

Steady State Turbulent ITER-like Plasmas with RF Drivers



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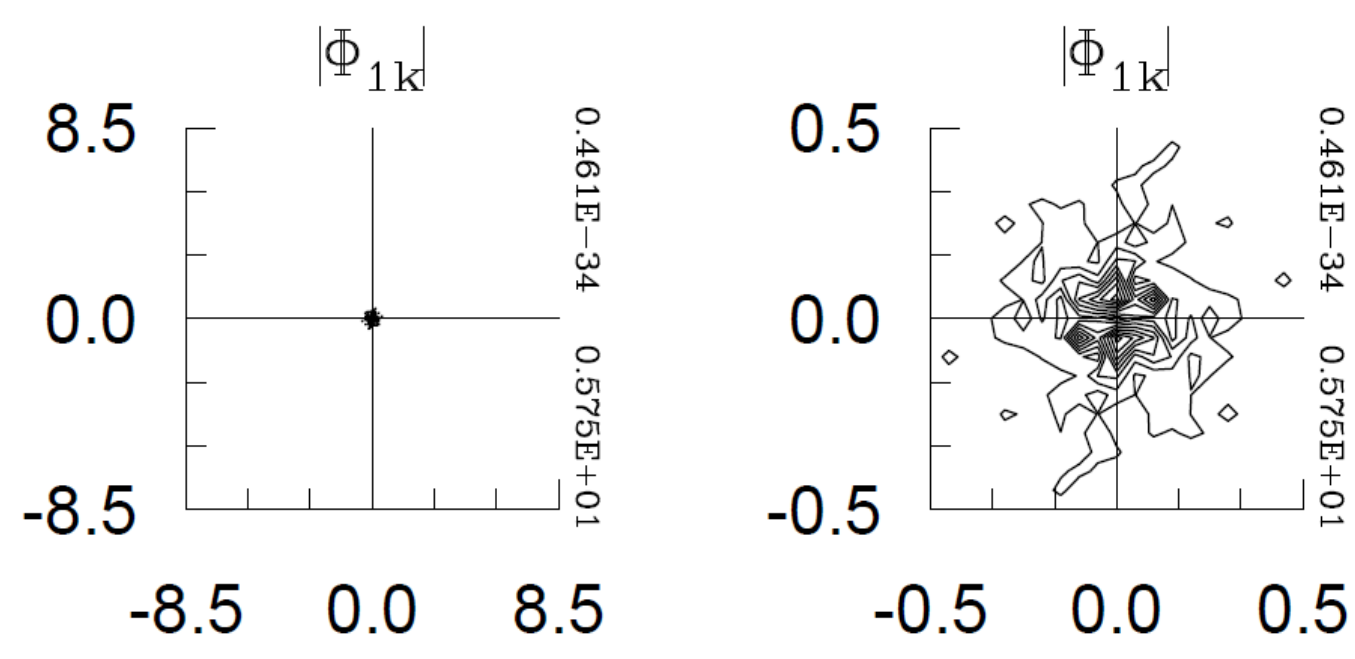
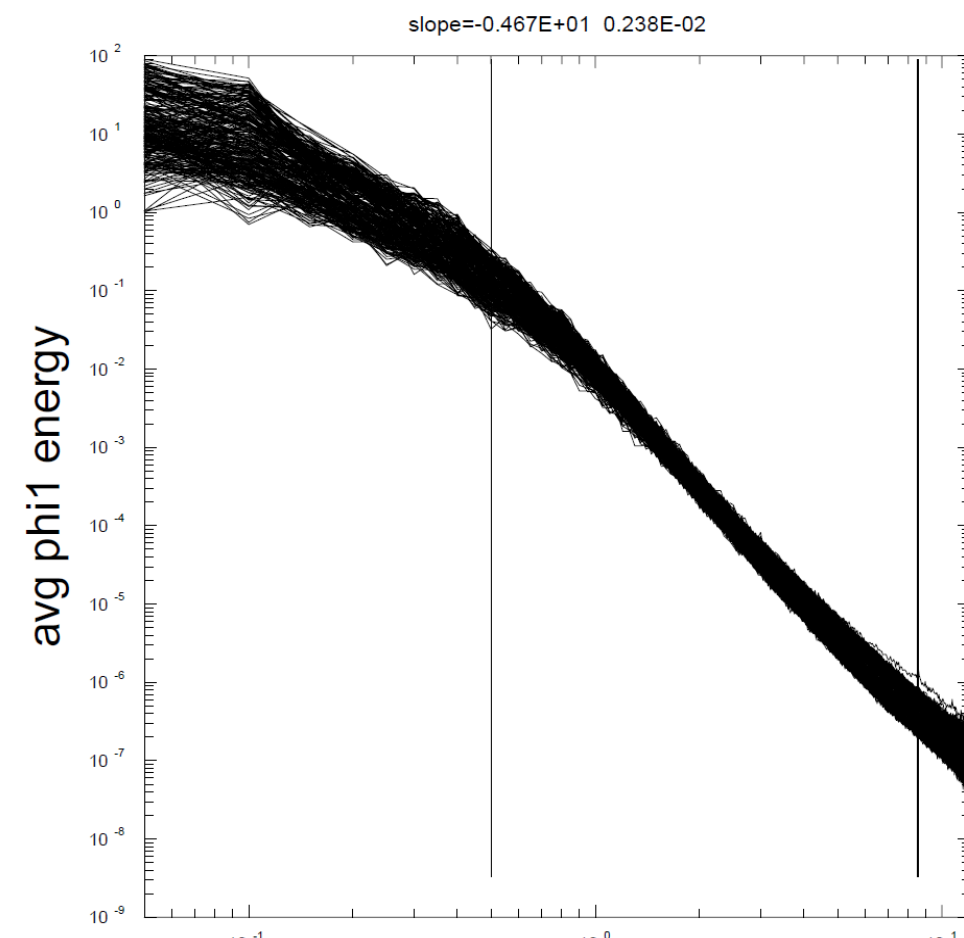
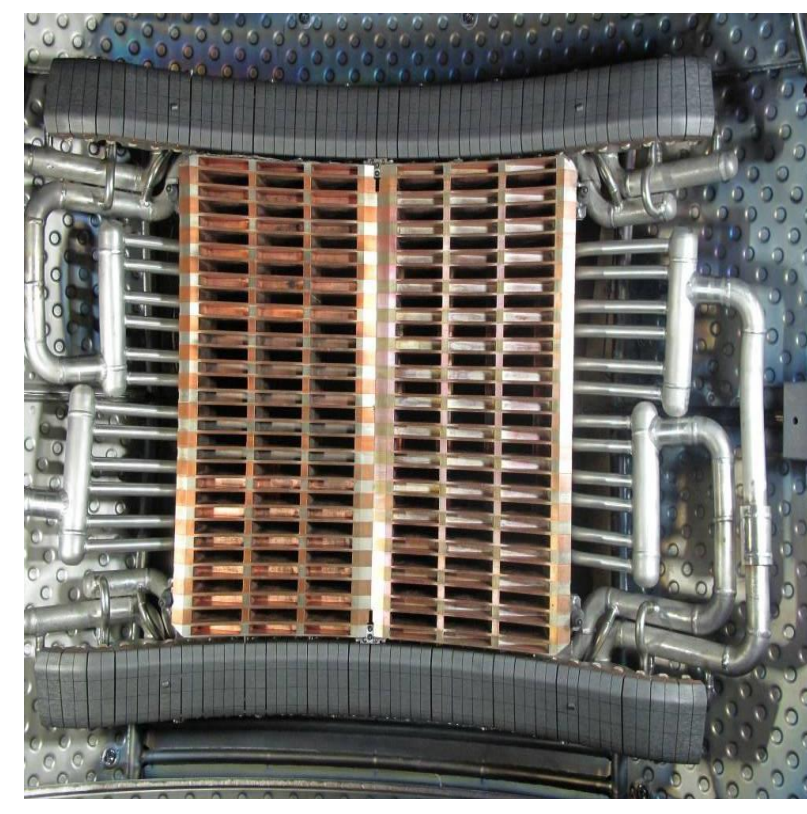
Introduction

