[3]See F. S. Crawford et al., Phys. Rev. Letters 2, 266 (1959).

[4]M. Gell-Mann, Nuovo cimento 5, 758 (1957).

[5]We report briefly the argument. The rule $\Delta T=\frac{1}{2}$ implies that the final pions appear in the combinations

$$\epsilon_{ikl}\varphi^{(k)}\varphi^{(l)},\quad \epsilon_{ikl}\frac{\partial\varphi^{(k)}}{\partial x_\nu}\frac{\partial\varphi^{(l)}}{\partial x_\nu},$$

$$\epsilon_{ikl}\frac{\partial\varphi^{(k)}}{\partial x_\nu}\varphi^{(l)},\ \text{or}\ \epsilon_{ikl}\varphi^{(k)}\frac{\partial\varphi^{(l)}}{\partial x_\nu}.$$

Of such expressions only the last two differ from zero and they are equal apart from sign.

[6]J. D. Good, Phys. Rev. 113, 352 (1959).

[7]O. Hori, Nuclear Phys. 17, 227 (1960).

[8]Particular models including Σ particles are being investigated by Dr. Bassetti, whom we wish to thank for useful discussions.

ESTIMATE OF THE NEUTRAL π-MESON LIFETIME

R. F. Blackie, A. Engler,* and J. H. Mulvey
The Clarendon Laboratory, University of Oxford, Oxford, England
(Received September 21, 1960)

The lifetime of the π^0 meson may in principle be determined from an analysis of K^+-meson decays at rest in nuclear emulsion. Events are selected in which the $K_{\pi 2}$ mode, $K^+\rightarrow\pi^++\pi^0$, is followed by the decay of the π^0 meson to give a direct electron pair,[1] $\pi^0\rightarrow e^++e^-+\gamma$. Both the velocity and the direction of flight of the π^0 mesons are determined by the kinematics of the K-meson decay and the presence of the direct pair allows the point of decay of the π^0 to be found.

Harris, Orear, and Taylor[2] first proposed this method of estimating the π^0 lifetime, and using 12 events found in Ilford $G5$ nuclear emulsion stacks were able to set an upper limit to the lifetime at $\sim 7\times10^{-16}$ second. In the present experiment Ilford $L4$ emulsions of smaller grain size ($\sim 0.3\ \mu$ rather than the $0.6\ \mu$ typical of $G5$) have been used in an attempt to increase the spatial resolution of the method. The preliminary results, based on measurement of 26 events, suggest a finite mean lifetime $\sim 3\times10^{-16}$ second.

Thirty examples of K^+-meson decay accompanied by a direct electron pair have been found in a total of 27 000 K^+-meson endings examined. Measurements of the ionization of the secondaries have shown 2 events to be τ' or $K_{\mu 3}$ decays; there remains a possible 12 % contamination due to decay by the $K_{\mu 3}$ and K_{e3} modes but the effect on the result is small.

The measurements have been performed using a projection apparatus to form an image of the event on a screen at a magnification ~ 7500. Each grain in the tracks of the π^+ meson, the electron pair, and the K-meson ending was then traced. The length of track used for the meson and electrons was $\sim 30\ \mu$. From the drawing, the coordinates of the center points of each grain were taken and this information was used to compute best-fit lines to the π^+ and electron tracks by minimizing $\sum h_i^2$, where h_i is the perpendicular distance from a grain center to the fitted line. This calculation was performed on the Oxford University Ferranti "Mercury" digital computer. At the same time the program computed the distance d between A, the foot of the perpendicular from the center of the last K-track grain to the π^+ line (the estimated origin of the π^0), and the point B, the intersection of the π^+ and one of the electron lines (the estimated point of decay); this calculation is illustrated by Fig. 1.

If the π^+-meson track has a dip angle α, the π^0-decay path is then $x=d\sec\alpha$. In those cases where both electron tracks of the pair were used, the estimate of d was obtained by taking an average using $1/\csc^2\theta$ as a weighting factor. Three drawings were made for each event and an average value used for the result.

This method of determining the mean decay

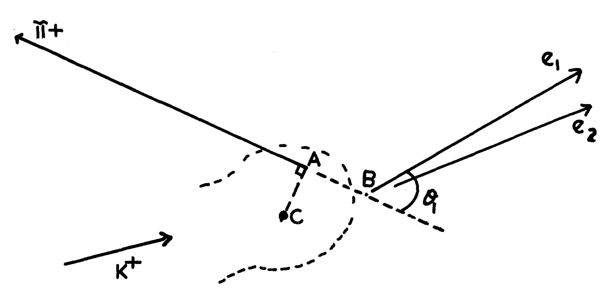

FIG. 1. Diagram showing the procedure for estimating the projected flight path of the π^0 meson. C is the center of the last grain in the K-meson track which is indicated by an irregular broken line.

path is at all stages free from subjective bias.

