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Bootstrap Dynamics and Particle Symmetries *

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There are two main avenues to the theory of particle symmetries:

the aesthetic approach based on a priori ideas, and the mechanistic approach. A mechanistic theory of the symmetries of strongly interacting particles starts from the observation that the validity of isotopic spin and SU_3 -symmetry has been established only within the strong interactions, and seeks within the strong interactions dynamical effects which are capable of producing the phenomena observed. Solutions of the complicated non-linear equations which arise from the requirement of dynamical self-consistency (so-called bootstrap models) do not have a random character, and even in simplified examples bear a close resemblance to the actual physical situation.¹⁻⁶ This provides a basis for hope in the ultimate success of the mechanistic approach.

Bootstrap models assume that in a first approximation the weak and electromagnetic interactions as well as unknown ultra high energy phenomena can be disregarded. They are constructed in terms of the unitarity and analyticity of the S-matrix and involve the hypothesis that all particles can be treated as being composite.⁷ The most convenient way to formulate these conditions seems to be through the Bethe-Salpeter equation, which avoids two difficulties of the more usual N/D formalism. In the

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latter method, the problem of subtractions, which is sometimes referred to a Regge-pole analysis of cross-channel reactions^{8,9}, is not yet well understood. Also, the three lines joining at a vertex are not treated symmetrically. In the Bethe-Salpeter method, a natural sequence of successive approximations automatically maintains "vertex symmetry".

The Bethe-Salpeter equation, in a generalized ladder approximation, leads to self-consistency equations of the following general form:¹⁰

$$g_{abc} = \sum_{\alpha\beta\gamma} D_{abc}^{\alpha\beta\gamma} g_{\alpha\beta\gamma} g_{\alpha\beta\gamma} g_{\alpha\beta\gamma} \quad (1)$$

$$1 = \sum_{\alpha\beta\gamma} W_{\alpha\beta\gamma} g_{abc} g_{\alpha\beta\gamma} g_{\alpha\beta\gamma} g_{\alpha\beta\gamma} \quad (2)$$

where the g 's are coupling constants and D and W , which are obtained in terms of certain integrals over vertex functions, depend only on the spins and masses of the particles indicated and are also homogeneous in the masses. These equations are supplemented by the further condition that the effective potential in other two-particle states not be so strong as to lead to additional particles with low masses, since the extra particles, for true self-consistency, should have been included from the beginning.

We have been especially interested in finding properties of these equations which depend on general or qualitative considerations, but are also pursuing more detailed calculations. We adopt the usual principle that the form of the functions should be dominated by the nearest singularities.⁷

It is often convenient to have, for comparison with the result of

more exact models, a simple soluble model. The following expressions, which incorporate the symmetry and homogeneity properties, provide an instructive model of a bootstrap system in which all of the particles have the same spin:

$$D_{abc}^{a\beta\gamma} = D_0 \left(\frac{abc}{a\beta\gamma} \right)^n, \quad W = W_0 \left(\frac{a^5}{a\beta\gamma bc} \right)^n \quad (3)$$

In Equation (3) we take $n > 0$, and we have denoted by $a, b, \dots$ the particle masses. This factorable expression has been applied to several soluble examples. For example, with eight (vector) mesons, one obtains, in addition to the SU_3 -symmetrical solution, a second solution in which there is a mass splitting according to the Gell-Mann-Okubo formula and which retains SU_2 symmetry. With this simple form of D and W , the magnitude of the dissymmetry is actually infinitesimal.

We have also studied properties of the interactions between baryons and pseudoscalar mesons in the static model. We have found that in previous treatments of Chew's "reciprocal bootstrap" model¹¹ of the nucleon, vertex symmetry has not been properly maintained. Moreover, use of the effective range approximation can lead to erroneous conclusions. Equations (1) and (2) provide a formulation which can retain the essential physical features of Chew's model while overcoming these objections.¹²

A static model of the interactions between pions and the particles $\Lambda, \Sigma, Y_1^*, Y_2^*$ has been studied by this method. This is not a complete bootstrap problem because the pion is treated as "elementary". Isotopic spin was also assumed. Reasonable values can be found for D and W (which fit the $N-N-\pi$ problem) for which the masses and coupling constants

necessarily satisfy global symmetry.¹² While this model does not have much physical significance, it provides a simple example of the dynamical determination of masses and coupling constants.

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