Integrated modelling of burning plasmas

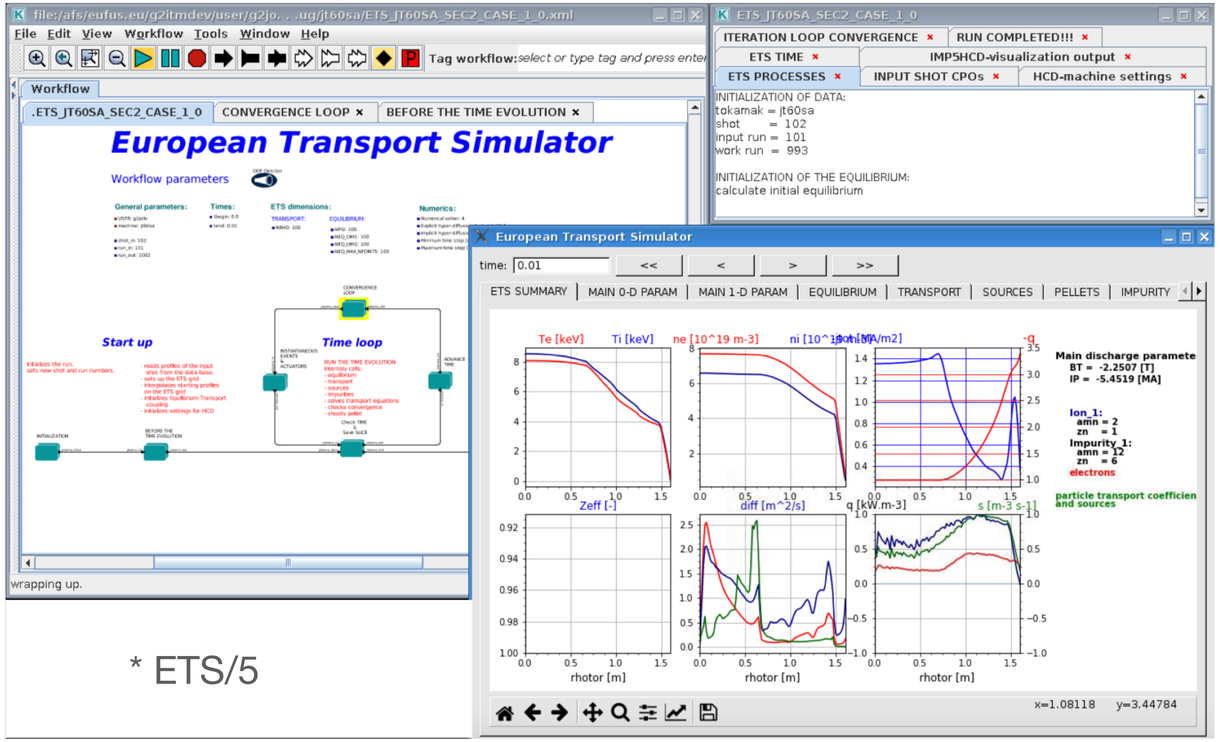
Coupling AE-EP actuators to the European Transport Simulator (ETS)

