❑ ITER high f_{rad} scenario modelling with High Fidelity Plasma Simulator HFPS

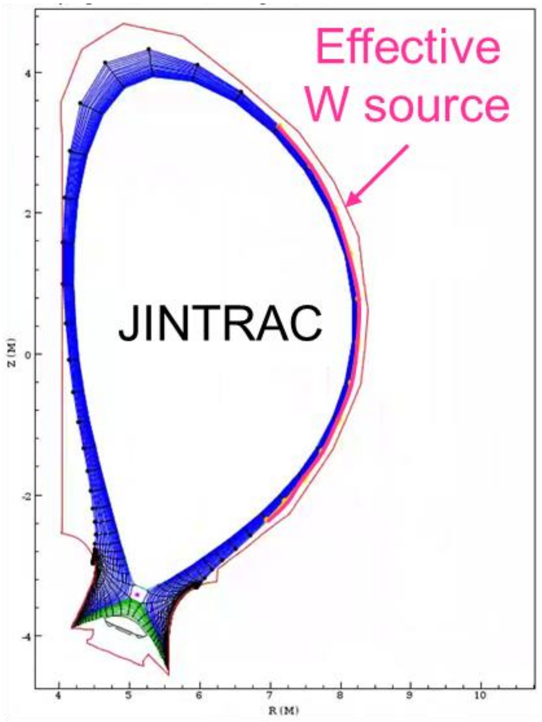
- High-fidelity plasma simulator has been applied to model integrated ITER scenarios for SRO, DT-1 and DT-2, including PF circuits, core-pedestal-SOL and plasma-wall/target interactions
- Focus on W production and core contamination impact of W wall due to ITER re-baseline [Loarte PPCF 2025, Pitts NME 2025]
- Potentially ELM free high f_{rad} scenarios to be considered:
  - 15 MA / 5.3 T DT baseline high Q_{fus} H-mode considering wall load limit with max. expected W wall source (worst case assumption)
  - 15 MA / 5.3 T DT XPR compatible high Q_{fus} L-mode / degraded H-mode with enhanced pellet fuelling
  - 15 MA / 5.3 T DT XPR [Korving EPS 2026]
- ITER HFPS components in use:
  - JINTRAC (core-edge-SOL transport with sources and exhaust, and kinetic control)
    - Core transport: TGLF-SAT2 + NCLASS/NEO, ECRH: GRAY
    - Pedestal: MISHKA+EPED1 / ITER EPED1-SOLPS scaling [Polevoi NF 2015] / ELM free pedestal models
    - SOL: Wiesen model [Wiesen PPFC 2011] with cont. transition to fixed $\chi_{far\ SOL}$ $D_{far\ SOL}$ / prescribed $\chi_{far\ SOL}$ $D_{far\ SOL}$ polygons in line with SOLPS-ITER Wide Grid calculations
    - DINA (free-boundary equilibrium evolution and magnetic control)

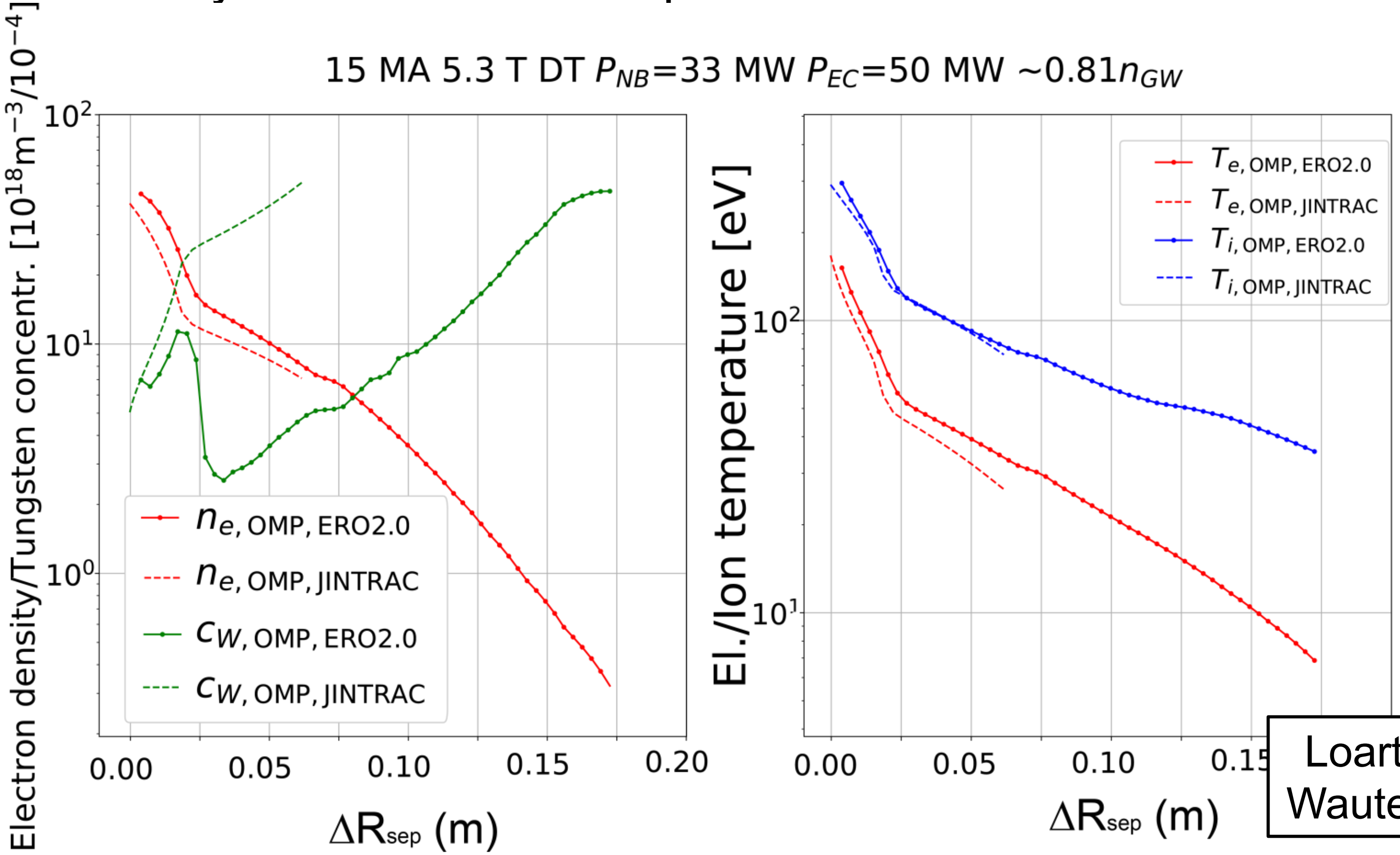
❑ ITER high f_{rad} scenario modelling with High Fidelity Plasma Simulator HFPS – W modelling

- W wall source emulated by prescribed W source at outermost far SOL layer (at 2nd X-point)
- Conservative assumptions on W release and transport:
  - Assumption of zero prompt W re-deposition
  - Zero W ion outflux imposed as far SOL boundary condition
  - No consideration of interaction between wall-released W / main ions and plasma in outer wall shadowed far SOL region
  - ~ Zero outward W convection in SOL
  - High $D_{W,ped}/\chi_{ped}$ ~ 1.0 reducing W screening effect in pedestal

❑ ITER 15 MA / 5.3 T DT H-mode high f_{rad}

- JINTRAC core plasma + near SOL + ad-hoc wall source to match $n_W/n_{e,sep}$ for "largest possible" W source
- P_{aux} ~ 80 MW and P_{fusion} = 500 MW with P_{sep}/P_{LH} > 1.5 → Q > 6 for "worst possible case"
- W pedestal screening confirmed as key to maintain fusion performance





