ENERGY DEPENDENCE OF THE SPATIAL ASYMMETRY OF POSITRONS IN $\pi^+ \to \mu^+ \to e^+$ *DECAY*

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WE have obtained previously[1] a value of 0.077 ± 0.012 for the asymmetry coefficient a, averaged over the entire spectrum, in the formula $dN = (1 + a \cos \vartheta)\, d\Omega$ for the angular distribution of positrons from the $\pi \to \mu \to e$ decay (ϑ is the angle between the directions of emission of the μ meson and the electron, $d\Omega$ is the element of solid angle). This value, found for a NIKFI-R emulsion, increases to 0.28 ± 0.02 when the emulsion is placed in a 17,000-gauss magnetic field. Such an increase makes it possible to obtain exact data on the energy dependence of the asymmetry coefficient, since even if the number of particles in the spectrum is the same, the statistical reliability of the measurement increases by almost four times over measurements made without the field. For the purpose of improving our measurements of the energy dependence of the coefficient of asymmetry and of obtaining a differential spectrum of this dependence, we have placed stacks of NIKFI-R photo emulsions, consisting of pellicles measuring $10 \times 10 \times 0.04$ cm, in a 17,000-gauss vertical magnetic field parallel to the plane of the emulsion, and exposed these emulsions in the synchrocyclotron of the Joint Institute for Nuclear Research to a beam of positive pions sufficiently slowed down by filters to make them stop in the emulsion.

The positron energies were measured by the method of multiple scattering using the Koritska MS-2 and MBI-9 microscopes. Some of the measurements were performed with a machine for semi-automatic measurement of the scattering. A total of 565 tracks was measured, selected in accordance with the following criteria: 1) the entire sequence of $\pi^+ \to \mu^+ \to e^+$ decays lies in one emulsion layer, 2) the vertex of the $\mu^+ \to e^+$ decay is not farther than $100\,\mu$ from the surface of the emulsion, 3) the lengths of the positron tracks are not less than $1\,\mu$, and 4) the projections of the μ-meson and positron tracks on the plane of the emulsion are inclined to the direction of the magnetic field at angles between 0 and $\pm 45°$ (first quadrant of the ocular scale) and $180 \pm 45°$ (opposite third quadrant of the scale).

It is easy to show that under these conditions the asymmetry coefficient is

$$a(\varepsilon) = 1.27 \frac{N_f - N_b}{N_f + N_b} \pm \frac{(1.27^2 - a^2(\varepsilon))}{\sqrt{N_f + N_b}} \tag{1}$$

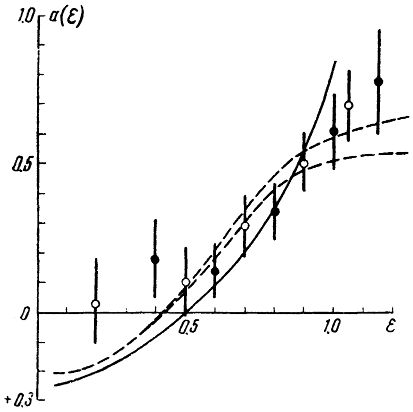
Here N_f is the number of decays "forward," at which the mu meson and positron are emitted in the same direction (i.e., the projections of the angle of emission on the emulsion plane, measured from the direction of the magnetic field, lie in the same quadrant of the scale), and N_b (number of "backward" decays) pertains to the opposite direction (angles of emissions of the μ meson and electron are in opposite quadrants of the scale). The positron energy was determined from the second differences at a signal-to-noise ratio equal to 4 or 5. Analysis of the data by third differences has shown that the effect of distortion on the measurements of the energy can be neglected. The relative statistical error was determined from the formula $\sigma = 0.8/\sqrt{n}$, where n is the number of cells. The distribution of tracks over σ was as follows:

σ, % =	8—15	15—20	20—25	25
N, % =	41	41	14	4

The results of the measurements are listed in the table, where the energy intervals and the corresponding values of N_f and N_b are given. The

