(TG3) Spectroscopy group report

Date: Oct. 18, 2022

Oct. 19, 2022 (T. Kawate, M. Yoshinuma)

Time: 10:13 – 18:43
Shot#: 180633 – 180788 (156 shots)
Prior wall conditioning: No
Divertor pump: Yes
Gas puff: H_2, D_2. He. Ar
Pellet: H_2 , H_2(Ne-doped), D_2, TESPEL(Ti/V/Mn, Fe/Ni/Cu)

NBI#(1, 2, 3, 4, 5)=gas(H, H, H, H, H)=P(-, 4.0, 3.0, 4.5, 3.2)MW
ECH(77GHz)=ant(5.5-U, 2-OUR)=P(0.703, 0.792)MW
ECH(154GHz)=ant(2-OLL, 2-OUL, 2-OLR)=P(0.723, 0.799, 0.825)MW
ICH(3.5U, 3.5L, 4.5U, 4.5L)=P(0, 0, 0, 0)MW
Neutron yield integrated over the experiment = 1.4×10^{13}

Topics

1. Analysis of different hydrogen isotopes pellet injection for code validation (N.Panadero, R. Sakamoto)
2. Ablation of high Z (neon) and hydrogen cryogenic pellets and its implication to ITER DMS design (A. Matsuyama, R. Sakamoto)
3. Impurity transport study in EC- and NBI-heated plasmas using VUV spectroscopy in experiment with TESPEL injections (T. Fornal, N. Tamura)
4. Impurity transport study in LHD D/H plasmas using VUV spectroscopy in experiment with TESPEL injection (M. Kubkowska, N. Tamura)

Analysis of different hydrogen isotopes pellet injection for code validation

N. Panadero (CIEMAT), R. Sakamoto (NIFS), B. Pégourié (CEA/IRFM), N. Tamura (NIFS), G. Motojima (NIFS), K.McCarthy (CIEMAT)

- **Shot number: 180633 – 180704**
- **Objetives:**
  - Injections of pellets into different plasma conditions for HPI2 comparison (**a deeper understanding of pellet ablation and plasmoid homogenization**
    - Different hydrogen isotope pellets
    - Different **plasma scenarios** (not critical, but $n_e(0) \sim 2e19$, $T_e(0) \sim T_i(0) \sim$ 1-2 keV)
    - Different **magnetic configurations**
- To be obtained from experiments:
  - Pellet **ablation light**
  - **Fast camera → pellet trajectory**
  - Electron **density** and **temperature profiles** before and after pellet injection (Thomson Scattering)

- **Shot number: 180633 – 180704 → 27 useful shots (+ 9 from Matsuyama's experiment)**
- **Configuration R_{ax} = 3.9 m vs R_{ax} = 3.6 m**
- **Heating: NBI, some ECRH (from Matsuyama's exp.)**
- **Density scan: 1.5, 2 & $3 \cdot 10^{19}$ m^{-3}**
- **Different pellet sizes**
  - **→ different pellet penetrations**
- **Hydrogen vs Deuterium pellets**

	R_{ax} = 3.9 m		R_{ax} = 3.6 m	
	Hydrogen	**Deuterium**	**Hydrogen**	**Deuterium**
3 mm	7	☒	7	☒
3.4 mm	☒	☒	5	2
3.8 mm	☒	☒	8	1

