(SG2, TC) Session Report

June 18, 2024 (T. Kobayashi)

Date: June 14, 2024
Time: 10:30 – 16:45
Shot#: 193272 – 193391 (120 shots)
Prior wall conditioning: He
Divertor pump: On
Gas puff: H_2, Ne, Ar
Pellet: -

NBI#(1, 2, 3, 4, 5) = gas(H, H, H, H, H)=P(2,1.9,1.9,4.3,2.8) MW
ECH(77GHz) = ant(1.5-Uo, 5.5-U, 2-OUR)=P(0.337,0.38,0.389) MW
ECH(154GHz) = ant(2-OLL, 2-OUL, 2-OLR)=P(0.58, 0.606, -) MW
ICH(3.5U, 3.5L, 4.5U, 4.5L) = P(-, -, -, -) MW

Topics

1. Study of MHD equilibrium, global stability and transport phenomena in an LHD plasma with zero rotational transform layer (K. Toi)
2. Real-time plasma control using turbulence level signal (H. Sakai)
3. Real-time plasma control under low-turbulence conditions focusing on turbulent transition (T. Kinoshita)
4. Effect of boron powder injection on density limit (F. Nespoli, K. Tanaka)

Study of MHD equilibrium, global stability and transport phenomena in an LHD plasma with zero rotational transform layer

K. Toi (Professor emeritus, NIFS), K. Ogawa

LHD experiment summary on 16 June 2024

Shot#: 193276-193310 (35 shots incl. NBI calibration shots)

Experimental conditions:

(R_{ax}, Polarity, B_t, γ, B_q) = (3.60 m, CW, 1.3 T, 1.2538, 100.0%)

Purpose: To study the characteristics of MHD equilibria, global stability and plasma transport in *LHD plasmas with zero-rotational transform* generated by strong counter NBCD and compare them with the *current clamping phenomena* in the *tokamak "current hole"*.

Results (see Figs.1 and 2):

- The achieved maximum current is ~125 kA, which is appreciably lower than the required target value of 150kA. Because of the limitations of P_{NB} and E_{beam} in 5-second operation, plasmas with zero-rotational transform were not produced in the experiments.
- n=0 mode is excited as same as the past experiment. It is thought to be the global Alfven eigen mode(GAE). Time evolution of ι_{min} can be estimated from the mode frequency. The mode frequency reaches the lowest value (~20 kHz) during the forced current ramp-down by co-NBCD. The mode is also detected by HIBP.
- Characteristic evolutions of Te and ne profiles are observed during the plasma current evolution.
- CXRS diagnostics yielded profiles of Ti, Vt, Vp and neon ion densities under limited plasma conditions of Ip ~ 75 kA, because of the electron density rises due to #4 and #5 NBI.

