Integrated modeling of tokamak reactor scenarios and impact of core-SOL coupling on plasma performance

E. Fable, M. Siccinio, A. Scarabosio, C. Angioni, and H. Zohm

Max-Planck-Institute for Plasma Physics, Garching b.M., 85748, Germany

To design a tokamak reactor scenario, including optimization and external plant elements down to the electrical output, a key ingredient is the plasma performance. The core and the edge of the plasma act together in a highly non-linear way to dictate the final fusion output and the received divertor heat loads.

Integrated modeling is thus required to get the full performance of the plasma, including divertor protection requirements. Of the latter, the most basics are: divertor temperature below the W (or say metal coating) sputtering limit, and divertor heat fluxes below the melting limit. The detached regime is the most favorable to get these conditions, and it is thus used as a "constraint" in searching for the design parameters. It is also mandatory to use 1D transport codes since 0D core scalings are often leading to unrealistic values of some parameters.

In the present work, 1D transport code ASTRA [1], coupled to a newly developed SOL model [2] is used to perform parameter scans in major radius R, magnetic field B_T, safety factor q, aspect ratio A, and confinement quality H(Iter 98y,2) to find where the plasma performance is maximized in terms of net production of electrical power (assuming some thermal/wall-plug efficiencies). Several constraints are also imposed on each scan point, including separatrix power above L-H threshold, divertor protection, and some assumptions on MHD limits ($\beta_N < 3$-4, $q_{95} > 3$).

The main result of this work is to show that the curves of constant net electrical power in the R-B_T plane are closed and have a well-defined shape determined by the plasma core/edge physics [3]. Other collateral implications for the choice of machine parameters are discussed, with the focus on the physics more than the engineering aspect.

References

[1] G. V. Pereverzev et al., IPP Report 5/42 (August 1991); E. Fable et al., Plasma Phys. Contr. Fusion 55, 124028 (2013)
[2] M. Siccinio et al., Plasma Phys. Contr. Fusion 58, 125011 (2016)
[3] M. Siccinio et al., in preparation for Nuclear Fusion (2017)