Confinement studies in the limiter phase of Wendelstein 7-X

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The design of W7-X allows for the exploration of magnetic field configurations optimized to overcome the deficiencies of stellarators. Taking benefit from the intrinsic steady-state capability of stellarators, long-pulse operation will be achieved by completing the actively cooled in-vessel components in a stepwise approach, including an island divertor. During its first operational phase (OP1.1), W7-X was operated in a limiter configuration with five uncooled inboard limiters. This caused high radiative losses and probably charge-exchange losses. The achieved global energy confinement times of between 50 and 150 ms are remarkable both in the absolute value and the relative performance with respect to the ISS04 stellarator scaling. Power degradation and density dependence are in agreement with the ISS04 scaling for a wide range of heating powers. Different behaviour is observed at very low densities and heating powers, where the energy confinement is degraded compared to ISS04. In that regime, the energy confinement time rises with increasing heating power. This seems to be caused by a shrinkage of the hot plasma core and indicates the presence of operational limits.

The neoclassical transport in the low \( n_e \) plasmas with \( T_e > T_i \) of OP1.1 was predominantly governed by core electron-root confinement (CERC) with positive radial electrical fields. Confinement properties of these plasmas will be presented together with first profile shaping effects by off-axis application of ECRH. Systematic power balance studies indicate that the energy confinement in OP1.1 was affected by radiative processes, neutral losses, and anomalous transport in addition to neoclassical fluxes. The results from OP1.1 provide an important reference for future divertor operation, since the plasma performance will be determined by the scaling of these loss and transport channels from OP1.1 conditions to the high-density plasmas in the \( 1/\nu \)-regime that W7-X was optimized for.