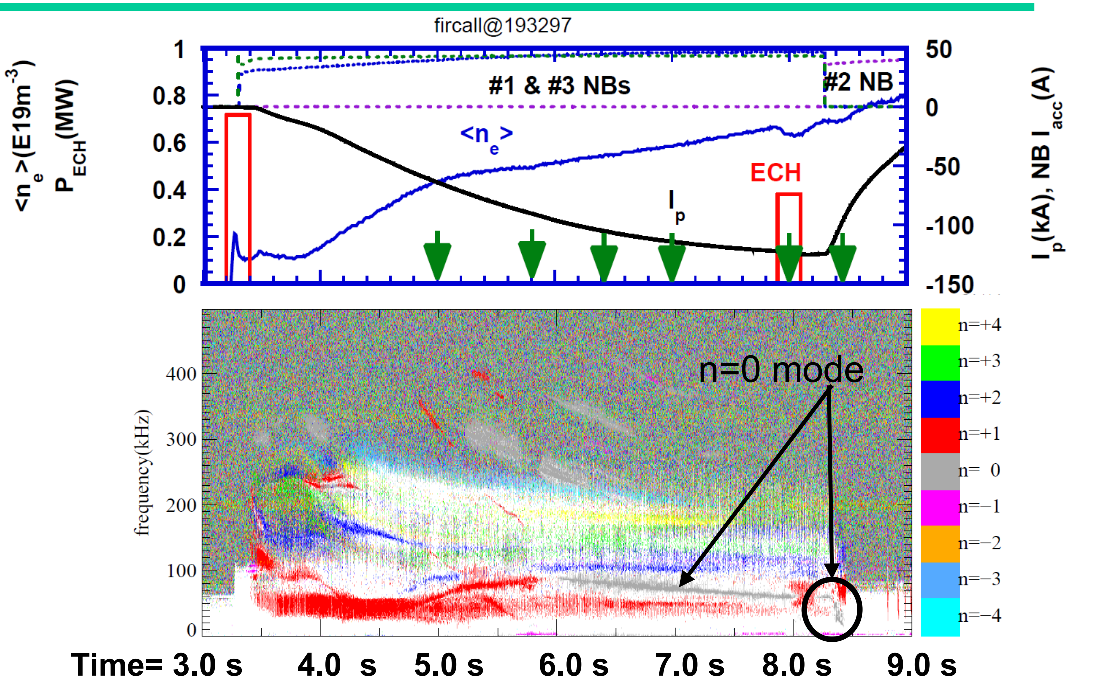


Fig.1 (upper)discharge waveform, (lower) toroidal mode number

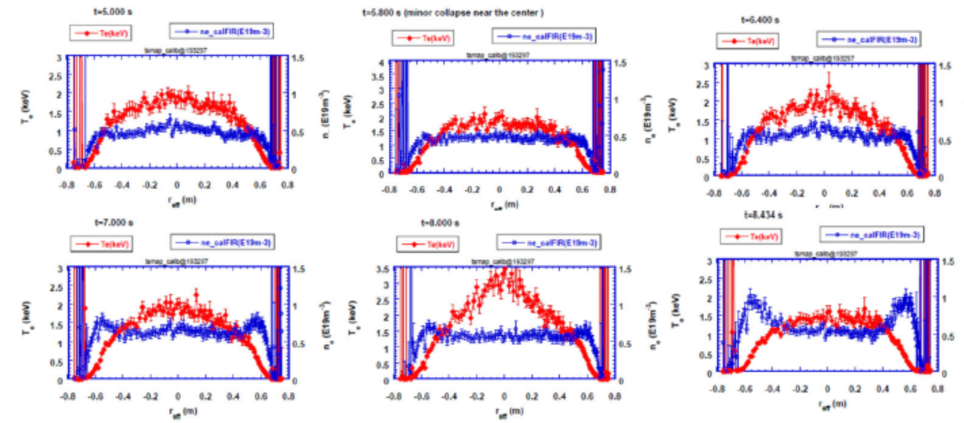


Fig.2 T_e (red) & n_e (blue) profiles at 6 time slices indicated by green arrows in Fig.1 (from the top-left to the right-bottom).

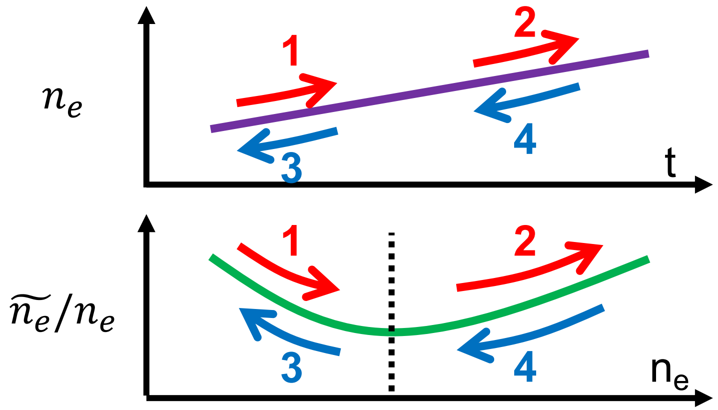
Real-time plasma control using turbulence level signal 2

