Self-consistent nonlinear kinetic modeling of runaway-electron dynamics

A. Stahl[1], O. Embréus[1], G. Wilkie[1], M. Landreman[2], G. Papp[3], and T. Fülöp[1]

[1] *Chalmers University of Technology, Göteborg, Sweden*

[2] *University of Maryland, College Park, MD, USA*

[3] *Max-Planck-Institute for Plasma Physics, Garching, Germany*

Runaway electrons represent the greatest threat to the plasma-facing components of a tokamak when they are highly energetic and constitute a significant fraction of the electron population, a regime which has not been previously accessible in modelling since it requires a nonlinear relativistic treatment. To address this problem, we present an efficient numerical tool called NORSE [1] for the study of runaway-electron momentum-space dynamics. The kinetic equation solved in NORSE includes a fully nonlinear relativistic collision operator [2], making it possible to consider scenarios where the electric field is comparable to the Dreicer field (or larger), or the electron distribution function is otherwise far from a Maxwellian (which can be the case already in present-day runaway experiments). This capability makes NORSE unique in the field of runaway-electron studies.

Using NORSE, we investigate the transition to a regime where the entire electron population experiences continuous acceleration, so-called electron slide-away [3, 4]. For the first time, we apply a nonlinear kinetic-equation solver to study the evolution of the electron distribution in an ITER disruption. We use an electric field calculated self-consistently, and show that the runaway-electron density becomes substantial, making the nonlinear treatment essential. In addition, we find that Ohmic heating and the rate of heat loss play an important role in determining the electron dynamics, with the latter affecting the average energy reached by the runaways by several orders of magnitude [5].

References

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