JINTRAC scenario modelling JT-60SA research phase I and II

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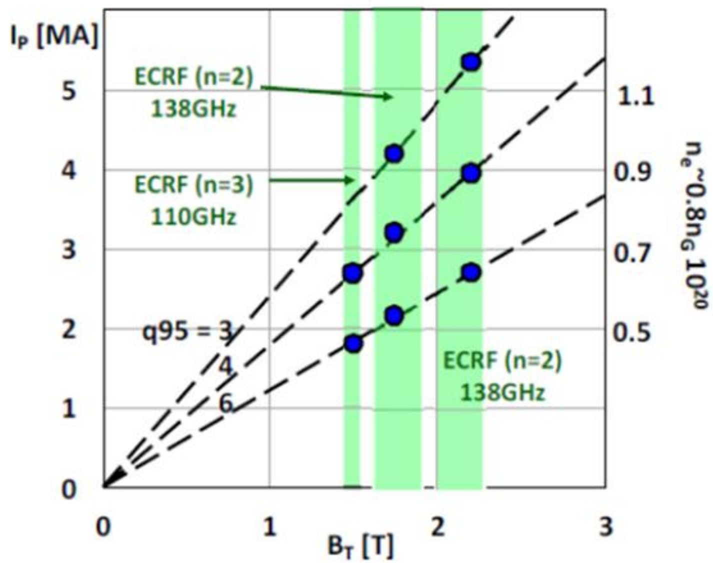
Introduction

- Modelling of scenarios for research phase I and II.
- Based on modelling of scaled down versions of full blown scenarios.
- Concentrate on ramp-up for scenario 2 (David Taylor) and 4.2 (Gerardo Giruzzi, Stefano Gabriellini, Vito Zotta).



Machine status considered

Table 1-5 Research phases and status of the key components

	Phase	Expected operation schedule		Annual Neutron Limit	Remote Handling	Divertor	P-NB Perp.	P-NB Tang.	N-NB	NB Energy Limit	ECRF 110 GHz & 138 GHz	Max Power
Initial Research Phase	phase I	2020–2021 (5M)	H	–		Upper Carbon	0	0	0	0	1.5MWx5s 2Gyrotrons	1.5MW
		2023 (2M)			R&D	Lower Carbon Div. Pumping	3MW 4units	3MW 4units		20MW x 100s	1.5MWx100s 2Gyrotrons + 1.5MWx5s 2Gyrotrons	19MW
	phase II	2023 (6M)	D	3.2E19			6.5MW 4units					26.5MW
		2024–2025 (8M)										33MW
Integrated Research Phase	phase I	2026– 2028	D	4E20		Lower monoblock-Carbon Div.Pumping	13MW 8units	7MW 4units	10MW 2units	30MW x 60s duty = 1/30	7MW x 100s 9Gyrotrons	37MW
	phase II	2030 –	D	1E21	Use	Lower monoblock-Tungsten-coated Carbon Div.Pumping						
Extended Research Phase		>5y	D	1.5E21		SN/DN monoblock-Tungsten-Coated Carbon Advanced Structure	16MW 8units	8MW 4units		34MW x 100s		41MW

