A non-linear relativistic solver for runaway-electron dynamics

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

[1]Chalmers University of Technology, Gothenburg, Sweden
[3]University of Maryland, College Park, MD, USA
[2]Max Planck Institute for Plasma Physics, Garching, Germany

Contact:
stahla@chalmers.se

Background

The more runaways, the greater the danger to the tokamak first wall. But linear kinetic tools break down once the runaway population becomes substantial. The dynamics cannot be studied in the cases of greatest importance.

What's new?

- NORSE: a new solver for the electron kinectic equation in homogeneous plasmas
- A relativistic, fully non-linear electron-electron collision operator is used

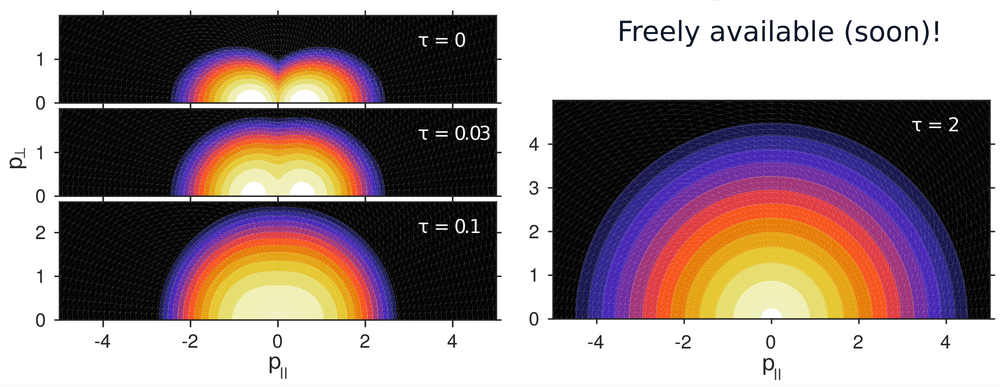
Conclusions

- Electric field heats thermal electron population; induces transition to the slide-away regime at $E<E_{SA}=0.215E_D$
- Non-linear effects crucial in ITER disruption scenario
- All electrons become runaways in ITER scenario
- Details of mechanisms of energy removal important

NORSE [1]

- NOn-linear Relativistic Solver for Electrons

Freely available (soon)!



Kinetic equation:

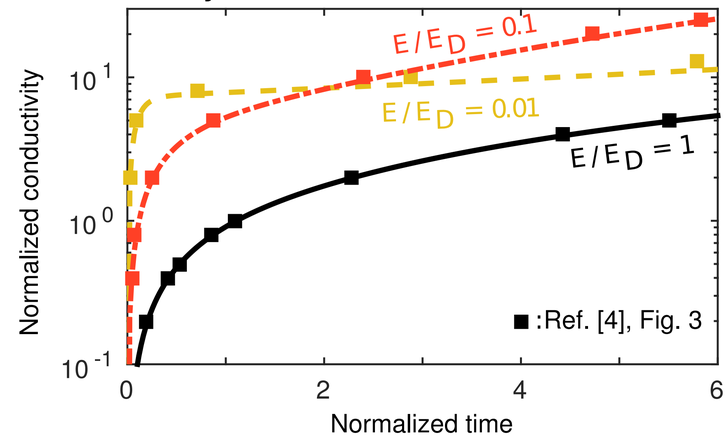
$$\frac{\partial f}{\partial t} - \frac{e\mathbf{E}}{m_e c}\cdot\frac{\partial f}{\partial \mathbf{p}} + \frac{\partial}{\partial \mathbf{p}}\cdot(\mathbf{F}_s f) = C_{ee}\{f\} + C_{ei}\{f\} + S,$$

