Observation of a New Decay Mode of a Heavy Meson*

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In an attempt systematically to detect unstable heavy particles giving rise to π mesons as decay products, we have traced back the trajectories of stopping π mesons in a stack of stripped emulsions. The part of the stack used for this purpose consisted of twenty-four 4-in.$\times$6-in.$\times$400μ G-5 stripped emulsions and was flown vertically at an altitude of 102 000 ft for 9 hours at geomagnetic latitude $\lambda = 55°$. The stripped emulsion was mounted on glass before development and each processed 4-in.$\times$6-in. plate was cut into four 2-in.$\times$3-in. plates for microscopic observation. The stack was aligned following a suggestion of Peters.[1] Tracks of heavy nuclei incident at small angles to the emulsion normal were located in the corners of each of the 2-in.$\times$3-in. plates; the plates were then mounted on $\frac{1}{8}$-in. thick 3-in.$\times$2-in. Lucite frames having a $\frac{1}{4}$-in. wide rim; a mixture of shellac and alcohol was used as a slow drying cement. The plates were consecutively adjusted so that each of the heavy nuclei markers was in proper position with respect to the preceding plate and were then left until the cement had set; the average time per plate was $\sim$20 minutes and alignment to within 200μ was obtained.

At the present time we have traced 299 π mesons, of which 150 were positive and 149 negative (the sign is determined since we observe either $\pi-\mu$ decay or a σ star). Of these, 116 π^+ and 103 π^- originated outside the stack; of those originating in the stack, 32 π^+ and 44 π^- came from stars having 3 or more prongs and 2 π^+ and 2 π^- originated from 2-prong stars. One π^+ meson of 4.3-mm range originates from the end of a stopping track (Fig. 1); there is no indication of any recoil. Since the π^+ undergoes a large angle scattering, its energy lies between 13.8 and 15 Mev. The stopping track has been traced through 14 emulsions and leaves the stack at a residual range of 1.6 cm.

Mass measurements have been made on the primary particle by scattering-range and ionization-range methods. The mass value

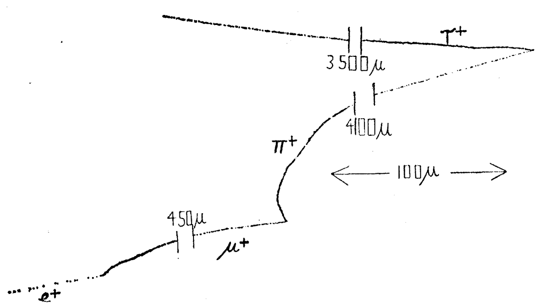

FIG. 1. Decay at rest of a heavy meson. This event is interpreted as $\tau^+\rightarrow\pi^++2\pi^0$. The sign is uniquely determined by the $\pi^+\rightarrow\mu^+\rightarrow\beta^+$ decay.

obtained from scattering measurement using the Bristol method[2] was $930\pm170m_e$, and a value of $1070\pm250m_e$ was obtained using the method of constant second differences;[3] the weighted mean of these is $975\pm170m_e$. The gap-density-range method[4] gave a value of $940\pm100m_e$. The weighted mean value of all measurements is $950\pm85m_e$.

There are two possible interpretations of this event: (1) capture at rest of a negative heavy meson[5] with the resulting production of a π^+ meson and no other charged particles, or (2) decay at rest of a positively charged heavy particle into a slow π^+ meson and one or more neutral particles. Though it is impossible to rule out the first alternative, this seems a less likely interpretation[6] than the second. If we then assume that this event represents the decay of a heavy charged meson, we can attempt to identify the primary with one of the known unstable particles of around $1000m_e$. These are the κ meson decaying according to $\kappa^\pm\rightarrow\mu^\pm+2$ neutral particles,[7] the χ meson assumed to decay by the scheme[8] $\chi^\pm\rightarrow\pi^\pm+$neutral particle ($E_\pi\approx120$ Mev) and the τ meson[9] decaying according to the scheme $\tau^\pm\rightarrow2\pi^\pm+\pi^\mp$. The unstable particle we observe certainly cannot be the κ meson, and the energy of the emerging π^+ is completely inconsistent with the assumed decay scheme of the χ meson. Though no particles have yet been observed decaying in two different ways, we believe the most likely interpretation is the alternate decay mode[10] of the τ^+ meson, $\tau^+\rightarrow\pi^++2\pi^0$. Since the Q value for τ decay into three charged π mesons is ≈72 Mev, our observed π^+ energy is consistent with this interpretation.

