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

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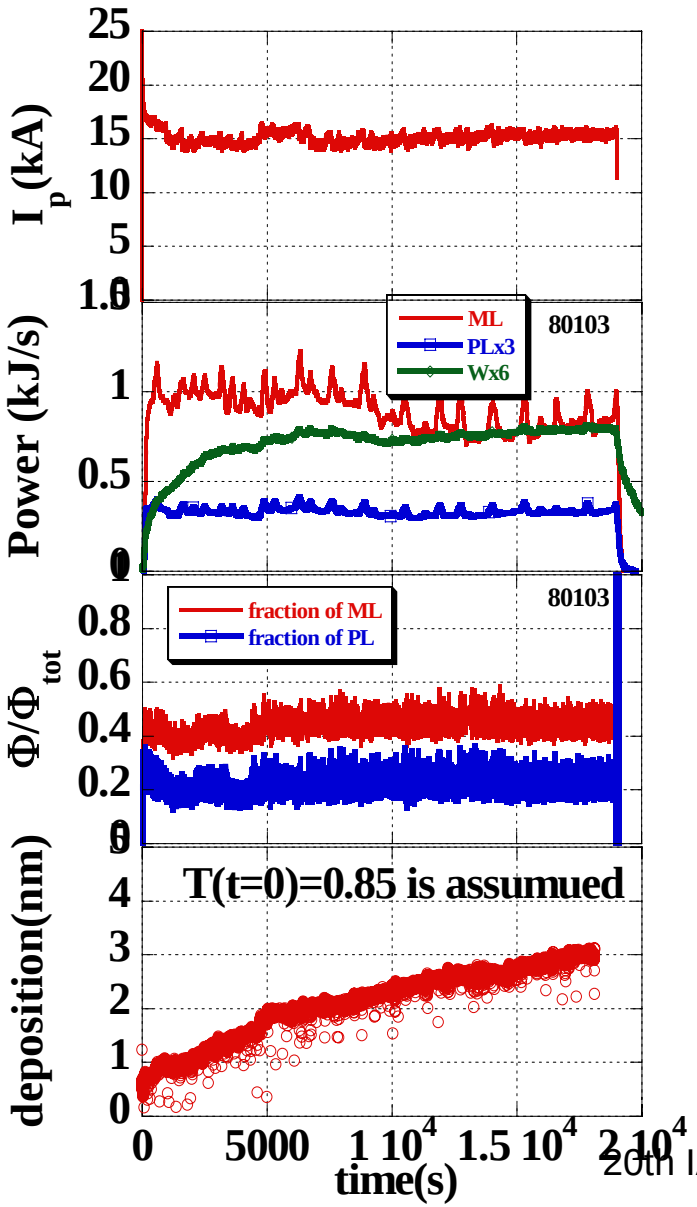
Contents

