EFDA

EUROPEAN FUSION DEVELOPMENT AGREEMENT

Task Force
INTEGRATED TOKAMAK MODELLING

EPS 2013 Poster Presentation

Modelling of JET hybrid scenarios with the European Transport Solver

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Introduction

- The ETS is a core transport code developed within the ITM
- 1 ½ D workflows based on the ETS are available that can simulate a tokamak experiment
- The ETS workflow used in these simulations has recently been benchmarked against other codes (D. Kalupin NF paper in discussion)
- Here, the goal is to validate ETS modules, particularly H-mode Bohm/gyro-Bohm (BgB) and NCLASS in different plasma conditions
- Simulations are for densities, temperatures, current diffusion and carbon content in JET hybrid scenarios

Experimental Scenarios

- Integrated modelling done for two different JET hybrid pulses in their stationary phases

- Both plasmas have a similar high-triangularity up-down symmetric shape, β_N = 2.7 and $H_{IPB98(y,2)} \approx 1.2$

Pulse #77922

Toroidal fied: 2.3 T
Plasma current: 1.7 MA
Upper / lower triangularity: 0.37 / 0.37
Elongation: 1.65
NBI power: 18 MW
Electron density: 6×10^{19} m^{-3}
Electron temperature: 5 keV

Simulation time: 47.8 s – 48.8 s

Pulse #79635

Toroidal field: 1.2 T
Plasma current: 0.8 MA
Upper / lower triangularity: 0.36 / 0.36
Elongation: 1.7
NBI power: 6 MW
Electron density: 3×10^{19} m^{-3}
Electron temperature: 3 keV

Simulation time: 45.5 s – 46.0 s

- Central densities and temperatures for pulse #79635 are approximately half in comparison with pulse #77922

Edge Pedestal Modelling

- Pedestal is modelled assuming constant transport coefficients inside an ETB
- Transport coefficients are much higher than inter-ELM values in previous TRANSP-EDGE2D simulations
- Higher values compensate for ELM-driven transport not being considered here
- With these values the calculated profiles match the experimental ones at the top of the pedestal

ETB for pulse #77922

$\rho > 0.87$: $D_i = 0.02\ m^2s^{-1}$

$\chi_i = 1.0\ m^2s^{-1}$ & $\chi_e = 1.7\ m^2s^{-1}$

ETB for pulse #79635

$\rho > 0.86$: $D_i = 0.02\ m^2s^{-1}$

$\chi_i = 3.5\ m^2s^{-1}$ & $\chi_e = 5.0\ m^2s^{-1}$

- Zero carbon transport is considered inside the ETB

Other Modelling Assumptions

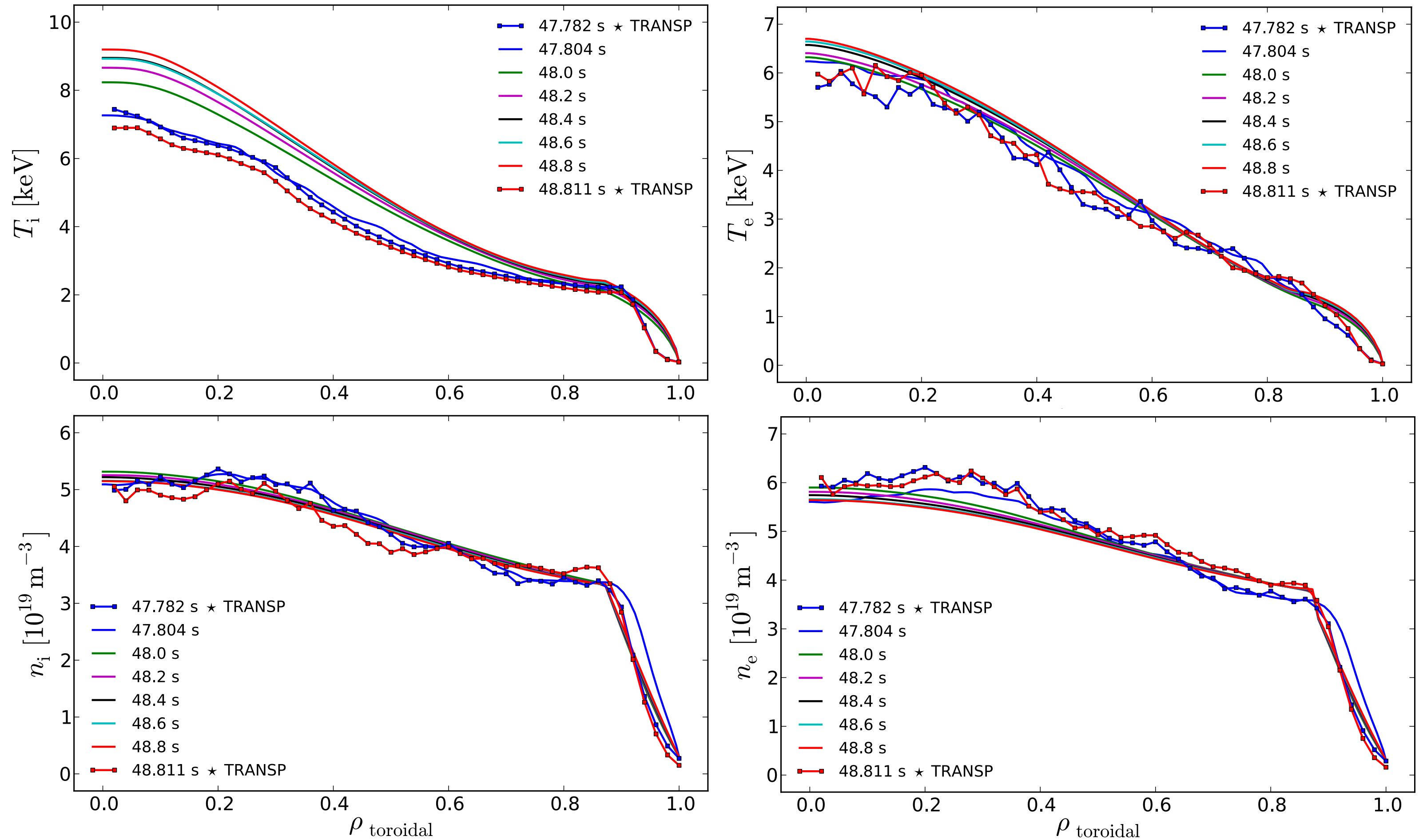
- Equilibrium calculated by SPIDER and CHEASE
- Anomalous transport given by H-mode BgB model from JETTO