Analysis of different hydrogen isotopes pellet injection for code validation

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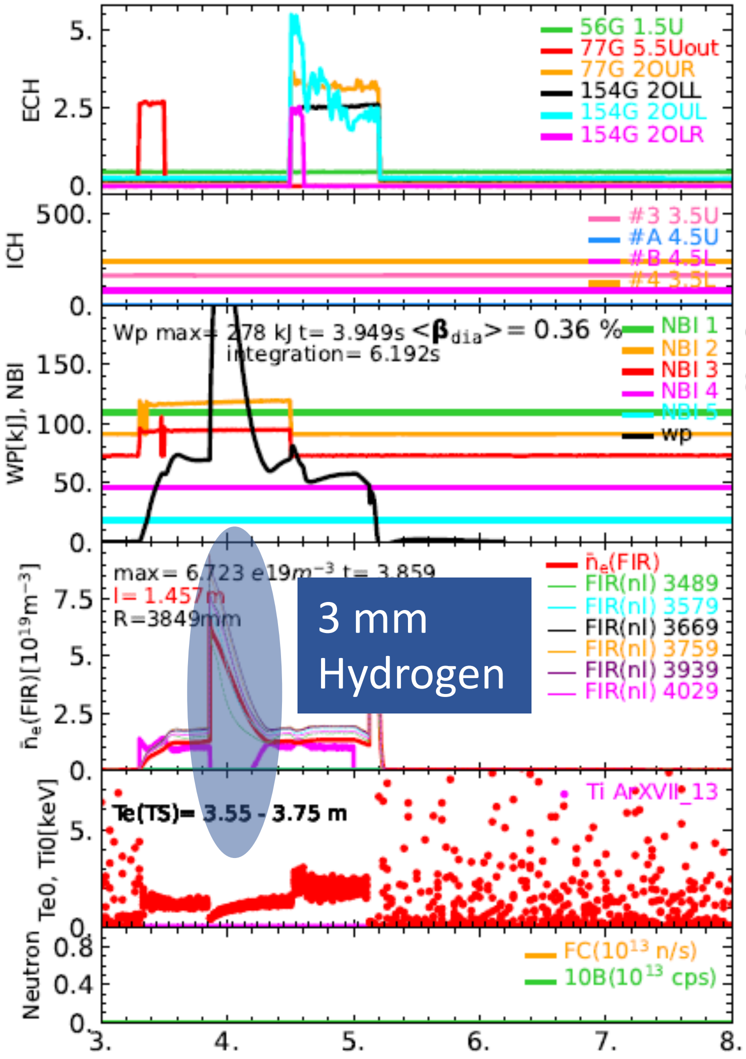
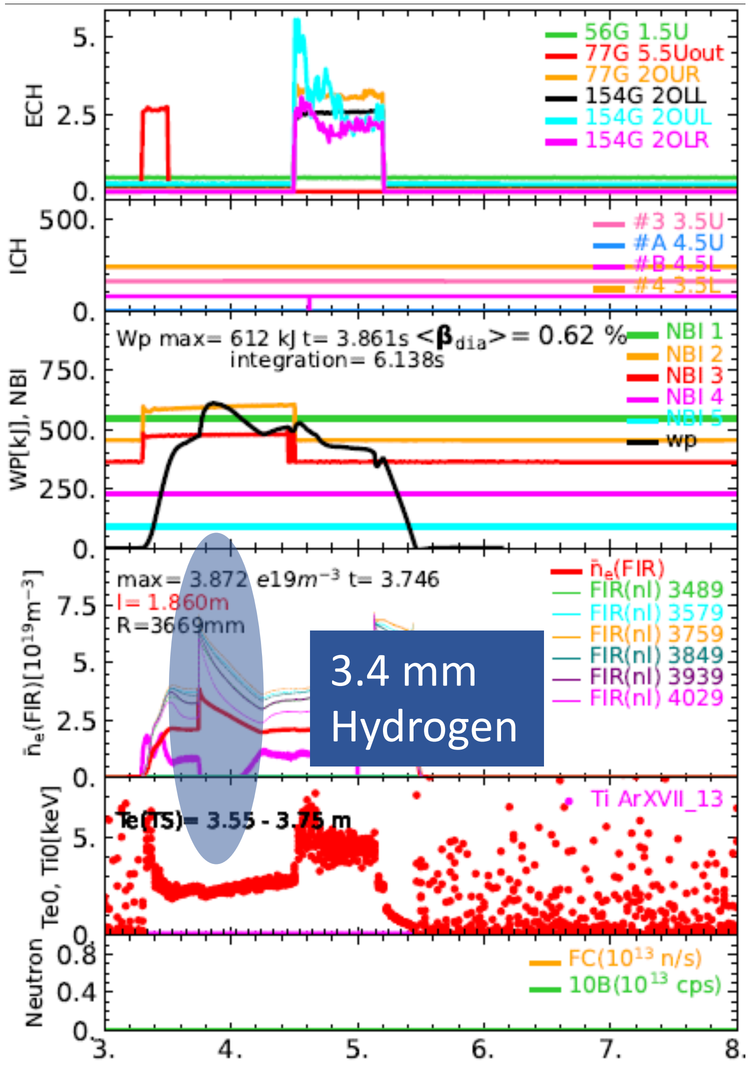
#180651: B=-2.538 T R_{ax}=3.900 m



