

Time-dependent integrated modelling of DTT scenarios using JINTRAC

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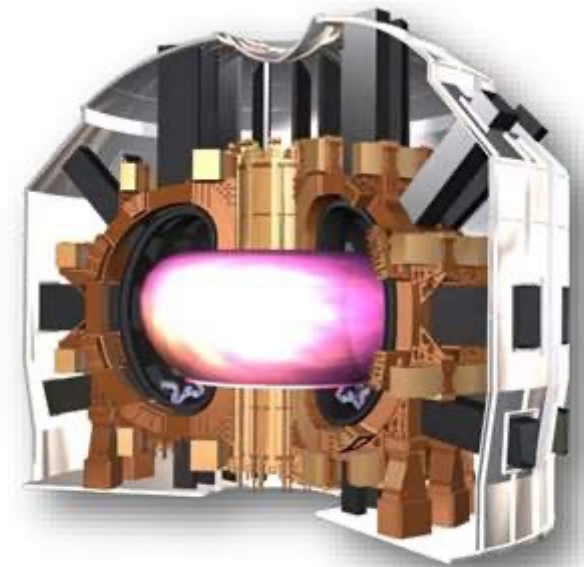


Outline

- Introduction
- Modelling of scenario A, A* and C
- IMAS database for DTT
- Motivation of time-dependent JINTRAC simulations
- Setting up a time-dependent JINTRAC simulation
- Comparison of JINTRAC results with ASTRA results
- Extending the modelling by employing JINTRAC-GRAY
- Preparation for the Advanced Scenario
- Future work

The Divertor Tokamak Test (DTT) facility

- The Divertor Tokamak Test (DTT) facility is currently under construction in Frascati (Italy).
- The main objective is to develop and test alternative power exhaust solutions to bridge the gap between ITER and DEMO in reactor-relevant operating regimes.



Heating phases and planed scenarios

Scenario	Ip (MA)	BT (T)	divertor	Power installed (MW)		
				EC	IC	NBI
A	2	3	SN/XD	8	0	0
A NT	1.5	3	NT	8	0	0
B	2	3	SN/XD	16	4.75	0
B NT	1.5	3	NT	16	4.75	0
C	4	6	SN/XD	16	4.75	0
C NT	3	6	NT	16	4.75	0
D	5.5	6	SN	16	4.75	5-10
D XD	4.5	6	XD	16	4.75	5-10
D NT	4	6	NT	16	4.75	5-10
D at low BT	2.75	3	SN	16	4.75	5-10
E	5.5	6	SN	32	9.5	10
E XD	4.5	6	XD	32	9.5	10
E NT	4	6	NT	32	9.5	10
E at low BT	2.75	3	SN	32	9.5	10

