EFDA Task Force
EUROPEAN FUSION DEVELOPMENT AGREEMENT
INTEGRATED TOKAMAK MODELLING

Institute for Plasma Physics Rijnhuizen

Numerical Codes for Electron Cyclotron heating and Current Drive

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TORAY-FOM ray-tracing code

Code status: 'on ITM-Gateway'
Solves 3D geometric optics ray-tracing equations

$$\frac{d\underline{r}}{dt} \equiv \underline{v}_{gr} = \frac{\partial\Omega}{\partial\underline{k}} = -\frac{\partial D/\partial\underline{k}}{\partial D/\partial\omega} \qquad \frac{d\underline{k}}{dt} = -\frac{\partial\Omega}{\partial\underline{r}} = \frac{\partial D/\partial\underline{r}}{\partial D/\partial\omega}$$

Gaussian wave beam modeled with rectangular grid of rays.

Options for cold or warm (weakly and fully relativistic) ray-trajectories.

Equilibrium: provides a choice of

Analytic circular magnetic equilibrium including Shafranov shift

2D equilibria from bi-cubic spline fits to EQDSK data

Density and temperature profiles either analytic form or from cubic spline fit to data

option to include a magnetic island

Power absorption (choice of)

Weakly relativistic (1st and 2nd harmonic lowest order FLR)
Fully relativistic (arbitrary range of harmonics and of terms in FLR expansion)

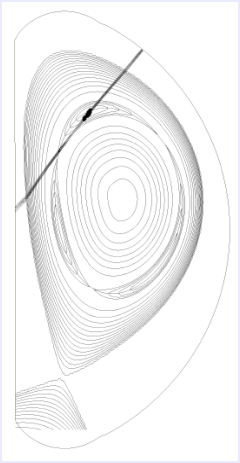
Adjoint Current Drive calculation (choice of)

Cohen R.H. 1987 *Phys. Fluids* **30** 2442
Lin-Liu Y.R.et al. 2003 *Phys. Plasmas* **10** 4064

ITER scenario 2

Lower Steering Mirror

3/2 mode



RELAX bounce averaged Fokker-Planck code

Code status: 'on ITM-Gateway'
Solves 2D velocity + 1D real space Fokker-Planck equation

$$\frac{\partial f_e}{\partial t} = \left\langle \sum_s C(f_e, f_s) \right\rangle_{\phi_B} - \left\langle \left\langle \hat{\Gamma}_{ql} \right\rangle_{\phi} \right\rangle_{\phi_B} - \left\langle q_e \hat{E} \cdot \hat{b} \frac{\partial f_e}{\partial p_{\parallel}} \right\rangle_{\phi_B}$$

General equilibria from spline fits to EQDSK data

Quasi-linear EC diffusion operator

Gaussian wave beam modeled with grid of rays (obtained from ray- or beam-tracing codes).

$$D_{\mu\mu} = \frac{\pi e^2}{m_e^2 \omega} \frac{\gamma p_\perp^2}{B^2} |\bar{G}_\perp|^2 \frac{e^{-(\gamma - n\omega_c/\omega - N_\parallel x_\parallel)^2/\Delta Q}}{\sqrt{\pi \Delta Q}} \times \frac{P_0 e^{-\int \alpha ds}}{\Pi \cos\chi} \frac{B}{2\pi \tau_B v_\parallel R B_p}$$

Warm, Maxwellian plasma or fully consistent wave polarization.

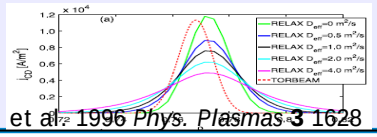
Collision operator (choice of)

(relativistic) Maxwellian back-ground
e-i collisions only in pitch-angle scattering

e-e momentum conserving correction

Isotropic background (energy conserving)

ITER scen 2
LSM 3/2 mode



Additional Physics

Radial diffusion
Parallel electric field
Finite orbit width effects: bootstrap current

Publications: Peeters A.G., et al. 1995 *PPCF* **37** 525
Westerhof E. et al. 1998 Comput. Phys. Commun. **93** 151
Peeters A.G. et al. 1996 *Phys. Plasmas* **3** 1628
Bertelli N. et al. 2009 *Nucl. Fusion* **49** 095018