H. Sakai (Kyushu Univ.), K. Tanaka, T. Kinoshita
K. Nagahara, Y. Ito

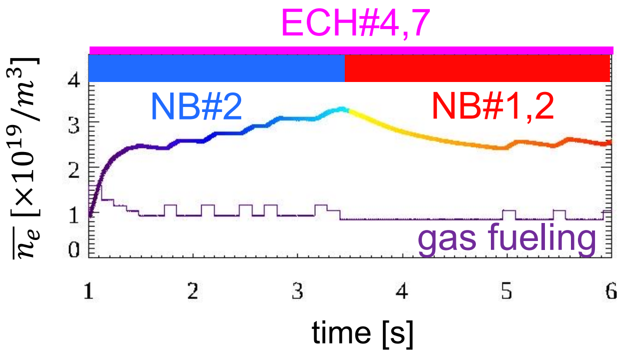
Shot No: #193322-193331, 193339-193341, 193347-193360 (total=27shots)
Experimental conditions: (R_{ax}, Polarity, B_t, γ, B_q) = (3.6 m, CW, 2.75 T, 1.2538, 100 %)
Gas-puff: H_2

Motivation

In 6/12, turbulence control experiment had been performed and the control for **constant** heating had been succeeded. Therefore, a new method was tried to control the lowest turbulence level (TL) under **different** heating conditions during control.



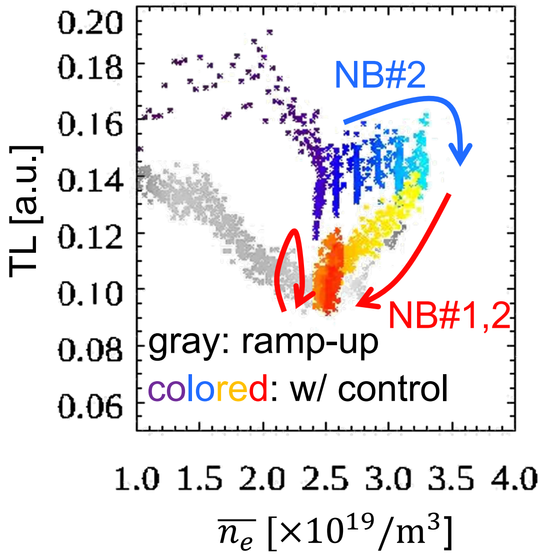
	Logic	gas
1:	$\frac{dn_e}{dt} > 0$ and $\frac{d(\widetilde{n_e}/n_e)}{dt} < 0$	weaken
2:	$\frac{dn_e}{dt} > 0$ and $\frac{d(\widetilde{n_e}/n_e)}{dt} > 0$	weaken
3:	$\frac{dn_e}{dt} < 0$ and $\frac{d(\widetilde{n_e}/n_e)}{dt} > 0$	strengthen
4:	$\frac{dn_e}{dt} < 0$ and $\frac{d(\widetilde{n_e}/n_e)}{dt} < 0$	keep



Result

- ✓ Unfortunately, the control did not converge in blue phase, but in red phase, the control converged and the turbulence level was maintained at a minimum value.
  → The minimum value could be found even if the heating changed during the process of control.

- ✓ In the control using gas puffing, overshoot in TL was noticeable because the TL varied greatly depending on the strength of the gas. However, on the electron density, the overshoot was suppressed to a small level.



Real-time plasma control under low-turbulence conditions focusing on turbulent transition

T. Kinoshita(Kyushu Univ.), Y. Morishita(Kyoto Univ.),
N. Kenmochi, H. Funaba, K. Tanaka, H. Sakai (Kyushu Univ.)

Shot No: #193311~193346 (36shots)

Gas-puff: H

Experimental conditions: (R_{ax}, Polarity, B_t, γ, B_q) = (3.6 m, CW, 2.75 T, 1.2538, 100 %)

