Integrated core-SOL modelling including impurity: ITER H-mode plasma

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Approaches to integrated core-SOL modelling

- **Coupling of complex core-SOL codes (eg. JINTRAC):**

  - self-consistent simulations of strongly non-linearly coupled core transport, H&CD, pedestal and SOL physics is an advantage

  - 2D SOL simulations are computationally expensive. Possible issues with core-SOL convergence

  - limited application, mainly for transients: ELMs, L-H transition, ...

- **One of alternative approaches: scaling for SOL integrated in core codes**

- **Combination of core code (ASTRA, CRONOS, JETTO) and COREDIV as a compromise: sufficient physics complexity and acceptable simulation speed**

  - core transport physics: theory-based transport, accurate H&CD simulations, equilibrium, current diffusion

  - impurity equations (COREDIV)

  - SOL-divertor (COREDIV)

- **Application to ITER H-mode (long pulse scenario): *effect of pedestal density on plasma performance***

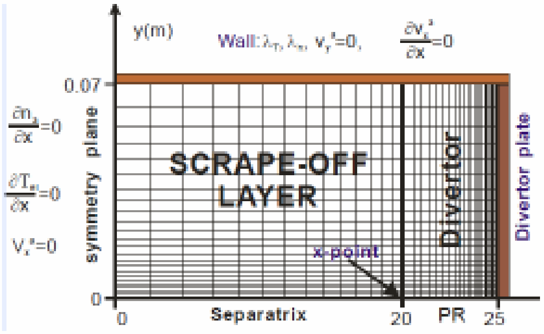
Coupled JETTO-COREDIV simulations for ITER H-mode plasmas

COREDIV

Core / pedestal: *simplified source and transport (H98-based), no equilibrium*

Fluxes →

← Boundary values



$$\Gamma_i, P_{rad}, P_{ion}, P_{Brem},$$
$$P_\alpha, Z_{eff}, P_j^{rad,k}, n_j^k$$
$$\Gamma^k_{j,'divertor'}, Q_{'divertor'}$$
$$Helium, impurity$$

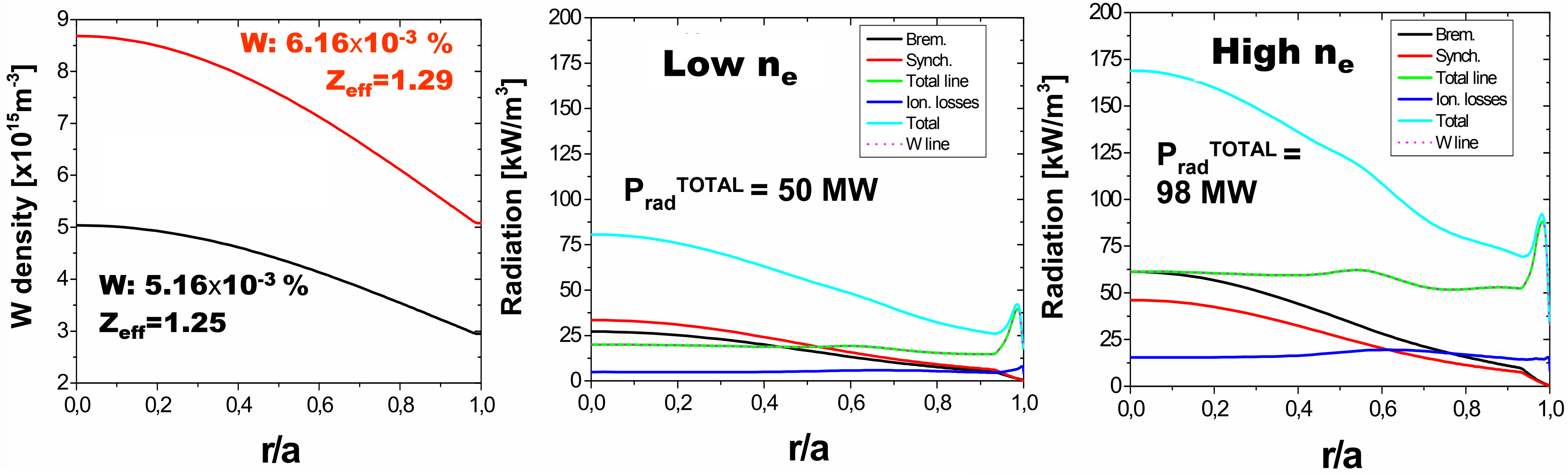
$$R, a, B_T, \varepsilon, \kappa, I_p$$
$$H_{98}, P^e_{aux}, P^i_{aux}$$
$$\langle n_e \rangle, n_{sep}, n_{sep}$$
$$T_{e(i),sep}, T_{e(i),ped}, \rho_{ped}$$

