Integrated modeling of tokamak plasmas:

Progresses and challenges towards ITER operation and reactor design

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The modelling of the nonlinear interplay between sources and sinks with the transported channels (heat, particle and momentum) has recently allowed us to understand mechanisms such as: the ion mix role on current diffusion during current ramp up in JET, TCV, WEST [1-3]; the role of heating mix on the background profiles on W core radiation required for collapse avoidance on JET, AUG and WEST [4-7]. In stationary phases, the energy content has been predicted with better precisions than empirical scaling laws with respect to I_p, B, size, fueling both in L and H modes on AUG [8,9]. Physics based integrated modelling is also tested in an automated manner on 5700 JET plateaus [10]. Such results have been possible thanks to the progresses in turbulent transport models: shaping impact in the resistive L mode edge in TGLF [11], Neural Network surrogates of QuaLiKiz trained on extensive databases [12,13].

Validation of physics based integrated modelling is mandatory to prepare ITER operation and its control schemes as well as to design future reactors. However, physics gaps remain on this path. For example, unlike today's devices, ITER-class devices will be opaque to neutrals and fueled by pellets. The balance between particle source and its transport in the pedestal will be highly modified. In absence of physics understating of the transport in the pedestal, extrapolation is uncertain. Moreover, in burning plasmas, the non-linear coupling between the energetic alpha particles, MHD and transport of both alphas and DT fuel is explored thanks to a hierarchy of models. Routes on how to address these challenges within integrated modelling are being implemented.

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