Summary of Fundamental Program

Guoyong Fu
Zhejiang University, Hangzhou, China

Statistics

- A total of 38 presentations given: 3 plenary, 23 invited, 11 orals, and 2 posters
- 12 theory, 18 simulation, 8 experiment
    - Zonal flow, turbulence and transport (10)
    - Energetic particle (8)
    - Reconnection and merging (5)
    - Multi-scale interaction (4)
    - Fundamental theory (3)
    - ELM, tearing mode (3)
    - Bifurcation, L-H transition (2)
    - Others (3)

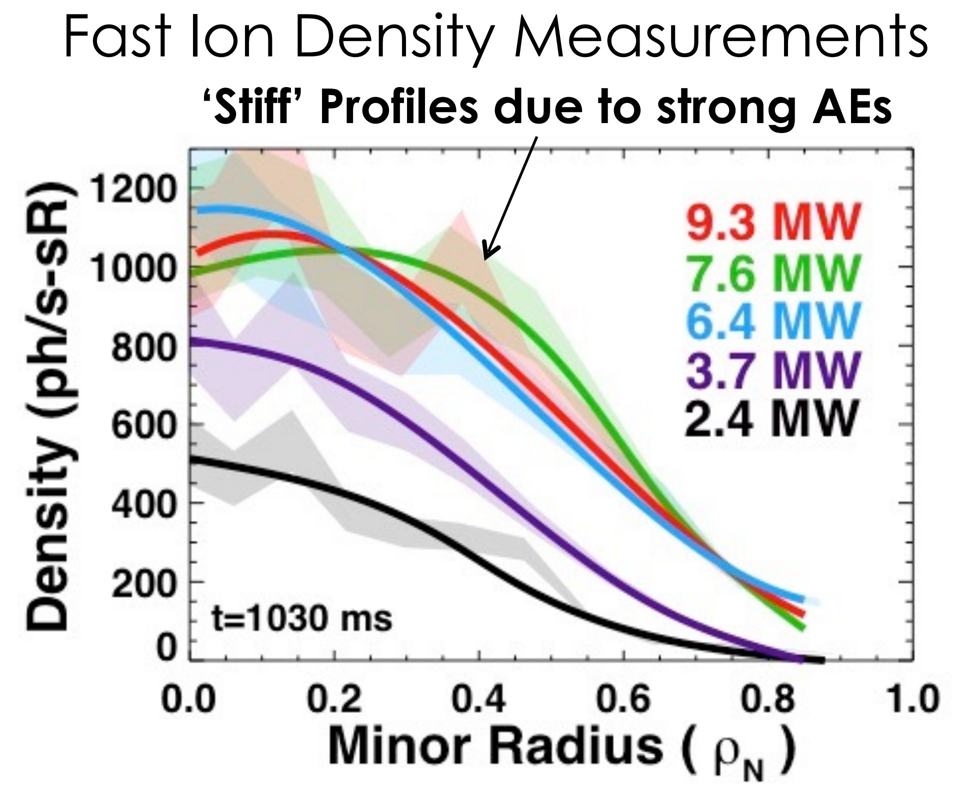
Outline

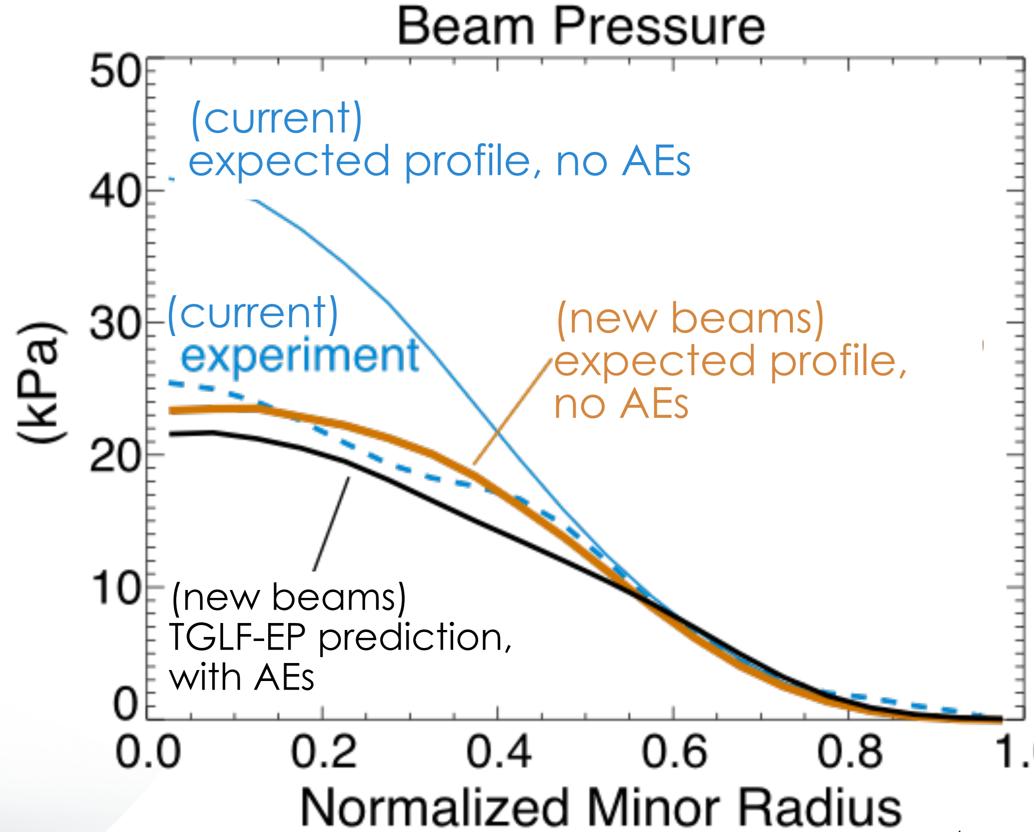
- Energetic particle (8)
- Fundamental theory (3)
- Bifurcation, L-H transition (2)
- Multi-scale interaction (4)
- Zonal flow, turbulence and transport (10)
- Reconnection and merging (5)
- ELM, tearing mode (3)
- Others (3)

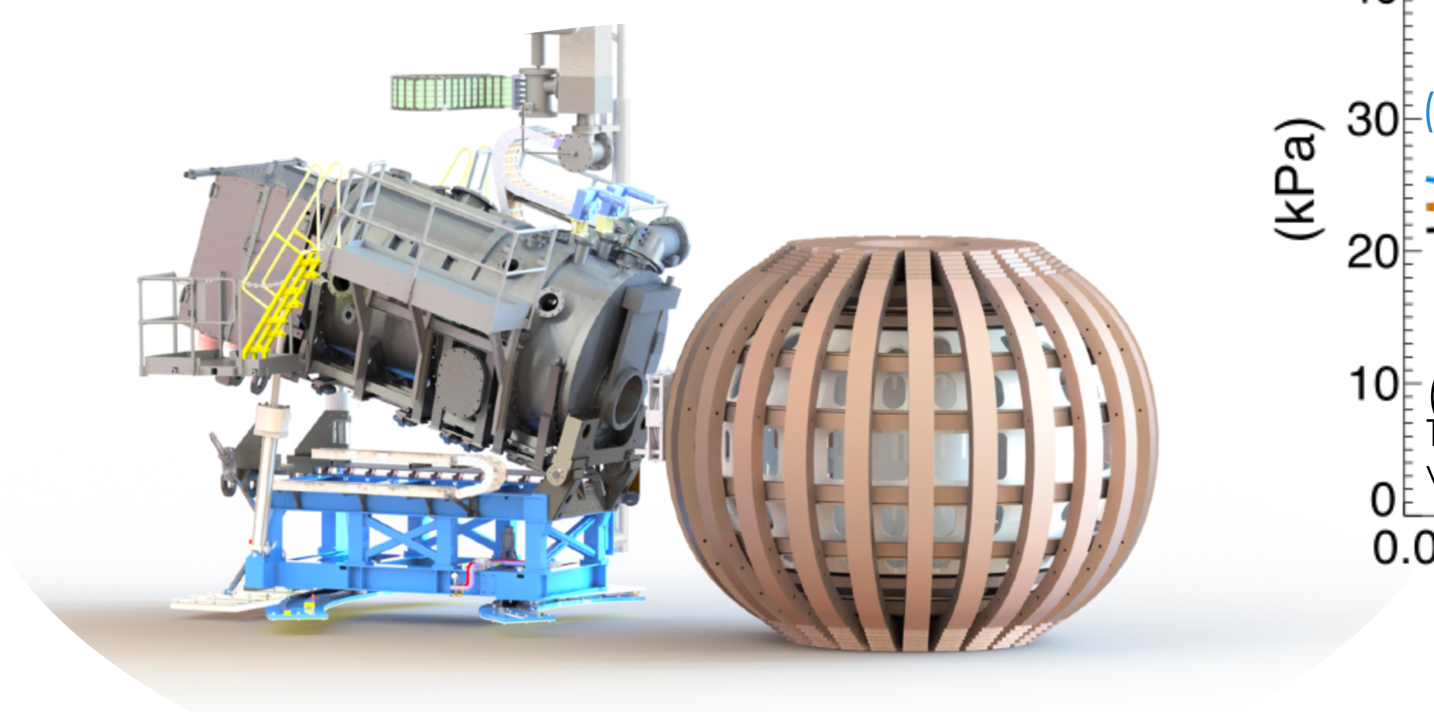
F-I16: "Multiple, Overlapping AEs Cause Fast Ion Orbit Stochasticity and Lead To Critical Gradient Transport"

(Cami Collins, GA)

- **Critical gradient transport causes 'stiff' fast-ion profiles, and fusion performance is reduced (neutron deficits of ~50%)**
  - Any effort to increase the fast-ion gradient (ex: additional beam power) results in more transport, losses
- **DIII-D's new off-axis beams will improve advanced tokamak scenarios**
  - New beams will create broader profiles close to critical gradient, therefore decrease AE transport
  - Preliminary critical gradient model (that includes AE transport) predicts profiles will be close to classical, neutrons deficits <10%.







DIII-D NATIONAL FUSION FACILITY

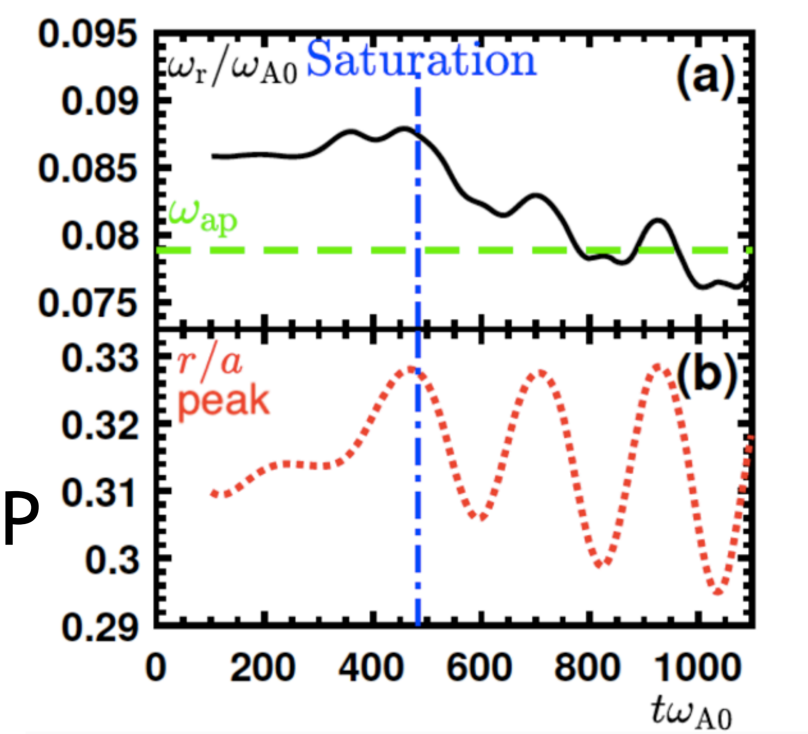
P22: On nonlinear dynamics of phase space zonal structures (F. Zonca, L. Chen, M. V. Falessi, Z. Qiu, ENEA & IFTS/ZJU)

Work supported by US DoE and NSFC grants, and by the EUROfusion Consortium

- Transport processes in collisionless fusion plasmas are described in phase space, where phase space zonal structures are introduced
- Phase space zonal structures account for fluctuation induced transport and describe the deviation of the reference state from local thermodynamic equilibrium
- A self-consistent nonlinear description is given for low-frequency fluctuations quasi-coherent (reduced dynamics) in the form of renormalized particle response and nonlinear Schrödinger-like equation for the fluctuation intensity (radial envelope)

HMGC hybrid Simulations

T. Wang,
X. Wang,
S. Briguglio
Submitted to POP



- Examples of applications to cases of practical interest are presented:
  - ◇ Relaxation of a warm beam (1D uniform plasma)
  - ◇ Whistler chorus chirping in Earth's magnetosphere (1D nonuniform plasma)
  - ◇ Nonlinear RSAE dynamics in DTT (3D reduced description)

ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

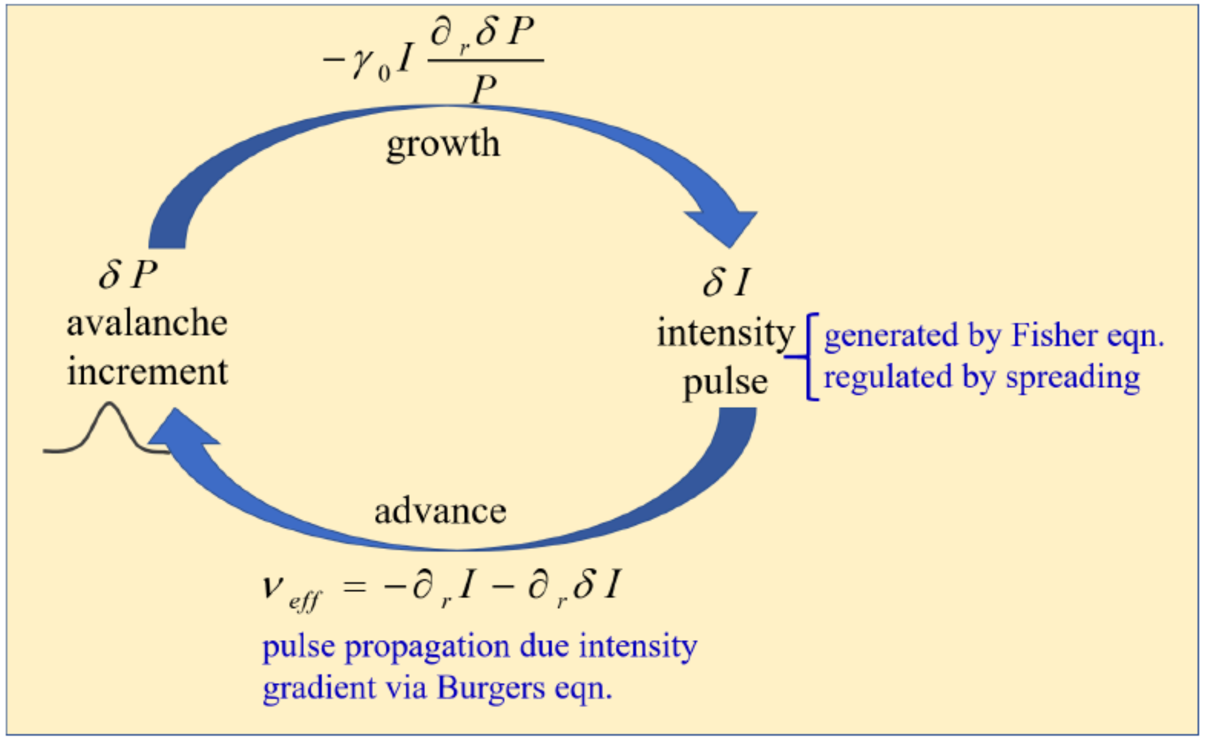
F-I4: "Theoretic study of the nonlinear energetic particle mode dynamics in tokamaks"

Ruirui Ma and Patrick H. Diamond, SWIP/UCSD

1. Described the avalanche from first principles; Showed the connection and progression from the K.E. to the macroscopic eqns. for δP and $\mathcal{I}$;

2. Obtained two coupled generalized Burger's eqn. and generalized Fisher eqn.;

3. EPM avalanches can be described by the model.



$$\partial_t \delta P_h + \mathcal{V}(\mathcal{I})\partial_r \delta P_h - \mathcal{D}(\mathcal{I})\partial_r^2 \delta P_h = S_0$$

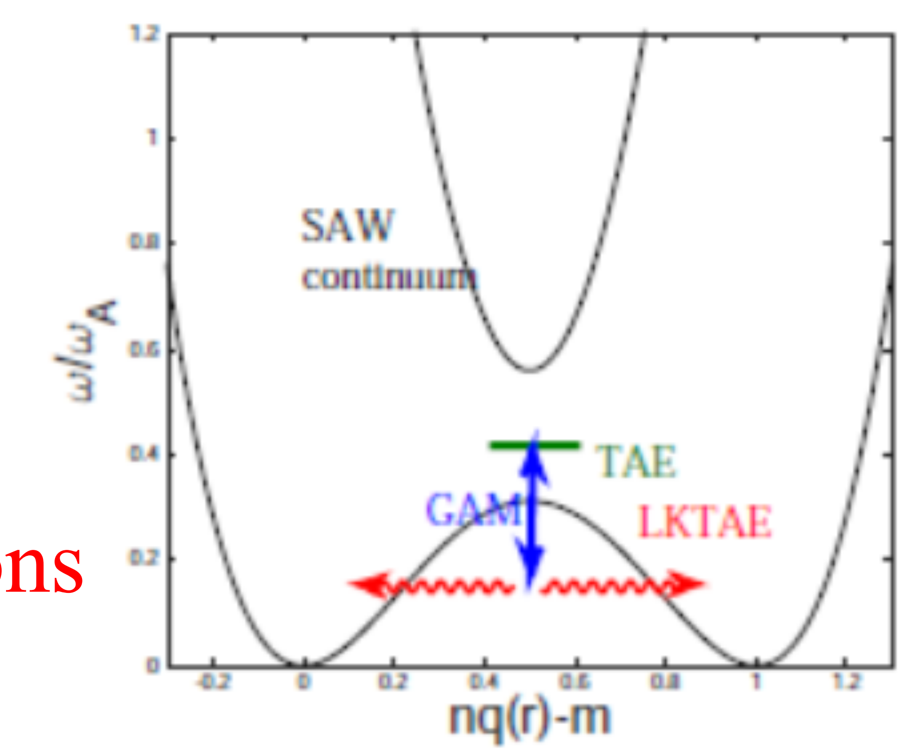
— Generalized Burger's eqn.

$$\partial_t \mathcal{I} - \nabla_\perp \mathcal{D}_\perp(\mathcal{I})\nabla_\perp \mathcal{I} - \alpha \mathcal{I}^2 = -\gamma_0 \mathcal{I}\left(\frac{1}{P_h}\frac{\partial}{\partial r}\delta P_h\right)$$

— Generalized Fisher eqn.

