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Plasma Prediction and Simulation in Support of Reactor Design and Operation at Tokamak Energy

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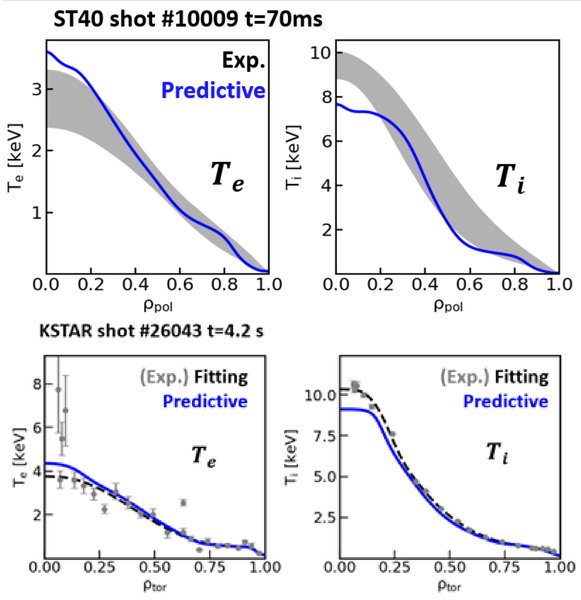
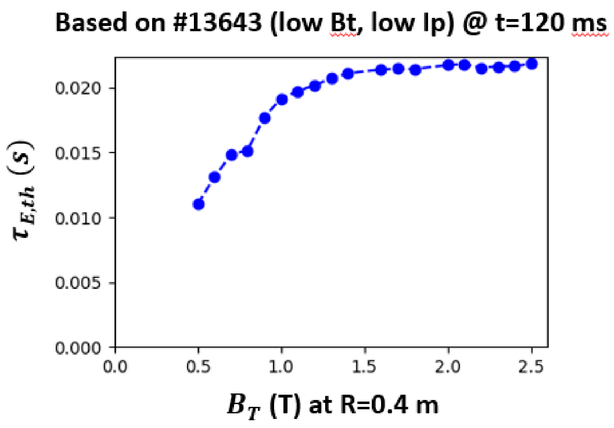
ABSTRACT

- Plasma prediction and simulation activities at tokamak energy are centred around providing capabilities for the operation, modelling and design of both existing spherical tokamaks (ST) and projected fusion pilot plants.
- This requires the development of validated plasma models based on tokamak data as well as targeted high-fidelity first-principles simulations
- Plasma models are deployed in simulation frameworks such as SOPHIA for the support of plasma operation or in the staged approach of the design of a fusion pilot plant.

ADVANCE PLASMA MODELS FOR STs

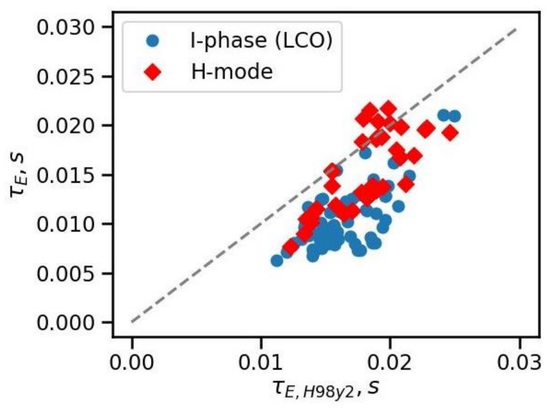
Experimental data available to model the plasma system in a ST fusion pilot plant are limited to small, low field, low current STs. How do we project in the absence of data? We use experiments on ST40 [2] and simulations.