- **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

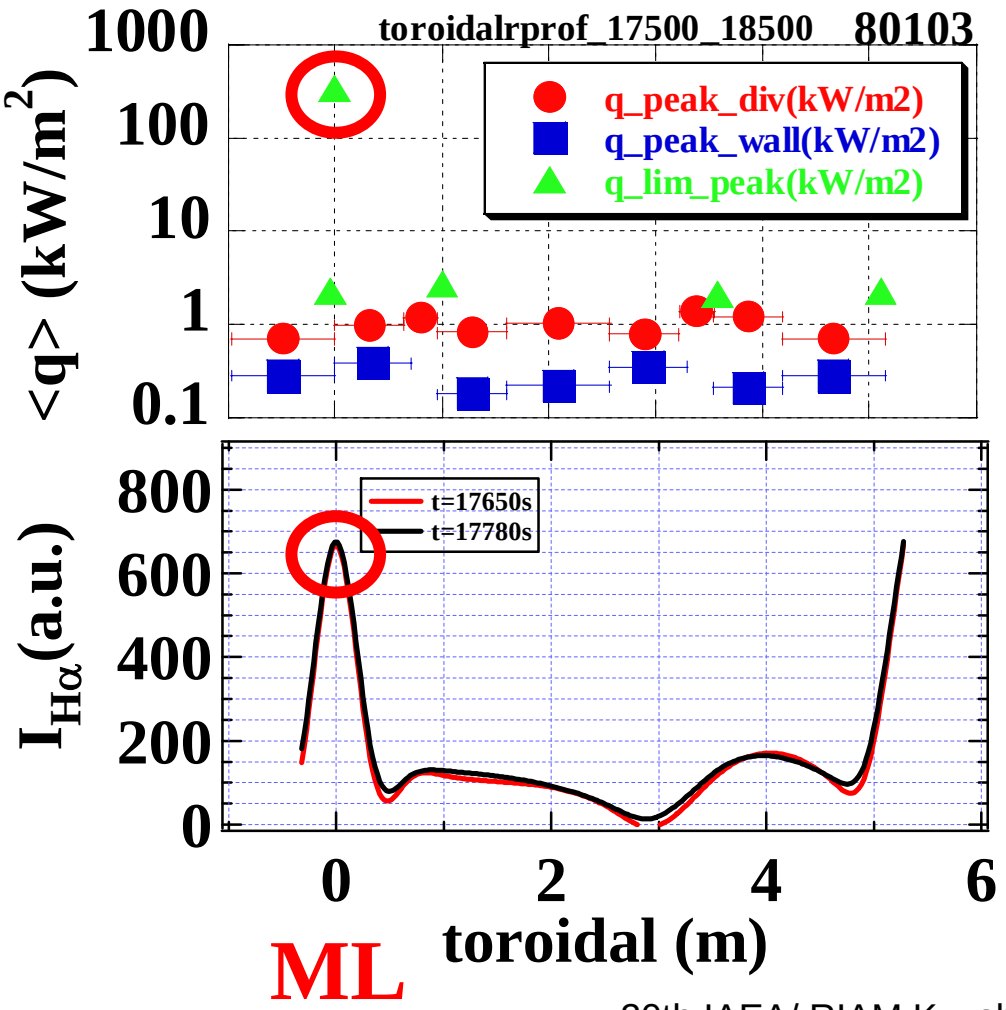
Sakamoto M. EX/P5-30

SSTO in TRIAM-1M



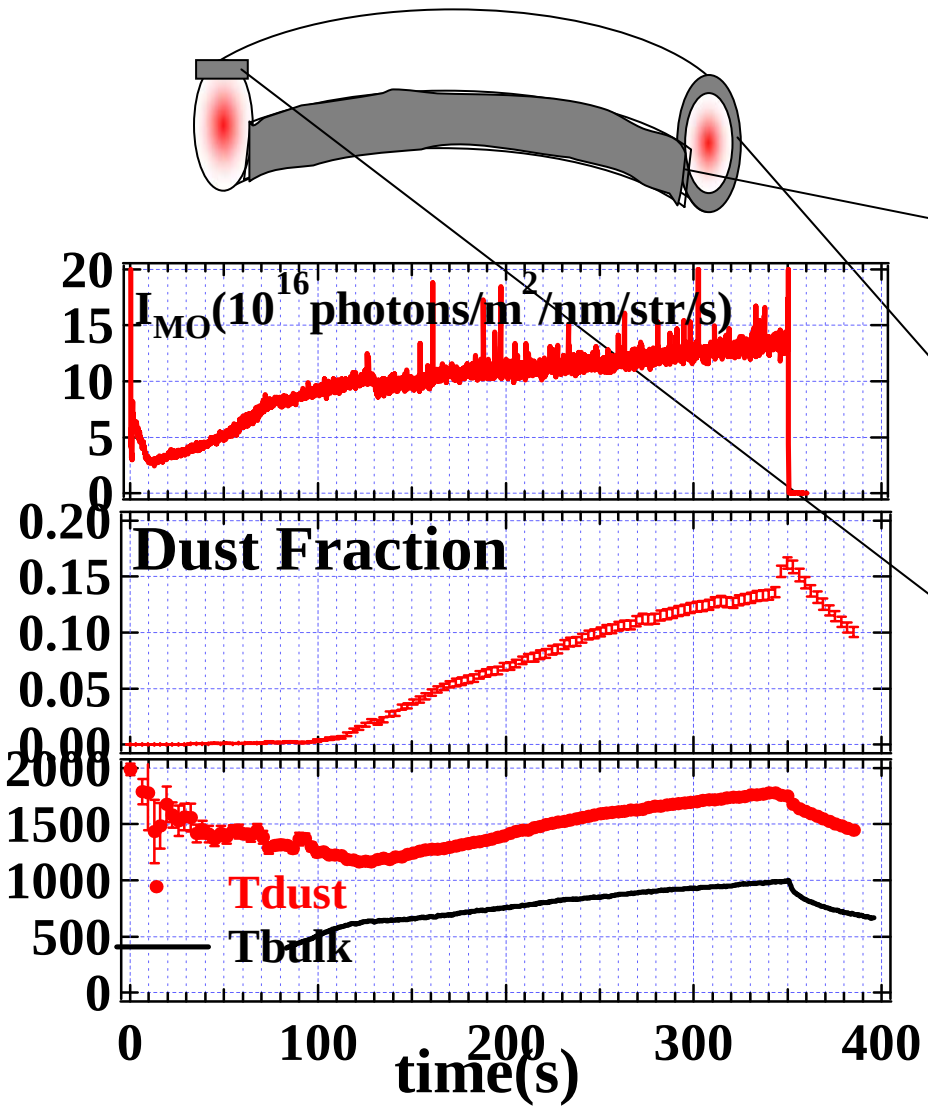
- **5 hour 16 min discharge was achieved by localizing PWI on a movable rail limiter ML and by reducing surface temperatures on PFCs.**
- **Under such conditions, toroidal distribution of heat load and recycling flux on PFCs are measured.**
- **In connection with wall pumping rate, in situ measurement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

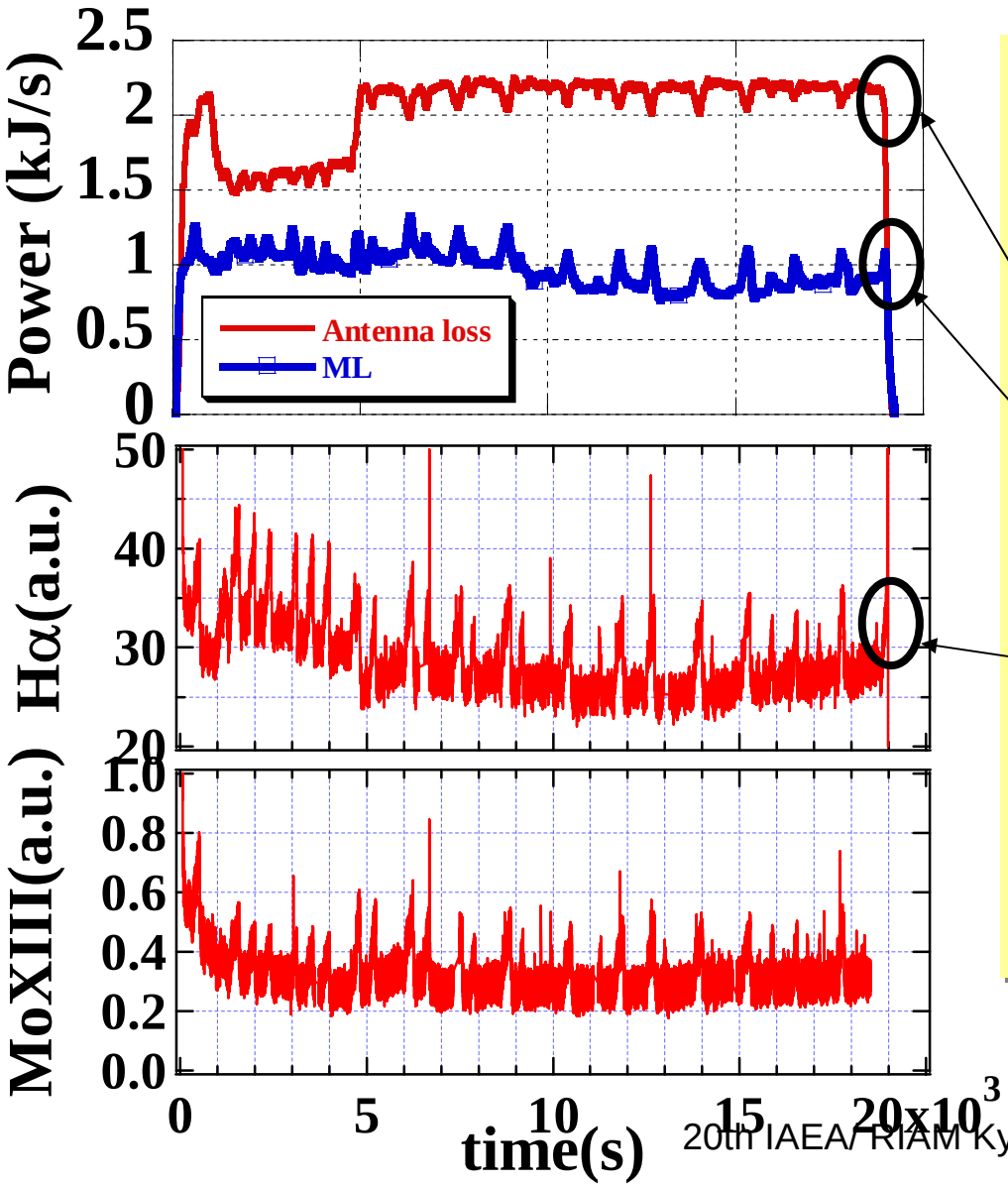
Metal deposition



Three measurements in connection with dust deposition on different PFCs.