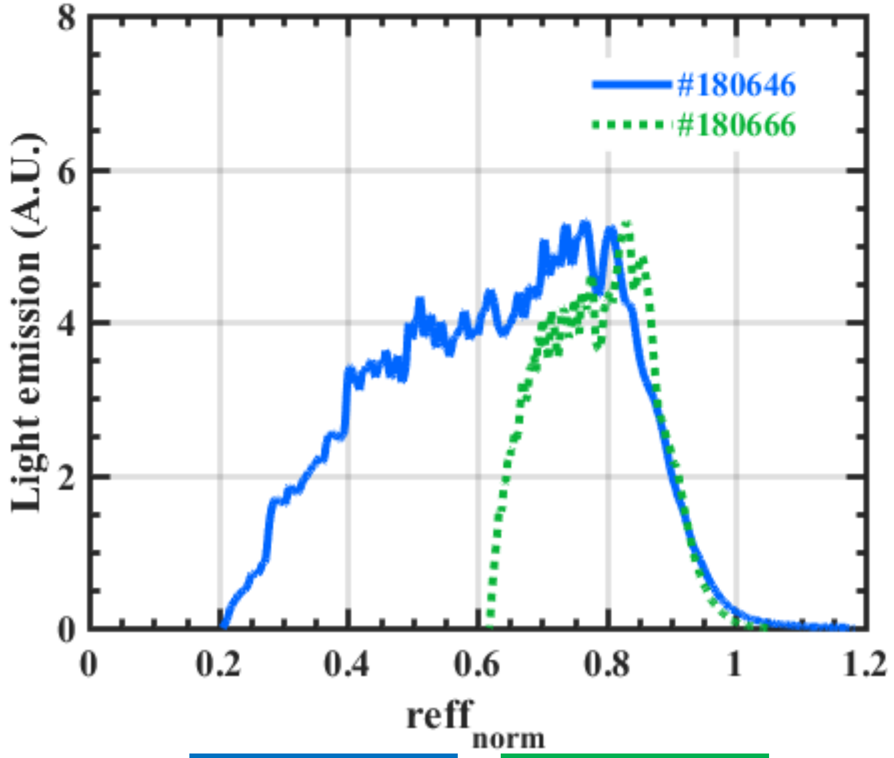
#180685: B=-2.750 T R_{ax}=3.600 m



Analysis of different hydrogen isotopes pellet injection for code validation

N. Panadero (CIEMAT), R. Sakamoto (NIFS), B. Pégourié (CEA/IRFM), N. Tamura (NIFS), G. Motojima (NIFS), K.McCarthy (CIEMAT)

