Description for the general public

Modern physical theories describe the world with ever increasing precision at the same time using ever more subtle mathematical language. As a result, checking the self-consistency of a given physical theory and finding its predictions in particular cases is often not an easy task. One of such theories is the quantum electrodynamics. It describes the interaction between the charged particles such as electrons and their antiparticles positrons with the light i.e. the electromagnetic radiation which is treated as a flux of particles without mass called photons. The predictions of the quantum electrodynamics were confirmed with precision reaching $1 : 100\,000\,000\,000\,000$, however, in spite of the spectacular successes our present understanding of its structure is still not completely satisfactory.

The quantum electrodynamics like other models of the quantum field theory is used to describe the collisions of particles which are investigated for example at the Large Hadron Collider near Geneva. The description of the above-mentioned collisions, often more precisely called the scattering processes, is the subject of the present project. It turns out that in the case of collisions of particles which interact only with massive particles it is possible to suppose that both before and after the collision the particles move along the straight lines and behave almost like free particles. This is the standard assumption which is however no longer true if some of the colliding particles can interact by the exchange of massless particles. Such situation occur for example in the quantum electrodynamics where the charge particles interact with one another via the exchange of massless photons. Because of the long-range character of the interactions mediated by massless particles the behavior of the charged particles participating in the scattering process is not similar to that of the free particles even long after the collision. This lead to a number of difficulties called the infrared problem. Main goal of the project is the solution of those problems and the formulation of the generalized scattering theory which is also applicable to the models with long-range interactions.

The above-mentioned difficulties which appear in the description of the scattering of the charged particles are directly related to the fact that those particles are always surrounded by some electromagnetic field called the Coulomb field. Because of its existence the charged particles cannot have precisely defined mass. Therefore, their theoretical description with the use of the standard methods is only approximate. On the other hand, since photons have zero mass their energy can be arbitrarily close to zero. Consequently, the energy conservation principle does not give any upper bound on the maximal number of photons produced in a given process. As a result, the consistent interpretation of the electromagnetic radiation emitted in the scattering of the charged particles as the flux of photons may not always be possible. The obtained results should improve our understanding of the above problems and make possible a better definition of the notion of a particle in the quantum field theories with the long range interactions.