(TG1) Multi-ion Plasma group report

Sep. 30, 2022 (N. Tamura)

Date: Sep. 29, 2022
Time: 11:17 – 18:44
Shot#: 179277 – 179404 (128 shots)
Prior wall conditioning: None
Divertor pump: Off
Gas puff: H_2
Pellet: Impurity pellet(C, LiF), TESPEL (PS, Al)

NBI#(1, 2, 3, 4, 5) = gas(H, H, -, H, H)=P(3.6, 3.3, -, 3.7, 4.2) MW
ECH(77GHz) = ant(1.5-Uo, 5.5-U, 2-OUR)=P(0.253, 0.253, 0.267) MW
ECH(154GHz) = ant(2-OLL, 2-OUL, 2-OLR)=P(0.205, 0.203, 0.237) MW
ICH(3.5U, 3.5L, 4.5U, 4.5L) = P(0.8, 0.8, 0.8, -) MW
Neutron yield integrated over the experiment = 1.2×10^{13}

Topics

1. Plasma/Device Commissioning (N. Tamura)
2. Commissioning of ICRF antenna (H. Kasahara)
3. Commissioning of 1.5UO ECH antenna (M. Nishiura and ECH group)
4. Commissioning of optical vortex ECH (T. Tsujimura and R. Yanai)
5. Robust pressure gauges (ITER and W7-X design) in LHD (U. Wenzel, V. Haak, and G. Motojima)

Plasma Commissioning (N. Tamura et al.)

Experimental conditions: (R_{ax}, Polarity, B_t, γ, B_q) =
(3.60 m, CW, 2.75 T, 1.2538, 100.0%): #179277 - #179367
(3.90 m, CW, 2.5385 T, 1.2538, 100.0%): #179368 - #179384

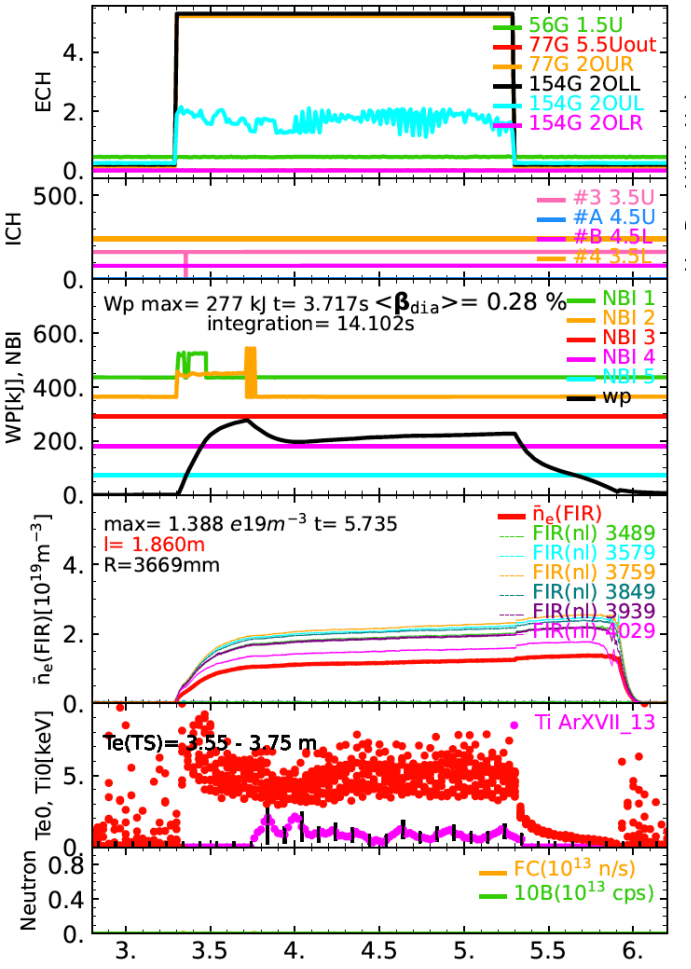
Goal of this experiment:

- To confirm the plasma startup and the stable sustainment of the plasmas
- To confirm the operation of diagnostics, data collection/display system, each heating devices (ECH, ICH and NBI)

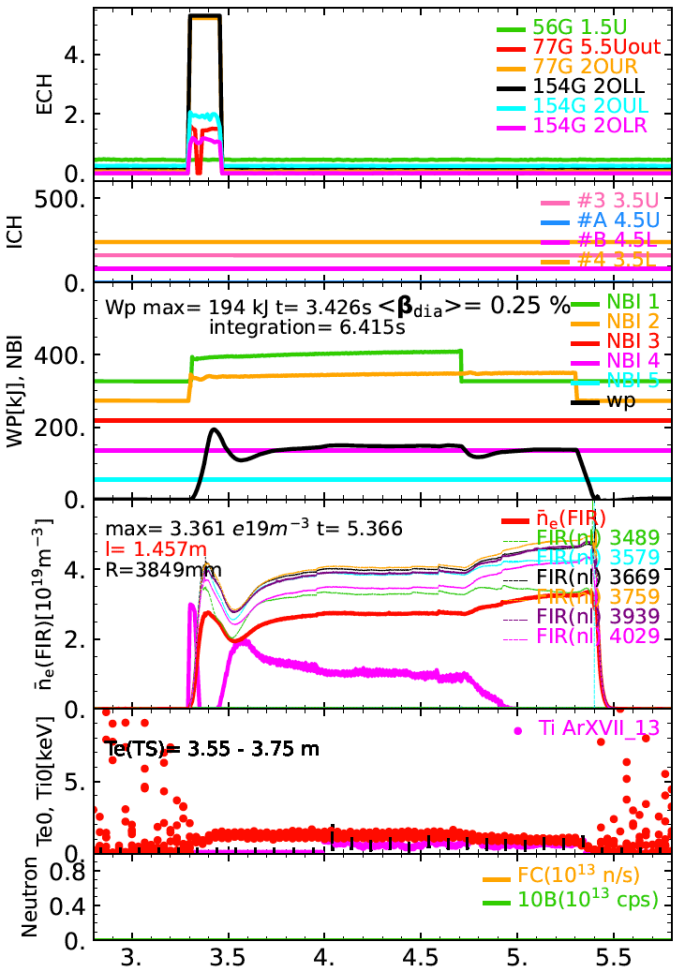
Results:

- We have confirmed **the stable sustainment of the EC-heated plasma and NBI(tang.)+ECH heated plasmas at both configurations, R_{ax} = 3.6 m and 3.9 m.**
- Commissioning is still needed to get of NBI (tang.+perp.)-heated plasmas with controllable density.

e.g., #179302 (R_{ax}=3.6m)



e.g., #179371 (R_{ax}=3.9m)



Device Commissioning (N. Tamura et al.)

Results:

Impurity pellet: OK

- Carbon pellets (#179297, 179298) and lithium fluoride pellets (#179299 - #179301) were successfully injected.

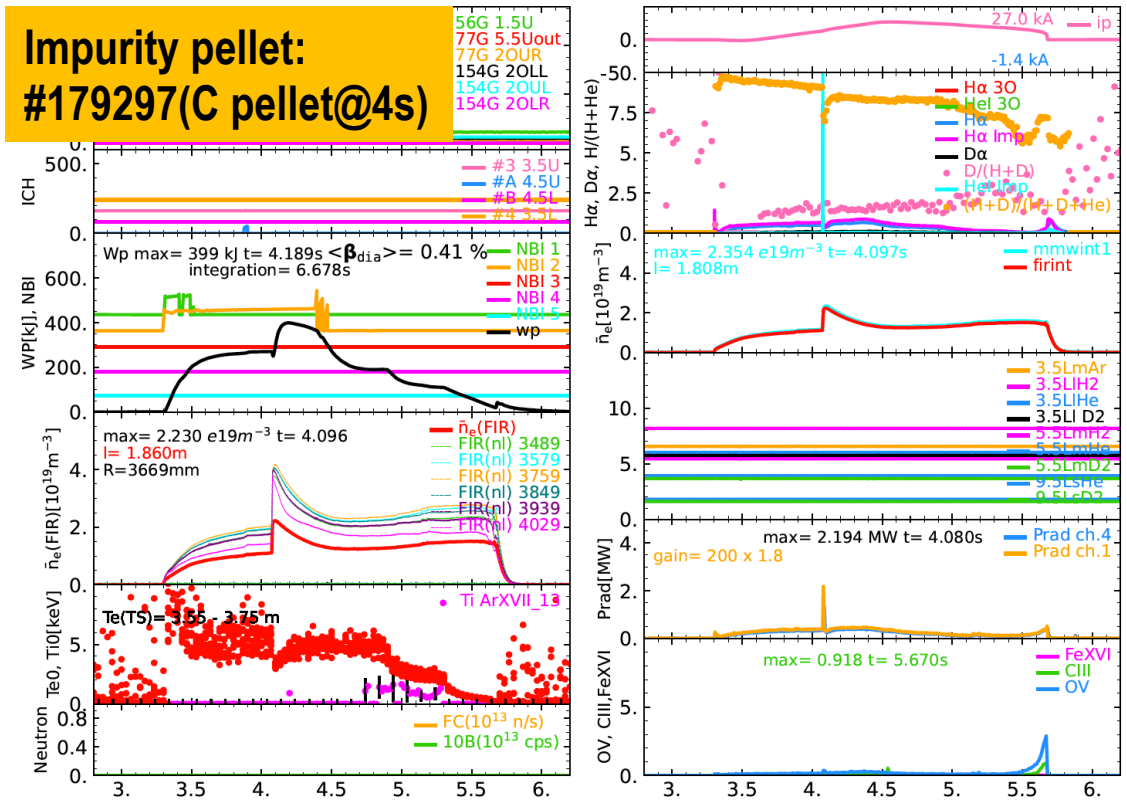
TESPEL: OK

- PS pellets (#179303 - #179306) and Aluminum pellets (#179307) were successfully injected.

