(TC) Report

Date: June 12, 2024 June 13, 2024 (T. Tokuzawa)
Time: 10:22 - 16:45
Shot#: 193036 – 193153 (118 shots)

Prior wall conditioning: None
Divertor pump: ON
Gas puff: H2, Ne Pellet: NO, IPD: NO

NBI#(1, 2, 3, 4, 5)=gas(H, H, H, H, H)=P(3.1, 2.8, 2.9, 3.5, 2.6)MW

ECH(77GHz)=ant(5.5-Uout (or 1.5U), 2-OUR)=P(337, 380)kW
ECH(154GHz)=ant(2-OLL, 2-OUL , 2-OLR)=P(389, 580, 606)kW
ECH(56GHz)=ant(1.5U)=P(-)kW
ICH(3.5U, 3.5L, 4.5U, 4.5L)=P(-, -, -, -)MW

Topics

1. Study on the effect of magnetic shear on mode structure and associated turbulent transport (Y. Kishimoto (Kyoto U.), K. Tanaka)) [#193036 - #193079]
2. Effect of the electric field on impurity transport (T. Ido (Kyushu U.), A .Shimizu) [#193080 - #193105]
3. Real-time plasma control using turbulence level signal (H. Sakai (Kyushu U.), K. Tanaka) [#193106 - #193130]
4. Real-time plasma control under low-turbulence conditions focusing on turbulent transition (T. Kinoshita (Kyushu U.), K. Tanaka) [#193131 - #193153]

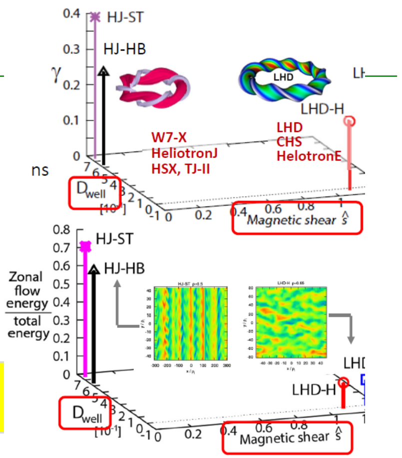
Study on the effect of magnetic shear on mode structure and associated turbulent transport （モード構造と乱流輸送における磁気シアの効果 ）

Points :

Proponent : **Y. Kishimoto**(Kyoto U.)
NIFS contact person: **K. Tanaka**

Member : H. Himura, A. Sanpei, T. Inoue (KIT), Y. Otani (QST), K. Imadera, A. Ishizawa, R. Matsui, D. Yu, W. Wang, J.Q. Li（SWIP）

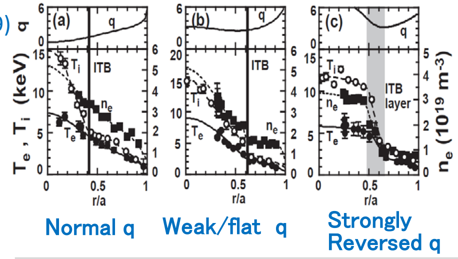
Ishizawa, et al. NF 57, 066010 (2017)



Motivation

- Magnetic structure, ι and/or q, and $\hat{s}$, are through to be a key control parameter in both tokamak and helical system.
- Weak and/or zero shear plasmas, where ballooning symmetry is broken, are interested, leading to ITBs, e.g. optimum shear (JET), where the magnetic field is no longer the primary factor to regulate the mode structure.

Shirai et al., NF 39, 1713 (1999)



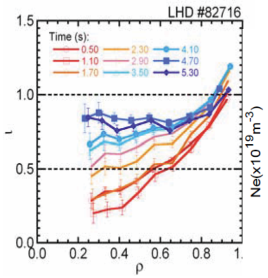
Zero shear **linearly unstable**
→ **nonlinearly stable** (ZF generation rate)

Work by T. Fukuda et al. using LHD (22nd IAEA , 2008)

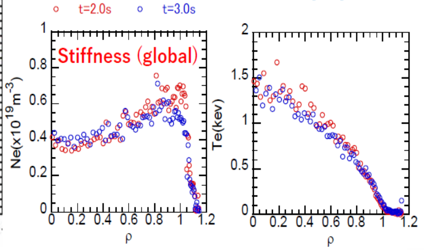
- Transport was studied by changing ι profile by NBCD (~100kA) in LHD, but showing L-mode characteristics.

