(TG1,2,4) group report

Date: Dec. 16, 2021

Dec. 17, 2021 (H. Kasahara, T. Kobayashi , N. Kenmochi)

Time: 9:45 - 18:45

Shot#: 175225 – 175379 (155 shots)

175229-175272(TG1), 175273-175297(TG2), 175298-175315(TG1), 175320-175333(TG2), 175334-175351(TG4), 175352-175379(TG1)

Prior wall conditioning: H2-Glow

Divertor pump: OFF

Gas puff: H2, He, Pellet: D2, H2, C,

Impurity: IPD(B_4C)

LID: No

NBI#(1, 2, 3, 4, 5)=gas(H, H, H, D, D)=P(3.3, 4.1. 3.8, 7.4, 5.9)MW

ECH(77GHz)=ant(5.5-U, 2-OUR)=P(0.70, 0.79)MW

ECH(154GHz)=ant(2-OLL, 2-OUL, 2O-LR)=P(0.98, 0.93, 0.99)MW

ICH(3.5U, 3.5L, 4.5U, 4.5L) = P(0.84, 0.76, 0.87, 0.55) MW

Neutron yield integrated over the experiment = 7.0×10^{15}

Submitted seven experimental proposals.

(TG1,2,4) group report

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Topics

1. Plasma conditioning and performance improvement in stellarator geometries through continuous boron carbide granule injection (R. Lunsford(PPPL), S. Masuzaki, TG1)
2. Non-linearity of transport and turbulence in mixture plasma (T. Kinoshita(Kyushu Univ.), K. Tanaka, TG2)
3. Mixture-induced phase transitions in multi-ion transport (Dinklage(IPP), N. Tamura, TG1)
4. Dependence of electron ITB threshold condition on isotope mass (T. Kobayashi, TG2)
5. Isotope mass effects on sustainment of e-ITB plasma (N. Kenmochi, TG4)
6. Transport in the isotope mixture plasma (K. Ida, TG1)
7. Transport study in ECRH superposed ion ITB plasma (H. Nakano, TG1)

- Carbon Microgranule injection into NBI(10s) and ECH & ICH(40s) heated discharges
  - Initial plan was for B_4C injection. Actual injection species determined post-run.
  - There is still much to be learned from these experiments despite unexpected species change

- Experimental Steps

✓ 1. Injections into NBI Heated discharges determine preliminary plasma response to impurity injection. This is accomplished while ECH and ICH pulses are extended.

✓ 2. Optimal injection quantity in ECH & ICH long pulse discharges

✓ 3. Repeated 20s powder injection discharges build up coating layer

✓ 4. Repeated reference discharges wear away coating layer to determine conditioning lifetime

Many thanks to all who helped with this exciting experiment

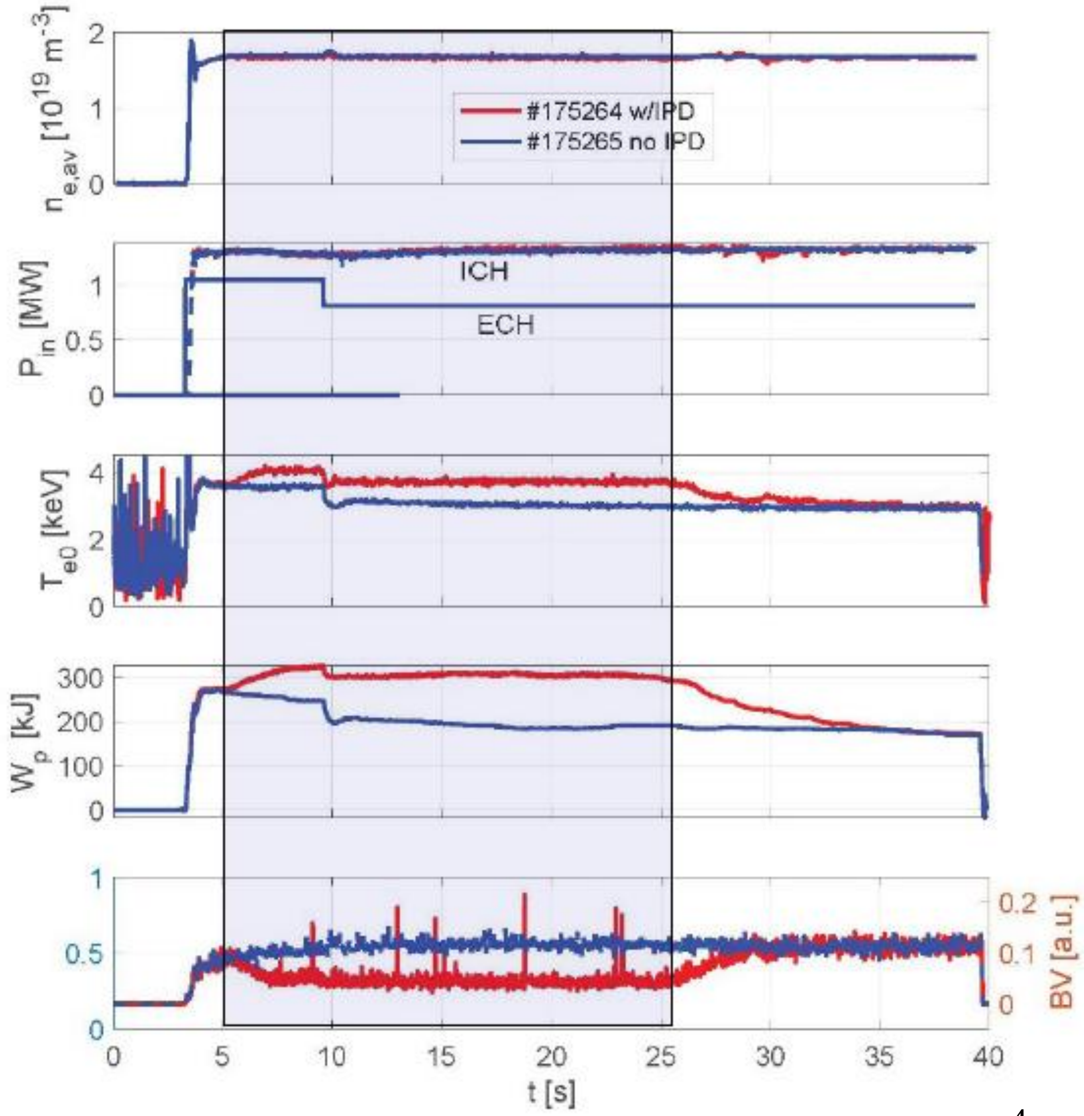
Strong increase of stored energy observed with C injection

