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The Physical State Space of Quantum Electrodynamics

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Abstract. Starting from the fact that electrically charged particles are massive, we derive a criterion which characterizes the state space of quantum electrodynamics. This criterion clarifies the special role of the electric charge amongst the uncountably many superselection rules in quantum electrodynamics and provides a basis for a general analysis of the infrared problem. Within this framework we establish the existence of asymptotic electromagnetic fields in all charge-sectors, find a general characterization of infra-particles and introduce a notion of asymptotic completeness.

1. Introduction

In striking contrast to the excellent experimental confirmation of quantum electrodynamics, the understanding of its conceptual foundations is still only of a rather qualitative nature. Besides the well-known infrared problems which one encounters in the interpretation of physical states at asymptotic times [1], the even more fundamental problem of defining a physical state space has not yet been solved in a satisfactory manner. It is the aim of the present contribution to clarify this point and thereby to provide a basis for a general discussion of the structure of quantum electrodynamics.

There are two related problems which one encounters in the definition of a state space. First, there exists the well-known difficulty that physical states carrying an electric charge cannot be constructed by applying local field operators to the vacuum state. This fact can be traced back to Gauss' law which implies that the electric charge of a particle can be determined by measuring the total electric flux through an arbitrarily large sphere surrounding the particle [2, 3].

The second complication, which is less frequently noticed although it has the same physical origin, consists in the fact that there exist uncountably many superselection sectors in quantum electrodynamics. This may be seen from the following heuristic argument: choosing some Lorentz system, the observable ϕ

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