Phase 1

2029-2034

Phase 2

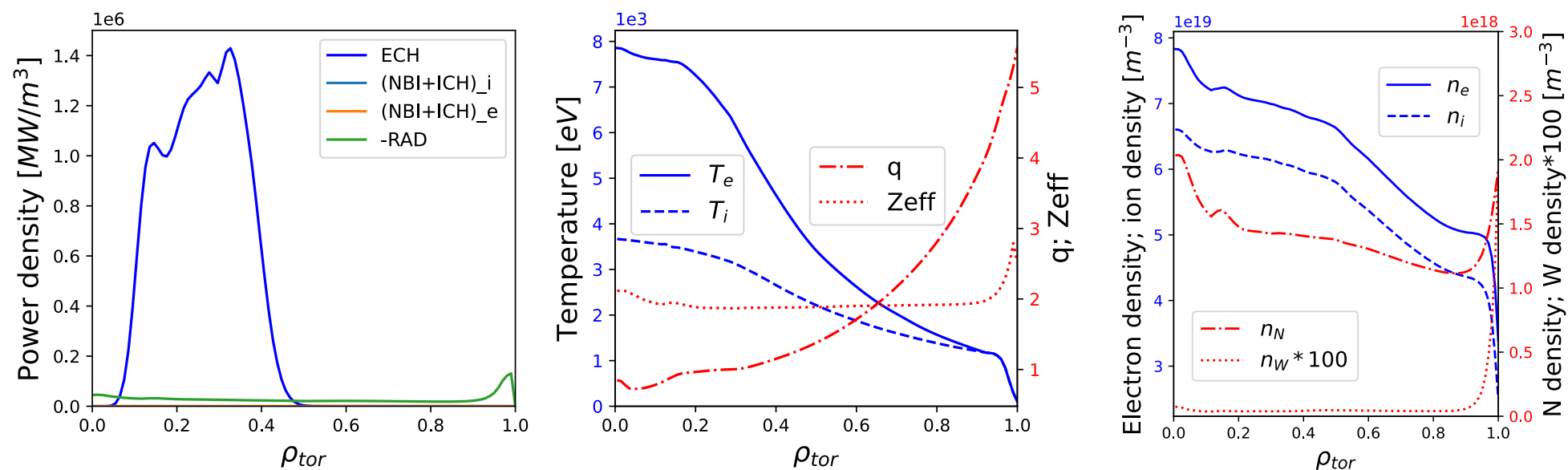
2034-2038

Phase 3

2038-onward

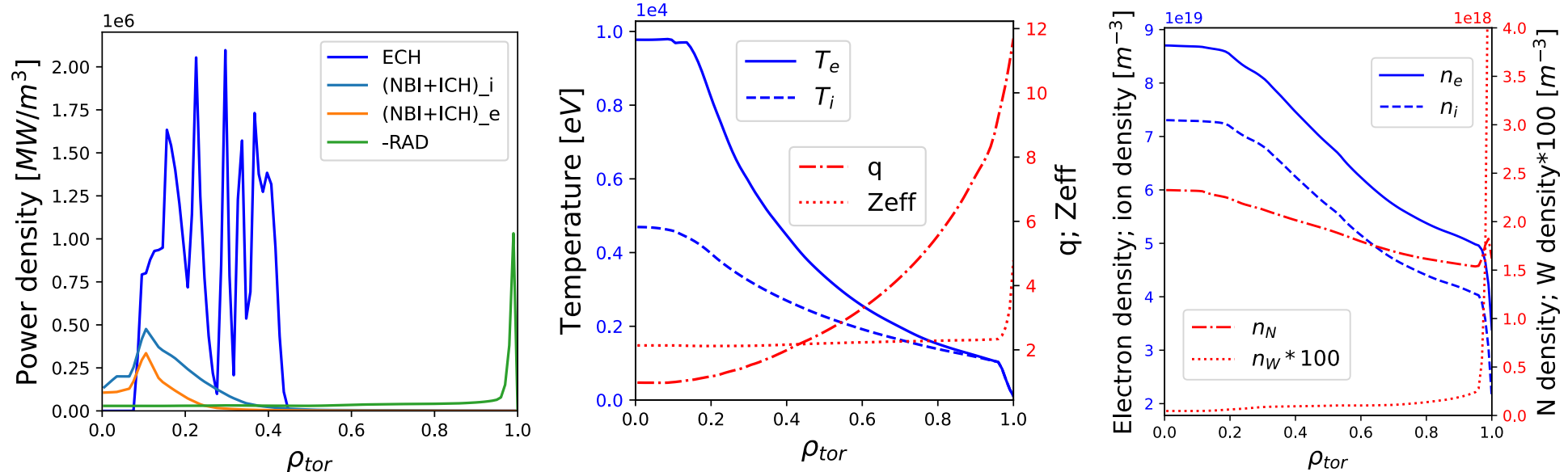
- Baseline flattop of scenario A, C and E has been modelled using JINTRAC and ASTRA [I. Casiraghi et al 2023]
- Baseline rampup of scenario A, C and E has been modelled using ASTRA [N. Bonanomi et al 2025]
- I updated the flattop simulations using JINTRAC

