7th APTWG
Nagoya Univ.
June 5 – 8, 2017

Summary of WG (C)

Mode competition in turbulence and MHD driven by energetic particle

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National Institute for Fusion Science

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1 Plenary, 1 Overview, 3 Oral, 11 Poster

Multiscale interaction and mode competition may be a key to clarify the mechanisms of the following phenomena.

- Shortfall problem in transport
- Nonlocal transport
- Isotope effect
- Abrupt phenomena (Disruption, sawtooth, ALE,,,)

:

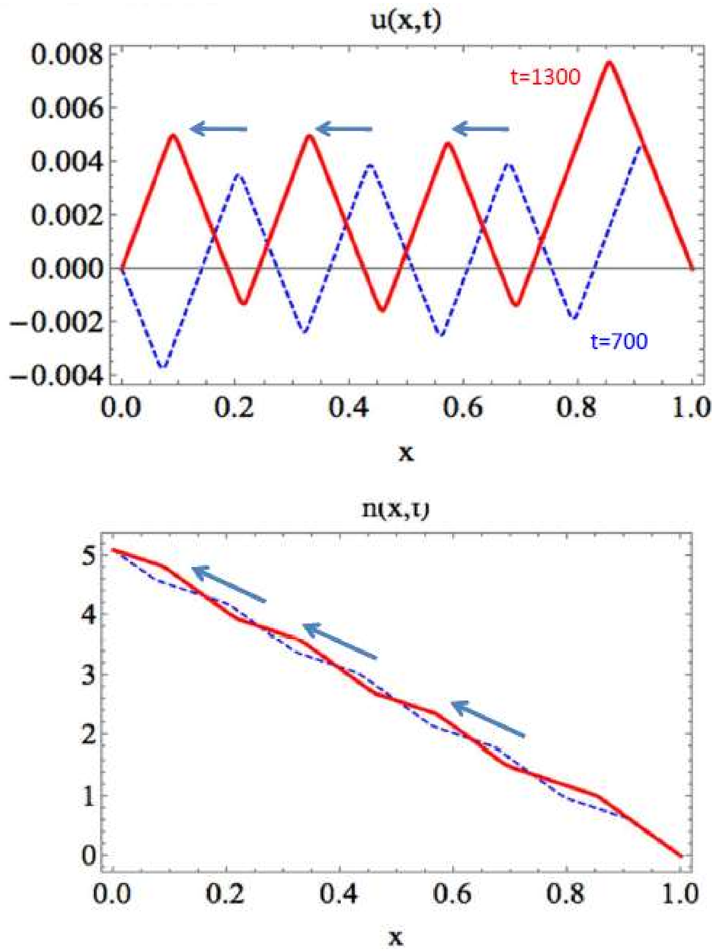
Physics of multiscale interaction has not been elucidated.

(C-OV1 P.H. Diamond in this conference)

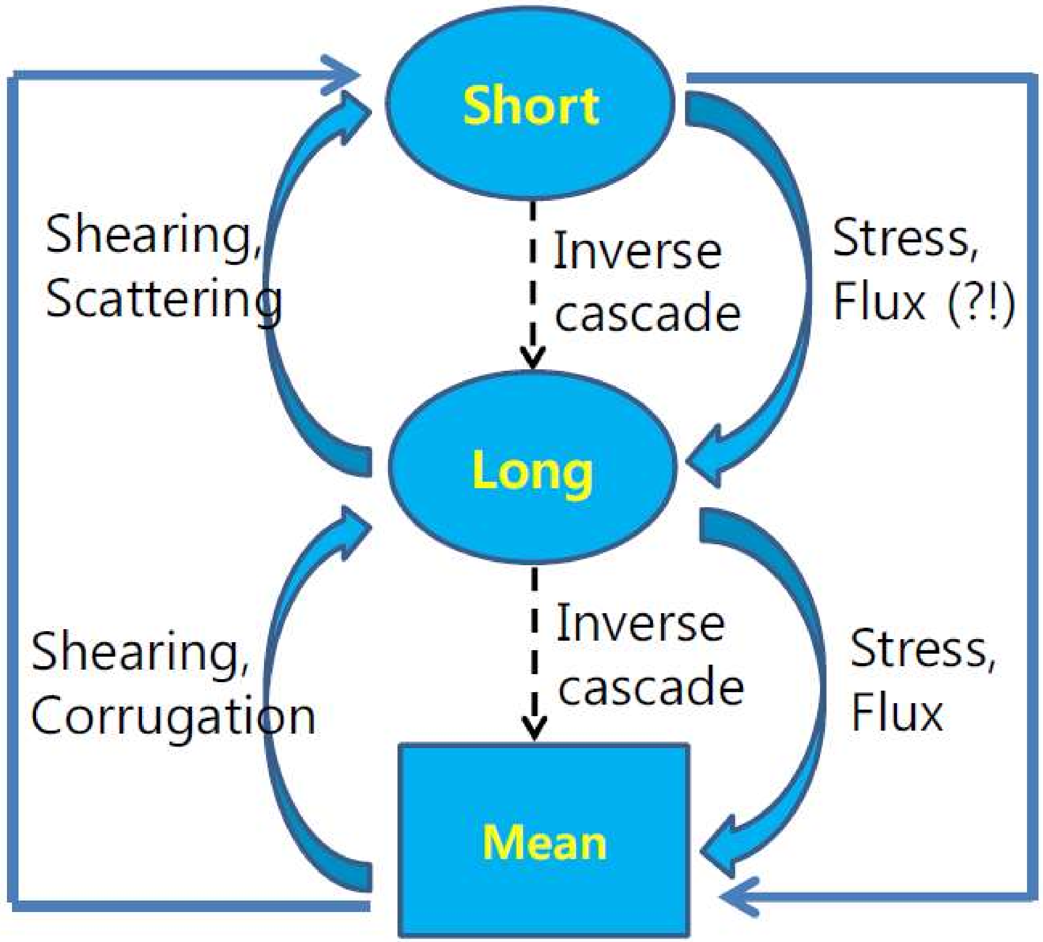
“Multi-scale physics still yield new questions for research”

C-OV1
P. H. Diamond

Dynamic staircase



Theory, reduced modeling is necessary for understanding large scale simulations.



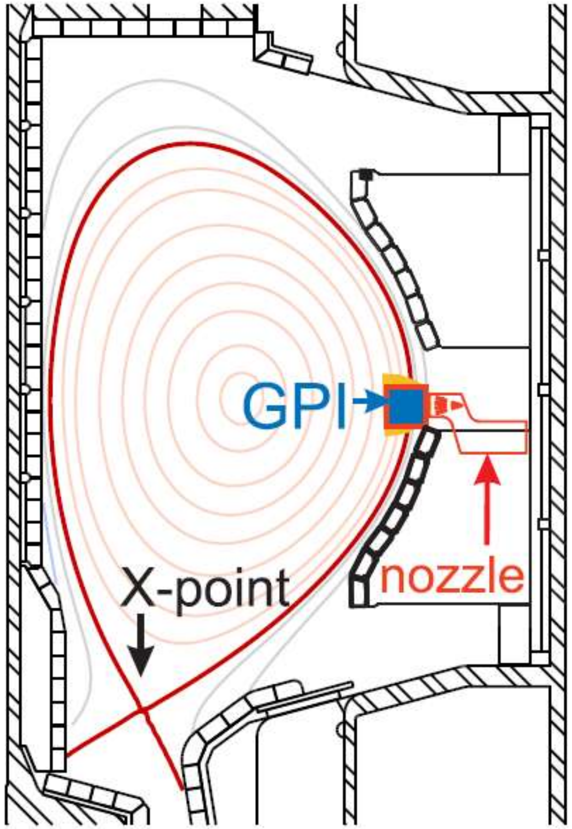
The Energy Transfer Function and 2D measurement reveal the GAM - ZF competition, quantitatively.

