Study of Nonlinear Fast Particle Transport in the Presence of Alfvén Waves for the ITER 15MA Scenario

Mirjam Schnellner¹, Philipp Lauber¹, Sergio Briguglio¹²

(1) Max-Planck-Institut für Plasmaphysik, Garching, Germany
(2) Centro Ricerche ENEA, Frascati, Italy
mirjam@ipp.mpg.de

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 HAGIS-LIGKA [Pincher’98,Lauber’07] model.

To help to understand the nonlinear phase space behaviour, a new test particle diagnostic has been implemented into HAGIS, the HAMILTONIAN MAPPING technique [Briguglio’14].

First HAGIS results

Linear HAGIS single mode simulations also reveal the most unstable behaviour between n=21 and n=31.

HAGIS slightly over-estimates the drive, due to the meaning of full effects, as well as background damping.

The resonance lines are broad due to the flat profile and overlap widely (i.e. are not complementary).

Multi mode behaviour can differ significantly from single mode behaviour: in certain cases, multi mode saturation amplitude and EP transport exceed by far estimates based on single mode simulations.

However, the behaviour depends strongly on the exact scenario (radial mode division, resonance pattern). This has also been found in earlier (ASDEX Upgrade related) studies [Schneller’12].

The HAGIS-LIGKA model has been used before to investigate ICRH heated ASDEX Upgrade discharges [Pincher’98,Lauber’07] (the experimental) observed [García-Muñoz’10] EP losses in the lowest energy range.

...by a redistribution that is complementary in phase space (intermediate case). This leads to strongly enhanced EP losses.

Towards the all-TAEs multi mode case:

Simulation with the n=10 to 35 TAEs of the main branch and two lower-n TAEs. The EP density was set to 50% of the TCR database value; background damping was ignored.

At what density will the low-n TAEs be unstable? How will multiple low-n and intermediate-n TAEs change the picture?

In the investigated multi-mode scenarios with more than 7 TAEs all branch TAEs exceed the single mode saturation level.

Conclusions & Outlook

- The linear, gyrokinetic LIGKA model predicts a “sea” of marginally unstable perturbations (up to n=35) for the ITER 15MA scenario, including weakly damped low-n side branches of TAE, located rather far outside.
- The hybrid, hybrid HAGIS code models nonlinearly the interaction of energetic particles with global waves. The wave properties are based on LIGKA calculations. Earlier realistic ASDEX Upgrade studies with the HAGIS-LIGKA model have revealed that multi mode saturation amplitudes and EP transport exceed single mode simulations. These findings were consistent with experimental observation.
- For the ITER 15MA scenario, the HAGIS-LIGKA model is used to investigate, whether linearly stable TAEs (e.g. side-branches) can be nonlinearly excited via phase space coupling effects. First simplified multi mode calculations reveal similar, nonlinear multi mode effects as in ASDEX Upgrade simulations. Ongoing work is addressing the conditions under which nonlinear excitation of the lower-n main TAE branch can lead to enhanced, domino-like energetic particle transport, exceeding single mode estimates.

The energy exchange best 2D wave (reducing) splits in the radial space (Pf).

The amplitude saturates due to flattening and radial decoupling. The power transfer (E) decreases.

First results of the nonlinear benchmark between HAGIS-LIGKA and HAGIS both find a scaling weaker than quadratic linear saturation amplitude and growth rate. This is expected if radial decoupling occurs (not resonance detuning).