NTM Stabilization with ECCD in JT-60U
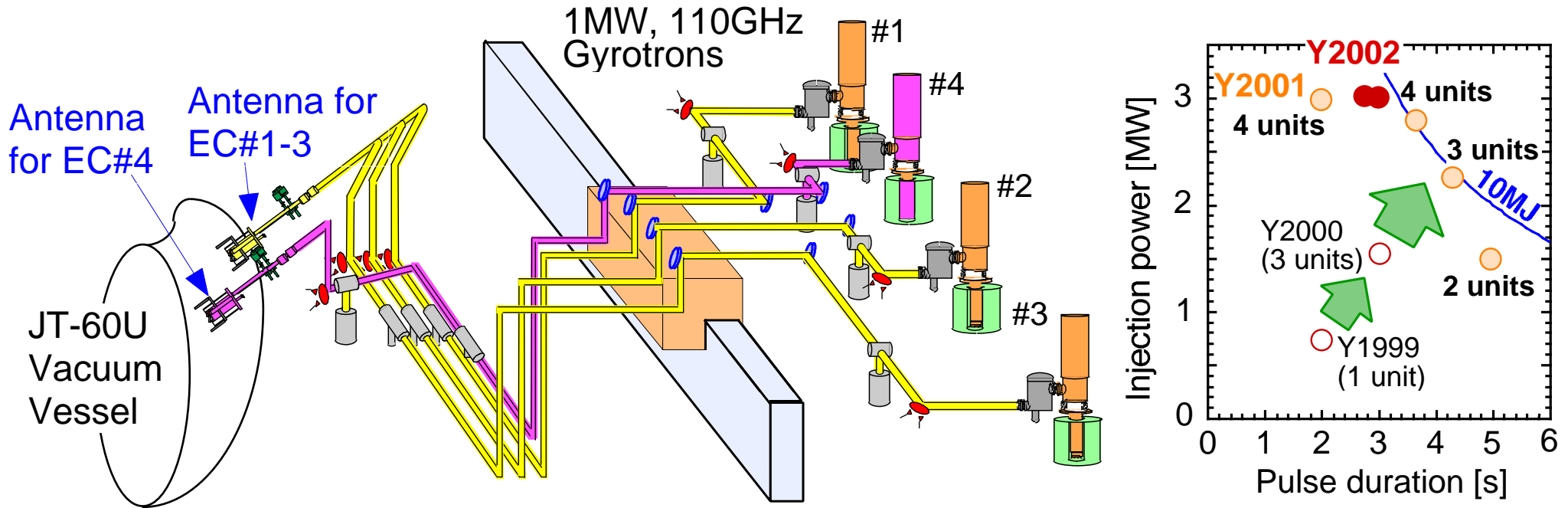
A.Isayama and JT-60 team
presented by T. Ozeki

Japan Atomic Energy Research Institute
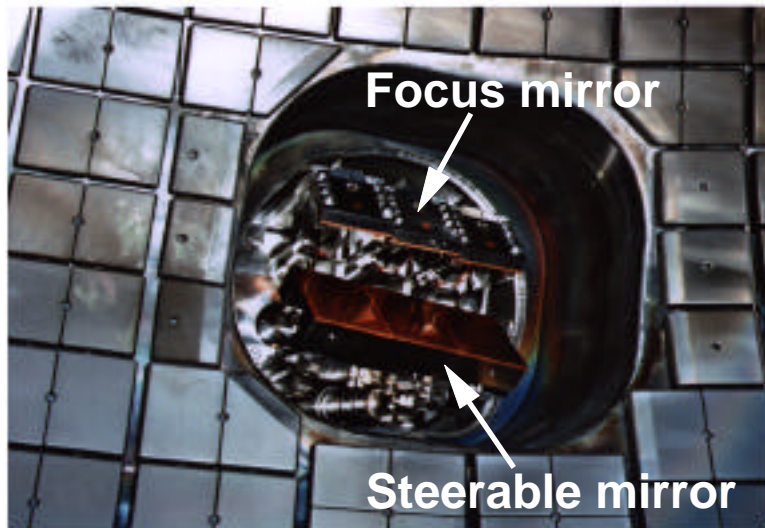**Naka Fusion Research Establishment**

ECRF System in JT-60U

1MW, 110GHz Gyrotrons

Antenna for EC#4

Antenna for EC#1-3

JT-60U Vacuum Vessel

#1 #4 #2 #3

Injection power [MW] vs Pulse duration [s]

Y2001 4 units
Y2002 4 units
3 units
10MJ
Y2000 (3 units)
2 units
Y1999 (1 unit)

