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Overview of Steady-State Tokamak Operation and Current Drive Experiments in TRAIM-1M

Presented by H. ZUSHI
RIAM Kyushu University

K.Nakamura, K. Hanada, K. N. Sato, M. Sakamoto, H. Idei, M. Hasegawa, A. Iyomasa, S. Kawasaki, H. Nakashima, H. Higashijima, T. Kuramoto, A. Tanaka, Y. Matsuo, T. Sugata, H. Hoshika, K. Sasaki, N. Maezono, M. Kitaguchi, N. Imamura, N. Yoshida, K. Tokunaga, T. Fujiwara, M. Miyamoto, M. Tokitani, K. Uehara, Y. Sadamoto, Y. Kubota, Y. Nakashima, Y. Higashizono, Y. Takase, A. Ejiri, S. Shiraiwa, S. Kado, T. Sikama, S. Tusji-Iio, T. Takeda, Y. Hirooka, K. Ida, Y. Nakamura, T. Fujimoto, A. Iwamae, T. Maekawa, O. Mitarai

RIAM Kyushu Univ.

Interdisciplinary graduate school of Eng. and Science Kyushu Univ.

JAERI, NIFS, Univ. of Tokyo, Univ. of Tsukuba, Kyoto Univ. Tokyo Institute of Tech. Univ. of electro-communication, Kyushu Tokai Univ.

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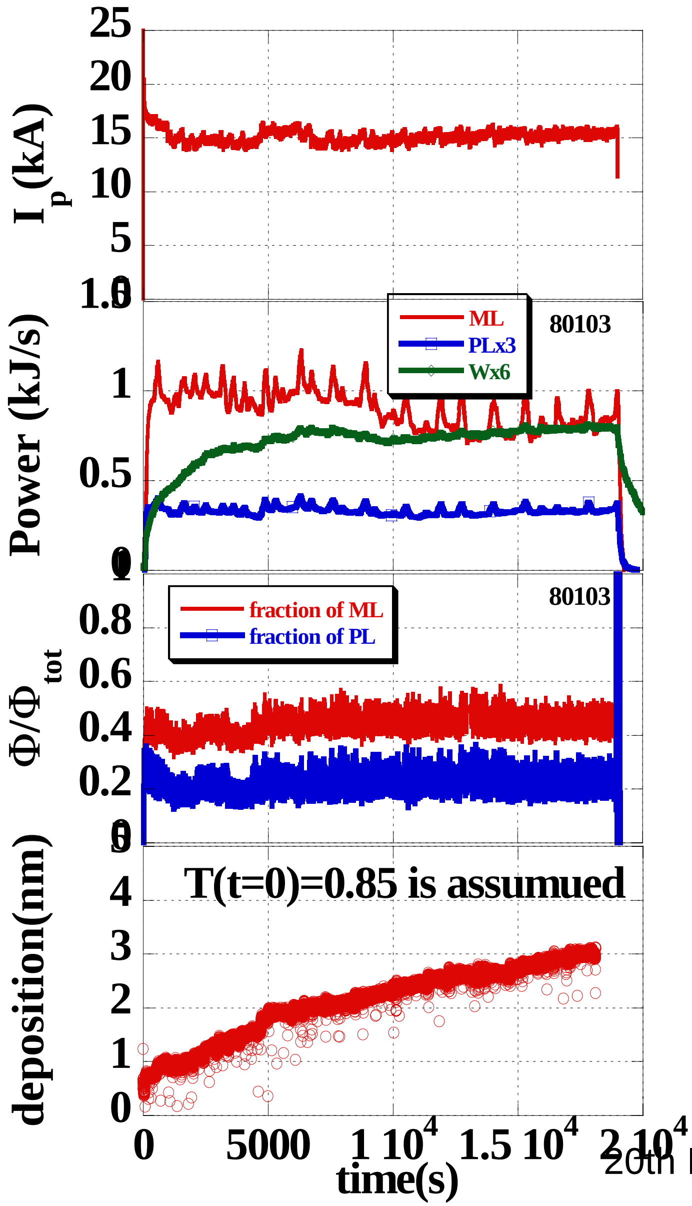
Contents

- PWI effects on SSTO (Five Hour Discharge)
- ITB study in SSTO
- Off-axis CD by fundamental X-mode
- Summary

