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The EUROfusion Tokamak Exploitation Program in support of ITER and DEMO

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The EUROfusion Tokamak Exploitation Work Package (WPTE) is running an extensive multi-machine coordinated program, combining medium-size devices (ASDEX-Upgrade, TCV, MAST-U and WEST) as well as large tokamaks like JET. The program leverages on the capabilities and peculiarities of single device, conceiving a coordinated effort aiming to provide answers to urgent questions raised by the ITER research plan, as well as to lay down the physics basis for the EU-DEMO conceptual design. The program culminated with the last and final Deuterium-Tritium campaign on JET, which focused primarily on ITER and DEMO relevant scenarios initially investigated on smaller tokamaks, and further extended to larger devices checking the compatibility with fusion relevant isotope mixes.

ITER-like scenarios with heat flux withstanding capabilities obtained via extrinsic impurity seeding have been extensively explored on JET. The operational space has been extended to 3MA in D, and to 3.2MA in D-T operation proving the capabilities to feature high performance plasma, with low-collisional pedestal and with divertor condition at least in high recycling regime. Still in support of ITER scenarios a multi-machine investigation of low ν^* pedestal collisionality, has been performed combining different devices as JET, TCV and MAST-U. The effort allowed to extend the analysis of peeling limited pedestal also in metallic devices, highlighting the influence of PFC materials on the boundary condition and pedestal performances.

Predicted ELM energy fluence in DEMO class devices, stimulated the exploration of small ELMs/no-ELM alternative, compatible with adequate confinement conditions as well as exhaust solution. On this respect a stepladder approach has been followed, exploring several alternatives in smaller devices, and then scaling up the most promising towards JET. Among small-ELMs regime, the Quasi Continuous Exhaust one has been extensively studied on ASDEX-Upgrade and TCV, focusing on heat and particle load, W accumulation compatibility and operational space in terms of heating schemes and magnetic equilibria: finally leveraging on theoretical predictions for the appropriate operational domain, the scenario has been successfully exported to JET both in DD and DT operation. As a further alternative for DEMO, the X-point radiator regimes (XPR), featuring good confinement properties and high radiation fraction has been obtained and investigated in all the WPTE devices both in H-mode and L-mode. The extrapolation to JET in both DD and DT exploited Argon and Neon impurity mixes, compatible with mixed isotope operation and capability of real-time control of XPR position and scenario has been successfully demonstrated.

Alternative Divertor Configuration (ADCs) investigation progressed both on TCV and MAST-U, as viable risk-mitigation approach for DEMO heat exhaust solutions. Several solutions including Snow-flake (SF), Super-X, X-Divertor and X-Point target have been explored, including their detachment capabilities, impurity compression with the appearance of an XPR in SF, as well as compatibilities with core performances.

Finally experiments with dimensionless parameter as close as possible to JT60-SA were performed on JET aimed to identify operational space at high β and mild MHD activity to support the scenario development for JT60-SA scenarios.

The contribution will summarise the key results, with emphasis on the cross-devices comparison to highlight the benefit of a coordinated program spanning several devices, with a wide operational space, as a key ingredient to increase confidence on physics interpretation as well as scenario extrapolation.