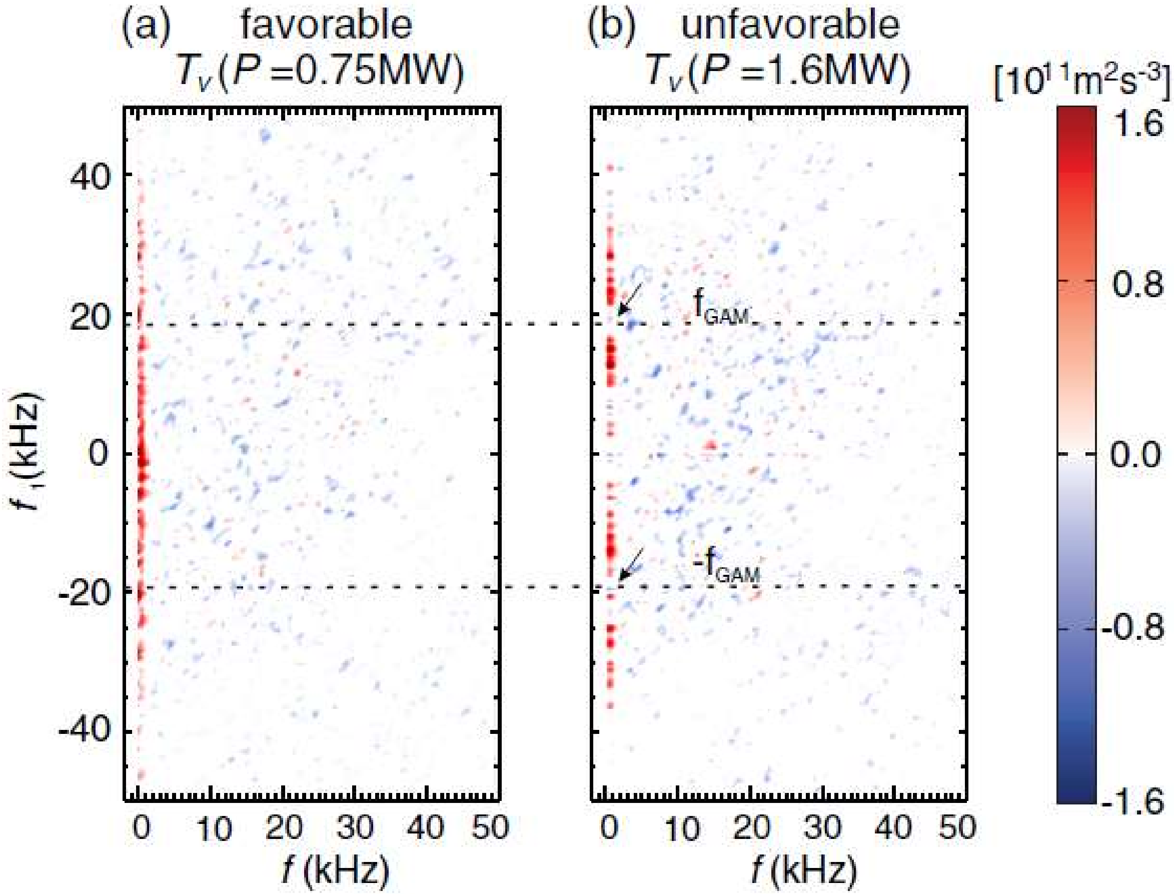
C-PL1
I. Cziegler

Energy Transfer Function

I. Cziegler, NF 55 083007 (2015)

$$T_v(f) = \sum_{f_1=-f_N}^{f_N} T_v(f_1, f) = -\sum_{f_1=-f_N}^{f_N} \mathrm{Re}\langle \bar{v}^{\theta}_{f} v^{r}_{f-f_1} \partial_r v^{\theta}_{f_1} \rangle$$

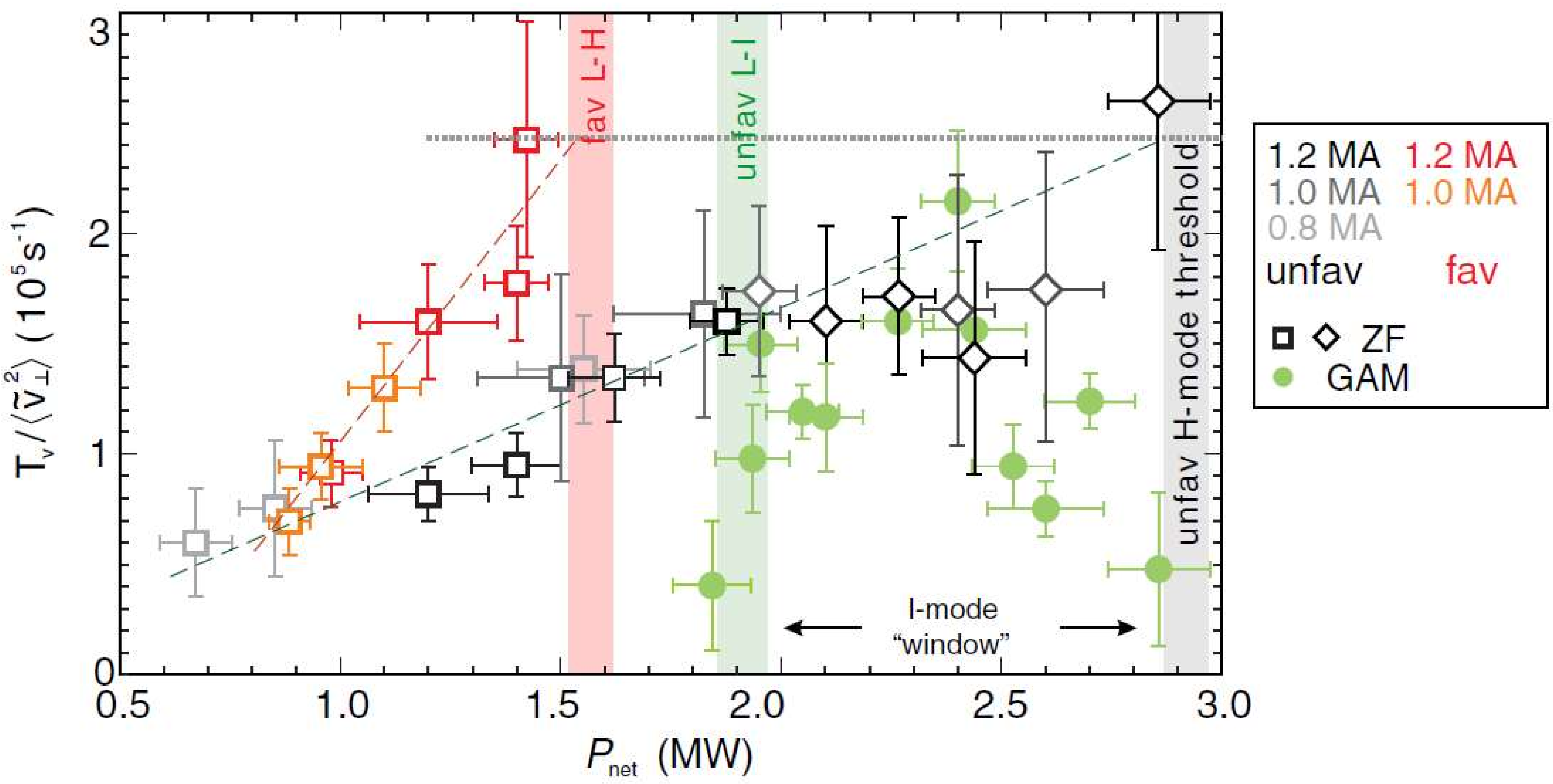




I. Cziegler, PRL 118, 105003 (2017)

C-PL1
I. Cziegler

I. Cziegler, PRL 118, 105003 (2017)



Analysis of entropy transfer rate quantitatively shows that the shearing model works for zonal flow excited in ITG turbulence in GK simulation.

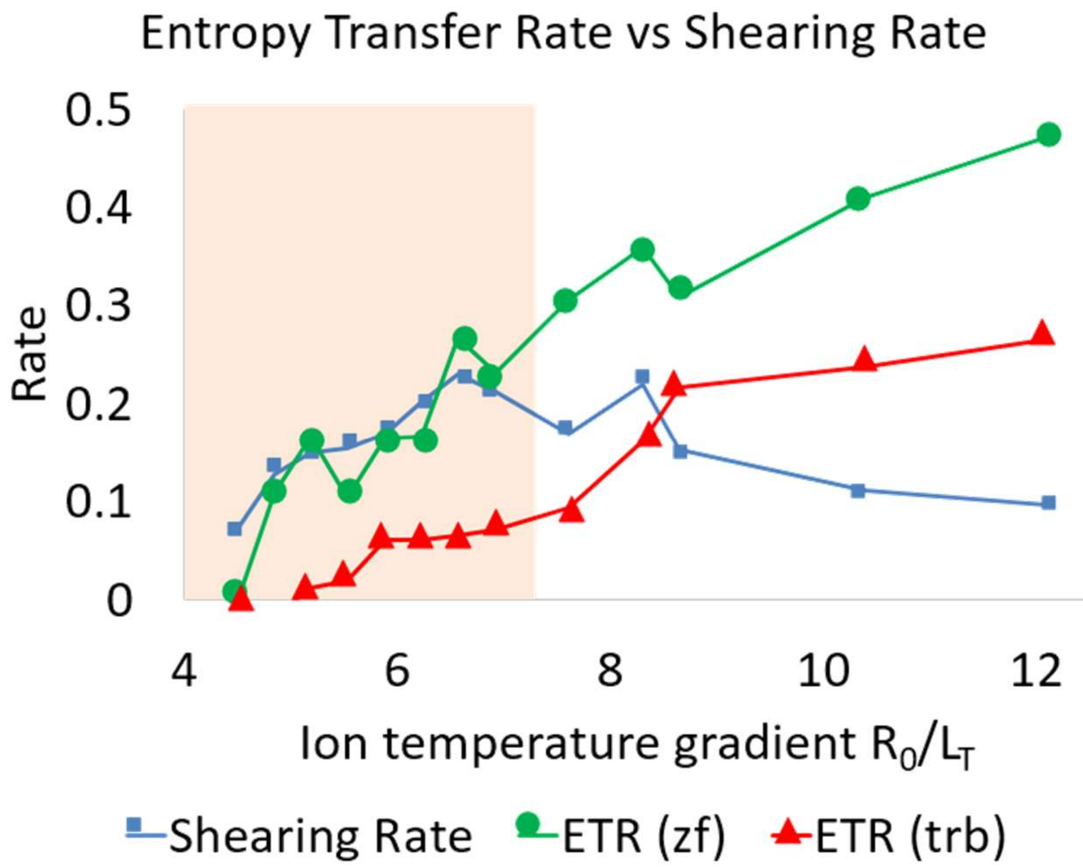
C-P30
T. Miura

Entropy Transfer Function

$$T_{\boldsymbol{k}_\perp} = \sum_{\boldsymbol{p}_\perp} \sum_{\boldsymbol{q}_\perp} \delta_{\boldsymbol{k}_\perp+\boldsymbol{p}_\perp+\boldsymbol{q}_\perp,0} J[\boldsymbol{k}_\perp | \boldsymbol{p}_\perp, \boldsymbol{q}_\perp]$$
$$= \left[\left(\Sigma_{\boldsymbol{p}_{zf}} \Sigma_{\boldsymbol{q}_{trb}} + \Sigma_{\boldsymbol{p}_{trb}} \Sigma_{\boldsymbol{q}_{zf}} \right) + \Sigma_{\boldsymbol{p}_{trb}} \Sigma_{\boldsymbol{q}_{trb}} \right] \delta_{\boldsymbol{k}_\perp+\boldsymbol{p}_\perp+\boldsymbol{q}_\perp,0} J[\boldsymbol{k}_\perp | \boldsymbol{p}_\perp, \boldsymbol{q}_\perp]$$
$$= T_{\boldsymbol{k}_\perp}(zf) + T_{\boldsymbol{k}_\perp}(trb)$$