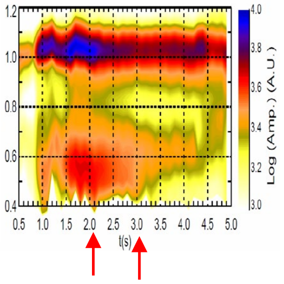
Conclusion : … the pronounced effect of magnetic shear in tokamaks was not obvious for plasmas with the turbulent structure pertaining to helical plasmas. (….) kinetic profiles respond little. (NIFS-901)

- A case considered that such a stiffness results in the operation under the critical threshold, P< P_c , for profile change
- PIC signals showed a reduction of turbulence in flat ι regime, so further studies be necessary, e.g. whether the phenomena results in linear stability or nonlinear effect



Profile stiffness for changing s





Revisit of experiment by T. Fukuda et al. (2008)

- We revisit the results using similar discharge as Fukuda et al., and study the relation between $\hat{s}$ and fluctuation spectrum by PCI and other advanced diagnoses.
- We will also add additional ECH to find the response between the finite shear case and week shear case.

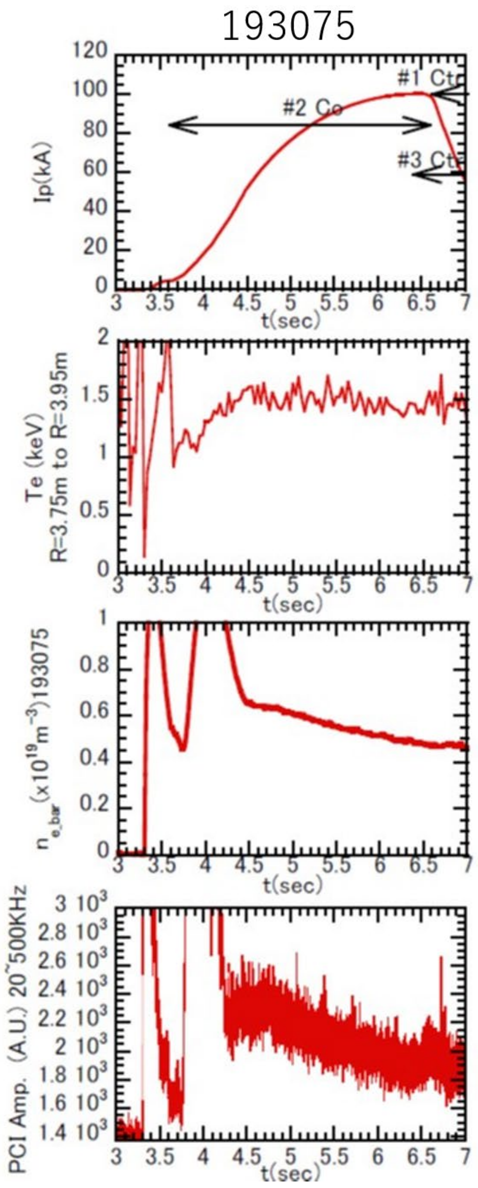
1sec
Strong shear phase
77GHz ECH

1sec
Flat shear phase
77GHz ECH

PNB #4 for (CXRS)
NB#3 for MSE (half source)
NB#1 Co. | NB#2 Ctr.
5sec → 3sec (start from 2sec) | 5sec → 3sec (start from 2sec)

Result

Shot 193035-193076
NNB were switch from co- to counter-injection in order decrease iota shear in core region.
2sec 4MW NNB and 3sec 3MW NNB were tried
Co-current was maximum 100kA, while it was 120kA in Prof. Fukuda's exp (#82716).
#82716 was CCW Bt, thus, #3NNB for MSE was co-injection and help to induce co-current, however, this experiments was CW Bt and #3NNB was ctr injection and decrease co-current.
Neon injection doubled maximum Ip
Figure shows time trace of #193075, where the highest co-Ip was observed.
Density feedback control was performed at 0.5x1019m-3, but neon injection made it difficult to keep density constant.
The line averaged density decreased in time after t=4.5sec to 6.5sec about 30%, but line integrated fluctuation amplitude decrease further about 45% suggesting turbulence level decreased under constant heating power.
Iota profiles will be analyzed.
Initial iota profile will be analyzed from differet shot with #3 injection from 4.5sec.



