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Edge simulations of an ASDEX Upgrade Ohmic shot.

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Introduction

Recent advances in diagnostics on AUG have caused us to re-look at Ohmic plasmas. In addition to excellent mid-plane electron density and temperature profiles (obtained from the YAG laser system positioned at the edge and the Li beam diagnostic [1]), two new developments are the availability of edge ion temperature measurements (from the Li beam system [2]) and the radial electric field (from Doppler reflectometry [3,4]). The divertor reciprocating Langmuir probe has also been re-activated [5].

The choice of looking first at an Ohmic shot was motivated by 1. the fact that the "standard" Ohmic shot ($I_p = 0.8MA$, $B_T = -2.1T$, $\bar{n}_e = 3.4 \times 10^{19} m^{-3}$) is repeated on every shot day means that we have data from a wide range of diagnostics; 2. the absence of ELMs makes the interpretation of the Li-beam diagnostics much easier; 3. the lower power means that the divertor reciprocating Langmuir probe can operate; 4. the absence of ELMs makes the modelling easier; 5. the lower power means that the drift terms in the edge simulation code are easier to operate; and 6. turbulence simulations were possible.

In any sort of modelling scenario, there is a trade-off between trying to match details or trying to match relatively robust results. For example, in the former case, a radially varying profile for the anomalous transport coefficients is likely to be chosen; in the latter, a single radially constant transport coefficient is chosen. In the former case, the simulations would be done with a kinetic treatment of the neutrals; in the latter case, a fluid treatment of the neutrals is sufficient. In the former case, impurities would be mandatory; in the latter they might be neglected. In this work, we have mainly adopted the latter approach for this investigation, using the SOLPS code ([6, 7] and references therein).

Results

In the initial approach, the core boundary density and power fluxes were fixed as well as the pumping of neutrals. The anomalous radial transport coefficients were then varied to produce the best possible match to the upstream density and temperature measurements, using the code without drift terms switched on.

The experimental data used, and the match by the code, is presented in figure 1.

The inferred anomalous radial transport coefficients were found to be: $D = 0.28\ m^2 s^{-1}$, $\chi_i = 0.516\ m^2 s^{-1}$ and $\chi_e = 0.435\ m^2 s^{-1}$.

A number of branches were then followed from this stage: 1. the core boundary condition was changed from a fixed density to a zero net particle flux, and an inward particle pinch term introduced (of $-0.75\ ms^{-1}$; χ_i changed to $0.620\ m^2 s^{-1}$ and χ_e to $0.522\ m^2 s^{-1}$) 2. the drift terms in the code were enabled; 3. a comparison with kinetic modelling, and with impurities, was performed

The comparison of the predicted radial electric field with that measured, is shown in

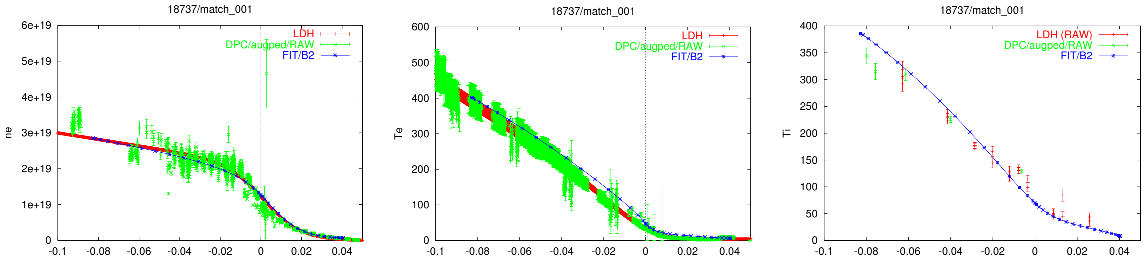

Figure 1: match of the code upstream electron density and electron and ion temperatures with those measured via the YAG Thomson and Lithium beam systems.

figure 2. No additional free parameters were introduced to obtain this result — the transport coefficients and boundary conditions were those obtained when using the non-drift code to match the upstream densities and temperatures.

