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Causal Charge Diffusion and Fluctuations in Heavy-Ion Collisions

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We present a relativistic causal description of conserved-charge diffusion for heavy-ion collisions and show that it produces measurable effects in observables such as the charge balance functions. Other descriptions, based on ordinary diffusion, are known to produce charge fluctuations which propagate with infinite velocity, thus violating a fundamental postulate of special relativity. We present an alternative approach based on Cattaneo diffusion which restores relativistic causality, and show how to generalize this approach to dynamical, rapidly evolving systems such as heavy-ion collisions. We demonstrate that this approach leads to measurable consequences for the balance functions constructed from electrically charged hadrons in a simple 1+1 dimensional Bjorken hydrodynamic model. We find that limiting the speed of propagation of charge fluctuations increases the height and reduces the width of these balance functions when plotted versus separation in rapidity. We conclude by estimating the numerical value of the associated diffusion time constant from AdS/CFT.

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