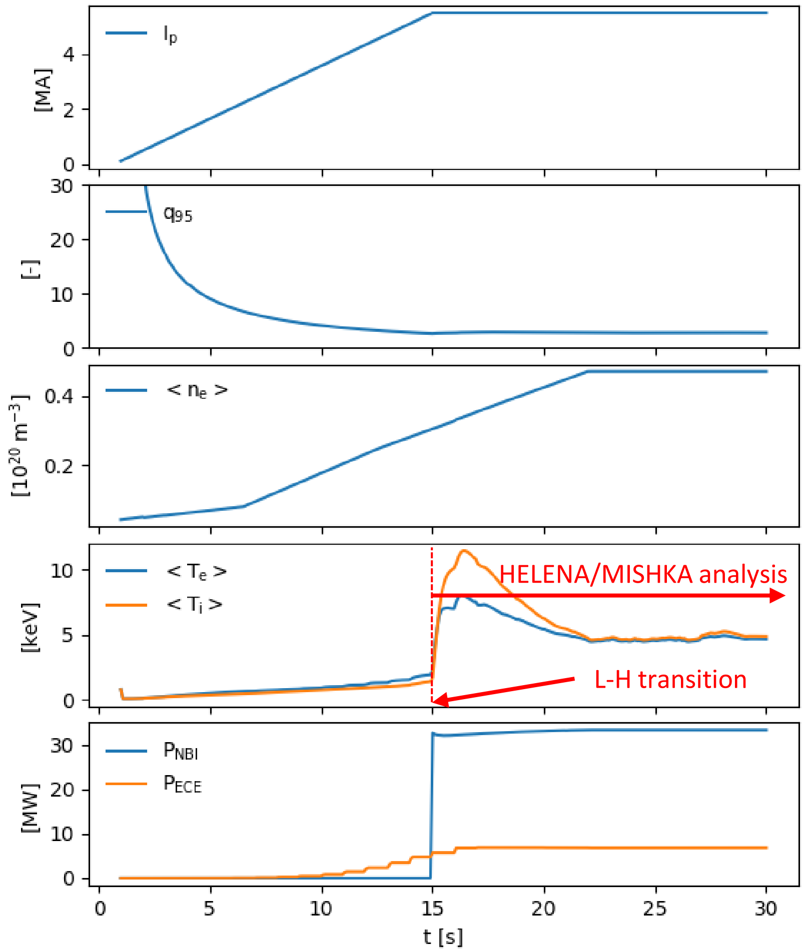
Upper Divertor (open divertor, inertia cooling) is always ready

Simulation plan

- Scenario 2 (baseline) ramp-up half current (2.1 MA / 1.8 T).
- Scenario 4.2 (hybrid) reproduce ramp-up of full blown scenario (Morales and Giruzzi with METIS).
- NBI predicted with PENCIL.