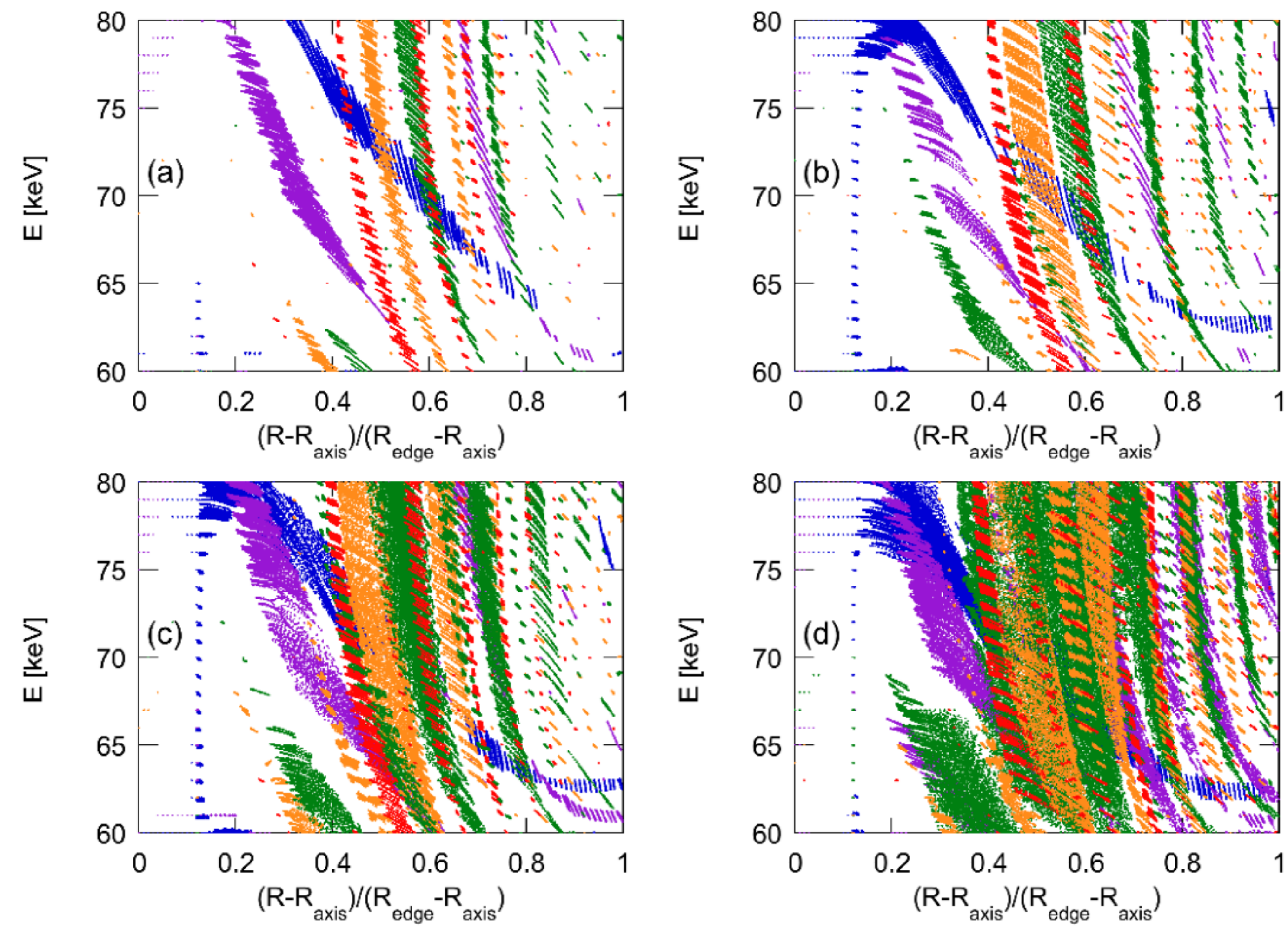
F-I1: Nonlinear decay and plasma heating by toroidal Alfven eigenmodes (Z. Qiu, L. Chen, F. Zonca and W. Chen, ZJU)

- A new TAE decay channel: TAE → geodesic acoustic mode (GAM) and lower kinetic TAE (LKTAE)
- Nonlinear process transfers power from fusion α to thermal species
- Analyzed using gyrokinetic theory: relevant and competitive for burning plasmas in future reactors
- Consequences on plasma heating and confinement:
  - TAE saturation
  - LKTAE radiative damping: "anomalous α slowing down"
  - GAM ion Landau damping: heating fuel ions ("α-channeling")
  - GAM modulate DW turbulence: cross scale coupling and confinement improvement



P-24 Y. Todo: "Energetic particle physics in fusion plasmas through computer simulation"

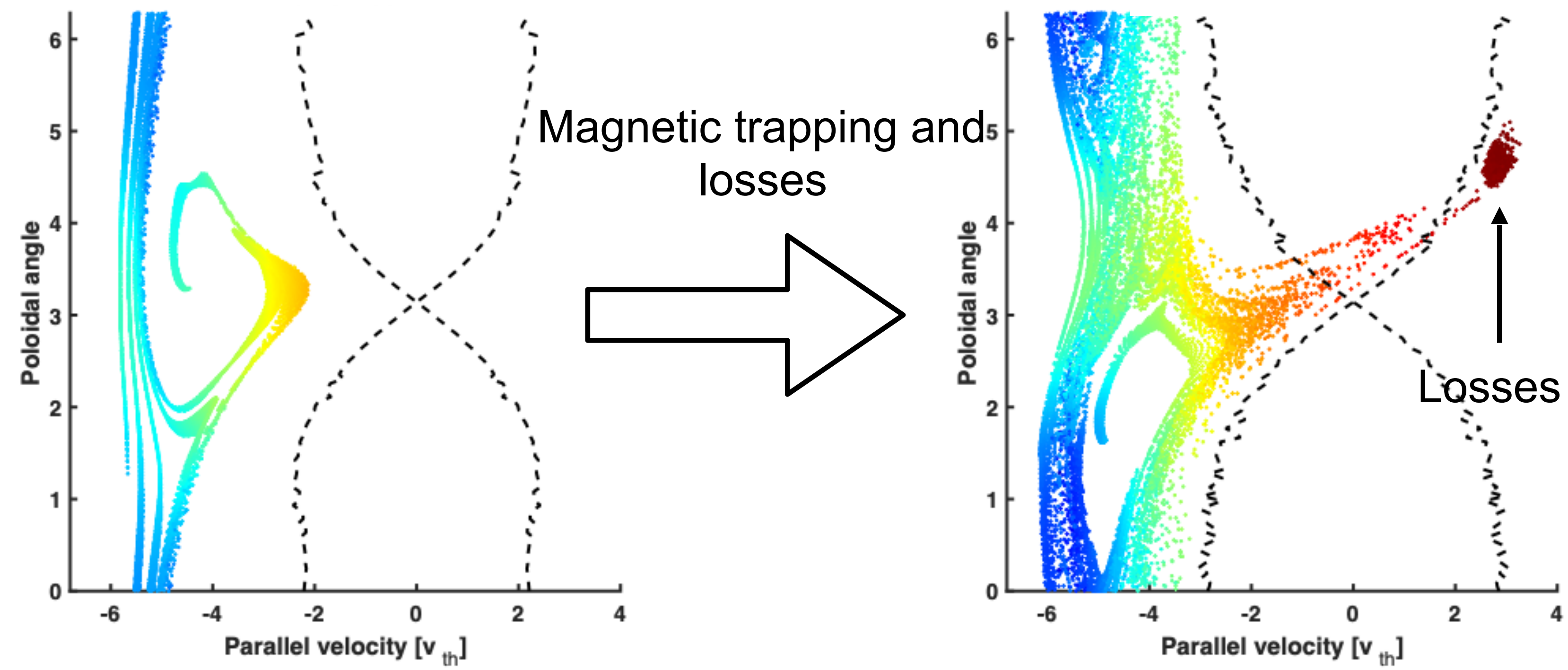
- A tutorial review on energetic particles (EPs) and Alfvén eigenmodes (AEs) in fusion plasmas
- Berk-Breizman's theory and simulation model
- Resonance overlap and overlap of higher-order islands -> global transport of EPs
- Hybrid simulation for EP and MHD
  - Validation on DIII-D



Phase space regions trapped by AEs (=resonances). With increasing beam power [(a)->(d)], the resonance overlap covers the phase space.

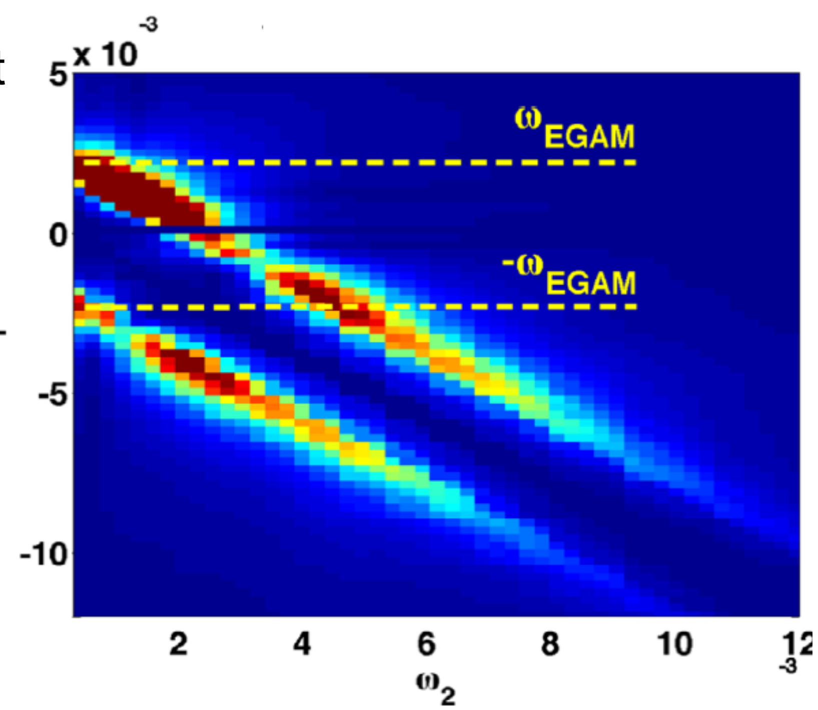
F-I3: "Impact of EGAMs on transport in fusion plasmas"
David Zarzoso

- Direct impact of EGAMs on particle trajectories: interaction EGAM island - trapping cone → chaotic regime and losses [Zarzoso NucFus 2018]

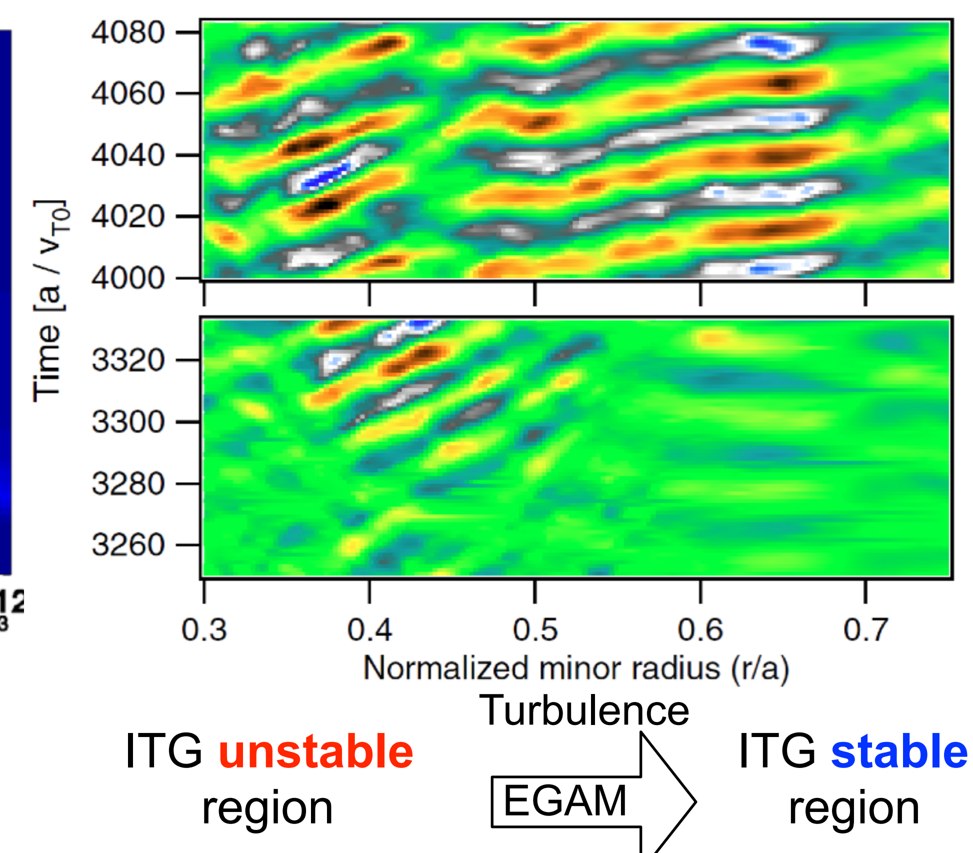


- Impact of EGAMs on turbulent transport → two effects observed:

1. Nonlinear energy transfer from oscillatory Zonal Flows (m=0, n=0 at EGAM frequency) to non axisymmetric modes [Zarzoso NucFus 2017]



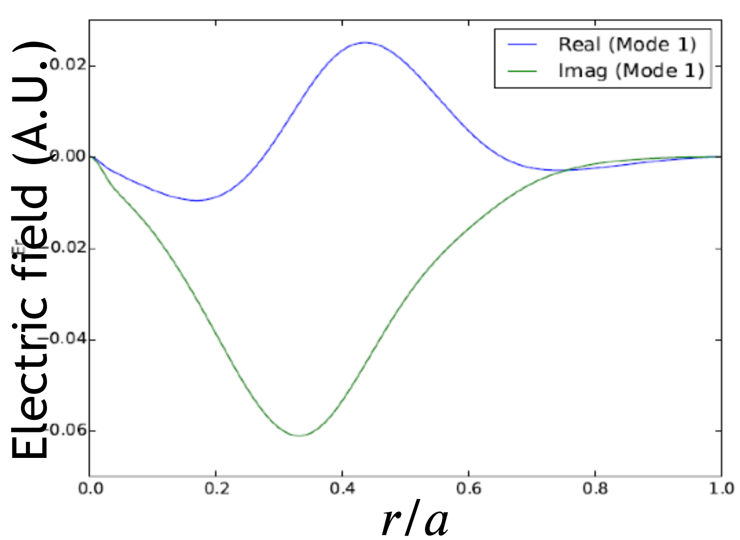
2. Complex interplay ITG avalanches and EGAM oscillations → EGAM as a mediator to spread turbulence from ITG stable to ITG unstable regions [Zarzoso PRL 2013]



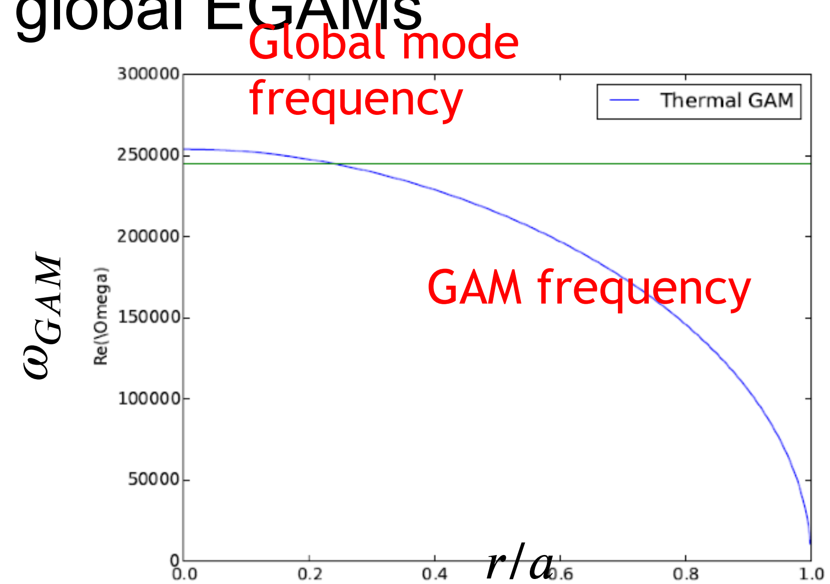
F-I2: “Linear and nonlinear dynamics of EGAMs driven by ICRH fast ions”