Entropy Transfer Rate

$$\mathrm{E}_{\boldsymbol{k}_\perp} = T_{\boldsymbol{k}_\perp} / S_{\boldsymbol{k}_\perp}$$
$$= T_{\boldsymbol{k}_\perp}(zf) / S_{\boldsymbol{k}_\perp} + T_{\boldsymbol{k}_\perp}(trb) / S_{\boldsymbol{k}_\perp}$$
$$= \mathrm{E}_{zf} + \mathrm{E}_{trb}$$

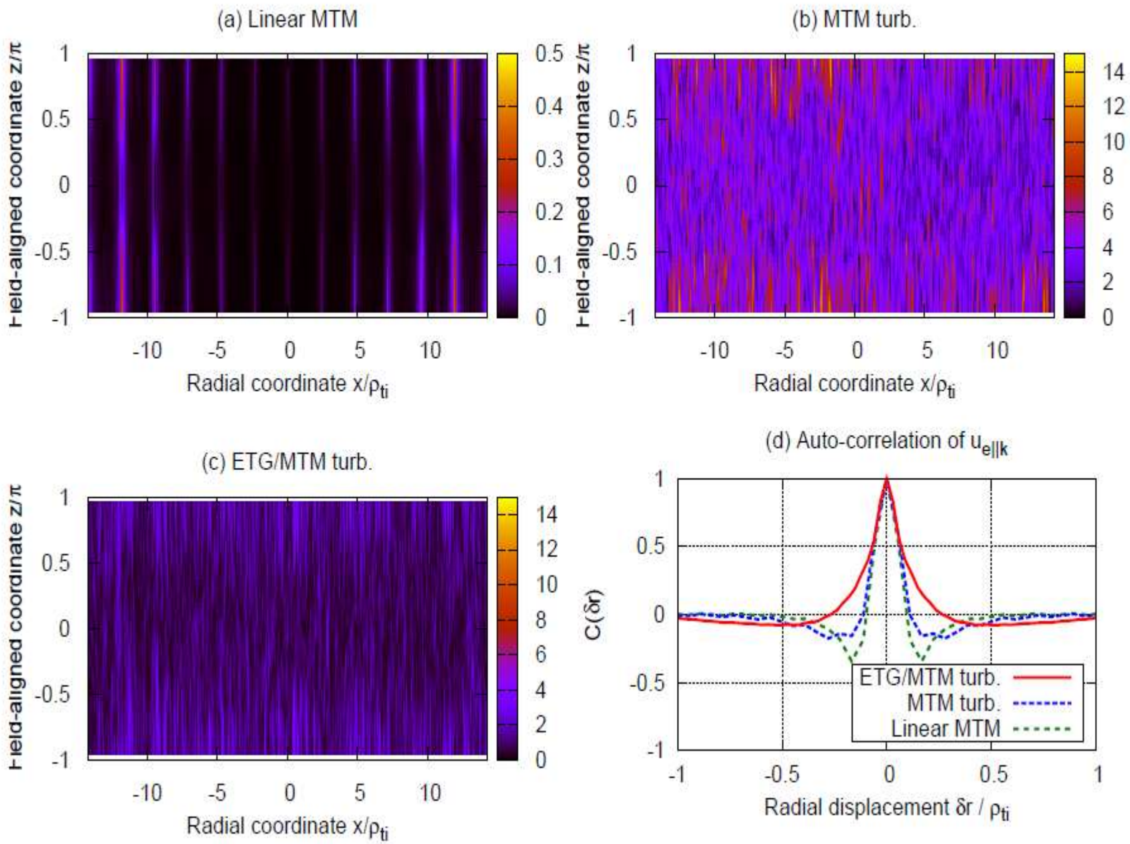


Multi-scale (Full-k) simulation reveals that short-wave-length ETG turbulence can suppresses long-wave-length MTM.

C-P8
S. Maeyama

S. Maeyama, 26th IAEA Fusion Energy Conference (2016)TH/P2-1

Electron parallel current structures



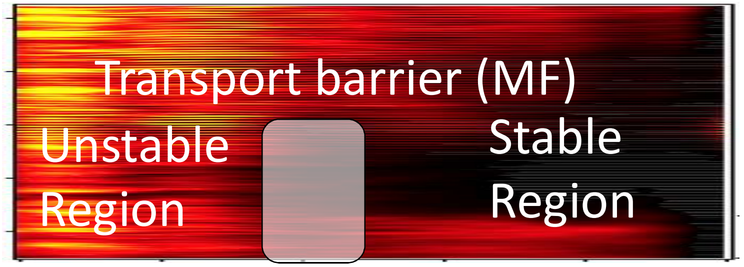
- Radially-localized current sheet of MTM is destroyed by ETG.
- Triad transfer analysis confirms that perturbed entropy of MTM (especially having high-kx) is transferred to finer modes via the coupling with ETG.

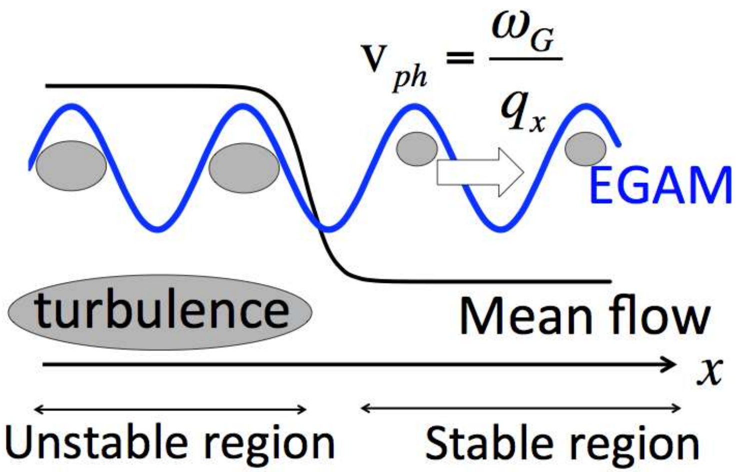
Energetic particle-driven mode (EGAM) traps and transfers turbulence.

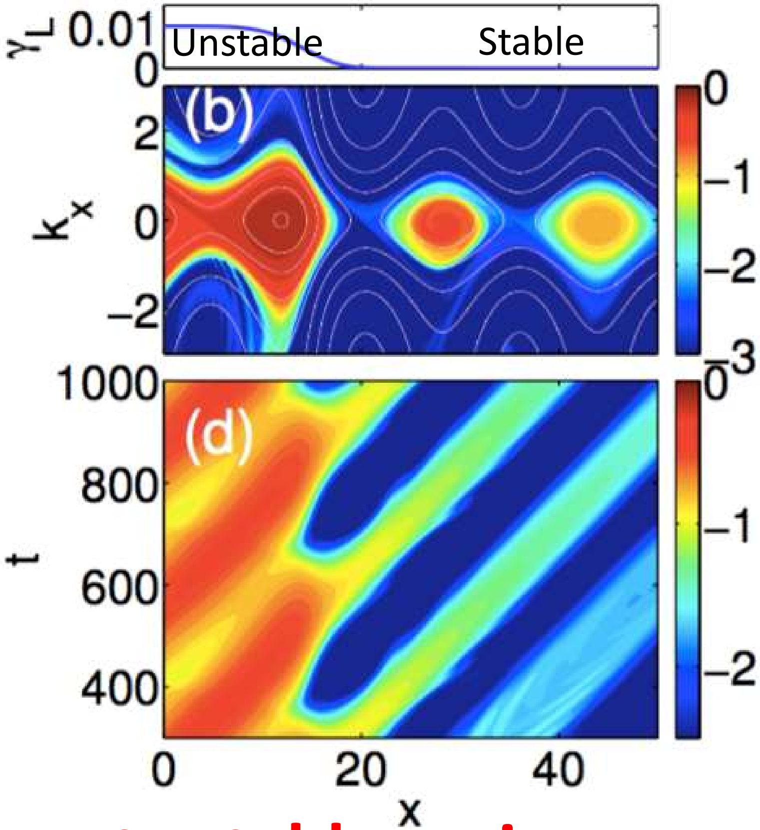
C-P4
M. Sasaki

Submitted to PRL (2017)