Loarte FEC 2025
Wauters EPS 2026

❑ ITER 15 MA / 5.3 T DT H-mode high f_{rad}

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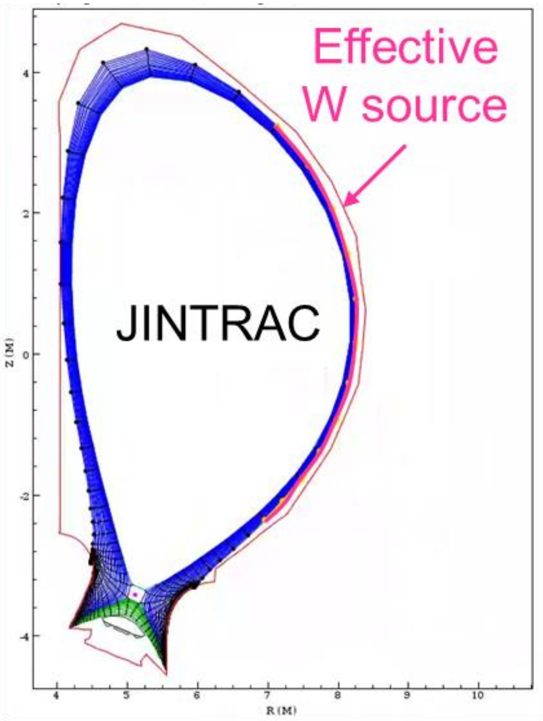
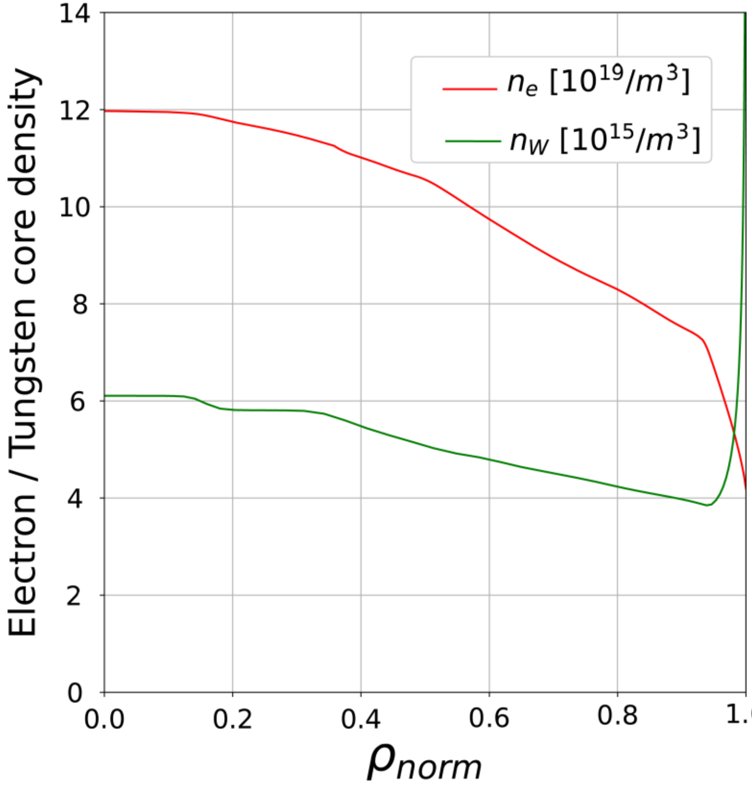
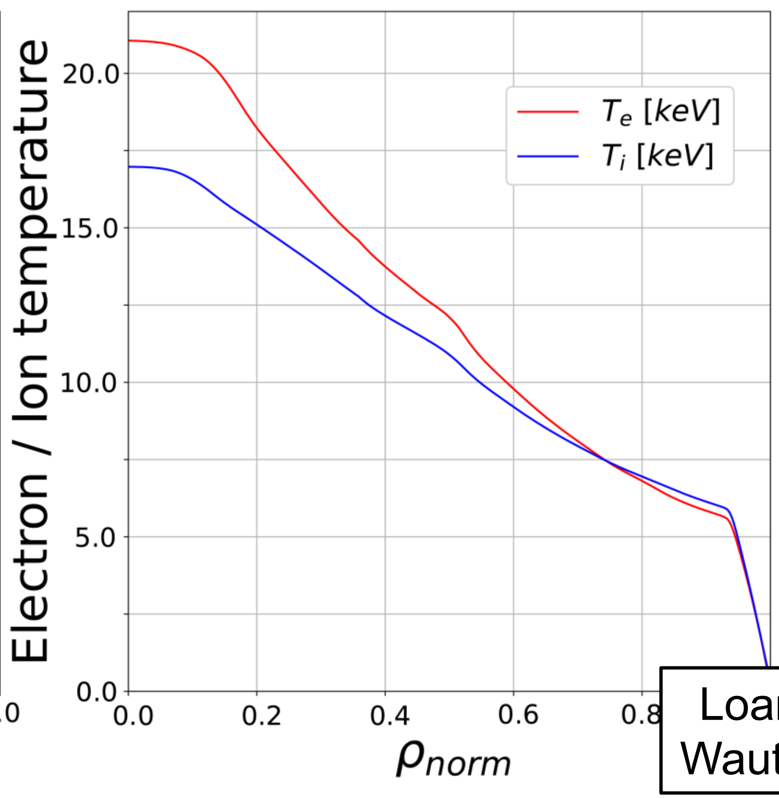


15 MA 5.3 T DT P_{NB}=33 MW P_{EC}=50 MW ~0.81n_{GW}





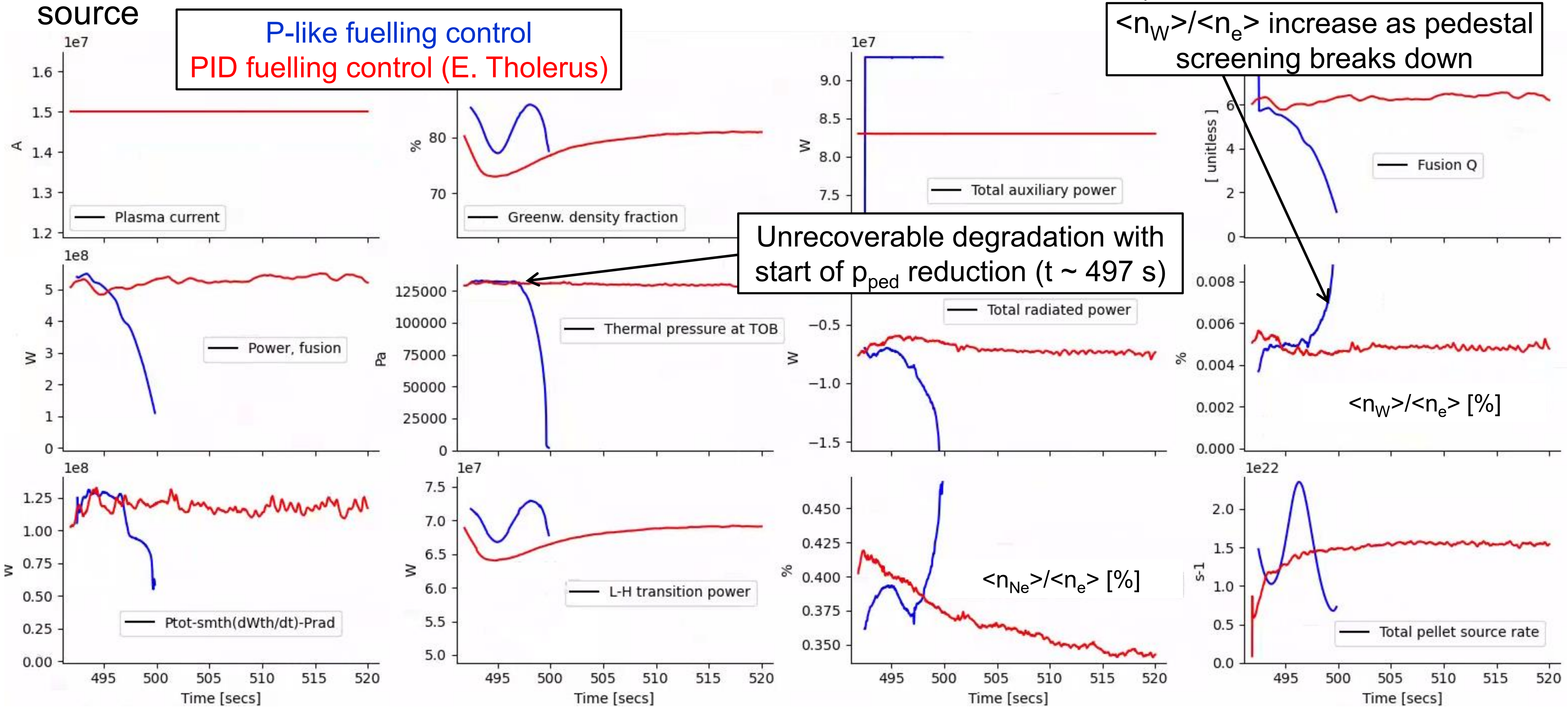
Loarte FEC 2025
Wauters EPS 2026

❑ ITER 15 MA / 5.3 T DT H-mode high f_{rad}

- JINTRAC core plasma + near SOL + ad-hoc wall source to match $n_W/n_{e,sep}$ for “largest possible” W source
- Pedestal conditions:
  - p_{ped} close to MHD limit but also close to ELM free conditions with given heat flux and pedestal transport
  - Pedestal transport assumed to increase when approaching $P_{L\text{-}H}$ (degraded H-mode close to transition threshold power [Sartori PPCF 2004], described by reduced pedestal turbulence suppression)
  - Fluctuations in heat flux in conditions close to worst case for W source may trigger unrecoverable p_{ped} reduction and transition to L-mode; heat and fuelling control required to mitigate such fluctuations
  - Operational space may be increased with consideration of potential pedestal widening in ELM free conditions (reduced pedestal gradients at similar p_{ped} could be sustained at reduced P_{net} and increased transport closer to $P_{L\text{-}H}$)

