A. A. Komar. *ψ-Particles: The Experimental and Theoretical Situation.* The general term "ψ particles" pertains to a group of recently discovered unstable bosons with masses ranging from 3 to 4 GeV and lifetimes 2–3 orders longer than the usual lifetimes of heavy hadrons.[1)] The first two terms of this set ψ(3095) and ψ(3684) were discovered at the end of 1974.[2)] During the past year, several more particles belonging to this group have been discovered[3–6]: ψ(2750), ψ(3410), and ψ(3510); there are also references to the existence of ψ(3550). Unstable boson formations ψ(4100) and ψ(4450) with widths that are now typical for massive hadrons, although they may be genetically related to ψ particles with smaller masses, have also been registered.

The interest in ψ particles is due primarily to their relative stability, which is unusual for such heavy elementary particles. The properties of ψ(3095) and ψ(3684) have now been studied in detail. The aggregate of the data indicates that these particles are hadrons: the conservation laws characteristic for strong interactions are observed in their interaction with other hadrons. The interaction cross sections of the ψ particles that have been studied have been found to be about an order smaller than the cross sections of known hadrons. Thus, the total cross section of interaction of ψ(3095) with nucleons at energies ~100 GeV is estimated at 1 mb.

There is every reason to believe that the other ψ particles are also hadrons, since they form from ψ(3095) and ψ(3684) when the latter emit a γ quantum (Fig. 1), i.e., as a result of minor restructuring.

The concept in which the ψ particle is a bound system consisting of a heavy quark and an antiquark and assigned the new quantum number "charm" is currently dominant in treatment of the nature of ψ particles. In this treatment, the smallness of the decay widths of ψ particles is explained by the small annihilation probability of heavy quarks, which may be due dynamically

1)That is, we are concerned with lifetimes of 10^{-20}–10^{-21} sec and, accordingly, decay widths of 0.1–1 meV.

2)For a detailed description of the situation early in the study of ψ particles, see[1,2].

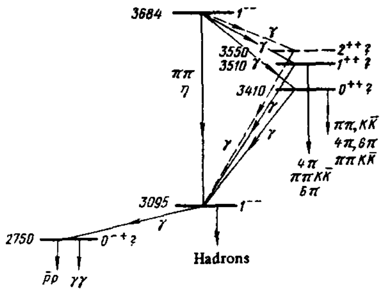

FIG. 1.

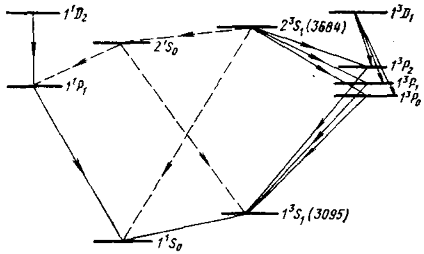

FIG. 2.

to an asymptotic-freedom effect (for details see[1,2]).

The recent discovery of new ψ particles [ψ(2750), ψ(3410), and ψ(3510)] was an important confirmation of the concept of the ψ particle as a bound system of heavy quarks, since it was *predicted*[7–8] on the basis of theoretical analysis of the energy spectrum of these systems that ψ particles will exist with masses intermediate between the masses of ψ(3095) and ψ(3684) and with a mass smaller than the mass of ψ(3095) (Fig. 2). The theory also indicated an important role of radiative transitions between ψ particles because of the suppression of hadron decays.

Validation of the above treatment of the nature of the ψ particle will mean recognition of the existence of the new "charm" quantum number in the physics of strong interactions and the prediction of a new class of elementary particles that are explicit charm carriers: "charmed" particles. Their masses are estimated at 2–3 GeV on the basis on data on the ψ particles. We do not yet have reliable direct evidence of the existence of "charmed" particles (except for isolated cases), but there are various interesting indirect indications of their existence, for example in two-muon neutrino processes.[9–10]

The discovery of the ψ particles was clear evidence of the complex structure of the world of elementary particles, indicated the possible existence of a whole sequence of new quarks, and once again underscored the importance of studying processes that unfold at high and ultrahigh energies.

[1]M. K. Gaillard, B. W. Lee, and J. L. Rosner, Rev. Mod. Phys. 47, 277 (1975).
[2]V. I. Zakharov, B. L. Ioffe and L. B. Okun', Usp. Fiz. Nauk 117, 227 (1975) [Sov. Fiz. Usp. 18, 757 (1976)].
[3]W. Braunschweig *et al.*, Phys. Lett. B57, 407 (1975).
[4]W. Tanenbaum *et al.*, Phys. Rev. Lett. 35, 1323 (1975).
[5]J. Heintze, DESY Preprint 75/34, September 1975.
[6]B. H. Wiik, DESY Preprint 75/37, October 1975.
[7]T. Appelquist *et al.*, Phys. Rev. Lett. 34, 365 (1975).
[8]E. Eichten *et al.*, *ibid.*, p. 369.
[9]A. Benvenuti *et al.*, *ibid.* 35, 1199.
[10]A. Benvenuti *et al.*, *ibid.*, p. 1203.

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