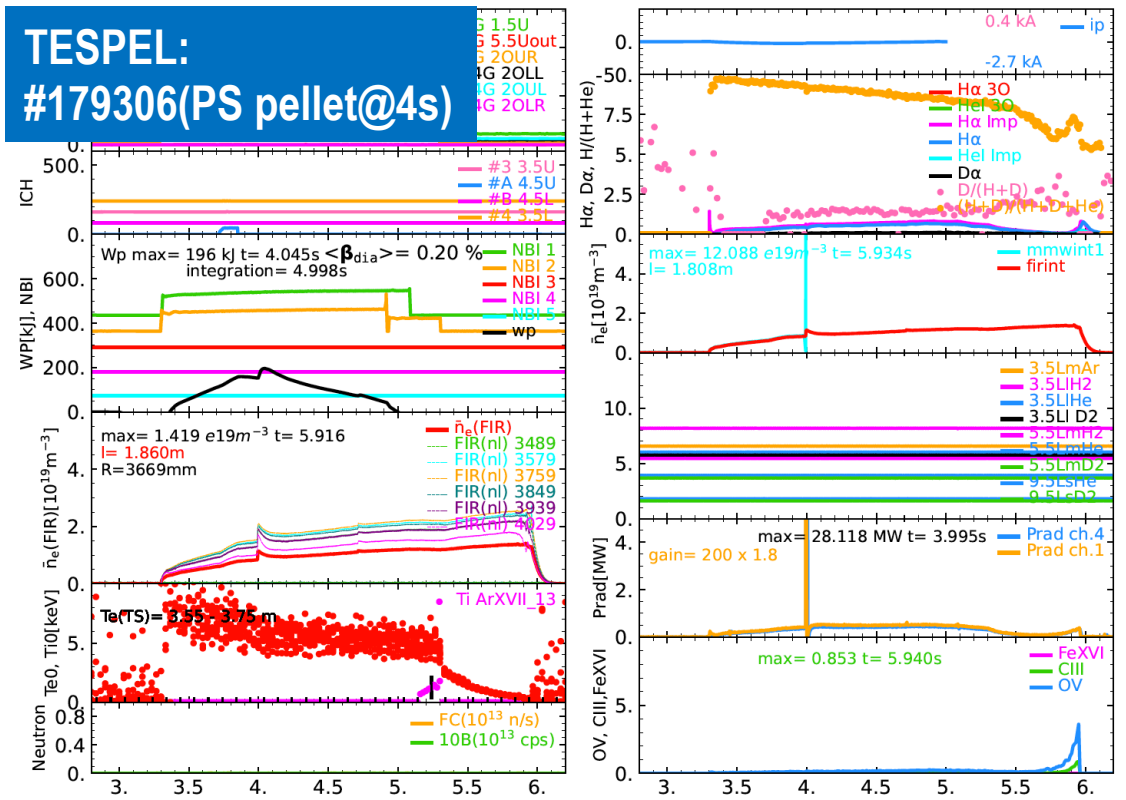
HIBP: OK, but more conditioning is needed

- HIBP could detect a secondary beam at the energy analyzer. But we still need the conditioning of the accelerator and the energy analyzer.

Impurity pellet: #179297(C pellet@4s)



TESPEL: #179306(PS pellet@4s)



Commissioning of ICRF antenna (ICH group)

Goal of ICRF antenna commissioning

- Exhausting gas from the ICRF antenna by repeated RF power injection
- Confirmation of the emission status of the ICRF antenna during the LHD experiment
- Confirmation of the impedance matching system using plasma
- Conditioning of high-power amplifiers by repeated operation

Motivation and objective

- Initial check for interaction between ICRF antenna and fast ions NBI particles.
- Checking the health of control equipment and identifying problems in operation.

Results

- No clear interaction on antennas was observed with an antenna–plasma gap of 6, 8, 10, and 12 cm.
- The RF power of more than 800 kW was injected from each antenna (3.5U/L and 4.5U)to mitigate the density increment during the ICRF power injection.
- The density increment was initially from 1e19 m-3 to about 3e19 m-3, but it was reduced to about 0.2~0.3e19 m-3, confirming that aging related to gas adhesion on the antennas has progressed.

Experimental conditions:
(R_{ax}, B_t, γ, B_q) = (3.60 m, CW 2.75 T, 1.2538, 100.0%)
Shot#179309 - #179334
L#1 1.5-UO(77GHz), 253kW

Purpose

For enhancing an availability of ECRH, a new injection scheme has been implemented since last campaign 2021.