  Model has been validated on JET hybrid plasmas (L. Garzotti EPS 2012)
- Neoclassical transport provided by NCLASS (no impurity transport) and NEOS
- NBI heat & particle sources calculated by TRANSP and stored in ITM database
- Experimental density and temperature profiles also processed by TRANSP

  No ion temperature or effective charge measurements for $\rho > 0.85$
- Carbon density evolved from an initial C+6 profile using the same anomalous transport coefficients as the main ions (BgB diffusion)

  This is a simple model with some limitations: no impurity sources or pinch

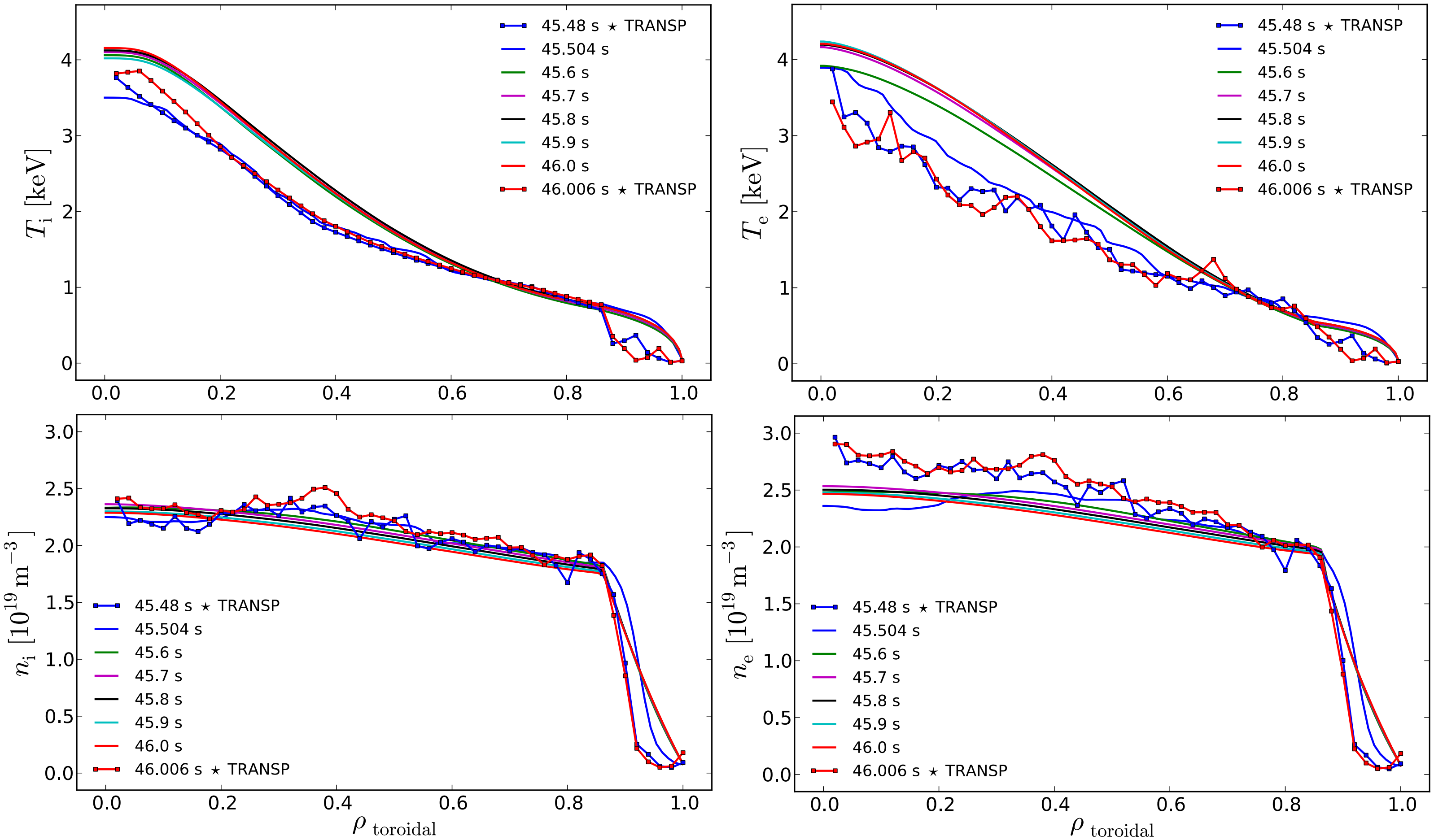
Modelling Results For Pulse #77922



- ★ The predicted ion temperature is overestimated at the plasma core
- ★ Electron temperature is quite well predicted, despite small discrepancy in the very core
- ★ The match between simulated and experimental densities is reasonable, particularly for ions, but