1. PWI effects on Steady State Tokamak Operation

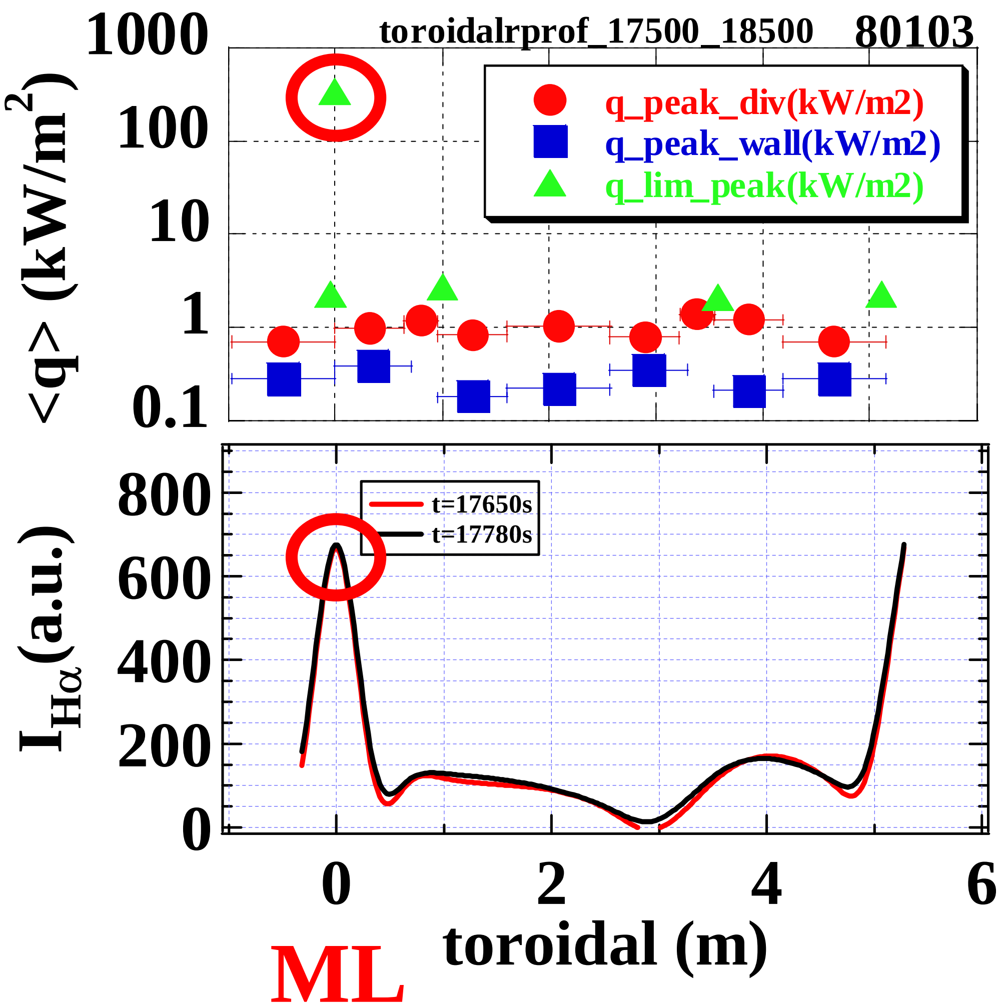
Sakamoto M. EX/P5-30

SSTO in TRIAM-1M



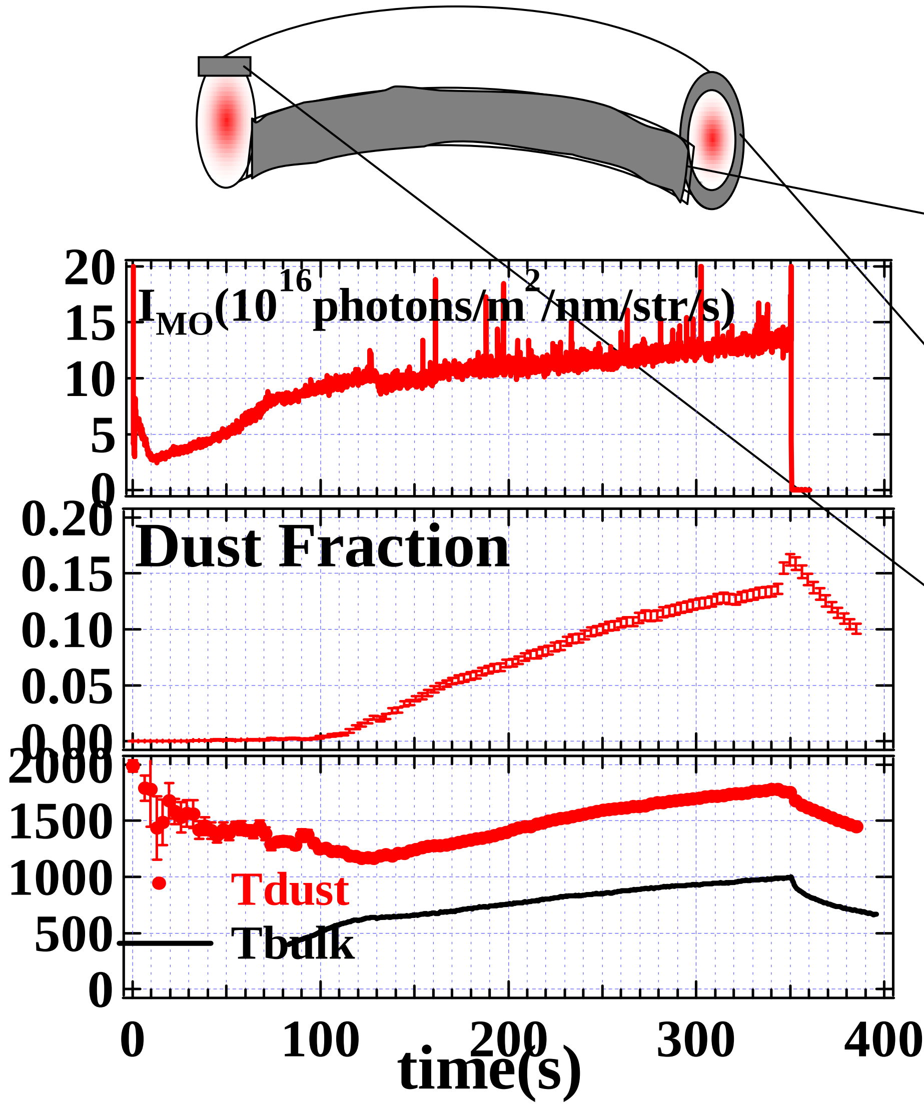
- **5 hour 16 min discharge was achieved by localizing PWI on a movable rail limiter ML and by reducing surface temperatures on PFCs.**
- **Under such conditions, toroidal distribution of heat load and recycling flux on PFCs are measured.**
- **In connection with wall pumping rate, in situ measurement of Γ_{Mo}^{dep} is carried out.**

Toroidal structures of <q> and Γ_H



- <q> and Γ_H are localized on the ML
- **34 %** of total heat load is deposited on ML and the rest are distributed among PFCs.
- <q> on ML is higher than others by 2~3 orders of magnitude.
- **40 %** of total recycling particle rate is also localized on ML.

Metal deposition



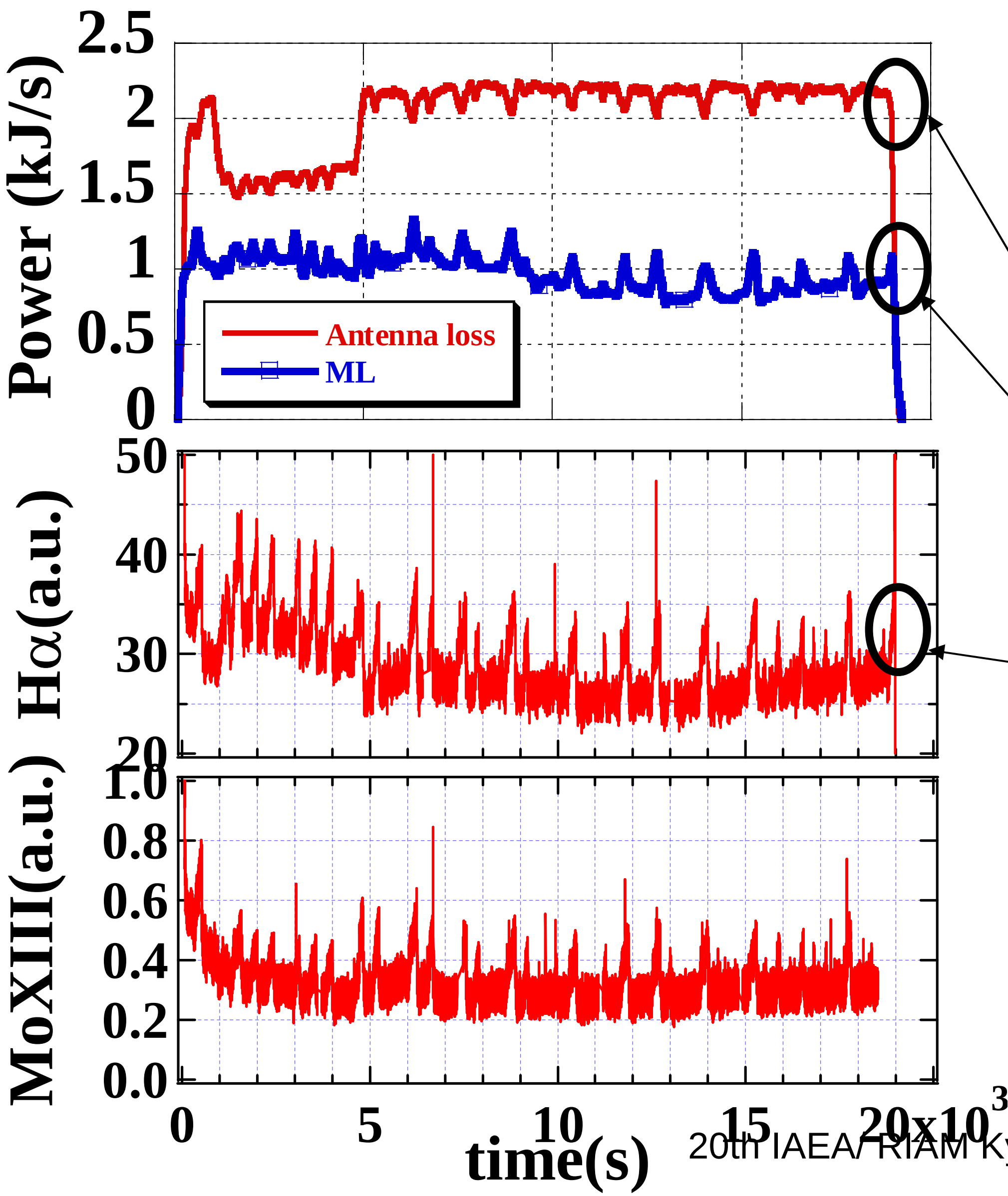
Three measurements in connection with dust deposition on different PFCs.

