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Causal Independence and the Energy-Level Density of States in Local Quantum Field Theory

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Dedicated to H. J. Borchers on the occasion of his 60th birthday

Abstract. Within the general framework of local quantum field theory a physically motivated condition on the energy-level density of well-localized states is proposed and discussed. It is shown that any model satisfying this condition obeys a strong form of the principle of causal (statistical) independence, which manifests itself in a specific algebraic structure of the local algebras ("split property"). It is also shown that the proposed condition holds in a free field theory.

1. Introduction

It is well known that the general postulates in quantum field theory, concerning locality, Poincaré covariance, and the spectrum condition, do not exclude models with manifestly unphysical properties. Examples are the generalized free field with continuous mass spectrum, which does not describe particles, or models with an infinite number of particles in the same mass multiplet, for which the familiar relation between spin and statistics need not hold. It has been a long-standing problem in the theory of local algebras [1, 2] and in the standard version of quantum field theory [3], to find conditions of a "local" character which would guarantee an interpretation of the theory in terms of asymptotic particle states.

A first step towards the solution of this problem was taken by Haag and Swieca [4], who pointed out that in any theory with a reasonable particle interpretation the number of states occupying a finite volume of phase space should be limited due to the uncertainty principle. Based on this physical input Haag and Swieca proposed a "compactness criterion" which every quantum field theory ought to satisfy if it is to describe particles. They also showed that their criterion excludes the above mentioned examples of physically unreasonable models. But the difficult problem of whether the compactness criterion ensures a particle interpretation remains open to date. (For some partial results cf. [5].) One may surmise that the compactness criterion is still too general and does not fully reflect the specific phase space properties of a particle theory.