EUROfusion

Moderate beta Baseline scenario in preparation to DTE2

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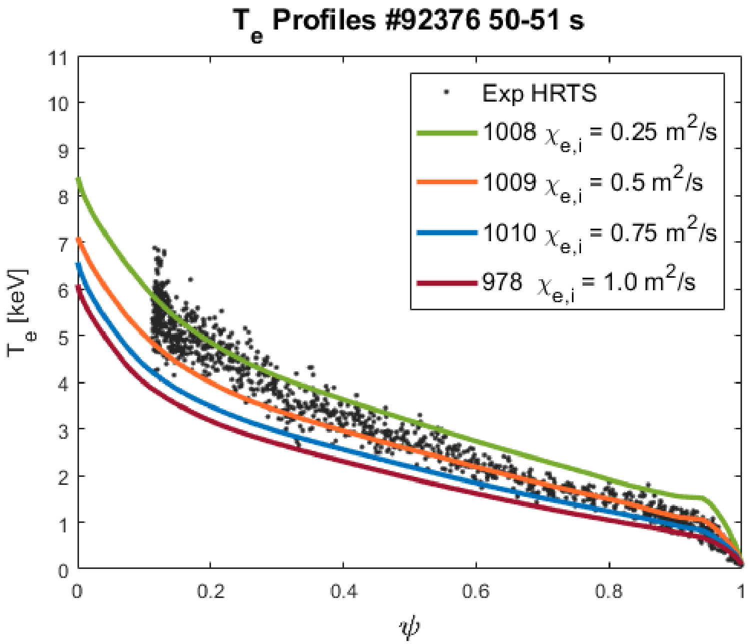
Summary

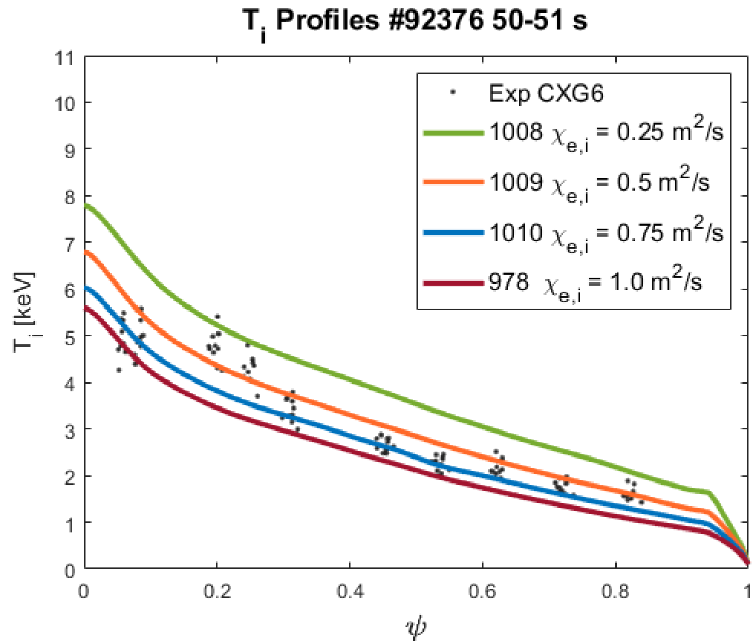
- Methodology and QuaLiKiz model.
- **Validation** on JPN 92376 (DD).
- **Validation** on DTE1 experiments (DT and DD).
- **Extrapolation capability:** blind prediction on JPN 96482 (DD).
- **DT extrapolations** (preliminary).

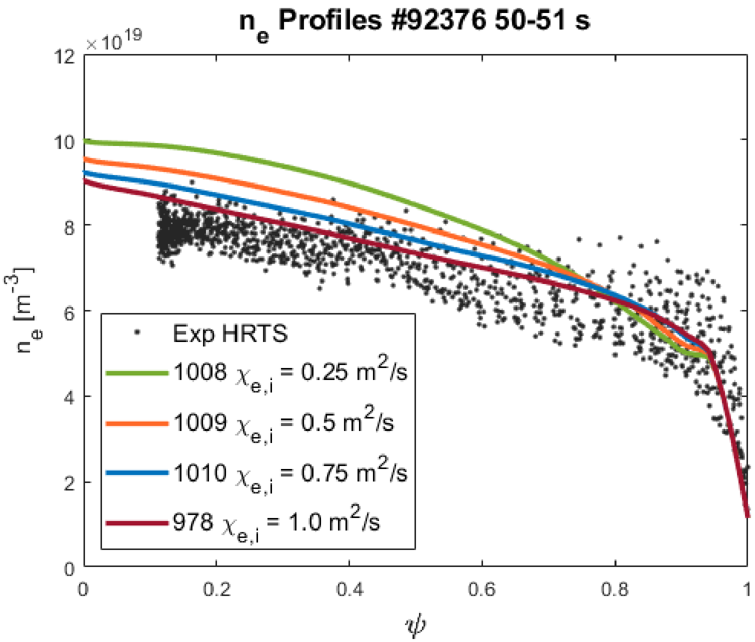
Methodology and QuaLiKiz model

- Fully predictive simulations with JETTO+SANCO+QuaLiKiz (7 channels).
- QuaLiKiz is a physics based model (quasi-linear gyro-kinetic model), perturbs the spectrum of instabilities to obtain the transport coefficients.
- JETTO uses the QLK transport coefficients for determine the fluxes.
- **Aim**: finding a set of simulation parameters (boundary conditions and internal settings) for reproducing the plasma profiles of the reference scenario;
- **Extrapolations**: increasing I_p and P_{aux} at constant f_{GW} , Z_{eff}, f_{rad} with the found optimised simulation parameters.

