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New results in the formalism and application of relativistic viscous hydrodynamics

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We derive relativistic viscous hydrodynamic equations for various forms of the non-equilibrium single-particle phase-space distribution function $f(x,p)$, and apply these results to relativistic heavy-ion collisions at the RHIC and LHC energies.

In the first part of this work, we derive hydrodynamic equations invoking the generalized second law of thermodynamics for two different forms of $f(x,p)$ within Grad's 14-moment approximation. We find that the relaxation times in these two derivations are identical for shear viscosity but different for bulk viscosity. These equations are used to study thermal dilepton and hadron spectra within longitudinal scaling expansion of the matter formed in relativistic heavy-ion collisions. For consistency, the same $f(x,p)$ is used in the particle production prescription as in the derivation of the viscous evolution equations. Appreciable differences are found in the transverse-momentum spectra corresponding to the two forms of $f(x,p)$. We emphasize that an inconsistent treatment of the non-equilibrium effects influences the particle production significantly, which may affect the extraction of transport properties of quark-gluon plasma [1].

In the second part, we consider an alternative Chapman-Enskog-like method, which unlike the widely used Grad's method, involves a small expansion parameter. We derive an expression for $f(x,p)$ to second order in this parameter. We show analytically that while Grad's method leads to the violation of the experimentally observed $1/\sqrt{m_T}$ scaling of the longitudinal femtoscopic radii, the alternative method does not exhibit such an unphysical behavior. We compare numerical results for hadron transverse-momentum spectra and femtoscopic radii obtained in these two methods, within the one-dimensional scaling expansion scenario. Moreover, we demonstrate a rapid convergence of the Chapman-Enskog-like expansion up to second order. This leads to an expression for $\delta f(x,p)$ which provides a better alternative to Grad's approximation for hydrodynamic modelling of relativistic heavy-ion collisions [2].

[1] R.S. Bhalerao, A. Jaiswal, S. Pal, and V. Sreekanth, Phys. Rev. C88 (2013) 044911.

[2] R.S. Bhalerao, A. Jaiswal, S. Pal, and V. Sreekanth, e-Print: arXiv:1312.1864 [nucl-th].

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