Kinetic Modeling of Runaway Electron Dynamics

NTUA contribution

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NTUA activities: Status and Plan

1. Calculation of all orbital frequencies of the guiding center electron trajectories for a given equilibrium (drift, bounce/transit frequency, orbit-averaged gyrofrequency), taking into account finite orbit effects (task 1c).

   Achievement:
   Orbital spectrum calculation for analytically and/or numerically given equilibria.

   Status(3/2015):
   Calculations for analytical equilibria have been implemented.
   Testing and benchmarking of first results.

   Plan (-12/2015):
   Results for runaway electrons in analytical equilibrium magnetic fields.
   Work on coupling with equilibrium codes - consideration of numerical equilibria.

NTUA activities: Status and Plan

2. Spectral analysis of perturbation modes in terms of the electron orbital spectrum and identification of resonance conditions for electron-mode interactions: kinetic modes (task 2a), MHD modes, RMP and turbulence (task 2b), magnetic ripple (task 2c).

   Achievement:
   Conditions for resonant electron-mode interactions and parametric investigation of synergetic effects under the presence of different types of modes in terms of RE generation and transport.

   Status (3/2015):
   Calculation of resonance conditions for any given perturbation mode in analytical equilibria have been implemented.
   Testing and benchmarking of first results.

   Plan (-12/2015):
   Calculation of the resonance width for each perturbation.
   Interaction with other groups for the definition of perturbation spectra of interest.

NTUA activities: Status and Plan

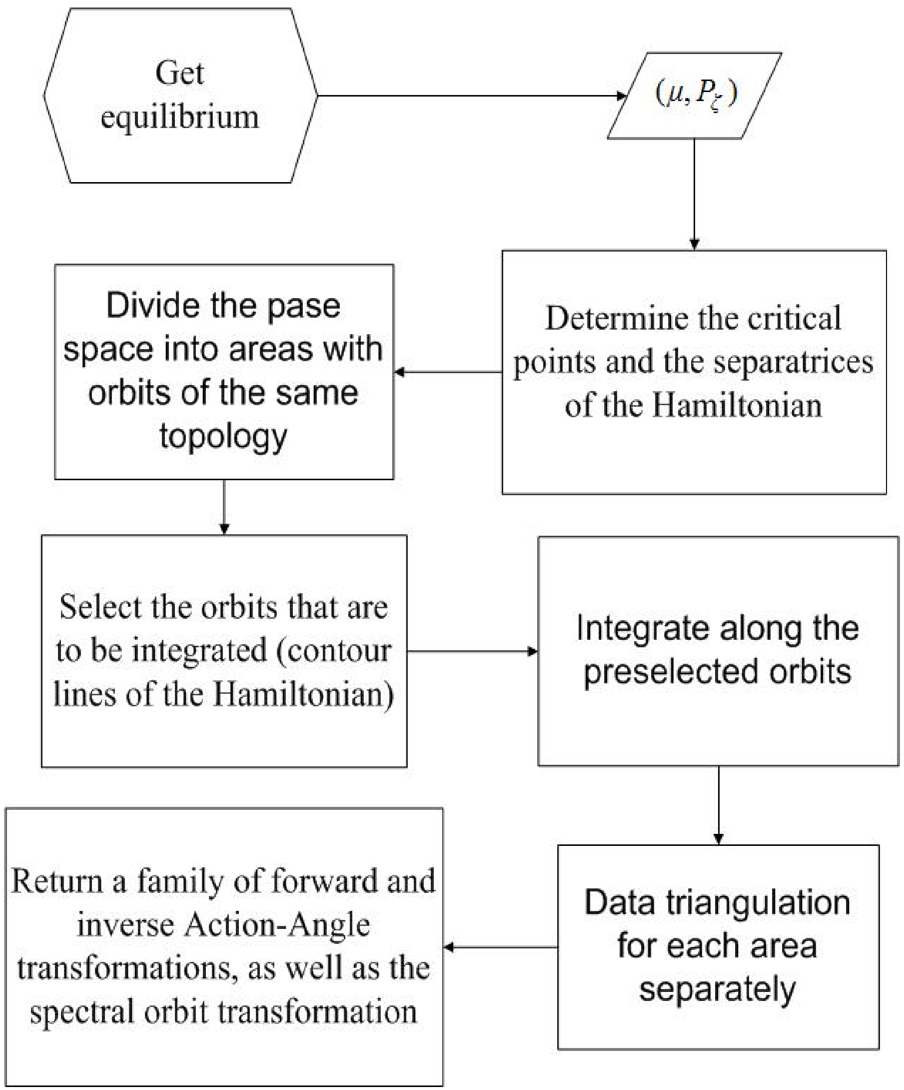
3. Utilization of the calculated resonance conditions for focusing the numerical investigations (by LUKE, ANTS and ASCOT) in specific electron phase space areas where these conditions are met (task 3a) and comparison with experimental data (task 3b).

   Achievement:
   Provide input regarding electron kinetic characteristics and perturbation mode parameters for further numerical investigation in terms of other codes within the project.
   Understanding and explanation of simulation and experimental data.

   Plan (-12/2015):
   Interaction with other groups running kinetic codes for the definition of cases of interest.

Numerical Action-Angle Transform

Algorithm Block Diagram



- The magnetic momentum and the toroidal canonical momentum are both constants of motion for the g.c. motion.
- The dynamic phase space has one degree of freedom à **semi-analytical knowledge of phase-space topology**.
- Phase space divided into different areas by separatrices à appropriate labeling.
- Each area has its own Action Angle Transformation.
- After the calculation we can **express every perturbation in the orbital spectrum**.

“Phase space engineering”

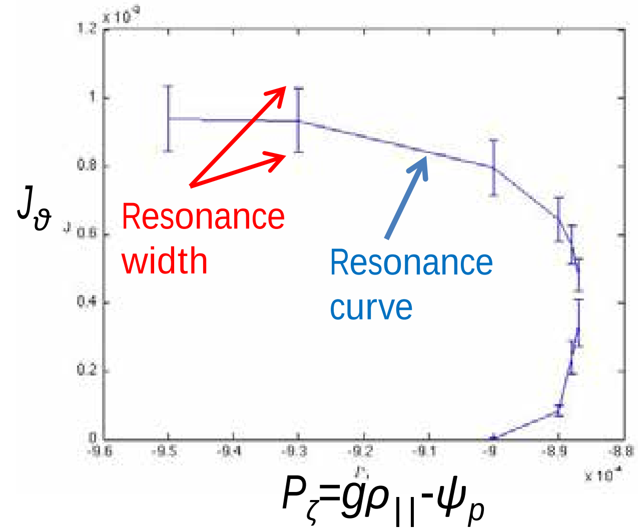
Ø **Immediate knowledge of the resonant orbits and the width of the resonance.**

Ø **Investigation of possible synergies for different perturbations in terms of controlling the electron distribution.**

Indicative first results based on numerical Action-Angle transform

Resonance with a single wave perturbation (*$m\varphi+n\zeta-\omega t$*)

Resonance condition in action space



Resonance conditions:

- are readily available from the orbital spectrum calculation
- are expressed in terms of the constants of the electron motion
- take into account orbit topology and finite orbit effects

Bifurcation of resonant orbits for electrons with μ: constant