- ECRH predicted with GRAY (implemented during last year).
- L-H transition from Martin scaling.
- Fully predictive simulations (deuterium density, ion and electron temperature and impurities). All the way to a few seconds into H-mode flat top.

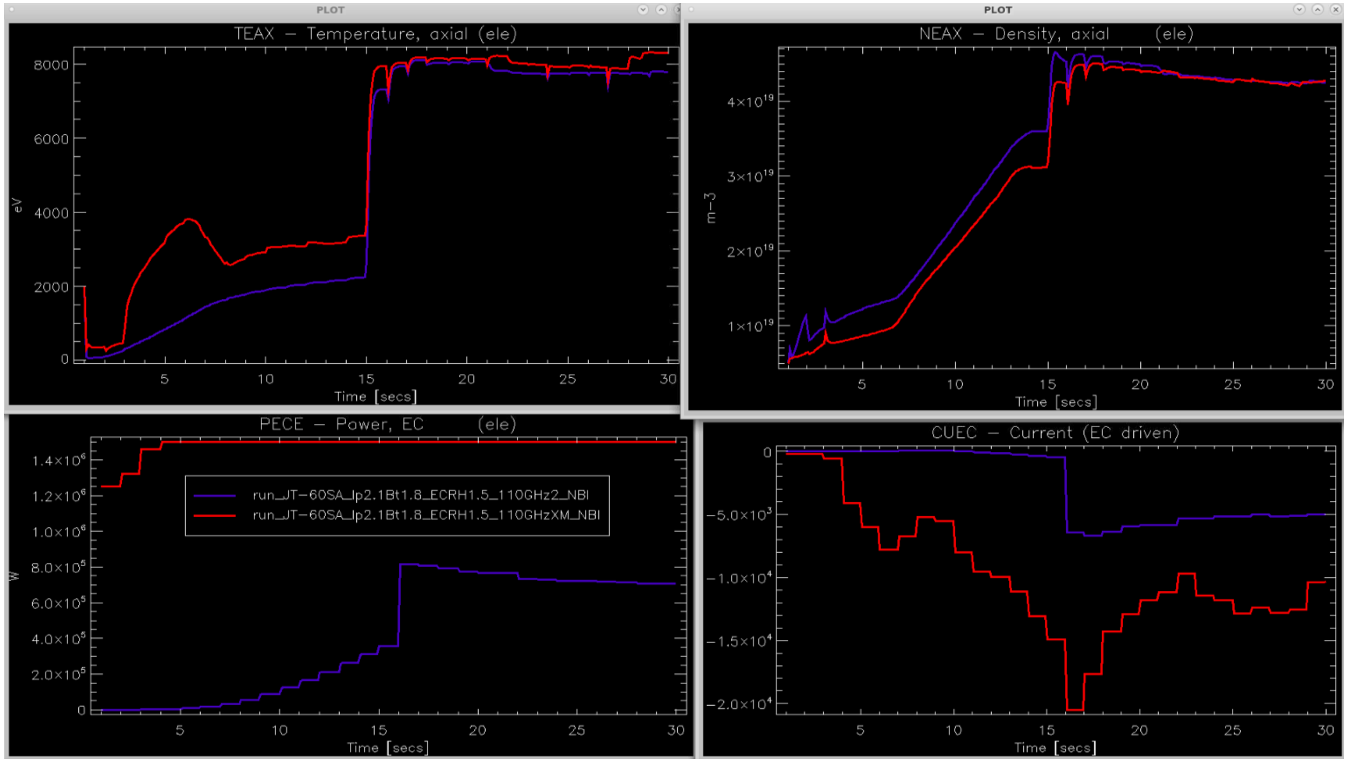
JINTRAC modelling of current ramp-up (scenario 2)

