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Abstract

Quantum Field Theory in Coordinate Space

By

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Quantum field theory describes the physics of elementary particles and their interactions. In these theories, the fundamental objects are the fields, while the particles are bundles of energy, or quanta, of various fields. A field is a physical quantity that has a value for each point in space and time, and can be thought of some stress in space. In order to provide a new coordinate-space perspective applicable to scattering amplitudes, in the first part of this thesis, the structure of singularities in perturbative massless gauge theories is investigated in coordinate space. The pinch singularities in coordinate-space integrals occur at configurations of vertices, which have a direct interpretation in terms of physical scattering of particles in real space-time in the same way as for the loop momenta in the case of momentum-space singularities. In the analysis of vertex functions in coordinate space, the well-known factorization into hard, soft, and jet functions is found. By power-counting arguments, it is found that coordinate-space integrals of vertex functions have logarithmic divergences at worst. In the second part, the perturbative cusp and closed polygons of Wilson lines for massless gauge theories are analyzed in coordinate space, and expressed as exponentials of two-dimensional integrals. These integrals have geometric interpretations, which link renormalization scales with invariant distances. A direct perturbative prescription for the logarithm of the cusp and related cross sections treated in eikonal approximation is provided by web diagrams. The sources of their ultraviolet poles in coordinate space associated with their nonlocal collinear divergences are identified by the power-counting technique explained in the first part. The ultraviolet finiteness of the web integrand is shown by relating an additive renormalization procedure for the massless cusp in terms of nonlocal ultraviolet subtractions to the web expansion. The results illustrate that webs behave like a unit almost like a single gluon, which can be interpreted as a "QCD string". Furthermore, coordinate-space perspective enables us to understand the running of the coupling in real space-time.

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