Dynamics of turbulence in wavenumber-space is studied. ⇨ EGAM traps turbulence





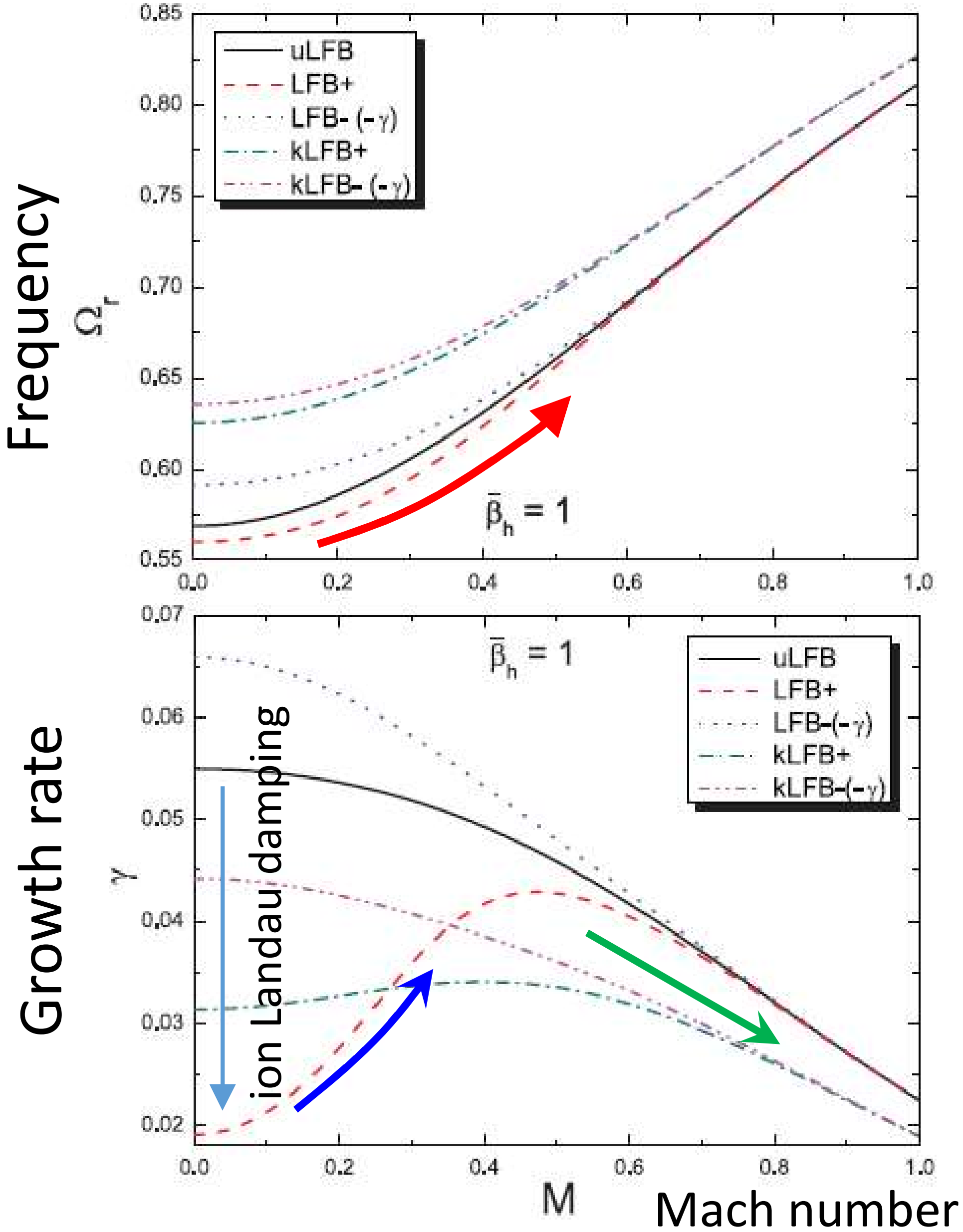


EGAM carries clumps of turbulence to stable region even across transport barrier!

Effects of toroidal rotation on EGAM have been investigated.

C-P2
H. Ren

H. Ren, Nucl. Fusion **57,** 016023 (2017)



The toroidal Mach number
increase Ω_r, and

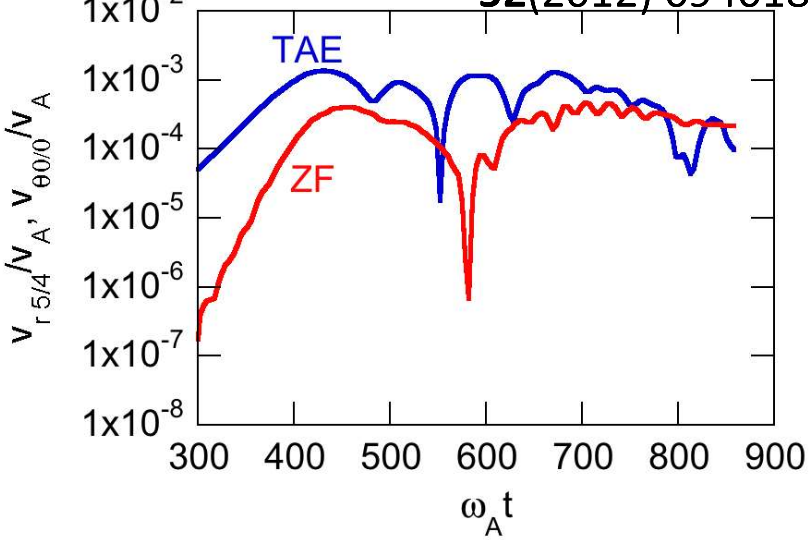
enlarges the growth rate when $\Omega_r < \Omega_{cri}$, and
decreases the growth rate when $\Omega_r > \Omega_{cri}$.

Interplay among TAEs and Zonal flow has been observed by a new hybrid simulation.

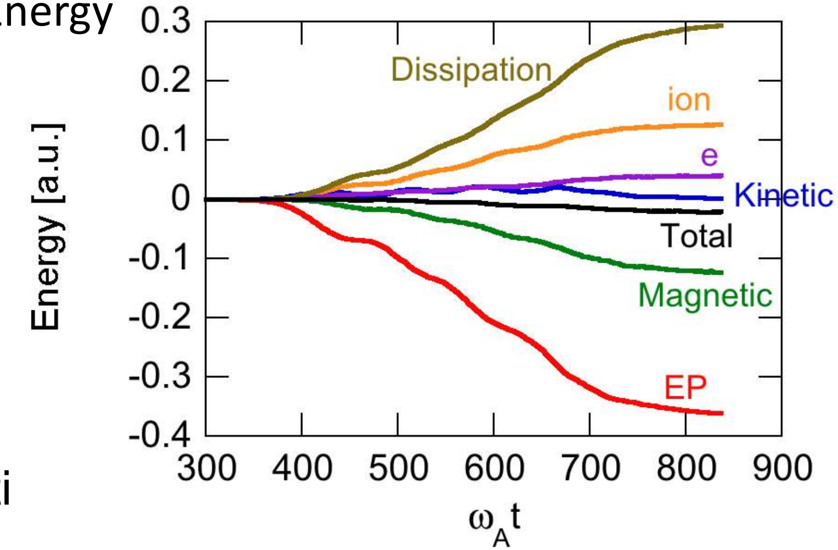
C-P11
Todo

Y. Todo, Nucl. Fusion **50** (2010) 084016
52(2012) 094018

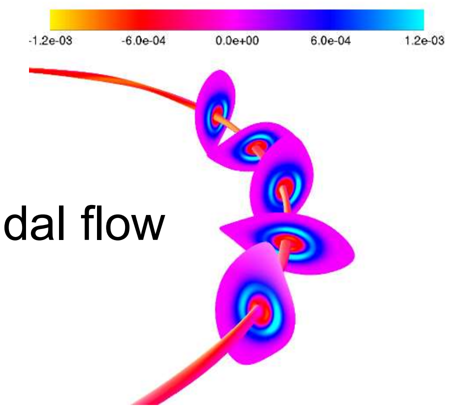
- A new hybrid simulation model
  - PIC: energetic particles + thermal ions
  - coupled with an extended MHD model
- Interplay among two TAEs and ZF
  - ZF grows two times faster than the TAE
- Energy transfer takes place:
  EP -> TAEs -> thermal ion
- EGAM in LHD

