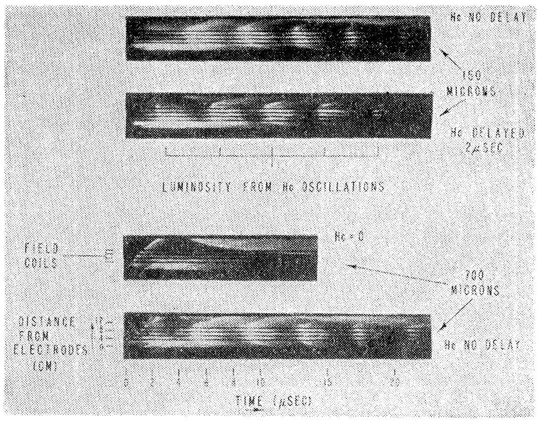

FIG. 1. Smear-camera photographs of a magnetically accelerated deuterium plasma as discussed in the text. Peak field: $H_c = 20\,000$ gauss. Tube diameter: 30 mm i.d. Primary discharge: 50 kv, 0.66 μf, 500 kc/sec.

The acceleration of a shock-heated deuterium plasma by the rising longitudinal magnetic field has been observed in smear-camera photographs. Photographs of the propagation of shock waves, with and without a pulsed magnetic field, are presented in Fig. 1. There is a marked increase in the velocity of the luminous front if the longitudinal field is switched on when the plasma passes the first turn of the coil (labeled "H_c no delay" in Fig. 1). The periodic luminosity at $\sim$4-μsec intervals is due to the oscillations of the longitudinal field.

Smear-camera photographs with the camera slit imaged normal to the direction of the field show that the plasma detaches itself from the tube walls and is compressed into the center of the tube at each half-cycle of the field oscillation as shown in Fig. 2. This radial compression brings about an increase in the internal energy of the gas behind the front leading to a corresponding increase in the longitudinal shock velocity.

The measured shock velocities 9 cm from the primary discharge (at the last coil) are given in Table I for two different ambient pressures. Temperatures estimated from the conventional Rankine-Hugoniot relations are also given in Table I. No direct measurement of the plasma temperature has yet been made so that the "temperature" should not be taken too seriously without further studies of relaxation phenomena which

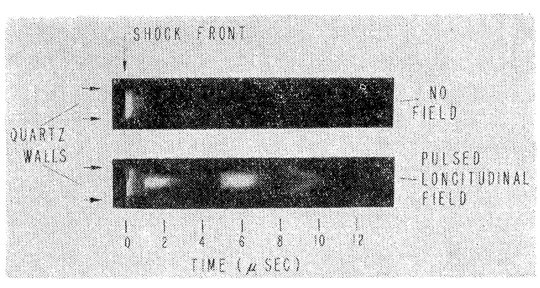

FIG. 2. Smear-camera photographs of the plasma behind a shock front with and without a pulsed longitudinal field. The field compresses the plasma into the center of the tube.

TABLE I. Shock velocities in deuterium 9 cm from the electrodes. (See Fig. 1.)

Identification in Fig. 1	Shock velocity (cm/μsec)	Rankine-Hugoniot temperature (°K)
$H_c=0$ (700 microns)	6.7±0.5	70 000
H_c no delay (700 microns)	11 ±1	240 000
H_c delayed 2 μsec (150 microns)	10 ±1	200 000
H_c no delay (150 microns)	18 ±1	700 000

determine the structure of the luminous fronts and the degree of contamination by impurities from the tube walls.

By connecting the coils in parallel, the high-conductivity shock-heated plasma successively reduces the inductance and increases the current in each turn as the front moves down the tube. Circular currents are then induced in the plasma which cause the magnetic energy density at the surface of the plasma behind the advancing front to be large compared to the magnetic energy density ahead of the shock wave. It is suggested that this mechanism is responsible for the compression and acceleration of the shock-heated plasma. With these techniques it is possible to eliminate the experimental difficulties encountered if each coil is connected to a separate condenser bank and then switched on just after the shock passes.