Reference scenario JPN 92376





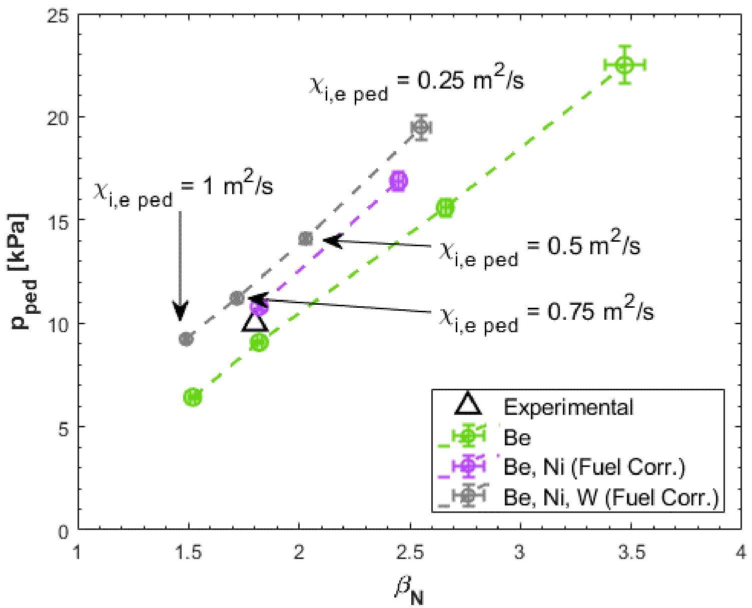


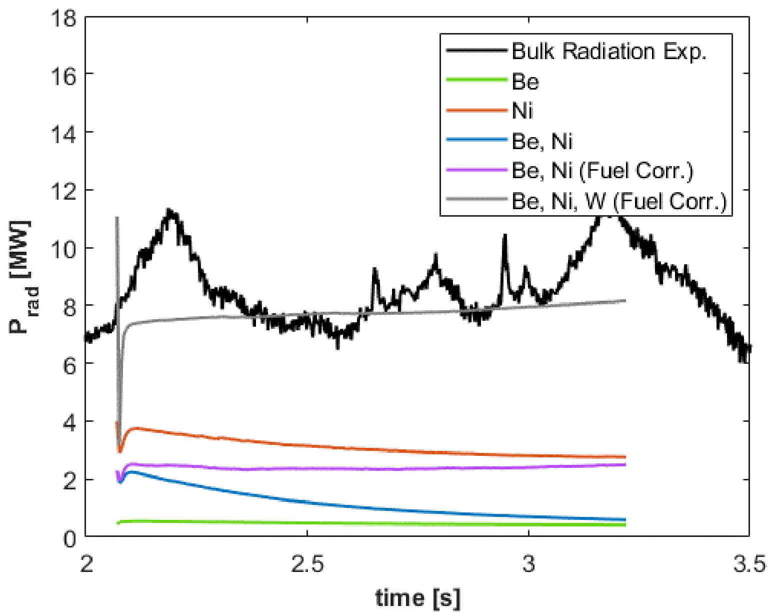
C36 DD #92376: 3.0 MA, 2.85 T, β_N = 1.8
P_{NBI} = 21.8 MW
P_{ICRH} = 4.4 MW (H minority)
Z_{eff} = 1.9 (Be dominant Ni, W)

The pedestal is reproduced imposing the electron density and the thermal conductivity;

The uncertainty in the extrapolations is determined by the pedestal conditions on thermal conductivity.

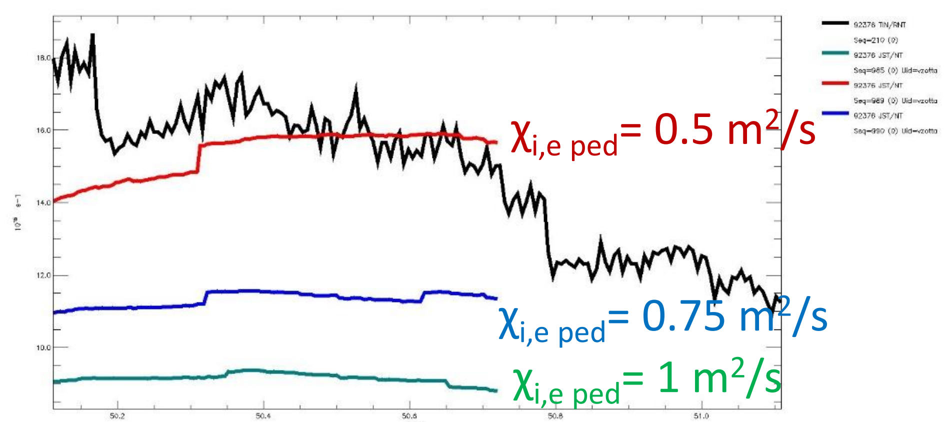
Reference scenario JPN 92376



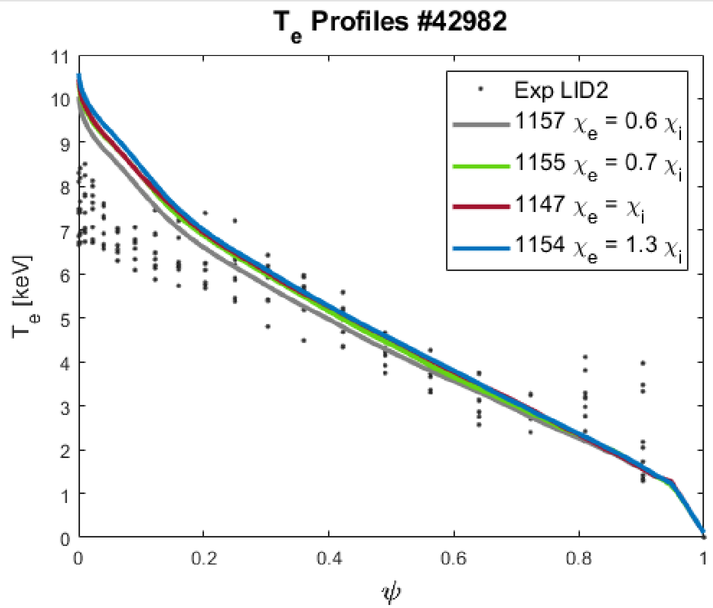


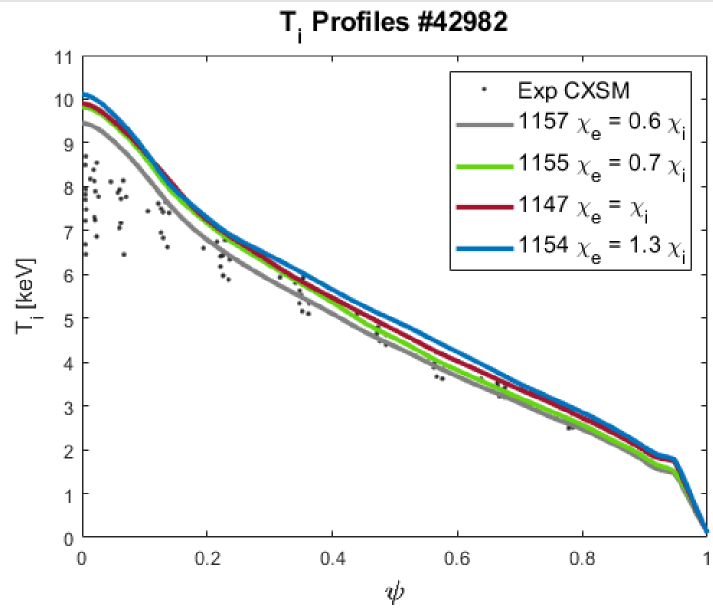
- The initial simulations have been performed in presence of a single impurity species.
- Simulated pedestal quantities can be compared with the experimental measurements;
- The impurities affect the dilution and the P_{rad} but also the pedestal conditions
- The match of the fuelling has been found to be important.

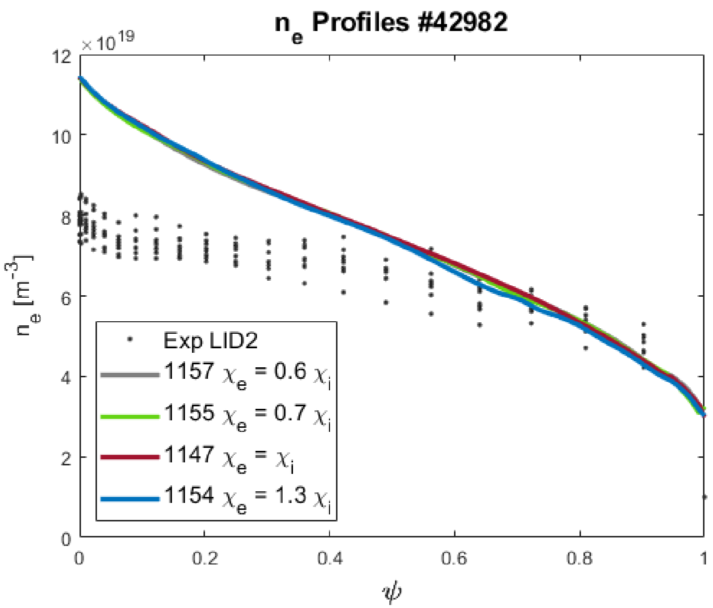
Neutron rate [10^{16} s^{-1}]



