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Evidence of Turbulence-Induced Ion Temperature Limitations In Wendelstein7-X[1]

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The stellarator Wendelstein 7-X is optimized for reduced neoclassical transport, allowing access to high-performance plasmas at high ion temperatures. Indeed, ion temperatures above 3 keV and energy confinement times above the ISS04-scaling were transiently achieved in post-pellet phases, from which it can be preliminary concluded that the optimization is effective. However, in the vast majority of discharges, the plasma performance is below neoclassical predictions, and the energy confinement time is at the level of the ISS04-scaling. For these discharges, Ti, in contrast to Te, is limited below 2 keV, suggesting a high degree of ion temperature profile stiffness. No dependence on the efficiency of collisional coupling between ions and electrons is observed. The addition of direct ion heating by NBI to such plasmas does not in general improve the situation. Also, no significant dependence on the magnetic configuration is found.
During the post-pellet high-performance phases, a clear reduction of density fluctuations is observed, strongly suggesting that turbulence stabilization is responsible for the higher confinement. This hypothesis is supported by GENE simulations, showing that the linear growth rate and nonlinear ion heat flux are minimized when the normalized ion temperature and density gradients are of similar magnitude and overlap. The effect is caused by a twofold stabilizing influence of trapped electrons in maximum-J configurations, enhanced ITG suppression, as well as by a relatively weak TEM response.
These findings demonstrate that the plasma performance in W7-X is to a large degree determined by turbulent losses. It is, therefore, important to study different methods and scenarios for turbulence reduction, e.g. H-mode-like regimes, or turbulence-optimized configurations.

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