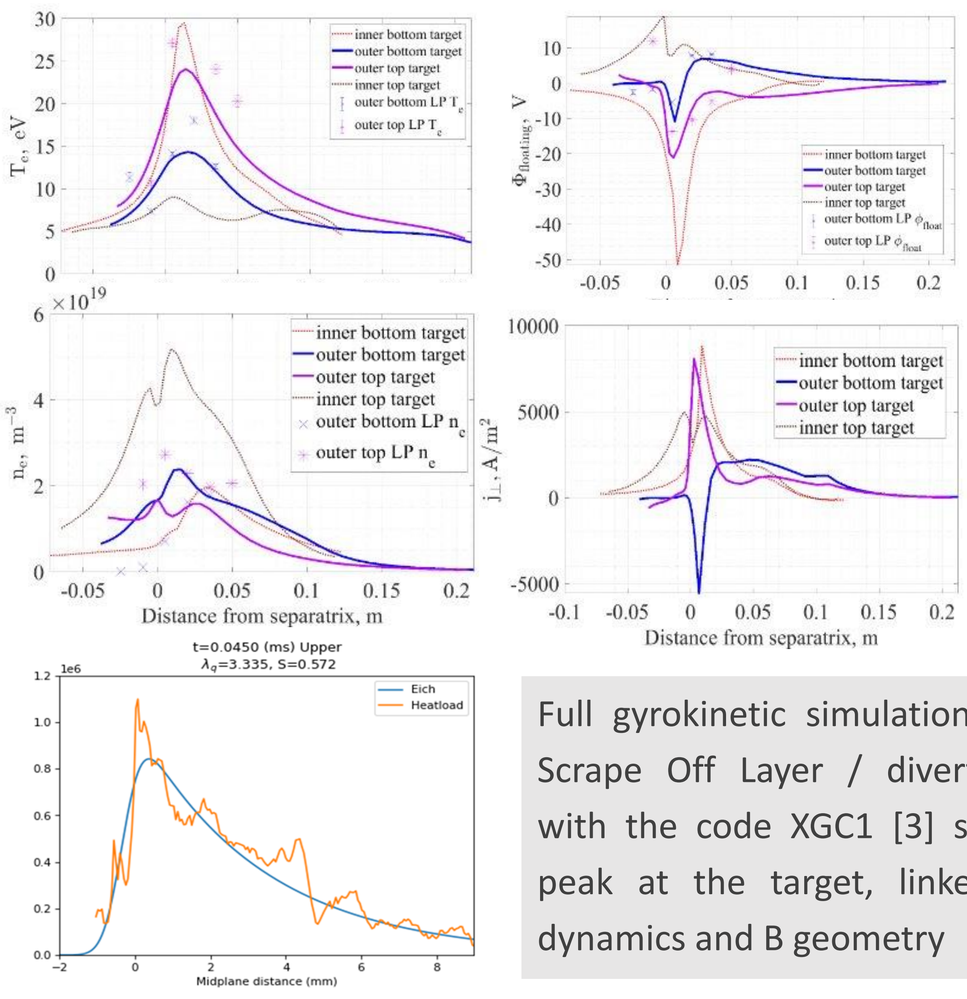


Confinement vs B in ST40 simulated with TRIASSIC [2]

Saturation of confinement at B>1T for a given plasma current is found. This result is confirmed by ST40 experiments [1]



H-mode plasmas in ST40 [1] are characterized by a wide pedestal, pressure gradient below the stability limit and are generally ELM free. These observations are consistent with NSTX results.

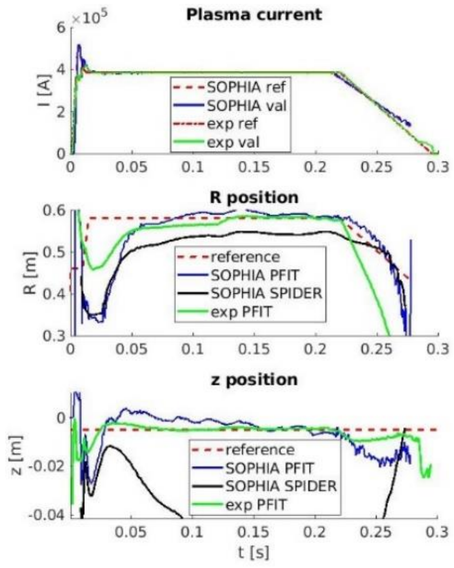


Narrow SOL is observed in ST40 H-mode plasmas. Scaling of the SOL width to reactor scale requires modelling its physics.

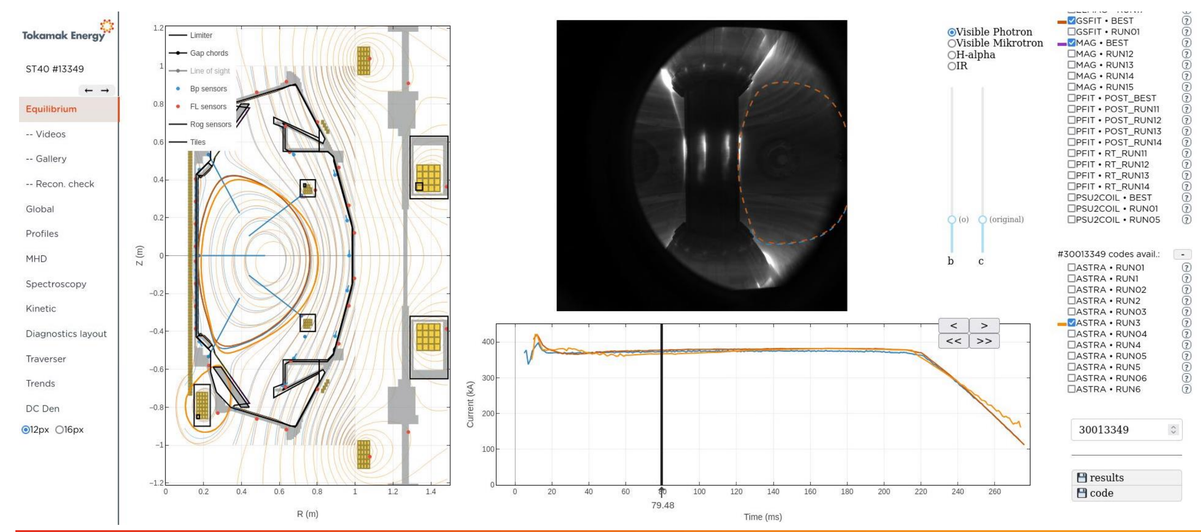
Full gyrokinetic simulations of the ST40 Scrape Off Layer / divertor performed with the code XGC1 [3] show a narrow peak at the target, linked to electron dynamics and B geometry

PLASMA FLIGHT SIMULATOR IN SUPPORT OF OPERATION

The main framework for simulating plasma operation at Tokamak Energy is SOPHIA [4], a versatile tokamak plasma simulator. It integrates models for the plasma, diagnostics, actuators and the plasma control system, providing a 'control room'-grade experience to the operator.

