(TG1) Multi-ion group report

Dec. 13, 2022 (G. Motojima)

Date: Dec. 9, 2022
Time: 13:12-18:42
Shot#: 185647-185747 (101shots)

Prior wall conditioning: No

Divertor pump: Yes
Gas puff: H_2, Ar
H/D pellet: No

NBI#(1, 2, 3, 4, 5) = gas(H, H, H, H, H/He) = P(3.7,3.8,3.4,2.3/3.8)MW

ECH(77 GHz) = ant(5.5-Uout, 2-OUR) = P(703,0) kW
ECH(154 GHz) = ant(2-OLL, 2-OUL , 2-OLR) = P(723,715,727) kW
ECH(56 GHz) = ant(1.5U) = P(-) kW
ICH(3.5U, 3.5L, 4.5U, 4.5L) = P(0.46,0.41,0.68,0.68) MW
Neutron yield integrated over the experiment = 3.8×10^{13} (TG1)
Topics

1. Search for optimal conditions of He beam injection into H-NBI heated plasmas (N. Tamura)
2. Observation of ultra higher harmonic ICEs during He beam injection (H. Igami)
3. Helium exhaust with closed helical divertor at the Large Helical Device (Stepan Sereda+(Univ. Wisconsin))
4. He removal w and w/o RMP(G. Motojima, K. Hanada(Kyushu Univ.))

Search for optimal conditions of He beam injection into H-NBI heated plasmas (N. Tamura on behalf of TG1)

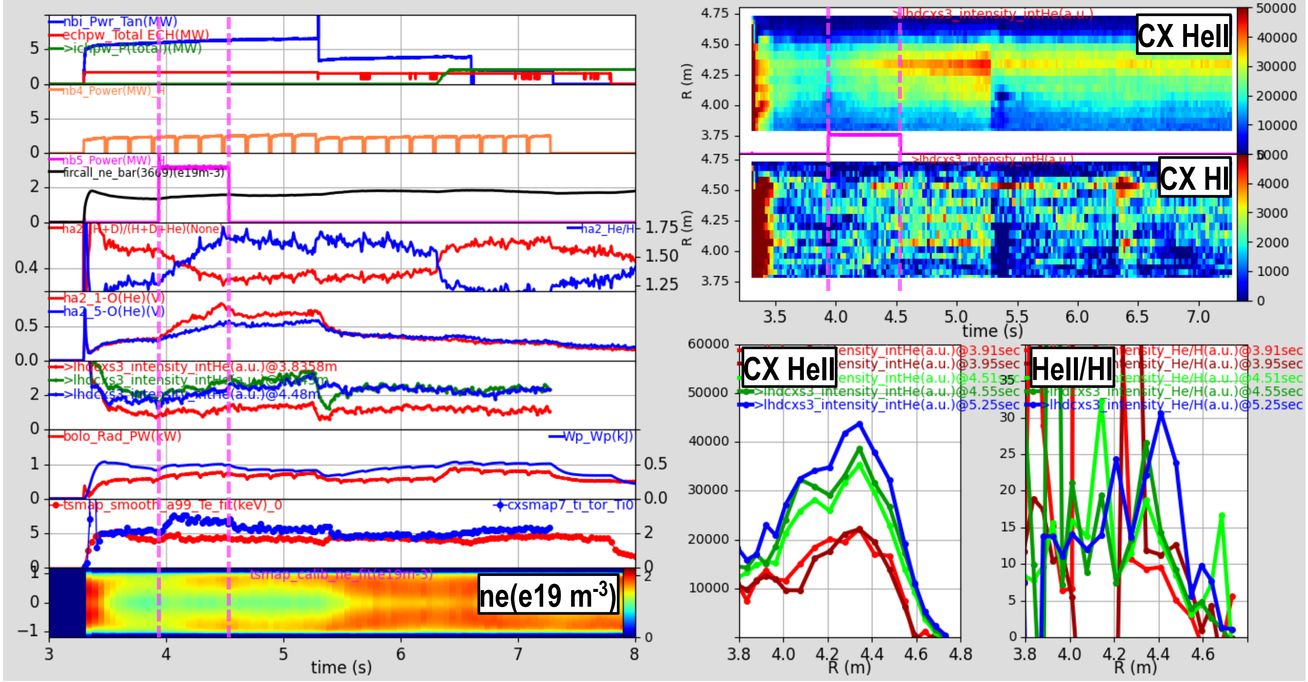
Experimental conditions, Shots: (R_{ax}, Polarity, B_t, γ, B_q) = (3.60 m, CCW, 2.7500T, 1.2538, 100.0%), #185644 - #185666

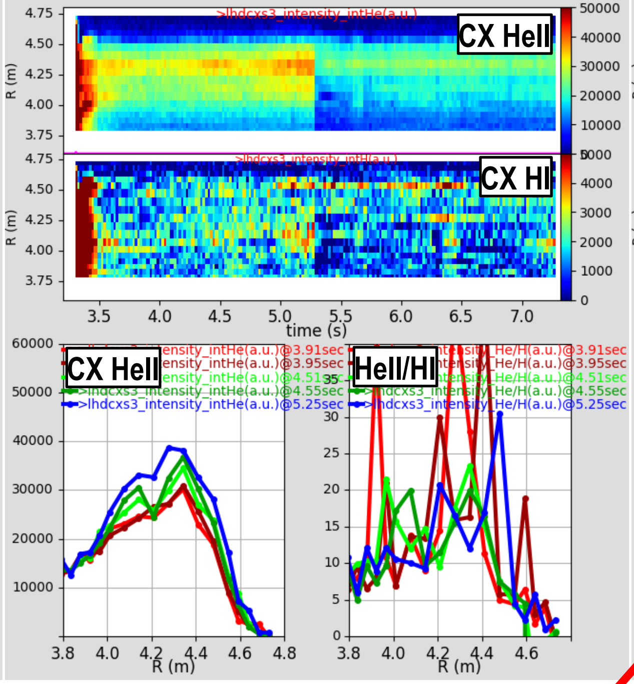
Goal of this experiment: Commissioning of the He beam injection with NBI#5 into LHD plasmas