Spatial structures of density, electric potential and density fluctuations in the core region during perpendicular NBI (T. Ido, A. Shimizu, M. Nishiura)

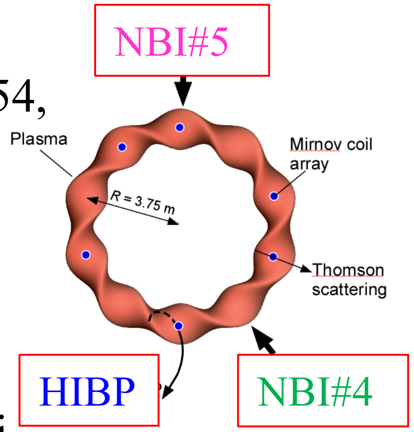
Shot #: 193080 - 193105

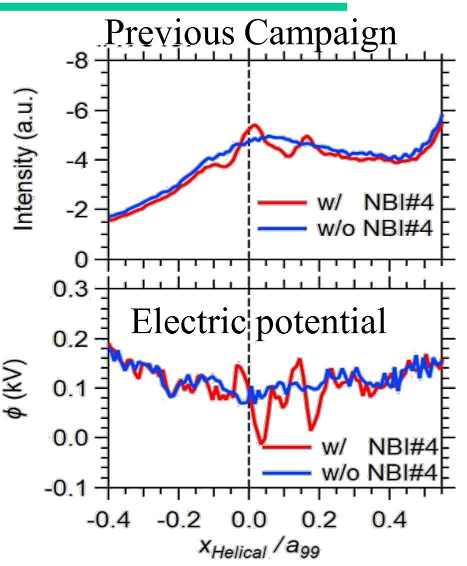
Experimental conditions: (R_{ax}, Polarity, B_t, γ, B_q) = (3.75m, +1.375 T, 1.254, 100%), $n_e \sim 0.5 \times 10^{19}$ (m^{-3})

Balanced tangential NBI + modulated perpendicular NBI

Background and motivation:

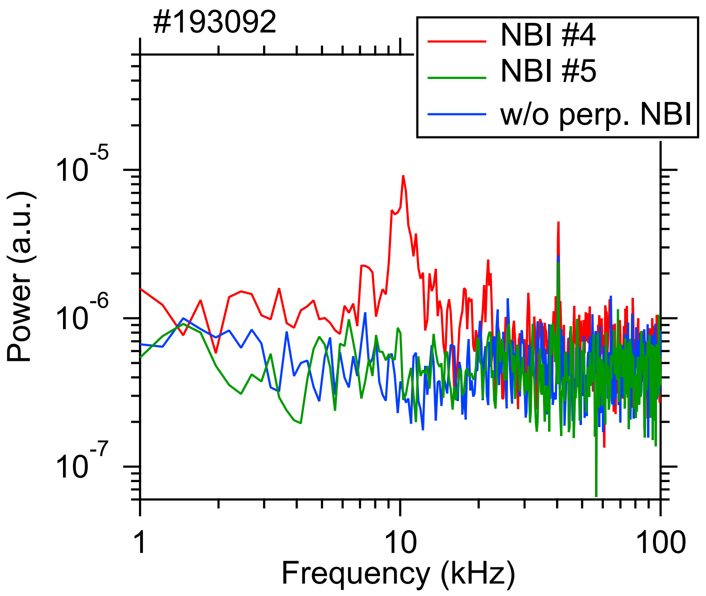
- The initial motivation of the experiment is to verify a theoretical study on the influence of energetic trapped particles on the electric fields. (Ref. H.Yamaguchi, IAEA-CN TH/P6-29 (2018)).
- In the previous campaigns, the peculiar spatial structures of ϕ and density profiles were observed in the central region during the perpendicular NBI #4, but not during the perpendicular NBI #5.
- The purpose of this experiment is to clarify their poloidal structures and to investigate the influence of the structures of the electric field on the turbulence and impurity transport.





Results:

- The intensity of the HIBP was so unstable that we could not analyze the ϕ and density profiles.
- Density fluctuations were observed near the core region only in the case of NBI#4. We will analyze the spatial structures of the fluctuations.