* This work was jointly supported by the Office of Naval Research and the U. S. Atomic Energy Commission.

1 A. C. Kolb, *Lockheed Symposium on Magnetohydrodynamics, 1956* (Stanford University Press, Stanford, to be published).
2 A. C. Kolb, Bull. Am. Phys. Soc. Ser. II, **2**, 47 (1957).
3 A. C. Kolb, Phys. Rev. **107**, 345 (1957).

Photoproduction of K^+ Mesons in Hydrogen*

P. L. DONOHO AND R. L. WALKER
California Institute of Technology, Pasadena, California
(Received July 1, 1957)

THE K^+ mesons produced in a liquid hydrogen target by the 1100-Mev bremsstrahlung of the California Institute of Technology synchrotron have been observed at several laboratory energies and angles. The K mesons are identified by means of momentum selection, a time-of-flight velocity measurement, and ionization loss in three scintillation counters. The apparatus used is shown schematically in Fig. 1.

Positively charged particles produced in the target are focused at counter C_2 by the magnetic spectrometer. Particles of momentum as high as 600 Mev/c may be focused. The momentum interval accepted, as determined by the width of C_2, is $\Delta p/p_0 = 0.100$. The solid angle of the magnet aperature is 0.0075 sterad.

Particles whose time of flight between C_0 and C_2 is correct for a K meson having the right momentum are

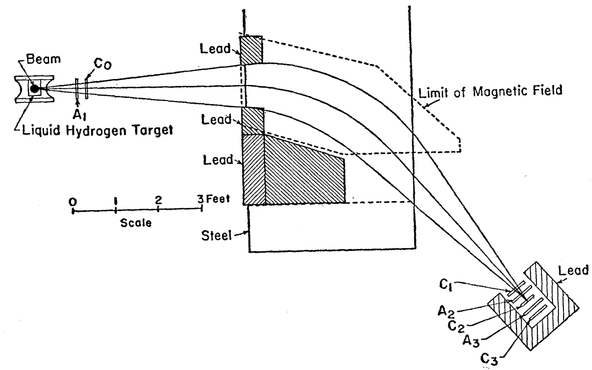

FIG. 1. Schematic diagram of the apparatus.

selected by requiring a coincidence between a suitably delayed pulse from C_0 and a pulse from C_2. These coincidences are detected by a circuit having a resolving time of approximately 4 mμsec. Since the difference in time of flight between K mesons and pions is only 4 mμsec at the highest momentum observed, not all pions could be eliminated by this means alone, and a further selection is made based on the pulse-height measurements described below. Protons of the same momentum as the K mesons being counted are stopped by absorbers A_2 and A_3. It is possible, however, that protons of higher momentum scatter from the magnet and reach C_2 with sufficient energy and the correct time of flight to be counted, and these scattered protons must also be eliminated by the pulse-height measurements. In addition, since the counting rate in C_0 is very high, owing to the proximity of the target, the accidental rate is not negligible, although it is reduced somewhat by absorber A_1, which prevents very low-energy particles from flooding C_0.

When a fast time-of-flight coincidence occurs in "slow" (0.1 μsec) coincidence with counters C_1 and C_3, the pulses in C_1, C_2, and C_3 are photographically recorded. The time-of-flight requirement results in one K particle out of 10 to 20 photographed scope traces. Most of the traces are clearly caused by pions, which are useful in giving calibrations for minimum-ionizing particles. (Without the time-of-flight requirement, and without absorbers A_2 and A_3 to stop protons, the ratios of K^+ to π^+ to protons is approximately 1:500:2000.) Since the K mesons are as little as 1.5 to 2 times minimum, the long tail of the pion pulse-height distribution makes it impossible to identify K mesons using only the pulses from a single counter. When the pulses from two of three counters are correlated, however, a fairly clear separation of K mesons from pions and protons results. Figure 2 shows counts at $\theta_{\text{lab}}=25°$ and $p=520$ Mev/c plotted according to the pulse heights in C_2 and C_3. There is definite grouping centered at the right K-meson position, as determined from the pion mean. There are some pulses of higher ionization loss probably representing scattered protons.