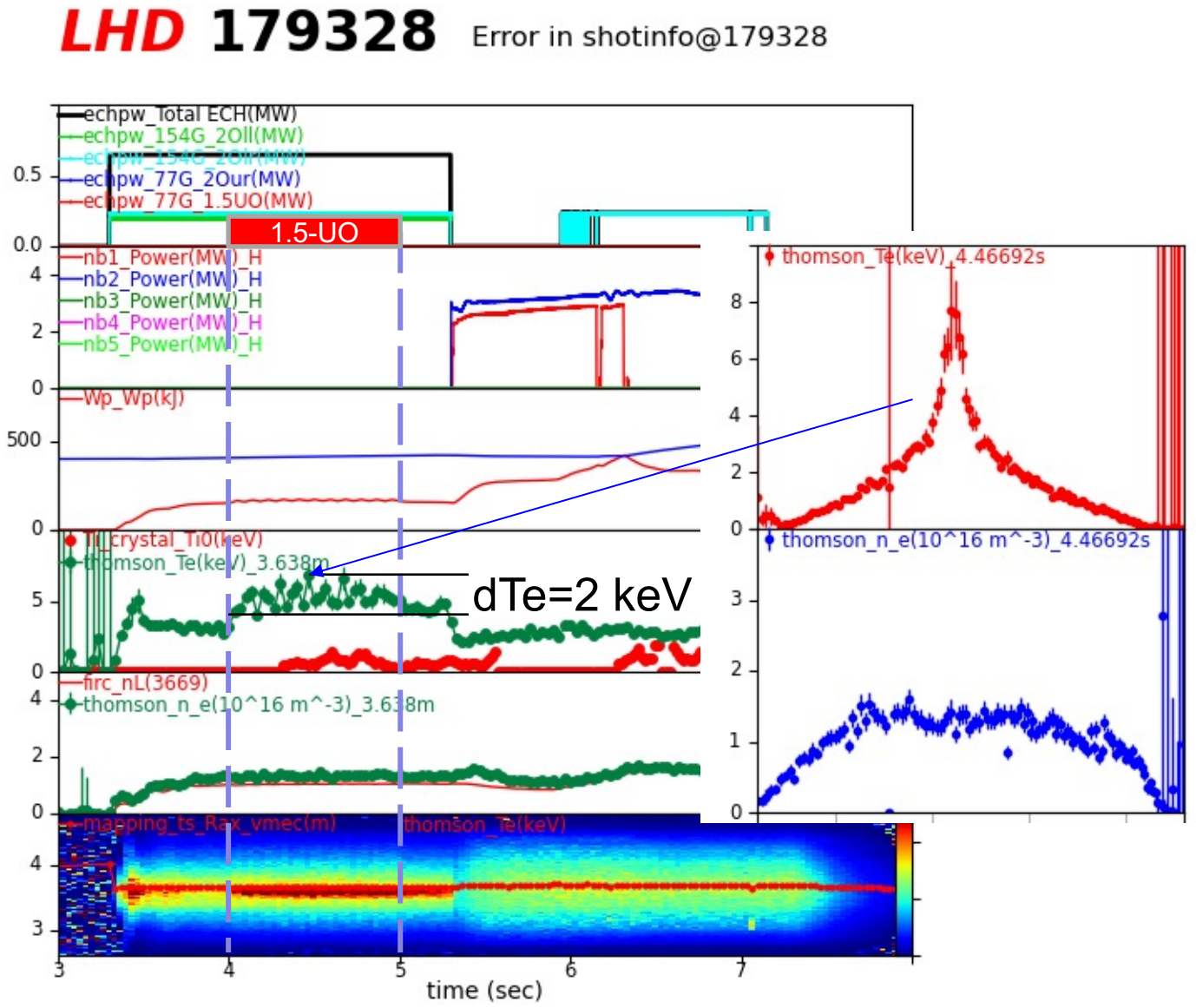
Merit

- high heating efficiency near the cut off density of 77 GHz.
- Current drive free.

Results

Modulated ECH is injected to obtain a deposition power.

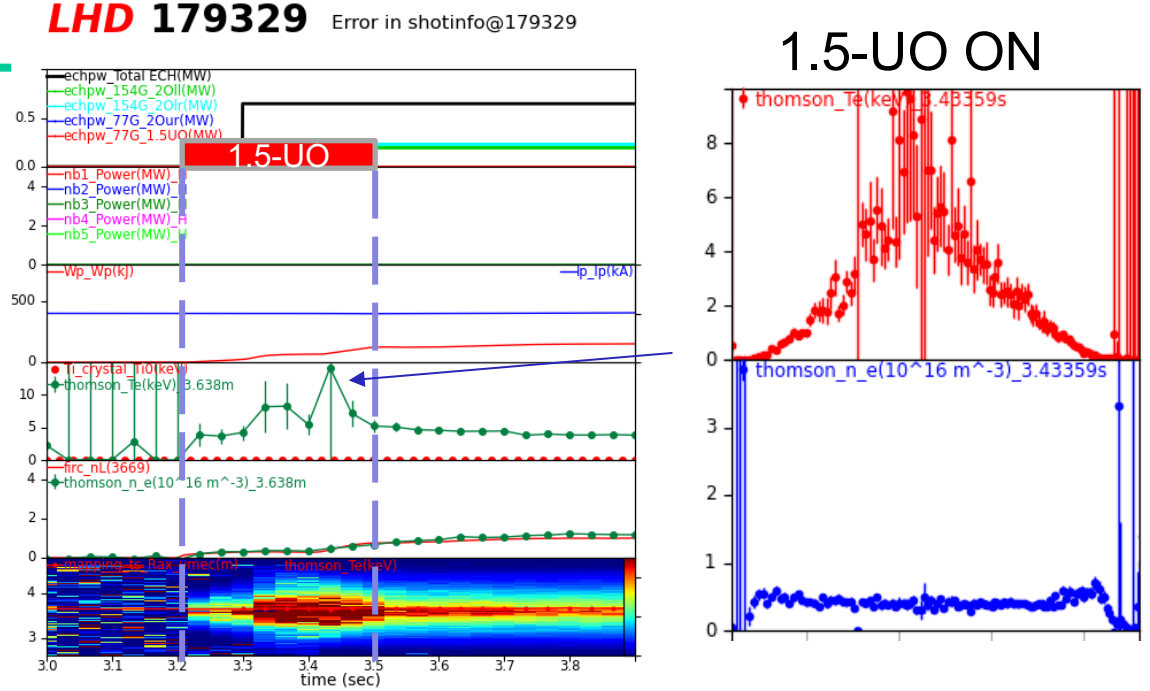
- dTe of 2 keV is achieved at 253 kW.



