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Thursday, November 7, 2013 - 12:00 PM

Multi-Time Wave Functions for Relativistic Quantum Field Theory

Abstract

In non-relativistic quantum mechanics of N particles, the wave function $\psi(q_1, \dots, q_N, t)$ is a function of $3N$ position coordinates and one time coordinate. It is an obvious idea that in a relativistic setting, such functions should be replaced by $\phi(t_1, q_1, \dots, t_N, q_N)$, a function of N space-time points called a multi-time wave function. In quantum field theory (QFT), it is common to use the Heisenberg picture; but if we use the Schrödinger picture, and if we use the position representation, then the wave function at time t corresponds to a vector in Fock space and can be regarded as a function on the configuration space of a variable number of particles (the union of $(R^3)^N$ over $N = 0$ to infinity). The corresponding multi-time wave function ϕ is a function on the union of $(R^4)^N$ over $N = 0$ to infinity, or on the subset of spacelike configurations. I discuss relevant evolution equations for ϕ corresponding to model QFTs, conditions for their consistency, the relation to the Tomonaga-Schwinger approach, and ways of implementing an ultraviolet regularization. This is joint work with Soeren Petrat.