Commun. math. Phys. 45, 35—52 (1975)

Communications in
Mathematical
Physics

Characterization of Particles by Means of Local Observables

Volker Enss

Abteilung für Theoretische Physik, Fakultät für Physik der Universität Bielefeld, D-4800 Bielefeld 1, Federal Republic of Germany

Abstract. We introduce the notion of singly localized states and use it to characterize the one-particle states as those states which are singly localized at all times. For theories which satisfy the Haag-Swieca compactness criterion, we show that a state has a discrete mass spectrum if and only if it is a "geometrical one-particle state".

Using a mathematical description of coincidence arrangements of counters we show that in asymptotically complete theories the asymptotic particle number is the asymptotic number of localization centres.

I. Introduction

In relativistic quantum theory a particle is usually defined to be a state that belongs to an irreducible representation of the Poincaré group. In an experiment, however, one identifies a particle by its localization properties, e.g. its track in a bubble chamber. A geometrical characterization of a one-particle state should allow for the experimental situation.

Apart from being very abstract, the usual particle definition has other drawbacks: In theories with long-range forces, like quantum electrodynamics, it is an open question whether the electron has a discrete mass or whether it is an "infraparticle" with continuous mass distribution [6]. In the latter case it would violate the usual particle definition, although it behaves like a particle in experiments.

In theories with short-range forces, the Haag-Ruelle scattering theory [5] provides the existence of states which can be interpreted as incoming or outgoing particle configurations. It relies on the conventional notion of a particle. It is not yet clear which physically plausible assumptions ensure an asymptotic particle interpretation of all states (asymptotic completeness).

As a contribution to these problems, we will characterize the particle states by their local properties, because the physically and mathematically basic objects in the theory are the local observables. We confine ourselves to theories with short-range forces.

In what follows, a "particle" will be any physical system which remains connected for all times when external forces are absent, i.e. a system that does not decay into subsystems which become separated and independent of each other. A particle of this kind can be a stable elementary particle, or a stable bounded