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Particle Localization in Field Theory

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Abstract. The localization properties of particles in field theory are studied with the help of a convenient mathematical description of counters. It is shown that field theory is capable of explaining the observed localization patterns. Apart from the usual axioms of field theory we have to assume some smoothness properties of the Green's functions in momentum space.

1. Introduction

Localizability is an essential ingredient of the intuitive notion of a particle. According to this notion a particle is an entity with some sort of stability, which is localized in a small region of space throughout its history, and which moves roughly according to the laws of classical mechanics, e.g., in a straight line if not subjected to external forces. This behaviour is exemplified by the well-known pictures of high energy events obtained in bubble chambers and similar instruments. These pictures show patterns of straight lines (in the absence of magnetic fields) joining in points, which can, most naturally, be explained as follows. The lines are tracks of particles. The particles proceed in straight lines until they meet another particle, whereupon they indulge in some reactions of a mysterious nature resulting in a certain number of other particles, which emerge from the region of interaction to proceed in straight lines, etc. This region of interaction is reasonably well localized in space (within the thickness of the tracks) and could presumably, by some more refined techniques, be localized in time to a similar degree of accuracy.

Field theory, on the other hand, is a theory of a continuum. Localized events of the type described above seem at first sight to be foreign to it. The definition of the term "particle" used in quantum field theory is indeed not based on this localization in x space, but instead, on the spectral properties of the energy momentum vector P_μ, i.e., a p space property. Roughly speaking, a particle is defined to be an object with a sharp value m of the mass, when the mass operator is $M^2 = P_0^2 - \mathbf{P}^2$. The question arises naturally whether this particle notion has anything to do with the more intuitive one discussed before. In other words:

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