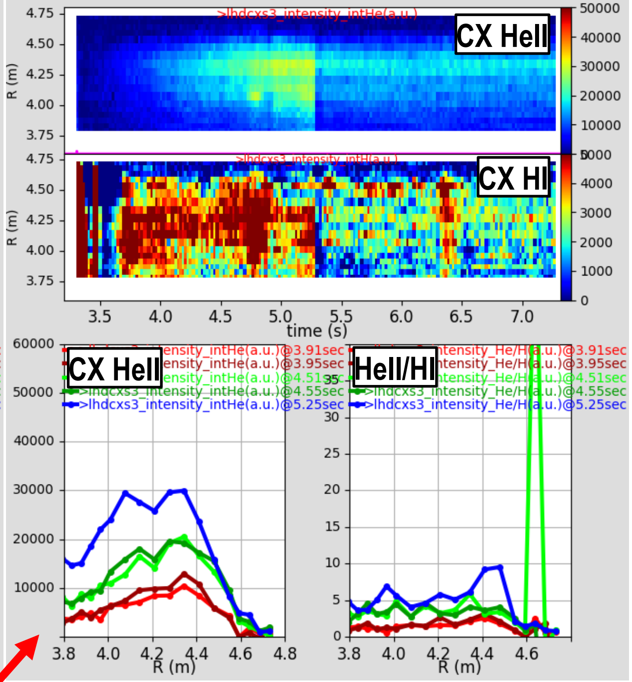
Main results of this experiment

- We achieved a lower target line-averaged density, ~ **1.5E19** m^{-3}, than that on Nov. 18
- To confirm the core fueling of He by the He-NBI, we have performed the experiments **with He beam injection**, **without He beam injection (but a He gas was introduced in NBI#5)**, and **without any operations in NBI#5 (just GV opened)**
  - ✓ We observed the bigger and more clear difference (between the He-beam injection and without beam injection) we have ever made

w/ He-beam injection (3.93s - 4.53s)	w/o He-beam extraction	w/o any operations in NBI#5 (just GV open), but the same target n_e







To achieve the same target ne, the H puff was done in a feedback manner.

Observation of ultra higher harmonic ICEs during He beam injection

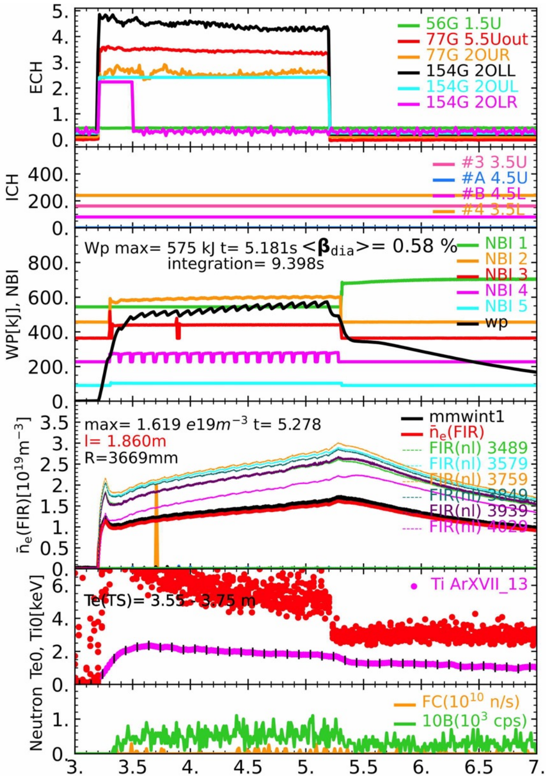
H. Igami

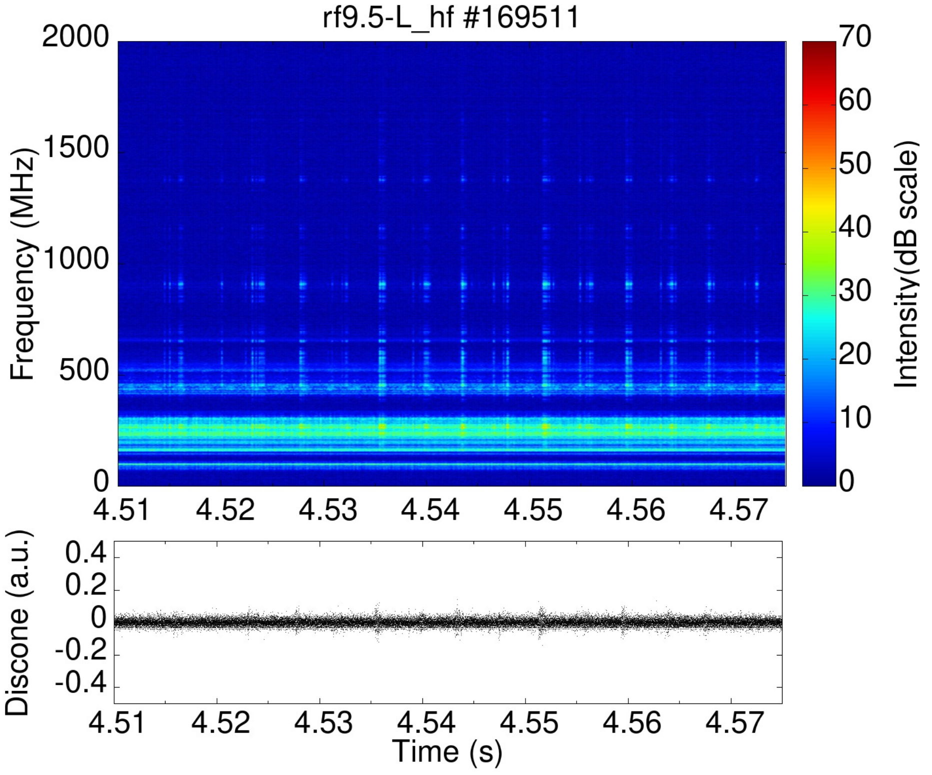
Shot #: 185667 - 185686

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

Background & Purpose:

- During He beam injection discharge #169511 (22nd cycle), bursty RF emissions were observed up to GHz range
- Intense large peaks appeared with interval of ~230 MHz with fine peaks of ~10/~20 MHz
- Excitation of similar RF bursts with D(2022/11/18)/H(2022/12/09) tangential and perp. beams, different background gas, and density to investigate the characteristics of wave-wave coupling between the lower hybrid wave and ion cyclotron harmonic waves was tried.