1) **in situ Γ_{Mo}^{dep} from optical transmission method**
(DPs : CX sputtering)
Zushi, 31st EPS 2004

2) **Ex situ thickness and H retention measurement**
(PLs ; SOL deposition
Miyamoto, 16th PSI 2004)

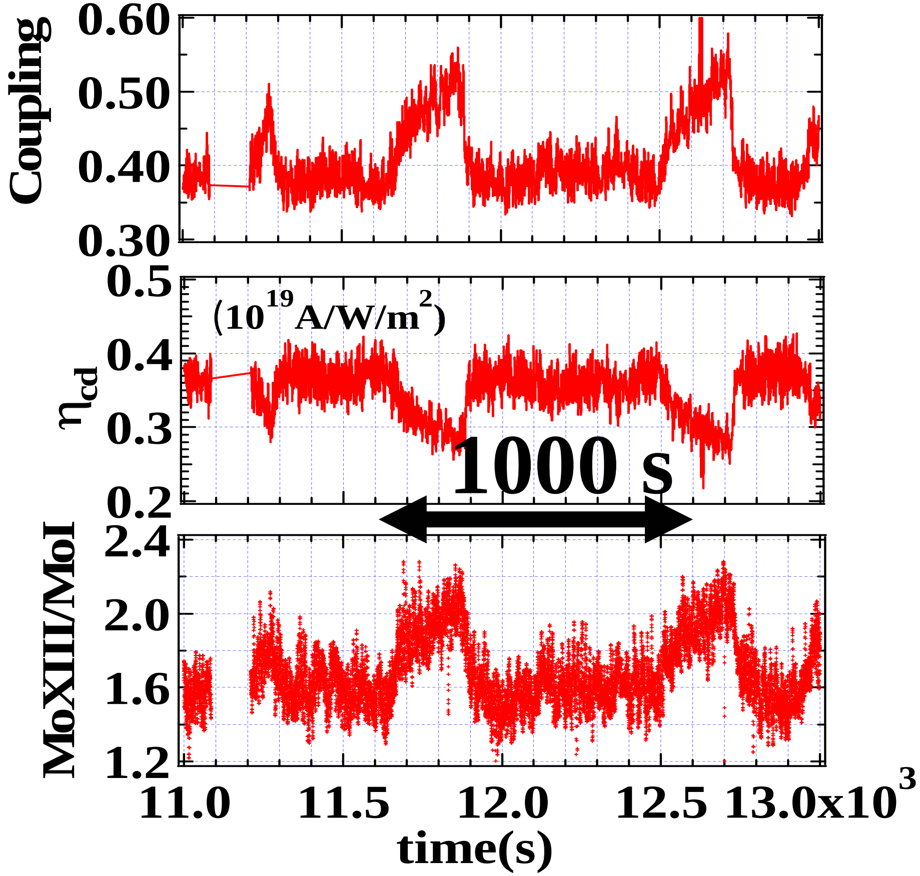
3) **Dynamics of main PWI surface (ML)**
IR spectrum, Visible, CCD, fast camera , IRTV
=> Tdust & coverage area
(Reicle R, JNM 2001)

Ultra Low Frequency Events



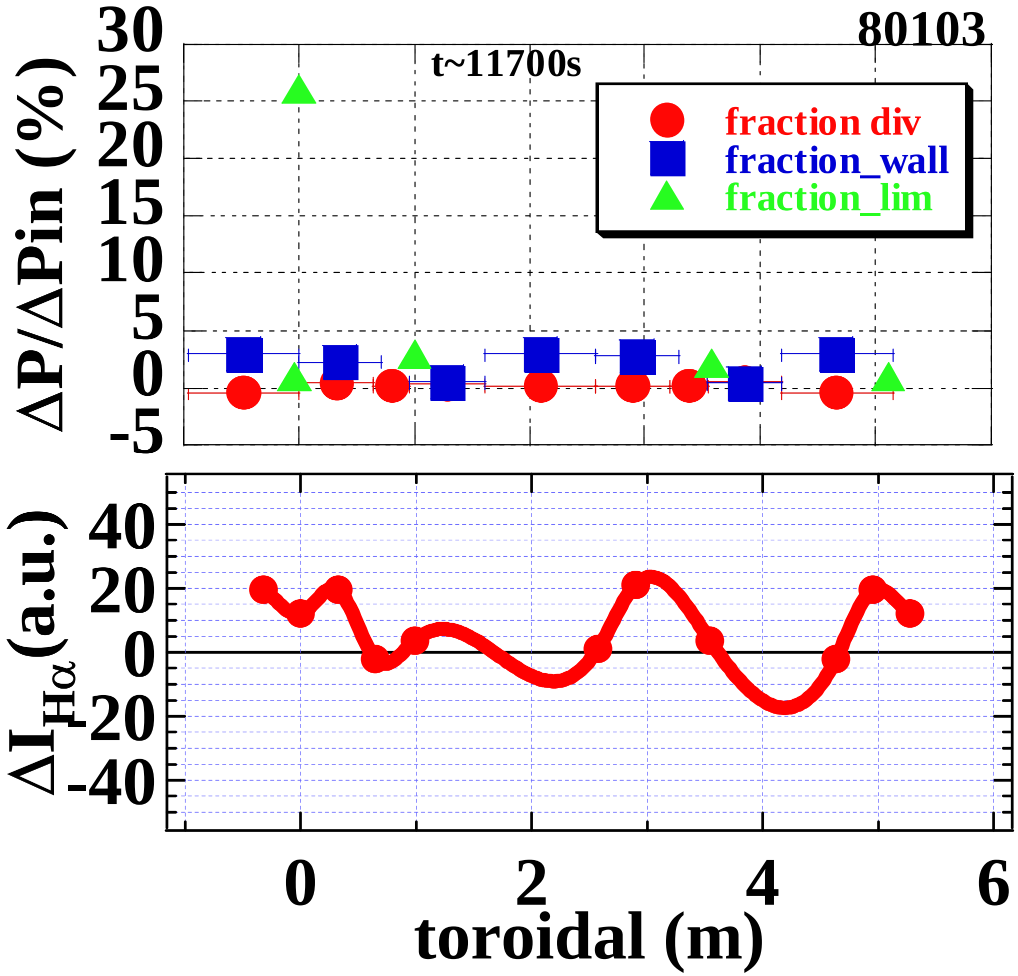
- Very low frequency semi-regular oscillations are found in signals on heat loads, particle recycling, and impurity influx and contents.
- Frequency ~ 1-2×10^{-3} Hz
  amplitude ~a few %– 100 %
- During the last ULF event, the five hour discharge terminated.