Real-time plasma control using turbulence level signal

H. Sakai (Kyushu Univ.), K. Tanaka

Shot No: #193106-193130

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

Gas-puff: H_2

Approach

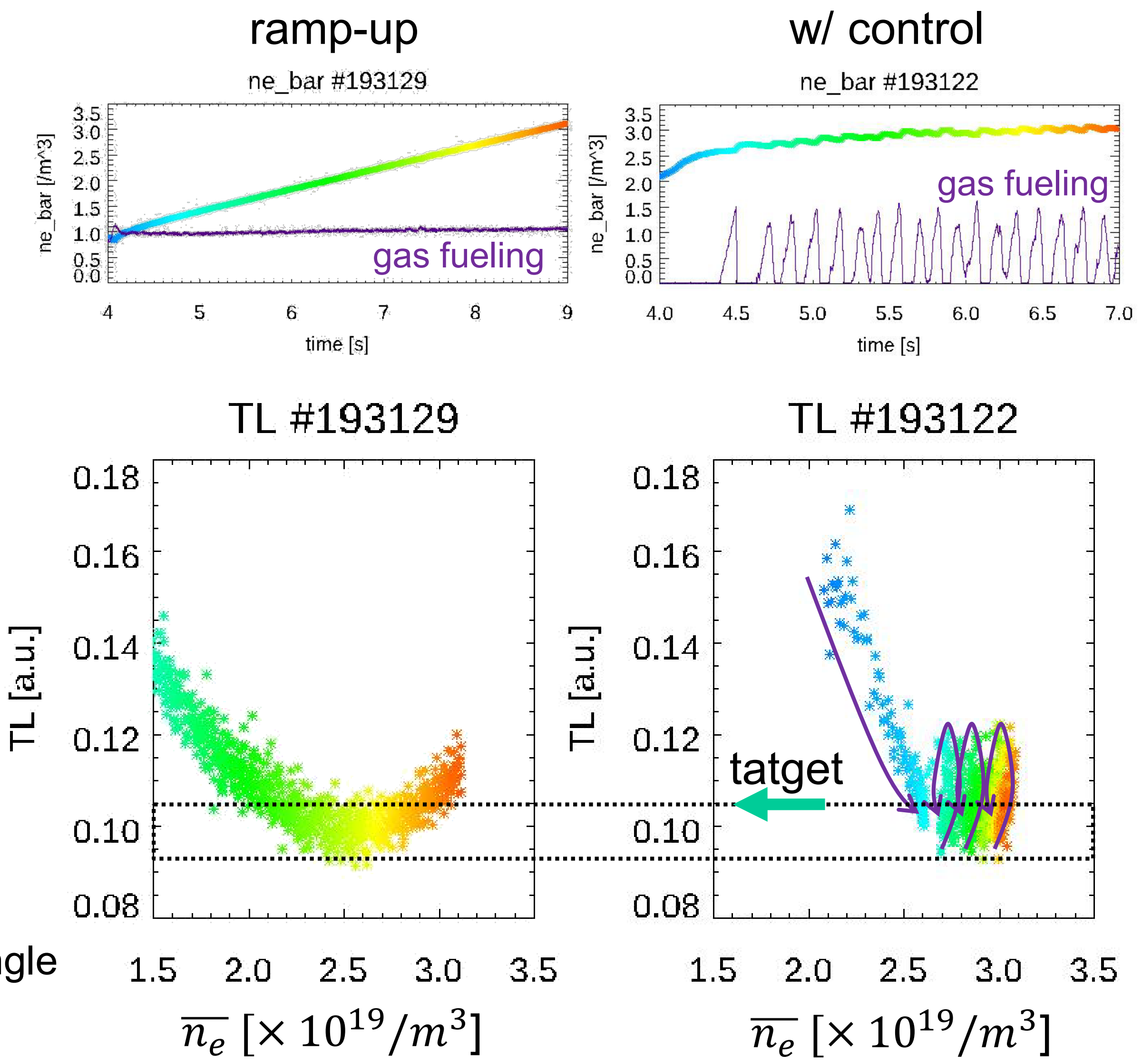
Turbulence is suppressed when turbulence mode changes between ITG and RI in LHD. Based on this physics, we tried to control the plasma in low turbulence using gas-fueling. Real-time turbulence level (TL) signal was used for FB control as target value. Heating power was fixed to use NB#1,2 and ECH#4,5,7.

Result

- ✓ Turbulence curve was appeared at ne~2.5-3.0x in the shot for ramp-up (this is good reproduction).
- ✓ If TL became larger than the target, gas fueling was turned off. The gas was turned on when it detects that it is far from the target value. Target value was evaluated by "the detected lowest value×1.1" Low TL plasma was successfully maintained.