Energy Interval	0—0.3	0.3—0.4	0.4—0.5	0.5—0.6	0.6—0.7	0.7—0.8	0.8—0.9	0.9—1.0	1.0—1.1	1.1
N_f	19	26	16	42	32	33	25	10	8	6
N_b	23	24	32	36	56	48	53	28	23	25

energy dependence of the asymmetry coefficient is shown in the diagram, where the abscissas represent the positron energy ϵ, expressed in fractions of the maximum positron energy in the μ-e decay, while the ordinates represent the asymmetry coefficient calculated from Eq. (1). The solid curve gives the value of the asymmetry coefficient from the theory of the two-component neutrino: $a(\epsilon) = 3 \times 0.28\,(1 - 2\epsilon)/(2\epsilon - 3)$ (here 0.28 ± 0.02 is the value of the asymmetry coefficient for a 17-kilogauss field). The dotted lines show the energy dependence of the asymmetry coefficient as smeared out by the statistical errors in the measurement of the energy and by the bremsstrahlung under the conditions of our measurements: the upper curve corresponds to 10% dispersion and to tracks 4 mm long, while the lower curve to 20%



dispersion and tracks 1 mm long. More than 85% of all the particles contained in the spectrum lie between these two extreme cases. The values of the asymmetry coefficient, shown as empty circles, correspond to energy intervals 0 — 0.4, 0.4 — 0.6, 0.6 — 0.8, 0.8 — 1.0, and 1.0. The filled circles are the values of the asymmetry coefficient for the shifted energy intervals 0.5 — 0.7, 0.7 — 0.9, 0.9 — 1.1, and > 1.1. These values are therefore not independent statistically, but do indicate the absence of an effect due to grouping of the data by intervals. The resultant differential spectrum of the values $a(\epsilon)$ increases rapidly with energy and agrees with the two-component neutrino theory. These measurements show no positive asymmetry at low energies. In our previous work,[2] performed with NIKFI-R photoemulsions ($a = -0.077 \pm 0.012$), an average asymmetry coefficient $a = +0.14 \pm 0.10$ was obtained in the energy region 0 — 0.3, whereas the value expected from the two-component theory was approximately +0.04. Were such high a value of the asymmetry coefficient real, a pronounced positive excess would appear in the present series of measurements. This, however, did not happen.

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ON A SYMMETRY IN τ^0 DECAY

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SUPPOSE the decay process $K_2^0 \to \pi^+ + \pi^- + \pi^0$ is invariant under charge conjugation. We shall show that then the angular distribution of the π^+ and π^- has the following symmetry:

$$F(-\mathbf{p}, \mathbf{p}') = F(\mathbf{p}, \mathbf{p}'), \qquad (1)$$

where $\mathbf{p}$ is proportional to the difference of the momenta of the π^+ and π^- in the center-of-mass system of the reaction (c.m.s.), and $\mathbf{p}'$ is the sum of these momenta.

Let us denote by $\langle \mathbf{pp}' | S | JM \rangle$ the transition amplitude from the initial state (the spin of the K meson is J, the spin projection M) to a state with definite values of $\mathbf{p}$ and $\mathbf{p}'$. It can also be called the wave function of the decay products, written in the momentum representation. As a function of the spherical angles ϑ, φ and ϑ', φ' of the momenta $\mathbf{p}$ and $\mathbf{p}'$, it can be put in the form of an expansion

$$\langle \mathbf{pp}' | S | JM \rangle = \sum_{l, \mu, l', \mu'} Y_{l\mu}(\vartheta, \varphi) Y_{l'\mu'}(\vartheta', \varphi') \langle l\mu p, l'\mu' p' | S | JM \rangle.$$

Assuming that if $J \neq 0$ the decaying K mesons are unpolarized, we have for the angular distribution in the c.m.s.:

$$F(\mathbf{p}, \mathbf{p}') \equiv \sum_M |\langle \mathbf{pp}' | S | JM \rangle|^2 = \sum Y_{l_1\mu_1}(\mathbf{n}) Y^*_{l_2\mu_2}(\mathbf{n}) Y_{l_1', \mu_1'}(\mathbf{n}') Y^*_{l_2', \mu_2'}(\mathbf{n}') \times \langle l_1\mu_1 p, l_1'\mu_1' p' | S | JM \rangle \langle l_2\mu_2 p, l_2'\mu_2' p' | S | JM \rangle^*, \qquad (2)$$

where the summation is taken over M, l_1, μ_1, l_2, μ_2, l_1', μ_1', l_2', μ_2'.

If charge parity is conserved, then $-1 = (-1)^l \cdot (+1)$, where $(+1)$ is the charge parity of the system of the π^0 meson, and $(-1)^l$ is the charge parity of the system (π^+, π^-). Therefore $(-1)^{l_1} =$