CHALMERS
UNIVERSITY OF TECHNOLOGY

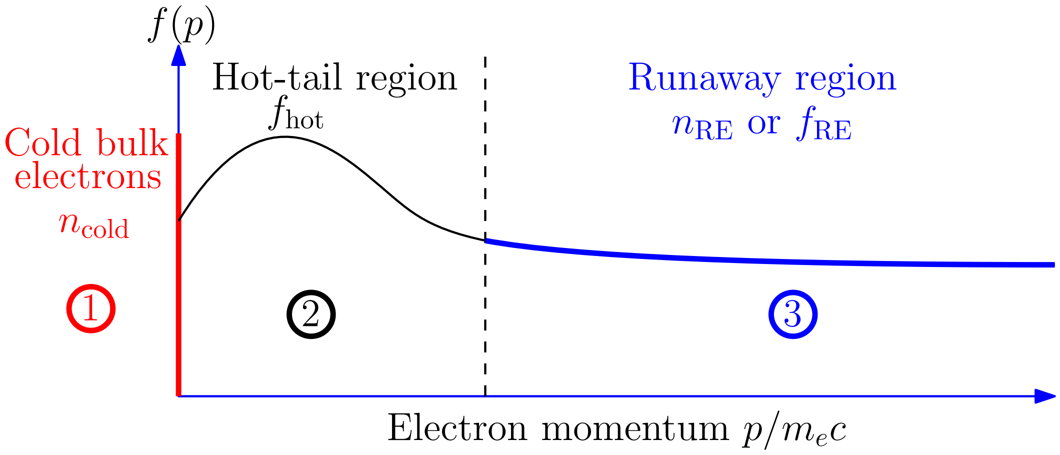
DREAM

The dreamers guide to runaway physics

O. Embreus and M. Hoppe

Features and buzzwords

- Fully implicit, non-linear, self-consistent solver for runaway generation during tokamak disruptions *(time-linearized mode also available)*
- Treating electrons as 1, 2 or 3 separate populations
- Numerical conservation of particle number and positivity (in the future?)
- Two-component code
  - High-performance kernel written in C++17 (with PETSc for linear algebra)
  - User-friendly frontend written in Python


$f(p)$
Hot-tail region
f_{hot}
Runaway region
n_{RE} or f_{RE}
Cold bulk electrons
n_{cold}
1
2
3
Electron momentum $p/m_e c$

- **Scalar quantities**
  - $I_{\mathrm{p}}(t)$: Total plasma current
  - $\psi_{\mathrm{edge}}(t)$: Poloidal magnetic flux at plasma edge
- **Fluid quantities**
  - $E_{\|}(t,r)$: Parallel electric field
  - $n_{\mathrm{cold}}(t,r)$: Cold electron density
  - $n_{\mathrm{hot}}(t,r)$: Hot electron density
  - $n_{\mathrm{i}}(Z,Z_0;t,r)$: Ion (charge state) densities
  - $n_{\mathrm{RE}}(t,r)$: Runaway density
  - $n_{\mathrm{tot}}(t,r)$: Total electron density
  - $j_{\mathrm{hot}}(t,r)$: Hot electron current density
  - $j_{\Omega}(t,r)$: Ohmic current density
  - $j_{\mathrm{tot}}(t,r)$: Total current density
  - $\psi_{\mathrm{p}}(t,r)$: Poloidal magnetic flux
  - $T_{\mathrm{cold}}(t,r)$: Cold electron temperature
- **Hot-tail grid quantities**
  - $f_{\mathrm{hot}}(t,r,p,\xi)$: Hot electron distribution function
- **Runaway grid quantities**
  - $f_{\mathrm{RE}}(t,r,p,\xi)$: Runaway electron distribution function

Scalars

- $I_\mathrm{p}(t)$: Total plasma current
- $\psi_\mathrm{edge}(t)$: Poloidal magnetic flux at plasma edge

Densities

- $n_\mathrm{cold}(t,r)$: Cold electron density
- $n_\mathrm{hot}(t,r)$: Hot electron density
- $n_\mathrm{i}(Z,Z_0;t,r)$: Ion densities
- $n_\mathrm{RE}(t,r)$: Runaway density
- $n_\mathrm{tot}(t,r)$: Total electron density

Distribution functions

- $f_\mathrm{hot}(t,r,p,\xi)$: Hot electrons
- $f_\mathrm{RE}(t,r,p,\xi)$: Runaway electrons

Current densities

- $j_\mathrm{hot}(t,r)$: Hot electron current density
- $j_\Omega(t,r)$: Ohmic current density
- $j_\mathrm{tot}(t,r)$: Total current density

Other quantities

- $E_\|(t,r)$: Parallel electric field
- $\psi_\mathrm{p}(t,r)$: Poloidal magnetic flux
- $T_\mathrm{cold}(t,r)$: Cold electron temperature

$$n_{\rm hot}: n_{\rm hot} = \int f_{\rm hot}\, \mathcal{V}' \mathrm{d}p\mathrm{d}\xi, \qquad \text{($f_{\rm hot}$ density moment)}$$

$$n_{\rm RE}: \frac{\partial n_{\rm RE}}{\partial t} = S_{\rm ava} - \int \hat{\boldsymbol{p}} \cdot \boldsymbol{\Phi}_{\rm hot}(p_{\rm max}, \xi)\, \mathcal{V}' \mathrm{d}\xi, \qquad \text{(avalanche+$f_{\rm hot}$ outflux)}$$

$$n_{\rm tot}: n_{\rm tot} = n_{\rm free} + n_{\rm bound}, \qquad \text{(electron conservation)}$$

$$j_{\rm hot}: j_{\rm hot} = \int e v_\parallel f_{\rm hot}\, \mathcal{V}' \mathrm{d}p\mathrm{d}\xi, \qquad \text{($f_{\rm hot}$ current moment)}$$

$$j_{\rm tot}: j_{\rm tot} = j_\Omega + j_{\rm hot} + ecn_{\rm RE}, \qquad \text{(current conservation)}$$

$$\psi_{\rm p}: \mu_0 \frac{j_\parallel}{B} \langle \boldsymbol{B} \cdot \nabla\phi \rangle = \frac{1}{V'} \frac{\partial}{\partial r} \left[V' \left\langle \frac{|\nabla r|^2}{R^2} \right\rangle \frac{\partial \psi}{\partial r} \right], \qquad \text{(flux diffusion)}$$

$$I_{\rm p}: I_{\rm p} = \frac{1}{2\pi} \int j_{\rm tot}(r)\, V' \mathrm{d}r, \qquad \text{(definition of $I_{\rm p}$)}$$