1P21, beyond which voltage it falls rapidly; it is independent of the potential applied to the remaining seven stages. An over-all gain of 25 million is then achieved by operating stages one and two at 120 volts each, and stages three through nine at 180 volts each. Pulse heights of 20 volts and more are then observed, which are sufficient to feed directly into oscilloscopes, coincidence, mixers, etc., without recourse to additional vacuum-tube amplification.

Since upwards of 1500 volts appear between adjacent anode and cathode pins, certain precautions were taken, such as slotting the base and socket, and wax impregnation. Since the peak current in the last few stages is quite high, these were by-passed with small mica capacitors.

For visual pulse observation, the photo-multiplier was mounted at the neck of an oscilloscope tube of the 5JP1 variety, with very short connections. The signal pulses showed a finite rise time of about 0.05 microsecond; this figure represents the period over which appreciable light emission by the anthracene takes place, the photo-multiplier output circuit being effectively an integrator of the photoelectrons. Variation of the decrement of the output circuit (by changing the load resistor) showed that pulse height attenuation became evident for decrements lower than 0.15 microsecond, in agreement with the rise time observation. This figure is indicative of the resolution time to be expected in normal practice. It is significant that the rise time of noise pulses originating at the photo-surface is visibly much more rapid, having no observable slope, and is much less affected by the circuit decrement.

Typical values for the output circuit elements:

circuit capacitance—15 micromicrofarads
load resistance —10,000 ohms.

The author wishes to acknowledge the encouragement and interest of Professors E. O. Lawrence and R. L. Thornton and the cooperation of the laboratory staff in pursuing these investigations. He also wishes especially to thank Messrs. Bell and DeBenedetti of the Oak Ridge National Laboratory for the clear, crystallized anthracene initially used in the described tests.

* This letter is based on work performed at the Radiation Laboratory under Contract No. W-4205-eng-48 with the Atomic Energy Commission.
[1] P. Bell and R. Davis, Bull. Am. Phys. Soc. 23, No. 3 (1948).

Cloud-Chamber Study of Meson Disintegration*

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June 21, 1948

WE have recently obtained several cloud-chamber photographs at sea level showing mesons which come to rest and disintegrate. The apparatus is shown in Fig. 1. The cloud chamber (I.D. = 11 inches; illuminated depth = 3 inches) is filled with argon and ethyl alcohol to a total pressure of 100 cm Hg before expansion. A $\frac{1}{4}$-inch thick aluminum plate was placed across the diameter of the chamber to act as a slow meson absorber. The chamber is mounted between Helmholtz coils producing a field of 1680 gauss.

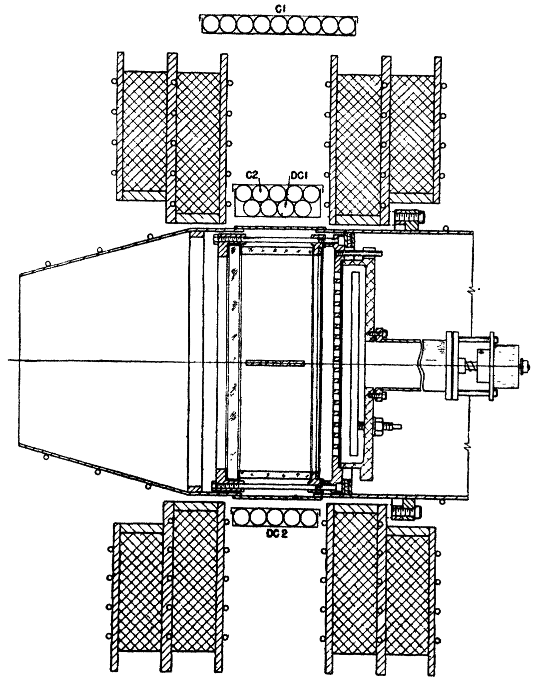

FIG. 1. Scale drawing of apparatus.

The counters are connected to a circuit which expands the cloud chamber when a simultaneous discharge in trays *C*1 and *C*2 is followed 0.7 μsec. to 4.7 μsec. later by the discharge of any one of the counters *DC*. This triggering arrangement heavily favors the detection of mesons which decay in or near the illuminated volume of the cloud chamber.

Figure 2 shows a positive meson which stops in the gas of the chamber after penetrating the plate. The track of the disintegration particle is clearly visible but is unfortunately short from the standpoint of curvature measurement.

We obtained six photographs showing positive mesons which stop in the plate. We also obtained a number of photographs in which heavily ionizing mesons which proba-

TABLE I. Momentum of the disintegration particle.

Film number	Sign of meson	Place of disintegration	Sagitta of track in mm	*pc* in Mev
77	+	plate	1.2	(20–50)
78	+	plate	3.3	42±12
84	−	glass	1.0	(70(?))
87	+	glass	3.5	53±15
89	+	gas	0.7	(20–50)
104	+	plate	3.5	43±9
106	+	plate	2.5	40±8
110	+	glass	1.5	(40±12)
111	+	plate	4.0	48±10
112	+	plate	4.0	42±8

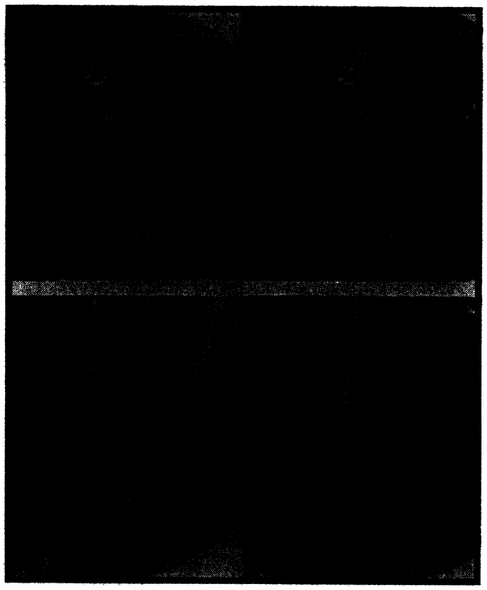

FIG. 2. Cloud-chamber photograph of a meson which penetrates a $\frac{1}{4}$-in. aluminum plate, stops in the gas (argon) of the chamber, and disintegrates with the emission of a lightly ionizing particle.