ITER 15 MA / 5.3 T DT H-mode high f_{rad}

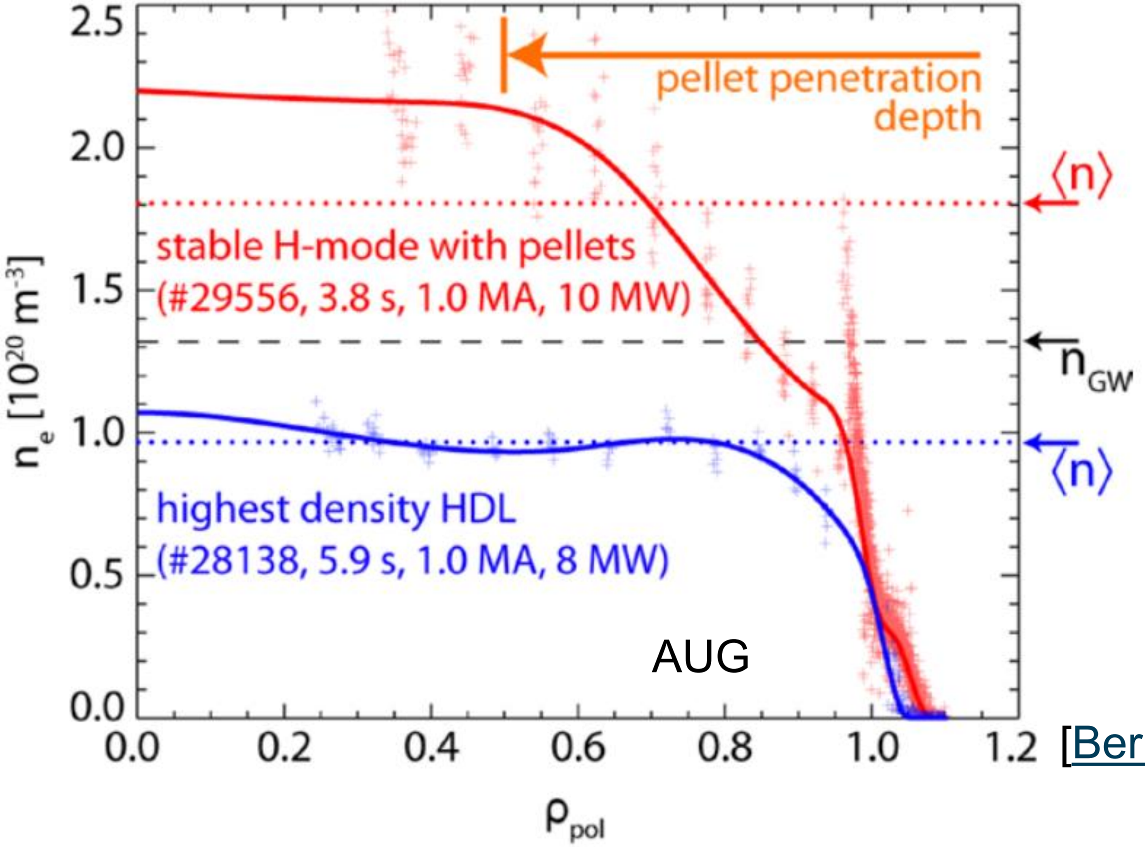
- JINTRAC core plasma + near SOL + ad-hoc wall source to match $n_W/n_e|_{sep}$ for “largest possible” W source



$f_{pel}\uparrow \rightarrow n_e\uparrow \rightarrow P_{rad}\uparrow \rightarrow P_{net}\downarrow \rightarrow \chi, D\downarrow \rightarrow n_e\uparrow$

❑ ITER 15 MA / 5.3 T DT high f_{pel} high f_{rad} L-mode

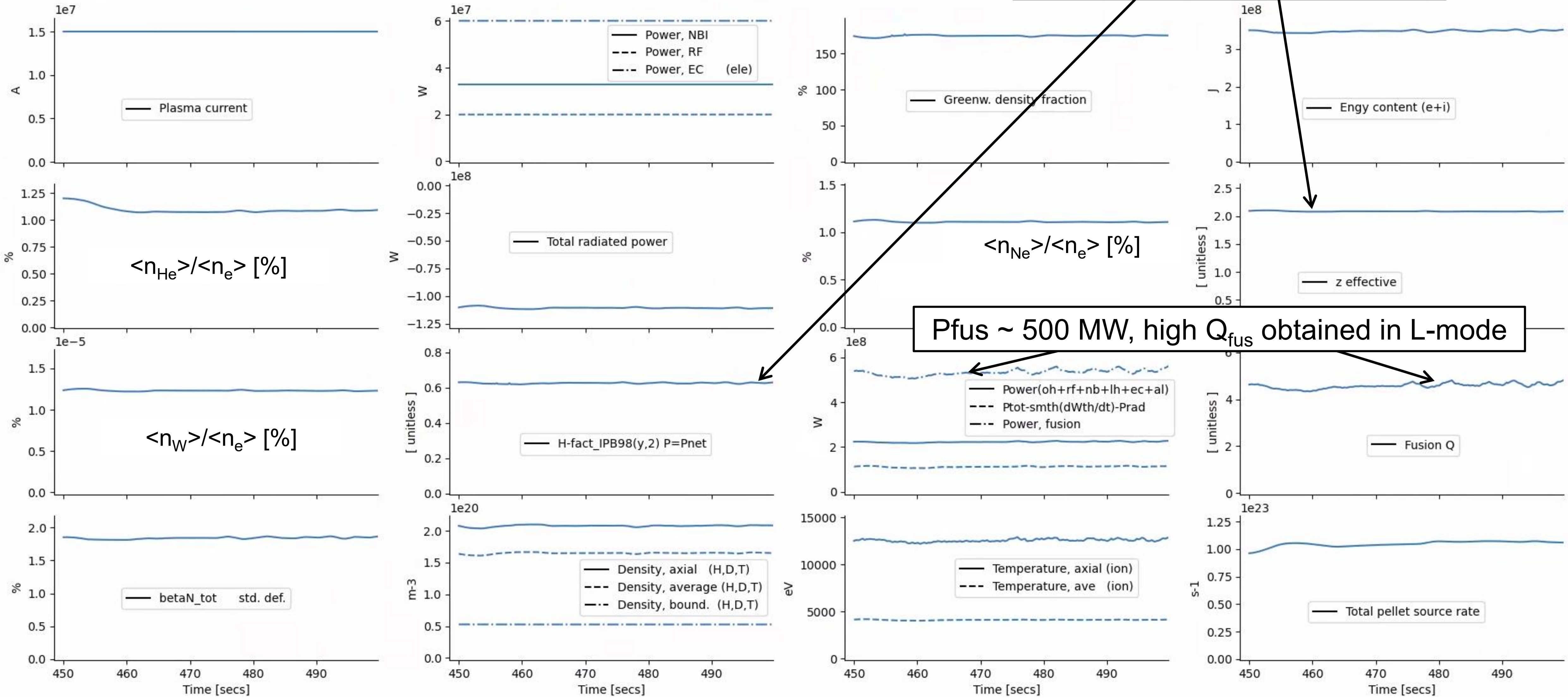
- JINTRAC core plasma modelling, high power high density L-mode sustained by pellet fuelling
- Core density exceeding n_{GW} in high power L-mode may be achievable [Giacomin PRL 2022, Sauter PPCF 2025]
- De-coupled core density exceeding n_{GW} in H-mode achievable for $n_{e,ped} < \sim n_{GW}$: [Lang NF 2012, Bernert PPCF 2015]:



[Bernert PPCF 2015]

