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Advanced Tokamak Investigations in Full-Tungsten ASDEX Upgrade

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The tailoring of the q-profile is the foundation of Advanced Tokamak (AT) scenarios. It depends on low collisionality ν^* which permits efficient external current drive and high amounts of intrinsic bootstrap current. At constant pressure, lowering n_e leads to a strong decrease of $\nu^* \sim T_\mathrm{e}^{-3}$.

After the conversion of ASDEX Upgrade to fully W-coated plasma facing components, radiative collapses of H-modes with little gas puffing due to central W accumulation could only be avoided partially with central ECRH. Also, operation at high β with low n_e presented a challenge for the divertor. Together, these issues prevented meaningful AT investigations.

To overcome this, several major feats have been accomplished: Access to lower n_e was achieved through a better understanding of the changes to recycling and pumping, and optionally the density pump-out phenomenon due to RMPs. ECRH capacities were substantially expanded for both heating and current drive, and a solid W divertor capable of withstanding the power loads was installed. A major overhaul improved the reliability of the current profile diagnostics.

This contribution will detail the efforts needed to re-access AT scenarios and report on the development of candidate steady state scenarios for ITER/DEMO. Starting from the 'hybrid scenario,' a non-inductive scenario ($q_{95} = 5.3$, $\beta_\mathrm{N} = 2.7$, $f_\mathrm{bs} > 40\%$) was developed. It can be sustained for many τ_E, limited only by technical boundaries, and is also independent of the ramp-up scenario. The β-limit is set by ideal modes that convert into NTMs. The T_i-profiles are steeper than predicted by TGLF, but nonlinear electromagnetic gyro-kinetic analyses with GENE including fast particle effects matched the experimental heat fluxes. We will also report on scenarios at higher q_{95}, similar to the EAST/DIII-D steady state scenario. The extrapolation of these scenarios to ITER/DEMO will be discussed.