- Kinetic modified MHD-like equations for SOL with I-mode physics, anisotropic pressure tensor from ion orbit losses and electron confinement in SOL.
 - Hamiltonian equations describes plasma relaxation/current drive with Helicity conservation and Chaotic B
 - Drift wave turbulence from steep electron temperature gradients in H-modes divertor produces strong scattering of the RF waves – modifies heating and current drive.
- Antennas / pde's for RF waves that drive $F_e(x, p, t)$
- Electron Phase Space Gradients driving ETG turbulence

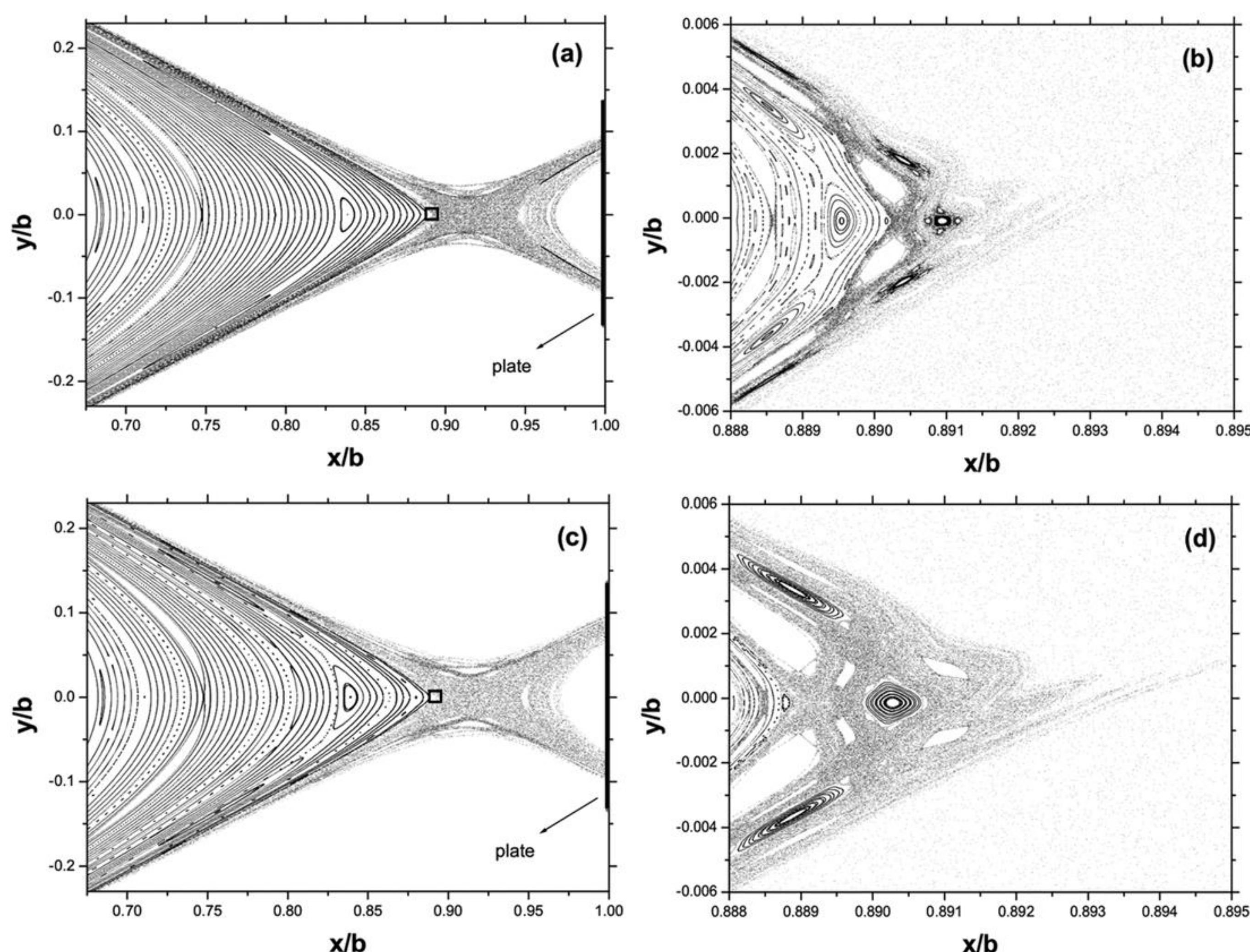
Single null X-point and

$$f_e(x, p_{\parallel}, p_{\perp}, t)$$

distribution has $T_{\parallel} \gg T_e$
 Validated by X-ray spect



Chaos along and across the Single Null Divertor and D- Plate



- LHCD is a proven method to maintain and control toroidal current profiles in a steady-state tokamak as demonstrated in Tore Supra and EAST tokamaks and expected in WEST.