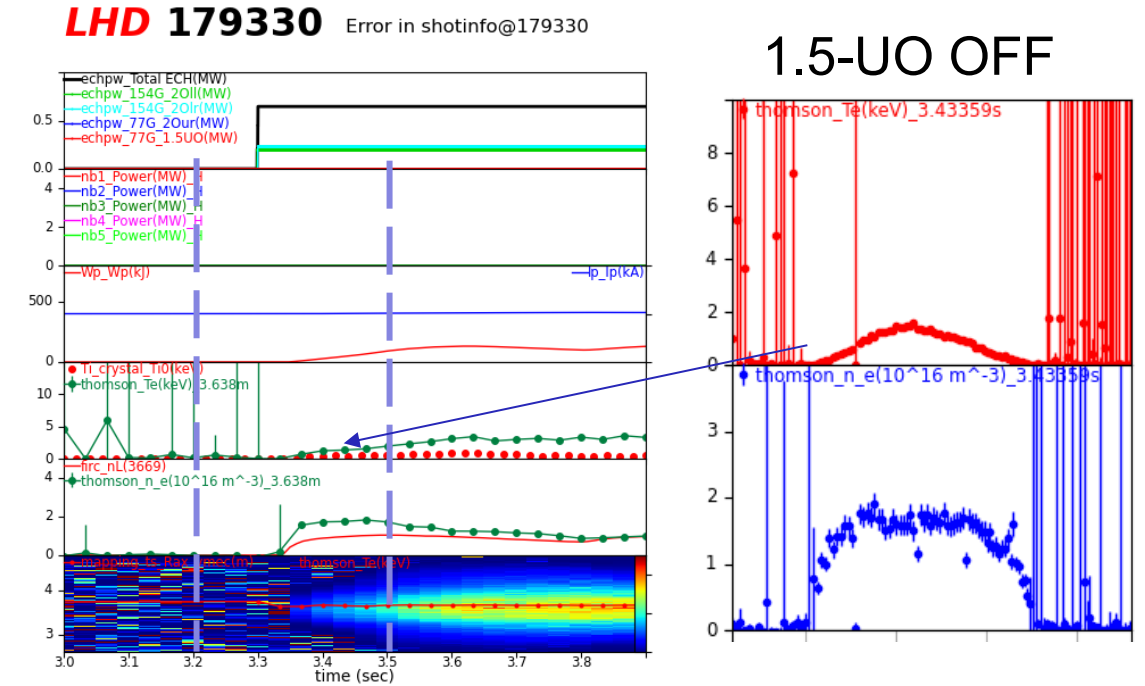
Plasma start-up by 1.5-UO ECH

- 1.5-UO ECH succeeded a plasma start-up at #179329.
- The electron temperature formed with other ECHs achieved Te ~ 8 keV at Ne ~0.5x10^{19} m^{-3}.

The reflection protection has been performed by tilting a final mirror angle toward an inner wall of the LHD. The maximum power limit was ~300 kW at the last campaign. We continue the test to overcome the limitation.



1.5-UO ON



1.5-UO OFF

Commissioning of optical vortex ECH

T. Tsujimura and R. Yanai

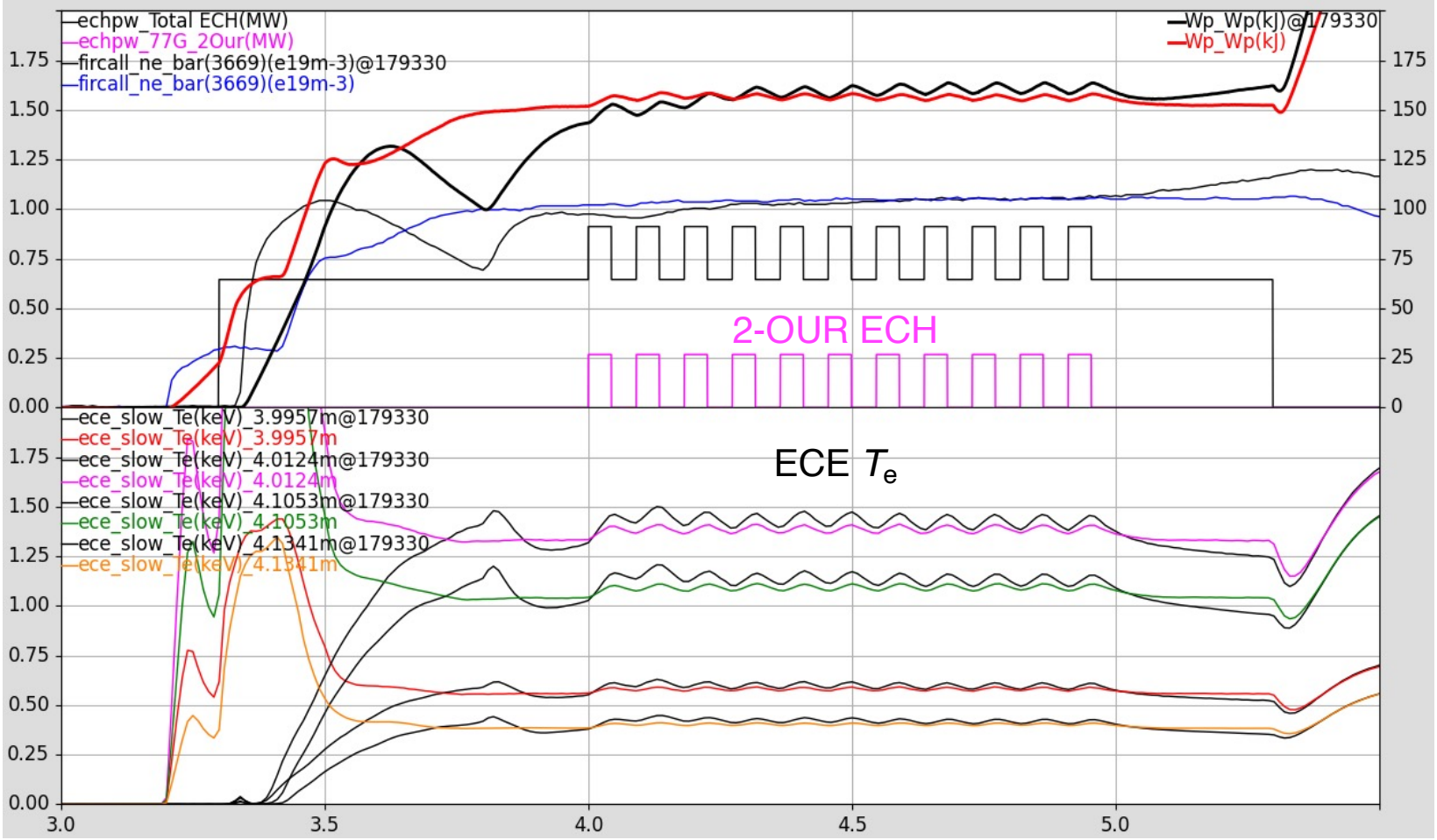
Experimental conditions:

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

Motivation:

- Our theory shows new propagation properties by using vortex EC waves.
- We experimentally investigate heating properties of optical vortex ECH.