Negative aspects of ULF events



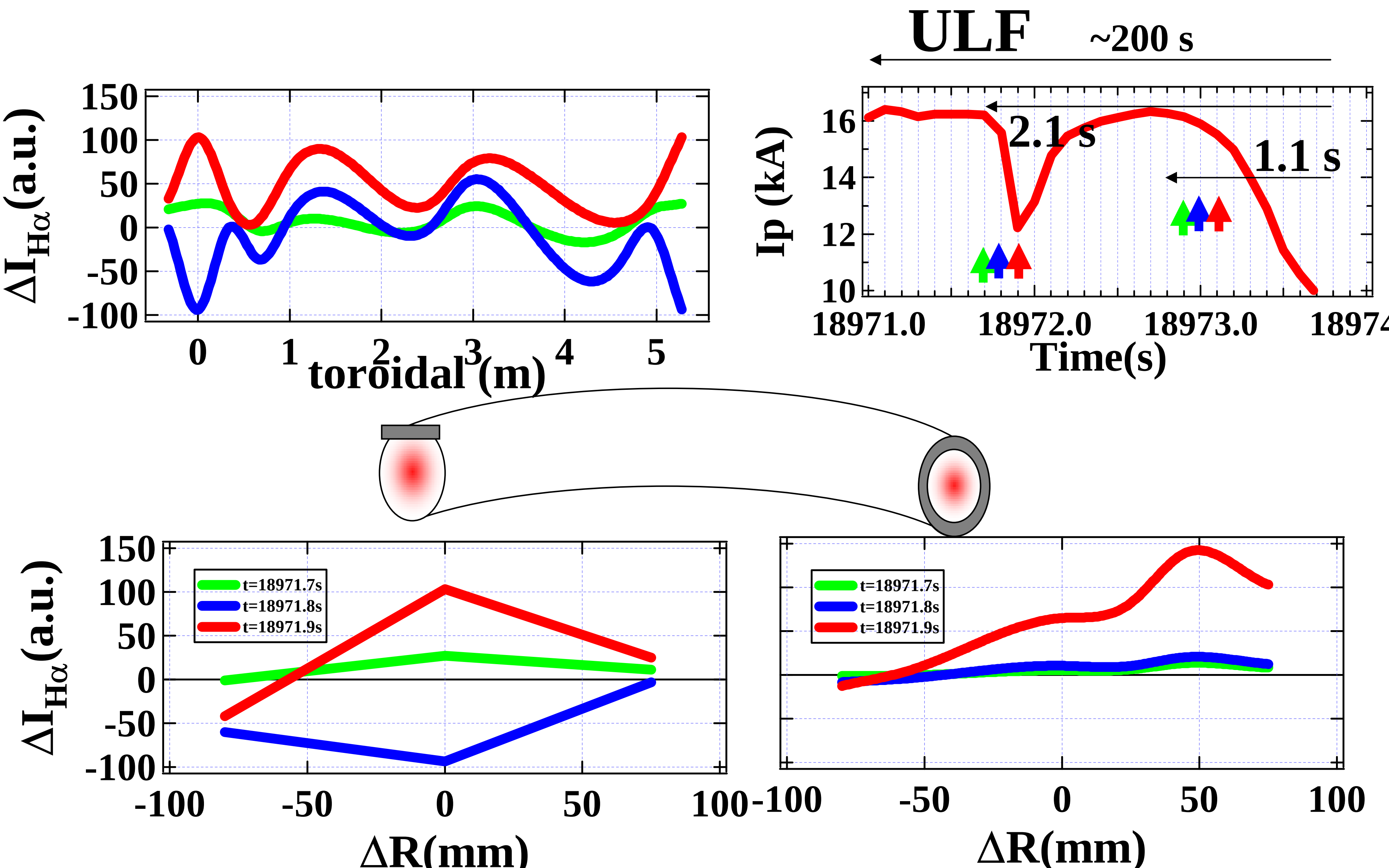
- ULF event lasts for > 300 s; consists of "Slow rise (decrease) and rapid recovery phases"
- Plasma – rf coupling increases, but current drive efficiency η_{CD} decreases during ULF events
- Impurity accumulation causes to reduce drive efficiency.
- SSTO is perturbed at every 1000 s by PWI driven ULF events.

Heat load/ recycling profile during ULF events



- **Difference between heat load and recycling on ML**
- **ΔP variation is quite localized on the ML.**
- **However, ΔHα is not so localized.**

