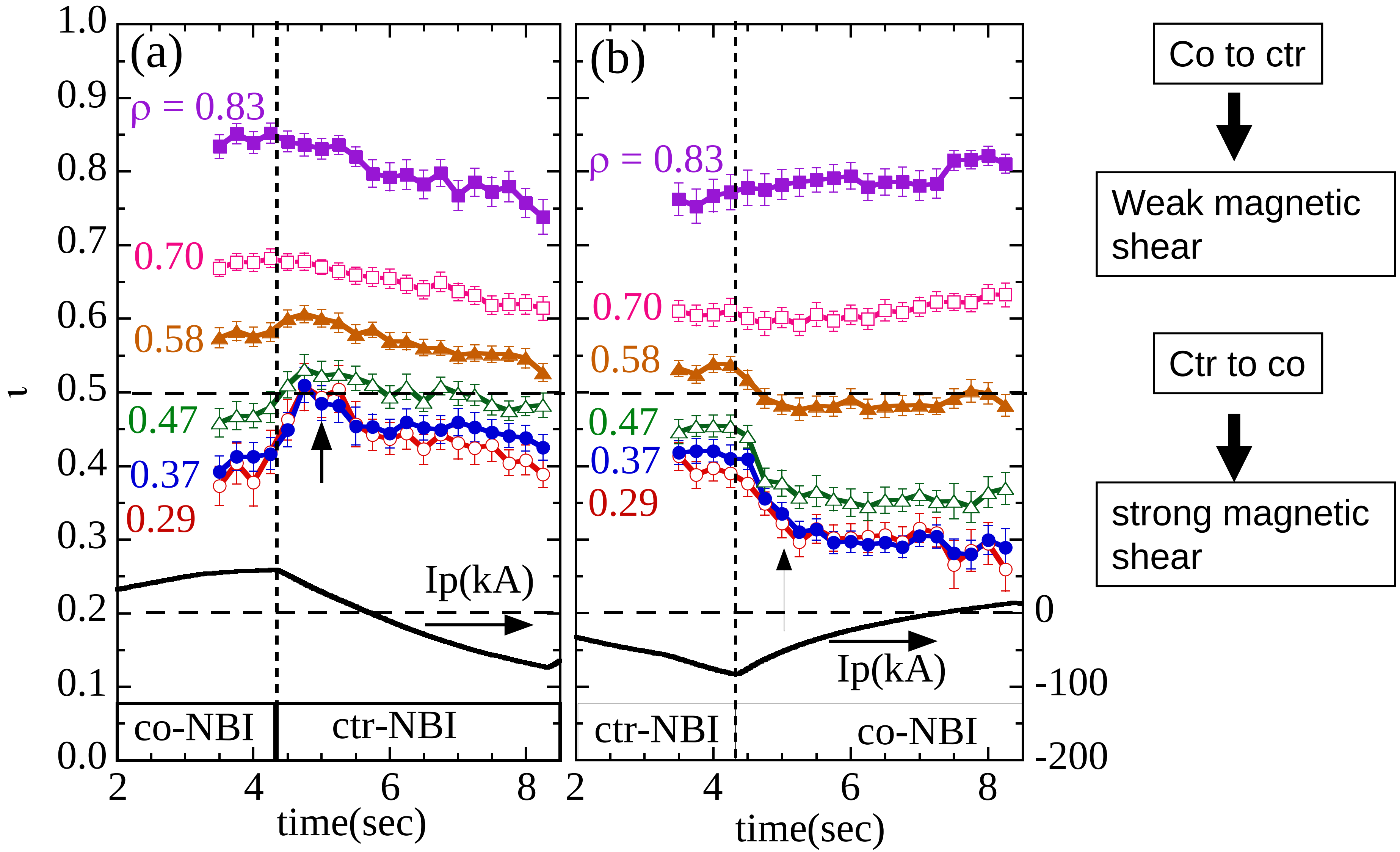
Magnetic island at low magnetic shear

Katsumi Ida

Bifurcation phenomena of a magnetic island and stochastization at a rational surface in a magnetic shear control experiment

