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Collision Theory for Massless Bosons

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Abstract. We present a complete solution of the collision problem for massless Bosons in four space-time dimensions.

1. Introduction

We continue here our discussion of the collision problem for massless particles in the setting of local, relativistic quantum theory. In two previous papers we have developed a collision theory for massless Fermions [1] and for waves in two space-time dimensions [2]. It is the aim of the present article to extend this analysis to models including massless Bosons.

As soon as massless Bosons take part in collisions one is faced with all kinds of infrared problems. The most spectacular one is the desintegration of charged massive particles into infraparticles [3]. A famous example of this phenomenon can be met in quantum electrodynamics where it is indicated by perturbation theory that the electron does not have a precise mass due to the Coulomb field which it carries along. The massless particles however manifest themselves as real particles with a precise mass in most of the models of physical interest: they appear either as a consequence of a gauge symmetry of the second kind or they result from a spontaneously broken ordinary symmetry via the Goldstone mechanism [4]. It is therefore no essential loss of generality if we restrict our attention to models in which at least the massless particles can be sharply defined as proper eigenstates of the mass operator.

Another difficulty in the presence of massless particles is connected with the construction of charged states from the vacuum. It is well known that locality of the charge carrying fields is in general not compatible with positivity of the metric in the state space. In quantum electrodynamics for example, one has either to abandon locality of the Fermi fields (as in the Coulomb-gauge) or one looses positivity of the metric (as in the Gupta-Bleuler gauge) [5]. For this reason gauge theories like quantum electrodynamics do not completely fit into the framework of this paper. However we want to emphasize that our arguments apply to the vacuum representation of the gauge invariant quantities in these models.