- Simulation based on *V. Ostuni et al 2021 Nucl. Fusion **61** 026021.*
- Fully predictive (current density and ion and electron temperature predictive, density feedback controlled).
- Equilibrium (ESCO), power deposition ECE (GRAY) and NBI (PENCIL) and L-H transition (Martin scaling) calculated self-consistently.
- Temperature pedestal height after L-H transition set by self consistent HELENA/MISHKA stability analysis.



Low field scenario

XM
OM

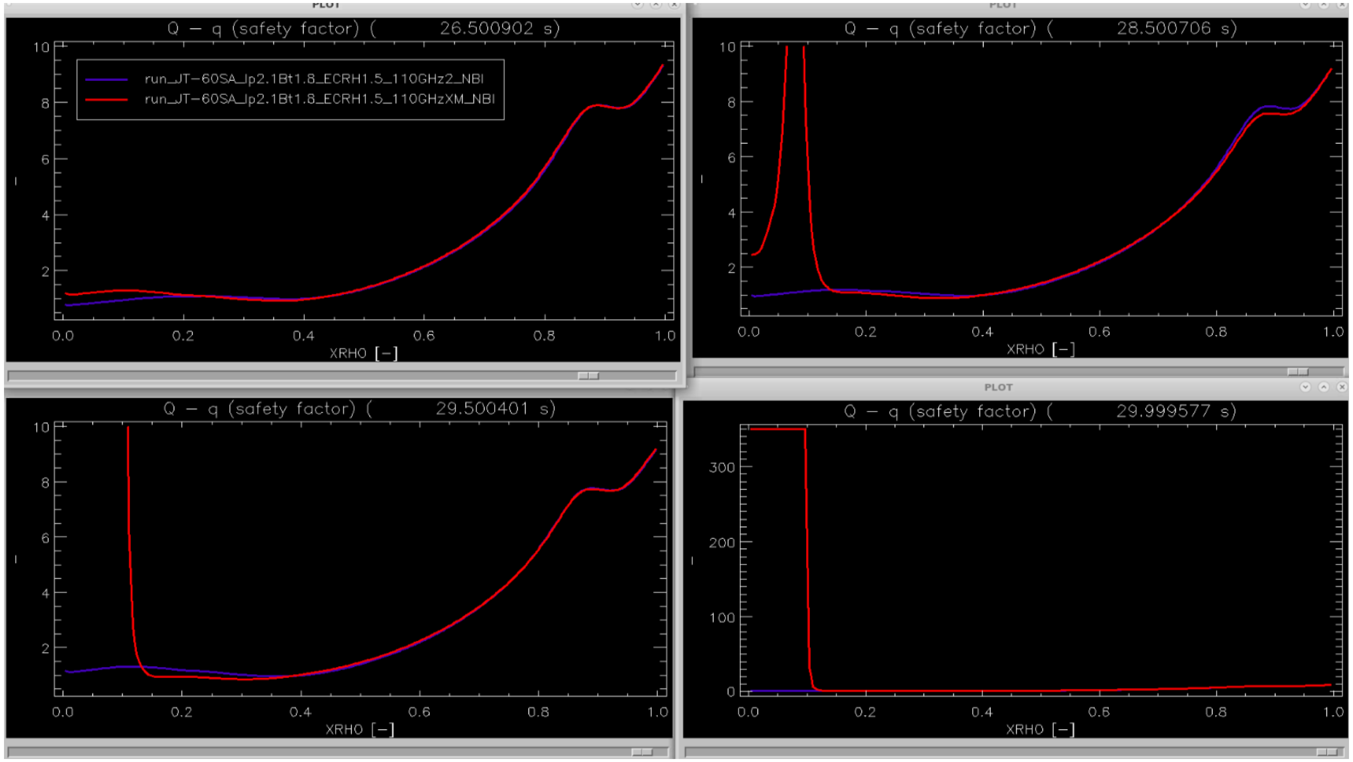


D. Taylor

- B_T 1.8T, I_p 2.1 MA: 110 GHz.
- Several exploratory runs attempted, various target densities and density ramps, various current ramp up speed. (Starting from full blown scenario).
- Tried O-mode (used in full blown case, poor absorption at ρ~0.2-0.3) and X-mode (nearly full absorption, more on axis).
- 1.5 MW coupled ECRH.

Low field scenario

XM
OM



- Problem with q profile reversal, but fixable numerically (to be done).

Future studies

- Agreed with C. Sozzi and ECRH team.
- For EC Stray studies during ramp-up:
  - Case a1) WG launcher, 2 gyrotrons, total 1.5 MW, 110 GHz , X2 polarization.
  - Case a2) WG launcher, 2 gyrotrons, total 1.5 MW, 110 GHz , X2 polarization, BT optimized for EC absorption.
  - Case b) Steerable launchers, 4 gyrotrons, total 3 MW, 110 GHz, X2 polarization.
  - Case c) Steerable launchers 2 gyrotrons total 1.5 MW, 110 GHz + 2 gyrotrons total 1.5 MW 138 GHz, X2 polarization.

- Toroidal perpendicular injection (no current drive).

- Steering settings (heating profile). ECRF aiming for:
  - core heating.
  - slightly off axis (q=1).

Scenario 4.2 ramp-up: Models and first simulations

- Scenario #4-2 (Advanced inductive): 3.5MA / 2.28T, $\beta_N = 3.0$, $q_{95} \approx 4.4$, $P_{add} = 37\ MW\ (P_{NNBI} = 10\ MW,\ P_{PNBI} = 20\ MW,\ P_{ECRH} = 7\ MW)$

