16th Workshop on MHD Stability Control:
Optimizing and Understanding the Role of Coils for Mode Control

Experimental Study of MHD Rotation in the Edge Plasmas of LHD

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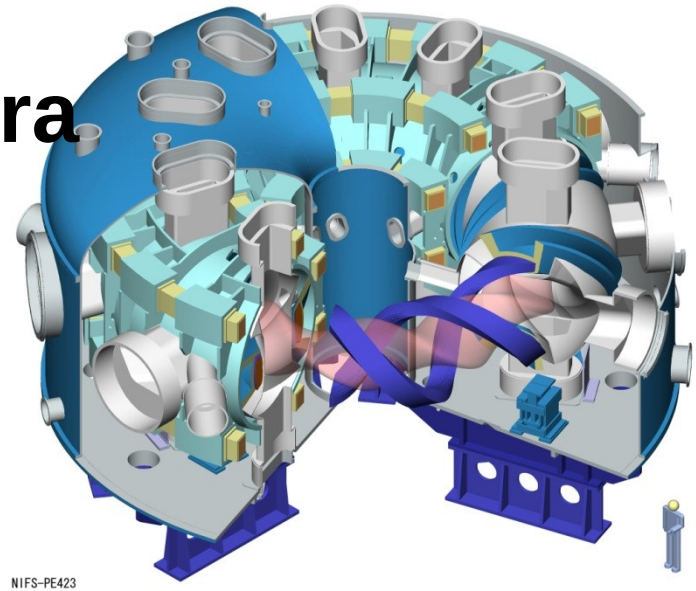


Agenda

- Motivation
  - > rotating mode
  - > non-rotating mode
- Observation of MHD activity like locked mode on LHD
- The relationship between both modes

- Discussion and summary

Motivation

— MHD activities have been investigated in various magnetic configurations of LHD for high beta plasma production

— Two types of MHD activities

Low magnetic shear : without rotation → **“Non-rotating” mode**

High magnetic shear : with several kHz → **“rotating” mode**

— Observation of MHD activity like locked mode when the transition occurs from rotating mode to NR one

>> However, tearing mode is estimated to be stable on LHD

Investigation of the relationship between rotating mode and NR one in order to clarify the characteristics of both modes

Introduction of both modes →

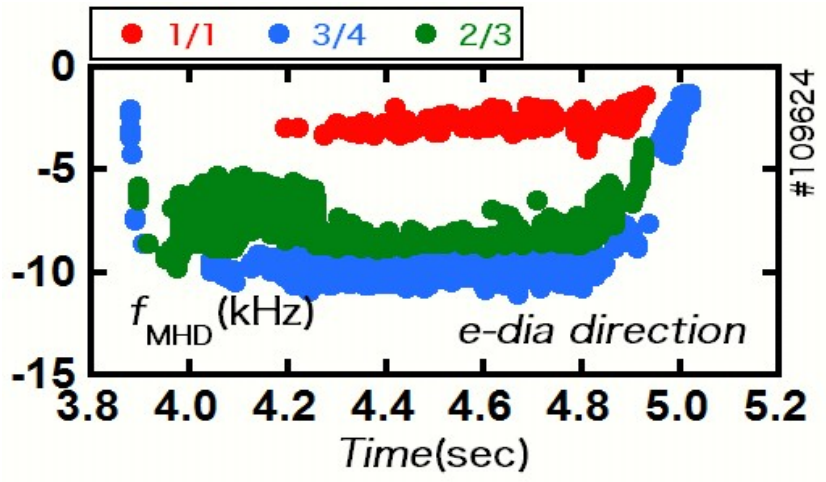
“Rotating” mode

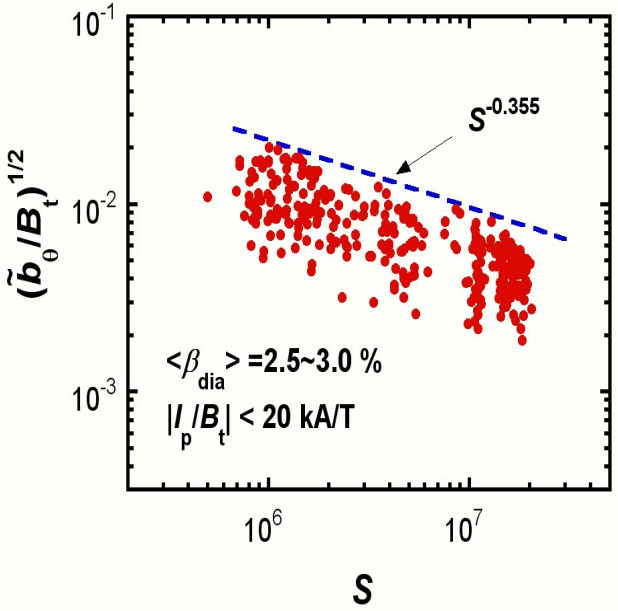
— Characteristics of rotating mode

① Rotational frequency is several kHz in the *e.d.* direction (laboratory frame)