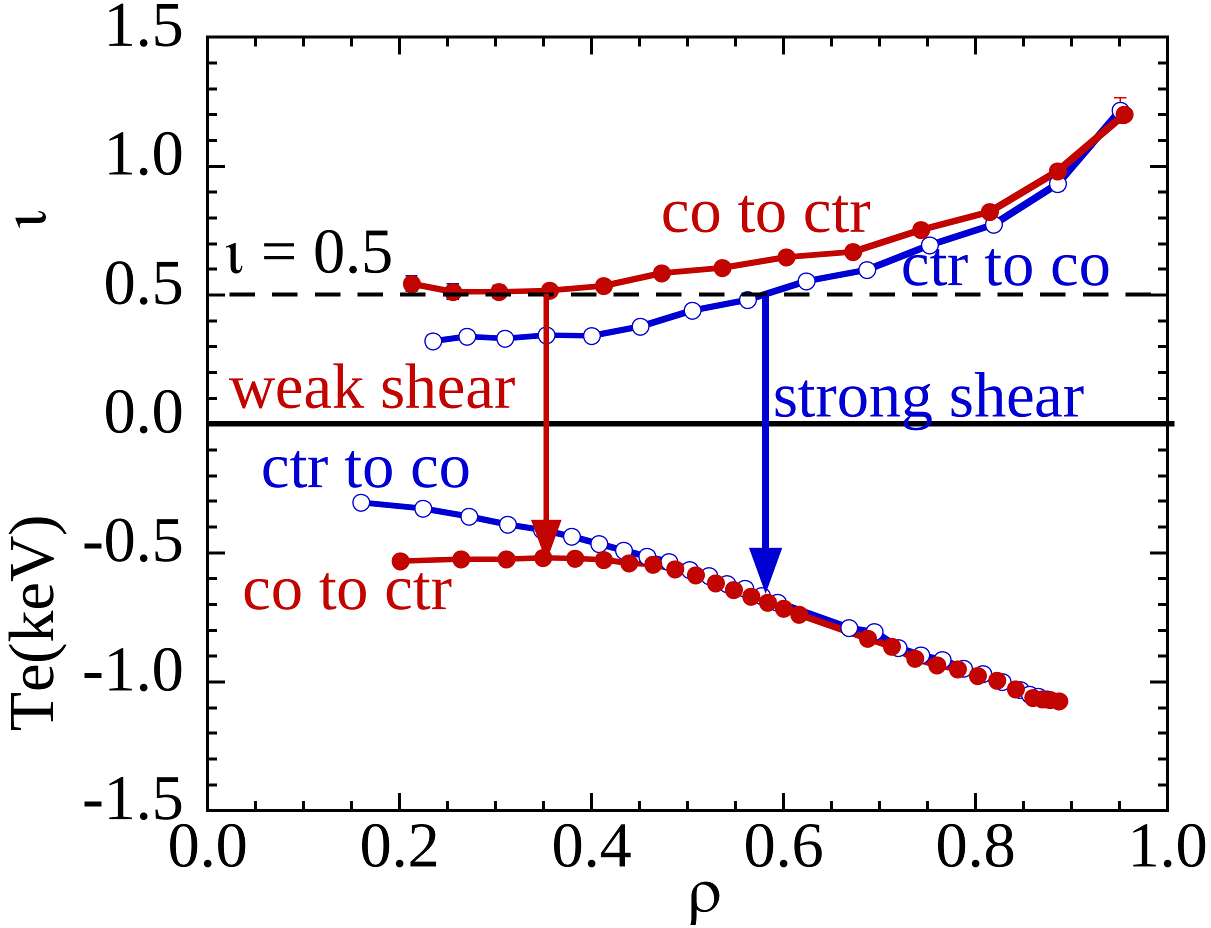
CWGM at National Institute for Fusion Science
23 October 2007