Jorge Ferreira and the WPCD team

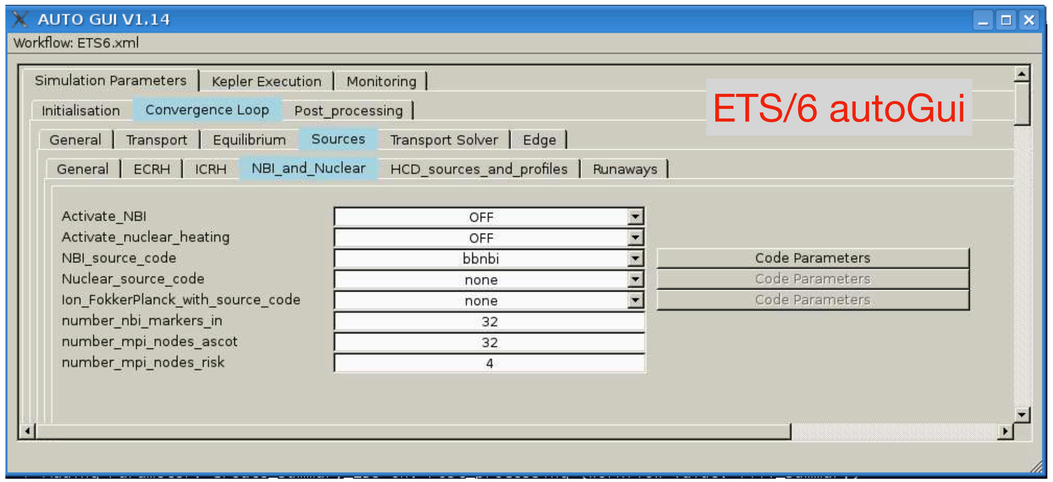
TSVV#10 kick-off meeting, 28 April 2021

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

European Transport Simulator



* ETS/5



Highlights

1) **Standard procedures to get INPUT DATA**
routinely available tools to prepare experimental data of JET / TCV / AUG / MAST / ITER in either IMAS or CPO standard format

2) **Easy framework for Verification and Validation**
integrated workflows have been verified & validated (in progress) tracking data provenance in IMAS data format. Using a standard data abstraction to interface codes and tools is crucial for portability and interoperability.

3) **Easy integration of new codes / models**
this capability is provided by IMAS

4) **High-fidelity modelling (selective levels of)**
ETS is reaching a level similar to state-of-the-art transport codes such as TRANSP (and surpassing in some areas)

5) Visualization and data processing
tools are available for easy visualization of input, simulated and machine data, and data exporting to other formats.

European Transport Simulator - EUROfusion GATEWAY and documentation

EUROfusion Gateway and ex-WPCD

1) **Wiki / Portal**

   https://wiki.eufus.eu/doku.php

2) **General support for codes and software (for hardware issues use link above)**

   https://gforge-next.eufus.eu/

3) **General WPCD documentation**

   https://wpcd-workflows.github.io

ETS 6 (on IMAS)

1) **Documentation**

   https://iterphysicswiki.euro-fusion.org/index.php?title=ETS-6_Documentation

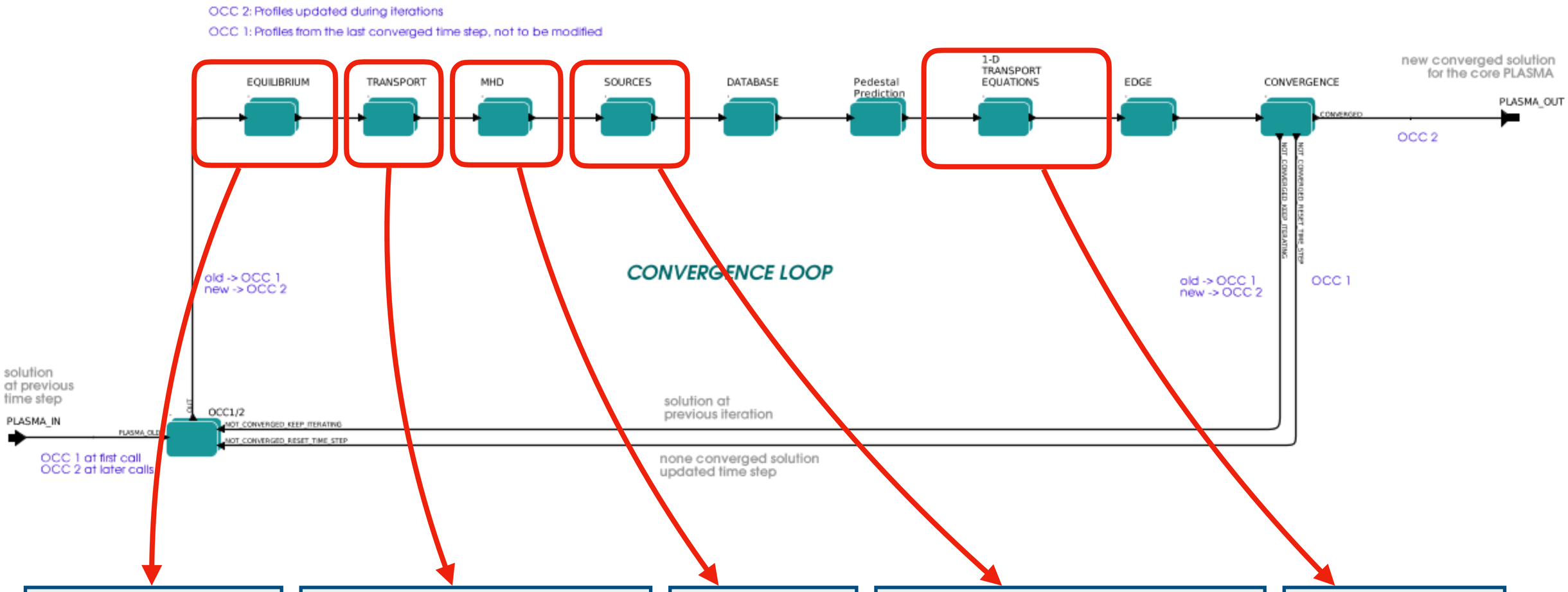
2) **Last training and modelling session - 23 Nov to 4 Dec 2020**