JINTRAC modelling of Scenario A flattop



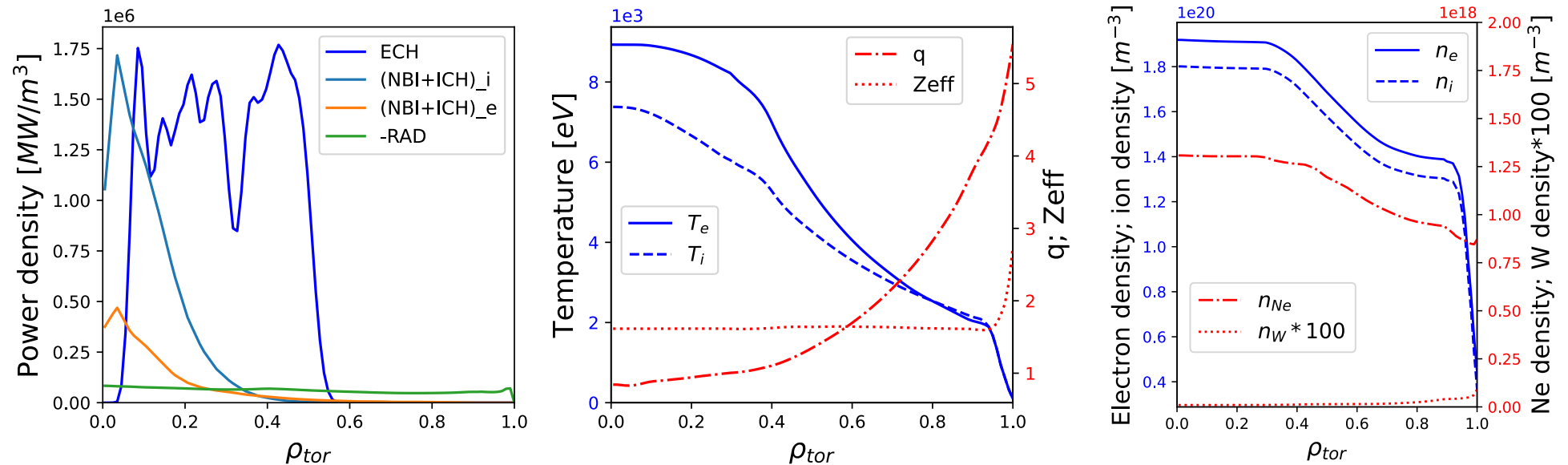
$I_p = 2MA$, $B_T = 3T$, 7.2 MW of ECRH

JINTRAC modelling of Scenario A* flattop



$I_p = 2\text{MA}$, $B_T = 6\text{T}$, 7.2 MW of ECRH, 1.5 MW of ICRH

JINTRAC modelling of Scenario C flattop



$I_p = 4\text{MA}$, $B_T = 6\text{T}$, 16 MW of ECRH, 4.75 MW of ICRH

Test of a scenario database based on SimDB

- JINTRAC outputs data in IMAS format
- Simulations can be stored and shared on a remote server.
- Web interface for searching. Command line client for pushing and pulling.
- Tools for easy visualizing and comparing.

ITER Simulation Database Version 0.7.0

SimDB Dashboard

alias eq ▼

code name eq ▼

ip eq ▼

b0 eq ▼

power_additional eq ▼

description eq ▼

Search Results COMPARE

☐	Alias/UUID	Status	Upload Date	
☐	11/1	passed	Mon, 13 Oct 2025 09:10:09 GMT	▼
☐	31/1	passed	Mon, 13 Oct 2025 09:13:10 GMT	▼
☐	61/1	passed	Mon, 13 Oct 2025 09:14:57 GMT	▼
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Description	DTT scenario A*, H-mode baseline SN. The plasma is with 7.2 MW of ECRH, 1.5 MW of ICRH and 6 T of toroidal magnetic field. Plasma current is 2 MA. PION and GRAY are called for heating. NCLASS and TGLF are	DTT scenario C, H-mode baseline SN. The plasma is with 16 MW of ECRH, 4.75 MW of ICRH and 6 T of toroidal magnetic field. Plasma current is 4 MA. PION is called for heating. ECRH profiles are prescribed. NCLASS	DTT scenario E, H-mode baseline SN. The plasma is with 32 MW of ECRH, 9.5 MW of ICRH, 10 MW of NBI heating, and 6 T of toroidal magnetic field. Plasma current is 5.5 MA. FACIT and	DTT scenario A, H-mode baseline SN. The plasma is with 7.2 MW of ECRH and 3 T of toroidal magnetic field. Plasma current is 2 MA. NCLASS and TGLF are