DTE1: 42982 (DT) Enhancement Scan

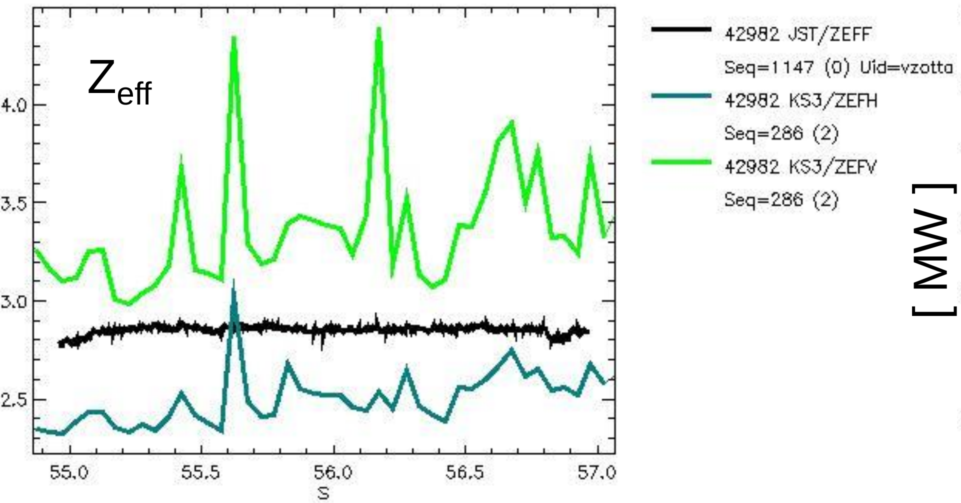


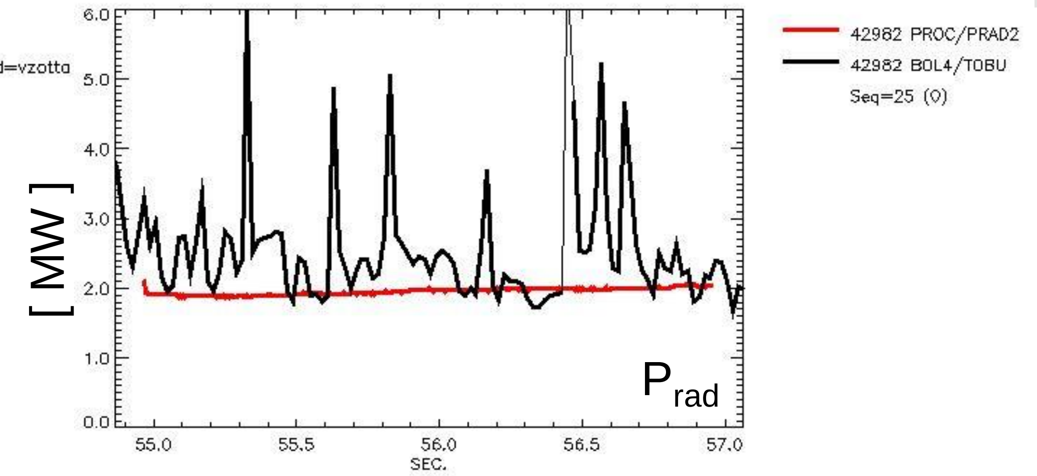


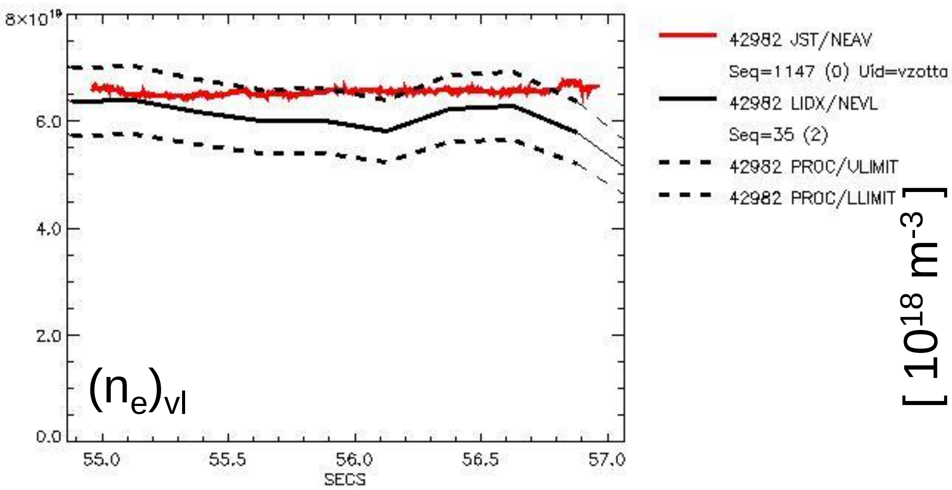


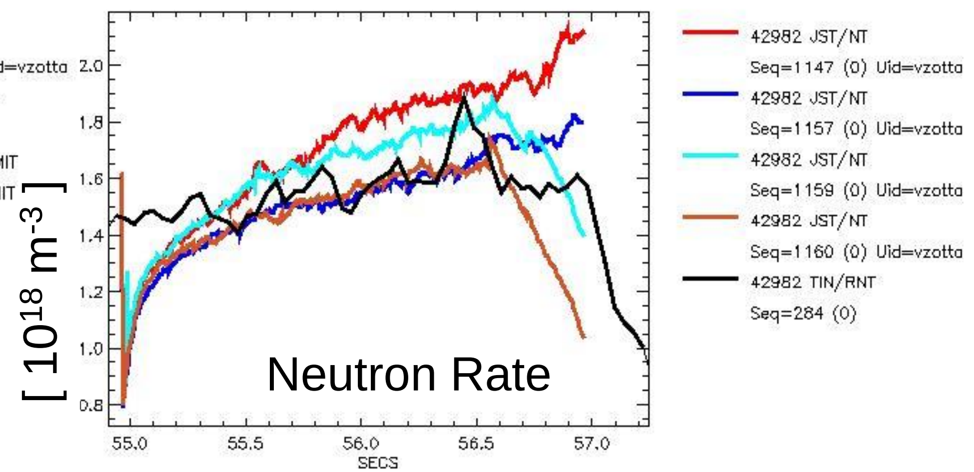
- The increase or reduction in the ion thermal conductivity at the pedestal seems to be insufficient to observe differences in the core electron density profiles;
- Slight differences can be found on the electron and ion temperatures (ion temperature profile not so bad);
- As noticed in O. Linder et al, Nucl. Fusion 59 (2019), high values of Z_{eff} can play a role in the suppression of the inner core transport.

DTE1: 42982 Checks on plasma par.



