Integrated modeling of H mode plasma in ASDEX Upgrade and Globus-M

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Introduction

Analysis of existing tokamak experiments and designing of new devices requires integrated consideration of all relevant phenomena in the core and the edge plasmas simultaneously. Below the first results of integrated modeling both for the core and the edge are presented. The 1D transport code for the core plasma is coupled with the 2D edge transport code so that the outputs of one code are used as boundary conditions for the other code. The 1D transport code ASTRA [1] and 2D edge transport code B2SOLPS5.2 [2] where chosen for the coupling. For calculation of the neoclassical ion heat flux the NCLASS [3] module was used, and corresponding flux limiting corrections to B2SOLPS5.2 were introduced.

Modeling was performed for ASDEX Upgrade NBI-heated H-mode shot #17151 and standard Ohmic H-mode shot (#25680) of spherical tokamak Globus-M. The inner boundary of the simulation domain for 2D code ($R = R^{(inner)}$) was chosen at the flux surface situated several centimeters deeper in the core (measured at the outer equatorial midplane) with respect to the pedestal while the outer boundary of 1D computational area coincide with a pedestal position ($R = R^{(ped)}$). Hence there exists an intersection of simulation domains for both codes, Fig 1. The aim of the modeling was to find such profiles of density, temperatures, heat and particle fluxes, particle and heat sources and sinks which would be close in the intersection region providing the smooth transition from the core to the edge.

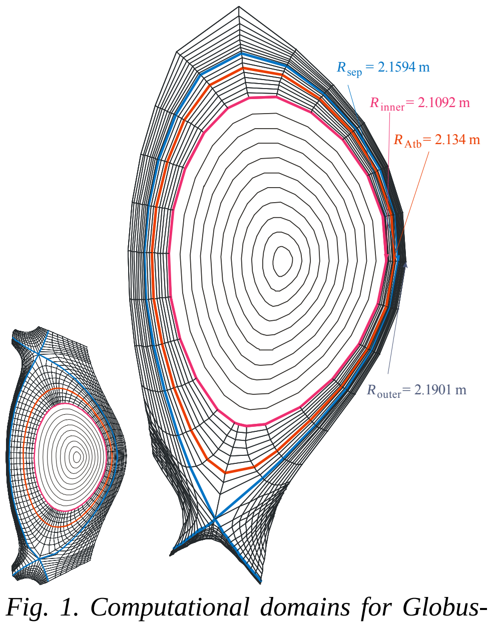

Fig. 1. Computational domains for Globus-M (left) and ASDEX-U (right).

An iterative algorithm for coupling of 1D and 2D codes

The following iterative algorithm has been developed. At each time step the 1D ASTRA code receives from the previous run of B2SOLPS5.2 code the following quantities: the pedestal density $n_e^{(ped)}$, electron and ions temperatures $T_e^{(ped)}$ and $T_i^{(ped)}$, and a surface averaged electron source caused by ionization of edge neutrals $\langle S_e(R)\rangle$. First three values are used as boundary conditions for corresponding balance equations, and the electron source is substituted into the right hand side of particle balance equation. The ASTRA code returns to B2SOLPS5.2 the total electron and ion heat fluxes $q_e^{(inner)}$ and $q_i^{(inner)}$ through the B2SOLPS5.2 computational domain inner boundary, the total particle source due to NBI inside this boundary $\Gamma_{NBI}^{(inner)}$ and a radial profile of neoclassical ion heat flux and heat conductivity (from NCLASS). The heat fluxes are used as boundary conditions for heat balance equations in B2SOLPS5.2 code, while for particle balance equation two possibilities are allowed: either to take a density $n_e^{(inner)}$ from ASTRA, or to use a condition for total ion flux through the inner boundary $\Gamma_i^{(inner)} = -\Gamma_N^{(inner)} + \Gamma_{NBI}^{(inner)}$, where $\Gamma_N^{(inner)}$ is a total flux of edge neutrals through the inner boundary.

Since flux surface shapes in ASTRA and B2SOLPS5.2 do not coincide, the correction to metric coefficients was introduced in ASTRA transport equations.

Simulations results

The calculated profiles of density, temperatures and fluxes are shown in Figs. 2 - 8. Note that besides density and temperature profiles the profiles of fluxes coincide in the whole intersection area. The transport coefficients (see Figs 6,8) are chosen in such way to provide best fit to experimental profiles. Fig. 9 shows 2D edge profiles of density, temperatures and potential for Globus-M, the radial electric field in the core at outer midplane is close to neoclassical one.