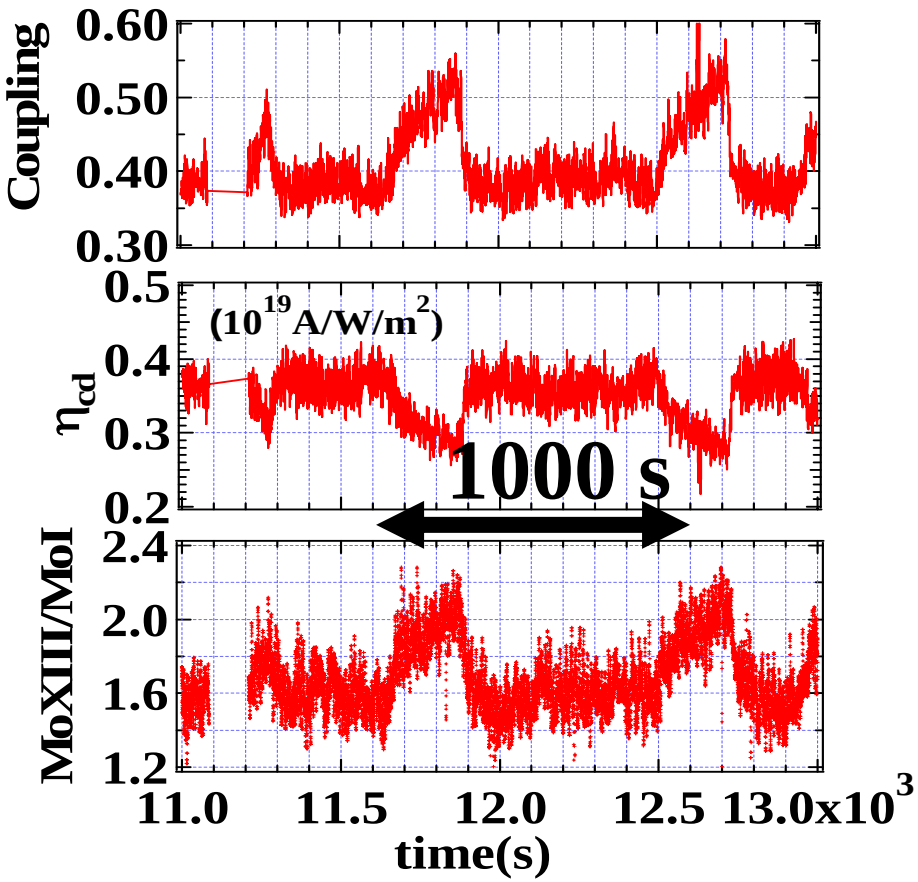
1) **in situ Γ_{Mo}^{dep} from optical transmission method**
   (DPs : CX sputtering)
   Zushi, 31st EPS 2004
2) **Ex situ thickness and H retention measurement**
   (PLs ; SOL deposition
   Miyamoto, 16th PSI 2004)
3) **Dynamics of main PWI surface (ML)**
   IR spectrum, Visible, CCD, fast camera , IRTV
   => Tdust & coverage area
   (Reicle R, JNM 2001)

Ultra Low Frequency Events



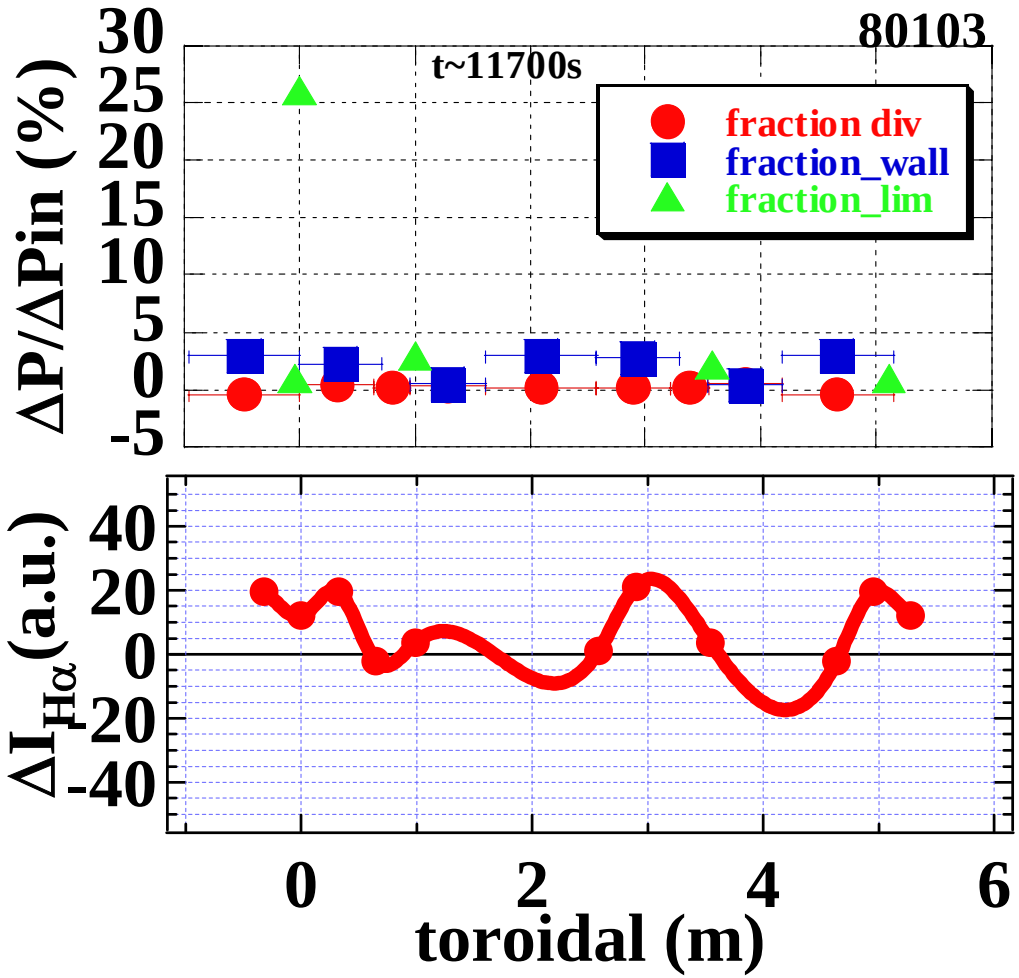
- Very low frequency semi-regular oscillations are found in signals on heat loads, particle recycling, and impurity influx and contents.
- Frequency ~ 1-2◈10^{-3} Hz
  amplitude ~a few %– 100 %
- During the last ULF event, the five hour discharge terminated.

Negative aspects of ULF events



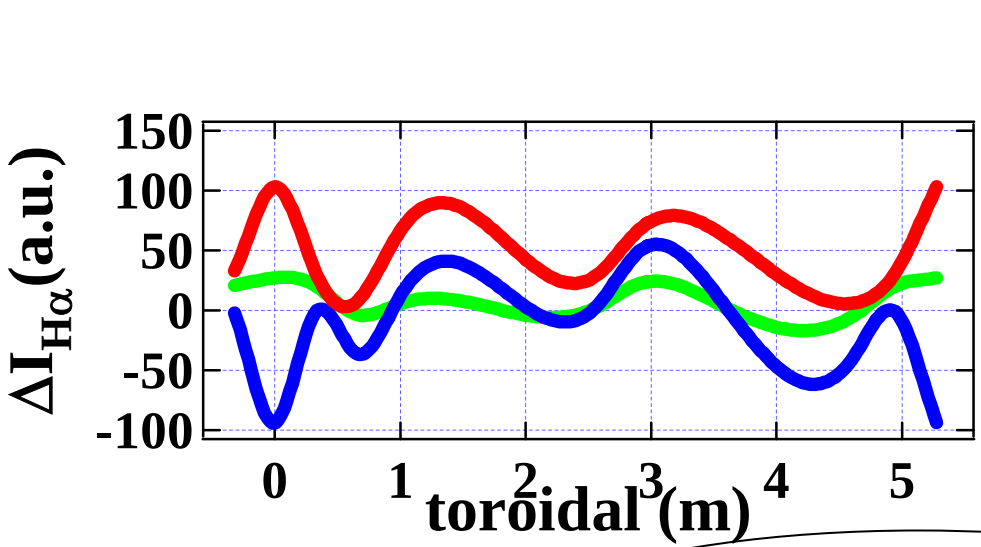
- **ULF event lasts for > 300 s; consists of "Slow rise (decrease) and rapid recovery phases"**
- **Plasma – rf coupling increases, but current drive efficiency η_{CD} decreases during ULF events**
- **Impurity accumulation causes to reduce drive efficiency.**
- **SSTO is perturbed at every 1000 s by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

