Study of Nonlinear Fast Particle Transport for the ITER 15MA Scenario

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In certain ITER scenarios, a "sea" of small-amplitude perturbations is likely. The crucial question then is, if the interaction between the "sea" of perturbations with the energetic particles (EP) will drive linearly stable or weakly unstable modes such that EP transport occurs in a domino effect.
To investigate this in detail -- for example the EP density threshold for a domino-like transport behaviour, first realistic multi-mode simulations are carried out for the ITER near-stability regime (15 MA scenario) with the hybrid driftkinetic-MHD code package HAGIS-LIGKA [Pinches'98,Lauber'07] .
To help to understand the nonlinear phase space behaviour, especially in multi-mode scenarios, a new analysation diagnostics has been implemented into HAGIS, the HAMILTONIAN MAPPING technique [Briguglio'14].

Challenges

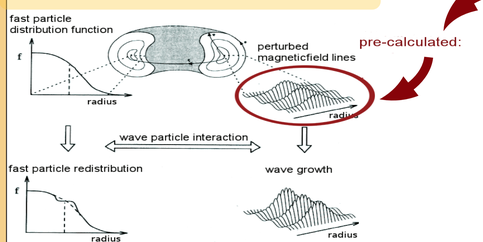
- up to more than 20 modes
- big machine and small modes (high-n)
- many poloidal harmonics

➡ high resolution
(=up to > 10 Mio. markers)

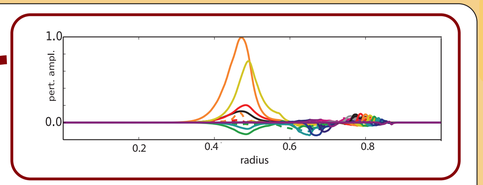
- small drive

➡ long simulation time
(ok, as slowing-down time ≈ 0.3 s)

The HAGIS-LIGKA model



[Pinches'98, Lauber'07]

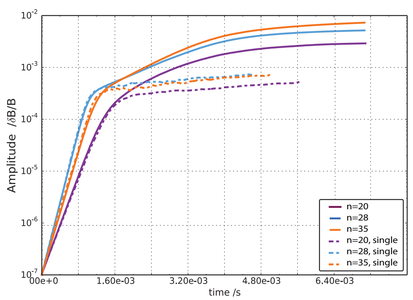


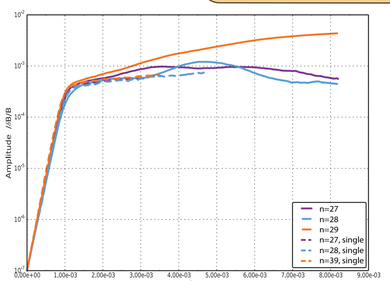
LIGKA is -gyrokinetic, non-perturbative
-linear, global
-eigenvalue solver

HAGIS is -drift-kinetic, PIC
-hybrid, perturbative,
-nonlinear, electromag.
new: passive species

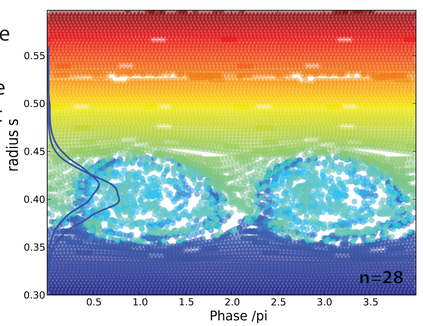
First HAGIS results

First multi mode results:





The HAMILTONIAN MAPPING technique [Briguglio'14] has been implemented into the code to allow for analyzing the phase space behaviour of the resonant EPs.
It will be used to improve the understanding of multi mode evolution and EP transport in complicated scenarios.

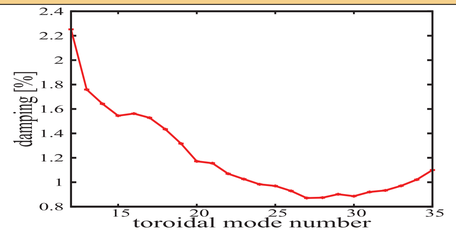


Multi mode behaviour can differ significantly from single mode behaviour, but depends strongly on the radial mode distances, which is consistent with earlier, more theoretical studies [Nucl.Fusion 52, 103019]

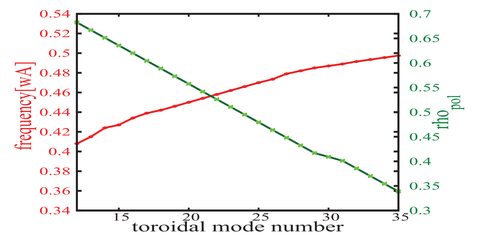
➡ **It is dangerous to estimate EP transport and mode drive in ITER multi mode scenarios quasi-linearly on the basis of single mode simulations.**

LIGKA results

LIGKA finds a broad mode spectrum, the least damped around *n*=28.



With increasing *n*, the mode radial position slightly decreases, the frequency increases.



The modes are located around $s \approx 0.4$, but some with many poloidal harmonics up to $s \approx 0.8$.