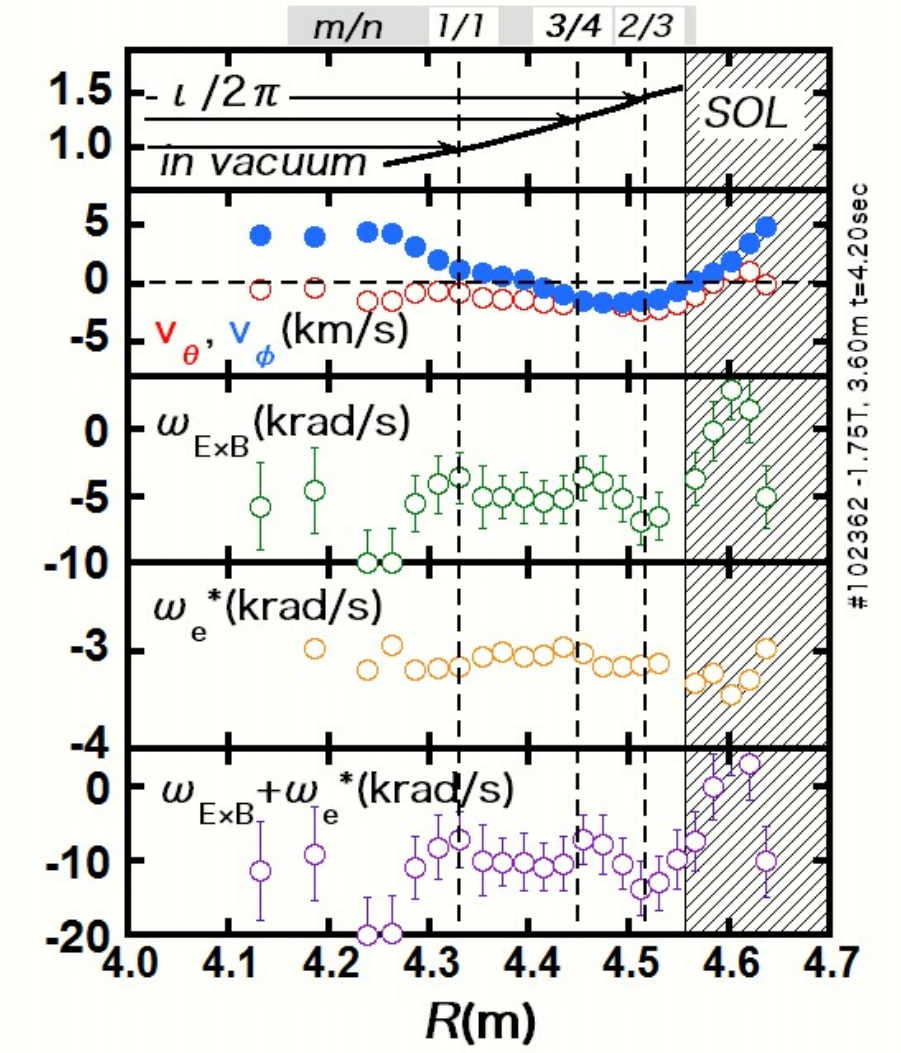
② Dependence of amplitude of m/n=1/1 mode on magnetic Reynolds number S is similar to that of linear growth rate ($\gamma \propto S^{-1/3}$) of resistive interchange mode

>> According to linear theory of interchange mode, this mode does NOT formed island configuration

