(TG4) Plasma instability group report

Feb. 15, 2022 (N. Kenmochi)

Date: Feb.10, 2022
Time: 9:45 - 11:15, 15:45-18:45
Shot#: 178734-178763 (30 shots), 178842-178903(62 shots)

Prior wall conditioning: No
Divertor pump: On except for 2-I
Gas puff: H2, N2, Ne, Ar, Kr, Pellet: No
NBI#(1, 2, 3, 4, 5)=gas(H, H, H, H, H)=P(2.0, 1.2, 1.8, 0, 0)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 = $7.4 \times 10^{10} + 5.1 \times 10^{10} = 1.3 \times 10^{11}$

Topics

1. Investigation of divertor detachment using superimposed impurity seeding (K. Mukai)
2. Feedback control detachment with ECRH and impurity gas puf (M. Kobayashi)

Divertor detachment using superimposed impurity seeding

K. Mukai

Background and objective

- Stable divertor detachment was observed in Ne+Kr superimposed seeding with short-pulse NBI for 1 s. [K. Mukai *et al*., NF 2021]
- Sustainment of the Ne+Kr seeding detachment using feedback control of Ne seeding and divertor pumping with long-pulse NBI.

Experimental condition

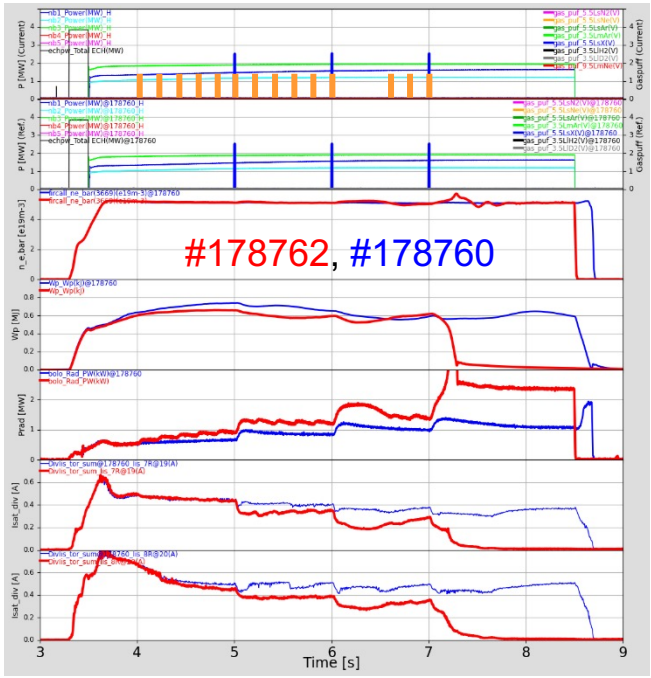
- #178734 ~ #174762 (29 shots)
- (R_{ax}, B_t, γ, B_q) = (3.60 m, -2.75 T, 1.254, 100%)
- NBI #1-3 ($P_{NBI,\ port}$ ~ 5 MW)
- $n_{e,\ bar}$ ~ 1, 5 x 10^{19} m^{-3}
- Divertor pumping: ON
- Gas: H (5.5-L, FB crtl. by FIR), Ne (3-I, FB crtl. by P_{rad}),
  Kr (3.5-L (~ #178746), 5.5-L (~ #178762), pre-programed)

Results

- Toroidally symmetric reduction of $I_{sat,\ div}$ was observed for 2 s with Ne+Kr seeding in both $n_{e,\ bar}$ cases.
- Further $I_{sat,\ div}$ reduction from Ne only or Kr only seeding was observed using Ne+Kr seeding especially in higher $n_{e,\ bar}$ case.
- In the case of Kr only seeding, decay time of P_{rad} in higher $n_{e,\ bar}$ case was much longer than that in lower $n_{e,\ bar}$ case although injected Kr amount in higher $n_{e,\ bar}$ case was half of lower $n_{e,\ bar}$ case.
- The $n_{e,\ bar}$ dependence of impurity transport can affect to the difference of the further $I_{sat,\ div}$ reduction.

