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Multiparticle fields method for the description of the bound states scattering

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All existing quantum field theories are formulated in terms of functions defined in the Minkowski space and possess the values from a set of operators. Such functions satisfy the equations which conserve their form during the Lorentz transform. As a result of these two points, within such theories, it is impossible to construct an operator which could change the coordinate dependence of the state keeping the temporal dependence intact. For example, it is impossible to construct an operator which creates a particle with certain momentum only –it is only possible to construct an operator which creates a particle with certain energy-momentum. This makes it difficult to describe the bound states within the relativistic quantum theory. In addition, a relativistic theory of bound states scattering, built on top of such models, would result in the conservation of the total energy-momentum four-verctor of the single-particle states (regardless of the quantization method and the method of dynamic problem solution –using the perturbation theory or not). So in QCD the total four-momentum of quarks and gluons in initial state will be equal to the total four-momentum of quarks and gluons in the final state. This is an obvious contradiction to the experiment, where the total four-momentum of hadrons is conserved, and not of their constituent particles. This problem is usually overcome using the parton model [1]. In this case the total four-momentum of hadron is given as a sum of the four-momenta of its constituent partons which do not interact with each other. This is obviously a way to only elude the mentioned problems, while the method of multiparticle fields aims at their solution. The basic idea of this method can be illustrated using the example of a two-particle field.

Consider a set of event pairs, where each pair is chosen from the Minkowski space for one of the particles. In [2] it was shown that the measurement of the quantum state of such particles must be done at the same time relative to the frame in which this measurement is done. So the multiparticle states are described on the subset of the Cartesian product of Minkowski spaces, which corresponds to the simultaneous events. We call it the subset of simultaneous events. We show that it is possible to derive the dynamic equations similar to the known Klein-Gordon-Fock and Dirac equations for the fields on such a subset. The solutions of the dynamical equations for the two-particle gauge field can be given in a form of two components. The first one plays the role of a potential of the particle interaction inside the bound particle, while the second one is the field which after the quantization describes the interaction between the bound particles. Curiously enough, the first component, which describes the interaction inside the bound particle, satisfies the dynamic equation which in its turn describes the confinement under certain boundary conditions, and the mechanism of spontaneous symmetry braking under some others.

This model may serve as an effective field theory for the description of the elastic and inelastic scattering of hadrons.

1) R. P. Feynman, Photon Hadron Interactions, 1. printing (Addison-Wesley, Reading, Mass, 1998).

2) N. O. Chudak et al Internal States of Hadrons in Relativistic Reference Frame, Ukr. J. Phys. 61, 1033 (2016)

3) N. N. Bogoliubov and D. V. Shirkov, Introduction to the Theory of Quantized Fields, 2d American ed (John Wiley, New York, 1980)..

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