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Long pulse operation in a W environment : feedback from WEST
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Record pulses in terms of injected energy and pulse duration at the superconducting WEST tokamak have been recently achieved. These have been obtained with an ITER-grade actively cooled divertor and with lower hybrid heating and current drive for up to 6 min and with 1.15 GJ of injected energy [1]. These long plasmas evidence the importance of material ageing, tungsten contamination and boronisation impact. A High Fluence campaign in attached divertor regime (cumulating 3 h of plasma, and reaching a divertor particle fluence equivalent to 1 ITER shot) demonstrated the formation of tungsten deposits, and their release under the form of UFOs impacting plasma operation [2, 3]. This process equilibrates after about 2h of plasma, with a rate of UFO generation saturating at about 6 UFO per minute of plasma. Actuators for coping with UFOs are essential, as their occurrence becomes more probable with extended pulse duration. Some of the few remote vessel elements that are not actively cooled were shown to outgas H species when approaching the GJ range, and to be conditioned progressively as long pulses were repeated, thus evidencing the need for an exhaustive cooling of the in-vessel components. Detached scenarios with nitrogen seeding (in particular the X-point radiator regime [4] where feedback control has been demonstrated for more than 10 s and also obtained in double null configurations) are currently developed to improve on two important long pulse aspects by (i) limiting the erosion of the divertor possibly limiting the level of UFOs observations (ii) improving the plasma performance in terms of confinement time and ion temperature via turbulence stabilisation. Additional beneficial effects were also observed on the tungsten core contamination, which robustly yields ~50% fraction of core radiated power in standard scenario and can be reduced down to ~40%. While the tungsten central peaking remains modest in these RF heated plasmas [5], increasing nitrogen content also reduces the central neoclassical W peaking [6]. New perspectives for WEST contributions to ITER include the extension of the low divertor temperature regime to Long Pulse Operation (over one minute), the characterization of W limiter operation (coordinated by ITPA), as well as further addressing high-injected energy challenges.
References
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