STATISTICAL QUESTIONS IN MESON THEORY

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The questions we are going to discuss have to do with the use of statistical methods in meson theory, when we perform certain calculations in an area in which the theory is most certainly wrong. In order, therefore, to lend some degree of reality to the discussion, it is probably well to begin with the experimental framework within which these problems arise.

It was found, about two decades ago, that the forces which act between nuclei, and between the individual components of a nucleus, exhibit the peculiarity that they are only operative when the particles involved are very close together (about 10^{-13} cm, or a ten billionth of the tip radius of a microgroove phonograph needle). At that time, the only forces which were known to act among particles of matter, the gravitational and electrical forces, both obeyed (and still obey) an inverse square law for the diminution of intensity with distance, and so were capable of extending their influence over large distances—as witness the stability of the solar system. Thus, the discovery of the short range forces posed a qualitatively new problem for physicists. This problem was considered by Yukawa who, guided by analogy with the electromagnetic field, concluded that the forces could arise from the spontaneous creation and exchange of elementary particles of finite mass. The argument, which is by now very well known, is that, if a particle is spontaneously created in such a situation, it can exist only for a time given by the uncertainty principle $\Delta E \Delta t \sim h$, or $\Delta t \sim h/\Delta E$. If, during this time, it travels with the speed of light c, it can go a distance equal to $hc/\Delta E$, which is then the range of the force it creates. In the case of light, $\Delta E = h\nu$, so that the range of the force is $c/\nu = \lambda$, the wave length of the light quantum exchanged. Since there is no upper limit to this, the range is quite large, and a more careful consideration leads to the inverse square law. Yukawa reasoned that, in order to limit the range, there must be a minimum energy for the exchanged particle, which is the case if it has a finite mass. Then the minimum energy is just the rest energy mc^2, and the range is h/mc. If this expression is compared with the known range of the forces, one finds that the mass of the particle responsible for the forces must be around 200 times that of an electron. Such particles had, in 1935, never been observed experimentally. Yukawa also predicted that these particles, if seen, would be radioactively unstable, since heavy nuclei were unstable. This last was a prediction that was gratuitous at the time.

These developments achieved sudden importance, shortly thereafter, when particles of mass around 200 were observed in the cosmic rays, and were, in fact, later