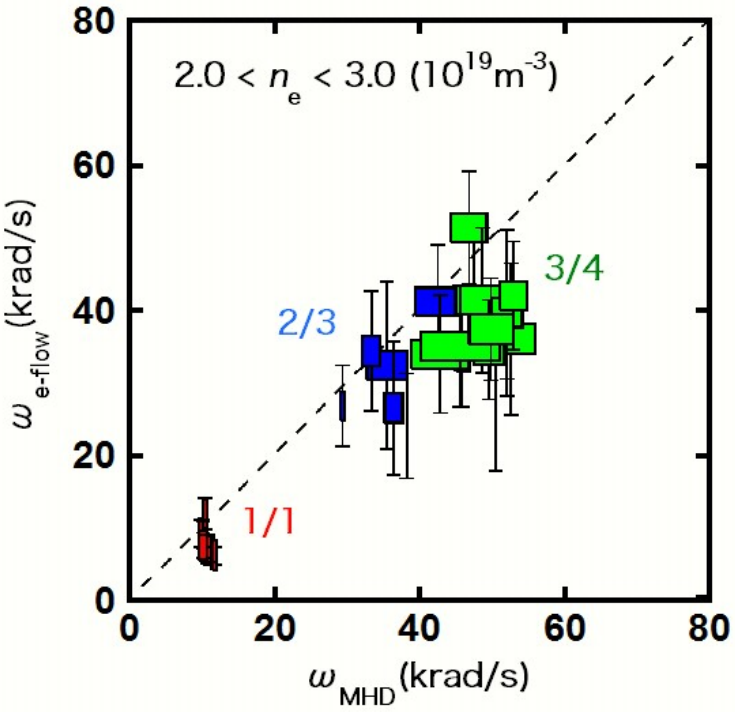




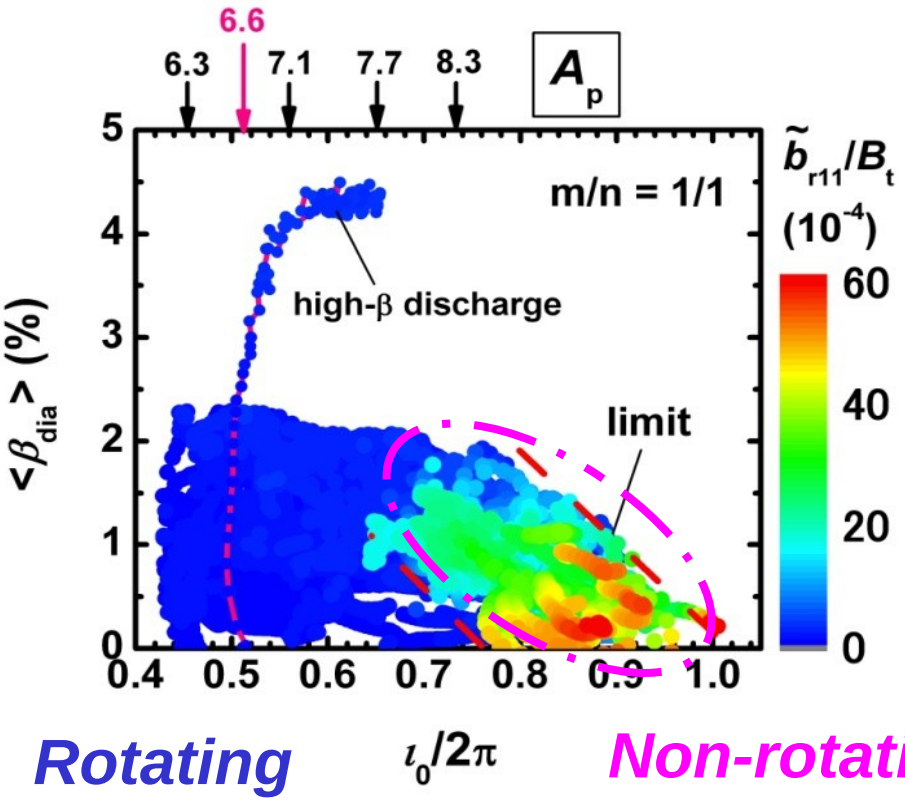
Relationship with plasma flow



③ Rotating mode rotates together with the electron flow within the measurement error



“Non-rotating” mode



— Characteristics of NR mode

① unstable in the low shear region (large A_p and I_p)

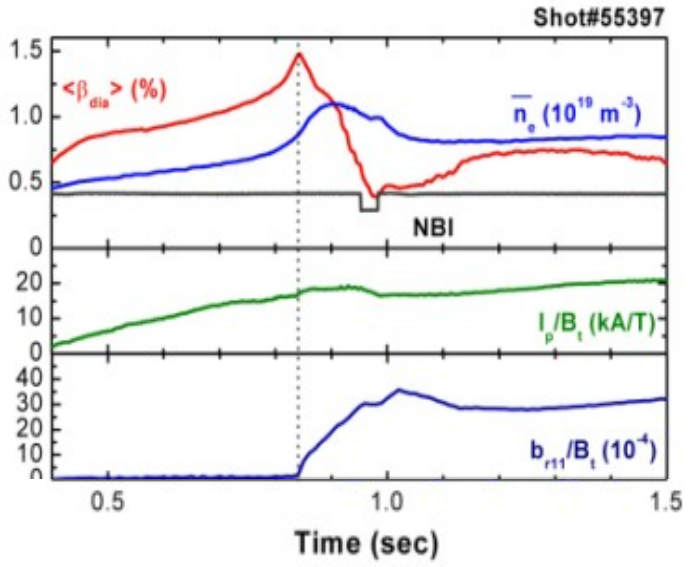
② Operation limit is qualitatively consistent with “ideal” stability boundary

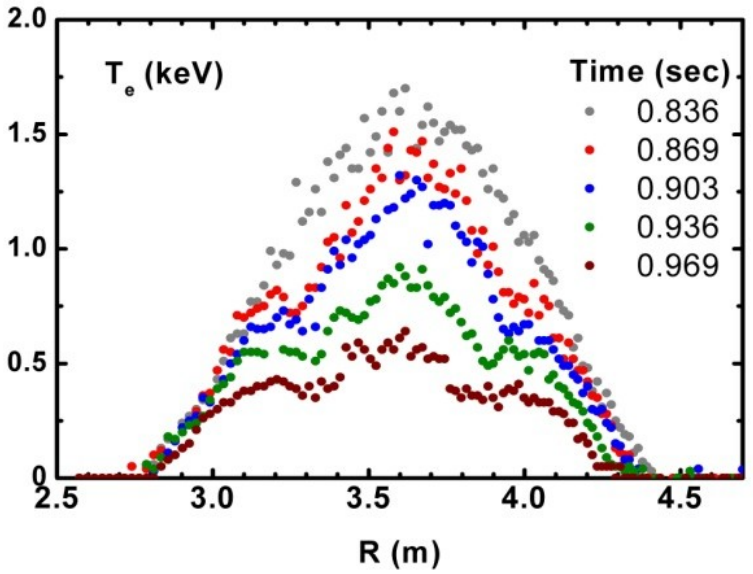
NR mode sometimes causes minor collapse →

Minor collapse due to NR mode

- Minor collapse in the core region is observed just after the amplitude of NR mode suddenly increases
- The mode caused *T*e profile-flattening around the resonance