JETTO (ASTRA, CRONOS): theory-based models (GLF23, TGLF, Weiland), peeling-ballooning model for pedestal

- **ITER H-mode scenario: 15 MA, 5.34 T, 33 MW (NBI) + 20 MW (ECRH)**
- **Low density (ref.):** n_{e_ped}=6e19 m^{-3}, $T_{e,ped}$ = 6.7 keV, $T_{i,ped}$ = 7.5 keV
- **High density:** n_{e_ped}=9.5e19 m^{-3}, $T_{e,ped}$ = 4.35keV $T_{i,ped}$ = 4.83keV
- **JETTO / GLF23, EPED, SOLPS boundary, no W →H98=0.85 at low and high ne, Q=**
- **COREDIV: effect of W?**

ITER H-mode: COREDIV simulations

I. Ivanova-Stanik, F. Köchl et al, PET 2013



- *Higher density is achieved by increasing gas puff (feedback: (8.8 -> 21.2)10^{21} 1/s)*

- *$D_{D,T}=0.35\chi_{i,e}$; $V_{D,T}$ adjusted to match the GLF23 ne peaking. Similar particle transport at low and high ne. Impurity transport is the same as main species*

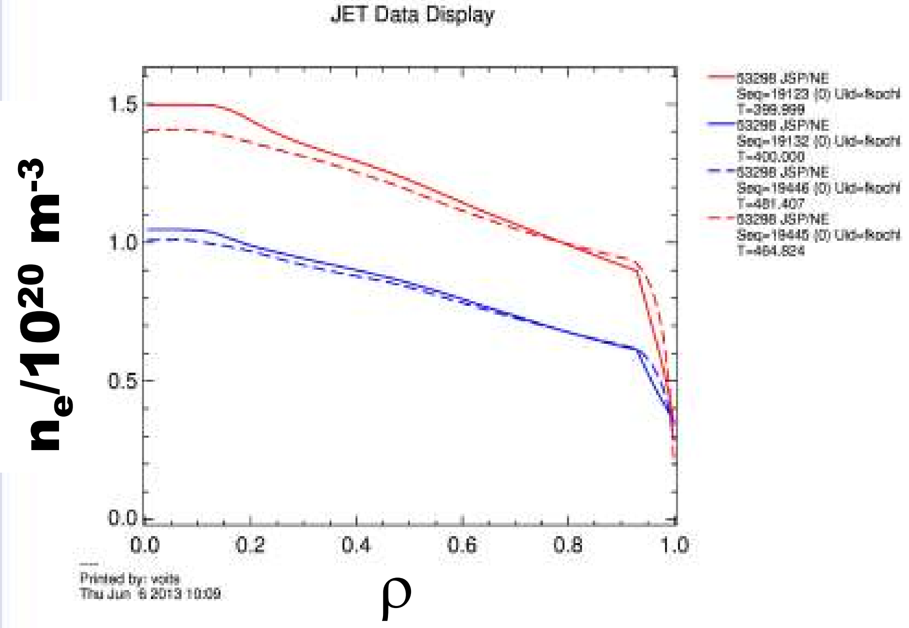
- *$P\alpha$ ↑, power to plate ↑, W sputtering ↑ with ne→ high nW and Prad. W concentration increases due to sputtering, not transport*

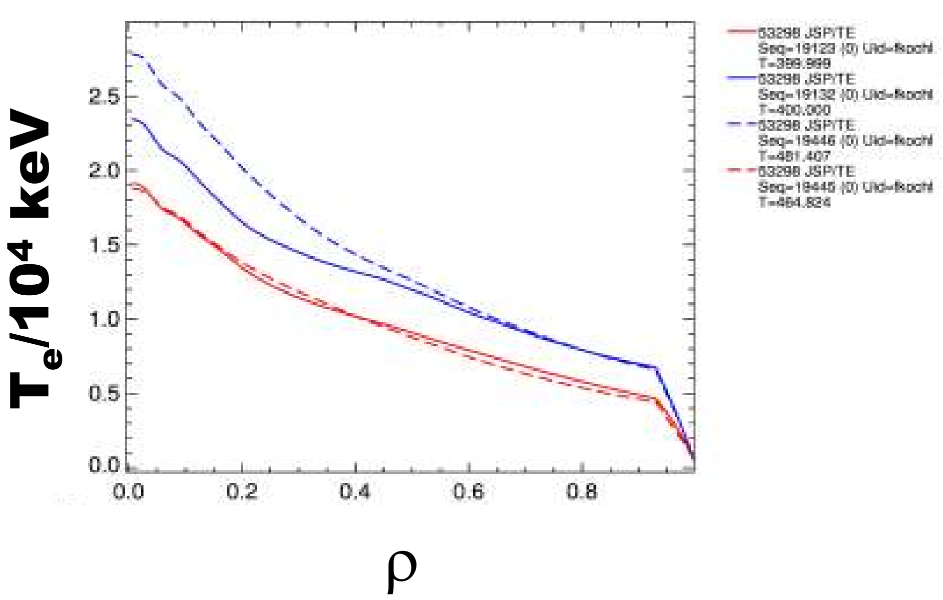
- *Increase of power to plate ~11% (strongly increased α-heating and W radiation partly compensate each other)*

