point.[4] In these measurements we showed that the concentration of He^3 in the vapor, while finite at 2.0°K, was immeasureably small at 1.82°K and quite possibly zero. The higher value for sample 5 is probably due to residual gas from sample 4 in the withdrawal line.

In view of an enrichment factor of 130 in sample 3, it appears that a very efficient He^3 separation apparatus could be designed using this heat flux method.

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[1] See Pollard and Davidson, *Applied Nuclear Physics* (John Wiley and Sons, Inc., New York, 1942), p. 183. We understand from Professor Pollard that the idea was due to Onsager. See also J. Franck, Phys. Rev. **70**, 561 (1946).

[2] J. G. Daunt, R. E. Probst, H. L. Johnson, L. T. Aldrich, and A. O. Nier, Phys. Rev. **72**, 502 (1947).

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Search for Gamma-Radiation in the 2.2-Microsecond Meson Decay Process

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THE meson decay process which is identified by a mean life of 2.2 microseconds[1] has been usually thought of as consisting of the emission of an electron and a single neutrino, as suggested by the well-known Yukawa explanation of the ordinary beta-process in nuclei. However, the Yukawa theory is at variance with the results of the experiment of Conversi, Pancini, and Piccioni,[2] and since there remains no strong justification for the electron-neutrino hypothesis,[3] a direct experiment to test an alternative hypothesis—*that the decay process consists of the emission of an electron and a photon, each of about 50 Mev*—has been performed.

The apparatus, illustrated in Fig. 1, consists of three rows of Geiger-Müller counters, A, B, and C, each having an effective area of approximately 38 cm×20 cm. Above A there are 15 cm of lead, and between A and B, 1.5 cm of lead. Mesons traversing A and B, and stopped in a graphite absorber 38 cm×19 cm×5 cm thick, produce decay electrons which may be detected in either B or C. Decay photons, if present, could also be detected in B or C, whose efficiency for gamma-radiation was increased by introducing 2.1 mm of lead between the graphite and both B and C. The twofold function of B—first, detection of the passage of a meson by a coincidence with A (event "(A, B)"), and second, detection of a decay electron (or photon) following "(A, B)"—is permitted by the circuit design. Although one of the eight counters of B (that through which the meson passed) is insensitive to the decay particle because of the long counter dead time, the use of B in this manner allows an advantageous geometry. The outputs of the three rows are mixed by circuits whose function is schematically shown in the diagram, and the following delayed events are finally recorded:

TABLE I. Delayed single and coincidence counting rates.

	$(B)_{del}$ (Counts/hr.)	$(C)_{del}$ (Counts/hr.)	$(B)_{del}+(C)_{del}$ (Counts/hr.)	$(B, C)_{del}$ (Counts/hr.)
With graphite plus lead—(104.2 hours of observation)	11.93 ± 0.34	12.26 ± 0.34	24.19 ± 0.48	0.21 ± 0.05
Without graphite plus lead—(77.2 hours of observation)	6.48 ± 0.29	4.64 ± 0.25	11.12 ± 0.38	0.43 ± 0.08
Net effect due to decay electrons from graphite plus lead	5.45 ± 0.45	7.62 ± 0.42	13.07 ± 0.62	

1. "$(B)_{del}$;" discharges of B occurring between 0.6 and 5.3 microseconds after "(A, B),"
2. "$(C)_{del}$;" discharges of C occurring between 0.6 and 5.3 microseconds after "(A, B),"
3. "$(B, C)_{del}$;" coincidences of B and C occurring between 0.6 and 5.3 microseconds after "(A, B)."

Runs were made with and without the graphite plus lead between B and C, and the results are presented in Table I. Other runs with graphite only, with lead only, and with other thicknesses of graphite and lead, were performed and these will be reported in a more complete account of the experiment. Check runs with a 1.6- to 6.3-microsecond delay gave results consistent with a mean life of 2.2 microseconds.

The observed rate $(B, C)_{del}$ could be due to the following causes:

(i) genuine electron-photon coincidences from the meson decay,
(ii) single decay electrons which traverse both B and C,
(iii) casual events.

The casual rate (iii), which is due essentially to mesons traversing B and C between 0.6 and 5.3 microseconds after an event "(AB)," has been estimated from the measured double and triple coincidence rates and from the characteristics of the circuits to be 0.22 ± 0.02 counts per hour. It is independent of the presence or absence of graphite plus lead. Effect (ii) should be detected only in absence of graphite plus lead, since otherwise the total thickness of material between B and C is of the order of the expected range of the electrons. We observe, in fact, that $(B, C)_{del}$ increases appreciably when the graphite plus lead is removed. The presence of this effect was verified by a sub-

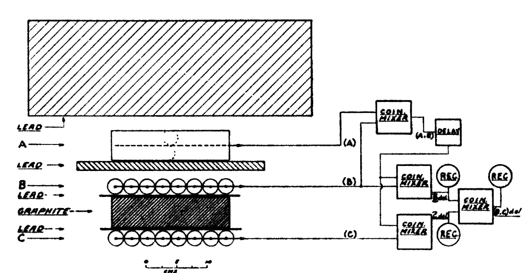

FIG. 1. Arrangement of apparatus.

sidiary experiment in which the number of decay electrons traversing both B and C was intentionally increased.