- Efficient and synergistic properties of RF drive for steady-state heating and current drive are partly due to ETG plasma turbulent transport.
- ETG turbulence modified by the RF and SOL chaotic orbits
- Complex structures along the SOL change Stability and Transport
- I-modes occur and electron phase space function $f_{3T}(p_{\parallel}, p_{\perp}, r, t; P_{RF})$ driven by the RF power $P_{RF}(t)$ long SOL are complex.

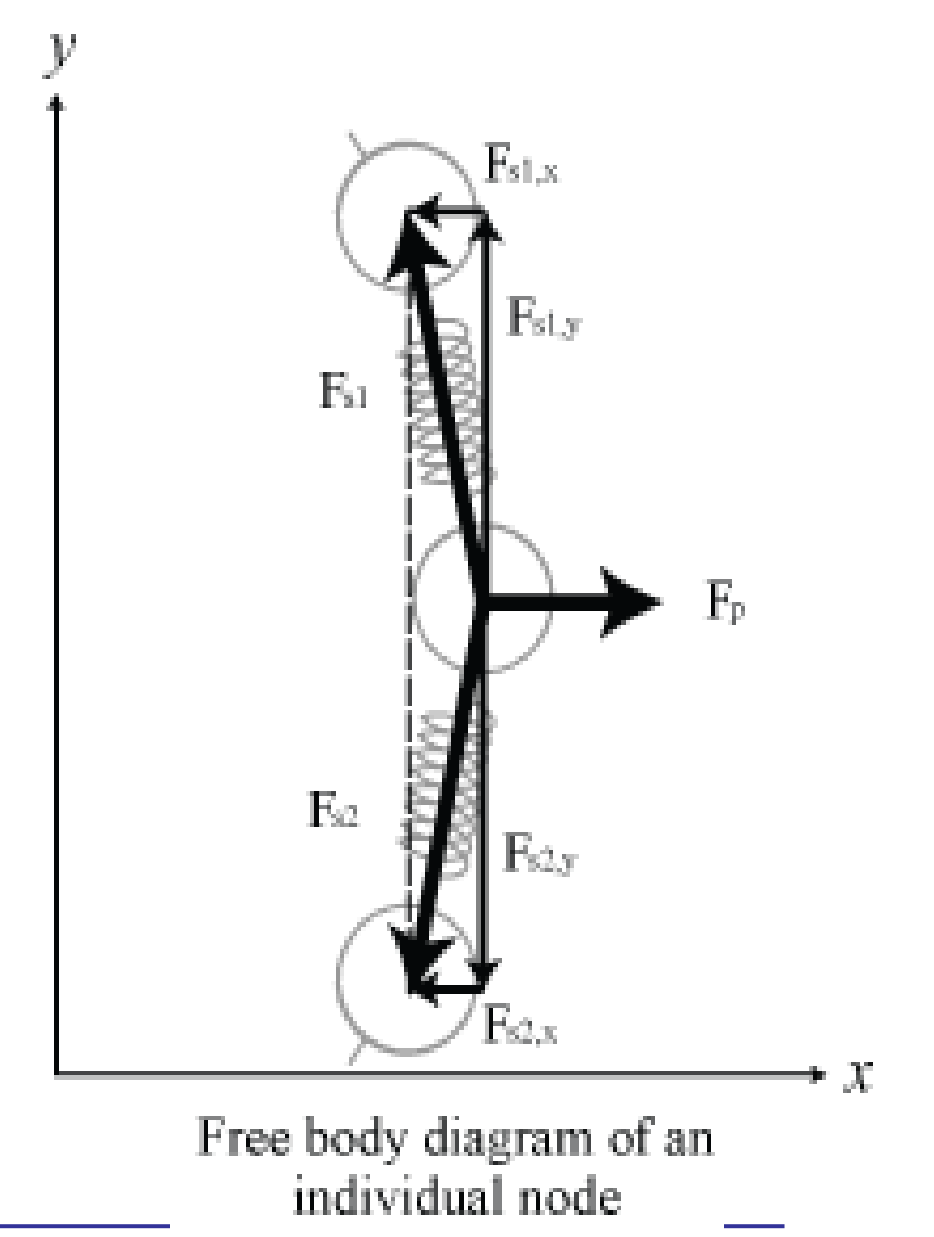
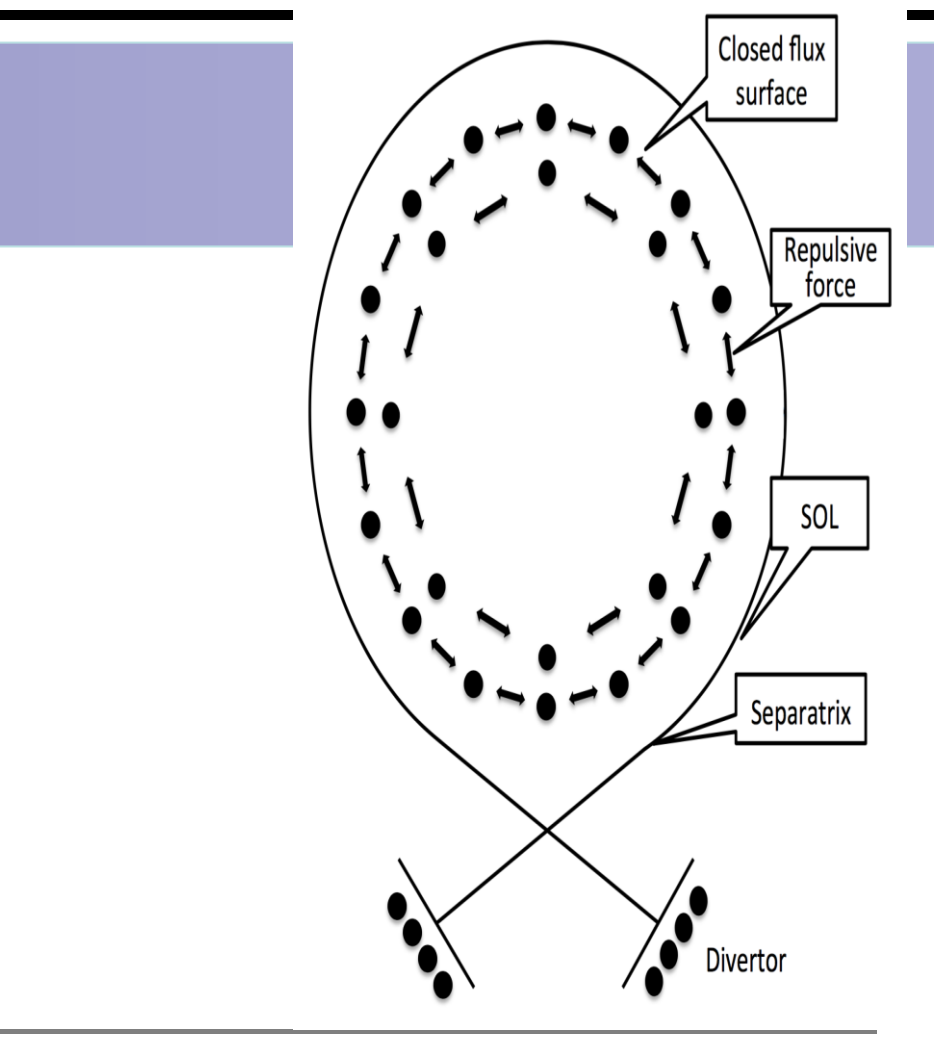