- ★ Densities don't show some details of the experimental profiles

  Gradient variations around ρ = 0.3 might have an effect on thermal transport

Modelling Results For Pulse #79635



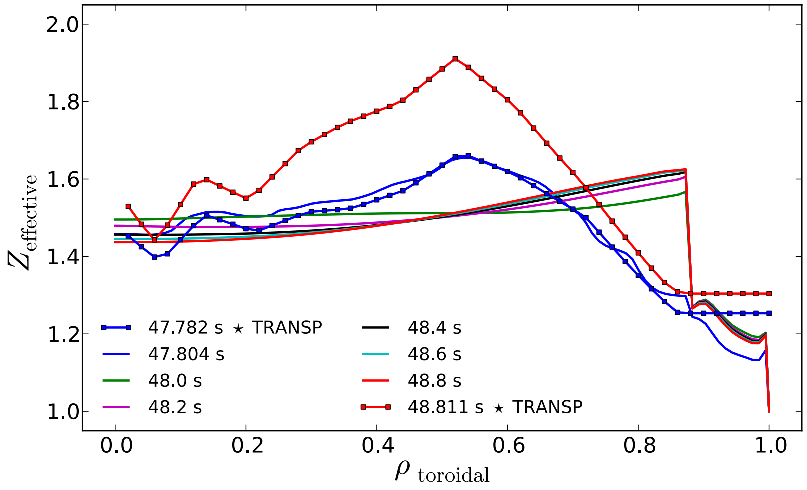
- ★ Results are not too different from pulse #77922
- ★ Better agreement between simulated and experimental ion temperatures than for pulse #77922
- ★ There is a large discrepancy in the electron temperature profiles

Discussion

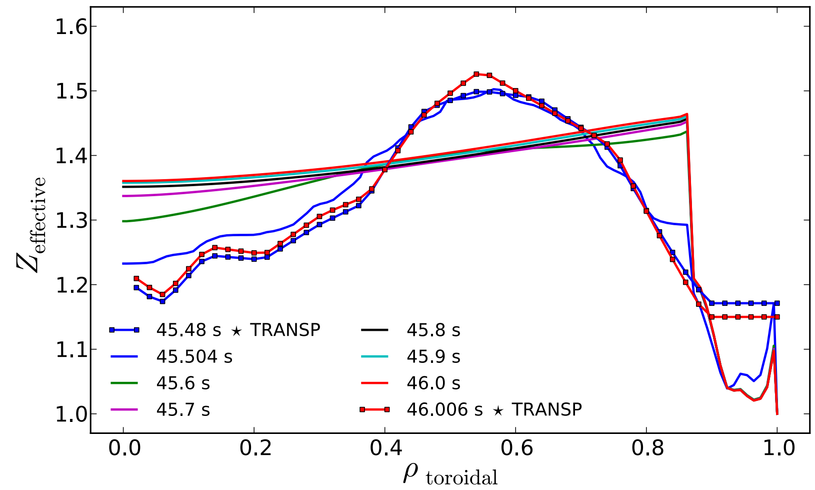
- There is a general good agreement between simulated and measured densities and temperatures
- Electron density is calculated from quasi-neutrality, so it depends on the calculated carbon distribution
- The predicted carbon distribution and effective charge are not entirely accurate
- For #79635 the core effective charge is overestimated but the predicted electron density is still low