❑ ITER 15 MA / 5.3 T DT high f_{pel} high f_{rad} L-mode

Relatively good confinement linked to ITG damping at high Z_{eff}

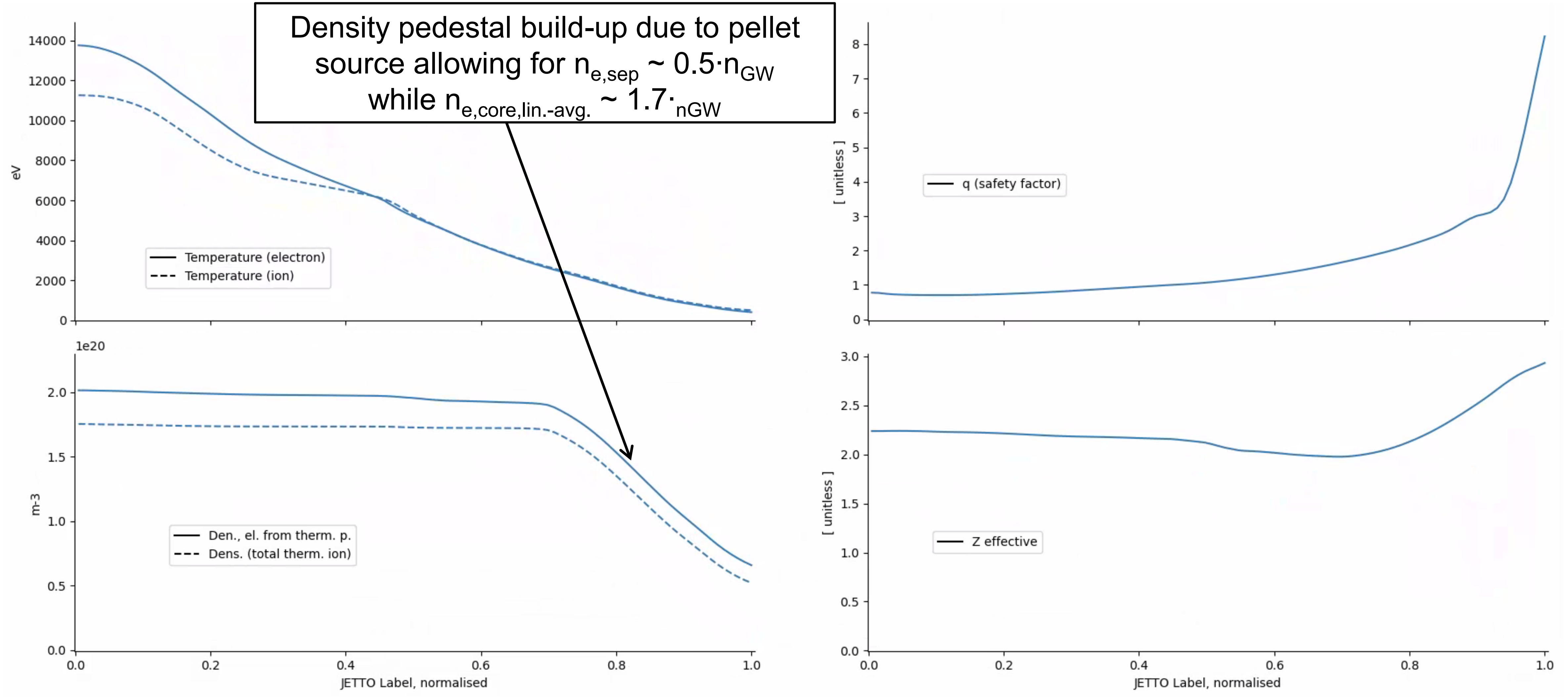


Pfus ~ 500 MW, high Q_{fus} obtained in L-mode

J. Zhang FEC 2025

❑ ITER 15 MA / 5.3 T DT high f_{pel} high f_{rad} L-mode

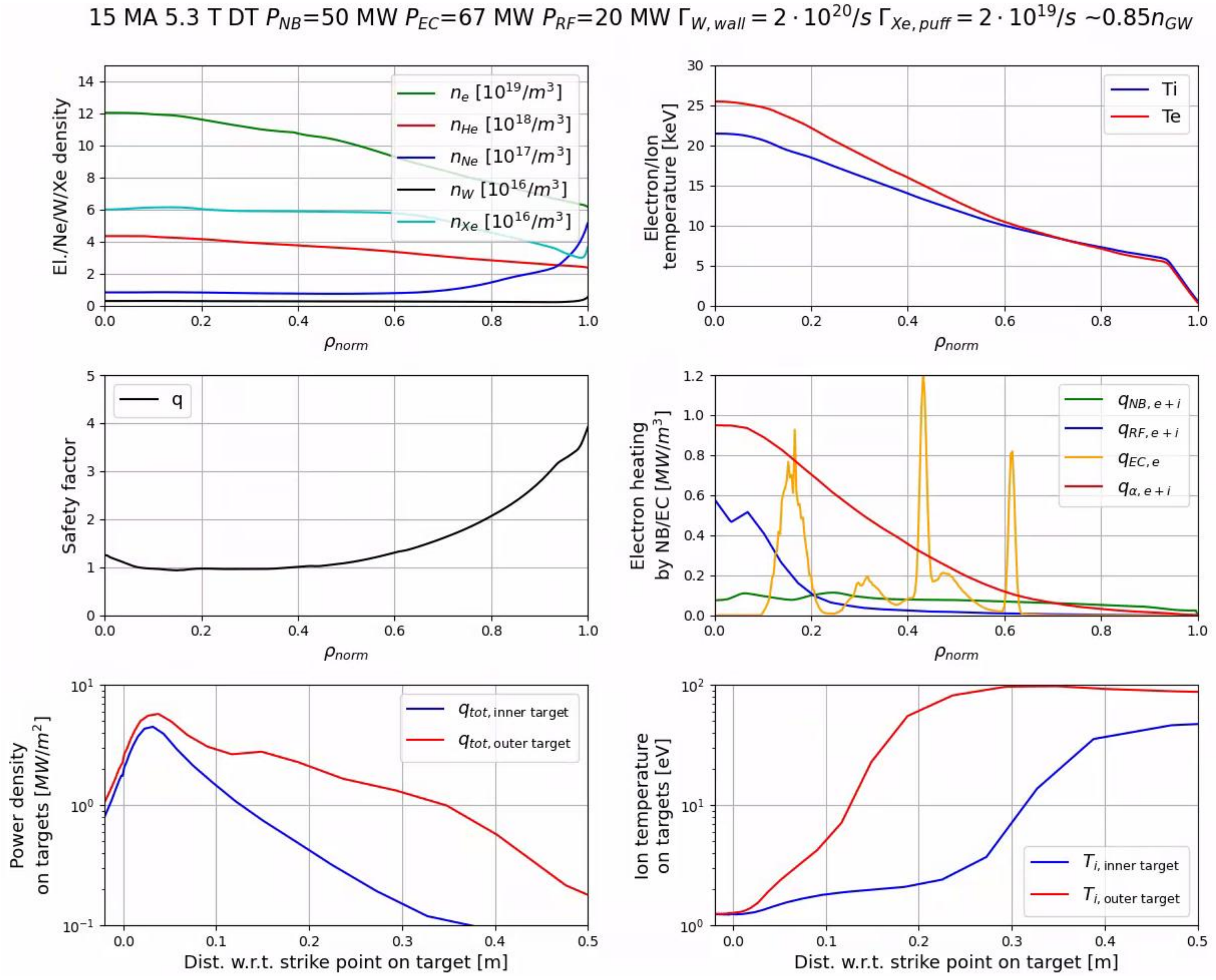
Density pedestal build-up due to pellet source allowing for $n_{e,sep}$ ~ $0.5 \cdot n_{GW}$ while $n_{e,core,lin.-avg.}$ ~ $1.7 \cdot_{nGW}$



J. Zhang FEC 2025

Core conditions qualitatively similar to stationary high Q_{fus} solution compatible with XPR regime [S. Korving IAEA 5th techn. meeting on divertor concepts 2025]

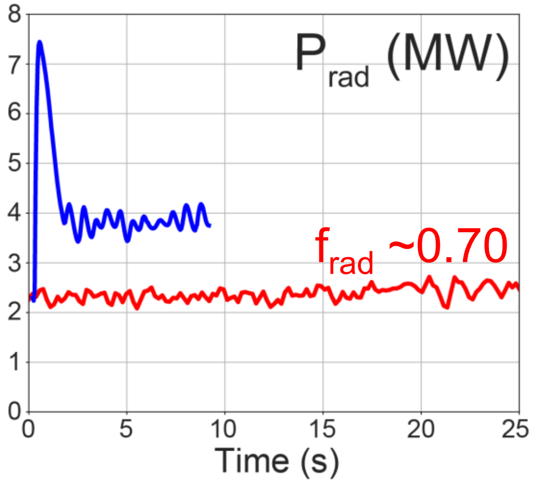
❑ ITER 15 MA / 5.3 T DT max. P_{AUX} high f_{rad} DEMO relevant H-mode with Xe