OV ECH (#179329), Conventional ECH (#179330)



Results:

- The newly installed bypass waveguide to make optical vortex mm-wave for ECH 2-OUR functioned properly by using waveguide switches during a shot interval.
- Optical vortex EC waves were successfully injected during 1 s without problems in VV.
- The estimated heating power was ~150 kW, lower than ~270 kW of conventional ECH, possibly due to transmission loss with the unoptimized transmission system.
- We will check heating characteristics of higher n_e plasma next time.

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Robust Pressure Gauges (ITER and W7-X design) in LHD

U. Wenzel*, V. Haak*, G. Motojima**

* Max-Planck-Institute for Plasma Physics Greifswald

** NIFS

EUROfusion

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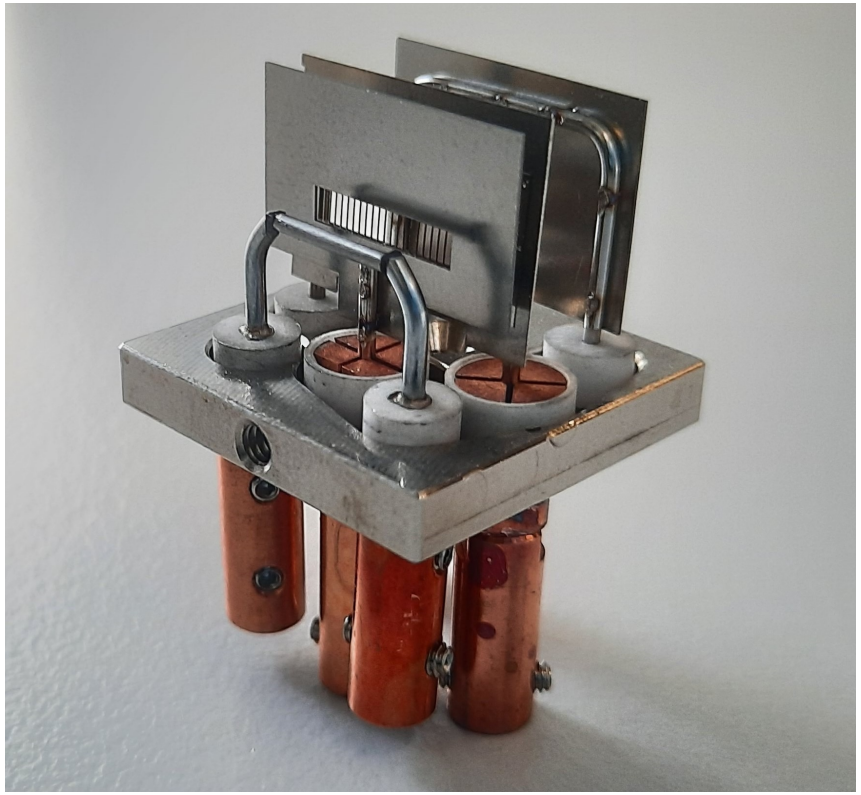
Pressure Gauges with New Cathode Materials

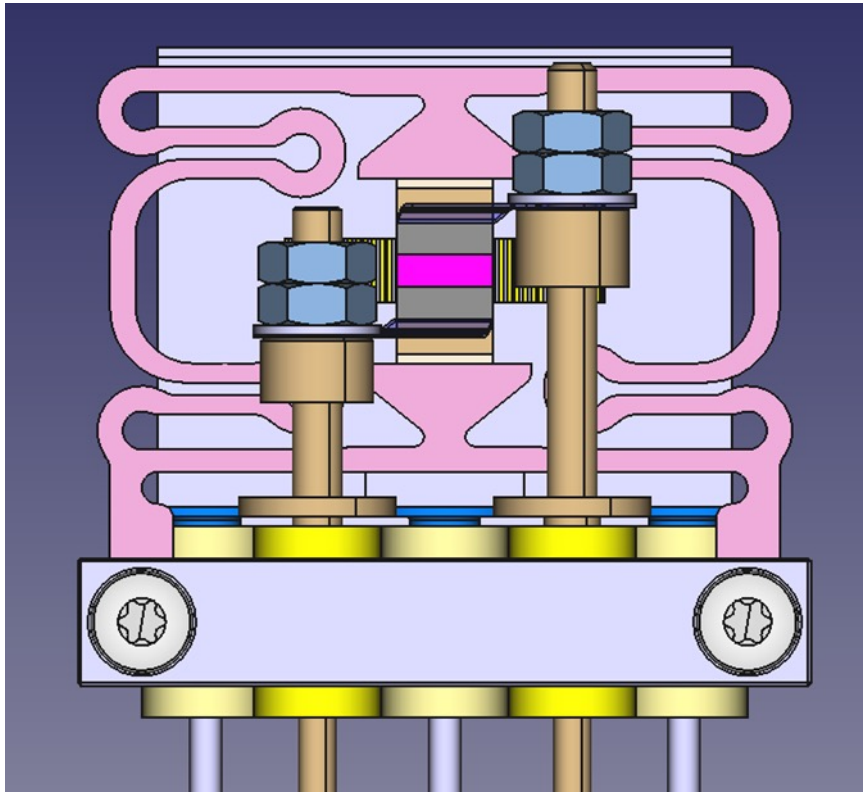


Pressure gauge with rod cathode (W7-X design)