BL 1, 2, 3, 4 : H beams

BL 5 : He beam, 61keV/1.35 MW

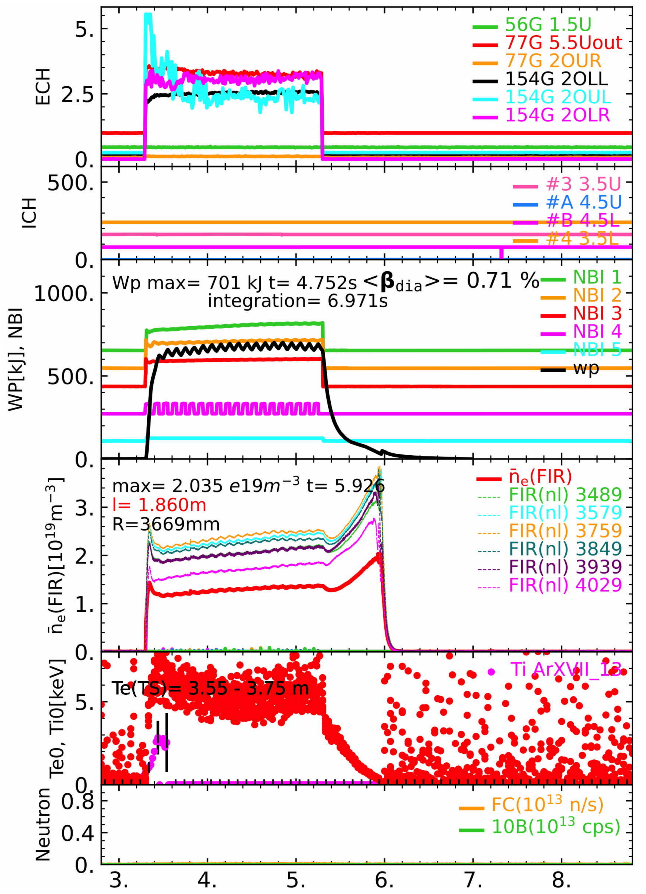
ne ~ 1.2 x 10^{19}m^{-3}

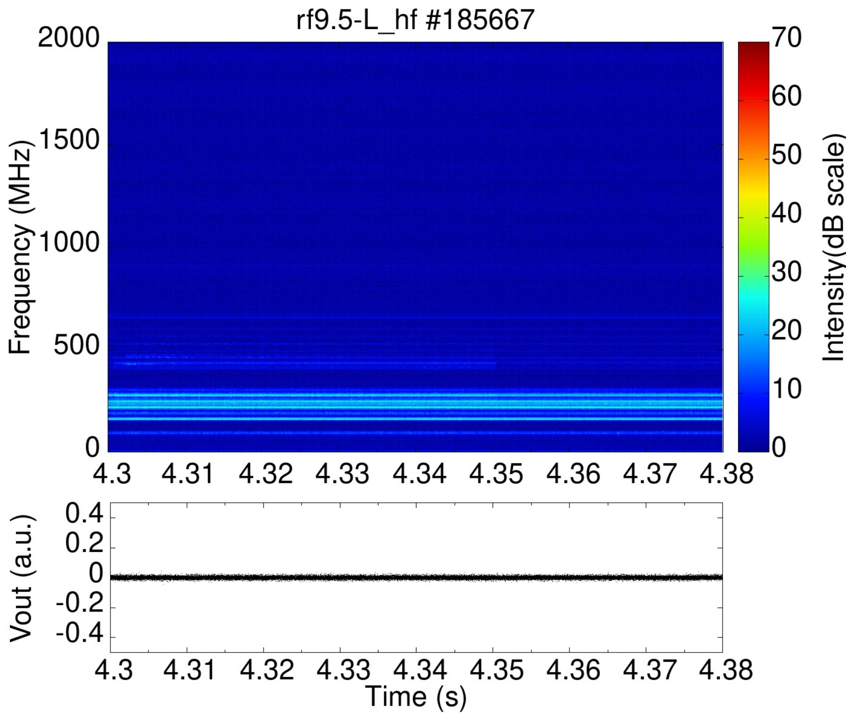
Observation of ultra higher harmonic ICEs during He beam injection

H. Igami

Experimental Results 1

- He beam of 67keV/(1.61-3.22)MW was superimposed to hydrogen tangential and perpendicular beams and ECRH
- Similar bursts were not observed