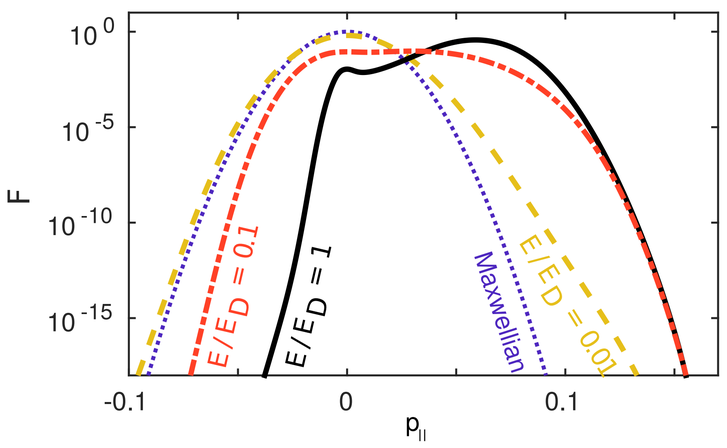
Arbitrary electron distribution; Arbitrary-strength electric fields; Non-linear relativistic Braams & Karney collision operator [2,3]; Time-dependent plasma parameters; 2D in momentum space; Synchrotron radiation reaction; Particle & heat sources

- 2D nonuniform finite-difference grid
- Mixed finite-difference--Legendre-mode representation for calculating potentials
- Semi-implicit time-advancement
- Matlab
- Efficient -- runs on a laptop

