The Lifetime of the Heavy Meson

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(Received October 21, 1948)

MESONS of mass about $300m_e$ have been produced by the 380-Mev alpha-particle beam of the 184-inch cyclotron.[1] These mesons are susceptible to $\pi\rightarrow\mu$-decay.[2] A preliminary investigation has been made of the loss of negative mesons from a beam of these particles, and since this beam is moving in a region at a pressure of 10^{-5} mm Hg, the assumption is made that this loss corresponds to the $\pi\rightarrow\mu$-decay process.

The alpha-particle beam in the cyclotron is in a horizontal plane. A target of $\frac{1}{16}$-inch graphite is provided, and then the mesons are selected by a semicircular spiral channel which rises $\frac{1}{2}$ inch vertically in one semicircle (180 degrees). At this point six photographic plates are exposed. The horizontal projection of the channel has an inner diameter of 4.5 inches and an outer diameter of six inches and is oriented in such a way that it selects negative mesons whose initial horizontal component of velocity is in the same direction as the alpha-particle beam at the target. A similar channel is provided for mesons spiraling downward at an equal angle, but it is unobstructed at the 180-degree position. These mesons then spiral downward, passing one inch below the center of the target and through another channel to the 540-degree position, having dropped 1.5 inches in $1\frac{1}{2}$ turns. At this point another set of six plates is exposed simultaneously with the first. The ratio of the number of mesons in these two sets of plates when corrected for geometry will give the loss of mesons in the time corresponding to one revolution in the magnetic field. This "cyclotron" time is independent of the speed of the meson. The desirable 360-degree focusing properties mean that in a uniform magnetic field the geometrical correction is simply a factor of three in the above case. Because the experiment was done in the fringing field of the cyclotron, room was left in the second part of the lower channel for the slight precession caused by this non-uniform field. The effect of the vertical focusing forces due to the fringing field was investigated theoretically and also experimentally by performing the experiment at different cyclotron radii. Most of the data were taken at a cyclotron target radius of 76 inches where the alpha-particle energy is 350 Mev. At this radius the correction for vertical focusing is negligible compared to the statistical uncertainty in the experiment. In order to check the possible presence of any unknown asymmetry, the channels were interchanged, so that the 180-degree channel spiraled down, and the 540-degree channel spiraled up. No difference could be detected and the two situations are represented with approximate equality in the final results. In each case a simultaneous background exposure was made at the 540-degree position in a channel which was an extension of the 180-degree channel. The plates placed here would record any mesons which originated in places other than the target. This background was negligibly small.

The following ingenious method for determining the ratio of the solid angles was conceived and executed by Dr. Wolfgang K. H. Panofsky and Mr. Ernest Martinelli. In order to check whether the above factor of 3 which corresponds to loss due to vertical divergence only and assumes identical focusing properties at 180° and 540° is actually correct, an experiment was performed using alpha-particles from a plutonium source in place of the mesons. Any loss of particles due to channel imperfections or other considerations would be detected in this manner. The experiment was performed by mounting a thick plutonium source of activity 10^6 counts/second in place of the graphite target. The size of the source ($\frac{1}{2}'' \times \frac{1}{8}''$) was chosen to represent as accurately as possible the target height and beam penetration into the target. The resultant assembly was exposed using type

[1] E. Gardner and C. M. G. Lattes, Science **107**, 270 (1948).
[2] C. M. G. Lattes, G. P. S. Occhialini, and C. F. Powell, Nature **160**, 453, 486 (1947).

E-1 Ilford photographic plates inclined at 48° to the beam in place of the meson plates used in the main part of the experiment. This assembly was exposed in the cyclotron vacuum with full field for eight hours with the source and oscillator of the cyclotron inoperative. Since the alpha-source is thick, it will give rise to a continuous energy spectrum from which only a narrow band is selected by the channel. Since the dynamics of the particles depends only on the $H\rho$, the difference in e/m of the mesons as compared to alpha-particles does not enter here, inasmuch as only a narrow angle range and energy range is accepted. The ratio of alpha-particles in the 180-degree position and the 540-degree position was then obtained by measurement on the alpha-particle plates by scanning over the identical vertical height at which the meson plates were exposed. The resultant curve indicates that the ratio is not exactly 3.0, as it should be in the ideal case but is actually 3.2 when weighted in accordance with the observed meson distribution. This small deviation produces a small correction to the meson half-life which has been used in the final results.

Some 250 plates have been exposed during the course of the investigation. Although a check was made on the thickness of the emulsion in the individual plates, the number of plates used was so large that the resulting correction was very small. Fortunately, the background of neutron recoils, etc., in the photographic plates was practically identical in the 180-degree and 540-degree positions, so that the search for mesons was made under identical conditions. The 18 plates of a run were all developed at once and received identical treatment.

Although all the mesons observed had a range consistent with a mass in the neighborhood of $300m_e$, it was decided to count only those mesons which ended in stars. Forty-eight star-producing mesons were observed in the plates at 540 degrees whereas the number expected on the basis of the experimental geometry ratio would be 92. The latter number is based statistically on a count of 254 mesons. Assuming a mass of $286m_e$ for the meson, the time for one revolution turns out to be 7.2×10^{-9} second. Therefore, the number of mesons obtained, together with the assumption mentioned earlier, indicates that the half-life of the star-producing negative mesons for $\pi\rightarrow\mu$ decay is $\left(7.7\begin{smallmatrix}+2.1\\-1.5\end{smallmatrix}\right)\times10^{-9}$ second, where the error indicated is the statistical standard deviation.[3] The mean life is $\left(1.11\begin{smallmatrix}+.31\\-.22\end{smallmatrix}\right)\times10^{-8}$ second.

The writer takes pleasure in acknowledging his gratitude to Dr. E. Gardner and Dr. C. M. G. Lattes for their kind suggestions and instruction in the use of their technique for investigating mesons. Thanks are due Mr. A. Bishop and Mr. F. Adelman and the cyclotron crew for help in making the bombardments. Thanks are also due Mr. Donald C. Stewart for the preparation of the alpha-particle source. The writer is grateful to Professor Ernest Lawrence for encouragement and for the opportunity to work in the Radiation Laboratory. This work was performed under the auspices of the Atomic Energy Commission. Most of the meson measurements were made at Los Angeles on a microscope furnished under ONR project NR022–053.

[3] Camerini, Muirhead, Powell, and Ritson, Nature **162**, 433 (1948).