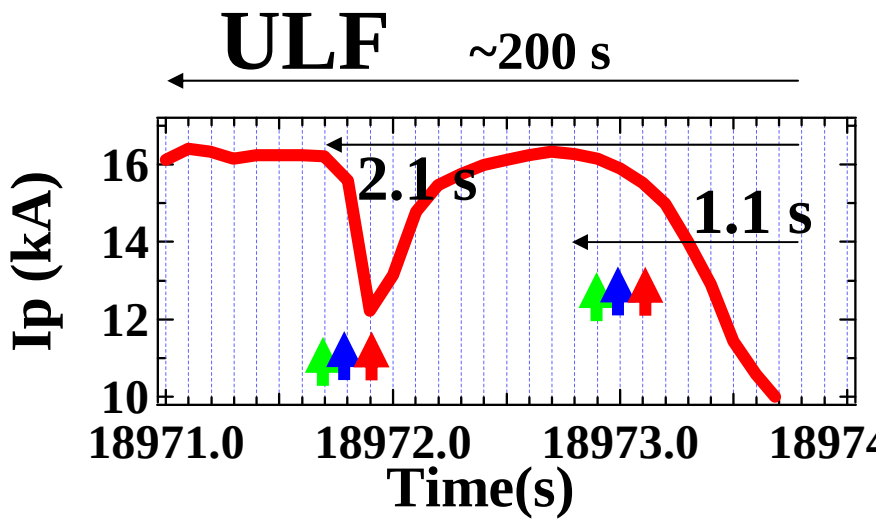
Heat load/ recycling profile during ULF events

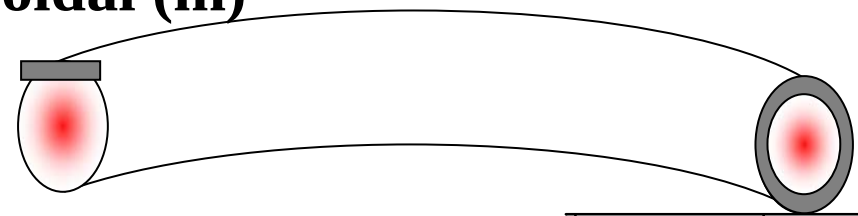


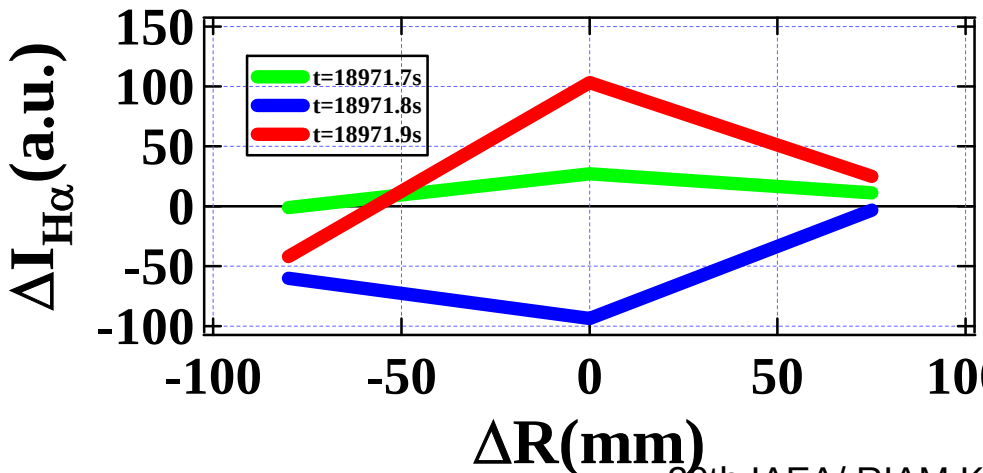
- Difference between heat load and recycling on ML
- ΔP variation is quite localized on the ML.
- However, ΔHα is not so localized.