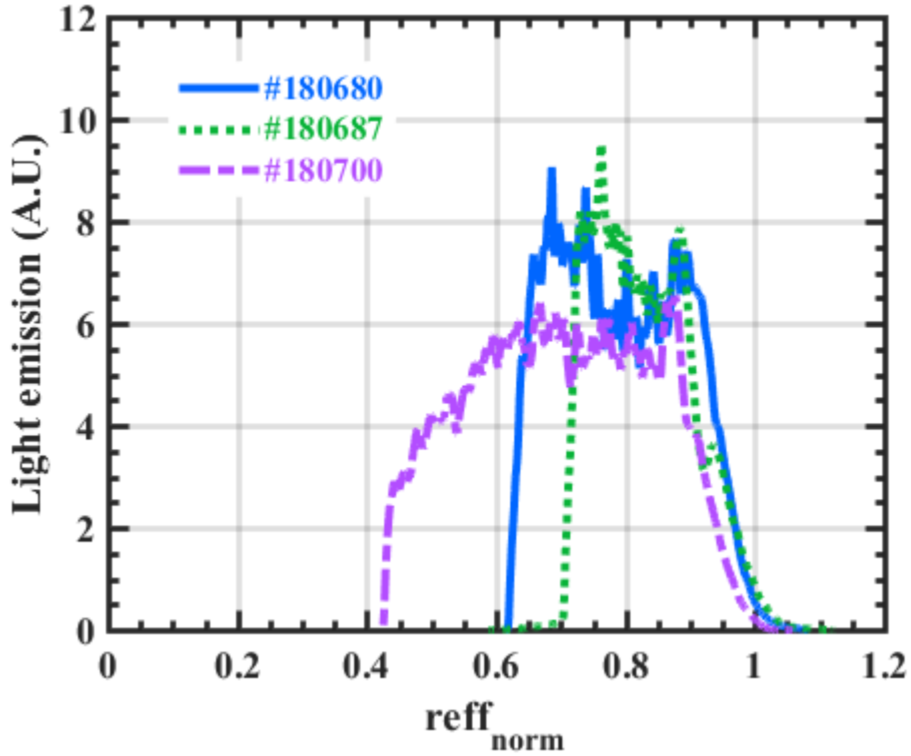
R_{ax}=3.900 m vs. Rax=3.600 m



3 mm Hydrogen R_{ax} = 3.9 m $2 \cdot 10^{19}$ m^{-3}	3 mm Hydrogen R_{ax} = 3.6 m $2 \cdot 10^{19}$ m^{-3}

Attention: T_e is quite different!!!

B=-2.750 T R_{ax}=3.600 m



3.8 mm Hydrogen $2 \cdot 10^{19}$ m^{-3}	3.4 mm Hydrogen $1.5 \cdot 10^{19}$ m^{-3}	3.4 mm Deuterium $1.5 \cdot 10^{19}$ m^{-3}

Ablation study of neon and hydrogen cryogenic pellets used by ITER DMS

A. Matsuyama (QST), R. Sakamoto, M. Goto,
R. Yasuhara, H. Funaba, M. Yoshinuma

Experimental condition:

(R_{ax}, Polarity, B_t, γ, B_q) = (3.9 m, CCW, 2.5385 T, 1.2538, 100.0%)
#180633-#180660 (28 shots)
(R_{ax}, Polarity, B_t, γ, B_q) = (3.6 m, CCW, 2.75 T, 1.2538, 100.0%)
#180661-#180704 (44 shots)

Objective and method:

- **ITER Disruption Mitigation System (DMS)** will inject a mixture of hydrogen and neon by means of Shattered Pellet Injection (SPI) and the extrapolation of the performance to ITER relies on the pellet ablation study.
- On the 22 cycle, we found that the 5%/10% neon pellets can yields deep material deposition as compared to pure H_2 pellet, which is explained by the suppression of the plasmoid drift. [Matsuyama et al., PRL (under review)]
- Key question: How much is the lowest neon quantity required for stopping the ExB drift?
  → Try injection of 1% neon doped hydrogen pellets

Pure hydrogen (ECH) 22nd cycle	1% Neon mixed (ECH) 23rd cycle	5% Neon mixed (ECH) 22nd cycle