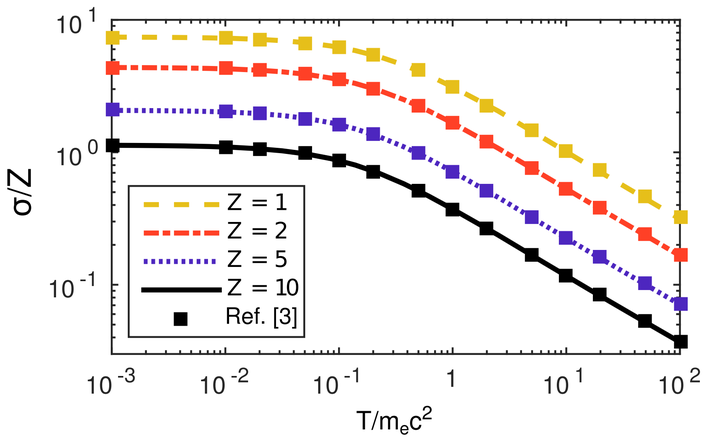
Benchmarks

- Non-linearity



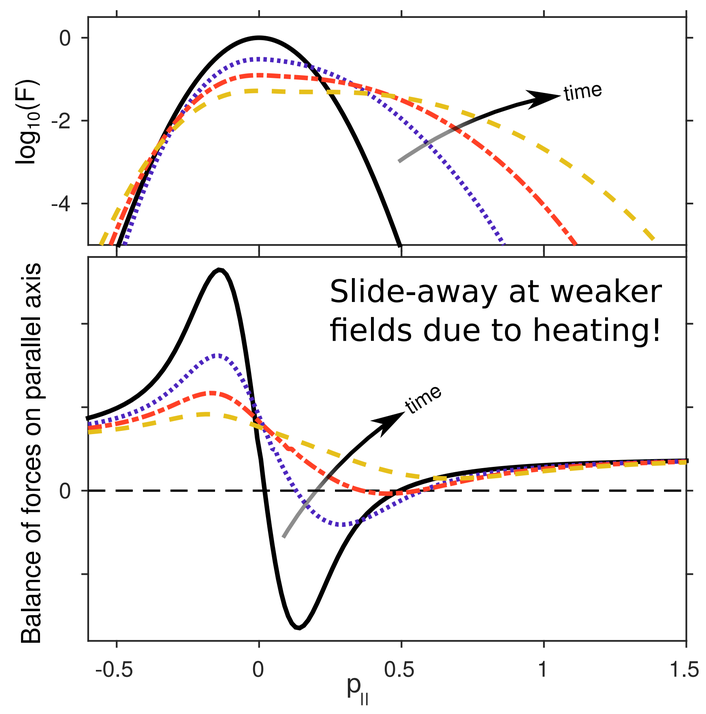


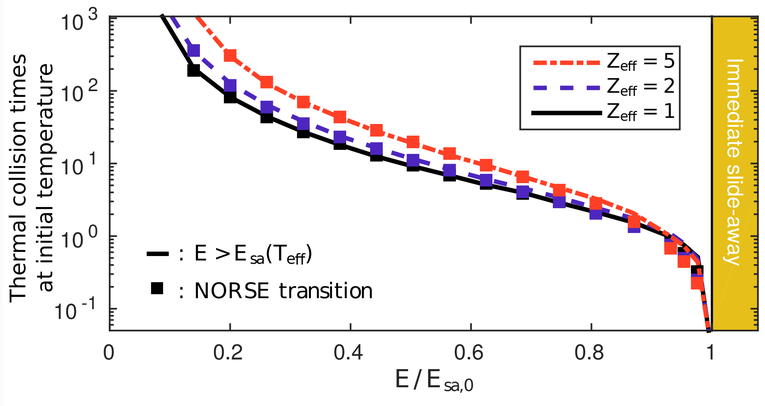
- Relativistic formulation

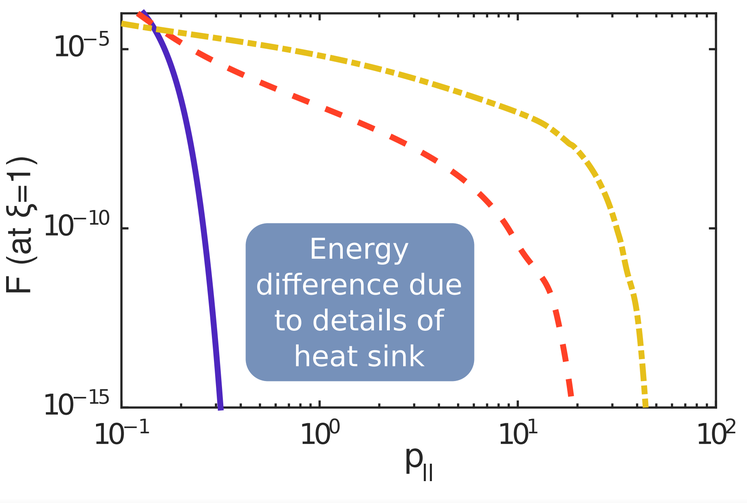


Transition to slide-away

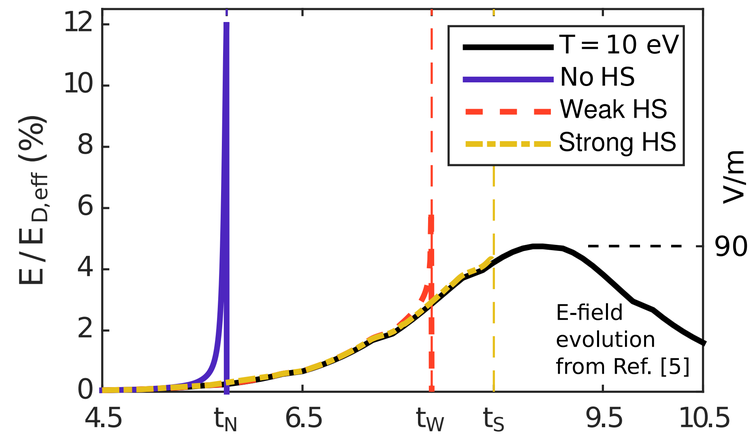
- All electrons accelerated -- positive force balance everywhere
- Linear theory: $E>E_{SA}=0.215E_D$

