Validation of tokamak magnetic equilibrium reconstructions using the SOLPS-ITER edge plasma transport code simulations

D. Svorc[1], K. Hromasova[2], J. Hecko[2], J. Adamek[2], M. Dimitrova[2],
M. Komm[2], H. Lindl[3], M. Sos[2], P. Vondracek[2], and the COMPASS team[2,*]
[1] *Faculty of Nuclear Sciences and Physical Engineering, CTU, Prague, Czech Republic*
[2] *Institute of Plasma Physics of the CAS, Prague, Czech Republic*
[3] *Max–Planck-Institut für Plasmaphysik, Garching, Germany* [*] *See the author list of [4]*

Introduction

Precise knowledge of the magnetic equilibrium of a tokamak discharge is vital for experiment control, data analysis, and simulations. [5] Reconstructions of the magnetic equilibrium of the COMPASS tokamak are, however, often inaccurate. [1][2] Several refinements to the reconstruction have been proposed during the operation of the COMPASS tokamak at the Institute of Plasma Physics, Czech Academy of Sciences. [3][4] SOLPS-ITER edge plasma transport code uses a magnetic equilibrium reconstruction to construct its computational mesh. In interpretative modeling, an inaccurate equilibrium reconstruction can affect the final model-experiment match. In this paper, we create several SOLPS-ITER simulations based on different equilibrium reconstruction variants of COMPASS L-mode discharge #17692 at 1120 ms. This allows us to investigate the effect of inaccurate equilibrium reconstructions on SOLPS-ITER modeling and to evaluate the equilibrium reconstruction variants.

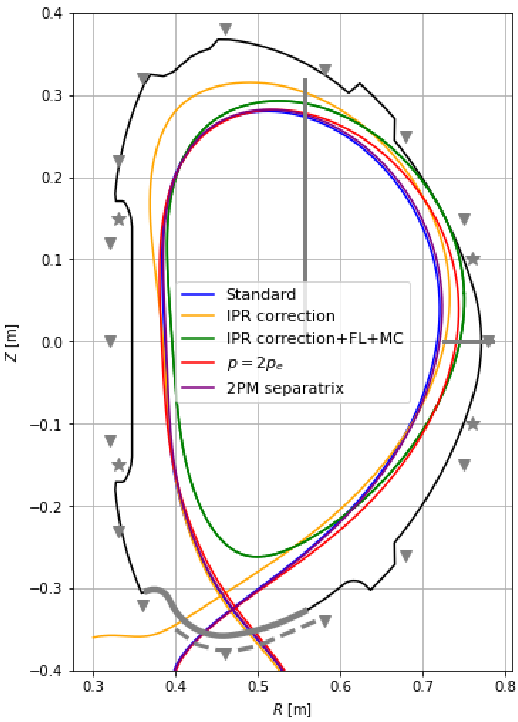

Figure 1: Separatrix position of equilibrium reconstructions on the COMPASS tokamak cross section.

Several edge plasma diagnostics were used in the evaluation. Upstream measurements were provided by the Thomson scattering (plasma top) and a reciprocating probe (outer midplane). Divertor measurements were carried out by an infrared camera, a swept probe array, and a combined probe array, which uses a combination of ball-pen probes and Langmuir probes. [6]