Motivation

- Time-dependent simulations of the ramp-up phase, predicting the evolution of temperature, density, current and so on of DTT scenarios are crucial
- JINTRAC has been used so far for time-dependent simulations of ITER and STEP, but never of DTT

So, in the 2nd year, I:

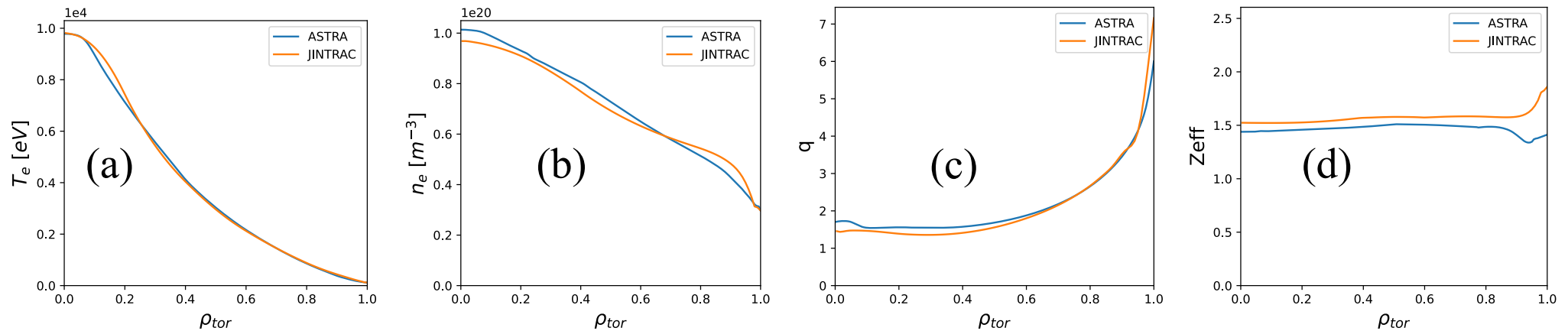
- Explore time-dependent simulation capability of JINTRAC for DTT
- Optimize a hybrid scenario based on scenario E, avoiding Sawtooth
- Develop an Advanced Tokamak scenario

Setting up a time-dependent JINTRAC simulation

Category	Initial state	Current	Geometry	Heating	Current drive	Boundary conditions
Quantities	$T_e(\rho_{\text{tor}})$, T_i (ρ_{tor}) , $n_e(\rho_{\text{tor}})$, $Z_{\text{eff}}(\rho_{\text{tor}})$, $q(\rho_{\text{tor}})$	$I_p(t)$	LCFS (R , Z , t), $R_0(t)$, $B_T(t)$	$Q_{\text{EC}}(\rho_{\text{tor}}, t)$, $Q_{\text{RF}}(\rho_{\text{tor}}, t)$, $Q_{\text{NBI}}(\rho_{\text{tor}}, t)$	$J_{\text{EC}}(\rho_{\text{tor}}, t)$, $J_{\text{NBI}}(\rho_{\text{tor}}, t)$	$T_{\text{sep}}(t)$, $n_{\text{sep}}(t)$