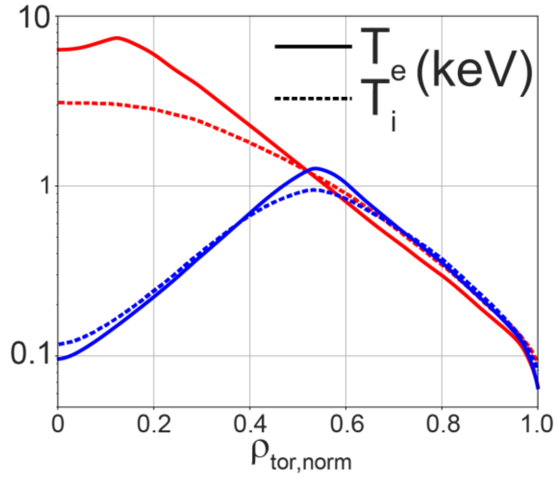


COCONUT (preliminary) with increased core Xe content; significant Xe radiation to consider also in SOL

❑ High frad imiter plasma operation at I_{pl} = 2 MA in H

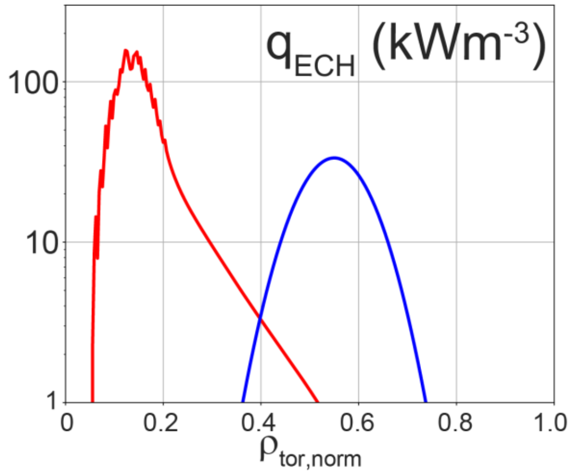
- Self-adjusting high W core contamination ($f_{rad,core}$ ~ 0.7-0.8, $c_W \sim 2\text{-}4\cdot10^{-4}$) providing Y_W ~ 1.0 in stationary conditions
- Requirement of central continuous EC heating to prevent hollow T_e with self-accelerating central W accumulation

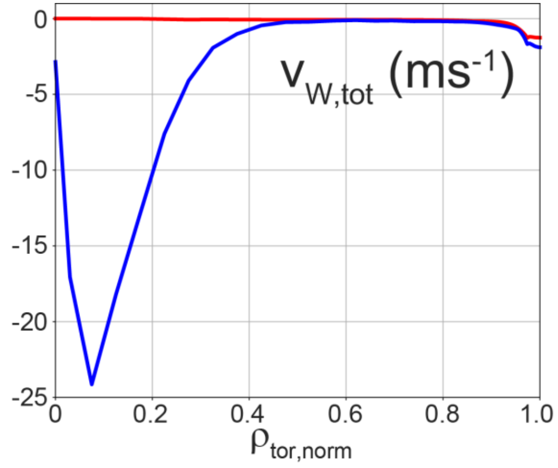


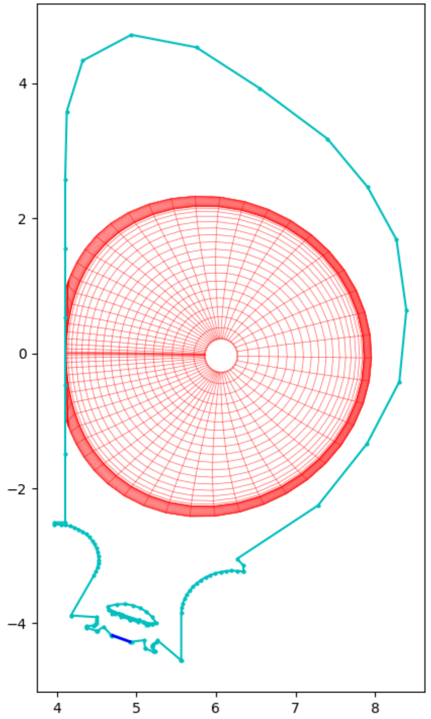


Red: central ECH
Blue: ECH shifted to off-axis at t = 0

Off-axis ECH → large increase in inwards W neo-classical transport







ITER, P_{IN} = 3.3 MW, I_p = 2.0 MA, B_T = 5.3 T

[Pitts NME 2025]