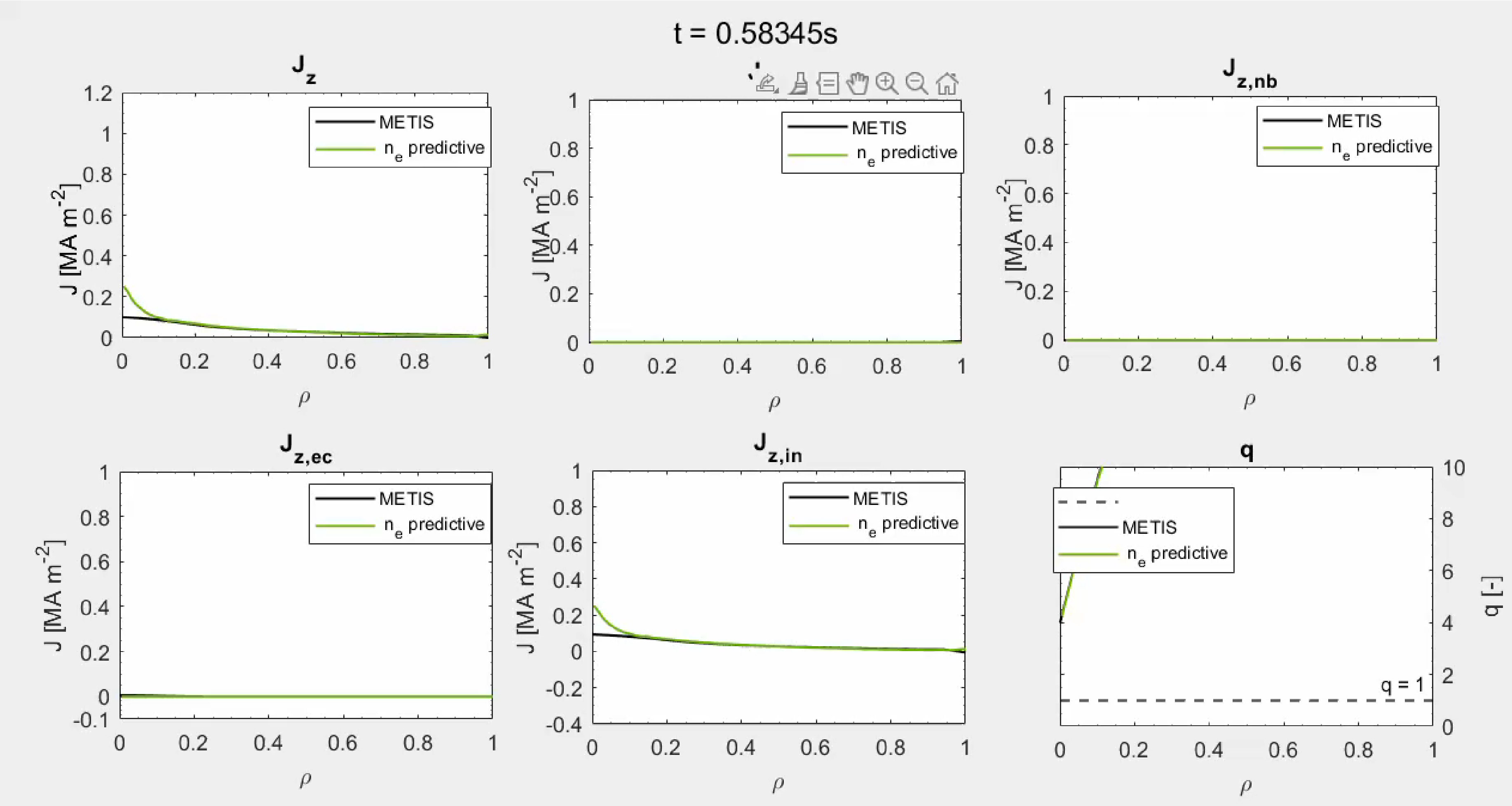
- The integrated modelling is being carried out within the **JINTRAC** suite of codes, using **JETTO** as fluid transport code, **BgB** as transport model, **ESCO** as equilibrium solver, **Pencil** for NBI heating deposition profiles and currents and **Gray** as beam-tracing code for ECRH and current drive.

- At first, we performed interpretative simulations, predicting the current density, then we used Pencil and Gray to compute respectively the NBI and ECRH heating deposition and current drive.

- Now we started predicting the density and modelling the L-H transition.