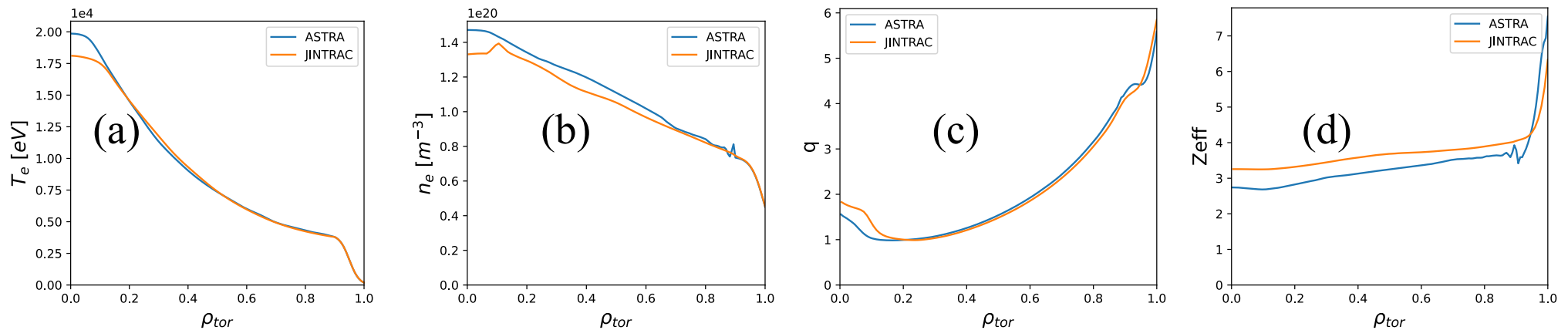
- JINTRAC reads the IMAS input for the initial state
- It updates the heating power and current drive during the simulation
- Feedback of volume-averaged electron density and ratio $P_{\text{rad}}/P_{\text{tot}}$

Comparison of JINTRAC results with ASTRA results



- A preliminary work of the Hybrid scenario is done by J. Lombardo and F. Auriemma using ASTRA
- I replicate the work using JINTRAC using the same setup
- The results show good match in T_e , n_e , q , and Z_{eff} . The figure shows a time slice in L-mode

Comparison of JINTRAC results with ASTRA results



- The results show good match in T_e , n_e , q , and Z_{eff} . The figure shows a time slice in H-mode
- Thus, the time-dependent simulation capability of JINTRAC is tested

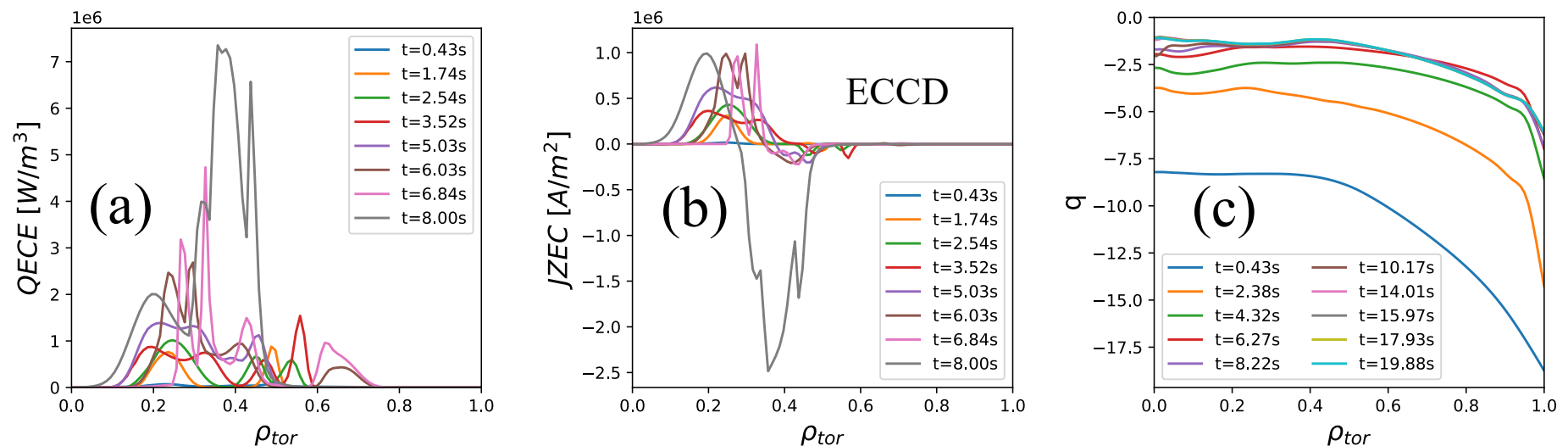
Optimization of electron cyclotron (EC) heating configuration