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[1] Lal, Pal, and Peters, Proc. Indian Acad. Sci. (to be published).
[2] M. G. K. Menon and O. Rochat, Phil. Mag. 42, 1232 (1951).
[3] Biswas, George, and Peters, Proc. Indian Acad. Sci. (to be published).
[4] D. M. Ritson, Phys. Rev. 91, 1572 (1953).
[5] Lal, Pal, and Peters, Proc. Indian Acad. Sci. (to be published). The 4 cases of heavy meson capture reported here were all characterized by having two or more charged fragments produced.
[6] The capture of a negative Fermion (κ meson) seems an unlikely explanation; the capture could occur as $\kappa^-+p\rightarrow\nu+n$; $E_n\sim110$ Mev which is insufficient for π-meson production. The capture of a boson (τ^-) could conceivably occur via the reactions (a) $\tau^-+\alpha\rightarrow\pi^++4n$, (b) $\tau^-+d\rightarrow2n$; $n+p\rightarrow\pi^++2n$. It seems unlikely that reactions of this type would leave no visible prongs or recoil, even in a light nucleus.
[7] C. O'Ceallaigh, Phil. Mag. 42, 1032 (1951).
[8] M. G. K. Menon, International Conference on Cosmic Radiation, Bagnères de Bigorre, France (1953).
[9] R. Brown *et al.*, Nature 163, 82 (1949).
[10] R. H. Dalitz, Proc. Phys. Soc. (London) 66, 710 (1953). Application of charge independence to τ^+ decay has as a consequence that the frequency of the $(\pi^+,2\pi^0)$ decay mode must exceed $\frac{1}{4}$ that of the $(2\pi^+,\pi^-)$ mode.

The Triple Gamma-Ray Cascade in Sb^{124}†

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Recently, two somewhat different schemes were proposed[1,2] for the disintegration of Sb^{124}. There is a significant difference between the two proposals which was tested in the present investigation. The scheme of Langer, Lazar, and Moffat calls for a triple cascade of 0.64-, 0.72-, and 0.603-Mev gamma rays. The other proposal[2] suggests that the 0.64-Mev gamma ray is not in coincidence with the 0.72-Mev gamma ray. Instead, it calls for an additional 0.71-Mev gamma in series with the 0.72- and 0.603-Mev radiations.

If one looks at triple gamma-ray coincidences, one expects, for the first case, a double-intensity unresolved peak at 0.62 Mev and a single-intensity peak at 0.72 Mev. For the second case, one expects a double-intensity peak at about 0.72 Mev and a single-intensity peak at 0.60 Mev.

Such threefold coincidences were studied using three NaI crystals equally spaced about a Sb^{124} source which was imbedded in a two-inch diameter cylinder of Lucite. The scintillations were detected by Dumont K1186 photomultipliers. The resolution for 0.661-Mev Cs^{137} radiation was 9 percent. The pulses were amplified and fed into a 0.2-μsec resolving time coincidence selector which accepted only those pulses in each channel whose height lay between a lower bound of 0.55 Mev and an upper bound of 0.76 Mev. Such a triple coincidence opened a gate for 3 μsec which permitted the suitably delayed but undistorted pulses from one of the amplifiers to be recorded on a multichannel pulse-height analyzer. Two different experimental arrangements were used. One employed a 10-channel analyzer with 1-v channels; the other used a 100-channel pulse-height recorder and a "window" amplifier which effectively yielded 0.5-v pulse-height resolution.

The results obtained from both experiments were essentially