Letters to the Editor

FURTHER SEARCH FOR THE $\mu \to e + \gamma$ DECAY

A. I. ALIKHANOV, A. I. BABAEV, M. Ya. BALATS, V. S. KAFTANOV, L. G. LANDSBERG, V. A. LYUBIMOV, and Yu. V. OBUKHOV

Institute of Theoretical and Experimental Physics

Submitted to JETP editor December 9, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **42**, 630-631 (February, 1962)

THE muon decay $\mu \to e + \gamma$ has not yet been observed, although the universal V-A theory of weak interaction calls for such a decay to exist, provided the muon and electron neutrinos are identical. It has been found experimentally[1,2] that the upper limit is $(1.6-2.0) \times 10^{-6}$ of the total number of μ decays.*

We undertook a further search for the $\mu \to e + \gamma$ decay, using a procedure in which spark chambers are combined with high-speed electronic circuitry.

The arrangement of the equipment is shown in the figure. A 70 MeV π^+-meson beam from the proton (680 MeV) synchrocyclotron of the Laboratory for Nuclear Problems of the Joint Institute for Nuclear Research was separated by I, II, O monitor coincidences. The intensity of the beam corresponded to 2300 π^+ mesons stopped per second in the target-counter O. The count of the coincidence O, $\bar{A}(4, 5, \bar{6}+7, 8, \bar{9}+1, 2, \bar{3}+10, 11, \overline{12})$ corresponded to the registered number of $\mu \to e + \nu + \bar{\nu}$ decays (the bar denotes anticoincidence with the given counters).

The fast coincidences O, 4, 5, 7, 8, $\bar{6}$, $\bar{9}$, $\bar{A}$ and 0, 1, 2, 10, 11, $\bar{3}$, $\overline{12}$, $\bar{A}$ with resolution time $\sim 10^{-8}$ sec produced a master signal triggering a generator that produced a high-frequency pulse on the high-voltage electrodes of the chambers. The tracks in both chambers were photographed in two projections by motion-picture cameras 1 and 2. A third motion-picture camera photographed simultaneously the oscilloscope that measured the time between the signals of the coincidences I, II, O, and O, 4, 5, 7, 8, $\bar{6}$, $\bar{9}$, $\bar{A}$ or 0, 1, 2, 10, 11, $\bar{3}$, $\overline{12}$, $\bar{A}$.

The six-layer cylindrical chamber B[3] registered the electron and the γ quantum of the muon decay. To convert the γ quanta, the cylinder in front of the two outer gaps was made of lead, while

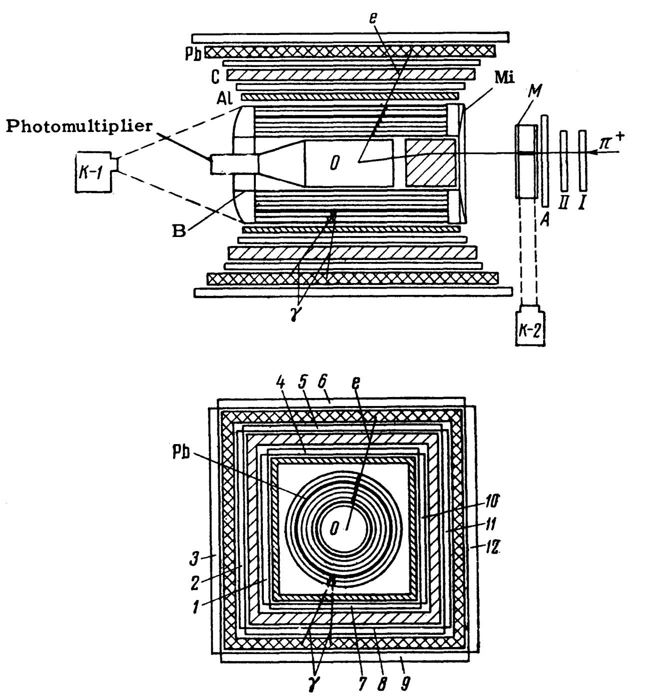

Diagram of equipment used to register $\mu \to e + \gamma$ decays. B – 6-layer cylindrical spark chamber, M – single-layer flat spark chamber, K-1, K-2 – motion picture cameras; Mi – mirrors to produce a stereoscopic picture of the event in the chamber. O, I, II, A, 1–12 – scintillation counters. The apparatus was shielded with lead and paraffin with boron on all sides

all others were made of aluminum. The electron-positron pair from the γ quanta was thus registered in the last two layers of the chamber, and the electron was registered in all six layers. The photography was through the end of the chamber, with a special mirror system used to obtain a stereoscopic image.

