H - I . PHOTOGRAPHIC - POST-DISCUSSION.

C.F. Powell.

The discussion reported above did not allow time for a summary of the main conclusions which follow from it, and I have been asked to make a brief appraisal of the present position :

I) Of the heavy charged mesons with masses in the interval between 900 and 1 500 m_e, it is established that particles of mass $970 \pm 5\ m_e$ exist which decay into three π mesons. The particles are referred to as τ mesons ; $\tau \rightarrow 3\pi$. Seventeen examples have been recorded in photographic plates, in all of which the particles decay "at rest". Of the 51 secondary π -particles from these events, eleven have been observed to reach the end of their range. Eight of them have thus been identified as positive, and three as negative, π -particles. This fact, and the observed co-planarity of the directions of emission of the three π -particles from each decaying τ -meson, makes it very probably that all, or most, of the particles which decay in this mode when arrested in photographic emulsions, are positively charged.

A few examples of the decay "in flight" of τ -mesons have been observed in Wilson chambers. In one case, the parent particle was negatively charged. The τ -mesons observed in cloud-chamber occur infrequently compared with charged V-particles. $N_{\tau^\pm}/N_{V^\pm} \sim 1/20$.

2) It is established that some heavy mesons, when arrested in photographic emulsions or in metal plates, decay with the emission of μ-mesons. This follows, on the one hand, from the direct observation of the β -decay of the secondary mesons, or from mass-measurements in photographic plates ; and, on the other hand, from experiments with expansion chambers in which the secondary particles are observed to traverse a total distance equal to several "interaction-lengths" in metal plates, without giving decisive evidence for a nuclear interaction.

The energy of the secondary μ -meson varies widely, - from very low values up to at least 200 Mev. It is therefore necessary to assume that the μ meson is accompanied by at least two neutral particles. Particles decaying in this mode are referred to as κ -mesons ; $\kappa \rightarrow \mu$ + 2 neutral particles.

3) Experiments with photographic plates suggest that heavy mesons may sometimes decay with the emission of a π -meson of energy $\sim$ 110 Mev. The evidence is not decisive ; it receives no support from observations with cloud chambers, but the latter are not inconsistent with the view that heavy mesons sometimes decay in this mode.

Since the energy of the secondary π -mesons appears to be unique, the transformation is written, tentatively : $\chi \rightarrow \pi$ +1 neutral particle.

4) Experiments with Wilson chambers indicate that photons with energy of the order of from 100 to 200 Mev are sometimes produced in the decay of heavy mesons. The photons, detected by the small cascades of electrons to which they give rise, appear to recoil from the secondary charged particle. The observations are compatible with a decay into two particles only, a charged particle and a photon, but this interpretation does not necessarily follow from the observations and must be treated with reserve.

5) All the direct measurements, made hitherto, of the mass of heavy charged mesons which come to rest and decay into a single charged particle are consistent with the view that all the particles have masses near, or equal, to that of the τ-meson. This result if taken alone, makes it permissible to assume, tentatively, that the particles, distinguished phenomenologically as τ, κ and χ-mesons, represent alternative modes of decay of particles of a single type, but it does not prove this assumption to be true.

6) There are two pieces of experimental evidence which suggest that among the κ-particles there are some which have masses significantly greater than that of the τ-meson :

I) The observation of the maximum energy of the μ-mesons produced in the decay of κ-mesons. If the κ-meson has a mass 970 m_e, the maximum energy of the μ-mesons, set by the conservation laws and assuming both neutral particles to have negligible rest-mass, is $\sim$ 150 Mev ; the corresponding values of p and $p\beta$ are $\sim$ 233 Mev/c and $\sim$ 211 Mev/c, respectively. Observations by expansion-chambers give no evidence for secondary particles with energies greater than this limit. In the other hand, measurements with plates provide several examples in which the secondary particles appear to have values of $p\beta$ substantially greater than that corresponding to the limit. It is well known that determinations of $p\beta$ by the scattering method can give high values due to statistical fluctuations. The probability that the high values in question are to be so interpreted appears, however to be small - less than I %.

