

# (TG4) Plasma instability group report

Date: Oct.14, 2022 Time: 9:45 -18:45 Shot#: 180469-180629 (161 shots)

## Prior wall conditioning: No

Divertor pump: No Gas puff: H2, N2, Ne, Ar Pellet: No NBI#(1, 2, 3, 4, 5)=gas(H, H, H, H, H)=P(3.9, 3.7, 2.4, 2.6, 3.2)MW ECH(77GHz)=ant(5.5-Uout (or 1.5U), 2-OUR)=P(0.70, 0.79)MW ECH(154GHz)=ant(2-OLL, 2-OUL, 2-OLR)=P(0.72, 0.80, 0.83)MW ECH(56GHz)=ant(1.5U)=P(0)MW ICH(3.5U, 3.5L, 4.5U, 4.5L)=P(0, 0, 0, 0)MW Neutron yield integrated over experiment =  $1.4 \times 10^{13}$ 

## Topics

- 1. Sustainment of divertor detachment by using feedback control impurity seeding (S. Masuzaki)
- 2. High radiation fraction detachment with RMP application (M. Kobayashi)
- 3. Ion temperature measurement in detached plasma with impurity seeding (Y. Hayashi)
- 4. Anomaly detection of radiation profile in radiative collapse (K. Mukai)
- 5. Prediction and maintenance of detached plasma by data driven approach (Y. Isobe)

Oct. 18, 2022 (R. Seki on behalf of N. Kenmochi)

S. Masuzaki

# Sustainment of divertor detachment by using feedback control impurity seeding

- Shot #: 180469 180511 ( $R_{ax}$ ,  $B_{t}$ ,  $\gamma$ ,  $B_{q}$ ) = (3.65 m, -2.7123 T, 1.2538, 100.0%) Working gas: H2
- In the Rax=3.65m configuration, the stable full detachment without impurity seeding has been obtained. On 14 Oct., the Ne seeding exp. in the Rax=3.65m configuration was conducted.



# Some Ne seeding scenarios were examined.

Shot#	Preprogrammed Ne puff	Feedback controlled Ne puff	Additiona l ECH
180489	t=3.8-3.81s, 5.5L 5V, 3I 3.3V	off	off
180496	off	off	off
180508	off	t=3.8s-, 5.5L 5V 10ms 5Hz Vth=2.5V	on
180509	t=3.8-3.81s, 5.5L 5V, 3I 3.4V	t=4.0s-, 5.5L 5V, 10ms, 5hz, Vth=2.5V	on
180510	t=3.8-3.81s, 5.5L 5V, 3I 3.5V	t=4.0s-, 5.5L 5V, 10ms, 5hz, Vth=2.5V	on

- ✓ The largest degree of detachment (DoD) was ~ 1/3. (180489)
- ✓ Feedback control of Ne puffing with Isat signal was conducted.

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- ✓ In the cases of #180508, Isat was decreased slowly by the feedback-controlled Ne puffing.
- The combination of preprogrammed Ne puffing and feedback-controlled Ne puffing could reduce Isat rapidly and keep the decreased Isat.



Sustainment of divertor detachment by using feedback control impurity seeding

#### **Background & objectives:**

Feedback control system of detachment is being upgraded to use divertor probe signal as an input parameter in stead of a bolometer signal. In the experiments on 5 Oct., a bug was found in the ECH feedback system. In the present experiment, the performance of the system is checked again.

#### **Results:**

The divertor probe signal was processed in real-time with FPGA to extract ion saturation current (lis) from probe characteristics. Ne was injected with 5Hz until lis decreases below a threshold (2.5V). ECH was injected when lis decreases below 2.6V. A correct behavior was confirmed for the gas puff & ECH system.

Longer sustainment of detached plasma will be tried in next experiments in December by fine tuning of the input parameters.



#### Acknowledgements:

We would like to thank Mr. K. Nagahara & Y. Mizuno for the support of the preparation of the systems.

(S. Masuzaki, M. Kobayashi, Y. Hayashi)

# High radiation fraction detachment with RMP application (M. Kobayashi et al.)

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#### **Background and objective**

The recent experiments of X-point radiator in tokamaks (AUG, EAST, TCV etc) showed a stable high radiation detachment (~90%). W7-X island divertor has demonstrated a stable >90% radiation. Also in LHD, a stable high radiation fraction (60-90%) has been achieved recently with edge magnetic island. These results show a critical importance of the edge magnetic topology (X-point, island) on detachment operation as a common physics in both tokamaks and helical devices.

The present experiment conducts a systematic scan of impurity amount with Ne and Ar to investigate an impact of impurity species on detachment with RMP, and explore mechanisms of the phenomena.

#### **Experimental condition**

R<sub>ax</sub>=3.90 m, 2.54T, γ=1.254, Bq=100%, CCW, I<sub>RMP</sub>=3000A, H plasmas, ECH ~ 2MW. Impurity was puffed at 3.8 sec.