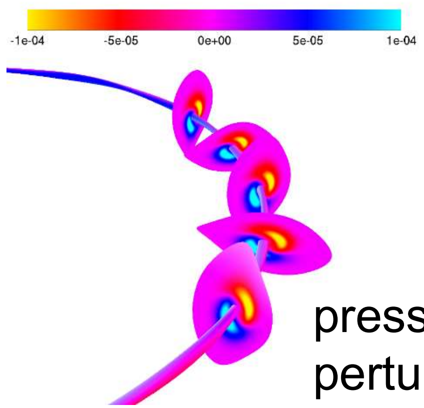


H. Wang, 26th IAEA Fusion Energy Conference (2016)TH/P4-11



poloidal flow



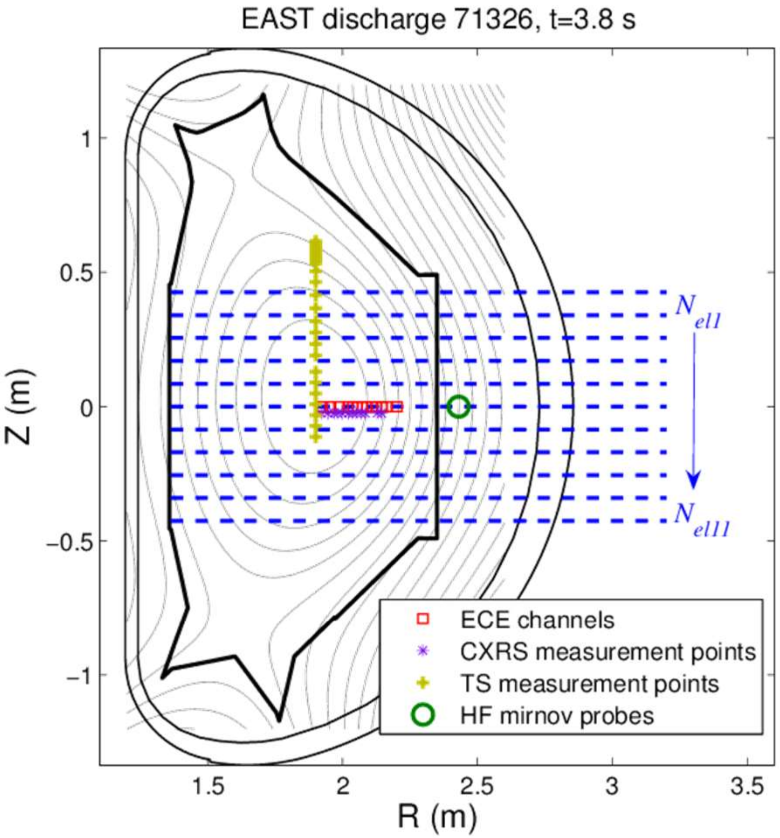


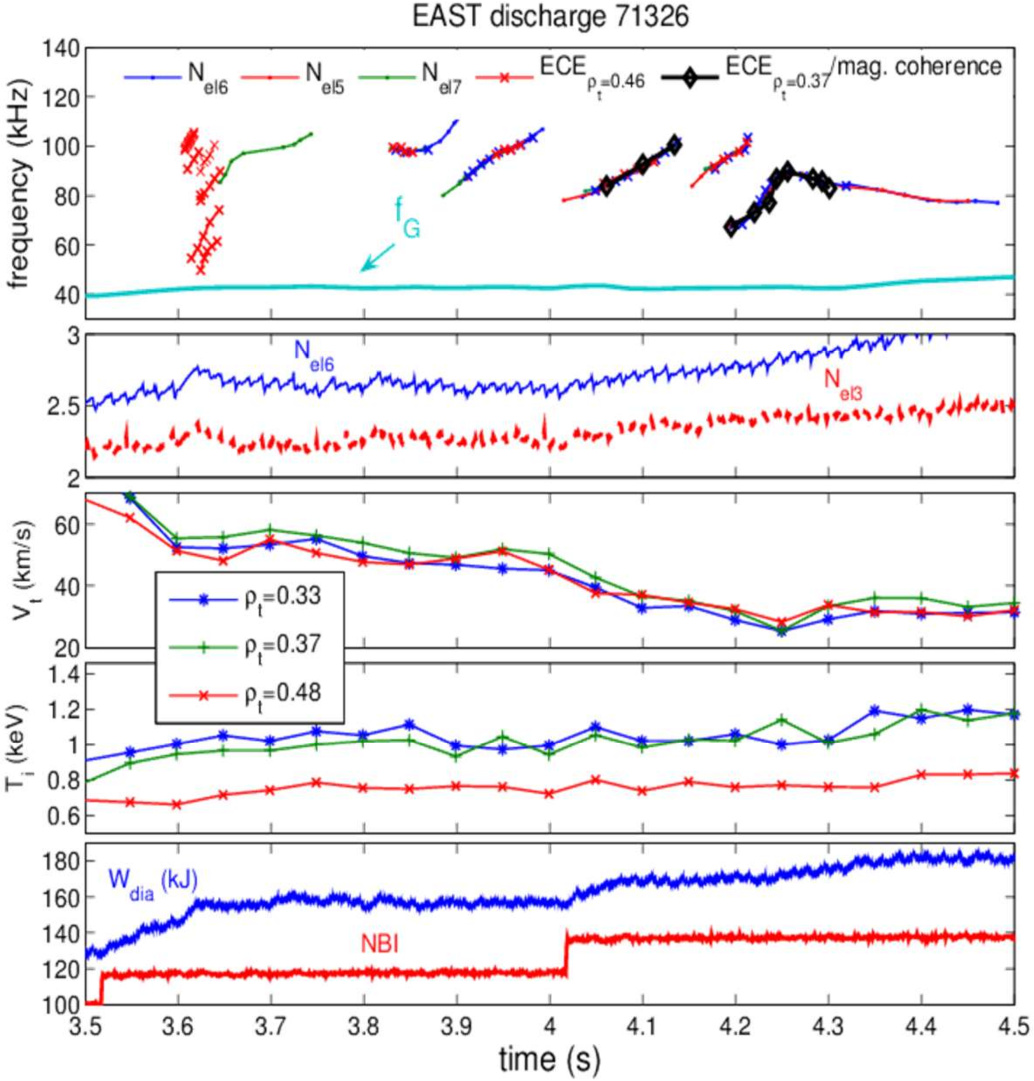
pressure
perturbati

RSAE has been observed in EAST tokamak.

C-P1
T. Zhang

RSAE is practically important to estimate q_0 for tokamak operation.





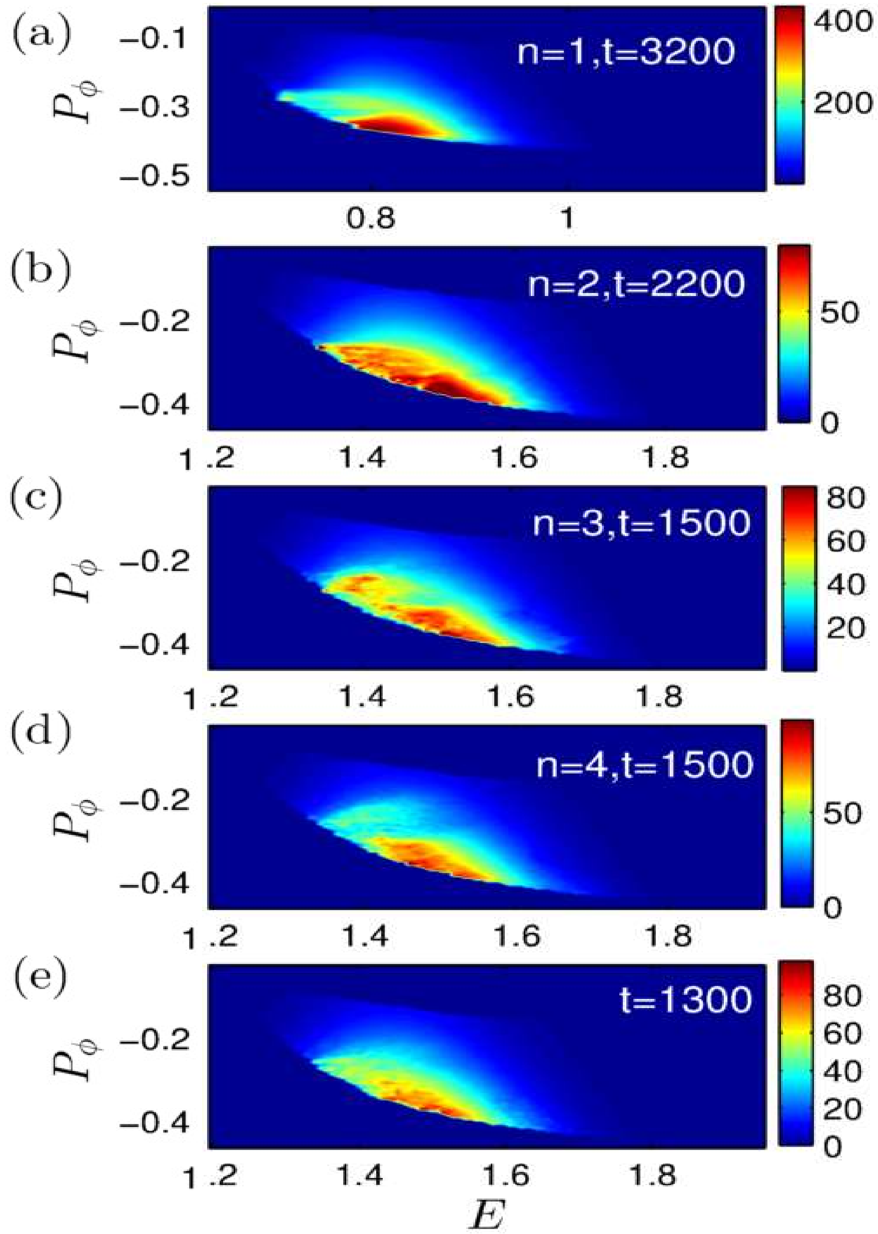
They are planning to install reflectometry for core region.

C-O2
Z. –Z. Ren

Energetic particle-driven modes in *q* = 1 region with the weak shear have been investigated by nonlinear simulation.