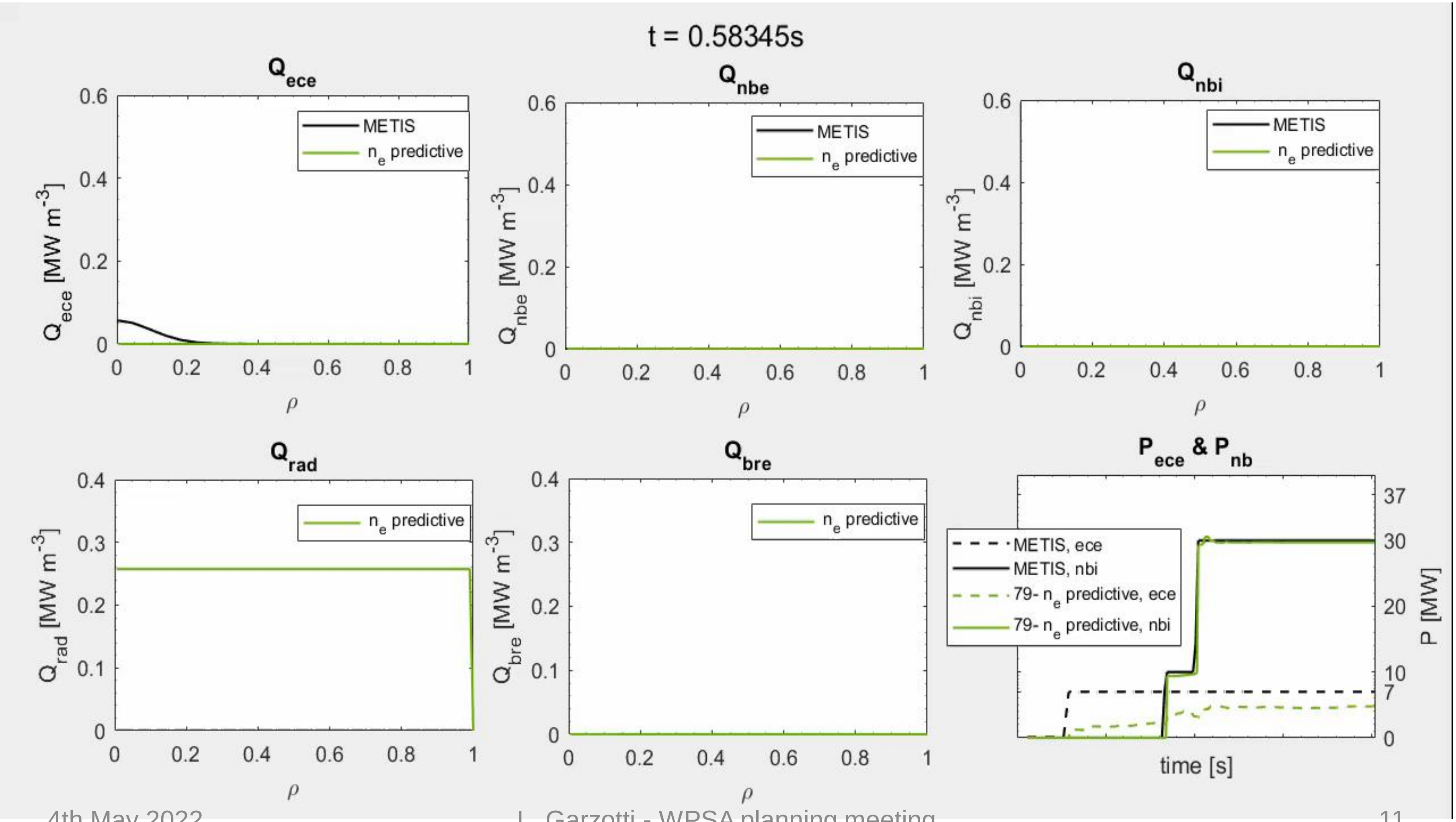
Evolution of current densities and q profile

In the simulation in green we are predicting the current density and electron density, while imposing the electron and ion temperatures. The $J_{z,nb}$ and $J_{z,ec}$ are computed respectively by Pencil and Gray.