$n_{e,\ bar}$ ~ 5 x 10^{19} m^{-3} #178762
Ne: 10 ms (5 Hz, FB), Kr: 5 ms x 3

#178760
Kr: 5 ms x 3



$n_{e,\ bar}$

W_p

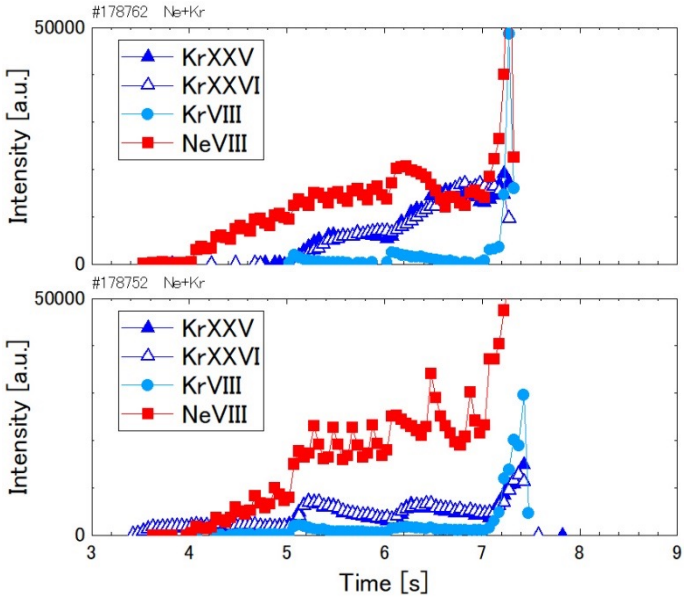
P_{rad}

$\Sigma I_{sat,\ div}$ @7R

$\Sigma I_{sat,\ div}$ @8R

#178762 (Ne+Kr)
$n_{e,\ bar}$ ~ 5 x 10^{19} m^{-3}

#178752 (Ne+Kr)
$n_{e,\ bar}$ ~ 1 x 10^{19} m^{-3}

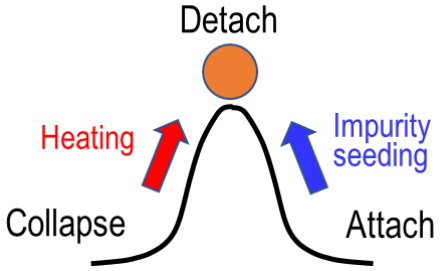


Feedback control of detachment with ECRH and impurity gas puff

M. Kobayashi

Background/objectives:

- In LHD, **stable detachment sustainment is difficult** except for the cases with RMP application.
- **Feedback control system of Impurity gas puff and ECH injection has been developed** since 21st cycle to realize stable detachment without RMP. In 22nd cycle, feedback impurity puff system with SSGP was developed, but it was not successful (report on 2, 12 Feb. 2021).
- In 23rd cycle, feedback impurity puff with normal puff (5.5L, 3.5L etc) has been developed. This experiment aims at **testing the new system and at sustainment of detachment combined with ECH feedback system**.



2 control knobs needed: Impurity & heating

Results: R_{ax}=3.90m, 2.54T, CCW, γ=1.254, B_q=100%

- The system reads bolometer signal in real-time and puffs impurity with10Hz until radiated power exceeds a certain threshold. This is demonstrated in Fig.1 with Ne puff from 5.5L. Quick response of radiation against Ne puff is obtained. (This was not possible with SSGP.)
- **The detachment was sustained until the end of NBI heating for > 3 sec. The divertor particle flux decreases at all toroidal sections.**
- Gradual increase of radiated power is obtained by increasing the threshold step by step. The radiation collapse occurs at more than 40% radiation power.