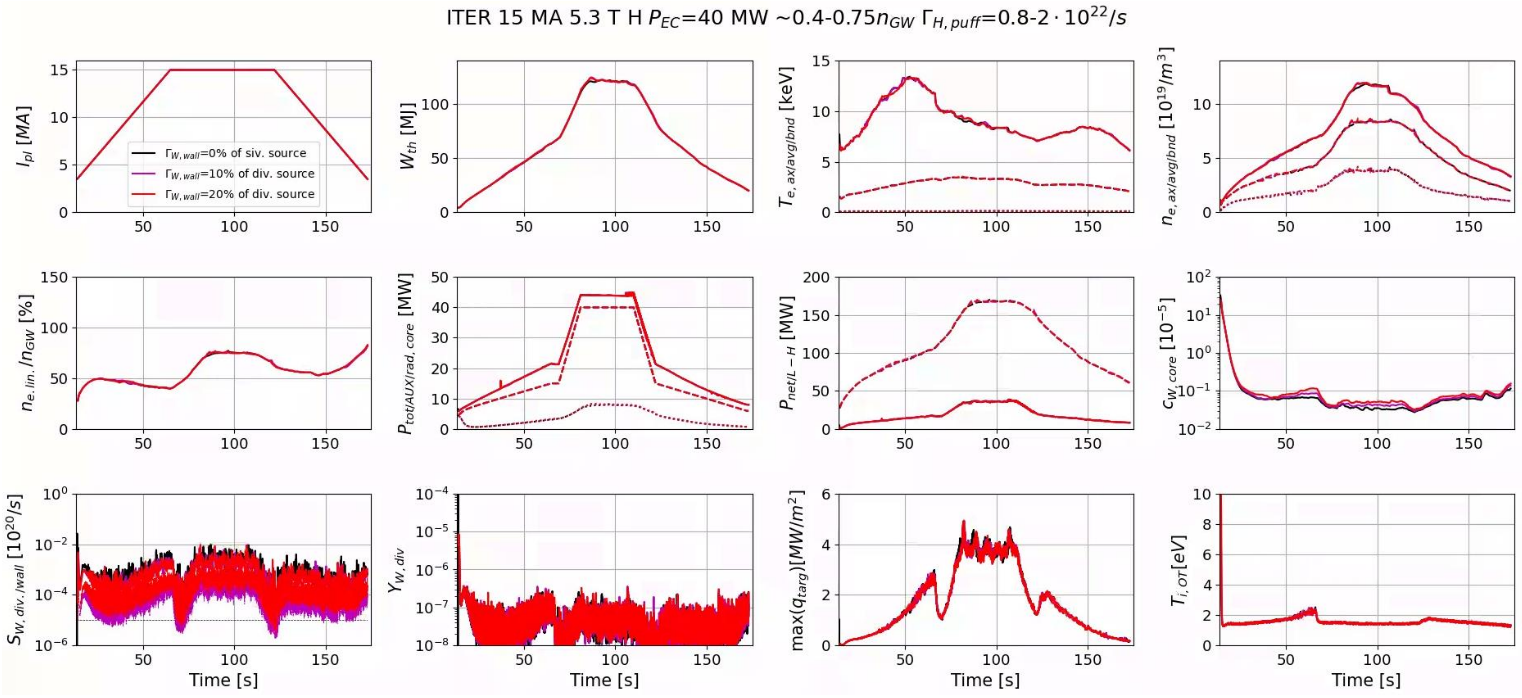
❑ TGLF-SAT2 settings

TGLF-SAT2 improved filter scheme

ITRTGLFBPER= 1
ITRTGLFBPAR= 0

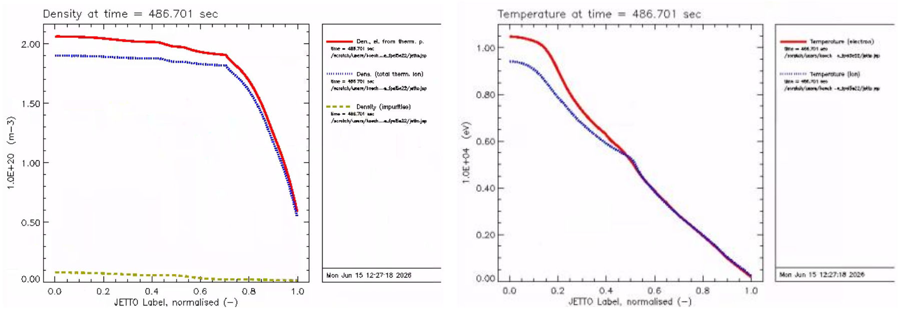
Di Siena NF 2025
Najlauoi NF 2024

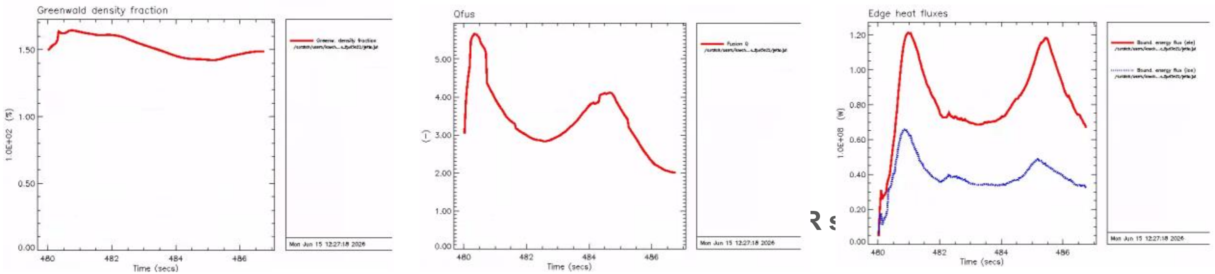
ITRTGLFMHD= 1 (true)
ITRTGLFNBAS= 6
ITRTGLF_KYGRID= 4
TRTGLFFILTER= -0.1
TRTGLFWIDTH= 3.0
TRTGLFWIDTHMIN= -0.3
TRTGLFZF = -1



Option to define regions with different TGLF model settings (e.g. TGLF-SAT2-EM vs. TGLF-SAT2-ES):

NLIST3/ITRDOWNSCMULT(1:2)
TCICONSTEXTXRHON
ITRTGLFBPARMULT(1:2)
ITRTGLFBPERMULT(1:2)





COCONUT high ne L-mode

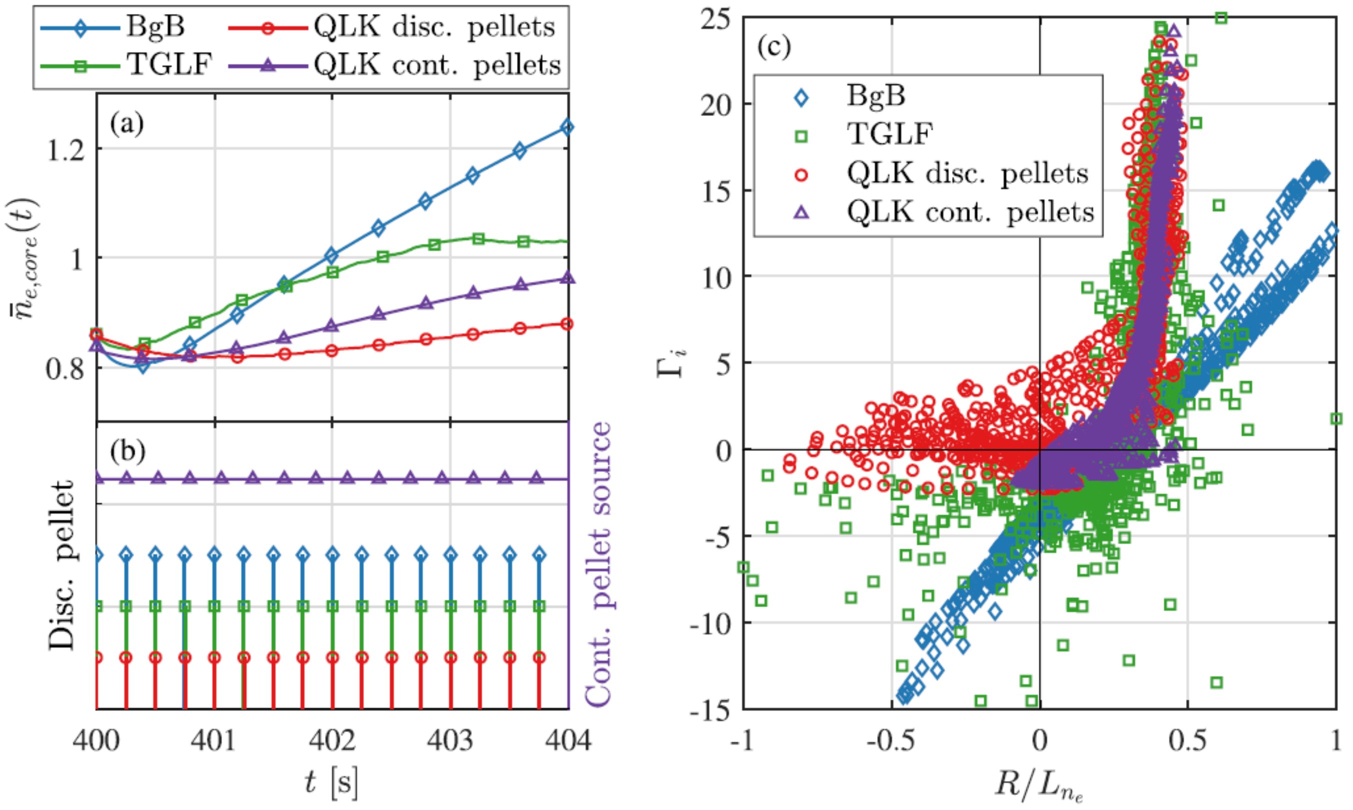
TCI model settings

TCI flux splitting scheme with TGLF

Recommended for JETTO:
ITRTGLFFLSP = 2
Recommended for COCONUT:
ITRTGLFFLSP = 7

High resolution settings required for modelling of fast transients (e.g. discrete pellet injection)

- Implicit correction scheme switched off or reduced to low level impact
- TCI call at every JETTO time step
- High TCI grid resolution to resolve localised gradient variation
- Max. JETTO time step limited to < 1 ms
- No smoothing of transport coefficients in time



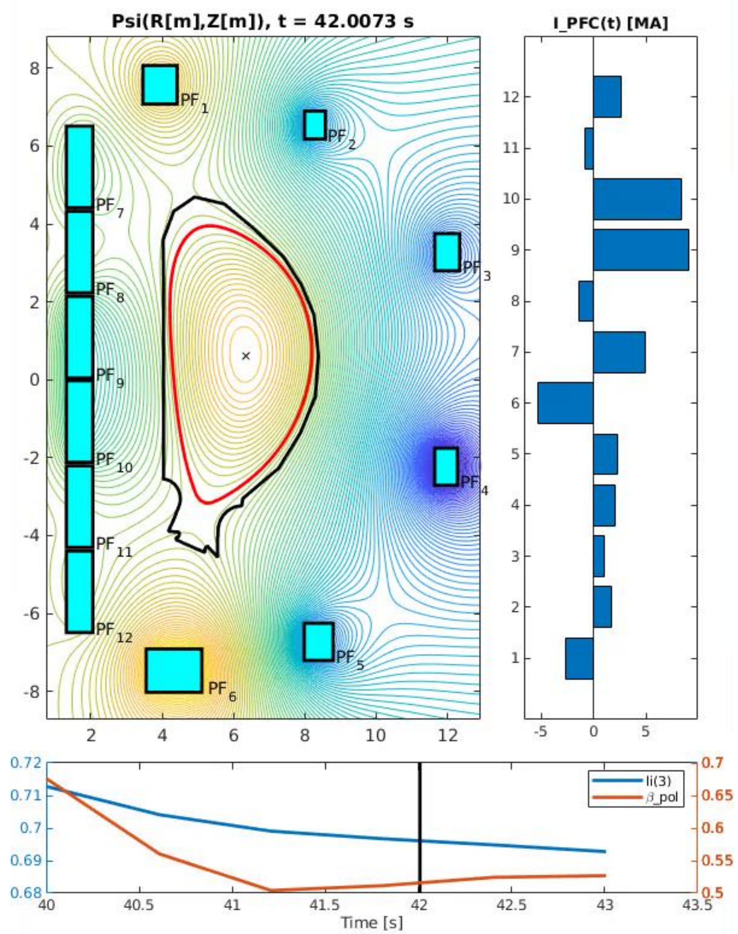
Post-pellet transport with edge density peak formation