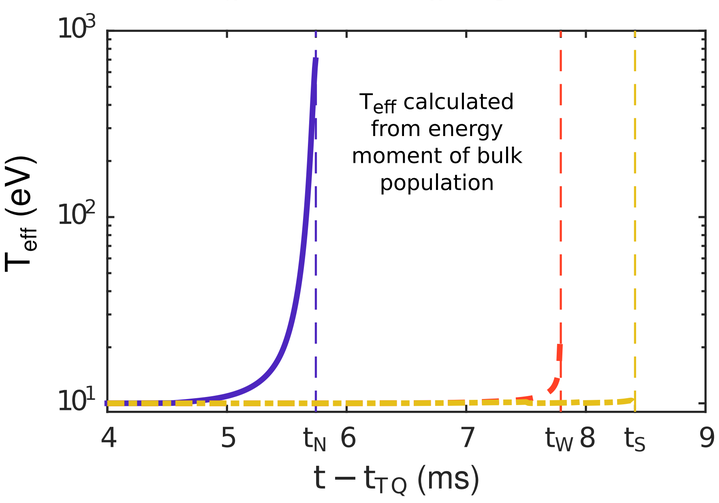


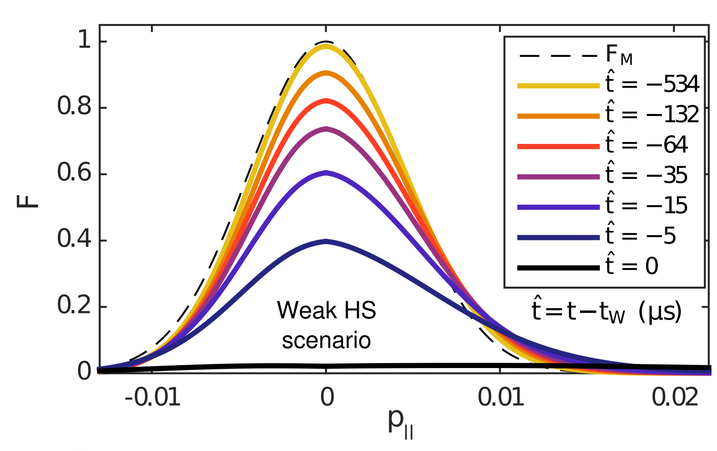


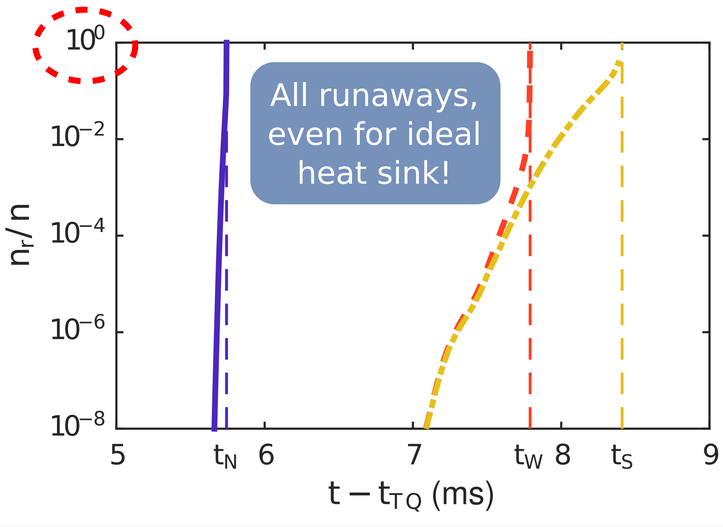


ITER disruption scenario









References:

[1] A. Stahl *et al.*, submitted to Comp. Phys. Comms., http://arxiv.org/abs/1608.02742
[2] B.J Braams and C. F. F. Karney, Phys. Rev. Lett., **59**, 1817 (1987)
[3] B.J Braams and C. F. F. Karney, Phys. Fluids B, **1**, 1355 (1989)
[4] S. M. Weng *et al.*, Phys. Rev. Lett., **100**, 185001 (2008)
[5] H. Smith *et al.*, Phys. Plasmas, **13**, 102502 (2006)