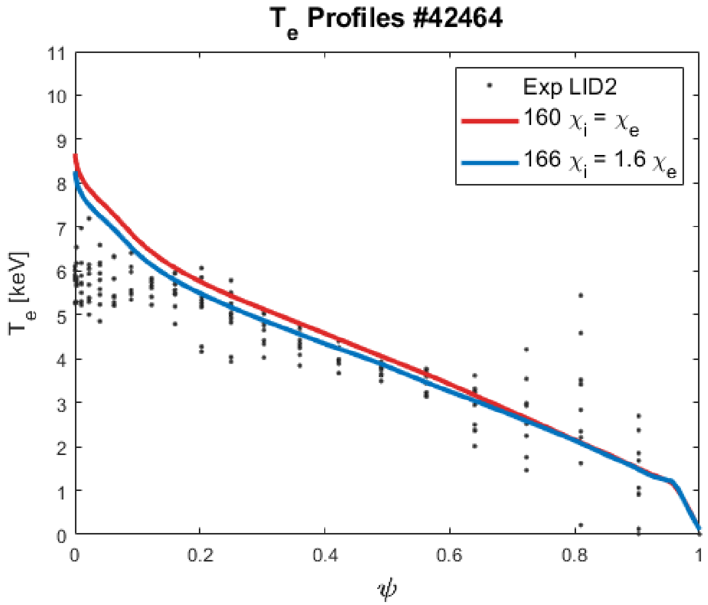


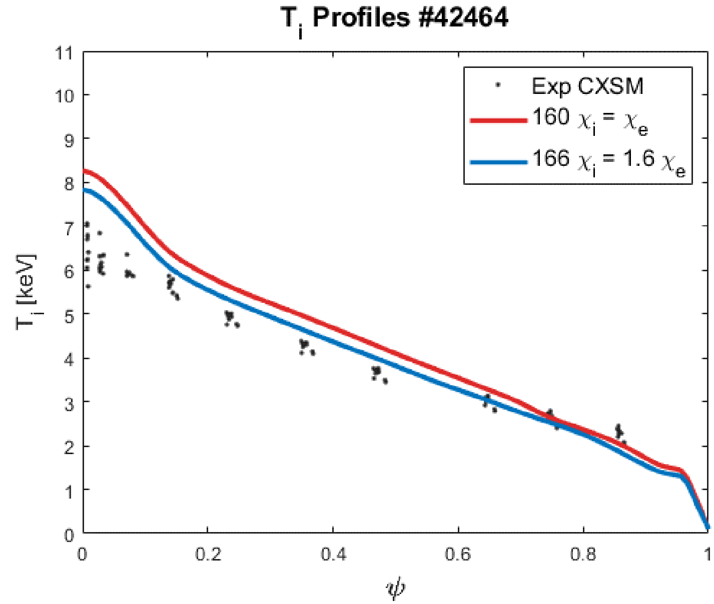


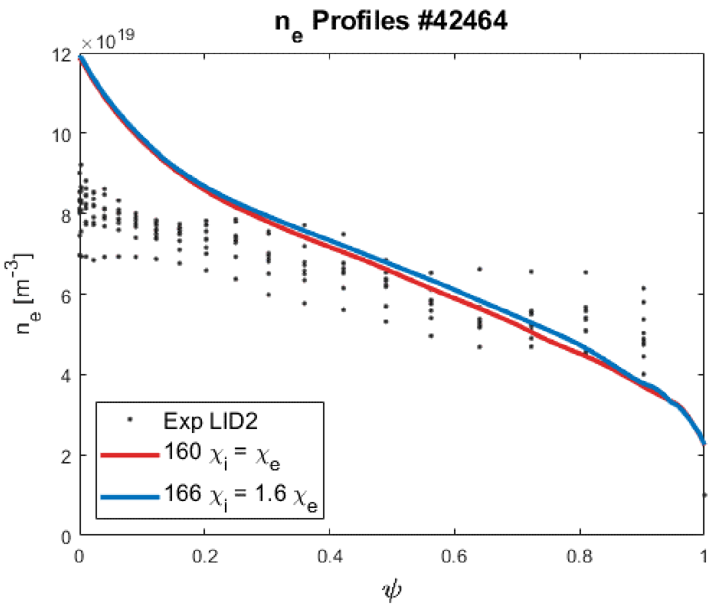


=> Shape of the profiles

DTE1: 42464 (DD) Enhancement Scan





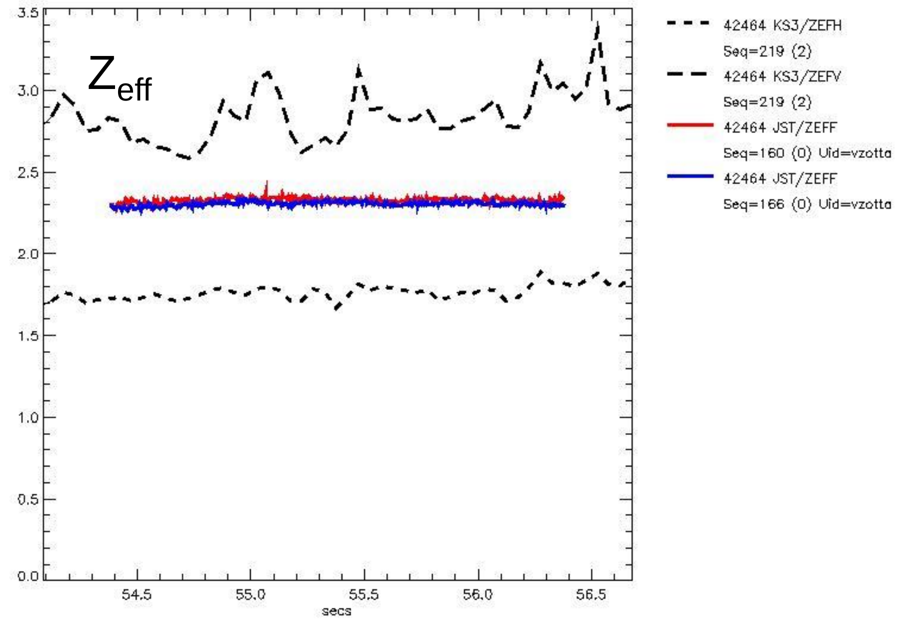


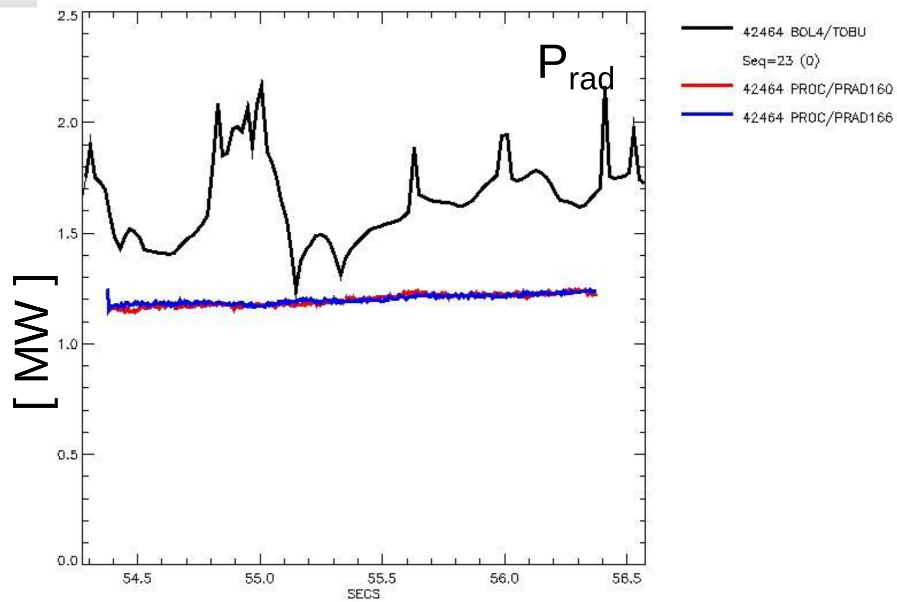
- DTE1 DD #42464: 3.8 MA, 3.8 T
  P_{NBI} = 17.8 MW
  P_{ICRH} = 0.5 MW (He^3 minority)
  Z_{eff} = 2.3 (C dominant and He^3)

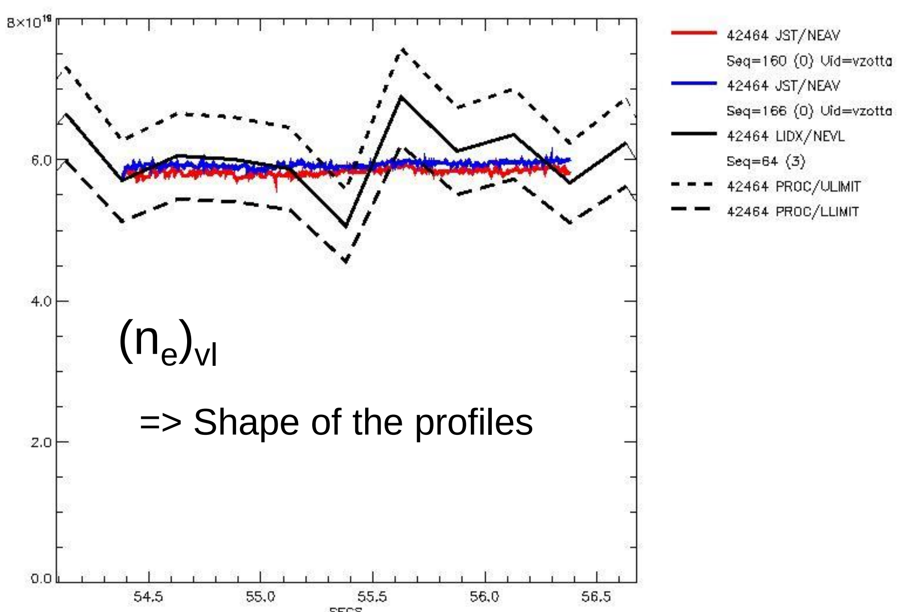
- The pulse has been already successfully simulated in JETTO with the Bohm gyro-Bohm model;