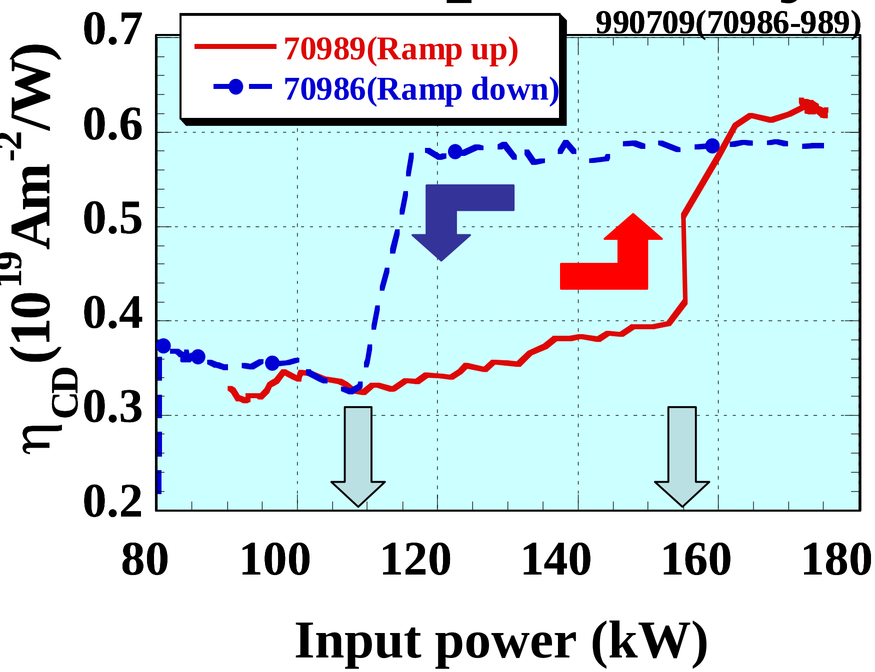
Perturbations & Termination

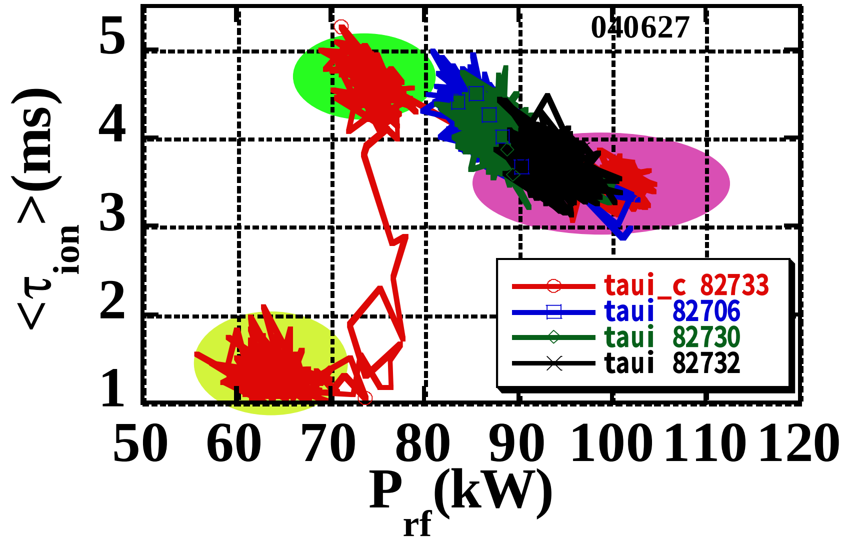


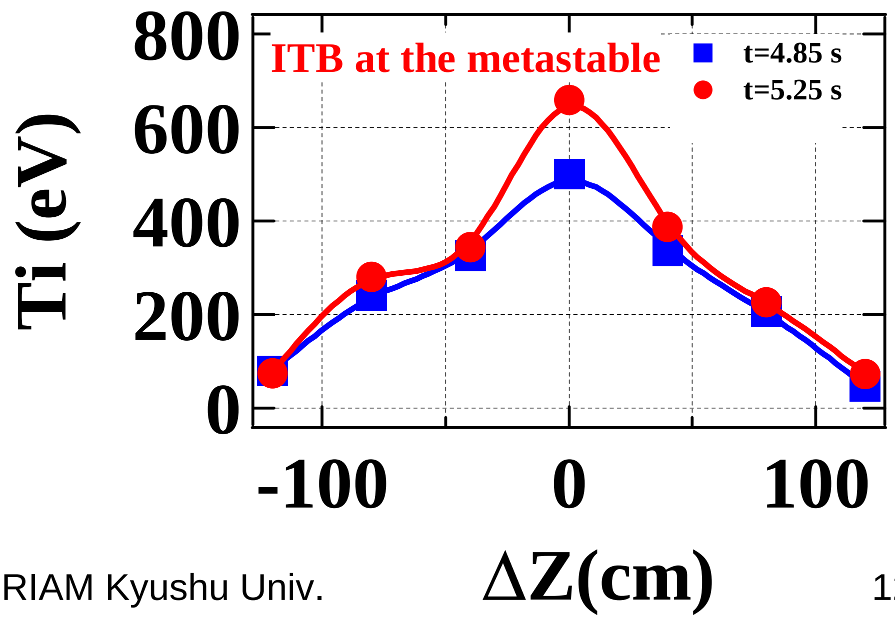
2. ITB formation
/sustainment
/collapse
in SSTO

Hanada K.　EX/P4-25

Ion ITB near the lower edge of the power hysteresis window





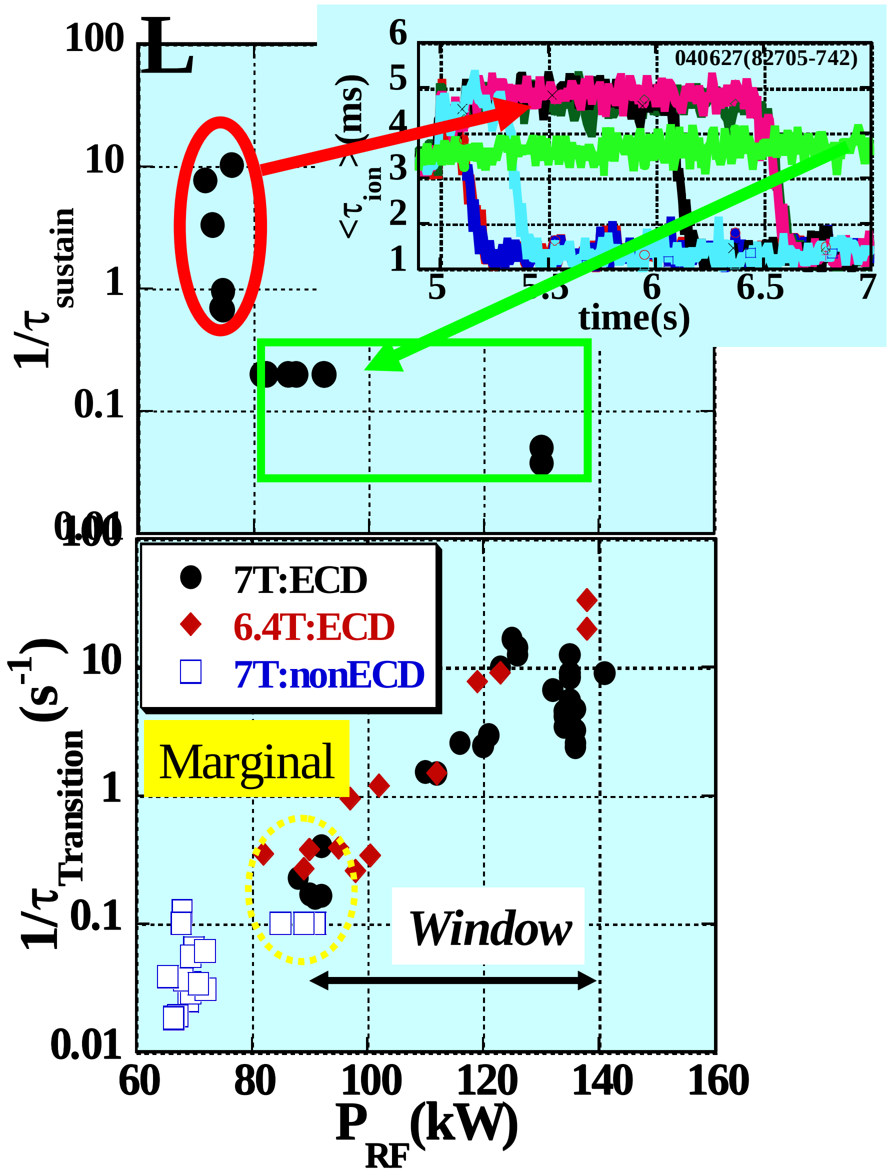


- Hysteresis window is observed even at dP/dt ~ 100W/10ms
- Pth(L=>ECD) > Pth(ECD=>L)
- <τ>ion=1.5<n>Ti(0)/Prf*Vp

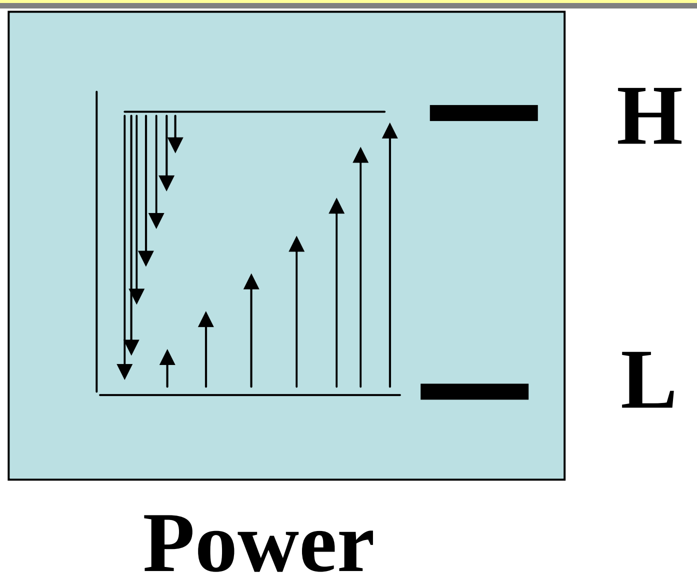
is used as a monitor of ion confinement property.

- ITB is found near the edge .

