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Causality in Quantum Field Theory with Nonlocal Interaction

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Abstract. It is proved that the S-matrix satisfies the Bogolubov microcausality condition in each order in perturbation theory in a quantum field theory with nonlocal interaction, where the nonlocality is introduced with the help of form factors being entire analytical functions of the order 1/2.

1. Introduction

It is well known that the principle of causality is the basis of all approaches in the theory of elementary particles. In quantum field theory this principle, like the postulates of relativistic covariance and quantum nature of phenomena in the microworld, is of fundamental importance (construction of the S-matrix [1], the Wightman axiomatic approach [2], dispersion relations [3] and so on).

In local quantum field theory causality is manifested as a requirement for the Heisenberg fields $\phi(x)$ to be locally commutable

$$[\phi(x), \phi(y)]_{-} = 0 \quad \text{for} \quad x \sim y \tag{1.1}$$

or as the microcausality condition for the S-matrix:

$$\frac{\delta}{\delta\phi(x)}\left(\frac{\delta S}{\delta\phi(y)} S^{+}\right) = 0 \quad \text{for} \quad x \lesssim y\,. \tag{1.2}$$

The both conditions are of a formal mathematical nature and are the postulates describing the mathematical structure of the fields $\phi(x)$ in (1.1) and of the S-matrix in (1.2) rather than requirements of physical causality. This is explained by the fact that the concept of point-like nature of events suggested in (1.1) and (1.2) is incompatible with the ideas of relativistic quantum mechanics.

Over the last time numerous attempts have been made to formulate the so-called physical condition of causality [4], i.e. to find minimal requirements on the amplitudes of physical processes which would guarantee the absence of any obviously noncausal phenomena in the macroworld. However, this problem remains still open and the conditions