Z.S. Qu, N. Yuen, M.J. Hole, M. Fitzgerald, B.N. Breizman, ANU

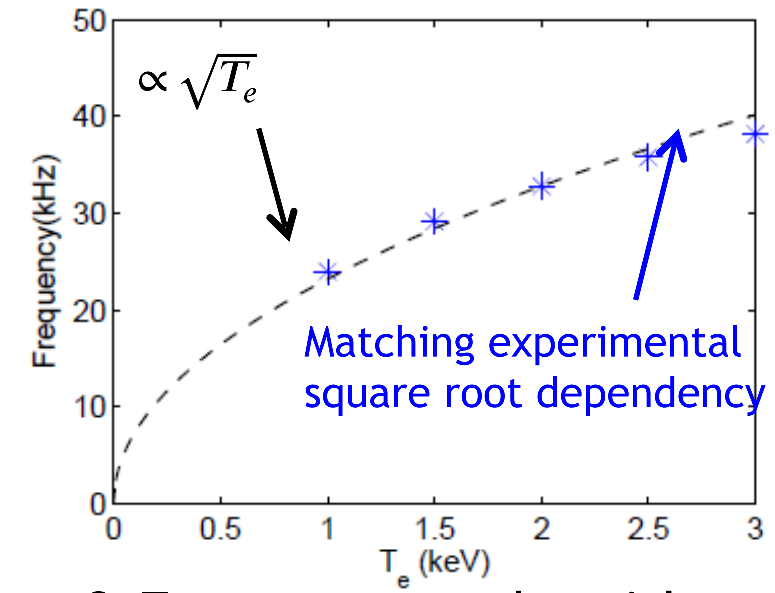
- ICRH fast ions can drive global EGAMs



1.Global mode found

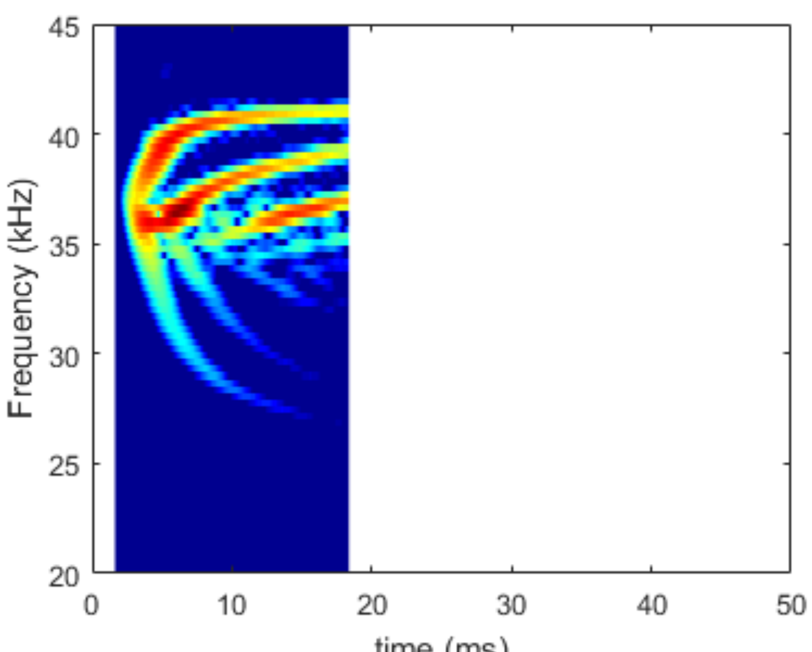


2.Mode frequency at core GAM frequency

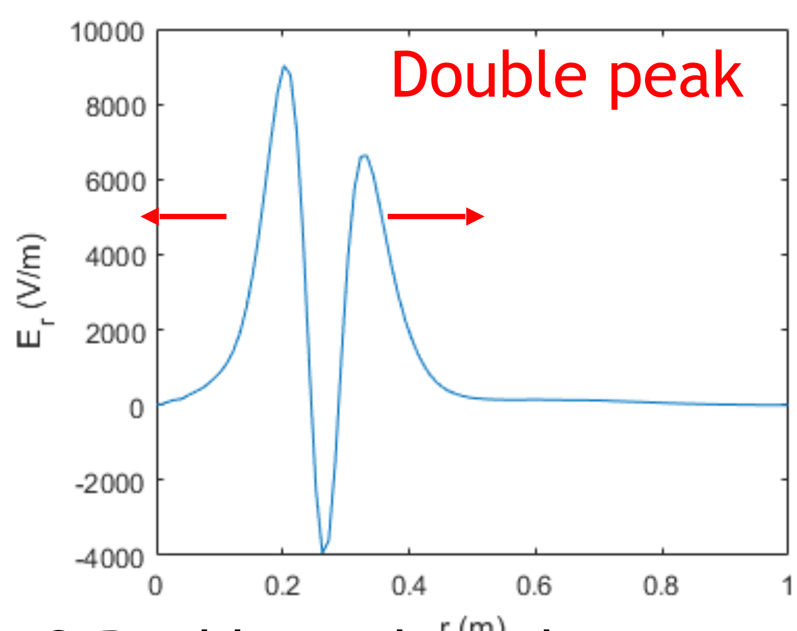


3.Frequency scale with

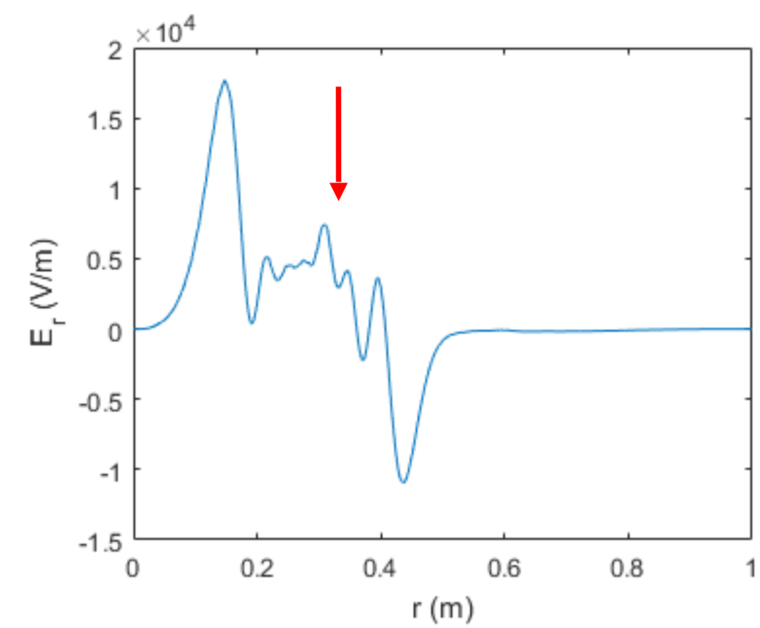
- Particle nonlinear simulation of chirping EGAM



1.Chirping behaviour found



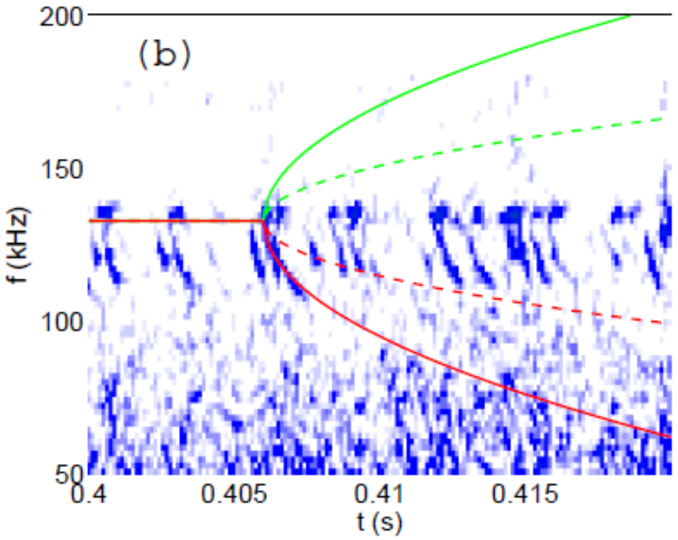
2.Double peak mode structure form when chirping started



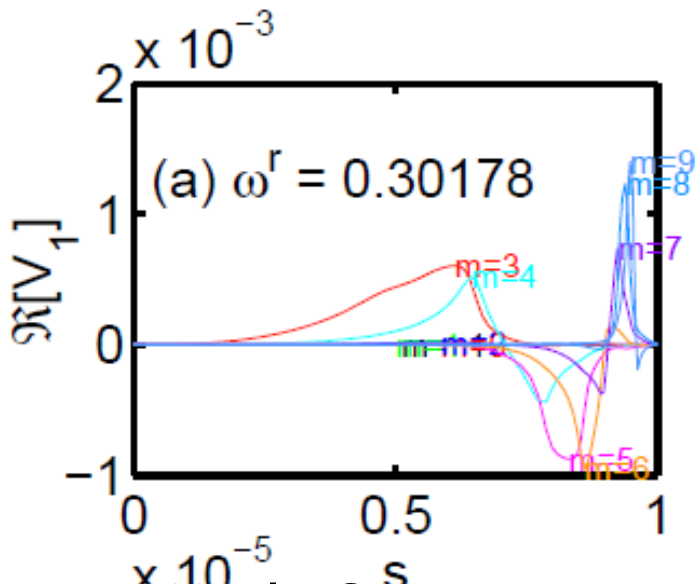
3.Highly oscillatory region develop between two peaks due to continuum damping

F-I5: “Energetic particle driven mode activity: advances in understanding from linear through hard nonlinear regime”
M. J. Hole, H. Hezaveh, Z. S. Qu, B. Breizman, B. Layden, R. L. Dewar, C. Michael, M. H. Woo, J. Kim, J. G. Bak, ANU

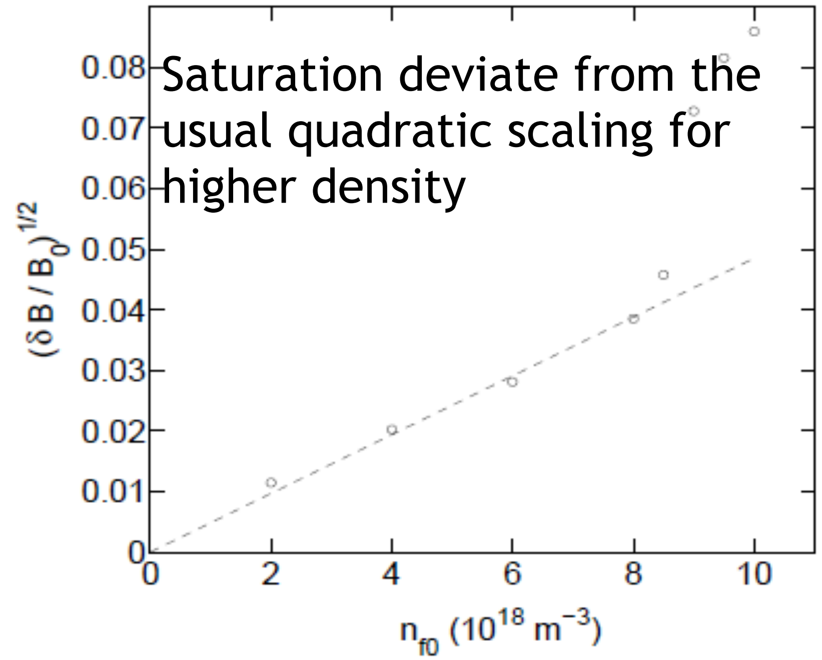
- Modeling of Bursty TAE modes observed on KSTAR



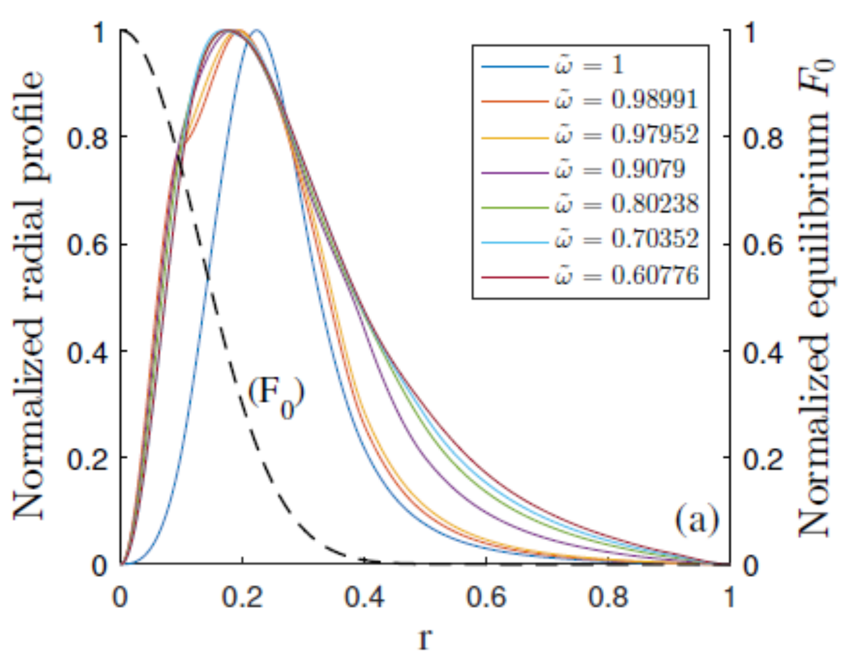
Spectrogram



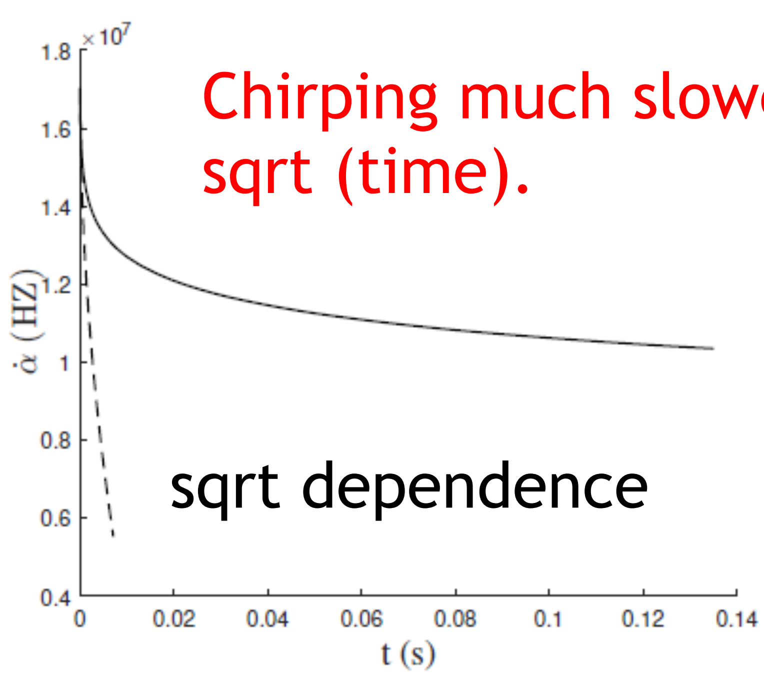
Mode Structure



- Long-range adiabatic chirping of Global Alfven Eigenmode



mode profile broadens during chirping



Chirping much slower than sqrt (time).

Outline

- Energetic particle (8)
- Fundamental theory (3)
- Bifurcation, L-H transition (2)
- Multi-scale interaction (4)
- Zonal flow, turbulence and transport (10)
- Reconnection and merging (5)
- ELM, tearing mode (3)
- Others (3)

Fundamental Theory

- F-I16, Yohei Kawazura, Univ. of Oxford,
“Relativistic Extended Magnetohydrodynamics: action formalism and physical properties”
- F-I19, Naoki Sato, Kyoto Univ. (U30 winner)
"Statistical Mechanics of Topologically Constrained Systems: Application to Self-Organizing Diffusion in Plasmas”
- F-O9, Dominique Escande, Aix-Marseille Univ,
“Derivation of Landau damping by N-body mechanics”

F-O9:"Three derivations of Landau damping & growth by N-body mechanics"

Dominique Escande, Aix-Marseille Univ.

- A pedestrian, short, yet rigorous, one germane to Kaufman's in a Vlasovian setting (1972): new Unambiguous mechanical understanding of Landau damping/growth: average synchronization of particles with the wave

- One showing waves damp because of phase mixing à la van Kampen (1955): new

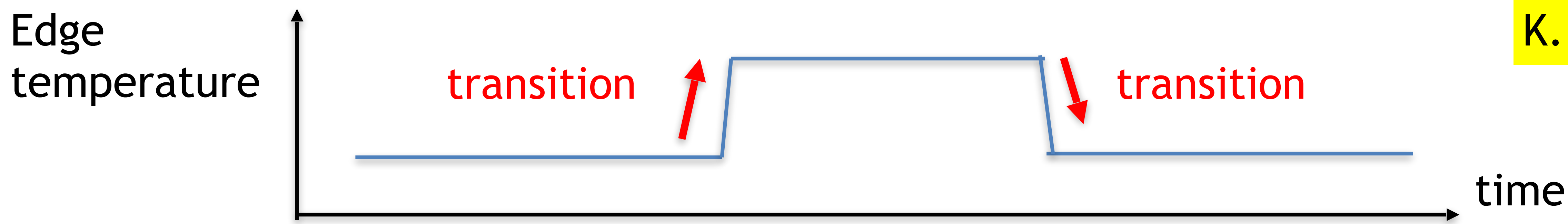
- One showing that the Vlasovian limit is singular (2017) and corresponds to a renormalized description of the actual N-body dynamics