bly stop in the glass wall of the chamber are observed. In three of these, there is a thin track which is in line with the point in the glass where the respective meson stops and may therefore be the disintegration particle. Table I gives the momenta (corrected for energy loss in the plate) with estimated probable error for all the measurable photographs obtained. The momenta enclosed in parentheses are not considered very reliable because of short track length. The last five photographs were taken after improvement in technique and are considered most reliable.

The results seem to indicate a preponderance of momenta in the range 40–50 Mev/c in contrast to the results of Anderson *et al.*[1,2] who report two disintegration tracks of momenta 24 and 25 Mev/c, respectively.

The momentum of the disintegration particle is of particular interest because some information can be obtained therefrom concerning the disintegration scheme of the meson. If two particles are produced in the disintegration, conservation of energy and momentum requires that the charged disintegration particle (assumed of negligible rest mass) have a unique momentum given by the relation

$$pc=\frac{(\mu c^2)^2-(\mu_0 c^2)^2}{2\mu c^2}, \quad (1)$$

where p is the momentum of the charged disintegration particle, c is the velocity of light, μ is the rest mass of the meson, and μ_0 is the rest mass of the neutral disintegration particle. If the disintegration gives rise to more than two particles it would not be unexpected for the charged disintegration particle to have a spectrum of momenta extending from zero to a maximum value given by Eq. (1), except that μ_0 should be replaced by the sum of the rest masses of all the neutral particles produced.

The present experiment will be continued with less absorbing material between the plate and the *DC* counters, so as to reduce the possibility that the triggering arrangement significantly discriminates against low momenta.

The writer wishes to acknowledge the constant support and kind encouragement of Professor Bruno Rossi who suggested the subject of this experiment.

* This work was supported in part by the Office of Naval Research.

1 Anderson, Adams, Lloyd, and Rau, Phys. Rev. **72**, 724 (1947).
2 Adams, Anderson, Lloyd, Rau, and Saxena, Rev. Mod. Phys. **20**, 334 (1948).

Excitation Time of Silver-Activated Zinc Sulfide on Electron Bombardment*

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July 1, 1948

AN experiment designed to study the promptness with which a phosphor excited by electron impact emits visible light was performed in this laboratory. In the specific case studied, the excitation by 4-kev electrons of a Dumont 5JP11 phosphor (silver-activated zinc sulfide), the rise time of visible radiation was found to be less than 10^{-8} second, the limit set by the amplifier system employed.

A laboratory-built oscilloscope was used employing a standard 5JP11 cathode-ray tube with a silver-activated zinc sulfide screen, and a vertical-deflection amplifier with a band width of 18 megacycles. The horizontal writing speed of the oscillograph was 8 inches per microsecond, and the sweep repetition rate was 1000 per second. The electron-accelerating potential was 4 kev.

The light from the cathode-ray tube was masked by a sheet of opaque paper pasted on the glass face. A vertical slit, approximately $\frac{1}{32}$ inch wide, was cut in this mask to allow the observation of a small portion of the horizontal sweep. A type 931 photo-multiplier tube was fitted with a one-inch diameter brass collimating tube approximately 8 inches long with a $\frac{1}{16}$-inch slit at its open end. The slit in the collimating tube was aligned with the vertical slit on the mask.

The output of the photo-multiplier tube was amplified in a wide-band preamplifier which, in turn, fed the wide-band, vertical-deflection amplifier of the oscilloscope. The opaque mask was arranged to allow the vertical deflection of the sweep to be visible to the observer but not to the photo-multiplier tube.

It was observed that the cathode-ray beam did not start to deflect directly at the masking slit, but was delayed along the sweep for a time corresponding to 0.04±0.01 microsecond. The rise time of the pulse was approximately 0.015 microsecond.

The delay and rise times of the amplifier were determined as follows: A thin strip of copper foil, approximately $\frac{1}{16}$ inch wide, was cemented to the glass face of the cathode-ray tube, covering the slit in the paper mask which had provided the light source in the measurement described above.

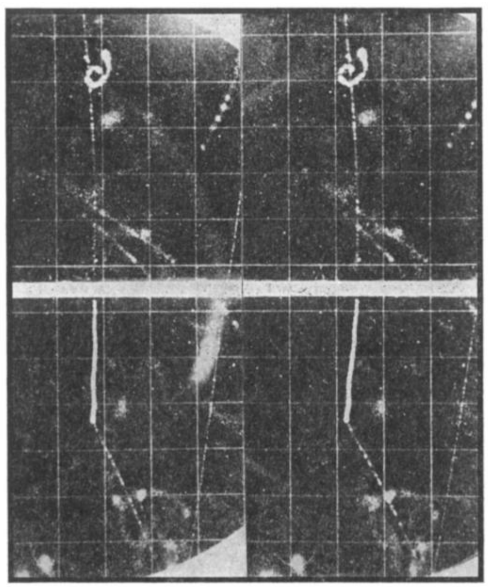

FIG. 2. Cloud-chamber photograph of a meson which penetrates a $\frac{1}{4}$-in. aluminum plate, stops in the gas (argon) of the chamber, and disintegrates with the emission of a lightly ionizing particle.