- GRAY is a ray-tracing code that can calculate the deposition of EC beam power and current drive based on realistic EC configurations.
- I optimize the EC gyrotron configuration to produce more ECCD than the preliminary work, which employed a simplified model.
- So, I create a workflow of optimization to control the q profile, making the best use of the available gyrotrons and sustaining the scenario as long as possible.

Workflow:

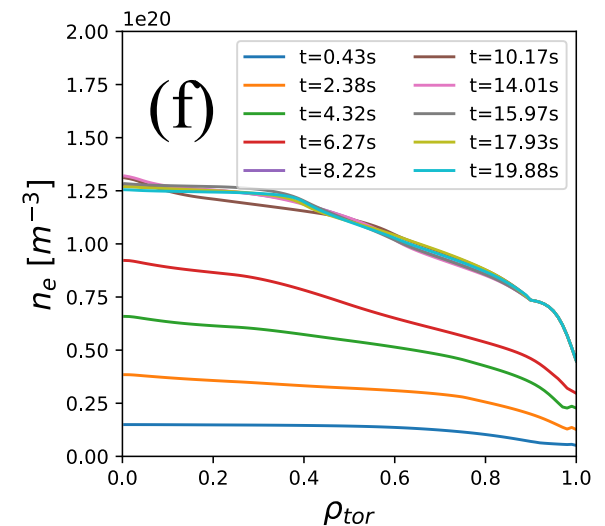
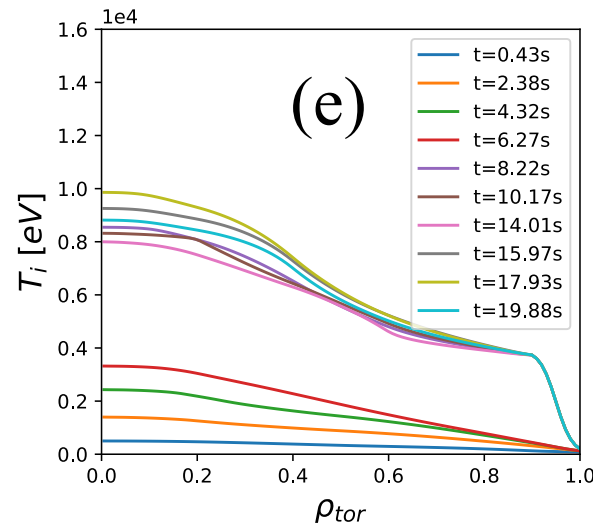
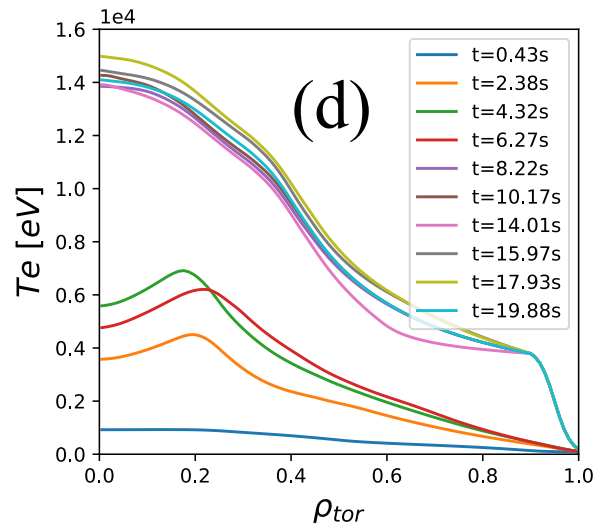
- 1) Preliminary equilibria at selected time slices
- 2) Scan of gyrotron poloidal and toroidal angles using stand-alone GRAY
- 3) Map of beam deposition location and profile width vs. angles
- 4) Selection of gyrotron angles, optimal with respect to the current efficiency and q profile control
- 5) Configure the time-dependent gyrotron angles of GRAY in JINTRAC
- 6) Run JINTRAC-GRAY to obtain the power density and current drive profiles
- 7) Run JINTRAC to evolve the plasma, using the obtained power density and current profiles