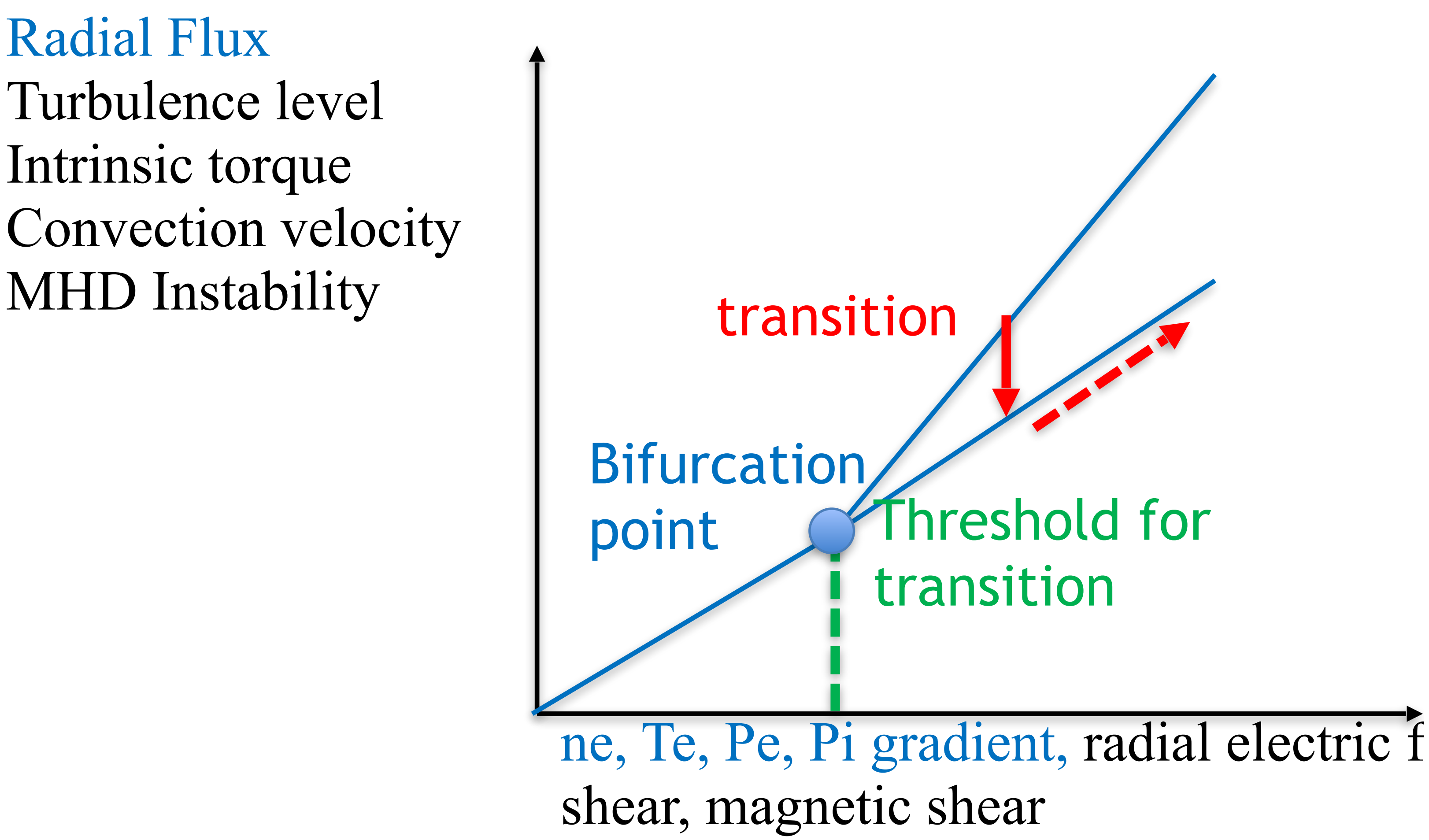
Outline

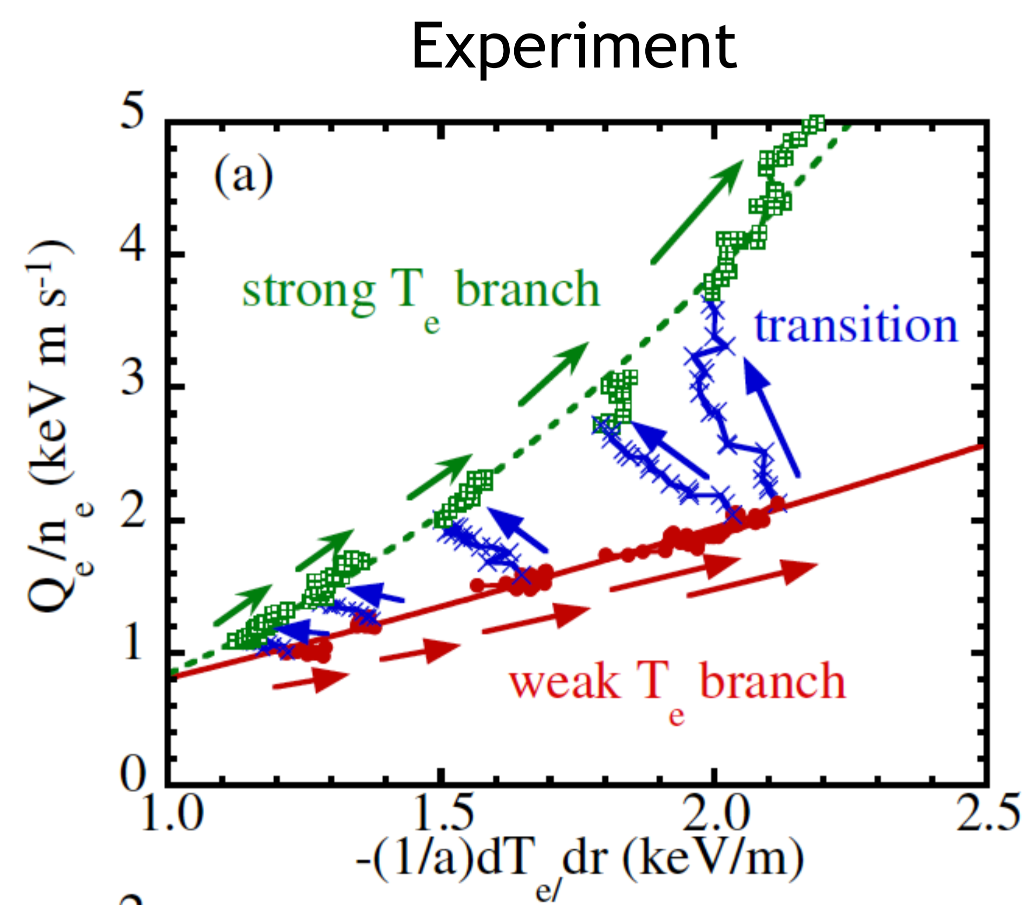
- Energetic particle (8)
- Fundamental theory (3)
- Bifurcation, L-H transition (2)
- Multi-scale interaction (4)
- Zonal flow, turbulence and transport (10)
- Reconnection and merging (5)
- ELM, tearing mode (3)
- Others (3)

P31:"Bifurcation and transition in magnetic confined plasma"

K.Ida



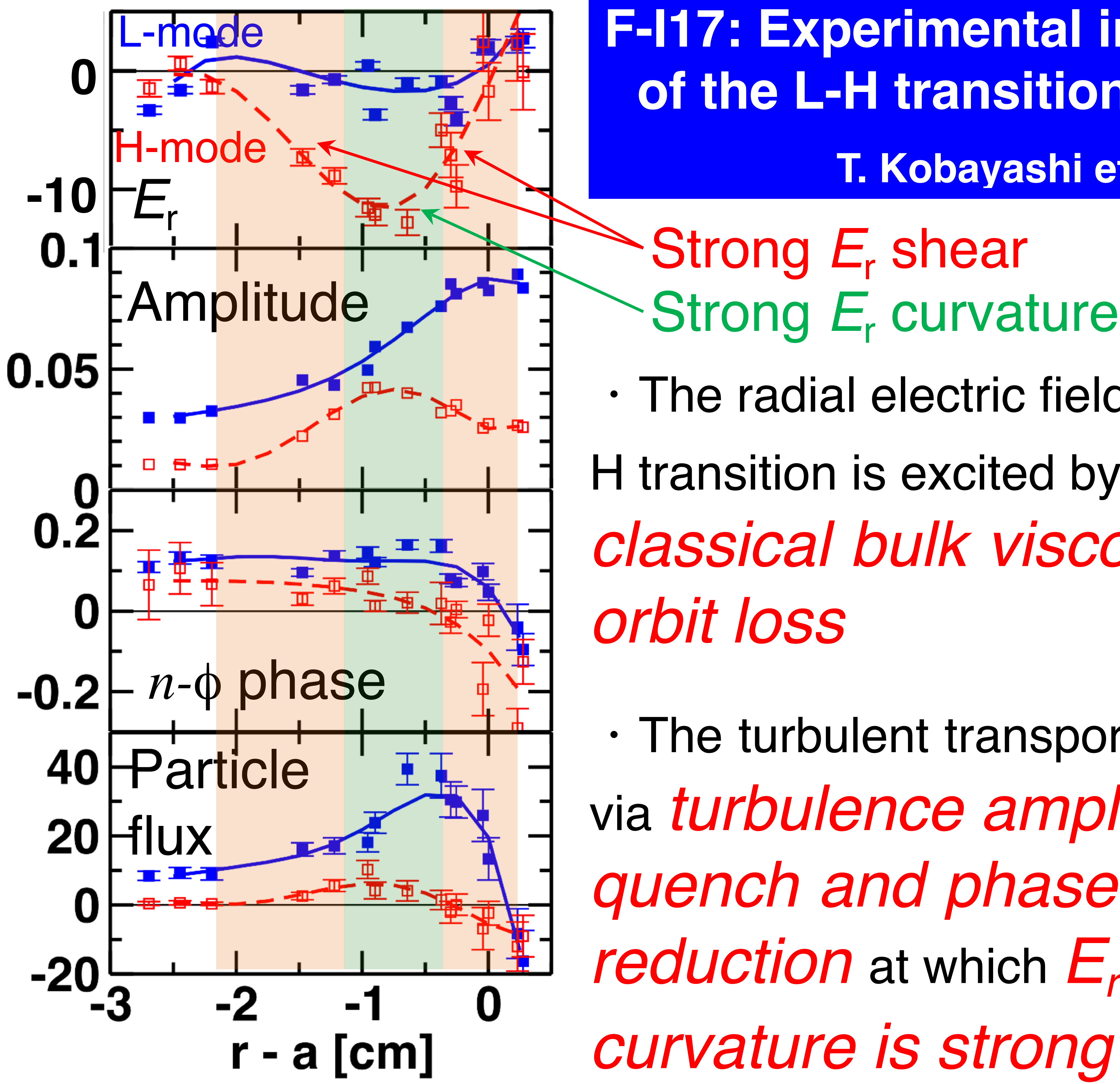




- Transition phenomena is a footprint of a bifurcation in the flux-gradient relation and other relations in the plasma.
- The transition can occurs above the bifurcation point, which is called "threshold".
- There are many bifurcation pnenonemon observed in the magnetic confined plasma and the "bifurcation study" was always "Pioneering work" and becomes mainstream 10 years later.

F-I17: Experimental investigation of the L-H transition dynamics

T. Kobayashi et al.



・The radial electric field across the L-H transition is excited by *the neo-classical bulk viscosity and ion orbit loss*

・The turbulent transport is suppressed via *turbulence amplitude quench and phase differ-ence reduction* at which *E_r shear and curvature is strong*

Outline

- Energetic particle (8)
- Fundamental theory (3)
- Bifurcation, L-H transition (2)
- Multi-scale interaction (4)
- Zonal flow, turbulence and transport (10)
- Reconnection and merging (5)
- ELM, tearing mode (3)
- Others (3)

F-I8: “Experimental Study of Multi-scale Interaction between (Intermediate, Small)-scale Microturbulence and MHD modes in EAST Plasmas”

P. J. Sun, ASIPP

- demonstrate the nonlinear coupling between microturbulence and MHD mode with bispectral analysis and envelope method, showing statistically significant bicoherence and modulated turbulent density fluctuation amplitudes correlated with the MHD mode.

- show that microturbulence spectral power is correlated to the 2/1 tearing mode and modulation effects on microturbulence by the 2/1 tearing mode.

F-I12: "Sawtooth heat pulses interacting with plasma flows, turbulence and gradients in the tokamak edge plasmas"

K. J. Zhao (Z.B, Guo), SWIP

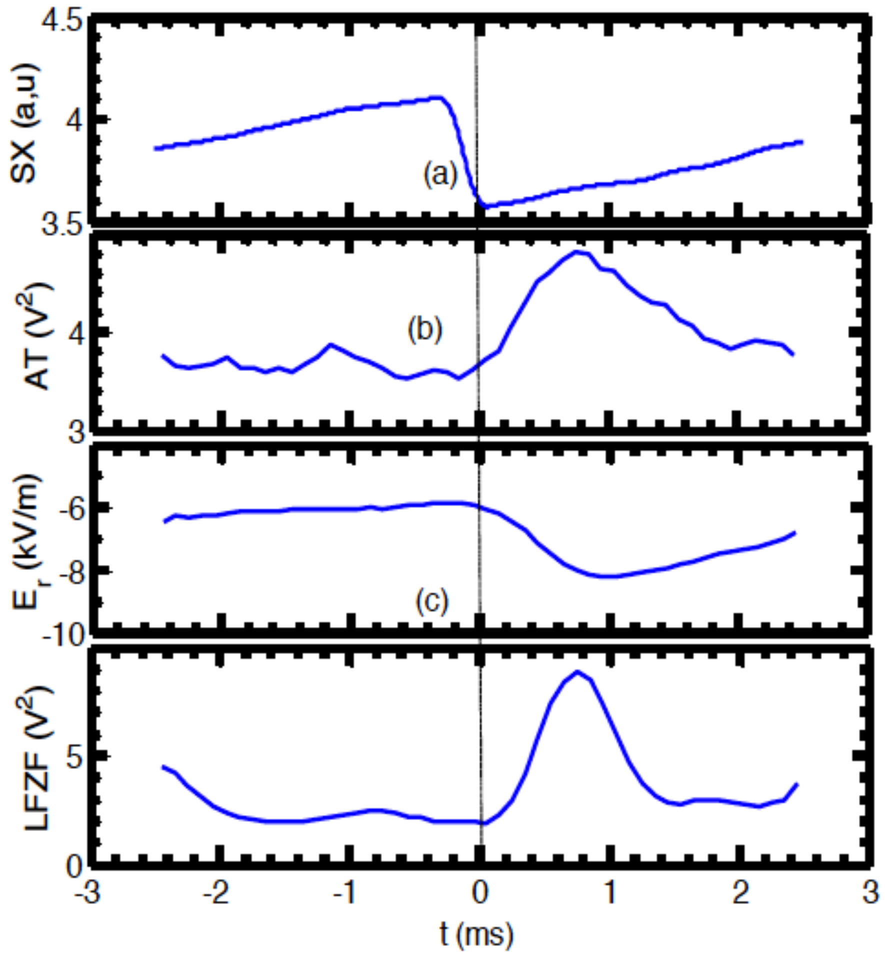


Fig 1. Conditional average of (a) soft X-ray signals, (b) turbulence intensity, and (d) LFZF intensity.

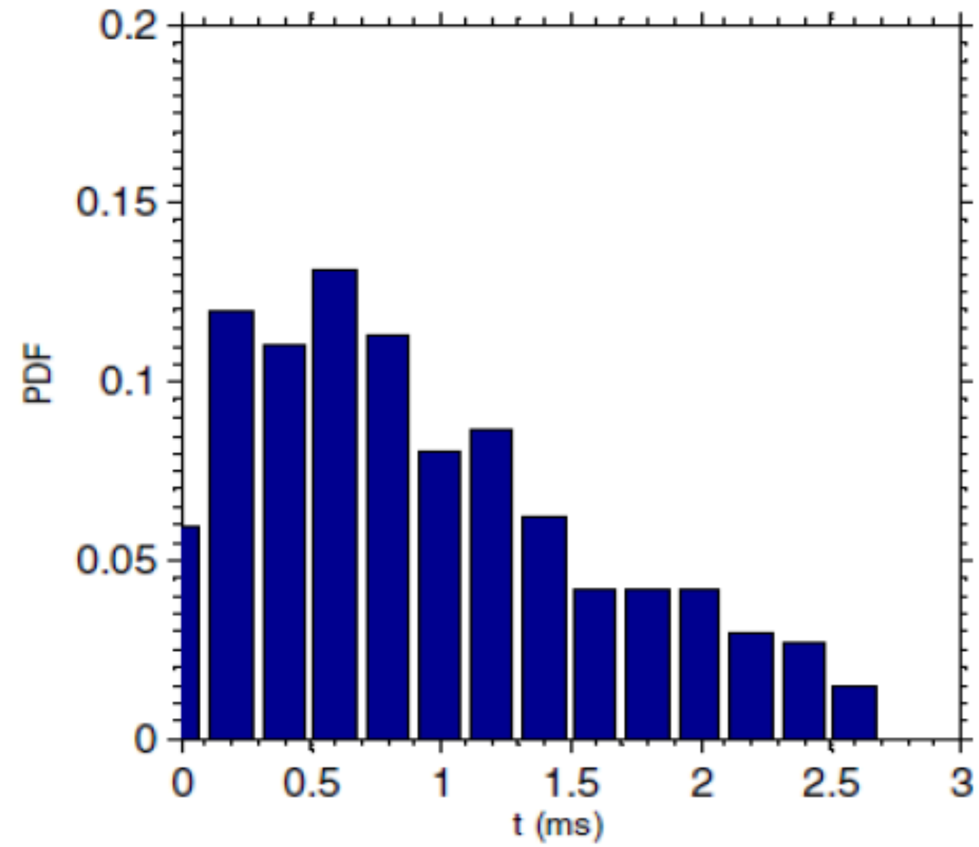
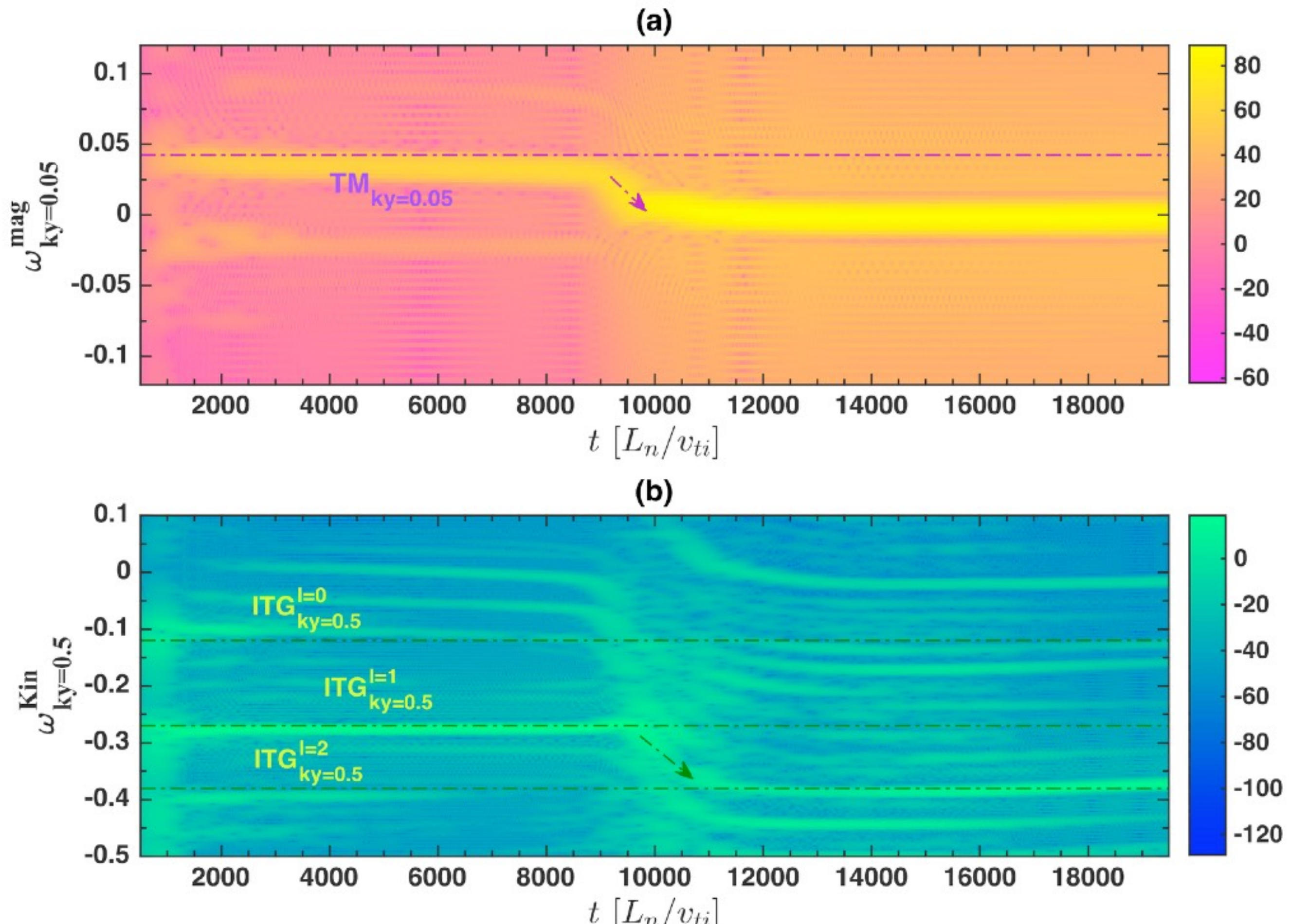