Motivation

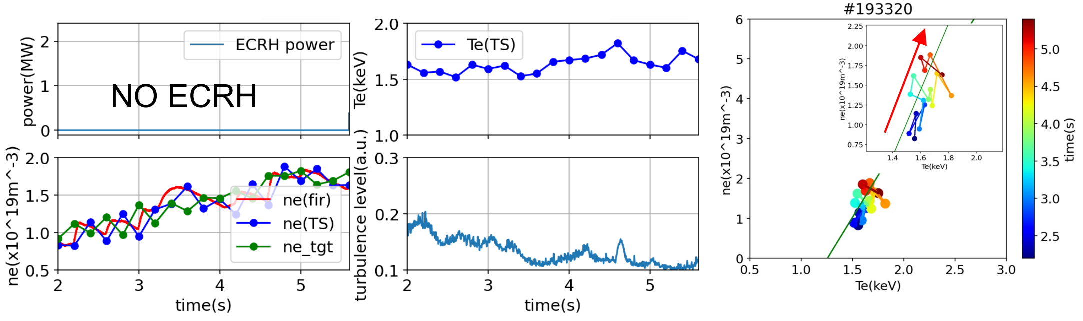
A turbulence and its driven anomalous transport are minimized when the dominate turbulence mode changes in LHD. The condition of turbulence transition is expressed by **n_e=4.20T_e-5.28 (TT condition)**. The aim of this study is to control the plasma to satisfy TT conditions and to realize low-turbulence plasma.

Results

- We successfully controlled the plasma along the TT.
- Approach 1 is n_e control under constant heating conditions. By following the TT conditions, n_e increase and T_e increase were observed simultaneously.
- Approach 2 is T_e control under constant n_e. The TT condition could be satisfied by ON/OFF control of ECRH, but the turbulence did not change.

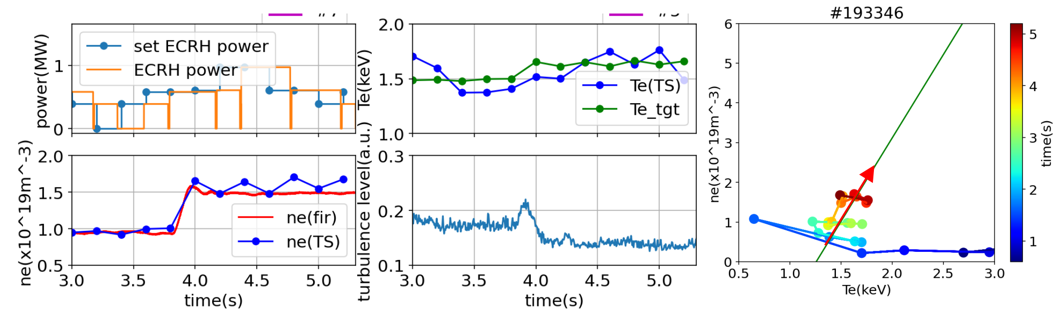
Approach1

w/ control #193320 Base heating: #1#2

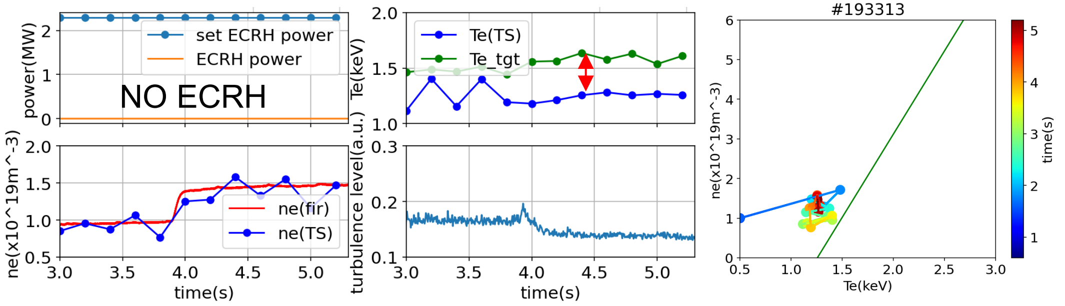


Approach2

w/ control #193346 Base heating: half power of #1#2



w/o control #193313 Base heating: half power of #1#2



Effect of boron powder on density limit and role of turbulence

F. Nespoli K. Tanaka S. Masuzaki M. Shoji

LHD experiment summary on June 12th 2024

Shot#: #193362-193391 (3 0shots)

