Towards the prediction and quantification of energetic particle transport and losses in fusion plasmas

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ABSTRACT

- Energetic particles (EP) are ubiquitous in fusion plasmas → Need to be well confined to ensure steady-state operation [1,2]
- In present and future fusion devices, tearing modes can be excited, especially with q-profiles typical of hybrid and advanced scenarios of the JET tokamak.
- In the next JET experimental campaign, with DT plasmas, a significant population of alpha particles can be produced.
- In the paper it is shown that tearing modes can lead to significant losses of alpha particles due to anomalous transport.

BACKGROUND

- Previous studies have analyzed the topic of transport and losses of EP in the presence of one single helicity electrostatic mode, resulting in anomalous transport of EP [3,4].
- For magnetic perturbations, seminal work by Mynick [5] reported the fact that the large magnetic drift of EP can introduce periodicity in the trajectories that couple to the tearing mode, resulting in the generation of higher order harmonics.
- Experimental evidences in DIII-D [6], AUG [7] and EAST [8] of losses of EP in the presence of a tearing mode.
- In this paper: we focus on the .transport and losses of fusion-born alpha particles in a JET-like tokamak.

THE GCT CODE

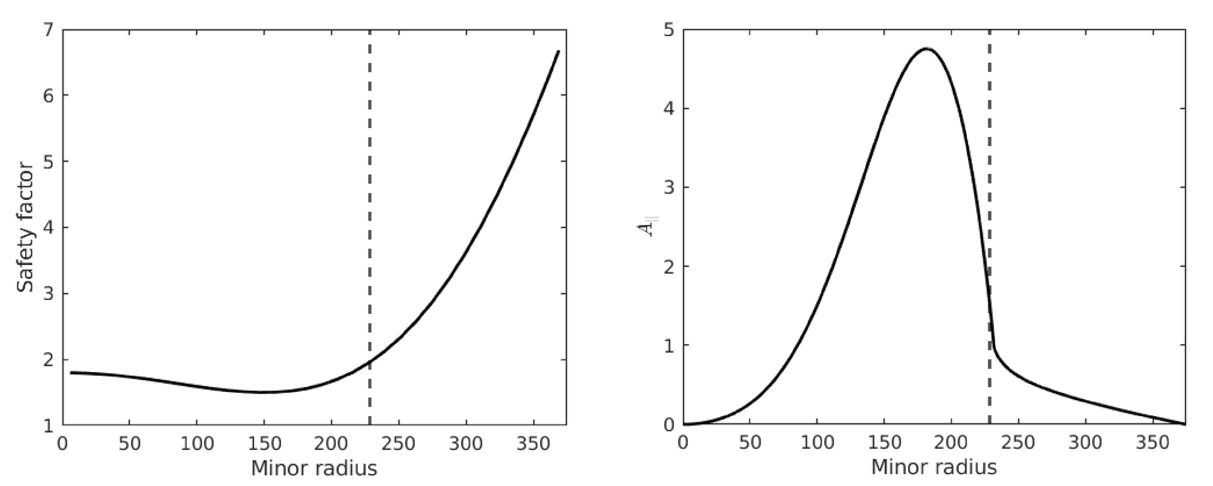
GCT solves the equations of motion of guding-centres in co-variant formulation in an arbitrary 3D magnetic equilibrium, in the presence of externally imposed 3D electro-magnetic perturbations, taking into account the gyro-average and the collisions.