- H-fill, $n_e \sim 1.5 \times 10^{19}$ m^{-3}
- ECH & ICH Injection for 40s
- **175264 : IPD injection at 0.3V from 5 – 25s**
- **175265 : Reference Discharge**

Indicates that performance increases observed with particulate injection may be due to profile modifications and larger Zeff rather than the well known conditioning effect of B on carbon PFCs (limiter and divertor)

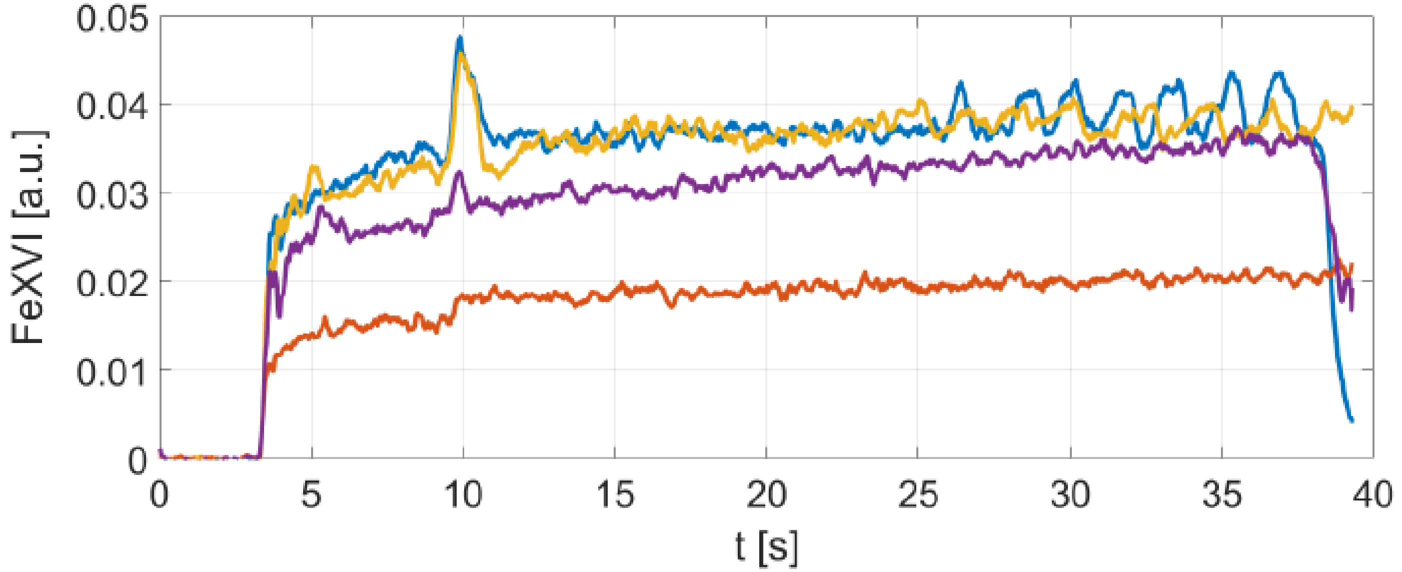
Change in turbulence characteristic observed with PCI, too soon to make definitive statements

The injected carbon is highly mobile, it was seen in several camera views during injection. It is possible that these injections were at least some what effective in conditioning the first wall SS tiles.