■ Nonlinear results:

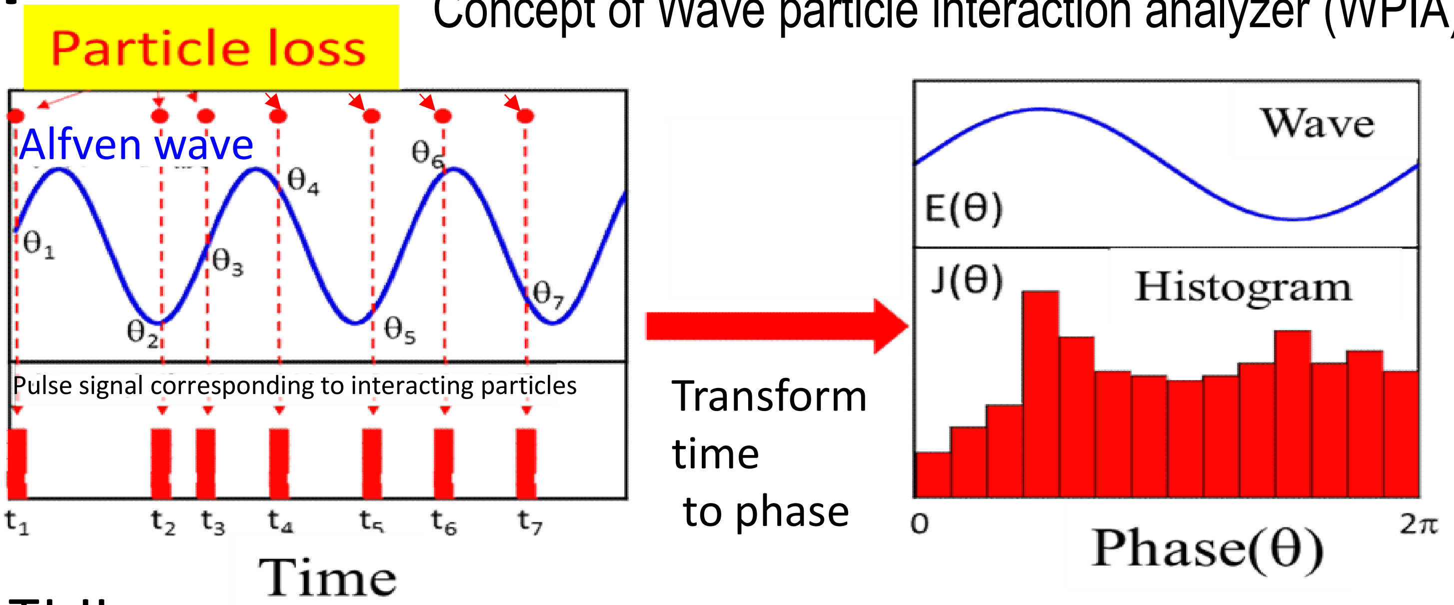
- ➢ The fluid nonlinearity reduces the saturation level of the n=1 component, while it hardly affects high n components.
- ➢ The flattening region of energetic particle distribution due to high-order harmonics excitation is wider than that due to n=1 component, although the n=1 component has higher saturation amplitude.

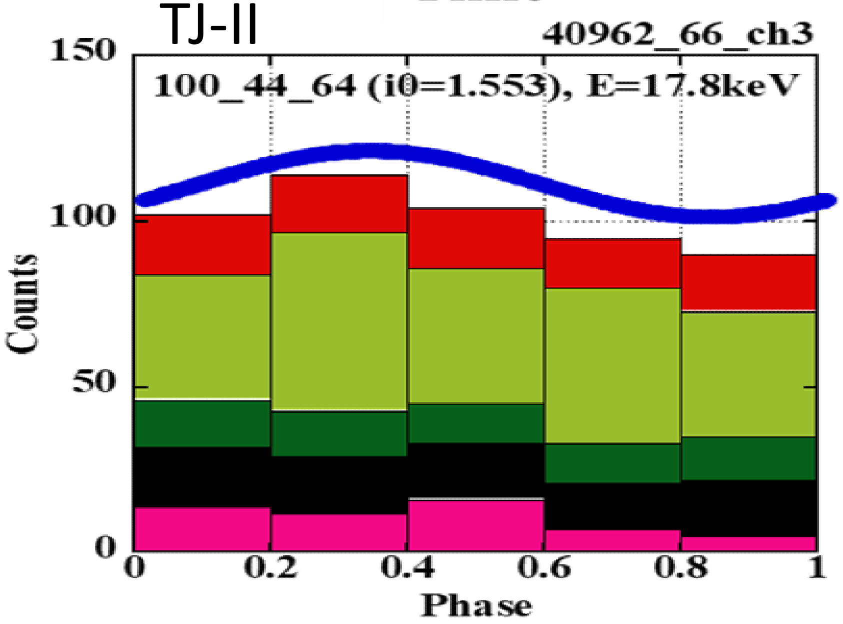


Wave-particle interaction analyzer is being developed.

C-P7
K. Nagaoka

Concept of Wave particle interaction analyzer (WPIA)



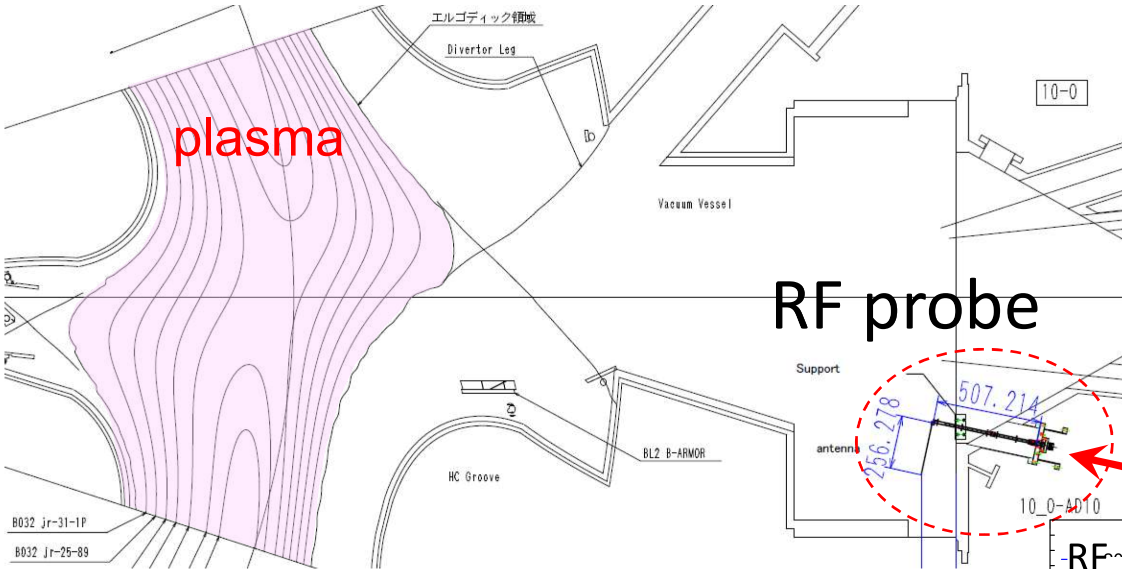


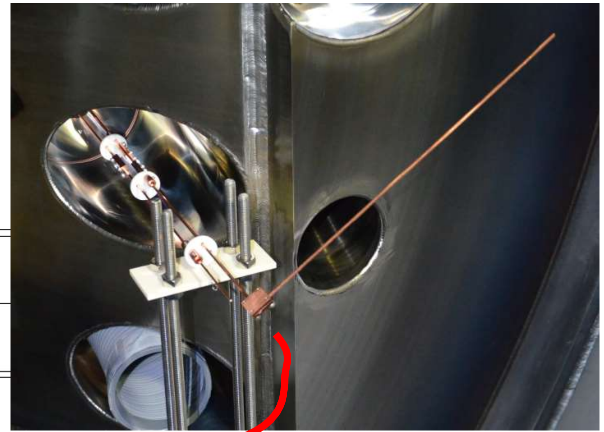
Response of energy distribution function to Alfven eigenmode will be measured.

Preliminary results were obtained in LHD, Heliotron J and TJ-II .

RF radiation detectors are installed in LHD as an indicator of fast ion losses or redistribution.

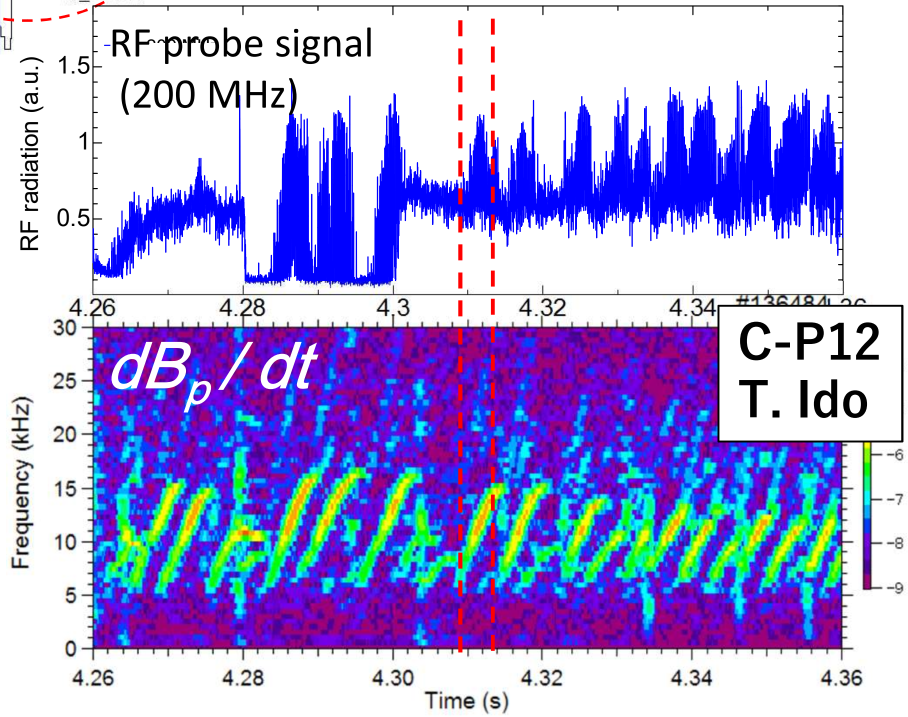
C-P9
T. Akiyama





Simple system and easy installation

- New mode with a chirp-up frequency are observed near the edge region. (Acoustic mode?)
- Amplitude around 200 MHz increases intermittently during the chirp-up. These behaviors would suggest fast ion losses.