Antenna for EC #1-3

Focus mirror

Steerable mirror

Antenna for EC #4

Rotatable

Focus Mirror

Steerable Mirror
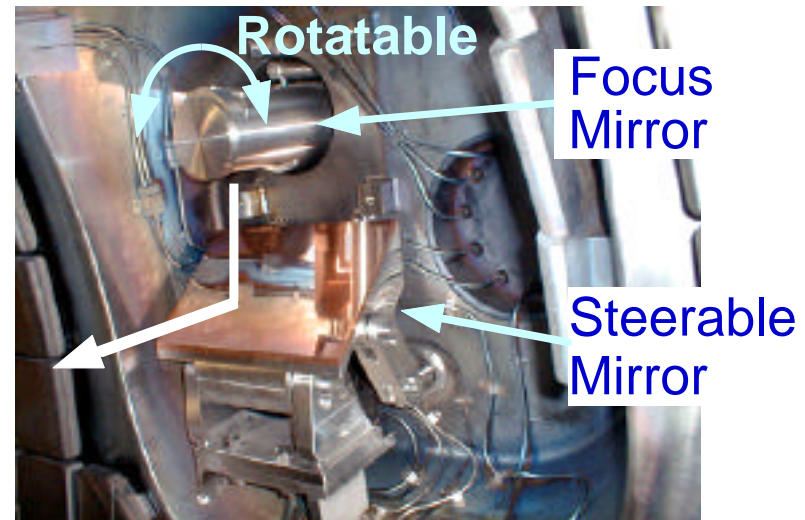
Real-time NTM stabilization system has been developed.

—————————————————————————— JT-60U ——

1. Coarse estimation of mode location ➡ 2. Fine tuning using $\tilde{T}_e$ profile ➡ 3. EC mirror steering

Z[m]

f_{EC}

Steering mirror

EC

ECE

2   3   4   R[m]

R_s

Real-time calculation of plasma shape with a given q-profile

M-shaped amplitude profile

[%]

R_s at step 1

5

$\tilde{T}_e / \bar{T}_e$

4

3

2

1

Local min.: island center

E41666(11.1s)
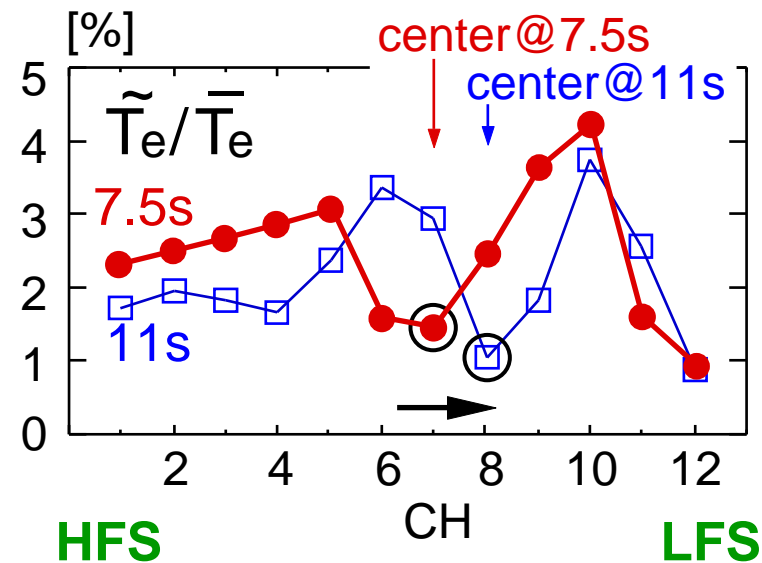
0
3.5   3.6   3.7   3.8
R [m]

