Physics model development and extensive validation of predictive integrated modelling

within the new EU framework programme 2021-2027 (TSVV11 activity)

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To prepare ITER operation and contribute to DEMO design, a cohesive plan to extend the state-of-the-art in predictive integrated tokamak simulation, and validation methodologies thereof, has been endorsed by EUROfusion under the acronym of TSVV11 *(Theory, Simulation, Validation and Verification task on 'Validated frameworks for the Reliable Prediction of Plasma Performance and Operational Limits in Tokamaks).* The team, objectives and first accomplishments of this activity will be presented.

Our main focus is on physics module development and extension towards building pragmatic capability of full-pulse-simulation from the core to the SOL. The first results and long-term strategy will be presented for: development and validation of reduced turbulence models in L-mode up to LCFS, and including isotope effects and all ions; reduced neoclassical models, including poloidal asymmetries most relevant for W impurities; MHD modules adequate for ramp-up and ramp-down; reduced pedestal and SOL models accounting for the fueling impact; breakdown and burn-through modules with self-consistent equilibrium and plasma evolution.

The status for full-pulse predictive modelling capability will be reviewed: from breakdown to termination, including assessing proximity to operational limits such as coil currents, MHD, impurity events, and heat and particle exhaust with targeted validation on EU tokamaks.

The modelling framework preferentially developed will be Python-based, coupling of modules developed by WPCD for the HCD workflow with the JETTO and Edge2D-EIRENE transport modules [Pinches AAPPS 2020]. This High Fidelity Pulse Simulator (HFPS) presently allows core-edge-SOL coupled simulations for multi-channel transport, including multiple ions and radiation (from low Z to W). New IMAS-adapted modules will be coupled as they become available. This modelling framework will be continuously delivered to the physicists involved in tokamak exploitation thanks to yearly training; a detailed, accessible documentation and a user friendly GUI.

Taking advantage of the IMAS data format, extensive and automated validation of the predicted quantities will be put in place. Integrated modelling advanced preparation pipelines including automated fitting procedures will be generated. Automated simulation execution, validation workflows including Uncertainty Quantification, and database storage, will be developed. Consistency checks in 0D, 1D, and 2D synthetic diagnostics will be implemented for a hierarchy of modelling use-cases.

Within this project, the HFPS framework will also be demonstrated for ITER First Plasma scenarios and the pre-fusion-power-operation (PFPO) phase, responding to requested R&D in support of the ITER Research Plan. The physics-based full pulse predictive capability validated within TSVV11 will be an input to the plasma model needed in the flight (or pulse design) simulator which will be developed in parallel via other means.