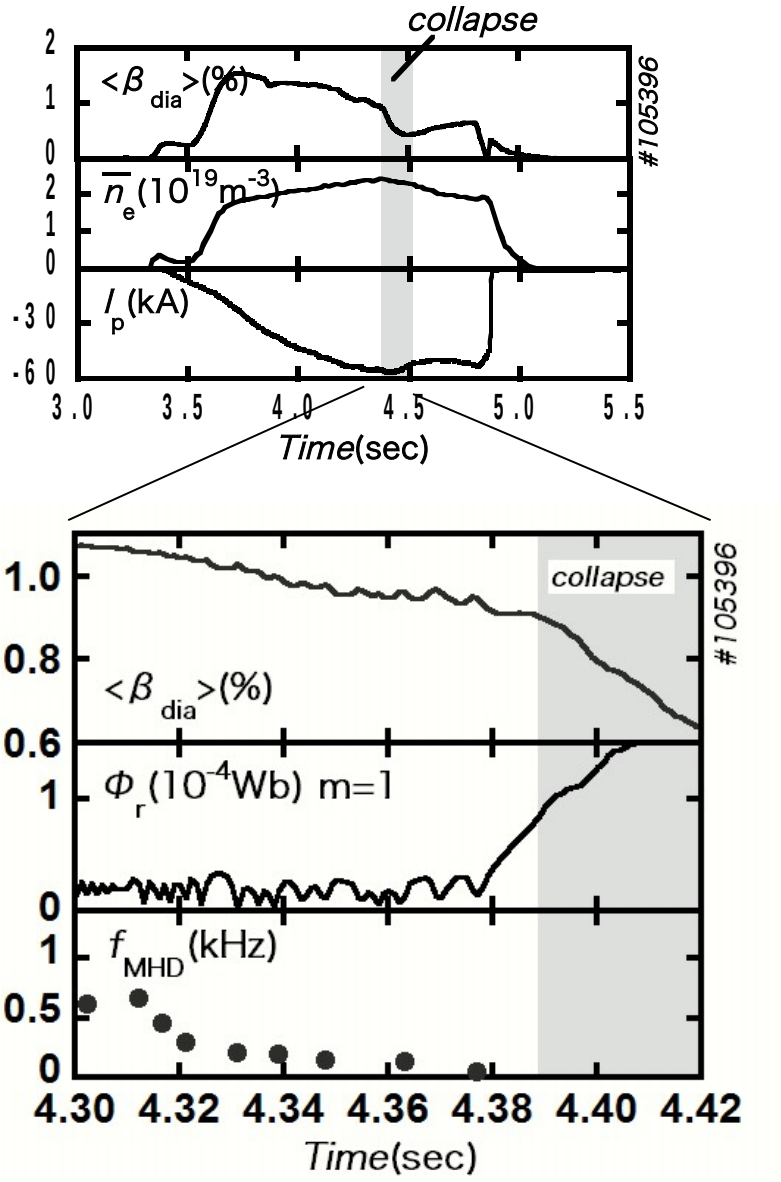
Loss of beta $\triangle\beta/\beta$ is greater than 50%





Observation of locked mode
in discharges with excited rotating mode

Observation of the transition to NR mode



— The m/n=1/1 rotating mode is excited after the start of a discharge

→

— Rotating mode slows down to 0kHz

— Amplitude of NR mode grows

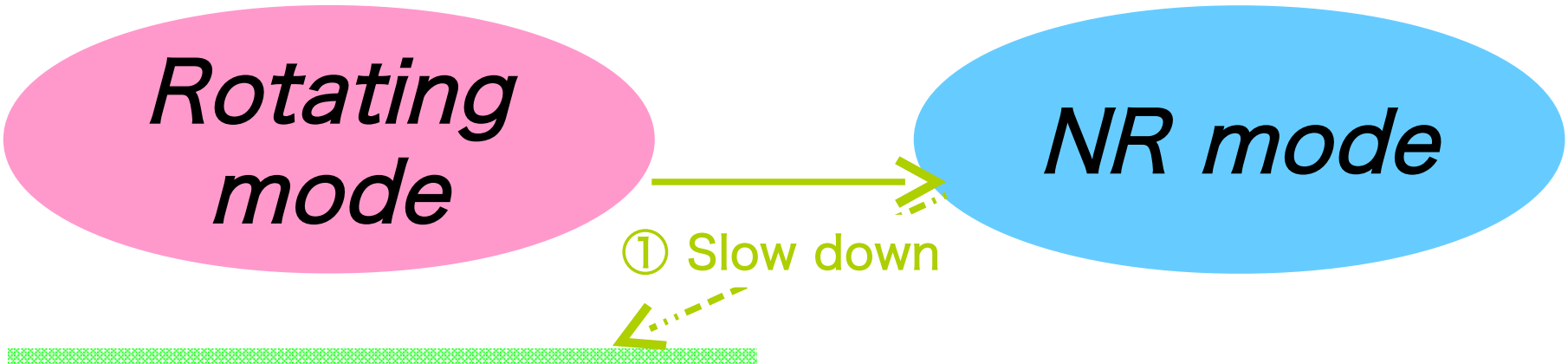
>> Minor collapse is observed

Observation of MHD Activity like "locked mode" in tokamaks

Why is interchange mode locked??