Conditioning observed in changes to Fe signature

While reductions in Fe and O observed during injections may be due to profile modification and impurity flushing, we also see reductions during <u>reference discharges</u> possibly indicating a conditioning effect



LHD 175254 : Beginning of conditioning series

LHD 175260 : Mid-run reference

LHD 175269 : After conditioning injections

LHD 175271 : Post High Density Disruptive Collapse

Nonlinearity of transport and turbulence in mixture plasma (T.Kinoshita)

Experimental condition

(Rax, Polarity, Bt, γ, Bq) = (3.6 m, CCW, 2.75 T, 1.2538, 100.0%)
175284 - 175297 (14 shots) : D/(H+D) = 0.25-0.3

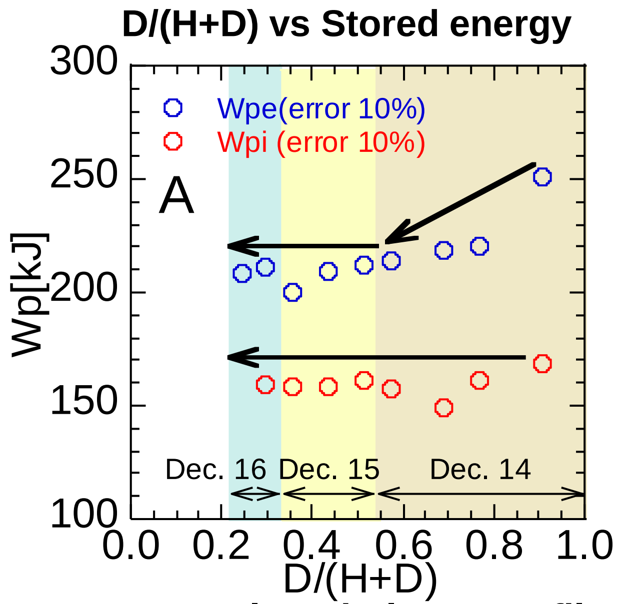
Motivation

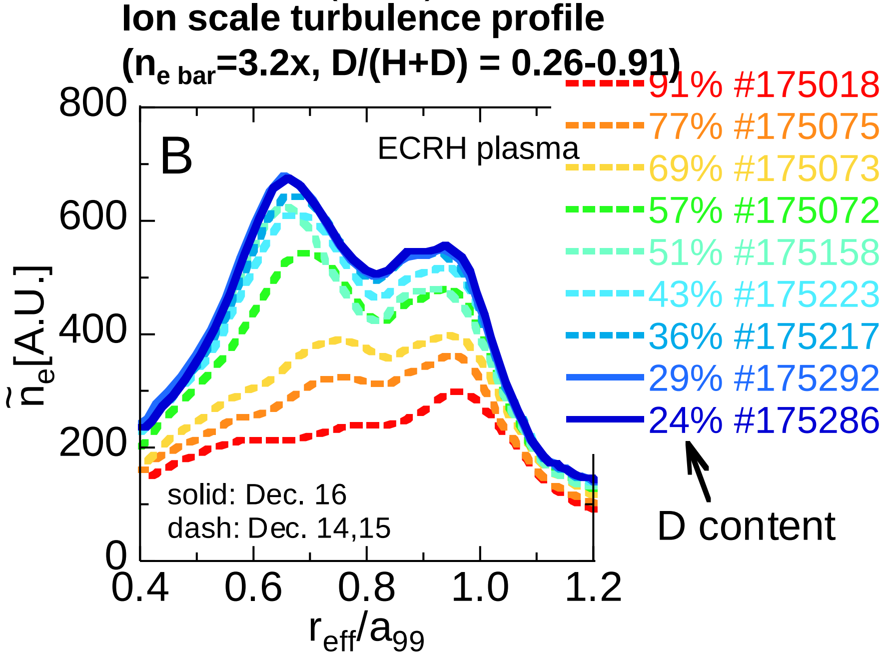
- In pure H and D plasma, isotope effect of plasma confinement was observed at $n_{e\_bar}>3.0\times10^{19}m^{-3}$.
- Investigation of ion mass dependence of plasma confinement is helpful to understand turbulence characteristics in LHD, and to predict the performance in the future DT mixture plasma.
- We obtained the data with D/(H+D) = 0.35 - 0.9 on Dec. 14 and 15.

Initial result

- We successfully obtained turbulence data at the following conditions.
  - ✓ $n_{e\ bar}$=1.0 - 4.0x$10^{19}m^{-3}$ with D/(H+D) = 0.25~0.3
- Electron stored energy is deceased with decreasing D/(H+D) for 0.5 < D/(H+D), and to be constant for D/(H+D) < 0.5. (Fig. A)
- Ion stored energy is constant regardless of D/(H+D) within error. (Fig. A)
- Ion scale turbulence measured by PCI was enhanced with decreasing D/(H+D) for 0.5 < D/(H+D), however, saturated for D/(H+D) < 0.5. (Fig. B)

➡ Ion mass dependences of ion scale turbulence electron stored energy are qualitatively agreement.





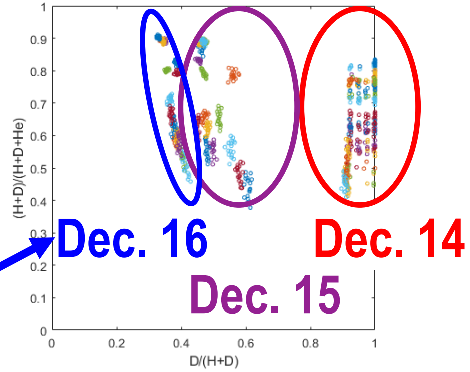
Mixture-induced phase transition in multi-ion transport (A. Dinklage, N. Tamura et al.)