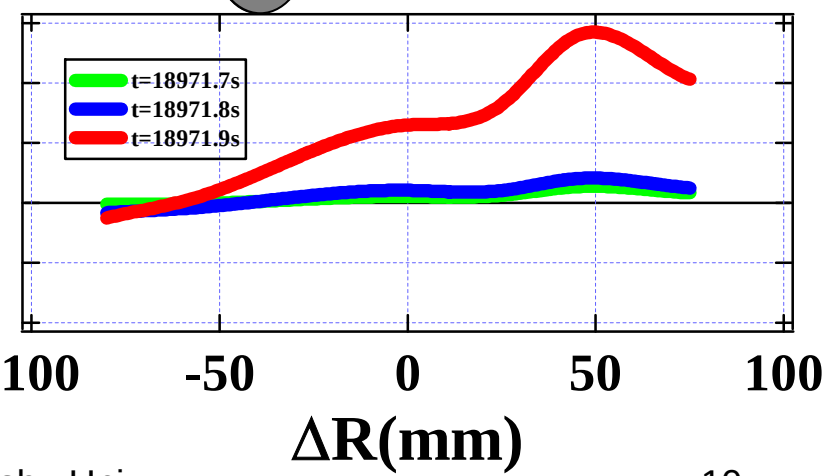
Perturbations & Termination







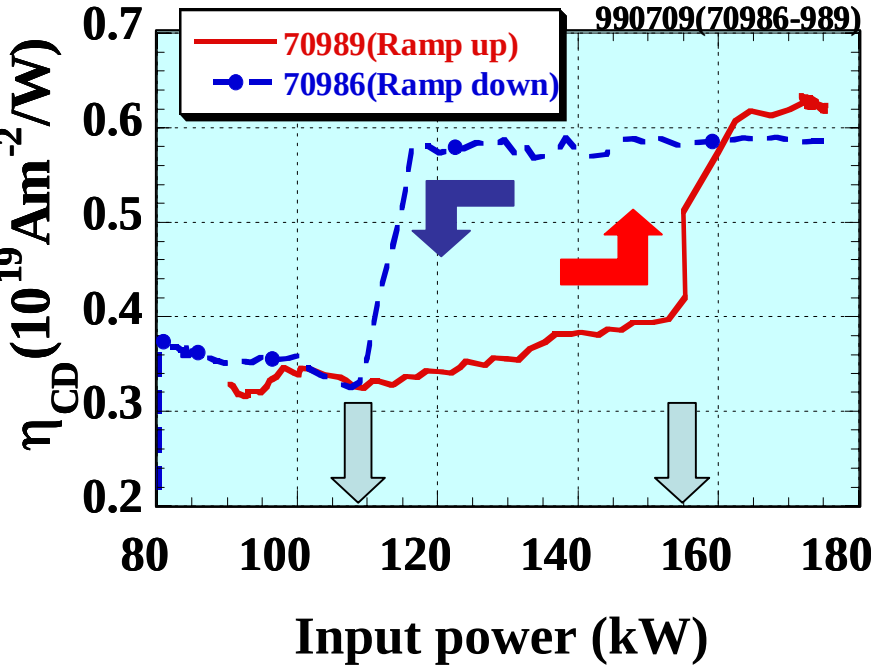


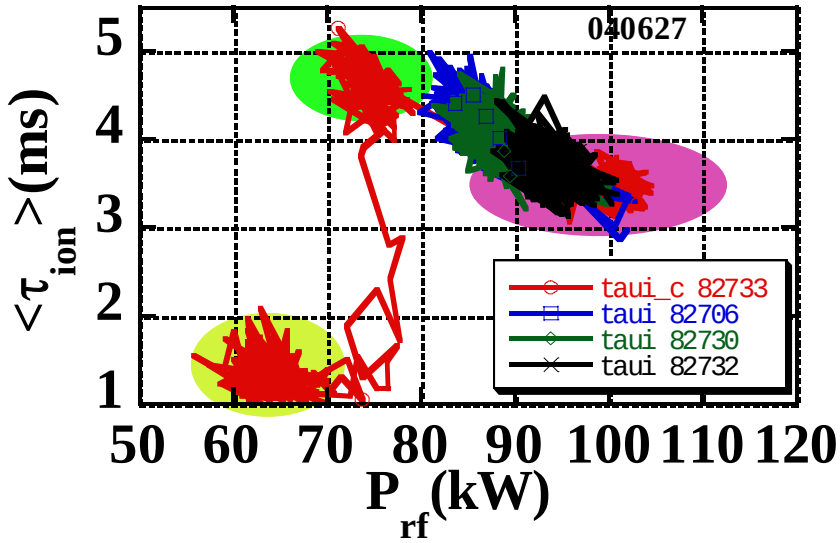


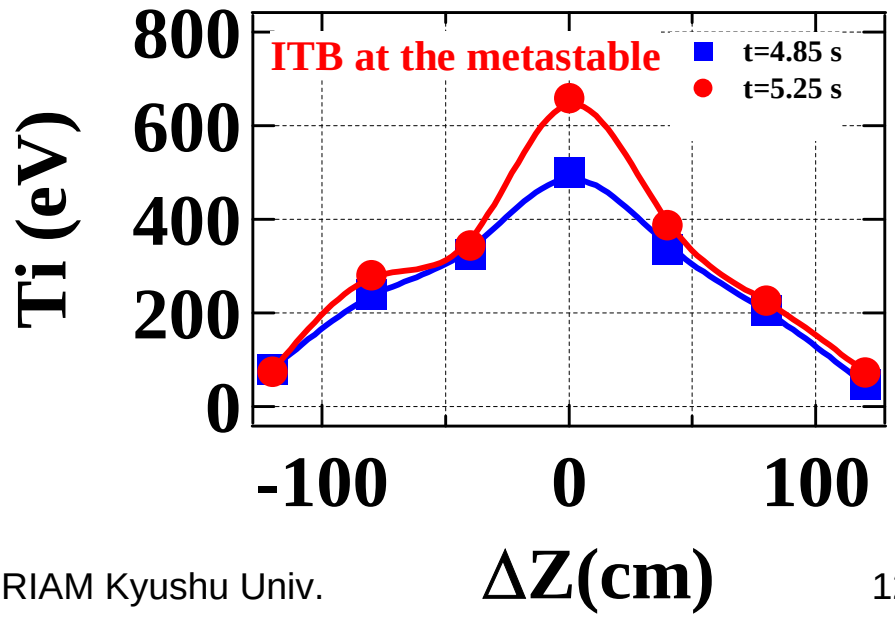
2. ITB formation /sustainment /collapse in SSTO

Hanada K. EX/P4-25

Ion ITB near the lower edge of the power hysteresis window





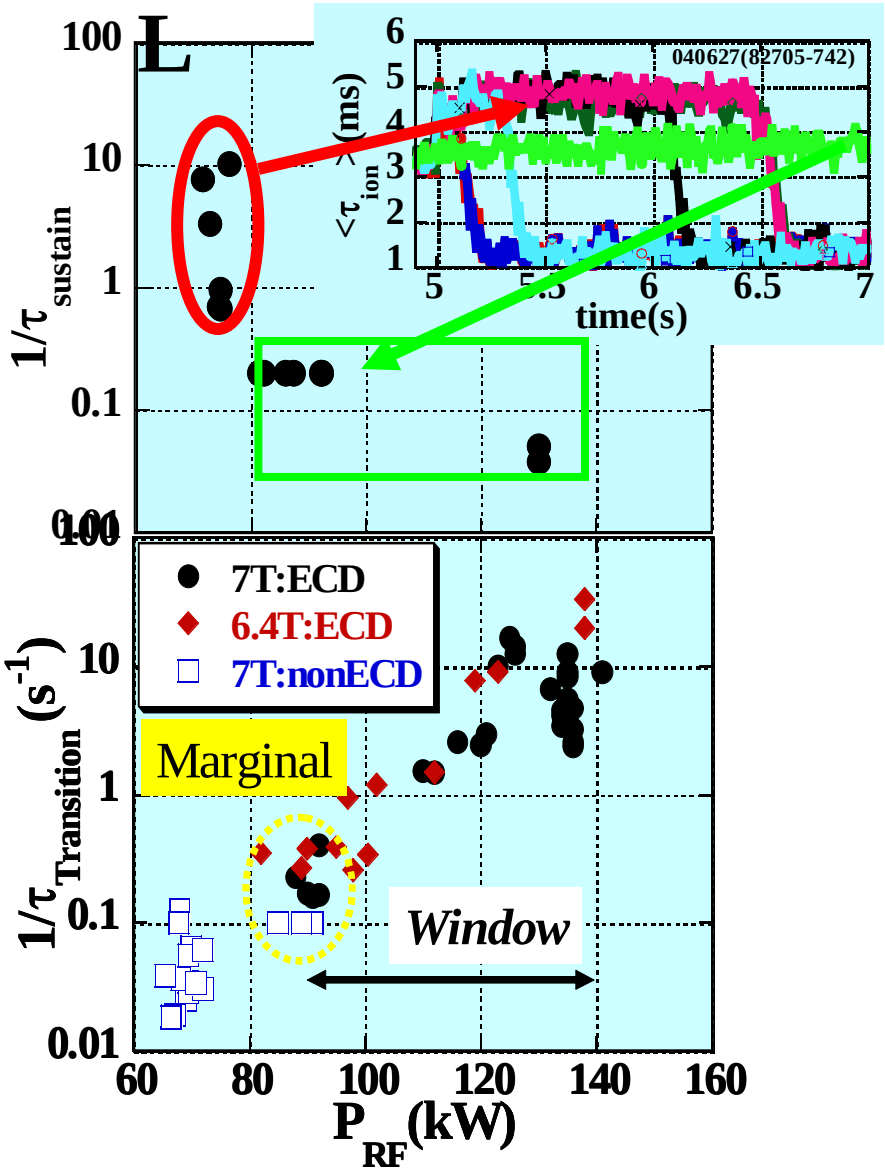


- Hysteresis window is observed even at dP/dt ~ 100W/10ms
- Pth(L=>ECD) > Pth(ECD=>L)
- <τ>ion=1.5<n>Ti(0)/Prf*Vp

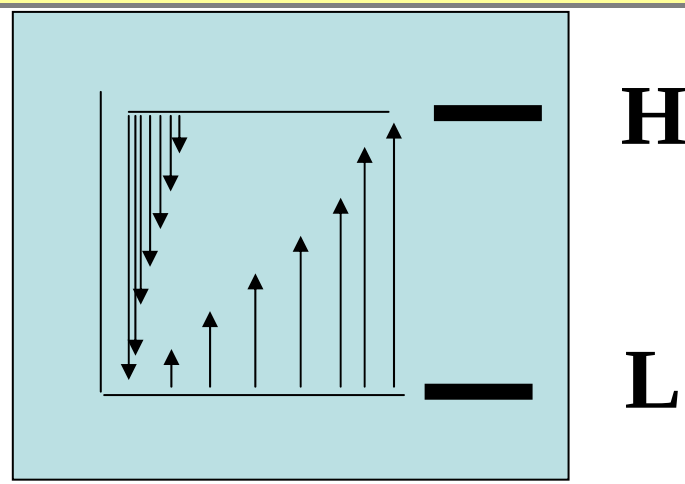
is used as a monitor of ion confinement property.