Severe problems in LHD with crystalline LaB6 cathodes during D-D operation caused by neutrons

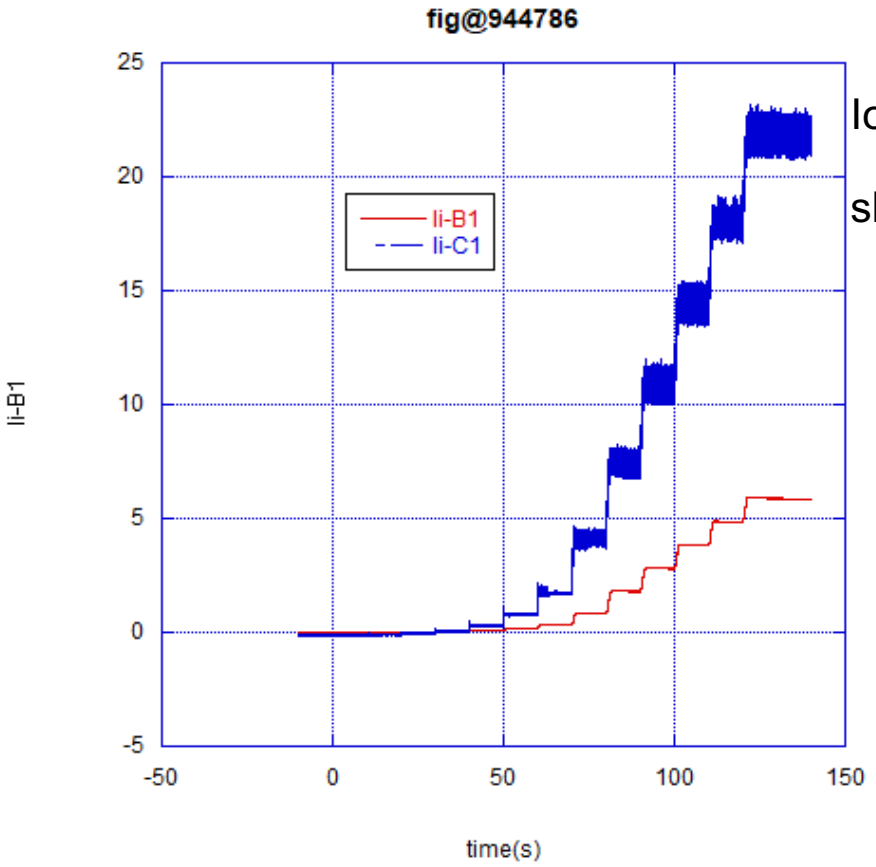
Test of the ITER design with sandwich cathode made of ZrC

Test of the rod design with sintered LaB6 cathode



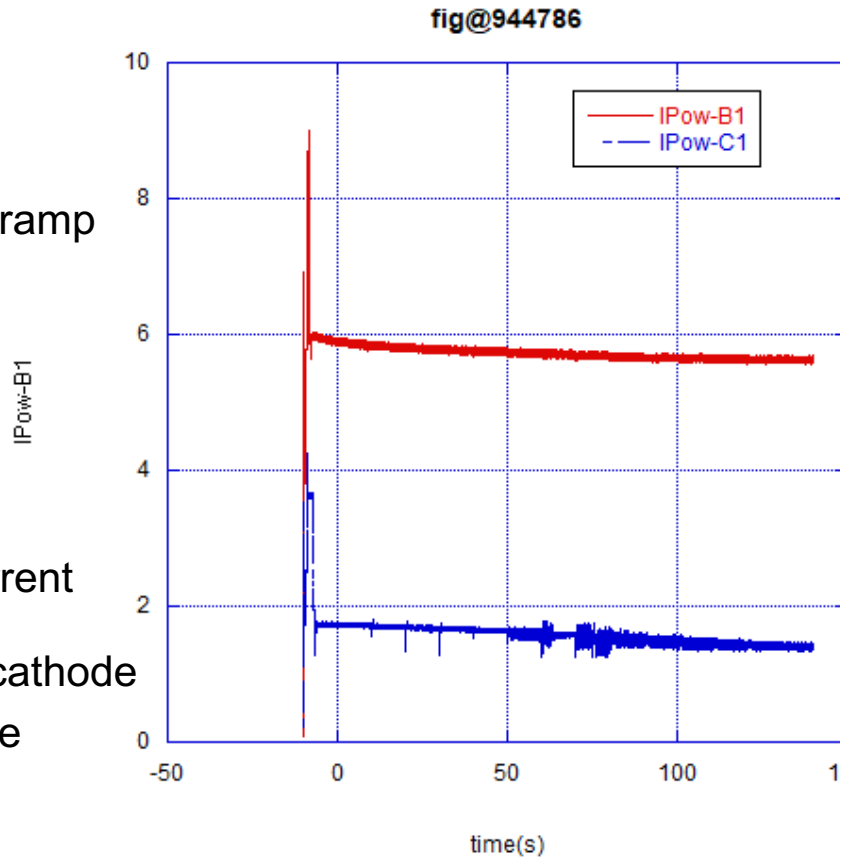
Pressure gauge with sandwich cathode (ITER design)

