However, since these mesons are locally produced, they must be heavy, according to current ideas.

Unfortunately all our pictures of these events do not show so unequivocally that the short track is due to a nucleon or heavier particle. However, we have not observed any electrons to emerge from the ends of any of the short tracks.

We therefore conclude that these events show sigma-mesons which produce one-pronged stars, and for the present, put aside the less pleasant idea that $\mu$-mesons rarely decay. Why we saw no $\pi$-$\mu$-electron events remains to be investigated. It also must be investigated whether it is a property of argon alone, or of other of the lighter elements also, predominantly to boil off a single charged particle upon acceptance of a heavy meson.

We were ably and invaluably assisted in operating the heavy machinery by Thomas Mersereau. We are indebted to Professors B. B. Rossi and J. R. Zacharias for the advice and encouragement they gave us. We wish to express our appreciation to the many members of the staffs of M.I.T. and the Inter-University High-Altitude Laboratory, who helped us.

* This work was supported in part by the joint program of the Office of Naval Research and Atomic Energy Commission.

## Temperature Dependence of Scintillations in Sodium Iodide Crystals

W. C. ELMORE
*Swarthmore College, Swarthmore, Pennsylvania**

AND

R. HOFSTADTER
*Princeton University, Princeton, New Jersey**

November 19, 1948

THE high speed "Microoscillograph"[1] and a new fast amplifier[2] have been employed in studying the temperature dependence of radium gamma-ray induced scintillations in thallium activated sodium iodide crystals.[3] In these studies light pulses were conducted by internal reflection along the length of a one-foot transparent fused quartz rod.[4] The crystal sample was placed, within a furnace, next to one polished end of the quartz rod. The photomultiplier was kept at room temperature and positioned at the other end of the quartz rod. After transformation of the light pulse to a current pulse, the photomultiplier signal was amplified approximately 200 times and brought to the plates of the Microoscillograph through short leads. Permanent records of the traces are obtained on the target photographic plates of the Microoscillograph. To obtain the records, a ten millicurie source was placed within a few inches of the crystals and random sweeps were used.

The polycrystalline NaI (Tl) samples were prepared by fusing in vacuum Baker and Adamson reagent grade sodium iodide together with 1 percent, by weight, of thallium iodide. The preparation is sealed off in a quartz tube in which the fusion takes place. Other samples were made containing 0.1 percent and 0.02 percent of Tl I.

At the present time the data allow only rough estimates to be made of the duration and pulse shape of the light emitted during a scintillation. This is due to the circumstance that the observed pulses do not show a unique shape or behavior. Some pulses, particularly the larger ones, rise as fast as the rise time of the amplifier ($\sim 2\times 10^{-8}$ sec.), while others build up to a maximum value over an interval of perhaps 0.1 microsecond. Still others show only an irregular structure. It is probable that the number of quanta, detected by the photomultiplier in the average scintillation, is not large enough to smooth statistically the pulse shape to a recognizable form. A distortion of the true pulse form also occurs in the larger pulses since they drive the amplifier into a non-linear region.

The results for duration of the light pulse are the following. At room temperature most pulses, whatever their shape, terminate in about 0.4 to 0.7 microsecond. At 150°C the pulses are over in about 0.3 to 0.4 microsecond. At 345°C the larger pulses decay to zero in approximately 0.15 microsecond. These results do not preclude the occurrence of single electron pulses following the main pulse by a time of the order of twice the given pulse duration.

We have also examined pulses obtained with the 0.1 percent and 0.02 percent Tl I samples and, for the same excitation, have observed fewer pulses than in the 1 percent sample but have noticed no change in the duration or shape of the individual pulses. We have also compared the total amount of light detected by the photomultiplier in a large scintillation at room temperature and at 345°C. At room temperature from three to five times as many quanta are detected per scintillation as in the corresponding case at the higher temperature. It is not known whether this result corresponds to a real decrease in the number of emitted quanta or to a shift in frequency of the emitted light band, although it is suspected that the former is the case.

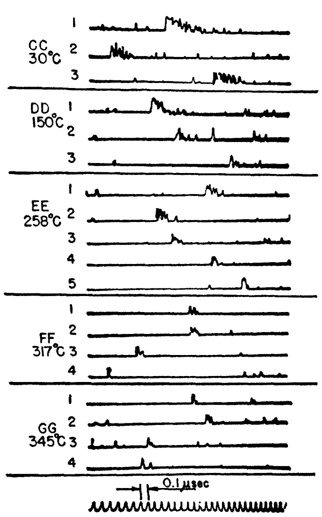


FIG. 1. Pulses showing sharp rise.

