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Predictive multi-channel flux-driven modelling to optimise ICRH tungsten control in JET

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The evolution of the JET high performance hybrid scenario, including central accumulation of the tungsten (W) impurity, is reproduced with predictive multi-channel integrated modelling over multiple confinement times using first-principle based models. 8 transport channels ($T_i, T_e, n_D, n_{Be}, n_{Ni}, v_{tor}, j$) are modelled predictively with self-consistent predictions for sources, radiation, and magnetic equilibrium, yielding a predictive system with multiple nonlinearities which can reproduce observed radiative temperature collapse after several confinement times. The mechanism responsible for W accumulation is inward neoclassical convection driven by the main ion density gradients and enhanced by poloidal asymmetries due to centrifugal acceleration. The slow timescale of bulk density evolution sets the timescale for central W accumulation. Prediction of this phenomenon requires a turbulent transport model capable of accurately predicting particle and momentum transport (QuaLiKiz) and a neoclassical transport model including the effects of poloidal asymmetries (NEO) coupled to an integrated plasma simulator (JINTRAC). The modelling capability is applied to optimise the available actuators to prevent W accumulation, and to extrapolate in power and pulse length. Central NBI heating is preferred for high performance, but comes at the price of central deposition of particles and torque which pose the risk of W accumulation. Several benefits of ICRH to mitigate W accumulation are examined: The primary mechanism for ICRH to control W in JET are via its impact on the bulk profiles and turbulent diffusion, which are insensitive to details of the ICRH scheme. High power density near the axis is found to be best to maximise the beneficial effects of ICRH against W, but changing the minority species or its concentration does not significantly change the W behavior. With attention to the location of the ICRH resonance and MHD stability, high performance hybrid scenario discharges of 5s at maximum power should be possible in the coming campaign, and a controlled and steady fusion performance in the subsequent JET DT campaign. This work demonstrates the integration of multiple first-principle models into a powerful multi-channel predictive tool for the core plasma, able to guide JET scenario development to its objectives of higher performance and longer pulses.

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Author: Dr CASSON, Francis (CCFE, Culham Science Centre, Abingdon, UK)

Co-authors: Dr CZARNECKA, Agata (Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland); Dr BOURDELLE, Clarisse (CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France.); Dr ANGIONI, Clemente (Max--Planck-Institut fuer Plasmaphysik, EURATOM Association, D-85748 Garching, Germany); Dr CHALLIS, Clive (CCFE, Culham Science Centre, Abingdon, UK); Ms BELLI, E. A. (General Atomics); Dr LERCHE, Ernesto Augusto (LPP-ERM/KMS); Dr KOECHL, Florian (CCFE, Culham Science Centre, Abingdon, UK); Dr CORRIGAN, Gerard (CCFE, Culham Science Centre, Abingdon, UK); Mr PATTEN, Hamish (Ecole Polytechnique Federale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-1015 Lausanne, Switzerland); Dr MLYNÁŘ, JAN (Institute of Plasma Physics of the Czech Academy of Sciences); Dr CITRIN, Jonathan (FOM DIFFER - Dutch Institute for Fundamental Energy Research); Dr GRAVES, Jonathan (Ecole Polytechnique Federale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-1015 Lausanne, Switzerland); Dr KIROV, Krassimir (CCFE, Culham Science Centre, Abingdon, UK); Dr GARZOTTI, Luca (United Kingdom Atomic Energy Agency - Culham Centre for Fusion Energy); Dr GONICHE, Marc (CEA, IRFM); Dr SERTOLI, Marco (Max-Planck-Institut fuer Plasmaphysik, EURATOM Association, D-85748 Garching, Germany); Dr VALISA, Marco (Consorzo RFX, Italy); Dr MANTSINEN, Mervi (Catalan Institute for

Research and Advanced Studies, Barcelona, Spain SPAIN); Mr FICKER, Ondrej (Institute of Plasma Physics of the Czech Academy of Sciences); Dr KNIGHT, Peter (CCFE, Culham Science Centre, Abingdon, UK); Dr BILATO, Roberto (Max-Planck-Institut fuer Plasmaphysik, EURATOM Association, D-85748 Garching, Germany); Dr BRETON, Sarah (CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France.); Dr JOHNSON, Thomas (KTH Royal Institute of Technology, Stockholm, Sweden); Dr BARANOV, Yuriy (CCFE, Culham Science Centre, Abingdon, UK)

Presenter: Dr CASSON, Francis (CCFE, Culham Science Centre, Abingdon, UK)

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