It is apparent, therefore, that the change in the contribution of effect (ii) to $(B, C)_{del}$ prevents an estimate of the contribution of effect (i)—electron-photon coincidences—being made by comparing the rates $(B, C)_{del}$ with and without graphite plus lead. However, we can compare $(B, C)_{del}$ with graphite plus lead with the estimated casual rate (iii) to conclude *that each decay electron is not accompanied by a photon of about 50 Mev*. The difference $(B, C)_{del}$ with graphite plus lead minus the casual rate is $0\begin{cases}+0.06\\-0\end{cases}$ counts per hour. We expect, on the other hand, that the contribution of effect (i), if present, to $(B, C)_{del}$ would be about one count per hour. This is a conservative estimate based on the number of single decay particles from graphite plus lead detected in B and C (13 per hour), assuming an average efficiency of 15 percent for detection of a 50-Mev gamma-ray in our system,* and taking into account losses of coincidences due to geometry.

Our negative result is consistent with the experiments on the genetic relationship[4] between the hard and soft components in the lower atmosphere. The mechanism of the 2.2-microsecond decay process remains, however, unknown. Should it consist of the emission of an electron and a neutral meson, as recent evidence[5,6] seems to indicate, the nuclear *capture* of a light negative meson may be accompanied by the emission of one neutrino, as previously suggested.[3]

* The absorption coefficient for a 50-Mev gamma-ray in lead was taken as 1 cm^{-1}. The secondary pair of electrons would be emitted in a strongly forward direction with an average range of about 10 g/cm^2.

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[4] We are indebted to Professor G. Bernardini for drawing to our attention his discussion of this subject at the Nuclear Physics International Conference, Cambridge, England (1946) and a comprehensive article by G. Bernardini, B. N. Cacciapuoti, and B. Querzoli, Nuovo Cimento **3**, 349 (1946).
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On the Phase Shift Approximation in the Theory of Pressure Broadening of Spectral Lines

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THE collision damping theory of broadening of spectral lines is still widely used in discussions of experimental results. Lately, some new contributions to this theory have been published.[1] Former attempts to give a quantum-mechanical foundation to the collision damping theory were discussed in a previous paper.[2] A new attempt in this line has been made recently by Foley.[3] According to Foley the wave mechanical theory proposed by the present writer[2] leads to the Lorentz line form for the conditions assumed in collision damping theories (phase shift approximation). Unfortunately, Foley's argument is liable to criticism. Foley adopts the distribution $e^{-T_i/T_0}/T_0$ in the parameter $T_i=R_0/v$, in which R_0 is the radius of the container, v the velocity of gas molecules, $T_0=R_0/\bar{v}$, and $\bar{v}$ their average velocity. This distribution does not result from Maxwell's distribution law[4] and thus does not correspond to the real distribution. This alone suffices to invalidate Dr. Foley's results.

But even if this incorrect distribution be adopted, further calculations, if carried out correctly, lead to results differing from those of Foley. Because of the dropping of a "numerical factor" (normalization factor, which, as inspection shows, depends on T_i!), the evaluation of "overlap" integral in phase shift approximation leads Foley to the expression

$$A(\omega_i)=\frac{\sin\omega_i T_i}{\omega_i}\quad{}^{5}$$

instead of

$$A(\omega_i)=\frac{\sin\omega_i T_i}{\omega_i T_i}.\quad{}^{6}$$

If the corrected expression for $A(\omega_i)$ is used and another factor, the density of translational energy levels[7] (also omitted by Foley) taken into account, the integral

$$\int_0^\infty dT_i\frac{\sin^2\omega_i T_i}{\omega_i^2 T_i}\frac{e^{-T_i/T_0}}{T_0}=\frac{\log(1+4\omega_i^2T_0^2)}{8T_0\omega_i^2}\quad{}^{8}$$

is obtained instead of Foley's

$$\int_0^\infty dT_i\frac{\sin^2\omega_i T_i}{\omega_i^2}\frac{e^{-T_i/T_0}}{T_0}=\frac{T_0^2}{1+4\omega_i^2T_0^2}.$$

However, the "overlap" integral in Foley's approximation may be useful in the calculations of the intensity distribution in the core of the broadened line, if "collisions" with large collision parameters (small phase shifts) are also taken into consideration. Clearly, the last type of collisions must contribute considerably to the intensity in the core of the line.

Some further remarks should be added. According to Foley, "any line broadening theory which considers a single perturbing atom and then averages over-all transitions of this system will always yield a line form which diverges at the center." Actually, the asymptotic distribution (Kuhn's distribution) obtained in the above way in the previous paper[2] diverges at the line center. However, the discussion of applicability of this distribution[2] shows that it does so only owing to the approximations made by its derivation. The same discussion shows that its applicability is not restricted to high concentrations of perturbing atoms, as supposed by Foley. It can be used up to the lowest concentrations if other factors do not cause its failure.

On the whole the situation remains as it was before the publication of Foley's paper. One has either to demonstrate rigorously that the Lorentz formula can be obtained from the quantum-mechanical theory proposed by the writer or to modify (or to reject) one of these theories.

The subsequent note by Dr. Foley obviously contains not only modifications of some of the assumptions on which his original calculations were based ($T_i=R_i/v$ with R_i