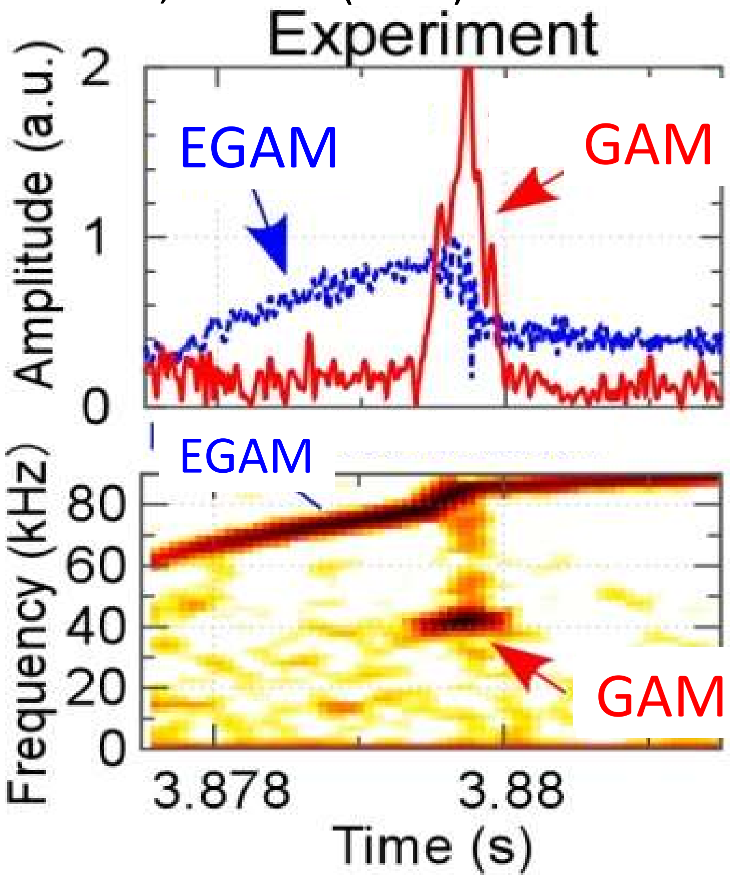


C-P12
T. Ido

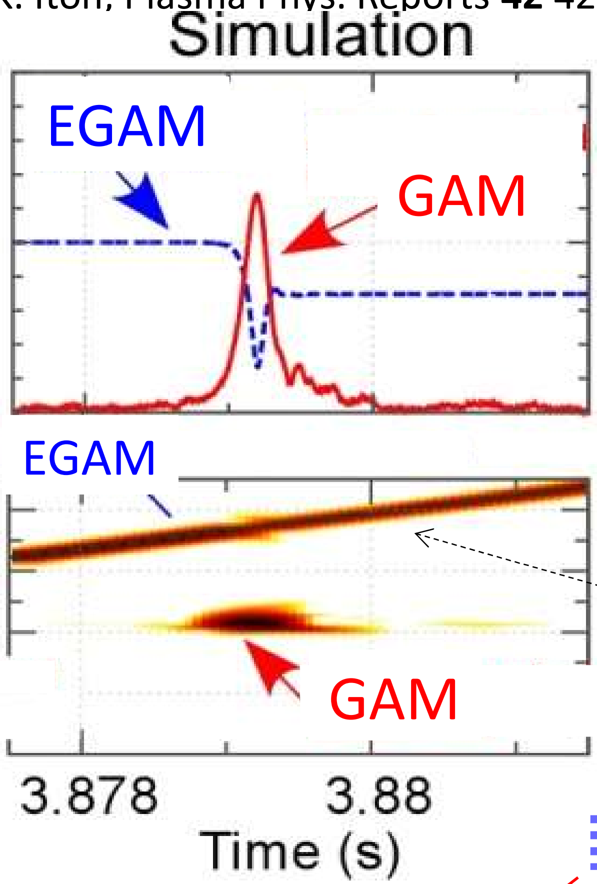
Interaction between phenomena with slow time scale and fast time scale is important.

C-P12
T. Ido

T. Ido, PRL **116**, 015002 (2016).

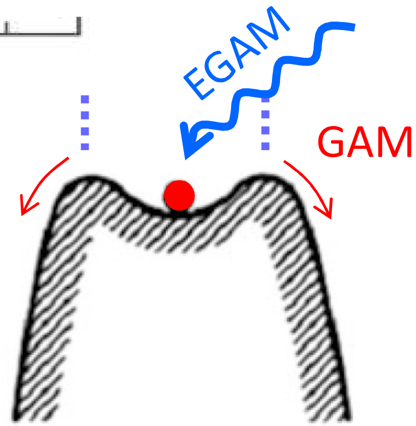


M. Lesur, PRL **116**, 015003 (2016).
K. Itoh, Plasma Phys. Reports **42** 428 (2016)



** The initial amplitude of the EGAM is given.*

** The chirping frequency of EGAM is given.*



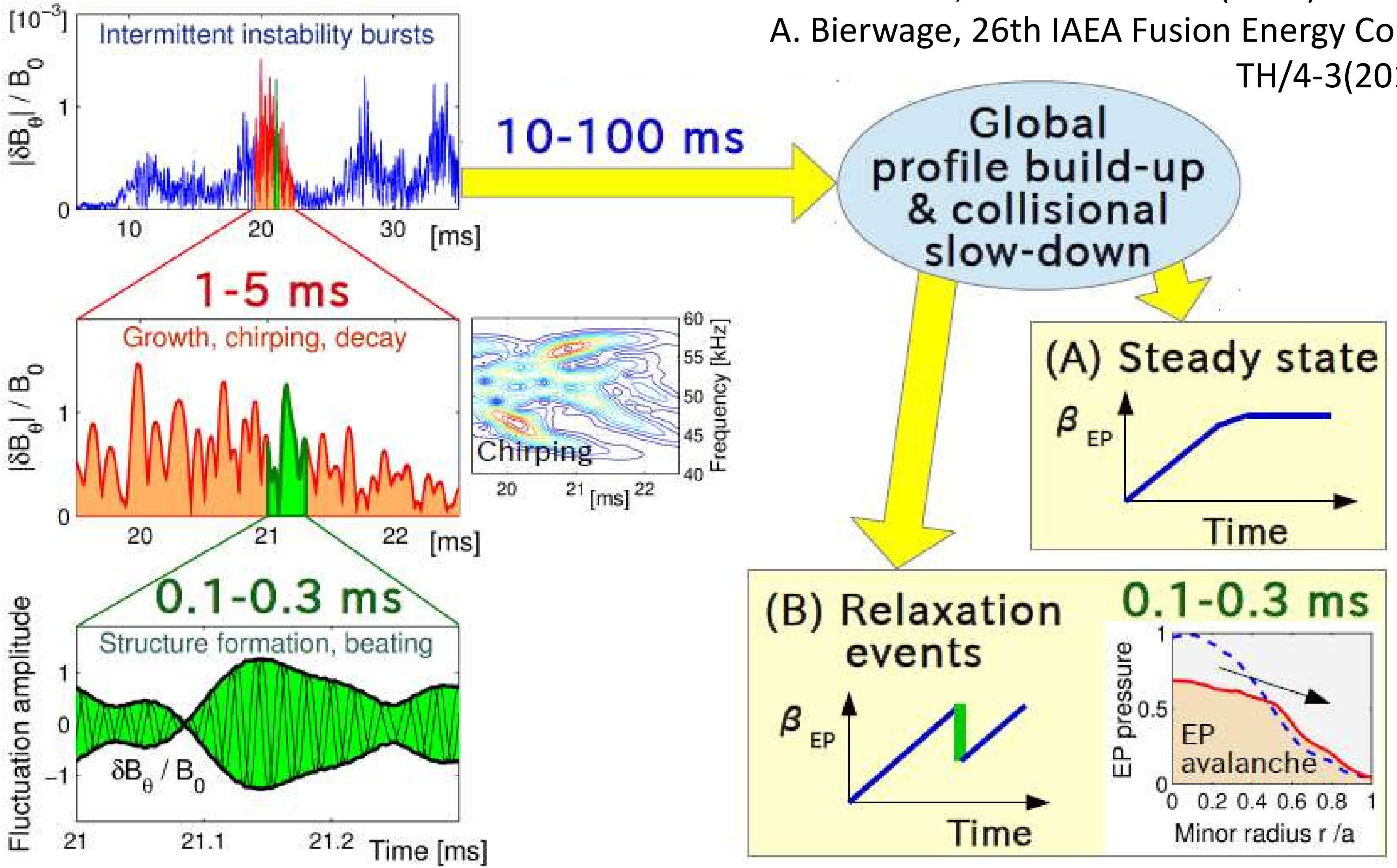
The GAM is triggered by the EGAM through parametric coupling.
↓
Once the amplitude of the GAM exceeds a threshold, kinetic nonlinearity and fluid mode coupling make the GAM unstable.
(**subcritical instability**)

Abrupt event has been simulated by a hybrid code MEGA with multi phase method .