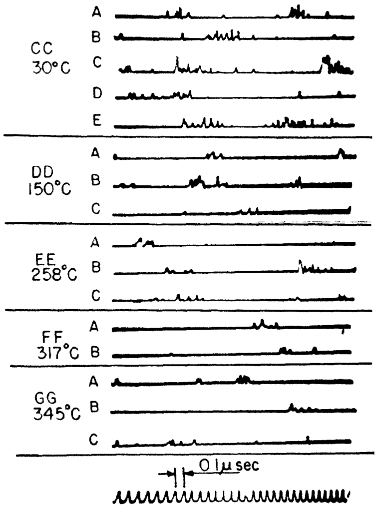


FIG. 2. "Irregular" pulses.

Figures 1 and 2 show typical pulses at the various temperatures. The pulses in these figures represent approximately the photomultiplier current (not integrated current). This is due to the low value of the anode load resistance at the photomultiplier.

* Research carried out at Brookhaven National Laboratory, Upton, Long Island, New York under the auspices of the Atomic Energy Commission.
[1] G. M. Lee, Proc. I.R.E. **34**, 121W (1946).
[2] W. C. Elmore, to be published.
[3] R. Hofstadter, Phys. Rev. **74**, 100 (1948).
[4] This technique has previously been used by G. B. Collins. We are indebted to Dr. Collins for loan of a quartz rod.

## Energy of the Disintegration Product of a Light Mesotron*

J. C. FLETCHER** AND H. K. FORSTER***
*California Institute of Technology, Pasadena, California*
November 8, 1948

IN a series of cloud-chamber observations performed at sea level, a photograph was obtained which is interpreted as the disintegration of a negative mesotron which comes to rest in a graphite plate.

The experiments were performed with an Argon-filled cloud chamber 22 inches in diameter, with a lighted area 2-inches deep, illuminated from the sides by two Argon discharge tubes. The chamber was placed in a magnetic field of 4700 gauss, uniform to $\pm 4$ percent within the illuminated area. Three graphite plates, each 1.1 cm-thick (2.0 g/cm$^2$) were inside the chamber; 33 cm of lead and two coincidence counters were placed above it. A schematic diagram of the apparatus, showing the arrangement of chamber, lights and cameras, is shown in Fig. 1.

On the photograph reproduced in Fig. 2, a particle is seen which enters the lower left-hand portion of the cloud chamber through the front glass and comes to rest in the bottom graphite plate. A lightly ionizing particle is seen to emerge from below the plate at an angle of about 90° with the entering particle. Its curvature and ionization indicate that it is a fast particle of negative charge. From comparison of the density of the track of the incoming particle with that of the outgoing particle it is quite apparent that the former is heavily ionizing. It should be pointed out that the difference in appearance of the tracks on the two photographs is characteristic for an arrangement of lights and cameras similar to that shown in Fig. 1, in which the light coming from the tracks must be scattered through widely different angles in order to reach the two cameras. The energy of the particle emerging below the plate is found to be $28.1 \pm 1.5$ Mev by curvature measurement. This value is in very good agreement with the energy calculated from the energy loss in the several traversals of the graphite plates. The disintegration particle traverses the graphite plates five times and this affords a very good opportunity to obtain an upper limit for its mass. Extensive measurements of the energy loss of knock-on electrons of various energies in graphite plates were carried out.[1] It is well known that this energy loss is subject to statistical fluctuations; however, from statistics of the experimentally obtained values, the probability could be calculated that, in a specific case, the energy loss of an electron of a given energy in traversing 1 cm of graphite deviate from the mean (and theoretical) value by a given amount. Curvature measurements of the particle in the photograph before and after each traversal of a graphite plate together with the information obtained on the statistical fluctuation of the energy loss to be expected, allow then to place an upper limit on the mass of the particle: there is a probability larger than 0.95 that the mass of the particle is smaller than 7 electron masses. After careful measurement and reprojection of the two tracks it was concluded that they intersect 3 cm from the front glass, well within the illuminated region of the chamber. However the slight possibility that the two tracks pass within a small distance accidentally, cannot be excluded.

Interpretation of the event as the disintegration of a light mesotron and estimation of the point of intersection of the two tracks within the graphite leads to a value of

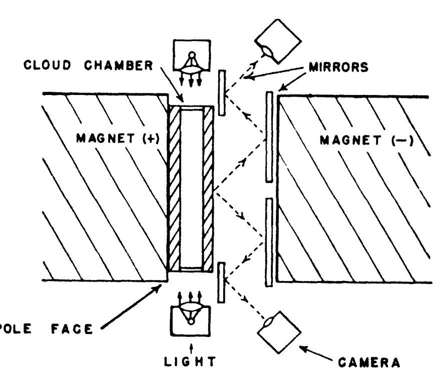


FIG. 1. Schematic diagram of apparatus.