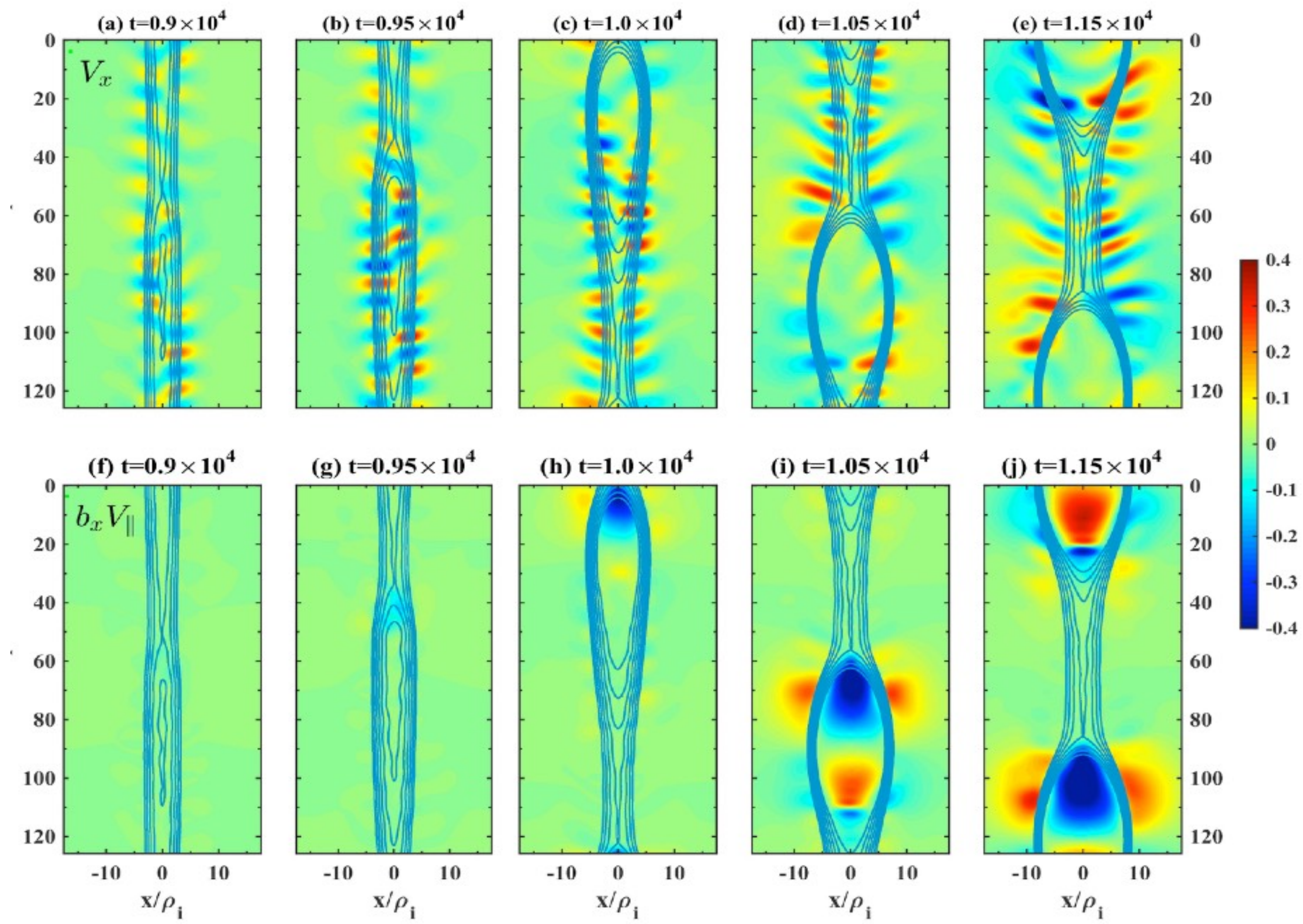
Fig 2. PDF of the delay time for the L-I transition, following sawtooth crashes.

F-I7: "Nonlinear interaction between drift-tearing-modes and slab-ITG-modes" (Lai Wei et. al., DLUT)

- During the transition phase from ITG-dominated stage to TM-dominated stage, **frequency chirping phenomenon** induced by the **eigenmode transition** of ITG modes is identified.
- Electromagnetic transport feature around the magnetic island is discussed.



Frequency spectra for TM & ITG



EM transport near the magnetic island

F-I21 S. Maeyama, "Electron-scale effects on ion-scale turbulence in Tokamak plasmas"

ITG/ETG turbulence

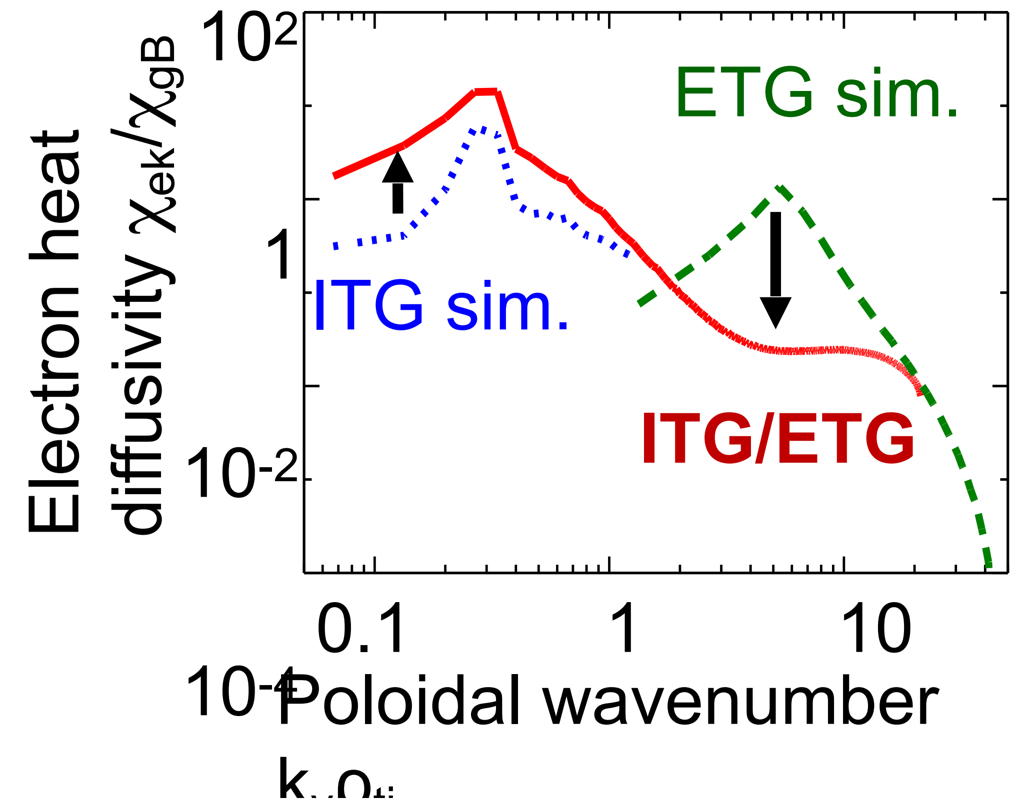
[Maeyama'15PRL; Maeyama'17NF]

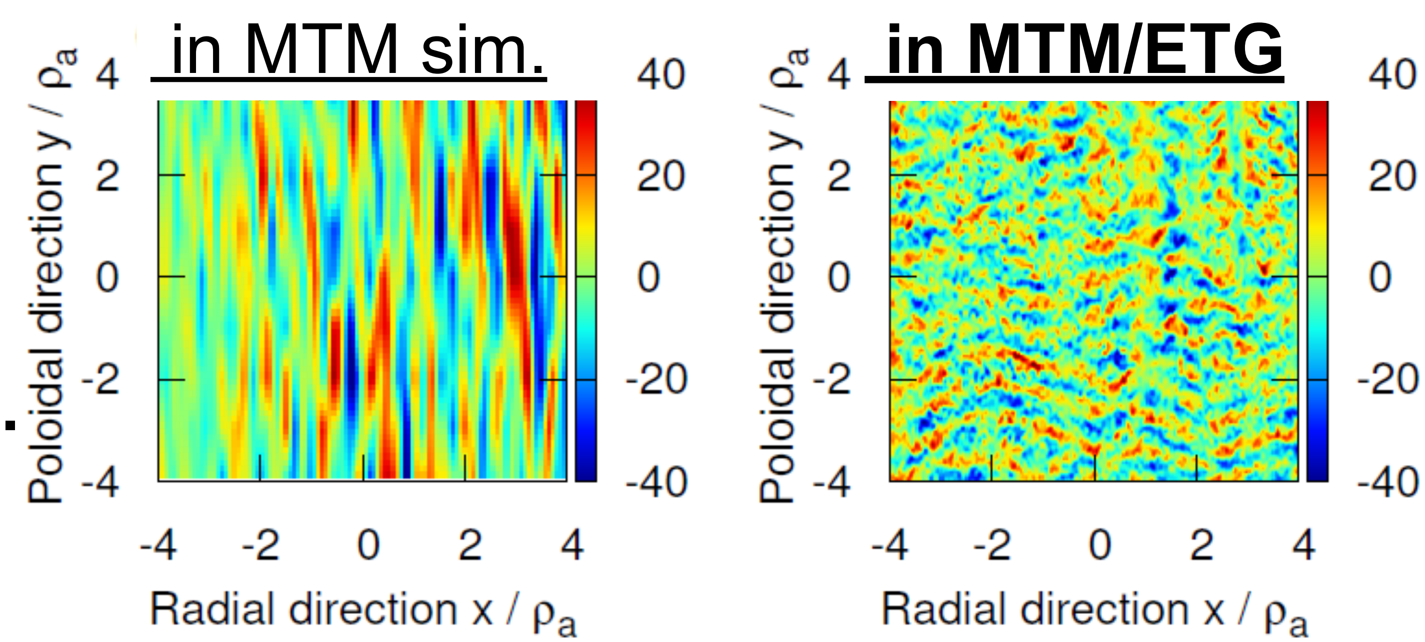
- **Suppression of ETG by ITG**

— Short-wave-length ITG turbulent eddies distort ETG streamers.

- **Enhancement of ITG by ETG**

— Short-wave-length ZF created by ITG with kinetic electrons are damped by ETGs.





MTM/ETG turbulence

[Maeyama'17PRL]

- **Suppression of MTM by**

Outline

- Energetic particle (8)
- Fundamental theory (3)
- Bifurcation, L-H transition (2)
- Multi-scale interaction (4)
- Zonal flow, turbulence and transport (10)
- Reconnection and merging (5)
- ELM, tearing mode (3)
- Others (3)

[F-I10]

Modern Gyrokinetic Description of Residual Zonal Flows

T.S. Hahm Y.W. Cho and T.S. Hahm, submitted to Nucl. Fusion

- α-particles enhance residual zonal flows with $k_r\rho_{i,eff} \sim 10^{-1}$.
- For 10% concentration, $\sim 10\%$ enhancement at $k_r\rho_{i,eff} \sim 10^{-1}$ is expected.
- So effects can be considerable for ITER, and significant for DEMO and reactors.
- $R_{ZF}\left(k_r\rho_{i,eff}\right) = \frac{\chi_{cl}}{\chi_{Neo}+\chi_{cl}}$

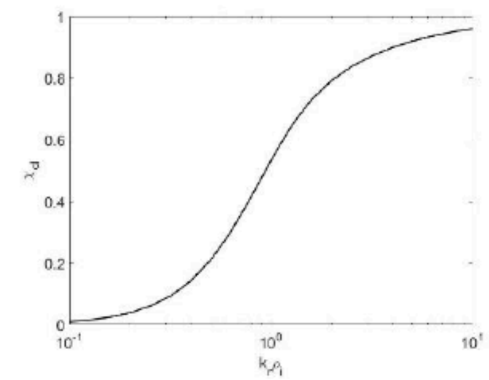
  i) χ_{cl} is a monotonically increasing in k_r, ($\sim tanh$-like shape)

  Transition occurs at lower k_r in the presence of energetic α's

  $(k_r\rho_{i,eff} \sim 10^{-1}, k_r\overline{\rho_\alpha} \sim 1)$

  ii) χ_{nc} peaks at similar k_r value and decreases as a function of k_r for higher k_r.

  i, ii) $\Rightarrow R_{ZF}$ is enhanced for $k_r\rho_{i,eff} \sim 10^{-1}$



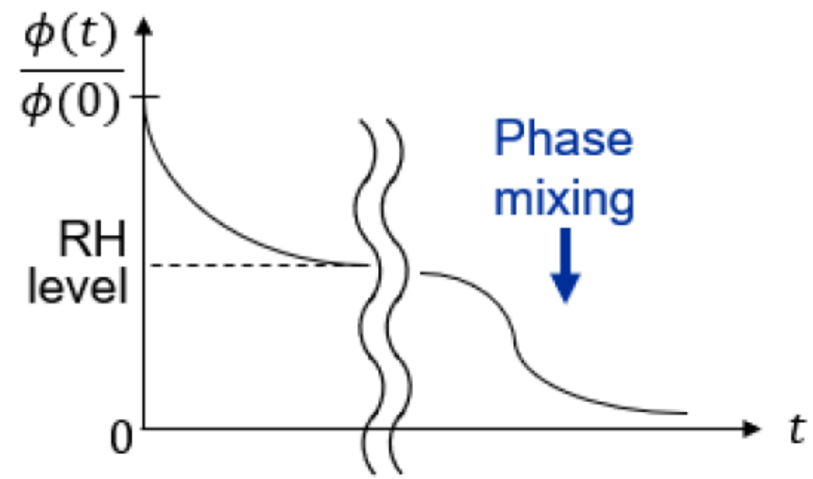
[F-O4] # Zonal flow decay in tokamaks with resonant magnetic perturbations: role of broken axisymmetry

G.J. Choi and T.S. Hahm

Nucl. Fusion **58**, 026001 (2018)

- Extended theoretical works of Rosenbluth-Hinton '98 and Sugama-Watanabe '05 to study effect of resonant magnetic perturbations (RMPs) on zonal flows in tokamaks.

- Secular radial drift of bounce/transit centers due to non-axisymmetric RMP field causes phase-mixing of zonal flows, leading to a long-term collisionless decay of zonal flows toward zero level.



- The rate of RMP induced decay $\gamma_{\rm RMP} = nqk_r\rho_{\rm Ti}(v_{\rm Ti}/R)\,\delta_{m_0}/\epsilon$ is proportional to toroidal mode number of RMP n, zonal flow radial wavenumber k_r, ion temperature T_i, and normalized amplitude of the resonant component of RMP δ_{m_0}.

- The n-dependence of RMP induced zonal flow decay is consistent with results of KSTAR experiments on increase of L-H transition threshold with n =1 and n=2 RMPs.

- The RMP induced zonal flow decay is expected to be comparable to the collisional zonal flow damping for intermediate and short wavelength zonal flows in present day tokamaks, and to dominate in future machines such as ITER.