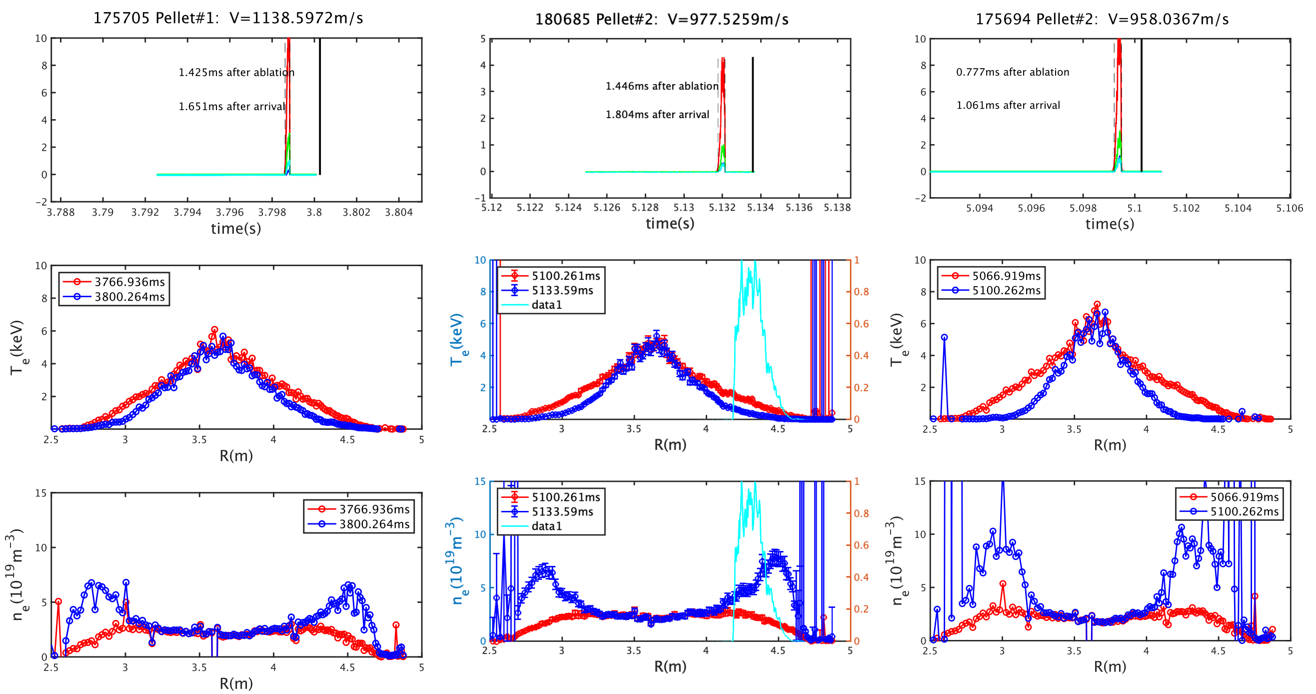


Fig. 1 T_e & n_e profiles after injection

Results

- We found that the post-injection profiles in ECH plasmas are very similar between pure H_2 and 1% Neon doped pellets.
  → We demonstrated that there is a lower threshold for neon quantity to stop the drift for given target plasmas (given T_e) (major objective of this work has been achieved).
- The pellet penetration depths have also been scanned with a variation of the background density (and T_e).
- Advanced measurements (Fast TS, Fast camera, CXRS, Spectroscopy) to be analyzed.

Impurity transport study in EC- and NBI-heated plasmas using VUV spectroscopy in experiment with TESPEL injections (T. Fornal, 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: #180705 - #180748

Goal of this experiment

- To obtain the data by using **TESPELs containing triple tracers** for comparisons with the future results in W7-X

Background & Motivation

- Investigation of impurity decay times in dependence of atomic number (Z) under given plasma conditions
  - ✓ Estimate an impurity decay time on the line intensity evolution for injected elements (**Ti, V, Mn, Fe, Ni, Cu**) and various density levels of plasma using EUV/VUV spectrometer SOXMOS (its wavelength range from 15 to 33 nm with a 133.6 g/mm grating)
- Comparison of experimental results obtained in EC and NBI heated plasmas with a considered electron density range of 1 - 5E19
  - ✓ Data in EC-heated plasmas is obtained in the experiments proposed by M. Kubkowska
- Comparison of the experimental results in H and D plasmas
  - ✓ We will do the same experiments on Nov 1st in D plasmas

Impurity transport study in EC- and NBI-heated plasmas using VUV spectroscopy in experiment with TESPEL injections (T. Fornal, N. Tamura et al.)

Results

- **(Ti/V/Mn, Fe/Ni/Cu)-TESPELs are successfully injected** into the NBI-heated LHD **H** plasmas with n_e up to 3E19 m^{-3}
  3 heating patterns are applied
  A) NBI#2+NBI#3
  B) NBI#5+NBI#4(20ms on + 180ms off)
  C) NBI#5+NBI#4(180ms on + 20ms off)

Ti/V/Mn

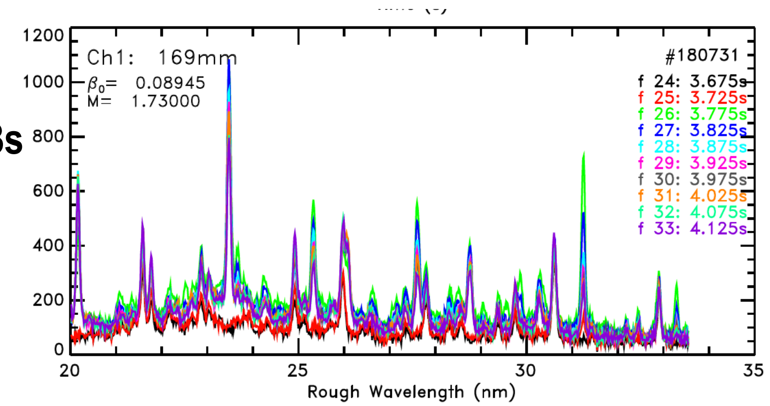
	Pattern A	Pattern B	Pattern C
1e19	✓	✓	✓
3e19	✓	✓	✓