BL 1, 2, 3, 4 : H beams

BL 5 : He beam, 67keV/1.61 MW

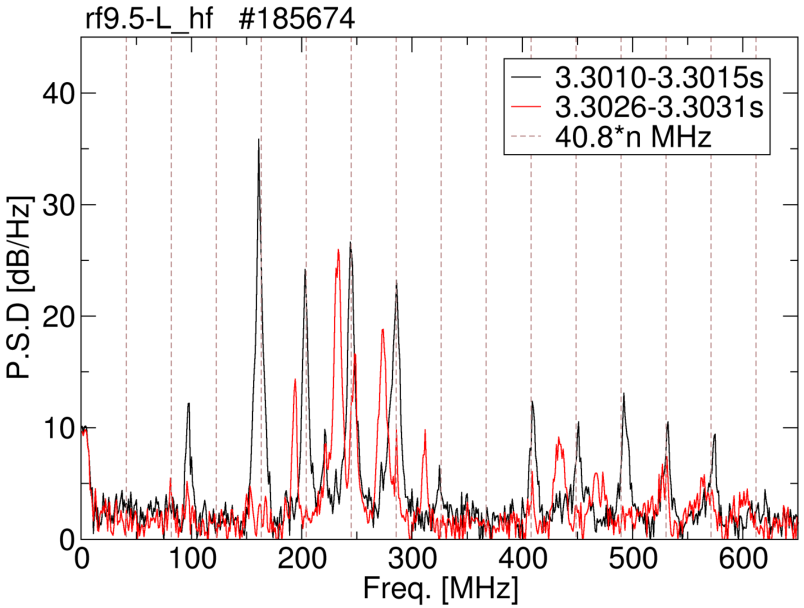
ne ~ 1.2 x 10^{19}m^{-3}

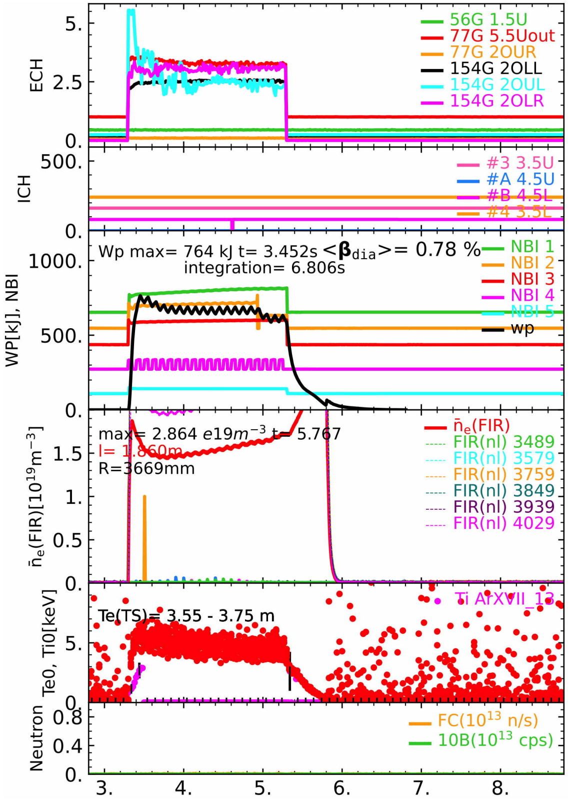
Observation of ultra higher harmonic ICEs during He beam injection

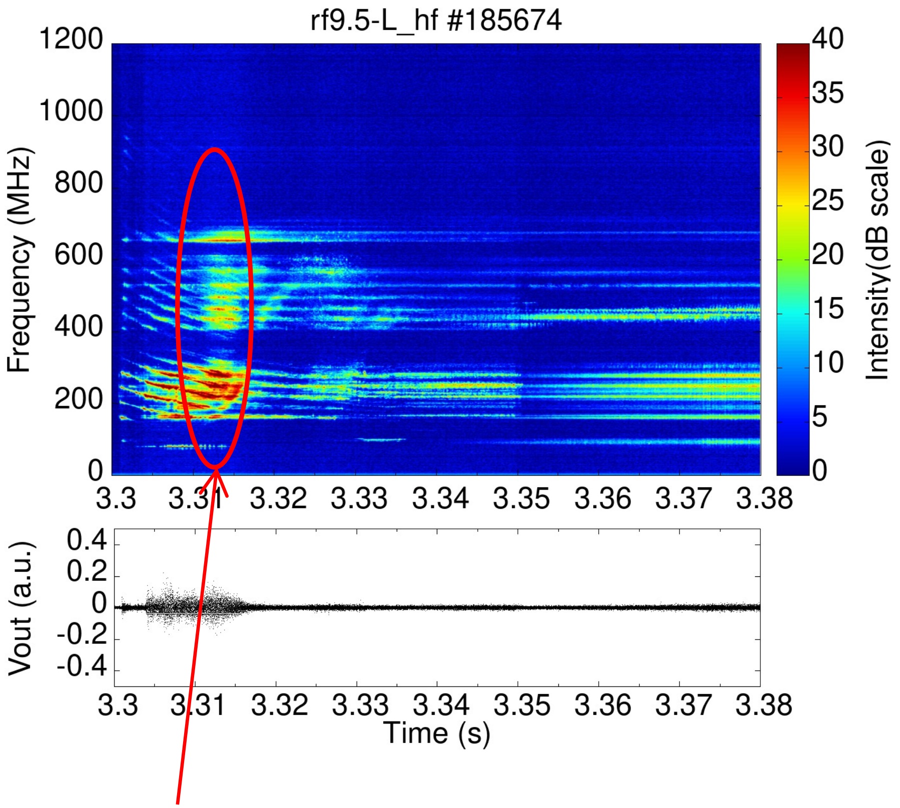
H. Igami

Experimental Results 2

- At the plasma initiation phase, intense peaks of spectra at higher integer multiples of ICR frequency (40.8MHz) and between such higher ICR harmonics were observed
- ICW and IBW might be excited near the plasma core region







BL 1, 2, 3, 4 : H beams
BL 5 : He beam, 67keV/3.2 MW
ne ~ 1.2 x 10^{19}m^{-3}

When two branches (ICW and IBW?) merge, the peak intensity at each “merging frequency” increases

Helium exhaust with closed helical divertor at the Large Helical Device LHD: experiment on 9th December

Stepan Sereda[1], K. Ida[2], M. Kobayashi[2], H. Funaba[2], O. Schmitz[1]

1 - University of Wisconsin – Madison, Department of Engineering Physics, Madison, WI, USA

2 - National Institute for Fusion Science, High Density Plasma Physics Research Division, Toki, Japan

