Problems concerning the measurement of mass of mesons

The necessity of separation of function in the particular case involving measurements of ionization density is apparent from the aspect of ionization also. For measurements to the order $1\%$, methods not involving counting of drops fail; that based on the frequency of agglomeration of drops, statistically, that based on total scattered intensity of light from dense tracks for several reasons, but particularly because this intensity is so sensitive to the exact age of track under conditions when diffused drops are competing for water. Drop-counting requires for statistical purposes a count of about $10^4$ drops and is particularly sensitive to exact composition of chamber gas. It is certain that to achieve the required accuracy, ample diffusion of drops must be allowed to a degree far beyond what is tolerable in a momentum-measuring chamber, while for any probable size of chamber the lightest gases are useless on account of low specific ionization.

Since momentum measurements are a necessary feature of any exact mass determination, it is useful to draw special attention to the chamber distortions, which are comparable in importance with, but much less well understood than, the normal multiple scattering, for which the valuable derivations due to E. J. Williams (1940) are now universally applied. Work in London and Manchester (Blackett and Brode, 1936; Blackett and Wilson, 1937; Wilson, 1938) has shown that, in a chamber designed for precision work, distortions arise mainly from convective drift existing before expansion, and that under careful control these distortions are small and lead to a Gaussian spread of curvature errors. The reduction of distortion to this straightforward form is of the highest value, and is greatly to be preferred to any error distribution with a long "tail" of large distortions; for we are not primarily dealing with our data statistically; tracks are selected precisely because, relative to other factors, they are of unexpected curvature, while unless distortion is gross, there will be no internal evidence concerning it on a single photograph. It is essential that any photograph, selected because it shows some unusual curvature, shall be known to be a normal member of a family with known distortion properties.

REFERENCES


THE ABSORPTION OF SLOW MESONS BY AN ATOMIC NUCLEUS

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Yukawa and Okayama (1939) showed theoretically that very slow mesons (those practically at rest) have a considerable probability of being absorbed before decaying. Later Araki and Tomonaga (1940) pointed out that the sign of the electric charge of the meson has a decisive importance in the process of absorption, owing to the Coulomb interaction with the nuclear charge. They
showed that the absorption probability of a positive meson is negligible and that, therefore, all positive mesons should decay. Negative mesons, however, have (when at rest) an absorption probability which is very nearly unity; this probability is large, not only in condensed matter but also in a gas.

This prediction of Araki and Tomonaga seems to be confirmed by the following facts:

(i) All mesons which have been observed to decay in a cloud chamber were of positive sign (Kunze, 1933; Williams and Roberts, 1940; Shutt et al., 1942). Further, none of the negative mesons which have been observed to stop in a cloud chamber was found to emit a decay electron (Nishina et al., 1937; Maier-Leibnitz, 1939; Shutt et al., 1942).

(ii) As pointed out first by Rasetti (1941), only about one half of the mesons which come to the end of their range disintegrate (with a lifetime of the order of microseconds).

(iii) Rasetti’s result has been confirmed by a recent experiment by Conversi, Pancini and Piccioni (1945). These authors have shown directly that at rest the positive meson has a much greater probability of disintegrating than the negative meson. This result is a direct proof that negative mesons are absorbed by nuclei before decaying when at rest. Indeed, the only alternative explanation of this result would be to assume that negative and positive mesons have very different lifetimes for radioactive decay. But such an assumption does not appear to be compatible with cosmic-ray observations.

Suppose, therefore, that the negative mesons are in fact absorbed by nuclei. The question arises as to what happens to the rest energy of the meson. A priori there are two possibilities in agreement with the conservation of energy:

(i) The total amount of the rest energy of the meson (about 100 Mev.) is spent on exciting the nucleus.

(ii) A considerable amount of the rest energy of the meson “escapes” and is not absorbed by the nucleus. This second case would arise if either a high-energy neutron or a γ ray (“ radiative capture”) were emitted in the process of absorption. The emission of a “neutretto” could also be considered.

In the first case, i.e. excitation of the nucleus, one would expect a priori that the high excitation energy would lead to the emission of at least one proton with high probability, particularly in the case of light nuclei. There are some cloud-chamber photographs (Nishina et al., 1937; Maier-Leibnitz, 1939; Shutt et al., 1942) apparently showing a negative meson at the end of its track, but none is known which shows a proton starting from the end of the meson track.

It appears to be worth while, therefore, to consider more closely the theoretical aspect of the different possible mechanisms of absorption of slow mesons in nuclei. Up to the present this problem has been discussed as a one-body problem (Yukawa and Okayama, 1939). It does not seem quite certain that such a procedure can give the right order of magnitude of the probability for the different mechanisms of absorption of slow mesons by nuclei.

To obtain the simplest test of this point, we have discussed the comparatively simple problem of the absorption of a meson by a deuteron. The results of this discussion seem to justify the doubts about the one-body procedure and appear to
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give some useful information on the more general problem. The calculations have been performed only for the case of mesons of spin zero because it seems unlikely that the cosmic-ray meson has spin one (Christy and Kusaka, 1941).

The chief results are the following:

(a) The cross-section for absorption by a deuteron depends very much on the assumptions about the isotopic spin dependence of nuclear forces. For instance, the cross-section for capture of a slow pseudoscalar meson without emission of radiation is given by

\[ \sigma = \frac{4\pi g^2 e^2 \mu^2 \sqrt{e}}{3c^2 M_{12}^2 p_0 K^2} \]

\[ \cdot \begin{cases} 0.64 \text{ "symmetrical" forces} \\ 0.16 \text{ "neutral" forces} \end{cases} \]

Here \( \mu \) is the mass of the meson, \( M \) the mass of the proton, \( e \) the binding energy of the deuteron, \( K \) the momentum of the meson, \( p_0 \) the momentum of either neutron after the capture of the meson, \( g \) is one of the coupling constants of the interaction between the meson field and the nucleon (dimension of an electric charge; the other constant, involving only a relativistic part of the interaction, has been assumed equal to zero). Further, the ratio of radiative capture probability to non-radiative capture is about 0.3 for symmetrical forces and 1 for neutral forces.

(b) Selection rules for the absorption of mesons arise, not only from the necessity of conservation of parity and angular momentum, but also because the wave function of the nucleons must be anti-symmetrical with respect to all the variables (position, spin and charge). We wish to emphasize that it is completely impossible to account for (b) in the one-body picture and that the neglect of (b) may in certain cases give a wrong result by several orders of magnitude. For instance, taking (b) into account, one finds that the probability of absorption of a scalar meson is in general much smaller than the probability of absorption of a pseudoscalar meson. This result, which could not be foreseen without considering (b), may be interesting because it may suggest a method of deciding whether the cosmic-ray meson is scalar or pseudo-scalar.

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