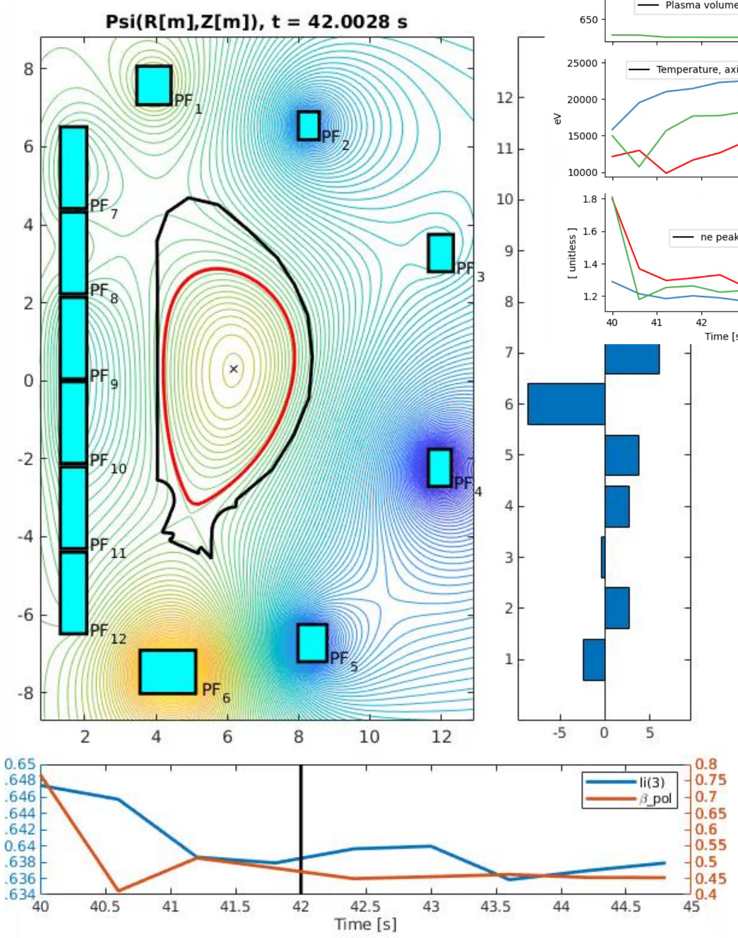
Orrico NF 2025
Panera NF subm.
Zhang NF subm.

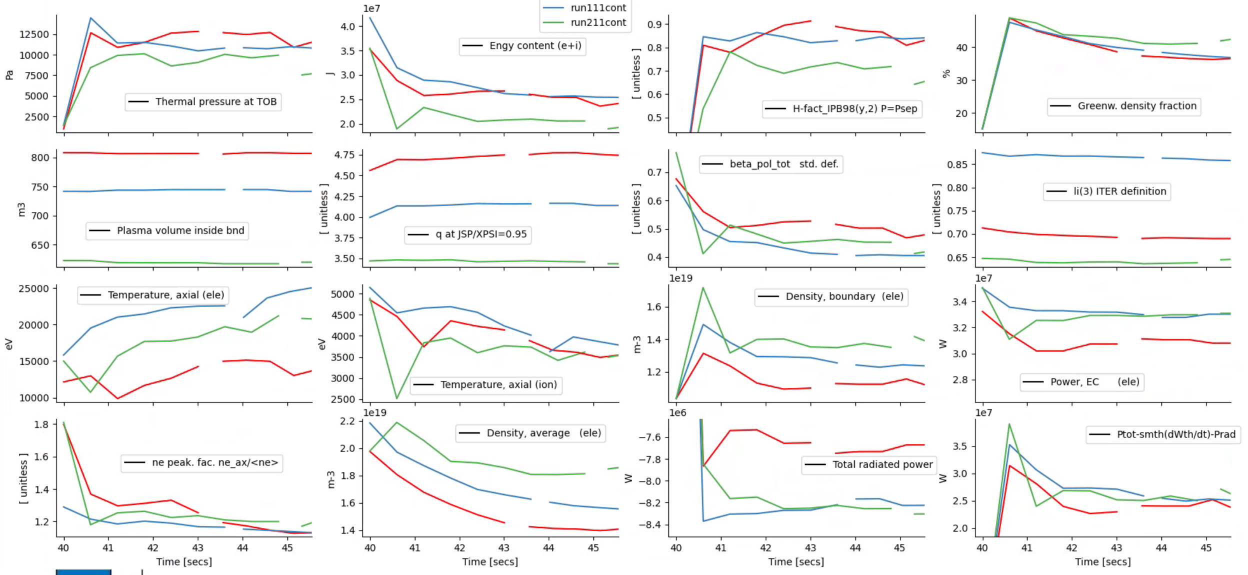
❑ ESCO-inverse, EPED1+MISHKA

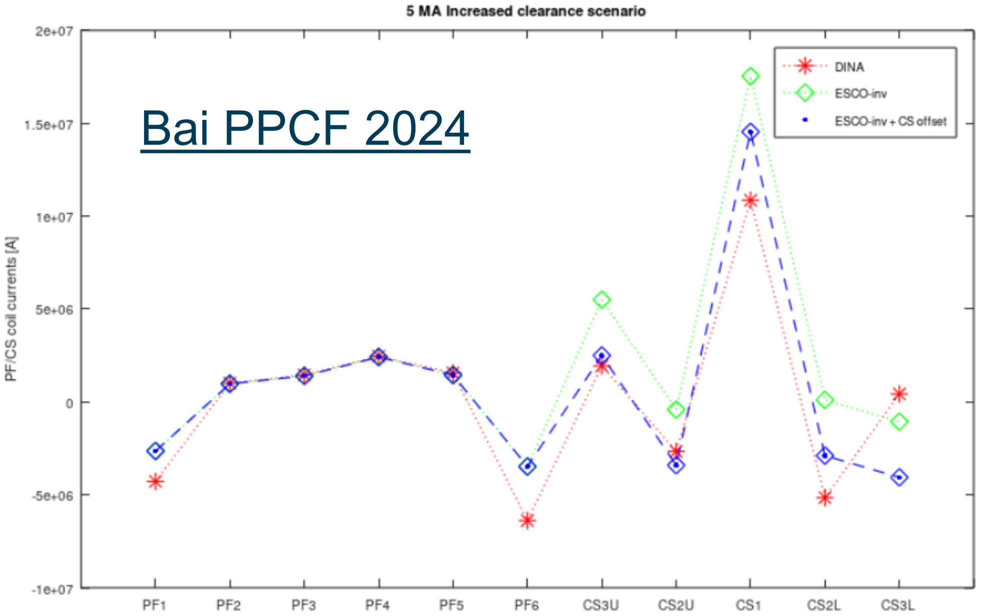
Pedestal modelling scheme
ITEREPED1PRED = 2

ITER 5 MA 2.65 T with varying boundary shape, PF coil currents evaluated by ESCO-inverse, EPED1+MISHKA used for pedestal prediction