LHD meeting – 13.12.2022

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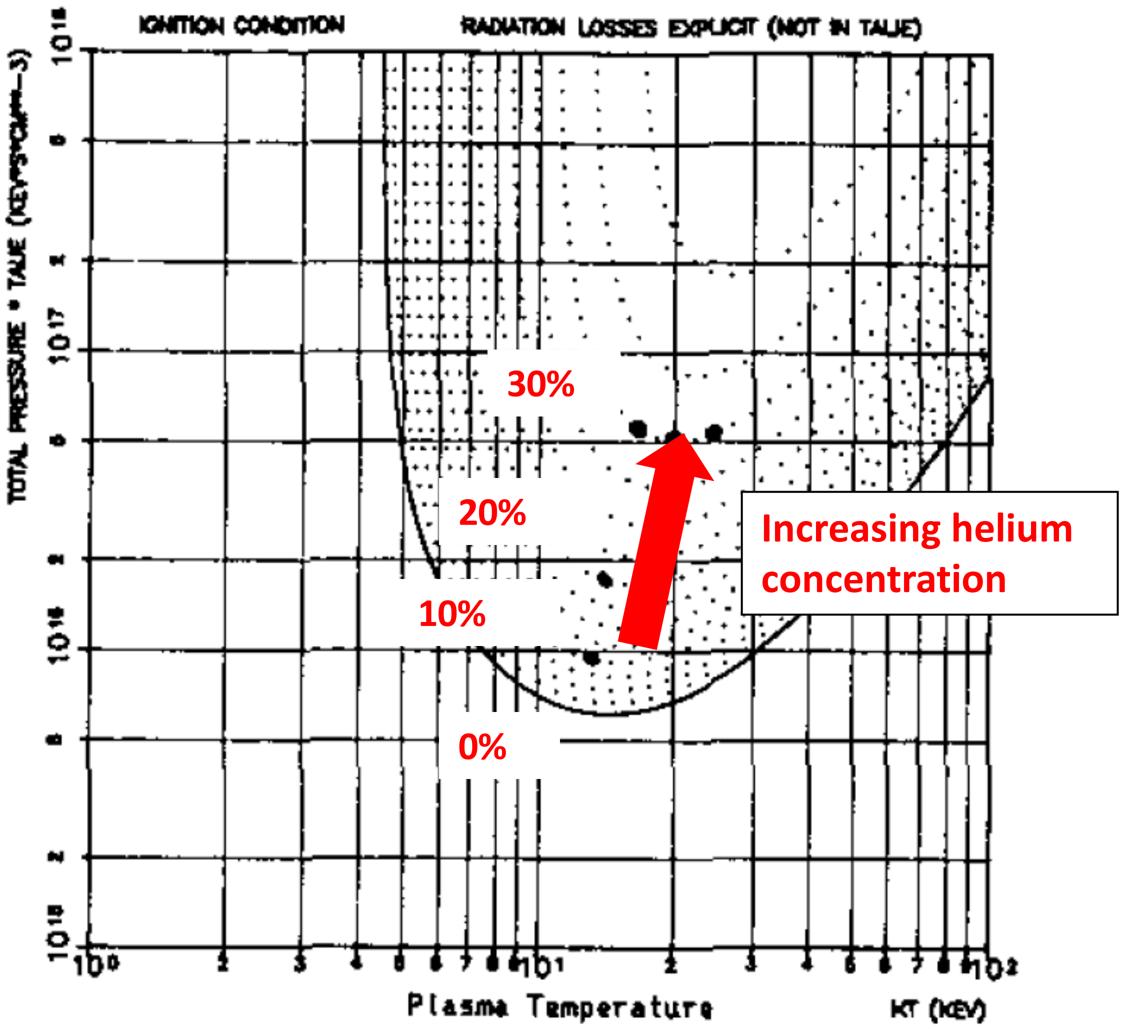
Motivation: Helium ash must be exhausted efficiently in a future reactor



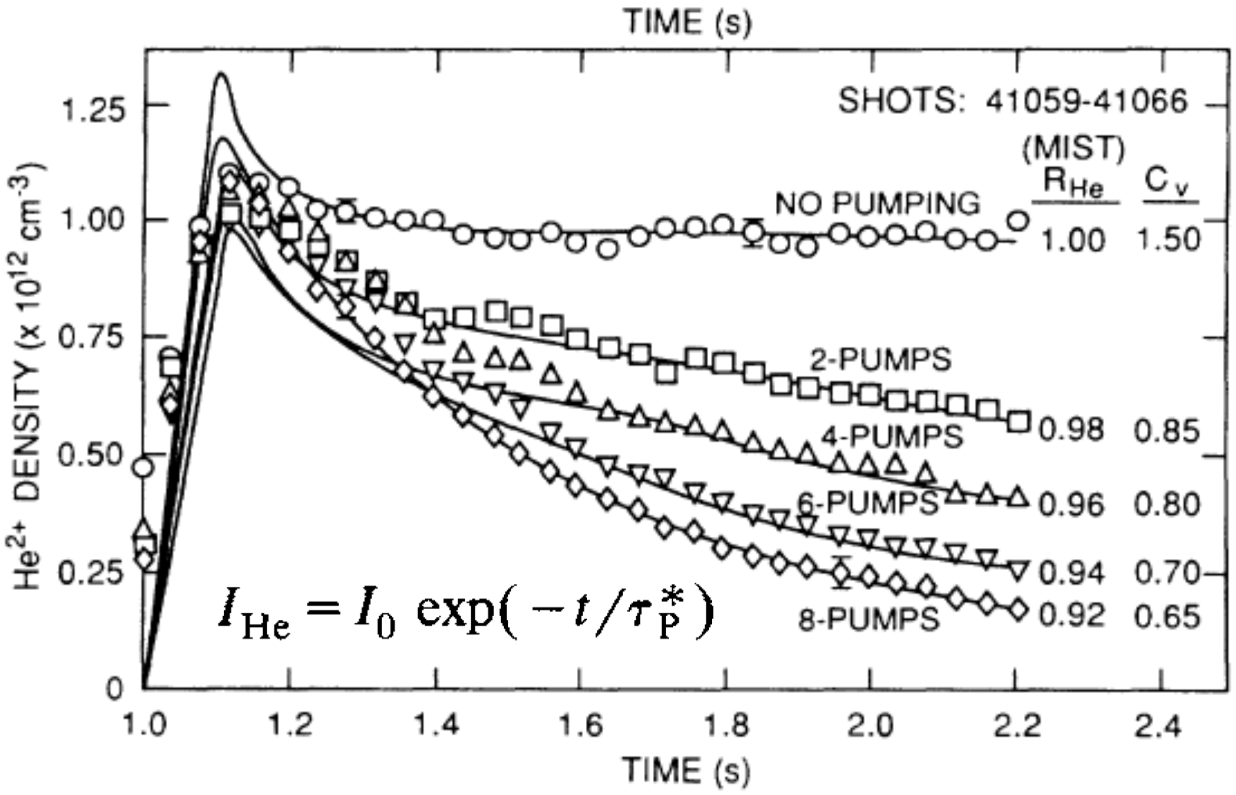
[Reiter, D. et al., PPCF 33 (1991) 13, 1579]