In the present work:

- Hamiltonian composed of the magnetic potential only

$$A_{\parallel}(r,\theta,\varphi,t) = A_{\parallel}(r)\cos(m\theta + n\varphi - \omega t)$$

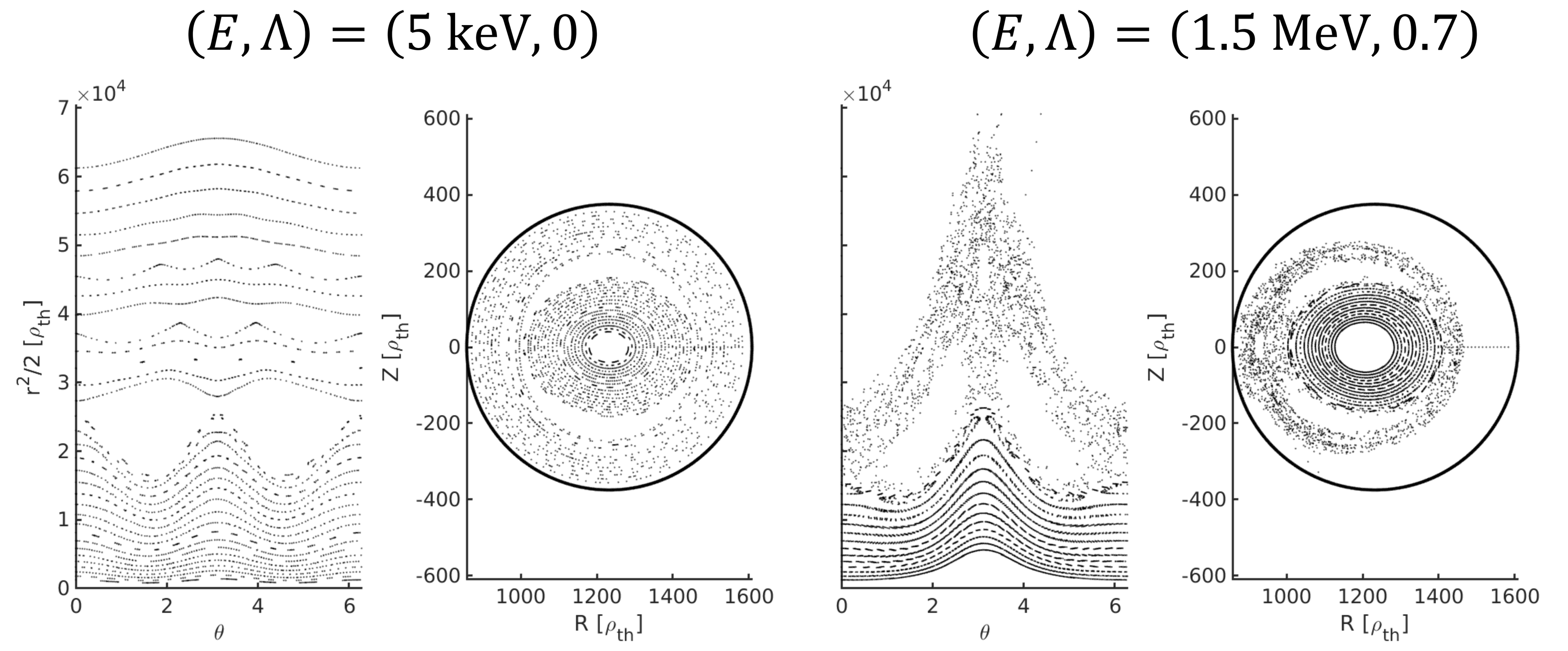
- $(m,n,\omega) = (2,-1,0)$ and $A_{\parallel}(r)$ calculated using a shooting module, as done in [9].
- No collisions and no gyro-average operators.
- Reversed q-profile exhibiting $\Delta' > 0$ (tearing unstable).



