Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is five weeks prior to the date of issue. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length.

Remarks on H. W. Lewis' Paper "On the Reactive Terms in Quantum Electrodynamics"[1]

SAUL T. EPSTEIN
The Institute for Advanced Study, Princeton, New Jersey
November 25, 1947

IN connection with the results of Lewis, it should be noted that once one knows the differential cross section, $\varphi\sigma$, to the first non-vanishing order in $\alpha(=e^2/\hbar c)$ for a process in which a free particle interacts with an electromagnetic field, there is an almost trivial method for determining the correction of order α which has to be applied to this result because one has used the experimental, not the mechanical rest mass of the particle in computing it. This correction, combined with the usual radiative corrections of order α, may be expected to yield a finite result.

To find the correction we remark that the effect of a change in the particle's rest mass (that is, the difference between experimental and mechanical rest masses) on the plane waves, density of states, incident flux, and other quantities entering into the calculation of a cross section is to change the value of M, the parameter representing the mass, and through this the value of the energy defined by $E^2=C^2P^2+M^2C^4$, where P is the particle momentum. P is, of course, unchanged. Hence the first-order correction in $\varphi\sigma$, due to the mass difference δM, is

$$\delta(\varphi\sigma)=\frac{\delta(\varphi\sigma)}{\delta M}\cdot\delta M,$$

where, before differentiation, $\varphi\sigma$ has been expressed as a function only of the mass and of the momenta, and where for δM we substitute the electromagnetic rest mass of the free particle to order α, however, with a minus sign because the experimental mass is greater than the mechanical mass.

Lewis has mentioned my application of this simple method to the problem of radiative corrections to electron scattering; we will consider here the corrections to the scattering of a Pauli-Weisskopf particle by a central field. Two cases will be discussed: (I) the potential is an electrostatic potential and (II) the potential is a world scalar $V(\Lambda)\Psi\Psi^*$, Ψ, being the particle wave function.

We have, keeping just the relevant terms,

$$\varphi\sigma_I\alpha P^2+M^2C^2,$$

$$\varphi\sigma_{II}\alpha\frac{P^2+M^2C^2}{P^2+M^2C^2},$$

$$\delta M=-\frac{\alpha}{\pi M}\int K\varphi K+\cdots,$$

where the dots represent both infinite and finite terms.[2] Therefore, for small momenta

$$\frac{\delta(\varphi\sigma_I)}{\varphi\sigma_I}=-\frac{2\alpha}{\pi M^2}\left(1-\frac{P^2}{M^2C^2}\right)\left(\int K\varphi K+\cdots\right),$$

$$\frac{\delta(\varphi\sigma_{II})}{\varphi\sigma_{II}}=-\frac{2\alpha}{\pi M^2}\left(1-\frac{P^2}{M^2C^2}\right)\left(\int K\varphi K+\cdots\right)+\frac{2\alpha}{\pi M^2}\left(1-\frac{P^2}{M^2C^2}\right)\left(\int K\varphi K+\cdots\right).$$

Dancoff[3] has studied the radiative corrections to this problem. Since in I the part of $\varphi\sigma_I$ which contributes is just the product of the density of states and the incident flux, he found only finite corrections, and did not find the negative of the mass correction because, as Lewis has discussed, he used an inconsistent perturbation method. For the same reason he did not find the negative of the first term in II. However, he does find the nagative of the second term (when the electrostatic terms found by Lewis are included) plus finite terms. Thus, we see that by considering all the corrections we get a finite result in both cases, removing the anomaly found by Dancoff.

Clearly this same procedure will be helpful in determining the mass corrections in Compton scattering, bremsstrahlung, and other processes.

I would like to thank H. W. Lewis and Professor J. R. Oppenheimer for many stimulating discussions.

[1] H. W. Lewis, Phys. Rev. 73, 173 (1948).
[2] V. Weisskopf, Phys. Rev. 56, 72 (1939).
[3] S. M. Dancoff, Phys. Rev. 55, 959 (1939).

On the Mean Life of Negative Mesons

G. E. VALLEY AND B. ROSSI
Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts
November 24, 1947

THE cloud-chamber apparatus, previously described by one of us,[1] has been reconstructed in such a way as to allow measurement of the decay times of individual positive or negative mesons which stop in the specimen block S (compare Fig. 1, reference 1). The time-measuring apparatus is in principle similar to that described by Rossi and Nereson.[2,3]

The decay time is registered by a ballistic meter which is photographed on the same picture as is the cloud chamber.

With this apparatus we have observed that slow mesons of both signs decay in a specimen of type 61-S Duralumin (98 percent Al, 1 percent Mg) and have succeeded in accumulating sufficient data to make rough determinations of the mean lives of the positive and negative mesons.

Our results are shown in Fig. 1 in the form of integral decay distributions. When analyzed by the method of Peierls[4] the mean lifetime is, for the positive mesons 2.19 ±0.24 microseconds, and for the negative mesons 0.74 ±0.17 microsecond.

During the experiment, 32 negative and 147 positive mesons were observed to decay after 1.1 microsecond from their time of arrival at the apparatus. This is in agreement with a previous finding of Bernardini and Pancini[5] to the effect that in aluminum both positive and negative mesons decay, but that the *observed* number of positive decays is considerably larger than that of negative decays.