Magnetic shear is controlled by NBCD



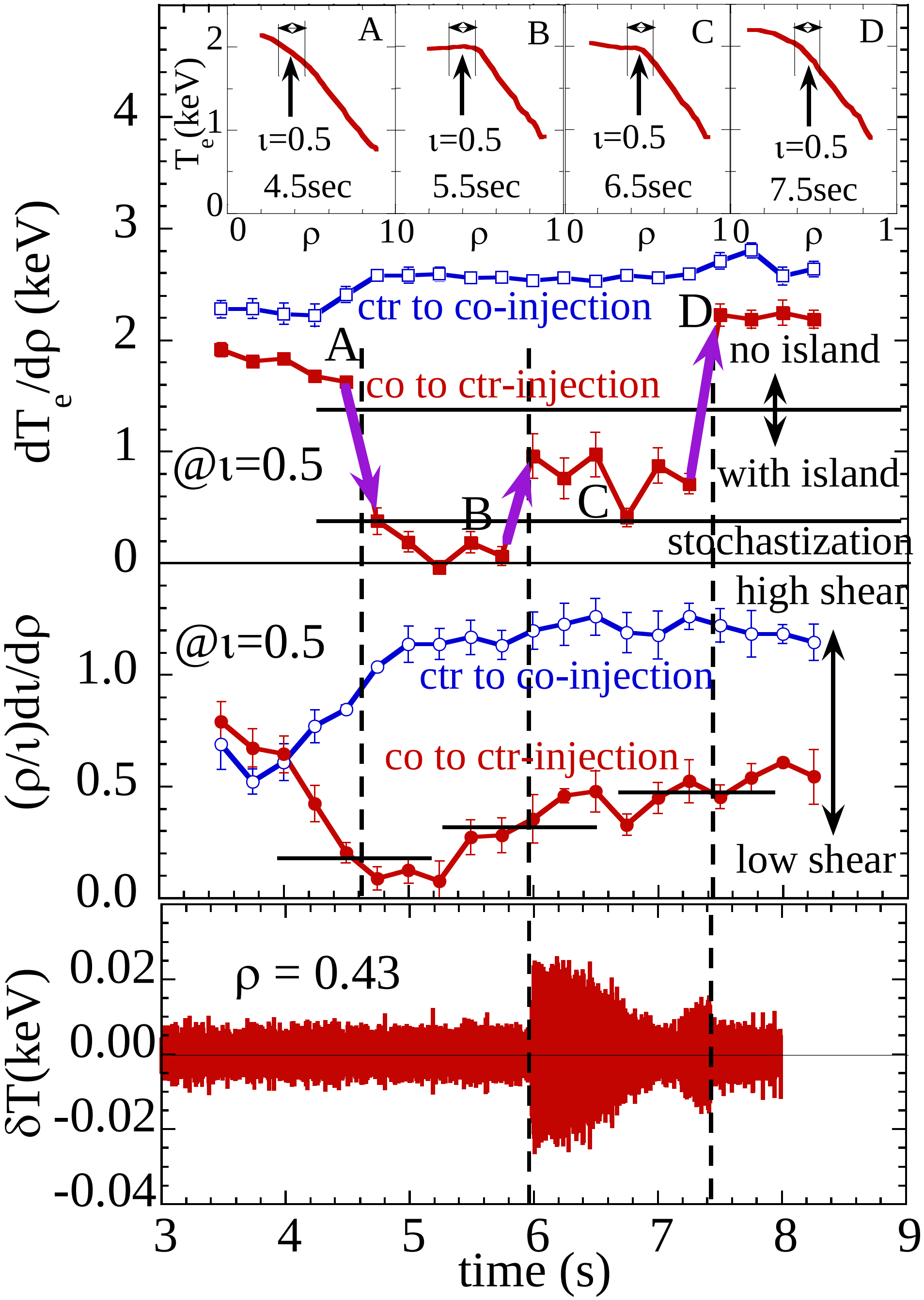
Time evolution of rotational transform at various plasma radii and total plasma current in the plasma with the neutral beam injection (a) from co-injection to counter-injection and (b) from the counter-injection to co-injection.