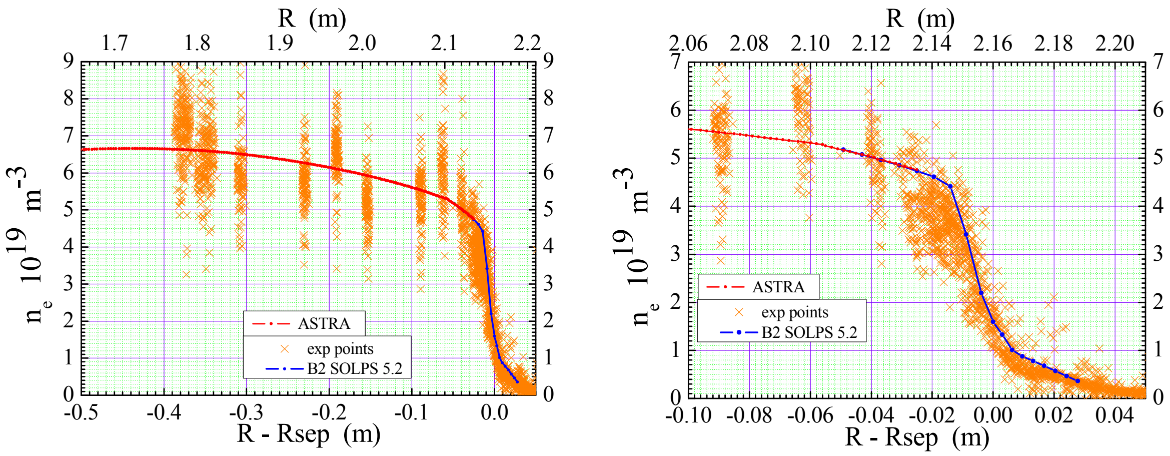

Fig. 2. Electrons density profile for ASDEX Upgrade. Left: full; right: edge region.

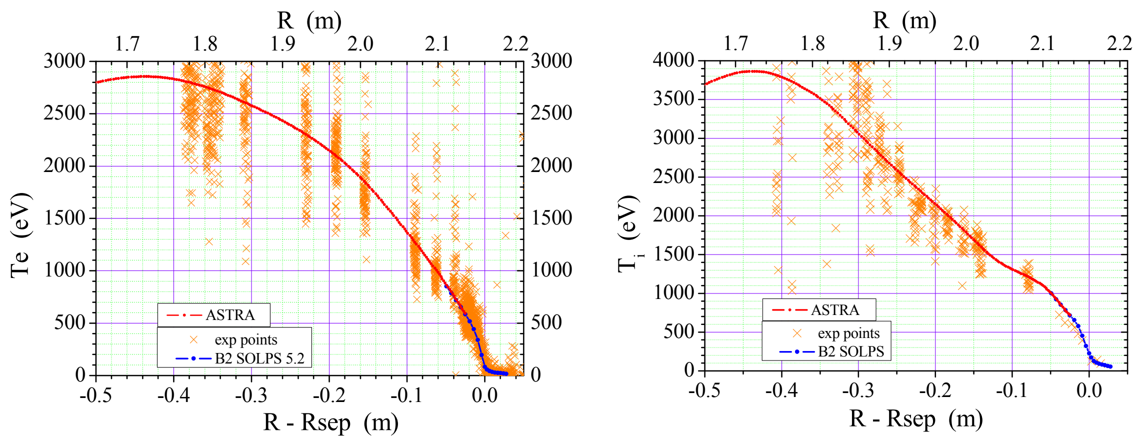

Fig. 3. Electron and ion temperature profiles for ASDEX Upgrade.

The electron and ion heat fluxes $q_e^{(inner)}$ and $q_i^{(inner)}$ at $R = R^{(inner)}$ are calculated in ASTRA according to NBI heating power distribution between ion and electron channels and collisional heat exchange, while in the pure B2SOLPS modeling these fluxes are usually assumed to be equal. However, account of the correct distribution of the power between electron and ion channels in the integrated modeling does not change significantly target density and temperature distributions. Note also that boundary values $n_e^{(ped)}$, $T_e^{(ped)}$ and $T_i^{(ped)}$ for ASTRA simulations calculated in B2SOLPS are not taken arbitrary as in the pure 1D approach. The sensitivity to these values is demonstrated in Figs.7-8 for Globus-M, where due to lack of diagnostics the edge profiles are unknown.

