The LUKE code for ions

Modelling the anisotropy of ion distributions under ICRH

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Introduction

- Models for the anisotropy of ion distributions under ICRH needed for
  - Measurements [1,2]
  - Reduced modelling [3-6]
- Research task: contribute to benchmarking effort of anisotropy models with results from a full 2D Fokker-Planck solver.
- Method: the LUKE code [7] has been adapted for ions, including quasilinear diffusion.

LUKE for ions

- LUKE for ions solves $\partial f_0/\partial t = C(f_0) + Q(f_0)$
  - Ion distribution function $f_0(p, \xi_0)$
  - Momentum p and pitch $\xi_0 = \xi(B_{\min})$
  - Bounce averaged, thin orbit width limit
  - Collisions $C(f_0)$ against a thermal background
  - Quasilinear operator $\mathrm{Q}(f_0)$ [8,9]
- Pitch distribution, $\chi = f_0/\langle f_0 \rangle_{\xi_0}$
  - Pitch average $\langle \dots \rangle_{\xi_0} = \ell^{-1} \int_{-1}^{1} \dots p|\xi_0|\tau_B \mathrm{d}\xi_0$
  - $\ell = \int_{-1}^{1} p|\xi_0|\tau_B \mathrm{d}\xi_0$, τ_B is bounce time
- $Q(f_0)$ with diffusion coefficients, e.g.

$$D_{pp}^{\mathrm{RF}} = (1-\xi_0^2)\frac{Z^2e^2}{2\tau_B}\sum_s |J_0E_+ + J_2E_-|^2\,|\tau_\mathrm{r}|^2\,B/B_0$$

  - $\tau_\mathrm{r} = \int e^{i\nu}\mathrm{d}t$; $\nu = \int(\omega - n\Omega_c - \boldsymbol{k}\cdot\boldsymbol{v})\mathrm{d}t$ is phase; s are stationary points, $\dot{\nu} = 0$.

Conclusions

Results of LUKE for ions show that

- Strong local quasilinear diffusion with collisional pitch scattering allow for shifted peak location of the pitch distribution,
- Gaussian distributions w.r.t. pitch or Λ capture the single-peaked pitch distribution well,
- The parallel temperature is limited by pitch scattering as predicted by Stix.

References

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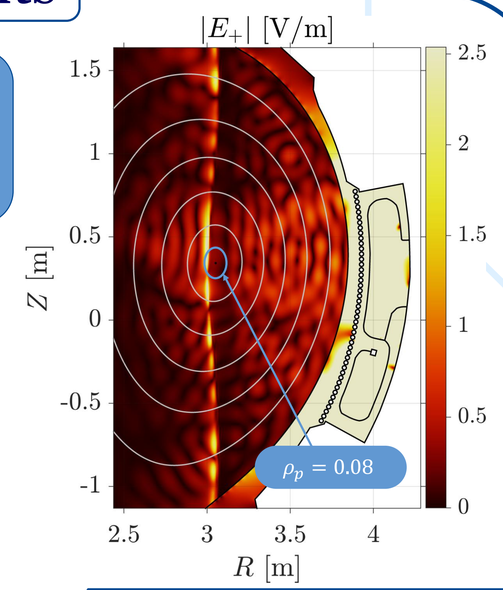
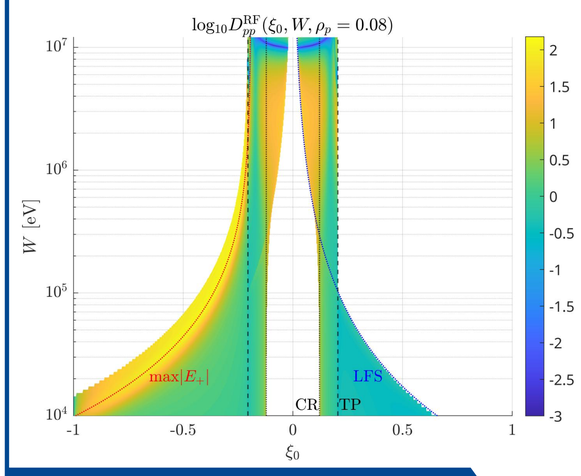
Results

JET-like plasma, minority heating of 3% ^{3}He in D plasma; $P = 5$MW; $n_\phi = 15$; on axis: $n_e = 8 \times 10^{19}$ m^{-3} and $T = 3$ keV.

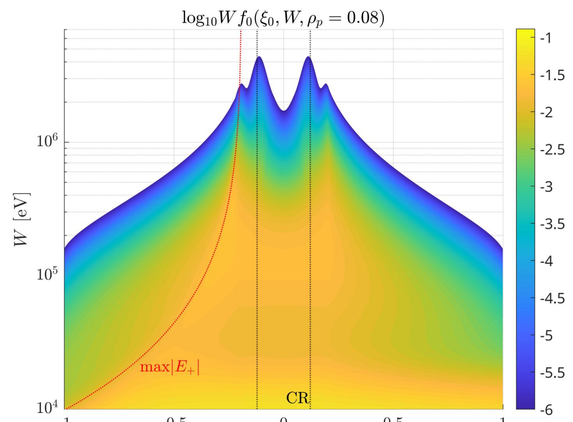


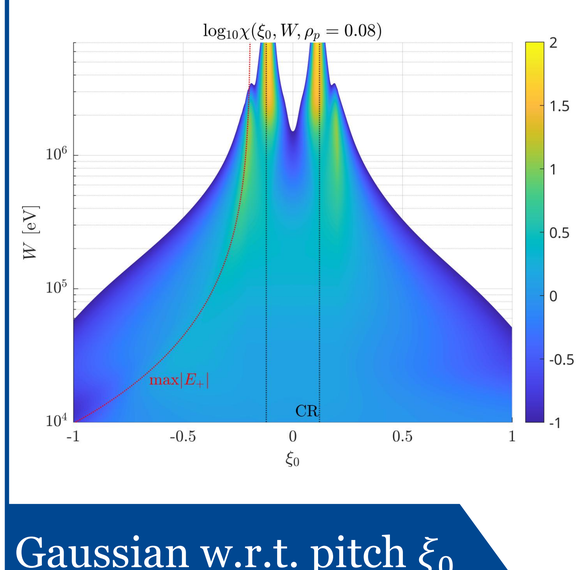
Wave fields from full wave solver FEMIC [10] show strong $|E_+|$ at L-cutoff.



Strong RF diffusion at strong $|E_+|$. CR: cold resonance, $\omega = \Omega_c$; TP: trapped-passing boundary; LFS: low field side on mid plane.

Distribution Wf_0 exhibits main "rabbit ears", but also, secondary peaks associated with strong $|E_+|$.





Pitch distribution χ is peaked close to strong $|E_+|$ at 1-2 MeV; expected peak at CR because of RF characteristics [11].

Gaussian w.r.t. pitch ξ_0 (smooth rabbit ear model), or $\Lambda = 1 - \xi_0^2$, fits pitch distribution well. Dendy model [12,5] lacks smoothness.

Transition from isotropic case, where pitch angle scattering ensures $T_\parallel = T_\perp$, to anisotropic case, where $T_\parallel$ limited by $\sim W_\gamma/4$, as predicted by Stix [13].

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