ON THE QUESTION OF A RESONANT ππ INTERACTION

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THE question of a resonant $\pi\pi$ interaction has been the subject of much discussion[1-9] in the recent past. So far, however, there is no convincing experimental proof that such an interaction exists. It is therefore of value to discuss experiments in which this interaction may manifest itself. In the present note the angular correlation of π mesons is analyzed for the case of stopped antinucleons annihilating according to the scheme

$$\bar{p} + p \text{ (or } \bar{n} + n) \to \pi^+ + \pi^- + \pi^0. \tag{1}$$

Let us make the assumption which was made by other authors[5-9] and which is in agreement with Belenkiĭ's[10] ideas regarding the inclusion of a resonant interaction between particles, that the reaction (1) may proceed through two channels:

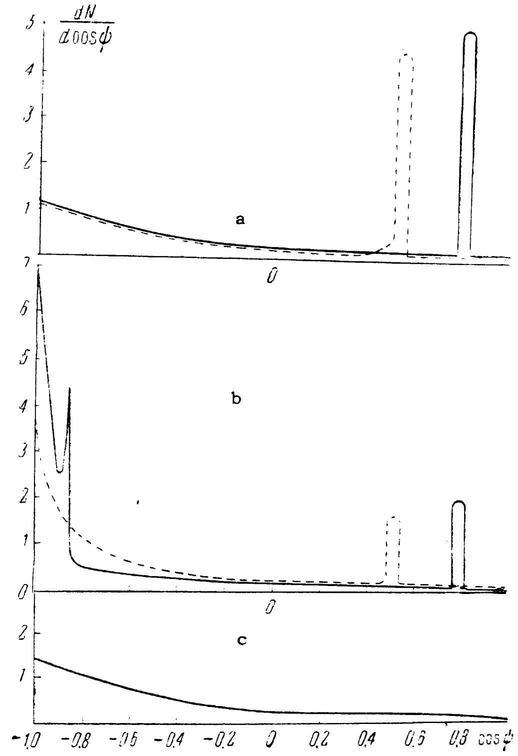
$$\bar{N} + N \to 3\pi, \tag{2}$$

$$\bar{N} + N \to \sigma + \pi \to 3\pi, \tag{3}$$

where the symbol σ denotes a π-mesic "isobar" — a "particle" of mass $m_\sigma = (3-4)\mu$ (where μ is the mass of the pion), spin J and isospin I, which decays into two pions with a lifetime of the order of, or somewhat larger than, nuclear times. By making use of isotopic invariance we obtain the probabilities for the final states in reaction (3) for various possible values of I (see table; the decay products of the isobar are put in parentheses).

Final state	$I=0$	$I=1$	$I=2$
$(\pi^+\pi^-)\pi^0$	$^5/_6$	$^1/_6$	$^2/_{15}$
$(\pi^-\pi^0)\pi^+$	—	$^5/_{12}$	$^3/_{10}$
$(\pi^+\pi^0)\pi^-$	—	$^5/_{12}$	$^3/_{10}$
$(\pi^0\pi^0)\pi^0$	$^1/_6$	—	$^4/_{15}$

Assuming that the σ decays isotropically in its proper coordinate system, we find the distribution of the number N of pairs of pions as a function of the angle ψ between them in the laboratory system. It turns out that the pions from the decay of the σ form narrow pairs whereas the pion produced directly together with one of the "decay" pions form a wide pair.



As can be seen from the table, the relative fraction of pairs of the first and second type in the case of charged pions in reaction (1) will be significantly different depending on the value of I. The figure shows the dependence of $dN/d\cos\psi$ on $\cos\psi$ for I = 0, J = 0 (a) and I = 1, J = 1 (b) for two values of m_σ: $m_\sigma = 3\mu$ (solid curve) and $m_\sigma = 4\mu$ (dotted curve). In constructing these curves statistical theory* was used to determine the relation between processes (2) and (3). The curves for I = 2 are not shown since in this case the situation qualitatively differs little from the case I = 1 as can be seen from the table. The analogous graph for the process (2) alone (absence of a resonant interaction) is shown in Fig. (c). The curves differ significantly from each other and therefore a comparison with appropriate experimental data may yield some information on the resonant $\pi\pi$ interaction. The curves in the Figs. (a) and (b) are calculated for the minimum possible values of J; for larger values of J the relative contribution of process (3) will increase and the difference between the curves will be even more pronounced.

In conclusion I express my gratitude to I. L. Rozental' and M. I. Podgoretskiĭ for a discussion of these problems, and also to Z. S. Maksimova for numerical calculations.