EC

Steering mirror
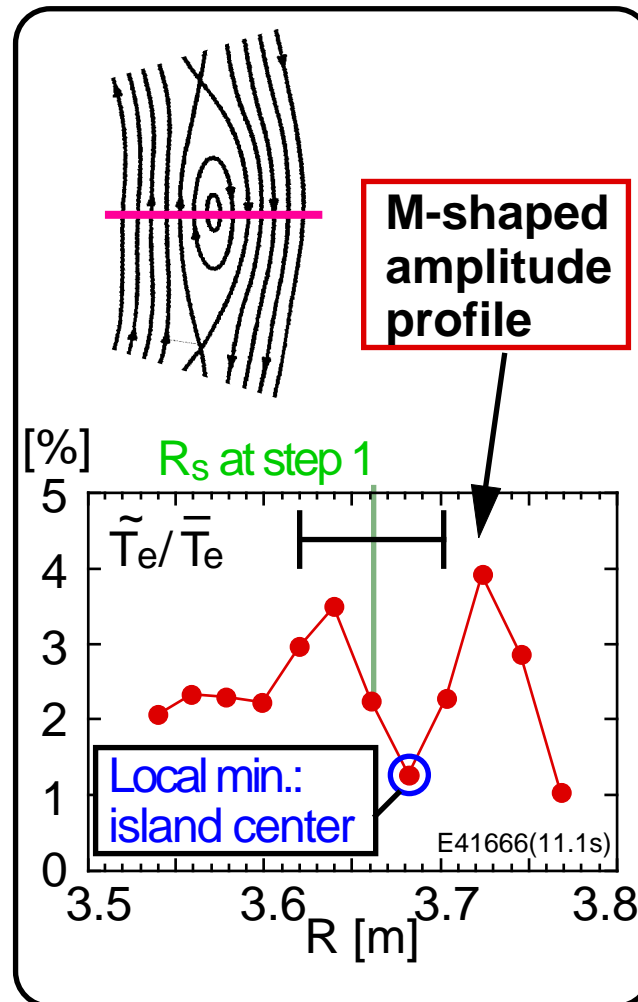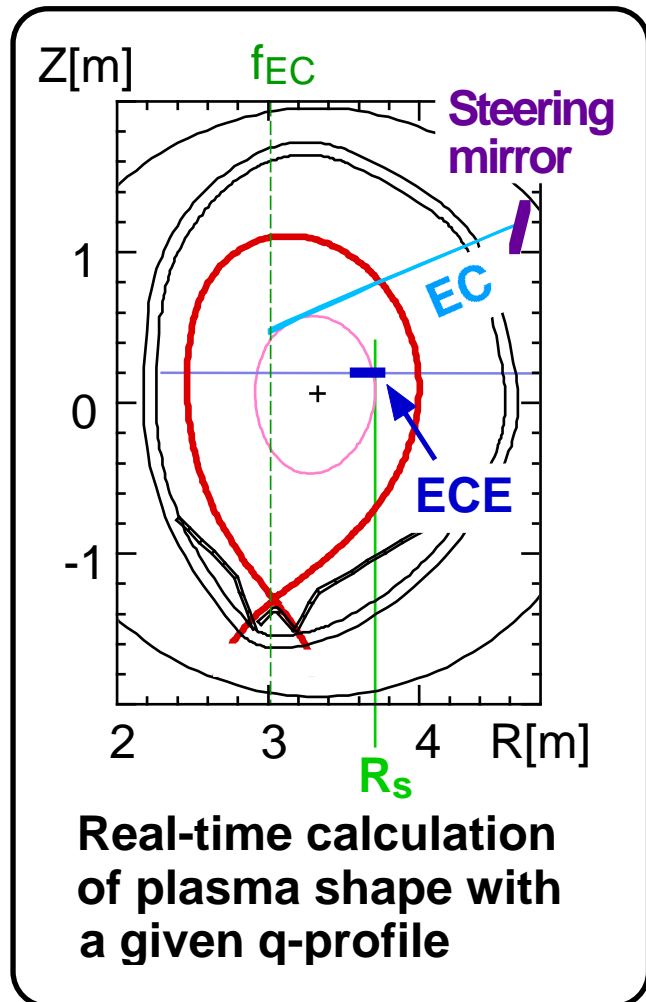
• Calculation: 10ms