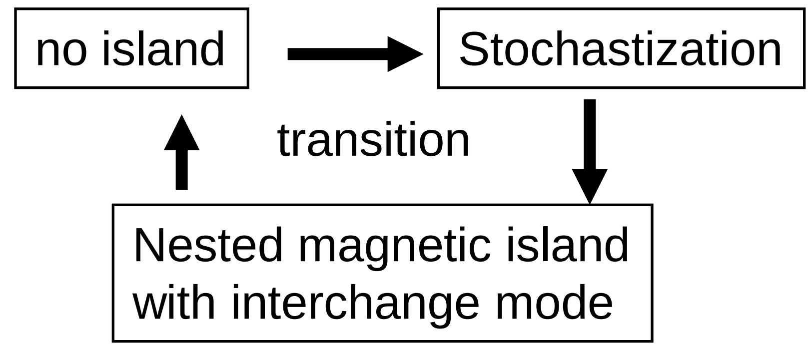
Flattening of Te with weak magnetic shear at rational surface of iota =0.5

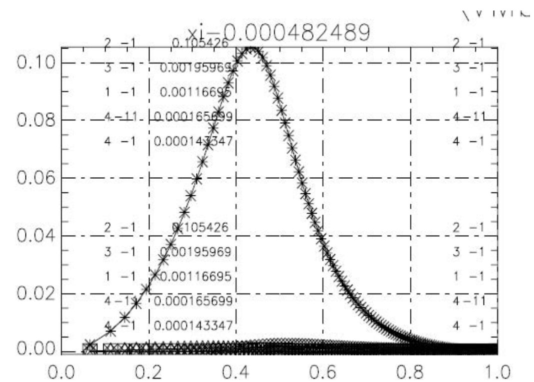


Radial profile of rotational transform and electron temperature in the plasma with weak magnetic shear (at t = 5sec in the discharge with co to ctr-injection) and a strong magnetic shear (at t = 5sec in the discharge with ctr to co-injection)