Experimental conditions:

(R_{ax}, Polarity, B_t, γ, B_q) = (3.60 m, CW, 2.75 T, 1.2538, 100.0%)

Purpose:

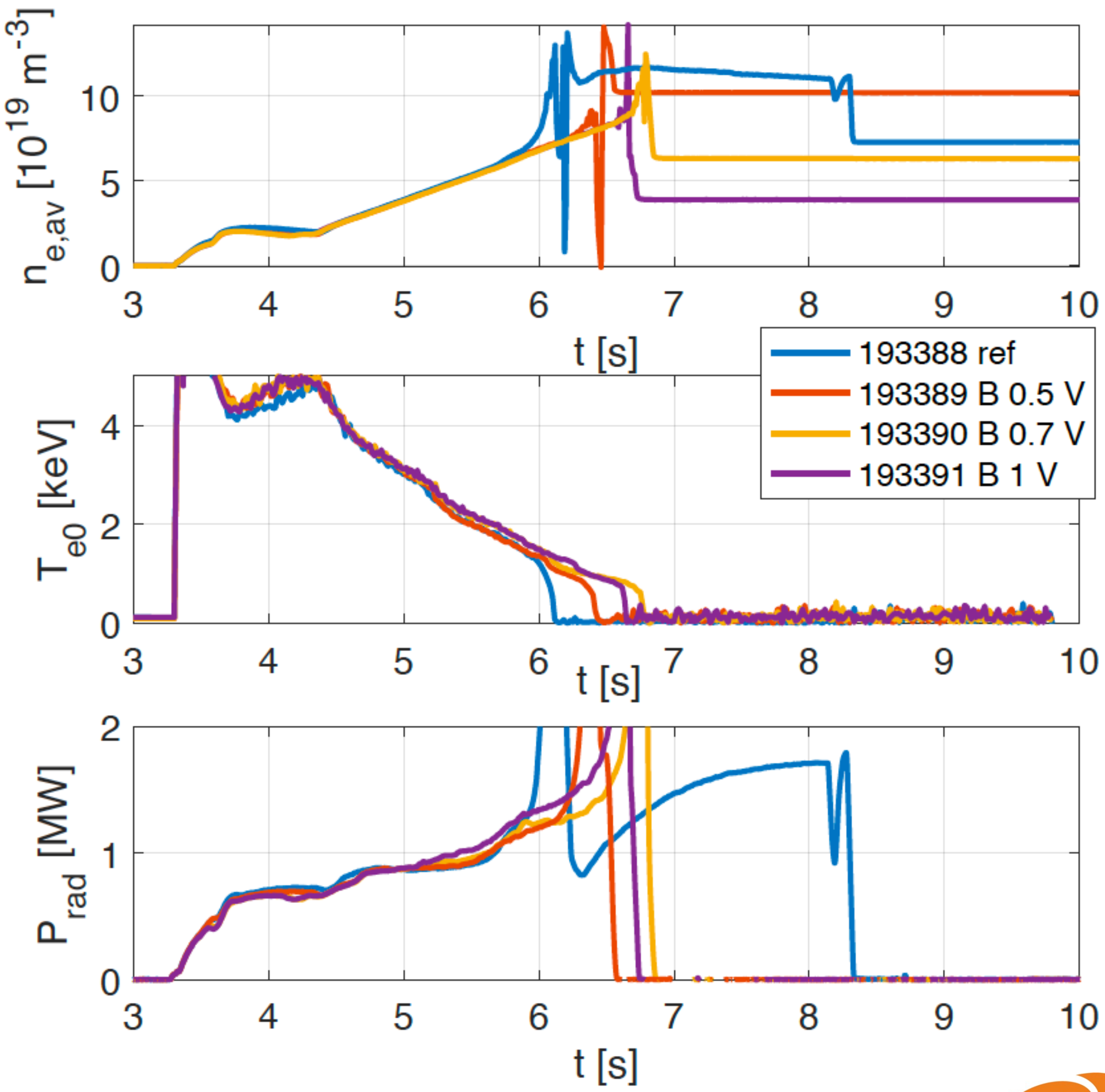
: Study effect of B powder injection on density limit, possibly to be increased since B injection decreases both
intrinsic impurities, radiated power
Turbulence