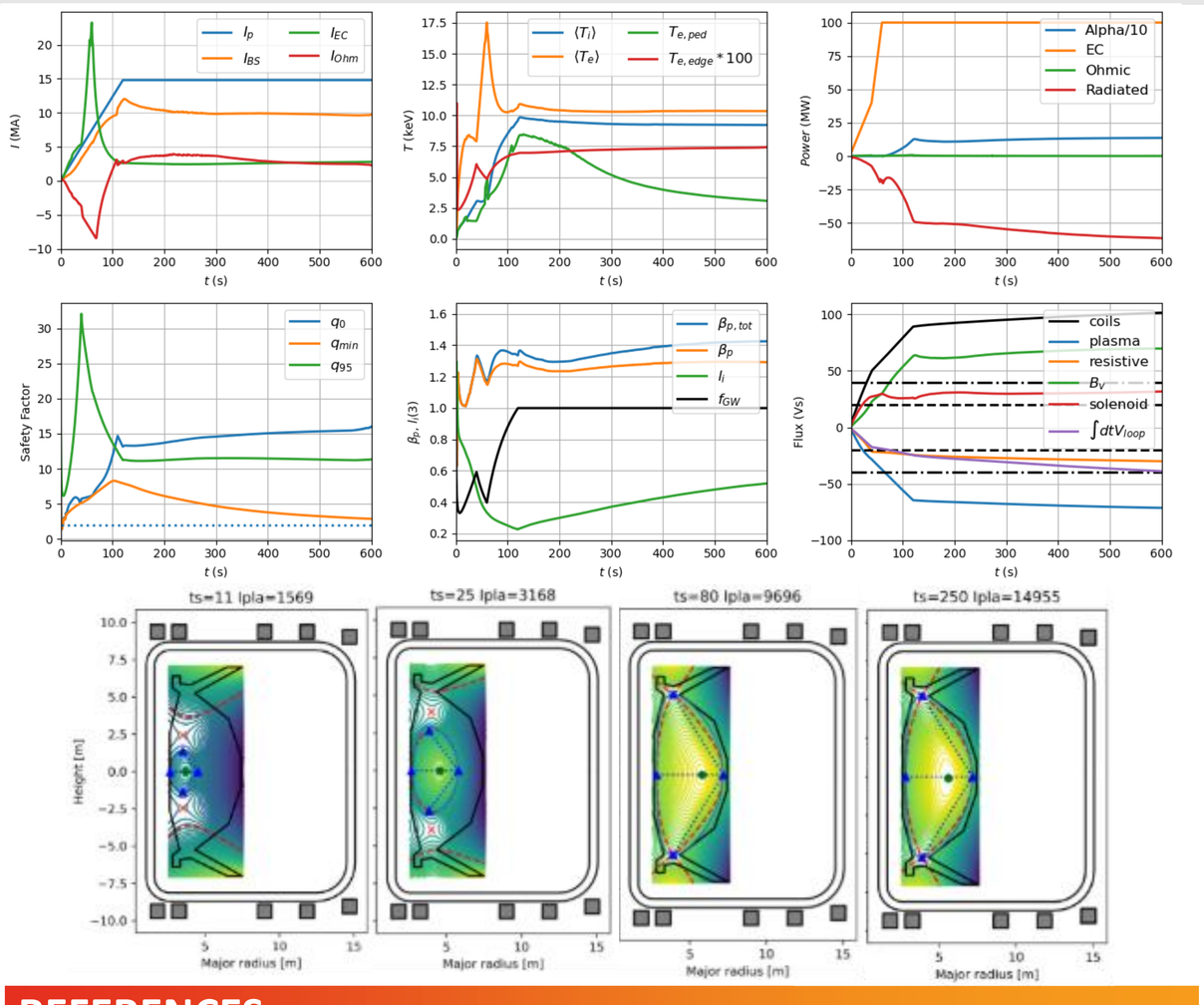


By design, SOPHIA is a machine-independent tool that can be deployed on any MCF device. Using the MATLAB/Simulink environment, in the present implementation SOPHIA integrates the transport code ASTRA, which is tightly coupled to the equilibrium code SPIDER, as well as models for diagnostics, actuators and the control system.



INTEGRATED PLASMA SIMULATOR FOR REACTOR DESIGN

Tools used / developed at Tokamak Energy for the staged approach to the design of a reactor-grade plasma [8] are PyTok, ST-FUSE [5], METIS-FREEGS [6,7] along with SOLPS-ITER and FORGE for SOL and divertor modelling and optimization.



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