Fe/Ni/Cu

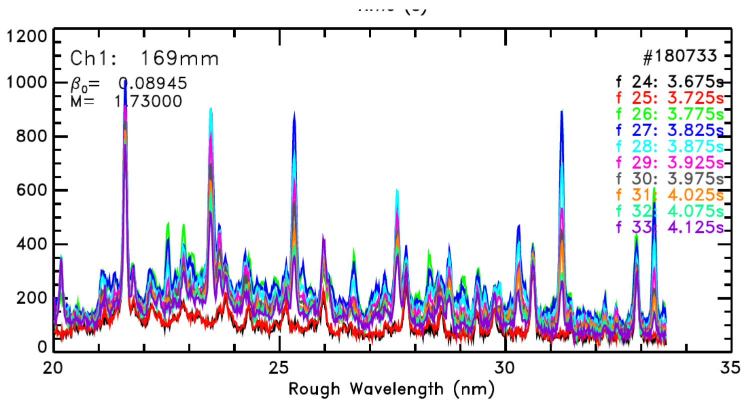
	Pattern A	Pattern B	Pattern C
1e19	✓	✓	✓
3e19	✓	✓	✓

- We obtained data in all the heating patterns
- Emission lines from Ti(22), V(23), Mn(25), Fe(26), Ni(28), Cu(29) have been observed clearly (see right figs.) → To be analyzed

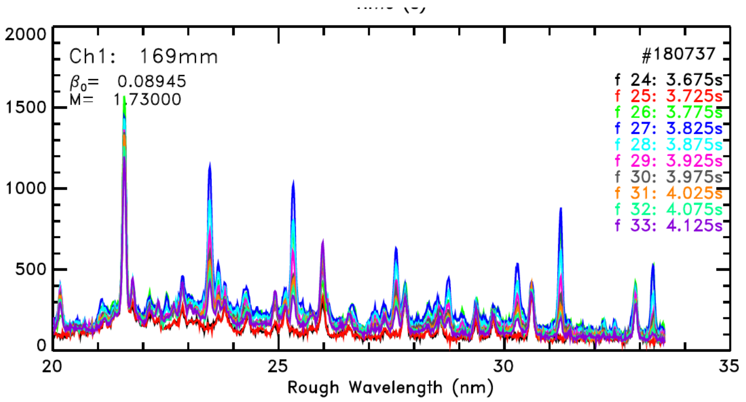
A) NBI#2+NBI#3, #180731@n_e~3e19 m^{-3} Ti/V/Mn-TESPEL@3.73s



B) NBI#5+NBI#4 (20ms on + 180ms off), #180733@n_e~3e19 m^{-3} Ti/V/Mn-TESPEL@3.73s



C) NBI#5+NBI#4 (180ms on + 20ms off), #180737@n_e~3e19 m^{-3} Ti/V/Mn-TESPEL@3.73s



Impurity transport study in LHD D/H plasmas using VUV spectroscopy in experiment with TESPEL injection (M. Kubkowska, 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: #180749 - #180788

Background

- In the recent LHD experiment, a successful TESPEL injection was obtained for an electron density of 1 – 2 $\times 10^{19}$ m^{-3}. For higher density experiment was not conducted or the plasma was collapsed. The main aim of this experiment is to obtain the data by using TESPELs containing triple-tracers (Ti/V/Mn and Fe/Ni/Cu) to complete the data obtained in the last experimental campaign and for comparison with the future results in W7-X.

Objectives

- Estimate the impurity decay time based on the line intensity evolution for injected elements
- Estimate the impurity decay time based on the line intensity evolution for various electron density of plasma (1-5E19).
- Calculation of turbulent and neoclassical radial transport of the impurities, as well as their diffusion and convection coefficients (in collaboration with CIEMAT).
- Preliminary calculation of the TESPEL shell ablation and deposition (in collaboration with CIEMAT)

Impurity transport study in LHD D/H plasmas using VUV spectroscopy in experiment with TESPEL injection (M. Kubkowska, N. Tamura et al.)