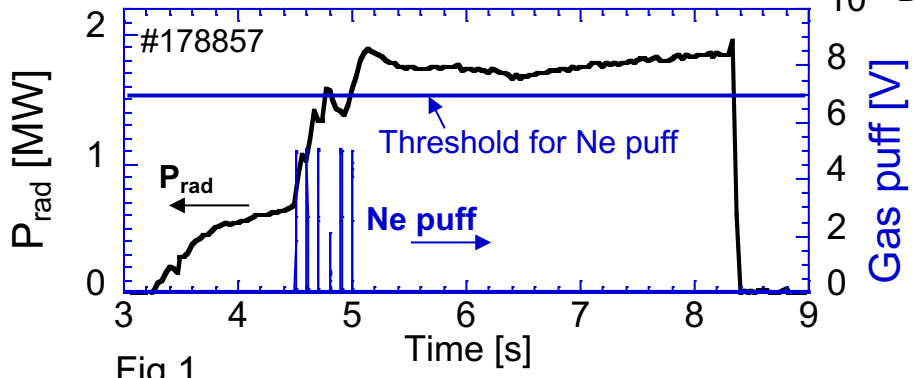


Fig.1

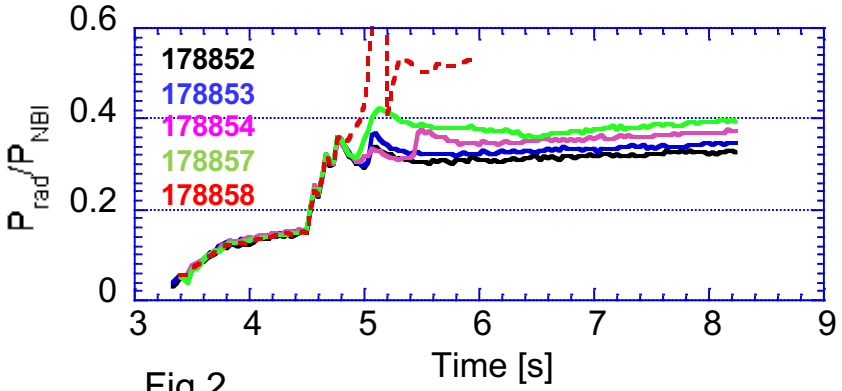
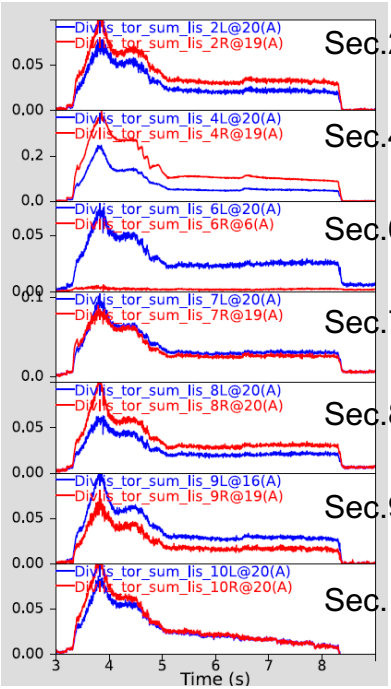


Fig.2

Divertor particle flux (#178857)



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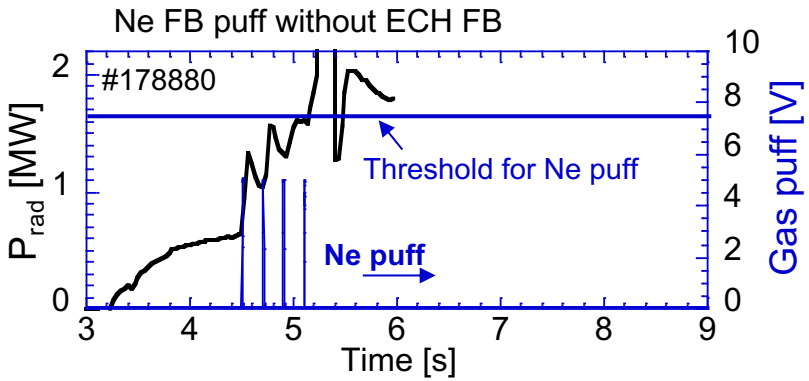
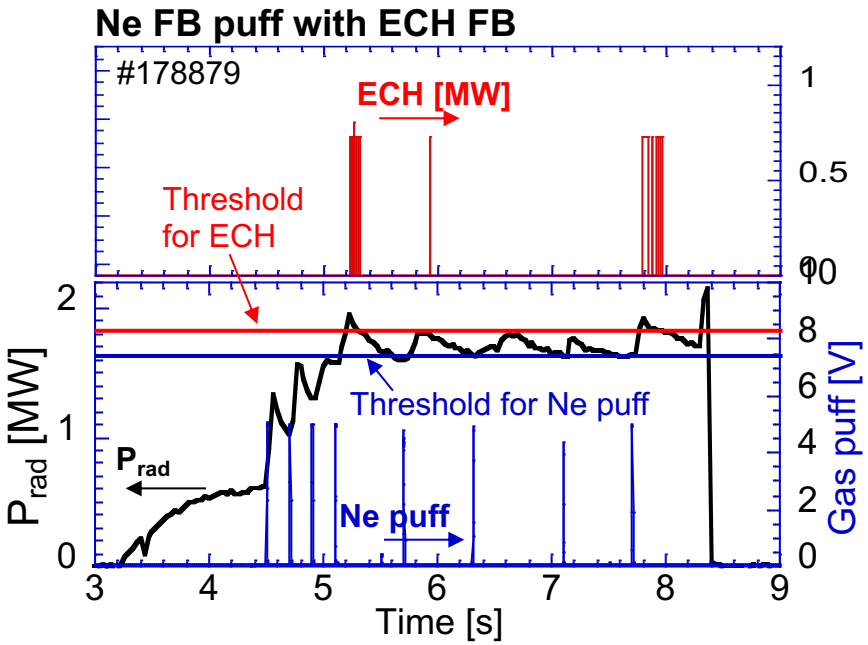
Feedback control of detachment with ECRH and impurity gas puff