Effective helium confinement time is a key quantity to qualify island divertor

$$\tau^*_{He} = \tau_\alpha + R/(1-R)\tau_{He}$$

Core confinement	**Recycling**
Core plasma	**Edge plasma**
Fueling from fusion	**Fueling from recycling** **Exhaust**
HeNBI-5	**Gas injection 3.5L**

Exhaust of helium from system can be investigated by effective particle confinement time measurements for helium $\tau^*_{p,He}$



[Hillis, D. et al., PRL 65 (1990) 16, 2382] [Bosch, H.-S. et al., PPCF 39 (1997) 1771-1792]

Core confinement of helium can be measured with core helium source

We used NBI-5 for short helium source injection to plasma core

Exhaust efficiency is function of neutral pressure, pumping efficiency and flux

$$\epsilon_{He} = p_{(0,He)} \cdot S_{eff}/\Gamma_{He}$$

Neutral pressure gauge (spectroscopic Penning gauges, Prof. Funaba)

In-situ calibration

Spectroscopy

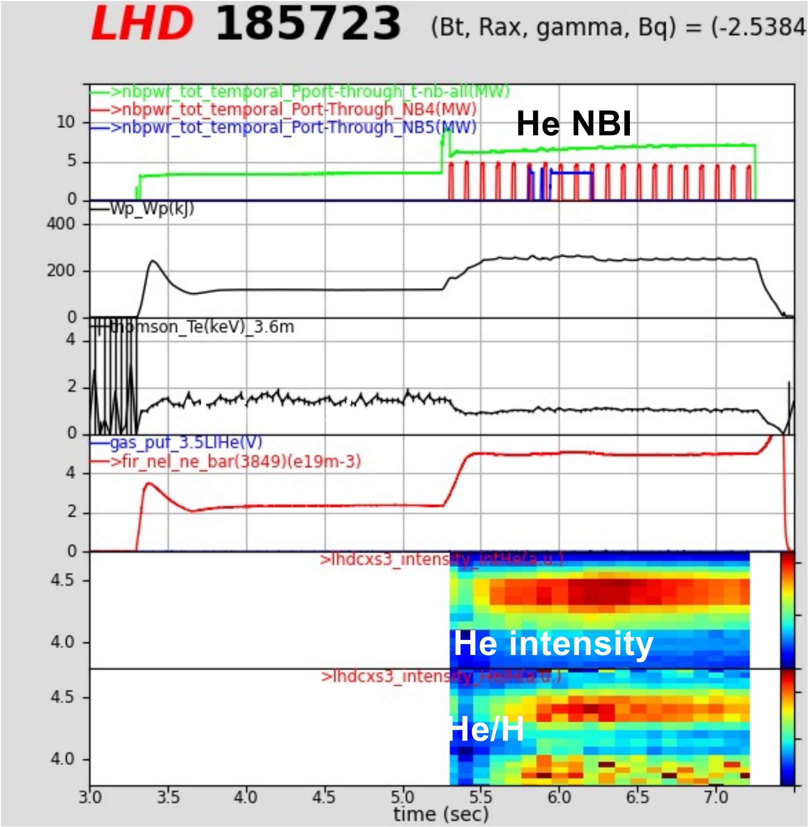
Exhaust efficiency is a combination of scrape off layer (SOL) and pump exhaust

$$\epsilon_{He} = \epsilon_{SOL} \cdot \epsilon_{Pump}$$

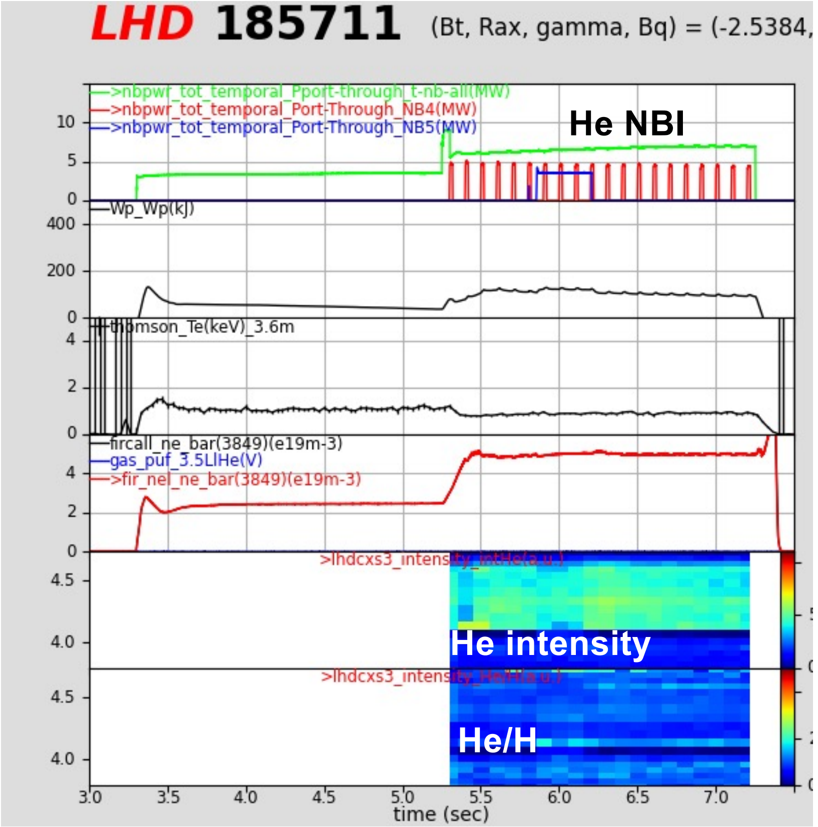
[Samm, U. et al., JNM 196-198 (1992) 633]

Enhanced helium exhaust for edge source with RMP in outward shifted configuration was confirmed when n=1 RMP at 3.3kA is applied