  This causes a mismatch in the electron density gradient
- A higher density gradient should contribute to remove electron temperature discrepancy
- These results should become better once impurity transport is improved

Pulse #77922



Pulse #79635

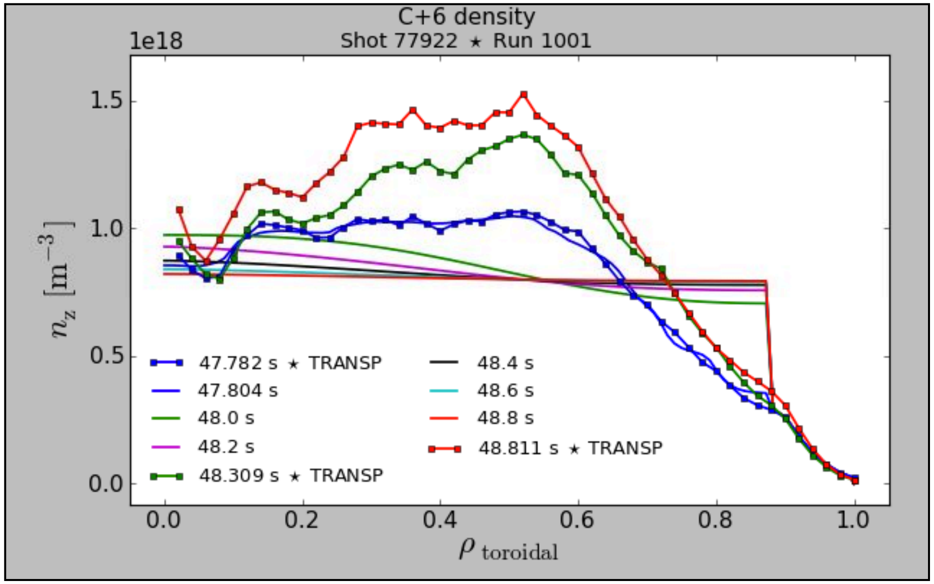


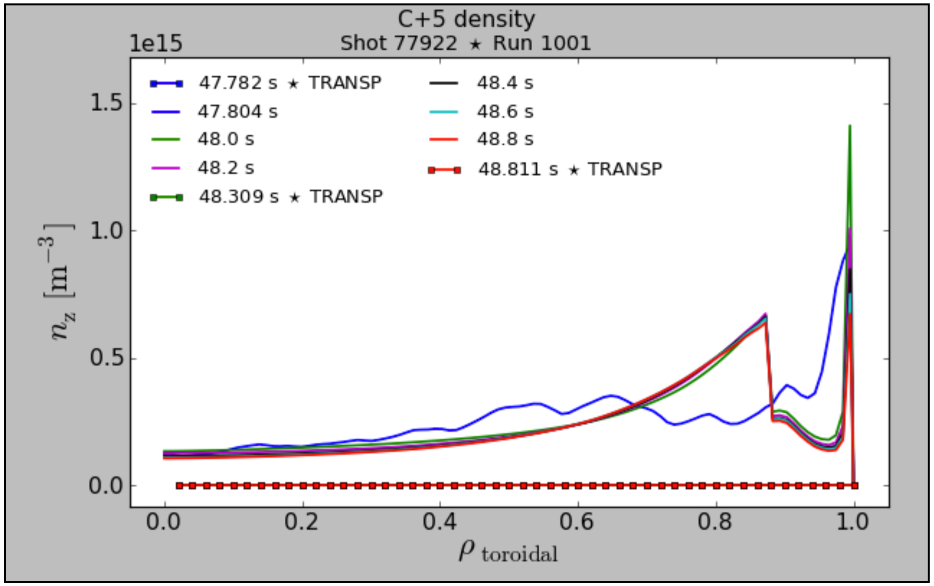
Effective charge: experimental vs. predicted by the ETS

Issues with Impurity Modelling

Pulse #77922

Not in the paper — for discussion only





- The ETS evolves all charge states from an initial C+6 only carbon density profile, but...
- C+6 (from experimental n_e and $Z_{effective}$ profiles) dominates over lower charge states in ETS simulations

  So why was the electron density underestimated?
- No impurity sources considered: not able to reproduce carbon accumulation around $\rho = 0.5$
- No pinch, only BgB diffusion, so carbon profile becomes flat and cannot replicate measured $Z_{effective}$
- How to impose an experimental profile of $Z_{effective}$ in the ETS? Need a pinch model — neoclassical?