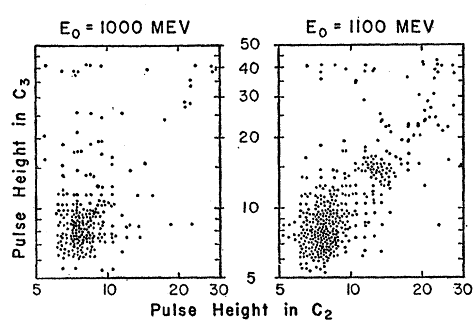

FIG. 2. Correlations in the pulse heights from counters C_2 and C_3 showing the pion peak and the cluster of points caused by K mesons. These data are for a momentum $p=520$ Mev/c and a lab angle 25°, corresponding to K mesons produced by 1060-Mev photons. The data on the left, taken with a synchrotron energy $E_0=1000$ Mev, represent the background.

If the reaction $\gamma+p\rightarrow K^++\Lambda^0$ is assumed, then the proton energy interval contributing to the K-meson counting rate is only 40 Mev. Background is measured by reducing the synchrotron energy to a point just below this interval. If the above reaction is the one taking place, no K mesons should be counted, whereas little change in the background of protons and pions would be expected. The background counting rate as measured in this way is 5 to 25% of the normal K-meson counting rate and can be attributed to K-meson production in the Mylar target wall, and to pions giving large pulses in all three counters. This low background counting rate confirms the associated photoproduction of strange particles by showing that the reaction $\gamma+p\rightarrow K^++n$ contributes less than 10% to the K^+ photoproduction. K^+ mesons from the reaction $\gamma+p\rightarrow K^++\Sigma^0$ have not been observed in this experiment because the maximum energy of the synchrotron is not high enough as yet.

TABLE I. Yields and cross sections in the center-of-mass system for K^+ particles produced in the reaction $\gamma+p\rightarrow K^++\Lambda°$.

p_{lab} (Mev/c)	θ_{lab}	E_0 Mev	k Mev	$\theta_{\text{c.m.}}$	Yield (counts/10^{15} Mev)	$\sigma(\theta_{\text{c.m.}})$ (10^{-31} cm²/sterad)
520	25.4°	1100	1060	65°	15.7±2.0	3.8±0.5
425	34.4°	1100	1060	90°	6.4±1.3	3.2±0.5
340	44.1°	1100	1060	110°	1.8±0.6	1.3±1.0
422	25.5°	1100	1000	72°	11.4±2.7	2.7±0.4
361	31.1°	1100	1000	90°	4.6±1.1	2.5±0.4
340	25.2°	1100	960	90°	4.7±0.8	2.7±0.4
			Background Runs			
520	25.4°	1000	...	...	4.2±2.1	...
425	35.4°	1000	...	...	1.0±0.8	...
422	25.5°	940	...	...	0.4±0.4	...
340	25.2°	925	...	...	1.1±0.8	...

Because of the long distance between the target and the focus of the spectrometer, the decay in flight of the K mesons causes a reduction in counting rate of 65% to 80%, depending on the momentum being observed. A further reduction in the counting rate occurs because the time-of-flight coincidence circuit is only 60% efficient.

This efficiency has been measured by comparing the counting rates for both pions and protons obtained using this circuit with those obtained using another circuit which simply requires a slow coincidence of C_1, C_2, and C_3 and which is presumably 100% efficient. The efficiency thus measured is 60% for both pions and protons and thus, by interpolation, for K mesons.

The results obtained to date are presented in Table I. In addition to the indicated statistical errors, there is a systematic error of perhaps 20 to 50% because of uncertainties in the incident photon intensity. A calibration of the beam monitor has not yet been made, and, probably more important, the bremsstrahlung spectrum is not accurately known near the cutoff energy, E_0, where most of the measurements were made. Both these calibrations will be made in the near future. Complete results of this experiment will be presented at a later date.

* This work was supported in part by the U. S. Atomic Energy Commission.