LHD #185723, R_{ax}=3.9m, $I_{n=1}$=0kA, density 4.5 x 10^{19} m^{-3}



LHD #185711, R_{ax}=3.9m, $I_{n=1}$=3.3kA, density 4.5 x 10^{19} m^{-3}



Initial inspection of data suggests:

- **Faster decay of helium signals with RMP**
- **Higher fueling w/o RMP**
- **Peak helium level is reached sooner with RMP**

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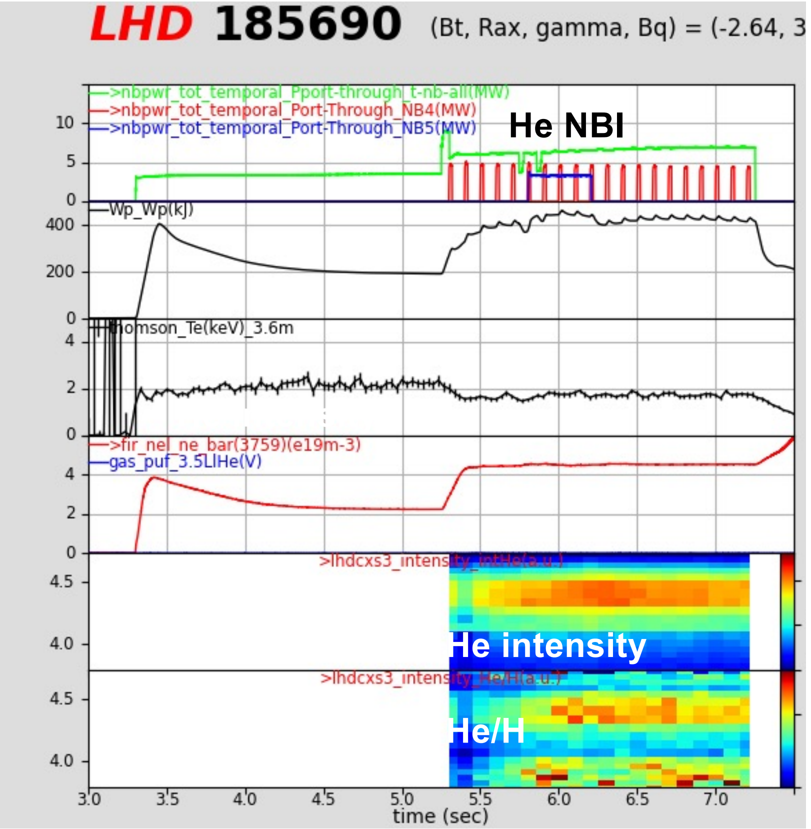
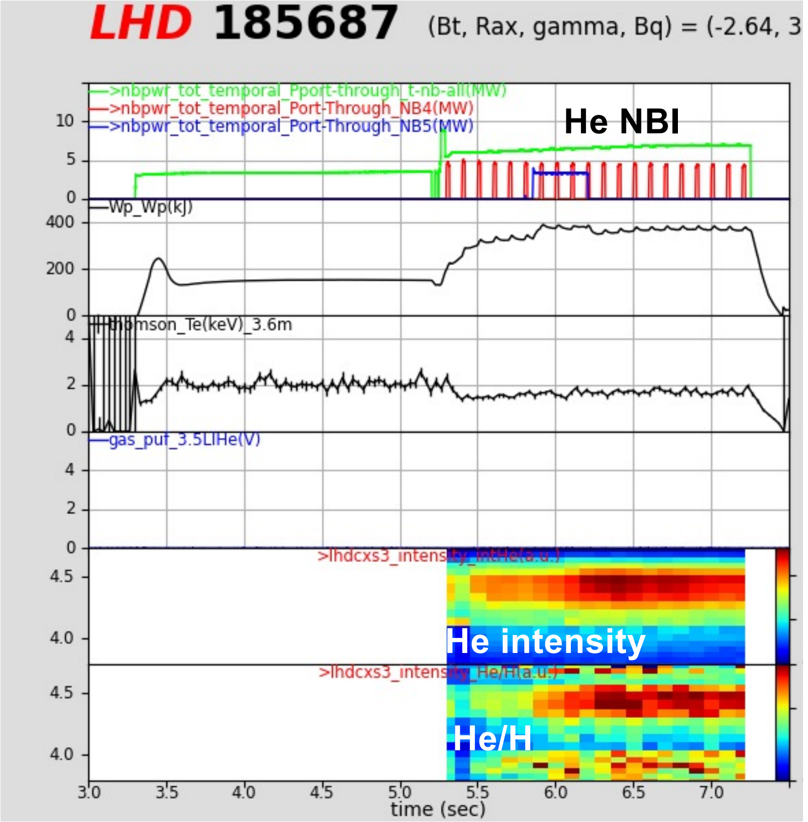
Reduced helium exhaust for edge source with RMP in medium shifted configuration was confirmed when n=1 RMP at 3.3kA is applied

LHD #185690, R_{ax}=3.75m, $I_{n=1}$=0kA, density 4.5 x 10^{19} m^{-3}



LHD #185687, R_{ax}=3.75m, $I_{n=1}$=3.3kA, density 4.5 x 10^{19} m^{-3}



Initial inspection of data suggests:

- Slower decay of helium signals with RMP
- Lower fueling w/o RMP

Data analysis needs and plan forward

Documentation of plasma and effect on He

- **Radial profiles:** He_int, H_int, He/H, H/(H+He)
- **Plasma profiles:** $n_e(r_{eff}/a)$, $T_e(r_{eff}/a)$, $T_i(r_{eff}/a)$
- **Neutral measurements:** WISP Penning gauges
- **2-D spectroscopy:** He intensities, extract 2-D n_e and T_e maps

Summary

- Successful measurement in the outward (Rax=3.9 m) and medium (Rax=3.75 m) shifted configurations
- RMP application improves He exhaust for the Rax=3.9 m case and reduces it for the Rax=3.75 m case
- Both He-NBI and He puffs were performed
- WISP gauge for partial pressures was operating
- Next step: deep data analysis