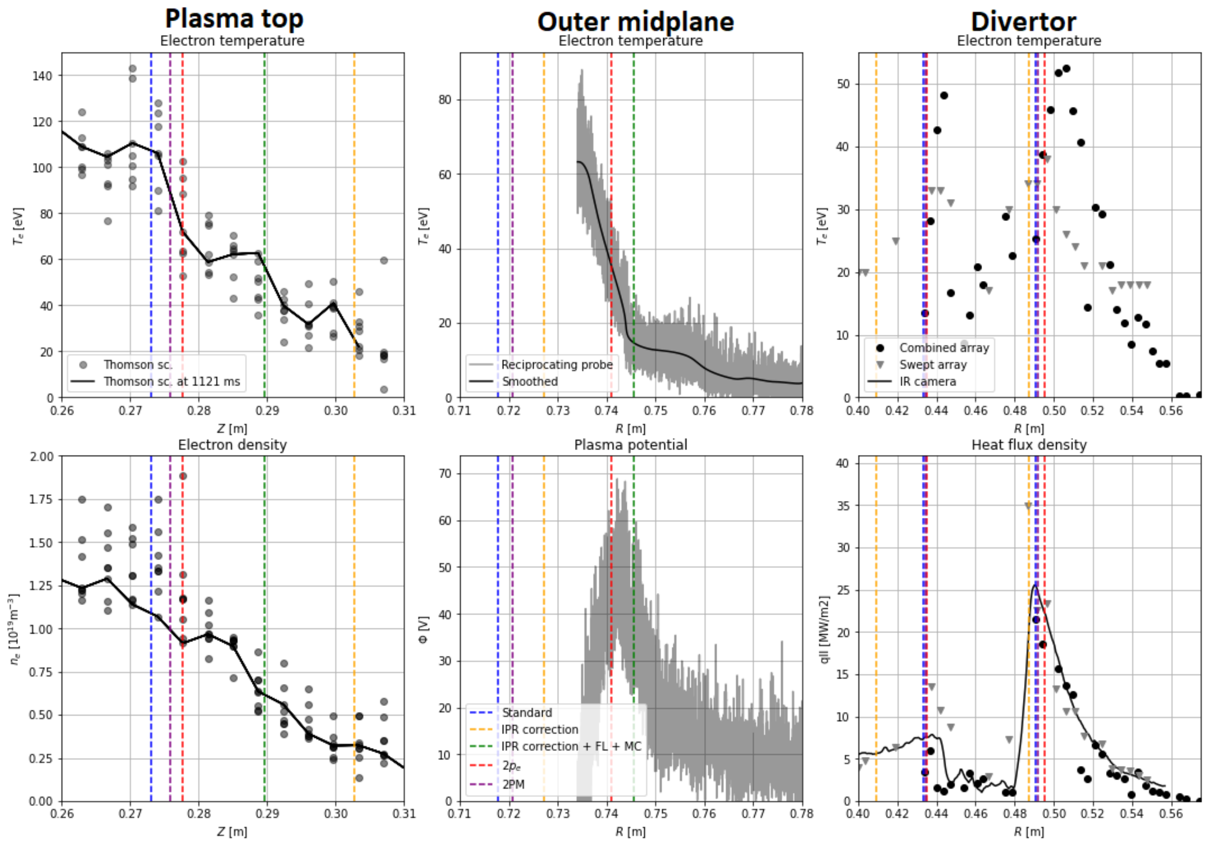

Figure 2: Comparison of the separatrix positions (vertical lines) with diagnostic measurements. Left column: plasma top, middle column: outer midplane, right column: divertor.

Magnetic equilibrium reconstructions

Figure 1 shows the five equilibrium reconstruction variants considered. The equilibrium reconstructions are created by the EFIT++ code based on different input constraints. (i) The ’standard’ reconstruction uses data from various diagnostics, notably including 16 Inner Partial Rogowski (IPR) coils to constrain the solution. (ii) Reconstruction with corrected IPR coil positions and angles. [3] (iii) Reconstruction with IPR corrections and also using measurements from Mirnov coils and flux loops. [3] (iv) Reconstruction using realistic pressure profile measured by the Thomson scattering diagnostic, while assuming $p = 2p_e$. (v) The final variant uses divertor probe measurements and the two-point model to constrain upstream separatrix position to improve the standard reconstruction.

Figure 2 shows the position of the separatrix for each equilibrium reconstruction compared to diagnostic measurements. For each equilibrium, there are significant differences in the measured electron temperature and density at the separatrix at both upstream locations. This presents a problem when trying to match the SOLPS-ITER simulation to the experiment. This was corrected by shifting the separatrix at the plasma top and at the outer midplane.

