ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

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SYMMETRY OF STRONGLY INTERACTING SYSTEMS WITH HYPERCHARGE $Y = 0$.

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In a recent paper[1] analysing various experimental data we have come to a conclusion that systems of strongly interacting particles with the total hypercharge[2] $Y = 0$ possess special type of symmetry, namely their characteristics are independent of the isotopic spin value 'T'.

Below we present mathematical formalism necessary to describe this symmetry which want to call the symmetry of hyperneutral systems and discuss some consequencies of it.

One of the puzzling features of the newly observed resonances in pion-pion and pion-hyperon systems is the degeneracy of their properties in respect to isotopic spin value. The well known examples of such a degeneracy are ζ and η -mesons[3, 4] ρ and ω -mesons[5] [6], Y_1*, and Y_0* - resonances[7][8]. Experiment apparently shows that the quantum numbers (mass, spin, parity) with exception of isotopic spin coincide in each pair. This is in striking contrast with the properties of π - N resonances to which always a single value of isospin can be ascribed and for which change of isotopic spin value means drastic change of the resonance characteristics.

The peculiarity of the new resonances however is that all of them have hypercharge $Y = 0$, what is not the case for π- N resonances. We think that it might be very significant and point to a very important role which hypercharge plays in strong interactions[9]. Accordingly we propose to distinguish the hypercharged and hyperneutral systems of strongly interacting particles. We assume that the latter class of systems reveals new type of symmetry which leads to degeneracy in isotopic spin.

Experimental data now available give no exclusions from this regularity. Besides already mentioned examples we may point to Σ and Λ particles, which are known to have spin ½ and nearly equal masses[12] and to $\tilde{N}N$ and K^-N systems. Many features of the interaction of the last two systems may be explained if in conformity with our assumption we put scattering amplitudes equal for $T = 1$ and $T = 0$ channels $S^{T=1} = S^{T=0}$ [13]

Let us now turn to mathematical formulation of the new type of a symmetry. If there given operator S (which may be S – matrix, hamiltonian or mass operator), operator of hypercharge Y and operators of isotopic spin T_i then as usual we assume

$$[S, T_i] = 0 \qquad [S, Y] = 0 \qquad [T^2, Y] = 0 \qquad [T_3, Y] = 0 \qquad [T_i, Y_j] = i\epsilon_{ijk} T_k \tag{1}$$

Let us also postulate existence of the operators D_n such that

$$[D_n, T^2] \neq 0 \quad ; \qquad [D_n, Y] \neq 0 \tag{2}$$

$$[D_n, S] = R$$

where

$$< Y = 0/R/ Y = 0 > = 0 ; \quad < Y \neq 0 / R / Y \neq 0 > \neq 0$$

Existence of the operators D_n leads immediately to the degeneracy of hyperneutral systems in respect to the isotopic spin. That is matrix elements $< Y = 0 / S / Y = 0>$ do not depend on T -value.

Postulating existence of D_n -operator we actually assume that in case of huperneutral system we are dealing with the group, wider than the group of isotopic rotations R_3. This extended group is reduced to R_3 when $Y \neq 0$.

Several examples of the extension can be given e.g. unitary group u (3), group of four-dimensional rotations R_4 and others, but the question which is the right one can be solved only by comparing the predictions of different group formalism with experiment. Certainly it is appealing to find a minimal group, containing R_3 as a subgroup and satisfying our conditions (1) and (2). For the further consideration we shall take R_4 as the nearest coming to our criterion. The group of four-dimensional rotations R_4 is generated by six infinitesimal operators $I_{\alpha\beta}$ (rotations in α β plane α, β 1,2,3,4) satisfying following commutation relations

$$[I_{\alpha\beta}, I_{\gamma\delta}] = i[\delta_{\alpha\gamma} I_{\beta\delta} + \delta_{\beta\delta} I_{\alpha\gamma} - \delta_{\beta\gamma} I_{\alpha\delta} - \delta_{\alpha\delta} I_{\beta\gamma}] \quad (3)$$

$$I_{\alpha\beta} = - I_{\beta\alpha}$$

If we form

$$\vec{L} = \vec{e}_1 I_{23} + \vec{e}_2 I_{31} + \vec{e}_3 I_{12}$$

$$\vec{A} = \vec{e}_1 I_{14} + \vec{e}_2 I_{24} + \vec{e}_3 I_{34}$$

the commutation relations read

$$[L_i, L_j] = i\epsilon_{ijk} L_k$$

$$[L_i, A_j] = i\epsilon_{ijk} A_k \quad (4)$$

$$[A_i, A_j] = i\epsilon_{ijk} L_k$$

Especially interesting are linear combinations $\vec{M} = \frac{1}{2}(\vec{L} + \vec{A})$ and $\vec{N} = \frac{1}{2}(\vec{L} - \vec{A})$ which form two commuting sets of three-dimensional rotations

$$[\vec{N}, \vec{M}] = 0 \, ; \; [M_i, M_j] = i\epsilon_{ijk} M_k \, ; \; [N_i, N_j] = i\epsilon_{ijk} N_k \quad (5)$$

The R_4-group has been used already by different authors[14] for the classification of the elementary particles. A. Salam and J. Polkinghorne in particular proposed to identify T_i with M_i and Y with N_3. One can immediately see that with this prescription it is impossible to find among $I_{\alpha\beta}$ operators with the properties of D_n

Our prescriptions now are

$$T_i = L_i \; ; \quad D_i = A_i$$

It is clear that all the conditions of (1) and (2) will be satisfied if we postulate the invariance of $< Y = 0 / S / Y = 0 >$ under R_4.