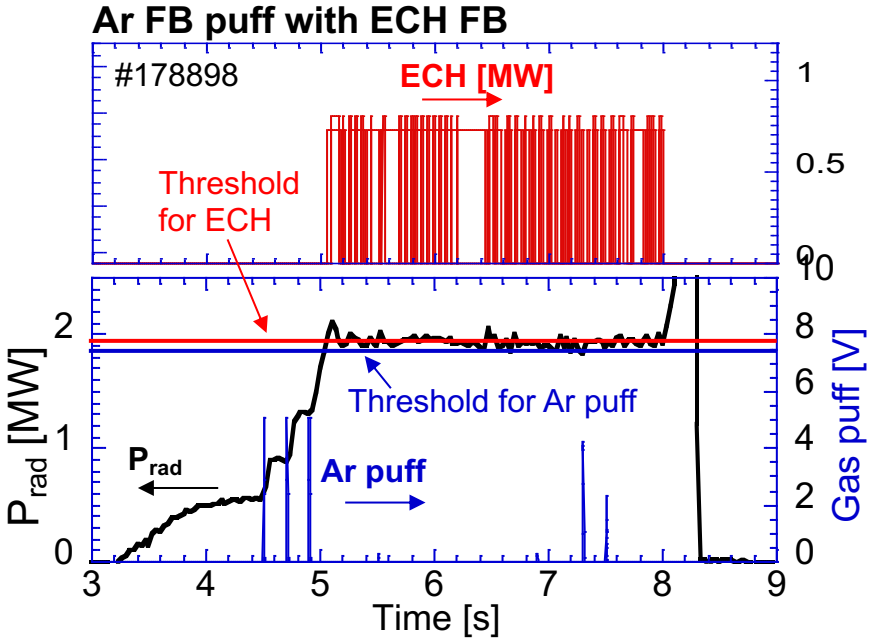
M. Kobayashi

- **The impurity FB system is combined with ECH FB injection** to sustain detachment. Ne is puffed until Prad exceeds a threshold (blue line), while ECH is injected when Prad exceeds threshold (red line) to avoid radiation collapse. **A stable detachment control was demonstrated (#178879) for more than 3 sec.**
- Without ECH FB injection, the radiation collapse occurs (#178880).

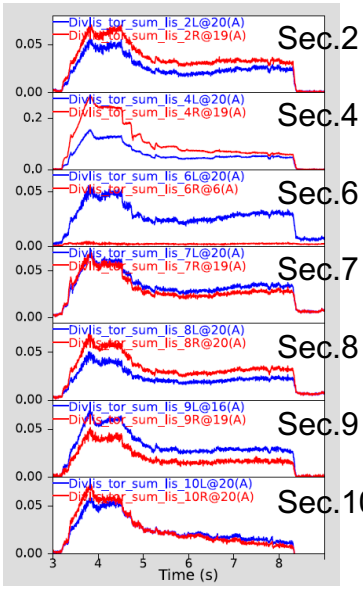


- Similar operation with Ar puff was attempted. **A stable detachment control with Ar was realized.**
- The achieved **steady-state radiated power is higher in Ar (~42%) than Ne (~36%).**
- In both cases, divertor particle flux decreases at all toroidal sections

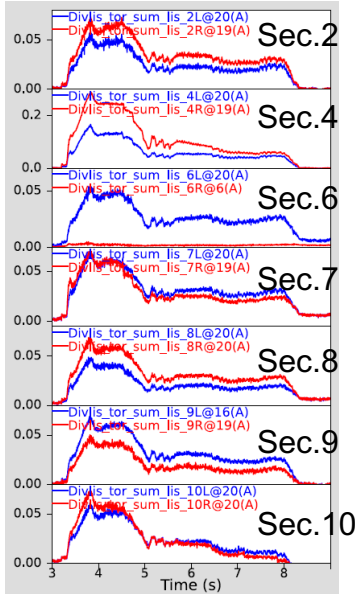




Divertor particle flux



Divertor particle flux



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Feedback control of detachment with ECRH and impurity gas puff

M. Kobayashi

- If we try to go beyond 40% radiation, **divertor re-attachment occurs** (t = 6 - 7 sec) due to excess in ECH power.
- Feedback loop to cause re-attachment:
  With ECH injection, edge Te recovers, but total radiation increases due to increase of total input power
  → ECH injection is kept → divertor reattaches

- **Divertor particle flux has to be used as input parameter of feedback control to avoid this issue.**

- Spectroscopy data will be analyzed for further understanding of the detachment control.

Many thanks:
To Mr. Y. Mizuno, Mr. K. Nagahara for developing the programs for ECH & gas puff system,
To Dr. T. Tsujimura, Dr. Y. Yoshimura, Dr. N. Kenmochi for ECH operation,
To Dr. K. Mukai and Dr. B.J. Peterson for providing the bolometer signals.