Results

- **(Ti/V/Mn, Fe/Ni/Cu)-TESPELs are successfully injected** into the ECR-heated LHD **H** plasmas with n_e up to 4E19 m^{-3}
  - ✓ The combination of tracers is different from the previous campaign (quadruple: **V/Mn/Ni/Fe** or **V/Mn/Ni/Cu**) ← **Too much!**

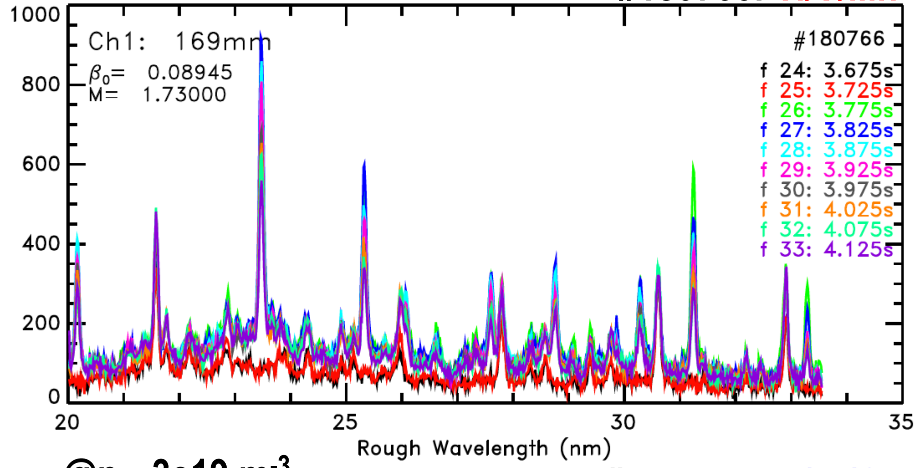
Ti/V/Mn

	1e19	(Opt: 2e19)	3e19	(Opt: 4e19)
3 x 154 GHz (2.35 MW)	✓	Not conducted	✓	Not conducted
2 x 154 GHz (1.53 MW)	✓	✓	✓	Not conducted

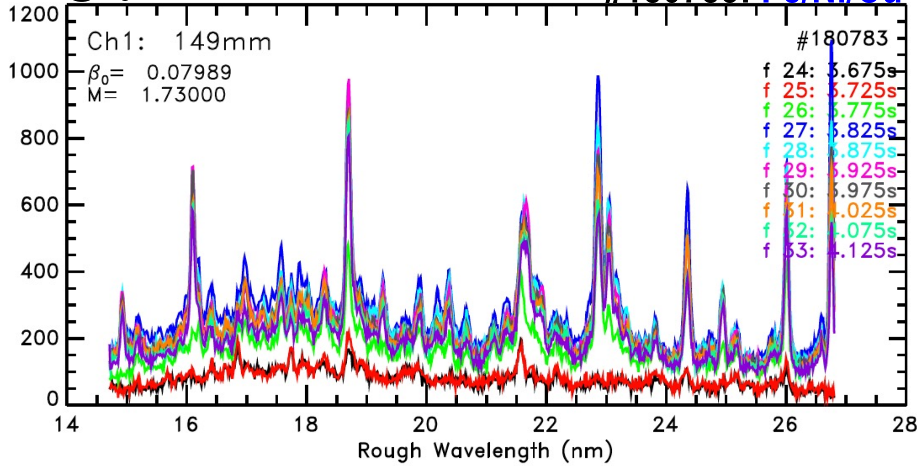
Fe/Ni/Cu

	1e19	(Opt: 2e19)	3e19	(Opt: 4e19)
3 x 154 GHz (2.35 MW)	✓	✓	✓	✓
2 x 154 GHz (1.53 MW)	✓	Not conducted	✓	Not conducted

@n_e~3e19 m^{-3} **#180766: Ti/V/Mn**



@n_e~3e19 m^{-3} **#180783: Fe/Ni/Cu**



- Emission lines from Ti(22), V(23), Mn(25), Fe(26), Ni(28), Cu(29) have been observed clearly (see right figs.) → To be analyzed
- Experiments in D plasmas will be done on Nov.1st