Calibration in hydrogen (944782) and deuterium (944786) by pressure ramps with B field



Ion current

shows the pressure ramp



Heating current

shows the cathode performance

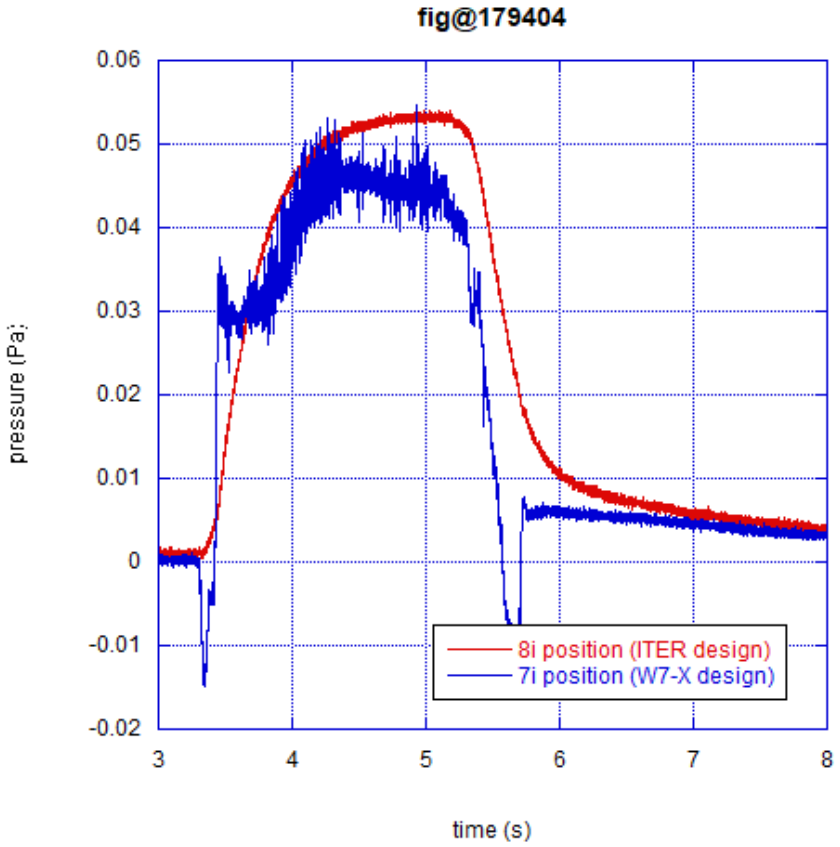
Red – ITER sandwich design

Blue – W7-X rod design

Stable behaviour of the cathodes in deuterium

Heating current decreases with pressure

Sequence of plasma shots with 2 tang. neutral beams H→H Density 2, 3, 4*10^{19}m^{-3} as a reference for later D→D operation

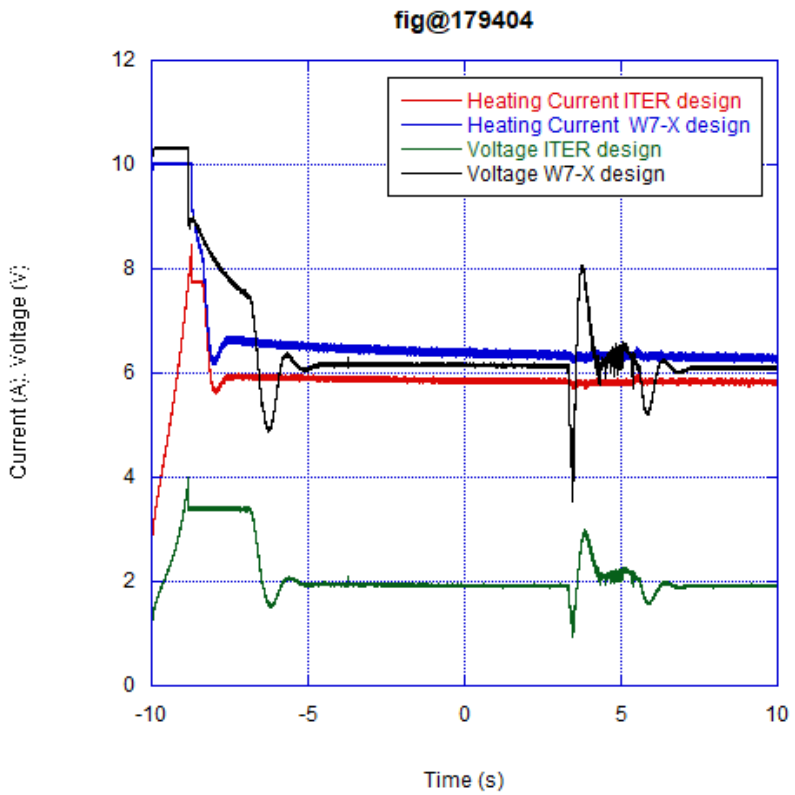


Last shot of the sequence:
Divertor pressure was 0.05 Pa

Power consumption of the cathodes

LaB6 12 W

ZrC 36 W



Cathode performance was very stable during the shot sequence and very close to the power consumption during calibration

Summary

Very good performance of the pressure gauges at the begin of the campaign during H-H operation

Reference scenario was defined for the D-D operation

Next performance check will be made at the end of D-D operation