Lifetime of ECD/ITB against reduced Power

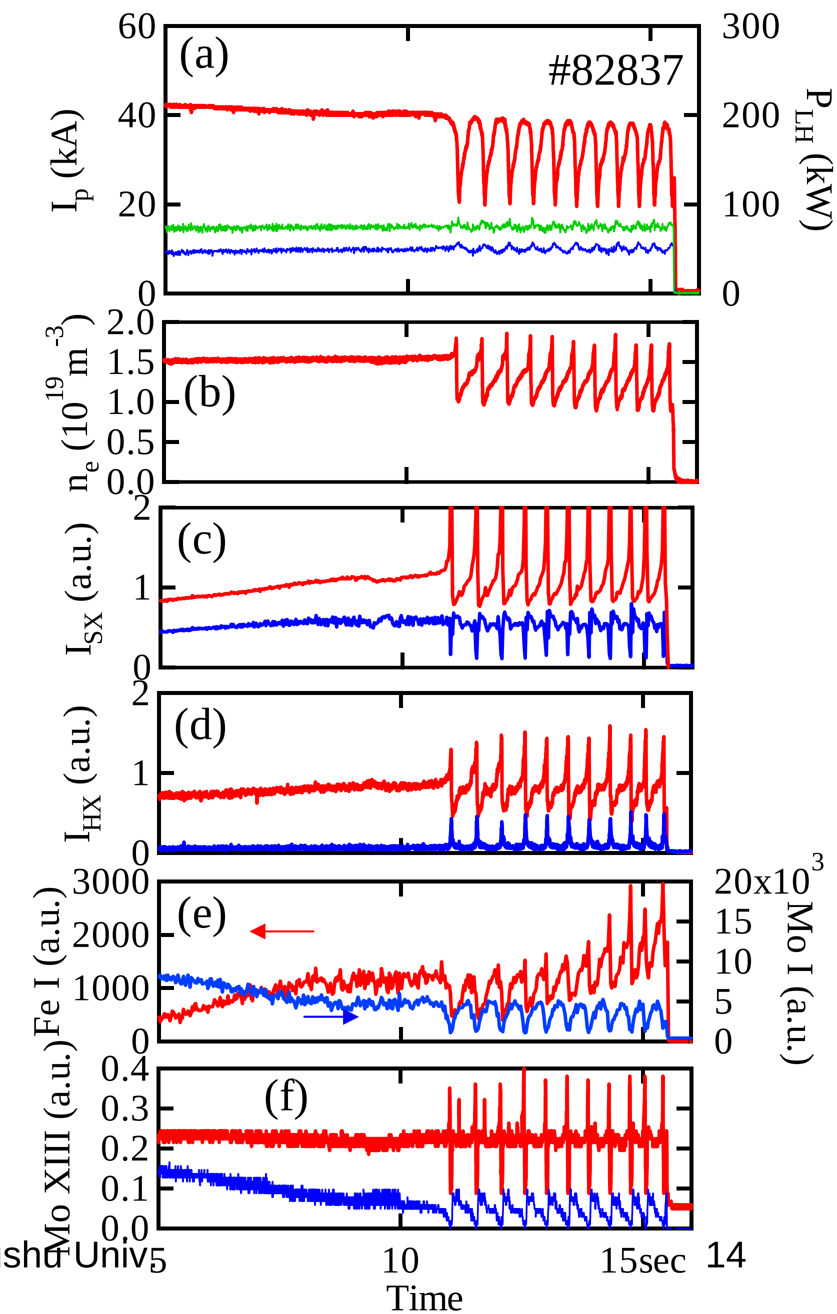


- Life time is ~5 s just above the hysteresis power window, and it goes down 0.1 s ~ 1.5 s under the same power condition.
- From comparison with a logarithmic power dependence, barrier formation, sustainment, collapse seem to have different P –dependence.

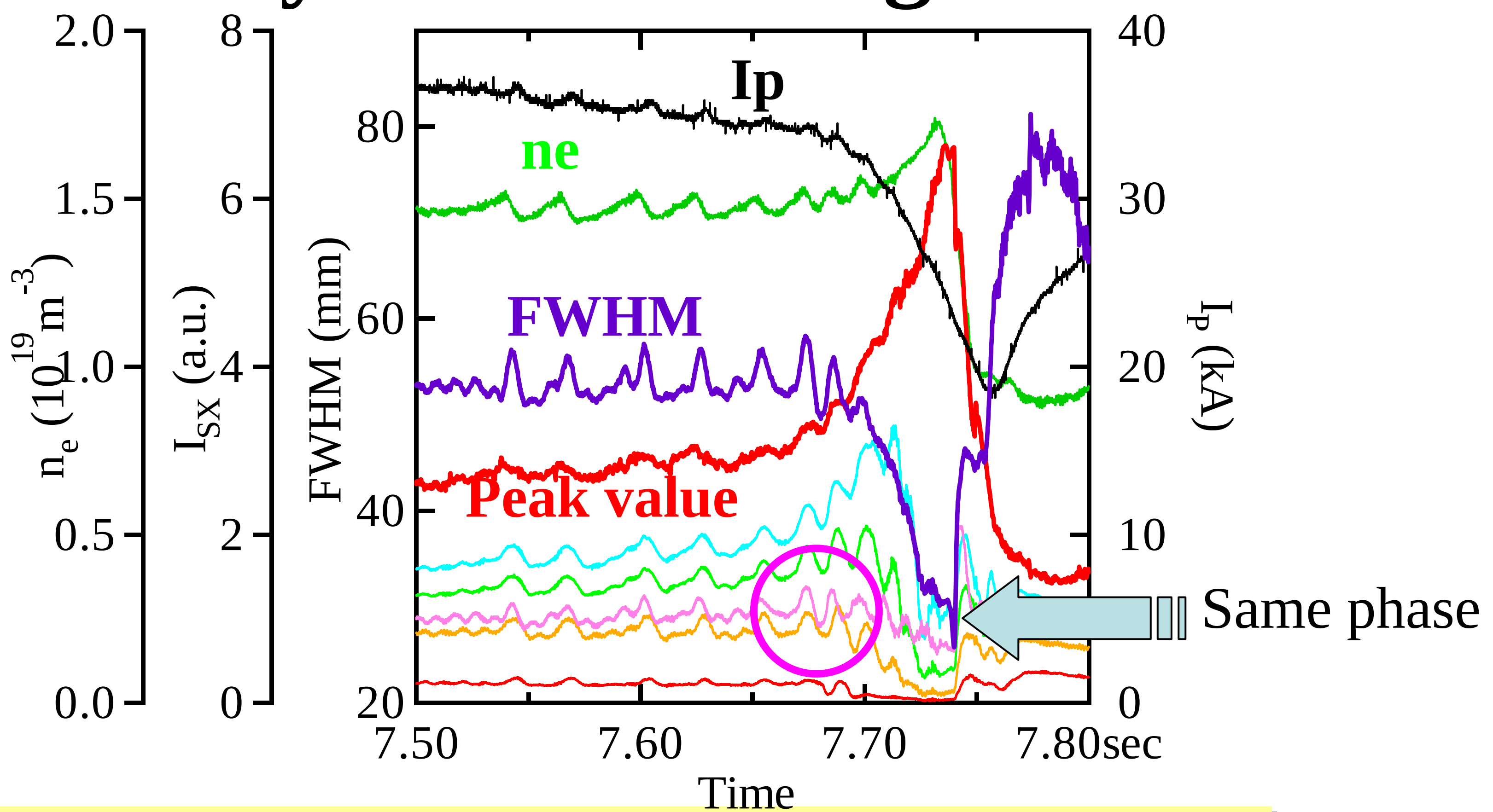


Sustainment & collapse of ITB

◆**Combined $\Delta\Phi_{LH}$ (N||=1.8+N||>1.8) scenario is chosen to make a hollow $j_{LH}(r)$.**
◆**Self-organized slow sawtooth oscillations appear as an obstacle.**
◆**The periods of the oscillation is comparable to $\tau_{L/R}$.**
◆**Fe influx increases, though Mo is constant.**