Relationship NR mode and rotating mode

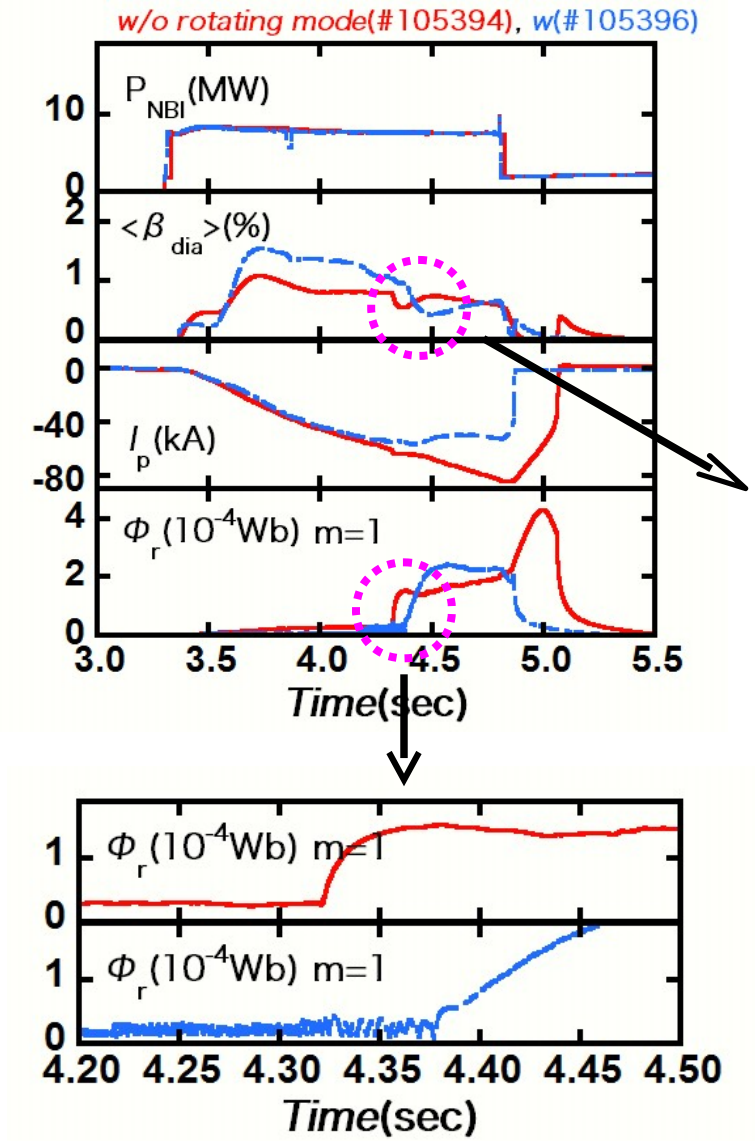
m/n=1/1



collapse

Minor collapse is observed after rotating mode slows down to 0kHz

Appearance of NR mode without the transition



— NR mode was observed without transition from rotating mode

— Loss of beta is small in a discharge without excited 1/1 rotating mode regardless of lower plasma current