Magnetic Configuration: (R_{ax}, Polarity, B_t, γ, B_q) = (3.60 m, CCW, 2.75 T, 1.2538, 100.0%)
Shots: 175298-175312 (15 shots)
Goal of this experiment:

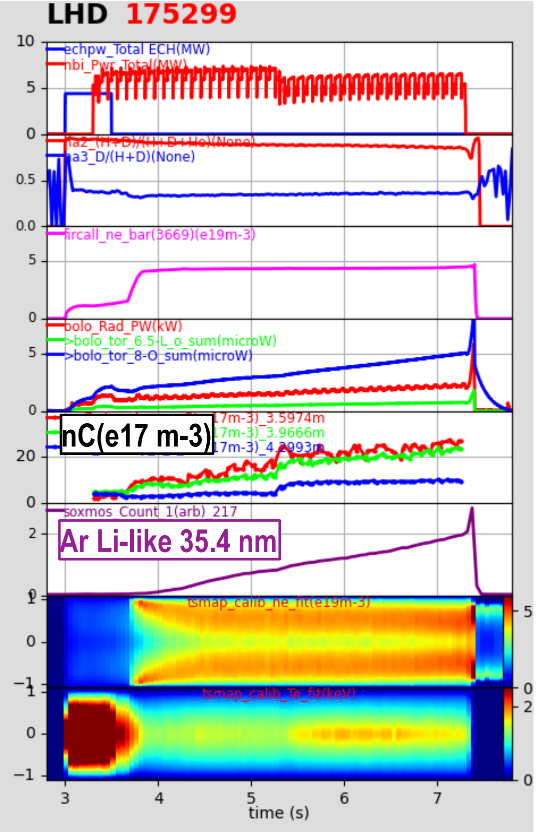
- To study the change of the impurity accumulation window in H/D/He-mixed plasmas

Results:

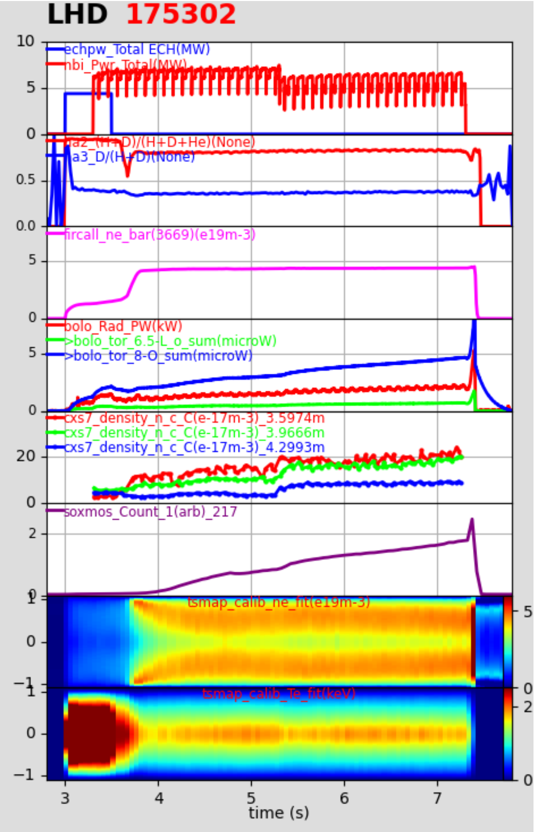
- We tried to change the He contents in the plasma by using different gas puff settings around n_{e_bar} of 4e19 m^{-3} under the **H-dominated condition**
  - ✓ **Coverage of hydrogen rich plasmas limited**



