AWBS kinetic modeling of electrons with nonlocal Ohm's law in plasmas relevant to inertial confinement fusion

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The interaction of lasers with plasmas very often leads to nonlocal transport conditions, where the classical hydrodynamic model fails to describe important microscopic physics related to highly mobile particles. In this study we analyze and further propose a modification of the Albritton-Williams-Bernstein-Swartz collision operator Phys. Rev. Lett 57, 1887 (1986) for the nonlocal electron transport under conditions relevant to ICF. The electron distribution function provided by this modification exhibits some very desirable properties when compared to the full Fokker-Planck operator in the local diffusive regime, and also performs very well when benchmarked against Vlasov-Fokker-Planck and collisional PIC codes in the nonlocal transport regime, where we find that the effect of the electric field via the nonlocal Ohm's law is an essential ingredient in order to capture the electron kinetics properly.

I. INTRODUCTION

The first modern attempts at kinetic modeling of plasma can be traced back to the fifties, when Cohen, Spitzer, and Routly (CSR) [1] demonstrated that the effect of Coulomb collisions between electrons and ions in the ionized gas predominantly results from frequently occurring events of cumulative small deflections rather than occasional close encounters. This effect was originally described by Jeans in [2] and Chandrasekhar [3] proposed to use the diffusion equation model of the Vlasov-Fokker-Planck type (VFP) [4].

A classical paper by Spitzer and Härm (SH) [5] provides the computation of the electron distribution function (EDF) in a plasma (from low to high Z) with a temperature gradient accounting for e-e and e-i collisions. The resulting expressions for current and heat flux are widely used in plasma hydrodynamic models.

The distribution function based on the spherical harmonics method in its first approximation (P1) [6] is of the form $f^0 + \mu f^1$, where f^0 and f^1 are isotropic and μ, is the direction cosine between the particle velocity and the temperature gradient. It should be emphasized that the SH solution assumes a small perturbation of equilibrium, i.e. that f^0 is the Maxwell-Boltzmann distribution and μf^1 represents a very small anisotropic deviation.

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