ONETEARING MODE → CHAOTIC TRANSPORT

Higher order harmonics observed when increasing the energy and the pitch angle of the alpha particles → Overlap → Chaotic transport

$(E,\Lambda) = (5\ \mathrm{keV}, 0)$ $(E,\Lambda) = (1.5\ \mathrm{MeV}, 0.7)$

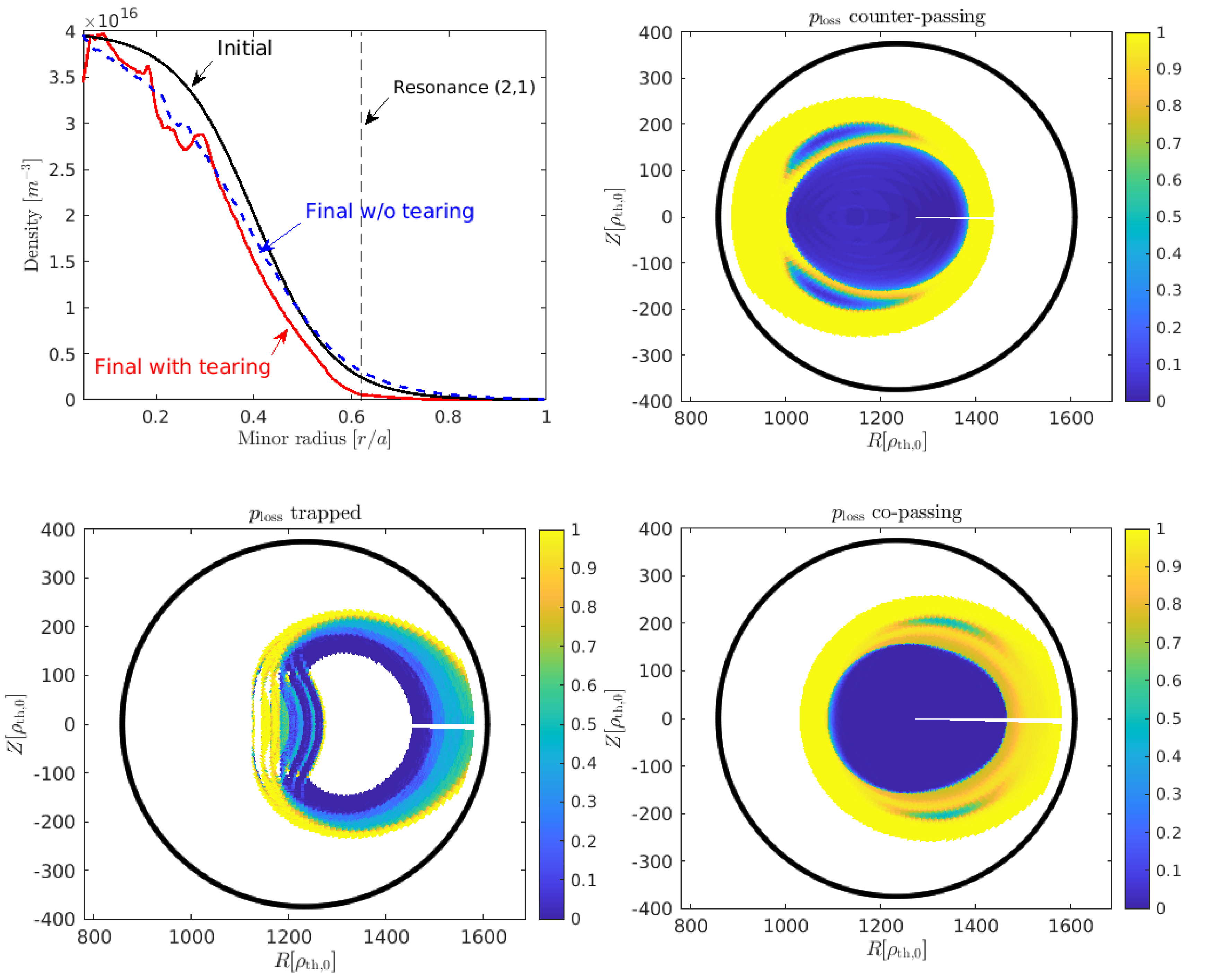


ANOMALOUS TRANSPORT OF ALPHA PARTICLES

Modification of an initial density profile (see figure 15 of Ref. [10])