The following step is to describe the elementary particles in terms of irreducible representations of R_4. The existence of the degenerated quadruplets ζ, η, ρ, ω (further designated as ζ_ν and ρ_ν) makes it plausible that they transform as vectors in 4-space i.e. belong to the representation (½, ½). In analogy it is tempting to assume that π -meson also transforms as a 4-vector that is it has fourth component π_0^0 similar in all respects to the π, besides being isoscalar, as it has been suggested earlier[15] by one of us (AM.B.). The nondiscovery of π_0^0 despite numerous efforts may only indicate that its interaction with hypercharged systems is weaker than it was usually assumed. This is no wonder because in the case of hypercharged systems our symmetry does not work. In case of hyperneutral systems ($\tilde{N} N$, $K^- N$) π_0^0 -meson must appear on equal grounds with π^0. With the above prescriptions an important result readily follows: a particle (or a system) which transforms as a 4-vector cannot decay (go) in two particles transforming as 4-vectors. This statement based on the fact that the direct product of two 4-vectors, being reduced, does not contain 4-vector in itself. The formulated selection rule forbids decays of ζ_ν and ρ_ν -mesons in two π -mesons (ζ and ρ -modes) but allows three pion decays (η and ω modes). The latter however may have small probability due to the small phase space as it has been discussed recently in the literature [16]. In this way we can explain the narrow widths of ζ , η , ω -resonances. The broad width of the ρ -resonance from this point of view must be caused by the external reasons, such as electromagnetic transitions between ρ and ω -mesons [17] which is possible when their mass-splitting is taken into account.

If we go further and assume that both Y_1^* , Y_0^* and Σ , Λ form 4-vectors then the same selection rule will forbid decays of hyperon resonances into $\Sigma(\Lambda)$ and $\pi(\pi_0^0)$ and explain the narrowness of their widths [18].

Among general consequences of the discussed symmetry one of the most curious is that the reaction channels connected with each other according Mandelstam suggestion (substitution law) from our point of view belong to different groups (hypercharged and hyperneutral) and hence must have different symmetry properties. This conclusion is in agreement with the available experimental data. Let us take reactions

$$\pi + N \rightarrow \pi' + \pi' \qquad (1) \qquad\qquad N + N \rightarrow \pi_\nu + \pi_\nu \qquad (2)$$

$$p + n \rightarrow p' + n' \qquad (3) \qquad\qquad p + \tilde{p} \rightarrow n + \tilde{n} \qquad (4)$$

The cross-sections of the reactions (2) and (4) are known to be very small whereas that of (1) and (3) are large enough. In the framework of our symmetry it is easily understable. The absence of (4) follows from equality $S_{T=1} = S_{T=0}$ If we ascribe to the $N\tilde{N}$ system the transformation properties of the 4-vector we shall immediately forbid reaction (2) and analogous reactions

$$N + \tilde{N} \rightarrow \Lambda + \tilde{\Lambda} \quad , \quad N + \tilde{N} \rightarrow \Sigma + \tilde{\Sigma} \; ; \; N + \tilde{N} \rightarrow \rho_\nu + \pi_\nu \; ; \; N + \tilde{N} \rightarrow \rho_\nu + \rho_\nu$$

etc. Whether it is possible to understand the properties of these reactions on the basis of substitution law and principle of analicity is an open question. May be new symmetry implies severe limitations on the various amplitudes.

Up to this point we discussed different selection rules following from the new symmetry and said nothing about accuracy with which symmetry works. The estimate of the accuracy may be obtained from the measured masses of the quadruplet components. Everywhere the ratio $\frac{m_1 - m_0}{m_1}$ (m_1 -mass of the triplet, m_0 -mass of the singlet) is of the order of a few percent, and only in the case of Σ , Λ it reaches 6,7% . This means in particular that the mass of the π_0^0 must differ from π , by several MeV. The relations between cross-sections (squares of matrix elements) must be observed with the accuracy of about 10%. The cross-sections of the forbidden reactions must be approximately several hundreds times smaller than the allowed ones what is realized in the best measured case of the reaction $p + \tilde{p} \rightarrow \pi^+ + \pi^-$

An additional constraint on the symmetry comes from the condition that kinetic energy of the process must be large in comparison with mass splitting of quadruplet components. The nonobservance of the last condition may be of importance in consideration of the inelastic channels of $K^- p$ interaction at small energies.

Recently the interests to the different types of generalyized symmetries have revived [20].

The symmetry discussed above has in our opinion an advantage of being nearly as accurate as the isotopic invariance and having well defined domain of validity ($Y = 0$).

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12. The problem of $\Sigma - \Lambda$ relative parity is not solved yet. According our scheme it must be even .

13. Recall the drastic difference of corresponding amplitudes in the case of NN scattering (hypercharged system).

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18. There is still another possibility in treating the widths of the resonances. The hyperneutral systems anologous to the systems of zero charge can be described by the definite value of hypercharge parity (analogy to charge parity).
If we choose π_ν and ρ_ν mesons to have even and ζ_ν -meson to have odd hypercharge parities, then decays of ρ and ω -mesons will be allowed of ζ and η -mesons-forbidden. This explains also the non occurrence of $\rho \to \eta + \pi$ decays /20/ To forbid the decays of hyperon resonances it is sufficient to choose opposite hypercharge parities for $Y_1^* \ (Y_0^*)$ and $\Sigma \ (\Lambda)$.

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