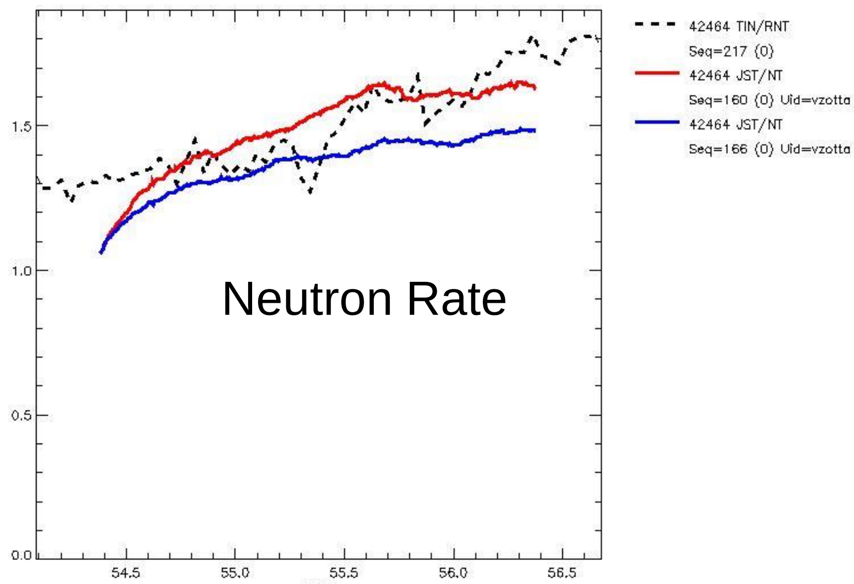
- Increased peaking with respect to the DT case;

DTE1: 42464 Checks on plasma par.