Bifurcation phenomena of magnetic island

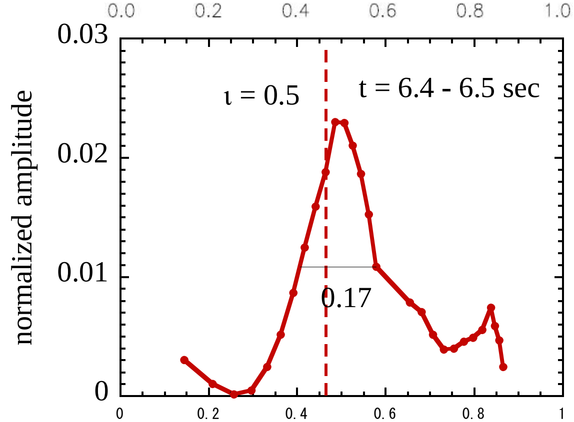






calculation

Interchange mode structure



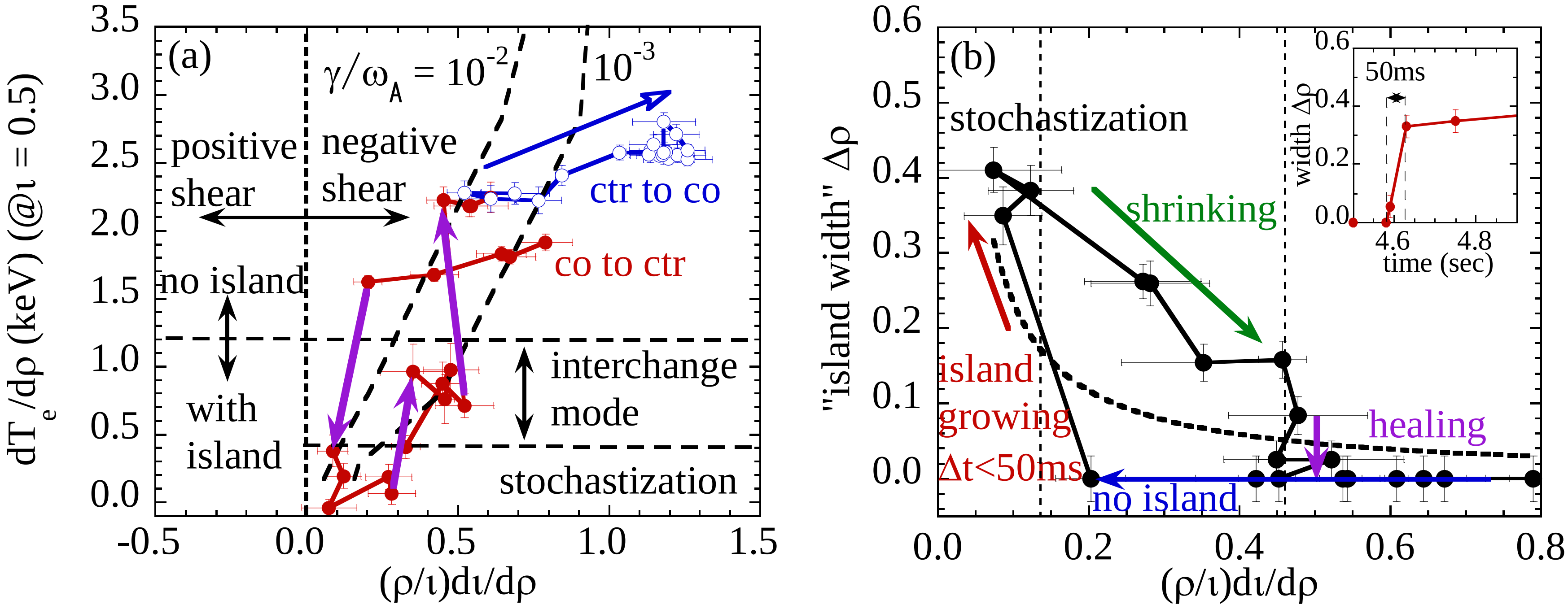
experiment

Relation of island width to magnetic shear

Island healing → island stochastization:
no interchange mode

stochastization → nesting island → healing
interchange mode is excited

Clear hysteresis is observed
In the relation between island
width and magnetic shear



(a) Electron temperature gradient averaged over Δρ = 0.1 around the ι = 0.5 rational surface and (b) size of magnetic island as a function of magnetic shear at ι = 0.5 rational surface.

Time scale and critical value of the bifurcation (comparison with theory)

$$\frac{\partial \hat{A}}{\partial t} = \frac{1}{\tau_R}\left[2|\Delta_0'|\left(\frac{\delta^2}{r_s^2}\frac{1}{\hat{A}} - 1\right)\hat{A}^{1/2}\right.$$

External driven term

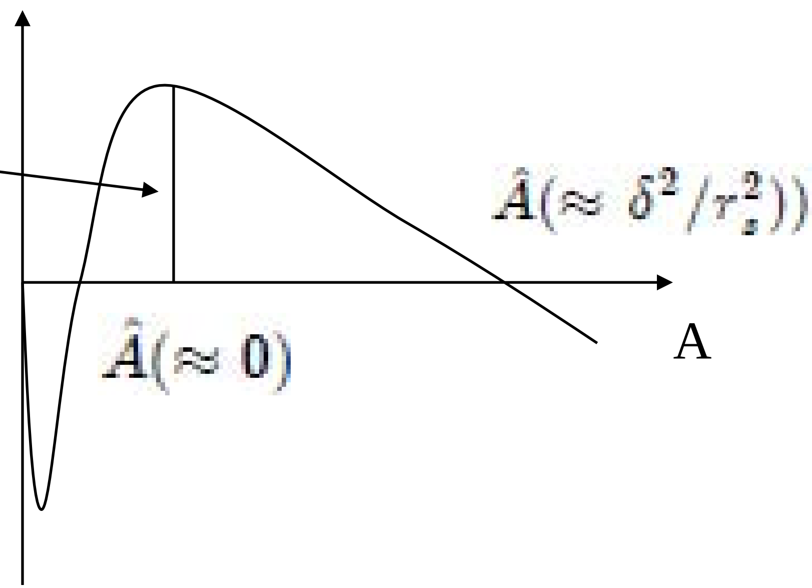
$$\left. -2\epsilon^{1/2}\beta_p\alpha_{pe}\left(\frac{L_q}{L_p}\right)^2 \frac{(\rho_b/r_s)^2\hat{A}}{(\rho_b/r_s)^4+\hat{A}^2}\right] \quad (1)$$