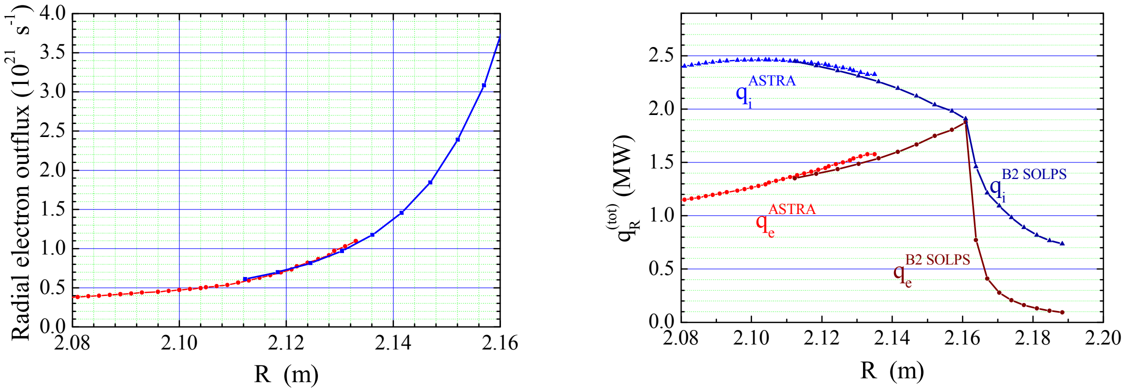

Fig. 4. Radial particle and heat fluxes for ASDEX Upgrade.

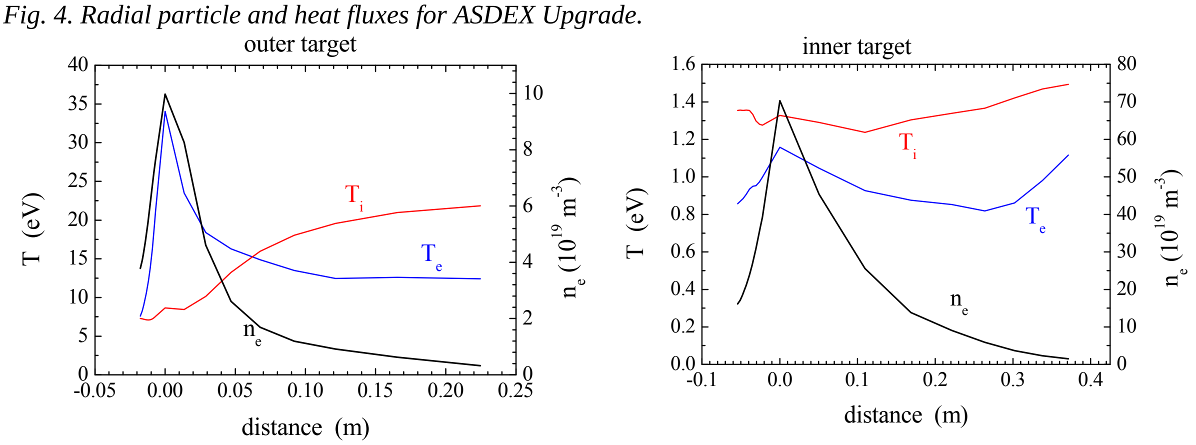

Fig. 5. Temperature and density distribution along divertor targets in ASDEX Upgrade.

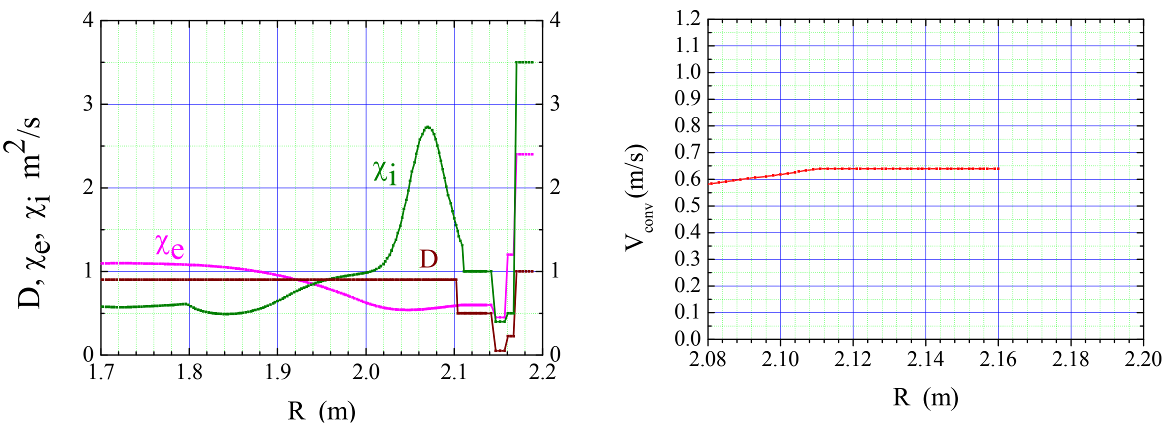

Fig. 6. Transport coefficients for integrated modeling of ASDEX Upgrade.

As a result, the integrated modeling was performed for ASDEX Upgrade and Globus-

M. The simulated parameters are consistent with 2D particle source distribution in the core as well as with NBI particle sources and heating power coming from the core to the edge. The developed integrated modeling scheme could be used as a predictive tool for ITER and other future devices.