   https://iterphysicswiki.euro-fusion.org/index.php?title=ETS_training_and_modelling_session_23_November_-_4_December_2020

3) **ETS developer guide**

   https://iterphysicswiki.euro-fusion.org/index.php?title=ETS-6_Developers_guide

European Transport Simulator - Kepler workflow



Grad - Shafranov Solver
eg. CHEASE, HELENA, GKMHD, SPIDER

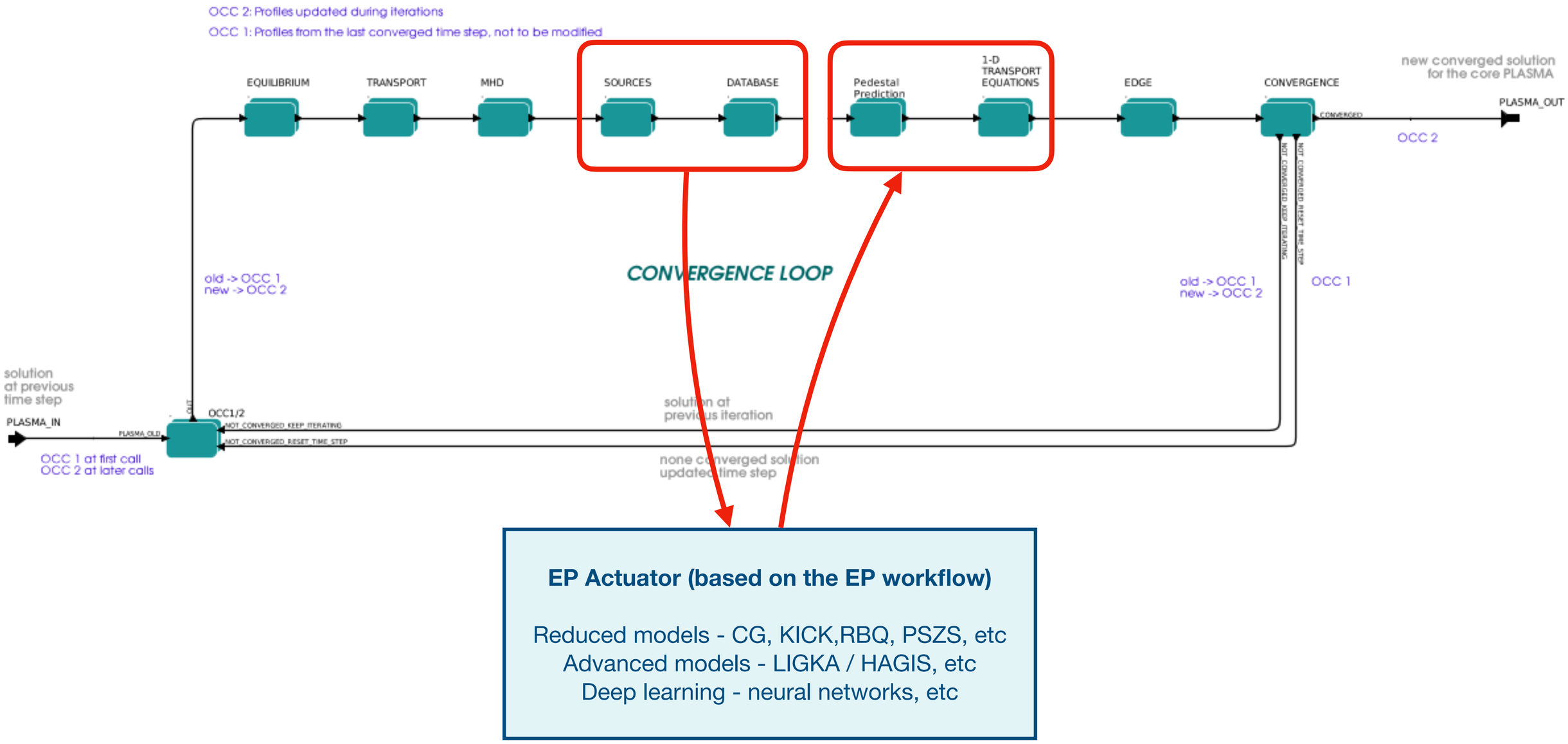
Core/pedestal transport models
eg. BGB, EDWM, MMM, TGLF, NCLASS, etc

