LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

Decay of Negative Mesons in Matter

A VERY drastic change in the present conception of the interaction of mesons with atomic nuclei was suggested by Fermi, Teller and Weisskopf[1] as a result of the experiments by Conversi, Pancini and Piccioni[2], who observed the behaviour of positive and of negative cosmic ray mesons coming to rest in iron or graphite. They find that in iron, disintegration electrons are observed only for positive mesons. According to Tomonaga and Araki[3], this is to be expected because negative mesons—in contrast to positive ones—after being slowed down can approach the nucleus and be absorbed by it in view of the strong interaction postulated by Yukawa to explain nuclear forces. In graphite, on the other hand, decay electrons were observed from both positive and negative mesons. Fermi *et al.* concluded that this was in sharp disagreement with expectation, because according to their estimate it takes only about 10^{-12} sec. until a negative meson in a solid reaches its lowest orbit, from which it should be captured by the nucleus in less than 10^{-18} sec. Since the natural decay time is only 10^{-6} sec., they conclude that from negative mesons no decay electrons should be expected, in contrast to the experimental evidence in graphite.

To calculate the slowing down of mesons with an energy below 2,000 eV. (that is, with smaller velocity than that of the electrons of the solid) these authors use a Fermi gas of free electrons as a model of the solid. I wish to point out that, for non-conductors in any event, this model does not seem to be adequate, and that a better model might be obtained in this case by using an assembly of electronic oscillators as a model of the solid. That this model leads to results entirely different from the free-electron model follows from the fact that a point charge e moving with constant velocity v transfers energy proportional to v^2 to free electrons, but proportional to exp $(-a\omega/v)$ to an oscillator (frequency $\omega/2\pi$, closest approach a) if $a\omega \gg v$. In this connexion a result obtained by Pelzer and me[4] may be of interest. A point charge moving with constant velocity v through a dielectric with dielectric constant ε having a proper frequency $\omega/2\pi$ transfers to it energy at a rate

$$\frac{\varepsilon - 1}{\varepsilon}\,\frac{e^2}{a_0}\,\omega\gamma e^{-2\gamma}, \text{ approximately,}$$

if $\gamma = a_0\omega/v \gg 1$. Here a_0 is of the order of the zero-point amplitude of the oscillators of which the dielectric is composed. Taking $e^2/a_0 = 10$ eV., $\omega = 10^{16}$ sec.$^{-1}$, $(\varepsilon - 1)/\varepsilon \simeq 1$, and $\gamma = 15\,(13)$ (= ratio of velocities of electrons and mesons of equal energy) yields a rate of loss of only 10^5 (10^7) eV. per sec.

No doubt this crude method of calculation requires considerable improvement to obtain quantitative results. It serves, however, to show (i) that the model of oscillators leads to times of slowing-down which are larger by many orders of magnitude than those of a free-electron model, and (ii) that the rate of loss of energy is a quantity which (in view of the exponential factor) is very sensitive towards variation of $a\omega/v$ and may lead to slowing-down times just above or below the decay time of mesons. It seems possible that even in metals a modification of the method used by Fermi *et al.* might be necessary, taking account of the screening of the charge of the moving meson.

Therefore it seems that the drastic change suggested by Fermi, Teller and Weisskopf[1] need not be contemplated at present, but that very detailed calculations will be required to make predictions about the slowing-down time of mesons.

I wish to express my thanks to my colleagues of this Laboratory for interesting discussions.

H. FRÖHLICH

H. H. Wills Physical Laboratory,
University of Bristol,
Royal Fort, Bristol.
June 23.

[1] Fermi, Teller and Weisskopf, *Phys. Rev.*, **71**, 314 (1947).
[2] Conversi, Pancini and Piccioni, *Phys. Rev.*, **71**, 209 (1947).
[3] Tomonaga and Araki, *Phys. Rev.*, **58**, 90 (1940).
[4] Fröhlich and Pelzer, E.R.A. Report, to be published.

Definition of Nuclear Quadrupole Moments

THE quadrupole moment of a nucleus is usually defined[1] as "the quantity $(3z^2 - r^2)_{Av}$, where the average is taken over the nuclear charges for the state which has the maximum component of spin I in the z direction". This seems to imply that the average is taken over all the protons in the nucleus; but if this be so, it is impossible to reconcile the measured values of nuclear quadrupole moments quoted by Mattauch[2] with current ideas of nuclear size. Thus the quadrupole moment of tantalum is reported to be 6×10^{-24} cm.^{2}, which seems incompatible with a nuclear radius of about 9×10^{-13} cm. It seemed desirable, therefore, to examine carefully the derivation of the measured values.

All the quadrupole moments so far measured have been determined spectroscopically by analysing the deviation of the hyperfine structure from the interval rule. In all cases the calculation has depended ultimately on the theoretical work of Casimir[3]. Reference to Casimir's essay reveals that he defines the quadrupole moment as $Q = \int\rho(3z^2 - r^2)d\tau$, where ρe is the charge density of a volume element $d\tau$ and the integral is taken over the whole of the nucleus. Casimir calls this an average and writes it $\overline{(3z^2 - r^2)}$; but the use of the term 'average' in this context appears to have caused some confusion, for the following reason. If the quadrupole moment is regarded as due to a single proton, the remaining protons being assumed to have a spherically symmetrical distribution and therefore contributing nothing to the integral, then Q as so defined is the average value of $(3z^2 - r^2)$ for that proton. On the other hand, if each proton in the nucleus is regarded as contributing to the quadrupole moment, then the average value of $(3z^2 - r^2)$ over all protons is Q/Z, where Z is the total number of protons. Thus each of the quantities Q and Q/Z can, with some justification, be called an 'average' of $(3z^2 - r^2)$, depending on the system over which the average is taken. If one bears in mind that the quantities which have been measured experimentally are the values of Q, and not of Q/Z, they are seen to be of the expected order of magnitude.

It should be pointed out that whereas most writers on the subject adopt Casimir's convention in calling Q the 'average', this is not universally so. For example, Feather[4] explicitly defines the quadrupole