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Abstract

Full Text

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DEGENERACY WITH RESPECT TO ISOTOPIC SPIN AND HYPERCHARGE

(Presented by Academician I. E. Tamm on 28 IV 1962)

One of the authors of the present note has expressed considerations ⁽¹⁾ in favor of the possible existence of quadruplets of particles very close in mass, with identical properties and differing only in the values of isotopic spin ($T = 1$ and $T = 0$). Recently, Gell-Mann ⁽²⁾, analyzing the latest experimental data on resonances in π -meson and π -meson-hyperon systems, again drew attention to the presence of remarkable coincidences in the properties of particles belonging to isotopic multiplets with $T = 1$ and $T = 0$. To the authors of the present note these coincidences in the properties of particles appear to be far from accidental, and below one possible interpretation of them is examined.

From the experimental data currently available it follows that practically every multiplet with $T = 1$ can be assigned a singlet with $T = 0$, possessing the same quantum numbers and having a very close mass. These include the recently discovered ζ - and η -mesons ^(3, 4), the previously found ρ - and ω -mesons ^(5, 6), the Y_1^* - and Y_0^* -resonances ^(7, 8), as well as the Σ - and Λ -particles.

For greater clarity we have collected the data pertaining to all these particles in Table 1.

Table 1

$T =$ 1	$T = 1$	$T = 1$	$T =$ 1	$T =$ 0	$T = 0$	$T = 0$	$T =$ 0	$\frac{m_0 - m_1}{m_1}, \%$
particle	$m_1,$ MeV	s	P	particle	$m_0,$ MeV	s	P	
π	140	0	—	$\pi_0^0?$				
ζ	575	1	—	η	550	1?	—?	4.3
ρ	750	1	—	ω	780	1	—	4
Σ	1190	1/2		Λ	1115	1/2		6.3
Y_1^*	1385	3/2		Y_0^*	1405			1.4

It follows from the table that the only exception to the symmetry under discussion is the π -meson, for which no analogue of the π_0^0 -meson has yet been

found.

We shall return to the discussion of this point below, and for now continue our examination of the table.

It is known that, generally speaking, strong interactions depend sharply on the value of the isospin of the interacting system. A vivid example of this is the $\pi-N$ interaction. It would seem that this circumstance contradicts the existence of a symmetry leading to degeneracy of the properties of physical systems with respect to isotopic spin. A careful analysis of the table, however, shows—

means that all particles entering into it possess one common property—hypercharge Y^* , equal to zero; in this they differ radically from the $\pi-N$ system, for which the hypercharge $Y = 1$ (the same may be said of the hypercharged $K\pi$ -, $K\Sigma$ -, $\pi\Sigma$ -systems). The fact that the hypercharge is equal to zero in the presence of degeneracy in isotopic spin may prove to be very significant and may point to the important role that hypercharge plays in strong interactions. It seems to us that hypercharge has a deeper physical meaning than the quantum number “strangeness,” as Schwinger has already noted ⁽⁹⁾.

From the facts presently available, the following basic conclusion suggests itself: hypercharge is such a characteristic of a system as determines the strong dependence of its properties on isotopic spin. When it is equal to zero, the dependence on isotopic spin disappears and degeneracy sets in. From this assertion there follows first of all the fact that the masses of particles with $Y = 0$, belonging to different isotopic multiplets, are close, and that all the other quantum numbers coincide. This could serve as an indication for experimental searches in cases where these quantum numbers (spin, parity) are poorly established. Hence, in particular, there follow spin $s = 1$ and negative parity for the η -meson, identical parities for the Σ - and Λ -particles, and spin $s = 3/2$ for the Y_0 -resonance. Similar coincidences of properties should also occur for newly discovered particles (resonances).

An interesting conclusion may be drawn concerning resonances in the $\Sigma\pi$ -system. Here closely lying resonances should be observed in states with isotopic spin $T = 0, 1, 2$. Opposite conclusions follow for the $K\pi$ -, $K\Sigma$ -, $\pi\Sigma$ -systems. In these cases a sharp dependence on the values of isotopic spin should be observed. Resonances should exist only at fixed values of T . Indeed, the K^* -resonance is observed at the values $T = 1/2$, and there is no indication of a nearby resonance with $T = 3/2$.

Since the masses of bound states (resonances) are closely connected with the properties of the matrix elements of the S -matrix (the positions of the poles), the latter must possess the same kind of dependence on hypercharge. Hence it follows at once that the cross sections of interaction in the $\bar{N}N$ - and K^-N -systems must be degenerate in isotopic spin in all channels (elastic and inelastic).

A brilliant confirmation of this conclusion is the equality of the cross sections for the interaction $\bar{p}p$ and $\bar{n}p$ over the whole measured range of energies (see,

for example, ⁽¹⁰⁾). It is easy to show that this follows from the equality of the scattering amplitudes for states with $T = 0$ and $T = 1$.

From this, incidentally, there is also obtained the curious consequence that the cross sections for annihilation of the $\bar{N}N$ system into an even and an odd number of π -mesons are equal to one another. Unfortunately, the available data on the K^-N -interaction do not yet permit such an analysis to be carried out in this case.

The symmetry under discussion, confirmed by numerous facts, definitely testifies in favor of the existence of the π_0^0 -meson. Its nonobservation in various searches ⁽¹¹⁾ may indicate only that its interaction with nucleons is weaker than was usually assumed. This is naturally consistent with the circumstance that the nucleon carries hypercharge, and its interaction with the isosinglet π_0^0 may be entirely different from that with the isotopically triplet π -meson.

The concept of hypercharge arises most naturally when one considers representations of the four-dimensional rotation group of isotopic space ⁽¹²⁾. The existence of degeneracy in isotopic

* Hypercharge $Y = S + B$, where S is "strangeness," B is the baryon number.

spin, lifted by the presence of hypercharge, apparently indicates the important role played by this group in the consideration of strong interactions.

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