Stabilization by the polarization current

$$\hat{A} = A_s q^2 R/(B r_s^3 q')$$

There are two solutions of normalized amplitude of vector potential

The time scale of the bifurcation is determined by the height of eq (1)

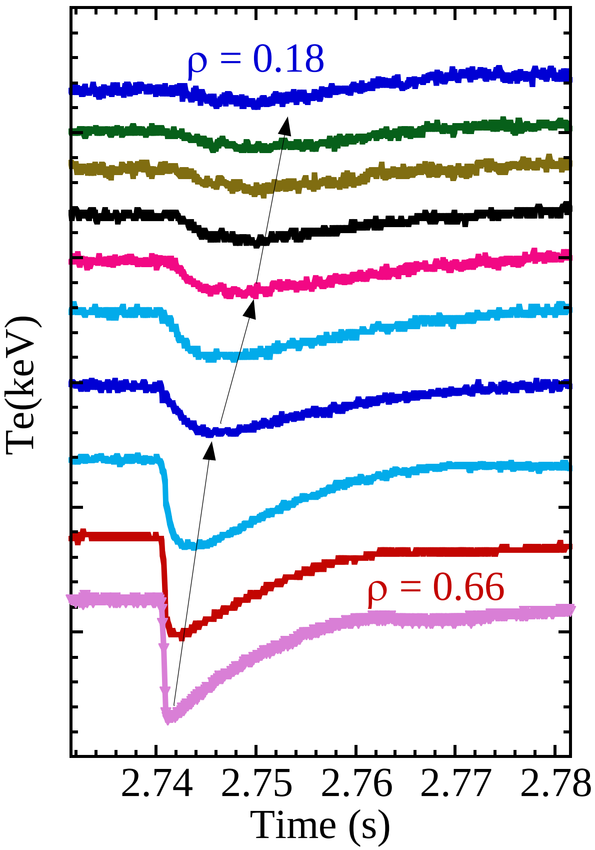


Theory predict time scale is order of few to 20-30ms and δ/ρ_b is 5

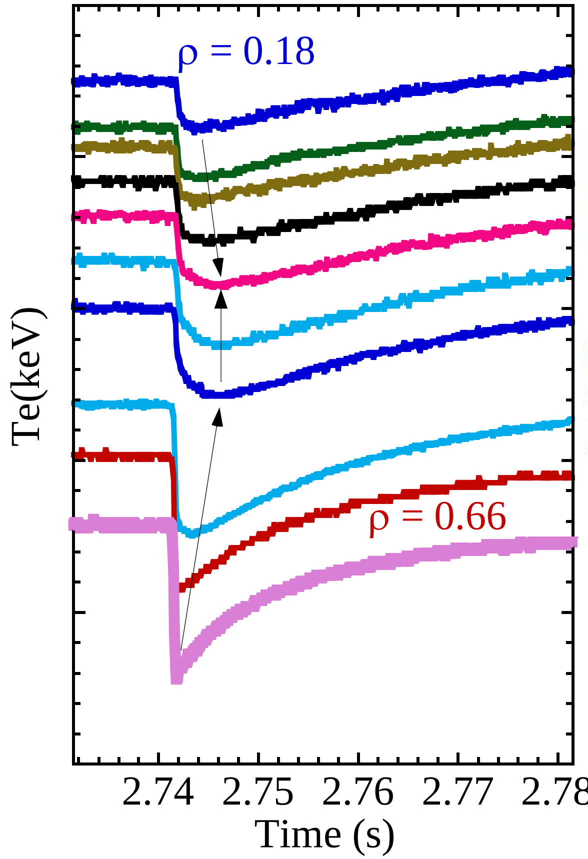
They are consistent with the measurements time scale < 50ms and δ/ρ_b is 5.3