• Mirror scan: $R_{dep}/ t \sim 10$cm/s

A 3/2 NTM at high beta (β_N=1.5, β_p=1.1) has been completely stabilized with the real-time system.
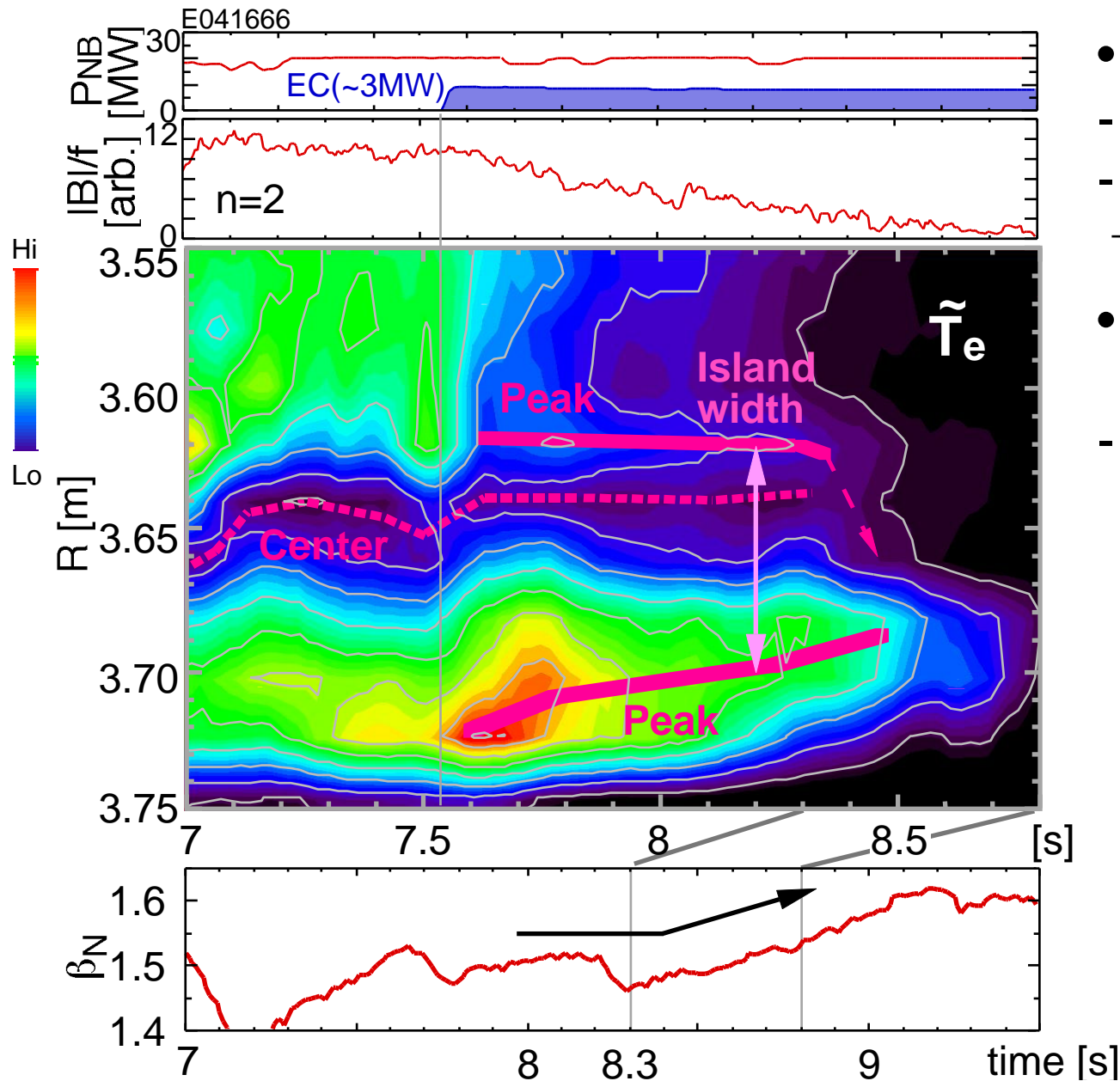
JT-60U