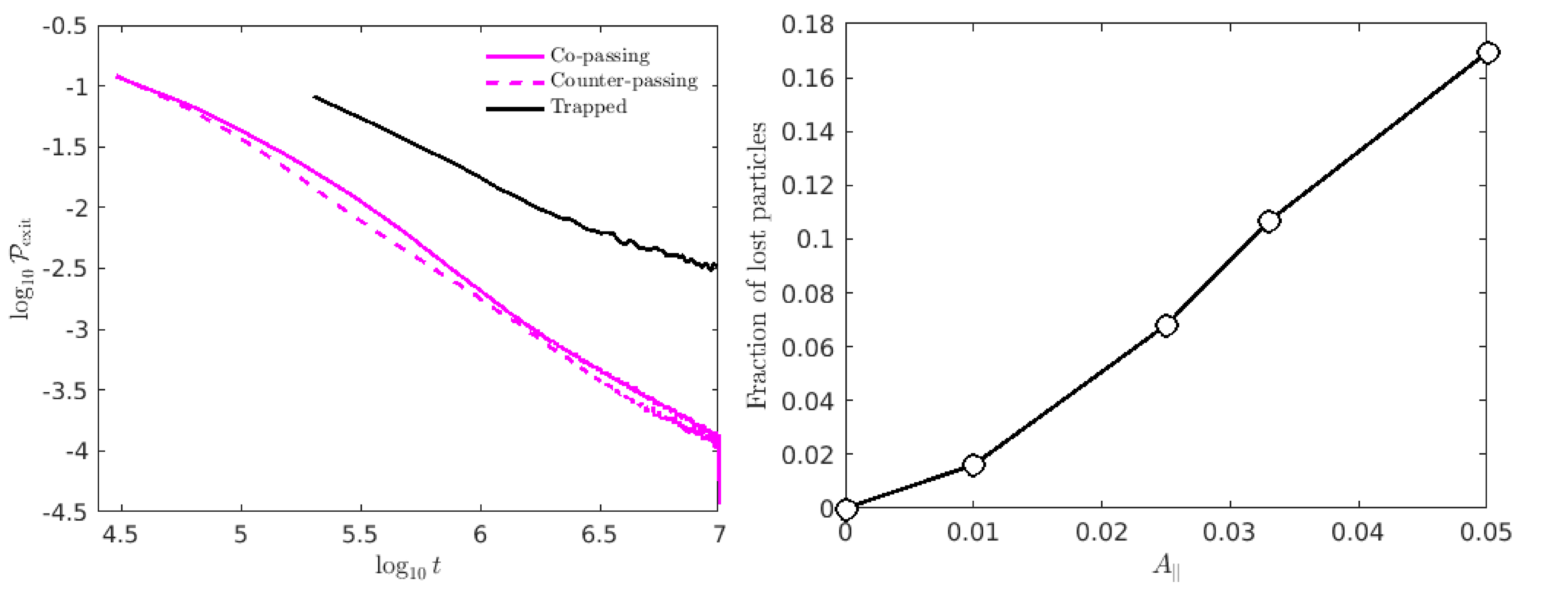
- Without tearing mode → Prompt losses
- With tearing mode → Depletion in the region $0.3 \leq r/a \leq 0.8$

Impact due to losses of passing (co- and counter-) and trapped α particles.



Large exit times → heavy tailed PDF → non diffusive transport

Fraction of lost particles at 50 ms (< Spitzer time) can reach up to 17%



CONCLUSION

- Transport and losses of fusion-born alpha particles in a JET-like tokamak under the simplification of concentric circular flux surfaces.
- Large magnetic drift of alpha particles leads to the formation of higher poloidal harmonics in phase space, which can eventually overlap and result in chaotic regions
- Significant losses at times < Spitzer time due to anomalous transport.

ACKNOWLEDGEMENTS / REFERENCES

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