Cold pulse propagation

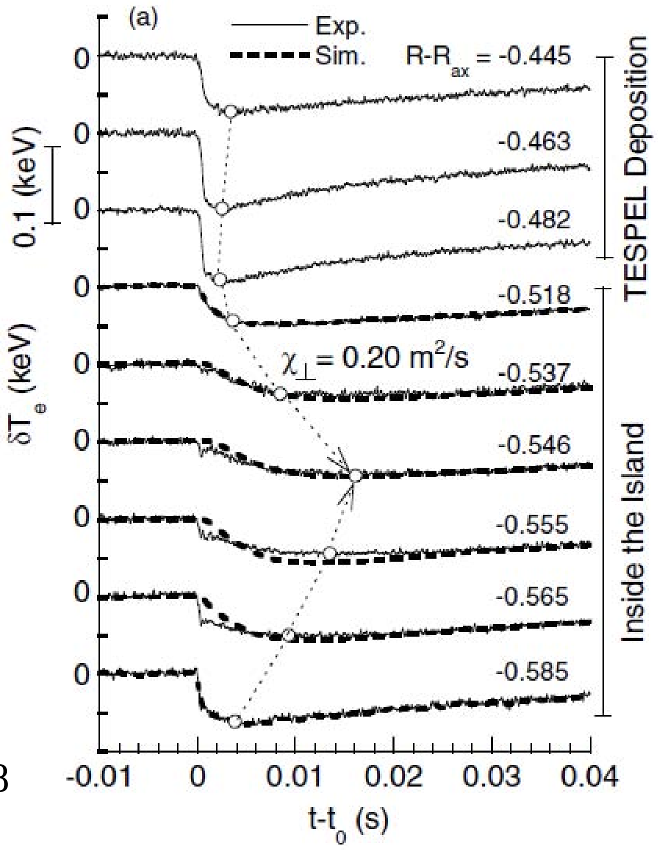
No magnetic island



2/1 island at low shear



1/1 island at high shear

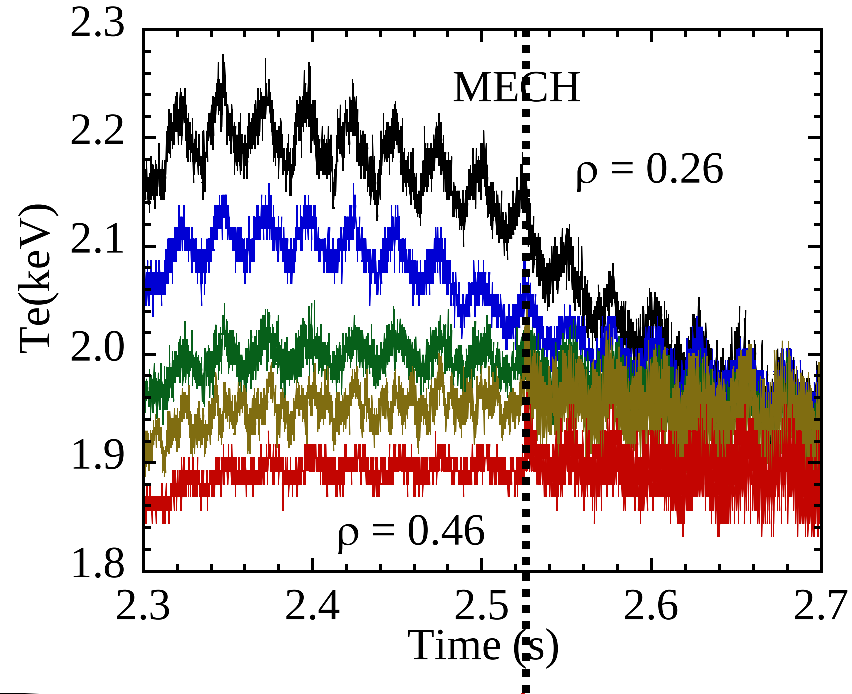


pulse propagation consistent With thermal diffusivity from power balance analysis