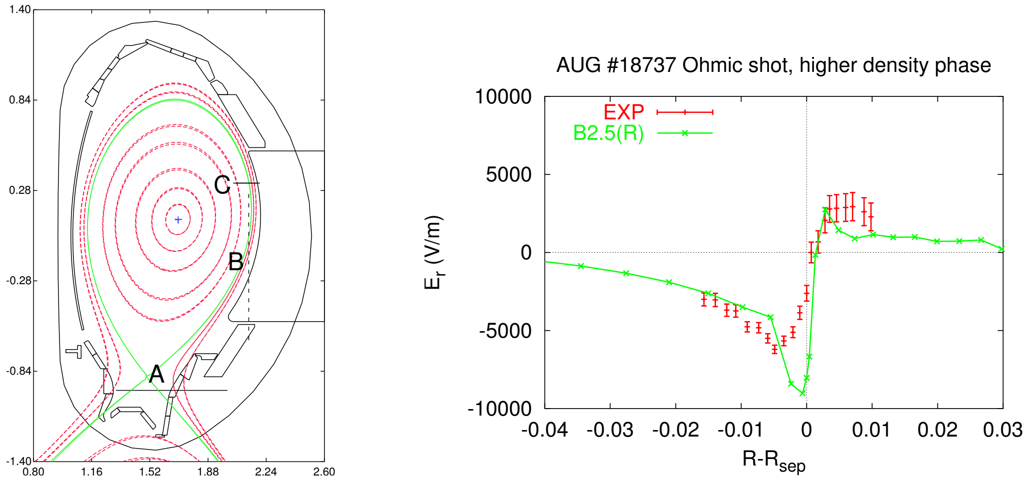

Figure 2: Left: cross section of ASDEX Upgrade showing the magnetic equilibrium at the modelled time, as well as the position of the reciprocating divertor Langmuir probe (A), the positions of the vertical Thomson electron temperature and density measurements (B), and the position of the Lithium beam electron density and ion temperature measurements (C). Right: comparison of the midplane radial electric field from the code with that measured by Doppler reflectometry.

The comparison of the simulation with the divertor reciprocating Langmuir probe is shown in figure 3. Again, no additional fitting of parameters has been performed. It can clearly be seen that the run with drifts provide a better match to the experiment than the run without drifts. Impurities are also likely to play a stronger role in the divertor than upstream, and have been neglected for these runs.

The runs with drifts also give a better match for the target profiles, figure 4. As a reminder, no additional fitting of transport parameters from those derived by fitting the mid-plane profiles has been performed, and these are runs without impurities and with the fluid neutral model.

Comparisons of the simulations performed using the fluid neutral model with those done using the kinetic model show reasonable agreement, particularly if the neutral kinetic flux limiter was set to 1.0, figure 5, as recommended in [8]. The agreement at the target is also good.

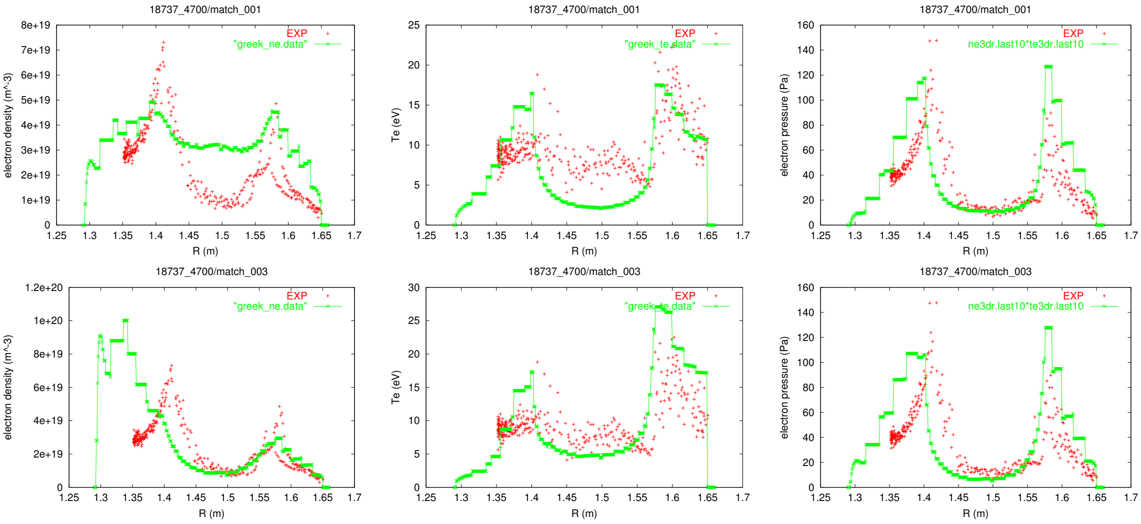

Figure 3: Comparison of the code output with data from the divertor reciprocating Langmuir probe. From left to right: electron density, temperature and pressure. Top: without drifts, Bottom: with drifts.

