μ^+ -mesons from decays of μ^+ -mesons contained in the beam.

Our results show that $\sim 3.9\%$ of $\pi^+ - \mu^+$ -decays are not accompanied by a visible positron track and, besides, tracks of positrons in $\sim 1\%$ of the events are unsuitable for angle measurements due to the small length of the projected track.

A simple calculation leads to the conclusion that the number of μ^+ -mesons from $\pi^+ - \mu^+$ -decays stopping in the glass and the walls of the chamber amounts to 2.4%. It can be shown that these do not introduce any change in the shape of the distribution and the value of the asymmetry factor, assuming the validity of Eq. (1).

Distortion of the angular distribution of positrons due to omission of some decay events can occur only when the probability that an event is omitted depends on the angle between the tracks of the positron and the μ^+ -meson. We identified all events by the characteristic kinks in the tracks of $\pi^+ - \mu^+ - e^+$ - or $\mu^+ - e^+$ decays. The most probable omissions in fast scanning in the presence of a considerable chamber background occur for events in which the tracks of the two mesons and the positron differ little in direction. In other words, positrons moving forwards or backwards at small angles to the direction of the μ^+ -meson are most likely to be overlooked. Considerations given below make it possible to avoid this.

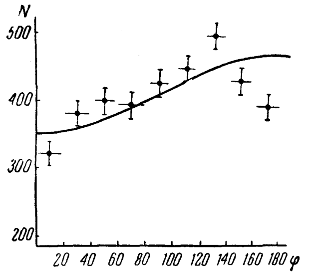

FIG. 4. Angular distribution of $\pi^+ - \mu^+ - e^+$-decay positrons in the plane of projection obtained in the first series of measurements (preliminary result)

The histogram in Fig. 4 was obtained as the result of the first scanning, and that in Fig. 2a — of the second. Variation in the number of positrons in the extreme angle intervals and better agreement between the theory and the experimental result in the second histogram are clearly visible.

The above mentioned errors can be avoided if we choose a different characteristic of the decay for its identification, namely, (as it is the practice in emulsion work) the presence of a kink corresponding to the $\pi^+ - \mu^+$ -decay of a stopped π^+ -meson, and do not look for the presence of a positron. In that case, possible omissions of some events will not change the form of the angular distribution of positrons about the direction of μ^+ -mesons.

The analysis shows that a marked distortion of the shape of the angular distribution can occur in our experiment by omission of the $\pi^+ - \mu^+ - e^+$ -decay events in scanning the film.

4. DISCUSSION OF RESULTS

The value for the asymmetry factor a found in our experiment, $a = -0.19 + 0.03$, is in good agreement with the results of the Liverpool group ($a = -0.17 + 0.03$),[5] the group of the Physical Institute of the Academy of Sciences, U.S.S.R. ($a = -0.21 + 0.035$)* and of the work of Pless et al. ($a = -0.18 + 0.05$).[6] The mean weighted value of all the experiments is $a = -0.187 + 0.017$. This value is determined not only by the relation between theoretical variants but also by the depolarization of μ^+ -mesons in propane. The asymmetry factor for the elementary process a_e is obtained accounting for the depolarization factor. This can be done using the data of the Chicago group[7,8] which obtained for the asymmetry factor in C (and in metals) the value $a_C = -0.244 + 0.01$ and for $a_{prop} = -0.175 + 0.015$.

It has been shown[7,8] that the time of depolarization is much shorter than the half-life of the μ^+ -meson. The ratio a_{prop}/a_C determines the degree of depolarization of μ^+ -mesons in propane. It is clear that the above ratio is independent of positron energy and the degree of polarization of the μ^+ -meson beam. The asymmetry factor for the elementary process, obtained from the mean experimental value of a given above equals $-0.256 + 0.033$.

Under the assumption that μ^+ -mesons originating in the decay of stopped π^+ are totally polarized and decay according to the scheme $\mu^+ \to e^+ + \nu + \bar{\nu}$, the ratio ξ between the interaction variants[1,2] equals $-3a_e$. In the case of a partial polarization of the μ^+ -meson the value $-3a_e$ represents the lower limit of ξ. The value $\xi \geq 0.77 \pm 0.10$, calculated from the mean value of the asymmetry coefficient, is in a very good agreement with the results of emulsion work, $\xi \geq 0.8 \pm 0.15$.[9]

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TEMPERATURE ANOMALY IN THE RESISTANCE AND THE HALL EFFECT IN GOLD

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The dependence of the Hall effect on temperature and magnetic field was studied in samples of gold with normal and abnormal temperature dependence of the resistance. A jump was observed in the Hall constant of an "anomalous" sample at a field of 8 kOe. The magnitude of the jump increased with decreasing temperature. A field strength of 8 kOe is the value at which the anomalous temperature dependence of the resistance vanishes.

1. INTRODUCTION

As is well known (see the references to the literature in Ref. 1) the Ohm's-law resistance in a series of metals (Au, Cu, Ag, Mg and, apparently, Mo)[2] shows an anomalous temperature dependence, consisting in the fact that as the temperature is lowered, the resistance of these metals falls, reaches a minimum at some temperature denoted by T_{min}, and then begins to rise. It was noticed in a series of articles[2–5] that the dependence of this rise on temperature could be satisfactorily represented in the form

$$\frac{\Delta r}{r_{\min}} = \frac{r(T) - r_{\min}}{r_{\min}} = \text{const} + a \log(1/T) \quad \text{for } T < T_{\min},$$

where r_{min} is the resistance at T_{min}. In the work of Ref. 5 carried out by us on gold samples, it was shown that $\Delta r/r_{min}$ decreased in a magnetic field and reached zero for some value H_k. In the same work it was noticed that, for a value of the field equal to H_k, a discontinuous change in the slope of the Hall electric field $E_y(H)$ was observed.

It was of interest to carry out a more detailed investigation of the Hall effect in dependence on temperature and magnetic field using gold samples with both normal and anomalous-type resistances, which allowed us to clarify the connection between anomalous resistance and the Hall effect.

2. METHOD OF MEASUREMENT

To prepare samples we had at our disposal two batches of gold naturally occurring: a foil of 0.05 mm and a plate 1 mm thick. Both batches were 99.99% pure. A spectral analysis of the gold is given in Table I.

The sample Au-1, together with current and potential leads was cut out of the foil, as shown in