MHD actuators
eg. NTMs

HCD and impurity related sources
eg. NBI: BBNBI/ASCOTor NEMO/SPOT
ICRH: CYRANO/LION, FOPLA/TORIC,
ECRH: GRAY / TORBEAM, etc

1D transport solver
supporting many implementations and numerical solvers

European Transport Simulator - coupling of the EP actuator to ETS



EP Actuator (based on the EP workflow)

Reduced models - CG, KICK,RBQ, PSZS, etc
Advanced models - LIGKA / HAGIS, etc
Deep learning - neural networks, etc

European Transport Simulator - coupling of the EP actuator to ETS

Plasma state IN

Plasma equilibrium

DM/MHD/**equilibrium**

1D surface averaged profiles

DM/CORE/**core_profiles**
DM/CORE/**core_sources**
DM/CORE/**core_transport**

Distributions
(markers and >1D)

DM/HCD/**distribution_sources**
DM/HCD/**distributions**

MHD

DM/MHD/**mhd_linear**

EP Actuator
(based on the EP workflow)

MHD tracking codes
LIGKA

Reduced models
CG, KICK,RBQ, PSZS, etc

Advanced models
LIGKA / HAGIS, etc

Deep learning / AI
neural networks, etc

Plasma state OUT

1D surface averaged profiles
(including non-thermal species)

DM/CORE/**core_profiles**
DM/CORE/**core_sources**
DM/CORE/**core_transport**

Distributions
(markers and >1D)

DM/HCD/**distribution_sources**
DM/HCD/**distributions**
> new IDS is needed to store phase-space diffusion and related data from EP actuator

MHD

DM/MHD/**mhd_linear**
(This IDS will be probably extended)

IMAS IDSs containers in black

Coupling EP actuator to ETS - technical actions and issues

1) **Porting the EP workflow to the GATEWAY (May/June)**

   should be straightforward since the EUROfusion Gateway fully supports IMAS (and CPO)