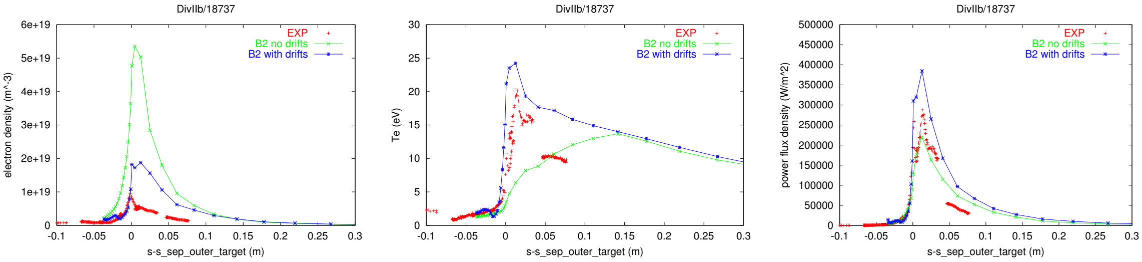

Figure 4: Comparison of the code output with data from the target Langmuir probes. From left to right: electron density, temperature and power (for the experiment, based on a sheath transmission factor of 8).

Gyro-fluid turbulence runs [9] were also performed (but for an earlier phase of this discharge with a somewhat lower density) using the measured temperatures and densities, and their gradients. The inferred transport coefficients were $\chi_i = 0.15\ m^2 s^{-1}$ and $\chi_e = 0.49\ m^2 s^{-1}$, but with about 1/6 of the power in the ion channel (the above edge transport modelling had assumed the power equally divided between ions and electrons), and a total power about 2/3 of that in the experiment.

The 1d NEOART neoclassical transport module was implemented in the B2 code [10], and the neo-classical ion transport level on closed field lines was found to be about $0.1\ m^2 s^{-1}$ (based on the pure D plasma), below that inferred from the plasma transport simulations but not too far from that from the turbulence code.

Summary

Excellent measurements of the upstream edge electron and ion temperatures, electron density and electric field have been made for the AUG “standard” Ohmic shot. SOLPS simulations have been performed to produce the best possible match of the upstream temperature and density measurements under various assumptions, producing estimates of the radial energy and particle transport coefficients. Under the assumption of equal power flows via the electrons and ions at the core boundary, the ion thermal diffusivity was found to be $0.52\ m^2 s^{-1}$ and the electron thermal diffusivity $0.44\ m^2 s^{-1}$. The ion

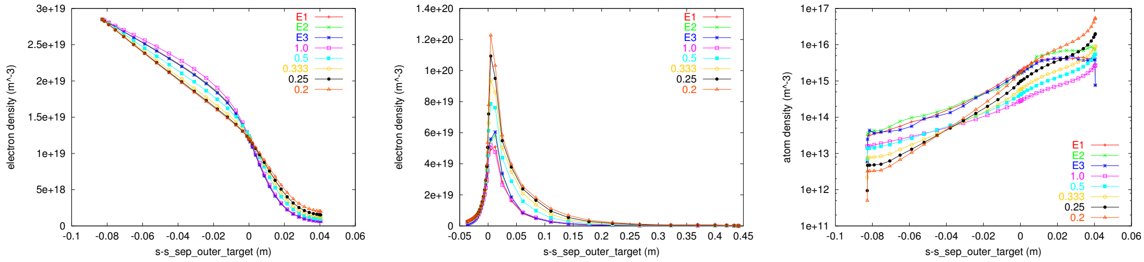

Figure 5: Comparison of the code results done with kinetic and fluid neutrals. From left to right: upstream electron density, outer target electron density and upstream neutral density (atoms only for the kinetic results). E1, E2, E3: runs with kinetic neutrals with differing amounts of pumping; 1.0, 0.5, 0.333, 0.25, 0.2: the neutral flux limiter used in the fluid neutral treatment (1.0 was used in the results previously presented).

neo-classical thermal diffusivity was found to be about 0.1 m^2s^{-1}. For slightly lower density conditions, gyro-fluid turbulence simulations based on the experimentally measured gradient lengths found the ion thermal diffusivity to be 0.15 m^2s^{-1} and the electron thermal diffusivity 0.49 m^2s^{-1}, but with about 1/6 of the power in the ion channel. In addition, when run with the drift terms enabled in SOLPS, the calculated radial electric field compares well with that measured.

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