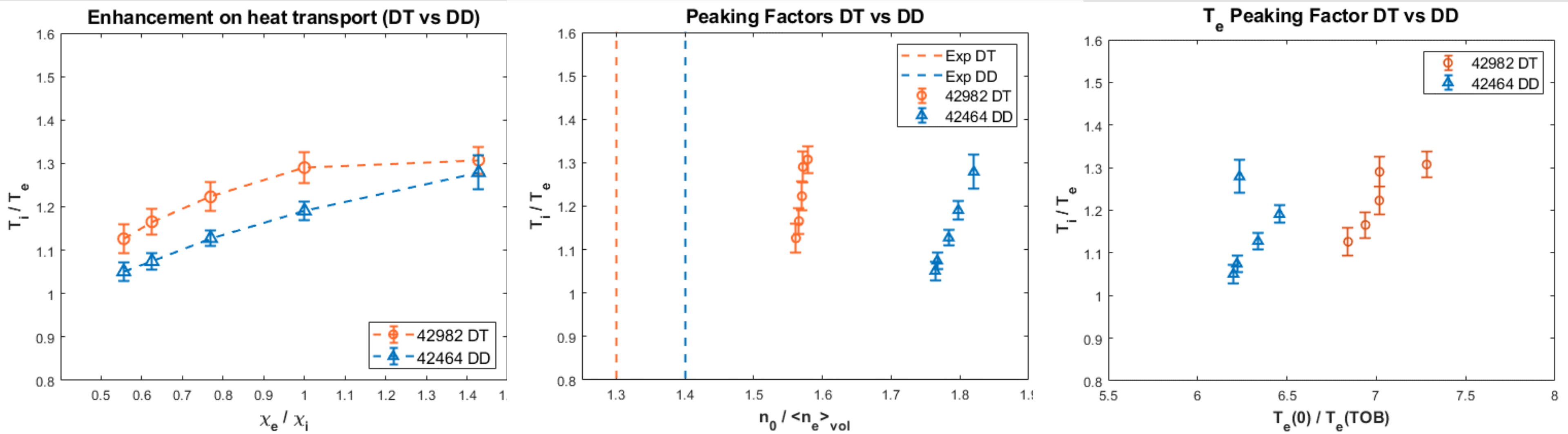








DTE1: DT vs DD Peaking Factors

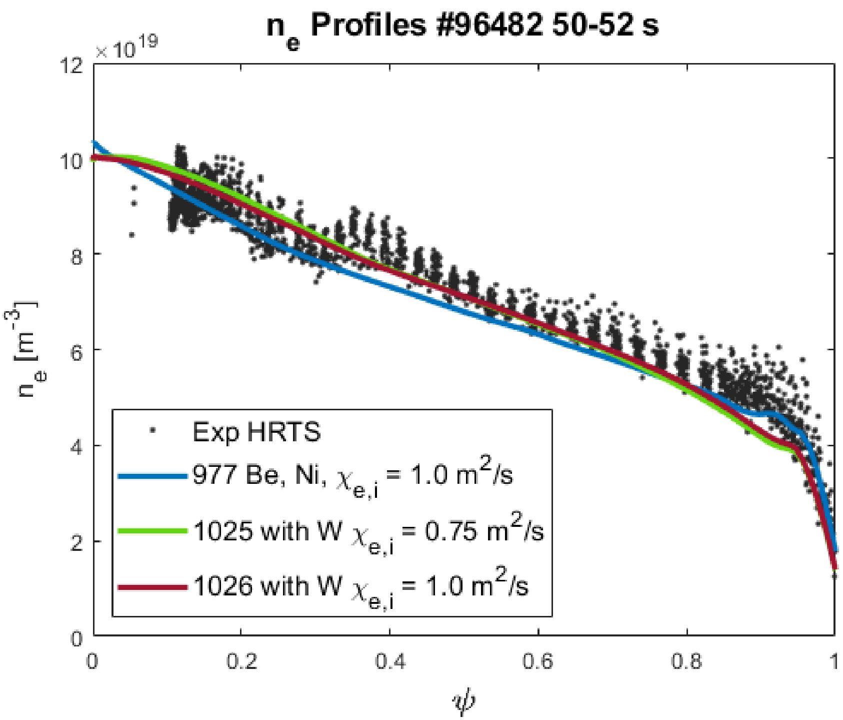


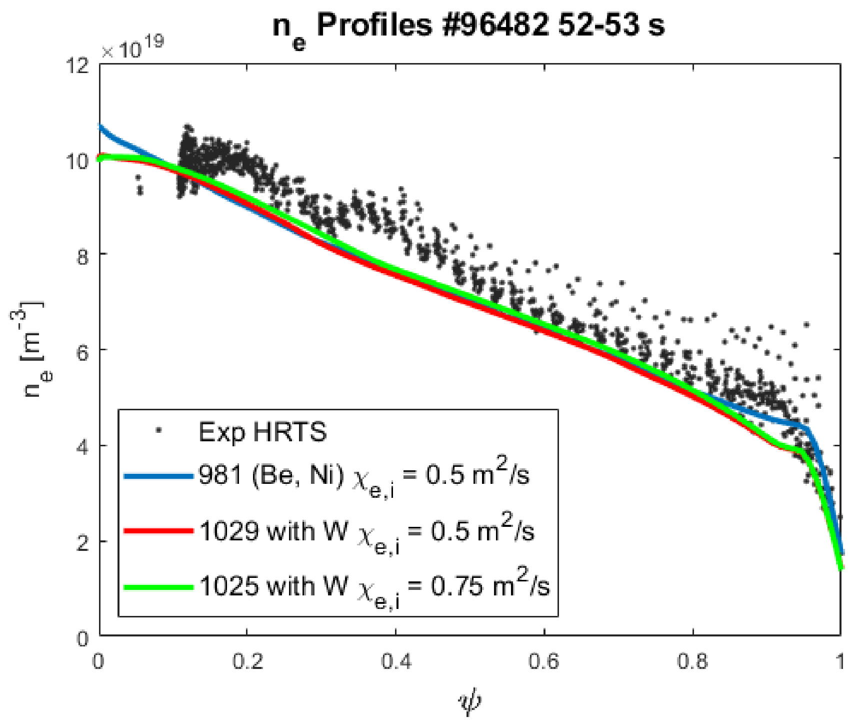
- The density peaking factor on QuaLiKiz simulations changes due to the $n_e(ped)$ while the $n_e(core)$ seems to be insensitive to the enhancement of the thermal conductivities as shown with the profiles;

- The figures are representing form left to right:
  1 – how the enhancement of the thermal conductivity in the pedestal changes the T_i/T_e in the pedestal;
  2 – using the previous T_i/T_e how the density peaking factor changes;
  3 – the changes in the electron temperature peaking factors for a T_i/T_e ratio;

- **DT vs DD comparison**:
  DT – higher temperature pedestal ratio could be seen as the presence of the isotope effects in QuaLiKiz, the over-peaking in density is lower than in the DD case, and it seems to be less sensitive to the pedestal temperature ratio variations ;
  DD – the peaking in the density seems to be enhanced both in the experiments and in simulations;

Extrapolation Capability on JPN 96482



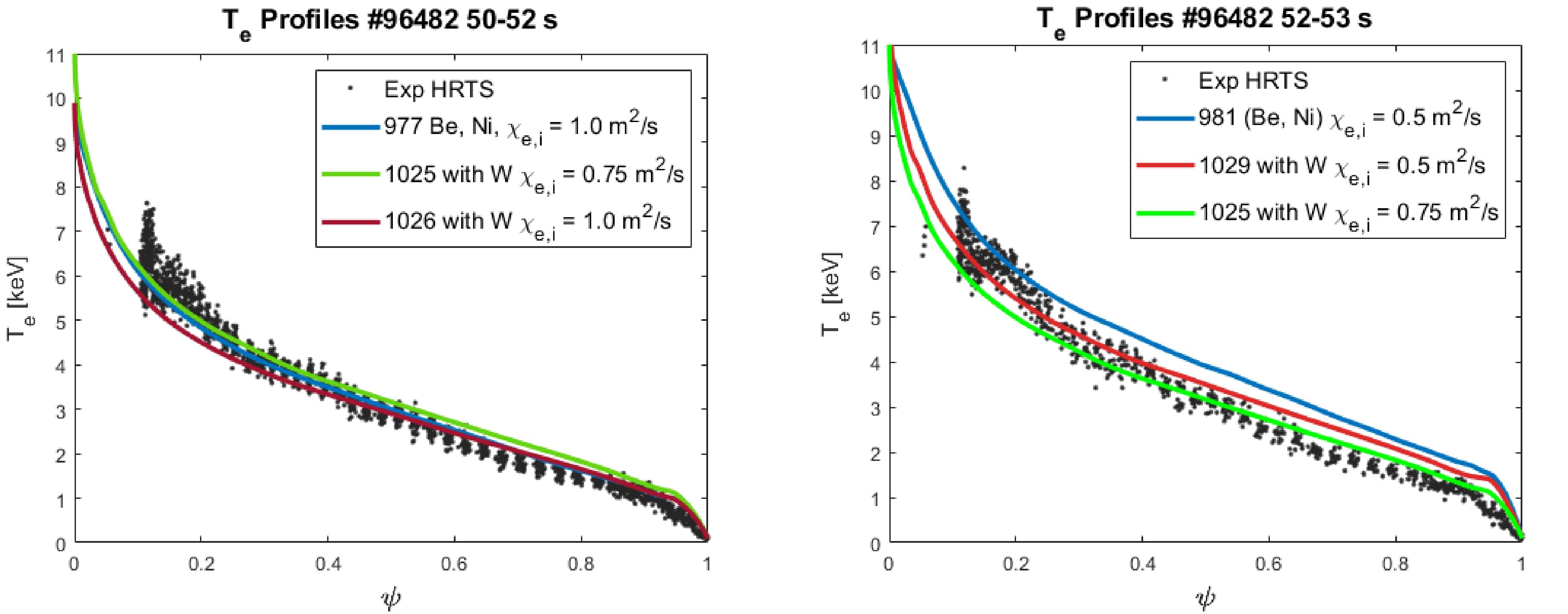


- C38 DD #96482: 3.5 MA, 3.3 T, β_N = 1.9
  P_{NBI} = 29.5 MW
  P_{ICRH} = 4.9 MW (H minority)
  Z_{eff} = 1.7 (Be dominant Ni, W)

- The JPN 96482 evolves from a first phase at lower performance to a second phase at higher performance;

- **Blind prediction** with the scaling and the experimental P_{aux};

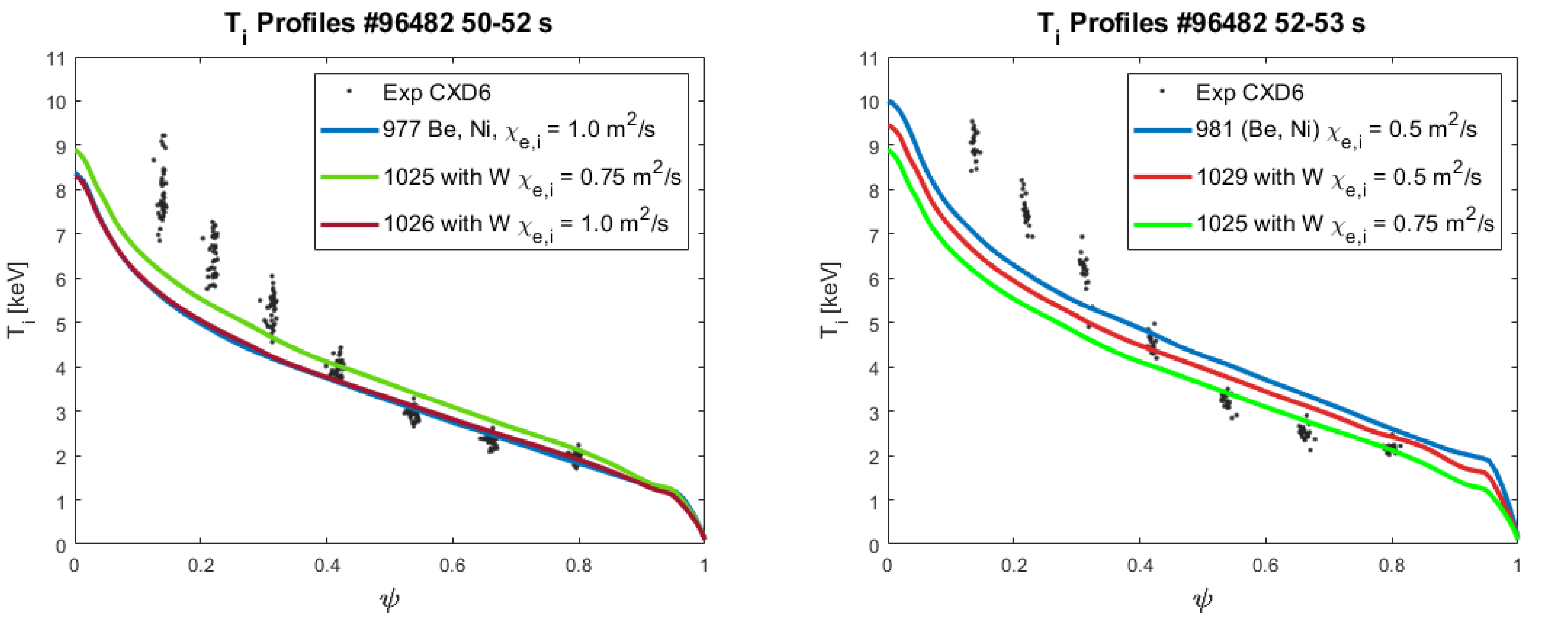
Extrapolation Capability on JPN 96482



- The agreement on the electron temperature profiles results improved by introducing the presence of W in the impurity mixture;