Following a suggestion due to Harris, Orear, and Taylor,[2] the error, σ_i, in a measurement x_i was assumed to be related to the geometry of the ith event in the following way:

$$\sigma_i = \sec\alpha(a^2 + b^2 \csc^2\theta)^{1/2}.$$

$b \csc\theta$ is a contribution to the error from the determination of the π, e intersection B, and a is a term related to the error in A.

The constants a and b have been obtained from measurements on 30 cases of τ decay, using exactly the same procedure to determine a distance d for a pair of π tracks and the K ending. The values obtained were $a = 0.063\ \mu$ and $b = 0.084\ \mu$.

The results of measurements on 26 of the Dalitz pair events have been analyzed. Using as a weighting factor the quantity $1/\sigma_i^2$, the weighted mean distance is $0.147 \pm 0.042\ \mu$. This corresponds to a mean lifetime of $(3.2 \pm 1) \times 10^{-16}$ second.

Since the distribution in true π^0 path length is exponential, the distribution in x_i is not normal and the weighted mean is not the most efficient estimator for the mean decay path. The likelihood function for the observed set of x_i and σ_i has therefore been calculated and the maximum likelihood estimate for the mean lifetime is 3.3×10^{-16} second. The curve in Fig. 2 shows the relative probability of obtaining this set of measurements as a function of the lifetime. The values fall to 1% relative probability at $\sim 2 \times 10^{-17}$ second and $\sim 10^{-15}$ second.

A recent estimate of the π^0 lifetime by a dispersion theory method[3] suggests that the present results of experiments on proton Compton scattering are consistent with a lifetime within the limits 5×10^{-19} second and 10^{-16} second.

A further study of the estimation of errors, and of confidence limits for the lifetime is in progress and a fuller account of the experiment will be published elsewhere.

We wish to thank Dr. E. J. Lofgren and Dr. W. Wenzel of the Lawrence Radiation Laboratory, Berkeley, for the opportunity to obtain a K^+-meson exposure at the Bevatron, and for the hospitality received at the laboratory by J. H. M. during the preparations. We thank the William Waldorf Astor Foundation for support of the irradiation. We gratefully acknowledge our debt to Professor H. K. Ticho, Professor D. H. Stork, and Professor G. Goldhaber who designed and set up the beam separation system and who gave invaluable help and advice before and during the exposure. It is a pleasure to thank Professor D. H. Wilkinson for his interest and encouragement.

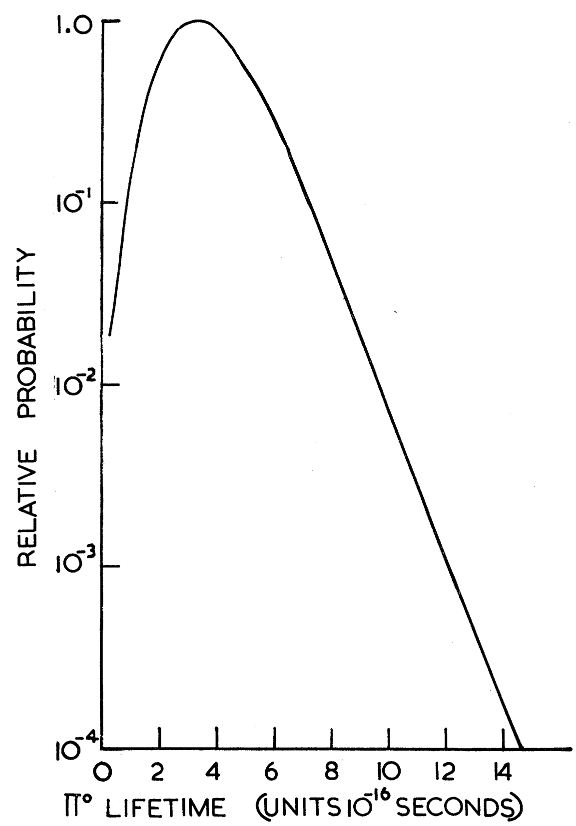

FIG. 2. The relative probability of observing the set of 26 measurements of x as a function of the π^0-meson lifetime.

*Now at the Physics Department, Duke University, Durham, North Carolina.

[1]R. H. Dalitz, Proc. Roy. Soc. (London) A64, 667 (1951).

[2]G. Harris, J. Orear, and S. Taylor, Phys. Rev. 106, 327 (1957).

[3]M. Jacob and J. Mathews, Phys. Rev. 117, 854 (1960).