#### **Results (Ne)**

- With increasing Ne puff, Te decreases at the island, and P<sub>rad</sub> increases. The Te at ٠ outboard side shows significant drop accompanied by peaking of density profile inside island. This is a typical signature of thermal condensation instability (MARFE). As a result, radiated power effectively increases, since  $P_{rad} =$  $c_{imp}n_e^2L(T_e).$
- When the MARFE occurs, decay time of P<sub>rad</sub> becomes infinity, implying Ne is • effectively confined in the island, and in-out pressure imbalance is clearly observed. 1500
- The pressure imbalance inside the island suggests an existence of flow from inboard to outboard side, which may effectively confine Ne at the MARFE location (?).
- Maximum radiation is ~68%.





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## High radiation fraction detachment with RMP application (M. Kobayashi et al.)

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#### Results (Ar)

- In the case of Ar, Te at the island is "locked" to 80eV against the Ar puff scan, and pressure is balanced between in and outboard side.
- Radiated power increases gradually, but decays time seems similar for Ar puff amount. Maximum radiation is ~ 50%.

The results indicate that temperature dependence cooling function (impurity species) plays an important role to trigger thermal condensation (MARFE) at the island and to enhance radiation.

Spectroscopic data will be analyzed to investigate relevant atomic process in this phenomena.



Ion temperature measurement in detached plasma with impurity seeding Y. Hayashi, T. Sugiyama, S. Masuzaki

#### **Background and objective**

- To investigate the energy balance between ions and electrons in detached plasma with impurity seeding, Ti measurement by ion sensitive probe was performed.

#### **Experimental condition**

- #180469 ~ #180629 (Piggyback)
- $(R_{ax}, B_{t}, \gamma, B_{q}) = (3.65 \text{ m}, -2.712 \text{ T}, 1.254, 100\%)$
- $(R_{ax}, B_{t}, \gamma, B_{q}) = (3.90 \text{ m}, -2.538 \text{ T}, 1.254, 100\%)$
- NBI #1-5
- $n_{\rm e, \ bar} \sim 1-5 \ {\rm x} \ 10^{19} \ {\rm m}^{-3}$
- Divertor pumping: OFF
- Gas: H, Ne, Ar

#### <u>Results</u>

- Ti could not analyzed due to the problem on the circuit.
- Te and ion particle flux at divertor leg were analyzed.

- Particle flux showed the slight reduction at the peak position, indicating detachment by Ne seeding, while Te did not show significant difference between two discharges.



Position [mm]

# Anomaly detection of radiation profile in radiative collapse K. Mukai

#### **Background and objective**

- Investigation of precursor radiation structure of radiative collapse (RC)
- Investigation of magnetic configuration dependence of the precursor

#### **Experimental condition**

- #180512 ~ #180543 (32 shots)
- $(R_{ax}, B_t, \gamma, B_q) = (3.60 \text{ m}, -2.75 \text{ T}, 1.254, 100\%),$ (3.90 m, -2.5384 T, 1.254, 100%)
- NBI #1, 2, 4, 5
- $n_{\rm e, \ bar}$ : ramped-up to ~ 14 x 10<sup>19</sup> m<sup>-3</sup>
- Divertor pumping: OFF
- Gas: H (5.5-L, FB crtl. by FIR)

#### <u>Results</u>

- 2-D radiation profiles were obtained using IRVBs at 6.5-U (100 Hz) and L (50 Hz).
  3.6 m: 8 (w/ RC) and 8 (w/o RC) shots
  3.9 m: 4 (w/ RC) and 5 (w/o RC) shots
- Anomaly detection will be conducted using AutoEncoder, AnoGAN etc...
- FTS was performed with event trigger to measure the time evolutions of  $n_{\rm e}$  and  $T_{\rm e}$  profiles just before the RC, although the laser power is not sufficient unfortunately.
- Data in previous experiments will be mined.
- Similar experiment with CW polarity will be conducted on Dec. 21, 2022.



#### FOV of 6.5-U IRVB



# Prediction and maintenance of detached plasma

# by data-driven approach (Y.Isobe, H.Yamada (UTokyo), M.Kobayashi et al.)

### **Background and objective**

- To aim at quantitative clarification of the boundary condition between attachment and detachment by datadriven approach and then to provide hints to exploration of underlying physics of plasma detachment.
- Fulfilling data with CIII (missing due to saturation in the previous exp.)

## **Experimental Condition**

- R<sub>ax</sub>=3.9m, B=-2.54T, I<sub>LID</sub>=1220–3300A
- Seek for transition boundary with surveying RMP amplitude, power scan and ramping up density

## <u>Results</u>

- Dataset has been extended including CIII
- See typical discharges with detachment

## <u>Scope</u>

- Revision of analysis based on extended dataset
- Investigation of anomaly detection by PCA including CIII data