- 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.



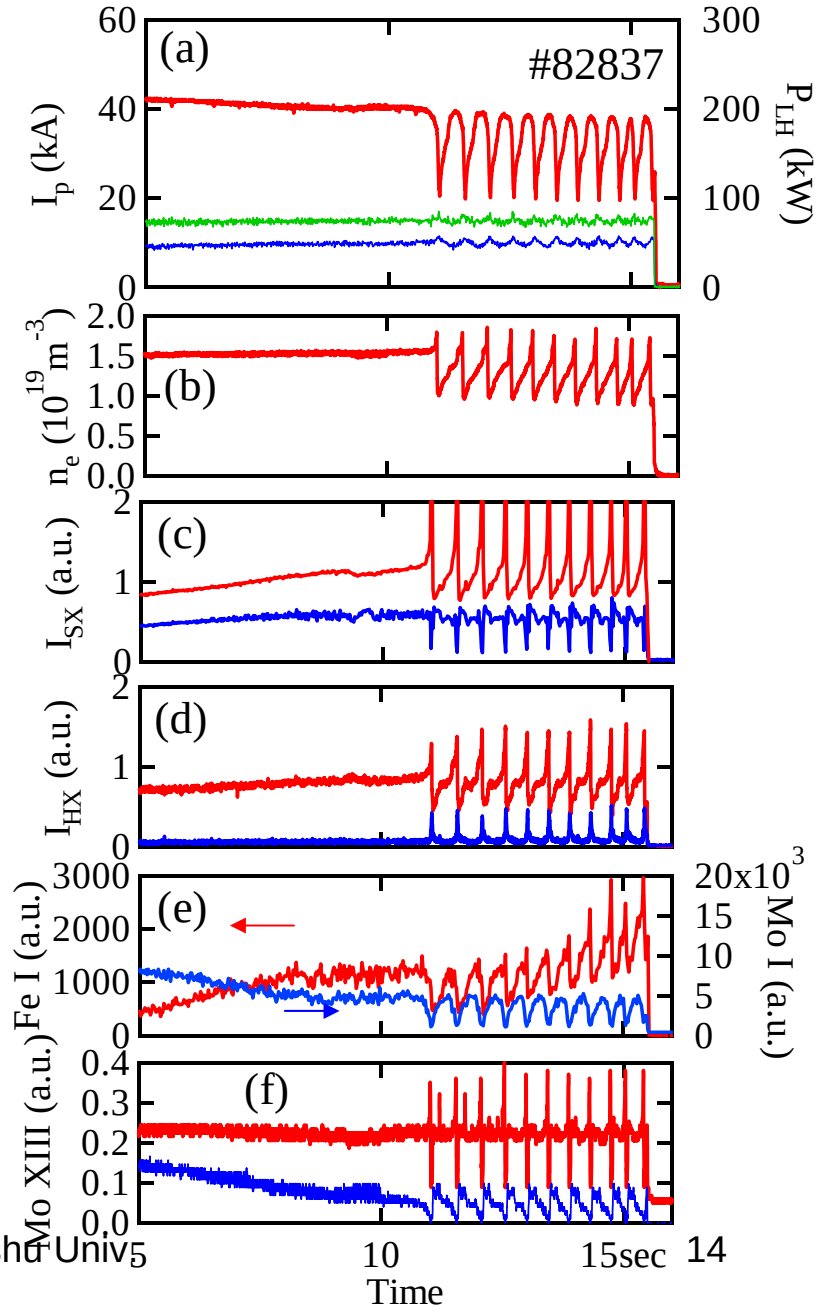
Sustainment & collapse of ITB

◆Combined $\Delta\Phi_{LH}$ (N||=1.8+N||>1.8) scenario is chosen to make a hollow $j_{LH}(r)$.

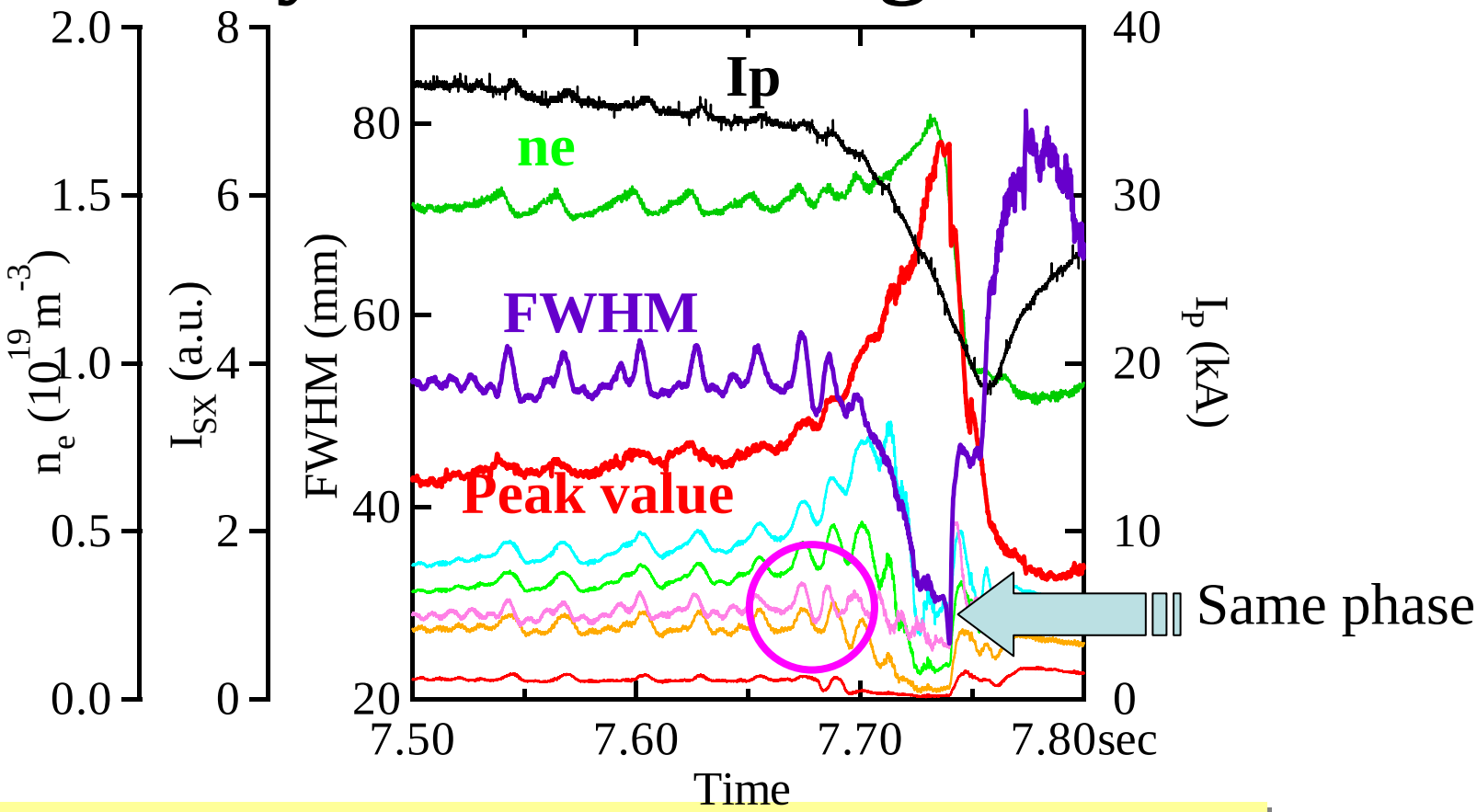
◆Self-organized slow sawtooth oscillations appear as an obstacle.