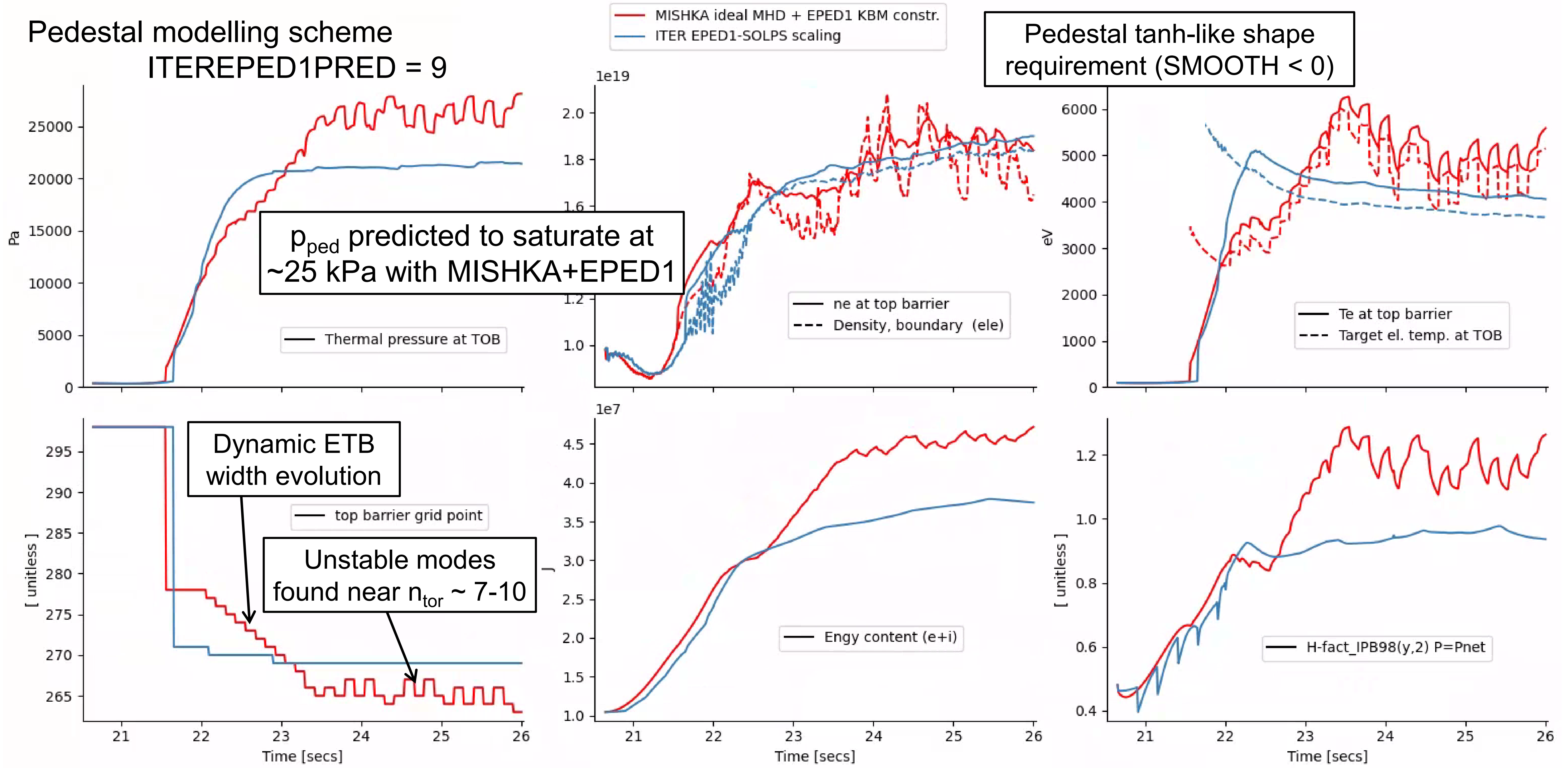






Bai PPCF 2024

❑ ITER 5 MA / 2.65 T D H-mode (with Ne seeding), EPED1-MISHKA feedback on pedestal width



❑ HFPS DINA-JINTRAC

COCONUT simulations in loose / tight coupling to DINA

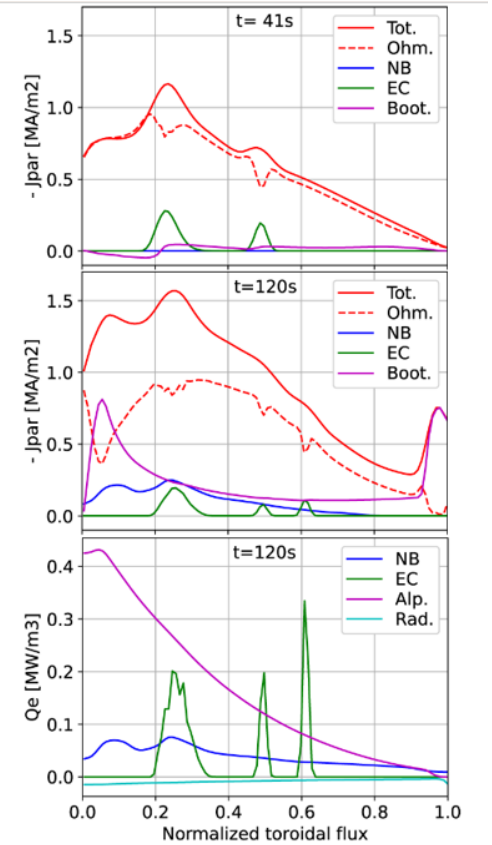


FIG 6. Parallel current density and electron power deposition profiles in the DINA-JETTO simulation of 15MA/5.3T ITER Baseline applying the close coupling scheme.

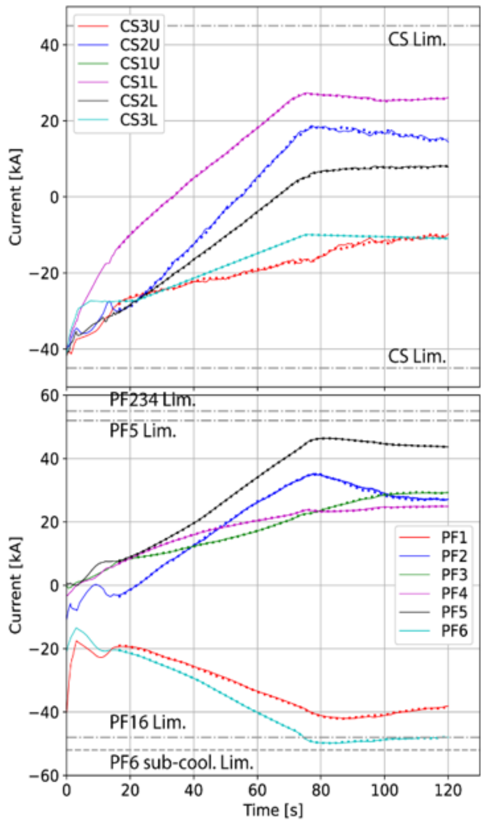


FIG 7. Time traces of poloidal field coils in the DINA-JETTO simulation of 15MA/5.3T ITER Baseline applying the close coupling scheme (solid lines) and interpretative DINA stand-alone simulation (dotted lines). Coil currents limits are shown in grey dashed and dash-dotted lines.

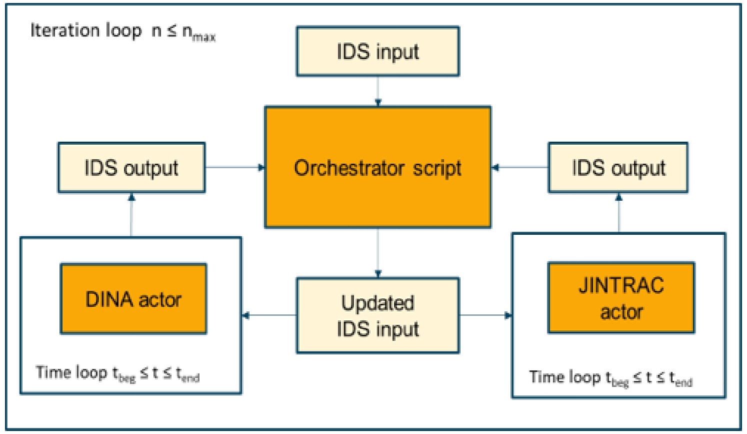


FIG 1. Loose coupling scheme applied to exchange simulation data between stand-alone DINA and JINTRAC runs executed for a given scenario segment.

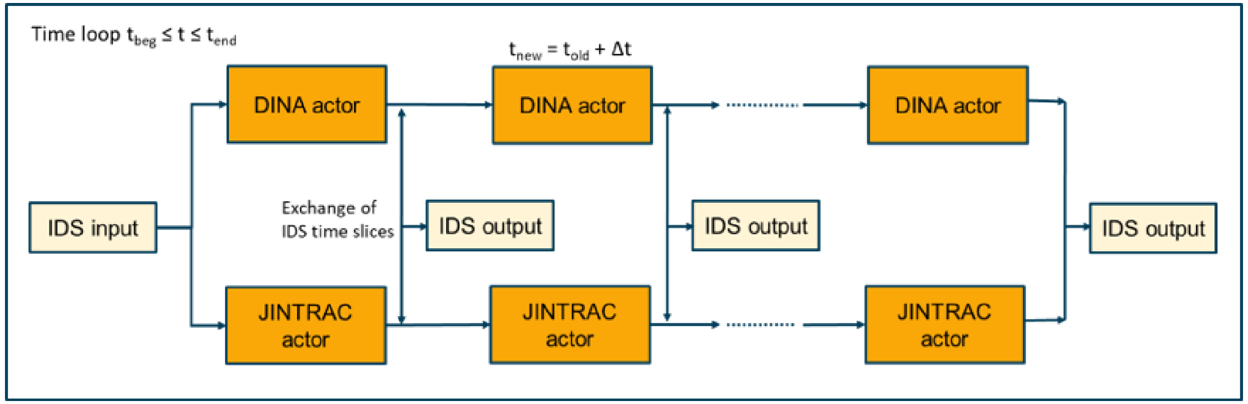


FIG 2. Close coupling scheme applied to exchange simulation data during the single execution of DINA and JINTRAC runs.

DINA open source:
https://github.com/iterorganization/DINA-IMAS

Kim FEC 2025
Jaegon EPS 2026