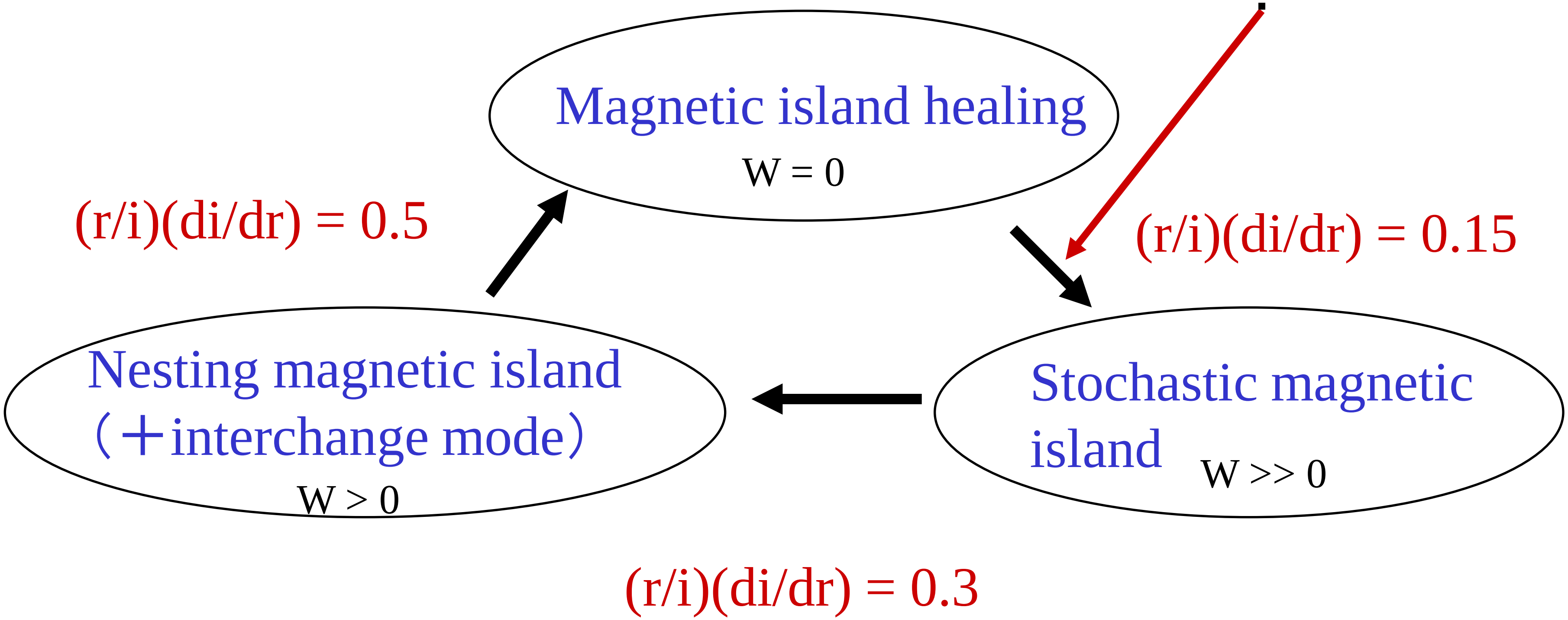
Fast pulse propagation → stochastic magnetic island

Slow pulse propagation → Nesting magnetic island

Magnetic island and magnetic shear



When the magnetic island becomes stochastic perturbation of Te due to ECH modulation spreads within the magnetic island



Summary

There are three phases of magnetic island depending on the strength of magnetic shear at the rational surface observed in LHD

There phases are characterized by
1 Magnetic island is healed by high magnetic shear
2 Nesting magnetic island appears at rational surface associated with interchange mode at medium magnetic shear
3 The magnetic island becomes stochastic at low magnetic shear

A clear hysreresis in the relation between the size of the magnetic island and the magnetic shear is observed.

The time scale and critical values for the bifurcation observed is consistent with the theoretical prediction