Zonal flows driven by the turbulent energy flux and the turbulent Reynolds stress

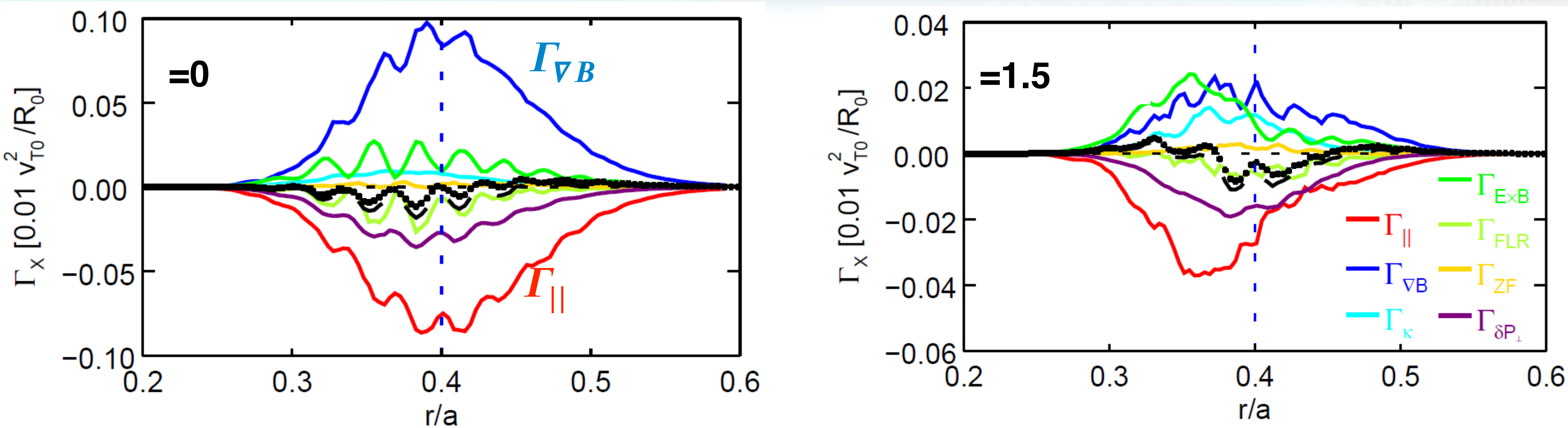
- F-O3, Shaojie Wang, “Zonal flows driven by the turbulent energy flux and the turbulent toroidal Reynolds stress in a magnetic fusion torus”

- F-O5, Debing Zhang, “Transport of poloidal momentum due to the electrostatic turbulence based on the gyrokinetic theory”

$$\partial_t E_r = -B_P \frac{1}{n m_i} \frac{1}{r} \partial_r \left(r \Pi_{r\zeta,i} \right) - \frac{1}{ne} \partial_r \left[\frac{1}{r} \partial_r \left(r \frac{2}{3} \mathrm{Q}_{r,i} \right) \right] + B_T \frac{1}{n m_i} \frac{1}{r} \partial_r \left(r \Pi_{r\theta,i} \right). \quad (2)$$

-

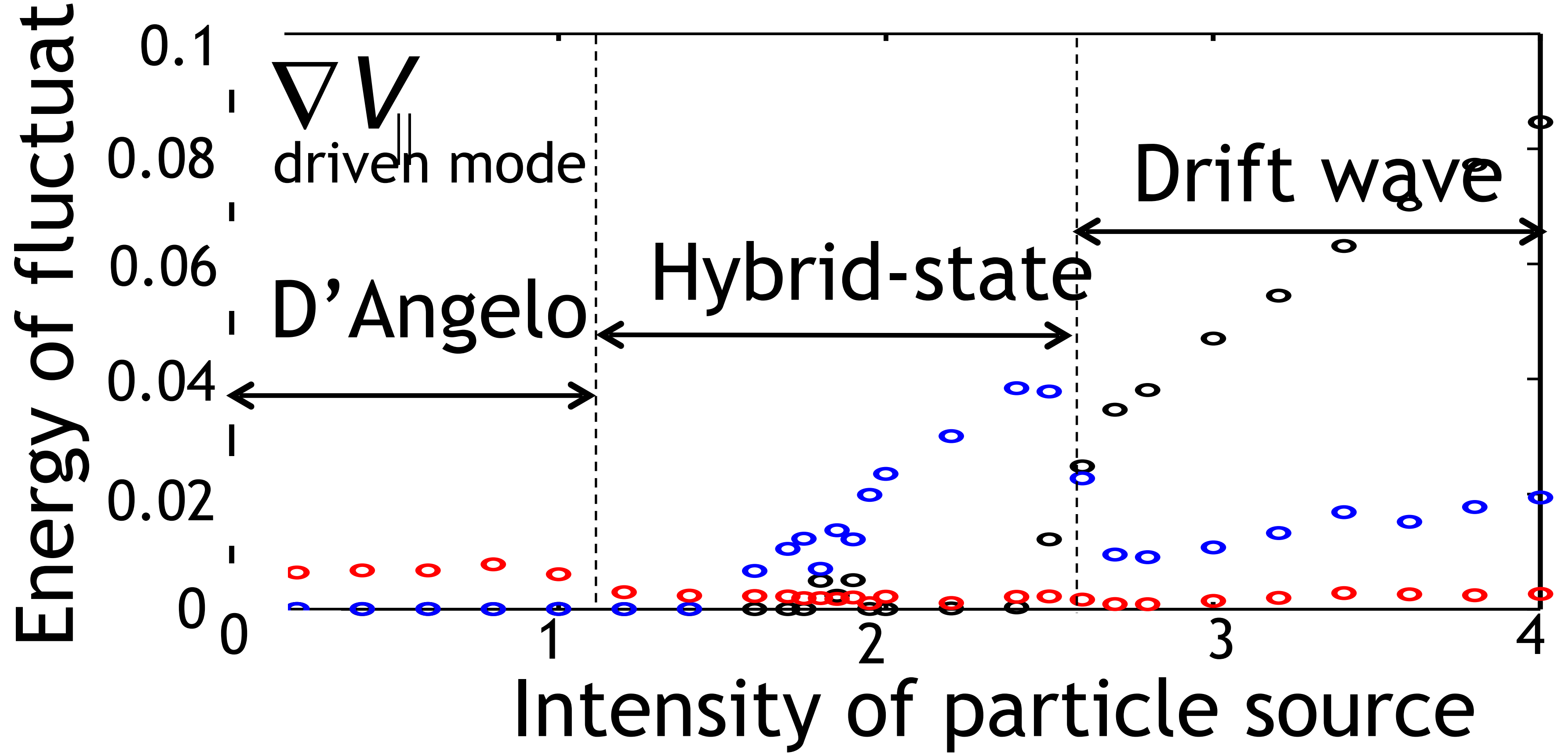
F-I11: “Identification of the role of parallel compression in the zonal flow generation” Sumin Yi

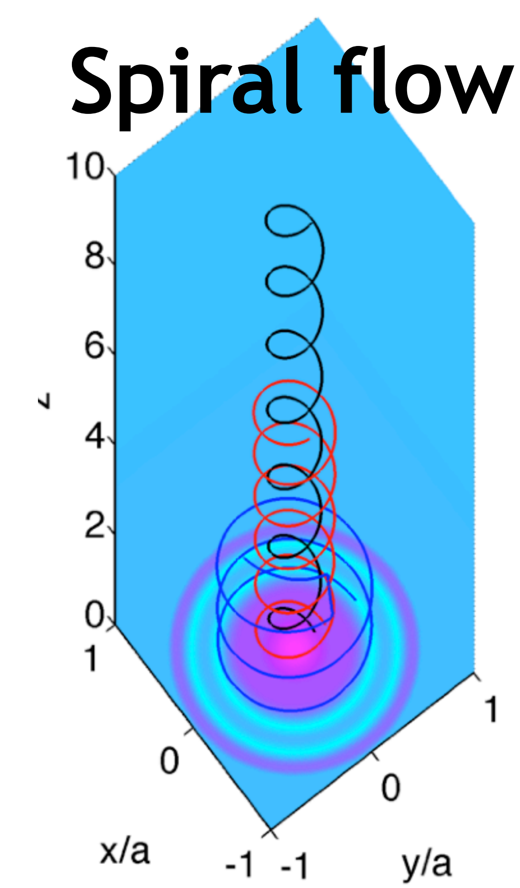


- It is found that from gyrokinetic simulations of toroidal ITG turbulence, a clearly different zonal flow radial pattern emerges with equilibrium parallel rotation shear .
- A potential vorticity transport analysis elucidates the zonal flow generation mechanism with equilibrium parallel rotation shear.
- In the absence of rotation, the dominant contributions to the net PV flux come from the parallel compression and the grad-B drift , and to be largely cancelled out each other.
- With a finite parallel rotation shear, the parallel compression-driven flux becomes dominant over the grad-B drift-driven one, leading to a change in the radial zonal flow profile.

F-I20: Selection of flow chirality in drift-mode and D'Angelo-mode fluctuations, M. Sasaki

Using 3D turbulence simulation,
the bifurcation of turbulence is obtained.





Flow topology (chirality) changes
with the change of turbulent state,
→ A fundamental process to determine the flow topology

F-I22, P. Henequin, IPP

Plasma turbulence structure in the ASDEX Upgrade tokamak

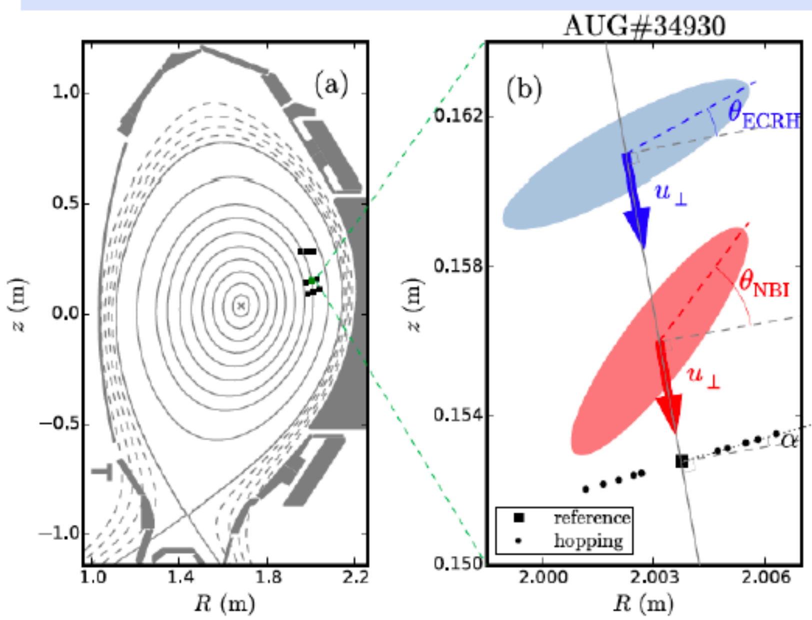
IPP Garching, Germany // LPP Ecole Polytechnique, France // PFSC MIT, USA

P. Hennequin et al

- **Joint measurements** using multiple channels & techniques, access to turbulence structure to **confront/validate simulations**
  - **k spectra**, size, anisotropy, **tilt**
  - cross phase between density and temperature fluctuations

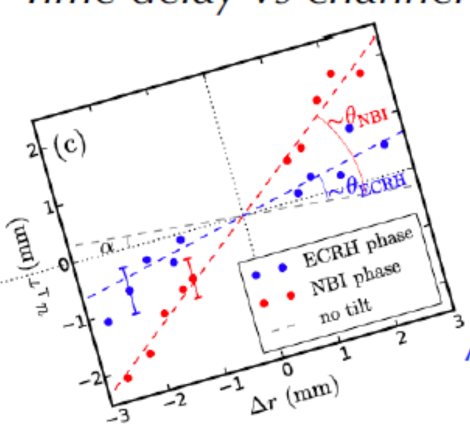
FreethyPoP18

First measurements of **eddy tilting** identified using Correlation Doppler Reflectometry, in ion and electron heated plasmas
change in tilt angle mainly from different ExB flow shear.
-Open the possibility to study
- competing effects between drives and interaction with flows

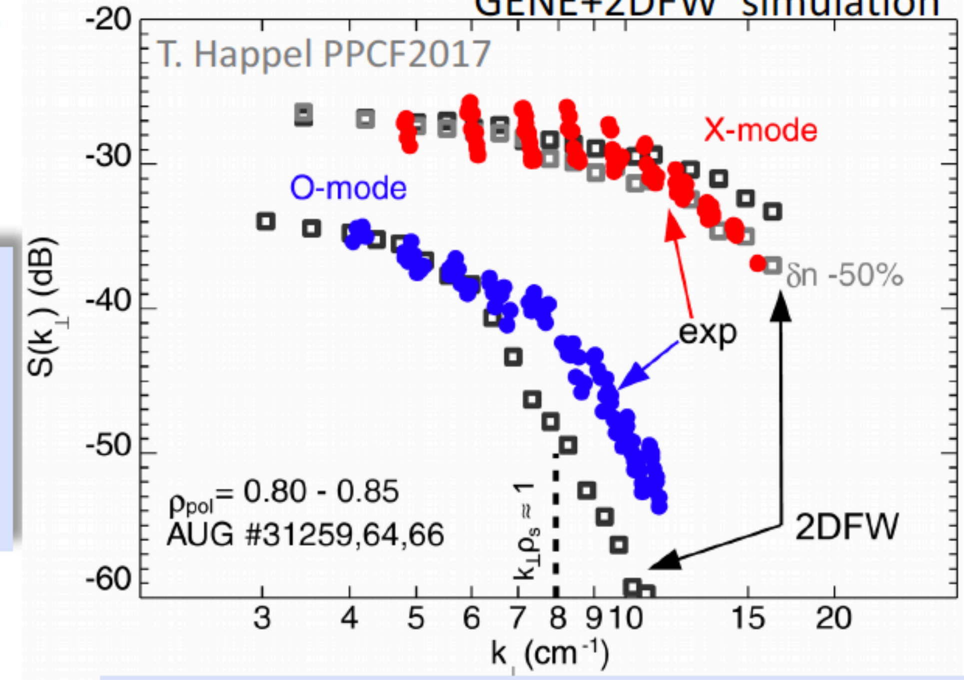


PinzonEPS2018, submitted to PRL

Time delay vs channel separation



k spectra Experiment & GENE+2DFW simulation



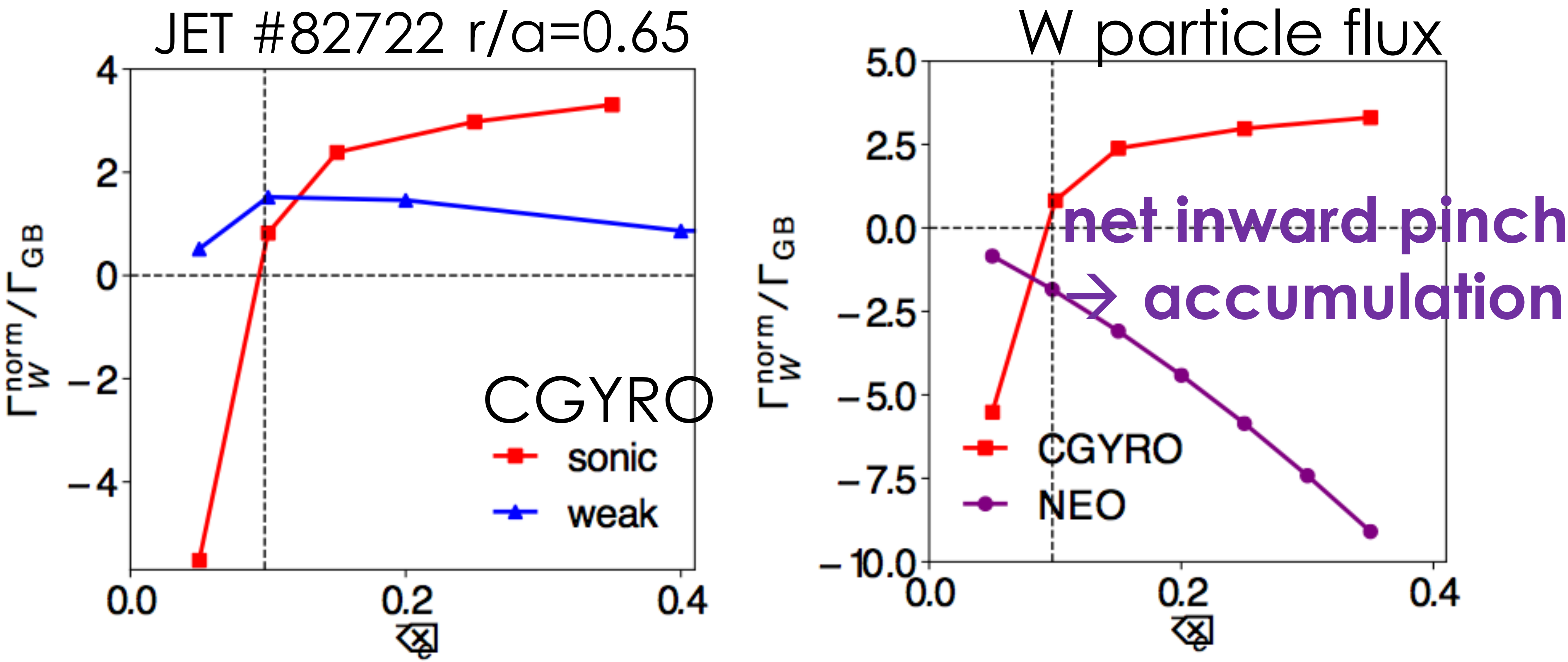
Use of full wave as synthetic diagnostic permitted to reconcile the disparity between measurements
-Key for comparison to simulation and study of energetics and transfer vs scales

Also GK simulations correctly capture radial eddy size
- 2 scales @ short and long distance

HennequinEPS2015,FreethyPoP18

F-I23, Emily Belli, GA

Centrifugal effects produce significant enhancements to the simulated transport of tungsten, and can lead to detrimental core accumulation.



Both the turbulent and neoclassical transport are important.

F-O10, "Interplay between impurity and DW-ZF system in D-T plasma"

J-TEXT Lab, HUST, Weixin Guo

- Theoretical research on the interplay between impurity and DW-ZF system in D-T plasma

wxguo@hust.edu.cn

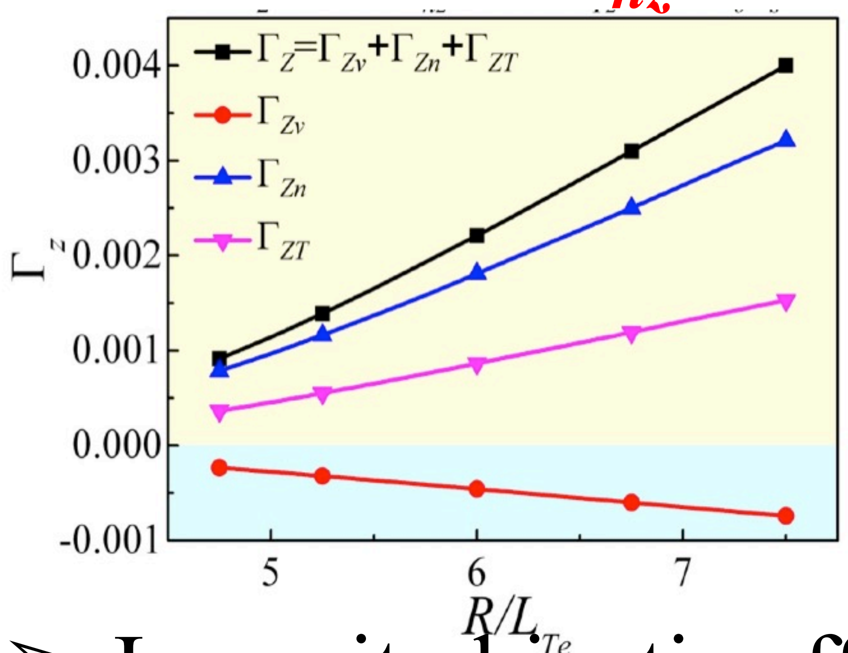
Refs: Weixin Guo, Lu Wang and Ge Zhuang
1. NF 57 056012 (2017).
2. NF 57 056012 (2017).
3. PoP 23 112301 (2016).