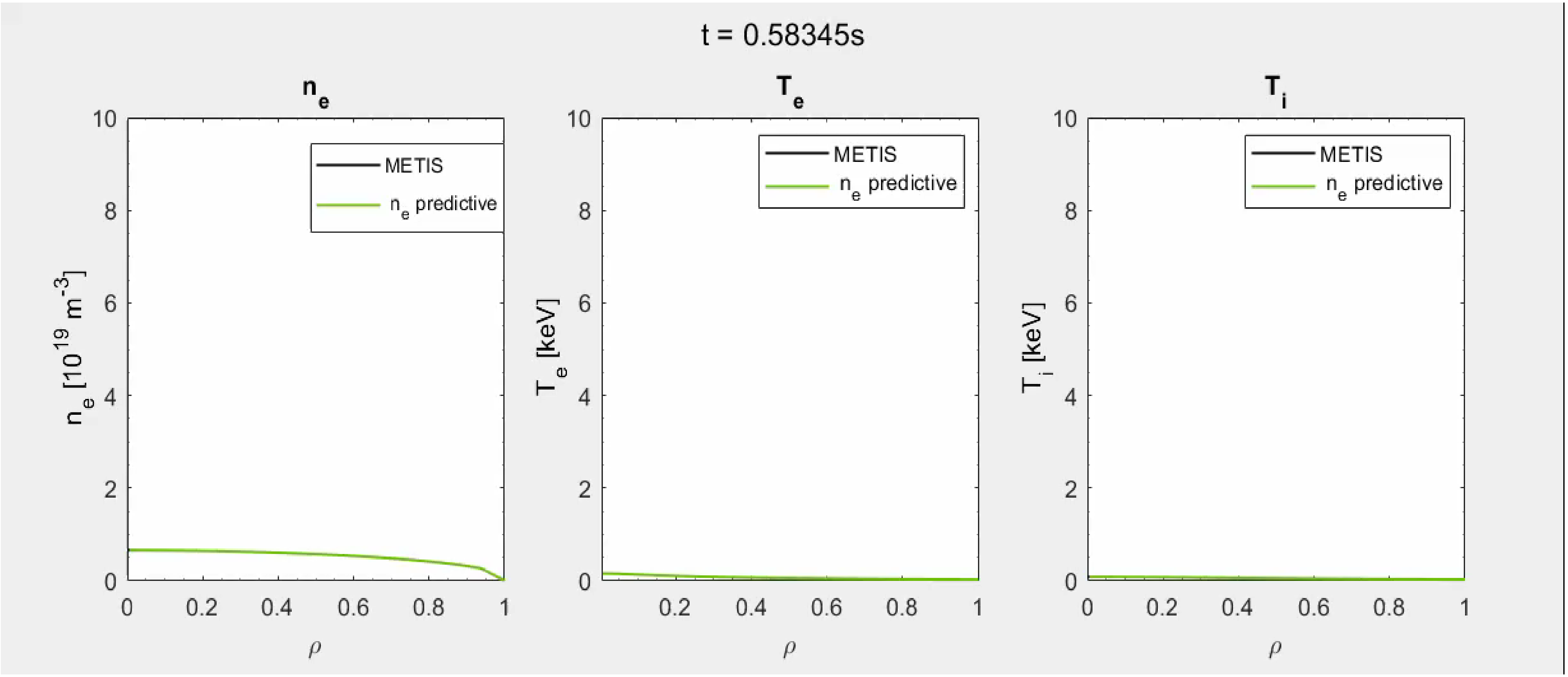
Evolution of the power density profiles

In the simulation in green we are predicting the current density and electron density, while imposing the electron and ion temperatures. The Q_{nb} and Q_{ece} are computed respectively by Pencil and Gray.



Evolution of the kinetic profiles

In the simulation in green we are predicting the current density and electron density, while imposing the electron and ion temperatures.



Conclusion and future plans

- Self consistent calculation of NBI and ECRH implemented.
- Modelling of the target scenario including the current start-up well advanced.
- Complete modelling of scenario 2 ramp-up.
- Complete nominal ramp up for scenario 4.2 and scale it down to lower current.
- Improve modelling of the flat-top where and is necessary (requests to be raised by other areas e. g. diagnostic and/or fast particle teams).