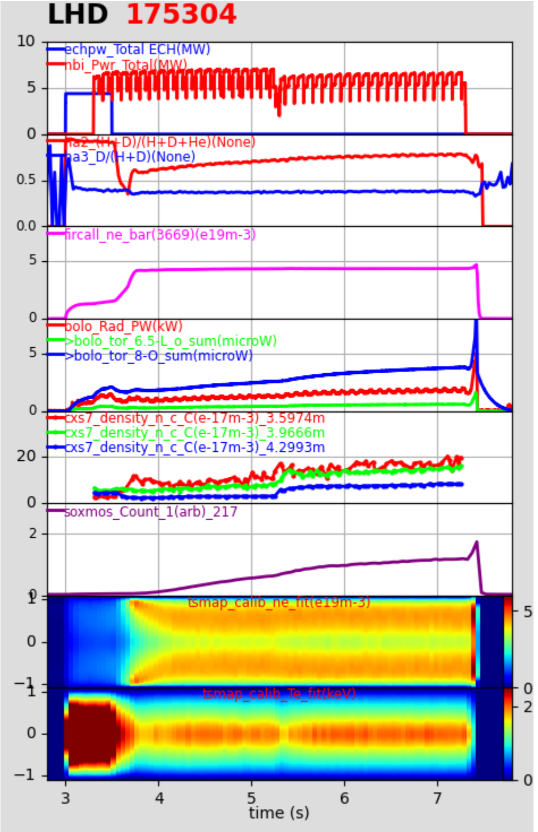
He puff(160 ms) 0.00 V



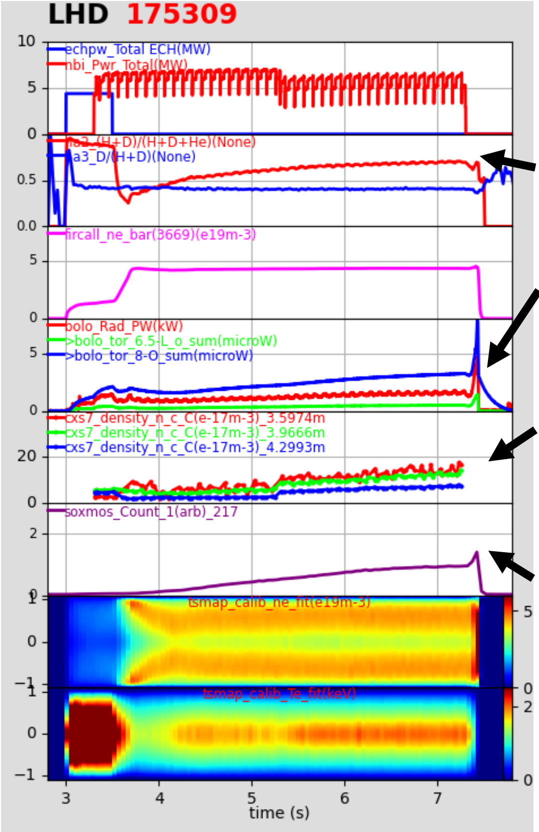
He puff(160 ms) 2.25 V



He puff(160 ms) 2.50 V



He puff(160 ms) 2.90 V



As **He contents** increased, ...

- **Bolometer signal level** decreased
- C-density level decreased
  - ✓ Less peaked?
- **Ar Li-like intensity level** decreased
  - ✓ Ar puffed@3.45s

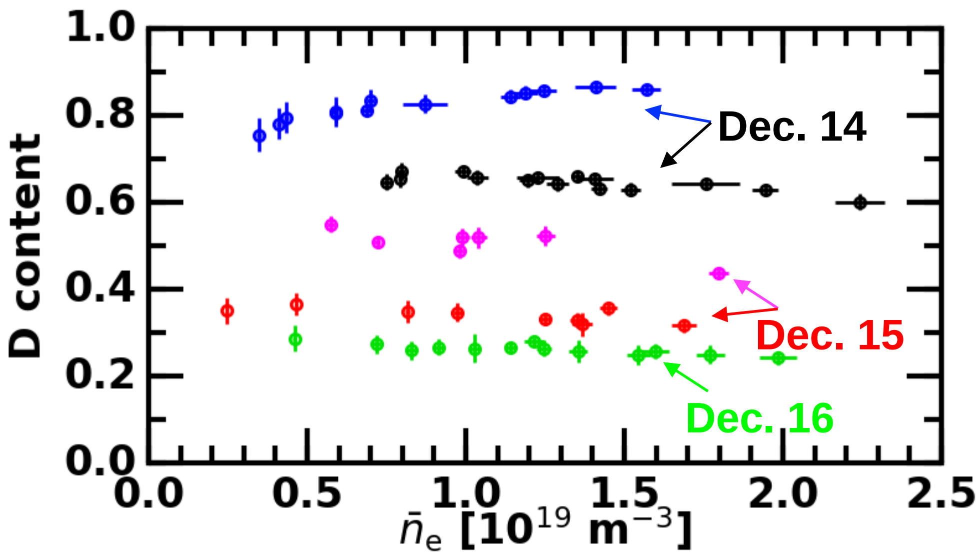
Isotope effects in threshold condition for electron ITB

T. Kobayashi

Shot #: 175320-175333
Experimental conditions: (R_{ax}, Polarity, B_t, γ, B_q) = (3.6 m, CCW, 2.75 T, 1.2538, 100 %)

Motivation

- In previous study, the threshold condition for electron ITB formation was found to be eased in deuterium plasmas than hydrogen plasmas.
- How the electron ITB threshold condition depends on the deuterium content is investigated.



Results

- Consecutive formation and deformation of electron ITB were realized by a modulation ECH.
- Line averaged density was scanned in shot-to-shot basis at D/(D+H)~0.25.
- In three days, systematic density scans were performed at five different D/(D+H) conditions, at 0.8,0.65, 0.5, 0.35, and 0.25.
- A signature that the ITB strength was reduced as D/(D+H) was decreased.

