Scalings for the energy confinement time and radiative density limit in Wendelstein 7-X

G. Fuchert[1], A. Alonso[2], C.D. Beidler[1], S. Bozhenkov[1], A. Dinklage[1], Y. Feng[1], M. Hirsch[1], A. Langenberg[1], Y. Turkin[1], N. Pablant[3], E. Pasch[1], F. Warmer[1], D. Zhang[1], R.C. Wolf[1], and the W7-X team

[1]*Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 14791 Greifswald, Germany;* [2]*CIEMAT, Madrid, Spain;* [3]*Princeton Plasma Physics Laboratory, Princeton, NJ, USA*

In the first two experimental campaigns of the new stellarator Wendelstein 7-X (W7-X), a positive density scaling of the energy confinement time has been observed. The density dependence is comparable to the empirical energy confinement time scaling for stellarators, the ISS04 [1]. It is not only found by scaling analyses of different experiments, but also during density ramps in individual experiments. Since the low-density hydrogen plasmas achieved so far are, however, far away from the high-performance plasmas W7-X was designed for, it remains to be shown that this trend can be extrapolated to reactor-relevant conditions. Such an investigation is hampered by the occurrence of radiative collapses at relatively low densities. Similar collapses are observed in most stellarators at a critical density depending on the heating power and the impurity concentration. Under given machine conditions this can be considered as a type of (radiative) density limit often referred to as the Sudo (density) limit [2].

The density and power scaling of the energy confinement time is investigated for the limiter and first test divertor campaigns of W7-X and the scaling obtained is then employed to evaluate a simplified model for the radiative density limit [3]. A critical density has been calculated and a reasonable agreement with experimental data is found. However, comparing hydrogen and helium plasmas in different magnetic field configurations it is shown that the radiative density limit in W7-X is an *operational limit* where the critical density varies between different scenarios, probably due to differences in the plasma wall interaction, island geometry and main edge radiators (presumably C, O and H in hydrogen and additionally He in helium plasmas). This opens an interesting perspective where the critical density can not only be influenced by improving the machine conditions (e. g. by boronization), but also by scenario development.

References

[1] H. Yamada et al., Nuclear Fusion **45** 1684 (2005)

[2] S. Sudo et al., Nuclear Fusion **30** 11 (1990)

[3] P. Zanca et al., Nuclear Fusion **57** 056010 (2017)