Extending the modelling by employing JINTRAC-GRAY



- EC power density and current drive profiles are optimized based on the physics of power balance and current diffusion.
- I put counter-current ECCD near the magnetic axis and co-current ECCD near $\rho_{tor}=0.4$.
- I find that the duration with $q_{min}>1$ for this plasma can be extended from 10s to about 20s.

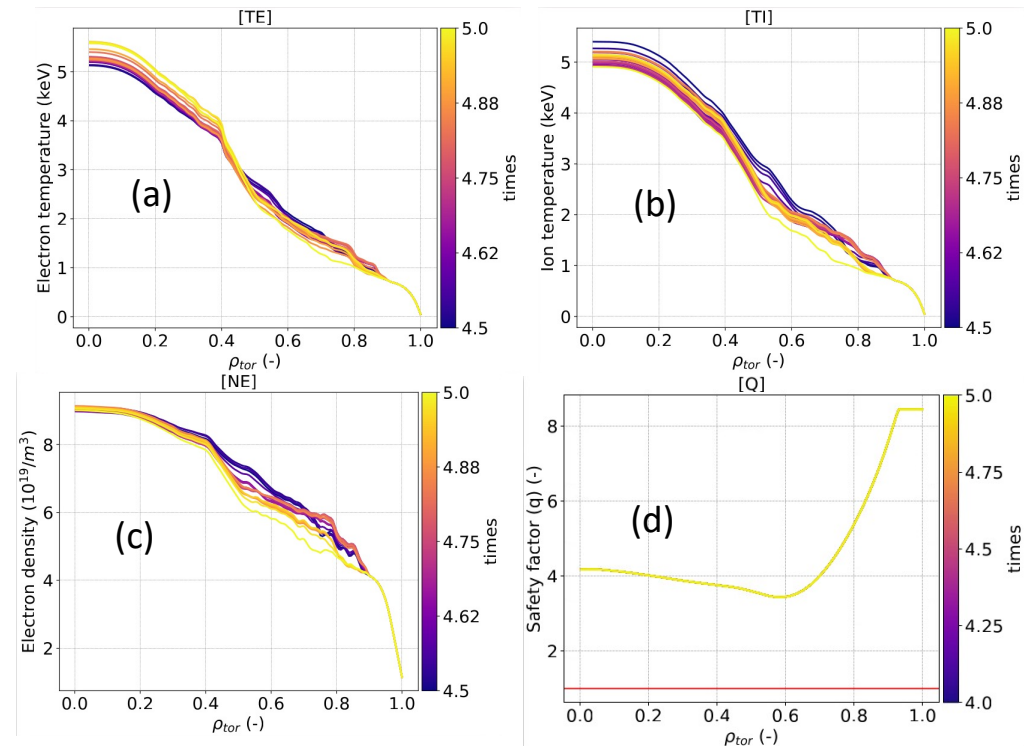
Extending the modelling by employing JINTRAC-GRAY