Isotope mass effects on sustainment of e-ITB plasma

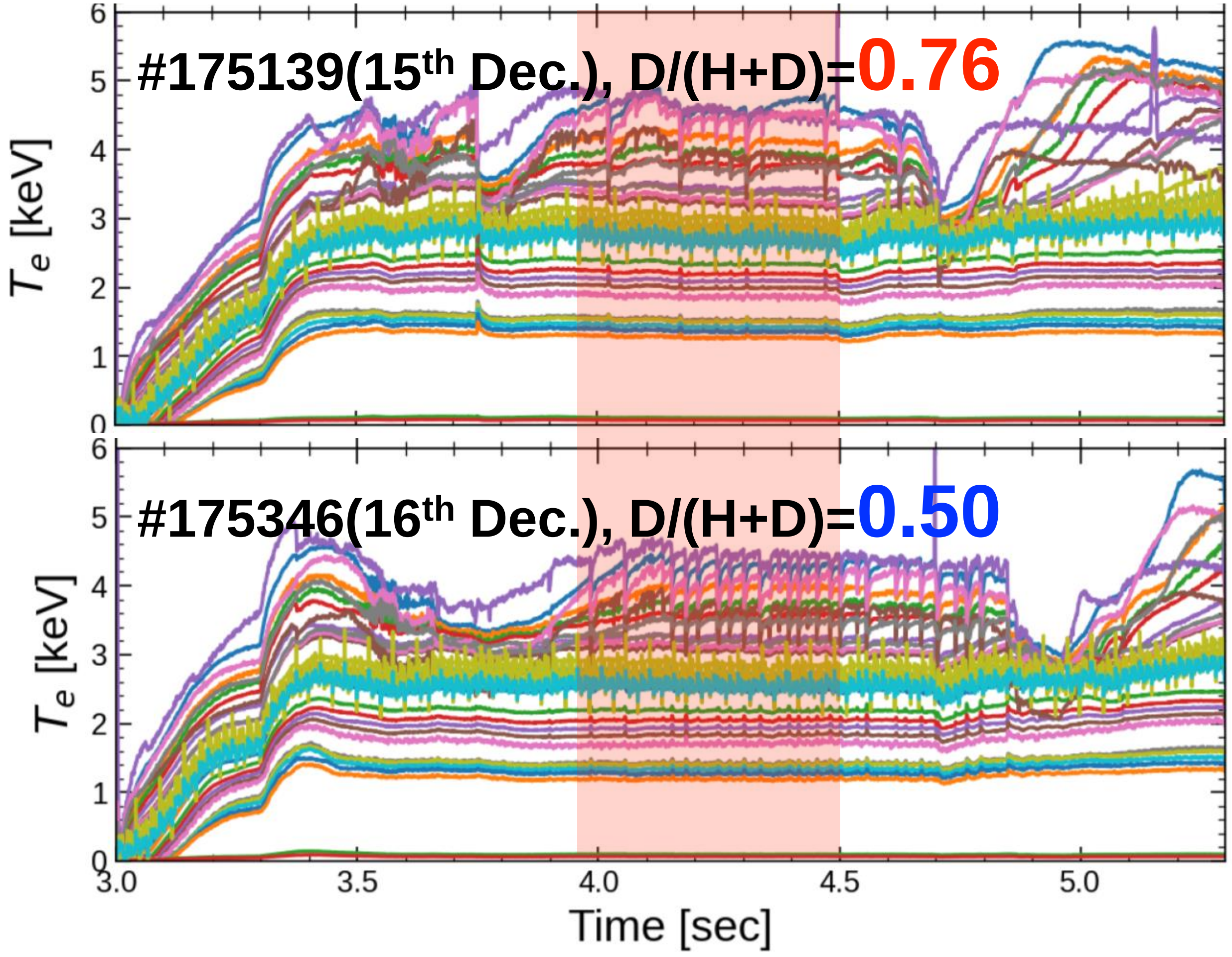
(N. Kenmochi)

Experimental conditions:

(R_{ax}, Polarity, B_t, γ, B_q) = (3.6 m, CCW, 2.75 T, 1.2538, 100.0%)

Co. to Ctr. current drive at center region (#175334 - #175351), Hydrogen rich plasma

Objective: To clarify the isotope mass effect of the eITB sustainment and turbulence/heat pulse propagation.