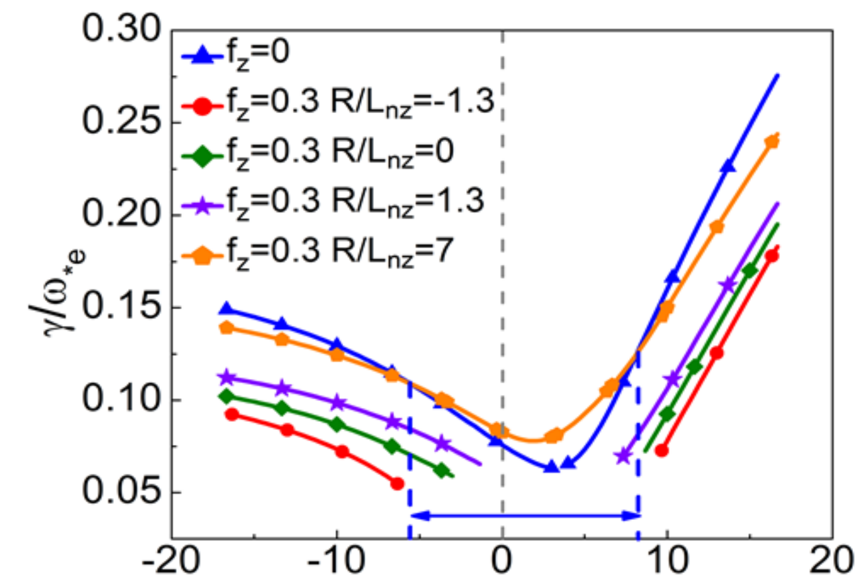
1. Impurity effects on ITG/CTEM instability
   - ✓ Impurity with inwardly (outwardly) peaked density profile stabilizes (destabilizes) the instability
2. How various impurities affect multi-scale ZF
   - ✓ Relatively higher temperature He^{2+} → residual ZF and driven by CTEM
3. Isotopic dependence of residual ZF (with impurity) and impurity transport driven by ITG turbulence
   - ✓ Light impurities weaken the isotopic dependence of
   - ✓ Isotopic effects may be not good for expelling helium ash

A:Effects of Impurity Ions Dynamic:

B: New TEMs:

$R/L_{nz}= 20$





- Impurity kinetic effects can not be neglected. (A-1)
- Direction of Γ_z depends on the direction of R/L_{nz} and R/L_T
especially R/L_{nz}. (A-2)

- TEM can be excited by either positive or negative R/L_{Te}. (B-2)

Outline

- Energetic particle (8)
- Fundamental theory (3)
- Bifurcation, L-H transition (2)
- Multi-scale interaction (4)
- Zonal flow, turbulence and transport (10)
- Reconnection and merging (5)
- ELM, tearing mode (3)
- Others (3)

F-I13, "Direct Access to the Burning Plasma by High-Power Reconnection Heating of Merging Tokamaks", Y. Ono, U. Tokyo

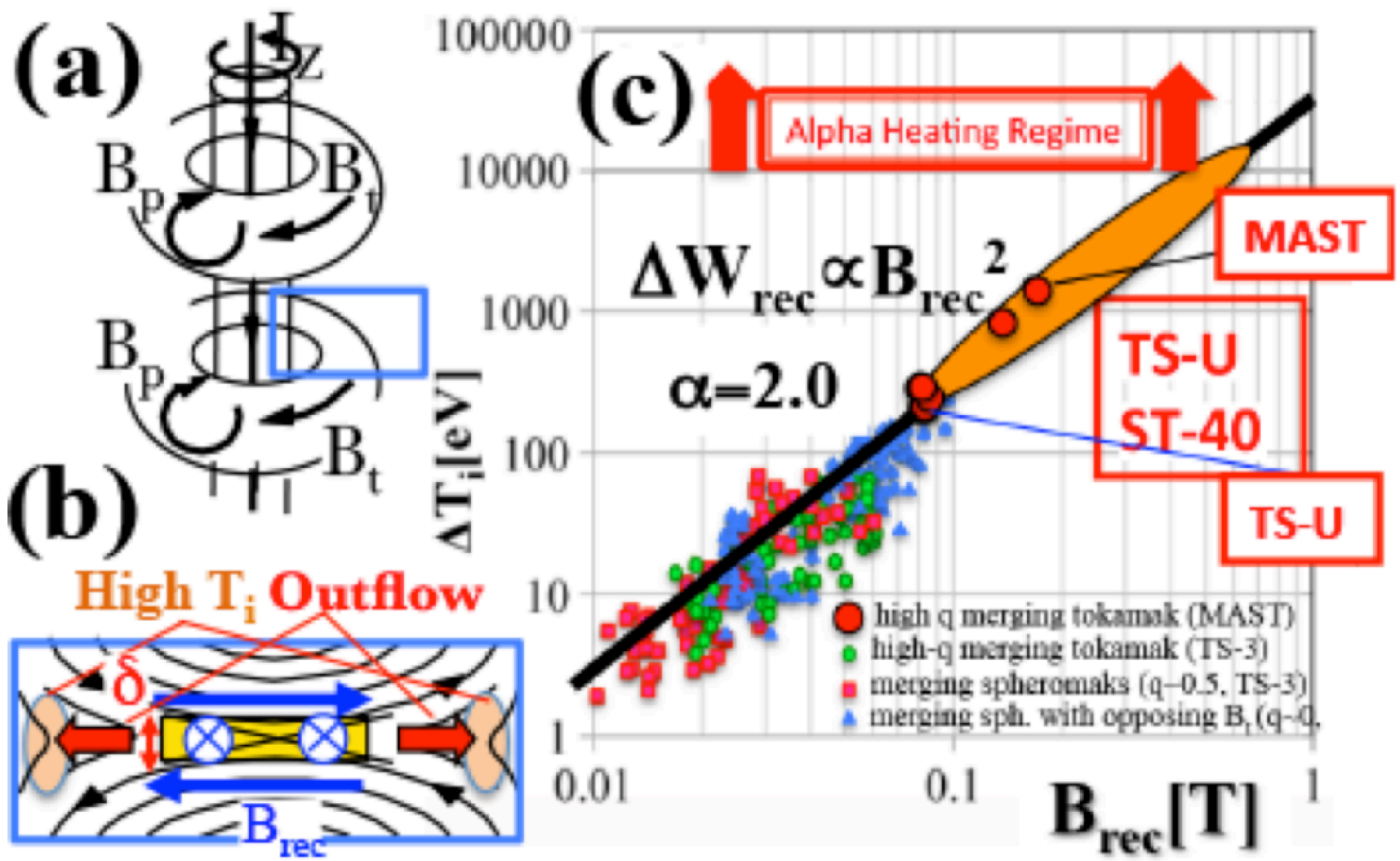


Fig. 1 (a) Two merging ST plasmas (top) and their X-point region (bottom), (b) dependence of ion temperature increment ΔT_i on reconnecting magnetic field B_{rec} of merging STs and spheromaks under constant electron density n_e~$1.5x10^{19}m^{-3}$.

•

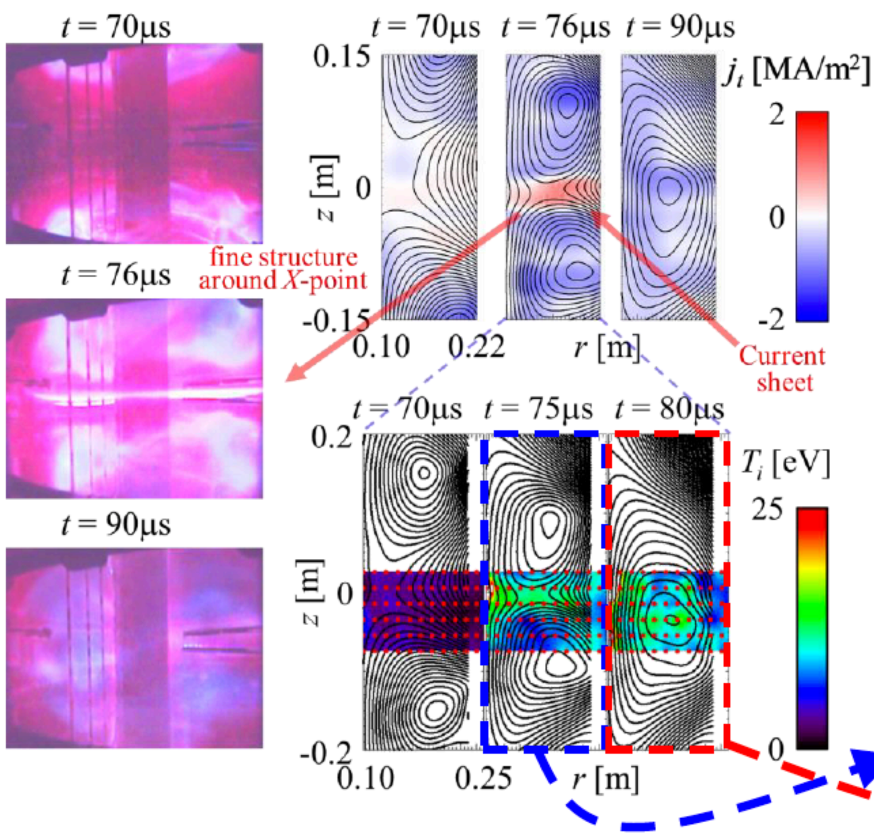
F-O8: H. Tanabe (univ. Tokyo)

Investigation of global ion heating/transport process during merging/reconnection startup of spherical tokamak in TS-3U

Guide field reconnection forms two types of characteristic heating structures

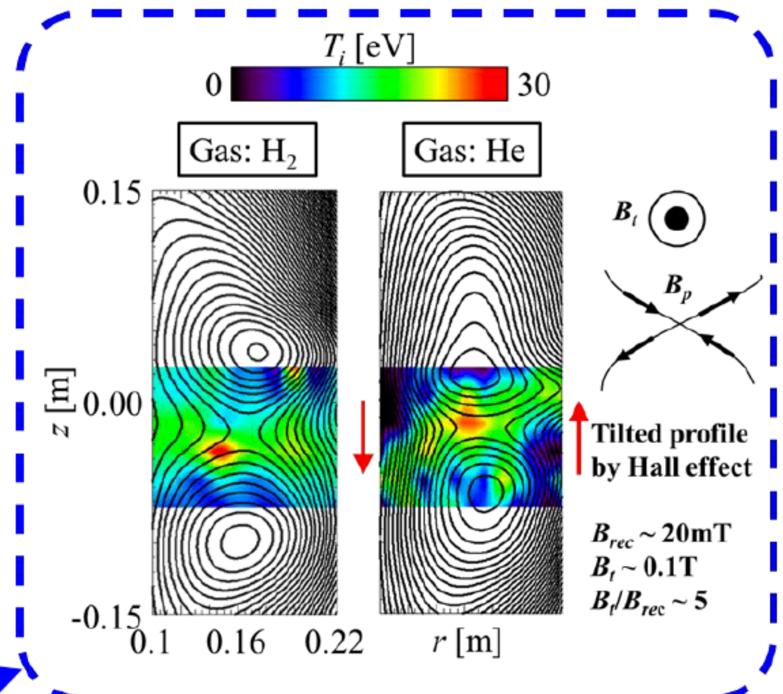
Heating time scale

- Phase1: during merging
- Phase2: after merging



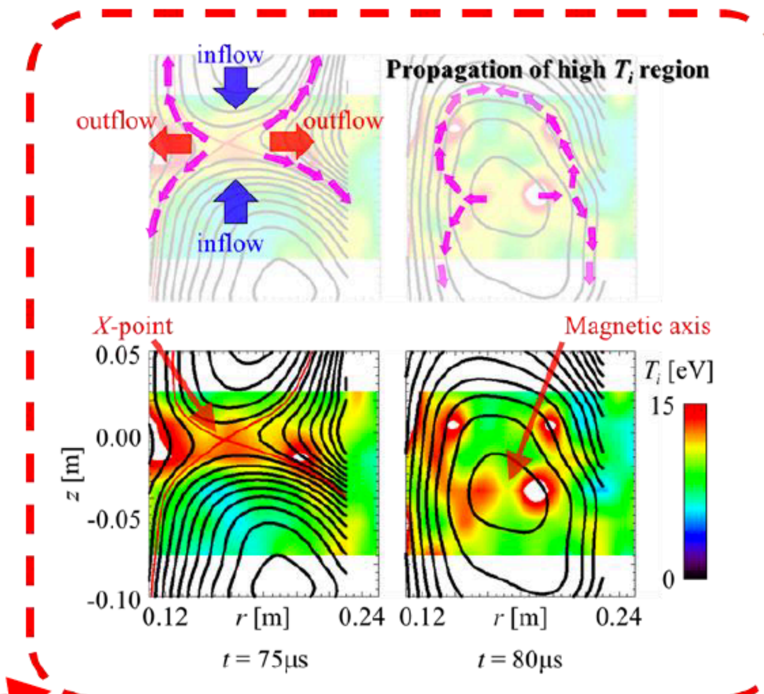
Phase1: ~ acceleration phase ~

- Heating around diffusion region
- Tilted profile formation with higher mass ratio (Hall effect)



Phase2: ~ confinement phase ~

- Contribution of better toroidal plasma confinement
- Downstream heating propagate vertically on closed flux surface



F-I15: PARTICLE SIMULATION STUDIES ON EFFECTIVE ION HEATING DURING MAGNETIC RECONNECTION (S. USAMI, ET AL.)

- By means of **particle simulations**, ion heating mechanism during magnetic reconnection in the presence of guide magnetic field is studied.
- **Ion are effective heating,** since **a circle- or an arc-shape velocity distribution** (Fig. 1) is formed.
- Our theory can explain the following dependence observed in plasma merging experiments in STs.
  - *The ion heating energy is proportional to the square of the reconnection magnetic field.*
  - *The ion temperature is lower as the guide magnetic field is stronger.*
- Our simulation results are consistent with the above tendencies as shown in Figs.2 and 3.

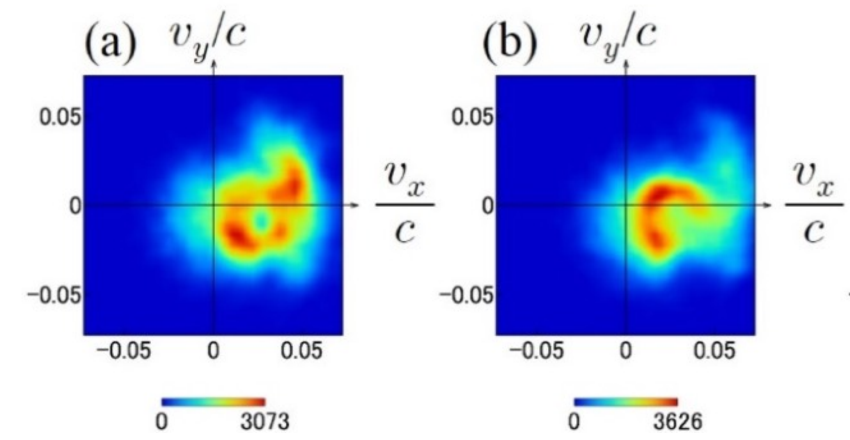


Fig.1: Ion velocity distributions

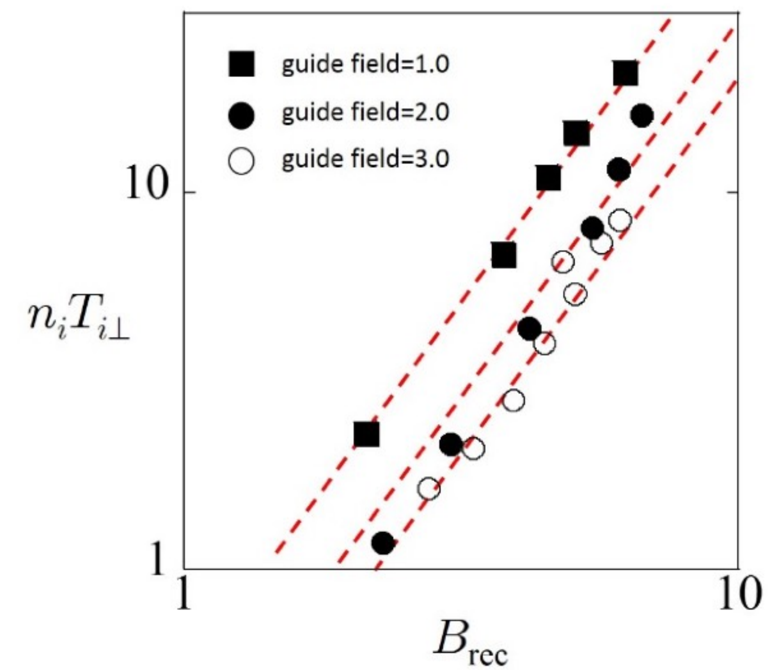


Fig.2: Ion heating energy vs. reconnection magnetic field. The red lines denote the theoretical lines.

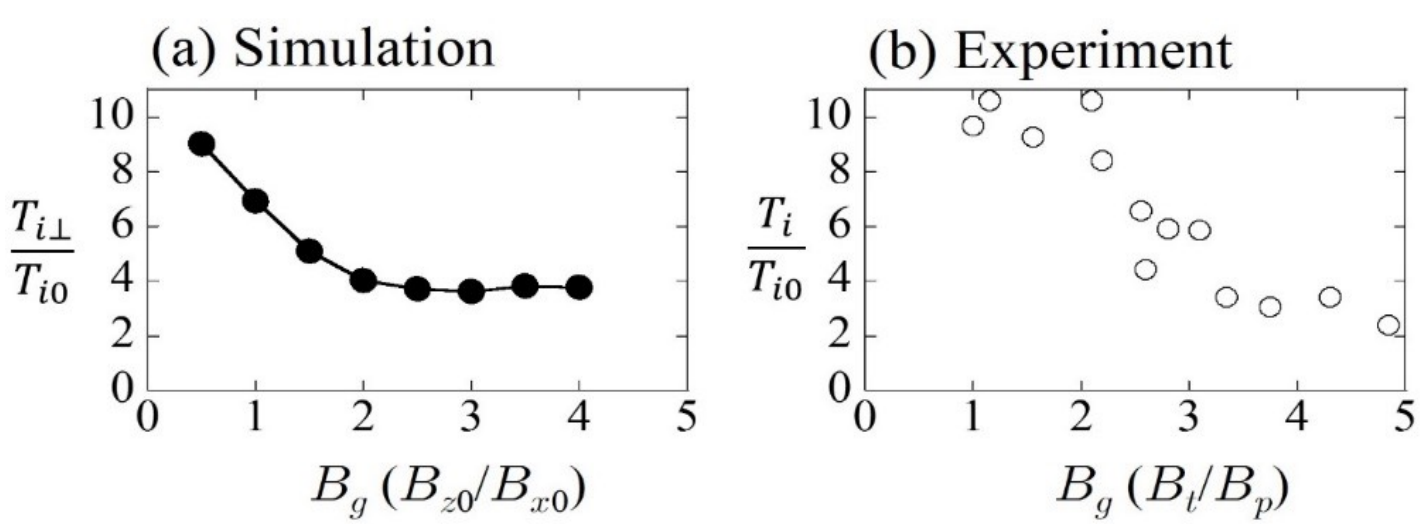


Fig.3: Ion temperature vs. guide magnetic field

F-I14: “Electron and Ion Heating/Acceleration in Driving Magnetic Reconnection”

C. Z. Cheng, U. Tokyo

- During the driven magnetic reconnection process a part of the magnetic energy is converted into the plasma energy.
- electrostatic electric field is produced by the decoupling of the electron and ion dynamics .
- In the weak guide field case (Bg < Bp), The ions gain energy mainly from the electrostatic potential drop as they move from the upstream into the downstream region.
- the increase of ion temperature is proportional to the square of the upstream merging poloidal field.