ITB dynamics during SSSO

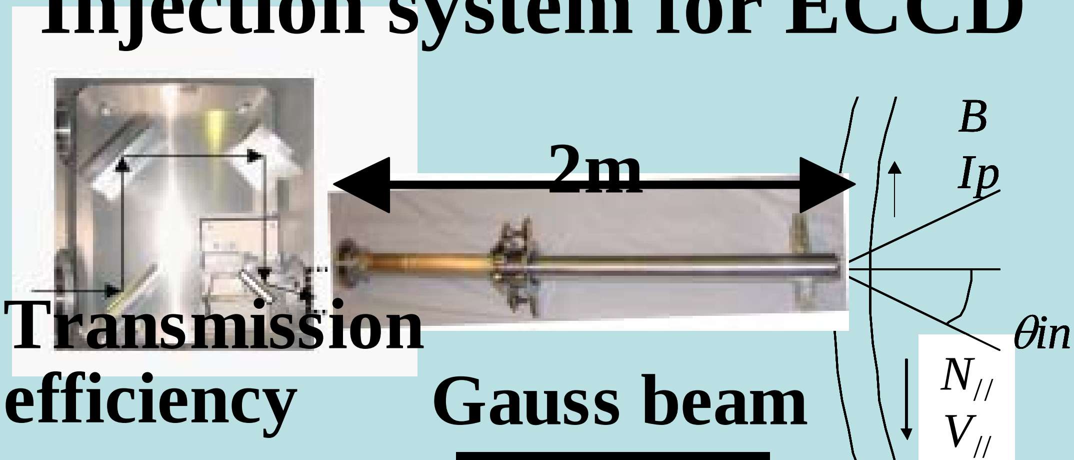


◆m=0 type oscillations found on ne/SX signals before the crash, indicating radial oscillation of ITB foot.

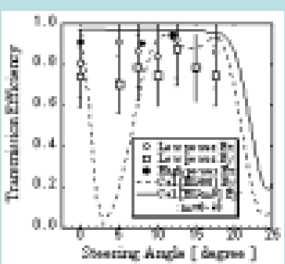
◆At ~0.1 s before the crash, ITB foot shrinks rapidly and then ITB itself collapse.

3. Off-axis CD by 1st X-mode

A steering antenna(<19°)
Injection system for ECCD

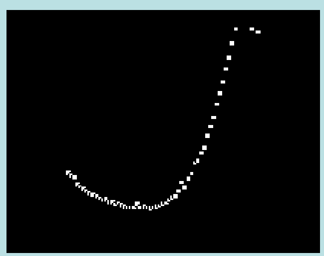


Transmission efficiency

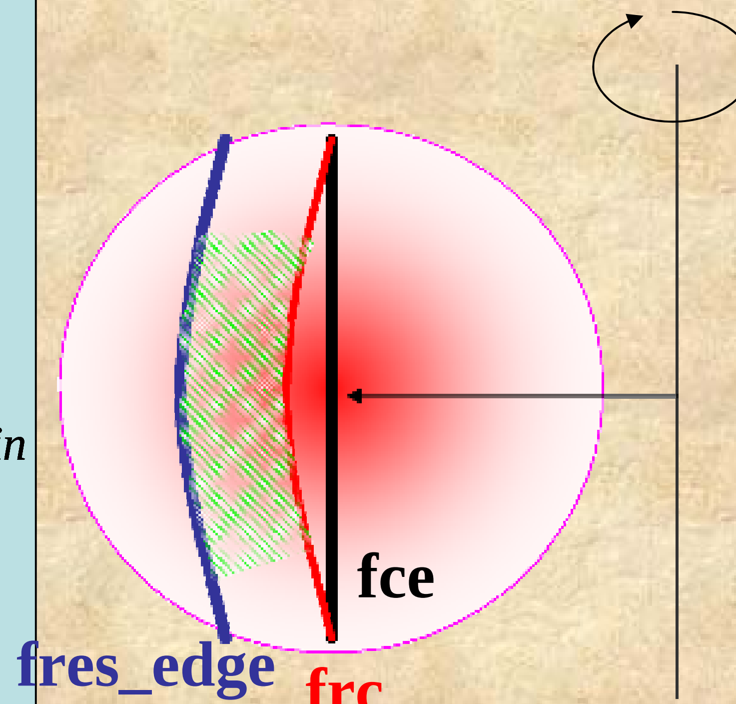


~0.95

Gauss beam



1/e~20mm



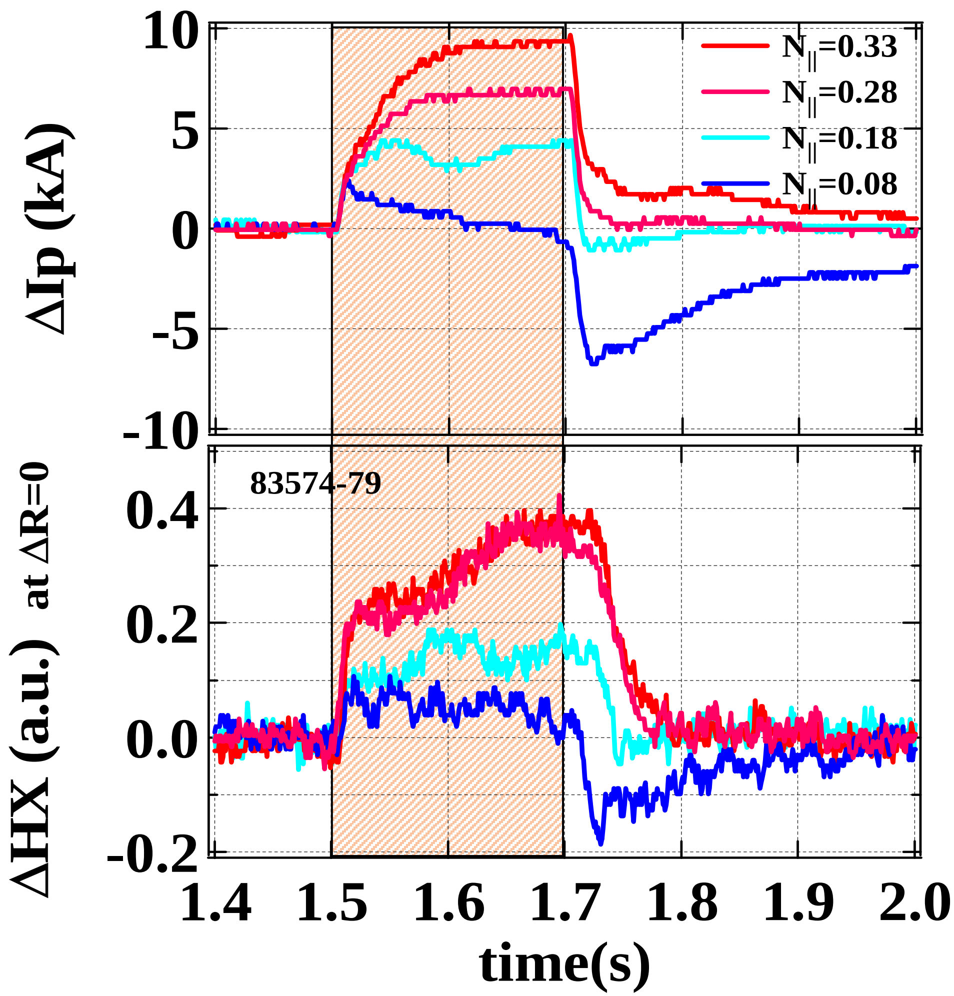
$$f = f_{ce} / \gamma + k_{||} v_{||}$$

: resonance condition

$$\gamma = 1 + E / mc^2$$

Idei H. PD 1/2

Oblique X-mode ECCD (coupled to energetic electrons)