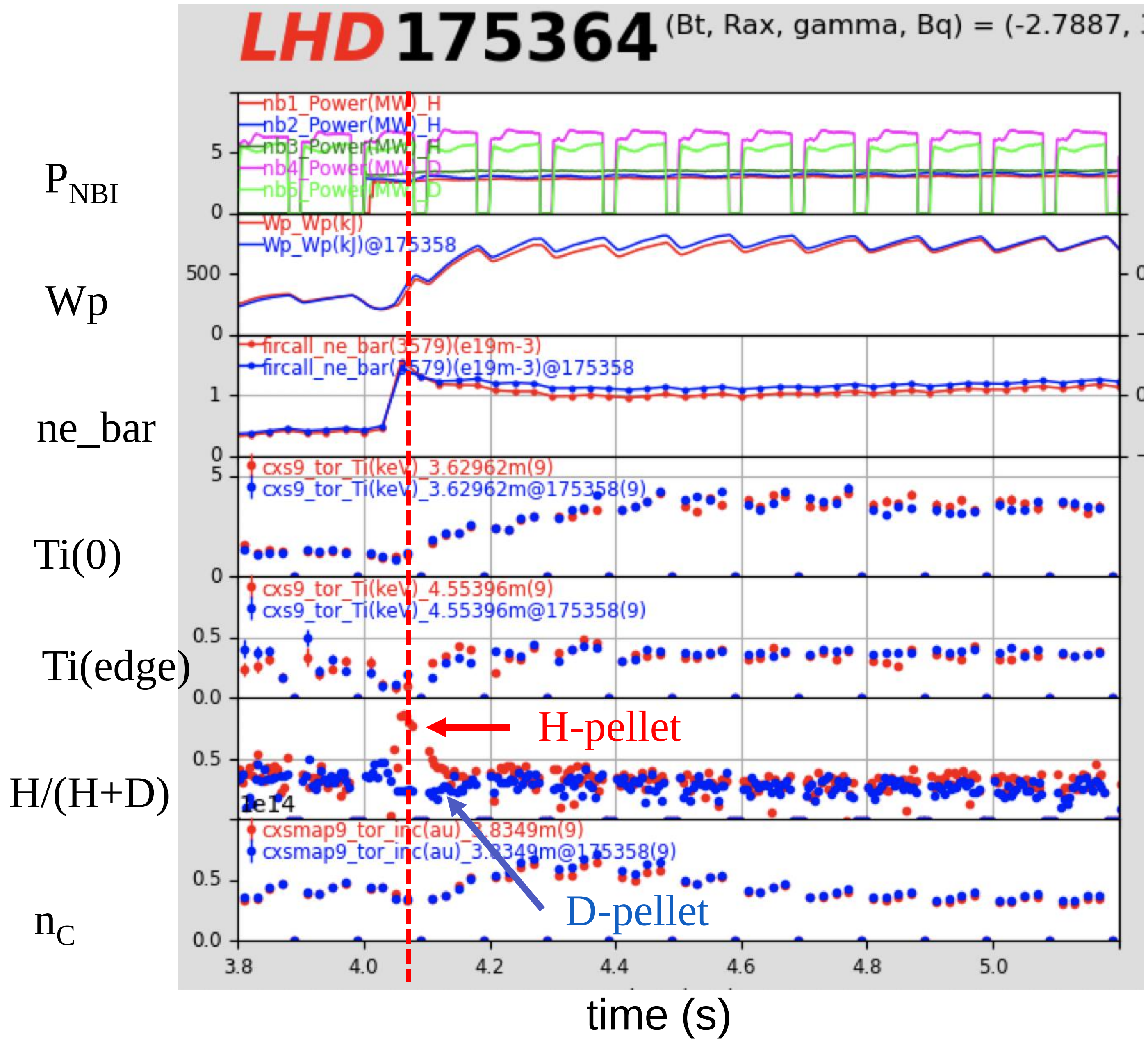


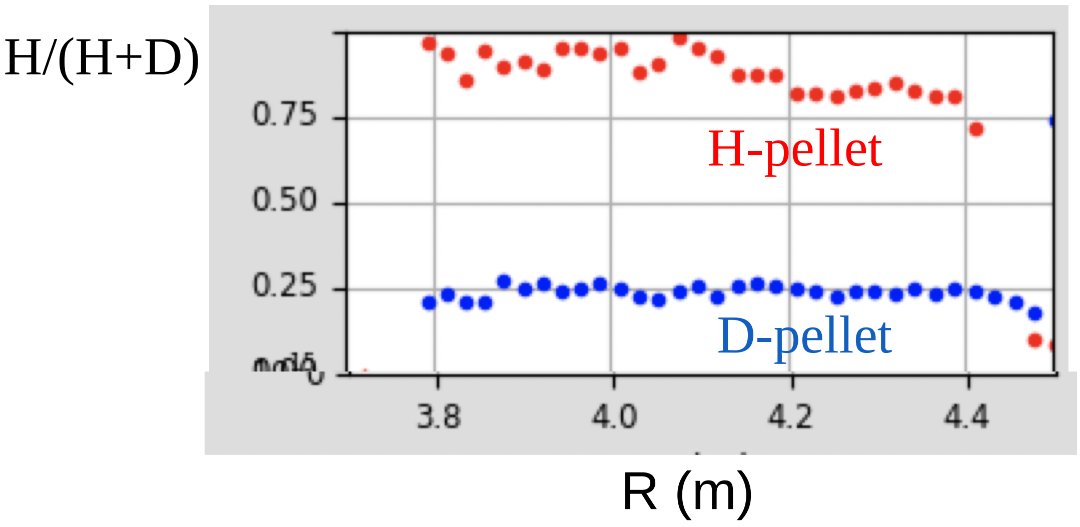
Results:

- ✓ D/(H+D) = 0.3 -> 0.5
- ✓ Minor collapse of eITB was observed around m/n=1/2 magnetic island.
- ✓ The electron-scale turbulence and magnetic fluctuation rapidly increase just before the minor collapse.
- ✓ The measurement position of e-scale turbulence was scanned in a shot-to-shot basis.
- ✓ High-speed Thomson scattering (20 kHz) measurement was successfully operated.
- ✓ It is possible that the frequency of the minor collapse increases as the percentage of hydrogen increases.
- ✓ The effects of isotope mass for the relationship between T_e profile, heat pulse, and turbulence will be investigated.