Next objective (6/14)

- ✓ The heating pattern will be varied over time within a single discharge to confirm if the TL is always minimal at that time.



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

Shot No: #193131~193153 (23shots)

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

Gas-puff: H

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

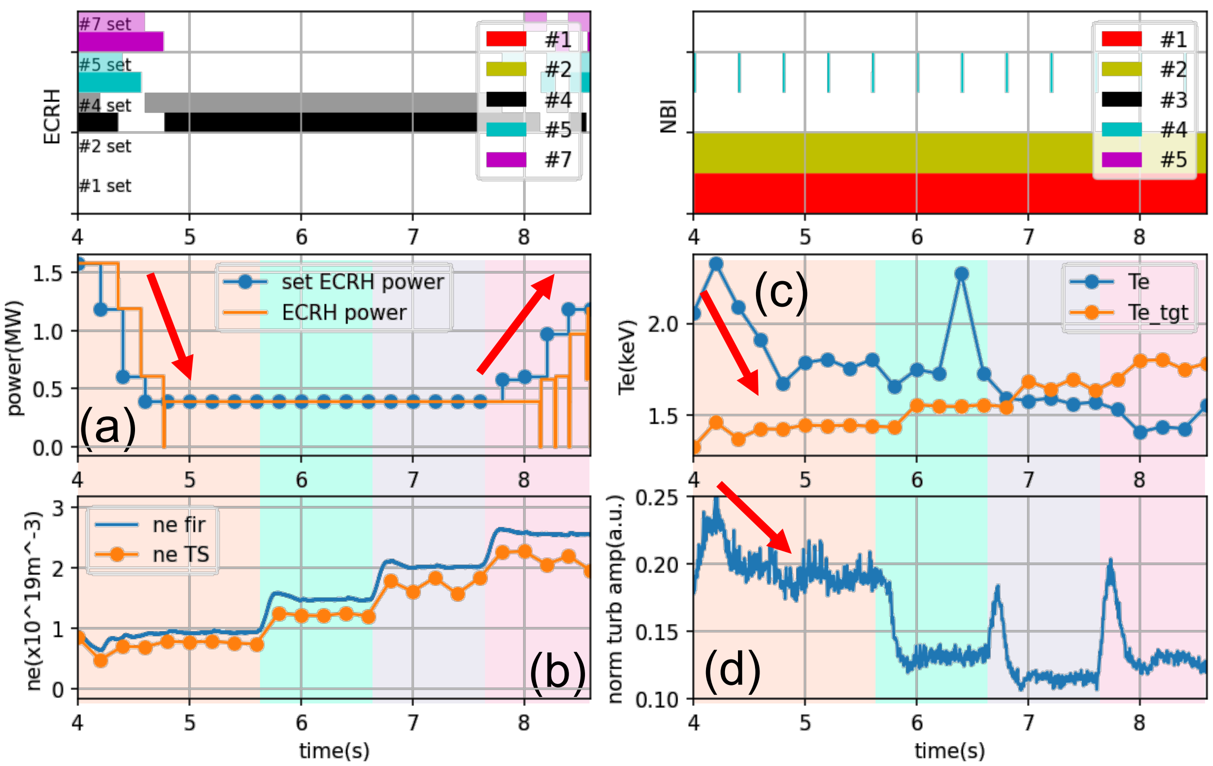
Motivation

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**=4.20**T_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

- Two different approaches were used to satisfy the TT condition. One is T_e control under constant n_e. The other is n_e control under constant heating conditions.
- The right figure shows an example of the former T_e control approach. Here, n_e was changed stepwise by feedback control.
- At t=4-5s, since target T_e (T_{e_tgt}) is much higher than current T_e (Fig(c)), the heating power are reduced (Fig(a)). As the temperature decreases, the turbulence level also decreases. However, due to the high NBI heating, the temperature could not be lowered any further at t=5-5.6s. At t=5.6-6.6s, T_{e_tgt} increased slightly and turbulence decreased significantly as it became closer to T_e. At t=6.6-7.6s, T_{e_tgt} and T_e are almost the same, which means that the TT condition is satisfied. As the result the turbulence is minimized. At t=7.6~, the density increases further and T_{e_tgt}>T_e, so the heating power increases.

#193151, mode:2, setECRH delay=0s



Plan The NBI base heating power is reduced to allow room for temperature control by ECRH.