C-O3
A. Bierwage

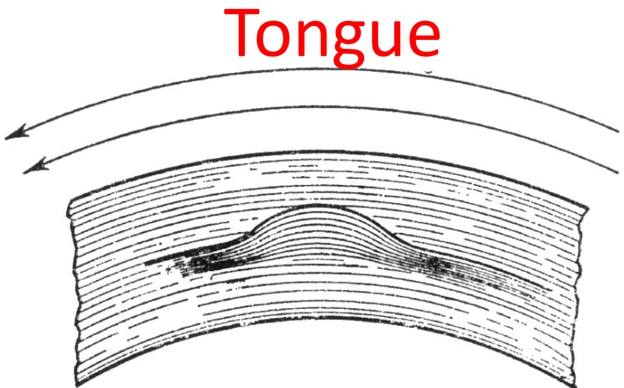
(interlaced 4ms intervals of fast classical Monte-Carlo simulation + 1ms of slow hybrid simulation)

Y. Todo, Nucl. Fusion 54 (2014) 104012
A. Bierwage, 26th IAEA Fusion Energy Conf., TH/4-3(2016)

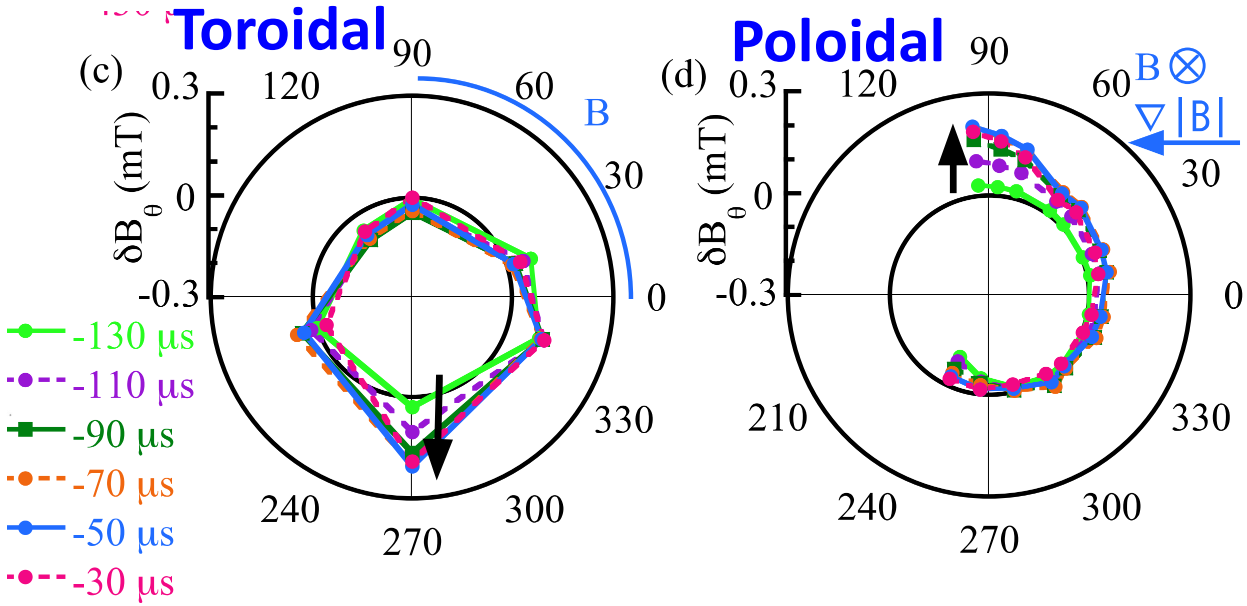


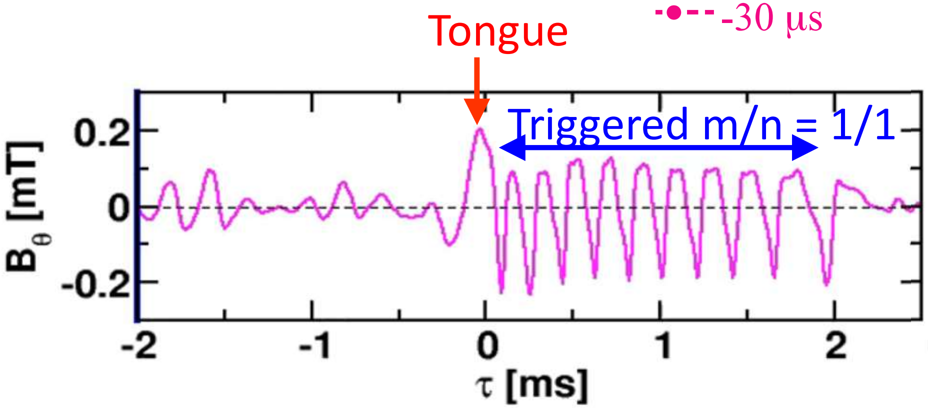
A “tongue” structure has bee observed. (Poloidally and toroidally localized perturbation)

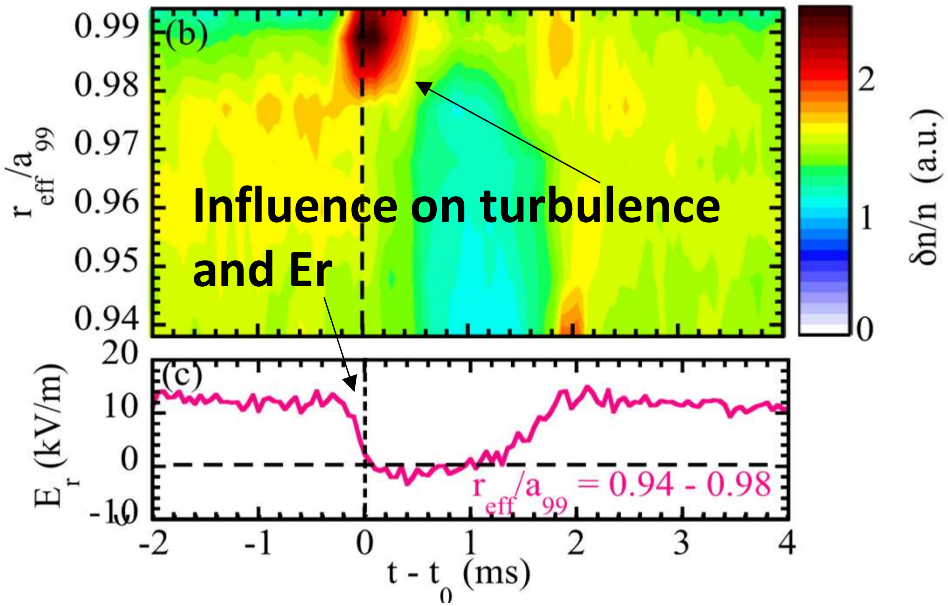
C-O1
K.Ida



La Artsimovish A Physicist’s ABC on Plasmas (1976)





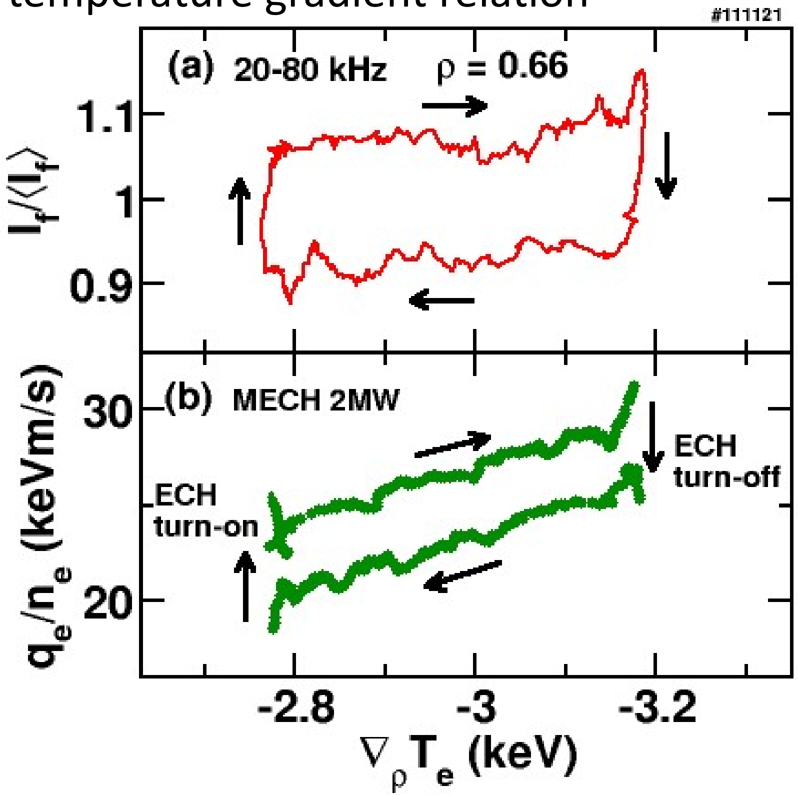


K.Ida Sci. Rep. 6 (2016) 36217

Heating directly drives turbulence. The mechanism may explain an aspect of the isotope effect on plasma confinement.

C-P5
S. –I. Itoh

Hysteresis in heat flux and temperature gradient relation



S. Inagaki, et al., Nucl. Fusion **53** (2013) 113006

S.-I. Itoh and K. Itoh, Sci. Rep. 2 (2012) 860

$$I = \frac{1}{1-\Gamma_h} I_0$$

$$\Gamma_h = \gamma_h \chi_0^{-1} k_\perp^{-2}$$

represents the competition between drive by heating and decay by background turbulence.

If $\chi_0 \propto A^{0.5}$ (GyroBohm),

$$\Gamma_h \propto A^{-0.5}$$

S.-I. Itoh and K. Itoh, Nucl. Fusion **57** (2017) 022003