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From Kadanoff-Baym dynamics to off-shell parton transport

Nonequilibrium many-body theory or quantum-field theory has become a major topic of research for transport processes in nuclear physics, in cosmological particle physics as well as condensed matter physics. In particular the dynamics of heavy-ion collisions at various bombarding energies -- as representative of complex systems with strongly interacting particles or fields -- has always been a major motivation for research on nonequilibrium quantum many-body physics.
The lectures demonstrate how to achieve a quantum transport theory from the Kadanoff-Baym equations in a first order gradient expansion. All approximations are explicitly studied in case of φ^4-theory where the Kadanoff-Baym equations are solved numerically and compared to various limiting cases. The resulting transport equations for particles of finite width (or inverse lifetime) allow for a transparent picture of the off-shell dynamics. Simple cases are presented for illustration as well as examples for relativistic nucleus-nucleus collisions. The application to off-shell transport of partonic systems requires an explicit separation of space-like and time-like quantities due to the short life-time of the effective degrees of freedom. The spectral properties of the effective 'quarks' and 'gluons' are determined by a fit of the entropy density to results from lattice QCD. The resulting dynamical quasiparticle approach matches well with lattice QCD thermodynamics and allows for a transparent extension to finite quark chemical potential μ as well as out-of-equilibrium situations. Effective mean-field potentials as well as interaction matrix elements are extracted in the temperature range from T_c to 10 T_c and implemented in off-shell parton transport. The resulting parton transport approach is employed to study the dynamics of thermalization as well as hadronization at the phase boundary.