Result1:

- ~3.6 MW NB heating
- ~3.6 MW NB heating + 1.5 MW ECH

- Density ramps without and with B powder injection

- No clear effect of powder observed in the lower power scenario, plasma terminated earlier if too much powder injected
- Higher density reached with powder injection with respect to reference case in the higher power scenario
- Higher density increases with amount of injected power, collapse earlier if too much powder injected
- Slight increase of Te during powder injection.



- ✓ Role of turbulence are investigated.
- ✓ Time evolution of electron density was control to have flat top after ramp up phase. This is in order to find controllable density limit.
- ✓ $n_{e\ max}$ of flat top was scanned. At $n_{e\ max}$ =8.5x10^{19}m^{-3}, flat top density was controlled, while at $n_{e\ max}$ =9.25x10^{19}m^{-3}, plasma collapsed.
- ✓ Boron powder did not help to improve the density controllability.

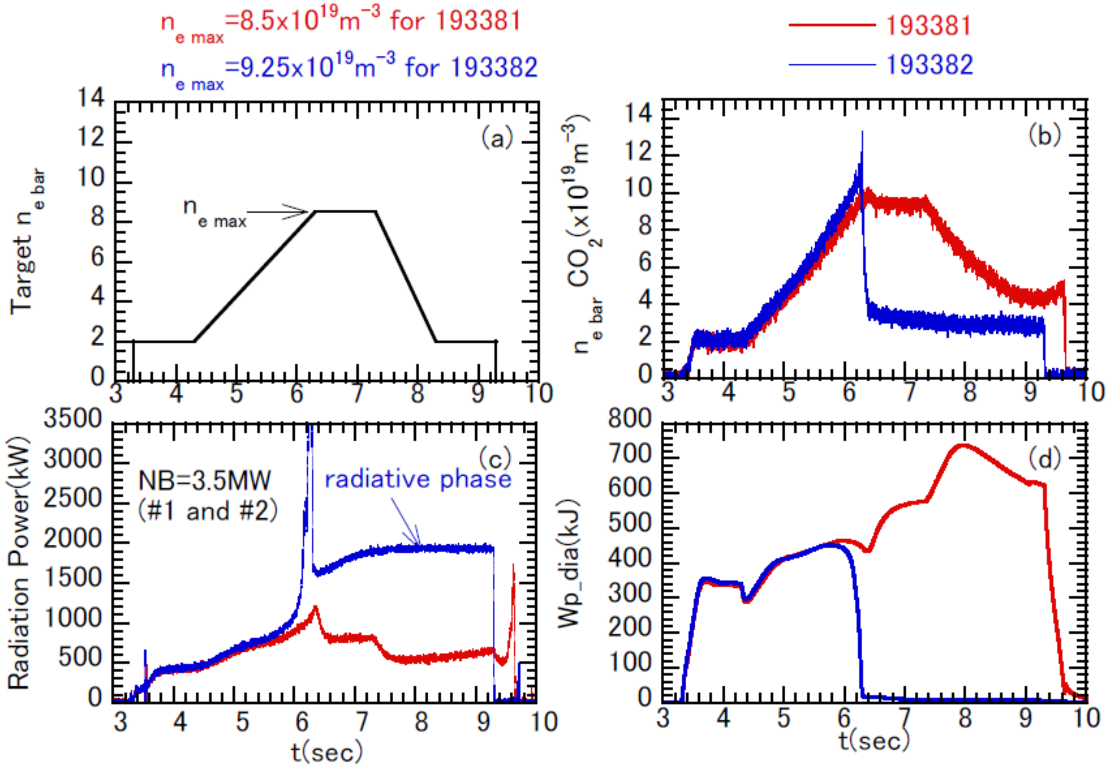


Fig.1 Time trace of density control experiments

- ✓ Turbulence expands from reff/a99~0.9 toward inner and outer in both shot, however, the expansion is stopped when density reach to flat top in 193381.