*The peaks for small angles have almost a "δ-function" character and are therefore shown in a somewhat distorted form in order to make it easier to see the relation between the areas under various portions of the curves.

[1] F. J. Dyson, Phys. Rev. **99**, 1037 (1955).
[2] G. Takeda, Phys. Rev. **100**, 440 (1955).
[3] H. Miyazawa, Phys. Rev. **97**, 1399 (1955).
[4] W. Frazer and J. Fulco, Phys. Rev. Lett. **2**, 365 (1959).
[5] E. Eberle, Nuovo cimento **8**, 610 (1958).
[6] T. Gotô, Nuovo cimento **8**, 625 (1958).
[7] V. I. Rus'kin, JETP **36**, 164 (1959), Soviet Phys. JETP **9**, 113 (1959); JETP **37**, 105 (1959), Soviet Phys. JETP **10**, 74 (1960)
[8] F. Cerulus, Preprint (1959).
[9] V. S. Barashenkov and V. M. Mal'tsev, JETP **37**, 884 (1959), Soviet Phys. JETP **10**, 630 (1960).
[10] S. Z. Belen'kiĭ, JETP **32**, 1171 (1957), Soviet Phys. JETP **5**, 952 (1957).

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DESTRUCTION OF SUPERCONDUCTIVITY BY A CURRENT

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IT was shown by Shubnikov and Alekseevskiĭ[1] as early as 1936 that when the superconductivity of a cylindrical specimen is destroyed by a current, there is a sharp jump in resistance to a value which is less than that in the normal state, and then the resistivity gradually returns to its normal value. This phenomenon was examined theoretically by London[2] and by Landau.[3] It was shown that the resistance jump must be $0.5\,R_n$ (R_n being the resistance in the normal state).

In the first experiments[1,4] the jump was greater than the theoretical value and reached $0.7 - 0.8\,R_n$, and Scott[5] suggested a dependence of R_c/R_n (R_c is the resistance of the specimen for the critical current) on the specimen diameter, due to the surface energy. It therefore seemed interesting to carry out measurements on specimens of different diameters. In addition, by using specimens of different purity, it would be possible to test Kuper's[6] view on the connection between the magnitude of the resistance jump and the ratio of specimen diameter to the mean free path.

Specimen No.	Diameter, cm	Length, cm	$10^3\rho_n$, $\Omega\cdot$cm at 3.8° K	$\frac{10^4 R_{3.8°}}{R_{300°}}$
1	0.050	6.3	1,37	0.80
2	0.032	3.7	1.70	0.96
3	0.0181	0,81	1.97	1.28
4	0.0083	0.50	2.30	1.51
5	0.0041	0.90	2.65	2.0
6	0.034	1.65	18	15
7	0.0181	0.82	20	17
8	0.0083	0.43	20	17
9	0.0041	0.78	20	17

We made two series of specimens from two tin samples of different purity. The specimens were prepared from wires obtained by extruding the metal through fine holes. The specimen characteristics are shown in the table. They were mounted on a frame and placed horizontally in a Dewar vessel to avoid a temperature gradient along the specimen. The earth's magnetic field was compensated to an accuracy of 3%. From the measurements, curves were obtained of the dependence of R_c/R_n on the temperature of the helium bath for various specimens (Fig. 1). In the value of R_n

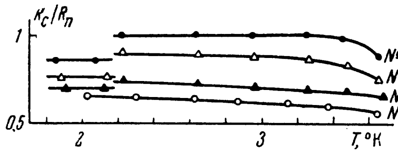

FIG. 1

account was taken of the effect of the magnetic field of the current. When the values of R_c/R_n at temperatures above and below the λ-point are compared, it can be seen that the heating of the specimen above the temperature of the helium bath has a considerable effect. The dependence of R_c/R_n on the heat flow from the specimen per unit area, q, is shown in Fig. 2. (The points on the curves for each temperature correspond to the specimens 1, 2, 3, 4, 5, 6, 7, 8 and 9 of the table.) The shapes of the curves suggest that R_c/R_n depends primarily on q. It is probable that the dependence, found by Scott, on the diameter of the specimen is mainly determined by the dependence of q on d, since $q \sim H_c^2\rho_n/d$ (ρ_n is the specific resistivity of the specimen).

If the variation of R_c/R_n with q is extrapolated to $q = 0$, the limiting value depends on temperature (increasing with falling temperature) and is about 0.5 only near T_c. It is not impossible that the reason for this is the surface forces between the superconducting and normal phases, which increase with decreasing temperature.