◆The periods of the oscillation is comparable to $\tau_{L/R}$.

◆Fe influx increases, though Mo is constant.



ITB dynamics during SSO



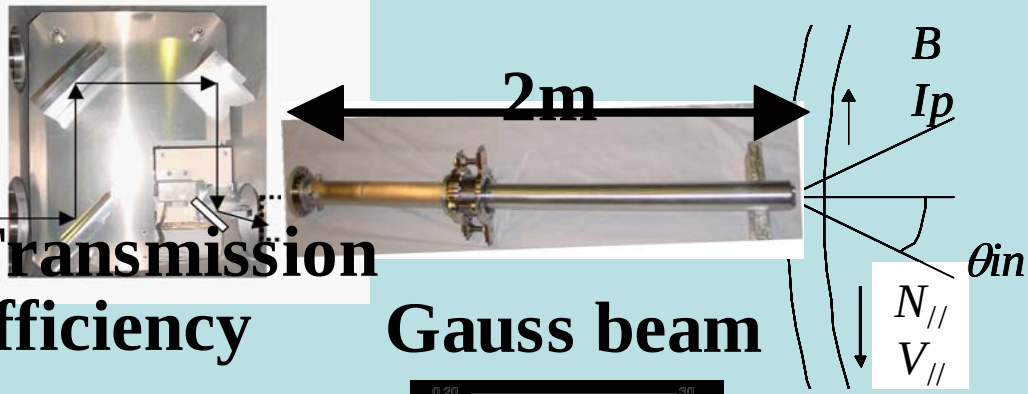
◆**m=0 type oscillations found on ne/SX signals before the crash, indicating radial oscillation of ITB foot.**

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

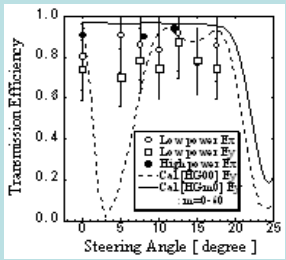
3. Off-axis CD by 1st X-mode

A steering antenna(<19°)

Injection system for ECCD

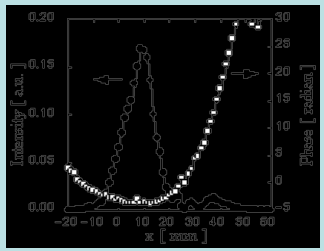


Transmission efficiency

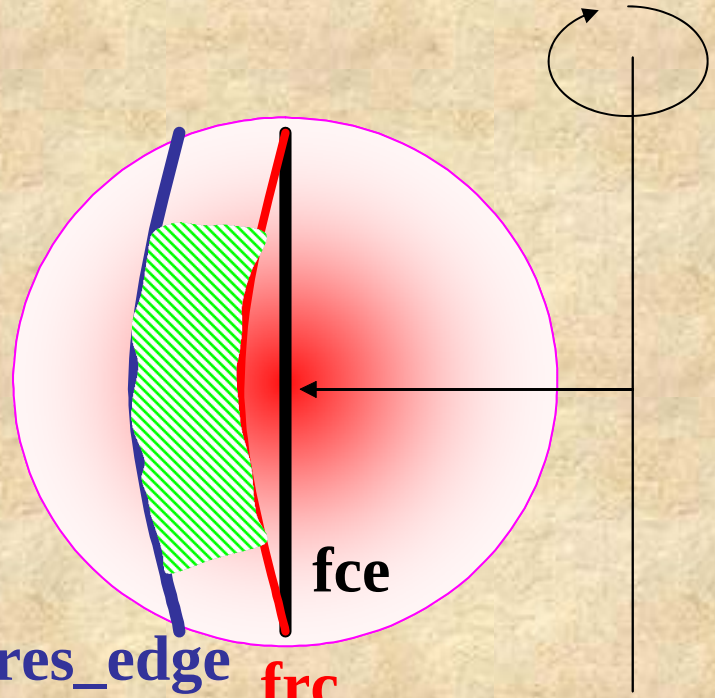


~0.95

Gauss beam



1/e~20mm



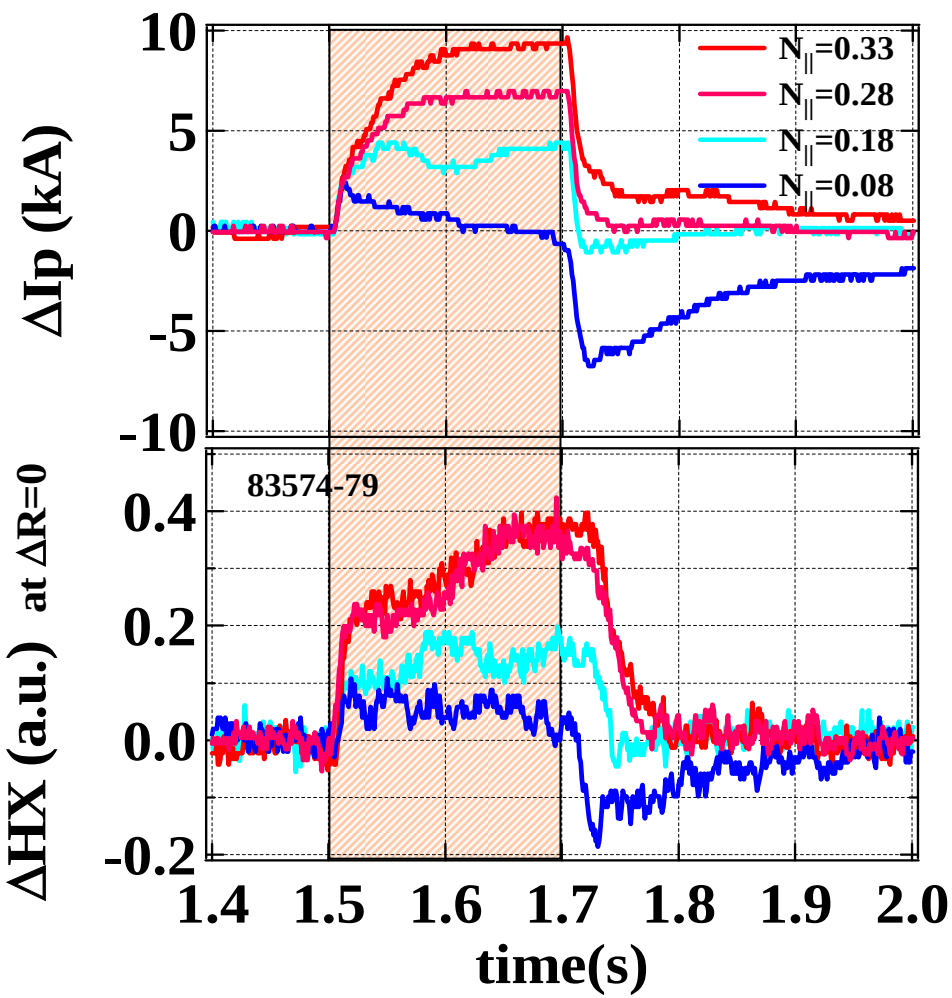
$$f = f_{ce} / \gamma + k_{\|} v_{\|}$$

: resonance condition

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

Idei H. PD 1/2

Oblique X-mode ECCD (coupled to energetic electrons)