Photoproduction of K^+ Mesons from Polyethylene*

A. B. Clegg, M. P. Ernstene, and A. V. Tollestrup

California Institute of Technology, Pasadena, California

(Received July 1, 1957)

The photoproduction of positive K mesons from polyethylene by the 1.1-Bev bremsstrahlung beam of the Caltech synchrotron has been studied by using a telescope of four scintillation counters. A value for the yield of K mesons at 37.5 degrees in the laboratory has been obtained and also we have been able to distinguish the tau-decay mode from the rest of the main decay modes and find that within our experimental error it is in the same proportion to K_L decays as is found for K mesons produced in other reactions.

The K^+ mesons in this experiment were identified by means of their range, rate of energy loss, mean lifetime, and the energy loss produced by the decay particle in the counter in which they stop. A telescope consisting of four scintillation counters selected particles according to their range and rate of energy loss. Events were observed in which charged particles pass through the first two counters and stop in the third; the fourth counter was used to veto particles which passed through counter 3. Pulse-height windows were set on counters 1 and 2 corresponding to the proper energy loss for K^+ mesons, but which excluded pions and protons stopping in counter 3. Two such counters were used to improve the rejection of pions; if only one were used a proportion of the pions would not be rejected because of the larger pulses produced by the Landau effect. Fast pulses from counter 3 corresponding to a proper coincidence were displayed on an oscilloscope and photographed; the width of the pulses was 8 millimicroseconds. The film was scanned for double pulses, the first being the incoming K^+ meson and the second the outgoing decay particle. Approximately seventy of these events were found. There was a small contamination of pion decays, but we were able to confirm our observation of K^+ mesons by selecting events in which either the primary pulse was too large to be a stopping pion or the secondary pulse was too large to be the 4-Mev muon from pion decay. Secondary pulses corresponding to energy losses of up to 50 Mev in the counter were seen. We were able to select 21 events in which the secondary was definitely too large to be due to pion decay, and we found that the separations between the initial pulse and second pulse of this uncontaminated sample were completely consistent with a single lifetime. We believe these events definitely to be K^+ mesons. The mean life observed for these photoproduced K^+ mesons is 13.9 ± 3.1 millimicroseconds.

In detail, we observed to types of events:

(1) K_L decays with a small decay pulse;
(2) τ decays with a large decay pulse.

We can calculate the efficiency for seeing the former quite well and so can determine the yield. The efficiency for detection of decay pulses was computed by a Monte Carlo calculation. This calculation gave the distribution of the ranges in the counter of secondaries of K mesons stopping in the counter. This could then be converted into a pulse-height spectrum of secondaries assuming K^+ mesons to be 57% $K_{\mu2}$ and 28% $K_{\pi2}$. (The dependence of our yield on these ratios is not critical; it depends only on the assumption that most K^+ mesons decay producing one lightly ionizing secondary.) The observed spectrum, within the limitation of poor statistics, compared well with that calculated. We choose to express the yield as a cross section for the reaction $\gamma+p\rightarrow K^+ + \Lambda^\circ$, assuming all the protons in the polyethylene are free. We get a cross section of $(3.0\pm1.0)\times10^{-31}$ cm^2 steradian^{-1} for the production of 140-Mev K^+ mesons at a laboratory angle of 37.5° and a bremsstrahlung end point of 1.1 Bev. For the above reaction from free protons this corresponds to a photon energy of 1.06 Bev and a center-of-mass angle of 95°. We have not accurately calculated our efficiency for seeing τ decays, but from an estimate we can say the ratio of τ to K_L decays is 1:14 to an accuracy of a factor of two. This is the same as is observed for K^+ mesons produced by charged particle bombardment. We found the mean life for τ decay to be 12.2 ± 3.7 millimicroseconds.

A check on our method of measuring lifetimes was obtained from our pion calibration runs where we observed the mean life for π^+ mesons to be 25.4 ± 1.9 millimicroseconds.

* This work was supported in part by the U. S. Atomic Energy Commission.