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Locality and the Structure of Particle States

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Abstract. Starting from the principle of locality of observables we derive localization properties of massive particle states which hold in all models of relativistic quantum theory, including gauge theories. It turns out that particles may always be regarded as well localized distributions of matter, although their mathematical description might require the introduction of non-local (unobservable) fields, which are assigned to infinite string-like regions. In spite of the non-locality of these fields one can show that such particles obey Bose- or Fermi (para) statistics, that to each particle there exists an antiparticle and that collision states of particles exist. A selfcontained exposition of the underlying physical ideas is given in the Introduction, and some perspectives for the structure of field–theoretic models arising from our analysis are discussed in the Conclusions.

1. Introduction

Many qualitative features of particle physics, such as the existence of antiparticles, the phenomenon of particle statistics and the formation of asymptotic particle configurations in collision processes have found a theoretical explanation based on the assumption that particle states are well localized excitations of some vacuum state. In the Wightman-framework of quantum field theory one converts this physical picture into the hypothesis that particle states can be constructed by applying local field operators to the vector representing the vacuum [2]. A physically more transparent formulation has been given by Doplicher, Haag and Roberts [3, 4]. Using only the concept of local observables, these authors expressed in an algebraic setting the assumption that particle states cannot be distinguished from the vacuum by measurements in the spacelike complement of sufficiently large, but bounded regions of Minkowski space.

These descriptions of localization properties are perfectly adequate for charged particles in theories with a global gauge symmetry. But it is well known that they cannot be applied to particles carrying an electric charge: since it is possible to

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