with transition : $\Delta\beta/\beta$ ~ 50%

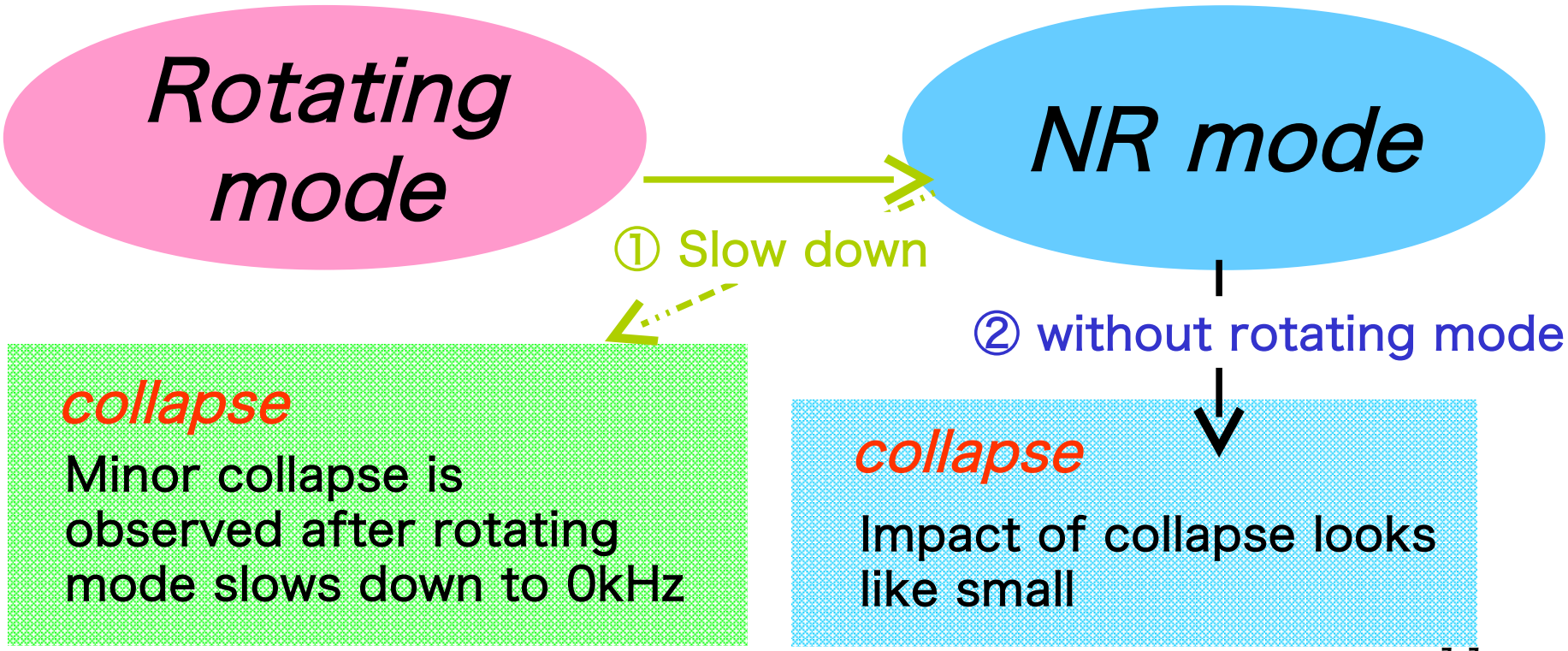
without : ~ 35%

— Te-flattening occurs in both discharges

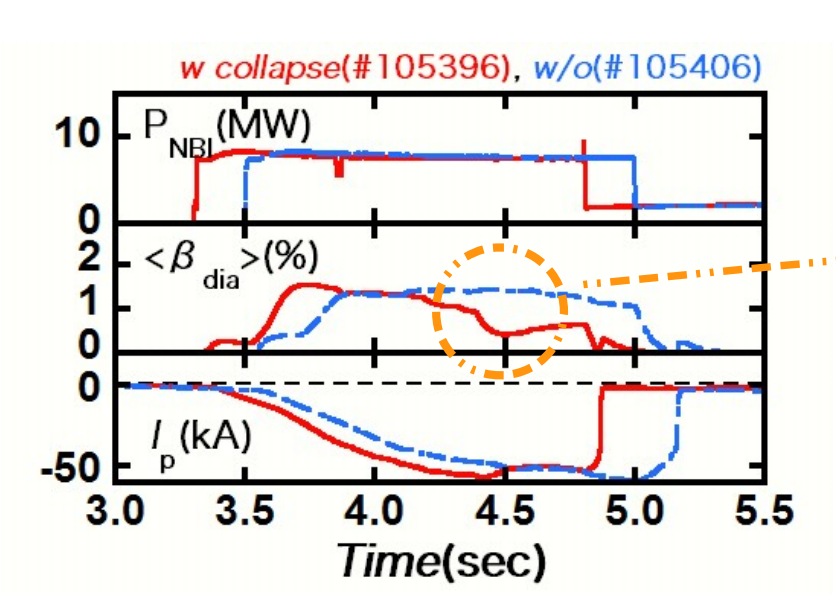
— Precursor is NOT observed in a discharge without the transition

