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When Does a Quantum Field Theory Describe Particles?*

By

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Abstract. We give a criterion which has to be satisfied in a Quantum Field Theory in order to allow a complete particle interpretation of the theory. The notion of "essentially localized states" in Field Theory is re-examined.

I. Introduction

The usually accepted postulates of relativistic quantum field theory, namely Lorentz invariance, local commutativity, causality, and the structure of the energy-momentum spectrum are not sufficient to ensure an interpretation of physical states entirely in terms of asymptotic particle configurations. This fact is demonstrated by the well known example of a generalized free field with continuous weight function [1]. This model satisfies all the above requirements if the weight function is suitably chosen*** yet it does not allow a complete particle interpretation.

It is the purpose of this paper to suggest a possible criterion that would distinguish between field theories with and without particle interpretation.

This criterion is a generalization to relativistic quantum field theories of the old quantum mechanical argument: the number of quantum states of a particle in a finite phase space volume Ω is finite, namely Ω/h^3.

Pursuing for the moment an intuitive argument one would expect that in a theory with short range forces and particle interpretation a physical state which at time $t = 0$ is essentially localized in a finite region of space and has limited energy will quickly evolve into a state described by a configuration of essentially non-interacting particles, finite in number and still localized in a finite space volume with finite energy.

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*** Lorentz invariance, local commutativity and the energy momentum spectrum are immediately evident. "Primitive causality" is violated if the weight function does not decrease rapidly enough for large mass values [2] but is satisfied for models with a fast decreasing weight function [3].