F-O7: "On Lorentz invariants in relativistic magnetic reconnection"

Xiaogang Wang, HIT

- Construct the relativistically invariant definition for the relativistic magnetic reconnection.

$$I_1 \equiv \frac{1}{2} F^{\mu\nu} F_{\mu\nu} = B^2 - E^2 ,$$

and

$$I_2 \equiv \frac{1}{4} F^{\mu\nu *} F_{\mu\nu} = \frac{1}{4} \varepsilon^{\mu\nu\lambda\tau} F_{\mu\nu} F_{\lambda\tau} = \mathbf{E} \cdot \mathbf{B} ,$$

For 2D X-points in the
ıgnetic nulls, we can get

$$\Re \approx \frac{\left(\left| I_{1,MIN} \right| h_{+0} \right)^{1/2}}{I_{1,MAX}^2} .$$

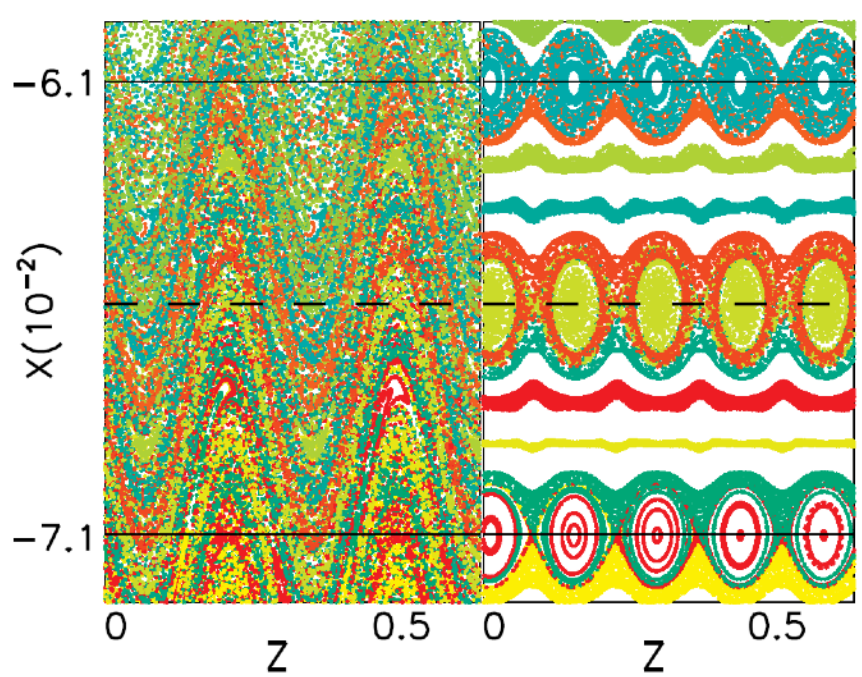
Outline

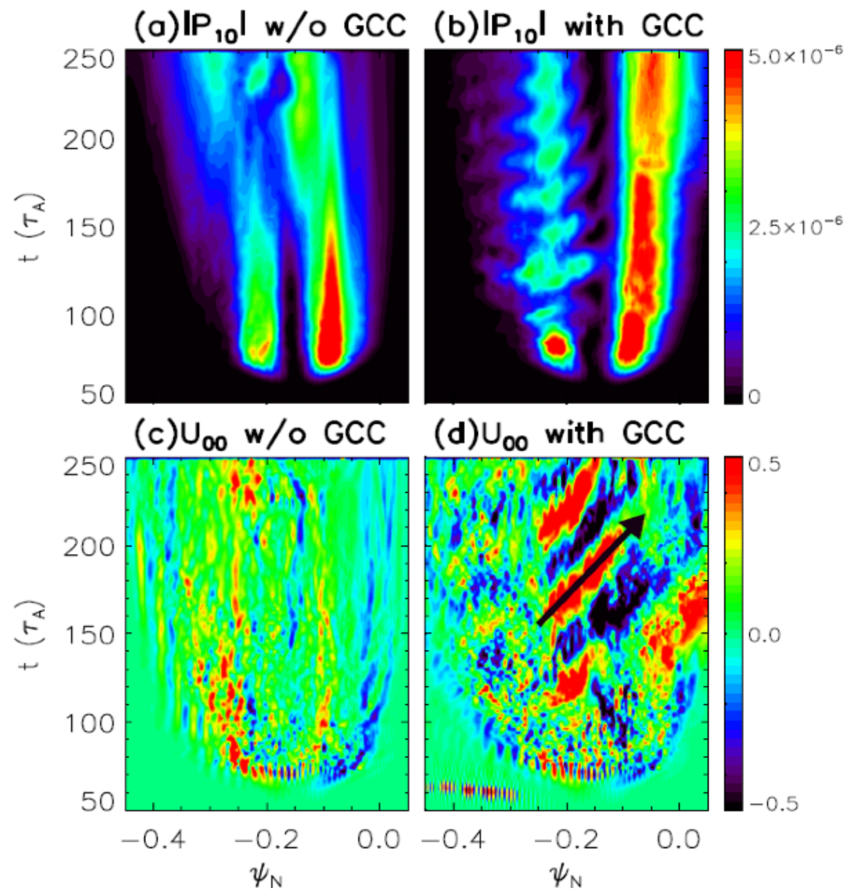
- Energetic particle (8)
- Fundamental theory (3)
- Bifurcation, L-H transition (2)
- Multi-scale interaction (4)
- Zonal flow, turbulence and transport (10)
- Reconnection and merging (5)
- ELM, tearing mode (3)
- Others (3)

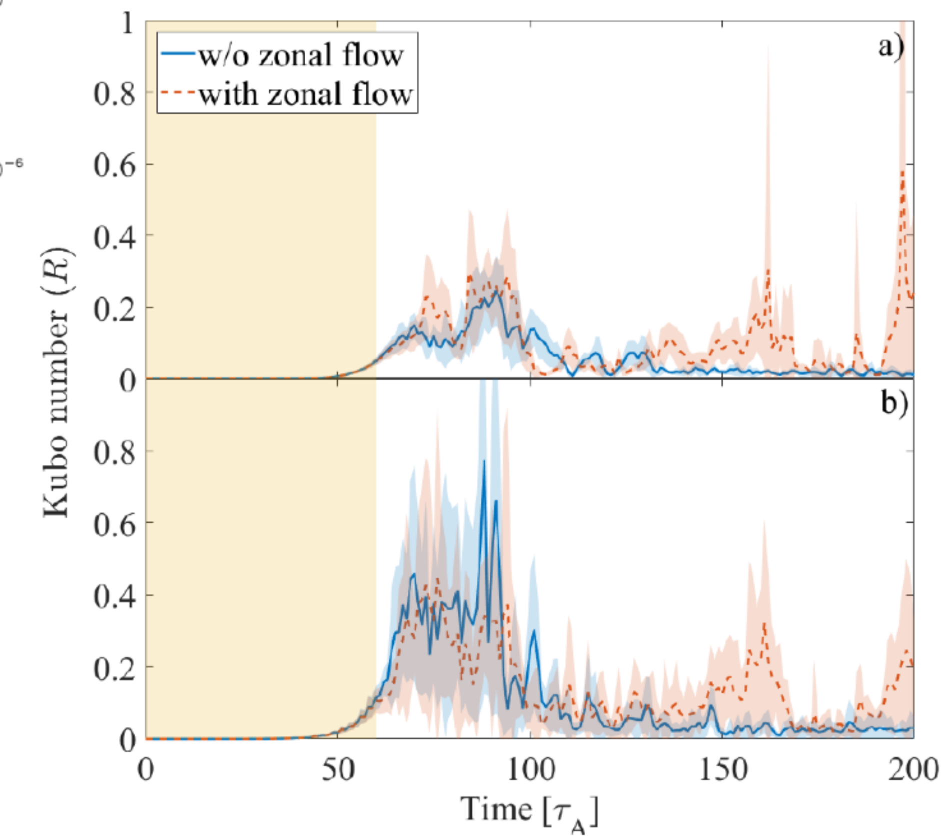
F-I18: “Stochastization and transport during pedestal collapse simulation”(H Jhang et al)

3D MHD simulations reveal rich nonlinear physics phenomena involved in edge pedestal collapse dynamics

- ✓ Stochastization of magnetic fields due to nonlinearly driven tearing modes and reconnection → Transport of magnetic field is likely to be quasilinear since $R_m < 1$ even in a very strongly driven pedestal collapse
- ✓ GAMs appear when a strong zonal mode is driven and lead to subsequent secondary crashes



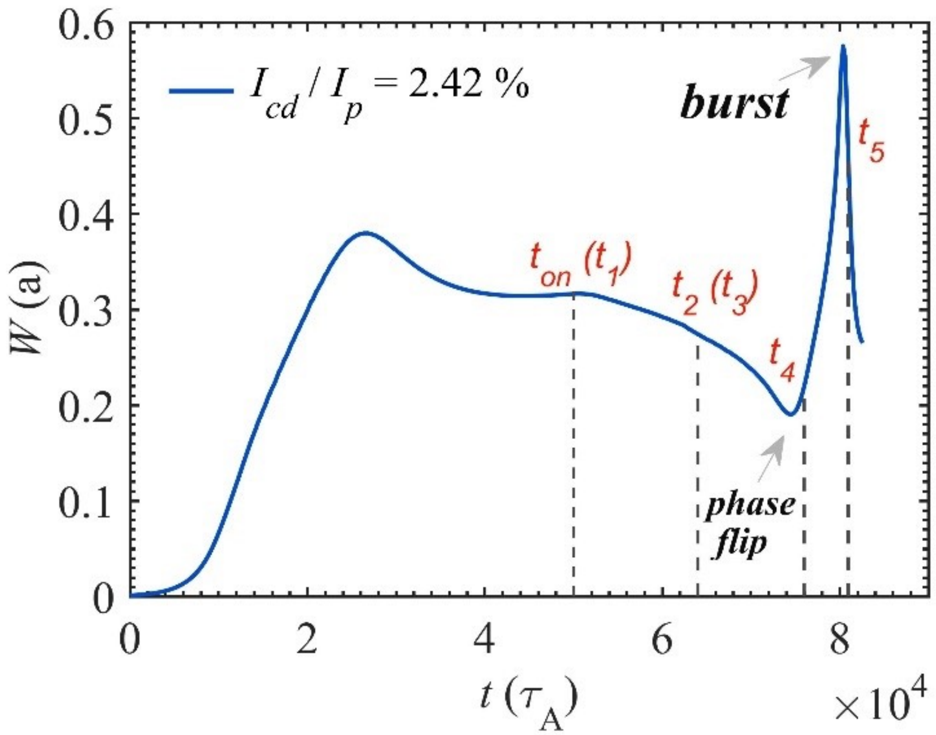




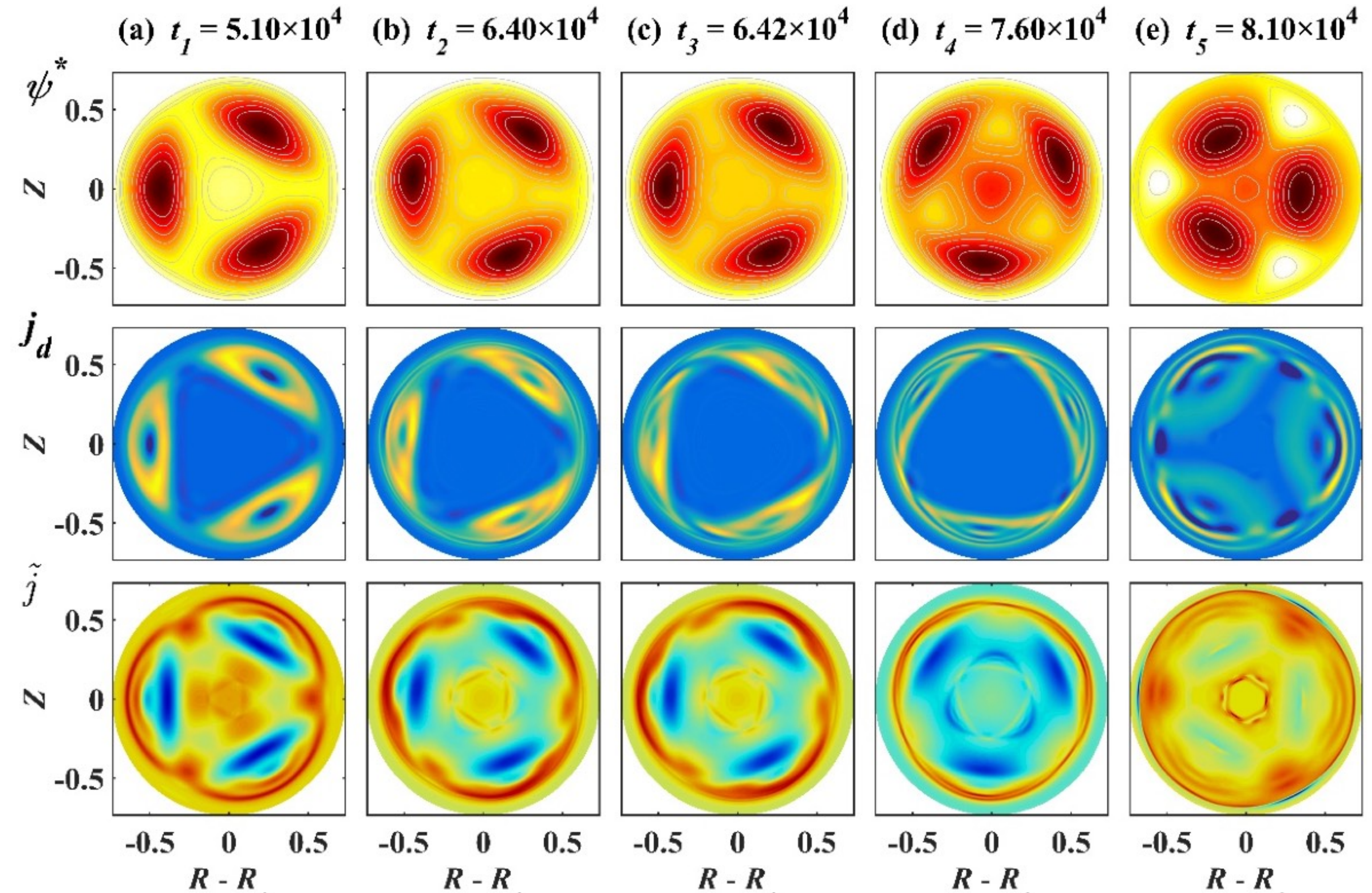
F-O1: "Effect of ECCD on NTM in RMS tokamak"

"phase flip" occur for NTM cases

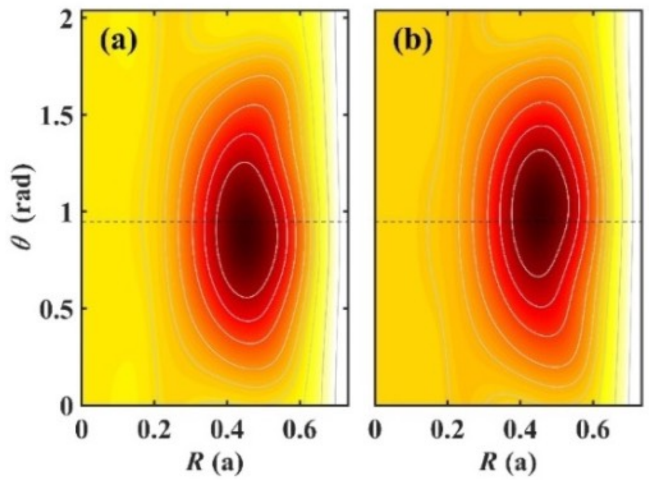
Z.-X. Wang, U40 award,
Dalian U of Tech., China



Contours of the magnetic island, the EC current density and perturbed current density



The fine structure of the island



- ➢ The strong zonal field induced by neo-classical current can intensely couple with the 3/1 harmonic, which causes the intense fluctuation of the rational surfaces.
- ➢ With the fluctuation, the EC current is not able to steadily deposit and effectively compensate the missing bootstrap current. Finally, the "phase flip" occurs and leads to the burst.

Outline

- Energetic particle (8)
- Fundamental theory (3)
- Bifurcation, L-H transition (2)
- Multi-scale interaction (4)
- Zonal flow, turbulence and transport (10)
- Reconnection and merging (5)
- ELM, tearing mode (3)
- Others (3)

Other topics

- F-O2, Xianyuan Xiao, “Charge Conservative Geometric Structure Preserving Particle-in-Cell Scheme for the Relativistic Vlasov-Maxwell System”

- F-I9, Yuichi Yatsuyanagi, “Kinetic understanding of self-organization in long-range interacting systems evidenced by numerical simulations on PEZY-SC”

- F-O12, Vladimir Kocharovsky, “Spatial spectrum of quasi-magnetostatic turbulence at the growth, saturation and decay phases of Weibel instability in collisionless plasma”

- F-O2, “Charge Conservative Geometric Structure Preserving Particle-in-Cell Scheme for the Relativistic Vlasov-Maxwell System”, Xianyuan Xiao, USTC

1. The geometric PIC scheme for the RVM system is developed
2. It is symplectic structure preserving, and has excellent long term conservative property
3. Discrete gauge invariance and conservation of charge is also complied
4. Massive parallel implement using the *SymPIC* code
5. Dispersion relation and energy conservation are numerically verified.