The accuracy in the determination of the collinearity of the events was limited by the multiple scattering of the electron in the target and in the chamber, and by the accuracy of the measurement. In the first projection (plane perpendicular to the beam) the error in the determination of the angle was 4.8°, while in the second (inside the chamber) it was less than 20°.

The flat single-layer chamber M was intended for a determination of the coordinates of the point of entrance of the π^+ meson in the O counter, in a plane perpendicular to the beam. If the e, γ event registered in chamber B is genetically related to the pion passing through the chamber M, then the point of entry of the pion in the target should be in 80% of the cases not farther than 2 cm from the continuation of the straight trajectory of the electron (to the first projection in chamber B).

The solid angle of the installation used to register the $\mu \to e + \gamma$ events was 1.6π sr.

The counting efficiency for a 53-MeV electron from the $\mu \to e + \gamma$ decay should be 40%. The counting efficiency of 53-MeV γ quanta was 15%. The overall counting efficiency for $\mu \to e + \gamma$ events, with account of the processing criteria employed, was 0.8%.

Altogether, 5.5×10^8 stopped π^+ mesons were counted in the O counter after 66 hours of operation.

The processing of the e, γ events resulted in six cases in which the angle between the electron and the γ quantum was in the interval 174—144° in the first projection and 180—140° in the second projection in chamber B; not one event was counted in the interval 180—174° in the first projection.

The remaining events are most likely $\mu \to e + \nu + \bar{\nu} + \gamma$ decays. From a theoretical estimate we can expect under the conditions of our experiment about 5 radiation decays in the 174—144° interval and one case in the 180—174° interval in the first projection.

It follows from our measurements that the upper limit of the $\mu \to e + \gamma$ decay constitutes 5×10^{-7} of the ordinary decay, with 90% reliability. The measurements are continuing at the present time.

The authors are grateful to V. P. Dzhelepov and A. A. Tyapkin for interest in the work, and also to A. S. Kronrod, Yu. A. Simonov, and M. V. Terent'ev for many calculations.

*The value 1.2×10^{-6} (90% reliability) given in [2] for the upper limit is an underestimate. Calculations by Poisson's method yield a limit of 1.6×10^{-6} for the data obtained in [2].

[1] Berley, Lee, and Bardon, Phys. Rev. Lett. 2, 357 (1959).

[2] Frankel, Hagopian, Halpern, and Whetstone, Phys. Rev. 118, 589 (1960).

[3] V. S. Kaftanov and V. A. Lyubimov, PTÉ (Instruments and Measurement Techniques), in press.

Translated by J. G. Adashko
96

EXPERIMENTAL ESTIMATE OF PROBABILITY OF β DECAY OF THE π^+ MESON

A. F. DUNAĬTSEV, V. I. PETRUKHIN, Yu. D. PROKOSHKIN, and V. I. RYKALIN

Joint Institute for Nuclear Research

Submitted to JETP editor December 9, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) 42, 632-635 (February, 1962)

THE rare form of charged-pion decay

$$\pi^{\pm} \to \pi^0 + e^{\pm} + \nu, \tag{1}$$

which can be called the pion β decay* in analogy with β decay of the nucleon, has remained practically uninvestigated experimentally, owing to its exceedingly low expected probability and the resultant large experimental difficulties. A theoretical analysis of this process first made by Zel'dovich [2] has shown that within the framework of the Fermi-Yang model the β decay of a pion is analogous to a Fermi nuclear β transition of the type $J = 0 \to J = 0$, and should be consequently characterized by the same value of ft as the decays of nuclei belonging to this type (for example, $O^{14} \to N^{14*}$). It would follow therefore that the probability of pion β decay should amount to only about 10^{-8} of the probability of ordinary muon decay $\pi^{\pm} \to \mu^{\pm} + \nu$. With development of the theory of universal weak interaction, [3] interest in the pion β decay has increased greatly in connection with the need for an experimental verification of the conservation of vector current, a hypothesis derived from the deep analogy between weak and electromagnetic interactions. The first to call attention to this analogy were Gershteĭn and Zel'dovich, [4] who pointed out as long ago as in 1955 that the constant of weak vector interaction may possibly not be normalized by strong interactions. If the foregoing hypothesis is accepted, then the probability of pion β decay should be calculated exactly, in spite of the fact that strongly-interacting particles participate in the decay process: [3]

$$w(\pi^{\pm} \to \pi^0 + e^{\pm} + \nu) = G^2\Delta^5/30\pi^3 \qquad (\hbar = c = 1). \tag{2}$$

Here G is the weak vector interaction constant and Δ is the mass difference between the charged and neutral pion. The electromagnetic and kinematic corrections to formula (2) are small [5] (several per cent). From a comparison of (2) with the known probability of ordinary charged pion decay it follows that if the vector current is conserved,