Our value for the mean lifetime of positive mesons is in agreement with previous determinations of the mean lifetime of mesons brought to rest in absorbers of high atomic number; in this case it is known that only positive mesons give rise to delayed emission of decay electrons. According to our results, the composite decay curve of positive and negative mesons in aluminum is the sum of two exponentials. However, the fact that within the experimental accuracy the decay curves in aluminum published by Nereson and Rossi[1] and by Ticho[6] can be represented by a simple exponential for times longer than one microsecond, does not contradict our findings because at one microsecond the number of surviving negative mesons is a small fraction of the number of surviving positive mesons. For the same reason it would not be expected that this effect would have been detected by Sigurgiersson and Yamakama.[7]

From the approximate equality in the number of positive and negative mesons in the atmosphere it is known that the natural lifetime of negative mesons cannot be appreciably shorter than that of positive mesons. The large difference which we find between the *apparent* lifetimes of positive and negative mesons in aluminum can be explained easily if one assumes that mesons may be captured by nuclei. This nuclear capture process will only take place for negative mesons because the electrostatic interaction brings negative mesons close to the nuclei and keeps positive mesons away. If $\tau 0$ is the mean lifetime before decay (which is here assumed to be exactly the same for positive and negative mesons) and τc is the mean lifetime of negative mesons before capture, the apparent mean lifetime of negative mesons, τa, is given by the expression $1/\tau a=1/\tau 0+1/\tau c$.[8] Under the same assumption, the fraction of negative mesons which undergo spontaneous decay is $f=\tau a/\tau 0$. With the values of $\tau 0$ and τa quoted above, one obtains $f=0.36\pm 0.08$. On the other hand, extrapolation of the decay curves of negative and positive mesons to $t=0$ gives the following value for the ratio N^-/N^+ between the numbers of negative and positive mesons which give rise to delayed coincidences: $N^-/N^+=0.6\pm 0.2$. This ratio does not represent the exact fraction f of negative mesons which decay in aluminum because (1) positive mesons are slightly more abundant than negative mesons, (2) some of the mesons are absorbed in the brass walls of the counters rather than in the aluminum, (3) the natural time lags of G-M counters slightly affect the absolute number of observed delayed coincidences. After correcting for the above effects, one obtains for f the value: $f=0.7\pm 0.25$, which is greater than that calculated on the basis of the observed mean lifetimes. Not much weight, of course, can be attached to this discrepancy until the statistical errors have been reduced by further experiments which are now in progress. Also the possibility that the apparatus may discriminate in favor of negative mesons has not yet been carefully tested. If the discrepancy were confirmed, it might be interpreted to indicate that the nuclear capture of negative mesons is often accompanied by the emission of particles which can be detected by the G-M counters. Another interesting possibility is that negative mesons are never captured by nuclei, but that their natural lifetime is shortened by the proximity of the nucleus, perhaps on account of the strong electric field existing in this region. If this is the case, the fraction f should turn out to be one, a value consistent with our determinations. The assumption that negative mesons do not undergo nuclear capture would explain the failure to detect stars at the end of meson tracks in cloud-chamber pictures, and would also be in agreement with the recent results of Lattes, Occhialini, and Powell.[9] However, some of Rasetti's early results[10] may be difficult to explain under the hypothesis that in heavy elements the disappearance of a meson is always accompanied by the emission of a decay electron.

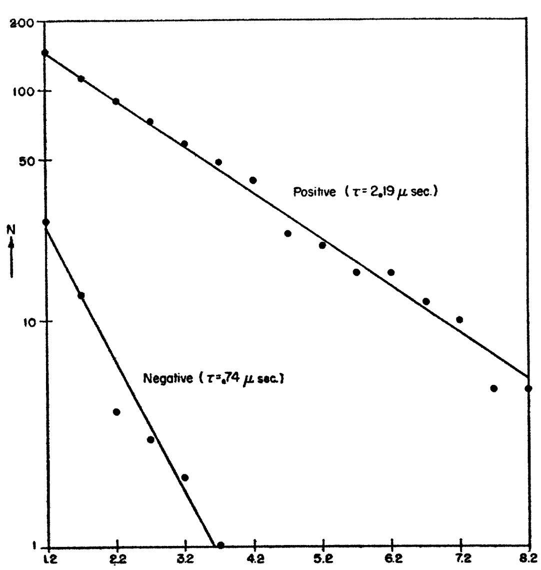

FIG. 1. Integral decay plots for positive and negative mesons which have been stopped in aluminum.

This work was supported in part by the Office of Naval Research, Contract N5 ORI-78, U. S. Navy Department.

[1] G. E. Valley, Phys. Rev. 72, 772 (1947).
[2] B. Rossi and N. Nereson, Phys. Rev. 62, 417 (1942).
[3] N. Nereson and B. Rossi, Phys. Rev. 64, 199 (1943).
[4] R. Peierls, Proc. Roy. Soc. 149, 467 (1935); Dr. Peierls has kindly extended the scope of these calculations for us in a private memorandum.
[5] The writers are much indebted to Dr. Bernardini and Dr. Pancini for a private communication of this still unpublished result, which concentrated their interest upon aluminum.
[6] H. K. Ticho, Phys. Rev. 72, 255 (1947).
[7] T. Sigurgiersson and A. Yamakama, Phys. Rev. 71, 319 (1947).
[8] The thought that the apparent lifetime of negative mesons must be different from their natural lifetime if a competition exists between spontaneous decay and nuclear capture, appears to have occurred independently to various physicists, including the writers. It has been described by H. K. Ticho and M. Schein in a recent letter to this journal. (Phys. Rev. 72, 248 (1947).)
[9] C. M. G. Lattes, G. P. S. Occhialini, and C. F. Powell, Nature 160, 453 (1947).
[10] F. Rasetti, Phys. Rev. 60, 198 (1941).