2) **Coupling EP workflow to ETS (July to September)**

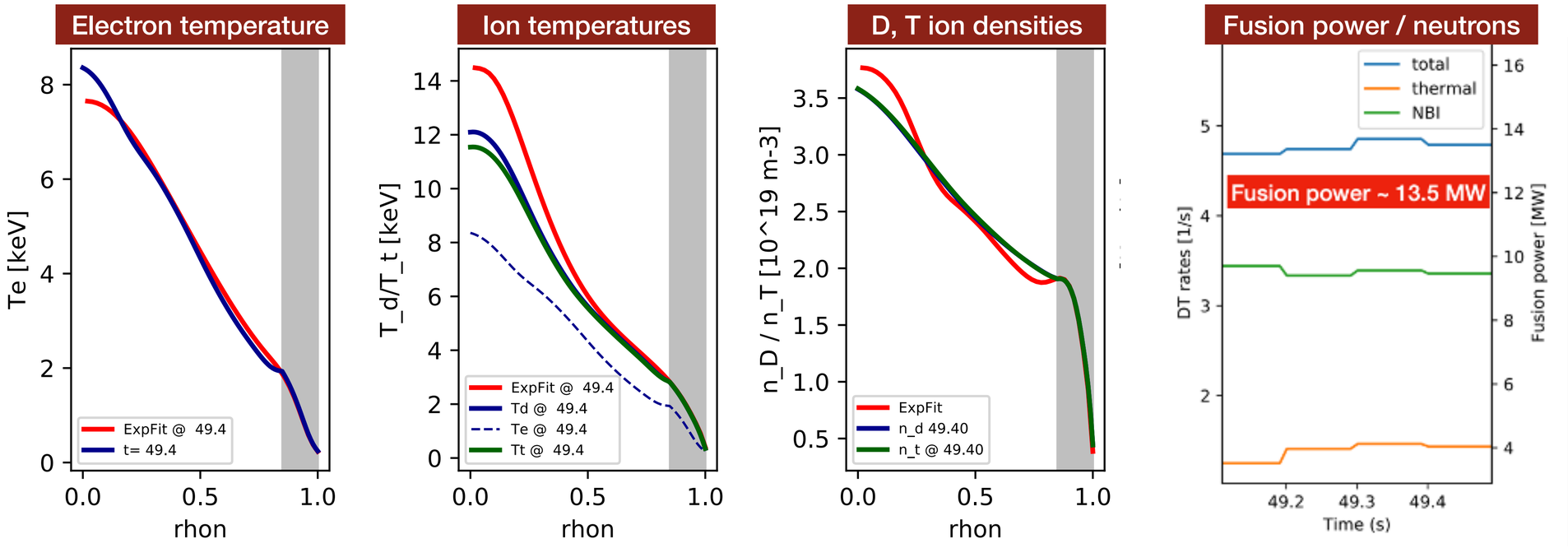
   ETS 5/6 is built on KEPLER (MATLAB/simulink like) whereas the EP workflow is based on python. ETS already includes python based actors - eg. pellet actor, PENN pedestal model, but the interface is not exactly similar. No major issue are foreseen, but it can take some time, especially if we decide to add Kepler interface to the EP workflow.

3) **Agree on a few use cases and test a simple reduced model (September / December)**

   use cases can be based on ongoing ETS modelling for JET and ASDEX - JET “after-glow” experiments, strong EP-driven pulses from AUG and JET-DT modelling and experiments (DT this year?)

Typical use case - JET DT scenario, simulated or real data (this year)

Typical DT modelling of a JET hybrid scenario with ETS/5



Anomalous core transport is modelled with state-of-the-art quasi-linear codes such as QuaLiKiz or TGLF, and HCD sources are fully consistent with full distributions from NBI taken into account.

The natural next step is to include the effects of driven Alfvén Eigenmodes on energetic particle (EP) transport

Fitted experimental thermal measurements for the DD hybrid reference are shown in red

Integrated modelling of burning plasmas

Thank you!