

## Latest performance achievements of the Wendelstein 7-X Stellarator

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Within the timeframe of 2024/25, the superconducting stellarator Wendelstein 7-X (W7-X) has completed three successful experimental campaigns along extensive systems upgrades, in particular with regard to the heating systems and the installation of a steady-state pellet injector.

W7-X has made significant progress in its three major strategic goals across various magnetic field geometries:

- (1) enhanced performance through profile shaping,
- (2) extended safe long-pulse operation, and
- (3) characterization of detachment and turbulent transport.

The development of high performance plasmas is a key step towards demonstrating the reactor-capability of the stellarator concept. Several strategies were developed to achieving high performance aiming to suppress turbulence via shaping of the density profile. Compared to our previous results, this approach allowed us to reach a nearly ten times higher fusion triple product  $n_e T_i \tau_e$  of  $1.2 \times 10^{20} \text{ m}^{-3} \text{ keVs}$  with a plasma stored energy of nearly 1.8MJ – setting a new record for the triple product in stellarators.

Another key advantage of stellarators is their intrinsic and safe steady-state operation capability with minimal need for control systems. To demonstrate this, W7-X has reached a new milestones by not only operating for nearly 10min with an energy turnaround of 2GJ, but doing so while protecting the divertor with stable detachment and control of the bootstrap current – underscoring the success of recent W7-X upgrades.

Lastly, the flexibility in the magnetic configuration space of W7-X is actively exploited to obtain insights into the evolution of plasma turbulence and scrape-off-layer dynamics. Of particular interest is the sensitivity of detachment and divertor heat loads with respect to edge magnetic field modifications of the magnetic island. The experimental results demonstrated effective detachment control over a range of magnetic configurations – a crucial insights for the safe operation of a future stellarator reactor.

In conclusion, W7-X has made critical advancements in stellarator plasma performance, turbulence suppression, long pulse operation, and detachment control – each relevant for a future stellarator reactor concept.