Runaway-Current Sustainment by Lower-Hybrid Waves

Recently a theory has been proposed to explain the low-density current-drive experiments.[1] The model is based on an ingenious idea and its distinctive features are consistent with the experimental observations. However, the authors have assumed a steady state too prematurely.

In contrast to the runaway case[2] there is indeed no dc electric field to accelerate the electrons in the region $[v_c, v_D]$. Because of that the authors of Ref. 1 have to assume that the distribution function displays a negative slope there; thus they may balance the backward flux due to collisions with the quasilinear diffusion by the plasma waves. However, this assumption is inconsistent with the pitch-angle diffusion by the anomalous Doppler effect which happens in the adjacent region $v > v_D$ and must manifest itself in the region $[v_c, v_D]$ by the advent of a positive slope. Since the equations used in the model are the same as in our quasilinear code[2] we have tested the model numerically.

We found that, for a realistic range of parameters, the preformed runaway tail cannot be maintained and the current carriers relax toward the bulk of the electron distribution (cf. Fig. 1). Thus, we claim that the authors' model is inconsistent with their equations.

The characteristic time of the relaxation is given by the slowest time among all the different processes involved, viz. the collision time. Therefore, the fraction of electrons in the tail evolves according to

$$\Delta n = \int_{v_c}^{\infty} \frac{\partial F}{\partial t}\, dv = \int_{v_c}^{\infty} dv\, \frac{\partial}{\partial v}\left[\nu(v)\left(vF + \frac{\partial F}{\partial v}\right)\right] = -\nu(v_c)\, v_c F(v_c).$$

Now since Δn is given by

$$\Delta n = F(v_c)(v_D - v_c + T/v_D),$$

we obtain an exponential decay of the tail,

$$\frac{\Delta n}{\Delta n_0} = \exp\left[-\nu(v_c)\frac{v_c}{v_D - v_c + T/v_D}\, t\right].$$

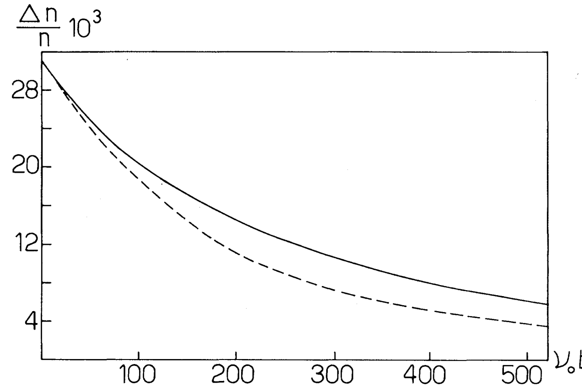

FIG. 1. Fraction of electrons in the tail vs time. We display two cases of rf strength: $D_{class}/D_{LH} = 10^{-2}$ (dashed line) and $D_{class}/D_{LH} = 10^{-3}$ (solid line). Location of the rf spectrum: $v_{min} = 9.9v_e$, $v_{max} = 30v_e$. The different behavior is related to an increase in T. The other parameters are $v_c = 3.3v_e$, $\omega_{ce}/\omega_{pe} = 3$, $\nu_0/\omega_{pe} = 10^{-6}$.

This formula agrees reasonably well with our computational experiments. With typical parameters $v_c = 3$, $v_D = 9$, $T = 50$ it gives an e-folding time of the order of 10^2 collision time.

Thus the proposed mechanism does not allow a significant steady-state current to be sustained by the rf field only. Instead the preformed runaway tail is slowly drained; one may guess that the electron distribution function eventually reaches Fisch's solution, viz. a plateau with an extremely small height beyond v_D, and therefore with a negligible current.

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Received 13 July 1982
PACS numbers: 52.35.-g, 52.50.Gj

[1]C. S. Liu, V. S. Chan, D. K. Bhadra, and R. W. Harvey, Phys. Rev. Lett. 48, 1479 (1982).
[2]L. Muschietti, K. Appert, and J. Vaclavik, Phys. Fluids 25, 1187 (1982).

