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Nuclear Theory

The initial spectrum of fluctuations in the little bang

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High parton densities in ultra-relativistic nuclear collisions suggest a description of these collisions wherein the high energy nuclear wavefunctions and the initial stages of the nuclear collision are dominated by classical fields. This underlying paradigm can be significantly improved by including quantum fluctuations around the classical background fields. One class of these contributes to the energy evolution of multi-parton correlators in the nuclear wavefunctions. Another dominant class of unstable quantum fluctuations grow rapidly with proper time τ after the collision. These secular terms appear at each loop order; the leading contributions can be resummed to all loop orders to obtain expressions for final state observables. The all-order result can be expressed in terms of the spectrum of fluctuations on the initial proper time surface. We compute, in $A^\tau=0$ gauge, the essential elements in this fluctuation spectrum--the small quantum fluctuation modes in the classical background field. With our derivation in QCD, we have all the ingredients to compute inclusive quantities in heavy ion collisions at early times including i) all--order leading logs in Bjorken $x_{1,2}$ of the two nuclei, ii) all strong multiple scattering contributions, and iii) all-order leading secular terms. In the simpler analogous formalism for a scalar ϕ^4 theory, numerical analysis of the behavior of the energy-momentum tensor is strongly suggestive of early hydrodynamic flow in the system. In QCD, in addition to studying the possible early onset of hydrodynamic behavior, additional important applications of our results include a) the computation of sphaleron transitions off-equilibrium, and b) "jet quenching", or medium modification of parton spectra, in strong color fields at early times.

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