$f_{S0}^{(i)}$ = fraction of time the ith observed scatter is expected to have appeared as an observed pseudostop.

$f_{10}^{(i)}$ = fraction of time the ith observed 1-prong star is expected to have appeared as an observed pseudostop.

$f_{20}^{(i)}$ = fraction of time the ith observed 2-prong star is expected to have appeared as an observed pseudostop.

$f_{21}^{(i)}$ = fraction of time the ith observed 2-prong star is expected to have appeared as an observed pseudo 1-prong star.

Having defined the above quantities, one may write down the following relations:

$$N_S r_{S0} = \Sigma f_{S0}^{(i)}/(1-f_{S0}^{(i)}),$$
$$N_2 r_{20} = \Sigma f_{20}^{(i)}/(1-f_{20}^{(i)}-f_{21}^{(i)}),$$
$$N_2 r_{21} = \Sigma f_{21}^{(i)}/(1-f_{20}^{(i)}-f_{21}^{(i)}),$$
$$(N_1+N_2 r_{21})r_{10} = \Sigma f_{10}^{(i)}/(1-f_{10}^{(i)}).$$

(The summations are carried over all the events in the categories for which the particular $f^{(i)}$'s do not vanish.)

It is now possible to calculate the value of the N's providing one makes the following two assumptions: (1) $N_0 \equiv 0$, i.e., there were no real — as opposed to pseudostops; (2) $r_{10} \approx \bar{r}_{10}$, where

$$\bar{r}_{10} = [f_{10}^{(i)}/(1-f_{10}^{(i)})]_{Av}.$$

One may now write

$$N_S = [n_S + N_S r_{S0}],$$
$$N_0 = 0,$$
$$N_1 = [n_1 + (N_1 + N_2 r_{21}) r_{10}] - N_2 r_{21}(1+\bar{r}_{10}),$$
$$N_2 = n_2 + N_2 r_{20} + N_2 r_{21}.$$

The results of these computations are displayed in Table I. The standard deviations have been determined from the number of events of each kind observed; i.e., $N_S\cdot[1\pm(1/n_S)^{\frac{1}{2}}]$, $N_1\cdot[1\pm(1/n_1)^{\frac{1}{2}}]$, and $N_2\cdot[1\pm(1/n_2)^{\frac{1}{2}}]$.

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The Mean Life of Negative μ Mesons Stopped in Iron* †

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The mean life of negative cosmic-ray μ mesons stopping in an iron absorber has been found experimentally to be 0.21 ± 0.06 μsec. The upper limit to the mean number of neutrons produced is very roughly one per meson captured by an iron nucleus.

THE development of hydrogenous scintillating liquids suitable for efficient and fast detection of neutrons in the 1 to 10-Mev range[1] has made it possible to extend measurements of the mean life of stopped negative μ mesons to materials of higher atomic number than could be studied previously with Geiger counters.[2] The scintillator is used to detect neutrons (or gamma rays) resulting from the interaction of the stopped meson with the nucleus. The time delay is measured between the arrival of the meson in the stopping material and the detection of the nuclear disintegration. An extensive experiment of this sort has recently been reported by the Princeton group.[3] The present experiment was completed before publication of the Princeton measurements on iron. Its result is in agreement with their more precise result, constituting an independent confirmation.

Figure 1 shows the geometrical disposition of the counter tubes and the absorber and also the nature of the input circuits. Counter trays A_1 and A_2 each contain ten brass-walled Geiger counters of 1 inch diameter by 25.4 cm effective length, which are connected to a two-stage pulse amplifier. Between these two trays is an iron filter 15.2 cm thick, and below them is the absorber, a 30.5 cm cube of iron. Through the middle of this cube runs a brass cylinder 2 in. in diameter and 31.6 cm long, containing a scintillating solution of 2 grams/liter of terphenyl in xylene. Two EMI 5311 photomultiplier tubes look into the ends of the column of liquid. The amplified outputs, B_1 and B_2, of these tubes are connected in coincidence to suppress noise. Underneath the absorber cube is a third tray C similar to the A_1 and A_2 trays, and containing twelve Geiger counters of 1 in. diameter by 50.8 cm effective length. This C tray covers most of the solid angle subtended by the absorber cube at the A_1A_2 telescope.

Pulses from the A_1 and A_2 trays are fed to a coincidence circuit[4] of 0.22-μsec resolving time, which produces an output signal that is fixed in time relative to the earlier of the two input pulses. This output signal is used to initiate the timing process of a ten-channel delay discriminator[5] which measures the time between signals from the A trays and the scintillation counter B. In order to minimize the timing changes caused by variations in pulse height, the amplified B_1B_2 coinci-

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[1] Jastram, Benade, Cleland, and Hughes, Phys. Rev. **81**, 327 (1951).
[2] T. Sigurgeirsson and A. Yamakawa, Phys. Rev. **71**, 319 (1947); H. K. Ticho, Phys. Rev. **74**, 1337 (1948); A. H. Benade and R. D. Sard, Phys. Rev. **76**, 488 (1949).
[3] Keuffel, Harrison, Godfrey, and Reynolds, Phys. Rev. **87**, 942 (1952).
[4] Such a circuit was first used by M. L. Sands [Rossi, Sands, and Sard, Phys. Rev. **72**, 120 (1947)].
[5] The time base of this discriminator is adapted from the Los Alamos Model 300 Sweep.