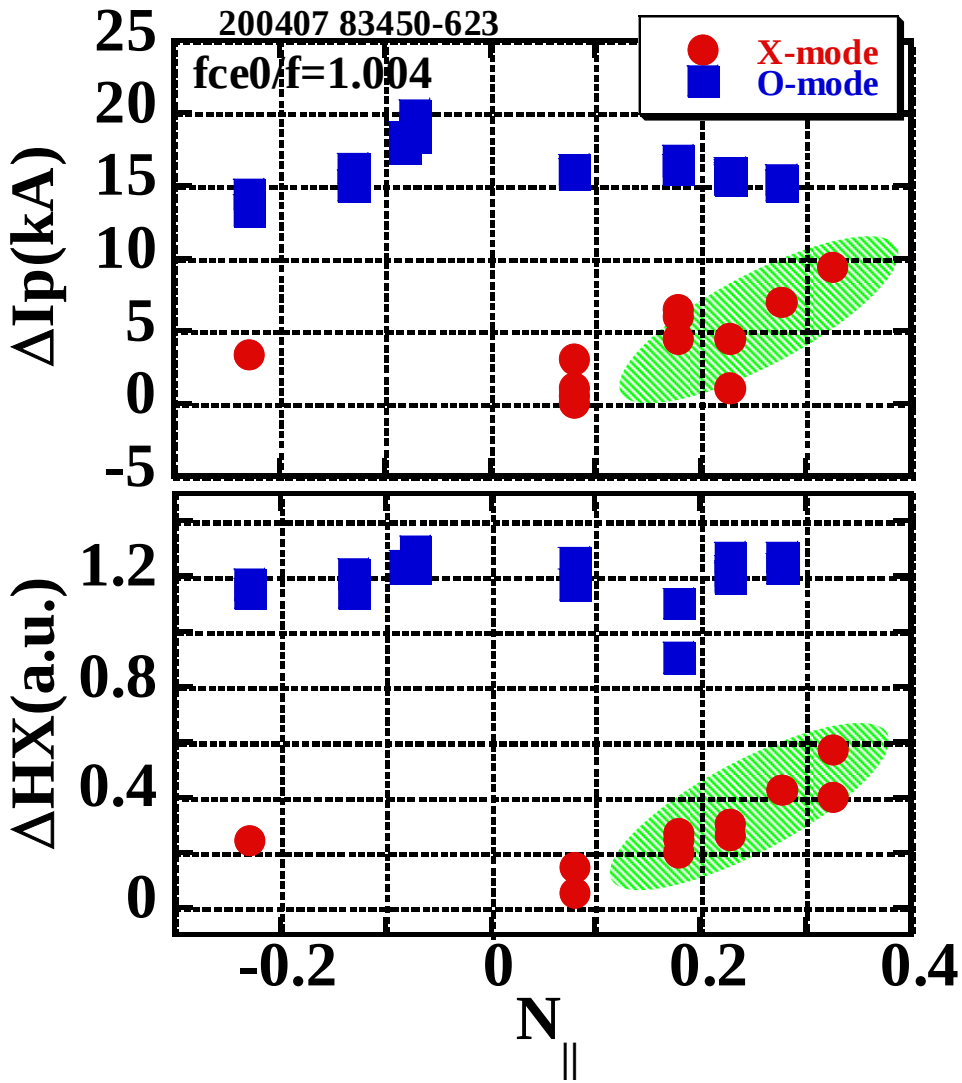


1) 100 kW 170 GHz
2) $f_{ce0}/f\sim1$, $n_e\sim0.8\text{-}1\times10^{19}m^{-3}$
3) Elliptically polarized X-mode are injected into LH plasmas at various angles.

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

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

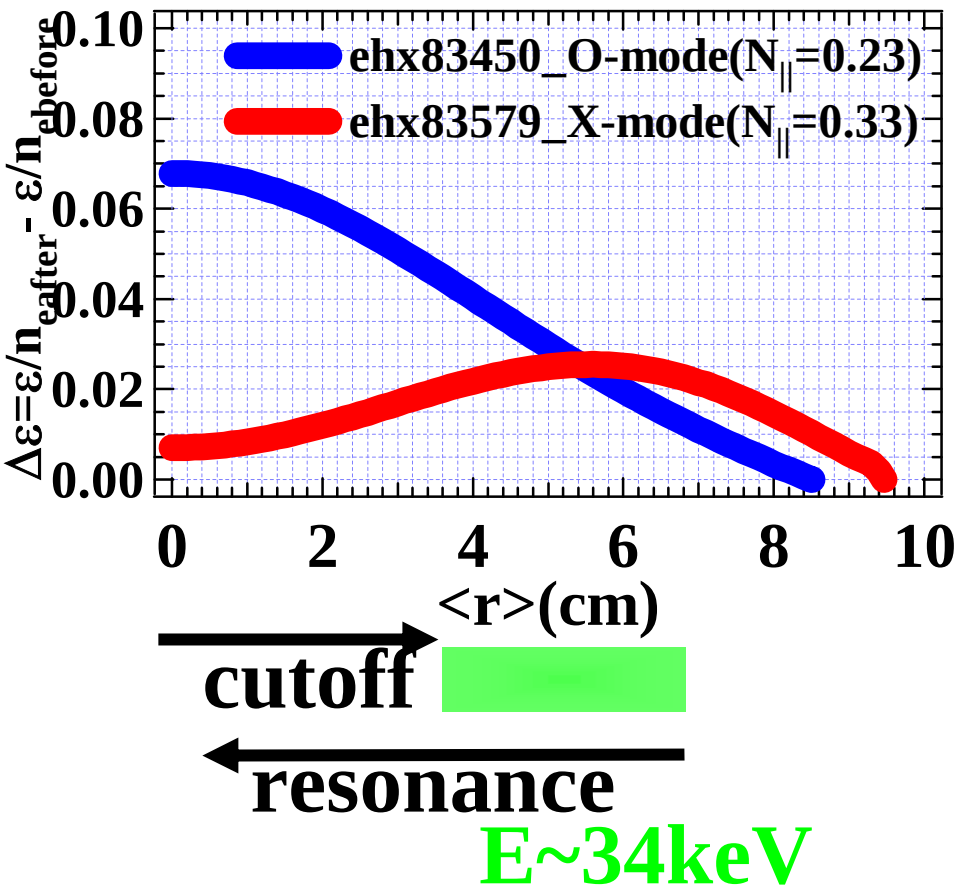
$N_{||}$ dependence of OX-ECCD



- 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~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.**