	Low ne	High ne
Pα [MW]	79.4	140.1
Core radiation [MW]	41.92	89.97
Radiation fraction	0.378	0.505
Power to plate [MW]	76.05	85.32
T_e plate [eV]	25.45	33.55
n_e plate [$x10^{20}$m-3]	2.1	1.43
Recycling coefficient	0.9958	0.989
Sputtering flux, 1/s	1.1e20	1.9e20

Work in progress

JETTO simulations with W radiation from COREDIV (F. Koechl)



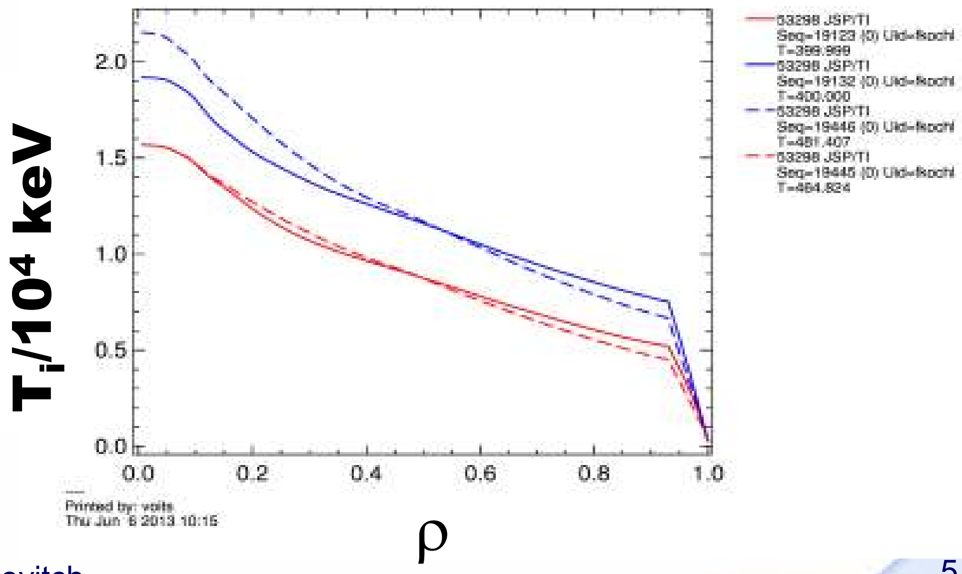


- Initial GLF23/JETTO runs with C impurity (solid) is compared to JETTO run with W and He concentration and radiation from COREDIV (dashed)

- low ne: Pα= 74→92 MW

- Increased radiation is compensated by higher Pα (lower dilution) when C is replaced with He and W

- high ne: Pα= 80.5→92 MW, but P_{LH} = 77 MW → no H-mode solution



Sensitivity to local transport (impurity, main species and thermal) is particularly high with dominant alpha heating

- **High sensitivity to $D_{D,T}/\chi_{i,e}$. In present ITER simulations $D_{D,T}/\chi_{i,e}$ =0.35**
  - *when $D_{D,T}/\chi_{i,e}$ =0.1 no self-consistent solution at high density (large He concentration, low $P\alpha$, high radiation)*
  - *larger $D_{D,T}/\chi_{i,e}$ margins for flat ne profiles → transport of main species determining the ne peaking is important*
  - *difficult to reduce $D_{D,T}/\chi_{i,e}$ uncertainty using present experiments ($D_{D,T}/\chi_{i,e}$=0.1-0.35 gives similar results for JET plasmas)*

- **Fusion performance is sensitive to core thermal transport model: at given H98 factor the GLF23 and scaling-based models predict different Ti shape and $P\alpha$ ($P\alpha$=84 MW (GLF23) and $P\alpha$=140 MW (scaling-based))**