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Overview of long pulse, high fluence and high heat flux operation in WEST full tungsten

J. Gaspar[1], J. Bucalossi[2], Y. Corre[2], M. Diez[2], R. Dumont[2], A. Ekedahl[2], N. Fedorczak[2], A. Grosjean[3], P. Maget[2], P. Manas[2], Ph. Moreau[2], E. Tsitrone[2] and the WEST team* and the EUROfusion Tokamak Exploitation team**

[1]Aix Marseille University, CNRS, IUSTI, Marseille, France, [2]CEA, IRFM, F-13108 Saint-Paul-les-Durance Cedex, France, [3]University of Tennessee, Knoxville (UTK), *See http://west.cea.fr/WESTteam, **See the author list of E. Joffrin et al 2024 Nucl. Fusion 64 112019.

e-mail (speaker): jonathan.gaspar@univ-amu.fr

Next step fusion devices will face unprecedented heat loads and particle fluence with thousands of hours of plasma exposure on Plasma Facing Components (PFCs). An extensive tungsten (W) PFC testing programme is conducted in the WEST tokamak, which is equipped with an ITER-grade actively cooled divertor [1], including shaped monoblocks (MBs) with a toroidal bevel as foreseen for ITER. The steady state heat load measured on the ITER-grade PFCs ranges from 4 to 6 MW/m^2 in standard L-mode discharges, and up to ITER relevant values of 12 MW/m^2 during dedicated experiments for PFC testing at high power (see figure 1).

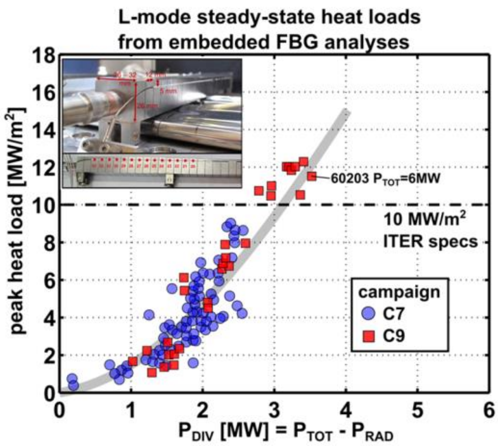

Figure 1: Peak heat flux versus Pdiv=Ptot-Prad

Upon sufficient seeding, the divertor plasma transits within microseconds into a stable, dense and cold (Te < 3 eV at target) regime featuring an X-Point Radiator (XPR) [2], with strongly mitigated heat loads and tungsten erosion. The study of exhaust physics with the long pulse X point radiator regime, up to 35s, has been extended to different plasma magnetic configurations (double null and upper/lower single null) and interpreted by SOLEDGE modelling in view of assessing its potential use in future devices [3]. This modelling gives encouraging results as the so-called “Te cliff” and XPR like radiative patterns are obtained consistently in simulations. Integrated modelling of core conditions suggests that the experimental improvement of confinement (Te +20% and Ti +35%) during seeding and XPR is a combined result of mitigated core tungsten contamination (taming of divertor tungsten sources) and core dilution effects from nitrogen ions.

In recent campaigns, a strong effort has been placed on long duration plasma scenarios (well beyond 100 s), which is relevant for plasma-wall interaction phenomena. The long pulse scenario development, supported by integrated modelling, has resulted in a record pulse duration of 1337 s (~22 minutes), with injected energy of 2.6 GJ (see figure 2). A total of seven pulses with duration exceeding 500 s have so far been carried out in WEST.

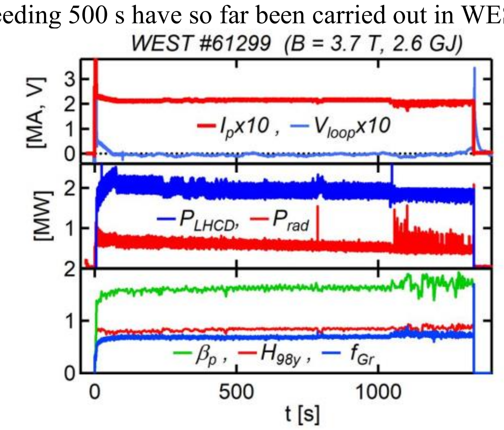

Figure 1: Main plasma parameters of discharge #61299

The extensive long pulse and high fluence campaigns in WEST have now led to a cumulated plasma exposure of more than 12 hours on the ITER-grade divertor and a particle fluence of about 2.10^{27} part/m^2, which corresponds to a few ITER pulses. When running repetitive long pulses an increasing number of radiative events is observed, becoming significant once the cumulated injected energy reached ~20GJ [4]. These radiative events are related to loose flakes ejected from the redeposited layers near the inner strike points on the divertor target. A new laser cleaning technique has been successfully developed to remove these deposits during a vessel vent.

So far, the divertor has not shown any signs of degradation in terms of heat exhaust capability, but W deposited layers of a few tens of micrometer thickness [5] and crack networks are observed on the top surface on some MBs [6].

References

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