To bring these observations into accord with the assumptions that $\tau \equiv \kappa$; or that $m_\tau \sim m_\kappa$, it is necessary to assume either (a), that there are unsuspected systematic errors in the measurements ; (b), that they are due to rare statistical fluctuations ; (c), that they are due to alternative physical processes other than those considered, or (d), to a combination of one or more of these factors.

(II) The measurements of Daniel and Perkins on the masses of heavy mesons directly emitted from nuclear disintegrations give a mean value of about 1210 m_e; and there are no individual values in the mass"spectrum"less than 950 m_e.

It is reasonable to assume tentatively that the fact heavy mesons created in the high-energy events are identical with those with approximately the same velocity, observed in experiments with Wilson chambers, which appear to have masses of the order of 920 $\pm$ 40 m_e. The latter values are not significantly different from those of the slow particles discussed in (5).

The above apparent contradiction in the mass values can be resolved, and the assumptions that $\tau = \kappa$, or that $m_\tau \sim m_\kappa$, can be maintained, if it is assumed that the mass measurements of Daniel and Perkins are subject to unrecognised systematic errors. Alternatively, it may be assumed that the heavy particles of mass $\sim$ 1210m_e are indeed emitted from high-energy disintegrations, but that they decay in flight, with a mean lifetime of the order of 3×10^{-11} secs, and transform into particles of mass 970 m_e. In general, such a transformation should lead to a deviation in the track of the particle, but the deviations may be small if most of the difference in mass appears as the rest-mass of the secondary neutral particle or particles.

Nuclear Capture of Negative Heavy Mesons.

There appears to be a large disparity between the number of heavy mesons observed to decay in nuclear emulsions and the number which interact nuclei. The evidence obtained with Wilson chambers shows that positively and negatively charged V-particles occur with approximately equal frequency. Since the particles appear to be directly created in nuclear interactions, it would be reasonable to assume that they are strongly interacting. If so, when arrested in solid substances, they would be expected to produce observable disintegrations. Very few such disintegrations have been found, altough many laboratories have made a well-directed search.

It is difficult to make a reliable estimate of the ratio of the number of heavy mesons decaying to the number producing a recognised nuclear interaction because of the different methods of search employed in different laboratories, but a conservative estimate suggests that it is at least five to one. If the particles observed to decay are all positive, it then follows that only about a fifth of the negative heavy mesons, when arrested in photographic emulsions, produce effects due to nuclear capture comparable with those due to negative π-mesons.

Conclusions.

In this situation it appears premature to attempt to give final answer to many questions of great interest and importance, especially as observations of much greater precision will soon be made with the new techniques described at the conference. Among many interesting experiments, the following appear to be particularly important :

I) Accurate measurements of the masses of heavy mesons, (a), by the momentum-range method using expansion chambers ; and (b), by the various methods employing photographic emulsions, in the new and much more favourable conditions given by the use of "stripped" emulsions. Mass measurements are particularly important in cases in which the nature of the secondary charged particle can be established.

2) Measurements of greater precision on the mass and distribution in energy of the secondary charged particles found in the decay of heavy mesons.

3) Observations on the γ-radiation emitted in the decay of heavy mesons in order to decide whether it is compatible or not with the two body-decay of heavy mesons ; and whether it must be attributed to a recoiling γ-ray or, alternatively, to the emission of a π°-meson.

4) Observations of greater statistical weight on the mass of heavy mesons emitted from high energy nuclear disintegrations, their mean lifetime and their interaction-length.

5) Observations of greater statistical weight on the frequency of occurence of the nuclear interactions of heavy mesons at the end of their range in comparison with the number decaying, and on the detailed characteristics of the resulting disintegrations.