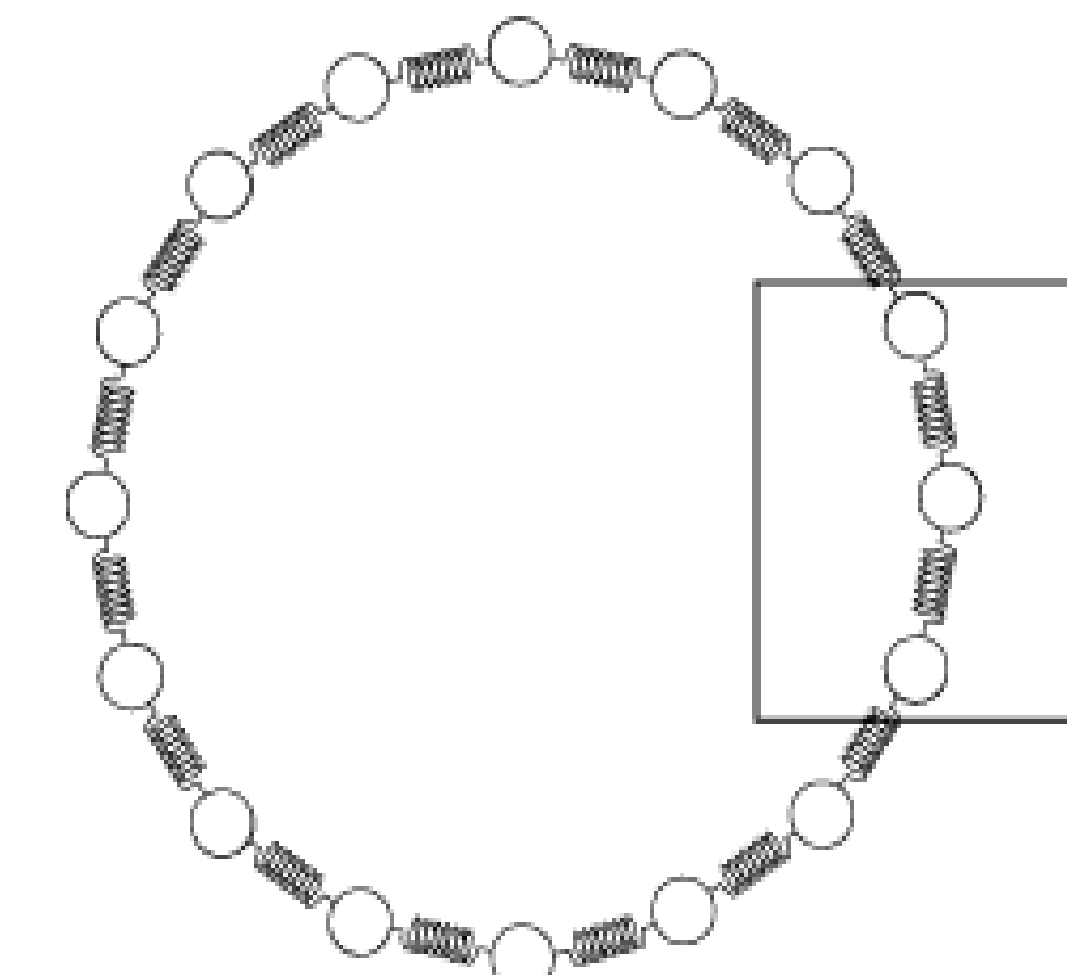
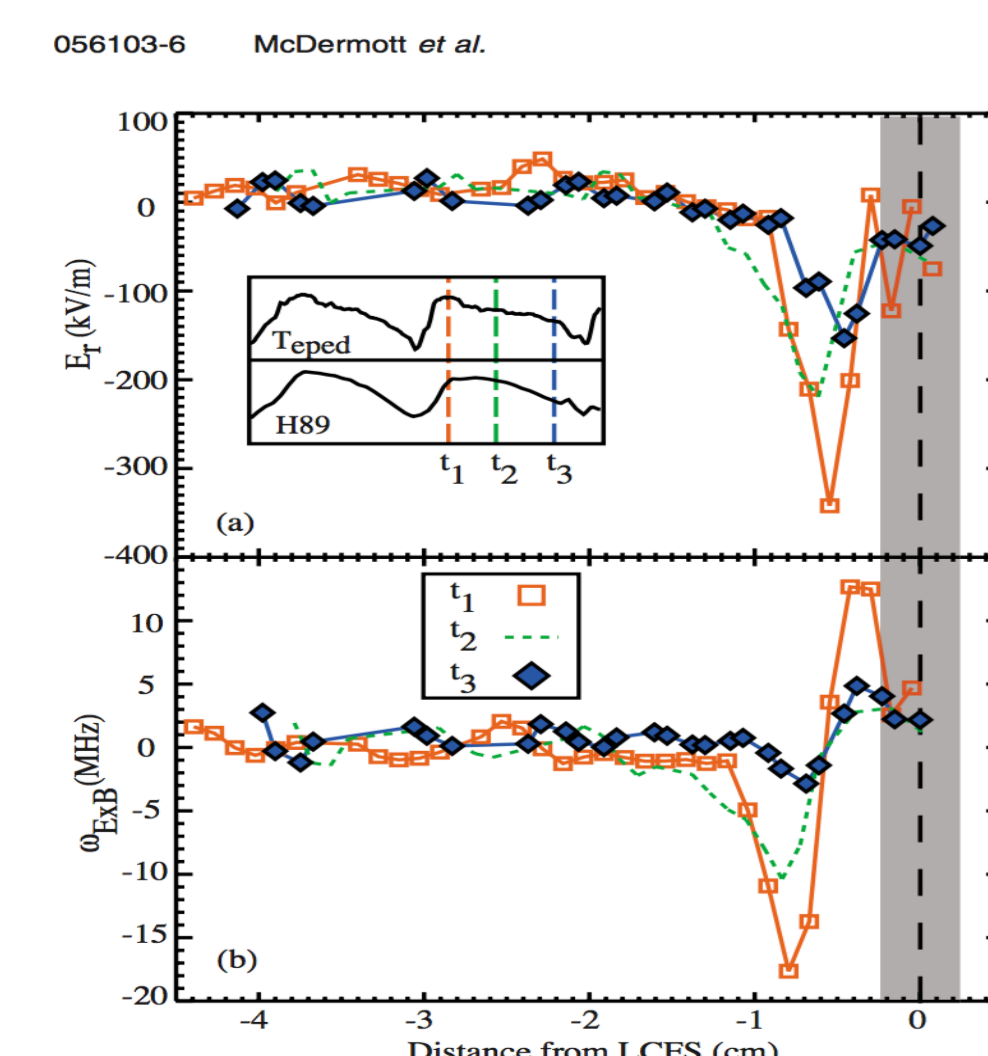
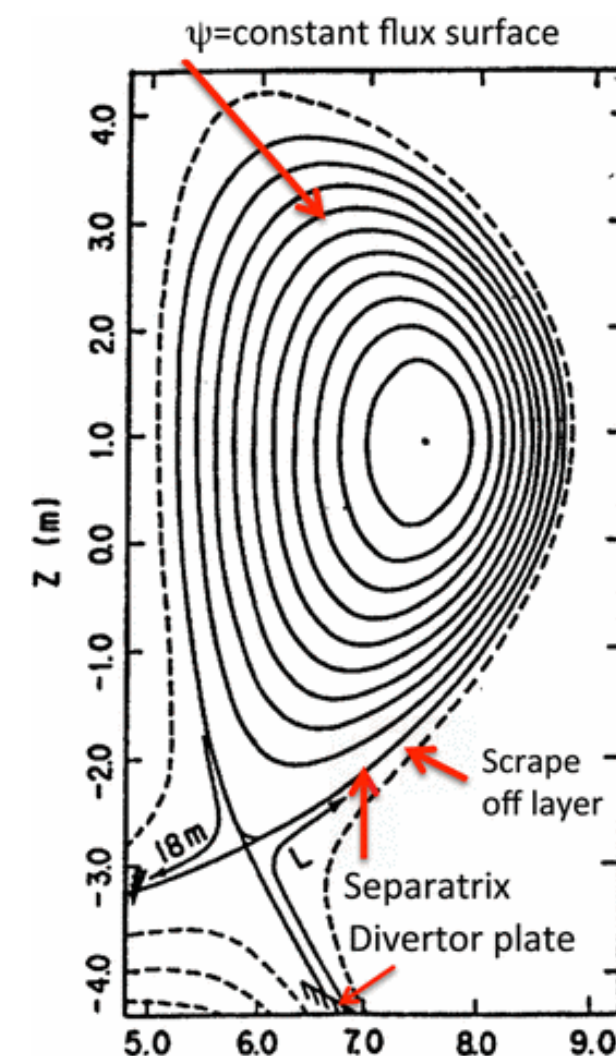
- (i) Radial gradients of the moments $j_{\parallel}(r)$, $T_{e\parallel}(r)$, $T_e(r)$ and $q_{\parallel}(r)$ change the complex stability problem for the low frequency electromagnetic turbulence and the associated transport.
- (ii) Turbulent pitch-angle scattering from magnetic turbulence weakens the current drive efficiency but provides stability against the runaway currents of induction driven toroidal currents.