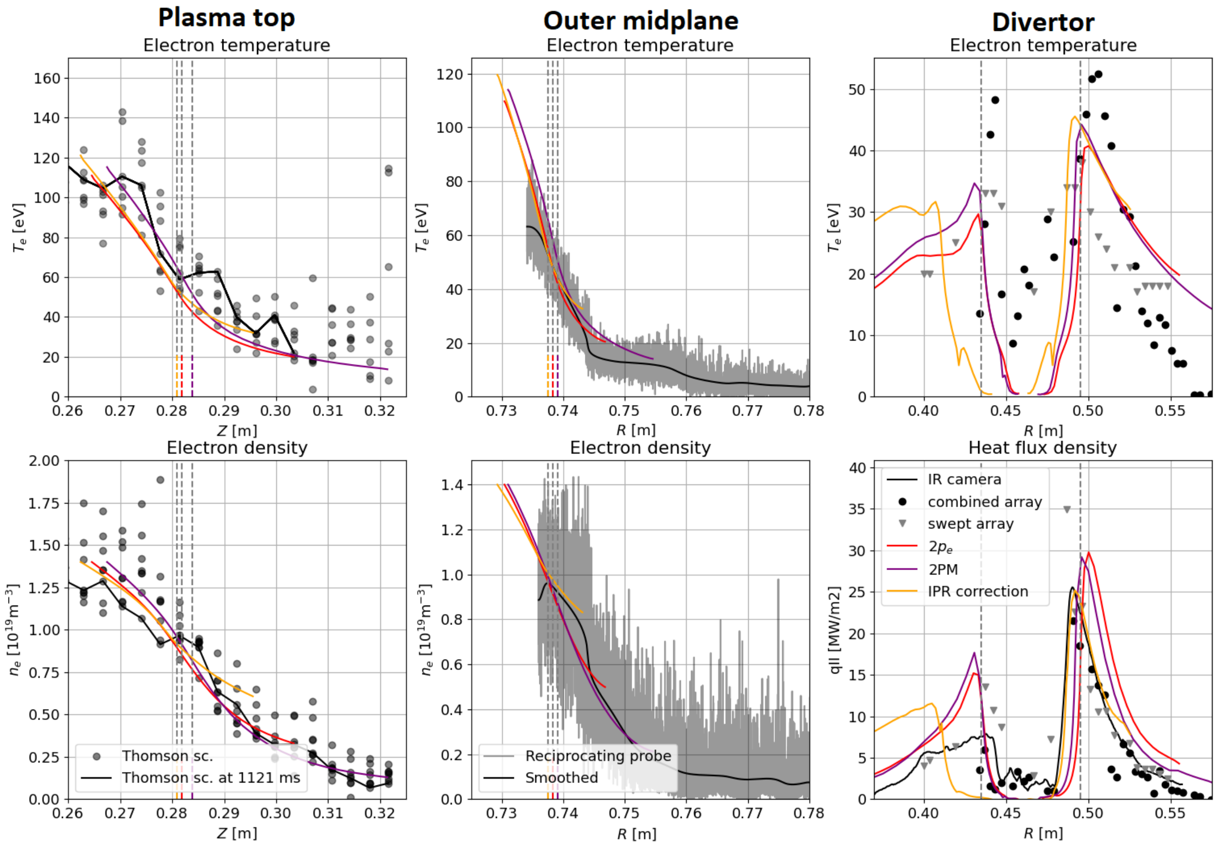

Figure 3: Comparison of the SOLPS-ITER simulation data based on different equilibrium reconstructions with diagnostic measurements. Left column: plasma top, middle column: outer midplane, right column: divertor.

Interpretative SOLPS-ITER simulations

The COMPASS discharge #17692 used was in L-mode with $B_T = -1.38$ T, $I_p = 200$ kA and line-averaged density $\bar{n}_e = 2 \cdot 10^{19}$ m^{-3}. The SOLPS-ITER simulations were run with B2.5 coupled with EIRENE, deuterium only, and no drifts. The '$p = 2p_e$' equilibrium reconstruction was chosen to build a mesh for initial SOLPS-ITER simulations. These initial runs were used to find the anomalous diffusion coefficients $D_n = 0.3$ m^{2}s^{-1}, $\chi_e = \chi_i = 1.2$ m^{2}s^{-1} and the boundary conditions $n_{e,\text{core}} = 1.4 \cdot 10^{19}$ m^{-3}, $P_{SOL} = 150$ kW. The separatrix shifts at the plasma top and at the OMP are two additional free parameters. The match was found by running parameter scans and selecting values that provide the best match with diagnostic measurements.

The same boundary conditions and transport coefficients were then used as inputs for simulations using different equilibrium reconstructions. The separatrix shifts were found independently for each simulation. Figure 3 shows the comparison of these simulations with diagnostic measurements. The figure shows only small differences between simulation profiles, and they fall within the fluctuations of the diagnostic measurements. This shows that using different and

Reconstruction	ΔR [mm]	ΔZ [mm]	R [mm]	Z [mm]
$p = 2p_e$	-3	4	738	282
2PM	18	8	739	284
IPR corrected	10	-22	738	281

Table 1: Separatrix shifts and separatrix position found for each SOLPS-ITER simulation.

inaccurate equilibrium reconstructions does not significantly alter the SOLPS-ITER simulation results as long as they are corrected. The method of these corrections by shifting the position of the separatrix also seems to be valid, as it does not lead to significant differences in simulation results. The '$p = 2p_e$' equilibrium reconstruction using pressure profile from Thomson scattering required the smallest separatrix shifts, so we deem it the most accurate. The ideal separatrix positions for each simulation, shown in table 1, were found to fall within a few millimeters of each other. This suggests that a better position of the separatrix was found using SOLPS-ITER.

Conclusions

The SOLPS-ITER code has been used to compare the different equilibrium reconstructions on the tokamak COMPASS discharge #17692 and to study their effect on the model-experiment match. Using inaccurate equilibrium reconstructions was found to minimally affect the SOLPS-ITER simulation results as long as they are corrected. The method of these corrections by shifting the separatrix position was found to be valid. A more precise position of the separatrix was found, which can be used as a further constraint to improve the equilibrium reconstructions.

Acknowledgments

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