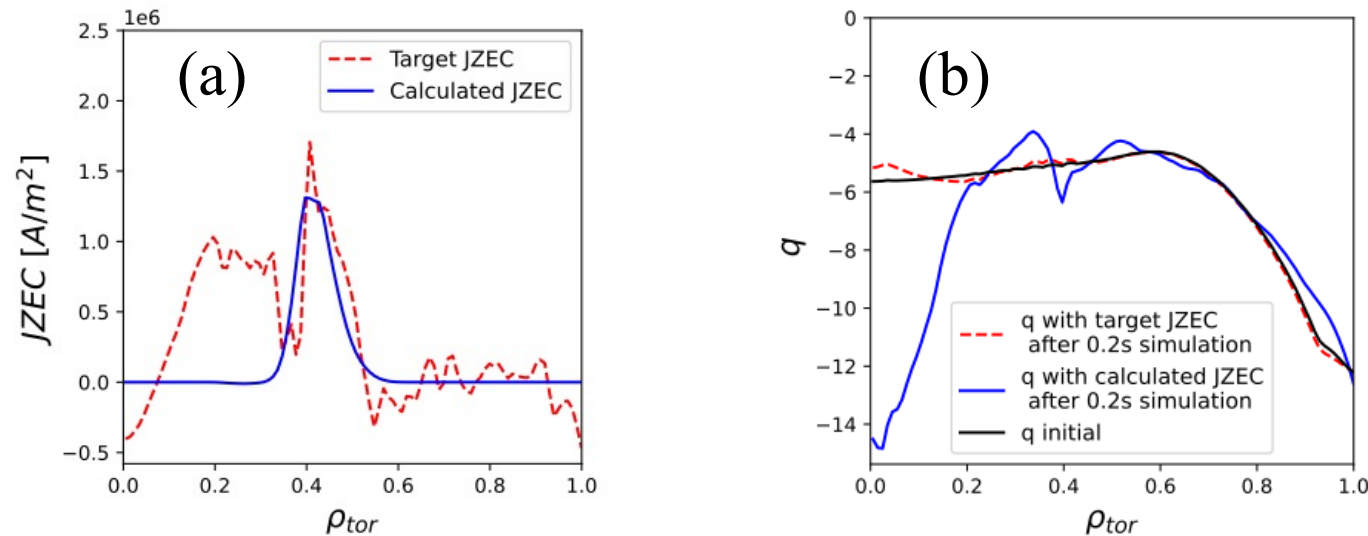
- The evolution of T_e , T_i and n_e

Preparation for the Advanced Scenario

- A preliminary advanced scenario has been developed by F. Auriemma using ASTRA
- The plasma current is 0.95 MA, the toroidal field is 3 T and total auxiliary power is about 20 MW (16 MW ECRH and 4 MW ICRH).
- I run JINTRAC-GRAY simulations to test if such q profile can be realized in DTT and maintained in time



Preparation for the Advanced Scenario



- I obtain a target JZEC profile using the relation $J_{tot} = J_{OH} + J_{BS} + J_{EC}$, assuming $J_{OH}=0$
- After 0.2s of simulation time, the simulated q with the interpretive target JZEC shows little divergence from the initial q , but the simulation with GRAY calculation shows large divergence, especially in $\rho_{tor} < 0.2$.
- Due to the large Shafranov shift of this equilibrium, the ECH does not resonate in $\rho_{tor} < 0.2$.

Conferences and publications

- Hu Q, et al., 2026 , Exploring operational scenarios of DTT through core-edge integrated modelling, proceedings of 52nd EPS Conference on Plasma Physics (European Physical Society)
- Auriemma F, et al., 2026 Time dependent advanced scenario modelling on present and future fusion devices, proceedings of 52nd EPS Conference on Plasma Physics (European Physical Society)
- Fusco V, et al., 2026 MHD stability analysis and studies of Alfvénic modes with energetic particles in DTT, proceedings of 52nd EPS Conference on Plasma Physics (European Physical Society)
- Lombardo J, et al., 2026 Time dependent simulations of DTT Hybrid scenario, paper in preparation
- Giruzzi G, et al., 2026 The Divertor Tokamak Test facility research plan Nucl. Fusion 66 116017
- Vianello N, et al., 2026 Results from the last DD and DT JET campaigns in the framework of the EUROfusion Tokamak Exploitation Work Package activity Nucl. Fusion 66 116010

Future work

- Modelling of DTT Advanced Tokamak Scenario: time-dependent modeling using JINTRAC
- Integrated modelling of JET QCE discharges