Anisotropic Pressure from Large Ion Orbit losses in the SOL Plasma

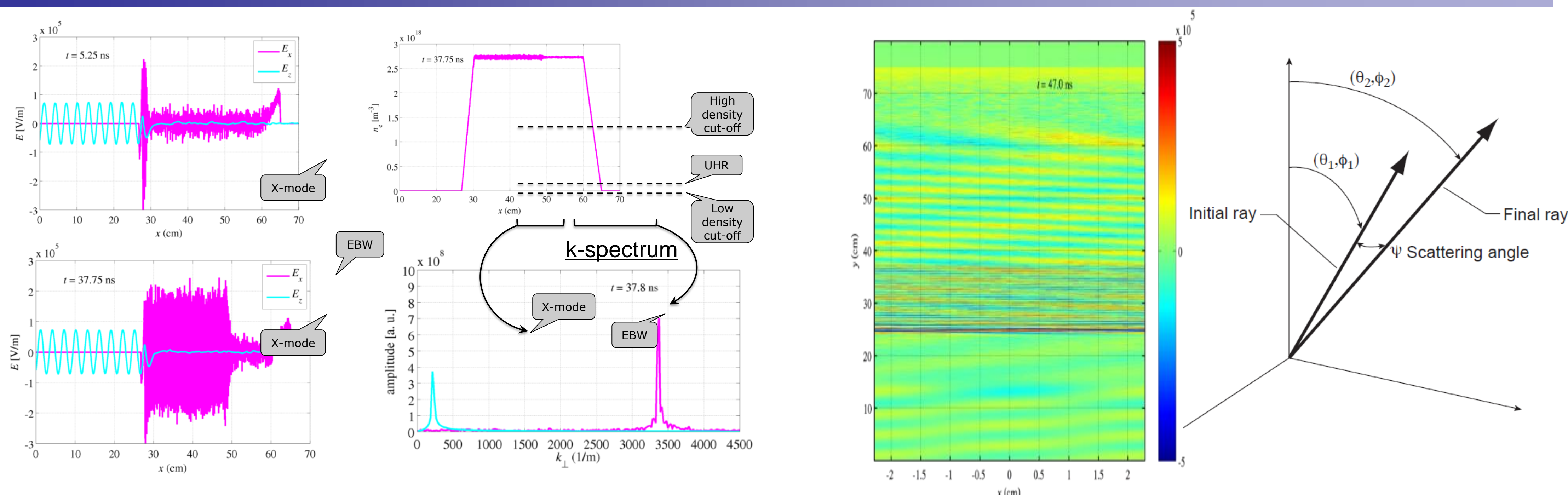
Non-neutralized electrons confined in closed field line repel each other giving a linked spring system.

The repulsion between electrons leads to an outward hoop force -- similar to the thermal pressure but from electric potential. Creates stabilizing effect.

The repulsive force differs from surface to surface, that affects the system magnetic well.



PIC Simulations for ECH propagation and mode conversion from vacuum to high density in 1D and 2D



Conclusions and Summary

- LHCD and ECH RF are effective methods to maintain and control the moments $j_{\parallel}(r)$, $T_{e\parallel}(r)$, $T_e(r)$ steady-state profiles.
- Efficient and synergistic properties of RF drive for steady-state heating and current drive are connected to ETG plasma turbulent transport.
- ETG turbulence is modified by the RF driven e-phase space density function $f_{3T}(p_{\parallel}, p_{\perp}, r, t; P_{RF})$ driven by the ECH and LHCD powers $P_{RF}(t)$'s.
- (i) Radial gradients of the moments $j_{\parallel}(r)$, $T_{e\parallel}(r)$, $T_e(r)$ and $q_{\parallel}(r)$ change/control the complex stability/transport problem and the chaos along the Magnetic Separatrix.
- (ii) Modeling of electron and ion dynamics along the SOL. induction driven toroidal currents.

References – websites and Acknowledgments

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