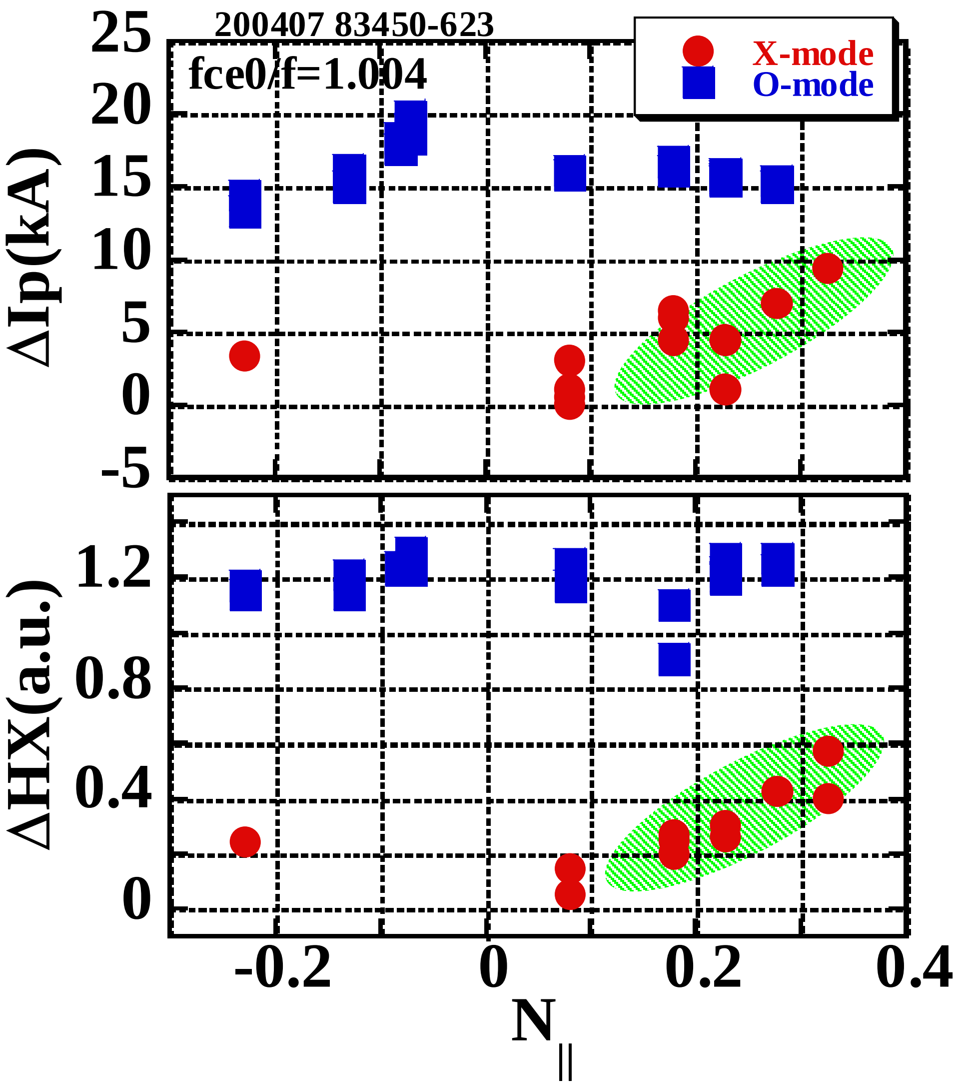


1) 100 kW 170 GHz
2) $f_{ce0}/f \sim 1$, $n_e \sim 0.8\text{-}1 \times 10^{19} m^{-3}$
3) Elliptically polarized X-mode are injected into LH plasmas at various angles.

◆ΔIp increases with increasing $N_{||}$, which is consistent with relativistic Doppler resonance.

◆ΔHX behave similarly, suggesting the coupling with energetic electrons.

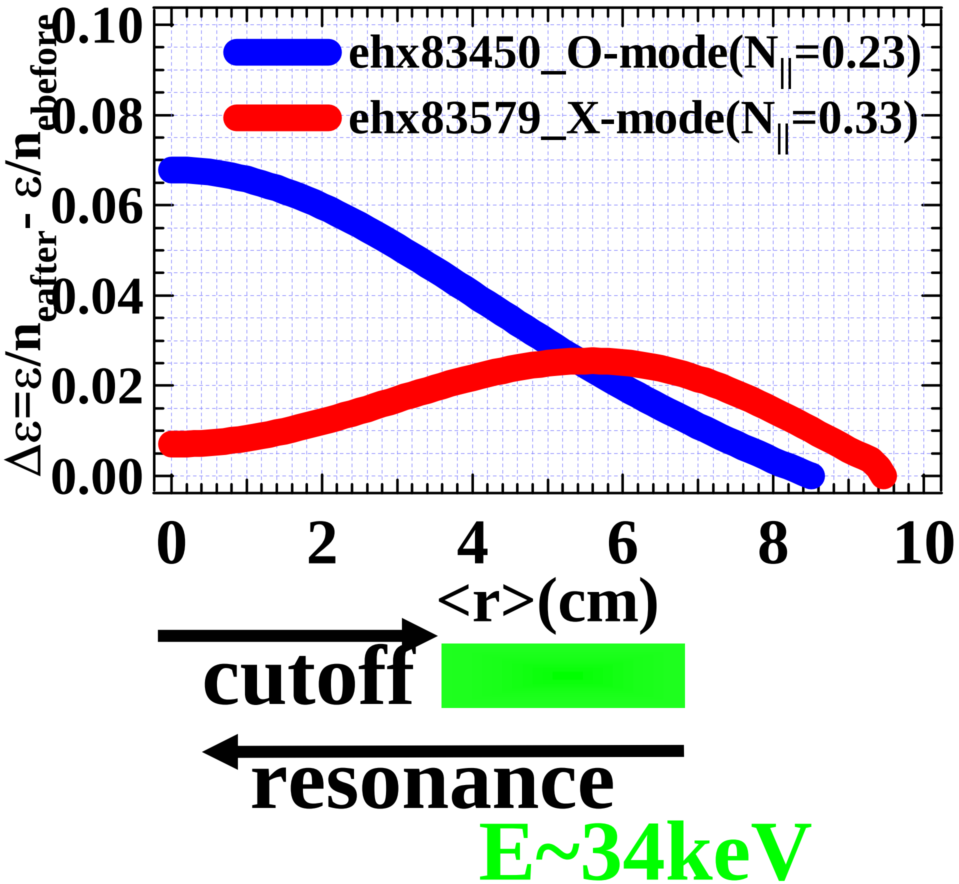
$N_{||}$ dependence of OX-ECCD



- The relativistic Doppler resonance condition can be fulfilled and becomes wider with increasing N||, with the consequence that both ΔIp and ΔHX increase above $N_{||} = 0.2$.
- On the contrary O-mode results show a week N|| dependence, suggesting thermal electron coupling.

Off axis X-mode CD

$$\Delta\varepsilon_{HX}(r) = \varepsilon/n_{eECCD} - \varepsilon/n_{eLHCD} \sim j_{tail}(r)$$



- **Hollow ε_{HX} is consistent with the off-axis X-mode ECCD scenario.**
- **The peak of the hollow roughly corresponds to the resonance region.**
- **The O-mode (N||=0.23) shows a peaked profile, suggesting on-axis heating at $f \sim f_{ce0}$ resonance.**

Summary

- ✓ **Heat load/ particle recycling/ impurity deposition are studied in 5 hour discharge. ULF events are found and termination phase are studied.**

- ✓ **ITB formation is found by combined LH phasing scenario, transition probability between ECD and non-ECD, and ITB sustainment and collapse are studied in full current drive plasma.**

- ✓ **Fundamental OX-ECCD scenario is demonstrated in LHCD plasma using the steering antenna.**