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I_p=1.5MA, B_t=3.7T, q_{95}=3.9
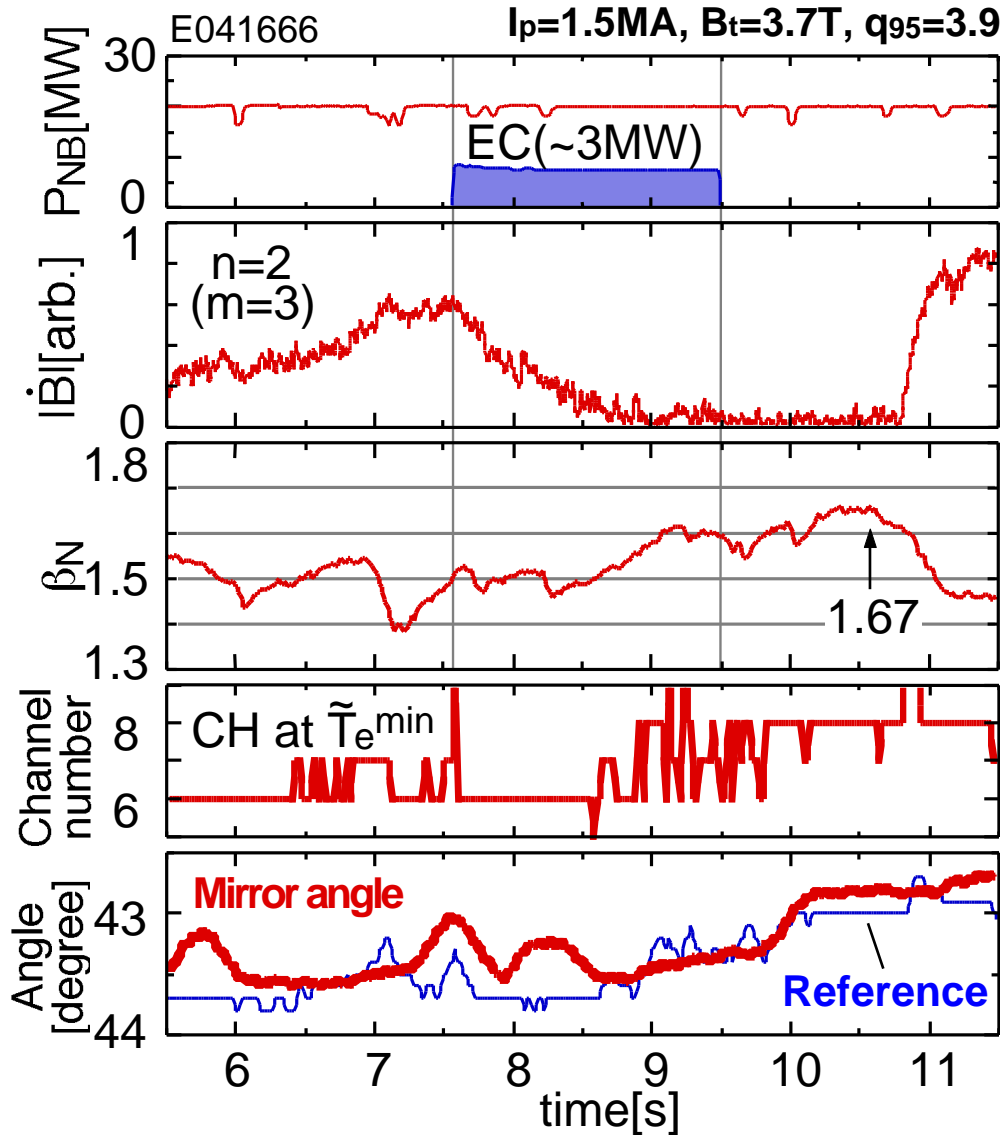
- **β_N increased** by the stabilization, and **even after the EC turn-off**
  → **Confinement improvement**
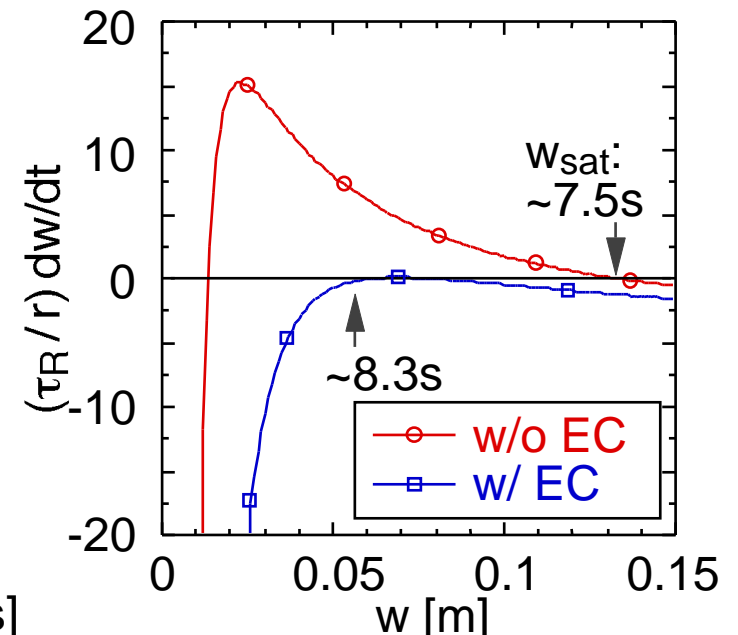 (H_{89}: 1.8 → 1.9; HH_{y2}: 1.0 → 1.1)

Perturbation decreases asymmetrically during the stabilization.

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- Just after the EC injection,
- $\tilde{T}_e$ at HFS: **decrease**
- $\tilde{T}_e$ at LFS: **increase**
  → **Asymmetry** ...future work

- Rapid decrease in island width at 8.3s:
- Consistent with the modified Rutherford eq.

Summary

Real-time NTM stabilization system has been upgraded and applied to experiment.

- Real-time plasma shape calculation & coarse estimation of mode location were implemented.

- Real-time NTM detection & mirror steering of EC injection were demonstrated.

- Complete stabilization of NTM in finite beta region was obtained.

- Increase in β_N and H-factor was achieved.

Stabilization process has been measured in detail.

- Rapid decrease in the island width after the slow decrease is consistent with the modified Rutherford equation.

- Asymmetry in electron temperature perturbation profile is remained as a future work.