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He removal w and w/o RMP

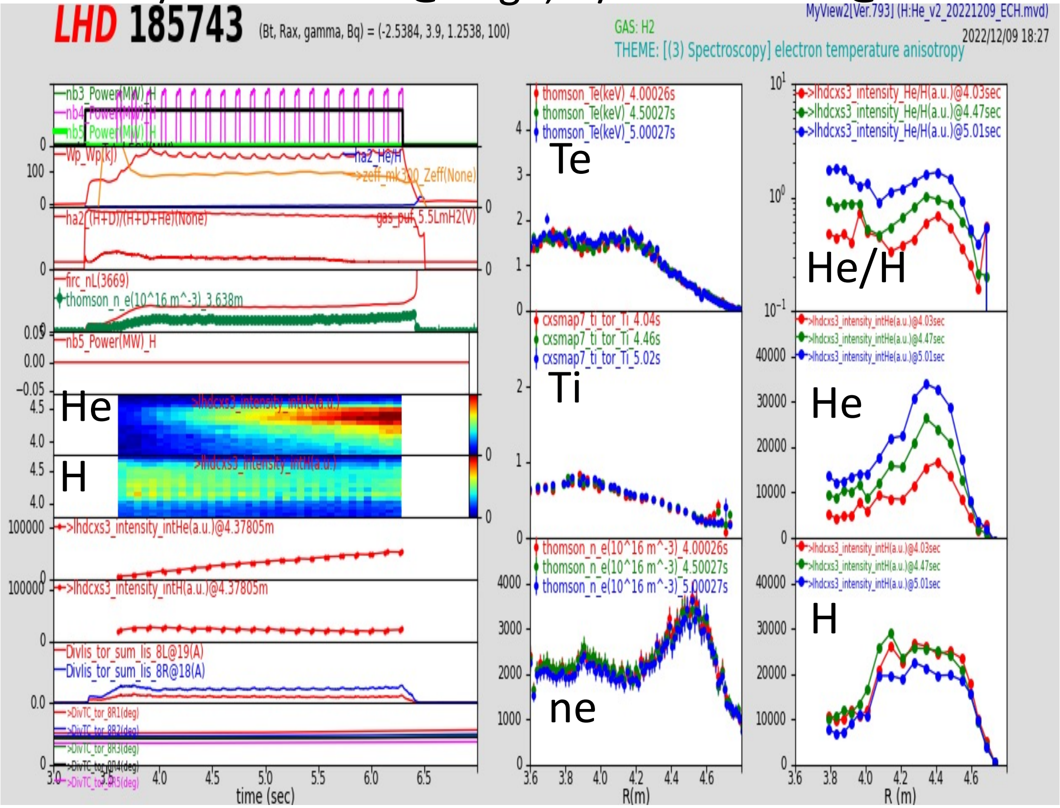
G. Motojima, K. Hanada (Kyushu Univ.)

✓ #185729-185747 R=3.9m, B=-2.538T, γ=1.254, Bq=100%

Hydrogen NBI and ECH discharges were conducted to remove He from the wall w and w/o RMP

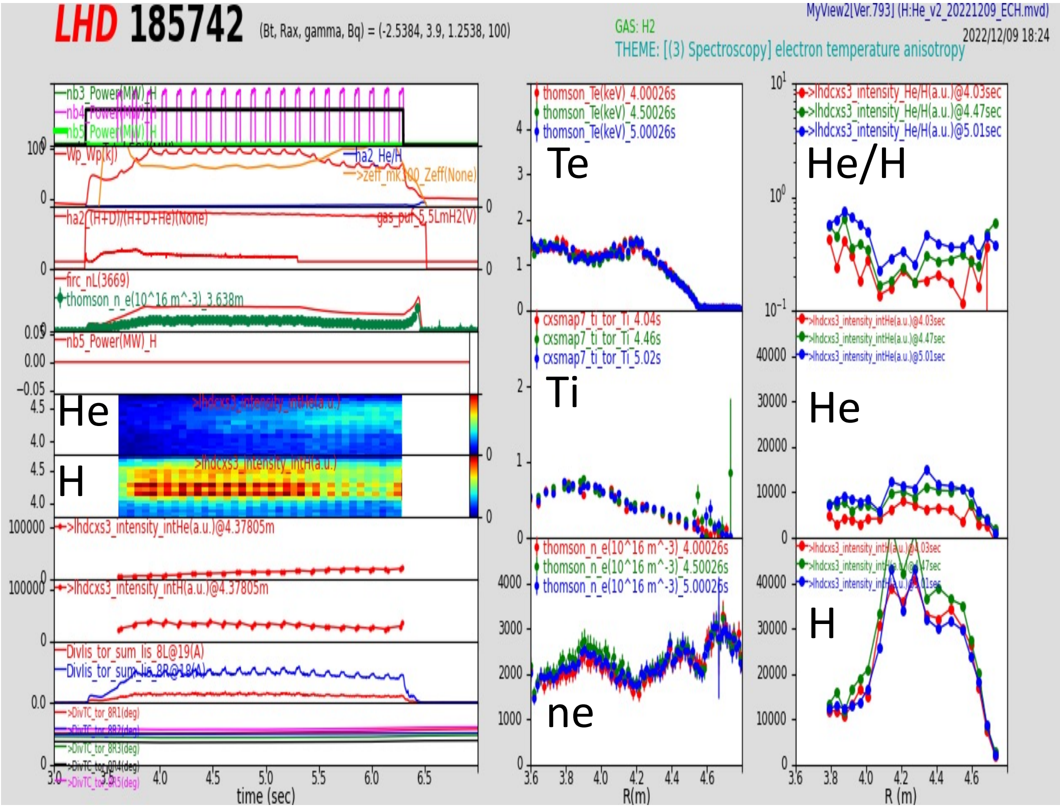
w/o RMP

H/H+He~0.88 @edge, H/H+He~0.44 @bulk



w RMP

H/H+He~0.88 @edge, H/H+He~0.71 @bulk



- ✓ The RMP flattens the edge temperature and increase the edge density.
- ✓ In the case w RMP, the amount of helium in the bulk is reduced and, conversely, the amount of hydrogen is increased. These results in a higher H/(He+H) in the bulk w RMP. -> RMP reduces influx of He from edge to the core and increasing influx of H from the edge to the core? It seems to be selective transport happened.