Isotope effect on ion-ITB plasma (Ti(0) ~ 4 keV)

K.Ida and M.Yoshinuma





Hydrogen fraction by pellet was succeeded.
H/(H+D) = 0.8-0.9 immediately after H-pellet
H/(H+D) = 0.25 immediately after D-pellet
However, the fraction decays within 50 ms before the central ion temperature reaches to the peak of 4 keV

The stored energy and electron density are slightly higher for D-pellet than that for H-pellet discharge

The reached central ion temperature is almost identical between H-pellet and D-pellet discharge

H/D ratio scan experiment: High T_i discharge with off-axis ECRH (H. Nakano)

Background and Objective

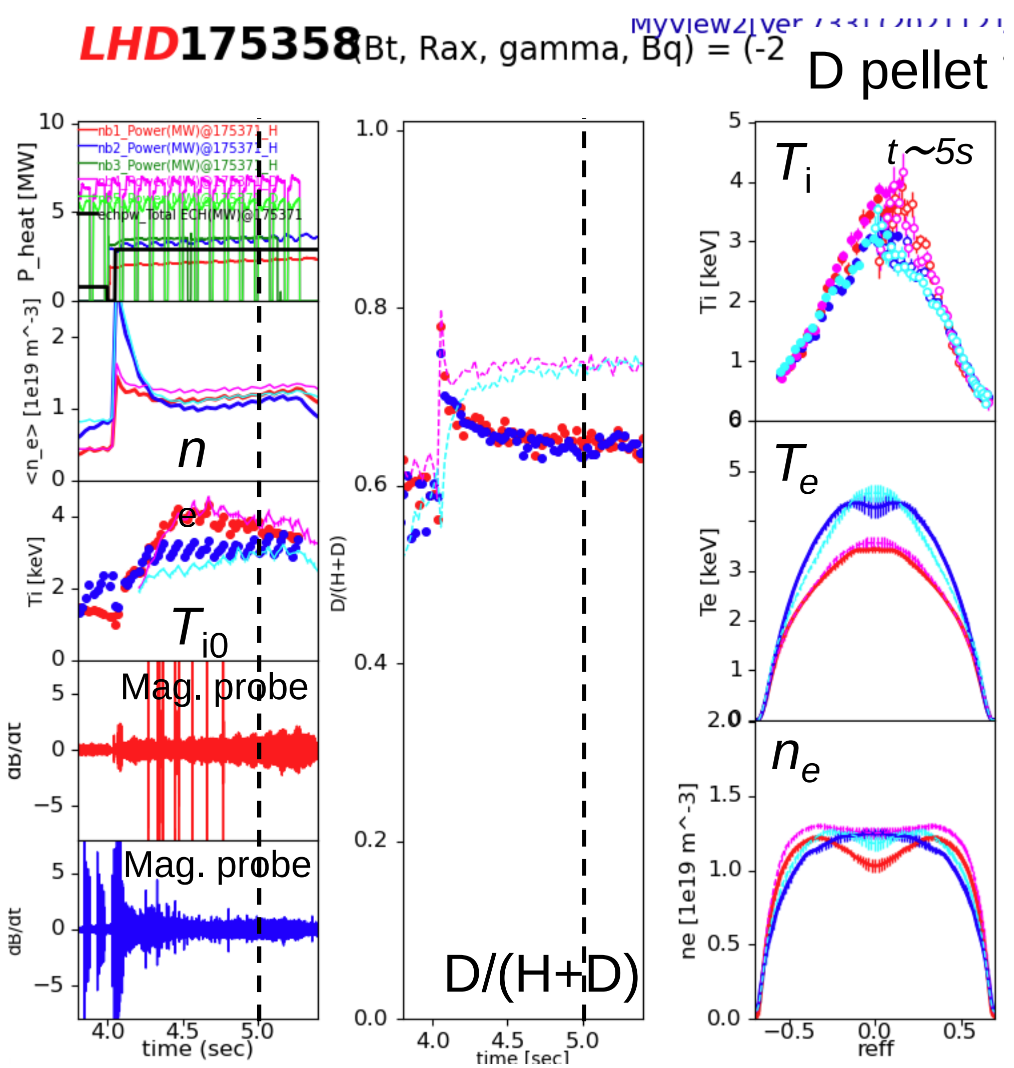
- The ECRH superposition in peripheral region to the high T_i discharge with He puff, carbon pellet, and full power NBI (#1-3:H, #4-5:D) improved the thermal confinement.
- Influence of the H/D ratio on the the high T_i discharge with the off-axis ECRH is studied

Experimental Condition (Third day for H/D ratio scan exp.)

- The off-axis ECRH superposed high T_i discharge with hydrogen, deuterium, and carbon pellets in continuous three days experiments.

Results

- Three levels of D/(H+D) ratios (90, 70, and 60 % around t = 5 sec) has been obtained in the three days experiments.
- Similar effects of the off-axis ECRH on the high T_i discharge confinement were shown in three D/(H+D) ratios, e.g.: Lower T_{i0}, and $\nabla T_{i,\ core}$, higher T_{e0}, and $\nabla T_{i,\ periphery}$, and
- However, slight differences of the effects by D/(H+D) ratio were observed, e.g.: T_i,T_e, and n_e profiles etc. Detail analysis including transport and fluctuation analyses will be done.



ECRH	rho	Pellet	LHD#
x	-	D/H	175358
o	0.6	D/H	175371

Light color lines show results in higher D/(H+D) ratio (yesterday).