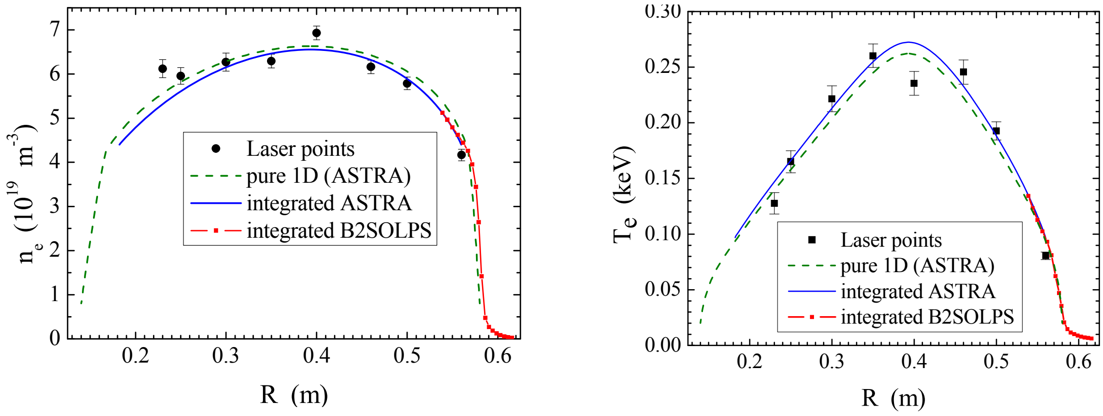

Figure 7. Electron temperature and density profiles in Globus-M. Results of simulation by standalone ASTRA code are also shown.

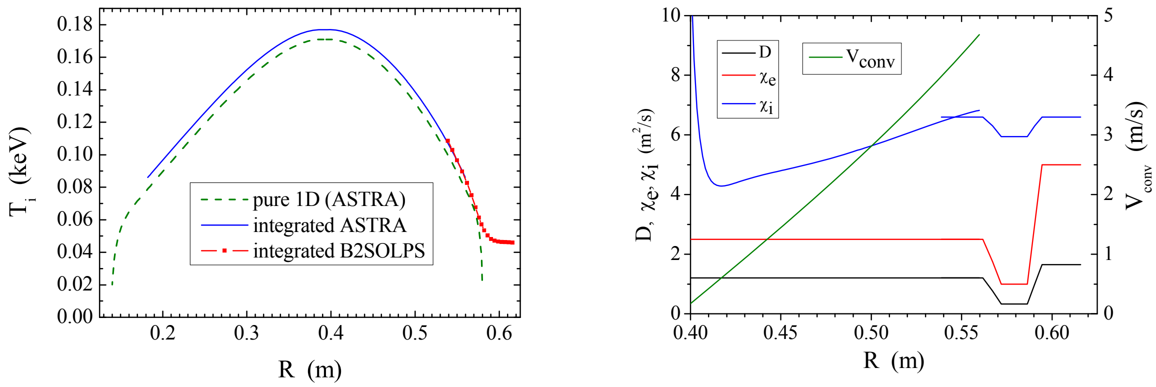

Figure. 8. Ion temperature profiles and transport coefficients in Globus-M.

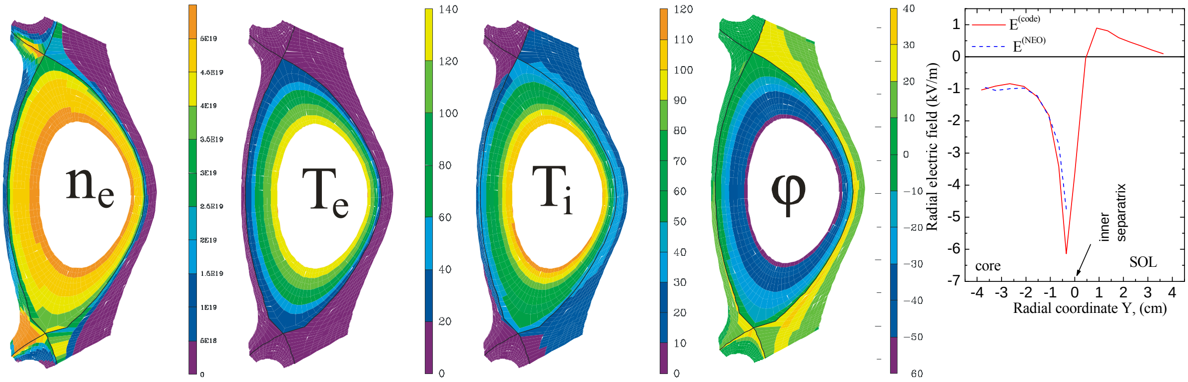

Figure 9. 2D profiles of density, temperature and potential at the edge, and a radial electric field for Globus-M.

Acknowledgements

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References

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