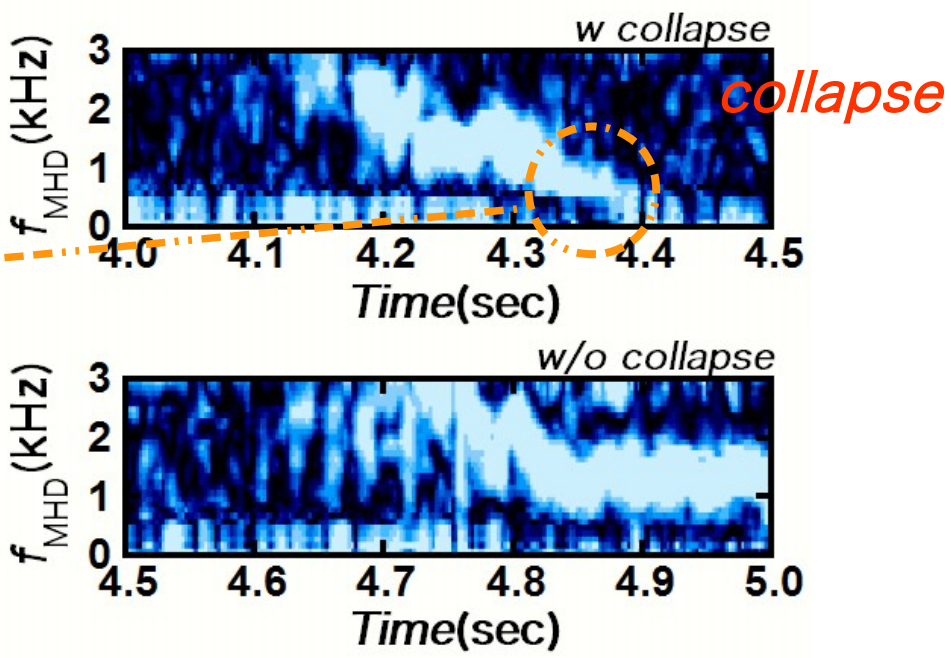
Relationship NR mode and rotating mode

m/n=1/1



Comparison between w/ and w/o collapse



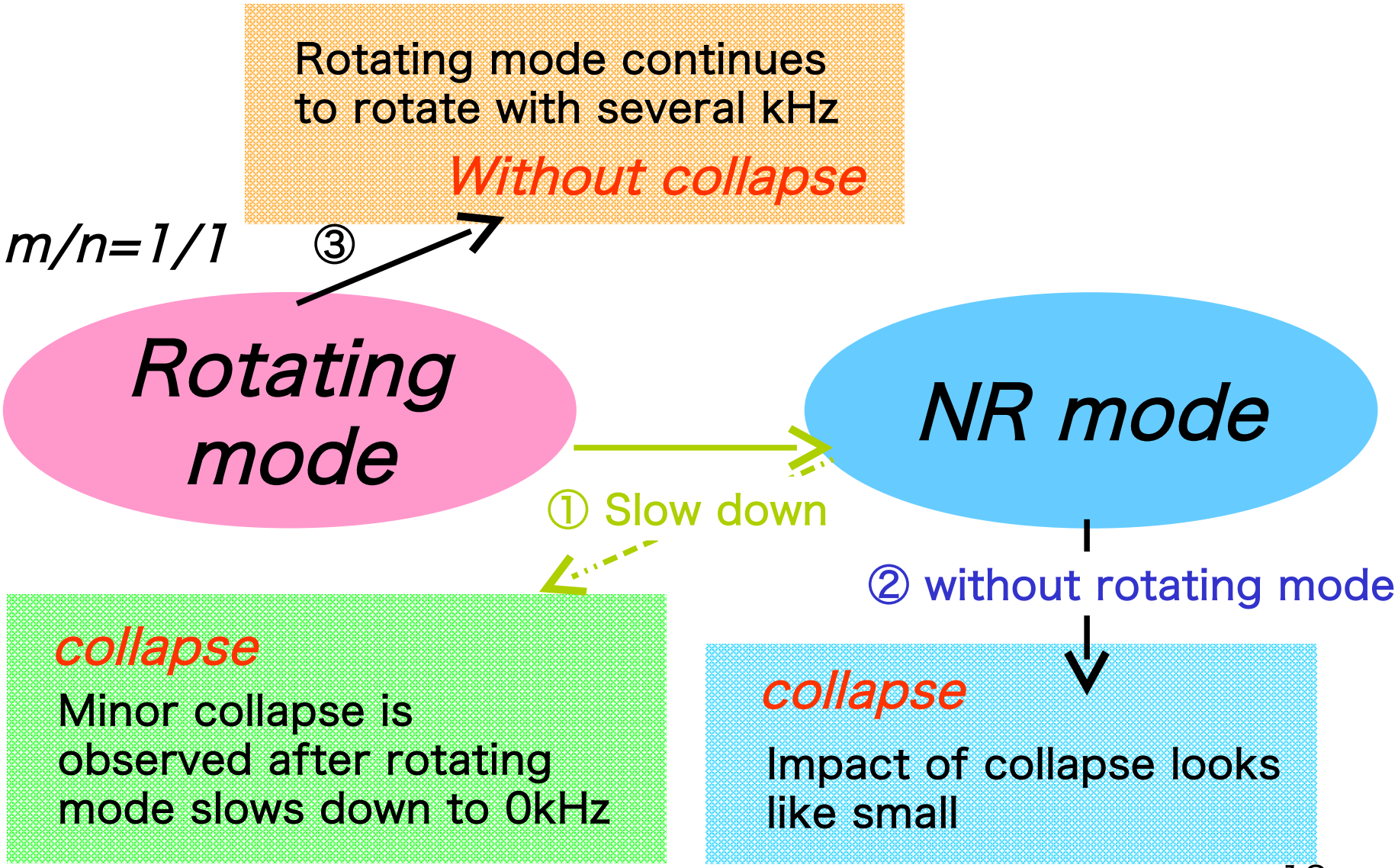


— Magnetic shear (A_p and I_p) is equivalent between discharges

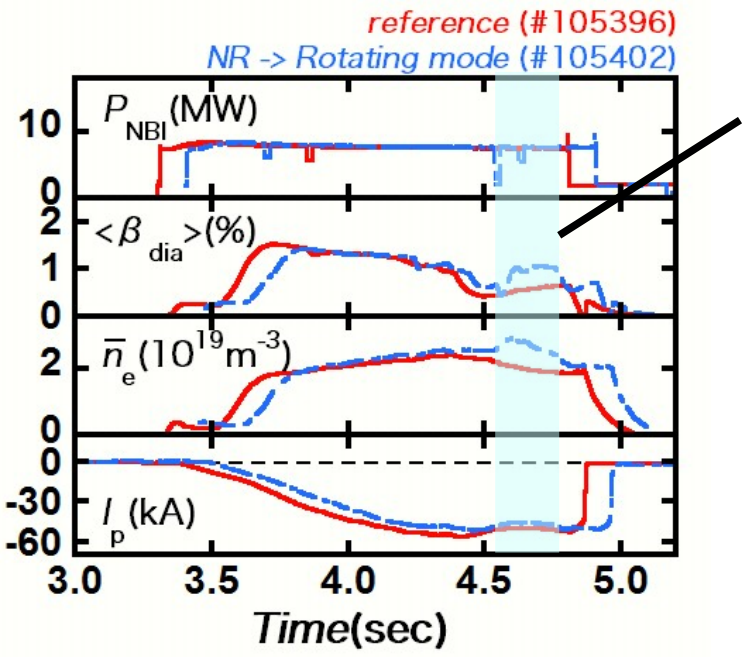
with collapse	without collapse
Mode frequency becomes almost zero before collapse	Mode frequency keeps ~1.0 kHz

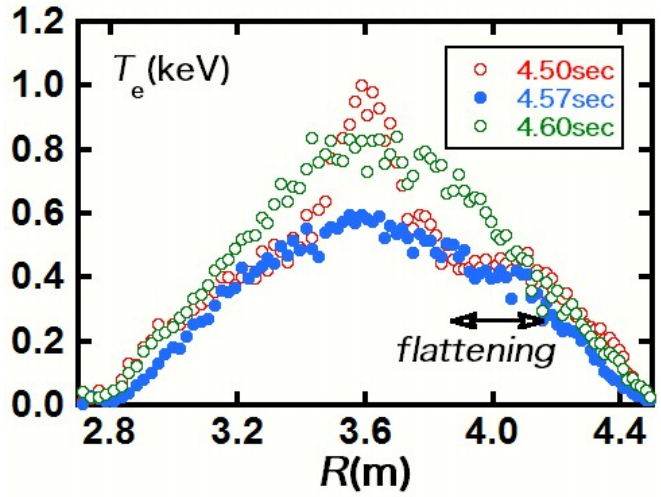
Mode rotation is a key parameter for stabilization of NR mode