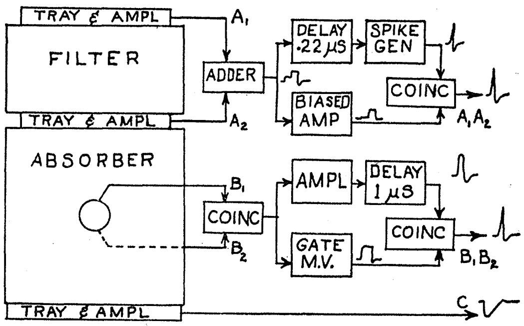

FIG. 1. Geometrical arrangement of counters and absorber, together with a representation of the input circuits.

dence signal is sent to the delay discriminator through a 1μsec delay line and a gate circuit which "opens" only if the original coincidence pulse is large enough to trigger a gating multivibrator whose rise time is much less than 1μsec. The delay discriminator is provided with a double set of registers. Events in which the particle stops or misses the C tray are recorded in the "a" set of registers, while penetrating events giving an A_1A_2C coincidence go into the "b" set. These events shown in the "b" registers give rough information on the distribution of random counter lags and instrumental timing errors. Two discriminator channels record "negative" delays of B relative to the A trays, and one records "prompt" events. A series of four channels 0.1 μsec in width begins at 0.05 μsec, these being followed by three wider channels extending out to about 1.7 μsec.

The calibration of the apparatus was based ultimately on a 2.500-Mc/sec crystal-controlled oscillator. During the experiment, time relations were known with an uncertainty from all causes of 6 mμsec or less.

The distribution of events recorded in the "a" registers of the delay discriminator is the sum of two exponentials, with mean lives τ_0 ($=2.2$ μsec) and τ_-, which are associated with the stopping of positive and negative μ mesons, respectively. The number of negative meson events occurring in the last two delay channels is negligible, so that an exponential of mean life τ_0 fitted to the data in these channels may be used to calculate the distribution of positive meson events in the earlier channels. Figure 2 shows the differential distribution of negative meson events per 0.1 μsec wide delay channel; this was obtained by subtracting the estimated positive meson component from the observed distribution of counts. It has been shown[6] that random timing errors merely change the observed amplitude, but not the mean life of an exponential distribution, provided that counting begins later than the longest possible random lag. The events occurring in the first delay channel are not shown in the figure, since the distribution of timing errors extends into this interval.

The method of Peierls[7] is used to obtain an estimate of the mean life τ_- from the data displayed in Fig. 2. The "background rate" used to estimate the uncertainty in τ_- is taken to be the average rate per tenth μsec channel of the positive-meson component. The "signal-to-noise" parameter λ is found to be 0.67 under this assumption. Because of the smallness of λ, the uncertainty was computed numerically from Peierls' Eq. (27). This calculation gives $\tau_-=(0.21\pm0.06)$ μsec, which is in agreement with the value (0.16 ± 0.03) μsec obtained by the Princeton group. The line drawn in Fig. 2 corresponds to $\tau_-=0.21$ μsec.

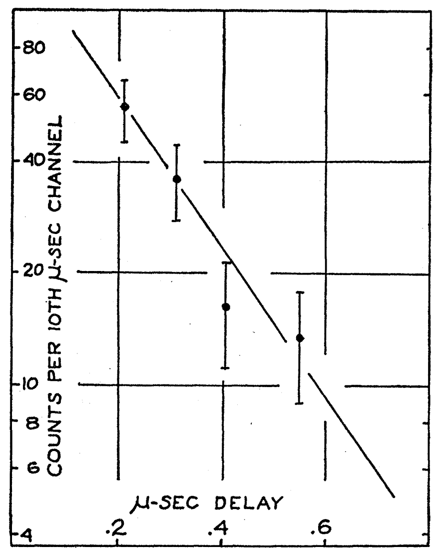

FIG. 2. Differential delay distribution of counts from stopped negative μ mesons. The line corresponds to $\tau_-=0.21$ μsec.

An upper limit to the mean number of neutrons per μ-meson interaction $\bar{m}$ is obtained by assuming that all of the delayed coincidences are due to neutrons. Measurements of the neutron detecting efficiency for a Ra-α-Be source at various places in the absorber, weighted according to the measured meson flux at each place, give

$$\bar{m}=0.5^{+0.4}_{-0.2}$$

when the effect of random timing errors is neglected. The data recorded in the "b" channels of the delay discriminator do not well determine the distribution of errors, but plausible assumptions of its form cannot raise the multiplicity figure by more than a factor of two.

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[7] R. Peierls, Proc. Roy. Soc. (London) 149, 467 (1935).