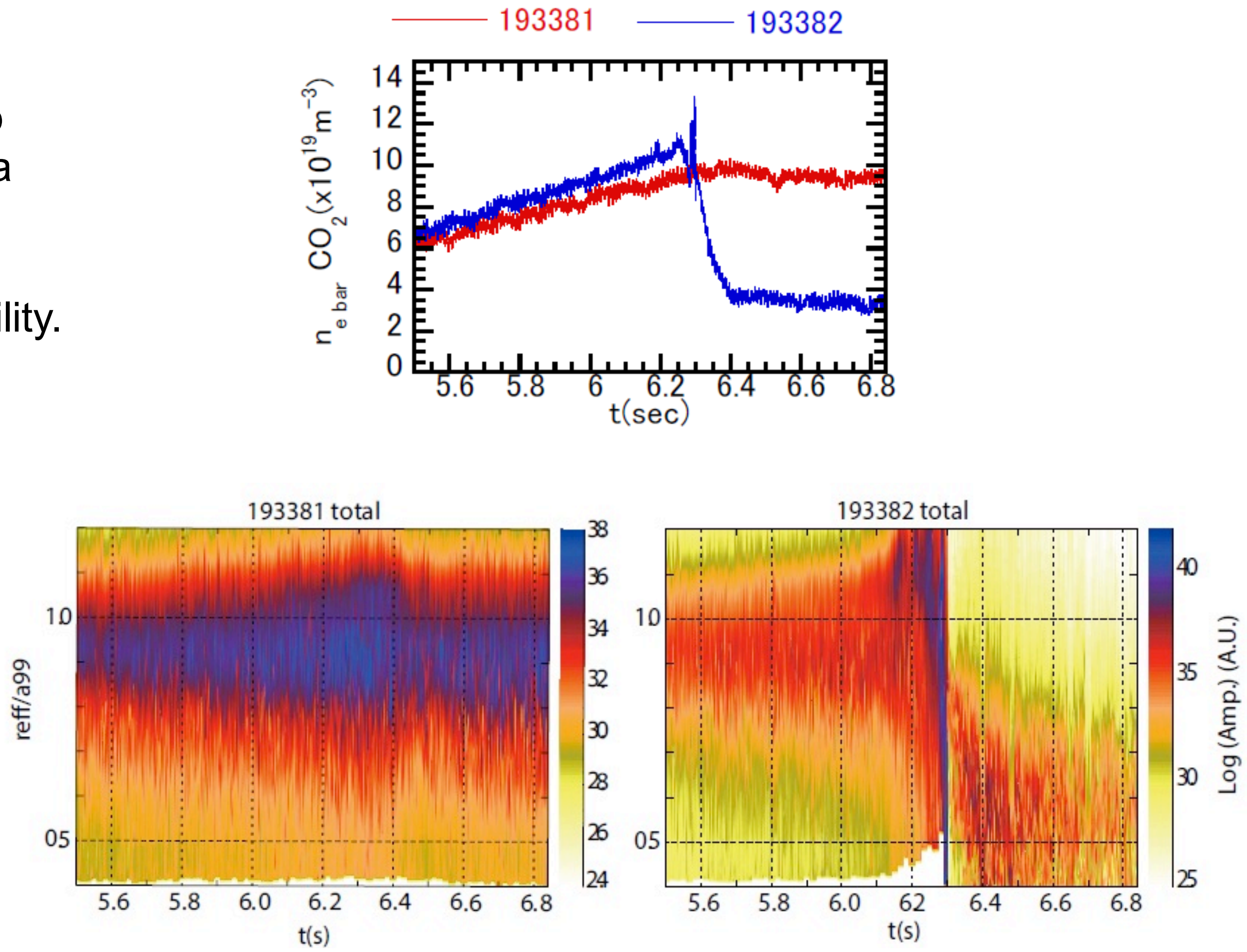


Fig.2 Expanded trace of $n_{e\ bar}$ and turbulence amplitude

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