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ENERGY DEPENDENCE OF THE ANGULAR CORRELATION OF POSITRONS FROM $\pi \to \mu \to e$ DECAY

Kh. P. BABAIAN, N. A. MARUTIAN, K. A. MATEVOSIAN, and M. G. SARINIAN

Physics Institute, Academy of Sciences, Armenian S.S.R.

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The energy dependence of the angular correlation of positrons was investigated for 405 $\pi \to \mu \to e$ decay events in nuclear emulsion. The experimental energy dependence of the backward-forward ratio for the emitted positrons agrees with the predictions of the two-component neutrino theory.

LEE and Yang[1] have shown that nonconservation of parity leads to angular correlation in meson and hyperon decays and in various Fermi interactions. Landau[2] has suggested that in these interactions conservation of parity and of charge conjugation do not occur independently; instead we have conservation of "combined inversion," which is the product of space reflection and charge conjugation. The discovery of parity nonconservation has led to the two-component theory of the neutrino.[2-4]

Parity nonconservation in $\pi \to \mu$ decay results in polarization of the muon spin parallel or antiparallel to the direction of motion. Subsequent decay of the muon leads to angular asymmetry of positrons as a function of energy; this is given in the two-component neutrino theory by

$$dN = 2N\varepsilon^2 [(3 - 2\varepsilon) + \lambda \cos\theta (2\varepsilon - 1)]\, d\varepsilon\, d(\cos\theta), \quad (1)$$

where ϵ is the ratio of the positron energy to the maximum possible energy, θ is the angle between the muon and positron directions, and λ is a theoretical constant ranging from -1 to $+1$.

The first article by Garwin and his coworkers[5] reported a slight increase of the asymmetry parameter with energy. The results given in their second article[6] are in quite good quantitative agreement with the two-component neutrino theory.

Vaisenberg and Smirnitskii[7] investigated the energy dependence of the asymmetry parameter in 120 $\pi \to \mu \to e$ decay events in the Ilford G5 emulsion and found qualitative agreement with the theory. In the second article by the same workers,[8] where 580 events have been studied, it is shown that the asymmetry parameter increases rapidly as the positron energy increases.

The present work was performed on part of a 9-liter stack of 600-μ Ilford G5 emulsions which were exposed in Italy for 6 to 7 hours at a height of ~ 27 km. We had previously[9] studied the angular distribution of positrons in 2160 $\pi \to \mu \to e$ decay events completed in a single layer, where the $\mu \to e$ decay occurred not less than $30\,\mu$ below the surface of the developed emulsion and the projection of the positron track in the plane of the emulsion was $\geq 15\,\mu$. The solid angle between the muon and positron tracks was determined to within 2°. For the asymmetry parameter we obtained

$$A = -(0.135 \pm 0.043).$$

For the purpose of determining the energy dependence of the asymmetry parameter, we selected events with positron tracks longer than $1000\,\mu$, which were more than 1 cm distant from the edges of the plates (to avoid edge distortions). For 405 events which satisfied these requirements the dis-

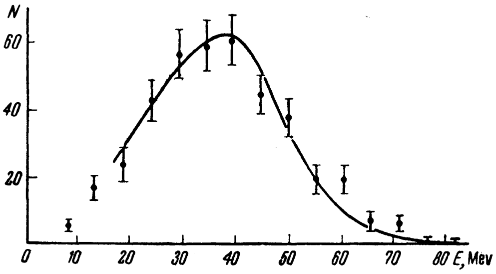

FIG. 1

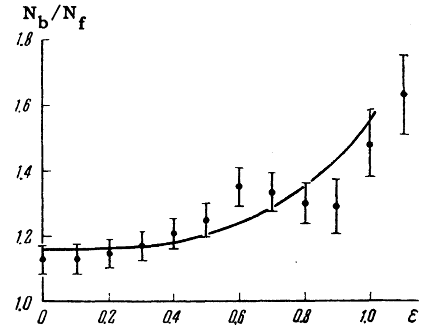

FIG. 3

tribution of positron track lengths was as follows:

Track length, mm	1–2	2–3	3–4	4–5	5–6	6–7	7–8	>8
Number of tracks	194	91	54	26	18	10	8	4

In determining positron energies by the multiple-scattering method for tracks $\leq 2000\,\mu$ the cell length was $50\,\mu$, while for longer tracks the cell length was $100\,\mu$. The positron energy was determined with an error which varied from 25% to 10% at the beginning and end of the distribution, respectively.

For an approximate evaluation of the Michel parameter ρ, it has been assumed that our experiment involves the same smearing of the theoretical spectra ($\rho = 0$, 0.25, 0.5, 0.75) as in reference 10. The χ^2 method gave $\rho = 0.62 \pm 0.14$. Figure 1 shows the experimental distribution and "smeared" theoretical curve for $\rho = 0.62$ plotted as the average of the curves for $\rho = 0.5$ and $\rho = 0.75$. The good agreement between the experimental points and the curve is an argument in favor of the assumption mentioned above.

Figures 2a and 2b represent the experimental distributions of positrons emitted forward ($0° \leq \theta \leq 90°$) and backward ($90° \leq \theta \leq 180°$), respectively. In 218 events the positron was emitted backward, while in the remaining 187 events it was emitted forward. These spectra show a small shift of the distribution peaks, which also results

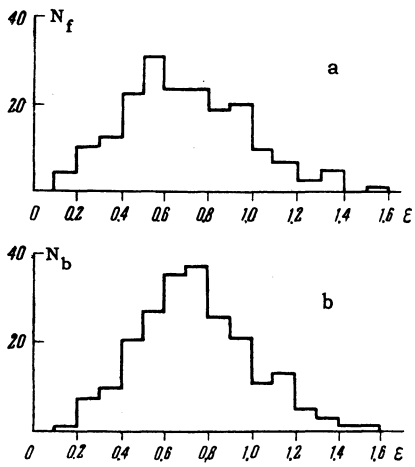

FIG. 2

from the energy dependence of asymmetry.

Figure 3 shows the theoretical curve (calculated without taking into account the spread of measured values and bremsstrahlung) for the energy dependence of the ratio between N_b, the number of positrons emitted backward, and N, the number of positrons emitted forward; the mean weighted asymmetry parameter was $A = -(0.141 \pm 0.013)$ and its theoretical increase with energy was taken into account. The mean weighted value was obtained from the articles listed in the table. Figure 3 also shows the experimental points normalized to their theoretical values for $\epsilon = 0.3$.

Source	Number of events	− A
Rome,[11] cosmic rays	1028	0.222 ± 0.067
Bristol,[12] cosmic rays	1562	0.08 ± 0.05
Copenhagen,[13] cosmic rays	817	0.17 ± 0.07
Moscow,[8] " "	2000	0.120 ± 0.039
Erevan,[19] " "	2160	0.135 ± 0.043
Chicago,[14] accelerators	2000	0.174 ± 0.038
Göttingen,[15] "	2003	0.095 ± 0.044
Rochester,[16] "	1048	0.19 ± 0.06
Cambridge,[17] "	3021	0.149 ± 0.033

The asymmetry parameter for the investigated 405 $\pi \rightarrow \mu \rightarrow e$ decay events increases from $A = -(0.153 \pm 0.086)$ for $\epsilon = 0.1$ to $A = -(0.400 \pm 0.220)$ for $\epsilon = 1.0$. These results also support the two-component neutrino theory.

With experimental errors taken into account the correlation sign is observed to change in the energy range $\epsilon = 0.4$ to 0.7.

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