- A slight overprediction of the pedestal electron temperature appears in the 2nd phase of the discharge;

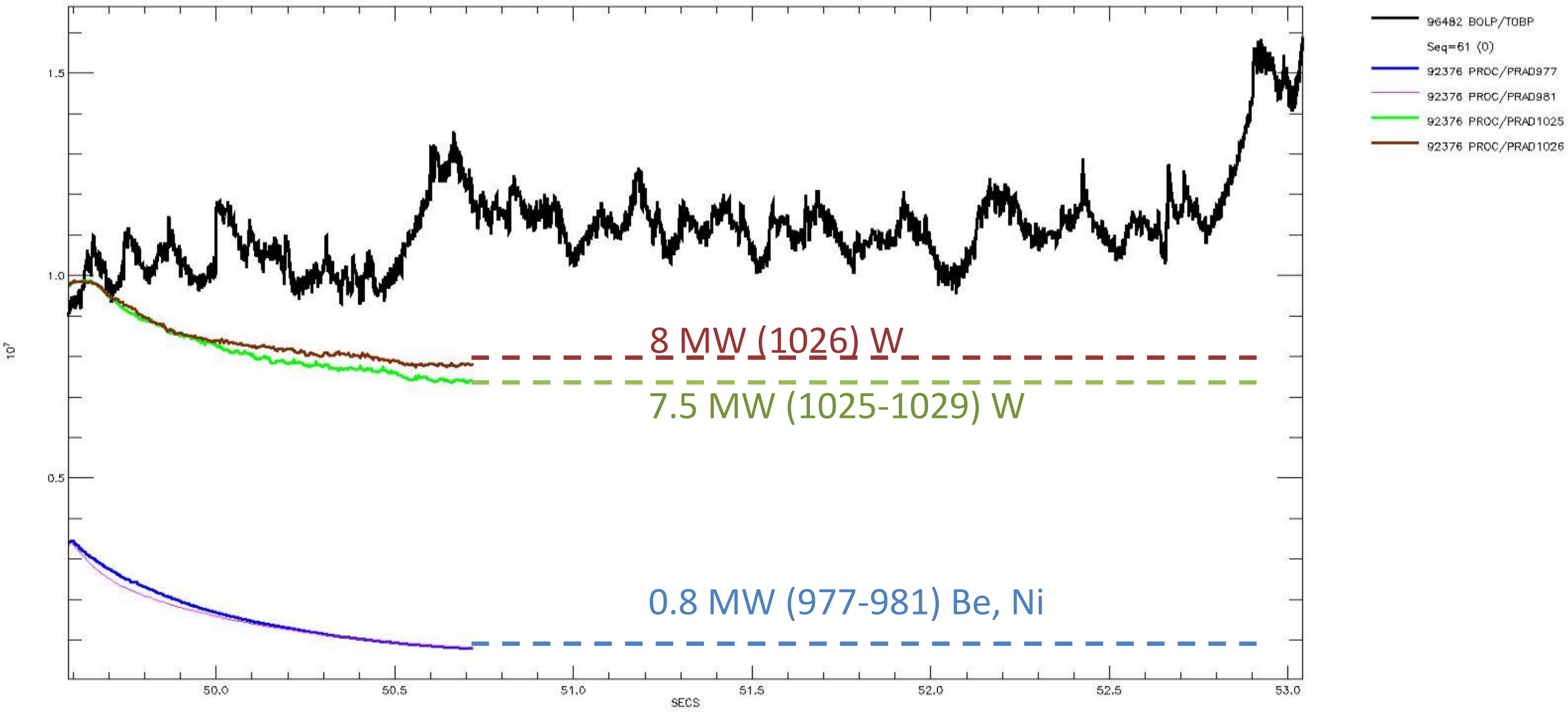
Extrapolation Capability on JPN 96482



- The presence of W decreases the ion temperature due to the radiation, the ion temperature gradient results unmatched for $\psi < 0.5$ (poloidal flux coordinate);

- The temperature gradients are not well matched;

Extrapolation Capability on JPN 96482

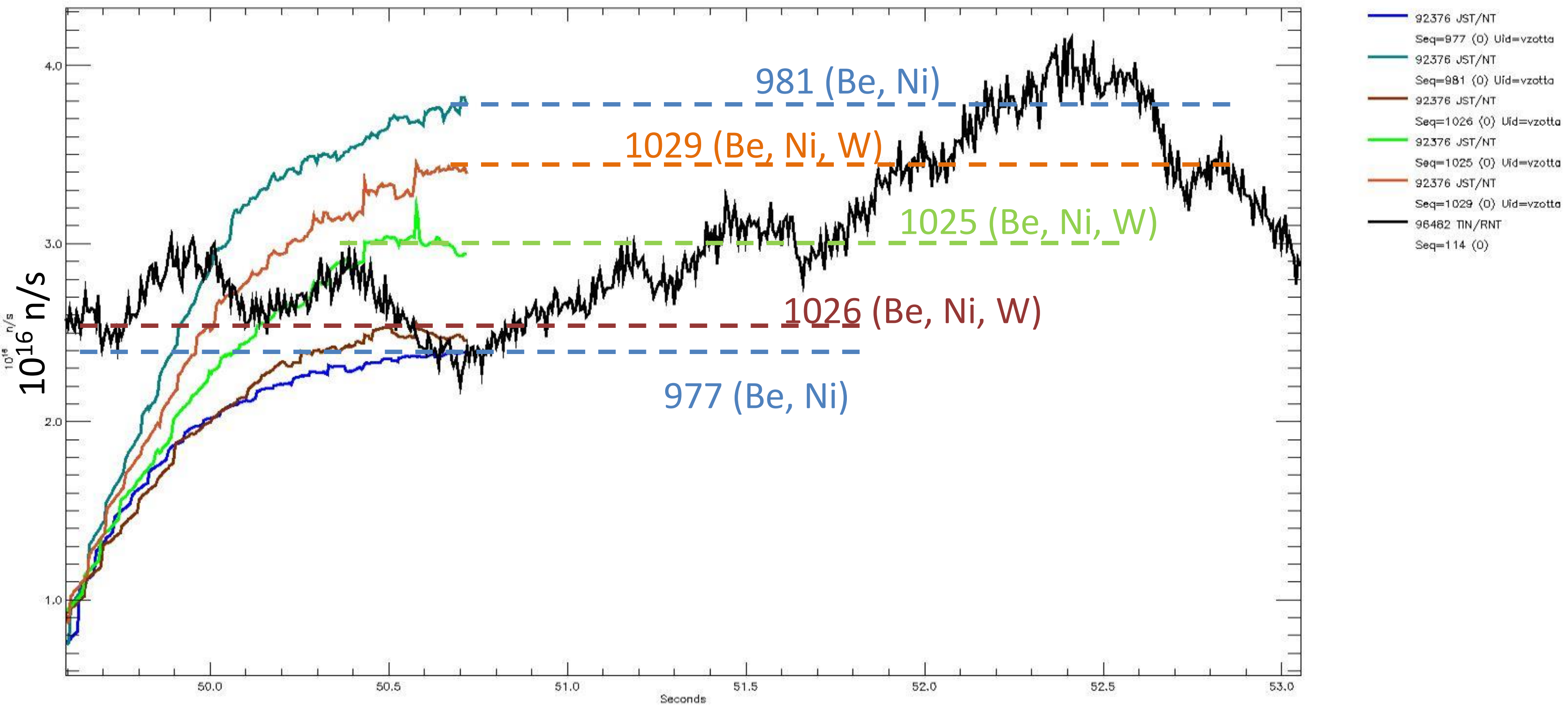


- The agreement on the radiated power results still unmatched, but the cause of that can be related to the nature of the blind prediction:

  Z_{eff}(simulation) = 1.9 = Z_{eff}(exp#92376) ≠ Z_{eff}(exp#96482)

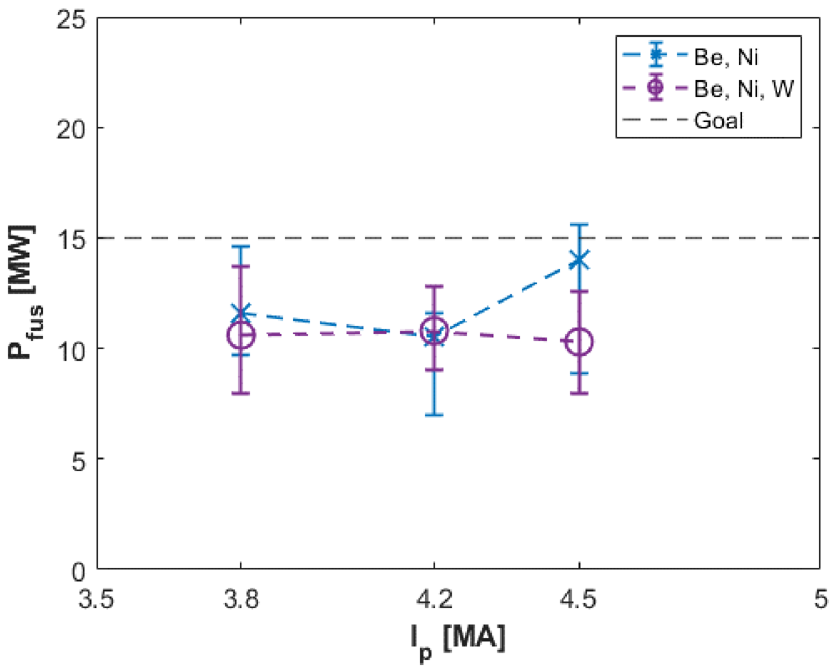
  => The experimental impurity concentrations can't be matchad at all;

Extrapolation Capability on JPN 96482



- The trend of reproducing the first phase (at lower performance) by imposing χ_{ped} = 1 m^2/s and the second phase (at higher performance) with a χ_{ped} ϵ [0.5, 0.75] m^2/s results confirmed also in the cases with W;

DT extrapolations: Full power



- DT extrapolations at f_{GW} = const (ref. 92376):

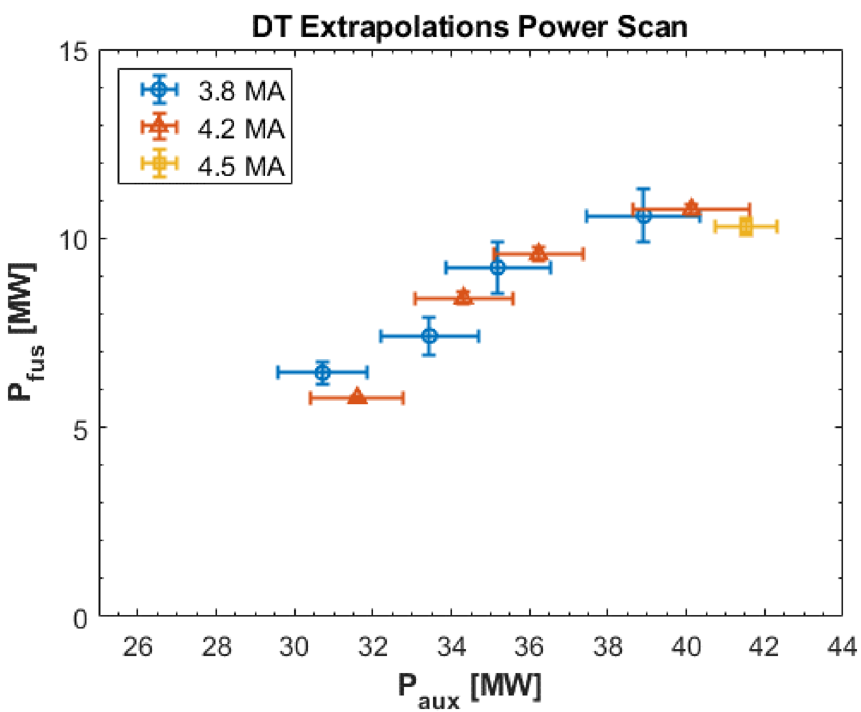
  Impurities: Be, Ni, W
  Z_{eff} = 1.9 = const
  $f_{rad} \approx 0.3 \approx$ const
  (=> Be dilution enhanced)

- The uncertainties are related to the ETB conditions;

- The performance seems to saturate between 3.8MA and 4.2 MA (the scaling increases the density with the increasing of current, but the P_{aux} achievable is limited).

- The effects on dilution and radiated power are under investigation as well as the differences in the additional power deposition profiles.

DT extrapolations: Power Scan



- DT extrapolations at f_{GW} = const (ref. 92376):

  Impurities: Be, Ni, W
  Z_{eff} = 1.9 = const
  $f_{rad} \approx 0.3 \approx$ const
  (=> Be dilution enhanced)

- Plan for the Power scan (NBI + ICRH):
  - 40-42 MW = 34 MW + 8 MW
  - 38 MW = 32 MW + 6 MW
  - 36 MW = 32 MW + 4 MW
  - 33 MW = 29 MW + 4 MW

- **The uncertainty on the P_{aux} depends on the coupling of the ICRH with the plasma during the time evolution of the simulations.**

- This is a conservative estimation (ETB intermediate condition + enhancement of dilution)

Conclusions:

- **Validation on JPN 92376:**
  - We found a good agreement on the experimental time traces and in the experimental profiles during the plat top phase;
  - The model has been tuned and an optimised set of simulation parameters has been chosen;

- **DTE1 simulations:**
  - We found a good agreement on the experimental time traces;
  - The density peaking factor overprediction can not be solved with this version of QLK, we will try with the new version that will be released soon;
  - The DT cases are less sensitive to the peaking problems, suggesting that with a fine tuning in DD (as done for the JPN 92376) there should not be present an overprediction in the DT density peaking;

- **Extrapolation capability:**
  - For the first time we have shown the possibility of reproducing with a blind prediction the JPN 96482 with the simulation settings found on JPN 92376;
  - The extrapolation strategy can be used at least in the DD case;

- **Further work:**
  - Studying of DT extrapolations is ongoing;
  - Ne seeded baseline JPN 96994 is under studying;
  - The new modelling on the last campaigns involves the use of TGLF model in T17-07;
  - We are starting the simulation of JPN 97781 high performance hybrid scenario;