Relationship NR mode and rotating mode



Observation of the transition to Rotating mode





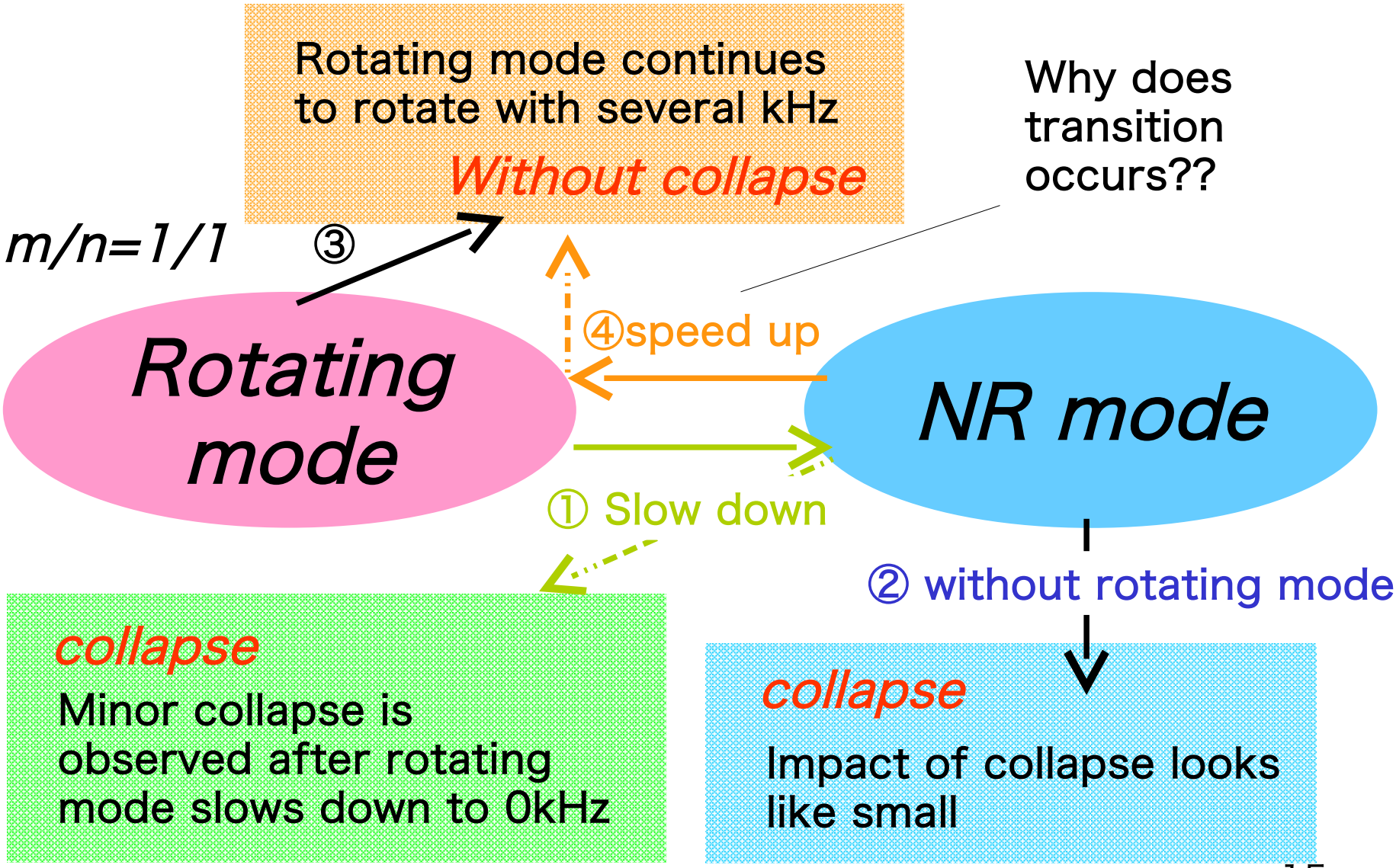
m/n=1/1 Rotating mode is excited

— Magnetic shear is equivalent between discharges

— Minor collapse in both discharges was observed after mode locking

— Beta rapidly increases due to disappeared Te-flattening just after m/n=1/1 rotating mode is excited without external torque input

Relationship NR mode and rotating mode



Discussion

Why does rotating mode slow down?

Tokamaks : Interaction between error filed (or resistive wall) and tearing mode

LHD : Rotating mode is estimated to resistive interchange mode
>> This mode is NOT formed magnetic island
→ nonlinear effect??

— However, radial mode configuration caused by the island formation has not been observed so far on LHD

Summary

Rotating mode

S dependence of the mode amplitude suggests it is resistive interchange mode

rotation of rotating mode is consistent with electron flow within the measurement error

Non-rotating mode

Transition from rotating mode to non-rotating one has been observed in the discharge

Impact of NR mode on beta loss is small without the transition

Future work

Comparison with locked mode on tokamak devices